

Solutions to Tutorial Problems

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ex. 2 (Knight ex. 34.4)

$$P_{\text{source}} = 0.60 \text{ W} \quad \text{at} \quad 1.9 \text{ GHz}, \quad d = 10 \text{ cm}$$

$$I = \frac{P_{\text{source}}}{4\pi r^2} = \frac{0.60 \text{ W}}{4\pi (0.10 \text{ m})^2} = 4.78 \text{ W/m}^2$$

$$I = \frac{c\epsilon_0}{2} E_0^2 \rightarrow E_0 = \sqrt{\frac{2I}{c\epsilon_0}} = \sqrt{\frac{2(4.78 \text{ W/m}^2)}{(3.00 \times 10^8 \text{ m/s})(8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2)}} = 60 \text{ V/m}$$

$$B_0 = \frac{E_0}{c} = \frac{60 \text{ V/m}}{3.00 \times 10^8 \text{ m/s}} = 2.0 \times 10^{-7} \frac{\text{V}\cdot\text{s}}{\text{m}^2} = 0.2 \text{ } \mu\text{T}$$

→ Note that since $E_0 \gg B_0$, the interaction of EM waves w/ respect to matter is due primarily to the electric field

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ex. 1 (Knight ex. 33.6)

1 By the right-hand rule, the magnetic field of the upper loop points up. It decreases rapidly after the switch is opened.

2 The field due to the upper loop passes through the lower loop. It creates a flux through the lower loop that is up and decreasing.

3 The induced field needs to point upward to oppose the change in flux.

4 A new current induces an upward magnetic field.

Switch opens.

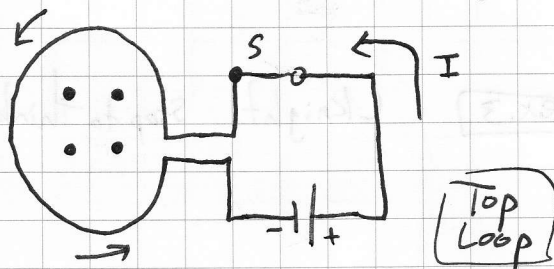
Current is dropping fast.

Induced current

\vec{B}

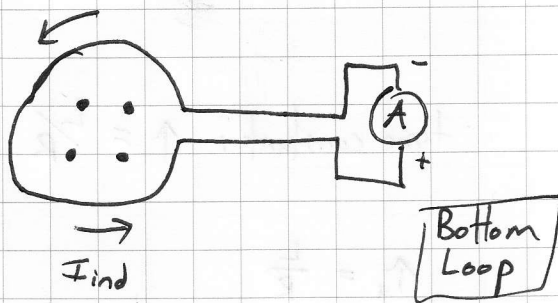
\vec{B}_{induced}

- Use RHR to show field in upper loop points up (or out of the page as drawn here)



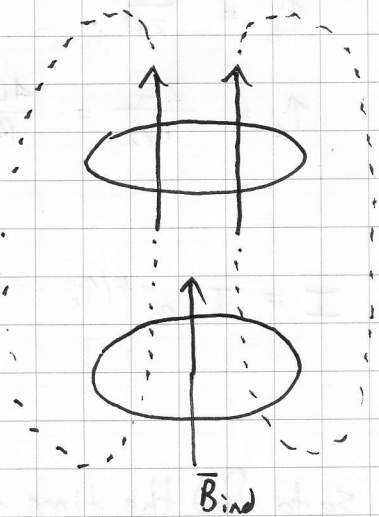
- Opening switch cause rapid decrease in current and therefore a rapid decrease in the magnetic flux

- Such will also cause a decrease in the (upward) magnetic flux through the bottom loop



- Via Faraday's Law and Lenz's Law (i.e. $\mathcal{E} = -\frac{d\Phi_m}{dt}$), a current will be induced in the lower loop so to resist the change in the flux. To do such, that induced field must point upwards (so to oppose the change in flux)

- Seen from above, this is then a CCW current (or a positive one as shown by the way the ammeter is connected)

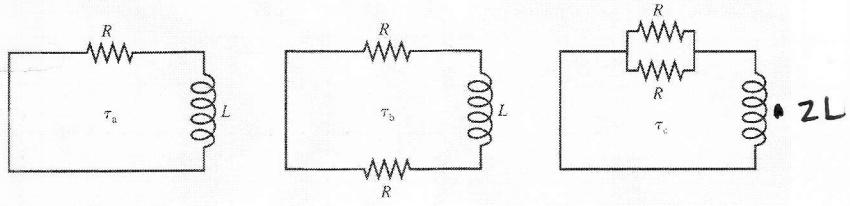


NOTE: If leads to ammeter were flipped, the sign ~~direction~~ of the current would also flip.

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ex. 3

(knight 'stop to think' 33.7 modified)



time constant: $\tau = L/R$

$$\tau_a = \frac{L}{R}$$

$$\tau_b = \frac{L}{2R}$$

$$\tau_c = \frac{2L}{R/2} = \frac{4L}{R}$$

so $\tau_c > \tau_a > \tau_b$

therefore circuit c will be the slowest

$$I = I_0 e^{-t/\tau_c} \quad \text{NOTE } I_0 = \frac{V_0}{R_{eq}} = \frac{2V_0}{R} \quad (\text{since } R_{eq} = \frac{R}{2} \text{ for circuit c})$$

so to find the time to reach 10%, we simply have

$$t_{10} = -\tau_c \ln(0.1) = -\frac{4L}{R} \ln(0.1)$$

$$I(t_{10}) = \frac{2V_0}{R} \underbrace{e^{-t_{10}/\tau_c}}_{=0.1} = 0.2 \frac{V_0}{R}$$

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