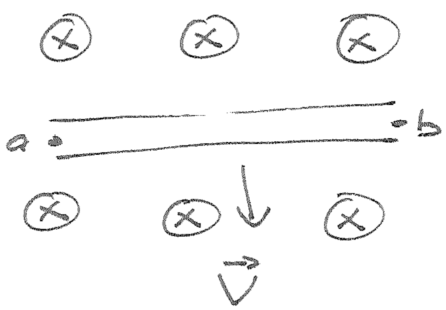
Physics 152, HW #7

Mastering Physics: 8 Questions from Chapter 25

ONE written Question

Motional EMF



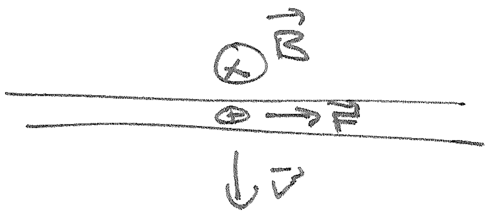
NOTE: The Direction for $\vec{B}$ on Mastering is opposite to the original problem. So all of your answers there would be opposite to the ones here.

$L = 33cm = 0.33m$

$B = 0.39T$

$V = 7m/s$

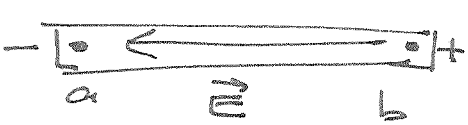
a) Which point has positive charge



By RHR, $\vec{F}$ on positive is $\rightarrow$

$\Rightarrow$ b has positive

b)



$\vec{E}$ goes from $\oplus$ to $\ominus$ $\Rightarrow$ from b to a

c) at Equilibrium $F_{mag} = F_e \Rightarrow |q|vB = |q|E \Rightarrow E = vB$

$\Rightarrow E = (7m/s)(0.39T) = 2.73\ V/m$

Unit: $\frac{m \cdot T}{s} = \frac{\cancel{m} \cdot N/A \cdot \cancel{m}}{s} = \frac{N}{A \cdot s} = \frac{N}{C/\cancel{s} \cdot \cancel{s}} = \frac{N}{C} = V/m$

our first unit for E

d) Which point At Higher Potential? $\vec{E}$ points in direction of decreasing Potential ⇒ From b to a ⇒ b at Higher.

e) What is V_{ab} ⇒ ΔV across Rod?

$$\Delta V = EL = (2.73 V/m)(0.33 m) = 0.9009 V = 0.901 V$$

f) What $\mathcal{E}_{ind}$? $\mathcal{E}_{ind} = \Delta V = 0.901 V$

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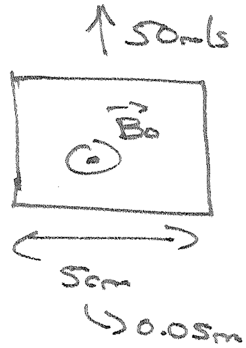


$B_0 = 0.2T$

$R = 0.25\Omega$

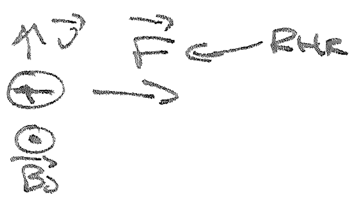
Motional EMF: $\mathcal{E}_{ind} = vBL = (50\,m/s)(0.2T)(0.05m) = 0.5V$

$\mathcal{E}_{ind} = I_{ind}R \Rightarrow I_{ind} = \frac{\mathcal{E}_{ind}}{R} = \frac{0.5V}{0.25\Omega} = 2A$

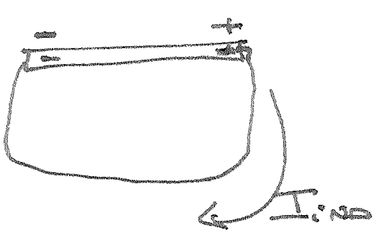
b) Direction?

Two ways to do this:

Force:



Bar on top goes into field first, so it "acts like" the battery



Flux: As bar goes into field, flux is increasing. Lenz's Law $\Rightarrow \vec{B}_{ind}$ tries to cancel by being ⊗

RHR $\Rightarrow$ Clockwise

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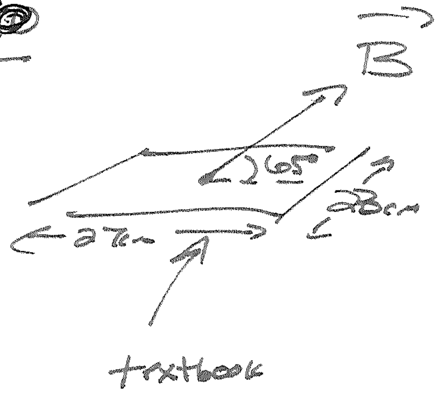
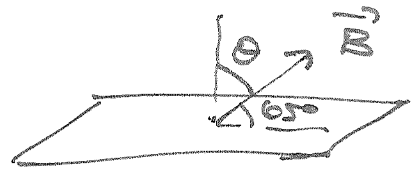


$B = 5\times10^{-5}\,T$

Loop's direction is at 90°

$\Rightarrow$

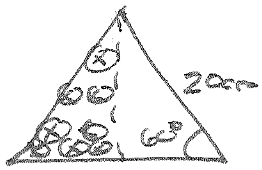


$\theta = 90° - 65° = 25°$

$\Phi = AB\cos\theta$ $\quad A = (23\,cm)(27\,cm) = (0.23\,m)(0.27\,m) = 0.0621\,m^2$

$\Phi = (0.0621\,m^2)(5\times10^{-5}\,T)\cos 25° = 2.814\times10^{-6}\,Wb = 2.8\times10^{-6}\,Wb$

25.13



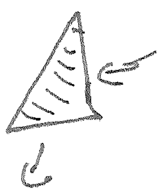
$B = 0.1T$

$\Phi = BA\cos\theta$

Axis also into page $\Rightarrow \theta = 0°$

$\Rightarrow \cos 0° = 1 \Rightarrow \Phi = BA$

But A = Area of part with magnetic field $\Rightarrow$



$20cm \sin 60° = 17.32cm$

$= 0.1732m$

$\frac{20cm}{2} = 10cm = .1m$

$\therefore A = \frac{1}{2}(.1m)(.1732m)$

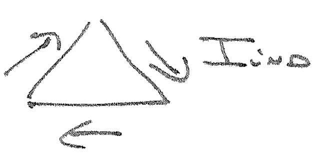
$= 0.00866m^2$

$\therefore \Phi = (0.1T)(.00866m^2) = 8.66\times10^{-4}Wb = 8.7\times10^{-4}Wb$

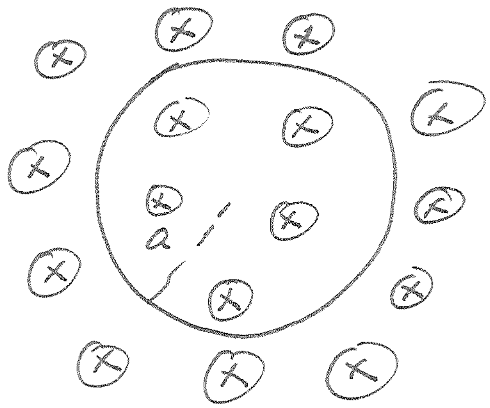
b.) if Flux decreases in 0.5s : $\mathcal{E}_{ind} = \left|\frac{\Delta\Phi}{\Delta t}\right| = \left|\frac{0 - 8.7\times10^{-4}Wb}{0.5s}\right| = \frac{8.7\times10^{-4}Wb}{0.5s} = 0.00174V$

c.) If B decreases $\Rightarrow$ decreasing Flux so B_{ind} will try to maintain

so $\vec{B}_{ind}$ is ⊗ so RHR $\Rightarrow I_{ind}$ is "clockwise"



Electromagnetic Induction



$a = 35\,mm = \frac{35}{1000}\,m = 0.035\,m$

$R = 0.033\,\Omega$

$B_0 = 1.2\,T$ decreased to zero

$I_{ind} = 0.2\,A$

How long?

A) What Direction is $\vec{B}_{ind}$? B_0 decreasing $\Rightarrow$ Decreasing Flux $\Rightarrow$ $\vec{B}_{ind}$ tries to maintain by also being $\otimes$

b) $\vec{B}_{ind}$ is $\otimes$, so RHR $\Rightarrow$ I_{ind} is Clockwise

c) Faraday's Law: $\mathcal{E}_{ind} = \left|\frac{\Delta\Phi}{\Delta t}\right|$

Ohm's Law: $\mathcal{E}_{ind} = I_{ind} R = (0.2\,A)(0.033\,\Omega) = 0.0066\,V$

Only magnitude of B_0 changing $\Rightarrow$ $\Delta\Phi = B_f A - B_i A = (B_f - B_i)A$

$= (0 - 1.2\,T)\underbrace{\pi(0.035\,m)^2}_{\text{Circle}} = (-1.2\,T)\pi(0.035\,m)^2 = -0.004618\,wb$

so $|\Delta\Phi| = 0.004618 \, wb$

$\mathcal{E}_{IND} = \frac{|\Delta\Phi|}{\Delta t}$ ∴ $0.0066V = \frac{0.004618 \, wb}{\Delta t}$ ∴ $\Delta t = \frac{0.004618 \, wb}{0.0066V}$

∴ $\Delta t = 0.699718 s = 0.7 s$

d) IF Δt MADE SMALLER THAN $\mathcal{E}_{IND}$ would be bigger, so I_{IND} would Also be bigger.

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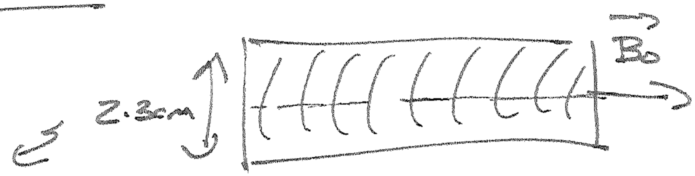


radius
$r = 1.15cm = 0.0115m$

$N = 1000$

$B_i = 0.15T$, $B_f = 0$

$\Delta t = 12ms = 12(1\times10^{-3}s)$
$= 0.012\,s$

$\vec{B}_0$ is parallel to Axis $\Rightarrow$ Angle Between them is ϕ

$$\Rightarrow \Phi = AB\cos 0^\circ = AB = \pi r^2 B$$

$$\mathcal{E}_{IND} = N\left|\frac{\Delta\Phi}{\Delta t}\right| = N\left|\frac{\pi r^2 B_f - \pi r^2 B_i}{\Delta t}\right| = N\left|\frac{0 - \pi r^2 B_i}{\Delta t}\right| = N\left|\frac{-\pi r^2 B_i}{\Delta t}\right|$$

$$\Rightarrow \mathcal{E}_{IND} = +\frac{N\pi r^2 B_i}{\Delta t} = \frac{(1000)\pi(0.115m)^2(0.15T)}{(0.012s)}$$

$$\Rightarrow \mathcal{E}_{IND} = \cancel{519.34}\ 5.193V \Rightarrow \mathcal{E}_{IND} = 5.2V$$

25.19

$25\text{mm} = \frac{25}{1000}\text{m} = 0.025\text{m}$, so radius, $r = 0.0125\text{m}$

Eyeball!

$$\frac{\Delta B}{\Delta t} = 50\,T/s$$

The max EMF would occur with $\Phi = AB\cos 0^\circ = AB$

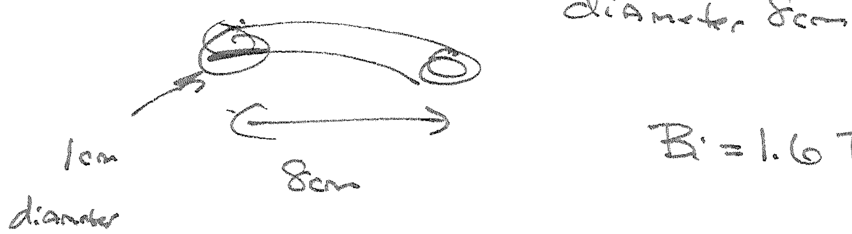
$$\varepsilon_{ind} = \left|\frac{\Delta \Phi}{\Delta t}\right| = \left|\frac{\Delta}{\Delta t}(AB)\right| = A\frac{\Delta B}{\Delta t} = \underbrace{\pi r^2}_{\text{Circle}}\frac{\Delta B}{\Delta t}$$

$$\therefore\ \varepsilon_{ind} = \pi(0.0125\text{m})^2(50\,T/s) = 0.0245\,V = 0.025\,V$$

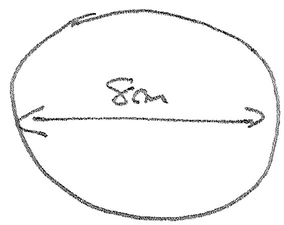
$$0.025\,V \times \frac{1000\,mV}{V} = 25\,mV$$ ← Enough to trigger an action potential.

Note: I simplified this problem on Mastering, so

25. 61 there ARE EXTRA Calculations in these Solutions.



$B_i = 1.6\,T \quad B_f = 0\,T$ in $0.3\,s$



TO FIND FLUX THROUGH THE loop, we USE 8cm diameter $\Rightarrow$ 4cm radius

$\Rightarrow r = 0.04m$

MAX INDUCED EMF OCCURS WITH $\theta = 0°$, $\Phi = BA\cos 0° = BA$

$= B\pi r^2$

$\therefore \quad \Delta\Phi = B_f\pi r^2 - B_i\pi r^2 = 0 - B_i\pi r^2 = -B_i\pi r^2$

but $|\Delta\Phi| = +B_i\pi r^2$

$\mathcal{E}_{IND} = \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{B_i\pi r^2}{\Delta t} = \frac{(1.6T)\pi(0.04m)^2}{0.3s} = 0.0268V$

Just 1 Loop

Power Dissipated $P = I^2R$ ~~$+ \mathcal{E}_{IND}$~~ OR $\frac{\Delta V^2}{R}$ $\Delta V = \mathcal{E}_{IND}$

To Find R: $R = \frac{\rho L}{A_{cs}}$

A_{cs} ← Cross-Sectional Area

So $A_{cs} = \pi r_{cs}^2$

r_{cs} ← RADIUS of Crosssection

$\Rightarrow \frac{1cm}{2} = 0.5cm = 0.005m$

L = LENGTH of Loop = Circumference = π diameter = $\pi(0.08m)$ ← 8cm

$$\therefore R = \frac{(13\,\Omega\cdot m)(\cancel{\pi})(0.08m)}{\cancel{\pi}(0.005m)^2} = 41600\,\Omega$$

$$P = \frac{(0.0268V)^2}{41600\Omega} = 1.726\times10^{-8}\,\text{Watt}$$

$$P = \frac{\text{Energy}}{\text{time}} = \frac{Q}{\Delta t}$$ ← Heat

$$\Rightarrow Q = P\Delta t = (1.726\times10^{-8}\,\text{Watt})(0.3s)$$

$$= 5.1796\times10^{-9}\,J$$

$$= 5.2\times10^{-9}\,J$$

b) $Q = mc\Delta T$ m = density × Volume = density × $(\pi r_{cs}^2)(L)$

(πr_{cs}^2) ← Area of Cross-section

(L) ← Length = Circumference

$\therefore \quad m = \text{density} \times \pi r_{cs}^2 \times \pi \text{ diameter}$

$$m = 1.1\times10^{3}\,\frac{kg}{m^3} \times \pi(0.005m)^2 \times \pi(0.08m)$$

$$= (1.1\times10^{3}\,\tfrac{kg}{m^3})(1.97\times10^{-5}\,m^3) = 0.0217\,kg$$

Finally, $\Delta T = \dfrac{Q}{mc} = \dfrac{5.2\times10^{-9}\,J}{(0.0217\,kg)(3600\,J/kg\cdot K)} = 6.65\times10^{-11}\,K$

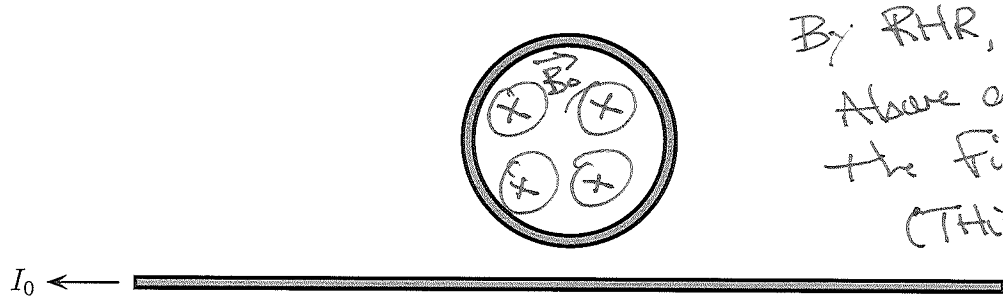
$$= 6.7\times10^{-11}\,K$$

$$= 6.7\times10^{-11}\,°C$$

IN OTHER WORDS, NOT AT ALL!

Written Question #1: A long straight wire has current I_0 flowing through it as shown. Above the wire, but in the same plane, is a wire loop. Due to changes in the straight wire's magnetic field, $\vec{B}_0$, a current will be induced in the loop.

Fill in the following table giving the directions of the straight wire's field $\vec{B}_0$ (at the loop's location), the induced magnetic field in the loop $\vec{B}_{Ind}$, and the loop's induced current I_{Ind} under the following conditions. (If there is no induced field or current, simply write "None".) For full points, you must include an explanation of how you determined your answers.



By RHR, at any point above a straight wire, the field is into page. (This flips to be ⊙ when current I_0 changes direction)

to change direction $\vec{B}_0$ must first decrease ⇒ $\vec{B}_{Ind}$ = ⊗, then it must increase while being ⊙. ⇒ $\vec{B}_{Ind}$ = ⊗ still

Condition	Direction of $\vec{B}_0$	Direction of $\vec{B}_{Ind}$	Direction of I_{Ind}
I_0 is constant	⊗	NONE	NONE
I_0 is increasing	⊗	⊙	Counterclockwise
I_0 is decreasing	⊗	⊗	Clockwise
I_0 suddenly switches direction	From ⊗ to ⊙	⊗	clockwise

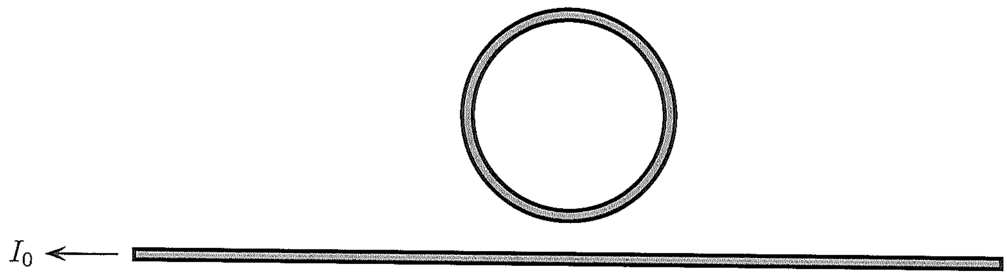
$B_0 = \frac{\mu_0 I_0}{2\pi r}$ for straight wire ⇒ Flux directly prop. to I_0

I_0 constant ⇒ Constant Flux ⇒ No induction

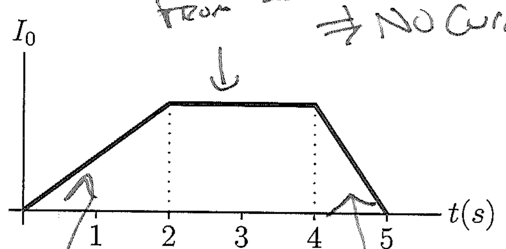
I_0 increasing ⇒ increasing Flux. Lenz's Law ⇒ $\vec{B}_{Ind}$ tries to cancel by being ⊙, RHR for current loop ⇒ CCW I_{Ind}

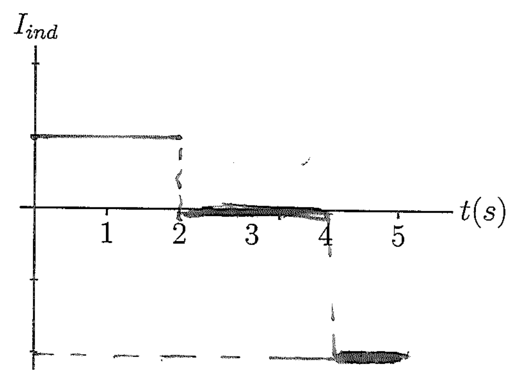
I_0 is decreasing ⇒ DECREASING Flux ⇒ $\vec{B}_{Ind}$ tries to maintain by being ⊗ ⇒ Clockwise I_{Ind}

Written Question #2: For the same wire and loop as in question #1, the current through the straight wire changes in time as shown by the graph. Sketch the corresponding graph for the loop's induced current. Graph counter-clockwise induced current as positive. There are no numbers on the vertical axis (and you don't have enough information to determine them), but your graph should have the correct shape and relative values. (The field of the straight wire is not uniform, so finding the flux through the loop is tricky. It can be shown, however, that the amount of flux is directly proportional to the current I_0.)



From 2s to 4s, constant I_0 ⇒ No Current





From 0 to 2s increasing I_0 ⇒ Counterclockwise current (#1 tells us this.) ⇒ positive. Straight line ⇒ constant slope ⇒ constant $\mathcal{E}_{ind}$ and $I_{ind} = \frac{\mathcal{E}_{ind}}{R}$ ⇒ constant I_{ind} ⇒ positive Horizontal Line

From 4s to 5s, I_0 decreasing ⇒ clockwise current ⇒ "Negative" @ straight line ⇒ Negative horizontal I_{ind}

Steeper slope ⇒ Larger $\mathcal{E}_{ind}$ and Larger I_{ind}