PHYSICS OF NANOSCALE DEVICES

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PRE-REQUISITES : Basic knowledge of electrostatics and classical electron transport theory would be desirable for this course. Nevertheless, the course would build from basics and continue to the advanced topics.

INTENDED AUDIENCE : UG III/IV-year students in Electronics and Communication Engineering/ PG I year students in Microelectronics and VLSI.

INDUSTRIES APPLICABLE TO : The following companies might value this course (as it overlaps with their domain, I haven't had any communication with these companies about the course though): 1. Intel 2. Analog Devices 3. Synopsys

COURSE OUTLINE :

This course will introduce senior undergraduate and beginner postgraduate students to the basic physics of novel miniaturized (mesoscopic and nanoscopic) devices. As the device size is reducing, electrons' behavior in these devices is changing drastically. As a result, the electrical properties of these devices need to be understood in a more fundamental way. The course would start from the basics of quantum mechanics and equip the students to delve into advanced topics in nanoscale devices.

ABOUT INSTRUCTOR :

Prof. Vishvendra Singh Poonia is Assistant Professor in the Department of Electronics and Communication Engineering, Indian Institute of Technology Roorkee. His core research focus is on quantum technologies – quantum computing, quantum photocell, quantum random number generator etc. Before joining IITR as a faculty member, he was postdoctoral fellow at the Weizmann Institute of Science, Israel. He completed his PhD from Indian Institute of Technology Bombay and B.Tech. from Indian Institute of Technology Roorkee.

COURSE PLAN :

Week 1: Introduction to nanoelectronics – device scaling, how device physics is fundamentally different in mesoscopic and nano devices – voltage drop, heat dissipation etc., Necessity to understand and invoke quantum mechanics in nanoelectronics.

Week 2: Introduction to quantum mechanics, Schrödinger equation, Free electron wavefunction, Particle/electron in a box, electrons in a solid.

Week 3: Introduction to KP model, Brillouin Zones, KP model – origin of energy bands in solids.

Week 4: Density of states – 0D, 1D, 2D, 3D conductors, Fermi function, The notion of modes in a conductor.

Week 5: Conductance, Bottom-up approach, Landauer's formalism, Ballistic and Diffusive transport – transmission, transition from ballistic to diffusive transport.

Week 6: Introduction to MOSFET – A barrier-controlled device, MOSFET electrostatics.

Week 7: MOSFET 2D electrostatics, MOSFET Capacitance.

Week 8: High-K dielectric, Strained Si technology, Quantum confinement in MOSFET.

Week 9: ETSOI-MOSFET, Transport in MOSFET, Ballistic MOSFET.

Week 10: Ballistic injection velocity in MOSFET, Thermoelectric effects and thermoelectric devices.

Week 11: Quantum dot devices – quantum capacitance, IV characteristics, self-consistent method.

Week 12: Introduction to ab initio simulation, NEGF, Summary of the entire course.