Physics 355 - Classical Mechanics

Session: Fall 2026
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Office Hours: MTWTh 11:00 AM – Noon
Class Meetings: TTh 9:30 AM – 10:45 AM
Location: South Engineering 221
Final: Thursday, December 17, 2025, 3:30 PM – 5:30 PM

Course Materials

- The primary text for the course will be "Classical Mechanics", by John R. Taylor, published by University Science Books (ISBN: 1-891389-22-X).
- Although there are some integrals and formulas listed inside the front and back covers of the text, you will find an additional book of integral tables to be quite useful. A widely used one is the *Mathematical Handbook of Formulas and Physics* in the Schaum's Outline Series. It will prove to be a valuable resource for the rest of your academic career.
- You are expected to have already taken Physics 2 (PHYS 252) and Calculus III (MATH 259), and either have taken or be currently enrolled in differential equations (MATH 266).

Course Description

From the NDSU Bulletin: Basic concepts, single and coupled oscillators, variational calculus, Lagrangian and Hamiltonian dynamics, central force motion, accelerated coordinate systems. Prereq: PHYS 252 and MATH 265. Co-req: MATH 266.

The course familiarizes students with the theoretical methods and techniques of classical mechanics at an intermediate level. This includes a variety of mathematical and computational techniques – especially the Lagrangian and Hamiltonian formalisms – for setting up and solving differential equations to determine the motion of individual particles and systems of particles. Students develop problem-solving skills needed to master the rigor of theoretical physics and understand the fundamental roles of symmetries and conservation relations in classical mechanics.

At the most basic level, this course can be thought of as a study in "What happens when things interact?" In other words: "Given a force acting on an object, what does it do?" Other areas of physics primarily consider *how* or *why* things interact (for example, electrodynamics is the study of how electric charges interact with one another, where general relativity is concerned with gravitational interactions), or what happens when *many* things interact (statistical and thermal physics), or what happens when *very small* things interact (quantum mechanics). In this course we will be concerned with cases where we have no more than a handful of objects of moderate size (larger than atoms) interacting. In doing so, we will develop the tools to talk about important concepts such as force, energy, and momentum that will be crucial in your future physics studies.

I will assume that you have taken the introductory physics sequence and are familiar with the topics covered there, along with a basic understanding of differential and integral calculus. Additionally, you should have a basic knowledge of vectors and vector algebra. Any mathematical topics needed beyond these will be introduced/reviewed as necessary.

Learning Outcomes (General)

1. Develop the skills of a physicist: checking units, limiting cases, developing conceptual and mathematical skills
2. Comfortably apply advanced mathematical techniques to physical problems
3. Apply Lagrangian and Hamiltonian dynamics to physically interesting systems
4. Analyze and model the motion of objects on complex settings

Feedback

If you have any concerns about the course or suggestions on how it may improve, please let me know! I am happy to consider and implement student suggestions, and I have had success implementing such suggestions in previous courses.

Course Standards

In this course we will use *standards-based grading*. This is different than the usual "points-based grading" that you are likely used to. A "standard" represents a core idea or skill you should learn in a junior-level Classical Mechanics course, and is something that should stay with you past when you are "tested" on it.

You will be given multiple opportunities to demonstrate your *proficiency* with each standard. To be judged as proficient ("meeting the standard"), you'll need to show that you can solve a variety of problems related to that standard *largely correctly*, with no *fatal flaws* in your reasoning and process. This will be done via in-class quizzes, each of which will cover a few standards. Unlike a more traditional course, if you do not pass one or more of the standards, you have the opportunity to re-test on any standards, provided you meet the re-testing requirements (see below)

Throughout PHYS 355 you'll be given opportunities to show you are proficient with the following 18 Standards.

Solve simple applications of Newton's 2nd Law

1. Construct the equations of motion for a variety of systems using Newton's 2nd Law in Cartesian and polar coordinates.
2. Solve Newton's 2nd Law for these systems to get the solutions to the equation of motion.

Solve Newton's 2nd Law in cases of Simple Drag

3. Construct, solve, and interpret Newton's 2nd Law in cases of motion involving linear drag.
4. Construct, solve, and interpret Newton's 2nd Law in cases of motion involving quadratic drag.

Use Momentum Ideas to explain physical situations

5. Apply momentum conservation to inelastic and elastic collisions.
6. Apply momentum conservation to construct and solve "the rocket equation" for a variety of scenarios.
7. Find the Center-of-Mass of an extended object and the Moment of Inertia for that object about a given axis, and use these with the principle of Conservation of Momentum to solve/explain various physical situations.

Use Energy Ideas to explain physical situations

8. Relate work to change in kinetic energy, relate conservative forces to potential energy.
9. Use work-energy ideas to solve for the motion of physical systems, both mathematically and graphically.

Solve Fundamental cases of Simple Harmonic Motion

10. Describe why simple harmonic motion is ubiquitous in physics, and approximate a variety of systems as simple harmonic oscillators
11. Solve and describe the motion of simple harmonic oscillators, in cases with and without damping.
12. Solve the damped-driven oscillator, determine the resonance frequency, and explain how Fourier Series are used to simplify solving the damped-driven oscillator for an arbitrary periodic driving force.

Use the Calculus of Variations to find functions which extremize integrals

13. Construct and solve the Euler-Lagrange Equations for a given physical situation, for both single and multiple dependent variables.
14. Use Hamilton's Principle to construct the Lagrangian and find (and solve) the equations of motion for a variety of physical systems.
15. Construct the Lagrangian (and find the equations of motion) when some of the Generalized Coordinates are in a non-inertial frame, be able to connect invariance of the Lagrangian to conservation laws, and use Lagrange Multipliers to set up (and solve) the equation of motion for systems with constraints.

Understand and Apply properties of Coupled Oscillations

16. Construct, solve, and analyze the equations of motion for two coupled simple harmonic oscillators.

Understand and Apply Hamiltonian Mechanics to Simple Systems

17. Construct the Hamiltonian from the Lagrangian, and solve (and analyze) Hamilton's Equations of Motion for simple systems.

18. Identify conserved quantities via Ignorable Coordinates.

Grades

Final grades in the course will be determined according to the number of standards you are proficient with.

16-18 Standards: A	12-15 Standards: B	8-11 Standards: C	4-7 Standards: D	1-3 Standards: F

How do you *get* to proficiency with a standard? In short: preparation, participation, and practice.

Preparation

Prior to most classes you'll have assigned reading out of our textbook, and possibly an video to watch and think about or some problems to attempt. While I don't expect you to have mastered anything after just reading about it, it is important to complete this preparation so you are ready to participate in the class activities.

Participation (Classtime)

We will have a number of in-class activities in which you need to actively participate, rather than being a passive "receiver". This will include some typical lecture (where you being "active" means being engaged and asking questions), but also includes some shorter Conceptual Questions that we'll work on and discuss both individually and as a class, as well as In-Class Tutorials covering the basis of relevant standards.

Practice (Homework)

For each standard, you will be provided with a problem set to practice your skills in the relevant standards and to prepare you for the quiz. These are not graded, but you will receive feedback on them so you know what standards you need to improve on before the quiz. Additionally, turning in the homeworks *on time* is a *requirement* to be able to re-test on any standard.

When submitting your homework, you should pay attention to the following guidelines:

1. It should be neat and presentable.

2. It is to be written on loose-leaf, perforated, or plain paper (no notebook "frillies").

3. Each problem should be started on a separate page.

4. The pages must be stapled, with the staple in a position that does not obscure what you've written on any of the pages.
5. The pages should be in order (numbering your pages helps with this!).
6. You must re-state the problem which you are attempting to solve, at least briefly.
7. Answers should be clearly labeled (boxed, highlighted, bold, etc.).
8. If you worked with anyone else on your assignment (which you are encouraged to do!), you must indicated key contributions that your other group members made.
9. You may also typeset your assignments using any program that you prefer (LaTeX, *Mathematica*, LibreOffice, Word, etc.), if you wish. If you decide to do this, make sure you are spending more time doing the *physics* than you are dealing with formatting issues!

Your homework should not only contain equations and mathematical procedures, but also *sentences* which describe the *physics* of what is happening. Each solution should include the following "expert" problem solving steps:

1. Describe the physical system – particles, interactions, charges, fields, or whatever else is relevant.
2. Clarify geometrical relationships, usually with the aid of a coordinate system.
3. Identify relevant physical principles, such as Newton's laws or conservation laws.
4. Identify simplifying assumptions, such as whether or not to use a particle or continuum model, whether or not to include air resistance, etc.
5. Adding details as needed, such as drawing a free-body diagram.
6. Insert the relevant quantities into the relevant equations and solve for the answer.
7. *Check* the answer to see that it makes sense by looking at units and *interpreting* the result.

Most of the *physics* is contained in the first five steps and step 7, yet many people think of step 6 as "doing physics". This is what sets physics apart from "word problems" in a math course; you have to know the relevant physics to even write down the mathematical problem you need to solve! Don't forget the last step either, you should never underestimate the usefulness of checking units and limiting cases to make sure that an answer makes sense. I know it has helped me catch a mistake more times than I can count.

Quizzes & Retesting

Every few weeks you'll be given an in-class Quiz to work on independently which covers a few standards. I have put tentative quiz dates in the schedule in this syllabus, but they may need to be adjusted. You will always have at least 1 week of notice prior to a quiz.

If you do not demonstrate proficiency on any standard, that's okay! You are allowed up to two retakes for all Quizzes, *as long as you turned in the relevant homework assignments on time.* This means that you must turn in *your best honest effort* at the problems prior to the Quiz. This is so I can provide feedback on what you need to work on before the quiz itself. Retakes will be on the same standard involving similar, but different problems. You may retake each standard up to 2 times.

Office Hours

See the front page for office hours. If you need to meet outside of those times, email me and we should be able to work something out. During office hours, we can discuss anything that you wish (homework, grading, concepts, exams, topics of interest, etc.) If there is something of a personal nature, it would be best to make a separate appointment.

Accommodations

Any students with disabilities or other special needs who need accommodations in this course are invited to share these concerns or requests with the instructor and contact the Center for Accessibility and Disability Resources http://www.ndsu.edu/accessibility-disability as soon as possible.

Course Policies

Attendance & Participation

You are expected to come prepared each day and to participate in the discussion and problem-solving. If you miss a class, it is your responsibility to get the missed notes (from a classmate) and any assignments given.

According to NDSU Policy 333 www.ndsu.edu/fileadmin/policy/333.pdf, attendance in classes is expected. Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor as soon as possible and are encouraged to provide Activation Orders.

On Academic Dishonesty

The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

You are highly encouraged to work with your fellow students, and to seek out their assistance or the assistance of the instructor, in all of your studies. Working with another person is highly beneficial for both people when there is a healthy working relationship. However, whatever you turn in must be your own work and words. Copying someone else's work and turning it in as your own is a case of academic dishonesty. You are not permitted to collaborate with anyone else on exams.

If you have any questions about what constitutes academic dishonesty it is your responsibility to ask before the assignment is due.

AI Policy

The official "AI Policy" in this class is that I ask that you not use any generative AI for any portion of the course (for reasons I will explain), and the following use cases are explicitly not allowed:

- Using generative AI, or any outside tools, during in-class assessments (quizzes)
- Using generative AI to complete assigned homework, or to assist in the writing of solutions to assigned homework
- Submitting any of the material I provide to generative AI or similar tools for the purposes of summarizing information - despite not looking the best, they took a lot of time to create, and I do not consent to having AI trained on them.

The AI Policy on **my** use of AI is the same - I shall not use it in **any** capacity (creating assignments, creating lecture slides, creating solutions, creating exams, creating announcements, replying to your emails, etc.). Any use of AI-created materials on my end is entirely accidental (i.e. - maybe an image I found was created by AI and that wasn't disclosed). If you feel that something I used was AI-generated, please let me know and I will remove & replace it ASAP.

I also promise to not **shame or judge** anyone that says they used AI on the homeworks. I will always do my best to help you, regardless of what other help you have sought out previously.

As mentioned above, I implore you to not use any generative AI tools for this class (or any other class, really). The reason is that using these tools fundamentally cheats **you** out of what you should be getting out of the course, which is the ability to reason and problem solve quantitatively and conceptually, specifically within the realm of physics. Using AI to solve or explain the homework shortcuts the (admittedly difficult) task of learning leaving you unprepared, not just for the exams but for anything that uses those quantitative skills later.

Using AI "correctly" is extremely difficult to do (personally, I don't feel it is possible to use it correctly in an educational setting). If you're asking it for facts or to solve problems, it's prone to hallucination, which means you need to know the answers to the questions you're asking anyway in order to trust the output. It obfuscates and invents sources, so you can't check its work. If you ask AI to show its "reasoning", that reasoning is highly context dependent and prone to biases in the original dataset that the AI was trained on (which is basically the entire internet, which contains a lot of nonsense). If you ask it to summarize course materials or lecture notes for you, then you aren't developing the skills to be able to do so yourself, and you may miss the underlying reasons why the elements it picks out are important.

Ultimately, your education is an investment you make in **yourself**, you are actively "building" yourself over these years with new knowledge and skills. I encourage you to resist any urge to outsource that to AI.

FERPA Statement

Your personally identifiable information and educational records as they relate to this course are subject to FERPA.

Course Schedule

We will not have a set course schedule. The pace and content of the course will be determined as it progresses. However, I intend to cover Chapters 1–7, 11, and 13 with time left over for a topic or two to be decided.

Week 1	Newton's Laws & Differential Equations
Week 2	Polar Coordinates, Projectile Motion, Drag
Week 3	Momentum, Center of Mass, & Angular Momentum
Week 4	Line Integrals, Work, Conservative Forces - **Quiz 1 (Standards 1 & 2)**
Week 5	Curvilinear 1D systems, Central Forces, Elastic Collisions
Week 6	1D & 2D Oscillations (No Damping) - **Quiz 2 (Standards 3 & 4)**
Week 7	Damped Oscillations, Driven Oscillations, Resonance
Week 8	Calculus of Variations & Euler-Lagrange Equation - **Quiz 3 (Standards 5, 6, & 7)**
Week 9	Fourier Series - **Quiz 4 (Standards 8 & 9)**
Week 10	Lagrange's Equations of Motion
Week 11	Lagrange's Equations & Constraints - **Quiz 5 (Standards 10, 11, & 12)**
Week 12	Generalized Momenta & Lagrange Multipliers
Week 13	Coupled Oscillators - **Quiz 6 (Standards 13, 14, and 15)**
Week 14	Central Force Motion
Week 15	Hamilton's Equations of Motion - **Quiz 7 (Standards 16, 17, & 18)**

Advice

Here are some helpful tips for success in the course, from my own personal experience and suggestions of other professors.

1. If you are having trouble, ask for help! Help is available through me via my office hours (or other appointment), other faculty in the department, and your fellow students.
2. Read the appropriate sections of the text *before* the relevant lecture session. That way, you're seeing the material for the second time, and are much better prepared to ask questions on things you're having trouble understanding.
3. When reading the text, be sure to read *critically*. That is, ask questions and take notes! If something is not clear, make a note of it so you can ask in class. You should also be working through steps done (or omitted) in class and the text. As a friend of mine once said "The exam will NOT ask if you agree with our solution, but will asked you to come up with your OWN solution."
4. This course will likely take a significantly greater amount of time than your previous courses, both in completing the homework and understanding the concepts. It is critical that you start your homework assignments as early as possible, as you may need a few days to solve the problem sets.
5. Don't work for more than a few hours on a problem if you're stuck! Switch to another problem (which may cause you to think about the troublesome one in a different way), and find assistance. That being said, do not despair if it is not obvious what to do after 5 minutes of thinking. These problems will require some extra thought.
6. Don't panic. Physics is hard. Like anything else worthwhile, it will take practice and perseverance to succeed, but the rewards are well worth it.

Additional Resources for Students

It is *normal* to feel overwhelmed at the best of times, but especially now. As a member of the NDSU community, resources are available for you should you need help in dealing with adverse reactions to things happening in the world today. A variety of resources are listed below:

For students on campus and remotely (telehealth):
Counseling Services: 701-231-7671; https://www.ndsu.edu/counseling/
Disability Services: 701-231-8463; https://www.ndsu.edu/disabilityservices/
Student Health Service: 701-231-7331; https://www.ndsu.edu/studenthealthservice/
Dean of Students Office: 701-231-7701; https://www.ndsu.edu/deanofstudents/

In a crisis or emergency situation: Call University Police: 701-231-8998
Call 9-1-1
Go to a Hospital Emergency Room Go to Prairie St. Johns for a Needs Assessment: 701-476-7216 (510 4th St. S.)
Call the FirstLink Help Line: 1-800-273- TALK (8255) or 2-1-1
Call the Rape and Abuse Crisis Center: 701-293-7273