1 Course Overview

Classical mechanics is the study of (in principle) deterministic motion of "macroscopic objects" (the collective motion of many atoms together, thought of as a single object or as a continuous fluid) in the limit that one can ignore Planck's constant $\hbar$. Newtonian mechanics, in which one assumes that the velocities of objects are much lower than the speed of light $c$, is a subset of classical mechanics: Einstein's special theory of relativity can also fit within this framework. As with quantum mechanics and thermodynamics, classical mechanics is a general conceptual framework with a variety of applications such as terrestrial engineering, celestial mechanics, and fluid dynamics.

In principle, electricity and magnetism and general relativity both fall under this rubric. One usually teaches them separately and without using the general Lagrangian framework developed here, at least before graduate school.

Our goal will be a deep understanding of the Lagrangian and Hamiltonian formalisms, which have great conceptual and computational power, and which are central to quantum mechanics as well. (This is no accident as classical mechanics emerges from quantum mechanics in a very particular way). Personally I found Lagrangian mechanics and the calculus of variations to be one of the most beautiful subjects I learned as an undergraduate. It was certainly one of the most important.

As with all such methods courses, I have some additional agendas as well. One is to introduce or reinforce various mathematical concepts by teaching them in a practical context: especially differential equations, variational calculus, and linear algebra. Another is to build up experience developing simple-but-not-too-simple mathematical models which capture the essential physics of a complicated system with a few parameters (that one can either try to derive, or fit to experiment).

The official prerequisite is Physics 20a.
2 Essential information

• Instructor: Albion Lawrence.


• Class time: T-F 11-12:20. Location: TBA, as soon as I know myself.

• Office hours: 1 scheduled hour a week, to be negotiated. You are also welcome to make an appointment by email (especially for, but certainly not restricted to, those who have a conflict with office hours). Advance warning is always best; like most faculty, my schedule can fill up pretty quickly.

• Contact info:
  – Office: Abelson 344
  – Phone: 781-736-2865
  – email: albion@brandeis.edu. In general, expect at least 24 hours for a response unless it is a genuine emergency (eg medical/legal/family) or a mistake in a problem set.
  – Online communications: additional readings, problem sets, problem set solutions, announcements, and lecture notes will be posted to the LATTE page for the course. I will announce these when I post them.

• Grader: depends on enrollment.

• Basis of grades: Quizzes, in-class problem solving, and ”reading questions” 10%. ”R Problem sets, 30%; Midterm, 20%; Final, 40%.

• Lecture format. The lecture time will be a blend of traditional lectures, some short in-class quizzes and group exercises, discussion, and possibly occasional board work by the students. Lectures will follow the textbook roughly but not exactly or completely – the goal is to motivate the material, explain the key points, go over conceptually tricky points, and add material. The official textbook is considered somewhat advanced, and is in addition rather terse (it will be one of the smaller textbooks you’ll buy). So I will be leaning heavily on the lectures to
organize the material, and depend on you to ask questions during and after the lectures.

I will post scanned copies of the notes to LATTE, usually after each class. I recommend you take your own notes as well; this facilitates engagement with the material in real time. (My notes may not include responses to questions, for example – and some of these can be substantive). I strongly encourage questions during class.

- **Workload.** In general, as per Brandeis policy, success in this 4 credit hour course is based on the expectation that students will spend a *minimum* of 9 hours per week in preparation for class (readings, problem sets, preparation for exams, etc.)

- **Reading.** I will post reading assignments at least weekly, mostly from the required text but also from additional material I will post on LATTE. The reading will include things I did not cover in class, and I will often assign reading on a subject to be completed before I cover that subject in class. I will regularly ask you to post questions to LATTE based on the assigned reading.

- **Problem sets.** Problems will be handed out every Tuesday. I will often assign a short problem to be completed by Friday, in order to prepare you for the lecture, but the bulk of the problem set will be due the following Tuesday. I will drop the lowest homework in computing your final percentage.

The problem sets are meant to be challenging but fun. You are strongly advised to look them over and take an initial crack at them early on. First, you will know quickly what does and does not totally confuse you, and can either ask questions (of me or your fellow students) and do the needed background preparation (reading etc.) Secondly, if you spend some time attacking the problem early on, you may find that you keep working on them subconsciously. The problem sets are not written to be doable in a single evening.

I encourage students to discuss the problem sets with each other. The work you present at the end must be your own: you may solve the problem collectively, but the writeups should be independent (if you have understood the solution, this will come naturally). Identical problem sets, or problem sets essentially identical to what can be found in a
known book or online will be treated as plagiarism, and will be dealt with according to the guidelines written in the Rights and Responsibilities student code.

- **Quizzes and in-class problems.** I will regularly give quizzes during class based on assigned reading and prior assignments. These are meant to be "low-stakes", and are meant to help you consolidate your understanding. They are also to help me monitor how much you are learning. I will also give problems to be solved in class by small groups. These latter will be graded very loosely on a "pass/fail" basis, just to make sure people are actively participating. I will drop the lowest 2 quizzes in computing your final percentage, to take care of sick days and days you just couldn’t get out of bed.

- **Exams:** these will be closed-book but open-note; electronic devices will not be allowed. The midterm will be given mid-late October (you will be given at least 2 weeks’ notice), with the precise timing based on how I think the lectures are progressing.

## 3 Subjects covered

These are aspirational: I don’t expect to get through everything, and the order may change.


3. More on small oscillations

4. Rigid body motion

5. Special relativity (if time)

6. Hamiltonian mechanics
4 Required and Suggested Reading

After considerable thought and discussion with my colleagues, I realized that there just isn’t a perfect book for this course. I decided to err on the side of a somewhat sophisticated book that would contain almost everything I hoped to cover. I’ve included a list of additional books that may help, and encourage you to take a look.

- **Required**: *Mechanics* by Landau and Lifshitz. This is a classic book in advanced mechanics from the famous ”course in theoretical physics” developed for students at the Landau Institute for Theoretical Physics in Moscow. It is in many ways a beautiful book, containing all of the essentials you need in the subject, and a large number of important worked problems; it should be on the shelf of every serious physicist by the time they reach graduate school. It does not make a good primary textbook at this level (I thought about it, and decided it would cause a revolt). It is a bit too advanced, and is very compactly written, so intuition may be hard to glean from it. It also does not cover some subjects I hope to cover, such as special relativity. I may use some of its sections on small oscillations (in which case I will post the relevant reading on the LATTE page).

- **Recommended**: *Mathematical Methods in the Physical Sciences*. We assign this book in Physics 20a with the idea that it will be useful throughout your undergraduate career. It is excellent for reviewing mathematical subjects you are rusty on; furthermore, it has a nice section on the calculus of variations, which is an important part of this course.

- **Recommended**: *Classical Mechanics* by Goldstein, Poole, and Safko. This is a classic graduate-level text in the subject. It is probably too advanced for an introductory course, and has a number of crucial mistakes, but is a useful reference. Prior editions (by Goldstein alone) will also serve: I will note that Professor Fell, who often teaches this course, prefers those editions.

- **Recommended**: *Mechanics: From Newton’s Laws to Deterministic Chaos*, by Florian Scheck. This is somewhat advanced. It has a large number of worked problems. I used this last year and found that the logical organization was a bit jumbled, but there are some good things in it.
• *Classical Mechanics*, J.R. Taylor. This is a very popular and well-reviewed textbook, used in many respectable places. I found it to be at too low of a level for this course. But it is extremely well-written and may be a useful supplement.

• *Recommended*: *An Introduction to Mechanics* by Kleppner and Kolenkow. Physics 15a students will know this (all too?) well; for 11a students this book will sit between their course and this one. All of the classic examples (Circular motion, the harmonic oscillator, the Kepler problem, rigid body motion) are worked out in detail, and the sections on special relativity are very nice.

• *Recommended*. *Lectures on Physics, volume 1*, by R.P. Feynman. This is a beautiful book, if a little dated (the parts on particle physics, for example). It was intended for first-year Caltech students, so it does not cover Lagrangian and Hamiltonian mechanics in any seriousness, though it touches on them. Still, it contains a lot of insight and is worth looking at if you are confused by some point.

• *Recommended*. *Classical Dynamics: a contemporary approach* by José and Saletan. This uses a modern, geometric approach to the subject. Prof. Fell has used this book in previous years. It is nicely written, but he has told me that in retrospect it is a bit too mathematically advanced for Physics 100.

• *Recommended*. *Mathematical Methods of Classical Mechanics*, by V.I. Arnol’d. This is a graduate/advanced undergraduate-level mathematics textbook – I recommend this for the mathematically inclined. The opening 3 chapters are very physical and readable, however.