First Course Handout

PHY 312 Quantum Processes in Low Dimensional Semiconductors
(2025-2026, Semester I)
Department of Physics, IIT Kanpur

Low-dimensional semiconductors lie at the heart of modern science and technologies, from nanoscale transistors to quantum computing and single-photon devices. This course provides a foundational understanding of quantum processes in low-dimensional systems, bridging fundamental physics with cutting-edge technology.

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Prerequisite: The course requires prior knowledge of basic quantum mechanics (at the level of PHY114/PHY201), electrostatics-electrodynamics and electronics.

Course Contents: Introduction to low-dimensional semiconductors, highlighting the scientific and technological significance of quantum confinement. Characteristic length scales for quantum phenomena. Low-dimensional semiconductor material growth using molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD). Electronic properties of low-dimensional systems, including quantum wells, quantum wires, quantum dots, and strained layers. Optical properties of semiconductors such as absorption and luminescence of excitons. Transport phenomena in mesoscopic and quantum structures, covering tunneling, Coulomb blockade, charging effects, ballistic transport, and conductance in nanostructures with an emphasis on the Boltzmann equation and Landauer-Büttiker formalism. Transport in the presence of a magnetic field from both semiclassical and quantum perspectives. Aharonov-Bohm effect and an introduction to the quantum Hall effect. Decoherence and dephasing in semiconductor quantum systems with brief discussions on spin qubit, single-electron sensing & single-photon detectors.

Recommended Books:

1. “The Physics of Low-dimensional Semiconductors” by John H. Davies
2. “Physics of Semiconductor Devices” by S.M. Sze and Kwok K. Ng
3. “Solid State Electronic Devices” by Ben G. Streetman and Sanjay K. Banerjee
4. “Semiconductor Nanostructures: Quantum states and electronic transport” by Thomas Ihn
5. “Introduction to Solid State Physics” by Charles Kittel

Classes: Wednesday and Friday 10:30 – 12:00 hrs. Venue: (To be declared)

Office Hours: Monday and Thursday from 17:00 to 19:00 hrs.

Division of Marks

- Assignments (4) / Quiz (2): 30 % weighted
- Mid-Sem Exam: 60 Marks (30 % weighted)
- End-Sem Exam: 80 Marks (40 % weighted)

Attendance: Attendance is mandatory and should, in any case, be greater than 60 % (excluding approved leaves). Attendance will determine whether students can make it to the next upper grade if their performance is at the borderline of two grades.