Physics 322 Fifth Homework

02/09/2021

Due 02/11/2021

1. We are going to do a problem on angular momentum in fields. The magnetic field will be produced by an infinitely long solenoid with n turn per meter, carrying a current, I. The solenoid has a radius,R, and it is filled with and infintely long rod that has a uniform charge density, ρ_Q, and a uniform mass density, ρ_m. Why infinitely long? So we can ignore the field at the ends. What is the price? Everything needs to be caculated per unit length.

   (a) Find the electric and magnetic fields inside the solenoid.

   (b) USe your field to determine the field momentum density, $\vec{g}$.

   (c) Use the momentum density to find the angular momentum density, $\vec{l}$.

   (d) We will assume the the magnetic fileld has an amplitude of one Tesla. The radius of the solenoid is 1 centimeter. The mass density is 1 gram per cubic centimeter. And that the charge density is about 9×10^{-4} Coulombs per meter cubed, which is approximately the density that would result in the surface field being the breakdown field of air. How fast will the charged cylinder be rotating if I ramp the current in the solenoid to zero?

2. In our last homework we worked out some properties of this weird classical model of the electron and learned that it doens't make much sense. Let's revisit it in terms of angular momentum. I will warn you that this is not a standard calculation, it's just something I was playing around with. As a reminder, the cahge of the electron is $e = 1.6^{-19}$ Coulombs. And, it's magnetic moment is, $m = -9.3 \times 10^{-24}$ Joules per Tesla. Just like last week we will leave the radius of the electron as a parameter that we will fit at the end.

   (a) Use the electric and magnetic field generated by an electron of radius R to generate the momentum density associated with the fields, $\vec{g}$.

(b) Use the momentum density to generate an angular momentum density for the eelctron's fields.

(c) Integrate the angular momentum density to find the total angular momentum

(d) OK. Here is where we go outside the norm. The ratio of an object's magnetic moment to its angular momentum is a quantity known as the gyromagnetic ratio, usually denoted by γ. Classically, assuming that mass and charge are distributed in the same way, $\gamma = \frac{Q}{2m}$. It is a quantity that get's measured for fundamental particles because deviations from this indicate interesting things about mass and charge. The gyromagentic ratio for the electron is $\frac{\gamma_e}{2\pi} = 28,000$ megahertz per Tesla, where I have divided by two pi to make your calculation simpler to evaluate dimensionally. The actual value is know to something like 17 decimal places but I have cut it off. the theory of Quantum Electrodynamics predicts its value to something like twelve decimal places, making it one of the most successful theoretical predictions in all of Physics. Use the gyromagnetic ratio to determine a value for the radius of the electron. How does this value compare with last week's?