Homework 1

PHYSICS 304
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Questions

1. Because a magnetic moment is defined as

$$\boldsymbol{\mu} = \frac{q}{2m}\mathbf{L}$$

For an electron, the charge $q = -e$. The direction of $\boldsymbol{\mu}$ will always be opposite of $\mathbf{L}$.

2. The Stern-Gerlach experiment uses an inhomogeneous magnetic field to create a non-zero net force on particles. If the magnetic field were uniform, there would be zero *net* force on the electron's orbit—but instead it would only exert a non-zero torque and the particle would not experience any deflection in its trajectory. This is similar to loops of current in magnetic fields.

3. No. If the particle had a non-zero net charge, the particle would experience a Lorentz force, $q\mathbf{v} \times \mathbf{B}$.

Problems

1. The total magnetic moment is given as

$$\boldsymbol{\mu} = \boldsymbol{\mu}_0 + \boldsymbol{\mu}_s = \frac{-e}{2m_e}\left\{\mathbf{L} + g\mathbf{S}\right\}$$

Since we're only concerned with the change in energy from spin, we can omit the orbital momentum as it remains constant in both states. Then, we can take the component (μ_z) in the direction of $\mathbf{B}$.

$$\begin{aligned} \boldsymbol{\mu} &= \frac{-e}{2m_e}g\mathbf{S} \\ \mu_z &= \frac{e}{2m_e}gS_z = \frac{\hbar g e}{2m_e}m_s \end{aligned}$$

The change in magnetic quantum numbers is $\Delta m_s = 1$, with the change in energy between the aligned and unaligned states as

$$\Delta E = \frac{\hbar g e B}{2m_e} \approx \frac{\hbar e B}{m_e}$$

Equating this to the energy of a photon,

$$\begin{aligned} \Delta E \approx \frac{\hbar e B}{m_e} &= \hbar\omega = 2\pi\hbar f \\ f = \frac{eB}{2\pi m_e} &= \frac{\left(1.60 \times 10^{-19}\,\mathrm{C}\right)(0.35\,\mathrm{T})}{2\pi \cdot 9.11 \times 10^{-31}\,\mathrm{kg}} \\ &\approx 9.8\,\mathrm{GHz} \quad \square \end{aligned}$$