Lecture: 18 (iq16)

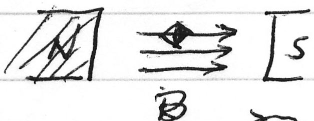
Announcement:

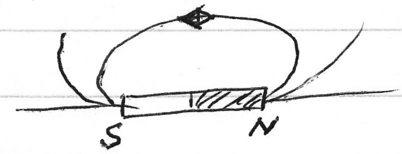
1. Two problems in h3.
   - Comment on **Ch17-h3, 005**
   - A modified problem based on Ch17, **h3, 010-011**.
2. Magnetic field pattern and compass needle.
   - Biot Savart's law- Micro. The qv source of B, B^{qv}. Cross product: **Clicker 1-3**
   - RHR1 follows from Biot-Savart law
   - Biot Savart's law- Macro. The $I\Delta L$ source of B, B^{I}
   - Measurement of B^{I} from a long wire. **Clicker 17-1**.
3. B at O of a circular arc **Clicker 17-3**
4. B due to a long wire segment:Integration.
   - Symmetric case (textbook example)
   - Long wire approximation
   - Semi-longwire clicker
5. The three RHRs **Clicker 17-4**

Announcement:

1. My office hour: 9:15 to 10:15.
2. You may set up an appointment including other hours to meet with me to discuss your midterm1 performance. (Bring your redo midterm1 work when you come.)

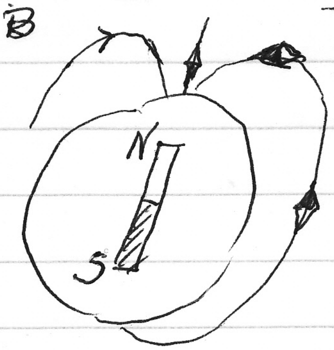
1. Magnetic field pattern + compass needle



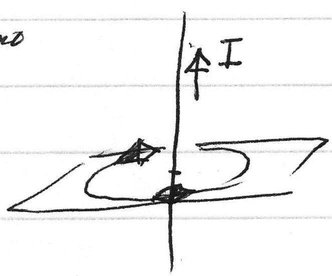


Bar magnet

Earth:



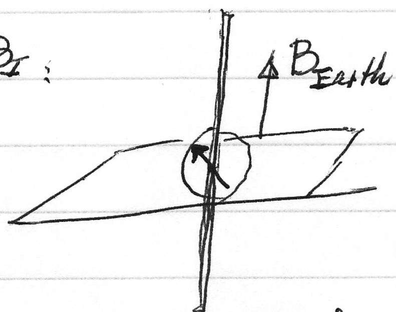
Demo

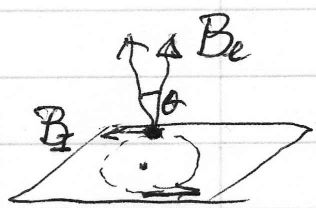


RHR_1

Measurement of B_I:

Place compass behind the wire

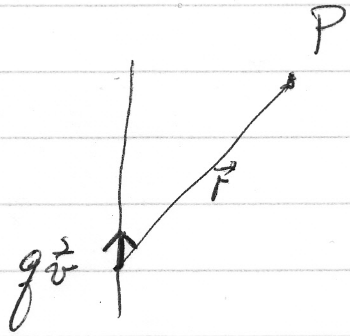


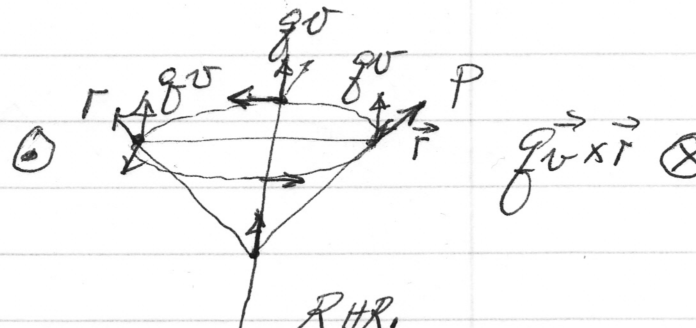


$$\tan\theta = \frac{B_I}{B_{Earth}}$$

Clicker 17-1 By inspection

Point Source	field
q	$\vec{E} = \frac{kq}{r^2}\hat{r}$
Biot-Savart Law $\Rightarrow$ $q\vec{v}$	$\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{q\vec{v}\times\hat{r}}{r^2}$
qa	Radiation field - $\vec{E}_{rad}$, $\vec{B}_{rad}$

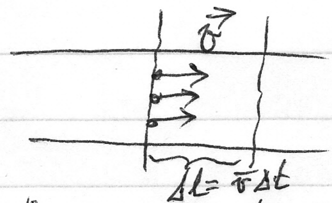




RHR,

Consequence of Biot-Savart

Biot-Savart Law — Source $I\Delta l$ $\quad \Delta\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{I\Delta\vec{l}\times\hat{r}}{r^2}$



Drift velocity

over time interval Δt

Current: $\Delta N q\vec{v} = \Delta N q \frac{\Delta l}{\Delta t} = \left(\frac{\Delta N q}{\Delta t}\right)\Delta l = I\Delta l$

$\frac{\mu_0}{4\pi} = 1\times 10^{-7}$ SI units

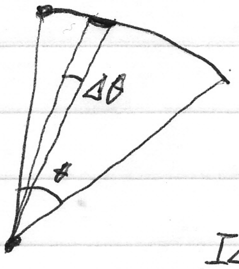
Comp with E : $k = \frac{1}{4\pi\epsilon_0}$

B : $\left(\frac{\mu_0}{4\pi}\right)$

$\frac{\text{Tesla } m^2}{\text{Amp } m} = \frac{T m}{A}$.

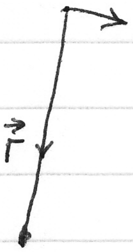
Circular arc: Given: I, R, θ

Find: B at O



$$\Delta\vec{B} = \left(\frac{\mu_0}{4\pi}\right) \frac{I\Delta\vec{l} \times \hat{r}}{r^2}$$

Clicker 17-3



Dir: $I\Delta\vec{l} \times \hat{r}$ $\otimes$

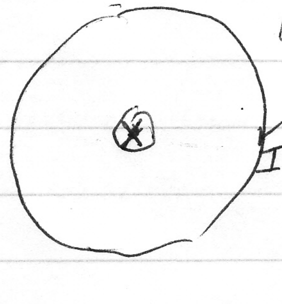
$I\Delta l \, \hat{n} \sin 90^\circ$

$= I\Delta l$ $\otimes$

$$\Delta B = \frac{\mu_0}{4\pi} \cdot \frac{I\Delta l}{r^2}$$

$$B_\theta = \int_0^\theta \Delta B = \frac{\mu_0}{4\pi} \frac{I r \Delta\theta}{r^2} \Big|_0^\theta = \frac{\mu_0}{4\pi} \frac{I\theta}{r}$$

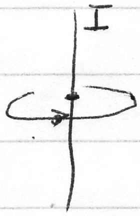
Loop $\theta = 2\pi$ $\quad B_{loop} = \frac{\mu_0 I}{2r}$



RHR$_3$

Clicker 17-4

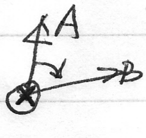
RHR$_1$



B_p^I

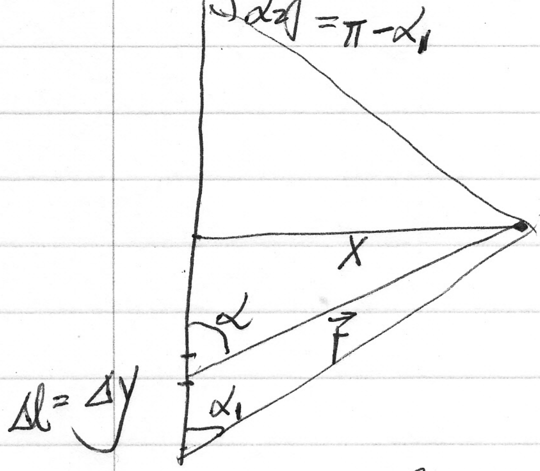
RHR$_2$ $\quad \Delta B = \frac{\mu_0}{4\pi} \frac{I\Delta l \times \hat{r}}{r^2}$

$\vec{r} \times \Delta l$ $\otimes$



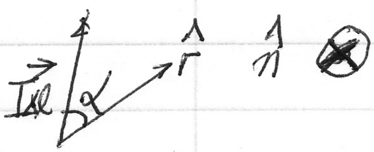
Cross Product Rule

Long wire:



$$\Delta \vec{B} = \frac{\mu_0}{4\pi} \frac{I \Delta \vec{l} \times \hat{r}}{r^2}$$

$$I \Delta \vec{l} \times \hat{r} = I \Delta l \sin \alpha$$



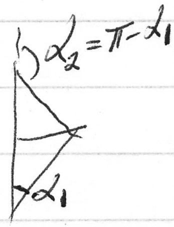
$$\Delta B = \left(\frac{\mu_0}{4\pi}\right) \frac{I \Delta y}{r^2} \sin \alpha$$

Recall Math I.D.: $\frac{\Delta y}{r^2} = \frac{\Delta \alpha}{x}$

$$\therefore B = \int \Delta B = \left(\frac{\mu_0}{4\pi}\right) I \int_{\alpha_1}^{\alpha_2} \frac{\Delta \alpha}{x} \sin \alpha$$

$$= \frac{\mu_0 I}{4\pi x} \left(-\cos \alpha\right)\Big|_{\alpha_1}^{\alpha_2}$$

$$= \frac{\mu_0 I}{4\pi x} \left(\cos \alpha_1 - \cos \alpha_2\right)$$



$\xrightarrow{\text{Symmetric}}$ $\frac{\mu_0 I}{4\pi x} \cdot 2 \cos \alpha_1 = \frac{\mu_0 I}{4\pi x} \cdot \frac{L}{\sqrt{x^2 + \left(\frac{L}{2}\right)^2}}$

$$\cos \alpha_1 = \frac{\frac{L}{2}}{\sqrt{x^2 + \left(\frac{L}{2}\right)^2}}$$

$\xrightarrow{\text{Small } x}$ $\frac{\mu_0 I}{2\pi x}$

Clicker: 18-1

Long wire: $x \ll \frac{L}{2}$ $\quad B = \frac{\mu_0 I}{2\pi x}$

Semi long wire: $B = \frac{\mu_0 I}{4\pi x} \cos \alpha_1 \leftarrow \frac{\frac{L}{2}}{\sqrt{x^2 + \left(\frac{L}{2}\right)^2}}$

$$= \frac{\mu_0 I}{4\pi x}.$$