

**2009 Fall – Course Syllabus**  
**ECSE-6220: 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 are emphasized, including the postulates of quantum mechanics, wave-particle duality, uncertainty relation, the Kronig-Penney model, and perturbation theory. In addition, the course covers areas such as semiconductor statistics, doping, heterostructures, transport, and tunneling.

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. 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 are 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 9:00 AM – 11:30 AM**; Location: **Jonsson Engineering Center Room 4104**).

**Office hours:** Directly after class

**Teaching assistant (TA):** **Sameer Chhajed** Email: <[SameerChhajed@gmail.com](mailto:SameerChhajed@gmail.com)>. Please present homework to TA before mid-term and final exam. TA will verify that you did homework and keep your score. Homework score shall be on an **effort basis** (in contrast to *performance basis*).

**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, and homework with a relative weight toward the final grade of 40 %, 40 %, and 20 %, respectively. All exams will be open-book exams.

**Mandatory statement on “Learning Outcomes”:** This course will teach students a range of knowledge and skills. The knowledge and skills acquired are the learning outcomes of this course and we summarize them as follows:

- Students will become proficient in the understanding of the physical foundations of solid-state devices including their quantum-mechanical foundations, carrier-dynamics foundations, and transport foundations.
- Students will become able to analyze state-of-the-art solid-state devices, particularly compound semiconductor devices based on heterogeneous materials.
- Students will become able to use the principles learned in the course to design modern solid-state devices and evaluate their designs.

For further information on outcome-based learning, see Wikipedia, 2009: < [http://en.wikipedia.org/wiki/Outcome-based\\_education](http://en.wikipedia.org/wiki/Outcome-based_education) >

**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?** This is the use of someone else’s work without crediting the source.
- **What is an “ad verbatim” reproduction?** This is an exact word-by-word reproduction.
- **What is paraphrased reproduction?** This is a reproduction using very similar words and phrases.
- **What is a phrase?** This is a sequence of two or more words.
- What is the penalty for academic dishonesty? The penalty is reduced or no credit and may result in failing the course.
- **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 for this invention.