PHY 303/573 – Analytical Mechanics

Fall 2021

General Course Information

Last updated: 2021-08-12 11:27

Prerequisites: PHY 251 and PHY 277 or permission of department; MAT 303 or MAT 305 or AMS 361 or MAT 308. 3 credits.

Overview

Analytical Mechanics is the generic name given to a number of theoretical approaches to Classical Mechanics in which *vectorial* quantities of motion take a less prominent place than in Newton's original approach. While Newton's formulation of Classical Mechanics proved tremendously successful and became the defining paradigm of our scientific age, its direct generalization potential turned out, from a historical perspective, to be rather limited. In contrast, the methods of Analytical Mechanics — the Lagrangian and the Hamiltonian formalisms, the Hamilton-Jacobi theory, the principle of least action, the idea of phase space, and the beautiful and deep relation between symmetries and conservation laws expressed by Noether's theorem — led to powerful and far-ranging generalizations. In some form or another their essential principles sit now at the heart of modern theoretical physics and play a central role in such varied fields as relativistic mechanics, general relativity, quantum mechanics, statistical mechanics, classical and quantum field theory. Our aim in this course will be to retrace this conceptual shift and walk the bridge between the Newtonian mind frame and the modern "analytical" one.

A more concrete goal of the course is for you to learn to solve classical mechanical problems using the methods and concepts of Analytical Mechanics. The mathematical level of the course should be considered as advanced, in accordance with the listed prerequisites. In particular, **you will be expected to have a solid working command of algebra and multivariate calculus.** For a successful outcome, you should anticipate to spend a substantial amount of time every week preparing for the course and working on the homework assignments.

Basic Info

Instructor

Radu Ionaş

Email: Radu.Ionas@stonybrook.edu (Reserved for personal/private issues. When inquiring about homework-related issues please c.c. our TA as well.)

Office hours: TBA

Teaching Assistant

TBA

Email: ...

Lectures

MW from 4:25–5:45 pm, Melville Library W4550

Course Administration

The course administration will be done mainly through Blackboard. Important course announcements will be posted there or sent to you by class email. Also, I will endeavor as much as possible to post the lecture slides ahead of each lecture, in the Course Documents section.

Required Materials

An electronic device with a video camera and microphone, capable of supporting Zoom, and a reliable internet connection capable of streaming video.

Textbook and Other References

The recommended textbook for this course is

- D. Morin — *Introduction to Classical Mechanics With Problems and Solutions*, 2009 (1st ed.)

In a previous iteration of the course we used

- L. N. Hand, J. D. Finch — *Analytical Mechanics*, 1998 (1st ed.)

The first book emphasizes applications and problem-solving, while the second one emphasizes theory to a greater extent.

The canonical references in the field are

- L. D. Landau, E. M. Lifshitz — *Mechanics*, 1960 (the first volume in a magistral ten-volume *Course of Theoretical Physics*)
- H. Goldstein — *Classical Mechanics*, 1951 (with the latest, extended 3rd edition from 2005 including also C. P. Poole and J. L. Safko as authors).

Many other books exist, covering a varied range of difficulty levels, pedagogical approaches, and mathematical tastes. (Scientists have noticed that, alongside frustration, a common side effect of studying Analytical Mechanics consists of developing strong contrary opinions about these books.) Among the freely available resources which you might find useful to consult, and to which I may refer from time to time, are

- Professor Martin Roček's lecture notes (to be made available in Blackboard).
- Professor Konstantin Likharev's book on *Classical Mechanics* (2013), part of his *Essential Graduate Physics* series.
- Professor Derek Teaney's notes for the corresponding graduate-level course.
- D. Tong — *Lecture Notes on Classical Dynamics*.
- S. Golwala — *Lecture Notes on Classical Mechanics*.
- J. C. Baez, D. K. Wise — *Lectures on Classical Mechanics*.

If you need a refresher of the fundaments of Newtonian mechanics there are again many books that you could try, depending on your needs and taste. The recommended textbook has a few chapters which you might find helpful for that. In addition, I will list just one other reference, freely available online, from a master of the trade:

- R. Feynman — *Lectures on Physics*, vol. I.

Homework

Homework will be assigned weekly on Thursdays and will be due on the *second* Monday after that, in the lecture. It will consist of several problems, some of which are going to be quite challenging; you should expect to spend several days studying the corresponding theory and working on them. The penalty for missing the submission deadline will be of 10%/day. To account for mishaps and unforeseen events, at the end of the semester the lowest two homework grades will be dropped. In exchange for this no deadline deferral requests will be granted, regardless of justification. (Exceptions will be made for very serious reasons, such as medical emergencies or mental hardship.) Discussing the homework with your colleagues is not only allowed but strongly encouraged; however, the solutions you submit must be entirely your own work. Ten percent of each homework score will grade the quality of the presentation.

Exams

There will be one midterm and one final exam. These are scheduled on TBA, and Dec. 8, from 8:30 – 11:00 pm, respectively.

Grades

Your *course score* will be calculated based on the following percentage weights:

Midterm exam	25%
Final exam	50%
Homework	25%

Letter grades for the course will then be assigned on a curve, which I reserve the right to choose as I see fit, in accordance with the difficulty of the exams. There will be no possibility of earning extra credit at the end of the semester.

Note that in the event that adverse developments in our epidemiological circumstances will prevent taking any one of the exams in-person, this grading scheme may be changed.

Course Outline

The following is a tentative list of some of the topics that I plan to discuss throughout the semester:

- Mathematical preliminaries and a review of Newton's laws
- Mechanics in non-inertial frames
- Lagrangian mechanics
- Variational calculus
- Simple and coupled linear oscillators
- Central forces and Kepler's problem
- Noether's theorem
- Hamiltonian mechanics

- Canonical transformations
- The Hamilton-Jacobi equation
- Dynamics of rigid bodies

Student Accessibility Support Center Statement

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, 128 ECC Building, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at

http://www.stonybrook.edu/commcms/academic_integrity/index.html

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.