F20 PHYSICS 137B: HW 5

October 2 at 5 pm

September 22, 2020

1 Griffiths problems

Do the following problems from Griffiths: 7.20, 7.21, 7.24, 7.28

2 Other problems

2.1

The eigenstates of a rotating dumbbell, with moment of inertia I,

$$E_l = \frac{\hbar^2 l(l+1)}{2I}, \tag{2.1}$$

are $(2l+1)$-fold degenerate. In the event that the dumbbell is equally and oppositely charged at its ends, it becomes a dipole. The interaction energy between such a dipole and a constant, uniform electric field $\mathbf{E}$ is:

$$\hat{H}' = -\mathbf{d}\cdot\mathbf{E}, \qquad (\hat{H} = \hat{H}_0 - \mathbf{d}\cdot\mathbf{E}). \tag{2.2}$$

The dipole moment of the dumbbell is $\mathbf{d}$. Show that to terms of first order, this perturbing potential *does not separate* the degenerate E_l eigenstates.

2.2

Consider again the dipole moment described in Problem 2.1. If both ends are equally charged, the rotating dipole constitutes a magnetic dipole. If the dipole has angular momentum $\mathbf{L}$, the corresponding magnetic dipole moment is

$$\boldsymbol{\mu} = \frac{e}{2mc}\mathbf{L}, \tag{2.3}$$

where e is the net charge of the dipole. The interaction energy between this magnetic dipole and a constant, uniform magnetic field $\mathbf{B}$ is

$$\hat{H}' = -\hat{\boldsymbol{\mu}}\cdot\mathbf{B} = -\frac{e}{2mc}\hat{\mathbf{L}}\cdot\mathbf{B}, \qquad (\hat{H} = \hat{H}_0 - \hat{\boldsymbol{\mu}}\cdot\mathbf{B}). \tag{2.4}$$

(a) If $\mathbf{B}$ points in the z direction, show that $\hat{H}'$ separates the $(2l+1)$-fold degenerate E_l energies of the rotating dipole.

(b) Apply these results to the one-electron atoms to find the splitting of the P states. (Neglect spin-orbit coupling.)(*Note*: This phenomenon is an example of the *Zeeman effect*.)