

2012 Fall Semester

2012



424 Physics “Quantum Mechanics II”

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Class: 9:20 am - 10:35 am TR Lewis 511

Prerequisites: PHY 369 (or equivalent course in quantum physics) and its prerequisites.

Credits: 3

Grades will be based on

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

Recommended 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
- Eugen 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)

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. Basics of Quantum Mechanics. Dynamical equations. Perturbation theory

Preliminary reading assignment: Refresh your memories on fundamentals of matrix QM (Ch. 1-13).

(Time evolution operator, Schrödinger, Heisenberg and interaction picture. Two-level system: time-independent and time-dependent problems. Perturbation theory: time-independent perturbation.)

Part I. Solving time-dependent problems of quantum mechanics

17. * Time-dependent perturbation /*follows textbook Chapter numbering/

17.1 Basic formalism	293
17.2 Harmonic perturbation and Fermi's golden rule	296
17.3 Transitions into a group of states and scattering cross-section	299
17.4 Resonance and decay	303

18. Interaction of charged particles and radiation in perturbation theory.

18.1 Electron in an electromagnetic field: the absorption cross-section	318
18.2 Photoelectric effect	323
18.3 Coulomb excitations of an atom	325
18.4 Ionization	328
18.5 Thomson, Rayleigh, and Raman scattering in second-order perturbation	331

Part II. Scattering in quantum mechanics

19. Scattering in one dimension. (independent study)

(Reading assignment)

19.1 Reflection and transmission coefficients	342
19.2 Infinite barrier	344
19.3 Finite barrier with infinite range	345
19.4 Rigid wall preceded by a potential well	348
19.5 Square-well potential and resonances	351
19.6 Tunneling	354

QUIZ on scattering

20. Scattering in three dimensions – a formal theory.

20.1 Formal solutions in terms of Green's function	358
20.2 Lippmann–Schwinger equation	360
20.3 Born approximation	363
20.4 Scattering from a Yukawa potential	364
20.5 Rutherford scattering	365
20.6 Charge distribution	366
20.7 Probability conservation and the optical theorem	367
20.8 Absorption	370
20.9 Relation between the T-matrix and the scattering amplitude	372
20.10 The S-matrix	374
20.11 Unitarity of the S-matrix and the relation between S and T	378
20.12 Properties of the T-matrix and the optical theorem (again)	382

21. Partial wave amplitudes and phase shifts.

21.1 Scattering amplitude in terms of phase shifts	386
21.2 χ_l , K_l , and T_l	392
21.3 Integral relations for χ_l , K_l , and T_l	393
21.4 Wronskian	395

21.5 Calculation of phase shifts: some examples	400
22. Analytic structure of the S-matrix.	
22.1 S-matrix poles	407
22.2 Jost function formalism	413
*22.3 Levinson's theorem	420
*22.4 Explicit calculation of the Jost function for $l = 0$	421
*22.5 Integral representation of $F_0(k)$	424
<u>Part III. Advanced theory of angular momentum</u>	
26. Rotations and angular momentum.	
26.1 Rotation of coordinate axes	479
26.2 Scalar functions and orbital angular momentum	483
26.3 State vectors	485
26.4 Transformation of matrix elements and representations of the rotation operator	487
26.5 Generators of infinitesimal rotations: their eigenstates and eigenvalues	489
26.6 Representations of J^2 and J_i for $j = 1/2$ and $j = 1$	494
26.7 Spherical harmonics	495
28. Addition of angular momenta.	
28.1 Combining eigenstates: simple examples	518
28.2 Clebsch–Gordan coefficients and their recursion relations	522
28.3 Combining spin $1/2$ and orbital angular momentum l	524
29. Irreducible tensors and Wigner–Eckart theorem.	
29.1 Irreducible spherical tensors and their properties	529
29.2 The irreducible tensors: $Y_{lm}(\theta, \varphi)$ and $D_j(\chi)$	533
29.3 Wigner–Eckart theorem	536
29.4 Applications of the Wigner–Eckart theorem	538
*29.5 $SO(3)$, $SU(2)$ groups and Young's tableau	541
<u>*Part IV. Additional topics (*if time allows)</u>	
*24. Approximation methods for bound states and scattering.	
*24.1 WKB approximation	450
*24.2 Variational method	458
*24.3 Eikonal approximation	461
*25. Lagrangian method and Feynman path integrals.	
*25. Lagrangian method and Feynman path integrals	469
*25.1 Euler–Lagrange equations	469
*25.2 N oscillators and the continuum limit	471
*25.3 Feynman path integrals	473
*27. Symmetry in quantum mechanics and symmetry groups.	
*27.1 Rotational symmetry	502
*27.2 Parity transformation	505
*27.3 Time reversal	507
*27.4 Symmetry groups	511
*27.5 $D_j(R)$ for $j = 1/2$ and $j = 1$: examples of $SO(3)$ and $SU(2)$ groups	514
*30. Entangled states.	
*30.1 Definition of an entangled state	549
*30.2 The singlet state	551
*30.3 Differentiating the two approaches	552
*30.4 Bell's inequality	553