ECE 377 Course Syllabus

Fall 2019

Principles of Electronic Devices

Time:	M, W, F 10:20 – 11:10 AM
Place:	Room 223 Natural Resources Bldg
Section:	001

Instructor: Qi Hua Fan
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Office Hours: Wed. 3:00-4:30 PM, Fri. 3:00-4:00 PM, or by appointment

Prerequisite: PHY 184 and ECE 202

Text: *Solid State Electronic Devices*, 6th ed., by Ben G. Streetman and Sanjay Banerjee
Principles of Electronic Materials and Devices, 3rd Ed., by S. O. Kasap

Course web page: https://d2l.msu.edu/

Books and Notes on Reserve in the Engineering Library

1. "Principles of Electronic Materials and Devices," 3rd Ed., by S. O. Kasap. Call #: TK453 .K26 2006
2. "Solid State Electronic Devices," 6th ed., by Ben G. Streetman. Call #: TK7871.85 .S77 2006

Grading		
	Homework	20%
	Exam I	20%
	Exam II	20%
	Final Exam	30%
	Project	10%

4pt scale course grades will be determined as follows:

<table>
<tr><td>4.0</td><td>3.5</td><td>3.0</td><td>2.5</td><td>2.0</td><td>1.5</td><td>1.0</td><td>0.0</td></tr>
<tr><td rowspan="2">top ~1/5 class grades</td><td rowspan="2">next ~1/5 class grades</td><td rowspan="2">next ~1/5 class grades</td><td rowspan="2">next ~1/5 class grades</td><td colspan="4">~1/5 class</td></tr>
<tr><td></td><td>Course grade less than 65%</td><td>Course grade less than 60%</td><td>Course grade less than 50%</td></tr>
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- Exact divisions of the above grades will be at the instructors discretion based on such things as clear divisions in mastery of the course material, completion of assignments given, improvement in grades, participation in class activities.
- The exams are closed book, but equations and important graphs will be provided.
- Homework assignments can be found on the course web page, and will be announced in class.
- Makeup Policy: A zero will be given for missed assignments unless extenuating circumstances exist and/or arrangements are made with the course instructor prior to the assignment due date.

Topics	Lectures (Approximate)
Atomic Structures and Bonds (Chapter K1)	2
Crystal Structures (Chapter K1)	2
Elementary Quantum Theory (Chapter K3)	4
Modern Theory of Solids (Chapter K4)	5
Semiconductors (Chapter K5)	6
The p-n Junction (Chapter K6, S5)	7
Field Effect Transistors (Chapter S6, K6)	6
Bipolar Junction Transistors (Chapter S7, K6)	6
Advanced Electronic Devices (Chapter S8, K6)	2

Course objectives

At the completion of the course, the students should be able to:

a. Describe the atomic arrangements for common semiconductor crystal structures.
b. Identify the Miller indices of directions and planes.
c. Apply the postulates of quantum mechanics for simple problems.
d. Carry out simple solutions to Schrödinger's equation.
e. Identify the distinction between metals, insulators, and semiconductors from the energy-band perspective.
f. Identify direct gap and indirect gap materials from the energy-band perspective.
g. Calculate the equilibrium carrier concentration in a given semiconductor at a specific temperature and doping level.
h. Determine the non-equilibrium carrier concentration in a given semiconductor by solving the continuity equations.
i. Calculate values of mobility, and electrical conductivity and resistivity.
j. Solve problems involving drift currents.
k. Solve problems involving diffusion currents.
l. Sketch the energy band structures for a *p-n* junction in equilibrium and with an applied bias.
m. Determine values for the contact potential, depletion layer width, and internal electric fields for a *p-n* junction in equilibrium and with bias.
n. Describe the derivation of the current-voltage characteristics of *p-n* junctions.
o. Calculate the depletion width capacitance for a given *p-n* junction.
p. Describe basic performance limits on *p-n* junctions, such as speed, and break-down voltage.
q. Identify Schottky diodes based on an energy-band diagram.
r. Identify Ohmic contacts based on an energy-band diagram.
s. Sketch the energy bands of MOS structures.
t. Calculate the threshold voltage of a MOSFET device.
u. Describe the derivation of the current-voltage characteristics of a MOSFET using the physical structure and material properties of the device.
v. Apply the derivation of the current-voltage characteristics of a BJT from the physical structure and material properties of the device.
w. Describe BJT performance parameters, including the emitter injection efficiency and base-transport factor and relationship to the physical structure.
x. Describe the Ebers-Moll model and its relationship to basic SPICE parameters.

Academic Honesty: Article 2.3.2 of the Academic Freedom Report states that "the student shares with the faculty the responsibility for maintaining the integrity of scholarship, grades, and professional standards." In addition, the ECE Department adheres to the policies on academic honesty as specified in General Student Regulations 1.0, Protection of Scholarship and Grades, and in the all-University Policy on Integrity of Scholarship and Grades, which are included in *Spartan Life: Student Handbook and Resource Guide*. Students who commit an act of academic dishonesty may receive a 0.0 on the assignment or in the course.

You are encouraged to work together on the homework assignments but the final write-up of the problems turned in for grading must be your own work.

Approximate Timeline

No.	Topics Covered	Reading
1	**Part 1**: Introduction	Chapter K1
2	Atomic Structures and Bonds	K1.1-K1.3
3	Crystal Structures	K1.8
4	Crystal Planes, Directions, and Defects	K1.9, K1.10
5	**Part 2**: Introduction to Quantum Mechanics	Chapter K3.1
6	Schrödinger’s Equation, Basic Postulates	K3.2
7	Simple Quantum Mechanics Problems	K3.3-K3.6
8	Atomic Orbitals, Quantum Numbers	K3.7
9	**Part 3**: Modern Theory of Solids	Chapter K4.1
10	Energy Band Formation	K4.2, K4.3
11	Effective Mass	K4.4
12	Density of States	K4.5
13	Fermi-Dirac Statistics	K4.6
14	Review for Exam	
15	**Exam 1** (Parts 1-3)	
16	**Part 4**: Semiconductors	Chapter K5.1
17	Electrons and Holes, Intrinsic & Extrinsic Materials	K5.1, K5.2
18	Direct and Indirect Energy Gaps	K5.11
19	Carrier Concentration, Temperature Dependence	K5.3
20	Charge Neutrality, Recombination, Diffusion	K5.4, K5.5
20	Mobility, Hall Effect, Optical Absorption	K5.6, K5.7
21	Schottky Junctions, Ohmic Junction, Heterojunctions	K5.9, K5.10
22	**Part 5**: *P-N* Junction: Ideal P-N Junction	K6.1
23	*P-N* Junction: Contact Potential, Equilibrium Band Diagram	K6.2
24	*P-N* Junction: Space Charge, Built in Fields	K6.2
25	*P-N* Junction: Depletion Width, Excess Carrier Injection	K6.3
26	*P-N* Junction: Switching, Capacitance	K6.3
27	*P-N* Junction: Diode Equation, Non-Idealities	K6.4-K6.5
28	Review for Exam	
29	**Exam 2** (Parts 4-5)	
30	**Part 6**: FET: Load Lines, and Pinchoff Voltages	S6.1
31	FET I-V Behavior, MESFET	S6.2, S6.3
32	MOSFET: Ideal Structure	S6.3
33	MOSFET: Accumulation, Depletion, Inversion	S6.4
34	MOSFET: Threshold Voltage	S6.4
35	MOSFET: Capacitance, I-V Behavior	S6.4, S6.5
36	**Part 7**: BJT: Device Design, Carrier Flow, Definitions	S6.5
37	BJT: Minority Carrier Injection Profiles	S7.1
38	BJT: I-V Characteristics, Ebers-Moll	S7.2
39	BJT: Ebers-Moll, Switching	S7.4
40	BJT: Non-Idealities, HBT	S7.5, S7.6
41	BJT: Ebers-Moll, Switching	S7.7
42	BJT: Non-Idealities, HBT	S7.5, S7.6
43	**Part 8**: Optoelectronic Devices: Photodetectors, LED	S8.1, S8.2
44	Solar Cells	K6.10
	Final Exam (Parts 4-7)	