QFT

Chapter 64: The Magnetic Moment of the Electron

Magnetic Moment

- The magnetic moment is a classical quantity that we reinterpret in the light of QFT.
  - Classically, the magnetic moment is what interacts with an external magnetic field. The potential energy of a magnet in an magnetic field is U = - m dot B.
    - For a permenant magnet, this is a function of charge separation, m = q dot
    - For a magnetic induced by a moving current, the general formula is m = .5*q*(r cross v)
  - In terms of QFT, we look at this as the expectation value of the terms in the Hamiltonian that involve the magnetic field. [this is equation 64.7].
    - We can interpret the particle states as sharply-peaked Gaussians, and a creation operator.
    - Then it’s just a matter of solving equation 64.7 for mu; this is done in the text, and again in problem 64.1.

Magnetic Moment, continued

- To measure (theoretically or experimentally) a magnetic moment, you need to apply a magnetic field.
  - In calculations, it is easiest to choose a constant magnetic field in a convenient direction. Srednicki's choice of A = (0, Bx, 0) is convenient for the discussion in the chapter, but may not be convenient in problem 64.1.
- Our result is $\mu = g\frac{1}{2}\frac{e}{2m}$
  - e/2m is the Bohr magneton: if we took a bowling ball with charge +1, its magnetic moment would be the Bohr magneton times its angular momentum
  - The minimum angular momentum is ½. So we might naively expect g = 1.
  - In fact, we derived in the text that g = 2 + alpha/(pi) + ….
- This is a real success of physics:
  - Classical physics would not have any spin magnetic moment at all
  - Quantum physics would be off by a factor of 2, and the correction
  - QFT gets it exactly right – in fact, the experimental/theoretical agreement for this value is the best result in all of science.
    - This is a profound result. Most of our successes so far depend on setting a free parameter properly, so one could argue that we haven't done much yet. This correct calculation for the Lande factor is a huge success for QFT.

Electron Spin Resonance

- It is likely you had to measure g in an undergraduate lab.
  - This lab always confused the hell out of me, so let's try to explain it here.
- We start by firing microwaves from an absorber to a receiver, placing a chemical containing unpaired electrons in the path.
  - Initially the chemical doesn't do anything, so the absorption spectrum is a flat line.
  - The chemical can be something like $K_3[Cr(CN)_6]$
- Next an external magnetic field is applied
  - This breaks the degeneracy between spin up and spin down electrons, as electrons now align themselves with or against the magnetic field (with is lower energy)
- The external field is varied until the difference between the two energy levels exactly matches the frequency of the microwaves.
  - At this point, the microwaves will be absorbed, is that energy is enough to cause a "spin with" electron to become a "spin down" electron. This shows up on the absorption spectrum.
  - This relationship between the magnetic field and the Zeeman Splitting is enough to mathematically measure the magnetic moment, and by extension the Lande factor.