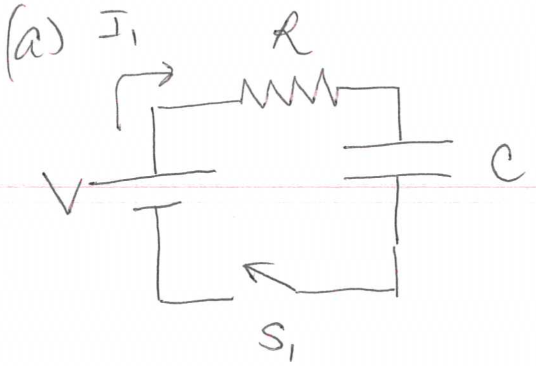
Slide #3 RC Circuits

(a) 

Capacitors behave like shorts at short times

$$I = \frac{dQ}{dt} = \frac{d\,CV}{dt} = C\frac{dV}{dt}$$

$$= \frac{C}{dt}\Delta V$$

goes to ∞ as $dt \to 0$

$$I = \frac{V}{R}$$

(b) solve problem:

$$V_c = V\left(1 - \exp(-t/\tau)\right)$$

$$Q = CV_c = CV(1 - e^{-t/\tau})$$

$$\tau \equiv RC$$

$$I = \frac{dQ}{dt} = \frac{CV}{\tau} e^{-t/\tau}$$

$$= \frac{V}{R} e^{-t/\tau}$$

$t \to 0^+$

$$I = \frac{V}{R}$$

Slide #4 RC Circuits

See previous page.

(a) at long times, cap's act like an open circuit

$$I = \frac{C\,\Delta V}{dt} \qquad dt \to \infty$$

$$I = 0\,\Delta V \qquad R \to \infty.$$

(b) for solution method, see p. 1.

Slide #5:

$$\tau = RC.$$

$$-V + IR + \frac{Q}{C} = 0 \qquad \text{Kirchhoff's Voltage rule.}$$

$$\uparrow$$

$$\frac{dQ}{dt}$$

$$\frac{dQ}{dt} = \frac{CV_0}{CR} - \frac{Q}{CR}$$

$$\frac{dQ}{-CV_0+Q} = -\frac{dt}{RC}$$

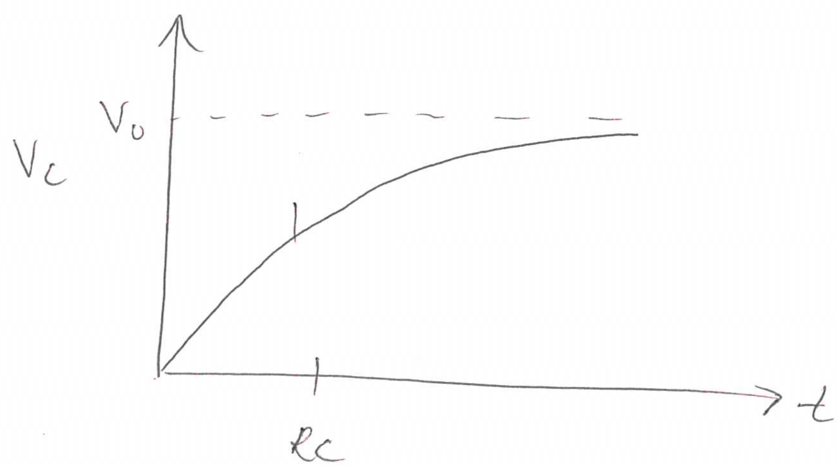
$$\log\frac{(Q-CV_0)}{(Q_0-CV_0)} = -\frac{(t-t_0)}{RC} \qquad t_0=0$$

$$\frac{Q-CV_0}{-CV_0} = e^{-t/RC} \qquad \tau = RC. \checkmark$$

$$Q = -CV_0\, e^{-t/RC} \quad \ldots$$

Slide #6

$$V_c = V(1-e^{-t/\tau})$$



Slide #7

$$\tau = RC = \text{const.}$$

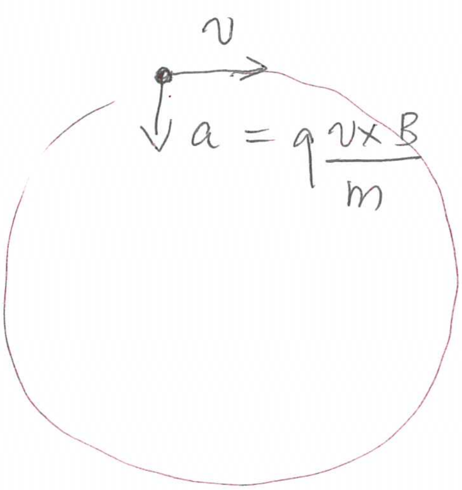
$$R \to 2R \qquad \boxed{C \to C\tfrac{1}{2}} \qquad \Big| \quad RC \to RC \checkmark$$

both I + Q change since

$$Q = \underset{\text{different}}{C}V \xrightarrow{\text{same}} \frac{C}{2}V \qquad \underline{\text{different}} \qquad Q \to \frac{Q}{2}$$

$$I = \frac{dQ}{dt} \quad \text{also } \underline{\text{different}}. \qquad I \to \frac{I}{2}$$

Mass Spec Slide # 8



$$a = \frac{v^2}{r} \quad \text{for circular motion.}$$

$$a = q\frac{vB}{m} = \frac{v^2}{r}$$

$$r = \frac{vm}{Bq}$$

$r = $ const if $\frac{m}{q}$ is const.

$$m \to 2m \Rightarrow \boxed{q \to 2q.}$$

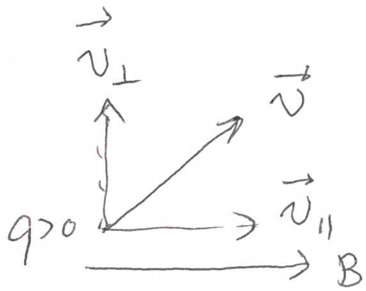
Slide # 9

Velocity Selector.

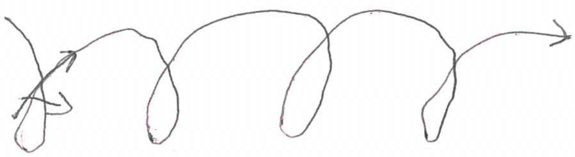
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) = 0 \qquad \underline{\text{undeflected}}$$

$$\vec{E} = -\vec{v} \times \vec{B}.$$

Slide # 10



Makes a helix.



"Left handed"

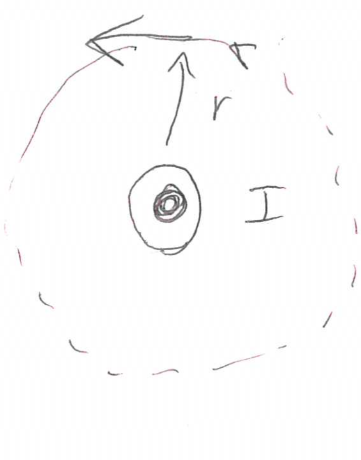
Slide # 11

Ampère Law

$$\oint d\vec{l} \cdot \vec{B} =$$

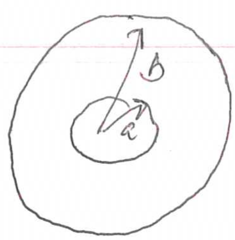
$$2\pi r B = \mu_0 I$$

$$\vec{B} = \frac{\mu_0 I}{2\pi r} \hat{\theta}$$



Slide 12 Weird Wires

I (out)



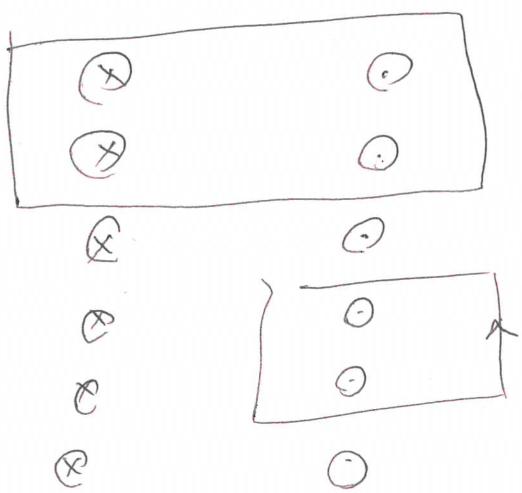
Current density $j = \underbrace{\dfrac{I}{\pi(b^2-a^2)}}_{\text{area.}}$

$$\vec{B} = \frac{\mu_0 I_{enc}(r)}{2\pi r} = \frac{\mu_0 I_0}{2\pi r}\begin{cases} 0, & r < a \\ \dfrac{r^2-a^2}{b^2-a^2}, & a < r < b \\ 1, & b < r. \end{cases}$$

Slide # 13

Solenoid

Ampére Law



$\oint d\vec{l} \cdot \vec{B} = 0$

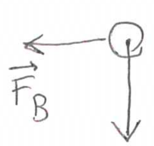
$\oint d\vec{l} \cdot B = LB = InL\mu_0$

$\vec{B} = 0$

$$\boxed{\vec{B} = -\hat{j}\, In\mu_0}$$

Slide 14

Rotates CW.



$I\vec{L} \times \vec{B}$

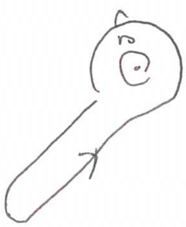
$(-\hat{j}) \times \hat{k} = -\hat{i}$

Slide # 15

Current flow CCW in the loop.

Slide # 16

assume small.



$$A = \pi r^2$$

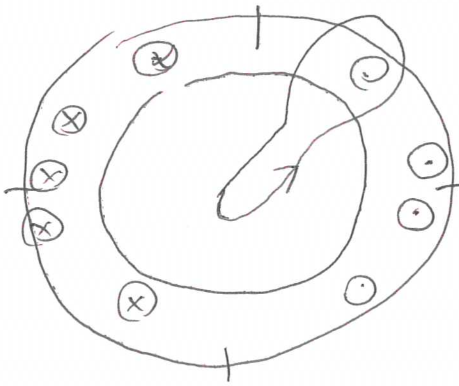
$$\Phi_B = \int d^2A \; \hat{n} \cdot \vec{B} \cong A B_0 \cos \omega t$$

$$\mathcal{E} = -\frac{d}{dt} \Phi_B = \omega A B_0 \sin \omega t .$$

$\mathcal{E} > 0$

Use lenz's law to figure out

0 emf



0 Emf. sign (Check).

$\mathcal{E} < 0$

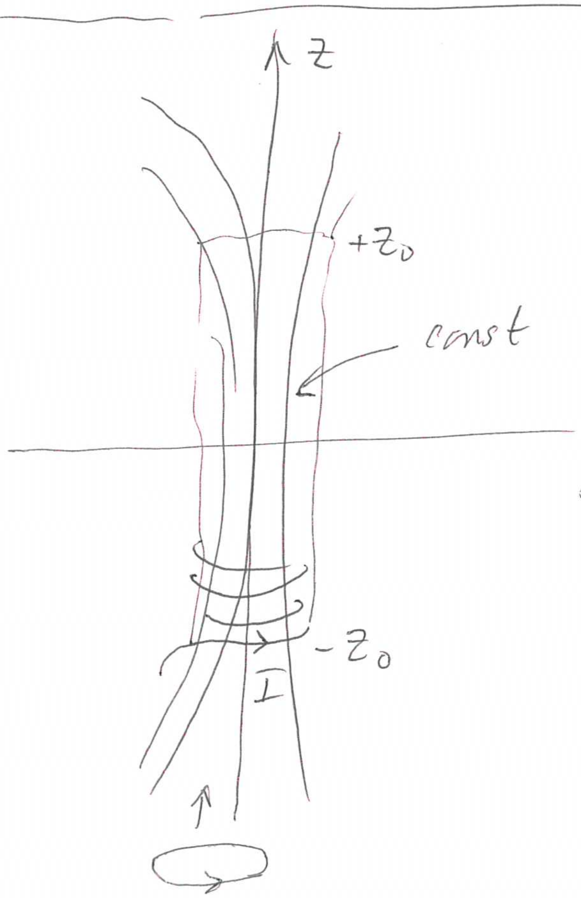
$$\mathcal{E} = \omega A B_0 \sin \omega t.$$

$$I = \frac{\mathcal{E}}{R} = \frac{\omega A B_0}{R} \sin \omega t$$

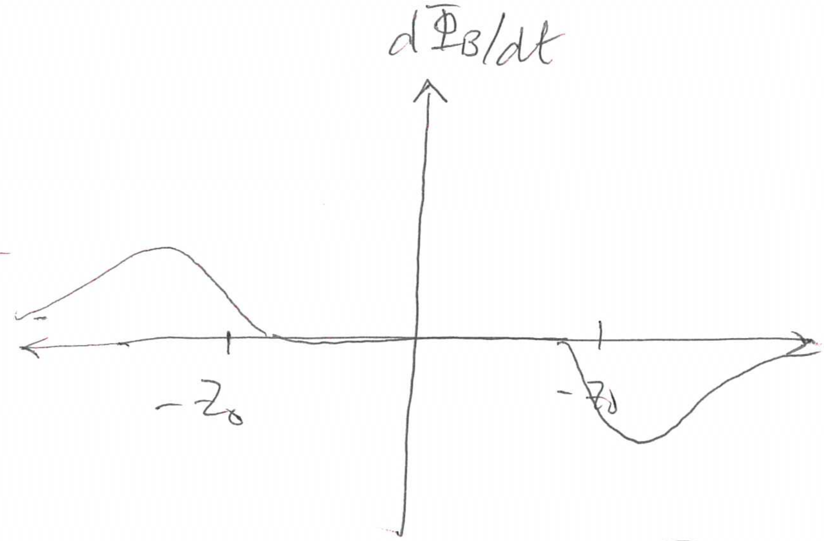
$$\text{Power} = \mathcal{E} I = \boxed{\frac{(\omega A B_0)^2}{R} \sin^2 \omega t.} = \;?$$

$$\text{Power} = \tau \frac{d\theta}{dt} = \tau \omega =$$

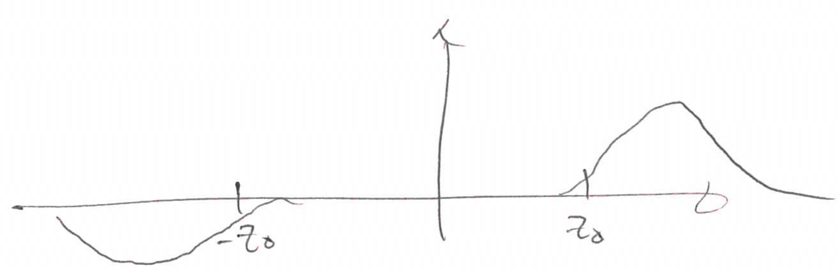
$$\boxed{\vec{\tau} = -\omega \frac{(A B_0)^2}{R} \sin^2 \omega t. \quad \hat{k}}$$



$\Phi_B > 0 \quad \forall \quad z$



$I \propto - d\Phi_B/dt.$



Slide #20

Torques & Dipoles.

$$\tau = \underbrace{\vec{\mu} \times \vec{B}}$$

max magnitude when $\perp$.

$\Rightarrow$ (C)

Smallest: (E)

Slide #21

Torque for A and B roughly = ($\perp$). Due to non-linearity, (A) is a bit bigger.