PHYS-GA-2059 SYLLABUS
Physics of Low-Dimensional Systems
Fall 2018

Text: Lecture notes will be provided. Following textbooks will be partially covered.

- The Physics of Low-dimensional Semiconductors: An Introduction, John H Davis
- The quantum Hall effect by Prange and Girvin
- Perspectives in Quantum Hall Effects: Novel Quantum Liquids in Low−Dimensional Semiconductor Structures, Sankar Das SarmaAron Pinczuk
- Introduction to Superconductivity, by Michael Tinkham
- Topological Insulators and Topological Superconductors, B. Andrei Bernevig

prerequisite: Introduction to Solid State physics
Instructor: Javad Shabani, Office: 1071, Phone: (212) 992 8629
Class Hours: MW**: 12:30-1:45pm**
Office Hours: **MW**: 2-2:30pm and by appointment
Email: **jshabani@nyu.edu**

Course Plan (tentative)

A broad overview of materials science and physics of low-dimensional semiconductor structures will be presented. Emphasis will be on the fabrication and physics of high-mobility carrier systems in low-dimensional structures. Examples include two-dimensional, one-dimensional (quantum wire), and zero-dimensional (quantum dot) systems.

HWs: Weekly basis
Two midterms
Final Presentation: Student will give a 20-min presentation on a paper of the reading list towards the end of the semester.

1. Summary of key properties of semiconductors and motivation for low dimensional structures (1 lecture)

2. Energy bands. (1 lecture)
   Free electron model, Fermi surfaces, carrier density, density of states, energy bands (nearly-free electron model and tight-binding model), effective mass.

3. Electrons and holes in Si. (1 lecture)
   Intrinsic carrier concentration, envelope function, doping, Si and GaAs lattice and band

structures, valley degeneracy, HH and LH bands, surface states.

4. Electrical transport. (1 lecture)
   Boltzmann transport equation, scattering time approximation, mobility, Einstein relation, scattering mechanisms, phonons, screening
5. Schottky barriers and Ohmic Contacts (2 lecture)
   Metal/semiconductor interfaces, transport mechanisms, Ohmic contacts.

6. Heterostructure devices (3 lecture)
   Band bending at the interface, modulation doping, HEMT, alloy semiconductors, lattice matched and mismatched structures, growth techniques

7. Two dimensional (2D) solids (3 lecture)
   Potential wells in semiconductor heterostructures; transport, quantum life-time, conductivity of a two dimensional electron gas, subband filling

8. Graphene and 2D materials (2 lecture)
   Atomic structure, Electronic properties, Solution-exfoliation and Chemical vapor deposition.

9. Quantum Hall effect (3 lecture)
   Landau levels, degeneracy, tranpost in quantum limit

10. Topological Insulators (2 lectures)
    Topology in toy models, Hamiltonians and symmetry

11. Nanowire devices (1 lecture)
    Growth, electrical and optical devices, carbon nanotube, devices on flexible substrates

12. 1D Ballistic transport (1 lecture)
    Ballistic transport, quantum point contact, Landauer-formalism, ballistic FET

13. 0D dimensional devices (1 lecture)
    Quantum dots, Coulomb blockade phenomena, Kondo effect, superconducting dots, Single electron transistors

14. Magnetism and spintronics (2 lectures)
    Magnetic materials, Magnetoresistance effects, spin injection, SFET

15. Superconductivity and superconducting devices (2 lectures)
    Tunnel junctions, weak links, super-current, BTK model.

16. Topological superconductivity (1 lecture)
Kitaev chain, Majorana fermions

17. Quantum computing (1 lecture)
Quantum parallelism, entanglement, topological and superconducting qubits