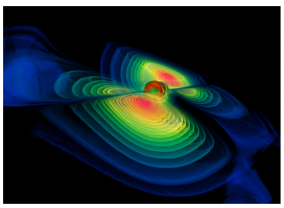
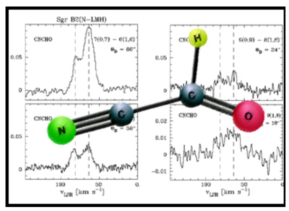
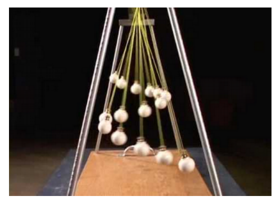
   

Physics 218
Oscillatory and Wave Phenomena

Spring Semester, 2021

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<u>General Course Information</u>

In this course, we will investigate the physics of periodic motion – i.e., motion that regularly repeats. Periodic motion plays an important role in nearly every branch of physics and is ubiquitous in everyday life. Sound waves, water waves, radio waves, visible light, the flow of charge in certain circuits, the vibration of atoms in a crystal, and even the behavior of certain fundamental particles in the early universe all manifest this behavior.

The common thread which unites all of these these phenomena is not *physical* — indeed, the physical principles which govern the corresponding systems are very different! Rather, it is *mathematical*: the equations which describe how the relevant physical quantities evolve or change in each system turn out to have a very similar mathematical form. We will therefore focus a great deal of attention in this course on the mathematical tools useful for describing and studying systems which exhibit periodic motion, including power series, complex variables, linear algebra, Fourier analysis, and a variety of strategies for solving differential equations. We will also examine why so many different physical systems exhibit these phenomena. Learning to recognize mathematical analogies between seemingly unrelated physical systems and exploit those analogies to solve problems lies at the core of what it means to "think like a physicist."

All of this makes this course a challenging one, but it makes it a rewarding one as well. Indeed, you can look forward to being able to do all of the following by the time this semester concludes.

- You'll be able to assess whether **oscillatory motion** is likely to arise in a given physical system and to describe that motion quantitatively.
- You'll be able to apply the techniques of **linear algebra** in order to analyze systems of coupled oscillators.
- You'll be able to apply the technique of **Fourier analysis** to oscillator systems.
- You'll learn a number of techniques for solving simple **ordinary differential equations** and be able to apply them in order to solve physics problems.
- You'll be able to **assess and report the uncertainty** in an experimental measurement.
- You'll be able to use **computational tools such as Python and Mathematica** in order to solve problems numerically that cannot be solved analytically.

The prerequisites for this course include Phys 133 or 152. In addition, since understanding the natural phenomenal we will be studying in this course involves solving differential equations and applying the principles of linear algebra, Math 264 is also a co-requisite. However, rest assured that we will also be getting an introduction to these topics in this course as well. An understanding of multi-variable calculus at the level of Math 263, which is a prerequisite for Math 264, is also implicitly assumed.

Components of the Course

The course will consist of class meetings, reading assignments in the text, homework problems, labs, three mid-term exams, and a final exam. These are described more fully below.

Class Meetings:

Class meetings will be held from **9:00 AM – 9:50 AM Eastern Time** each Monday, Wednesday, and Friday during the semester. These meetings will all take place over the Zoom platform at the same link, which is

- https://lafayette.zoom.us/j/91454008697

The password is provided on the course Moodle. Regular attendance at these class meetings is expected. A schedule of topics to be covered each day is listed on the course web page. Much of the material covered in this course – and many of the homework problems that you'll be working through – are quite challenging. It is therefore important that you come to class prepared to ask questions and to engage in discussions. You should be aware that class meetings will involve not only my lecturing to you about the material covered in the readings (which is not necessarily the best way for me to help you learn the material), but a variety of other activities as well – the benefit you get out of which is directly proportional to the effort you put in.

I would like us to be able to simulate the atmosphere of a physical classroom to whatever extent we can under these circumstances. For this reason, I would like to ask that you have your camera on during class meetings and to use the "gallery view" option on Zoom so that we can all see each other and respond to each other's visual cues. I will do the same. That said, if there are extenuating circumstances which make having your camera on an issue for you, please reach out to me for any concerns about this expectation as soon as possible and we will work out an equitable solution. Please mute yourself when you are not speaking in order to reduce background noise. Please raise your actual hand in order to take part in the discussion until we find our rhythm. If I do not see your actual hand, please raise your "digital hand." We will review how to do this and how to use other features of Zoom during our first class meeting.

Textbook:

The required textbooks for this course are

- Walter Fox Smith, *Waves and Oscillations* (Oxford University Press, 2010).
- John R. Taylor, *An Introduction to Error Analysis*, 2nd Ed. (University Science Books, 1997).

I will also be posting on the course Moodle a set of my own lecture notes on oscillatory and wave phenomena, entitled *Slightly Disturbed: A Mathematical Approach to Oscillations and Waves*. These notes focus much more on mathematical methods than does Smith's book and are therefore intended primarily as a supplementary text.

In addition to these required texts, given the mathematical nature of the subject material and the variety of special functions we will encounter over the course of the semester, you may want to have a good reference volume on mathematical methods in physics on hand. For this, I recommend the following:

- Mary L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd Ed. (Wiley, 2005).
- George B. Arfken, Hans J. Weber, and Frank E. Harris, *Mathematical Methods for Physicists*, 7th Ed. (Academic Press, 2012).

Finally, since we will be using both Python and Mathematica extensively in this course, you may find it useful to have a guide or tutorial for each that you can reference. A good introductory reference for Mathematica is:

- C-K. Cheung, Gerard E. Keough, Robert H. Gross, and Charles Landraitis, *Getting Started with Mathematica*, 3rd Ed. (Wiley, 2009).

A number of additional tutorials, programming guides, and other references for both Python and Mathematica are also available online. Links to some of the more useful ones for the applications we'll be dealing with in this course will be posted on the course web page.

Homework Assignments:

Working through problems is an essential part of this course. It gives you a chance to hone your critical-thinking and problem-solving skills while applying the concepts you'll be learning in class in new ways. For this reason, I will be assigning a number of homework problems each week which I feel provide practice with the most crucial aspects of the material we're covering in the course. A list of the problems included in each problem set will be posted on the course Moodle. Some of these problems will require nothing more than pen, paper, and a lot of careful thought; others are designed to give you some practice solving problems using computational tools like Mathematica or Python.

All homework problems are **due at 5:00 PM Eastern Time on the day indicated on the course schedule**, which is typically a Friday. Your work should be submitted in PDF format using the appropriate upload link on the course Moodle page. However, you do not need to typeset your homework in a fancy way. Writing your work out by hand on paper, scanning or photographing the pages, and converting the images to PDF format is perfectly acceptable. You may still turn in late homework for reduced credit (a 10% penalty for every 24 hours it is overdue) up until the beginning of the next class meeting (typically the following Monday at 9:00 AM Eastern Time). However, because we will frequently discuss homework problems in class, late homework will not be accepted beyond that point.

I wholeheartedly encourage you to work together on homework problems with other students in the class. This can be a very productive way of expanding your own knowledge, and working with other people to solve problems is a big part of how science is really done. However, the written work that you turn in to me must be your own work: it should reflect your own understanding and should be written up independently after all discussion between you and your peers is complete.

Midterm and Final Exams**:**

There will be three mid-term exams given during the course. **The first exam will be held on Mar. 5th, the second on Apr. 9th and the third on May 7th**. These tests are designed give you the opportunity to demonstrate how well you understand the material. Mid-term exams will be given during our usual class-meeting time, but class meetings will begin at **8:30 AM Eastern Time** on exam days in order to provide you with additional time to upload your exam to the course Moodle. In addition, there will also be a final exam at a date and time to be determined by the Registrar.

Laboratory:

The laboratory section of this course, which will be taught be Prof. Andy Dougherty, is an integral part of the course. In some labs, you'll be conducting hands-on experiments in order to explore the phenomena we'll be examining in course meetings; in others, you'll be honing your computational skills by performing numerical simulations of these phenomena. Weekly lab meetings, in which Prof. Dougherty will provide an introduction to each experiment, will take place from **11:00 – 11:50 PM Eastern Time each Thursday**. You will perform the actual experiments on your own time. Further information about the laboratory portion of this course will be provided by Prof. Dougherty during your first lab meeting.

Grading and the Honor Code

Course Grade:

Your grade in the course will be determined by the following criteria:

Homework	18%
Laboratory	25%
Mid-Term Exam I	12%
Mid-Term Exam II	12%
Mid-Term Exam III	12%
Final Exam	21%

Office Hours:

My official office hours this semester will be held on **Mondays from 10:00 – 11:00 AM Eastern Time, Wednesdays from 3:00 – 4:00 PM Eastern Time, Thursdays from 11:00 AM – 12:00 noon Eastern Time, and Fridays from 2:00 – 3:00 PM Eastern Time** unless otherwise noted on the course web page. What this means in a distance-learning context is that I will have a Zoom meeting open during each of those time windows, and you should feel free to join the meeting at any time within those windows if you have questions about any aspect of the course. The link for this office-hours Zoom meeting is

- https://lafayette.zoom.us/j/99772595796

The password is provided on the course Moodle. Please note that this is a different link from the one we will be using for class meetings. The reason is that these office hours are open to students from all courses I am currently teaching. If I am meeting with another student at the time you join the Zoom meeting, I may ask you to wait in the waiting room for a bit. However, if you and other students in the course have the same question, you can certainly meet with me as a group.

If you are unable to drop by during these official office hours, you may also email me to make an appointment to meet at some other time. However, I recommend that you do this as far in advance as possible in order to ensure that we can find a time to meet.

Intellectual Honesty:

All exams in this class are closed-book. Calculators are permitted, and you will also be provided with a document containing a list of useful equations and fundamental constants at the start of each exam. However, the use of any other resources is not permitted. When studying, working in the laboratory, or working on homework problems, I encourage you to work with other students. However, you may not consult a solutions manual or any other source for answers to the problems, and the write-up that you submit to me for each problem should be your own work.

As always, you are expected to abide by the principles of intellectual honesty and academic integrity outlined in the Lafayette Student Handbook, which can be found at

- https://conduct.lafayette.edu/student-handbook/

Other Useful Information

Accessibility Services:

In compliance with Lafayette College policy and equal access laws, I am available to discuss appropriate academic accommodations that you may require as a student with a disability. If you are requesting accommodations, you must register with the Accessibility Services Office (administered by the Academic Resource Hub) for disability verification and for the determination of reasonable academic accommodations. Accessibility Services will then provide me with a document which outlines what those accommodations are. I cannot provide accommodations until I receive such a letter. Requests for academic accommodations must be made within the first two weeks of the semester, except in unusual circumstances, so that suitable arrangements can be made in a timely manner.

Informal Surveys:

As the semester progresses, I want to hear from you how you feel the course is going, what you like, what you don't like, what your concerns are, and how you think the course could be improved. Therefore, throughout the semester, you'll have the opportunity to fill out short surveys and informal evaluations on the course Moodle so I can get your feedback.

Course Communication:

This syllabus, a list of assigned readings and problem sets, and other course materials will be posted on the course web page, which can be found at

- https://workbench.lafayette.edu/~thomasbd/Phys218-OscillationsWaves-Spring-2021/Phys218-OscillationsWaves-Spring-2021.html

In addition to the course web page, there is also a Moodle page for this course which I will frequently use in distributing course materials, communicating with the class, etc. The Moodle page can be found at

- https://moodle.lafayette.edu/course/view.php?id=20036

Occasionally, it may be necessary for me to communicate additional information (scheduling changes, clarifications about homework problems, etc.) to the class as a whole. When I do so, I will use your official Lafayette email addresses for all course-related correspondence, so make sure to **check your Lafayette email regularly**.

Privacy Statement Concerning Course Materials and Classroom Recordings:

At Lafayette College, all course materials are proprietary and for class purposes only. This includes posted recordings of lectures, worksheets, discussion prompts, and other course items. Re-posting such materials or distributing them through any means is prohibited. Such materials should not be re-posted or distributed through any means. You must request my permission prior to creating your own recordings of class materials, and any recordings are not to be shared or posted online even when permission is granted to record. Permission will be granted only when sanctioned as an academic accommodation in an official letter from the Accessibility Services Office. If you have any questions about proper usage of course materials please ask me. Please also be in contact with me if you have any concerns with being recorded during the course.

Online discussions in Moodle occurring during synchronous class sessions should also remain private and not be shared outside of the course. Courses using Moodle will make student information visible to other students in this class. Student information in courses is protected by the Family Educational Right to Privacy Act (FERPA). Disclosure of student information to unauthorized parties violates federal privacy laws and it must not be shared with anyone outside the class. Questions can be referred to the Registrar's Office.

Mandatory Credit-Hour Statement:

The student work in this course is in full compliance with the federal definition of a four-credit-hour course. The full policy and practice statement can be found on the Registrar's Office website at

- http://registrar.lafayette.edu/additional-resources/cep-course-proposal/

Winter-Weather Emergencies:

Given that this course is fully remote, you should assume that class meetings will occur as usual, despite any weather-related issues, even if campus offices open late or close early. In the rare event that class must be canceled, I will notify the class by email.

In Closing

On a final note, I want to make it clear that I'm aware of how difficult learning can be in such difficult and unpredictable times. I will do my best to be flexible in light of the complex and varied situations that you are facing, and I ask that you be open with me about these situations and alert me to any issues that arise. I will likewise let you know if my own circumstances change and will do my best to communicate any changes to the course schedule (or to any other aspect of the syllabus) to all of you in a timely manner.

Nevertheless, despite these uncertainties, we have a fascinating and rewarding semester ahead of us. True, the material we will be covering is challenging and quite abstract; however, it is also immensely rewarding. Systems which manifest oscillatory or wave phenomena appear seemingly everywhere in nature, and understanding them better will vastly enrich your understanding of the world around us, while the mathematical and computational skills you'll be practicing and honing in the process will serve you well in any field of physics – and in many fields outside of physics as well.

Course Schedule

The full, up-to-date schedule for the course, including due date for all assignments is available on the course web page.

Week	Topics and Readings	Due Dates
Week 1 2/8 – 2/12	**The Simple Harmonic Oscillator** Smith: 1.1 – 1.9; Thomas: 1.2 – 1.3, 3.1 – 3.3	HW1 (Due 2/12)
Week 2 2/15 – 2/19	**Examples of Simple Harmonic Motion** Smith: Ch. 2.1 – 2.2; Thomas: 2.1, 2.6 – 2.7	HW2 (Due 2/19)
Week 3 2/22 – 2/26	**Oscillations in Materials** Taylor: 1 – 4, Smith: 2.4 – 2.5; Thomas: 4.1 – 4.3	HW3 (Due 2/26)
Week 4 3/1 – 3/5	**Drag Forces and Damping** Smith: 3.1 – 3.4, 3.6; Thomas: 5.3 – 5.4	Midterm I (3/5)
Week 5 3/8 – 3/12	**Driven Oscillations** Taylor: 5; Smith: 3.5, 4.1; Thomas: 5.5, 6.1 – 6.2	HW4 (Due 3/12)
Week 6 3/15 – 3/19	**Resonance Phenomena** Smith: 4.2 – 4.7; Thomas: 6.3 – 6.7	HW 5 (Due 3/19)
Week 7 3/22 – 3/26	**Non-Linearity, Chaos, and Numerical Methods** Smith: 4.8 – 5.2; Thomas: 9.1 – 9.2	HW6 (Due 3/26)
Week 8 3/29 – 4/2	**Coupled Oscillations** Smith: 5.3 – 5.8	
Week 9 4/5 – 4/9	**The Mathematics of Coupled Oscillations** Smith: 6.1-6.3, 6.6; Thomas: 9.4-9.8	Midterm II (4/9)
Week 10 4/12 – 4/16	**Eigenvalues, Eigenvectors, and Normal Modes** Taylor: 8; Smith: 6.4 – 6.5, 6.7; Thomas: 9.9	HW7 (Due 4/16)
Week 11 4/19 – 4/23	**From Oscillations to Waves** Smith: 7.1 – 7.8; Thomas: 9.10 – 9.11	HW8 (Due 4/23)
Week 12 4/26 – 4/30	**Fourier Analysis** Smith: 8.1 – 8.5, 8.7; Thomas: 7.1 – 7.8	HW 9 (Due 4/30)
Week 13 5/3 – 5/7	**Traveling Waves** Smith: 8.6, 9.1-9.5	Midterm III (5/7)
Week 14 5/10 – 5/14	**The Medium and the Message** Smith: 9.6-10.3	HW10 (Due 5/12)
Week 15 5/17 - 5/21	**Reflection and Transmission** Smith: Ch. 10.5 – 10.7	HW 11 (Due 5/19)
Final Exam Week		Final (TBA)