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**Lecture: 19 (iq17)**

1. B at O of a circular arc **Clicker 17-3**
2. B due to a long wire segment:Integration. **Clicker 17-3**
   - Symmetric case (textbook example)
   - Long wire approximation
   - Semi-longwire clicker
3. The three RHRs **Clicker 17-4**
4. Comments on Ch18-h2 003-004. Line segments + a circular arc.
   a. Superposition principle.
   b. The part of B at P contributed by a semi-long wire
5. B along z due to a circular ring: Magnetic dipole moment of a loop. **clicker 18-2**.
   Added meaning to RHR3 -- current loop is equivalent to a magnetic dipole.

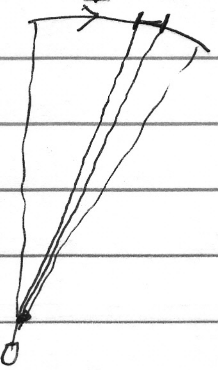
**Announcement:**

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.)

ig 17

1. Magnetic field at O due to a circular arc of $R, \theta$

$I$ $\Delta l = r\Delta\theta$ Find: $\vec{B}$ at O



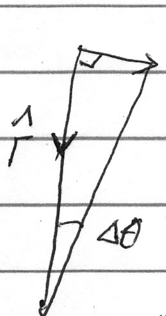
$$\Delta\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{I\Delta\vec{l}\times\hat{r}}{r^2}$$

mag: $\Delta B = \frac{\mu_0}{4\pi}\frac{I\Delta l}{r^2}\sin\alpha$

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

Clicker 17-3

Dir:

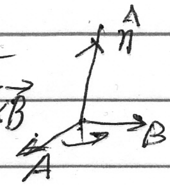


$\Delta l = r\Delta\theta$

$\hat{n}$: into $\otimes$

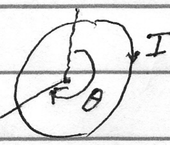
Cross product:

RHR2: $\vec{C} = \vec{A}\times\vec{B}$



$$\Delta B = \frac{\mu_0}{4\pi}\frac{I\overset{r\Delta\theta}{\Delta l}}{r^2}\sin\overset{90^0}{\alpha} = \frac{\mu_0}{4\pi}\cdot\frac{I\cancel{r}\Delta\theta}{r\cancel{r}} = \frac{\mu_0}{4\pi}\cdot\frac{I\Delta\theta}{r}$$

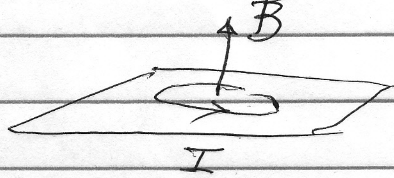
Integration: $B = \frac{\mu_0 I}{4\pi r}\int_0^\theta d\theta = \frac{\mu_0 I}{4\pi r}\theta$

Example:  Loop: $r$, $\theta = 2\pi$

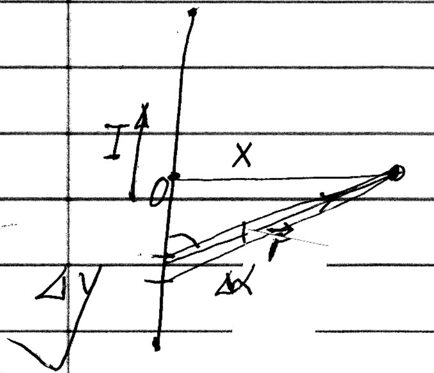
$$B_0^{loop} = \frac{(\mu_0 I)(2\pi)}{4\pi r} = \frac{\mu_0 I}{2r}.$$

Dir: $\otimes$

RHR3: $\vec{B}$ at O.



A long wire: Find $\vec{B}$ at P.




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

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

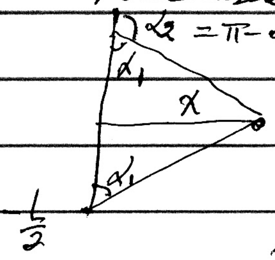
Mag: $\Delta B_{P} = \Delta B = \frac{\mu_0}{4\pi} \frac{I\Delta y}{r^2} \sin\alpha$ (dueto $I\Delta y$)

Recall a math idenity: $\frac{\Delta y}{r^2} = \frac{\Delta\alpha}{x}$

$$B = \frac{\mu_0 I}{4\pi} \int_{\alpha_1}^{\alpha_2} \frac{d\alpha}{x} \sin\alpha$$

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

Three cases: 1) Text book - symmetric rod $y = -\frac{L}{2}$ to $+\frac{L}{2}$




$$\cos\alpha_1 - \cos\alpha_2 = 2\cos\alpha_1 = \frac{2 \times \frac{L}{2}}{\sqrt{x^2 + \left(\frac{L}{2}\right)^2}}.$$

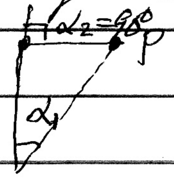
(See p721 last equation)

$$B = \frac{\mu_0 I}{4\pi x} \cdot \frac{L}{\sqrt{x^2 + (L/2)^2}}$$

2) Longwire case. $x \ll \frac{L}{2}$, $B \approx \frac{\mu_0 I}{4\pi x} \cdot \frac{L}{\left(\frac{L}{2}\right)} = \frac{\mu_0 I}{2\pi x}$.

check w 18-1

3) Semilong case: $\cos\alpha_1 - \cos\alpha_2 \longrightarrow \cos 0^\circ - \cos 90^\circ = 1$




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

3 RHRs -

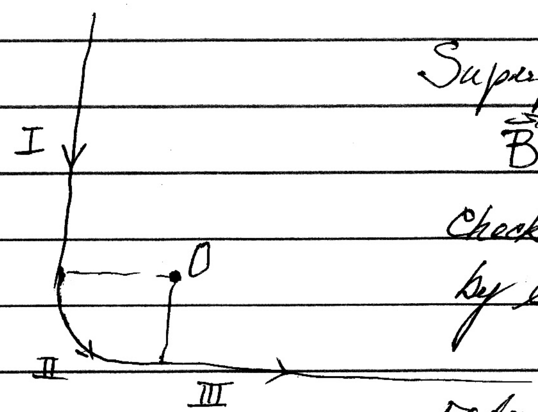
Dir of $\vec{B}$ due to a long wire

Dir of $d\vec{B}$ in $I d\vec{l} \times \hat{r}$

Dir of $B$ in a current loop

~~Clicker 17-4~~

4. Comment on h2-003-004

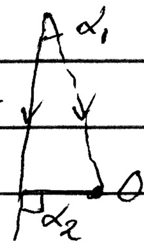



Superposition P. -

$$\vec{B}_o = \vec{B}_o^{\,I} + \vec{B}_o^{\,II} + \vec{B}_o^{\,III}$$

Check direction of $\vec{B}$ contributed by each segment is in the same direction so vector sum is reduced to simple addition.

Segment I : I



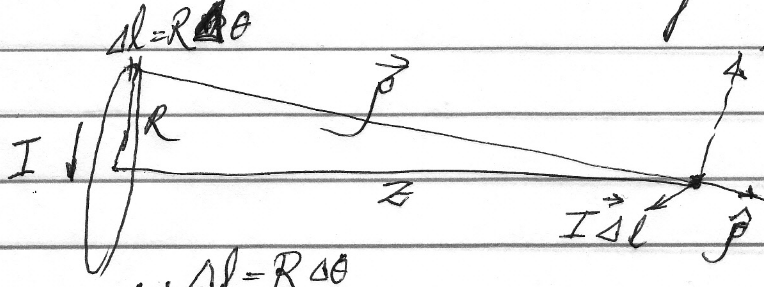

$\alpha_1 \approx 0$

$\alpha_2 = 90^\circ$

$[\cos\alpha_1 - \cos\alpha_2] = 1$

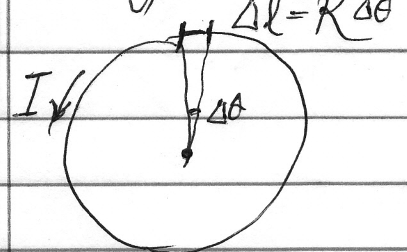
So: I is a semi-long segment.

5. B along z due to a circular ring. I, R



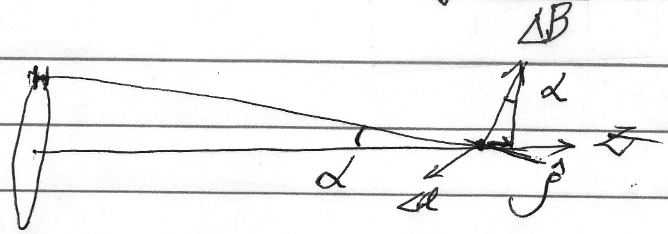

$$\Delta B = \frac{\mu_0}{4\pi}\frac{I\overset{R\Delta\theta}{\Delta l}}{\rho^2}\sin\alpha$$

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



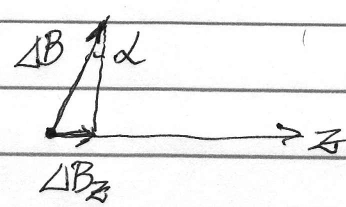

Dir: $\vec{I\Delta l}\times\hat{\rho}$

$$B_z = \int \Delta B_z = \frac{\mu_0}{4\pi}\frac{I\cdot 2\pi R}{\rho^2}\cdot\frac{R}{\rho}$$




$\Delta B_z = \Delta B \sin\alpha$

$\sin\alpha = \frac{R}{\rho}$




For $\rho >> R$, $\rho \sim z$

$$B \approx \frac{\mu_0}{4\pi}\cdot\frac{I\,2\pi R^2}{z^3}$$

$$= \left(\frac{\mu_0}{4\pi}\right)\frac{2\mu_{loop}}{z^3}$$

$\mu_{loop} = I\pi R^2 = IA_{loop}$, dir of $\mu_{loop}$ given by RHR.