Week 8 Homework

Physics 1B

February 28, 2007

1 Serway 20.1

An emf is caused by a change in flux, which can be produced by a change in magnetic field strength, magnetic field direction, or area perpendicular to the magnetic field. Since the magnetic field in this problem is constant (not changing in magnitude or direction), an emf can only be produced by changing the area perpendicular to the magnetic field. This amounts to rotating the loop or changing its area.

2 Serway 20.2

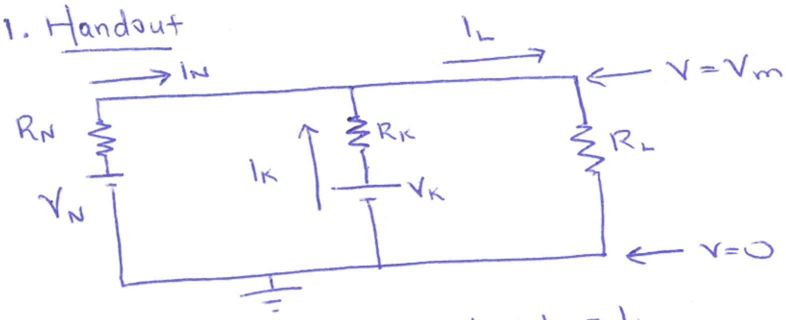
Yes. A falling magnet would create a magnetic field which changed in time, causing magnetic flux. This flux would induce an emf, the emf inducing current in the tube.

3 Serway 20.7

If the magnetic field was constant and the wearer of the bracelet perfectly still, no problem would occur. However, if the bracelet wearer moved or the magnetic field changed, this would cause a change in flux which would induce an emf in the bracelet. If the bracelet was a continuous band, this would create a large current, causing the bracelet to heat up. If the bracelet had a gap, the high voltage difference across the gap could cause charge carriers to jump across the gap (this is called an arc).

1B HW Week 8

1. Handout



① Junction rule: $I_N + I_K = I_L$

② Loop rule (outer loop): $V_N - I_N R_N - I_L R_L = 0$

③ Loop rule (right loop): $V_K - I_K R_K - I_L R_L = 0$

∘ Method: Because the voltage across R_L is $V_{membrane}$ and $V_{membrane}$ then is $I_L R_L$, we use the above 3 equations to find I_L. Then we use $V_{membrane} = I_L R_L$ to find $V_{membrane}$

∘ Combining ① (in form $I_K = I_L - I_N$) and ③,

$$V_K - (I_L - I_N) R_K - I_L R_L = 0$$

$$I_N = \frac{I_L (R_L + R_K) - V_K}{R_K}$$

∘ Combining I_N and ②,

$$V_N - \left[\frac{I_L(R_L + R_K) - V_K}{R_K}\right] R_N - I_L R_L = 0$$

$$I_L R_L + I_L \left(\frac{R_L + R_K}{R_K}\right) R_N = V_N - V_K \left(\frac{R_N}{R_K}\right)$$

$$I_L \left[R_L R_K + (R_L + R_K) R_N\right] = V_N R_K - V_K R_N$$

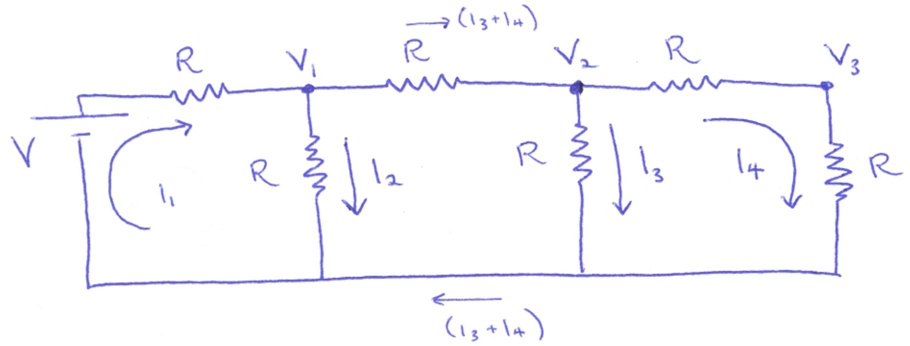
$$I_L = \frac{V_N R_K - V_K R_N}{R_L R_K + (R_L + R_K) R_N}$$

∘ Substituting into $V_{membrane} = I_L R_L$,

$$\boxed{V_{membrane} = \left[\frac{V_N R_K - V_K R_N}{R_L R_K + (R_L + R_K) R_N}\right] R_L}$$

IB Week 8 HW Handout

2.



Using the junction rule & $V=IR$,

① $I_1 = I_2 + I_3 + I_4$

② $I_1 = \frac{V-V_1}{R}$ (top left resistor) ③ $I_2 = \frac{V_1}{R}$ ④ $I_3 = \frac{V_2}{R}$ ⑤ $I_4 = \frac{V_3}{R}$ (right-most resistor)

⑦ $I_3 + I_4 = \frac{V_1 - V_2}{R}$ (middle top resistor) ⑥ $I_4 = \frac{V_2 - V_3}{R}$ (top right resistor)

Important physics ↑

Math—no physics ↓

Combining the above equations:

- ①–⑤ $V - V_1 = V_1 + V_2 + V_3$
  $2V_1 = V - V_2 - V_3$ (△)
- ⑤ & ⑥ $V_3 = V_2 - V_3$
  $V_2 = 2V_3$ (○)
- ④, ⑤, & ⑦ $V_2 + V_3 = V_1 - V_2$
  $2V_2 = V_1 - V_3$ (□)
- (○) & (□) $4V_3 = V_1 - V_3$
  $V_1 = 5V_3$ (♡)
- (△), (○), (♡) $2(5V_3) = V - 2V_3 - V_3$

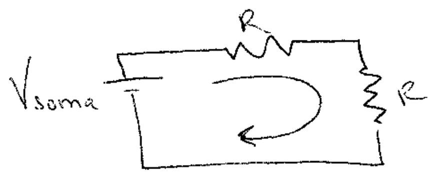
$$\boxed{V_3 = \frac{1}{13}V}$$

$$\boxed{V_1 = \frac{5}{13}V}$$

$$\boxed{V_2 = \frac{2}{13}V}$$

Week 8 HW Handout

3. In steady state (once the capacitor is charged, no current flows through the capacitor. The same current flows through both resistors.



Using Kirchoff's loop rules,

$$V_{soma} - IR - IR = 0$$

$$V_{soma} - 2IR = 0$$

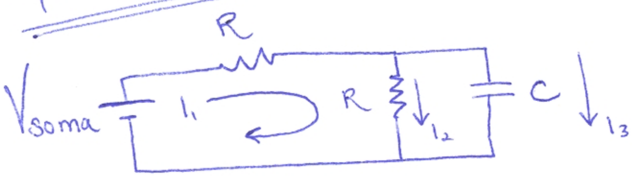
$$IR = \frac{1}{2} V_{soma}$$

= Voltage dropped across resistor R.

- Since the left resistor and capacitor are in parallel, the same voltage drops across both. $\therefore V_{cap} = \frac{1}{2} V_{soma}$

1B Week 8 HW

Handout #4



- Using the junction rule, $I_1 = I_2 + I_3$ (1)
- Using the loop rule, $V_{soma} - I_1 R - I_2 R = 0$ (2)

$$I_1 = -I_2 + \frac{V_{soma}}{R}$$

- Because the voltages across the capacitor and right resistor must be the same (because they are in parallel), $I_2 R = \frac{Q_3}{C}$. (3)

- Substitute (2) and (3) into (1)

$$-I_2 + \frac{V_{soma}}{R} = I_2 + I_3$$

$$\frac{-Q_3}{RC} + \frac{V_{soma}}{R} = \frac{Q_3}{RC} + I_3$$

- Recalling that current $I = \frac{\Delta Q}{\Delta t}$

$$\frac{\Delta Q_3}{\Delta t} + \left(\frac{2}{RC}\right) Q_3 = \frac{V_{soma}}{R}$$

- Comparing to the RC handout, we see $\tau = \frac{RC}{2}$ (inverse of the coefficient of Q_3). This makes sense because the capacitor only gets half as charged as it would in the absence of the parallel resistor.

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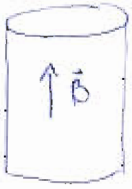
6. 

The magnetic field created in our solenoid is parallel to the axis of the solenoid, so θ in our definition of magnetic flux is 0. (θ is the angle between the line perpendicular to the area we're finding the flux through and the magnetic field.)

$$\Phi_B \equiv BA\cos\theta \; (= B_\perp A)$$

$B_{solenoid} = \mu_0 n I$ — n → turns per unit length

$$= (4\pi \times 10^{-7}\ T\cdot m/A)\left(\frac{250\ turns}{20.0 \times 10^{-2}\ m}\right)(15.0\ A)$$

$$= 2.356 \times 10^{-2}\ T$$

$$A = \pi r^2$$

$$= \pi\left(\frac{4.00 \times 10^{-2}\ m}{2}\right)^2$$

$$= 1.257 \times 10^{-3}\ m^2$$

$$\boxed{\Phi_B = 2.96 \times 10^{-5}\ Wb}$$

7. a) The normal of the shaded face points along $-\hat{x}$ (by convention, it points toward the outside of a surface).

$\Phi_B \equiv B_\perp A$ where $B_\perp$ is the component of B along the normal to the surface

$\therefore B_\perp = B_x$

$$\Phi_B = (5.0\ T)(2.5 \times 10^{-2}\ m)^2$$

$$\boxed{\Phi_B = 3.1 \times 10^{-3}\ Wb}$$

b) Since the field is constant, every field line that enters the cube also exits the cube.

$\therefore$ $\boxed{\Phi_B = 0}$ for the sum of all the sides.

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8. $\mathcal{E} = -N \dfrac{\Delta \Phi_B}{\Delta t}$

$\Delta t = 120 \times 10^{-3}$ s

$\Delta \Phi_{B_{max}} = (1.5\ T)[\pi \cdot (1.6 \times 10^{-3}\ m)^2] \cos 0 = 1.206 \times 10^{-5}$ Wb

$\Phi_{B min} = 0$

$\Delta \Phi_B = 1.206 \times 10^{-5}$ Wb

$N = 1$

$\mathcal{E} = -(1) \dfrac{(1.206 \times 10^{-5}\ Wb)}{120 \times 10^{-3}\ s}$

$\boxed{\mathcal{E} = -1.0 \times 10^{-4}\ V}$

10. Assuming the loop always stays in the plane of the paper so that the angle btwn the loop's perpendicular and $\vec{B}$ is zero,

$\mathcal{E} = -N \dfrac{\Delta \Phi_B}{\Delta t}$

$N = 1$

$\Delta \Phi_B = B \Delta A \cos \theta = (0.15\ T)[\pi (12 \times 10^{-2}\ m)^2] \cos 0 = 6.786 \times 10^{-3}$ W

$\Delta t = 0.20$ s

$\mathcal{E} = -(1) \dfrac{(6.786 \times 10^{-3}\ Wb)}{0.20\ s}$

$\boxed{\mathcal{E} = -0.034\ V}$