QUANTUM TRANSPORT

PROF. MADHU THALAKULAM
Department of Physics
IISER Thiruvananthapuram

PRE-REQUISITES : Introductory Quantum Mechanics & Introductory Solid State Physics

INTENDED AUDIENCE : Final year M.Sc. or integrated BS-MS students and Ph. D students

INDUSTRIES APPLICABLE TO : IBM, Philips Semiconductor, NTT Japan, SQC Sydney, D-Wave systems

COURSE OUTLINE :

Conventional transport theory though uses parameters derived from quantum mechanical principles such as energy gap and effective mass, mostly utilizes classical or semi-classical approach. Contrarily, electrical transport in mesoscopic systems is enriched by a number of exotic phenomena driven by the quantum nature of the charge carriers such as quantum tunneling, quantum Hall effects, conductance quantization, flux-quantization, Aharanov-Bohm effect, single-electron charging, Kondo effect and Josephson effects. This course is aimed at giving a comprehensive introduction to many of these phenomena and equipping the prospective students to understand the physical concept and follow the latest developments in this field. The content and lectures are aimed to cater to the senior undergraduate and graduate students aspiring to do their advanced research in area such as solid-state quantum computing technologies, quantum electrical sensing and metrology.

ABOUT INSTRUCTOR :

Prof. Madhu Thalakulam (Associate Professor, School of Physics, IISER Thiruvananthapuram) Education: 2012-2019: Assistant Professor, School of Physics, IISER Thiruvananthapuram; 2007: Ph.D. Applied Physics, Rice Quantum Institute, Rice University, USA; 2007-2010: Post-doctoral Researcher, University of Wisconsin, Madison, USA; 2010-2012: Post-doctoral Researcher, Quantum Phenomena Dept., Sandia National Laboratory, USA. Research Interests: (i)Transport in nanoscale devices such as QPCs, quantum dots, superconducting tunnel junction systems. (ii) Quantum dot spin qubits: Single spin manipulation and detection in quantum dot qubits. (iii) Quantum electrical measurement and back action in nanoscale devices. (iv) Devices on van der Waals materials and heterostructures

COURSE PLAN :

Week 1: Introduction, Quantum confinement effects in transport, Density of states

Week 2: Surface states & band bending, Metal semiconductor contacts Semiconductor heterostructures

Week 3: 2D electron systems, Quantum confinement by electrostatic shaping, Overview of device fabrication techniques.

Week 4: 2D systems: Flux quantization, Shubnikov-de Haas oscillations & Quantum Hall effect

Week 5: 2D systems: Weak-localization, Universal conductance fluctuations, Aharonov-Bohm effect

Week 6: 2D layered systems, Spin-Orbit coupling, topological insulators

Week 7: 1D systems: Quantum point contacts, Nanowires

Week 8: 1D systems: atomic point contacts, charge sensing techniques

Week 9: 0D systems: Gated Quantum dots, artificial atoms, Coulomb blockade, Single electron charging

Week 10: 0D systems: Shell filling, single electron states, Coupled quantum dots, spin-qubits

Week 11: Mesoscopic superconductivity: Josephson junctions, AC and DC Josephson effects, SQUID

Week 12: Quantum electrical Metrology, quantum electrical amplifiers