Ch. 29)

Michael Faraday (~1800)

Faraday's Law: A changing magnetic flux through a closed conducting loop induces a voltage (and ☺ a current).

$$\Delta V \; (\text{E.M.F.}) = -\frac{d\Phi_B}{dt}$$

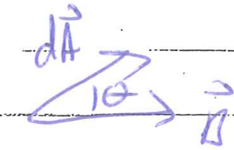
Aside: $\Delta V = -\int \vec{E} \cdot d\vec{s}$

Magnetic Flux: $\Phi_B = \int \vec{B} \cdot d\vec{A}$

Explicitly

as example
$$\vec{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$$
$$d\vec{A} = dx\,dz\,\hat{j}$$

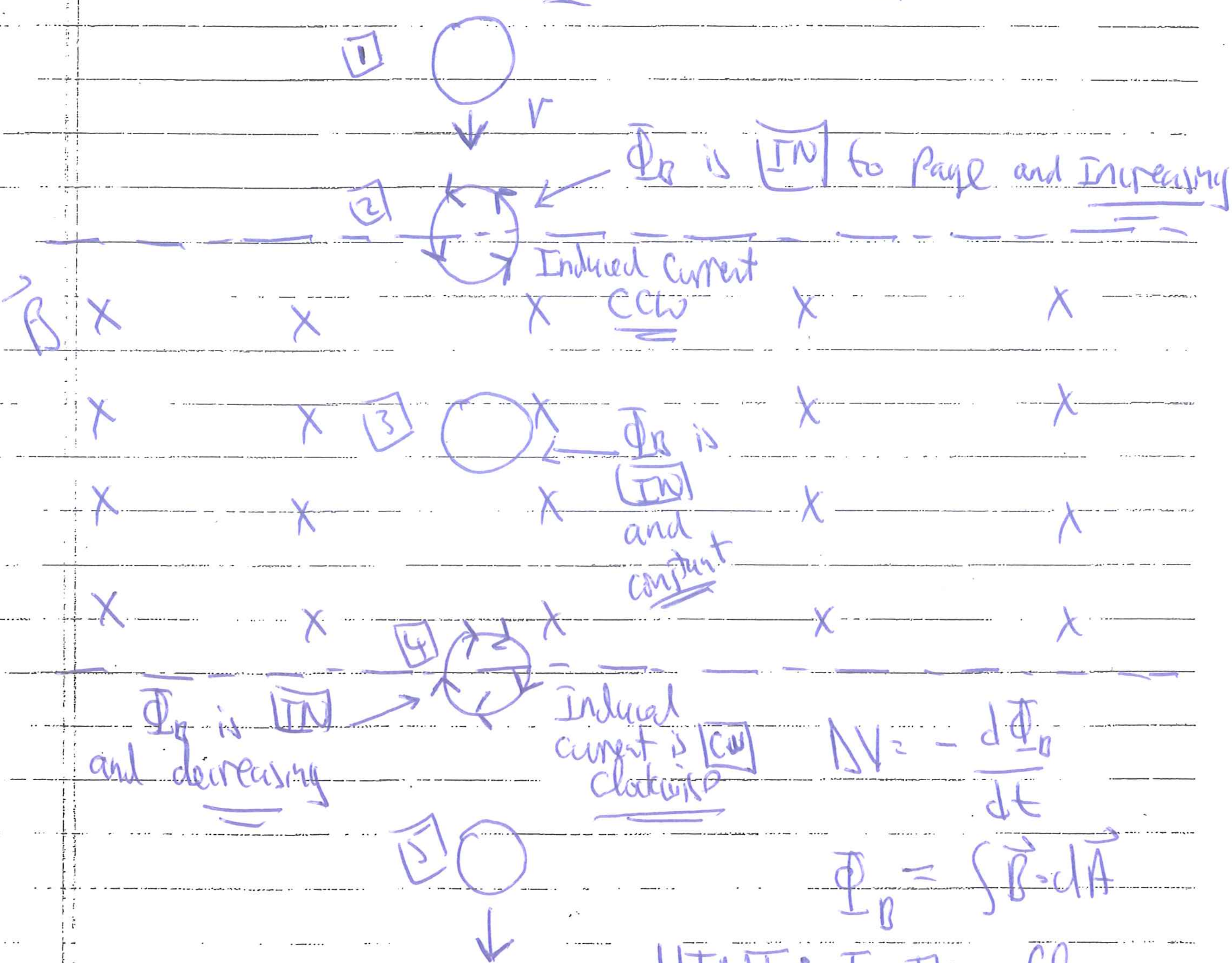
$\boxed{\text{OR}}$ $|\vec{B}||d\vec{A}|\cos(\theta)$



EXAMPLE

A conducting metal ring is dropped through a region of space containing a magnetic field, $\vec{B}$.

Field is uniform and constant



$$\Delta V = -\frac{d\Phi_B}{dt}$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

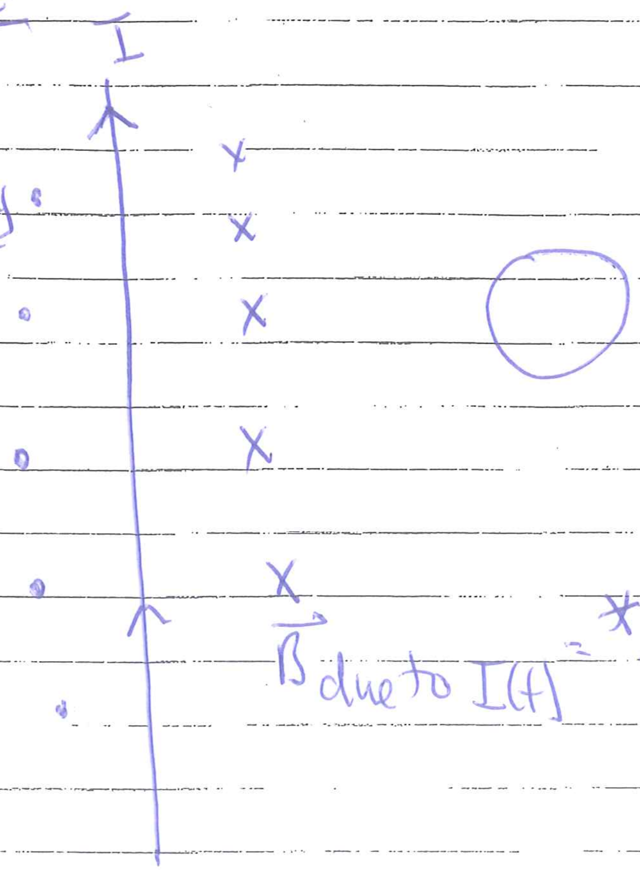
HINT: Is the flux changing?

Lenz's Law: Direction of induced current opposes the change in flux.
"Nature prefers the status quo"

HINT: How is flux changing? (increase or decrease)

EXAMPLE

Wire carrying current $I(t)$



$\vec{B}$ due to $I(t) = {}^{*}\dfrac{\mu_0 I(t)}{2\pi r}$

Is there a current induced in the loop and if so in what direction?

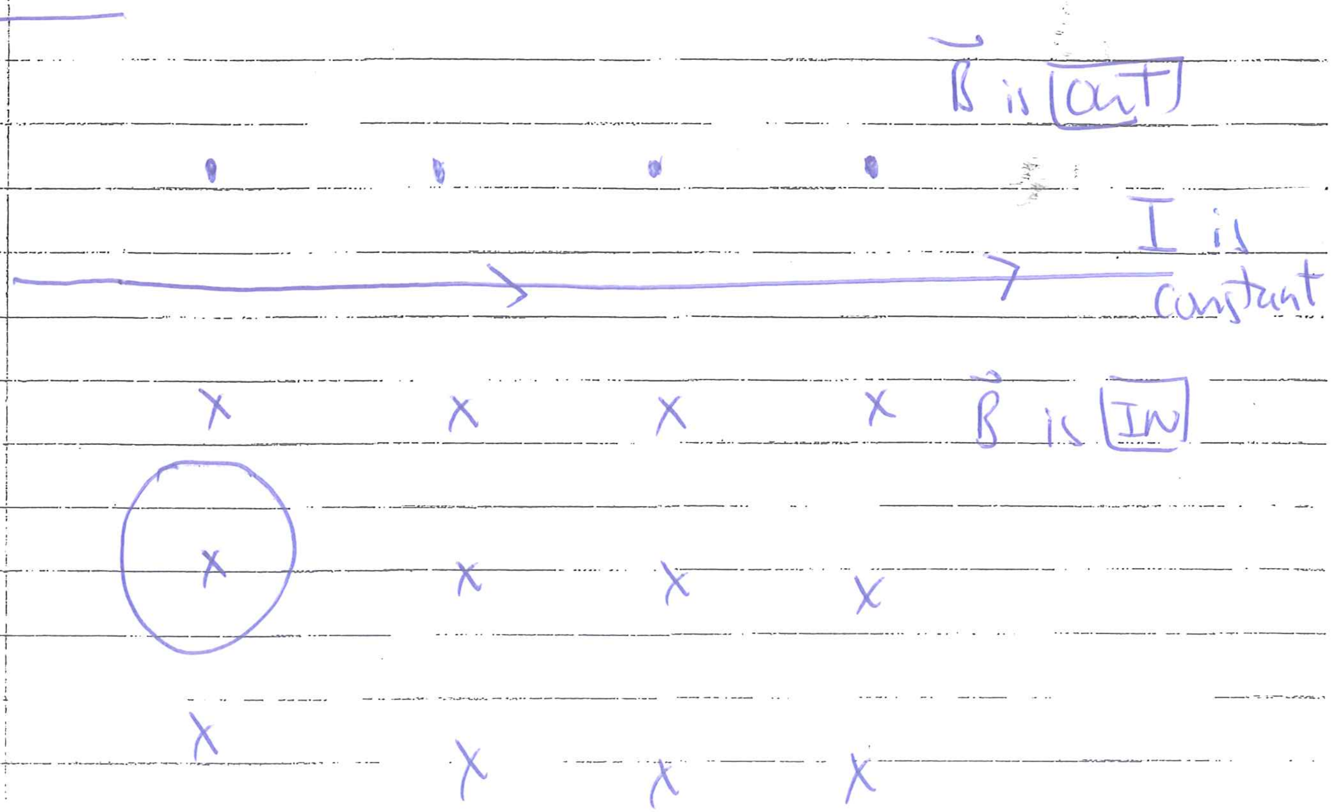
a.) $I(t) = \text{Constant}$
b.) $I(t)$ is increasing
c.) $I(t)$ is decreasing

a.) No. $\dfrac{d\Phi_B}{dt}$ is ZERO

b.) YES. Flux is $\boxed{\text{IN}}$ through the center. Since $I(t)$ is increasing, $\vec{B}$ is increasing.* $\therefore$ Induced current tries to push magnetic field out through center $\Rightarrow$ $\boxed{\text{CCW}}$

c.) YES. Flux is $\boxed{\text{IN}}$ through center. Since $I(t)$ is decreasing, $\vec{B}$ is decreasing.* $\therefore$ Induced current tries to push magnetic field $\boxed{\text{IN}}$ through center $\Rightarrow$ $\boxed{\text{CW}}$

EXAMPLE



Is there a current induced in the loop and if so in what direction (CW, CCW)?

a) Loop moved to right at constant speed.

b) Loop moved down @ constant speed.

c) Loop moved up @ constant speed. (not crossing wire)

ANS: a) Flux is not changing since $\vec{B}$ is constant $\boxed{\text{AND}}$ uniform for motion in this direction.. NO CURRENT INDUCED.

b) Flux IS changing since $\vec{B} = \frac{\mu_0 I}{2\pi r}$ $\boxed{\text{IN}}$.

In and decreasing $\Rightarrow$ Current is $\boxed{\text{CW}}$

c) Flux is changing since $\vec{B} = \frac{\mu_0 I}{2\pi r}$ $\boxed{IN}$

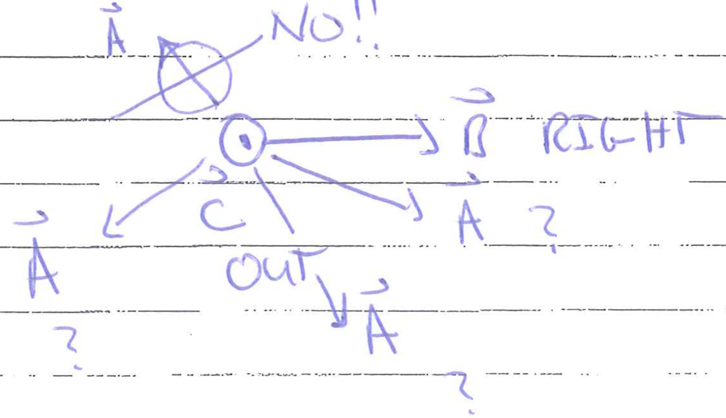
In and Increasing $\Rightarrow$ Current is $\boxed{CCW}$

SPEED ?

Questions about EXAM 2 Content

27.9] Recall vector cross product:

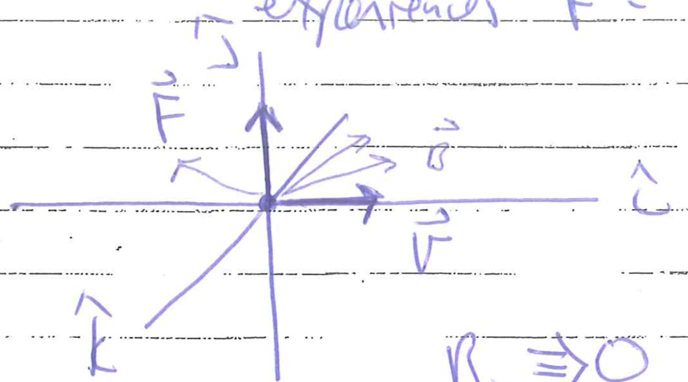
$\vec{C} = \vec{A} \times \vec{B}$



$\vec{B}$ is unknown.

Observation #1: Proton moving w/ $\vec{v} = 1.5*10^3 \hat{i}$

experiences $\vec{F} = 2.25*10^{-16} \hat{j}$



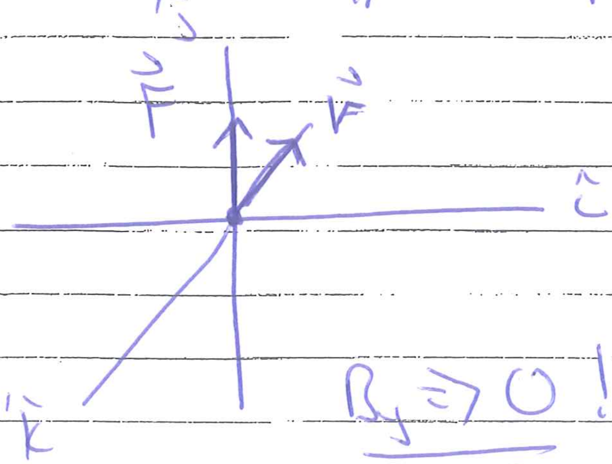
$\vec{F} = q\vec{v} \times \vec{B}$

positive

$B_y \Rightarrow 0$!!

B_z must be negative!!

Observation #2: Electron moving w/ $\vec{v} = -4.75\times10^{3}\,\hat{k}$
experiences $\vec{F} = 8.5\times10^{-16}\,\hat{j}$



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

↑ Negative.

$B_y \Rightarrow 0$!!

B_x must be positive !!

For the proton: $\vec{v} = 1.5\times10^{3}\,\hat{i}$ (V_x) $\vec{F} = 2.25\times10^{-16}\,\hat{j}$ F_y

$$\vec{B} = B_x\hat{i} + 0\hat{j} + B_z\hat{k}$$

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

$$\vec{v}\times\vec{B} = \begin{vmatrix} \overset{+}{\hat{i}} & \overset{-}{\hat{j}} & \overset{+}{\hat{k}} \\ V_x & 0 & 0 \\ B_x & 0 & B_z \end{vmatrix} = +0\hat{i} - V_x B_z\,\hat{j} + 0\hat{k}$$

$\boxed{\hat{j}}$ $F_y = q\,(\vec{v}\times\vec{B})_y$

$$2.25\times10^{-16} = (+1.6\times10^{-19})(-V_x B_z)$$

$$-0.938 = B_z$$

tesla

For the electron:

$\vec{v} = -4.75 \times 10^{3}\,\hat{k}$

V_z $\qquad B_y = 0$

$\vec{F} = 8.5 \times 10^{-16}\,\hat{j}$

F_y

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

$$\vec{v} \times \vec{B} = \begin{array}{ccc} + & - & + \end{array}\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0 & V_z \\ B_x & 0 & B_z \end{vmatrix} = 0\hat{i} - \hat{j}(-V_z B_x) + 0\hat{k}$$

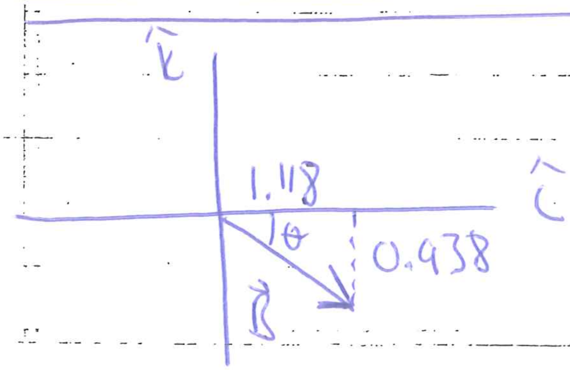
$\boxed{\hat{j}}$ $F_y = q(\vec{v} \times \vec{B})_y$

$$8.5 \times 10^{-16} = (-1.6 \times 10^{-19})(V_z B_x)$$

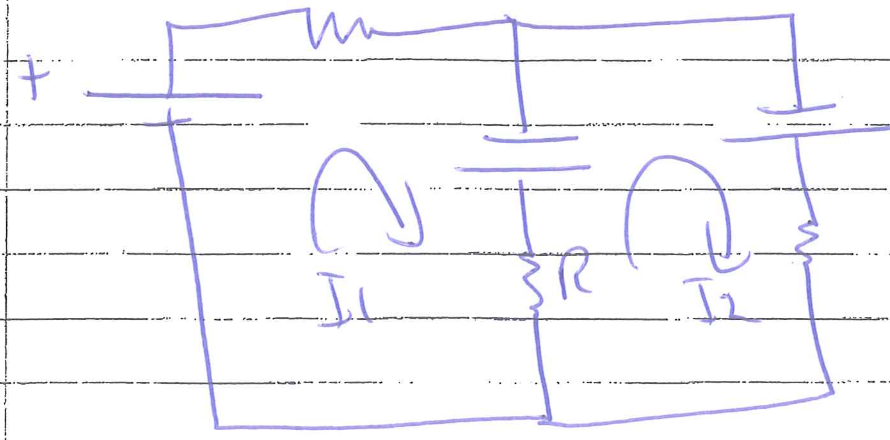
$$8.5 \times 10^{-16} = (-1.6 \times 10^{-19})(-4.75 \times 10^{3} B_x)$$

$$\underline{\underline{1.118 \text{ tesla}}} = B_x$$

$$\vec{B} = 1.118\,\hat{i} + 0\,\hat{j} - 0.938\,\hat{k}$$



$$\Theta = \tan^{-1}\left(\frac{0.938}{1.118}\right) = \underline{40^{\circ}}$$



$I_1 = +5$ A
$I_2 = +3$ A