PHYS 339
Advanced Quantum Mechanics and Particle Physics
Spring 2009

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Text

- Introduction to Quantum Mechanics, 2nd Ed., David Griffiths
- Introduction to Elementary Particles, 2nd Ed., David Griffiths

Additional Reading

- A Modern Approach to Quantum Mechanics, John Townsend.

  There are roughly two types of quantum mechanics texts: those which begin with wave mechanics and those which begin with the state representation. Griffiths is a good example of the former and Townsend a good example of the latter.

- Particle Physics Booklet.

  This is a handy reference for our current knowledge of particle physics. It is updated annually and you can (should) request a free copy at
  http://pdg.lbl.gov/cgi-bin/pdgmail/edit.pl

Course Description

This is two courses rolled into one, as the title suggests. While it would be easy to spend a semester on topics in advanced quantum mechanics, we will instead focus on some of the more essential topics and techniques. First, we will address issues of determinism and locality in the EPR paradox and Bell's inequality.. Then we will study time-independent perturbation theory, which we will apply to the hydrogen atom to describe the fine structure splitting of the energy levels. Next, we consider time-dependent perturbation theory, which allows us to calculate transition rates. And finally, we will study scattering, which is one of our most heavily used probes of the interactions between particles. These all play a central role in our understanding of fundamental particle physics.

However, quantum mechanics as you've learned it, and as we'll have covered it to this point, is strictly non-relativistic. The 20th century saw two revolutions in fundamental physics

— relativity and quantum mechanics — and they were born incompatible. Early on Dirac recognized this as an important conflict and set out to reconcile the two. He made heroic strides forward, but the full resolution required quantum field theory, which took many more people and a few more decades to sort out.

In our study of particle physics, then, we will begin with some essential features of special relativity. Then we will begin to explore the framework of *fully relativistic quantum mechanics*, such as Feynman diagrams, the Dirac equation, and calculating cross-sections and decay rates for fundamental processes.

Course Structure

The course material is drawn from the texts and the lectures. Assigned reading will be given on the board for the coming lecture, and should be done before the next lecture. Class time will be used to expand on the reading and to work through examples.

- **Homework** — A homework set will be assigned each class period and will be due at the beginning of the following class. You are encouraged to work together on the homework sets, though you must write up the problems yourself. I will randomly decide (based on a tossed die!) whether to collect the homework or have you self-grade it. I will provide guidelines for the self-grading, and solution sets for each homework set.

  No late homework will be accepted!. This is because the solution sets will already have been distributed, and because the goal is for you to be working on the problems while we are discussing the material. You will get to drop your lowest four homework grades.

- **Journals** — You are required to submit a journal entry for each reading assignment. These serve the purpose of encouraging you to do the reading and, more importantly, giving me a useful guide as to what we should spend lecture time on, i.e., letting me know what's already clear and what's confusing from the reading. Your journal entry should reflect that you've done the reading and can contain any or all of the following: a summary, parts you found confusing, parts you found clear, parts your particularly liked or disliked, or general comments about the course. These will be scored on a 2 point scale.

- **Exams** — There will be three midterm exams. The first and third will be in-class exams, but the second will be a takehome.

Grading

- Problem sets: 20%
- Journals: 10%
- 3 Midterm exams: 45% combined
- Final exam: 25%

Approximate Schedule

Dates	Topics	Reading
Jan 14–19	Spin, EPR Paradox, & Bell's Inequality	QM 4.4 & 12.1–12.2
Jan 21–26	Time-Independent Perturbation Theory	QM 6.1–6.2
Jan 28	Hydrogen Atom Review	QM 4.1–4.3
Jan 30–Feb 4	Fine Structure, Zeeman Effect, and Hyperfine Splitting	QM 6.3–6.5
Feb 6	Catchup and Review	
Mon, Feb 9	**Exam I**	
Feb 11–13	Time-Dependent Perturbation Theory	QM 9.1
Feb 16–20	Emission and Absorption of Radiation	QM 9.2–9.3
Feb 23–25	Scattering: Partial Wave Analysis	QM 11.1–11.3
Feb 27–Mar 2	Scattering: Born Approximation	QM 11.4
Mar 4	Lorentz Transformations and 4-vectors	EP 3.1–3.2
Mar 6	Catchup and Review	
Take-home	**Exam II — due Fri, March 20**	
Mar 20–23	Energy, Momentum, and Collisions	EP 3.3–3.5
Mar 25–27	Fermi's Golden Rule	EP 6.1–6.2
Mar 30–Apr 3	Feynman Rules for ABC Theory	EP 6.3–6.5
Apr 6–10	Dirac Equation	EP 7.1–7.2
Mon, Apr 13	**Exam III**	
Apr 15–20	Parity, Bilinear Covariants, and the Photon	EP 4.6 & 7.3–7.4
Apr 22–27	Feynman Rules for QED	EP 7.5–7.6
TBA	**Final Exam**	