

## COURSE HANDOUT

**ECE-605 (CORE ELECTIVE)**

ECE-6<sup>TH</sup> SEMESTER

ACADEMIC YEAR (2024-25)

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**CORE ELECTIVE:** Semiconductor device modeling and Simulation

Credits: 3

Duration of Course: 12 Weeks

Start Date: 20 Jan 2025

End Date: 11 Apr 2025

Link of the Course: [https://onlinecourses.nptel.ac.in/noc25\\_ee74/preview](https://onlinecourses.nptel.ac.in/noc25_ee74/preview)

About Course: This course is a foundation level course on semiconductor devices. Course consist of three broad topics (1) Semiconductors properties, (2) Devices and (3) governing equations along with their boundary conditions. Course objective is to develop a sound physical and intuitive understanding of semiconductor devices and achieve ability to make some key decisions while designing applications specific semiconductor devices.

Course Outcomes/ Course Objectives: N/A

Course Layout:

**Week 1:** Introduction -: Si-Based Nanoelectronics and Device Scaling, Nanoscale and Heterostructure Devices, Crystal structure-Unit cell and Miller Indices

**Week 2:** Reciprocal Space, Doping, Band Structure, Effective Mass

**Week 3:** Density of states, Electron Mobility, Semiconductor Statistics- Fermi-Dirac function and carrier concentration calculation

**Week 4:** p-n junction under equilibrium, derivation of I-V relation, Minority carrier diffusion equation, Non-idealities in the p-n junction diode (Breakdown and Generation-Recombination currents), Transistor configurations

**Week 5:** BJT- I-V relation and gain, Ebers-Moll model, Non-idealities in BJT, Gummel Poon Model, HBT, BJT Transient and small signal behavior, Metal-Semiconductor contact (Schottky Barrier/Diode, Ohmic Contacts) and capacitance characteristics, Thermionic emission current flow and fermi-level pinning.



**Week 6:** Field Effect Transistors (JFET, MESFET, HEMT), MOS Band diagram and C-V characteristics, Threshold voltage and Interface charges, MOSFET I-V, gradual channel approximation and frequency response, non-idealities and CMOS

**Week 7:** Semiclassical Transport Theory -: Distribution Function, Boltzmann Transport Equation (BTE), Relaxation-Time Approximation (RTA), Scattering and Mobility.

**Week 8:** Drift-Diffusion (DD) model-1 -: Drift-Diffusion Model Derivation and dielectric relaxation time, Taylor series expansion and Finite Difference method, Normalization, Scaling and Linearization of Poisson's Equation and Scharfetter–Gummel Discretization of the Continuity Equation

**Week 9:** Drift-Diffusion (DD) model-2 -: Generation and Recombination models, Derivation of SRH model, Boundary conditions, Gummel's Iteration Method and Newton's Method, Drift-Diffusion Application example

**Week 10:** Hydrodynamic Modeling -: As extension of DD model, Carrier Balance, Energy balance and momentum balance Equations, Direct solution scheme through Monte Carlo simulations

**Week 11:** Quantum Transport models -: Tunneling, Schrodinger equation and free particle, potential step, potential barrier, Transfer Matrix Approach, Quantum Mechanical corrections to standard approach.

**Week 12:** Examples through commercial device simulation tools, Models for DD, Hydrodynamic simulations, Mobility and G-R models, Selected Examples

### Books and References:

1. G. Streetman, and S. K. Banerjee, "Solid State Electronic Devices," 7th edition, Pearson, 2014.
2. S. M. Sze and K. N. Kwok, "Physics of Semiconductor Devices," 3rd edition, John Wiley & Sons, 2006.
3. D Vasileska, SM. Goodnick, G Klimeck, "Computational Electronics: Semiclassical and Quantum Device Modeling and Simulation," CRC Press 2010.
4. Selberherr Siegfried, "Analysis and Simulation of Semiconductor Devices", 1984

Assessment Criteria: Average assignment score = 25% of average of best 8 assignments out of the total 12 assignments given in the course.

Exam score = 75% of the proctored certification exam score out of 100

Final score = Average assignment score + Exam score

YOU WILL BE ELIGIBLE FOR A CERTIFICATE ONLY IF AVERAGE ASSIGNMENT SCORE  $\geq 10/25$  AND EXAM SCORE  $\geq 30/75$ . If one of the 2 criteria is not met, you will not get the certificate even if the Final score  $\geq 40/100$ .

Certificate will have your name, photograph and the score in the final exam with the breakup. It will have the logos of NPTEL and IIT Kharagpur. It will be e-verifiable at [nptel.ac.in/noc](http://nptel.ac.in/noc).

Only the e-certificate will be made available. Hard copies will not be dispatched.