Course syllabus
ECSE-6960: Physical foundations of solid-state devices

Course description: The course teaches the physical foundations underlying the operation of modern electronic and photonic solid-state devices. Quantum mechanical foundations will be emphasized. As the spatial dimensions of electronic and photonic heterostructure devices shrink, the inclusion of quantum mechanics provides a useful description of many physical processes. The course will give students a solid foundation for other microelectronics and photonics courses such as *Semiconductor Devices and Models 1*, *Semiconductor Devices and Models 2,* and *Optoelectronics*).

Instructor information: Prof. E. F. Schubert, Wellfleet Senior Constellation Professor, Rensselaer Polytechnic Institute, Department of Electrical, Computer, and Systems Engineering, 110 Eighth Street, Troy NY 12180, Phone: 518-276-8775, Email: EFSchubert@rpi.edu, Web: http://www.rpi.edu/~schubert/

Course materials: Course materials will be made available on course web site. Web site: **http://www.rpi.edu/~schubert/**. Files are in PDF format and can be printed. ***I strongly recommend using exclusively this web site***.

Lecture time and location: As scheduled (17.30 h in DCC 337).

Office hours: Thursday morning 9.00 – 10.00.

Teaching assistant: Mr. Qinghui Shao Email: shaoq@rpi.edu. Present homework to TA on regular basis. He will verify that you did homework and keep your score. Homework score will be on an ***effort basis***, ***not on a performance basis***. There is a fax machine available to turn in your homework. **The fax number is 518-276-8026**.

Level: The course is intended for first-year graduate students.

Pre-requisite: Undergraduate courses in electrical engineering, mathematics, and physics (e.g. RPI Physics I and II).

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; transport theory including Boltzmann transport equation.

Course objective: The objective of this course is to enable students understand the physical foundations of solid-state devices, in particular modern quantum-effect devices, and to apply knowledge in the design and analysis of devices. .

Text: Manuscript entitled "Physical foundations of solid-state devices" by E. F. Schubert will be provided to students as PDF files free of charge via the course web page.

Exams, term paper, homework, and grading: The course has one mid-term exam, a final exam, homework, and project with a relative weight toward the final grade of 40 %, 40 %, 10 %, and 10 %, respectively. All exams will be open-book exams.

Mandatory statement on academic dishonesty:

- Copying from a neighbor in an exam or turning in someone else's homework/reports/term papers as one's own constitutes academic dishonesty.

- The compilation, *ad verbatim* reproduction, or paraphrased reproduction of someone else's work in a written or oral report without citation of original source constitutes academic dishonesty.
- ***What is plagiarism and ad verbatim reproduction?***
  Plagiarism is the use of someone else's work without crediting the source.
  An ***ad verbatim*** reproduction is an exact word-by-word reproduction.
- ***Note***: Teamwork during class exercises and homework and use of other resources (calculators, books, etc.) are, of course, 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 its invention.

The instructor's penalty for any academic dishonesty is receiving no credit for disputed work. In addition, a student may be subject to disciplinary action by Rensselaer Polytechnic Institute.