Instructor: Prof. Slava V. Rotkin  
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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)


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  
• D. Bohm, Quantum Mechanics; Foundations and Applications, 3rd edition, Springer-Verlag (1994)  

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 $\sigma_x$ and $\sigma_y$ 106
   5.5 Eigenstates of $\sigma_x$ and $\sigma_y$ 108
   5.6 Eigenstates of spin in an arbitrary direction 109
   5.7 Some important relations for $\sigma_i$ 110
   5.8 Arbitrary $2 \times 2$ 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

   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

Part III. Additional topics

   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

   8.2 Delta-function potential 145
   8.5 Periodic potentials 151

*if time allows