ECSE-6968 "Quantum mechanics applied to semiconductor devices"

Instructor information:

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Course materials:

Course materials will be made available on course web site. Web site: http://www.rpi.edu/~schubert/. Files are in PDF format. The materials will be updated as the course progresses.

Lecture time and location: As scheduled

Office hours: Monday and Thursday 10 AM – 11 AM in CII 7111

Motivation:

Quantum mechanics plays an essential role in modern semiconductor heterostructure devices. The spatial dimensions of such devices are frequently on the scale of just Angstroms. In the domain of microscopic structures with dimensions comparable to the electron de Broglie wavelength, size quantization occurs. Classical and semi-classical physics no longer gives a correct description of many physical processes. The inclusion of quantum mechanical principles becomes mandatory and provides a most useful description of many physical processes in electronic and photonic heterostructure devices.

The proposed course for beginning graduate students will teach the fundamentals underlying the operation of modern electronic and photonic solid-state devices.

This course will give students a solid foundation for other microelectronics and photonics courses (e. g. SDM I / SDM II / Optoelectronics).

Level:

The course is intended for first-year graduate students

Title:

Quantum mechanics applied to semiconductor devices

Pre-requisite:

Elementary undergraduate courses in physics e.g. Physics I and II (PHYS 1100 and PHYS 1200).

Course content:

Historical overview of classical mechanics and the advent of quantum mechanics; the postulates of quantum mechanics; de Broglie hypothesis; Bohr–Sommerfeld quantization condition; position and momentum space; group and phase velocity; quantum mechanical operators; Heisenberg uncertainty principle; time independent and time-dependent Schrödinger equation; applications of the Schrödinger equation in nonperiodic and periodic semiconductor structures; quantum wells; Bloch theorem; Kronig–Penney model; superlattices; approximate solutions of the Schrödinger equations such as WKB and variational method; time-independent and time-dependent perturbation theory; harmonic perturbation and Fermi's Golden Rule; density of states and effective density of states in 3D (bulk), 2D (quantum wells), 1D (wires), 0D (dots) semiconductors (3D); classical and quantum statistics; ideal gases of atoms and electrons; Maxwell, Boltzmann, and Fermi–Dirac distribution; intrinsic and extrinsic semiconductors; shallow and deep levels; Bohr's hydrogen atom model; shallow and deep impurities; high doping effects; screening; Mott transition; band tails; semiconductor heterostructures; band discontinuities; tunneling in heterostructures; ohmic contact structures; metal-oxide-semiconductor structures; some electrical device structures; some optical device structures.

Text:
Manuscript entitled "Quantum mechanics applied to semiconductor devices" by E. Fred Schubert. Each chapter of the text will be provided to students as PDF file free of charge via a course web page. Most of text is available at this time.

Grading:
The final grade is composed of the following contributions: Midterm exam 40 %; Final exam 40 %; Homework 10 %; Project 10 %. The completion of your homework will be verified before the midterm exam and before the final exam.

Statement on academic dishonesty:

- Cheating on exams (such as copying from your neighbor) constitutes academic dishonesty.
- Turning in homework/reports/term papers as one's own, when they are not, constitutes academic dishonesty.
- A compilation of someone else's production/idea/work in a written or oral report must be attributed to the original source.
- The source of text passages stated in either paraphrased or *ad verbatim* form must be cited.
- Plagiarism is the use of someone else's production/idea/work without crediting the source. Plagiarism constitutes academic dishonesty.
- *Note*: Teamwork during class exercises and homework is allowed. The use of calculators is also allowed.
- *Note*: If something is well known (common knowledge), the original reference does not need to be cited. Example: We can use Newton's second law ($F = ma$) without citing Sir Isaac Newton. We can discuss transistors without crediting William Shockley with the invention of the transistor.

The instructor's penalty for any academic dishonesty in this course is receiving no credit for any disputed work. In addition, a student who commits an act of academic dishonesty may be subject to disciplinary action by Rensselaer Polytechnic Institute.