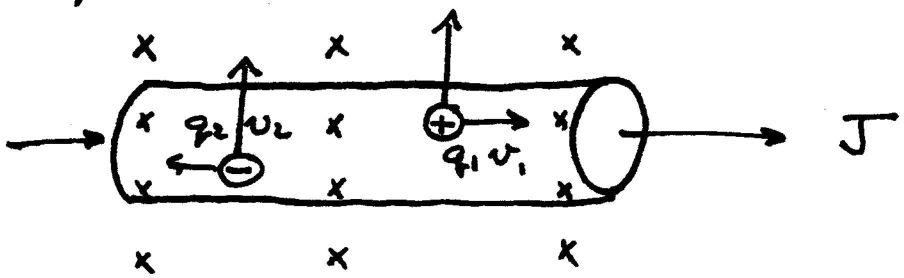
MAGNETIC FORCES ON CURRENT

Consider a conductor carrying current I, with cross sectional area A in $\vec{B}$ field



If there are n_1 positive charge carriers per unit V w/ drift velocity v_1

n_2 negative w/ v_2

Each charge feels force

$$F = q v B$$

a length of wire l will feel a force

$$F = \#\text{ pos carriers} \times q_1 v_1 B + \#\text{ neg carriers} \times q_2 v_2 B$$

$$= (n_1 A l)(q_1 v_1 B) + (n_2 A l) q_2 v_2 B$$

$$= (n_1 q_1 v_1 + n_2 q_2 v_2) A l B$$

$J = \Sigma n q v$ (remember?)

$F = J A l B$

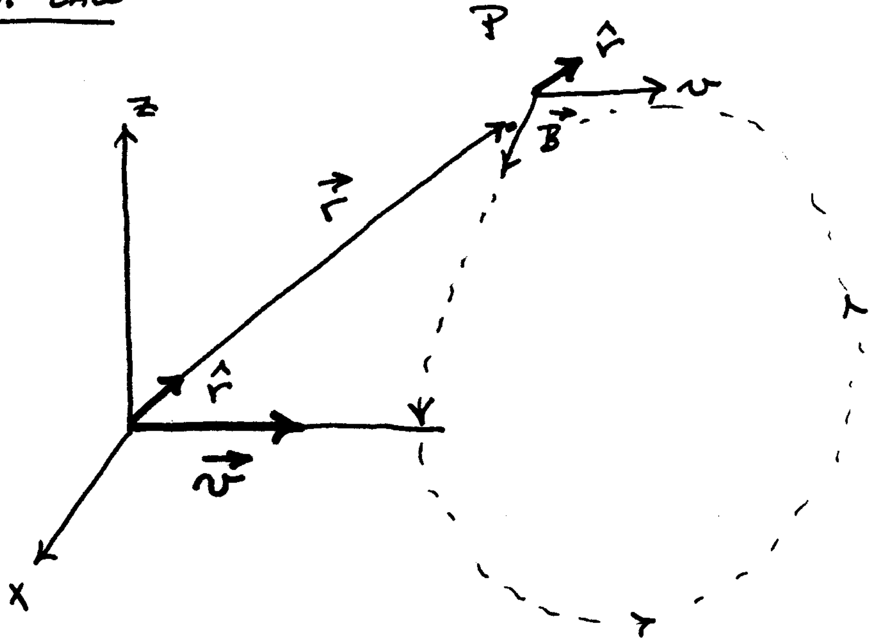
$I = JA$ (remember that too?)

$$\boxed{F = I l B}$$

MAGNETIC FIELDS FROM MOVING CHARGES

Moving charges respond to $\vec{B}$-field; what produces $\vec{B}$-field - MOVING CHARGES

BIOT LAW



$$\hat{r} = \frac{\vec{r}}{|r|}$$

is the unit vector in $\vec{r}$ direction

$$|\hat{r}| = 1$$

$$B = \frac{\mu_0}{4\pi} q \frac{\vec{v} \times \hat{r}}{r^2}$$

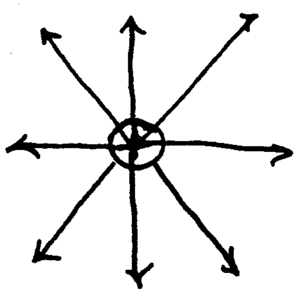
μ_0 = magnetic permeability

$= 4\pi \times 10^{-7}$ $N s^2 C^{-2}$

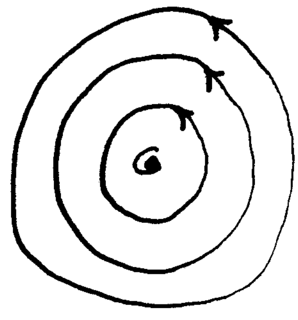
$$\mu_0 = \frac{1}{\varepsilon_0 c^2}$$

hmmm...

$\vec{E}$ field



$\vec{B}$



This can be generalized for current

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{I\, dl \times \hat{r}}{r^2}$$

remember $I = n q v A$. This can be integrated to find the magnetic field of a long straight wire:

$$\boxed{B = \frac{\mu_0}{2\pi} \frac{I}{r}}$$

Compare this to $\vec{E}$ from a long charged conductor

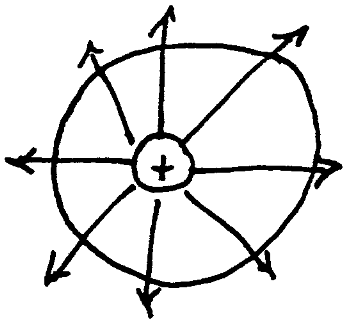
$$E = 2k \frac{\lambda}{r} = \frac{1}{2\pi \varepsilon_0} \frac{\lambda}{r}$$

Magnetic field lines are concentric circles around the wire

Wire carrying 1A current

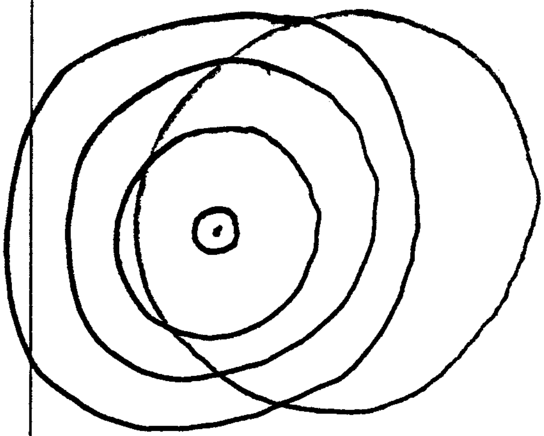
$$B = \frac{\mu_0}{2\pi} \frac{I}{r} = \frac{4\pi \times 10^{-7}}{2\pi} \cdot \frac{1A}{r}$$

$$= \frac{2 \times 10^{-7}\ T}{r}$$



$\vec{E} \Rightarrow$ Gauss's Law

$$\oint E_\perp \, dA = \frac{q}{\varepsilon_0}$$

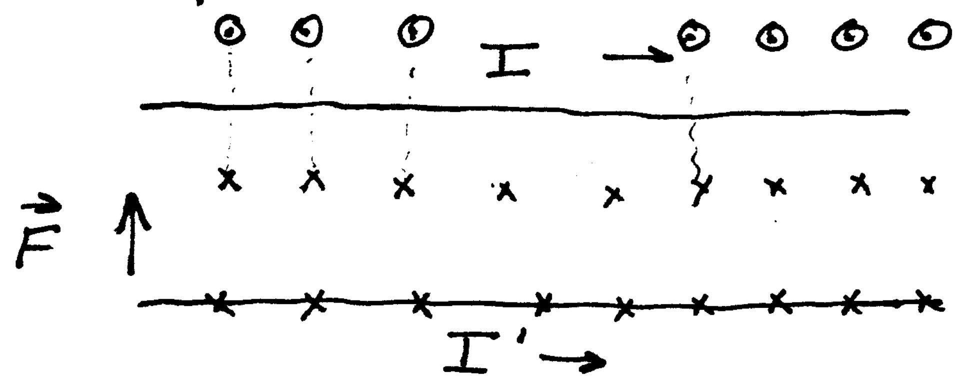


Since all $\vec{B}$ any closed surface will have # of lines entering surface = # lines exiting surface

# of lines crossing surface is proportional to flux Φ across surface. In $\vec{B}$ field flux across closed surface = 0

$$\oint B_\perp \, dA = \oint \vec{B} \cdot d\vec{A} = 0$$

Force from parallel conductors



$$B = 2k' \frac{I}{r}$$

$$F = I' \ell B = 2k' \ell \frac{I I'}{r}$$

Force per unit length

$$\boxed{\frac{F}{l} = 2k' \frac{I I'}{r}} = \frac{\mu_0 I I'}{2\pi r}$$

Same direction $\Rightarrow$ attraction
opposite direction $\Rightarrow$ repulsion

<u>Ampere</u> = I + infinite parallel conductors separated by 1m produce $F = 2 \times 10^{-7}\ N m^{-1}$

This assumes that $k' \equiv 10^{-7} N s^2 c^{-2}$

<u>Coulomb</u>

$$q = I t$$

$$1C = 1A \cdot 1s$$

Circular Magnetic Field Surrounding a Wire