2006 Fall – Course syllabus
ECSE-6968: 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, Rensselaer Polytechnic Institute, Department of Electrical, Computer, and Systems Engineering, 110 Eighth Street, Troy NY 12180, Telephone: 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. I recommend using this web site as it will contain the most current materials.

Lecture time and location: As scheduled (Time: Wednesday, 17.00 h; Location: TBA).

Office hours: Thursday morning 9.00 – 10.00.

Teaching assistant: **TBA** Email: **TBA**. Present homework to TA on regular basis. TA will verify that you did homework and keep your score. Homework score will be on an ***effort basis*** (not on a performance basis). Distance students: Please communicate with TA on how to turn in homework.

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; 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 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.