Physics GR6037/38 Professor Christ

04/13/2025

Tentative Schedule and Suggested Reading

I Fundamentals		
A Theory of Measurement 1. position and momentum space 2. Hilbert space 3. projection operators 4. eigenvalues and eigenvectors 5. continuous spectrum and resolution of the identity	• Baym: Ch. 3 (Ch 1. and 2. would good too) • G&Y: Ch. 2.1 and 2.2 • Lorch is a readable and short math book • Wikipedia discussion of hermitian and self-adjoint operators • Lorch, Reisz and Nagy and the Wikipedia article all discuss resolutions of the identity	*Sep 4, 9, 11, 16*
B Commutation and Uncertainty Relations 1. Gaussian wave functions 2. $[x_{\mathbf{op}}, p_{\mathbf{op}}] = i\hbar$ and the uncertainty principle 3. thought experiments	• G&Y Ch. 2.3 • Einstein-Bohr debates: Wikipedia	*Sep 16, 18*
C Time Development 1. Translations in space 2. Translations in time and the Schrödinger equation 3. Canonical quantization	• Baym: Ch. 5 • G&Y: Ch. 2.3, 2.4 and 2.5 • Useful to review classical Hamiltonian mechanics, perhaps in Goldstein: - Hamilton's equations, p 215 - Cannonical transformations, p 237	*Sep 23, 25*
D Simple Harmonic Oscillator 1. Eigenstates and eigenvalues of H 2. Coherent states	• Baym: Ch 4 • G&Y Ch 4.2 (a)-(d) • Power series solution: Schiff: pp 60-65	*Sep 25, 30, Oct 2*
E Semiclassical Limit. (WKB method) 1. propagating solutions 2. stationary phase approx. 3. Hamilton Jacobi theory 4. connection formulae a) Airy equation b) Stokes phenomena 5. Tunneling 6. 1-dimensional bound states	• G&Y Ch 4.5 • J. Heading • Goldstein: Ch 9 • Bender and Orszag: Ch 6.5, 6.6 • Understanding solutions to the Hamilton-Jacobi equations: Courant and Hilbert V II. Section II.	*Oct 2, 7, 9*

Tentative Schedule and Suggested Reading

II Applications		
A Angular momentum 1. Rotations, $O(3)$ and $SO(3)$ 2. Geometry of $SO(3)$ 3. Generators of $SO(3)$ 4. Spin-1/2 and $SU(2)$ 5. Spherical harmonics	• Baym: Ch 6, Ch 14. • G&Y: Ch 2.5, 3.1-3.4 • The topology of $SO(3)$: Wikipedia • General group theory: Hamermesh, Chevalley	*Oct 9, 14, 16, 21, 23, 28*
Midterm		**Oct 21**
B α decay	• Mentioned in Shankar: Ch. 16.2	*Oct 23, 28, Nov 6, 11, 13*
C Hydrogen atom Summary of hydrogen bound states.	• G&Y: Ch. 5.1-5.2 • Baym: Ch. 7	*Nov 13*
D Magnetic field and vector potential 1. Local gauge symmetry 2. Magnetic monopoles 3. Aharonov-Bohm effect	• Wikipedia discussion: ”Mathematical formulation” • G&Y: Ch 4.3.d, p 196	*Nov 13, 13*
E Hydrogen atom with $\vec{B}$ 1. Size of $\vec{A}^2$ term 2. Van Leewen’s theorem 2. Energy from orbital and spin magnetic moments	• G&Y: Ch 5.4 • Baym: Ch 14 • Huang: problem 7.4 and Sec 11.3	*Nov 13, 18*
III Perturbation Theory		
A Perturbation theory (non-degenerate) 1. Rayleigh-Schrodinger 2. Wigner-Brillouin 3. He atom electron-electron interaction 4.He ionization energy & variational method	• Baym: Ch 11 • G&Y: Ch 3.7(a) • Baym. pp. 242-244, G&Y: Ch 3.7(e)	*Nov 18, 20*

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B	**Perturbation theory (degenerate)** 1. 1st and 2nd order 2. Stark effect in Hydrogen 3. Polar molecules	• degenerate perturbation theory • G&Y: Ch 3.7(b) • Baym: pp 231-234 • G&Y: p 260 (complicated by inclusion of fine structure)	*Nov 25, Dec 2, 4*
IV Relativistc corrections to Hydrogen			
A.	**Coupling angular momenta** 1. Spin-orbit coupling 2. Tensor products 3. Decomposing products states $\vert j_1, m_1\rangle \otimes \vert j_2, m_2\rangle$	• Baym: Ch 15 • G&Y: Ch 3.5	*Dec 2, 4*
B.	**Fine structure of Hydrogen** 1. Relativistic kinetic energy 2. Thomas precession 3. Spin-orbit coupling	• G&Y: Ch 5.3	*Dec 9*
C.	**Hydrogen fine structure with $\vec{\mathbf{B}} \neq \mathbf{0}$** 1. Wigner-Eckart theorem 2. Irreducible tensor operators 3. Weak and strong field limits 4. Wigner 3-j symbols	• G&Y: Ch 7.6 • Baym: Ch 17 • wigner-3-j.pdf	*Dec 9, Jan 22*
D.	**Hyperfine structure of Hydrogen**	• G&Y: Ch 5.3 (b) and (c) • Baym: p 572	*Jan 22, 27*
V Quantum Statistical Mechanics			
A.	**Introduction** 1. Overview/Review 2. Density matrix 3. Von Neuman entropy	• Kittel and Kroemer: Ch 1, 2 and 3 • G&Y: Ch 2.2, Ch 12.5	*Jan 29, Feb 3, 5*
VI Quantum Computing			
A.	**Introduction** 1. Classical computer architecture 2. Quantum gates	• Nielsen&Chuang Chs. 1.1 and 1.2	*Feb 5, 10*

Tentative Schedule and Suggested Reading

B. Examples 1. Deutsch algorithm 2. Deutsch-Jozsa algorithm 3. Teleportation	• N&C Chs. 1.3 and 1.4	*Feb 10, 12*
VII Time dependent Hamiltonians		
A. Formal solution	• Baym: Ch. 5	*Feb 12, 17*
B. Sudden approximation		*Feb 17*
C. Adiabatic approximation 1. Berry's phase 2. Large time limit	• G&Y: Ch 7.7, 7.8 • Proc. Roy. Soc. London, A392, 45-57 (1984)	*Feb 17, 19*
D. Time-dependent perturbation theory	• G&Y: Ch. 2.4, 3.7 (c) • Landau-Lifshitz, p 140-143	*Feb 19, 24*
E. Decay of an unstable state 1. Introduction 2. Fermi's golden rule 3. Photoionization of Hydrogen 4. Wigner-Weiskopf method	• G&Y: Ch. 3.7 (d) • Baym Ch. 12 • Wigner-Weiskopf: Le Bellac Appendix C	*Feb 24, 26, Mar 3*
VIII Systems of identical particles		
A. General discussion	• Baym Ch 18 • G&Y Ch 11.1, 11.2	*Mar 3*
B. Bosons: second quantization	• Baym Ch 19 • G&Y Ch 11.1, 11.2	*Mar 5, 10*
C. Fermions: second quantization	• Baym Ch 17 • G&Y Ch 11.1, 11.2	*Mar 10*
D. Grassmann variables	• DeWitt; Ch 1.1	*Mar 12, 24*
E. Coulomb gas	• Baym: Ch 19, p 427	*Mar 24, 26*
IX Molecules		
A. Born-Oppenheimer approximation	• Baym p 471	*Mar 26, Apr 2*
Midterm		*Mar 31*
X Scattering theory		

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A. S-matrix approach, perturbation theory 1. Formula for cross section 2. Rutherford scattering 3. Positron scattering on Hydrogen	• Scattering from the S-matrix	*Apr 2, 7, 9, 14*
B. Stationary state scattering theory	• Cross section from stationary state approach • Baym Ch 9, 10 • G&Y Ch 8	*Apr 14, 16*
C. Partial wave expansion	• Baym Ch 9, p197 • G&Y Ch 8.1(a)	*Apr 21*
D. Optical theorem	• Baym Ch 9, p 201 • G&Y Ch 8.1(c)	*Apr 23*
E. Resonant scattering 1. Wigner-Weiskopf treatment 2. Incorporate rotational symmetry	• Baym Ch 9, p208	*Apr 23, 28*
XI Quantum treatment of light		
A. Quantum theory 1. Maxwell's equations in a box 2. Quantize classical Maxwell modes	• Baym Ch 13, p 271 • G&Y 10.1	*Apr 28, 30*
B. Atomic radiative decay 1. Decay rate 2. Selection rules	• Baym Ch 13, p 281 • G&Y Ch 10.4	*Apr 30*
XII Path integral formulation of quantum mechanics		
A. Derivation: single-particle quantum mechanics. 1. Canonical path integral 2. Feynman path integral	• Baym Ch 3, p 69 • G&Y Ch 2.7	*May 5*
B. Free particle case.	• G&Y Ch 2.7(b)	*Apr 29*