Physics 142 - October 25, 2007

Hello from Fermilab

http://www.fnal.gov

Last Time –

Lorentz Force Law

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Note the cross product here makes life 3d and hard to visualize – Please review the cross product if you have not done so already

For current in a wire

$$\vec{F} = i\vec{L} \times \vec{B} \quad \text{or} \quad L\vec{i} \times \vec{B}$$

Please check out Magnetic Field java applet on the class Web site!

Electrostatics

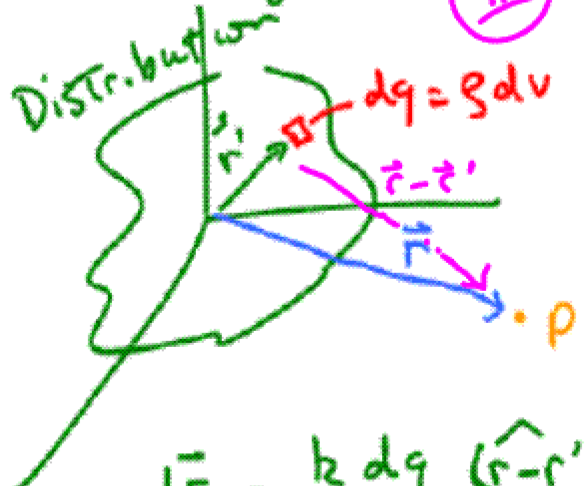
Coulomb's Law

(I)

$$\vec{E} = \frac{kQ\,\hat{r}}{r^2}$$

$$\vec{F} = q\vec{E}$$

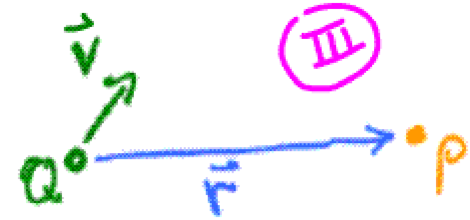
(II)



$$d\vec{E}_P = \frac{k\,dq}{(r-r')^2}\,(\widehat{r-r'})$$

Magnetostatics

Law of Biot-Savart



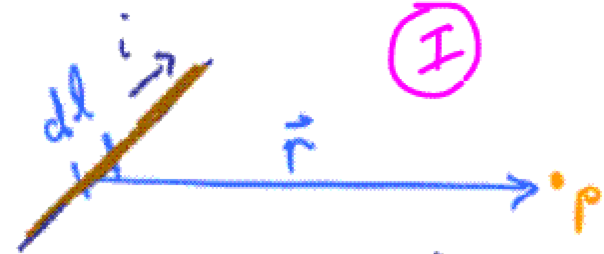
(III)

$$\vec{B}_{\substack{\text{at } P \\ \text{due to } Q}} = \frac{\mu_0}{4\pi}\,\frac{Q\vec{v}\times\hat{r}}{r^2}$$

$\mu_0 \equiv$ const. $\equiv$ Permeability of free space

$\hookrightarrow = 4\pi \times 10^{-7}\ \frac{T\cdot m}{A}$

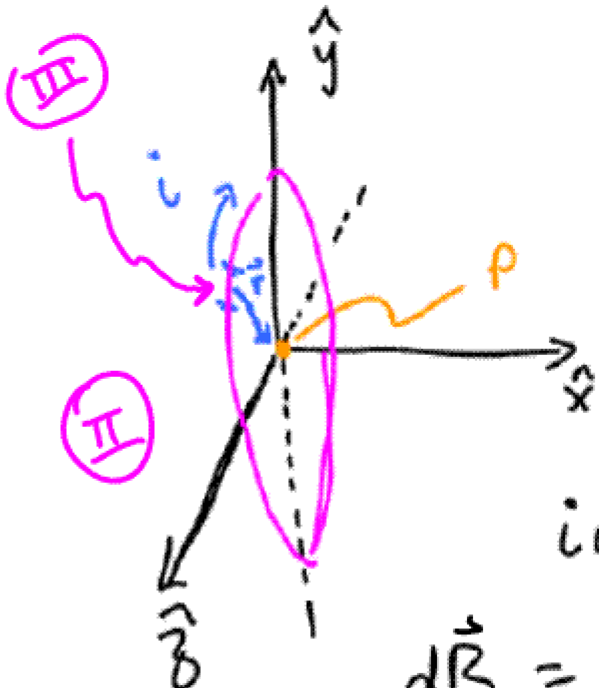
Distribution currents (not charges)



$$d\vec{B}(p) = \frac{\mu_0}{4\pi}\frac{i\,d\vec{l}\times\hat{r}}{r^2}$$

due to dl of current

differential form of Biot-Savart



Find $\vec{B}$ at origin

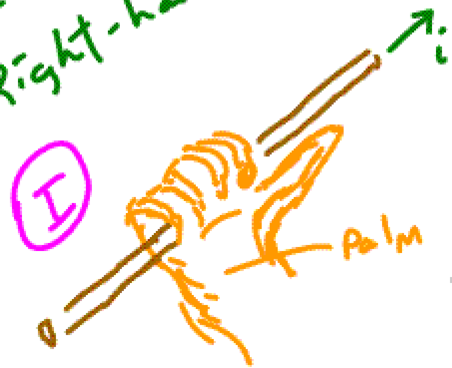
$$i\,d\vec{l}\times\hat{r} = i\,dl(-\hat{x})$$

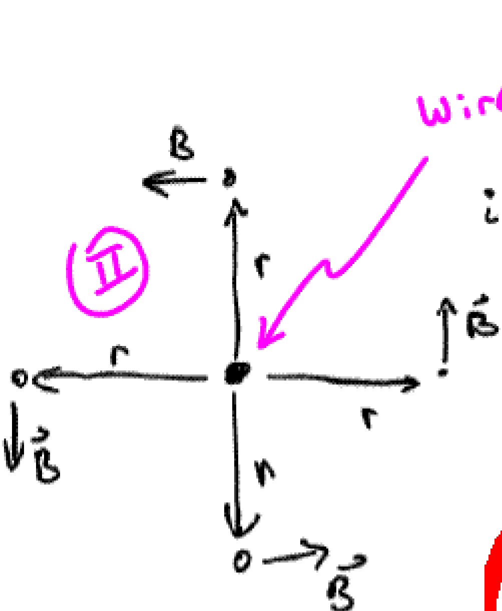
$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,dl}{r^2}(-\hat{x}) \qquad dl \simeq ds$$

IV

$$\vec{B} = \frac{\mu_0}{4\pi}\int_0^{2\pi r}\frac{i\,ds}{r^2}(-\hat{x}) = \frac{\mu_0}{4\pi}\frac{i}{r^2}2\pi r = \frac{\mu_0 i}{2r}(-\hat{x})$$

Yet Another Right-hand rule



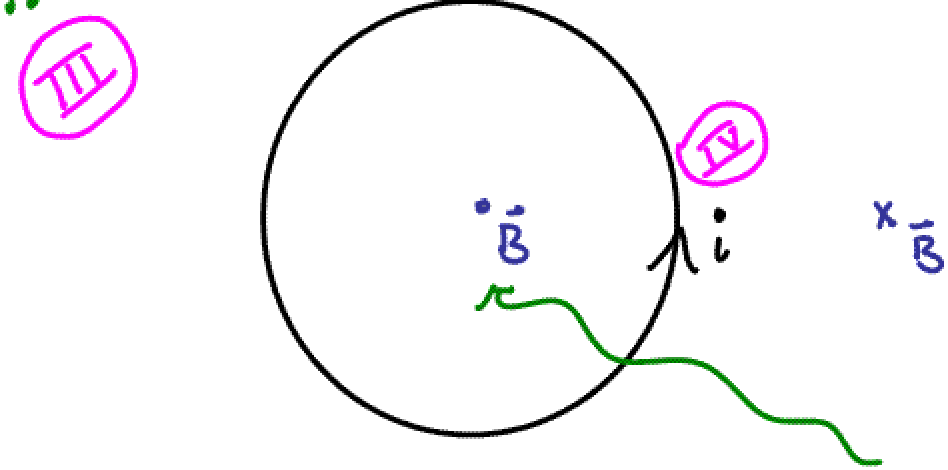


Field around current-carrying wire

See "magnetostatics" Java applet link on class website

... And Another

current loop



Curl fingers around loop of wire in plane of loop in direction of current

Thumb in direction of $\vec{B}$ in loop

Electrostatics

Gauss' Law

$$\int_{surf.} \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$

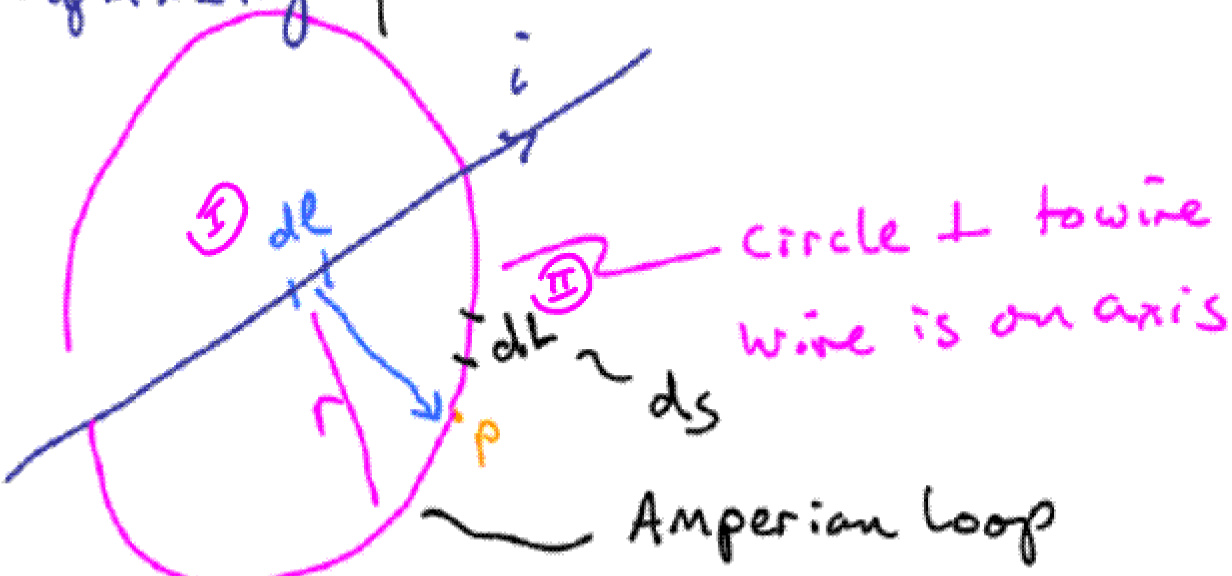
good for situations w/ particular symmetry

Magnetostatics

Ampere's law

$$\int_{\text{closed curve}} \vec{B}\cdot d\vec{s} = \mu_0 I_{enclosed}$$

sometimes $\vec{B}\cdot d\vec{l}$



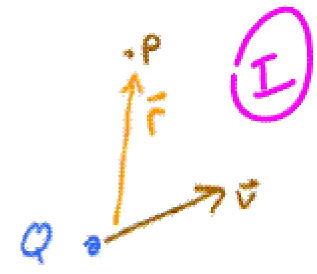
$$\oint_{\text{closed loop}} \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$$

$$|\vec{B}|\int_0^{2\pi r} ds = |\vec{B}|2\pi r = \mu_0 i$$

$$|\vec{B}| = \frac{\mu_0 i}{2\pi r} \quad \text{(I)}$$

Very useful to know/derive at will

... Sort of like "electric field of pt charge" in terms of utility



Biot-Savart

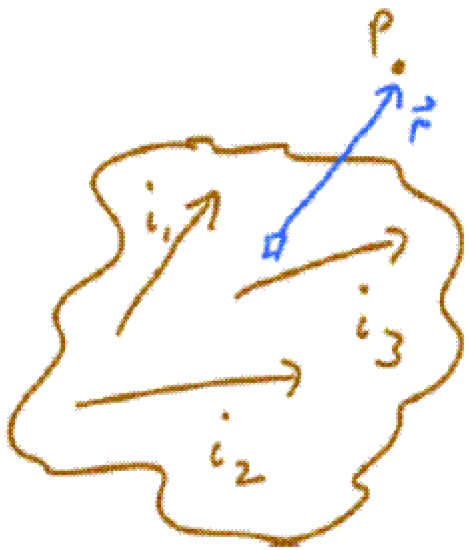
$$\vec{B} = \frac{\mu_0}{4\pi} \frac{Q\vec{v}\times\hat{r}}{r^2}$$

single charge moving

Important

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\,d\vec{l}\times\hat{r}}{r^2}$$

distribution of currents



Ampere's Law:

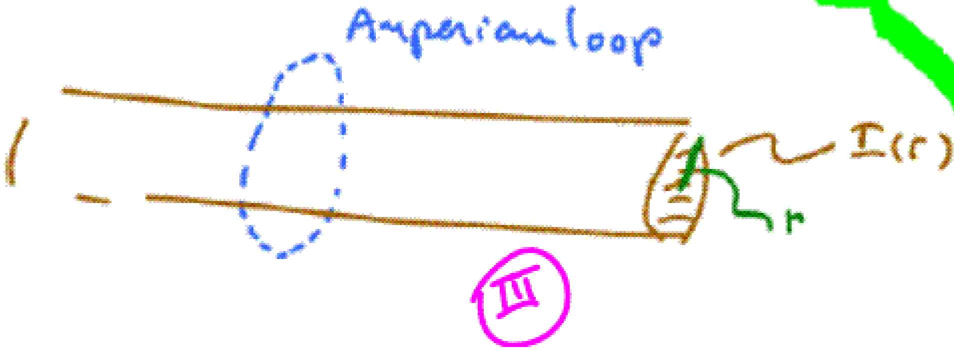
Important

$$\int_{\text{closed loop}} \vec{B}\cdot d\vec{\ell} = \mu_0 I_{enclosed}$$

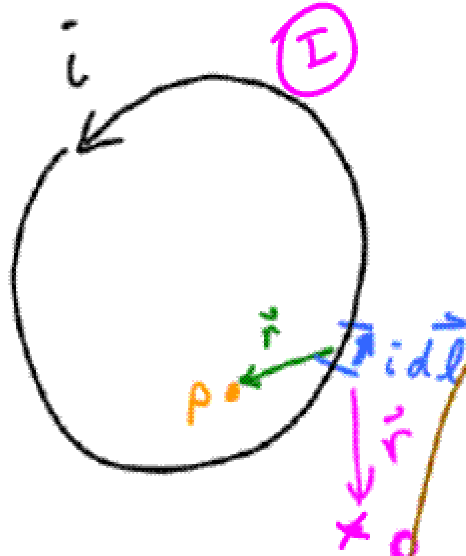
sometimes see (I) $\oint \vec{B}\cdot d\vec{\ell} = \mu_0 I_{encl}$

II $\int_c \vec{B}\cdot d\vec{\ell}$

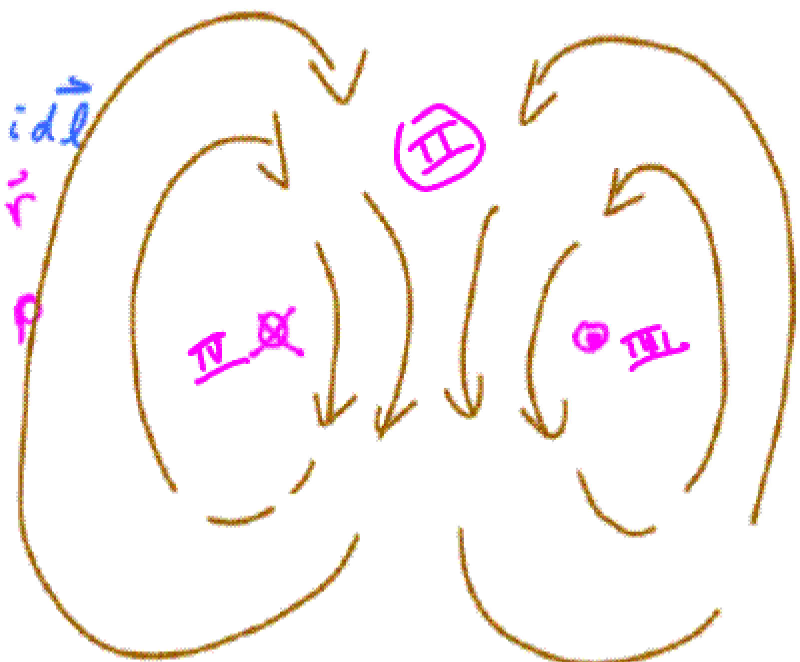
choose loop so $\vec{B}\cdot d\vec{\ell}$ simple
$|\vec{B}| = \text{constant}$



$\vec{B}$ Field of current loop

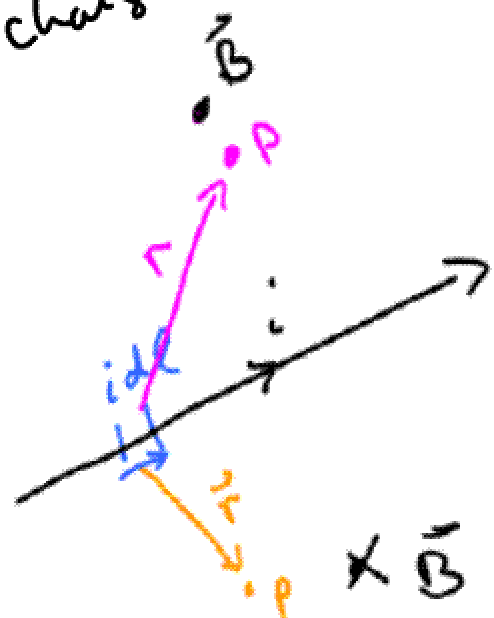


$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\vec{dl} \times \hat{r}}{r^2}$$



magnetic dipole

Closest Thing to Magnetic point charge



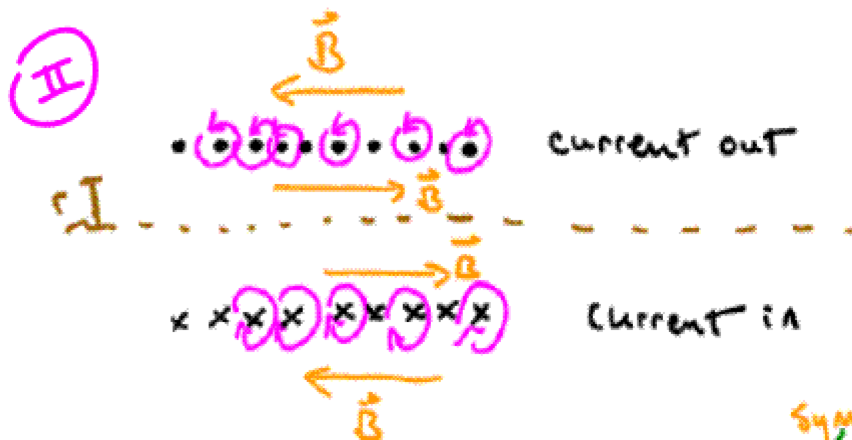
Note ... Not a monopole

Not a Source of Field

Why??

Field of an infinite Solenoid

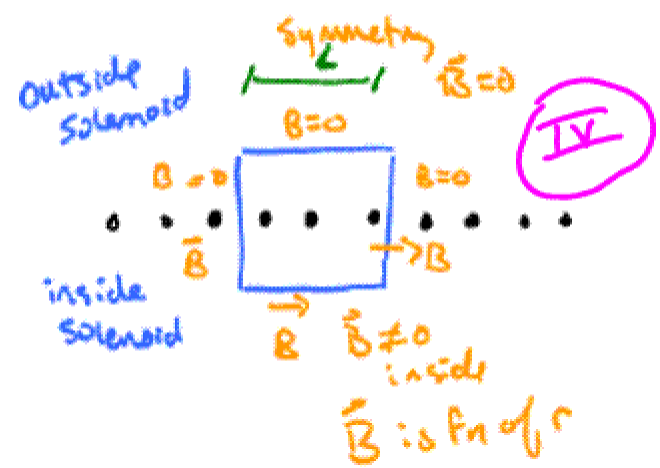
n loops / unit length

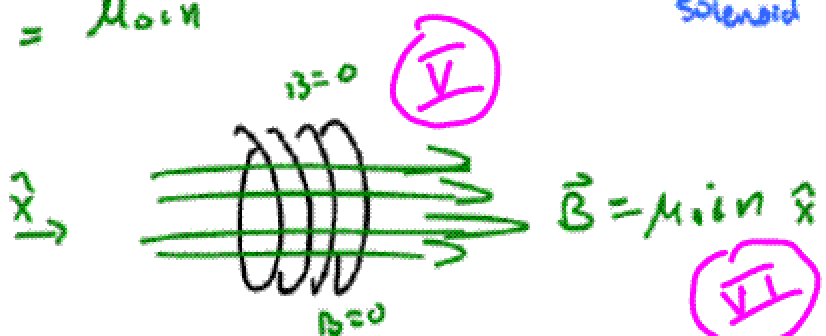


$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$$

$$|\vec{B}|\,L = \mu_0\, i\, n\, L$$

$$|\vec{B}| = \mu_0\, i\, n$$





Plays role similar to // plate capacitor in electrostatics