Semester - III

EC01 Electronic Devices
(3L:0T:0P) 3 credits

Pre-requisite: Class XI & XII School level Physics. Basic idea of Atomic structure and atomic particles, concept of electronic carriers like electrons; Fundamental concept of Classical Physics and its difference with Quantum Physics.

Learning Objective:

i) Initiation into the concepts of Quantum Physics at the very basic level so that the students of Electronics can grasp the fundamental concepts behind the working of the basic electronic devices that are used in electronic circuits.

ii) Ability to appreciate the areas of application, their comparative merits and demerits.

iii) Learn to use the devices effectively as circuit components and anlyse their performance in Electronic circuits.

Total 39 hrs (3 hrs x 13 weeks)

Module – 1: Introduction to Semiconductor Physics: **[12 hrs]**

Review of Quantum Mechanics – [3 hrs] (Difference between Classical & Quantum Theory, Uncertainty principle as regards to uniquely defining momentum and space coordinates or Energy and Time simultaneously; Duality of nature leading to operators and setting up of Schrodinger Wave equation; Importance of the wave function in calculation of expectation values);

Electrons in periodic Lattices, E-k diagrams [2hrs] (Concept of periodic lattice, potential and kinetic energies of electrons in an atom; Meaning of electron wave vector k and its relation with wavelength with electron wave),

Energy bands in intrinsic and extrinsic silicon [2hrs] (Energy band diagrams for intrinsic and extrinsic semiconductors with examples; concept of Fermi level)

Carrier transport: diffusion current, drift current, mobility and resistivity; sheet resistance, design of resistors [3hrs] (concept and simple expression for drift and diffusion currents, definition and significance of mobility, definitions and derivations for expressions of resistances);

Generation and recombination of carriers [1 hr] (Concept and basic equation);

Poisson and continuity equation [1hr] (Expression and basic significance).

*[**Learning Outcome**: The student will be able to spell out the basic conceptual differences between Classical and Quantum Physic; the student will be familiar with the quantum operators and be able to set up the Schrodinger Wave equation;*

The student will be able to name the periodic structures of different semiconductor materials used in devices and interpret the meaning of E and k in the E-k diagram; identify direct and indirect band-gap semiconductors from their E-k diagrams.

The student will be able to explain the shift in the position of the Fermi level with doping;

Student will be able to explain the cause of drift and diffusion of carriers and write down the expressions for the same; student will be able to define the term mobility and derive expressions for resistances; Given examples, the student must be able to calculate the values.

Student must be able to write down the generation – recombination expressions and set up Poisson's equation.]

***Module – 2: P-N junction:* [8 hrs]**

P-N junction characteristics [2hrs] (Basic concept of junction formation with junction potential and fields, effect of reverse and forward bias leads to rectification property)

I-V characteristics and small signal switching models [3 hrs] (Expression for I-V characteristics, junction capacitances and equivalent circuits);

Avalanche breakdown, Zener diode, Schottky diode [3 hrs] (Basic idea of junction break down phenomena and their application in Zener diodes; Application of metal-semiconductor junction to Schottky diode; Schottky compared to P-N diode.)

*[**Learning Outcome**: The student will be able to explain the space charge formation at the p-n junction with diagram; The student will be able to explain rectification due to biasing of the junction; The student will be able to derive expressions for field, voltage and capacitances at the junction by applying Poisson's equation;*

The student must be able to derive the I-V relationship and draw the small signal equivalent circuit;

The student must be able to identify the type of breakdown by studying the value of the Zener voltage;

The student must be able to explain rectification in a Schottky diode]

***Module – 3: Bipolar Junction Transistor:* [6 hrs]**

Bipolar Junction Transistor (BJT), I-V characteristics, Ebers-Moll Model [4 hrs] (Working of BJT as a Current Controlled device, Expression for current amplification factors α and β; Transistor action; junction currents and expression of junction currents derived from Ebers Moll model)

MOS capacitor, C-Vcharacteristics, [2 hrs] (Sources of capacitance and their variation pattern with reverse and forward biases)

*[**Learning Outcome**: The student will be able to explain why a BJT is a current controlled device; They must be able to write down expressions for the current amplification factors; Draw the current components; Explain transistor action; Draw Ebers-Moll model and write down the current components; The student should be able to identify the junction capacitances and explain how they vary with junction voltages.]*

***Module – 4: Field Effect Transistors*: [5 hrs]**

MOSFET, I-V characteristics, [3 hrs] (Concept of Gate isolation, inversion & channel formation, MOSFET – a voltage controlled device; why and how current flows; empirical current-voltage relation, MOS capacitance)

small signal models of MOS transistor [2 hrs] (Junction capacitances & small signal equivalent circuits).

*[**Learning Outcome**: Students will be able to explain with band diagram how inversion is effected in Enhancement MOSFET; Students must be able to explain how the MOS capacitance varies with Gate voltage; Draw the small signal equivalent circuit and mention the advantages of the MOSFET]*

***Module – 5: Optical Devices*: [3 hrs]**

LED, photodiode and solar cell; (Concept of spontaneous emission for working of LEDs; Concept of photo-voltaic effect; identifying the right quadrant for operation in the I-V characteristics of a photo-voltaic device to serve as either a photo-diode or a Solar cell;)

*[**Learning Outcome**: The student will be able to explain photo-electric effect, spontaneous emission and identify quadrants of operation for Photodiodes and Solar cells]*

***Module – 6: Integrated Circuits*: [5 hrs]**
Integrated circuit fabrication process: oxidation, diffusion, ion implantation, photolithography, etching, chemical vapor deposition, sputtering, twin-tub CMOS process.
*[**Learning Outcome**: The student must be able to describe the steps and explain their importance]*

Text Books:

1. Ben. G. Streetman, and S. K. Banerjee, "Solid State Electronic Devices," 7th edition, Pearson, 2014.
2. Sima Dimitrijec "Principles of Semiconductor Devices", Oxford University Press, 2006

Reference Books:

1. D. Neamen , D. Biswas "Semiconductor Physics and Devices," McGraw-Hill Education
2. Jacob Millman, Christos C Halkias and Satyabrata Jit, "Millman's Electronic Devices and Circuits", 4th edition, McGraw Hill Education 2015
3. S. M. Sze and K. N. Kwok, "Physics of Semiconductor Devices," 3rd edition, John Wiley&Sons, 2006.
4. C.T. Sah, "Fundamentals of solid state electronics," World Scientific Publishing Co. Inc, 1991.
5. Y. Tsividis and M. Colin, "Operation and Modeling of the MOS Transistor," Oxford Univ.Press, 2011.
6. Chinmoy Saha, Arindam Halder and Debarati Ganguly "Basic Electronics – Principles and Applications" Cambridge university Press.

Course Outcome:
At the end of this course students will demonstrate the ability to;
1. Understand the principles of semiconductor Physics
2. Understand and utilize the mathematical models of semiconductor junctions and MOS transistors for circuits and systems.

EC02: Electronic Devices Lab Hands-on experiments related to the course contents of EC01
(0L:0T:2P) 1 credit

Any 6 of the following experiments.
(2 weeksor 2x2 = 4 hrs for each experiment; 6x 2 = 12 weeks)

Experiment – 1: Identification of diodes by numbers to know their applicability and power handling capacity; Identifying the p and n terminals
Experiment –2: Select a Recitifier diode and study its I-V characteristics. Use this diode to set up a half wave and a Full wave rectifier and study their behavior.
Experiment –3: Select a switching diode and draw its I-V characteristics; Find out its cut-off frequency.
Experiment – 4: Indentify the emitter, base and collector of a BJT; Find out if it is a p-n-p or an n-p-n transistor; Bias a BJT in the Common-Emitter mode. (The concept and relationships have to be introduced in the laboratory)
Experiment – 5: Study of a MOSFET. *
Experiment – 6: Study of a Photo-diode. *
Experiment – 7: Study of a Solar Cell. *
Experiment – 8: Study of an LED. *
*Set up experiments to familiarize the student with the working of the devices.