ENEE 313 Introduction to Device Physics (3)

Sections 0101 & 0102, Fall 2006

University of Maryland, College Park

Instructor:	TA:
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Class/lab Schedule

3 hours of lecture, one hour of recitation

Class times: Lecture Tues Thurs 2:00-3:15pm JMP 3201
Recitation Section 0101 W 2:00-2:50pm EGR 1104
Recitation Section 0102 W 3:00-3:50pm EGR 1102

Office Hours: Thurs 10am-12pm (or by appt)
TA Office Hours: TBD

Course Description

This course covers the basic physics of electronic devices including crystal structure, fields in solids and properties of electrons and holes including diffusion and energy distributions. Current flow in Si is analyzed by drift and diffusion, and equations of motion of particles are derived. The p-n junction, depletion, fields and potentials are analyzed, and depletion and diffusion capacitance and current flow under forward and reverse bias are studied. The course culminates in the study of the operation of bipolar junction and metal-oxide field effect transistors, their physical structure, operation thresholds, current flow, capacitance and current-voltage characteristics.

Textbook and any Other Required Material

1. Sedra, A.S. and Smith, K.C., *Microelectronic Circuits*, Oxford University Press, 5th ed. (2004). ISBN 0-19-514251-9
2. On-line class notes on device physics: Jon Orloff, *Physical Operation of the P-N Junction, Diodes, and Transistors*

Course Objectives

The objectives of the class are to develop an understanding the physical mechanisms governing the operation of electronic devices such as the diode and the transistor. Students will then use this information to analyze and design analog electronic circuits.

a. Learn about the nature of electrons and holes in Si
b. Learn about diffusion and the energy distributions
c. Learn and solve the equations of motion for electrons and holes
d. Study the flow of drift and diffusion currents in doped Si
e. Learn about non-uniformly doped Si and the p-n junction
f. Study the flow of current through a p-n junction (diode)

g. Study depletion and diffusion capacitances
h. Study the physical structure and operation of BJTs and MOSFETs

Course Website: http://bb.eng.umd.edu/

Grading: Your final grade will be based on homework (30%) and three exams (70%) (approximate weighting).

Homework: Homework will be due by 5pm on the assigned date. They will be distributed from the class website. Late homework may be accepted at the discretion of the instructor and grader but will suffer grading penalties. Late homework must be delivered to me in my office or slid under the door. Do not put them in my mailbox. Please staple your assignments together; I will not take responsibility for lost sheets. If you go by another name than the one officially registered with the University, please write both names down for the first few assignments. While I encourage you to discuss course material with other students, the homework problems are to be completed independently. If your homework appears to be identical to another student's, you may be asked to demonstrate your understanding of the material to the instructor or TA in an oral quiz. Homework solutions that are not legible will not be graded.

Exams and Quizzes: Your final score will be based in part on two equally-weighted midterm exams and one final exam on Monday, Dec 18, 10:30am-12:30pm. The midterm exams will be given as take-home exams, with expectations announced in class at least one week in advance. Makeup exams are only possible for those with officially documented excuses (i.e. approved by the undergraduate studies office). Exam questions will be based on the material covered in class. All work for long answer questions must be shown in order to receive full credit.

Office Hours: Please come during regular office hours (Thurs 10am-12pm). Other times are fine, but by appointment ONLY. Questions about the homework, grading, or the material presented in class should be first directed to the TA.

Recitation Sections: The TA will review material, solve example problems, and answer questions about class material and homework during the recitation sections. Some supplementary class material may also be given during the recitations.

Course Materials Distribution: While some of the course material will be distributed in the class lecture, supplementary course material will be available from the class website. In the beginning of the course, I will attempt to verify that class notifications are reaching your email address, however, it will be your responsibility to ensure continued receipt of class information. All class announcements will be posted onto the class website as an alternative means of retrieving updated information. All lecture materials will be posted on the course website in advance of the lectures; it is your responsibility to make your own copies before class.

Absences: It is my intent to respect our diverse community's religious observances, so please inform me in writing (email) of any intended absences for religious observances in advance. Notice should be provided as soon as possible but no later than the end of the second week of classes.

Academic Integrity: Although I am not expecting to encounter this issue, I would like to make it very clear that academic dishonesty will not be tolerated. All work submitted for grading must be your own. The University of Maryland, College Park has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.shc.umd.edu. Academic dishonesty in this class includes outright copying of homework or deliberately taking unfair advantage of other students in the class; however, discussing homework problems is permissible and also encouraged. Instances of academic dishonesty will be referred to the Honor Council.

Topics Covered (and Approximate Dates)

1. Basic concepts for device physics (1.5 weeks – Aug 31, Sep 5, 7)
    - Crystal structure of Si and Miller indices
    - Electrical conduction in solids; drift currents
    - Resistivity
    - Relaxation time
    - Diffusion equation, continuity equation
    - Maxwell-Boltzmann distribution
2. Electron-hole pair (2 weeks – Sep 12, 14, 19, 21)
    - Electron-hole pairs, law of mass action
    - Acceptors and donors in Si
    - Lifetime of minority carriers
    - Drift and diffusion currents
    - Equations of motion for electrons and holes
    - Solutions of equations of motion
3. The p-n junction and some of its properties (2 weeks – Sep 26, 28, Oct 3, 5)
    - Depletion, fields and potentials
    - Behavior of the p-n junction under applied voltage
    - Depletion capacitance
    - Diffusion capacitance
    - Current flow through the p-n junction
    - Diode equation
4. Transistors (3 weeks – Oct 10, 12, 17, 19, 24, 26)
    - BJTS
        1. Ebers-Moll Equation
        2. Forward current gain

- MOSFETs
    1. Sub-threshold behavior
    2. Thresholds
    3. Triodic and saturated operation
    4. Capacitance
    5. Physical structure
    6. Scaling laws

5. Applications of Device Physics: Circuits (5 weeks)
    - Review (1.5 weeks – Oct 31, Nov 2, 7)
        1. Current mirrors, Cascode and Gilbert normalizer
        2. Differential pair, Multiplier
    - Transconductance Amplifier, Gm-C Filters (1 week – Nov 9, 14)
    - Two-stage Operational Amplifier (1 week – Nov 16, 21)
    - Feedback (1 week – Nov 28, 30)
    - ADC/DAC (1 week – Dec 5, 7)

While we will not be discussing it in class, it is expected that you are familiar with the program PSPICE and are able to use it to enhance your understanding of the various circuits to be presented in class. Some of the supplementary material on the web site may be in PSPICE form.

** For students interested in designing and fabricating integrated circuits, extra credit modules are available. The programs PSPICE and LEDIT can be used for integrated circuit simulation and design, and students may submit successful designs to the MOSIS service for fabrication of integrated circuits.