

Syllabus for ECEN 5006

Quantum Mechanics for Engineers

Fall 2003

Alan Mickelson

August 19, 2003

1 Purpose

This course is a senior level or a graduate entry level course that requires no background other than that that is usual to undergraduate engineering programs. Its purpose is distinct from that of quantum mechanics courses offered in physics departments. That engineers in a variety of disciplines may have need for some working knowledge of quantum mechanics need not be expounded. The applications of quantum theory to even everyday engineering (i.e. lighting engineering, transistor based electronics) are too numerous to list here or to list at all for that matter. This is a course designed for engineers and one whose design involved engineering philosophy. The engineer who knows that something exists will generally find a way to apply whatever it is she/he knows to something else (perhaps something completely different) if she/he finds the need to and has the desire to satisfy that need. That engineers with some working knowledge of quantum mechanics may find applications for their knowledge is a premise underlying this course. The purpose of this course is, therefore, to expose the engineers in the course to as much quantum mechanics as they can be exposed to in a semester and still come away with some working knowledge of what they have seen. Conversely, the purpose of the course is not to prepare those who take the course to someday contribute to the cutting edge of research in fields such as quantum field theory. The treatment of the individual topics included in this course will not be meticulous by any means. This course, though, is also an optics course and, therefore, the hope is to come far enough with the basics of quantum theory that we can find apply some the basics to optical phenomena as well as to optics practise.

2 Objectives

A general objective of this course is to present some overview of quantum mechanics. A complete coverage of so extensive a field cannot be given in a single semester or a single year or even a much longer period of time. Bearing this in mind, an enumerated set of specific objectives for the course could be summarized as in the following:

1. to learn how to make (simple) calculations of quantum mechanical quantities,
2. to understand when a quantum mechanical approach to a problem may be advantageous and/or necessary, and,
3. to be familiar enough with the quantum theory of optics that one can read and understand primary sources in the technical literature.

3 The text and the prerequisites

There will be two texts for the course. One is a more elementary text which is often used in undergraduate as well as graduate courses, the book of Richard W. Robinett entitled *Quantum Mechanics*, Oxford University

Press (1997). A second somewhat more advanced (first year graduate) text which is more devoted to applications in optics is that of Wolfgang P. Schleich entitled *Quantum Optics in Phase Space*. Robinett's book is the more qualitative of the two although it does cover the fundamentals and most of the (few) problems which can be treated "exactly" in quantum theory. The book of Schleich is somewhat more formal, but also contains numerous examples, and uses these numerous examples together with the theory in order to make the transition to the quantum theory of light less shocking than so many of the quantum optics texts which quantize Maxwell's equations in the first chapter rather than in the tenth as in this text. The two texts compliment each other in many ways. The course plan will be to use the text of Robinett up through the midterm and that of Schleich for the remainder of the course, although there will be cross referencing between the two whenever need be.

4 Topics covered

The 43 lecture periods of the course (1 of the 44 lectures to be presented will be devoted to an in-class midterm) will be split roughly equally among the four different topics:

1. Wave Particle Duality as embodied by Schrödinger's equation.
2. Bound states of quantum wells.
3. The quantum states of the electromagnetic (light) field.
4. The theory of the interaction of light and matter and its application to the generation of quantum states of light.

In the following paragraphs, some more specific discussion of each of the above enumerated topics will be given.

- 1. Wave particle duality as embodied by Schrödinger's equation** This part of the course will consist of 11 lectures and will cover much of the material of chapters 2-4 and 6-9 of Robinett. The idea of this part of the course is to demonstrate to the student how the techniques that she/he learned to treat elementary wave propagation also apply to the propagation of matter waves in free space as well as in materials.
- 2. Bound states of quantum wells** This part of the course will consist of 11 lectures and will cover much of the material of chapter 10 and chapters 16-18 of Robinett. It is bound sates that account for the properties of everyday matter as well as for the properties of the designer materials that make up most of the electronic and optoelectronics that we use in everyday life. It is the modifications to these bound states that will lead to the new technologies of the future.
- 3. Quantum theory of light and its some of its applications** This part of the course will consist of 10 lectures and will cover much of the material of chapters 3-5, 7 and 10 of Schleich. The states of the optical field are defined spatially and temporally by the bound states of electromagnetic resonators (electromagnetic quantum wells) as the coherence properties of the field are defined by the states of the quantum harmonic oscillator. In this part of the course, classical and quantum states of light will be derived and discussed.
- 4. The interaction of light and matter and the generation of quantum states of light.** This part of the course will consist of 11 lectures and will cover much of the material of chapters 11, 14, 16 and 18 of Schleich. May desirable operations can be carried out with light. A problem with optical waves is that they don't interact with each other without a material intermediary. It is in this part of the course that we begin to discuss how light can be controlled so as to do what we would like it to do.

month	part	day	day	day
		Monday	Wednesday	Friday
August	I	25	27	29
September		LD	3	5
		8	10	12
		15	17	19
	II	22	24	26
		29		
October			1	FB
		6	8	10
		13	15	MT
	III	20	22	24
		27	29	31
November		3	5	7
		10	12	
	IV			14
		17	19	21
		24	26	TD
December		1	3	5
		8	10	

Table 1: A color coded table to indicate in which part of the course a given lecture will its subject matter based. Abbreviations include LD for Labor Day, FB for fall break, TD for Thanksgiving Day and MT for midterm.

5 A class calendar

Given the class starting date of August 25 and that Labor Day this year falls on September 1, 2003, fall break extends from October 2-3, Thanksgiving Break is comprised of November 27-28, and the last day for classes is December 11 that leaves 3 lectures in August, 12 in September, 13 in October, 11 in November and 5 in December. With October 17 reserved for an in class midterm, that leaves 43 lectures. The plan is that part 1 of the course will occupy 11 lectures, up through September 19, part 2 will consist of 11 lectures up through October 17, part 3 the 12 lectures up through November 12, part 4 at least the last 10 lectures of the course. Table 1 summarizes these considerations.

6 Work load

Problems will be assigned with due dates of roughly every other week. There will be a project, which will require one to solve a more involved problem than those included in the problem sets.

7 Grading

The grade will be determined in roughly equal parts from performance on the homework, midterm, final and project.

8 Something on supplementary references

Below, in the section entitled **References**, I have included a markedly incomplete list of books that might prove useful. A number of these references are included simply because they were the books I originally studied some of these topics from. Do note before reading further that I have placed none of these books

on reserve in any of the CU libraries. There are so many good references that I have failed to list because I wasn't aware of or wasn't sufficiently familiar with them that it should be easy for anyone in the class to find a secondary source if she/he has a mind to. Hopefully, students in the class already have in hand a certain number of favorite references for things they have already studied. Hopefully, also, students who are keenly interested in the material here (or at least some part of it) will find new references during the semester that they will use for future reference.

The references are identified in complexity by the color of their reference number in the following reference list. Blue references are elementary, green ones are more on the level of this course, whereas red ones are advanced.

References

- [1] Richard P. Feynman. *The Feynman Lectures on Physics. Volumes I. II. and III.* Addison-Wesley (1963-1965).
- [2] Stephen Gasiorowicz. *Quantum Physics.* Wiley (1996).
- [3] Zoya B. Popović and Branko D. Popović. *Introductory Electromagnetics.* Prentice-Hall (2000).
- [4] Max Born and Emil P. Wolf. *Principles of Optics.* Cambridge University Press, Seventh Edition (1999).
- [5] Hermann Haken. *Light. Volume 1: Waves, Photons, Atoms.* New Holland Press (1981).
- [6] Hermann Haken. *Light. Volume 2: Laser Light Dynamics.* New Holland Press (1985).
- [7] Hermann Haken and Hans Christof Wolf, *The Physics of Atoms and Quanta.* Springer, Sixth Edition (2000).
- [8] John David Jackson. *Classical Electrodynamics.* John Wiley, Third Edition (1999).
- [9] Herbert Kroemer. *Quantum Mechanics.* Prentice-Hall (1994).
- [10] Rodney Loudon. *The Quantum Theory of Light.* Oxford Press, Third Edition (2000).
- [11] Richard W. Robinett. *Quantum Mechanics.* Oxford University Press (1997).
- [12] Leonard I. Schiff. *Quantum Mechanics.* McGraw-Hill (1968).
- [13] Wolfgang P. Schleich. *Quantum Optics in Phase Space.* Wiley-VCH Verlag (2001).
- [14] D. F. Walls and G. J. Milburn. *Quantum Optics.* Springer Verlag (1994).
- [15] Leonard Mandel and Emil P. Wolf, *Optical Coherence and Quantum Optics.* Cambridge University Press (1995).
- [16] Marlon O. Scully and M. Zubairy. *Quantum Optics* Cambridge University Press (1996).
- [17] Julian Schwinger. *Quantum Electrodynamics.* Dover (1958).
- [18] Steven Weinberg, *The Quantum Theory of Fields. Volume I: Foundations.* Cambridge University Press (1995).
- [19] Steven Weinberg, *The Quantum Theory of Fields. Volume II: Modern Applications.* Cambridge University Press (1996).