## ESG 333 Materials Science II: Electronic Properties (Required)

**Course Catalog description:**

. The free electron theory of metals is introduced and applied to the quantitative treatment of conductivity. The band theory of solids is developed quantitatively via the nearly-free electron model and Fourier analysis, and the transport properties of metals and semiconductors are discussed in detail. Carrier statistics in semiconductors is developed. Equilibrium and non-equilibrium PN junction behavior is explored, up to the Shockley equation.
*4 credits*

**Pre- or Corequisite(s):** ESG281 An Engineering Introduction to the Solid State or PHY 251 Modern Physics; ESG 302 or CME 304

**Text(s) or other required material:**
John Singleton, Band Theory and Electric Properties of Solids, Oxford University Press, 2001, ISBN: 0198506449

**Course learning outcomes:** The student should acquire a basic knowledge of the physics of electrical conductivity in metals and semiconductors, including the application of quantum mechanics and statistical mechanics to the analysis. The main example, studied in detail, is the PN junction diode.

**Topics Covered:**
Week 1-2. Metals: The Drude and Sommerfeld Models of Conductivity
Week 3 Hall Effect and Limitations of Free-electron Model
Week 2. Quantum Mechanics of Particles in a Periodic Potential: Bloch's Theorem
Week 3-4. Fourier Analysis of Nearly- Free Electron Model
Week 5. Particle-Wave Picture of Conductivity, Wave Packets, Dispersion
Week 6. Effective Masses, Electrons and Holes
Week 7. Metals, Semiconductors and Insulators in the Band Picture
Week 8. Carrier Statistics in Semiconductors
Week 9-10. Intrinsic and Extrinsic Semiconductors, Donors and Acceptors
Week 11. Inhomogeneous Semiconductors, Chemical Potential
Week 12 PN Junction Theory, I-V Characteristics

**Class/ Laboratory Schedule:**

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|---|---|---|---|---|---|---|---|
| ESG | 333 | Materials Sci II: Electr Prop | LEC | 1 | MWF | 9:35 AM | 10:30 AM |
| | | | REC | R01 | F | 10:40AM | 11:35 AM |
| | | | REC | R02 | F | 12:50PM | 1:45 PM |

**Contribution of Course to meet requirement of Criterion 5:** This course, the first of a two-semester sequence (with ESM 336), is primarily an introduction to the solid state, with an emphasis on conductivity in metals and semiconductors. The purpose is to apply mathematical analysis, using physical theory (quantum theory, thermodynamics), to the understanding of conductivity. The experimental and problem-solving aspects involve discussions of how to perform and analyze measurements to elucidate aspects of the theory of conductivity (experiments such as the Hall effect, I-V characteristics, x-ray absorption, cyclotron resonance, Tolman-Stewart measurement of inertia of conducting particles in metals). The student is challenged to think of their own ways to measure such properties.

**Relationship of course to program outcomes: see table**

**Person(s) who prepared this description and date of preparation:** Jonathan Sokolov, 6/28/09