

PH 411/511 INTRODUCTION TO QUANTUM MECHANICS

Fall-2007
Room SB2 -101
Tue & Th 16:00-17:50 PM
<http://www.physics.pdx.edu/~larosaa/>

Dr. Andres La Rosa
Office: SB-II-Room 418
Ph:725-8397 andres@pdx.edu
Office hour: F 14:00-15:00

Textbook: **R. Eisberg and R. Resnick**, “**Quantum Physics**,” 2nd Edition, Wiley, 1985. This good reference should fit very well for both students from engineering and physics majors.

We will complement the material with our own **lectures notes**, prepared particularly to cover the topics not extracted directly from the textbook above but particularly from: **Richard Feynman**, “**The Feynman Lectures on Physics**,” **Volume III**, Addison Wesley, 1989. This reference will be used very much in the first part of the course.

Students who already have the book written by Feynman may not need to buy the textbook by Eisberg and Resnick cited above. In fact, the Feynman book can be complemented with any other Quantum Mechanics book available in the PSU Library. Some particular good quantum mechanics books references are: **B. H. Bransden and C. J. Joachain**, “**Quantum Mechanics**,” Prentice Hall (2000); or **D. J. Griffiths**, “**Introduction to Quantum Mechanics**,” Pearson Prentice Hall (2005).

The first three books cited above will be available in the Library Reserved Room.

Grading: **Homework 30%** To be assigned regularly, along the lecture sessions
1st Exam 30% Tuesday, October 29th Time 16:00
Final exam 40% Tuesday, December 4th, Time 15:30

95-100 A	90-94 A-	85-89 B+	80-84 B	75-79 B-
70-74 C+	65-69 C	60-64 C-	55-59 D+	50-54 D

Lecture Notes Lectures notes that cover those sections of the course prepared following the Feynman textbook will be available at <http://www.physics.pdx.edu/~larosaa>

PH 411/511 INTRODUCTION TO QUANTUM MECHANICS

Fall-2007
Room SB2 101
Tue & Th 16:00-17:50 PM
<http://www.physics.pdx.edu/~larosaa/>

Dr. Andres La Rosa
Office: SB-II-Room 418
Ph:725-8397 andres@pdx.edu
Office Hours: F: 14:00-15:00

SYLLABUS

SECTION- I: The TRANSITION from CLASSICAL to QUANTUM PHYSICS

CHAPTER-1 ABOUT THIS COURSE

Introduction, philosophy of the course, course organization

CHAPTER 2 CLASSICAL PHYSICS (REVIEW)

2.1 Electromagnetism

(The Maxwell's equations, light as electromagnetic radiation, Michelson-Morley experiment, Lorentz' length-contraction hypothesis, the Lorentz' transformation.)

2.2 Special theory of relativity

(Electromagnetism and the principle of relativity, Einstein's principles of relativity, relationship of space-time coordinates in different inertial reference frames, required modification of the classical mechanics laws for compatibility with the relativity principles, relativistic mass, four-components vectors and symmetry)

CHAPTER 3 THE ORIGINS OF QUANTUM PHYSICS

3.1 Black body radiation

(Thermal equilibrium of radiation, classical approach to calculate average energy, Planck's hypothesis to calculate average energy.)

3.2 Particle-like properties of radiation

3.3 Wave-like properties of particles

3.4 Wave-particle duality

SECTION II: THE HEISENBERG'S PRINCIPLE and THE CONCEPT OF AMPLITUDE PROBABILITY

CHAPTER-4 WAVEPACKETS: DESCRIPTION OF THE FREE PARTICLE MOTION

4.1 Spectral Decomposition of the wavefunction (relative to base states) (The scalar product, spectral decomposition using complex variable: the Fourier transform, brackets notation.)

4.2 Phase Velocity and Group Velocity

Planes, traveling plane waves, phase velocity, Group Velocity

4.3 Description of a free-particle motion

(Wavefunction with a definite momentum, a wavepacket as a wavefunction.)

CHAPTER-5 QUANTUM BEHAVIOR: The WAVE-FUNCTION and the UNCERTAINTY PRINCIPLE

- 5.1 Quantum behavior of particles passing through two slits**
(The concept of Probability, contrast between experiments with bullets light, attempts to track electrons' trajectories)
- 5.2 The Heisenberg's Uncertainty Principle**
 - 5.2.A Uncertainty in the position Δx and linear momentum Δp .**
 - 5.2.B Use of the grating resolving power to show the uncertainty the measurement of the energy content ΔE of a pulse and the time Δt required for the measurement.** Gratings, phasors (addition of multiple waves), gratings and spectral resolution, condition for the minimum length time Δt required for the measurement of the energy E with a resolution ΔE .
 - 5.2.C. Uncertainty principle and the resolving power of a microscope.** Image formation and the resolving power of a lens. Watching electrons through the microscope
- 5.3 Interpretation of the Wavefunction**
The need of a wavepacket (rather than a single harmonic function) to describe a free particle motion, Einstein's interpretation of the granularity of the electromagnetic field, Max Born's probabilistic Interpretation of the wavefunction, the concept of ensemble. The philosophy of Quantum Theory

CHAPTER-6 THE AMPLITUDE PROBABILITY

- 6.1 Quantum mechanics description in terms of base-states**
- 6.2 Probability amplitude**
- 6.3 General guiding principles to assign amplitude probabilities**
- 6.4 Interference between Amplitude Probabilities**
 - 6.4.1 Two-slit experiment: Watching electrons' trajectories**
Adding amplitude-probabilities for events producing the same final state. Adding probabilities for vents producing different final states.
 - 6.4.2 Scattering from a crystal**
 - 6.4.3 Identical Particles**

SECTION- III THE HAMILTONIAN OPERATOR

CHAPTER-7 THE HAMILTONIAN MATRIX

How Do States Change with Time?

- 7.1 What are the base states?**
- 7.2 How do states change with time?**
 - 7.2.A The Evolution Operator**
 - 7.2.B The Hamiltonian Matrix**
- 7.3 General characteristic of the Hamiltonian Matrix**
 - 7.3.A Symmetric components**
 - 7.3.B Stationary states**

- 7.3.C Physical Interpretation of the Hamiltonian matrix
- 7.4 Two-State Systems
 - 7.4.A The ammonia Molecule
 - 7.4.A.a Case $H_{12} = H_{21} = 0$
 - 7.4.A.b Case: $H_{12} = H_{21} \neq 0$
 - Splitting of the energy levels
 - Stationary states
 - 7.4.B Spin $\frac{1}{2}$ particle in a magnetic field
- 7.5 Propagation in a Crystal Lattice
- 7.6 The Dependence of Amplitude on Position
- 7.7 Representation of the Wavefunction in the spatial and momentum space
 - 7.7.A Wavefunction in the Spatial Space
 - 7.7.B Wavefunction in the momentum Space
- 7.8 Expectation Values

CHAPTER-8 REPRESENTATION OF THE WAVEFUNCTION IN THE SPATIAL AND MOMENTUM SPACE

- 8.1 Propagation in a Crystal Lattice
- 8.2 The Dependence of Amplitude on Position
- 8.3 Representation of the Wavefunction in the spatial and momentum space
 - 8.3.A Wavefunction in the Spatial Space
 - 8.3.B Wavefunction in the momentum Space
- 8.4 Expectation Values

SECTION- IV THE SCHRODINGER EQUATION

CHAPTER-9 THE SCHRODINGER EQUATION (in one spatial dimension)

- 9.1 FINDING A DIFFERENTIAL EQUATION for the WAVEFUNCTION $\Psi(x,t)$
 - 9.1.A Arguments leading to the Schrodinger equation
 - 9.1.B Looking for a differential equation that is compatible with the de Broglie hypothesis and the conservation of energy
 - 9.1.B.a Case: Free particle (constant potential)
 - 9.1.B.b Particle in a potential $V=V(x,t)$
 - 9.1.C Normalization condition for the wavefunction
 - 9.1.D Expectation values
- 9.2 TIME INDEPENDENT SCHRODINGER EQUATION
 - 9.2.A The zero potential
 - 9.2.B The step potential
 - 9.2.C The barrier potential
 - 9.2.D The square well potential
 - 9.2.E The simple harmonic oscillator potential

CHAPTER-10 ONE ELECTRON ATOMS

- 10.1 SEPARATION of the TIME INDEPENDENT EQUATION
- 10.2 SOLUTION TO THE RADIAL COMPONENT

10.3 SOLUTION to the ANGULAR COMPONENT

SECTION- V IDENTICAL PARTICLES

CHAPTER-11 BOSON PARTICLES

11.1 States with two particles

11.1.A Case: Two distinguishable particles

11.1.B Two indistinguishable Bose particles

11.2 Density of probability

11.2.A Case: Two distinguishable particles

11.2.B Case: Two indistinguishable particles

11.3 States with n particles

11.3.A The case of distinguishable particles

11.3.B Bose particles