449 HW #5

In[5]:=
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<< "http://www.physics.wisc.edu/~tgwalker/448defs.m"
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1) Townsend 11.10

2) 11.11

3-4) A 131-Xe nucleus, spin $k = 3/2$, has the Hamiltonian $H = -\mu \mathrm{B}\, K_z + Q\left(K_x^2 - 5/4\right)$. Calculate the energy shifts to second order in Q.

5) An electric field $\mathcal{E}$ is applied to a Rb atom, producing the Hamiltonian $V = e\, z\, \mathcal{E}$. Calculate the shift in energy of the 5s state. You may assume that only the 5p excited state contributes to the shift. The radial matrix element is $\int dr\, P_{5s}\, r\, P_{5p} = 5.1\, a_0$, and the wavelength of a $5\, p \to 5\, s$ photon is 785 nm.

6) Plot the energies of the 1s and 2s states of antihydrogen, as a function of magnetic field. You must include the hyperfine interaction as well, in order to reproduce the figure in Nature 541, 506–510 (2017). The Hamiltonian for the hyperfine interaction between a proton (spin $\boldsymbol{I} = 1/2$) and an electron is $H_{\mathrm{hyp}} = \frac{8\pi}{3}\, \delta(\boldsymbol{r})\, \boldsymbol{\mu_s} \cdot \boldsymbol{\mu_p}$ where $\boldsymbol{\mu_s} = g_s\, \mu_B\, \boldsymbol{S}$, $\boldsymbol{\mu_p} = g_p\, \mu_N\, \boldsymbol{I}$, $\mu_N = \frac{m_e}{m_p}\, \mu_B$, $g_s \approx 2$, $g_p = 5.586$.