Master Course Syllabus for EE 280 (ABET sheet)

Title: Exploring Devices

Credits: 4

UW Course Catalog Description

Overview of modern electronic and photonic devices underlying modern electronic products including smartphones, traffic lights, lasers, solar cells, personal computers, and chargers. Introduction to modeling and principles of physics relevant to the analysis of electrical and optical/photonic devices. Prerequisite: PHYS122. Offered: Autumn/Winter/Spring

Coordinator: D. Wilson, Professor, Electrical and Computer Engineering

(Team) Faculty who have or are willing to teach this core course):
Anant Anantram, Tai Chen, Serena Eley, Kai-Mei Fu, Lih Lin, Arka Majumdar, Denise Wilson

Goals: To provide students with a broad and engaging overview of devices that are relevant to the design and operation of modern electronic and optical products by exploring underlying principles of semiconductors and light. Applications include basic digital logic gates and analog circuits, voltage regulators, battery chargers, shrinking CMOS (MOSFET) transistor technology, LEDs, photovoltaic (solar) cells, and related devices. This course prepares the student to take more advanced semiconductor and photonics courses and also apply knowledge gained in this course to advanced courses in VLSI, digital and analog circuit design, computer architecture, power systems, and similar areas in electrical engineering.

Learning Objectives: At the end of this course, students will be able to:
For Electronic Devices:

1. *Differentiate* a semiconductor from an insulator or a metal using energy band diagrams.
2. *Calculate* semiconductor conductivity based on doping levels and operating temperature.
3. *Use* pulse width modulation to build/generate a programmable voltage source using a microcontroller.
4. *Quantitatively extract* relevant device parameters from a characteristic curve for a diode, MOSFET (transistor). or similar electronic device.
5. *Qualitatively describe* the dynamic equilibrium of drift and diffusion in a diode.
6. *Calculate* drift and diffusion currents in diodes and similar devices.
7. *Identify and estimate* capacitance relevant to diode (pn junction) and MOSFET operation.
8. *Compute* channel current in the three major regions of operation in a MOSFET (transistor).
9. *Build and characterize* a basic inverter using MOS transistors
10. *Understand* and *characterize* the basic behavior of PN junction based photodetectors and photovoltaic cells.

For Optical Devices:

11. *Identify* fundamental parameters from the wave equation that describe propagation of light
12. Quantitatively *define* key performance metrics of photonic devices (e.g. photodiode responsivity, laser efficiency)
13. *Explain* how semiconductors play a major role in generation, propagation and detection of light.
14. *Identify* and *describe* emerging applications enabled by semiconductor optics.

Textbook:
McGraw Create consisting of the following chapters/components:
Fundamentals of Semiconductor Devices (Anderson and Anderson):
Chapter 1: Electron Energy and States in Semiconductors
Chapter 2: Homogeneous Semiconductors
Chapter 3: Current Flow in Homogeneous Semiconductors
Chapter 5: Prototype pn Homojunction (Diodes)
Chapter 7: The MOSFET
Chapter 11: Optoelectronics

Physics, Fifth Edition (Giambattista)
Chapter 22: Electromagnetic Waves
Chapter 23: Reflection and Refraction of Light
Chapter 25: Interference and Diffraction

Prerequisites by Topic:
1. Basic familiarity with Maxwell's equations.
2. Basic circuit analysis (KCL, KVL)
3. Exposure to and understanding of valence band and conduction band in materials.
4. Recommended -- Computational: Matlab, Python, Linux will be useful but not essential.

Topics:
1. Broad overview of solid-state and photonic devices – 0.5 week
2. Select exposure and introduction to underlying physics of devices including bonding and atomic structure – 0.5 week
   Lab 1: catalog resistors, characterize resistivity of conductors, introduce current limiting and breadboarding
3. Intrinsic and extrinsic semiconductors (emergence of bandgap and effect of doping), Metals, Insulators– 1 week
   Lab 2: characterize voltage sources and use pulse width modulation to create a programmable voltage source
4. PN junctions, drift and diffusion, diode I-V characteristics, diode circuits – 1 week
   Lab 3: build diode circuits including voltage regulators and battery testers
5. Carrier regeneration and recombination using photovoltaic cells and LEDs as examples (avoiding in-depth analysis) – 1 week
6. Operation of MOS capacitor and MOS Field-Effect Transistors– 1 week
   Lab 4: build photodetector circuits and characterize photodetectors
7. Contemporary transistor circuits (digital and analog) introduction – 1 week
   Lab 5: build photovoltaic (PV) circuits and characterize photovoltaic cells
8. Overview of photonics concepts and applications– 1 week
   Lab 6: construct and characterize basic inverters and other transistor circuits
9. Photonic devices: Lasers, LEDs (basic operating principles) – 1 week
10. Introduction to Silicon Photonics (basic principles) – 1 week
11. Contemporary topics (including introduction to quantum computing, AR/ VR display) – 1 week

Lab/project (optional, as time permits)
LED circuits applied to a holiday light display or similar project -- last 2-3 weeks of the course

Note: Labs do not always directly follow the content presented in class but content for each lab is covered prior to students beginning the lab, even if the lab lags 1-2 weeks behind the lecture material.

Course Structure: The main lecture meets for two 80-minute sessions per week or three 50 minute sessions per week. In addition, students attend one 110-minute quiz section each week which includes support for take-home laboratories (but does not require laboratory facilities). Lecture sessions typically consist of lecture interspersed with (a) examples which illustrate the application of important concepts; (b) demonstrations which illustrate these principles at work in real devices; or (c) student-centered activities including small group problem solving activities and think/pair/share exercises designed to reinforce understanding of basic concepts and resolve misconceptions.

Assignments in the course consist of homeworks, lab assignments (based on scaffolded laboratory reports), exams/quizzes, and (optional) a project. The project allows the student to apply device principles and use modern electronic and optical devices to simulate or construct a practical system.

Computer Resources: Completion of homework assignments and the project requires knowledge of Python, Matlab, or similar software, data presentation and word processing software (e.g. MS Excel, Word, Powerpoint), and basic breadboarding/circuit prototyping techniques.

Laboratory Resources: none required. The course has at-home/take-home laboratories and will require a lab kit. This course will require a technology fee to supply those kits.

Grading: Homework (20%), Lab Assignments (scaffolded laboratory reports) (30%), Quizzes (35%), Final Exam (15%). Homework is largely formative (designed and graded to advance student understanding) while the Quizzes and the Final Exam are summative (designed to evaluate student learning).

ABET Student Outcome Coverage: This course addresses the following outcomes:
H = high relevance, M = medium relevance, L = low relevance to course.

(1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.* (H)
The vast majority of the lectures and homework assignments deal with quantitatively applying fundamental principles of electronic and optical devices to device operation using math and physics expertise acquired from previous courses.

(3) *An ability to communicate effectively with a range of audiences* (M)

Several homework assignments will involve creating tutorials or demonstrations of fundamental principles and device operation. These tutorials will be designed with a specific audience in mind so that students become more fluent in communicating complex EE topics with a range of audiences.

(6) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions* (H)

In multiple homework assignments, students will collect data from optical or electronic devices or build small circuits/systems using those devices and collect data from those systems. Students will be required to compare experimental data to simulated or theoretical data to understand the impact of real-world operation and device variation on performance.

Prepared By: Denise Wilson, Arka Majumdar
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