Feb 13

Get Clickers and Whiteboards

Discussion: Biot-Savart Law

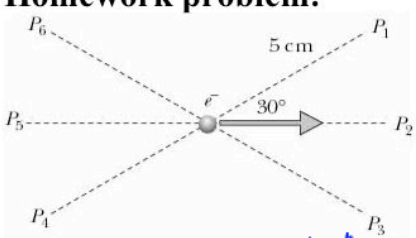
cross product

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

$$\vec{r} = \vec{r}_{obs} - \vec{r}_{source}$$

$$\frac{\mu_0}{4\pi} = 10^{-7} \frac{T \cdot m}{A} = 10^{-7} \frac{T \cdot m}{C/s}$$

Homework problem:



$$\vec{v} = \langle 4e6, 0, 0\rangle \, m/s$$

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

hatted

$$|\vec{v} \times \hat{r}| = |\vec{v}||\hat{r}| \sin\theta = |\vec{v}| \sin\theta = 4e6 \sin 30° \; m/s = 2e6 \; m/s$$

$$B = 10^{-7} \frac{T \cdot m}{C/s} \; 1.6e{-}19 \, C \; \frac{2e6 \; m/s}{(5e{-}2 \, m)^2} = 1.28e{-}17 \, T$$

if wrong

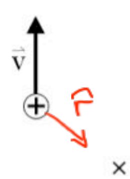
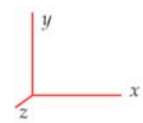
$$\vec{v} \times \vec{r} = m^2/s$$

$$\frac{T \cdot m}{C/s} \; C \; \frac{m^2/s}{m^2} = T \cdot m$$

VPython Demo: Moving charge

Clicker Questions

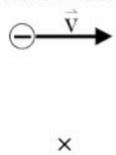
Q1

Direction of magnetic field at the observation location? 	A) +x B) –x C) +z D) –z E) zero magnitude	

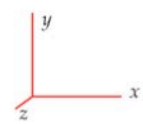
$$\hat{y} \times (\hat{x} + (-\hat{y})) = \hat{y} \times \hat{x} = -\hat{z}$$

Q2

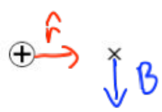
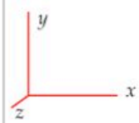
Direction of magnetic field at the observation location?



A) +y
B) –y
C) +z
D) –z
E) zero magnitude



Q3

At the observation location the magnetic field due to the proton is in the -y direction. What is a possible direction for the velocity of the proton? 	A) +x B) −x C) +z D) −z E) zero magnitude	

$$\hat{v} \times \hat{r} = -\hat{y}$$

$$\hat{v} \times \hat{x} = -\hat{y}$$

$$\hat{x} \times \hat{y} = \hat{z} = -\hat{y} \times \hat{x}$$

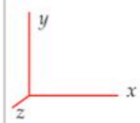
$$\hat{y} \times \hat{z} = \hat{x} = -\hat{z} \times \hat{y}$$

$$\hat{z} \times \hat{x} = \hat{y} = -\hat{x} \times \hat{z}$$

close

$$(-\hat{z}) \times \hat{x} = -\hat{y}$$

Q4

At the observation location the magnetic field due to the ***electron*** is in the -z direction. What is a possible direction for the velocity of the ***electron***?  	A) +x B) –x C) +y D) –y E) zero magnitude	

$\hat{v} \times \hat{r} = \hat{z}$

$\hat{v} \times \hat{y} = \hat{z}$ $\qquad$ $\hat{y} \times \hat{z} = \hat{v} = \hat{x}$

For extra credit

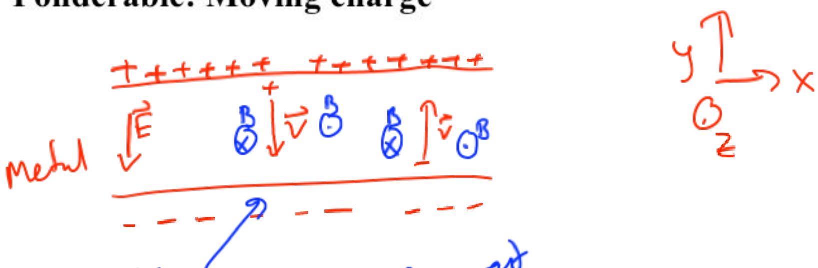
Q5

As a guess, what do you expect for the distance dependence of the magnetic field of a long, straight, current-carrying wire?	A) r B) no distance dependence C) 1/r D) 1/(r**2) E) 1/(r**3)

$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$ ← point charge → $\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}\hat{r}$

$\vec{B} \propto \frac{1}{r}$ line charge → $\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{2Q/L}{r}$

Ponderable: Moving charge



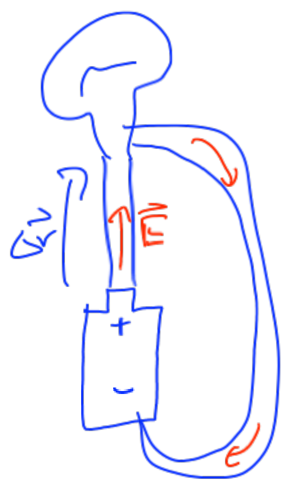
heats up plate

Proton starts from rest moves down, potential energy decreases

Then stops

Tangible: Looking at a bulb

$\Delta V = -\int \vec{E} \cdot d\vec{l}$



$\Delta V < 0$

Which way does $\vec{E}$ point

Simulation negative charges are moving

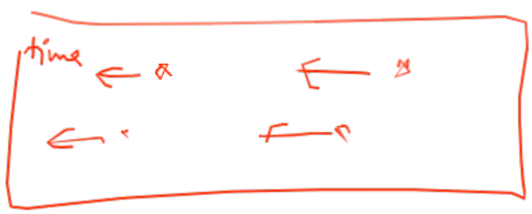
Tangible: Short circuit

Tangible: "Inside" current

The Ghost Inside

2.5 s

10 s



$I = C/s$

$$\frac{2\,nC}{2.5\,s} + \frac{2\,nC}{10\,s}$$

$$0.8\,nC/s + 0.2\,nC/s$$

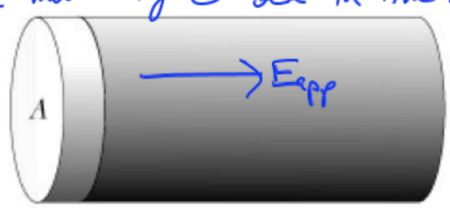
$$= 1.0\,nC/s$$

Discussion: Electron current/conventional current

Move at average speed $\bar{v}$

distance moved by e^- sea in time $\Delta t = \bar{v}\Delta t$

+



−

$\leftarrow$ $\bar{v}\Delta t$

vol of e^- move past slice of wire $= \bar{v}\Delta t A$

n = density of e^- = $\#e^-/m^3$

$\#e^-$ move past slice in $\Delta t = n(A\bar{v}\Delta t)$

$i = \frac{\#e^-}{time} = \frac{nA\bar{v}\Delta t}{\Delta t} = nA\bar{v}$ electron current

Conventional current

$I = \frac{\text{Charge}}{\text{sec}}$

$= |q| n A \bar{v}$

Ponderable: Details of current

n for copper = ?

mole of Cu has mass of 64g

1 e^- released / atom

density of Cu $9 g/cm^3 = 9\times10^3\ kg/m^3$

$$\frac{\#\text{ atoms}}{kg} = \frac{6\times10^{23}\text{ atoms/mol}}{0.064\text{ kg/mol}} = \ldots$$

$$\frac{\#\text{ atoms}}{m^3} = \frac{6\times10^{23}\text{ atom/mol}}{0.064\text{ kg/mol}} \times 9\times10^3 \frac{kg}{m^3} = 8.4\times10^{28}\frac{\text{atoms}}{m^3}$$

$n = 8.4\times10^{28}\ e^-/m^3$

Suppose $i = 3.4\times10^{18}\ e^-/s$, $A = 8\times10^{-7}\ m^2$ → What is $\bar{v}$?

$$i = nA\bar{v}$$

$$\bar{v} = \frac{i}{nA}$$

$$= \frac{3.4\times10^{18}\ e^-/s}{8.4\times10^{28}\ e^-/m^3 \times 8\times10^{-7}\ m^2}$$

$$= 5e\text{-}5\ m/s$$

A: Ag
B: Au
C: Al

Calc $n = ?$ $i = 3.4e18\ e^-/s$

$\bar{v} = ?$ $A = 8 \times 10^{-7}\ m^2$

A: $n_{Ag} = 5.8 \times 10^{28}\ e/m^3$, $\bar{v}_{Ag} = 7.3e{-5}\ m/s$

B: $n_{Au} = 5.9 \times 10^{28}\ e^-/m^3$, $\bar{v}_{Au} = 7.2e{-5}\ m/s$

C: $n_{Al} = 6.0e28\ e^-/m^3$, $\bar{v}_{Al} = 7.1e{-5}\ m/s$