CLASSICAL MECHANICS III (8.09/8.309) Fall 2021
Organization, Policies, & Course Outline

Lectures: TR 9:30-11:00am in 56-114

Lecturer: Prof. Iain Stewart

Contact via MIT Slack chat (preferred) or email iains@mit.edu

Office Hours: Monday 1-2pm or by appointment

(in or near 6-401 or over Zoom by prior arrangement)

Recitation Sections: 1) F 1:00-2:00pm in 26-328

2) F 2:00-3:00pm in 26-328

Recitation Instructor: Anjie Gao

Contact via MIT Slack chat (preferred) or email anjiegao@mit.edu

Office Hours: Friday 3-4pm or by appointment

(in or near 6-413 or over Zoom by prior arrangement)

Course Graders: Hyunseok Lee, Ahmad Taka, Xiuyuan Zhang

Course Manager: Denise Wahkor, Rm 4-315; Phone 253-4855; email denisew@mit.edu

Values statement

All students and instructors are expected to uphold the MIT Physics Community Values.

Course Software

8.(3)09 will be taught in person this semester. We will be making use of various online tools:

- **Canvas** Course Webpage: **https://canvas.mit.edu/courses/11271**
- **Zoom** (for Office Hours by prior arrangement, room for Iain, room for Anjie)
- **Piazza** for questions **signup link** (page linked through Canvas site)
- **MIT Slack** for direct chat messages with the course staff (preferred over email)

Syllabus

A course on advanced classical mechanics, including Lagrangian and Hamiltonian dynamics, as well as an introduction to fluid mechanics, and an introduction to chaos.

8.09 versus 8.309: The undergraduate course 8.09 and graduate course 8.309 meet jointly, and have the same midterm and final exam. The only distinctions between the two courses are small differences in the problem set assignments.

Prerequisites and Review Material:

Undergraduates must complete 8.223 with a grade of C or better before taking 8.09. If you have questions about your background, come talk with Prof. Stewart. If you feel rusty and would like to review material covered in Classical Mechanics II, consider rereading some of the sections 1-15,18,19,22,27,40,42,43,46 in *Mechanics* by Landau and Lifshitz. 8.03 is also recommended as a prerequisite although it is not required.

Course Documents

All course related documents (syllabus, problem sets and solutions, notes, handouts, announcements, etc.) will be distributed electronically over the web. Students should check the 8.09/8.309 home page regularly for updates and announcements. Grades for homework and tests will be posted on the web. If you are attending 8.09/8.309 as a listener then it is important to register as a listener in order to have access to all class material on the web page.

Grading and Exams:

Grades will be determined by a weighted average of problem sets (35%), a midterm (25%), and a final exam (40%). The course staff may also take into account other qualitative measures of performance such as class participation, improvement, and effort.

- The two hour midterm is planned for **Tuesday evening, November 2nd, 7:30-9:30pm, in our regular lecture room (56-114)**.
- There will be a three hour final exam scheduled during exam week in December.

Problem sets:

The 10 planned problem sets are an important part of 8.09/8.309. Sitting down and trying to reason your way through a problem not only helps you to learn the material deeply, but also develops analytical skills fundamental to a successful career in science. We recognize that students also learn a great deal from talking to and working with each other. We therefore encourage each 8.09/8.309 student to make his/her own attempt on every problem and then, having done so, to discuss the problems with one another and collaborate on understanding them more fully. **After any discussion, the solutions you write up and submit must reflect your own work.** They must not be transcriptions or reproductions of other people's work. Note that sometimes we may use problems from previous versions of 8.(3)09. We know that "bibles" exist with solutions to previous problems, and you should be aware that copying answers from them **is not acceptable**, and would also impede your learning.

Problem sets will be posted on the course web page and your answers must also be uploaded to the course webpage before the deadline. Most of the time they will be due before **6:00pm Boston time** on Mondays. Solutions will be posted on the web page later that evening or the next day. **We do not accept problem sets after the time they are due.** However, your lowest problem set score will be discarded at the end of the semester; only the remaining 9 will be used in determining your grade. Graded problem sets will be returned online. Concerns about problem set grading should be brought up with the recitation instructor.

Subjects and Topics:

1) *Lagrangian and Hamiltonian Mechanics with Constraints.* Euler-Lagrange Equations, Hamilton Equations, D'Alembert and Hamilton principles, Conservation Laws, holonomic and nonholonomic constraints, Lagrange multipliers.

2) *Rigid Bodies & Rotations.* Non-inertial coordinate systems, rotation matrices, Euler's theorem, Moment of Inertia Tensor, Euler Equations, Lagrangian for a spinning top with torque.

3) *Vibrations and Oscillations.* Simultaneous diagonalization of matrices for kinetic and potential energy. Using normal coordinates as generalized coordinates.

4) *Canonical Transformations and Hamilton-Jacobi Equations.* Generating functions for canonical transformations, invariants, Hamilton-Jacobi equation, action-angle variables. Kepler problem with action-angle variables.

5) *Perturbation Theory.* Time dependent perturbation theory, periodic and secular changes, precession of perihelion of mercury.

6) *Introduction to Fluid Mechanics.* Dynamics for continuous systems. Volume change, continuity equation, Euler equation, momentum and energy conservation, potential flows, and sound waves. Viscous flows and the Navier-Stokes equation. Drag force on surfaces. Reynolds number, Vortices, and Turbulence.

7) *Introduction to Chaos and Nonlinear Dynamics.* Fixed points and Limit cycles. Conservative and dissipative systems. Stability. Bifurcation classification. Poincare-Bendixson theorem. The Logistic Map. Liapunov exponents. Lorenz Equations. Fractals and Strange Attractors. Turbulence and Kolmogorov scaling.

Textbooks

- Latex Class Lecture Notes by Prof. Stewart
- Goldstein, Poole & Safko, *Classical Mechanics*, 3rd edition (required)

Goldstein will serve as the main text for the majority of our material. However, we will also cover material that is not in Goldstein, in particular in our discussion of fluid dynamics and chaos. For the latter there will be assigned readings from sources which will be posted on the course webpage. I do recommend the book

- Strogatz, *Nonlinear Dynamics and Chaos* (an accessible yet detailed discussion of nonlinear dynamics in both differential equations and iterated maps)

for the material on nonlinear dynamics. For additional reading you may consider some of the following texts which are available in the Physics Library or Hayden Library:

- Landau and Lifshitz vol.6, *Fluid Mechanics* and Symon, *Mechanics*. The first three chapters of Landau and Lifshitz cover the material for our introduction to fluid mechanics. We will only use the third chapter for our discussion of viscosity, and use a chapter from Symon for reading material on non-viscous fluids.
- Landau & Lifshitz vol.1, *Mechanics*. (Used for Classical Mechanics II and hence useful here for review)
- Thornton & Marion, *Classical Dynamics of Particles and Systems* (a useful reference at a somewhat lower level that Goldstein, may be clearer for some topics)