

#	PTS	SUBJECT	REMARKS
①	10	Derive Wien's Law from Planck Rad ⁿ Law ($\lambda_{\max} T = \text{const}$).	- new -
35) ②	10	Work out some numbers re Photo Electric Effect.	- new -
③	15	Algebraic details of Compton Scattering.	~ #①, Φ505 ('70).
④	10	Time & power scales for classical photo-effect.	- new -
30) ⑤	10	Most energetic photon-electron collision ($E_{\gamma}(\text{after}) > 0$).	- new -
⑥	10	H-atom transition rates per Correspondence Principle.	#③⑥, Φ520 (Win '91).
③ ⑦	10	Optimum aiming for a QM bullet (uncertainty relations).	#⑤, Φ505 ('70).
45) ⑧	20	Ground state of He(Z) atom via uncertainty relations.	Ter Haar # (3.5).
⑨	15	Time evolution of free-particle packet $A(x) \exp(ip_0 x/\hbar)$.	Ter Haar # (3.9).
④ ⑩	15	Balancing a QM pencil on its point.	Ter Haar # (3.76).
40) ⑪	10	Spreading of a QM wavepacket. Why don't people disappear?	~ #⑦, Φ505 ('70).
⑫	15	Probability density & current ρ & \mathbf{J} for KG Eqn.	#⑨, Φ505 ('70).
⑤ ⑬	10	Planewave solutions to KG Eqn. Explicit NR limit.	#②, Φ507 (Mid Term, '92).
30) ⑭	10	Algebra of Dirac delta fens: $\delta(kx) = \delta(x)/ k $, etc.	#⑩, Φ505 ('70).
⑮	10	$\chi_{\text{op}} = i\hbar \partial/\partial p \dots f(x) \rightarrow f(i\hbar \partial/\partial p) \neq F(p) \rightarrow F(-i\hbar \partial/\partial x)$.	#⑪, Φ505 ('70).
⑥ ⑯	10	Effect of complex potential $V \rightarrow V - \frac{1}{2} i\hbar \Gamma$ on prob. cons ⁿ .	- new -
40) ⑰	10	Effect of decay rate $\Gamma = \text{const} > 0$ on $\Psi(1D)$, and on $\langle p \rangle = m \frac{d}{dt} \langle x \rangle$.	- new -
220pts total ⑱	10	$p = -i\hbar \partial/\partial x$ & $E = i\hbar \partial/\partial t$ are Hermitian (from def ⁿ).	#⑫, Φ505 ('70).
⑲	10	Algebra of adjoint operators: $(q_1 q_2 \dots q_n)^\dagger = q_n^\dagger \dots q_2^\dagger q_1^\dagger$, etc.	#⑬, Φ505 ('70).
⑦ ⑳	10	Commutator identities: $[AB, C] = A[B, C] + [A, C]B$, etc.	#⑭, Φ505 ('70).
40) ㉑	10	QM Version of \mathbf{L} mom. $\mathbf{L} = \mathbf{r} \times \mathbf{p}$. $[L_x, L_y] = i\hbar L_z$, etc.	#⑮, Φ505 ('70).
㉒	10	Proof of QM Torque Equation: $(d/dt) \langle \mathbf{L} \rangle = \langle \mathbf{r} \times \mathbf{F} \rangle$.	#⑯, Φ505 ('70).
㉓	10	Show $L_z = -i\hbar \partial/\partial \phi$ in sph. cds. Then $[L_z, \phi] = -i\hbar$, etc.	#⑰, Φ505 ('70).
①	25	Estimate of ground-state energies via uncertainty relations.	new (Saxon #7, p.55).
11D-ERM ②	30	Condition for exsts-of-motion in QM stationary states.	new (Ter Haar #3.38).
150) ③	35	For 1D bound-state problem, show $E_{\text{gnd}} < V_{\min}$ not possible.	p.84a, Φ505 ('70) note
pts) ④	35	$(d/dt) \langle p^2/2m \rangle$, and QM version of the work-energy theorem.	#③, Φ505 ('70) Mid T.
⑤	25	Probability of $ x \leq \frac{1}{2}a$, when $\Psi(x) = N(a^2 - x^2)$ for $ x \leq a$.	#⑤, Φ505 ('70) Mid T.
⑧ ㉔	15	Particle in a 1D box: find $\langle x \rangle$ & $\langle p \rangle$, variances Δx & Δp , in state n.	- new -
50) ㉕	10	Particle in a 1D box at energy E_n : find force exerted on walls.	#⑳, Φ505 ('70).
㉖	10	Bound states for m in $V(x) = \infty, x < 0; = 0, \text{ for } 0 < x < R; = V_0 \text{ for } x > R$.	#⑲, Φ505 ('70).
㉗	15	Reflection & transmission for m @ $E > V_0$ incident on rect ^l well.	#㉑, Φ505 ('70).
⑨ ㉘	15	1D Schrödinger problem for $V(x) = -A\delta(x)$. Bound-state E.	#⑱, Φ505 ('70).
50) ㉙	10	Confluent Hypergeometric ODE: series & polynomial solutions.	#①, Φ507 (Win '92).
⑩ ㉚	15	Hermite polynomials: orthogonality & recurrence relations.	#②②+②③, Φ505 ('70).
60pts total ㉛	10	For 1D SHO, lowest energy $\geq \frac{1}{2} \hbar \omega$, per uncertainty rel ⁿ .	new (I. & L #2, p.71).

Φ506 PROBLEMS : Aut. 1993 (cont'd)

#	PTS	SUBJECT	REMARKS
(32)	15	$\langle p \rangle$ for SHO wavepacket. $\langle p \rangle = m \frac{d}{dt} \langle x \rangle$ & classical limit.	#(24), Φ505('70).
(10) (33)	10	For SHO eigenstate n , show $\langle n V(x) n \rangle = \frac{1}{2} E_n$.	#(25), Φ505('70).
(45) (34)	20	m in composite state $\Psi = \sum c_n \psi_n$ in a 1D box. Find $\{c_n\}$, etc.	#(27), Φ505('70).
(11) (35)	10	Variational gnd state of SHO via $\phi(x) = A[1 - (x /\alpha)]$.	#(20), Φ507 (Spr.'92).
(40) (36)	10	Variational gnd state via $\Psi = \Psi_0 + \lambda \phi$. Show energy $E = E_0 + \lambda^2 \epsilon_2 + \dots$	#(22), Φ507 (Spr.'92).
(37)	10	Orthogonality & completeness of eigenfns ψ_n (rigid box).	#(26), Φ505('70).
(38)	10	SHO ground state... expand $\Psi_0(x)$ in momentum eigenfns. Find $ c(k) ^2$, etc.	#(28), Φ505('70).
(12) (39)	10	WKB approxn for $J_V(x)$. Asymptotic form for $x \gg v \gg \frac{1}{2}$.	#(3), Φ507 (Spr.'92).
(50) (40)	10	Iterate Neumann series for $U_{n+1}(s)$ [see p. WKB 10].	#(25), Φ507 (Spr.'92).
(41)	10	SHO Energy Quantization via Bohr-Sommerfeld Formula.	#(26), Φ507 (Spr.'92).
(42)	20	QM Tunneling thru a Coulomb Barrier. Cold fusion?	#(28), Φ507 (Spr.'92).
(13) (43)	30	Analyse bound states of a double well via WKB.	#(29), Φ507 (Spr.'92).
(40)* (44)	10	Find and count energy levels for $V(x) = -V_0 \text{sech}^2(x/a)$.	- new -
FINAL (1)	30	Prove: $\langle \alpha p \beta \rangle = (im/\hbar)(E_\alpha - E_\beta) \langle \alpha x \beta \rangle$ for stationary states.	#(6), Φ505('70) Final.
EXAM (2)	45	Momentum distribution for ground state of 1D ∞ rectangular well.	#(8), Φ505('70) Final.
(315 pts) (3)	35	For a complete set, prove: $\langle k AB m \rangle = \sum_l \langle k A l \rangle \langle l B m \rangle$.	#(9), Φ507 (Spr.'92).
(4)	45	$\Lambda = a^\dagger a$, $aa^\dagger + a^\dagger a = 1$. Find eigenstates & eigenvalues for $\Lambda \lambda\rangle = \lambda \lambda\rangle$.	#(4), Φ505('70) Final.
(5)	40	Find a value for $\Delta x \Delta p$ in the n^{th} state of a SHO.	- new -
(6)	45	Lifetime for a particle trapped in a 1D box with δ -fn walls.	#(2), Φ506 (Feb.'72) Hour Test
(7)	35	WKB treatment of bound states in a very deep 1D well.	- new -
(8)	40	Variational estimate for bound-state energy in $V(x) = -A\delta(x)$.	- new -

* Total homework pts (sets 1-13): 535 pts (44 probs)
 midterm exam : 150 pts (5 probs)
 final exam : 315 pts (8 probs)
 1000 pts (57 probs)

<u>Date</u>	<u>#</u>	<u>Lecture</u>	<u>Assignment</u>
① Wed. 25 Aug.	1	Introduction. BB radiation: classical picture.	-
Fri. 27 "	2	BB radn: Planck Ansatz. Notion of photon.	① Probs. 1-3 (35 pts).
② Mon. 30	3	Correct BB. Photon dynamics. Photo Effect & Compton.	-
Wed. 1 Sept.	4	Finish Compton. Start Duality (pp. 1-2)	-
Fri. 3 "	5	Duality (pp. 2-3). Correspondence Principle (pp. 4-7).	② Probs. 4-6 (30 pts).
③ Mon. 6 "	-	HOLIDAY (Labor Day)	-
Wed. 8 "	6	Summary to date. deB Hypothesis. Wave packets.	-
Fri. 10 "	7	Wave packet Ex. Uncertainty Relations. H-atom (pp. 11-14).	③ Probs. 7-9 (45 pts).
④ Mon. 13 "	8	Further Properties of Wave Packets I (pp. Pack 1-4)	-
Wed. 15 "	9	Further Properties... II (pp. Pack 5-8). [3.78 pp/lect]	- (34 lect. pages to date)
Fri. 17 "	10	Schrödinger Eq I: pp. Sch. 1-6. Derivation. KG Eq.	④ Probs 10-12 (40 pts).
⑤ Mon. 20 "	11	Schrödinger Eq II: pp. Sch. 6-9. KG Eq. Continuity.	-
Wed. 22 "	12	Schrödinger Eq. III: pp. Sch. 10-13. Exp. Value Postulate.	-
Fri. 24 "	13	Schrödinger Eq. IV: pp. Sch. 14-16. pp. Ψ Summary.	⑤ Probs. 13-15 (30 pts).
⑥ Mon. 27 "	14	Schrödinger Eq. V: pp. Sch. 16-19. Ψ Eq. in extl. V.	-
Wed. 29 "	15	Schrödinger Eq. VI: pp. Sch. 19-21. Remarks. [3.67].	- (55 lect. pages to date)
Fri. 1 Oct.	16	Wave Mechanics I: Properties & Structure (pp. Prop. 1-4).	⑥ Probs 16-19 (40 pts).
⑦ Mon. 4 "	17	Wave Mechanics II: Prop. & Struct. of Ψ (pp. Prop 5-8).	-
Wed. 6 "	18	Wave Mechanics III: Final Conditions on Ψ (pp. Prop. 9-12).	-
Fri. 8 "	19	Wave Mechanics IV: QM Eqn. of Motion (pp. Prop. 13-16).	- no problem set
Mon. 11 "	-	HOLIDAY (Columbus Day)	-
Wed. 13 "	20	Wave Mechanics V: QM Observability (pp. 17-20).	-
Fri. 15 "	21	Wave Mechanics VI: Heisenberg's Uncertainty Rel's (21-24).	⑦ Probs 20-23 (40 pts).
⑨ Mon. 18 "	22	MIDTERM 11-1 PM, AJM 221. 5 probs., 150 pts.	-
Wed. 20 "	23	Summary: S. Eq. & Wave Mech's. Dirac postulates (24-27). [3.73]	- (82 lect. pages to date)
Fri. 22 "	24	Schrödinger Solns I. Bound states of a rect ² well (pp. 1-4).	⑧ Probs. 24-27 (50 pts).
⑩ Mon. 25 "	25	CANCELLED. Made up on 11/5/93 (Variational Aspects).	-
Wed. 27 "	26	Solns II: Reflection & Transmission at a rect ² barrier (pp. 5-9).	-
Fri. 29 "	27	Solns III: SHO -- Energies & Hermite poly's (pp. 10-14).	⑨ Probs. 28-31 (50 pts).
⑪ Mon. 1 Nov.	28	Solns IV: SHO -- details of wave fens $\Psi_n(x)$ (pp. 15-18).	- (100 lect. pages to date)
Wed. 3 "	29	Solns V: SHO -- wavepacket & classical motion (19-22).	-
Fri. 5 "	30	Solns VI: SHO by operators (1-4). Variational Aspects (1-4).	⑩ Probs. 32-34 (45 pts).
⑫ Mon. 8 "	31	Finish Variational Aspects (pp. 4-7).	-
Wed. 10 "	32	Expansion Postulate & Completeness I. (pp. 1-4) [3.71]	- (119 lect. pages to date)
Fri. 12 "	33	Expansion Postulate & Completeness II. (pp. 5-8).	⑪ Probs. 35-38 (40 pts).
⑬ Mon. 15 "	34	WKB I: Use of WKB, 1st sol ⁿ , remarks (pp. 1-5).	-
Wed. 17 "	35	WKB II: Remarks (cont'd). Arc models. Neumann (5-8).	-
Fri. 19 "	36	WKB III: Finish Neumann. Turning pt. problem (9-12).	- no problem set.
⑭ Mon. 22 "	37	WKB IV: Airy's ODE. Connection Formulas (WKB 12-16).	-
Wed. 24 "	-	HOLIDAY	-
Fri. 26 "	-	HOLIDAY (Thanksgiving)	-
Mon. 29 "	38	WKB V: Review. Connection forms. BS Quant ³ n (pp. 17-20).	⑫ Probs. 39-42 (50 pts).
Wed. 1 Dec.	39	WKB VI: Barrier Penetration. Field Emission (pp. 20-24).	-
Fri. 3 "	40	WKB VII: Double-Well & Double-Hump (pp. WKB 25-28)	-
⑯ Mon. 6 "	41	WKB VIII: Trapping & Metastable States (pp. 29-33)	⑬ Probs. 43-44 (40 pts).
Wed. 8 "	42	SS Pent. Th. I: Intro. & Master Eq. (pp SS 1-4).	- 164 pb. / 42 lectures
Fri. 10 "	43	SS Pent. Th. II: The λ series. 1 st order (pp. SS 1-8).	\Rightarrow 3.90 pp./lect. - no set

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Date	#
① Wed. 24 Aug.	1
Fri. 26 "	2
② Mon. 29 "	3
Wed. 31 "	4
Fri. 2 Sept.	5
③ Mon. 5 "	-
Wed. 7 "	6
Fri. 9 "	7
④ Mon. 12 "	8
Wed. 14 " (42)	9
Fri. 16 "	10
⑤ Mon. 19 "	11
Wed. 21 "	12
Fri. 23 "	13
⑥ Mon. 26 " (63)	14
Wed. 28 "	15
Fri. 30 "	16
⑦ Mon. 3 Oct.	17
Wed. 5 "	18
Fri. 7 "	19
⑧ Mon. 10 "	-
Wed. 12 " (86)	20
Fri. 14 "	21
⑨ Mon. 17 "	22
Wed. 19 "	23
Fri. 21 "	24
⑩ Mon. 24 "	25
Wed. 26 "	26
Fri. 28 " (108)	27
⑪ Mon. 31 "	28
Wed. 2 Nov.	29
Fri. 4 "	30
⑫ Mon. 7 "	31
Wed. 9 "	32
Fri. 11 " (129)	33
⑬ Mon. 14 "	34
Wed. 16 "	35
Fri. 18 "	36
⑭ Mon. 21 "	37
Wed. 23 "	-
Fri. 25 "	-
⑮ Mon. 28 "	38
Wed. 30 "	39
Fri. 2 Dec.	40
⑯ Mon. 5 "	41
Wed. 7 "	42
Fri. 9 " (174)	43

Lecture

Intro^d. Need for QM. BB Radⁿ. pp. 1-4.
 BB Radⁿ. Photon dynamics, pp. 4-8.
 Photo- & Compton Effects, pp. 9-12. Duality pp. 1-3.
 Duality: p. 4; Correspondence Principle; pp. 5-7.
 Duality: de Broglie Relations & Unc. Rel^s, p. 8-12.
HOLIDAY (Labor Day).
 Duality & Summary; pp. 12-14. Packets: pp. 1-2.
 Packets: pp. 2-7 (through packet broadening).
 Review & finish Packets: pp. 2-8. Start Sch. Eq. i pp. 1-2.
 Sch. Eq. pp. 2-8 (cons² of $|\psi|^2 dx$). [4.67]
 Sch. Eq. pp. 8-13 (exp² value postulate).
 Sch. Eq. pp. 13-16 (SUMMARY of uses of QM Wfens).
 Sch. Eq. pp. 17-20 (derive Sch. Eq. in ext^l pot^l).
 Sch. Eq. p. 21 (t-indep^t eq.). Properties... pp. 1-3.
 Properties of ψ (thru Hermitianity); pp. 4-8. [4.50]
 Properties of ψ & ψ' (thru E-quantization); pp. 9-12.
 QM Eqn of Motion; Commutators; Hamⁿ Egs., pp. 13-16.
 QM Observability, pp. 17-20. [sup 3 lectures via '93].
 Heisenberg Unc. Relⁿ: $\Delta A \Delta B \geq \frac{1}{2} | \langle C \rangle |$; pp. 21-24.
 Summary: Wave Mechanics, Dirac postulates: pp. 25-27.
HOLIDAY (Columbus Day)
 Schrödinger Solns I: rect. well, pp. 1-4. [4.30]
 Schrödinger Solns II: rect. barrier, pp. 5-9.
 Schrödinger Solns III: SHO... E_n & ψ_n , pp. 10-14.
 MidTerm Preview. Solns IV: SHO eigenfens, pp. 15-17.
 SHO wavefens. General Notion of Wave Packets, pp. 17-20.
MIDTERM: 7-9 PM. Probs ①-⑤ (300 pts).
 SHO wavepackets: ~ classical motion: pp. 19-22.
 SHO quantⁿ via a & a[†] ops; pp. 1-4. [4.15]
 Variational Aspects of Schrödinger Eq. pp. 1-4.
CANCELLED (CAR Q+2). Made up on 12/5 (SSPTh.).
 Variational Aspects II: pp. 4-7.
 Expansion Post. & Completeness I, pp. 1-4.
 Expansion Post. & Completeness II, pp. 5-8. [4.16]
 WKB I: Intro. Thru Neumann corrⁿ; pp. 1-6.
 WKB II: up thru Bohr-Sommerfeld Rule: pp. 7-11.
 WKB III: deB λ criterion. 1D barrier penetration; 12-16.
 WKB IV: Barrier \rightarrow Field Emission; Double well: pp. 16-19.
 WKB V: Double-hump problem: pp. 20-23.
HOLIDAY (Thanksgiving)
HOLIDAY
 WKB VI: Double-hump probⁿ: Trapping & decay: pp. 20-26.
 SSPTh. I: notions & Fund^l Eq^s: pp. 55-1-3.
 SSPTh. II: Soln by iteration, 1st order corrⁿs: pp. 4-6.
 SSPTh. III & IV: thru $E_n^{(2)}$, degenerate case: pp. 7-14.
 Non-Rel. H-Atom: pp. 1-6 (thru $R(p) \propto \text{CHG fen}$).
 Non-Rel. H-Atom: pp. 7-11, EVALUATION. [4.14]

Assignment

① Pr. 1-3 (35 pts). x
 - (Intro.)
 ② Pr. 4-6 (30 pts). x
 - (Unc. Rel^s)
 ③ Pr. 7-9 (45 pts). x
 - (Packets, KG Eq.)
 ④ Pr. 10-12 (40 pts). x
 - (δ -fen, $\chi_{op} \rightarrow i\hbar \partial/\partial p$).
 ⑤ Pr. 13-15 (30 pts). x
 - (Complex V; p & E Hermⁿ)
 ⑥ Pr. 16-19 (40 pts). x
 - (Commutators, QM & Mon.)
 ⑦ Pr. 20-23 (40 pts). x
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 - no assignment -
 - (rect^l wells)
 ⑧ Pr. 24-27 (50 pts). x
 - ($V \sim \delta$ -fen, some math.)
 - SHO gnd state.
 ⑨ Pr. 28-31 (50 pts). x
 - (Variational calcs
 - Completeness for ψ_n (box).)
 ⑩ Pr. 32-35 (40 pts) n
 - (WKB: quarks, cold fusion)
 ⑪ Pr. 36-37 (50 pts) x
 -
 - no assignment
 - (WKB: double well, etc.)
 - Spectrum for decaying state.
 ⑫ Pr. 38-40 (50 pts). x
 - (SS Partⁿ Theory)
 ⑬ Pr. 41-43 (30 pts) x
 -
 - Final is Mon. 12/12/94.
 - no assignment