**ELECTRICAL, OPTICAL and MAGNETIC PROPERTIES OF MATERIALS: 5500**

This is an Introductory Course. It is intended to equip the participant with the fundamentals required to understand electrical, optical and magnetic phenomena in all classes of materials. The information is presented within a solid state physics framework, and highlights how electronic structure determines electrical, optical and magnetic behavior. The participant should be able to understand more advanced electronic materials offerings after this course.

Text: Electronic Properties of Materials, R.E. Hummel, 4rd Edition, Springer.

Supplemental text and reading: Principles of Electronic Materials and Devices, 3rd Edition, McGraw-Hill

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**Open door policy**

**Grading**

Midterm: 40%

Final: 40%

Homework: 20%

**BE PUNCTUAL. SWITCH YOUR PHONE, TABLET, PHABLET OR OTHER ELECTRONIC GADGETRY OFF.**

**1. FUNDAMENTALS OF ELECTRON THEORY**

* The Wave-Particle Duality
* The Time-Independent Schrodinger Equation
* Solution of the Schrodinger Equation for Four Specific Cases

1. Free Electrons
2. Electron in a Potential Well (Bound Electron)
3. Finite Potential Barrier (Tunnel Effect)
4. Electron in a Periodic Field of a Crystal (the Solid State)

* Energy Bands in Crystals

1. One-Dimensional Zone Schemes
2. One- and Two-Dimensional Brillouin Zones
3. Three-Dimensional Brillouin Zones
4. Wigner-Seitz Cells (maybe not but we’ll see)

* Electrons in a Crystal

1. Fermi Energy and Fermi Surface
2. Fermi Distribution Function
3. Density of States
4. Population Density
5. Complete Density of States Function Within a Band
6. Consequences of the Band Model
7. Effective Mass

**2. ELECTRICAL PROPERTIES OF MATERIALS**

* Electrical Conduction in Metals and Alloys

1. Conductivity-Classical Electron Theory
2. Conductivity-Quantum Mechanical Considerations
3. Experimental Results and Their Interpretation
4. Pure Metals
5. Alloys
6. Ordering
7. Superconductivity
8. Thermoelectric Phenomena

* Semiconductors

1. Band Structure
2. Intrinsic Semiconductors
3. Extrinsic Semiconductors
4. Donors and Acceptors
5. Temperature Dependence of the Number of Carriers
6. Conductivity
7. Fermi Energy
8. Effective Mass
9. Hall Effect
10. Compound Semiconductors
11. Rectifying Contacts (Schottky Barrier Contacts)
12. Ohmic Contacts (Metallizations)
13. p-n Rectifier (Diode)
14. Zener Diode
15. Solar Cell (Photodiode)
16. Transistors: bipolar and MOSFETs

* Electrical Properties of Polymers, Ceramics, Dielectrics

1. Amorphous Materials
2. Conducting Polymers and Organic Metals
3. Ionic Conduction
4. Conduction in Metal Oxides
5. Amorphous Materials
6. Dielectric Properties
7. Ferroelectricity, Piezoelectricity, and Electrostriction

**3. OPTICAL PROPERTIES OF MATERIALS**

* The optical constants

1. Index of Refraction,
2. Damping Constant
3. Characteristic Penetration Depth, W, and Absorbance
4. Reflectivity, R, and Transmittance
5. Hagen-Rubens Relation

* Atomistic Theory of the Optical Properties

1. Free Electrons Without Damping
2. Free Electrons With Damping (Classical Free Electron Theory of Metals)
3. Special Cases
4. Reflectivity
5. Bound Electrons (Classical Electron Theory of Dielectric Materials)
6. Quantum Mechanical Treatment of the Optical Properties
7. Absorption of Light by Interband and Intraband Transitions
8. Optical Spectra of Materials

* Measurement of the Optical Properties: Spectroscopic Ellipsometry
* Optoelectronic Applications

1. Semiconductor Laser
2. Direct-Versus Indirect-Band Gap Applications
3. Light-Emitting Diodes (LEDs)
4. Homojunction versus Heterojunction Lasers
5. Passive Waveguides
6. Solar Cells

**4. MAGNETIC PROPERTIES OF MATERIALS…Perhaps (we’ve been threatening to get to this but always seem to run out of time at the end of the semester…).**

* Basic Concepts in Magnetism

1. Diamagnetism
2. Paramagnetism
3. Ferromagnetism
4. Antiferromagnetism
5. Ferrimagnetism

* Quantum Mechanical Considerations Paramagnetism and Diamagnetism Ferromagnetism and Antiferromagnetism