Quantum Mechanics

Unofficial Course Title: Quantum

Spring Semester (Terms 4 & 5) 2026, Deep Springs College, ***Prof. Brian Hill***

Directed Study Students: Lucinda Bean (DS 25) and Grisha London (DS 25)

Course meeting times: 9:30-10:55am, Mo/Th

Syllabus

The **Quantum Mechanics DS Proposal** will serve as our preliminary syllabus.

Daily Schedules

Detailed daily schedules will be kept retrospectively and are included below at the end of this PDF.

- **Daily Schedule-Term 4**
- **Daily Schedule-Term 5**

Overview

We will study quantum mechanics, starting with Spin 1/2 and Spin 1 systems, and conclude with Schrodingers Equation and some of its solutions, following Feynman, and with supplementary material from Moore when Feynman gets too advanced for an introductory course.

Normally one does not get to study quantum mechanics in the depth we will go into until the junior year as a physics major. To get to this level of quantum mechanics so quickly, we are short-circuiting past electromagnetism. A substantial cost of this is that you have not even encountered electromagnetic waves! So to understand quantum-mechanical waves we will first immerse ourselves in other, simple examples of waves. We also have to introduce you to complex numbers, which is normally done in a semester-long sophomore level mathematics course. We will learn the essential results from complex numbers following the first chapter of Churchill, Brown, and Verhey. The upshot is that this is an extremely ambitious course for first-years to take in their spring semester, who only have classical mechanics and calculus taken previously.

Nonetheless, by the end of our quantum mechanics studies, you will be able to do probabilistic calculations using the strange mixture of deterministic time evolution punctuated by non-deterministic measurement events. You will understand how systems with 2, 3, 6, and an infinite number of states. Following the propagation of particles through a crystal lattice, which has wave solutions, we will immerse ourselves in the Schrodinger equation as our final topic.

In summary, in this course you will encounter behaviors and theories so strange and wonderful that no human could have thought them up. Instead, nature rubbed the behaviors in the faces of physicists, who eventually, even miraculously, in the early 20th century, were able to understand and articulate what nature was showing them.

Texts

- Feynman, *The Feynman Lectures on Physics, New Millenium Edition,* Volume III
- Moore, *Six Ideas that Shaped Physics, 4th Ed,* Volume Q
- Churchill, Brown, and Verhey, *Complex Variables and Applications*

Grading

- 50% Homework
- 20% Full Participation in and Leadership of the Directed Study
- 30% Three Exams

Quantum Mechanics — Daily Schedule Term 4

Week 1 — Introduction to Quantum-Mechanical Interference — Introduction to Complex Variables

- Monday, Jan. 12 — Reading: Churchill, Brown & Verhey (hereafter, just "CBV"), Sections 1 and 2 of Chapter 1; Feynman, Volume III Chapter 1 — Problem Set 1: All the evens in the CBV reading
- Thursday, Jan. 15 — Reading: CBV, Sections 3 and 4 of Chapter 1; Feynman, Chapter III-2 — Problem Set 2: All the evens, in the CBV reading; Feynman 27.12, 27.14 and 27.21

Week 2 — Mathematics of Classical and Quantum-Mechanical Wave Interference and Diffraction

- Monday, Jan. 19 — Reading: CBV, Sections 5 and 6 of Chapter 1; Start Feynman, Chapter I-29 and part of I-30 — Problem Set 3: All the evens the CBV reading
- Thursday, Jan. 22 — Feynman, Conclude Chapter I-29 and part of I-30 — Problem Set 4: Feynman Problem 21.1; Derive the actual function of angle (not just the location of nodes and anti-nodes) for all the situations Feynman detailed in Chapter I-29; Feynman Problems 21.4, 21.5, and 21.6

Week 3 — Notation and Rules for Combining Quantum-Mechanical Probability Amplitudes

- Monday, Jan. 26 — Reading: Continue Feynman through III-3-2 (through means up to *and including*) — Problem Set 5: Wolfson, Chapter 14, Problems #24 and #46, Feynman Problems 27.6, 27.7, and 27.20, and my Gaussian problem
- Thursday, Jan. 29 — Reading: Finish Chapter III-3 — Problem Set 6: 1. Just for practice with the notation, write out Eq. 3.6 and the un-numbered equation that precedes it for the case where the first screen contains three slits, 1, 2, and 3, and the second screen contains two slits, a and b, and don't use ellipses, write all 6 terms out; 2. Do my handout; 3. 70.1; 4. 70.2; 5. 70.6; 6. 70.8

Week 4 — Exam 1 — Bose-Einstein Statistics

- Monday, Feb. 2 — **Exam 1** on CBV, Chapter 1, Wolfson, Chapter 14, and Feynman, Chapters I-29, I-30, III-1, III-2, and III-3 (glossing the Bohr atom, the Uncertainty Principle, and Feynman's emphasis on crystal diffraction patterns, even though the latter are experimentally and scientifically extremely important for discovering the lattice structure of crystals)
- Thursday, Feb. 5 — Reading: Feynman Chapter III-4 through Section III-4-4 — Review Section III-3-4 where identical particles were first introduced — Problem Set 7: 1. Exam Problem 4; 2. Exam Extra Credit Problem 6

Week 5 — Black-Body Radiation — Fermi-Dirac Statistics — Spin 1 Systems

- Monday, Feb. 9 — Reading: Finish Feynman Chapter III-4 — Problem Set 8: 1. 71.1; 2. 71.2; 3. 71.4; 4. 71.7; 5. 71.12 (hard but very worthwhile, and take a look at 71.13 if you want to know why it is so worthwhile)
- Thursday, Feb. 12 — Reading: All of Feynman Chapter III-5, and the supporting material from II-35 (up to but not including Rabi's method) — Prolem Set 9: 0.(a) Derive the angular momentum of a spinning sphere from first principles (the definition of angular momentum) and 0.(b) Derive the magnetic moment of a charged spinning disk, starting from the first princples (the definition of magnetic moment); Problems 1-4 are all four of Feynman's problems that go with Chapter III-5

Week 6 — Spin 1/2 Systems — Start Time-Dependence

- Monday, Feb. 16 — Reading: Do as much reading in Chapter III-6 as you need to do the problem set

(the tables at the end summarize all that Feynman derives) — Problem Set 10: 0. Prove using the formulas given in Section 5-7, what is claimed in the last paragraph of the section; Problems 1-3 are the first three of Feynman's problems that go with Chapter III-6; As Problem 4, redo the last problem on the previous problem set if you misinterpreted it (look briefly at the first few sentences of my solution to understand the intended interpretation)
- Thursday, Feb. 19 — Reading: Chapter III-7 — NB: The only thing you really have to know about relativity is what I quickly derived, which is (a) the relativistic generalization of Newtonian kinetic energy is $m\gamma c^2$ and (b) the relativistic generalization of Newtonian momentum is $p=m\gamma v$, (c) γ is a factor that appears when $dt/d\tau$ comes out of the relativistic generalization of the time derivative, and (d) you should easily be able to use approximations for γ to recover the usual Newtonian expressions — Problem Set 11: There is only one big problem for this chapter, and we will complete it for the next class, along with some related problems

Week 7 — Finish Time-Dependence — Start Hamiltonians

- Monday, Feb. 23 — Reading: Consolidate Chapter III-7 — Problem Set 11: Do the one big problem for this chapter, and the additional problems in **Handout and Problems to go with Chapter 7** — **Ripples in a Pond** demonstrates group velocity, with both normal dispersion and anomalous dispersion
- Thursday, Feb. 26 — Reading: Start Feynman III-8 (you will finish after the break) — You can get started on problem Set 12, the zeroth problem of which will be **Another Fourier Problem**, and the remaining three problems will be Feynman's three problems for Chapter III-8 (but none of this will be due until Monday, Mar. 16th)

Week 8 — Resonance Behavior — Start Hamiltonians of Two-State Systems

- Monday, Mar. 16 — Reading: Consolidate Chapter III-8 — Problem Set 12: The zeroth problem of which is **Another Fourier Problem**, and the remaining three problems are Feynman's three problemms for Chapter III-8
- Thursday, Mar. 19 — Reading: Feynman Chapter III-9

Week 9 — Exam 2 — Off-Resonant Behavior — Continue Hamiltonians of Two-State Systems

- Monday, Mar. 23 — **Exam 2** on Feynman Chapters 4 to 8 — Homework for next class: Carefully study Section 10-6 of Feynman (you will have to go back and pick up just a bit of Section 10-1 when studying 10-6) — Glance at Section 10-7, including the last paragraph — Glance at the problems for Chapter 10, which we start together in class on Thursday
- Thursday, Mar. 26 — Feynman Sections 10-1, 10-6, and 10-7 and starting on Feynman Problem 77.2

Week 10 — Exam 2 — Pauli Matrices — Finish Hamiltonian Formulation of *N*-State Systems

- Monday, Mar. 30 — Problem Set 13: Finish Feynman Problem 77.2 — Study Section 11-1 on the Pauli Matrices
- Thursday, Apr. 2 — Study Feynman Sections 11-2 and 11-3, and take a look at 11-4 — Do **Problem Set 14**

Week 11 — Electron Propagation in a Crystal Lattice

- Monday, Apr. 6 — Study Feynman III-11-6 — Do **Problem Set 15**
- Thursday, Apr. 9 — Study Feynman III-13-3 and III-13-4 — For Problem Set 16, follow Feynmans's "something you can play with on p. 13-6" suggestion and do Feynman Problem 80.1

Week 12 — Start Schrodinger's Equation

- Monday, Apr. 13 — Study Feynman III-16-1 and III-16-2 — For Problem Set 17, just do one more of Feynman's crystal lattice problems, Problem 80.2
- Thursday, Apr. 16 — Study Feynman III-16-3 and III-16-4 — For Problem Set 18, do the first of

Feynman's Schrodinger Equation problems, 83.1 — Part (e) of 83.1 may require a tricky argument, perhaps scaling out all the dimensional dependence of the integral

Week 13 — Qualitative Behavior and Solutions of Schrodinger's Equation

- Monday, April 20 — Study Moore Chapter Q.9 (essentially a review of Feynman Chapter III-16) and Moore Sections Q.10.1, Q.10.2, and Q.10.3 — For Problem Set 19, do Moore Problems Q9M.6, Q9M.7, and Q9D.2
- Thursday, April 23 — For Problem Set 20, do Moore Problems Q10B.7, Q10D.1, Q10D.4, and Q10D.8 — Read ahead in Moore Chapter 12 — Qualitative behavior of Shrodinger's Equation — Square Well and Harmonic Oscillator

Week 14 — Exam 3 on Wave Functions and Schrodinger's Equation — The Harmonic Oscillator

- Monday, April 27 — **Exam 3** is four Schrodinger Equation problems from Moore — On Monday, we will go over these problems: 1. Q12B.6, 2. Q12D.1, 3. Q12D.3, 4. Q12D.4 — Raising and Lowering Operators for the Harmonic Oscillator