APPLIED QUANTUM MECHANICS, SPRING 2008

ECEN 5060.379 (call #20218)/ECEN 4010.376 (call #20217),
Room: T-NCB 211, MWF 8:30-9:20am
Technology based class-taught via compressed video at OSU-Tulsa

Prerequisite: PHYS 3713 or consent of instructor

Textbook: F J Levi, Applied Quantum Mechanics, Cambridge University Press, Edition 2, 2006

Evaluation: HW 25%, Quiz 25%, Midterm 25%, Final 25%

Course outline:

Introduction: *Lectures 1 - 3*

Lecture 1

Diffraction and interference of electrons
When is a particle a wave?
THE SCHRÖDINGER WAVE EQUATION

Lecture 2-3

The wave function description of an electron of mass m_0 in free-space
The electron wave packet and dispersion
The Bohr model of the hydrogen atom
Calculation of the average radius of an electron orbit in hydrogen
Calculation of energy difference between electron orbits in hydrogen
Periodic table of elements
Crystal structure
Three types of solid classified according to atomic arrangement
Two-dimensional square lattice
Cubic lattices in three-dimensions
Electronic properties of semiconductor crystals
The semiconductor heterostructure

Using the Schrödinger wave equation: *Lectures 4 - 9*

Lecture 4-5

INTRODUCTION
The effect of discontinuities in the wave function and its derivative
WAVE FUNCTION NORMALIZATION AND COMPLETENESS
INVERSION SYMMETRY IN THE POTENTIAL
Particle in a one-dimensional square potential well with infinite barrier energy
NUMERICAL SOLUTION OF THE SCHRÖDINGER EQUATION
Matrix solution to the descretized Schrödinger equation

Nontransmitting boundary conditions
Periodic boundary conditions

CURRENT FLOW

Current flow in a one-dimensional infinite square potential well
Current flow due to a traveling wave

DEGENERACY IS A CONSEQUENCE OF SYMMETRY

Bound states in three-dimensions and degeneracy of eigenvalues

Lecture 6-7

BOUND STATES OF A SYMMETRIC SQUARE POTENTIAL WELL

Symmetric square potential well with finite barrier energy

TRANSMISSION AND REFLECTION OF UNBOUND STATES

Scattering from a potential step when effective electron mass changes
Probability current density for scattering at a step
Impedance matching for unity transmission

Lecture 8-9

PARTICLE TUNNELING

Electron tunneling limit to reduction in size of CMOS transistors

THE NONEQUILIBRIUM ELECTRON TRANSISTOR

Scattering in one-dimension: The propagation method: *Lectures 10 - 17*

Lecture 10-11

THE PROPAGATION MATRIX METHOD

Writing a computer program for the propagation method

TIME REVERSAL SYMMETRY

CURRENT CONSERVATION AND THE PROPAGATION MATRIX

Lecture 12-13

THE RECTANGULAR POTENTIAL BARRIER

Tunneling

RESONANT TUNNELING

Localization threshold
Multiple potential barriers

THE POTENIAL BARRIER IN THE δ-FUNCTION LIMIT

Lecture 14-15

ENERGY BANDS IN PERIODIC POTENTIALS: THE KRONIG-PENNY POTENTIAL

Bloch's theorem
Propagation matrix in a periodic potential

Lecture 16-17

THE TIGHT BINDING MODEL FOR ELECTRONIC BANDSTRUCTURE
Nearest neighbor and long-range interactions
Crystal momentum and effective electron mass
USE OF THE PROPAGATION MATRIX TO SOLVE OTHER PROBLEMS IN ENGINEERING

THE WKB APPROXIMATION
Tunneling

Related Mathematics: ***Lecture 18 - 21***

Lecture 18-19

ONE PARTICLE WAVE FUNCTION SPACE
PROPERTIES OF LINEAR OPERATORS
Hermitian operators
Commutator algebra

DIRAC NOTATION

MEASUREMENT OF REAL NUMBERS
Time dependence of expectation values
Uncertainty in expectation value
The generalized uncertainty relation
THE NO CLONING THEOREM

Lecture 20-21

DENSITY OF STATES
Density of states of particle mass *m* in 3D, 2D, 1D and 0D
Quantum conductance
Numerically evaluating density of states from a dispersion relation
Density of photon states

The harmonic oscillator: *Lectures 22- 25*

Lecture 22-23

THE HARMONIC OSCILLATOR POTENTIAL
CREATION AND ANNIHILATION OPERATORS
The ground state
Excited states
HARMONIC OSCILLATOR WAVE FUNCTIONS
Classical turning point
TIME DEPENDENCE
The superposition operator
Measurement of a superposition state

Lecture 24-25

Time dependence in the Heisenberg representation
Charged particle in harmonic potential subject to constant electric field

ELECTROMAGNETIC FIELDS

Laser light
Quantization of an electrical resonator
Quantization of lattice vibrations
Quantization of mechanical vibrations

Fermions and Bosons: *Lecture 26 - 29*

Lecture 26-27

INTRODUCTION

The symmetry of indistinguishable particles
Slater determinant
Pauli exclusion principle
Fermion creation and annihilation operators – application to tight-binding Hamiltonian

Lecture 28-29

FERMI-DIRAC DISTRIBUTION FUNCTION

Equilibrium statistics
Writing a computer program to calculate the Fermi-Dirac distribution

BOSE-EINSTIEN DISTRIBUTION FUNCTION

Time dependent perturbation theory: *Lectures 30 - 33*

Lecture 30-31

FIRST-ORDER TIME-DEPENDENT PERTURBATION THEORY

Abrupt change in potential
Time dependent change in potential

CHARGED PARTICLE IN A HARMONIC POTENTIAL
FIRST-ORDER TIME-DEPENDENT PERTURBATION

Lecture 32-33

FERMI'S GOLDEN RULE

IONIZED IMPURITY ELASTIC SCATTERING RATE IN GaAs

The coulomb potential
Linear screening of the coulomb potential
Correlation effects in position of dopant atoms
Calculating the electron mean free path

Time independent perturbation theory: *Lectures 34 - 37*

Lecture 34-35

NON-DEGENERATE CASE

Hamiltonian subject to perturbation W
First-order correction
Second order correction
Harmonic oscillator subject to perturbing potential in x, x^2 and x^3

Lecture 36-37

DEGENERATE CASE

Secular equation
Two states
Perturbation of two-dimensional harmonic oscillator
Perturbation of two-dimensional potential with infinite barrier