Advanced Quantum Mechanics

Syllabus and Introduction

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Office Hours: MWF 10:00 – 11:00 AM. You are welcome to stop by any other time when my door is open.

Course Content: Advanced quantum mechanics (or "QM II" for short) begins where ordinary quantum mechanics leaves off in two very important respects. First there is the issue of relativity. Relativity requires that space and time coordinates be treated in the same way, and this is not possible so long as one is tied to Schrodinger's equation, which is after all, first order in time and second order in space coordinates. This is not too hard to deal with. We use the Heisenberg picture, so that space and time coordinates appear together in the operators. We also need new wave equations, which depend on the spin of particles involved. The second respect is much more difficult: Ordinary QM describes particles that have existed for all time and will continue to exist forever. There are a few physical systems that fit this description, at least to a good approximation, but they are not very interesting! Take something as simple as a hydrogen atom making a transition from some excited state to its ground state. A photon is *created.* There is no completely honest way of treating this with conventional QM. Doing it right demands a completely new formalism. There are actually two quite different ways of doing this. In one approach, called "second quantization," the wave functions are made into operators by imbedding harmonic oscillator raising and lowering operators in them. The more modern approach uses path integrals and eliminates *all* operators from the formalism. Both formalisms are difficult and non-intuitive, and they are connected with ordinary QM by not much more than a leap of faith! On the long run, I suppose, one needs to learn both. I have decided not to cover path integrals this year in the hope of gaining some time to cover string theory late in the spring quarter. During the fall quarter we will follow the usual sequence and start with the second quantization of scalar fields.

Textbook: Some graduate courses are defined by their textbook. E&M is, by definition, that which is written in the latest edition of Jackson. Classical Mechanics consists of the material in Goldstein. This has been true since the books were first published over 40 years ago. This is *not* true of QM II. For one thing, the subject is still an active field of research. I have a long shelf full of obsolete field theory books, none of them more than a few years old. For another thing, almost all the field theory books have been written by and for elementary particle theorists. This is odd, since many of the techniques came out of and are still used in condensed matter theory. Finally, the material is really very advanced and sophisticated, so most books written on the subject don't make very good textbooks. There are three books written recently that come *close* to being real textbooks.

Gauge Theoreis in Particle Physics, Vol. I and II, I. J. R. Aitchison and A. J. G. Hey, Institute of Physics Publishing, 2004.

A Modern Introduction to Quantum field Theory, Michele Maggiore, Oxford University Press, 2005.

A First Book in Quantum Field Theory, Amitabha Lahiri and Palash B. Pal, Alpha Science International, 2005. This is a good book. Buy it!

I have also written the lecture notes for the course in book form. You can download the chapters from our website as we go along.

I should mention two recent books that purport to be texts but are really more useful as reference works.

Quantum Field Theory, Michio Kaku, Oxford University Press, 1993

An Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroder, Westview Press, 1995. This is the modern classic; the ultimate reference book.