

Physics 1412 - October 25, 2007

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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

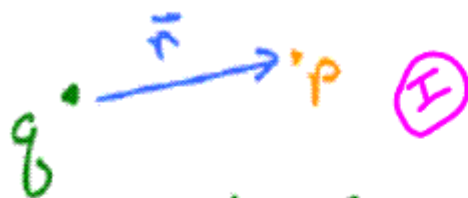
For current in a wire

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

Please check out Magnetic Field java applet on
 the class website!

Electrostatics

Coulomb's Law



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



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

Magnetostatics 3

Law of Biot-Savart

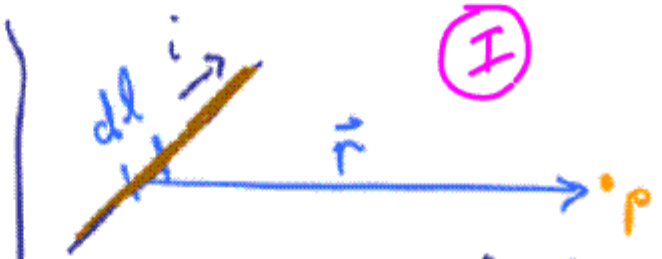


$$\vec{B}_{\text{at } P \text{ due to } Q} = \frac{\mu_0 Q}{4\pi} \frac{\vec{v} \times \hat{r}}{r^2}$$

$\mu_0 \equiv \text{const.} \equiv$ Permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} \frac{\text{T}\cdot\text{m}}{\text{A}}$$

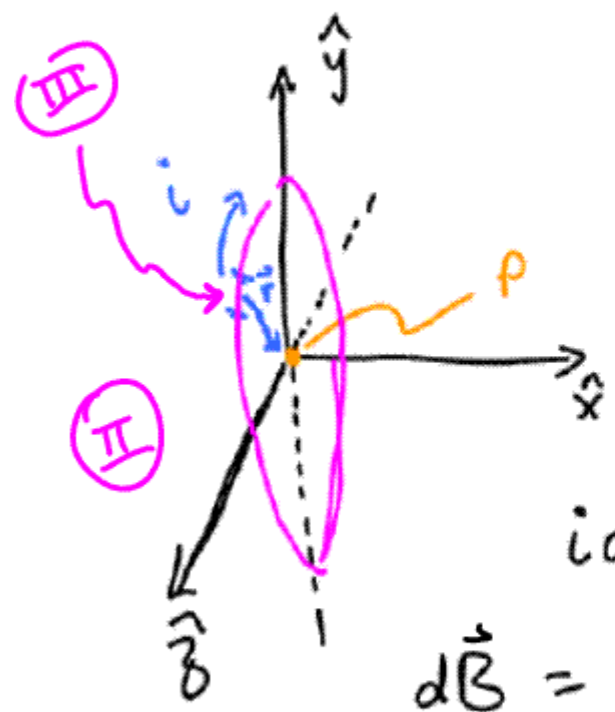
Distribution currents (not charges)



$$\vec{dB}(P) = \frac{\mu_0 i dl \times \hat{r}}{4\pi r^2}$$

due to
dl of
current

differential form
of
Biot-Savart



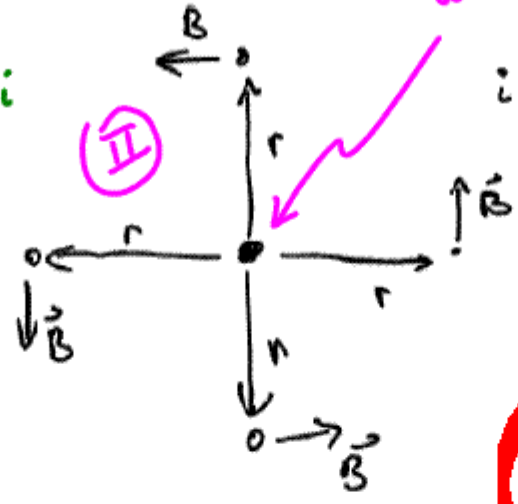
Find \vec{B} at origin

$$i dl \times \hat{r} = i dl (-\hat{x})$$

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

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

Yet Another
Right-hand rule



Wire-current out

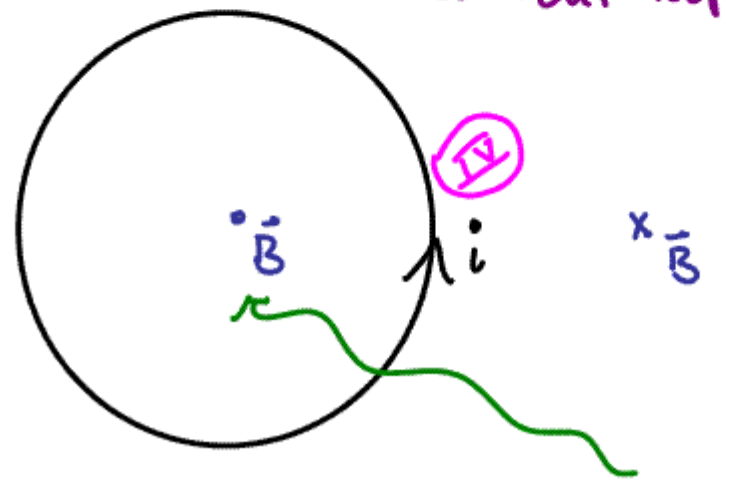
\vec{i} out

Field around
current-carrying
wire

See "magnetostatics"
java applet link on
class website

... And Another

III



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

$$\int_{\text{Surf.}} \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

good for situations
w/ particular
symmetry

Magnetostatics

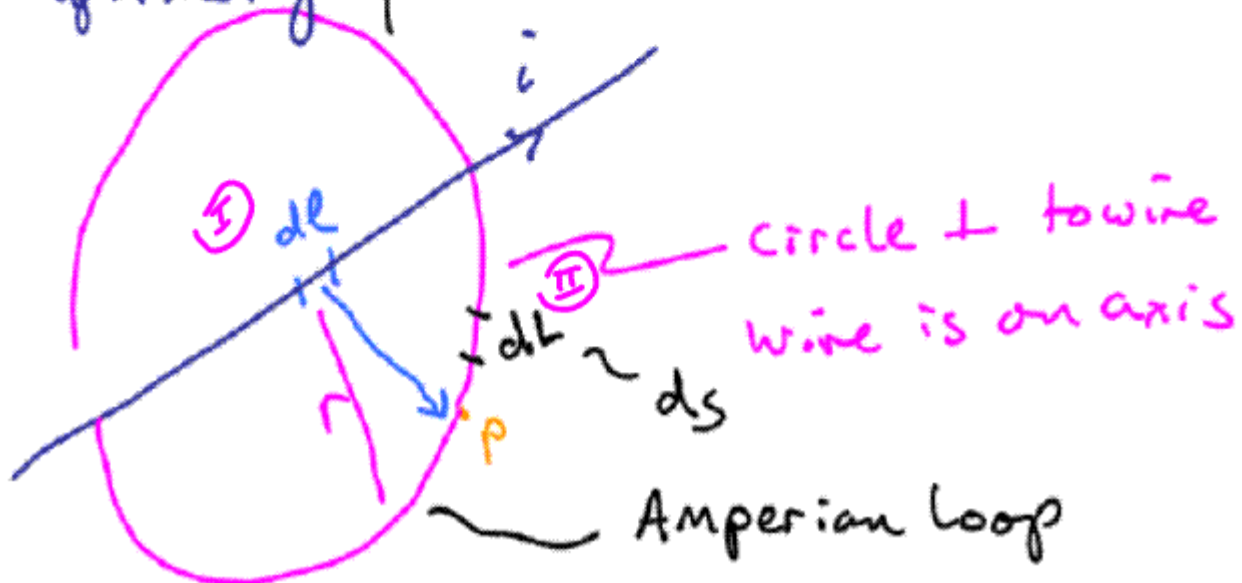
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Ampere's Law

$$\int \vec{B} \cdot d\vec{B} = \mu_0 I_{\text{enclosed}}$$

closed
curve

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



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

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

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

Very useful to know/derive at will

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

Biot-Savart

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

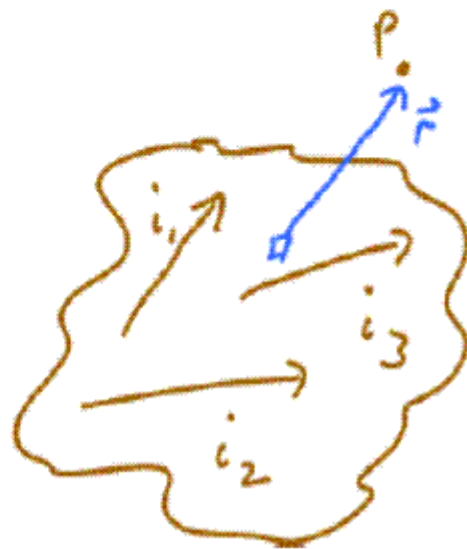
single charge moving



Important

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

distribution of currents



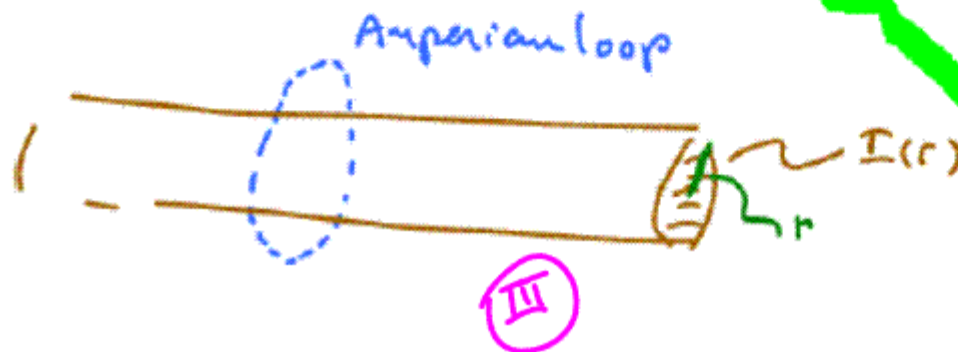
Ampere's Law:

Important

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

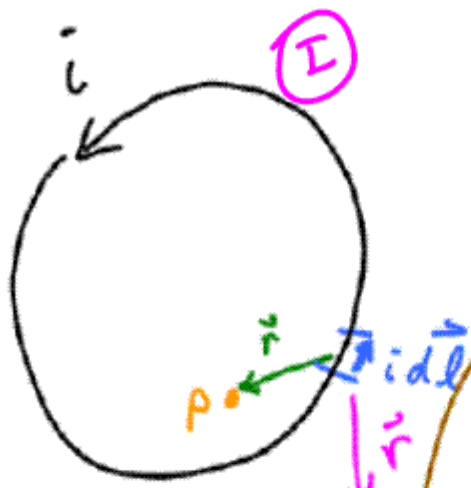
sometimes see $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{encl}}$

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



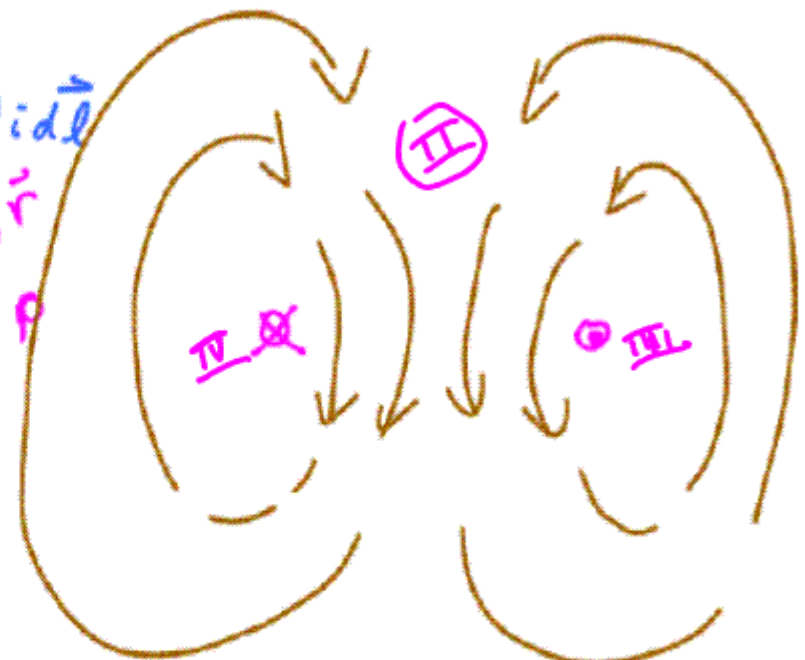
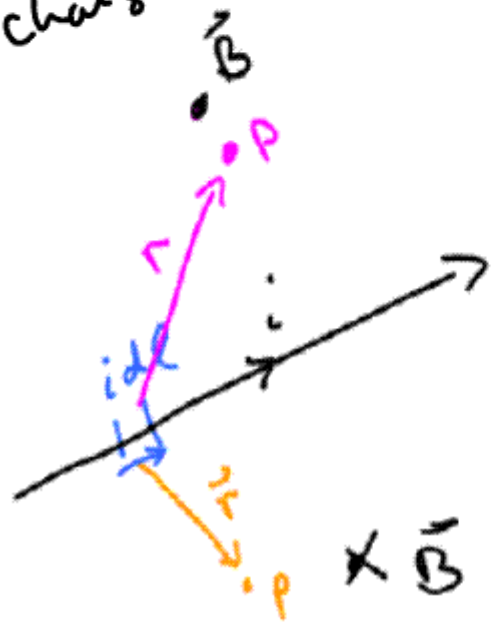
choose loop so
 $\vec{B} \cdot d\vec{l}$ simple
 $|\vec{B}| = \text{constant}$

\vec{B} field of current loop



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

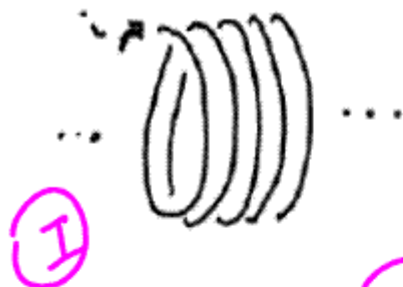
Closest Thing to Magnetic point charge



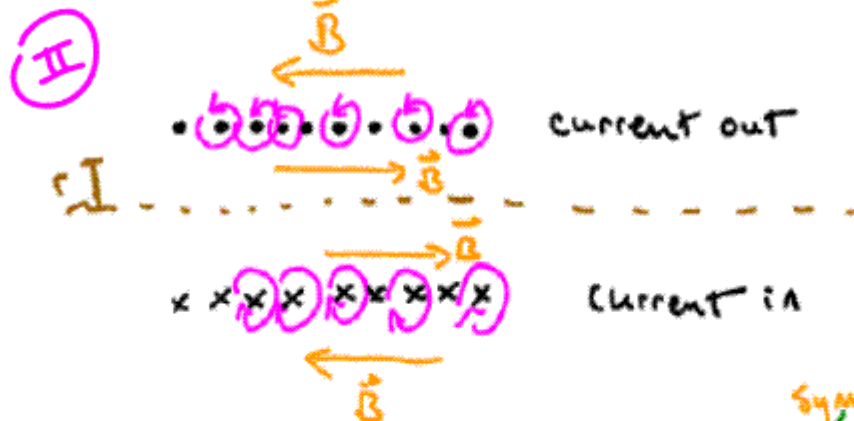
magnetic dipole

Note ... Not a monopole
 Not a source of field
 Why??

Field of an infinite Solenoid



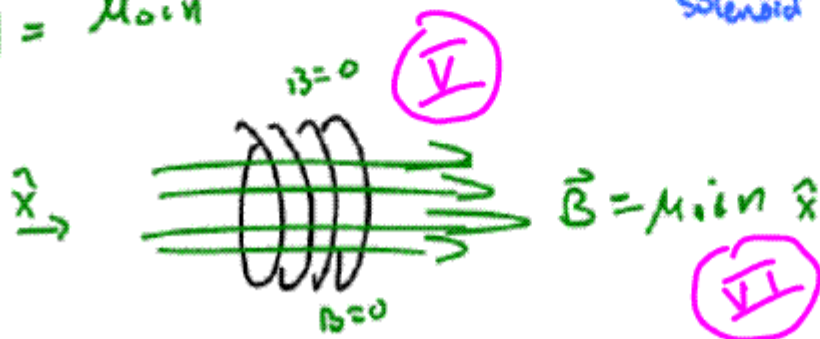
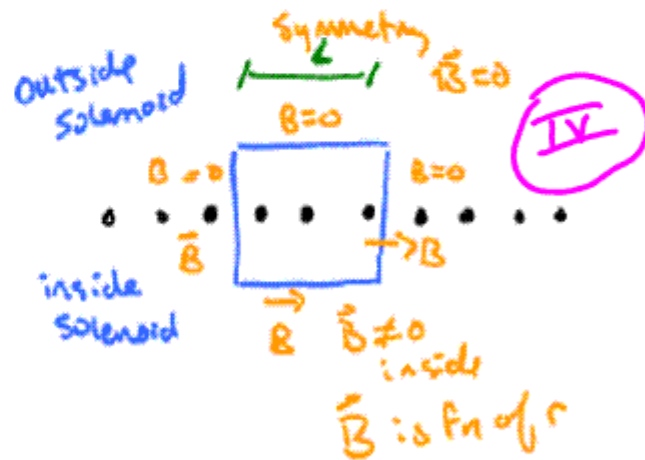
n loops / unit length



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

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

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



$$\vec{B} = \mu_0 i n \hat{x}$$



Plays role similar to // plate capacitor in electrostatics