Classical and Quantum Mechanics I

New York University, Department of Physics

Fall 2022 Course Syllabus

Course Information

Instructor Information

- **Instructor:** Matthew Kleban (he/him)
- **Teaching assistant:** Joan LaMadrid (he/him)
- **Matt's office:** 1005a
- **Matt's student hours:** TBD, 1005a + https://nyu.zoom.us/my/matthewkleban
- **Matt's phone:** x87710
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- **Joan's office:** 936
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Textbook & Course Materials

- **Main Texts:**
  - "Classical Mechanics" (3rd Ed), Goldstein, Safko & Poole, Pearson (2014)
  - "Modern Quantum Mechanics" (3rd Ed), Sakurai & Napolitano, Cambridge (2021)

- **Recommended Texts & Other Readings:**
  - "Mechanics," Landau and Lifshitz, Elsevier Butterworth-Heinemann (1976)
  - "Classical Dynamics: A Contemporary Approach," Jose and Saletan, Cambridge (1998)
  - "Essentials of Hamiltonian Dynamics," J. H. Lowenstein, Cambridge (2012)
  - "Quantum Mechanics: Non-Relativistic Theory" (3rd Ed), Landau and Lifshitz, Elsevier Butterworth-Heinemann (2004)
  - "Lectures on Quantum Mechanics" (2nd Ed), Weinberg, Cambridge (2015)
  - Roman Scoccimarro's class notes https://cosmo.nyu.edu/roman/courses/dynamics_2019/

Course Structure

The lectures are MW 9:30-10:45 AM in room 1067, and recitations are M 2:15-3:00 PM in 1045.

Grading

~Weekly problem sets (40%), midterm (25%), and final (35%)
- Grading Scale: 100%-93% A, 92%-90% A-, 89%-87% B+, 86%-83% B, 82%-80% B-, 79%-77% C+, 76%-73% C, 72%-70% C-, 69%-67% D+, 66%-65% D, <65% F

Course Objectives

The goal of this course is to learn the essentials of classical dynamics ($\hbar=0$), and then to begin to study the basics of quantum mechanics ($\hbar=1$). The second half of the course will be entirely quantum mechanics. We will not discuss relativistic mechanics ($c=\infty$).

Outline/Schedule

Lecture 1: Generalized coordinates, Lagrangian, Principle of Least Action, Euler-Lagrange Equations of Motion [Goldstein 2.1-2.3, Landau & Lifshitz 1-4]

Lecture 2: Symmetries and Conservation Laws, Noether's Theorem, Self-similarity [Goldstein 2.6-2.7, Landau & Lifshitz 10]

Lecture 3: Legendre transform, Hamiltonian, Hamilton's equations [Jose & Saletan 5.1.2., Goldstein 8.1-8.2, 8.6]

Lecture 4: Phase Space, Poisson brackets [Landau & Lifshitz 42, Goldstein 9.5]

Lecture 5: Canonical Transformations [Goldstein 9.1-9.3, Landau & Lifshitz 45]

Lecture 6: Generating functions [Goldstein 9.1-9.3, Jose and Saletan 5.3.3]

Lecture 7: Time evolution as a Canonical Transformation, Liouville's theorem, Hamiltonian Noether's theorem. [Goldstein 9.5-9.6,9.9, Jose and Saletan 5.3.4]

Lecture 8: Hamilton-Jacobi theory. Separability [Goldstein 10.1-10.4, Jose and Saletan 6.1]

Lecture 9: Action-Angle variables [Goldstein 10.6-10.7]

Lecture 10: Liouville-Arnold theorem, integrability [Jose and Saletan 6.2.2]

Lecture 11: Canonical Perturbation Theory [Goldstein 12.1-12.4]

Lecture 12&13: Invariant tori, resonances, KAM theorem [Goldstein 11.1-11.2, Jose and Saletan 6.2.3., 7.5.4]

Lecture 14: Adiabatic Invariance [Goldstein 12.5]

Lecture 15: Hilbert spaces, probability, measurement, canonical quantization (Sakurai1.2-1.4.4)

Lecture 16: Time evolution, Hamiltonian, Schrodinger equation, symmetries in QM (Sakurai 2.1.1-2.1.4, 2.2.1-2.2.3)

Lecture 17&18: Pure and mixed states, entanglement (Sakurai 3.4)

Lecture 19: Coordinate and momentum representations, uncertainty principle, wave behavior (Sakurai 1.4.5, 1.6, 1.7, 2.4)

Lectures 21 & 22: QM potentials in d=1, bound states, reflection and transmission coefficients, tunneling (Landau & Lifshitz 18-22, 25)

Lectures 23 & 24: Harmonic oscillator, displaced ground state, coherent states (Sakurai 2.3,2.5.2)

Lectures 25 & 26: Path Integral, propagators, solving harmonic oscillator with path integral (Sakurai 2.6)

Lecture 27: WKB approximation, Bohr-Sommerfeld (Sakurai 2.5.4)