Physics 472 - 2020

Quantum Mechanics

Problem Set 4

1. Consider classical Larmor precession of the electron spin in a uniform magnetic field $\mathbf{B}$ pointing along the z-axes. The precession describes the time evolution of the expectation value of the spin. The torque is $\boldsymbol{\mu} \times \mathbf{B} \to \langle \boldsymbol{\mu} \rangle \times \mathbf{B}$. Find the precession frequency.

2. Find the energy levels and the quantum states of an electron in state p (i.e., the orbital momentum quantum number is $l = 1$) in a magnetic field B. Assume that the field is pointing along the z-axis and that the g-factor is 2. Disregard the spin-orbit coupling, i.e., the interaction of the orbital motion and the spin.

3. (a) A meson is a bound state of a quark and an antiquark. Assume that both of these particles are in the s-state. Find the possible values of the spin of a meson. Calculate the total number of states first before you think of the possible values of the total spin and then for the spin values that you will have found.

   (b) For an electron in the s-state ($l = 0$) in a magnetic field $\mathbf{B}$ along the z-axis, find the expectation value $\langle S_y(t) \rangle$ and compare with what was found in class for $\langle S_x(t) \rangle$. Explain the result in view of the problem 1.

4. Calculate the Zeeman splitting of the energy levels for an electron in s state in a magnetic field of 1 T. Express this splitting in Joules, in electron volts, and in the frequency units given that the energy is related to the frequency as $E = hf$.

Each problems is 10 pt.