NIRMA UNIVERSITY

Institute:	Institute of Technology
Name of Programme:	B.Tech. Electronics & Communication Engineering
Course Code:	3EC602ME24
Course Title:	Semiconductor Device Physics & Modelling
Course Type:	Departmental Elective
Year of Introduction:	2024-25

L	T	Practical component				C
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Course Learning Outcomes (CLOs):

At the end of the course, students will be able to

1. comprehend the semiconductor physics and Quantum fundamentals. BL 2
2. model single and two junction semiconductor devices. BL 3
3. analyse different Models of MOS structures. BL 4
4. design and implement MOSFET circuits for VLSI design. BL 5

Unit No.	Contents	Teaching hours (Total 45)
I	**Semiconductor And Quantum Fundamentals:** metals, insulator, semiconductors, intrinsic and extrinsic semiconductors, direct and indirect band gap, free carrier densities, fermi distribution, density of states, Poisson and continuity equations, Boltzmann statistics, equilibrium carrier concentration, current flow mechanisms, drift current, diffusion current, mobility, band gap narrowing, resistance, generation and recombination, lifetime, internal electro-static fields and potentials, Poisson's equation, continuity equations, drift-diffusion equations, basic quantum mechanics, crystal symmetry and band Structure, 2D/1D Density of states, tunnelling	10
II	**PN junction diode:** thermal equilibrium physics, energy band diagrams, space charge layers, internal electro-static fields and potentials, carrier transport by drift, mobility and diffusion, diffusion length, ballistic transport, radiation effects. quantitative theory of pn junctions, steady state I-V characteristics under forward bias, reverse bias and illumination, junction capacitances. dynamic behaviour under small and large signals. breakdown mechanisms, wide and narrow diodes.	06
III	**Bi-junction transistor:** Quantitative theory of bipolar junction transistors having uniformly doped region and heavy doping effects, double diffused transistors, Ebers-moll model, static characteristics in early effect, saturation and inverse operation, breakdown mechanisms, punch-through, emitter efficiency, transport factor, junction and diffusion capacitance, transit times, parasitic, small-signal models.	06
IV	**Modelling of MOS transistor:** Basic concept of modelling, various level MOS model equation, variation of channel length in saturation and subthreshold mode, BSIM model, basic MOS capacitance model, gate-oxide and junction capacitance model, comparison of various level spice model	10

V	**MOS transistor design issues:** Short channel and ultra-short channel effects, effect on t_{ox}, effect of high k and low k dielectrics on the gate leakage and source-drain leakage, tunnelling effects, different gate structures in Ultra Deep Sub-Micron (UDSM), impact and reliability challenges in UDSM.	**05**
VI	**MOSFET devices:** Schottky barriers and ohmic contacts, steps of deriving a device model, types of device model, MOSFET models, double gate MOSFET, FINFET	**08**

Self -Study:

The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

Suggest List of Tutorials (not restricted to the following):
(Only for information)

Sr. No.	Title of the tutorial	Hours
1.	Carrier transport analysis part 1	01
2.	Carrier transport analysis part 2	01
3.	Recombination and generation effect on free carrier part 1	01
4.	Recombination and generation effect on free carrier part 2	01
5.	Single junction semiconductor device analysis	01
6.	Single junction semiconductor device PVT analysis	01
7.	Single junction semiconductor device analysis for reproduction of graph of data sheet	01
8.	Double junction semiconductor device analysis	01
9.	Double junction semiconductor device PVT analysis	01
10.	Double junction semiconductor device analysis for reproduction of graph of data sheet	01
11.	Modelling of various MOSFETs part 1	01
12.	Modelling of various MOSFETs part 2	01
13.	Channel effect on MOSFET part 1	01
14.	Channel effect on MOSFET part 2	01
15.	Channel effect on MOSFET part 3	01

Suggested Readings:

1. Y.P. Tsividis, The MOS Transistor, Tata McGraw-Hill
2. Nandita Dasgupta, Amitava Dasgupta, Semiconductor Devices: Modeling and Technology, PHI
3. S.M.Sze, Semiconductor Devices Physics and Technology, John Wiley