421mcd2018

Master Course Description for EE-421 (ABET sheet)

Title: Quantum Mechanics for Engineers

Credits: 3

UW Course Catalog Description

Coordinator: M. P. Anantram, Professor, Electrical and Computer Engineering

Goals: The focus of this course is to introduce students to quantum mechanics using 1D, 2D and 3D nanomaterials. The students will develop a working knowledge of quantization in quantum dots/wells/wires, band structure, density of states and Fermi's golden rule (optical absorption, electron-impurity/phonon scattering). Applications will focus on nanodevices, nanomaterials, and the basics of quantum information.

Learning Objectives: At the end of this course, students will be able to:

1. *Learn* to "think quantum" about current and emerging microelectronic devices.
2. *Solve* Schrodinger's wave equation analytically and numerically.
3. *Calculate* tunneling probabilities through single barriers and resonant tunneling structures.
4. *Learn* to apply the method of separation of variables.
5. *Calculate* the quantized energy levels in technological relevant examples: quantum dots, nanowires, quantum wells.
6. *Interpret* De Broglie's Uncertainity Principle and Energy-Time Uncertainity Principle.
7. *Learn* fundamentals of electron spin.
8. Use the tight binding method to *calculate* the energy bandstructure of graphene and nanotubes using Bloch's theorem.
9. *Calculate* the density of states in semiconductors and establish contact to material learnt in EE 331 (Circuit and Devices 1) and EE 482 (Semiconductor Devices).
10. *Learn* the basics of quantum information: qubits, entanglement, Bell's theorem, Grover's algorithm, quantum crypotography and quantum teleportation.

Textbook: The course is based on Lecture Notes written by M. P. Anantram, 2018.

Reference Texts:

1. Herbert Kroemer, *Quantum Mechanics: For Engineering, Materials Science, and Applied Physics,* Prentice Hall.
2. David A. B. Miller, *Quantum Mechanics For Scientists and Engineers,* Cambridge University Press.

Prerequisites by Topic:

1. Electricy and Magnetism (PHYS-122)
2. Differential Equations (MATH-307)

Topics:

1. Schrodinger's equation, interpretation, examples, uncertainty principle [2 weeks]
2. Closed and Open systems (quantum wells, dots and nanowires) [1 week]
3. Tunneling through single and double barrier structures [1 week]
4. Spins, Stern-Gerlach experiment, Hamiltonian in a magnetic field [1 week]
5. Quantum Information, qubits, Bell's Theorem, Grover's algorithm, quantum cryptography [1.5 weeks]
6. Crystalline solids, unit cell, basis vectors, Bloch's theorem, 1D semiconductor, graphene, carbon nanotube [1.5 weeks]
7. Density of states, electron density, current density, Buttiker Formula for current flow in nanodevices [2 weeks]

Course Structure: The class meets for two 100-minute lectures. There are regular homeworks, one midterm exam and a project at the end of the course.

Computer Resources: Matlab or Python (preferred)

Grading: The homework, exam and project are all equally weighted.

ABET Student Outcome Coverage: This course addresses the following outcomes:

H = high relevance, M = medium relevance, L = low relevance to course.

(1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.* **(M)** The course is primarily oriented towards quantum mechanical analysis of devices. Assignments require students to identify an engineering problem: design quantum nanostructures with specific energy level separation for light emission at a particular wavelength, design a tunnel barrier thickness to keep leakage current below a threshold.

(2) *An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.* **(M)** Students learn to use IBM's tools for quantum computing and perform computational experiments on entangled pairs and quantum measurement. The students will then rationalize the difference between the computational experiments and average values calculated analytically.

Prepared By: M. P. Anantram

Last Revised: January 21, 2019