The City College of New York

PHYS V1100: Analytical Dynamics

Graduate Classical Mechanics

Fall 2026

Instructor:	Professor Mark D Shattuck
Email:	markdshattuck@gmail.com
Class meetings:	Monday and Wednesday, 11:15 AM–1:00 PM
Room:	TBA
Office:	Steinman Hall T1M-16 / MR-414
Office hours:	Monday 1:00–3:00 PM, or by appointment
Course website:	`https://gibbs.ccny.cuny.edu/teaching/`

Course Description

This is a graduate course in classical mechanics at the level of Goldstein, Poole, and Safko. Students are expected to have previously studied mechanics at the level of Taylor and to be comfortable with ordinary differential equations, linear algebra, multivariable calculus, and basic numerical computation.

The course develops the Lagrangian and Hamiltonian formulations of mechanics, variational principles, symmetries and conservation laws, central-force motion, small oscillations, rigid-body dynamics, canonical transformations, Hamilton–Jacobi theory, perturbative and nonlinear dynamics, and classical continuous systems and fields.

A recurring theme of the course will be the connection between finite-dimensional and continuum mechanics. When useful, we will begin with a finite or discrete formulation and then take a continuum limit. This makes the roles of states, transitions, boundaries, constraints, and conservation laws explicit and also provides a natural connection to computation.

The official CCNY description of PHYS V1100 includes the Lagrangian and Hamiltonian formulations, central-force motion and the Kepler problem, scattering, rigid-body motion, canonical transformations, Hamilton–Jacobi theory, small oscillations, continuous systems and fields, and relativistic dynamics.

Prerequisites

The department lists PHYS V0100 (Mathematical Methods in Physics) as a prerequisite or corequisite. In practice, students should be comfortable with:

- undergraduate classical mechanics, including Newtonian mechanics, conservation laws, oscillations, and introductory Lagrangian mechanics;
- linear algebra, especially eigenvalues, eigenvectors, quadratic forms, and matrix factorizations;
- ordinary differential equations and basic partial differential equations;
- multivariable calculus and vector calculus;
- basic scientific computation.

Review will be provided when it is useful, but the course will move quickly toward graduate-level analytical mechanics.

Learning Goals

By the end of the course, students should be able to:

1. formulate mechanical systems using appropriate generalized coordinates and identify the information required for a complete dynamical state;
2. derive equations of motion from both discrete and continuum action principles, including the associated boundary terms;
3. use constraints, generalized forces, symmetries, and Noether's theorem systematically;
4. analyze central-force motion, effective potentials, orbital dynamics, the Kepler problem, and scattering;
5. formulate and solve small-oscillation problems using matrix methods and normal modes;
6. understand discrete systems with many degrees of freedom as a bridge to classical field equations and continuum limits;
7. analyze rigid-body rotations using rotation matrices, angular momentum, the inertia tensor, and Euler's equations;
8. formulate mechanics in phase space and use Hamilton's equations, Poisson brackets, canonical transformations, and Hamilton–Jacobi theory;
9. use action–angle variables, perturbative ideas, phase-space methods, and qualitative tools to study nonlinear dynamics;
10. use MATLAB and Python/NumPy to explore mechanical systems computationally and compare numerical, analytical, and geometric descriptions.

Course Materials

Primary course material. Lecture notes will be distributed for each class. These notes are intentionally broader than what can be covered during a single class meeting and are part of the assigned course material.

Principal reference.

H. Goldstein, C. Poole, and J. Safko, *Classical Mechanics*, 3rd ed.

We will roughly follow the level and scope of Goldstein, but not necessarily its chapter order or presentation.

Useful review and alternate references.

- J. R. Taylor, *Classical Mechanics*. Particularly useful for review of undergraduate mechanics.
- R. D. Gregory, *Classical Mechanics*. Available electronically through the CCNY library.
- S. T. Thornton and J. B. Marion, *Classical Dynamics of Particles and Systems*.
- L. N. Hand and J. D. Finch, *Analytical Mechanics*.
- L. D. Landau and E. M. Lifshitz, *Mechanics*.
- D. Tong, *Lectures on Classical Dynamics*, freely available online.

No single supplementary text is required. Readings will be suggested as the course develops.

Computation

Computation is part of the course rather than a separate numerical-methods unit. I will generally use **MATLAB** for in-class demonstrations because its interactive matrix-oriented interface is particularly convenient for mechanics. Parallel examples in **Python** will generally use NumPy arrays so that the correspondence with MATLAB is transparent.

Students may use either MATLAB or Python/NumPy for computational homework unless an assignment specifies otherwise. MATLAB is available to CCNY students through the College software resources.

Problem Sets and In-Class Problem Presentation

There will be approximately ten problem sets. They will contain a mixture of analytical derivations, conceptual questions, and occasional computational problems.

Problem solving is a major part of learning mechanics, but the problem sets are intended primarily as *practice and feedback*, not as high-stakes tests of individual mastery. Homework will therefore be graded mainly on serious engagement and completion rather than on obtaining every answer correctly. Mistakes are expected and are useful: submitted work will help identify topics that should be revisited in class.

Discussion with classmates is encouraged. Students may also use textbooks, notes, computational tools, and generative AI while working on homework, but do not start with AI. Use AI as a resource to enhance your understanding not as a short cut to the answer. A good prompt: "I'm having trouble understanding how to use Lagrange multipliers. Can you walk me through an example?" A bad prompt: "My professor gave this problem ¡paste¿; what is the answer?" The important goal is to use these resources to improve understanding rather than to replace it. Students remain responsible for understanding the work they submit and for being able to solve related problems independently on exams.

Problem sets may be legibly handwritten or typeset, but should be submitted electronically as a single PDF through Brightspace. Due dates will be given on each assignment. Full credit will be given for on-time submissions. If a submission is n weeks late, it will receive $\max(0, (3 - n)/3)$ of full credit.

In addition, selected homework sets will contain a problem designed specifically for an **in-class board presentation**. Approximately one such presentation will be scheduled each week, with each student normally presenting once during the semester. Presenters will be assigned in advance.

The presentation is a separate graded component of the course. The goal is not simply to display a correct final answer, but to explain the physical and mathematical reasoning clearly, organize a solution at the board, and respond to questions. The same outside resources permitted for homework may be used while preparing the presentation, including generative AI, but the student presenting must be able to explain and defend the solution in their own words.

Exams and Final Project

There will be three in-class exams and a final synthesis project.

The exams will provide the principal assessment of individual mastery. They will emphasize understanding, derivation, and the ability to apply familiar structures in new settings rather than memorization. Unless otherwise announced, exams will be closed-book, with an instructor-provided reference sheet when appropriate. No outside communication, generative AI, symbolic software, or other electronic assistance may be used on exams unless explicitly authorized.

The final project will ask each student to use the methods of the course to analyze a mechanical system in somewhat greater depth than is practical on a problem set. Projects may be analytical, computational, or a combination of the two. Possible topics include nonlinear oscillators, celestial mechanics, rigid-body motion, discrete or continuous fields, perturbation theory, resonances, Hamiltonian systems, or chaotic dynamics.

Generative AI and other computational tools may be used on the final project. This is intentional: one goal of the project is to practice using modern tools while maintaining intellectual control of the physics. Students are responsible for checking results, understanding the methods used, and clearly distinguishing their own analysis from externally generated material when appropriate. Detailed project instructions and a grading rubric will be distributed later in the semester.

Grading

Problem sets	10%
Exam I	20%
Exam II	20%
Exam III	20%
Final project	20%
In-class problem presentation	10%
Total	100%

Attendance and Preparation

Graduate mechanics is cumulative, and regular attendance is strongly recommended. Students should read the relevant lecture notes or assigned material before class when possible. Class meetings will emphasize derivations, examples, physical interpretation, questions, and computational demonstrations rather than simply reproducing the written notes.

If you must miss class, you are responsible for the material and announcements from that meeting. Please contact me early if a sustained circumstance is interfering with your ability to participate in the course.

Academic Integrity and Use of Generative AI

Students are expected to complete all academic work honestly and in accordance with the CUNY Academic Integrity Policy. This includes proper attribution of sources, appropriate collaboration, and following the rules specified for each assignment or examination.

The permitted use of generative AI depends on the purpose of the assignment:

- **Homework:** generative AI is permitted as a learning resource. Homework is graded mainly for serious engagement and completion rather than correctness. Students are responsible for understanding the work they submit.

- **In-class problem presentation:** generative AI may be used in preparation, but the grade is based on the student's own explanation, reasoning, and ability to respond to questions.
- **Exams:** generative AI and other outside assistance are not permitted unless explicitly authorized.
- **Final project:** generative AI is permitted. Students remain responsible for verifying results, understanding the physics and computation, and following any project-specific attribution requirements.

These policies are intended to align the use of outside tools with the purpose of each activity: homework is for practice and feedback; exams assess individual mastery; presentations assess ownership and explanation; and the project emphasizes synthesis and effective use of modern tools.

CCNY academic-integrity information is available at https://www.ccny.cuny.edu/academicaffairs/academic-integrityacademic-standards.

Accessibility and Accommodations

The AccessAbility Center/Student Disability Services coordinates appropriate accommodations for students with disabilities. Students who require accommodations should register through CUNY Accommodate and arrange for their approved accommodation information to be sent to the instructor. Students are encouraged to begin this process early so that accommodations can be implemented in a timely way.

AccessAbility Center information is available at https://www.ccny.cuny.edu/accessability.

Tentative Course Calendar

The calendar below is a working plan. The pace may be adjusted in response to the class, and the instructor may change topics or assignment dates as needed. Changes will be announced in class and through the course communication system.

Date	**Topic**
Aug. 31	States, dynamics, and the goal of physics; complete states and dynamical evolution; finite differences and information compression.
Sep. 2	Discrete mechanics: open chains and rings; quantities on nodes and edges; forces, boundaries, and the matrix form A^TCA.
Sep. 7	*College closed — no class.*
Sep. 9	Discrete action and finite-dimensional variation; discrete Euler–Lagrange equations; endpoint terms.
Sep. 14	Continuum limit; Hamilton's principle; Euler–Lagrange equations; integration by parts and boundary data.
Sep. 16	Generalized coordinates, configuration space, constraints, virtual displacements, and generalized forces.
Sep. 21	*No classes scheduled.*

Date	Topic
Sep. 23	Symmetry and conservation laws; finite transformations; Noether's theorem.
Sep. 28	Many coupled oscillators as a discrete field; normal modes and mode counting.
Sep. 30	Continuum systems and classical fields; field action and boundary terms; relativistic examples as appropriate.
Oct. 5	Central-force motion I: reduction of the two-body problem, angular momentum, and effective potentials.
Oct. 7	Central-force motion II: orbital geometry, Kepler problem, and scattering.
Oct. 12	*College closed — no class.*
Oct. 13 (Tue.)	**Exam I.** Tuesday follows a Monday schedule.
Oct. 14	Small oscillations I: quadratic approximation, mass and stiffness matrices, generalized eigenvalue problems.
Oct. 19	Small oscillations II: normal coordinates, degeneracy, symmetry, and continuum connections.
Oct. 21	Nonlinear oscillations, stability, phase-plane methods, and the limits of linearization.
Oct. 26	Rigid-body kinematics: rotations, angular velocity, rotation matrices, and geometric interpretation.
Oct. 28	Rigid-body dynamics: inertia tensor, angular momentum, Euler equations, and principal axes.
Nov. 2	Rigid-body applications: symmetric tops, precession, torque-free motion, and stability.
Nov. 4	**Exam II.**
Nov. 9	Hamiltonian mechanics I: Legendre transform, phase space, and Hamilton's equations.
Nov. 11	Hamiltonian mechanics II: Poisson brackets, phase-space flow, and conserved quantities.
Nov. 16	Canonical transformations and symplectic structure.
Nov. 18	Generating functions and canonical transformations in practice.
Nov. 23	Hamilton–Jacobi theory and separation of the equations of motion.
Nov. 25	*No classes scheduled.*
Nov. 30	Action–angle variables and integrable systems.
Dec. 2	Perturbation theory, adiabatic invariants, and resonances.
Dec. 7	Nonlinear Hamiltonian dynamics, Poincaré maps, integrability, and the onset of chaos.
Dec. 9	**Exam III.**
Dec. 14	Final-project presentations and course synthesis. *Last day of classes.*
Dec. 15–21	Final examination period. Final project write-up due during this period; exact deadline to be announced.

Important Fall 2026 Calendar Notes

The Fall 2026 term begins August 28. Because this course meets Monday and Wednesday, our first meeting is August 31. There is no class on September 7, September 21, October 12, or November 25.

On Tuesday, October 13, classes follow a Monday schedule, so this course will meet that Tuesday. The last day of classes is December 14, and the final-examination period is December 15–21.

The official calendar is available from the CCNY Registrar: Fall 2026 Academic Calendar.

Communication and Changes

Course announcements, assignments, and changes to the schedule will be communicated in class and through the course website or College course-management system. Students are responsible for checking these communications regularly.

The schedule and policies in this syllabus may be adjusted when needed to improve the course or respond to College requirements. Any substantive changes will be announced clearly.