PHYSICS 414 -- Homework Set #4

Due in class on Thursday, Oct 4.

Note that **no late papers will be accepted** for this homework assignment.

Do the following problem from Griffiths:

9.14 (pg. 363)

Also do the following four additional problems (note that one is on the following page):

(1) Calculate the rates of spontaneous and stimulated emission of radiation arising from the 2p→1s transition for atomic hydrogen (the Lyman α line) that is contained in a large cavity at 2000 K. What do you conclude?

(2) A hydrogen atom is in the 2*s* state. An electromagnetic wave – propagating along the *x* direction, polarized in the *z* direction, and with an intensity $I(\omega)$ – impinges on the atom. The wavelength of the electromagnetic radiation is very long compared to the size of the hydrogen atom. (Reminder: $\rho = I/c$.)

(a) What are the possible final states in which the hydrogen atom might end up? If there are any additional conditions that are necessary in order for a given final state to be populated, state them [and then assume them to be valid for parts (b) and (c)].

(b) Which of the final states from part (a) would you expect to have the largest transition rate from the 2*s* state, and why?

(c) Calculate the transition rate from the 2*s* state to the state that you specified in part (b).

(3) Print a copy of the attached sheet showing the low-lying levels of the O^{+1} ion.

(a) For each group of excited states with a given Configuration+Term, indicate *on your printed sheet* whether E1 transitions to the ground state should be "fast", "slow", or "strictly forbidden". For each transition that you expect to be slow or strictly forbidden, also indicate *on your printed sheet* the selection rule(s) that it violates. (Note: For strictly forbidden transitions, you only need to give one reason, even if the transition violates several different rules.)

(b) In class, we discussed "four-level" laser systems. For the three lower levels, we looked for sets of states *a*, *b*, *c*, with *a* the ground state, *b* an excited state with a fast E1 transition $b \rightarrow a$, and *c* a higher excited state with an E1 transition $c \rightarrow b$ that has a large matrix element, but is nonetheless much slower than $b \rightarrow a$ so that the lifetime of *c* will be quite a bit longer than that of *b*. Identify all Conf+Term pairs *b* and *c* that, together with the ground state *a*, would be good candidates for the lower three levels of a four-level O^{+1} ion laser system, and justify your choices.

Comment: The constraints imposed here are more restrictive than required in the real world to minimize the number of different combinations you need to consider.

(4) A neutron scatters elastically off a proton in a hydrogen atom. Before the scattering, the atom is at rest in the ground state. The scattering process occurs over a time τ that is very short compared to the atomic orbital period. After the scatter, the proton recoils with velocity v. (Make no assumption about the value of v, except that it is non-relativistic.) Calculate the probability that the (moving) atom will remain in the ground state as a function of $q = mv/\hbar$.

Hint: I found it very useful to consider the relationship between the hydrogen ground state wave function in coordinate space and in momentum space.

Primary data source Query NIST Bibliographic Database for **O II** (new window)

Martin et al. 1993 Literature on O II Energy Levels

Configuration	Term	J	Level (eV)	Reference
$2s^2 2p^3$	$^4S°$	$^3/_2$	0.00000	L11267
$2s^2 2p^3$	$^2D°$	$^5/_2$	3.324084	
		$^3/_2$	3.326567	
$2s^2 2p^3$	$^2P°$	$^3/_2$	5.017394	
		$^1/_2$	5.017640	
$2s2p^4$	^4P	$^5/_2$	14.857920	
		$^3/_2$	14.878156	
		$^1/_2$	14.888376	
$2s2p^4$	^2D	$^5/_2$	20.579945	
		$^3/_2$	20.580942	
$2s^2 2p^2(^3P)3s$	^4P	$^1/_2$	22.9662468	
		$^3/_2$	22.9793019	
		$^5/_2$	22.9989592	
$2s^2 2p^2(^3P)3s$	^2P	$^1/_2$	23.4191936	
		$^3/_2$	23.4415071	
$2s2p^4$	^2S	$^1/_2$	24.265005	
$2s^2 2p^2(^3P)3p$	$^2S°$	$^1/_2$	25.2856200	
$2s^2 2p^2(^3P)3p$	$^4D°$	$^1/_2$	25.6313467	
		$^3/_2$	25.6382308	
		$^5/_2$	25.6495851	
		$^7/_2$	25.6650357	
$2s^2 2p^2(^1D)3s$	^2D	$^5/_2$	25.661217	
		$^3/_2$	25.661346	
$2s^2 2p^2(^3P)3p$	$^4P°$	$^1/_2$	25.8316236	
		$^3/_2$	25.8373459	
		$^5/_2$	25.8487455	
$2s^2 2p^2(^3P)3p$	$^2D°$	$^3/_2$	26.2253990	
		$^5/_2$	26.2490322	
$2s^2 2p^2(^3P)3p$	$^4S°$	$^3/_2$	26.3047196	
$2s2p^4$	^2P	$^3/_2$	26.358273	
		$^1/_2$	26.379156	
$2s^2 2p^2(^3P)3p$	$^2P°$	$^1/_2$	26.5536847	
		$^3/_2$	26.5610929	