Reading Assignment: Sakurai, *Advanced Quantum Mechanics*, pp. 36–47; Notes 34. Some comments on Sakurai’s notation: He uses Heaviside-Lorentz units, which differ from Gaussian units in that $e^2$ is replaced by $e^2/4\pi$. He also uses real polarization vectors (linear polarization), which is why his polarization vectors lack the complex conjugate seen in the notes.

1. The perturbation expansion (34.6) 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.

2. Compute the lifetime of the 21 cm transition in Hydrogen, $1s_{1/2} (f = 1) \rightarrow 1s_{1/2} (f = 0)$. Here $f$ is the total angular momentum $F = L + S + I$, orbital plus spin for the electron plus spin for the proton. The splitting between the energy levels is given by Eq. (21.43), where $g_N$ is the proton $g$-factor, $\mu_N$ and $\mu_B$ 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 obviously 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 $R$ and surface temperature $T$, which radiates significantly in the ultraviolet. Assume $r \gg R$, 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 $r$, $R$, $T$, and other appropriate parameters. Ignore all atomic states except the $1s$ and $2p$. 