ECE 471: Semiconductor Devices

IN

Calculus

- Readily analytically calculate polynomial and exponential integrals and derivatives
- Understands hyperbolic trigonometric functions
- Intuitively and mathematically understands divergence and gradient

Differential Equations

- Able to solve 2nd order non-homogenous equations with initial conditions or boundary conditions
- Exposure to PDEs and separation of variables???

Electrostatics

- Intimately familiar with 1-D Poisson equation
- Able to solve E-field for arbitrary 1-D charge distribution
- Understand electrostatic potential in 1-D and relationship to E-field and charge distribution
- Fully understand the fields, charge, and voltage relationships in a parallel plate capacitor
- Knows the relationship J=sE and understands the concept behind each of the symbols

Electronics and Circuits

- Know the operating regimes of FETs and BJTs and how to write formulas and draw plots for the terminal I-V relationships.
- Be able to analyze single transistor circuits.
- Know the I-V characteristics of a diode with series resistance and be able to plot them..

High School Science

- Understand the periodic chart including valence
- Electrostatic, Lorentz forces on charged particles
- Kinetic energy – momentum relationship

Pre-requisites:

- ECE342 and MATH340 or MATH345

As of 12/9/08

Concepts:

- Electrons as waves
  - Wave particle duality
  - Existence of Schrodinger equation
  - E vs K relationship, effective mass
- Basic semiconductor bandstructure
  - Conduction band, valence band, bandgap
  - Density of states
- Carrier statistics
  - Intrinsic concentrations, doping
  - Occupied, unoccupied states, holes
  - Fermi-Dirac, Maxwell-Boltzmann distributions
- Carrier transport
  - Drift, mobility, velocity saturation
  - Diffusion, Einstein relationship
- Recombination
- p-n junctions
  - Depletion region, Cap vs V, I-V physics, built-in V
- BJTs
- Schottky diodes
  - Thermionic emission, I-V, built in V
- MOSFETs
  - Threshold V calculation, factors affecting it
  - Intro to MOSFET non-idealities

Applications:

- Device physics impact on transistor performance
- Impact of device scaling
- Need for numerical simulation tools

Tools:

- Mathcard or MATLAB
- PSpice transistor models

OUT

Semiconductor Device Basics

- Understands impact of semiconductor material parameters and device design parameters on device I-V relationships
- Describes simplified direct and indirect semiconductor band structure
- Calculates intrinsic, doped, equilibrium, and non-equilibrium carrier concentrations
- Describes Fermi level concept and calculates Fermi and quasi-fermi levels from carrier concentrations
- Understands assumptions behind Maxwell-Boltzmann approximation and when it is applicable
- Calculates conductivity of semiconductors from material parameters and excitation conditions
- Understands driving forces for drift and diffusion and how to calculate the corresponding currents
- Draws and interprets band diagrams for homogenous semiconductors, p-n junctions, BJTs, Schottky barriers, and MOS structures
- Understands simplified overview of technology for p-n junction, BJT, and MOSFET fabrication
- Describes the behavior of and carrier distributions in reverse and forward biased p-n junctions and BJTs.
- Quantitatively describes the charge and potential distribution of MOS structures in accumulation, depletion, flat band and inversion.
- Interprets MOS C-V plots.

Advanced Electronics

- Understands the basic structure and internal operation of BJTs and MOSFETs
- Understand the meaning of many PSpice model parameters
- Understands the origin and impact of velocity saturation on MOSFET I-V characteristics
- Understands the origin and impact of short channel effects on MOSFET I-V characteristics