Approval: 8th Senate Meeting

Course Name: Mesoscopic Physics and Quantum Transport

Course Number: PH601

Credits: 3-0-0-3

Prerequisites: PH 501 Introductory Solid State Physics or teachers consent

Intended for: UG/PG

Distribution: Elective

Semester: Odd/Even

Course Preamble: Rather a young branch of science, mesoscopic physics already has several exciting and instructive achievements over fundamental understanding and technological applications. This course highlights the mechanisms of the electronic transport at the mesoscopic scales where novel concepts of quantum mechanics are necessary. The course deals with the understanding of how the physics and quantum-rules are operative to the electronic transport in low dimensional structures.

Course Outline: The course is planned to get a broad overview of the world of mesoscopic physics and various approaches to study quantum transport and related phenomena in nanostructures. Among the topics covered are the length scaling in physics, conductance from transmission, scattering approaches, semi classical transport, interference, decoherenceeffects and concludes by emphasizing on the application of the mesoscopic physics with rapid evolution of novel materials and experimental techniques.

Modules:

1. Introduction [5 Lectures]

Drude and Somerfield modelfor electrons in solids, Quantum mechanics of particle in a box, Bloch states,Density of states and Dimensionality.

2. Mesoscopic physics [5 Lectures]

Mesoscopic phenomena and length scaling in physics,Quantum structures, Tunneling through the potential barrier, Coulomb blockade.

3. Quantum transport and Localization [7 Lectures]

Influence of reduced dimensionality on electron transport: Ballistic and Diffusive Transport, Single channel Landauer formula, Landauer-Buttiker formalism, Localization, Thermal activated conduction, Thouless picture,General and special cases of localization, Weak localization regime.

4. Quantum Hall effect [8 Lectures]

Origin of zero resistance, Two Dimensional Electron Gas, Transport in Graphene and two dimensional systems, Localizations in weak and strong magnetic fields, Quantum Hall effect,Spin Hall Effect.

5. Quantum interference effects in electronic transport [6 Lectures]

Conductance in mesoscopic systems,Shubnikov de Haas-Van and Aharonov-BohmOscillations, Conductance fluctuations.

6. Mesoscopic Physics withSuperconductivity [5 Lectures]

Superconducting ring and thin wires, weakly coupled superconductors, Josephson effects, Andreev Reflections, Superconductor-Normal and Superconductor-Normal-Superconductorjunctions.

7. Application of mesoscopic physics [4 Lectures]

Optoelectronics, Spintronics and Nanoelectronic Devices.

Text Books:

1. Y. Imri, *Introduction to Mesoscopic Physics,* Oxford University Press, 2008.
2. S. Datta, *Electronic Transport in Mesoscopic Systems,* Cambridge University Press, 1997

Reference Books:

1. S. Datta, *Quantum Transport*: *Atom to transistor*, Cambridge University Press, 2005.
2. B.L. Altshuler (Editor), P.A. Lee (Editor), R.A. Webb (Editor), *Mesoscopic Phenomena in Solids* (Modern Problems in Condensed Matter Sciences), North Holland (July 26, 1991).
3. D. K. Ferry, S. M. Goodnick, *Transport in Nanostructures*, Cambridge University Press, 2009.
4. N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Cengage Learning, 1976.
5. P. Harrison, *Quantum Wells,Wires & Dots: Theoretical and Computational Physics of Semiconductor Nanostructures, Second Edition,* WileyScience, 2009.