# Physics 114 - March 4, 2010

- Will be in touch soon w/ email about Exam 2

Will have workshops week of March 15-19
Will have P.S. due March 18

Certainly material that will be on EXAM

# Lorentz Force law

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

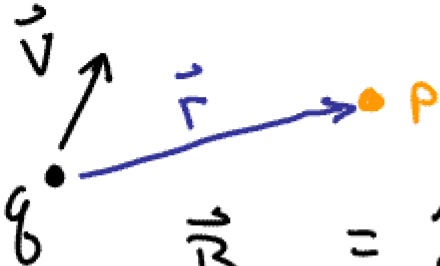
Force of $\vec{B}$ on moving charge

$$\vec{F} = i\vec{l} \times \vec{B} = l\vec{i} \times \vec{B}$$

Force of $\vec{B}$ on wire carrying current

# Law of Biot-Savart

<Magnetostatics> steady currents

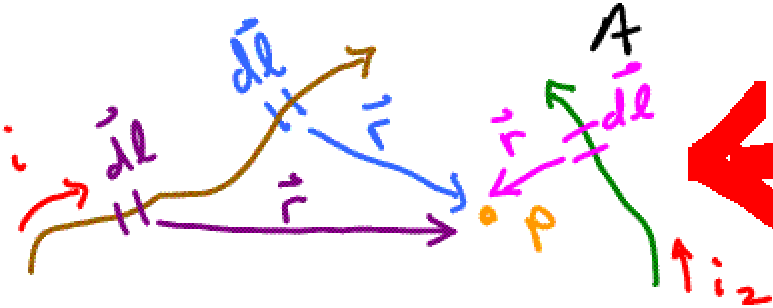



$\vec{B}$ at point p due to q moving with $\vec{v}$

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

$\mu_0$ = permeability of free space

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



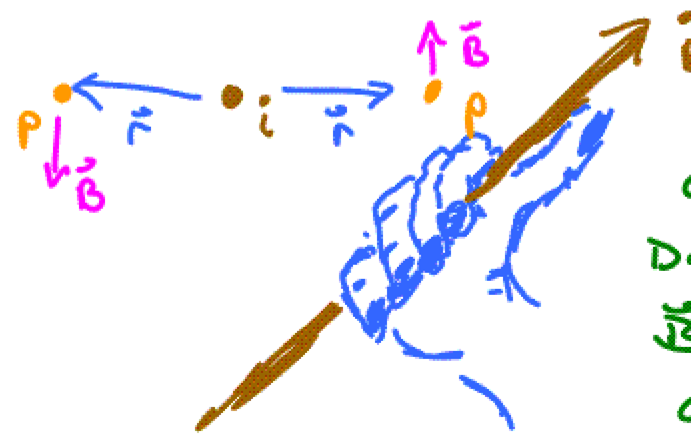

$\vec{B}$ at some point due to distribution of steady currents

$$\boxed{\vec{B}_p = \frac{\mu_0}{4\pi}\underbrace{\int \frac{i\,d\vec{\ell}\times\hat{r}}{r^2}}_{\text{Distribution of currents}}}$$

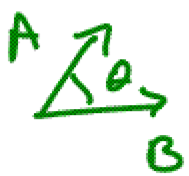
Particle cannon applet (Magnetic Force)

Magneto STATICS (Magnetic field) applet

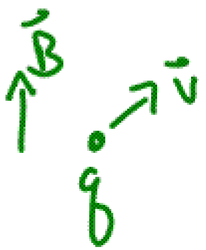
## Right-hand rules



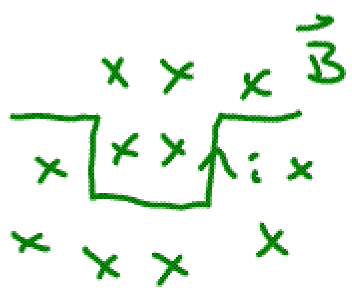

determine Direction of $\vec{B}$ around current i




$\vec{A}\times\vec{B}$

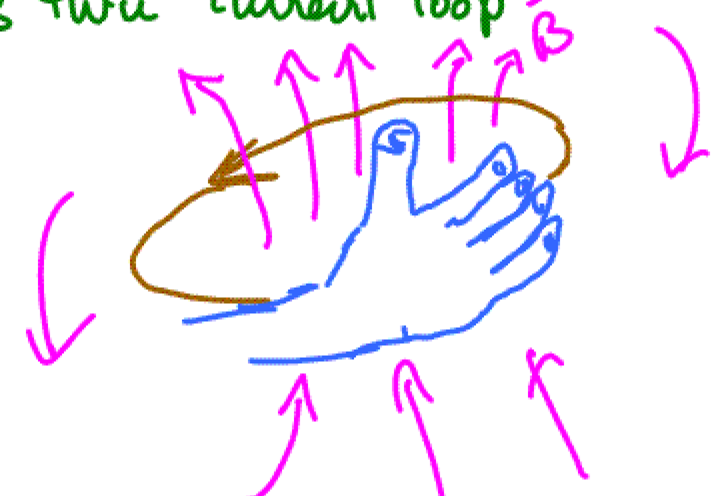



$\vec{F} = q\,\vec{v}\times\vec{B}$

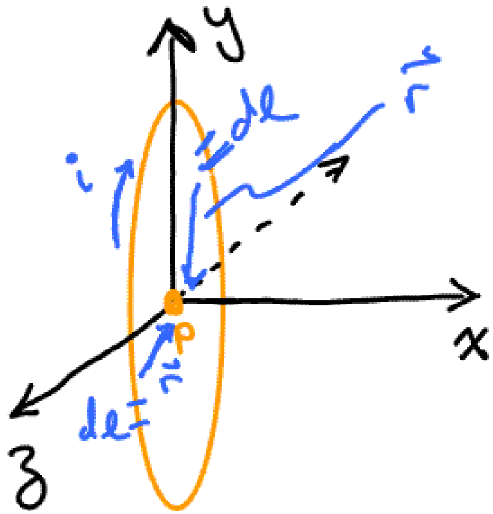



$\vec{F} = i\,\vec{l}\times\vec{B}$

Determine direction of $\vec{B}$ thru current loop



# Biot-Savart example

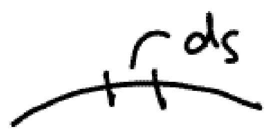



Find $\vec{B}$ at origin

RHR $\rightarrow$ $-\hat{x}$ is direction of $\vec{B}$

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

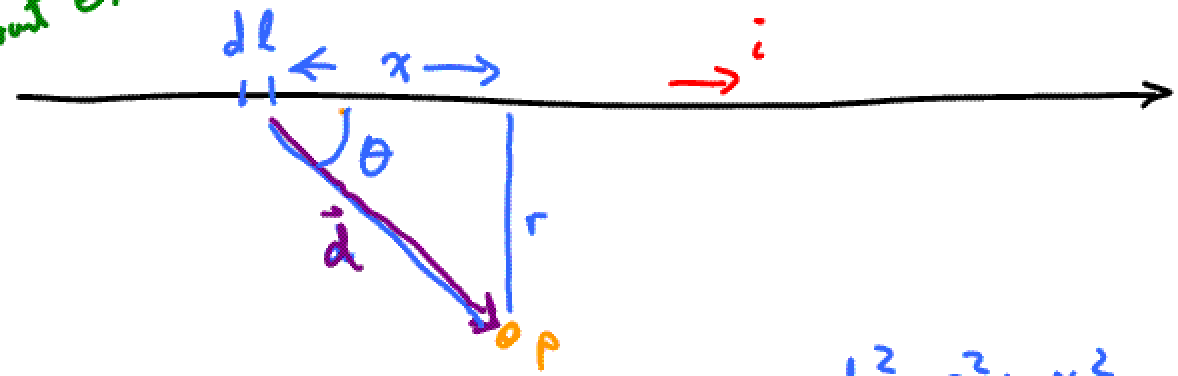
$i\,d\vec{l}\times\hat{r} \rightarrow i\,dl \rightarrow i\,ds$




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

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

Another Biot-Savart example




$$d^2 = r^2 + x^2$$

$$\vec{B}_P = \frac{\mu_0}{4\pi}\int_{-\infty}^{\infty} \frac{i\, d\vec{l} \times \hat{d}}{d^2}$$

$$d\vec{l} \times \hat{d} = |d\vec{l}| \sin\theta \qquad \sin\theta = \frac{r}{d}$$

$$\vec{B}_P = \frac{\mu_0}{4\pi} 2i \int_0^{\infty} \frac{\sin\theta\, dx}{r^2 + x^2}$$

$$\int \frac{dx}{(x^2+a^2)^{3/2}} = \frac{x}{a^2 (x^2+a^2)^{1/2}}$$

$$\vec{B}_P = \frac{\mu_0 2ir}{4\pi} \int_0^{\infty} \frac{dx}{(r^2+x^2)^{3/2}}$$

$\leadsto$ doable but a pain

## Electrostatics

### Gauss' Law

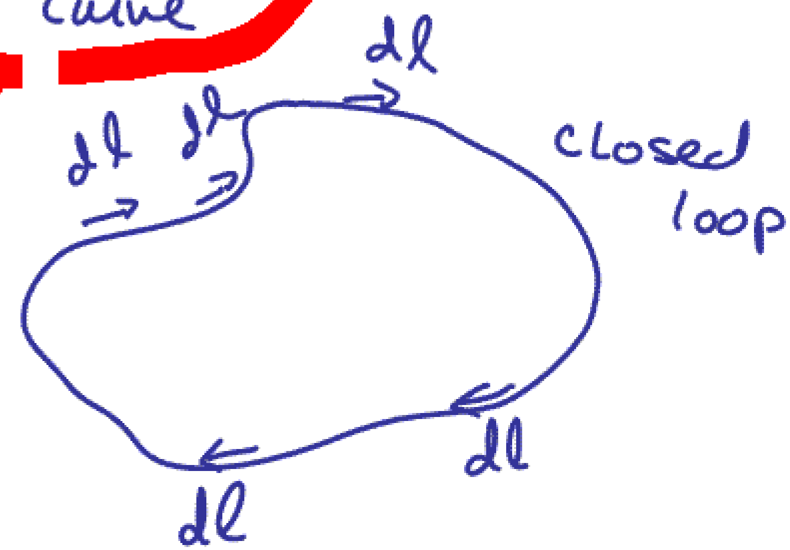
$$\int_{surf} \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$

General – Always True

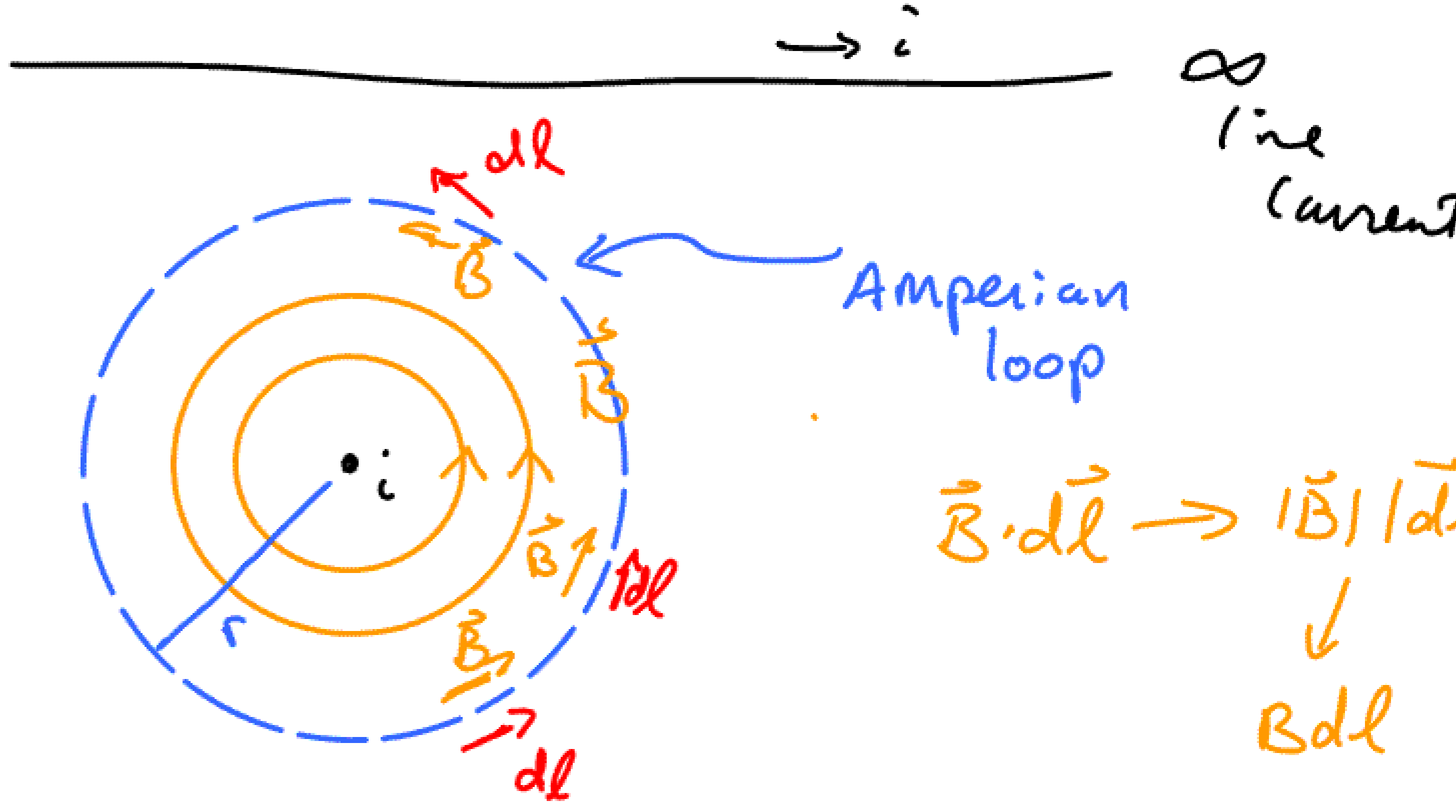
## Magnetostatics

### Ampere's Law

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



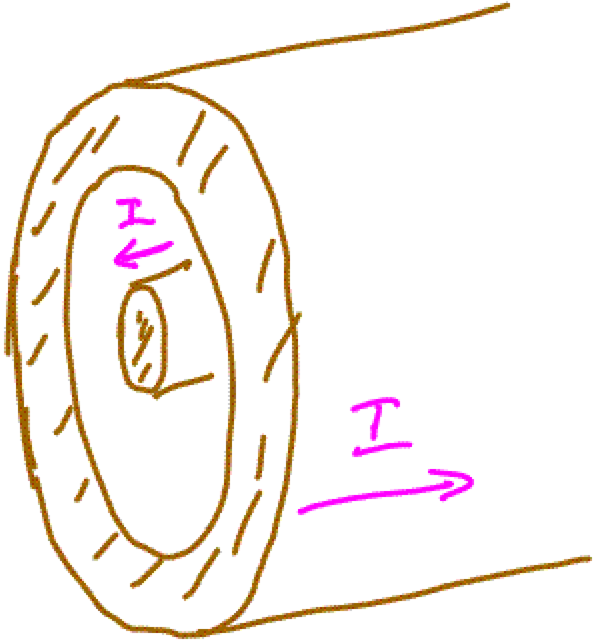

very useful under certain conditions of symmetry with proper choice of "Amperian loop"

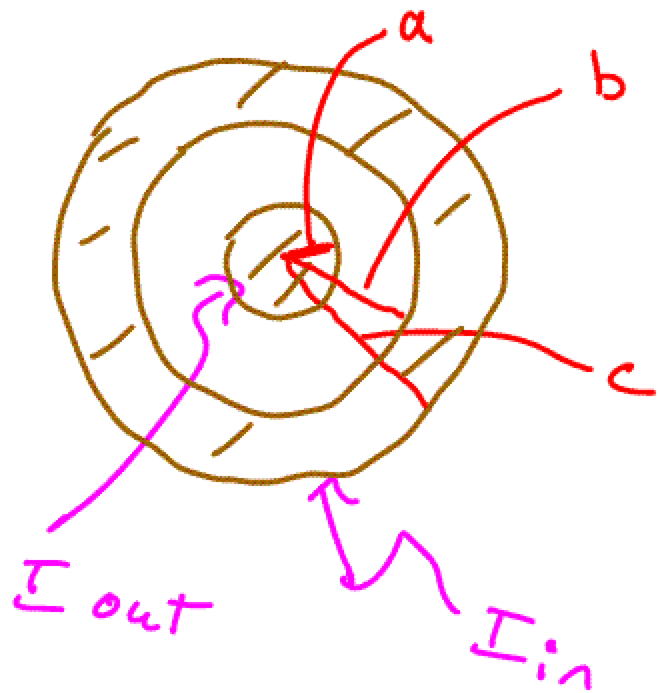



$$\vec{B}\cdot d\vec{l} \rightarrow |\vec{B}|\,|d\vec{l}|$$
$$\downarrow$$
$$B\,dl$$

$$\int \vec{B}\cdot d\vec{l} = \mu_0 I_{encl} \qquad |\vec{B}(r)| = \frac{\mu_0 i}{2\pi r}$$

$$\int B\,dl = B\int_0^{2\pi r} ds = B\,2\pi r = \mu_0 i$$




I distributed evenly across conductors

I uniform, I has uniform current density

Find $\vec{B}$ in all space ...

$r < a$

Amperian loop radius $r < a$

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

$$B\,2\pi r = \mu_0 \underbrace{i_{encl}}_{j\pi r^2}$$

$$j\pi r^2 = \frac{I}{\pi a^2}\pi r^2$$

$j \equiv$ current density / Area

$$I = |\vec{j}|\,A$$

$$I = I/\pi a^2 \qquad B(r) = \frac{\mu_0}{2\pi r}\frac{I\pi r^2}{\pi a^2}$$

$$B(r) = \frac{\mu_0 I r}{2\pi a^2}$$

Will look at $a<r<b$ and $b<r<c$ and $r>c$ Next class ...