

Preview

The following course will be offered this fall as special topics 500 course. In many cases, this course will serve as a elective course for seniors, and certainly serve as a graduate course for most engineering graduate students. This note is being written to let students be aware that this course could be very helpful to many who are interested in future engineering jobs in the high-tech area.

Quantum Mechanics for Engineering Devices

At one time, perhaps only 40 years ago, very few engineering courses touched on quantum mechanics (QM), which is the physics governing small structures. The vast majority of devices and products made back then had little connection or need for such understanding. However, times have changed considerably with a large number of engineering jobs in the high-tech area requiring at least some knowledge of this area, if not a great deal. Most chips in computers, gaming devices, cell phones, etc., all rely to a good extent on quantum mechanical aspects. Leading edge devices, namely, ones that the best companies are working on and developing, increasingly rely heavily on QM principles in a variety of ways. Any laser as well as most photonic devices, would not be explainable, never mind optimizable, without such understanding.

Most courses teach QM as a separate issue, simply going over the principles, without connecting to the vast quantity of devices in nano and micro technologies that are directly effected by these principles. In contrast, this course uses these applications as the starting point to aid students in understanding the fascinating world of QM, while equally emphasizing that QM is critical for engineering students intent on a future such growing areas as nanotechnology.

Syllabus:

When the phenomena and theory of quantum mechanics (QM) was first developed by physicists, starting in the early 1900s, the applications to engineering were few, if nonexistent. At the time, QM was an interesting and most curious physical theory, but not something one needed to know to make relevant engineering devices. Today, the situation is far different, as nearly all of nanotechnology, photonics, laser applications, solar cells, advanced instrumentation and sensors, and aspects of biotechnology, rely to a fair amount on QM principles. This course examines many of these key engineering applications and provides the necessary QM background behind them, thereby enabling engineering students to have a more unified view of applications and theory.

Introduction

- A survey of the historical and logical development of QM.
- Elementary initial application of the photoelectric effect.
- Heisenberg uncertainty principle

Schroedinger equation

- The standard non-relativistic QM wave equation.
- Its implication and interpretation.
- The representation of the wave equation in matrix forms.
- Harmonic oscillator and hydrogen atom
- Standard applications of QM

Band theory for periodic lattices

- The classic Kronig-Penney model for 1-dim periodic potentials
- An extension to generally periodic potential (Hill's eqn.)
- Imperfections: holes and electrons, localized bands
- Color centers in solids

Diodes (Zenner, LED, etc.)

- Basic structures and properties of several diodes
- Photo Diodes
- Avalanche photo-diodes
- Sensors and Actuators

Tunneling effects

Josephson junction

Cold emission

Quantum Dots

Radioactive decay

Spontaneous DNA mutation

Transistors

pnp and npn transistors

Field effect transistors as applied to microchips

tunneling, origin of holes,

Power transistors

Atomic Force Microscope

Initially developed using tunneling effects

Basic principles

The probe: A tiny probe with a few nanometer tip

Imaging modes: Contact, tap and non-contact.

Quantization of liquid Helium

He³-He⁴ dilution refrigerator as the closest approach to the absolute zero