Physics 327—Advanced Classical Mechanics
MFW 2:45 pm – 3:35 pm
Course Description, Spring 2024

Instructor:	Andrew Dougherty
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E-mail:	doughera@lafayette.edu
Web Page:	`http://workbench.lafayette.edu/~doughera/`
Course Web Page:	`https://moodle.lafayette.edu/course/view.php?id=27051`

Office Hours: Please feel free to e-mail or call at any time and ask a question or set up an appointment. As we start the semester, I will be holding in-person office hours. If you prefer to meet virtually, over Zoom, we will use the class link on our Moodle page.

You are not limited to the listed times. I will also normally be available on most other days during the free times indicated on my schedule.

Classes on Snow Days and Other Emergencies: If I am unable to make it to class, I will send out an email via Moodle.

Web Pages: All course assignments and documents will be posted to our Moodle site `https://moodle.lafayette.edu/course/view.php?id=27051`.

Description: This course presents a rigorous development of classical non-relativistic mechanics. Topics include nonlinear oscillators;, central-force motion, celestial mechanics and the N-body problem; Lagrangian and Hamiltonian formulations; rotation and rigid body motion; and collisions and scattering. We will use both analytical and numerical techniques to study these phenomena.

Prerequisites: Phys 218 (Oscillatory and Wave Phenomena); Math 264 (Differential Equations).

Text: *Classical Mechanics*, by John R. Taylor (University Science Books). Any additional resources needed will be linked from our Moodle site.

Student Learning Outcomes:

The main goal of this course is to help you understand, identify, and apply the fundamental principles of classical mechanics in a variety of situations. You should be able to use both qualitative reasoning and quantitative problem-solving skills in applying those principles. A second goal is to help you continue to grow in the *process* of doing physics, including skills such as developing and testing models, interpreting experimental data, solving problems, and communicating results.

Specifically, upon successful completion of this course, you should be able to

- Analyze physical situations using non-Cartesian coordinate systems.
- Understand and apply the principles of the calculus of variations.
- Use Lagrange's equations to solve mechanics problems.
- Evaluate two-body problems using the one dimensional central force formalism.
- Analyze phenomena in rotating reference frames.
- Calculate the rotational motion of three-dimensional bodies.
- Use generalized coordinates and the Hamiltonian formulation of mechanics.
- Use numerical tools to solve mechanics problems

Grades: Your grade will be based on written homework (40%), two tests (20% each), and the final exam (20%).

Tests: There will be two in-class tests on the dates indicated on the syllabus. These tests will likely consist of two parts: A short in-class section, and a longer open-book take-home portion. More details will be given closer to the test dates.

Final Exam: There will be a comprehensive final exam at a time to be arranged by the registrar. *Please do not make travel arrangements that may conflict with the exam before that time is set.*

Homework: Assignments will be given regularly and will ordinarily be due at the beginning of class on the dates indicated on the syllabus.

- You are encouraged to work together on homework assignments, but collaborations must be acknowledged and should not be one-way only. You must fully understand whatever work you turn in. See the section on Academic Honesty below for more details.
- Problems will be due at the *beginning* of class. **Late homework will normally not be accepted**.
- For written homework, I expect your work to be clearly organized and easy to follow. You should include not just numbers and calculations, but also include some text to explain *what* you are doing and *why.* This can often be quite brief, but it is *your* responsibility to make your reasoning clear; it is not the reader's responsibility to try to figure out what you meant. Homework that is incomplete or difficult to understand will not get full credit. The following guidelines are intended to help *you* present your work effectively:
    1. Be sure to include your name on each page.
    2. Each problem should be clearly labeled.
    3. It is often helpful to include figures. Any figures should have clear labels.
    4. Show your work clearly, and include all non-trivial steps. Use words to explain what you are doing and why. This can often be very brief, something like "Use conservation of energy."
    5. Allow plenty of space.
    6. Put a $\boxed{\text{box}}$ around your final solution, including correct units.
- **Illegible papers will not be accepted**. If I have difficulty reading or understanding your work, I may return it to you ungraded for re-submission. You may resubmit a legible version (along with the original) by the next class meeting, but that version must not have any new content—it must simply be a legible version of the original.
- Please look at the homework problems ahead of time and ask questions about them either in or out of class. I am happy to give whatever help you need, but it is important that you eventually learn to do these problems on your own—after all, that's what you will have to do on the tests.
- Homework will normally be due on Wednesdays. If you look at the problems ahead of time, I will be happy to spend class time on Mondays going over any difficulties that might arise.

Computer Work: Much of the most interesting and useful current research in classical mechanics involves systems where simple analytical solutions are no longer possible. Analytical solutions still often present the framework for further exploration, but they are not the final answer. Accordingly, we will explore methods to go beyond such solutions, both analytically, through perturbation theory, and numerically.

Some of the homework assignments will involve numerical calculations and simulations. Most of these will be done in a tool such as *Mathematica* or `python`. Although I will normally use *Mathematica*, you may use whatever tool you wish. I assume you are familiar with at least the basics of *Mathematica*, but will give explicit instructions for new, novel, or advanced features that we may use. I will post any *Mathematica* notebooks or `python` programs used in the class on the course web site. Please ask if you need further help. I want you to have time to think about the physics at hand, not get held up by syntax issues.

Academic Honesty: The fabric of science, and indeed any intellectual endeavor, is built on the integrity of all involved. Accordingly, I take academic honesty very seriously. I expect that you will abide by the "Principles of Intellectual Honesty" appearing in the Lafayette College Student Handbook.

Working with others is often a helpful way to learn physics. For this course–and indeed for most advanced courses in any discipline—I believe such collaboration to be an essential element for success. I encourage you to collaborate with each other, but unless specifically directed otherwise, all work you turn in *as* your own should *be* your own. My expectation is that everyone will be open to both giving and receiving aid from their peers.

Some students also find it useful to consult other texts, friends, and even a variety of on-line sources. In all cases, though the principles of academic honesty apply: All nontrivial collaborators and external sources must be acknowledged (apart from your textbook and instructor). You may seek help understanding a problem, but all work you turn in must be your own original work. Copying an answer from another source, such as CourseHero, Chegg, Bartleby, or a generative AI source, is a violation of the Academic Honesty Policy. Although some students believe that looking up solutions as soon as they get stuck helps their learning because they get immediate feedback, I would argue that the negatives of this approach outweigh any benefits.[1] In particular, merely looking up a solution:

- Creates a false sense of security that won't be there during exams.
- Can replace other healthy learning behaviors, such as: reading through the text for missing concepts or similar examples; asking a friend; asking a professor; taking a break and coming back to the question later; having a "Eureka" moment when out for a walk. These are all healthy learning behaviors, and doing less of them is a negative.
- Often fails to lead to actual learning. It won't necessarily help you the next time you encounter a somewhat similar situation.
- Can lead to a culture where it feels like everyone knows the answer all the time and being unsure of a solution feels abnormal. This is exactly backwards. Being unsure of a solution is normal.

Please read the department's Academic Honesty policy for the rules regarding collaboration. Feel free to ask if you have any questions about this policy.

[1] This discussion is based on one in Prof. Boekelheide's syllabus.

Your Responsibilities:

Read the text. Your text is a critical resource for this class—it is a source of definitions, facts, ideas, explanations, and derivations. I do not intend to spend class time simply repeating the text. Instead, class time will be used to elaborate those features, answer your questions, do examples, and practice applying those ideas to various physical situations.

Accordingly, you should read the text ahead of time. I have included a detailed daily syllabus so you know what the assigned readings for each day will be.

Ask questions. If you are confused, it is important that you stop me and try to sort it out rather than falling behind. *Please* interrupt and stop the class whenever anything isn't clear. Remember that if you are confused, there are almost certainly many others who are confused as well, and they would welcome your question.

Keep up with assigned work. A good rule of thumb is that you should anticipate spending approximately 12 hours a week for each college course. This means you should anticipate spending an average of 9 hours per week outside of class.

Plan ahead. Classical mechanics problems are often *long* and complex. They challenge you to extend what you know to ever-more realistic and complex situations. When you are doing a problem, the answer is usually not immediately obvious. It is not always easy to tell whether you are on the right track or not—sometimes you have to work for a while to tell. I am here to help. If you start on your homework ahead of time, I will be available to help you if you get stuck. Don't wait until the night before an assignment is due before starting it.

Participate in class. Your active engagement during class can play an important part in helping you to master the material. Class time will also be used to announce changes to the syllabus. I will also post everything to our Moodle site. It is *your* responsibility to keep up.

Inclusivity: All students should feel welcome in Physics class. We all bring our own unique perspective to class, and it is my intention that all students feel included in the intellectual community of the classroom. Unfortunately, the history of science is full of exclusion, so it's important to be explicit about inclusion.

Please contact me if you feel your identity is not being honored in class, if you have a preferred name or pronouns that I am not aware of, you observe religious holidays which conflict with coursework, or if there is something else that I should address. I am still learning, too, and your feedback is important to me.

Proper Usage of Course Materials: At Lafayette College, all course materials are proprietary and for class purposes only. This includes posted recordings of lectures, examples, tests, solutions, and other course items. Such materials should not be reposted. Online discussions should also remain private and not be shared outside of the course. 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. If you have any questions about proper usage of course materials feel free to ask me.

Generative AI Statement: See the general Academic Honesty section above.

Class Recordings: From time to time, it will be useful to record our classes for those unable to attend in person. I will make any such recordings available on a Google Drive shared within the class.

These recordings are for the use of this class only, and should not be shared outside of the class. If you have any concerns with being recorded during the course please let me know.

Federal Credit Hour Statement: The student work in this course is in full compliance with the federal definition of a four credit hour course. Please see the Registrar's Office web site
`https://registrar.lafayette.edu/wp-content/uploads/sites/193/2013/04/Federal-Credit-Hour-Policy-Web-Statement.doc` for the full policy and practice statement.

Andrew Dougherty Spring 2024
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Time	Mon.	Tues.	Wed.	Thurs.	Fri.
9:30					
10:20					
10:35					
10:45					
11:00					
11:25					
11:40					
12:15					
12:30					
12:55					
1:15		**Phys 338**		**Phys 338**	
1:40		HSC 017		HSC 017	
2:30					
2:45	**Phys 327**		**Phys 327**		**Phys 327**
3:35	HSC 017		HSC 017		HSC 017
4:00					
4:10					
4:30	**Phys 151**				
5:00	**Lab**	Committee	*Physics Club*		
5:30	HSC 119	Meeting			
6:00					
6:30					

ACADEMIC HONESTY GUIDELINES
Department of Physics

It is expected that each student taking courses in the Department of Physics is familiar with the statement "Principles of Intellectual Honesty" appearing in the Lafayette College Student Handbook. The following guidelines are intended to indicate how that statement pertains to your work in physics. Your instructor may have further guidelines for your specific course. We assume that students are honest; if you are not certain as to what is expected of you, consult your instructor before proceeding.

I. EXAMINATIONS:

1. Bring only those materials specifically authorized by your instructor. Frequently in the elementary courses, you will be permitted to bring in a formula sheet or you will be provided with one.

2. If you find that the seating arrangement is such that you can see someone else's paper, don't look! Better yet, ask if you can sit in another seat.

3. If you use a calculator, clear the answer before setting the calculator aside.

4. If you fail to hand in your paper at the end of the period you will be awarded a grade of zero for that test.

II. TAKE-HOME EXAMINATIONS: Take-home examinations are often assigned in some courses. Specific rules governing such tests will be announced by your instructor. The overriding principle, however, is that any work submitted be your own or be specifically credited to its source. There should be no discussion of the test questions with *anyone* other than the instructor.

III. HOMEWORK: You must acknowledge *all* collaborators. You are encouraged to learn from one another. You should first try to do homework problems on your own; after all you will have to do similar problems on your own in tests. However, discussion of difficult problems with others can help you to develop your own analytical skills and is encouraged, provided that, *after discussion* you write up solutions *on your own.* Do *not* borrow or lend homework papers. There is an important difference between discussing a problem with someone and copying his or her work. There have been students who have loaned papers to friends for a few minutes to "check answers", and been horrified to find themselves charged with academic dishonesty because their "friends" copied their solutions.

Please Note: The same ethical standards of academic integrity and honesty apply to the on-line homework as to the written homework, except that there is no place for you to specifically acknowledge collaboration. However, the same general rules apply.

IV. LABORATORY: Usually two or more students will work together in performing experiments and will submit reports of their work. In some courses, a single joint report may be submitted. Specific instructions will be announced by your instructor. If the words used to describe some part of the experiment are taken from some other source (such as the lab manual), then the source should be cited. (Reference to the lab manual can usually substitute for laborious copying.) If you consult with *anyone* about the experiment (e.g. students in your lab class other than your lab partner), that consultation should be acknowledged in your report. Do *not* borrow or lend a completed lab book or any portion of one.

V. PAPERS: Refer to the statement "Principles of Intellectual Honesty" in the Student Handbook.

Syllabus		**Phys 327**	**Spring 2024**
Jan.	22	Introduction	Ch. 1
	24	Drag Forces	Ch. 2:1-3
	26	Quadratic Drag; Numerical Integration	Ch. 2:4
	29	Calculus of Variations	Ch. 6:1–2
	31	Applications; HW #1	Ch. 6:3
Feb.	2	More than Two Variables	Ch. 6:4
	5	Lagrange's Equations	Ch. 7:1–2
	7	Constraints; HW #2	Ch. 7:3–4
	9	Applications	Ch. 7:5–7
	12	Conservation Laws	Ch. 7:8
	14	Lagrange Multipliers; HW #3	Ch. 7:10
	16	*Review*	
	19	**Test I**	Chs. 2, 6, 7
	21	Two-Body Central Force Problems	Ch. 8:1–2
	23	Effective Potential	Ch. 8:3–4
	26	Orbits	Ch. 8:4–8
	28	Perturbations; Precession; HW #4	
Mar.	1	The $N-$Body Problem	
	4	Noninertial Frames	Ch. 9:1–3
Virtual	6	Rotation; Coriolis Effect	Ch. 9:4–6
Virtual	8	Coriolis Effect; HW #5	Ch. 9:7–10
	11–15	*Spring Break*	
	18	Rigid Body Rotation	Ch. 10:1–2
	20	Principal Axes of Inertia; HW #6	Ch. 10:3–4
	22	Finding Principal Axes	Ch. 10:5
	25	Precession	Ch. 10:6
	27	Euler's Equations; HW #7	Ch. 10:7–8
	29	The Spinning Top	Ch. 10:9–10
Apr.	1	*Review*	
	3	**Test II**	Chs. 8–10
	5	Coupled Oscillators	Ch. 11:1–4
Eclipse	8	General Case; Normal Modes	Ch. 11:5–7
	10	Nonlinear Oscillators; HW #8	Ch. 12:1–3
	12	Phase Space	Ch. 12:4–7
	15	Poincaré Sections	Ch. 12:8
	17	Chaos; Logistic Map; HW #9	Ch. 12:9
	19	Hamiltonian Mechanics	Ch. 13:1–2
	22	Ignorable Coordinates	Ch. 13:3–4
	24	Applications; HW #10	Ch. 13:5–7
	26	Collisions	Ch. 14:1
	29	Cross Section	Ch. 14:2–3
May	1	Differential Cross Section; HW #11	Ch. 14:5
	3	Rutherford Scattering	Ch. 14:6

Final Exam (cumulative)

January 22, 2024