

2013 Spring Semester

369 Physics “Quantum Mechanics I”



Instructor: Prof. Slava V. Rotkin
rotkin@lehigh.edu
610-758-3904; Office: Lewis 414
Class: 9:20 am - 10:35 am TR Lewis 511

Prerequisites: PHY 31 (PHY 362 or equivalent course including introduction in atomic and quantum physics), MATH 205, PHY 215.

Credits: 3

Grades will be based on

- midterm exam (25%),
- homework and quiz (15%)
- textbook reading assignments and class/discussion activity (20%)
- final exam (40%)

Expectations:

You should expect to spend at least an hour of outside class study for every hour in class in addition to approximately an hour doing a homework assignment. Many students find it helpful to form study groups to work and discuss homework assignments with other students which is encouraged. It is an excellent way to learn physics. However, it is expected that finally each student will know how to work his/her problem for quiz, midterm or final without help. If you get stuck on a homework problem, see your instructor for help.

Office hours: TR 1:15 - 2:30 (schedule the meeting)

Textbook: *Quantum Mechanics with Basic Field Theory* by Bipin R. Desai, Cambridge University Press; (2009) #ISBN-10:0521877601 #ISBN-13:978-0521877602 (try to get the latest print, it contains less typo)

Recommended additional reading:

- **L. D. Landau and E. M. Lifshitz, *Quantum Mechanics (Non-Relativistic Theory)***
- J.J. Sakurai: *Modern Quantum Mechanics*, Addison-Wesley (1994)
- A. Messiah, *Quantum Mechanics*
- L. I. Schiff, *Quantum Mechanics*
- **S. Flugge, *Practical Quantum Mechanics*, Springer**
- E. Merzbacher, *Quantum Mechanics*, (3rd edition), Wiley, 1998.
- W. Thirring, *Course in Theoretical Physics 3: Quantum Mechanics of Atoms and Molecules*, Springer-Verlag (1990)
- D. Bohm, *Quantum Mechanics; Foundations and Applications*, 3rd edition, Springer-Verlag (1994)
- Edward L. Wolf, *Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience*, (2nd, Updated and Enlarged Edition). (2006)

This course will be enriched with the elements of the Nanoscience and will include special examples.

Accommodations for Students with Disabilities: If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, University Center C212 (610-758-4152) as early as possible in the semester. You must have documentation from the Academic Support Services office before accommodations can be granted.

Course Syllabus

0. Principles of Quantum Mechanics. Wave functions. Schrödinger equation.

Prelim reading assignment:

Refresh your memories on fundamentals of QM. Introduction in operators, wave functions. Wave packets, free particle motion, experimental observation, Schrödinger equation.

Part I. Introduction: Basic principles of quantum mechanics

1. Basic formalism

1.1 State vectors	1
1.2 Operators and physical observables	3
1.3 Eigenstates	4
1.4 Hermitian conjugation and Hermitian operators	5
1.5 Hermitian operators: their eigenstates and eigenvalues	6
1.6 Superposition principle	7
1.7 Completeness relation	8
1.8 Unitary operators	9
1.9 Unitary operators as transformation operators	10
1.10 Matrix formalism	12
1.11 Eigenstates and diagonalization of matrices	16
1.12 Density operator	18
1.13 Measurement	20

2. Fundamental commutator and time evolution of state vectors and operators.

2.1 Continuous variables: X and P operators	24
2.2 Canonical commutator $[X, P]$	26
2.3 P as a derivative operator: another way	29
2.4 X and P as Hermitian operators	30
2.5 Uncertainty principle	32
2.6 Some interesting applications of uncertainty relations	35
2.7 Space displacement operator	36
2.8 Time evolution operator	41
2.9 Dirac delta-function	44

3. Dynamical equations.

3.1 Schrödinger picture	55
3.2 Heisenberg picture	57
3.3 Interaction picture	59
3.4 Superposition of time-dependent states and energy–time uncertainty relation	63
3.5 Time dependence of the density operator	66
3.6 Probability conservation	67
3.7 Ehrenfest's theorem	68

Part II. Applications of the formalism of quantum mechanics

4. Free particles. (independent study)

(Reading assignment)

(Ch. 4: 1-11).

5. Angular momentum operators: Algebraic approach.	
4.12 Angular momentum commutators	98
4.13 Ladder operators	100
6. Particles with spin $\frac{1}{2}$.	
5.1 Spin $\frac{1}{2}$ system	103
5.2 Pauli matrices	104
5.3 The spin $\frac{1}{2}$ eigenstates	105
5.4 Matrix representation of σ_x and σ_y	106
5.5 Eigenstates of σ_x and σ_y	108
5.6 Eigenstates of spin in an arbitrary direction	109
5.7 Some important relations for σ_i	110
5.8 Arbitrary 2×2 matrices in terms of Pauli matrices	111
5.9 Projection operator for spin $\frac{1}{2}$ systems	112
5.10 Density matrix for spin $\frac{1}{2}$ states and the ensemble average	114
5.11 Complete wavefunction	116
5.12 Pauli exclusion principle and Fermi energy	116
7. Harmonic oscillator: One and Two-dimensional isotropic harmonic oscillator.	
9.1 Harmonic oscillator in one dimension	174
*11.1 The two-dimensional Hamiltonian	203
8. Exactly solvable two-level problems.	
13.1 Time-independent problems	223
13.2 Time-dependent problems	234
9. Introduction in perturbation theory: Time-independent perturbation for bound states.	
16.1 Basic formalism	277
16.2 Harmonic oscillator: perturbative vs. exact results	281
16.3 Second-order Stark effect	284
16.4 Degenerate states	287
16.5 Linear Stark effect	289
<u>Part III. Additional topics</u>	
*10. Coherent states.	
10.1 Eigenstates of the lowering operator	187
10.2 Coherent states and semiclassical description	192
10.3 Interaction of a harmonic oscillator with an electric field	194
10.4 Algebraic identities for exponential operators	199
*11. Gauge invariance, angular momentum, and spin.	
6.1 Gauge invariance	120
6.2 Quantum mechanics	121
6.3 Canonical and kinematic momenta	123
6.4 Probability conservation	124
*12. Some exactly solvable bound-state problems.	
8.2 Delta-function potential	145
8.5 Periodic potentials	151

*if time allows