Quantum & Solid State Physics

Fall Semester

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COURSE DESCRIPTION

The goals of the course are to: (1) to study quantum mechanics of atoms in order to understand properties and behavior of multi-particle systems, and (2) to obtain a physical understanding of materials in solid state (specifically semiconductor materials), in order apply these principles in the analysis and understanding of semiconductor devices (devices utilizing PN-junctions and transistors - to be studied in the subsequent course).

PREREQUISITES:
Physics (2), Linear Algebra

COURSE STRUCTURE:
This course will be taught in the following style: Both Quantum (Q) and Solid State Physics (SS) material will be taught in parallel throughout the semester, and the material in both will interconnect in exercises and exams.

COURSE TOPICS

Week 1: Course Introduction and objectives
Q: Introduction to Quantum mechanics: The photoelectric effect, two-slit diffraction.
SS: Fundamental characteristics of conductors, insulators, semiconductors, properties of solids: Resistivity and conductivity, periodic table, atomic bonding, energy levels in an atom (Bohr's model of an atom)

Week 2:
Q: Black body radiation, development of the Schrodinger equation from basic principles.
SS: Structure of materials, Semiconductor crystal structures, Defects in crystals

Week 3:
Q: The postulates of quantum mechanics, the physical interpretation of the wave function, use of operators, measurement process.
SS: Charge carriers in semiconductors: Electrons and holes, Thermal motion, Thermal recombination and generation, Effective mass

Week 4:
Q: Uncertainty principle. Time Independent (and dependent) Schrodinger equation. Schrodinger equation for the case of a free particle.
SS: Intrinsic and extrinsic semiconductors: Doping, N-type and P-type material, majority and minority Carriers, Temperature dependence on carrier concentration

Week 5:
Q: Schrodinger equation continued, particle in an infinite potential well.
SS: Compensation, Space Charge neutrality, Energy bands: Moving from Bond model to Band model

Week 6:
Q: Particle in a finite potential well, tunneling.
SS: Presence of an Electric Field in the Band model, Movement of carriers in semiconductor crystals, Drift and mobility

Week 7:
Q: Particle in an harmonic potential.
SS: Scattering mechanisms, Diffusion of electrons and holes, Transport equations

Week 8:
Q: Mathematical formalism: operators, Hermitian and Unitary operators, the eigenvalue problem.
SS: Einstein's Relation, Optical generation of carriers, Excess carriers

Week 9:
Q: Angular momentum.
SS: Steady state carrier generation, Application: Photodetectors, Solutions to various cases of illumination

Week 10:
Q: Hydrogen atom, atomic orbitals and chemical bonds.
SS: Continuity equations, Haynes-Shockley experiment

Week 11:
Q: Kroning-Penny model, Bloch Theorem.

SS: Density of States, Maxwell Boltzmann and Fermi-Dirac distributions, Fermi Function and Fermi level

Week 12:
Q: Reciprocal lattice (in one dimension), energy band structure in a crystal.
SS: Applying Fermi to semiconductors, energy band diagrams

Week 13:
Q: Effective mass.
SS: PN Junction Fabrication, PN Junctions at Equilibrium

ASSIGNMENTS

Homework assignments count for **15%** of the total grade. Collaboration is encouraged but you must do your own work! Late homework will not be accepted, unless a special exemption is approved by the instructor prior to the due date.

MIDTERM COURSE POLICY

A midterm exam will be scheduled in the beginning of the semester. During an examination, student shall not use books, papers, or other materials not authorized by the instructor. The midterm will count for **20%** of the total course grade.

FINAL COURSE POLICY

The final exam will cover the entire course material and will count for **65%** of the total course grade. Students will have a first exam, Moed A. If the student does not pass, they can retake the exam, Moed B. The last exam taken will be the student's final grade for the exam.

REQUIRED READING

Griffiths, D. *Introduction to quantum mechanics*
Streetman, B. *Solid State Electronic Devices*

ADDITIONAL READING

Kittel, *Introduction to solid state physics*, John Wiley & Sons.
Tang: *Fundamentals of quantum mechanics*, Cambridge press.
Miller, *Quantum mechanics for scientists and engineers.*
Pierret. *Advanced semiconductor Fundamentals*, Prentice Hall.
Ashcroft, *Solid State Physics*, Harcourt college publishers.