Physics 221B
Spring 2008
Homework 23
Due Monday, March 31 at 5pm

Reading Assignment: Rest of Notes 36, Notes 37; Sakurai, *Advanced Quantum Mechanics*, pp. 32–47.

1. The perturbation expansion (37.6) is valid if $E_{\text{wave}} \ll E_{\text{nucleus}}$. Compute the energy flux (in watts per square cm) of light for which the rms electric field of the light wave is equal to the electric field strength due to the proton in a hydrogen atom at the Bohr radius. There is current experimental interest in the physics that arises at such high fields. The fields are created by focussing laser light onto a small region.

2. Compute the lifetime of the 21 cm transition in Hydrogen, $1s_{1/2}$ $(f = 1) \to 1s_{1/2}$ $(f = 0)$. Here f is the total angular momentum $\mathbf{F} = \mathbf{L}+\mathbf{S}+\mathbf{I}$, orbital plus spin for the electron plus spin for the proton. The splitting between the energy levels is given by Eq. (23.43), where g_N is the proton g-factor, μ_N and μ_B are the nuclear and Bohr magnetons, respectively, and a_0 is the Bohr radius. Assume the upper state is unpolarized (equal probabilities of being in the different magnetic substates). The lifetime is the inverse of the Einstein A coefficient. This lifetime determines the radio power radiated by galactic clouds of atomic hydrogen.

3. A hydrogen atom is at distance R from a hot blue star with radius a and surface temperature T, which radiates significantly in the ultraviolet. Assume $R \gg a$, so that the light coming from the star is concentrated in a narrow range of solid angles. Assume the surface of the star radiates as a blackbody. Assume the atom is unpolarized. When the atom absorbs a photon, taking it from the $1s$ state to the $2p$ state, it absorbs the photon momentum and suffers a recoil; then in short order ($\sim 10^{-9}$ sec), it reemits a photon and drops back into the ground state. But since the reemission of the photon is isotropic (for an unpolarized atom), the average momentum transferred by the emitted photon is zero. In this way, the atom feels an effective force because of the absorption of photons from star. Find an expression for this force in terms of R, a, T, and other appropriate parameters. Ignore all atomic states except the $1s$ and $2p$.