Syllabus

PHYS 330L: Optics Laboratory
Fall 2020

Instructor: Dr. Vanderlei Martins (Office 429, Physics)
Office Hours: Tuesdays and Thursdays 2:00AM-5:00 PM during the Lab of the other session or by appointment. You can also see me during labs on Tuesday/Thursday.
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Location: Due to COVID-19 restrictions, this laboratory class will be performed remotely, with the students executing most (if not all) of the experiments at home. The instructor will provide a kit with supplies for the experiments.

Please see this Google doc for UMBC Policies and Resources during COVID-19.

Weekly meetings will be performed via webex and will allow for interaction between the individual groups, the TA, and the instructor.

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

Materials:

- **Blank lab notebook** with graph paper (See below). Available at school supply stores, bookstores and online.
- **Home labs** will require computer with internet connection, microphone and camera**;** smart phone for data acquisition, space for executing the experiments.
- **A laboratory kit** containing materials needed for the experiments will be provided to each student.
- **The kits must be returned** in full to the Instructor at the end of the class. Instructions for returning the kit will be provided during classes.

Optional Texts:

Optics by Hecht
Introduction to Optics by Pedrotti and Pedrotti
Fundamentals of Optics by Jenkins and White
Modern Optics by Guenther.
When UMBC is open, all of the above are on reserve in the AOK library and in the Physics Reading Room, and there is a lab copy of Hecht (which may NOT be taken from the lab).

Additional Text: *Introduction to Error Analysis*, by John R. Taylor
When UMBC is open, a copy of this text is available in the Alvin Meckler reading room in the Physics Building and in the lab. *You may consider buying your own copy, as it is a useful reference that will serve you throughout a career in physics or engineering.*

Overview

Welcome to Optics Lab! This semester you (in teams of 3 people) will get to re-create at home some important 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 lasers and CCD sensors) 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.

This is a junior-level lab, thus you will have 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. Feel free to discuss alternative projects with the instructor.

Learning Outcomes

PHYS 330L has two learning outcomes that contribute to the overall educational objectives set out by the Department for all Physics BS degree recipients:

1. The ability to communicate scientific information effectively, both verbally and in writing.
2. Demonstrated ability to design and carry out experiments using modern equipment and analyze and interpret experimental data.

Assessment of Learning Outcomes

The two learning outcomes will be assessed using the methods below. By the end of the course, students should be able to:

1. Follow a general laboratory guide and develop specific strategies for accomplishing prescribed measurement goals using available lab materials and equipment.

2. Write a mature laboratory report which includes the most common elements and organization of scientific papers published in journals today.

3. Replicate the key experiments demonstrating the nature of light and optical systems, such as: measuring the spectrum of a light source, measuring the thickness of an object using thin-film interference, characterizing single and double slits using a laser, measuring polarization properties of light, and measuring Brewster's angle.

4. Demonstrate an understanding of the concepts behind modern optics technology.

Class Organization

Due to COVID restrictions this lab was redesigned to be performed at home. Students will be provided with an experimental kit containing the materials needed for the performance of the experiments. In addition to the provided materials the students will need to have a computer with good internet access, microphone and camera, as well as a smartphone for data acquisition and display. Students who have any concern about these resources should contact and make arrangements with the instructor right away.
Students will be divided by the instructor in groups of 2 to 3 participants. The composition of the groups may change a few times during the semester. All groups will be performing the same experiment simultaneously.
Students are required to write a full/formal report for every experiments. The reports must be in PDF format (other formats will not be accepted), and students will upload all materials to their assignment slots on blackboards. All reports and assignments must be uploaded within the deadline. Late assignments will have penalties or, in same cases will not be accepted.

Pre-Lab Report: To ensure that you will not waste your time by starting the experiment unprepared, each student is required to hand in a pre-lab report of no more than 3 pages prior to the beginning of the experiment. The pre-lab is due by 11am of the day of first class for that experiment. The participation in that experiment and its final report will not be accepted unless the instructor approves the pre-lab report prior to the class.

In this document you should explain: i) the purpose of this experiment; ii) give a brief overview of the theories/principles underlying the experiment; iii) give an outline of your experimental approach; iv) provide sketches of the experimental setup.

More specifically you are expected to explain how you will use the equipment available for the lab, what kind of measurements you will make and what the purpose of these measurements is. Doing a good job on the prelab is important as it will assure that you will be able to use the lab time effectively and it will also

provide the basis for your lab report. You are allowed to use parts or even the full pre-lab report as part of your final report. Just make sure the final report is well written, with good flow.

Before performing the experiment the instructor will discuss your prelab with you to make sure that there are no issues that will compromise your safety and prevent you from completing the work. You are welcome to contact the instructor or the TA at anytime about the experiment, especially the availability of the equipment you may need. The pre lab is due before 11am at the day of the class. Your pre-lab should be submitted in PDF format. I will only take PDF files. Occasionally, the students will be asked to present their pre-lab material in power point format to the whole class.

For safety reasons, you will be turned away if your instructor believes that you are not prepared to perform the assigned experiment. When this happens, your grade on this experiment will be reduced by 50% automatically (your partner's grade is not affected). You (and possibly your partner) will be allowed to continue on this experiment later during the make-up weeks.

All members of a team must be active in doing the experiments. Each student is responsible for recording the progress and results of experiments in their individual lab notebook, which will be signed off by the TA at the end of each lab. Each student will then 'write up' the lab report *individually (no group efforts on this one!).* Lab write-ups (described in more detail below) are always due the following week, on Monday if you are in Tuesday's group or on Wednesday for Thursday's group, at 4 PM. This way you can spend the night before the lab on preparation for the upcoming lab rather than report writing. Occasionally, each student will give an informal presentation about the work she/he is doing.

Make-up lab policy
Make-up labs will be given only in the event of a documented issue or problem and the instructor must be notified as soon as possible. Having to go out of town on a recreational trip does not constitute a valid reason for requesting a make-up.

The second half of the semester begins with a second lecture day to introduce the additional labs. The lab groups will be reorganized.

The planned labs for these class (in no particular order) are:

- *Lenses and geometrical optics*
- *Index of Refraction*
- *Optics and spectroscopy*
- *Imaging and sensor characterization*
- *Diffraction and Gratings*
- *Polarized Light*
- *Atmospheric Optics Measurements*
- *TBD (to be determined)*

The last experiment (TBD) will depend on the evolution of the class and could be a project or a demonstration presented from the Optics Lab at UMBC.

Course grading

20% of your course grade will be based on your laboratory practices. That includes participation in the experimental work (5%) as judged by the instructor and the TA based on observation of the work in the lab and questions asked randomly during the lab session. The remaining 15% depends on the quality and completeness of the lab notebook.

5% of your course grade will be based on your individual oral presentations. Beginning the second week of actual experimental work, students will be selected randomly and asked to report on their current work in a semi-formal manner at the whiteboard. The technical correctness, completeness, and overall quality of the presentation will be assessed.

75% of your grade will be based your pre-labs and lab reports. During the first lecture, we will spend time going over the requirements 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.

Lab notebook

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 about $16*; they can also be obtained at many office supplies stores or online.

The notebooks are an essential part of 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. *The TA and I will sign-off on your lab notebook every week. The notebook is to be kept current and organized at all time. You must take not and record all steps and results from your experiments.*

You must produce plots and analyze your results in real time. As soon as you measure something, plot it right away. This is really important!!!

The lab notebook (not the formal report) is the place where everything about the experiment is recorded. It is written in chronological order as ideas are noted during preparation, observations and measured values are recorded during the measurement, and data evaluation and error estimation are carried out after the measurement. The lab notebook should have enough information to completely reconstruct the experiment and understand the evaluation in every detail. Even the conclusions can show up in the notebook in some preliminary way.

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! You can take pictures with your cell phone, 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).

Important Note: You must *always* attach good-quality pictures or scans of the relevant lab notebook pages to all reports. If you use pictures, try to apply some App that corrects for page and color deformation in order to produce a picture with a scanner-like type of quality. On the cell phone, I like to use an App called CamScanner. You can also use a regular desktop scanner.

Oral presentations

It is a common situation in real life, that a visitor walks in – often unexpectedly – and asks about the ongoing experiment. It is often a very important event, as the "visitor" can be a potential donor looking for a good place for his donation, a well-known scientist from another university or government lab, who is a potential post-doc advisor, a politician with budgetary responsibilities, a potential collaborator, etc. Sometimes the visitor is accompanied by the local boss, the thesis advisor, department chair, section director. Good performance can bring promotion, collaboration and funding. (Another opportunity for informal communication is a meeting at a conference.)

I will put everyone's name into a bucket and randomly pull out a name at an arbitrary time for a 3-5 min informal lecture and a few questions. You must be always ready. Sometimes I will let you speak uninterrupted, sometimes I will rather ask questions. I will not be mean and stand in silence if you cannot give a lecture right off the bat. I will ask questions to help you get going, just as an experienced visitor would.

A good informal oral presentation is like the abstract of a paper. It includes motivation, experimental methods, findings and main conclusions, all in one breath. Most visitors have very limited time and you want to tell as much as possible about your work.

Formal Lab Reports

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 all the

experiments.

We will discuss technical writing in physics during the initial lecture, 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 reports will be fairly similar, this feedback will give you a chance to revise and improve your technical writing skills as the semester progresses.

The Teaching Assistant will be grading the lab reports, and we will both provide extensive feedback. The grading will be based on the quality of both the experimental work **and** the technical writing. Whereas it is not always necessary to get the "right answer" to receive a high grade, fundamentally incorrect physics or poorly written lab reports will ensure a poor grade.

You will turn in your lab reports by 4 PM six days after the lab.
Late assignments (including reports) are usually not acceptable but in special circumstances, when accepted, the total number of points will be reduced as a function of the delay (normally at the rate of 10 points per day).

There is no formal length requirement for these reports, although they will typically be on the order of 4 - 6 pages long in single-spaced Times New Roman or similar font with figures and tables pasted in. The laboratory reports are to be written for an audience with similar background to yours, but without any knowledge of this particular experiment or ideas involved.

In addition to a title page, the typical report will consist of 4 main sections that may be divided to sub-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 mostly 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 4 - 6 pages!

At the end of the report, do not forget to attach the lab notebook scans (all in one PDF).

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

1. *Abstract:* A summary of the entire paper in 100-150 words. The Abstract is not a part of the main text. It should not contain new information; anything mentioned in the abstract must be repeated, usually in more detail, in the main text. It must include the motivation, methods, results and the main conclusions, all in a very

compressed form. It is an essential part of the paper. It is often freely available, even if the paper itself is not, thus users decide whether to buy and read the entire paper based on the Abstract. For some, the information in a good Abstract may be sufficient.

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 and in your own words. For example, it is not necessary to entirely re-derive the key equations, unless it seems appropriate. Nonetheless, it is important to emphasize that the intended audience needs to be able to comprehend the analysis. Any equation that is required for the data evaluation must be mentioned here or possibly in the next section. Figures are typically required in this section. References to things you do not derive or figures you do not make yourself are required.

3. *Procedure, experimental details, & results*: This section is the chance to show-off your experimental work. A list of the equipmental components 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 also contain the main results of your experiment: "we measured the volume of the tennis ball to be $(1.51 \pm 0.12)\text{x}10^{-4}$ m^3". Notice that the error and unit must be included. Plots of data, analysis, etc. are essential in this section. *Make sure that any tables and figures are clearly labeled, have a caption, and related to the text.*

4. Discussion and Conclusions: This will typically be a two or three paragraph summary of your work in a more general context. Keep in mind that the *Conclusion* is not the same as the *Result*. It does not repeat the details, but focuses on the meaning and consequences, possible problems, error sources, and improvements.

Your Duties

- Read the relevant lab *before the day you perform it.* Consult the background material. Make sure you know what you are going to do and what it all means before coming to lab.
- Prepare and turn in your pre-lab report by 11am before each experiment

starts.

- Carefully record the progress of the lab (including problems, mistakes, etc.) in your laboratory notebook. Include preliminary figures and graphs. Be sure to have the professor or TA sign the notebook before leaving each day.
- Write up the lab using the guidelines above for a formal report or for an informal reports. Turn it in by 4 PM six days after the lab**. All reports are submitted to blackboard, in a single PDF with all elements included.** Be advised that "forgetting" your scanned lab notebook pages can lose you 15 points! A rubric for the reports will be available on blackboard.
- Be prepared to make a mini oral presentation on the lab you are working on.

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. <u>There are also a series of questions that should be addressed in your lab reports</u>.

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.

<u>Safety</u>

1. 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 execution of the labs.** 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 tool*, 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 (laser pointers at home). **These lasers (even a laser pointer) can cause serious damage to the human (or pet's) eye. Never look directly into a laser beam, no matter how many times it has been reflected.**

- When in the actual lab at UMBC, always wear laser goggles when they are needed.
- At home, make sure the laser beam is contained in a geometry that prevents you or other people in your house to look directly at the beam. Sometimes, the safest geometry may be to perform the experiment on the ground. If you are using a table, make sure point the beam towards a wall or some other barrier that prevents anyone to look directly at the beam.
- Be especially careful with kids and pets around your experimental area.
- Only turn on the laser for the brief periods needed for the experiment.
- Treat all lasers seriously.

Do not take shortcuts with laser safety.

When using a laser in the lab, 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. At home, make everyone aware that the lasers are not toys and should

not be played with. Do not allow anyone else to “play” with the provided lasers and equipment.

2. If classes resume in the lab, 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.

4. Messy environment invites accidents, especially when visibility is limited, like in a darkened lab. Keep your workspace orderly. Play attention to electrical cords and the overall positioning of your equipment and setup.

5. Light sources may get hot. Be aware of it and prevent accidents and fire hazards. Only keep lights on for the time they are needed.

6. Be aware of the potential breakage of glass bulbs and lenses. CFL light bulbs in particular contain mercury inside and should be protected at all times.

7. Make sure you store your equipment safely and in an organized fashion after each experiment. Always place the components back in the correct box and containers.

Error Analysis

Error analysis is an important 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 with the estimated error and the error evaluation must be clearly presented in the Lab Notebook. 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," including experimental errors. 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 as a writing-intensive course.

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 half 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 the online sessions 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, or they forgot to measure a necessary quantity. It is a good idea to perform at least a brief analysis of your results and it is absolutely essential to **make some plots *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 let 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 or some documented emergency. Please don't skip a lab thinking you can just make it up. You only get one make-up session in very special circumstances… 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!