Finishing modern physics - week 8
Angular momentum, magnetic moment, Zeeman effect

**BOHR ATOM**

\[ f = ma \]

\[ 2\pi e^2 \left( \frac{1}{r^2} - \frac{1}{4\pi e_0 r^2} \right) \rightarrow \text{Solve for } r \]

Current \( I = \frac{\text{d}q}{\text{d}t} = \frac{e}{\text{period}} \)

Period = \( T = \text{circumference} \)

\[ J = \ldots \]

Area of e⁻ orbit \( A = \pi r^2 \)

Magnetic moment \( \mu = IA = \ldots \)

No.7 Write this using angular momentum \( L = mvr \)

Solve for \( vr \), plug into \( \mu = \ldots \)

Quantization of orbital angular momentum: \( L = n \hbar \) new quantum \# \( \)

Write \( \mu \) in terms of \( m_e \): \( \mu = \ldots = -\frac{m_e}{m_e} \)

Bohr magneton \( \mu_B = \ldots \)
Bohr atom: electron's orbit \rightarrow magnetic dipole

\[ \text{(DRAW B FIELD)} \]

Magnetic dipole experiences TORQUE in a magnetic field \( \mathbf{B} \)

Potential energy \( U = -\mathbf{\mu} \cdot \mathbf{B} \)

Zeran effect: energy levels SPLIT by \( \Delta U = \mu B \)

\[ \frac{30-2}{1005} \]

Orbital angular momentum QUANTUM NUMBER \( l = 0, 1, \ldots, (n-1) \)

magnetic quantum number \( m_l \) indicates DIRECTION of \( \mathbf{l} \)

Orbital angular momentum \( l = \sqrt{l(l+1)} \hbar \)

For \( B_2 \), \( l = m_l \hbar \)

If \( l = 2 \), then \( m_l \) can be 0, \pm 1, or \pm 2.

Do \( \frac{40\pm46}{1027} \)
45. (I) Verify that the Bohr magneton has the value \( \mu_B = 9.27 \times 10^{-24} \text{J/T} \) (see Eq. 40-12).

46. (II) Suppose that the splitting of energy levels shown in Fig. 40-4 was produced by a 2.0-T magnetic field. (a) What is the separation in energy between adjacent \( m_l \) levels for the same \( n \)? (b) How many different wavelengths will there be for 3d to 2p transitions, if \( m_l \) can change only by \( \pm 1 \) or 0? (c) What is the wavelength for each of these transitions?

\[
\begin{align*}
\text{(a)} & \quad \mu_B = -\mu_0 B = -\mu_0 m_e B \\
\text{(b)} & \quad \Delta n = \Delta m_l = \mu_0 B \\
\text{(c)} & \quad n = 2, m_l = 0, \pm 1
\end{align*}
\]

Transitions are allowed from \( \Delta m_l = 0, \pm 1 \)

\[
\begin{align*}
\frac{1}{\lambda_0} &= R \left[ \frac{1}{n^2} - \frac{1}{n'^2} \right] = \\
n &= 2, \quad n' = 3
\end{align*}
\]

\[
\begin{align*}
E &= \frac{\hbar c}{\lambda}, \\
\frac{dE}{d\lambda} &= \hbar c \frac{(\lambda^{-1})'}{\lambda^2} = \\
\Delta E &= \frac{\hbar c}{\lambda} \frac{\Delta \lambda}{\lambda} \\
E_0 &= \frac{\hbar c}{\lambda_0} \\
E_+ &= \frac{\hbar c}{\lambda_0 - \Delta \lambda} \\
E_- &= \frac{\hbar c}{\lambda_0 + \Delta \lambda}
\end{align*}
\]
Heisenberg Uncertainty Principle

Uncertainty in position $\Delta x \approx \frac{\lambda}{2}$ of light used to look at particle.

Photon can change particle's momentum by $\Delta p \approx \frac{h}{\Delta x}$

$$\Delta x \Delta p \approx \frac{\hbar}{2\pi}$$

$$\Delta x \Delta p \geq \hbar \frac{1}{2\pi} \quad \text{Do } \geq \frac{\hbar}{1000}$$

The more precisely we measure position (with light of small $\lambda$), the less precisely we can know momentum.

Time uncertainty $\Delta t \approx \frac{\Delta x}{c} \approx \frac{1}{c}$ (travel time of photon across object)

Photon can change particle's energy by $\Delta E \approx \frac{hc}{\Delta x}$

$$\Delta E \Delta t \approx h$$

$\Delta E \Delta t \geq h \quad \text{Do } \geq \frac{h}{1000}$