EE 362: *Electronic, Magnetic, & Optical Properties of Materials*

CATALOG DATA:

EE 362 Electronic, Magnetic, & Optical Properties of Materials Credits: 3

This course studies the behavior of materials of interest to electrical engineers and covers fundamental issues such as energy band theory, density of states, Fermi-Dirac statistics, equilibrium statistics in semiconductors, and Fermi energy. This foundation is then used to study topics such as conduction and semiconductor devices.Other topics include Peltier devices, optoelectronics, and piezoelectric devices.

Prerequisites: MATH 225, MATH 321 with a grade of "C" or higher, & (PHYS 213 or PHYS 209)

TEXTBOOK:

Semiconductor Physics and Devices: Basic Principles (4th Edition), Donald A. Neamen, McGraw Hill, 2012, ISBN 978-0-07-352958-5.

COORDINATOR:

Dr. Thomas P. Montoya, Associate Professor

GOALS:

Students should gain a basic familiarity with the properties of a variety of materials useful for electrical and electronic applications in order to apply them and to predict their behavior.

CLASS SCHEDULE:

Lecture: 3 hours per week.

TOPICS:

1. The Crystal Structure of Solids
    a. Semiconductor Materials
    b. types of solids
    c. space lattices
    d. diamond structure
    e. atomic bonding
2. Introduction to Quantum Mechanics
    a. Principles of Quantum Mechanics
    b. Schrodinger's Wave Equation
    c. Applications of Schrodinger's Wave Equation
    d. Extensions of the Wave Theory to Atoms
3. Introduction to the Quantum Theory of Solids
    a. allowed & forbidden energy bands
    b. electrical conduction in solids
    c. extension to three dimensions
    d. density of states function

   e. statistical mechanics
4. The Semiconductor in Equilibrium
   a. charge carriers
   b. dopant atoms and energy levels
   c. extrinsic semiconductor
   d. statistics of donors and acceptors
   e. charge neutrality
   f. position of Fermi energy level
5. Carrier Transport Phenomena
   a. carrier drift
   b. carrier diffusion
   c. graded impurity distribution
   d. Hall Effect
6. Nonequilibrium Excess Carriers in Semiconductors
   a. carrier generation & recombination
   b. characteristics of excess carriers
   c. ambipolar transport
   d. quasi-Fermi energy levels
7. The pn Junction
   a. basic structure of the pn junction
   b. zero applied bias
   c. reverse applied bias
   d. junction breakdown
8. The pn Diode
   a. pn junction current
   b. generation-recombination currents and high-injection levels
   c. small-signal-model of the pn junction
9. Fundamentals of the Metal-Oxide – Semiconductor Field-Effect Transistor
   a. two-terminal MOS structure
   b. capacitance-voltage characteristics
   c. Basic MOSFET operation
   d. frequency limitations
10. The Bipolar Transistor
   a. bipolar transistor action
   b. minority carrier distribution
   c. transistor currents & low-frequency common-base current gain
11. Special Topics
   a. thermoelectric devices
   b. piezoelectric devices
   c. dissimilar metal corrosion
   d. optoelectronics (time-allowing)

COMPUTER USAGE:

Students use pdf reader (Acrobat), D2L, MATLAB and/or MathCad, and Microsoft Office.

COURSE LEARNING OBJECTIVES (CLO):

Upon completion of this course, students should demonstrate the ability to:

A. Describe the physical structure of semiconductor materials.
B. Understand the basic concepts describing the behavior of bulk semiconductors, including the energy-band model, the Fermi function, and the calculation of electron and hole densities in semiconductors.
C. Understand the roles played by diffusion current, drift current, and generation-recombination in describing current flow in semiconductors.
D. Describe the electric fields and electric potential inside a pn junction.
E. Understand the operation of, and terminology used in describing and specifying the properties of MOS capacitors.
F. Understand the operation of, and terminology used in describing and specifying the properties of MOSFETs.
G. Understand the operation of, and terminology used in describing and specifying the properties of BJTs.
H. Understand operation of, and applications for piezoelectric & thermoelectric devices as well as understand dissimilar metal corrosion and means for preventing it.

RELATION OF COURSE LEARNING OBJECTIVES TO STUDENT OUTCOMES (SO):

These course learning objectives fulfill the following student outcomes for the B.S. EE program:

1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public, health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3) An ability to communicate effectively with a range of audiences.
4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environment, and societal contexts.
5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The following table indicates the relative strengths of each course objective in addressing the program's student outcomes listed above (on a scale of 0 to 4 where 4 indicates a strong emphasis)

CLO \ SO	1	2	3	4	5	6	7
A	4						
B	4						
C	4						
D	4						
E	4						
F	4						
G	4						
H	4						**2**

PREPARED BY:

Mr. Lowell Kolb
Revised by Thomas P. Montoya, Date: January 6, 2024
Last revised by Thomas P. Montoya, Date: January 9, 2025