

## **EE 3329 - Electronic Devices Syllabus**

### **EE 3329 – Electronic Devices Syllabus (“Extended Play”)**

#### **The University of Texas at El Paso**

The following concepts can be part of the syllabus for the Electronic Devices (EE 3329) course. Note that the list of topics cannot be covered in a semester, it is up to the individual instructors to choose what concepts they wish to cover.

#### **I. Introduction to Quantum Mechanics**

##### **\* Principles of Quantum Mechanics**

- Energy Quanta
- Wave-Particle Duality
- The Uncertainty Principle

##### **\* Schrödinger’s Wave Equation**

- The Wave Equation
- Physical Meaning of the Wave Function
- Boundary Conditions

##### **\* Applications of Schrödinger’s Wave Equation**

- Electron in Free Space
- The Infinite Potential Well
- The Step Potential Function
- The Potential Barrier

#### **II. Introduction to the Quantum Theory of Solids**

##### **\* Allowed and Forbidden Energy Bands**

- Formation of Energy Bands
- The Kronig-Penney Model
- The k-Space Diagram

##### **\* Electrical Conduction in Solids**

- The Energy Band and the Bond Model
- Drift Current
- Electron Effective Mass
- Concept of the Hole

- Metals, Insulators, and Semiconductors

### III. Metal-Semiconductor and Semiconductor Heterojunctions

#### \* Heterojunctions

- Heterojunction Materials
- Energy-Band Diagrams
- Two-Dimensional Electron Gas
- Equilibrium Electrostatics
- Current-Voltage Characteristics

### IV. Semiconductors: A General Introduction

#### \* General Material Properties

- [Composition](#)
- Purity
- [Structure](#)

#### \* [Crystal Structure](#)

- The Unit Cell Concept
- Simple 3-D Unit Cells
- Semiconductor Lattices
- Miller Indices

#### \* Crystal Growth

- Obtaining Ultrapure Si
- Single-Crystal Formation

#### \* Summary

### V. Carrier Modeling

#### \* Semiconductor Models

- [Bonding Model](#)
- [Energy Band Model](#)
- [Carriers](#)
- [Band Gap Energy and Material Classification](#)

#### \* Carrier Properties

- Charge
- Effective Mass
- Carrier Numbers in Intrinsic Material
- Manipulation of Carrier Numbers – Doping
- Carrier-Related Terminology

\* State and Carrier Distributions

- [Density of States](#)
- [The Fermi Function](#)
- Equilibrium Distribution of Carriers

\* [Equilibrium Carrier Concentrations](#)

- Formulas for  $n$  and  $p$
- Alternative Expressions for  $n$  and  $p$
- $n_i$  and  $np$  Product
- Charge Neutrality Relationship
- Carrier Concentration Calculations
- Determination of  $E_F$
- Carrier Concentration Temperature Dependence

## VI. Carrier Action

\* [Drift](#)

- Definition – Visualization
- [Drift Current](#)
- [Mobility and Scattering](#)
- Resistivity
- [Band Bending](#)

\* [Diffusion](#)

- Definition – Visualization
- Hot-Point Probe Measurement
- Diffusion and Total Currents
  - Diffusion Currents
  - Total Currents
- Relating Diffusion Coefficients/Mobilities
  - Constancy of the Fermi Level
  - Current Flow Under Equilibrium Conditions
  - Einstein Relationship

\* [Recombination – Generation](#)

- Definition – Visualization  
Band-to-Band Recombination  
R-G Center Recombination  
Auger Recombination  
Generation Process

\* Equations of State

- [Continuity Equations](#)
- [Minority Carrier Diffusion Equations](#)
- [Simplifications and Solutions](#)
- Problem Solving  
Sample Problem No. 1  
Sample Problem No. 2

\* Supplemental Concepts

- [Diffusion Lengths](#)
- [Quasi-Fermi Levels](#)

## VII. *pn* Junction Electrostatics

\* Quantitative Electrostatic Relationships

- Assumptions/Definitions
- Step Junction with  $V_A = 0$   
Solution for  $p$   
Solution for  $E$   
Solution for  $V$   
Solution for  $x_n$  and  $x_p$
- Step Junction with  $V_A \neq 0$
- Examination/Extrapolation of Results
- Linearly Graded Junctions

## VIII. *pn* Junction Diode: I-V Characteristics

\* [The Ideal Diode Equation](#)

- [Qualitative Derivation](#)
- Quantitative Solution Strategy  
General Considerations  
Quasineutral Regional Considerations  
Depletion Region Considerations  
Boundary Conditions  
“Game Plan” Summary

\* Derivation from the Ideal

- Ideal Theory Versus Experiment
- Reverse-Bias Breakdown  
Avalanching  
Zener Process
- The R-G Current
- $V_A \rightarrow V_{bi}$  High-Current Phenomena  
Series Resistance  
High-Level Injection

## IX. BJT Fundamentals

- \* Electrostatics
- \* Introductory Operational Considerations
- \* Performance Parameters

- Emitter Efficiency
- Base Transport Factor
- Common Base d.c. Current Gain
- Common Emitter d.c. Current Gain

## X. BJT Static Characteristics

\* Ideal Transistor analysis

- Solution Strategy  
Basic Assumptions  
Notation  
Diffusion Equations/Boundary Conditions  
Computational Relationships
- General Solution ( $W$  Arbitrary)  
Emitter/Collector Region Solutions  
Base Region Solution  
Performance Parameters/Terminal Currents
- Simplified Relationships  
 $p_B(x)$  in the Base  
Performance Parameters
- Ebers – Moll Equations and Model

\* Deviations from the Ideal

- Ideal Theory/Experiment Comparison
- Base Width Modulation
- Punch-Through

- Avalanche Multiplication and Breakdown  
Common Base  
Common Emitter
- Geometrical effects  
Emitter Area ? Collector Area  
Series Resistances  
Current Crowding
- Recombination – Generation Current
- Graded Base
- Figure of Merit

## **XI. MOS Fundamentals**

\* Ideal Structure Definition

\* Electrostatics – Mostly Qualitative

- Visualization Aids  
Energy Band Diagram  
Block Charge Diagrams
- Effect of an Applied Bias  
General Observations  
Specific Biasing Regions

\* Electrostatics – Quantitative Formulation

- Semiconductor Electrostatics  
Preparatory Considerations  
Delta-Depletion Solution
- Gate Voltage Relationship

\* Capacitance – Voltage Characteristics

- Theory and Analysis  
Qualitative Theory  
Delta – Depletion Analysis
- Computations and Observations  
Exact Computations  
Practical Observations

## **XII. MOSFETs – The Essentials**

\* Qualitative Theory of Operation

\* Quantitative  $I_D - V_D$  Relationships

- Preliminary Considerations

[Threshold Voltage](#)

[Effective Mobility](#)

- [Square-Law Theory](#)
- [Bulk-Charge Theory](#)
- Charge-Sheet and Exact-Charge Theories

### **XIII. Nonideal MOS**

\* Metal-Semiconductor Workfunction Difference

\* Oxide Charges

- General Information
- Mobile Ions
- The Fixed Charge
- Interfacial Traps
- Induced Charges
- Radiation Effects
- Negative-Bias Instability
- $\phi_{V_G}$  Summary

\* MOSFET Threshold Considerations

- $V_T$  Relationships
- Threshold, Terminology, and Technology
- Threshold Adjustment
- Back Biasing
- Threshold Summary