Lecture: 20 (iq18)

1. Second order small eps-expansion for a quadrupole charge system
2. B along z due to a circular ring: Dipole moment of a loop. clicker 18-2.
   Added meaning to RHR3.
3. Magnetic dipole moment of an atom
   - Current loop is like a magnet. It is a dipole source which generates $B^{\text{dipole}}$.
   - Measurement of a magnetic dipole of a bar magnet clicker: Direction of $B^{\text{earth}}$
   - Dipole moment of a H-like atom in terms of orbital angular momentum.
   - Quantum unit of atomic dipole moment clicker 19-4
   - Order of magnitude estimate of the macro-magnetic-dipole-moment of a bar magnet.
4. Ampere’s law
   - B due to a line segment – a simple example of the Ampere’s law.
   - Hints to homework problems

Announcement:

- Ch18-h2, 008. The two currents are assumed to have the same magnitude.
- Regular office hours: MWF 9:15 to 10:15.
- Review unit2:
Order expansion for \( V(x) \) of a quadrupole system.

Explanation on ch17-k3:088.

Given: Quadrupole charge system is defined by:

There's \( +Q \) at \( x= \pm d \), \( -2Q \) at \( x=0 \).

Find: \( V(x) \), where \( x \ll d \).

Explanation:

\[
V(x) = \frac{kQ}{x} \left[ \frac{1}{x+d} - 2 + \frac{1}{x-d} \right]
\]

\[
= \frac{kQ}{x} \left[ \frac{1}{x-e} - 2 + \frac{1}{1-e} \right] = \frac{kQ}{x} f(e)
\]

Notice to first order in \( e \)

\[ f(e) = (1-e) - 2 + (1+e) = 0. \]

Need to work to the order of \( e^2 \).

We work out expression:

\[
\frac{1}{1+e+e^2} \quad (1)
\]

\[
\left[ \text{Proof:} \right] \quad 1 = (1-e)(1+e+e^2) = (1+e+e^2) - (e+e^3+e^4)
\]

\[
-1 = e^3 \Rightarrow (1) \text{ is satisfied up to } e^3 \text{ term}
\]

Using (1), \( f(e) = \left[ \frac{1}{x/e} - \frac{1}{1-e} \right] = 1+(e-1)^2 = 2 + (1+e+e^2)
\]

\[
\Rightarrow e^2 = \frac{1}{2} \frac{1}{x^2}
\]

\[
V(x) = \frac{kQ}{x} \cdot \frac{2e^2}{x^2}
\]
2. \[ AB = \frac{(40) \text{ cm}}{2} \times \text{Wind} \]

\[ R = \frac{40 \times I_2 R \times R}{L^2} \]

\[ B_x = \frac{I_2 R \times R}{L^2} \times \left( \frac{40}{L^2} \right) \times \frac{10^2}{L^2} = \left( \frac{40}{L^2} \right) \times \frac{10^2}{L^2} \]

180°  \[ \text{Loop} = IA \]

3. **Mae's Micro Correspondance**

\[ \text{atomic dipole moment} \]

\[ \text{magnet} = (\frac{2}{3}) \times \mu \text{ magnet}, \mu \text{ magnet} = N \mu \text{ atom} \]

**Exp.**

1. **Check Final direction of **B**arth**

For the setup, show which the direction of \(\text{B**arth**}\)

**Choices:**

1) Up  \[ \text{Barst} \]  \[ \text{A** aborted** choice) up} \]

2) Right  \[ \text{Barst} \]  \[ \text{Also choice), up} \]

3) Down  \[ \text{Barst} \]  \[ \text{Barst} \]

4) Left  \[ \text{Barst} \]  \[ \text{Barst} \]
M_{\text{atom}} = IA = \frac{e}{J} \pi R^2 \quad T = \frac{2eR}{v}
\begin{align*}
\sqrt{M_{\text{atom}}} &= \frac{e}{2v} \pi R \\
\text{Angular mom.} \quad L &= m \pi R
\end{align*}

\text{Orbital: } M_{\text{atom}} = \frac{e^2}{\pi^2} \frac{L}{m} \quad \frac{e}{\pi m v}

\text{Ground state of } H-\text{like atom: } \pi \left( \text{best value of } L \right)

\text{Ampere's Law: }

\text{Long wire: }

\begin{align*}
\mathbf{B} &= \frac{\mu_0 I}{2\pi r} \\
\mathbf{B}_{2\pi r} &= \mu_0 I \\
\text{Ampère's loop: } \oint B \cdot dl &= \mu_0 I_L \quad \text{-- single example} \quad \text{of Ampère's Law}
Given: Total current $I_0$ flows thru a long conductor with a slit (See sketch)

Geometry:

\[ A_{\text{yl}} = \pi R^2 = A_1 \]
\[ A_{\text{hole}} = \pi (\frac{R}{2})^2 = A_0 \]

Area of conducting medium = $A_{\text{yl}} - A_{\text{hole}} = \frac{3A_1}{4} = A_D$

Assume $I_0$ flows out of the page, current density is constant

\[ J = \frac{I_0}{A_D} \]

Magnitude, $I_{\text{yl}} = JA_1$, $I_{\text{hole}} = JA_0$

\[ I_{\text{yl}} = \frac{I_0}{A_0} A_1 = \frac{4}{3} I_0 \quad \text{(out)} \]

\[ I_{\text{hole}} = \frac{I_0}{A_0} A_0 = \frac{1}{3} I_0 \quad \text{(into)} \]

Find: $B$ at $P$

$B = B_{\text{yl}} - B_{\text{hole}}$ (up, RHR)

$B_{\text{yl}} = \frac{\mu_0 I_{\text{yl}}}{2\pi R}$

$B_{\text{hole}} = \frac{\mu_0 I_{\text{hole}}}{2\pi (R - \frac{R}{2})}$