Syllabus

PHYS 330L : Optics Laboratory
Fall 2016

Instructor: Dr. Eileen Meyer (Office 312, physics)
Office Hours: Tuesdays and Thursdays 9-10:30 AM or by appointment, I will also generally be in the labs on Tuesday/Thursday from 1:00 – 5:15 PM
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Location: Physics 213, 214, "lecture" days will be in Physics 221

Required Texts: PHYS 330L Laboratory Manual, available as a PDF on blackboard

Materials: Blank lab notebook with graph paper (See below). Available at the bookstore.

Optional Texts: *Optics* by Hecht
Introduction to Optics by Pedrotti and Pedrotti
Fundamentals of Optics by Jenkins and White
Modern Optics by Guenther.
All of the above are on reserve in the AOK library.

Additional Text: *Introduction to Error Analysis*, by John R. Taylor
A copy of this text is available in the Alvin Meckler reading room in the Physics Building. *I highly recommend purchasing a copy if you are able, as it will serve you throughout a career in physics or engineering. However it is not required.*

Overview

Welcome to Optics Lab! This semester you (in teams of 3 people) will get to re-create some of the seminal experiments in optics. Some of these were first performed in the 19th century using equipment not much different than what you will be using in the lab, while other technologies (such as fiber optics) were not developed until a few decades ago. Today, optics is one of the most exciting and rapidly developing areas of experimental physics. Recent discoveries have led to dramatic advances in areas from astronomy to quantum computing. In addition, optics continues to enhance our lives through more practical applications such as advances in medicine, and bringing the internet to our homes and dorms.

As this is a junior-level lab, you will be encouraged to be more self-directed than in previous lab courses. You are also encouraged to experiment! If you wish to measure something in an innovative way, or try out something outside the lab

guides, do so! This is *your* lab.

Class Organization

The lab setup is divided between two rooms (213 and 214), each with 3 'bays' holding an experimental setup. In the first part of the semester after the initial introductory lecture (i.e. weeks 2-6), your group will rotate through each of the five labs numbered 1-5 in part I of your lab manual. As there is only 1 experimental setup per lab exercise, only one group can work on any given lab at a time. You'll be assigned a starting lab on day 1 and then work through the rest in order (go to lab 4 after lab 3, etc.). All members of a team must be active in doing the experiments, as 10% of your grade will go to 'participation' as assessed by the instructor and TA. Each student is responsible for recording the progress and results of experiments in a lab notebook, which will be signed off by the instructor at the end of each lab. Each student will then 'write up' the lab *individually (no group efforts on this one!).* Lab write-ups (further described below) are always due the following week, the day before the next lab at 4 PM and are worth 80% of the final grade. On two days during the semester, students will also practice informal oral presentations for 10% of their grade. After week 6, we will have an opportunity to make up a lab from the first session (usually needed for one that "just didn't work out") and a second lecture day to introduce labs 6-10, during which we will break-up and reform lab groups. Weeks 9-13 will rotate through the second lab manual, and the final week will again be a make-up day. **See the attached schedules for your session for details!**

Labs 1-5 and 6-10 are described in full in your two lab manuals. We list the titles here :

1. Lenses (**)	6. Diffraction and Gratings
2. Index of Refraction	*7. Polarized Light (**)*
3. Speed of Light	8. Fiber Optics
4. Michelson Interferometer (**)	*9. Holography (**)*
5. Interference in Thin Films	10. Special Applications

(**) for these labs, you will write a *short informal report* rather than a 3-5 page formal report.

Writing intensive program

PHYS 330L has been designated as the Writing Intensive (WI) course in the standard Physics curriculum. The basic idea is to give you an opportunity to learn technical writing skills for scholarly research in experimental physics. The primary mechanism for learning these skills is through writing *formal lab reports* for 6 of the 10 experiments that you will perform throughout the semester. The other two labs will be reported in an informal, shorter format described below.

We will spend time during the initial class lecture discussing technical writing in

physics, and you will be given feedback on each of your reports. We will re-visit this topic again at the mid-semester lecture (see schedule). Due to the fact that the general structure of the 6 reports will be fairly similar, this feedback will give you a chance to revise and improve your technical writing skills as the semester progresses. You will also have specific opportunities to re-write two of the lab reports in an effort to increase your grade. As outlined in the grading section below, your lab reports are worth 80% of your course grade.

Oral presentations and informal reports

In the sciences, it is frequently the case that scientists travel to conferences and give formal talks on their research. Publishing of results in peer-reviewed journals is the main method of formally communicating significant results. However, scientists also communicate with collaborators informally (via email, these days) and share results and discussions before writing up formal reports for publication in peer-reviewed journals.

In this course, in addition to the 6 formal lab reports (which mimic the paper-writing process in the sciences), you will practice two other common informal forms of scientific communication. For four of your reports (marked with a ** in the list above), you will write a concise email (may be printed as a letter and turned in if preferred) to the professor and TA, describing the experiment you did and the results you obtained. All of the essential questions in the lab manual must be addressed and you must attach a scan of your lab notebook for this experiment, in addition to any figures or tables referenced. Be sure to practice professional communication standards even though this is an informal report, and make sure your "colleagues" (i.e., the professor and TA) have all the information needed to evaluate what you did! The idea is to practice how you would communicate with colleagues or collaborators in the future – you will want them to know exactly what you did, what results you got (including error terms), and a short discussion on what it all means and what problems came up.

A second form of informal communication in the sciences, sometimes called the "elevator pitch", is when you have a few minutes of a colleague's attention to describe some (very important!) scientific discovery you have made. You will have the opportunity to give two brief (5 minute) individual oral presentations to the professor during the semester. During each of these presentations, you will review and explain an experiment of your choice at the whiteboard. As outlined in the grading section, these individual presentations count for 10% of your course grade (5% each). If you wish, you may 'volunteer' to give the oral presentation before I call you up if you feel you will be better prepared to do so that way. We will not begin the oral presentations until the last week of the first round of experiments.

Your Duties

- Read the relevant lab *before the day you perform it.*

- Carefully record the progress of the lab (including problems, mistakes, etc.) in your laboratory notebook. Include preliminary figures and graphs. See laboratory notebook guide below. Be sure to have the professor sign the notebook before leaving each day.
- Write up the lab using the guidelines below for a formal report or above for informal reports. Turn it in by 4 PM the day before the next lab**. All submissions are electronic, and the report must be a single PDF with all elements included.**
- Be prepared to make a mini oral presentation on any lab you have already completed.

Course grading

10% of your course grade will based on "class participation", which includes your level of participation in the experimental work, the quality of the experimental work, and lab notebook practices.

10% of your course grade will be based on your individual oral presentations. During the sixth week of the 1st session, I will start pulling out students for a 5 minute individual presentation at the whiteboard. You can choose any of the experiments you have done in the 1st Session, so you will have the chance to be well prepared. We'll repeat this procedure during the last few weeks of the 2nd Session (you may volunteer to go earlier if you wish). If we run out of time, I may need to have a few of these student presentations during the make-up weeks – make sure you do your two presentations by the final day!

80% of your grade will be based on the average of your formal and informal lab report scores. During the first lecture, we will spend time going over the grading scale for the lab reports. The grade will be based on a rubric which assigns points to each of the relevant aspects of the lab reports. If you are still struggling with your lab reports after a few weeks, a sample of a well-written lab report can be provided to help you develop a feel for what is required.

Lab Manuals

The laboratory manuals should serve as a guide to your experimental work for each of the experiments. *One of the keys to success in these labs is to pre-read the manual for the experiment you will be performing each week*. For consistency, the manuals are all organized as follows:

1. Reference Material: This provides a brief list of recommended reading associated with the experiment. These are listed in order of importance. This list is only a start…there are many other resources which may help you prepare for the lab and write your report. I highly recommend reading at least some of the reference material *before* showing up for the lab.

2. Purpose: This is typically a one or two sentence statement of the primary objective of the experiment. It typically describes the "result" you will try to obtain.

3. Overview and Theory: This section provides the big picture of the experiment. It typically includes a figure or drawing that provides an overview of the apparatus. A theory is then outlined which highlights the physics behind the effects that will be studied and measured. Be sure you fully understand and can derive the equations. If not, ask the TA or instructor for help. The theory will typically end up with an equation relating the desired "result" in terms of parameters you will measure in the lab.

4. Equipment: This provides a list of key equipment to be used in the experiments. However, it is important to emphasize that there are a lot of tools and other equipment that you should feel free to use. If you can devise an alternative way to make a measurement, please try it! If you find yourself thinking "I could do this better/differently if I had this type of wrench, or that type of lens, etc.", please ask. We have lots of stuff in the lab...we've probably got what you are looking for!

5. Procedure: This section provides a *guide* to what actually needs to be done in the lab.

6. Calculations and Questions: This final section asks you to make calculations based on the theoretical equations in the *Theory* section, and the measurements you have made in the *Procedure* section. These will typically be the "results" of your experiment. There are also a series of questions that should be addressed in your lab reports.

Finally, there are usually one or two *non-required questions*. These are typically beyond the scope of this course, but I encourage you to spend some time thinking along these lines. If you are able to address them, please include your thoughts in the lab reports. Go on and take a guess… "wrong answers" here will not affect your grades.

Lab Notebooks

You are required to obtain a standard laboratory notebook for this course. There are several varieties, but the best ones typically have a brown hard-paper cover, and roughly 100 sheets of ~ 9 1/4 X 11 3/4 inch graph paper. **Notebooks without graph paper are unacceptable.** *The UMBC bookstore sells these laboratory notebooks for $16*; they can also be obtained at many office supply stores.

These notebooks are an essential part of modern experimental research, and this course will emphasize developing the skills and habits necessary to document original scientific work. It's not easy to get in the habit of writing everything down,

but it's absolutely essential. You'll learn this first-hand when you sit down a few days later to write up your lab reports. *Before leaving each week, I need to sign-off on your lab notebooks. What I see is a big part of the "class participation" grade.*

You should make every effort to record and describe everything you are doing **(a good model is to assume you will not see the notebook for 10 years, and then want to reproduce your results!).** Write down anything and everything that seems important…and even some stuff that doesn't seem important.
At the end of an experiment, your lab notebook should be full of notes, numbers, data, *and lots and lots of figures*. Draw pictures of everything! Some people take pictures with their cell phones, print them out, and tape them in. The same goes for plots made with mathematics software etc. (Note: cell phone pictures may be shared between group members, but each should do their own plotting).

Formal Lab Reports

You will write a lab report for 6 of the 10 experiments. *Recall that 80% of your grade in the class will be determined based on the average score of your formal and informal reports.* The Teaching Assistant will be grading the lab reports, and we will both be providing you with extensive feedback. The grading will be based on both the quality of the experimental work, as well as the technical writing. Whereas it is not always necessary to get the "right answer" to receive a high grade, poorly written lab reports will ensure a poor grade. Specific details of the grading method can be seen in the Lab Report Guidelines for PHYS 330L (separate document available on Blackboard).

You will turn in your lab reports by 4 PM the day before the next lab. Late reports will be accepted, but their score will be reduced by 1 letter grade (10 pts) per day.

There is no formal length requirement for these reports, although they will typically be on the order of 3 - 5 pages long. The laboratory reports are to be written for an audience that is assumed to have some scientific background, but has never heard of this particular experiment or ideas.

In addition to a title page, the reports will consist of 4 main sections. The exact titles of the sections, and how you break them into subsections, may depend on the particular experiment you are describing, and the results you are trying to convey. Be sure that the end result is a coherent, and somewhat self-contained document. *Keep in mind that an average reader from your intended audience should be able to understand what is going on solely based on your lab report*. Do not assume they have read your lab manual. Do not plagiarize the lab manual or your partner's report! Your writing will need to be extremely clear and concise in order to accomplish this in something like 3 - 5 pages!

The 4 main sections of your lab reports can be loosely described as follows:

1. *Purpose:* This should typically be a one or two sentence statement of the main objective of your work. For example, if your experiment involved measuring the volume of a tennis ball, the Purpose might be something like, "A tennis ball can essentially be thought of as a spheroidal object. In this experiment, we determined the volume of a tennis ball by measuring it's diameter".

2. *Introduction, overview, & theory*: This section of the lab report provides the background and theory needed to understand what you are trying to do in the lab. It may resemble the analogous section in the lab manual, but should typically be much shorter. For example, it is not necessary to entirely re-derive the key equations, unless it seems appropriate. Statements of the kind, "It can be shown that the volume of tennis ball is given by 4/3 π_r3…" are usually suitable. Nonetheless, it is important to emphasize that the intended audience needs to be able to comprehend the analysis. In many cases, it may be better to provide a simple derivation of key equations. Figures are typically required in this section.

3. *Procedure, experimental details, & results*: This section is the chance to show-off your experimental work. A list of equipment is not necessary, or advised. Rather, describe your equipment and arrangement in the context of the overview and theory. In other words, how did you build something up that let you test the theory and/or make the measurements you needed?

For example, statements of the following tone are appropriate: "In order to measure the radius of the tennis ball, we developed a caliper made of rulers and hinges. This allowed us to measure the diameter of the ball, and the radius was determined by dividing this result in half. A graph of our results, as a function of caliper pressure, is shown in Figure 5. We found that the tighter we squeezed the caliper, the smaller the ball appeared. This introduced error into our measurements…''.
This section should contain also contain the main results of your experiment: "we measured the volume of the tennis ball to be $(1.51+/- 0.12)x10^{-4}$ m^3". Plots of data, analysis, etc. should be included in this section. *Make sure that any tables and figures are clearly labeled, and related to the text.*

4. Discussion and Conclusions: This will typically be a two or three paragraph summary of your work. Keep in mind that a *Conclusion* is typically not the same as a *Result*. For example, a discussion and conclusions might be in the spirit of, "Based on…, we conclude that measuring the volume of a tennis ball with calipers can provide a rough estimate of the actual volume. Our approach could be improved by incorporating a pressure sensor…. A better method might involve submerging the ball and weighing the displaced water…''. (note: hopefully your conclusions will be much more positive!)

Safety

Although our experiments are very well tested, and we do not anticipate any problems, it is important to realize that we will be working in an active laboratory environment which poses certain risks. **Our primary goal is to ensure our safety in the lab.** Some of the equipment relies on high voltages and current, and proper precautions must be taken at all times. If you are unsure about the operation of *any equipment or tools*, please ask the instructor or TA for help. The basic rule is to be over-careful.

Many of our experiments will involve the use of lasers. **These lasers can cause serious damage to the human eye. Never look directly into a laser beam, no matter how many times it has been reflected. Always wear laser goggles when they are needed. Do not take shortcuts with laser safety**.

When using a laser, be sure to turn on the "Laser In Use" sign that hangs outside the lab. This will alert visitors to the fact that a laser is turned on inside the laboratory.

2. Familiarize yourself with the location and contents of the first aid kit. It is mounted on a wall in the Foyer area of Rooms 213 & 214, and contains bandages, cleansers, etc.

3. The labs are equipped with a master "kill switch'". Familiarize yourself with the location of these switches. They are the big red buttons located just inside the laboratory doors. Pushing this button cuts off all power to the room. Don't worry …they do not shut down the entire building! In the event of an emergency, please use the "kill switch'" if appropriate.

Error Analysis

Error analysis is a key part of this lab. We will be trying to reduce errors and get the most accurate results that we can. Often times, this means repeating measurements multiple times to reduce statistical error. You are expected to perform error analysis for your results. Results should always be stated in forms like, "my lab partner is (2.0 +/- 0.2) meters tall", rather than "my lab partner is about 2 meters tall". Understand the difference between instrumental errors, systematic errors, and statistical errors in your experiments. You should use the methods of propagation of error*s* introduced in earlier courses such as PHYS122L. If you are not familiar with these ideas, please ask for help. We have handouts that may be of assistance. In addition, many students find the text *Introduction to Error Analysis*, by John R. Taylor, to be very helpful. A copy of this text is available in the Alvin Meckler reading room in the Physics Building.

Academic Integrity

As with all courses, Academic Integrity is required in PHYS330L:

By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating, fabrication, plagiarism, and helping others to commit these acts are all forms of academic dishonesty, and they are wrong. Academic misconduct could result in disciplinary action that may include, but is not limited to, suspension or dismissal. To read the full Student Academic Conduct Policy, consult the UMBC Student Handbook, the Faculty Handbook, or the UMBC Policies section of the UMBC Directory.
The issue of academic integrity, particularly with regards to plagiarism, can be confusing in writing up lab reports. This is primarily due to the fact that the expectations can be different for different courses.

In this course, I encourage you to work together as a team as much as possible on everything except the actual writing of the lab reports. The lab reports should be written entirely by you.

In other words, I encourage team members to meet and discuss their methods, calculations, and results outside of the lab. Working together on the analysis can be just as important and fulfilling as working together on the actual experiment. In almost all cases, the members of a team will have the same data in their lab notebooks; It is therefore entirely reasonable that the members of a team will have the same "results". Working together in obtaining these results is encouraged. However, I emphasize that the team members must not share in the writing of the lab reports. Each person must write up her or his lab report by themselves. This is a key part of your educational experience in PHYS330L.

It is also important to include adequate references in your lab reports. If textbooks, journal articles, etc., are mentioned in your report, you should reference these sources. Proper referencing will be an emphasis during the second Session of the course.

Six tips for success in PHYS 330L:

Because your grade is primarily based upon your lab reports, your success in the class is only limited by the effort you are willing to give. Some tips for succeeding in this regard are:

1. *Read the lab manual and reference material before you arrive each week.* The experiments can be overwhelming if you are thinking about them for the first time when you arrive in the lab. You should have a good understanding of the basic idea of the lab, as well as a solid grasp of the theory involved. In almost all of the labs, the theory derives a result in terms of a few quantities that you will measure in the lab. If you are comfortable with this before you arrive, you will be able to spend much more time on the precision of your measurements and the quality of your results. This is probably the biggest tip for success in PHYS 330L.

2. *Don't leave too soon*. Often times students will be in a rush to make their measurements, and flee the lab as soon as they are done. Later in the week, they analyze their data and realize that their results are way off! It is a good idea to perform at least a brief analysis of your results *before* you leave. That way, if your results are terrible or don't make any sense, you can debug your methods and re-take the data. Complete error analysis is not really necessary here; just get a quick idea if you did it right or not.

3. *Ask lots of questions*! Take full advantage of the TA and instructor. If something is not clear, do not it slip by. Ask as many questions as you can think of...we appreciate it!

4. *Don't rely on the make-up session*. Chances are you will need the make-up session to repeat an experiment that just didn't work out. Please don't skip a lab thinking you can just make it up. You only get one make-up session…save it for something you really need!

5. *Have fun!* Optics experiments can be extremely rewarding, but also extremely frustrating. Keep a good attitude alive when things aren't going well. Sometimes its just a simple tweak of a single knob that is needed to get back on track.

6. *Tinker and explore.* You'll get a great educational experience even by doing the minimum of what's "required" in the lab manual. However, this lab really is a great opportunity for exploration. We have a lot of equipment lying around; please use it all! Try to develop new methods; tinker and take things apart when appropriate!