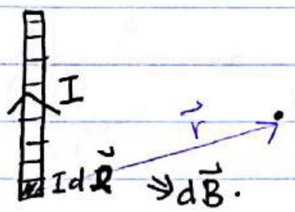
11/17/15

What happens when we don't have a nice symmetrical surface? We use the equivalent of Coulomb's Law!



$\vec{B}_{tot} = \int d\vec{B}$.

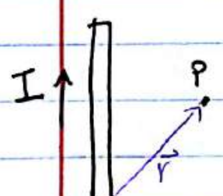
- there are no magnetic monopoles! we need to find an expression for $d\vec{B}$.

Biot-Savart law

Recall Coulomb's law:

$d\vec{E} \propto \frac{dq}{r^2}$, E_{TOT} (for a wire) $= \frac{\lambda}{2\pi\varepsilon_0 r}$ ← chg. density per unit length

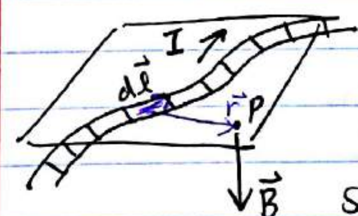
Analogy:



$\vec{B}_{TOT} = \frac{\mu_0 I}{2\pi r}$, $\vec{B}_{TOT} \sim \frac{I}{r}$, $\vec{B}_{TOT} = \int d\vec{B}$

by analogy ($d\vec{E}$) $d\vec{B}$ has a I/r^2 relationship.

However, I has a direction.



$\vec{B} \perp d\vec{l}, \hat{r} \Rightarrow B \propto (d\vec{l} \times \hat{r})$ ← unit vector

($\vec{B}$ depends on $d\vec{l}, \vec{r}$)

So,

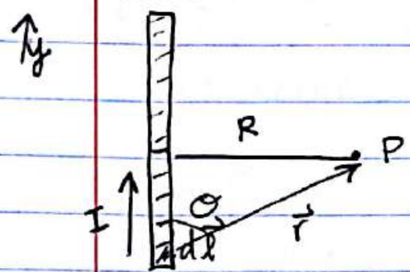
$$\boxed{d\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{r^2}(d\vec{l} \times \hat{r})}$$ (Biot-Savart Law)

*comment:

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$ — ↑ TOTAL FIELD ON P (NOT ONLY DUE TO CURRENT ENCLOSED BY PATH)

$d\vec{B} = \frac{\mu_0 I}{4\pi r^2}(d\vec{l} \times \hat{r})$ — ↑ FIELD ASSOCIATED W/ $Id\vec{l}$.

$\vec{B}$ in a wire



$$d\vec{B} = \frac{\mu_0 I}{4\pi r^2}\left(d\vec{l}\times\hat{r}\right) \qquad dl\times\hat{r} = d\vec{l}\sin\theta$$

$$B_T = \int_{-\infty}^{+\infty} d\vec{B}_z = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{+\infty}\frac{dl\sin\theta}{r^2}$$

$$\cancel{B_T\int} \qquad \cancel{B_T = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{+\infty}}$$

$y = -r\cos\theta = dl$

$R = r\sin\theta.$

$$\frac{y}{R} = \frac{-\cos\theta}{\sin\theta}, \quad y = \frac{-R\cos\theta}{\sin\theta}$$

$$dy = -R\frac{d}{d\theta}\left(\frac{\cos\theta}{\sin\theta}\right). = R\left(\frac{\sin^2\theta+\cos^2\theta}{\sin^2\theta}\right)d\theta = \frac{R}{\sin^2\theta}d\theta.$$

$\Downarrow$

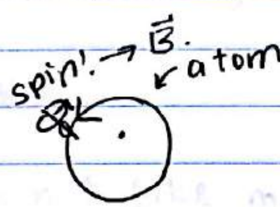
$$\underline{r = \frac{R}{\sin\theta}} \Rightarrow B_T = \frac{\mu_0 I}{4\pi}\int_{0}^{+\pi} \cancel{\frac{\sin^2\theta\, d\theta}{R}} \; \frac{\sin d\theta}{R}$$

$$= \frac{\mu_0 I}{4\pi R}\int_{0}^{+\pi}\sin\theta\, d\theta$$

$$= \boxed{\frac{\mu_0 I}{2\pi R}} \checkmark$$

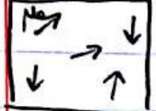
Dielectrics

q moving $\to \vec{B}$.



Materials

1) Paramagnetic 2) Ferromagnetic 3) DIAMAGNET

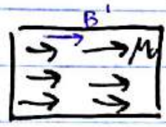


$\vec{\mu}_0$ = magnetic dipole moment of atom
$\vec{\mu}$ = net magnetic dipole moment

In this configuration, $\vec{\mu} = 0$.

Turn $\vec{B}_0$ on.

$\longrightarrow B_0$

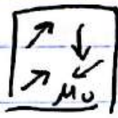


$\vec{\mu} = \sum_i \mu_0 \neq 0.$

$\vec{B}_{net} = \vec{B}_0 + \vec{B}'.$ $\qquad \vec{B}' = \mu_0 \vec{M}$ ← magnetization of material

Materials that respond this way to a field are paramagnetic.

Turn $\vec{B}_0$ off.

1) 

$\vec{\mu} = 0$. Paramagnet. weak interaction between μ_0.

2) 

B' (NOTHING CHANGED). Ferromagnet.
strong interaction between μ_0.

CURIE TEMPERATURE T_c

$T < T_c$, ~~paramagnet~~ ferromagnet.

$T > T_c$, paramagnet.

DIAMAGNET - does not like magnetic field. (make θ with field).