Physics 10164 - Exam #3C

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box. If you give more than one answer without indicating which is correct, you will definitely lose points, even if one answer is correct.

1. (30 pts) A RL circuit contains a 15 Ohm resistor, a 33 mH inductor, an open switch and a 24 Volt battery. At t = 0, the switch is closed, connecting the circuit.

a) What is the voltage drop across the resistor after 1 time constant has elapsed?

b) What is the voltage drop across the inductor at this time?

c) At what time t is the voltage drop across the inductor equal to 5.0% of its maximum possible value?

a) $I_{max} = \frac{\mathcal{E}_{max}}{R} = \frac{24}{15} = 1.6\,A$

$I = I_{max}(1 - e^{-t/\tau})$

$I = 1.6(1 - e^{-1}) = 1.0\,A$

$\Delta V_R = IR = \boxed{15\,V}$ $\qquad \tau = \frac{L}{R}$

b) $\boxed{\Delta V_L = 9\,V}$ (loop rule) $\qquad = .0022$

c) $\mathcal{E}_L = \mathcal{E}_{L,MAX}\, e^{-t/\tau}$

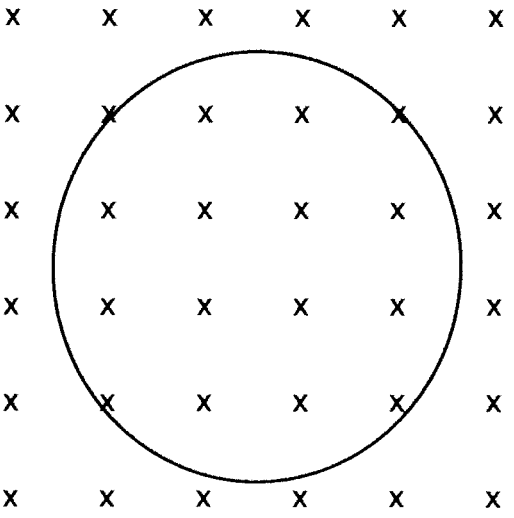
$\frac{\mathcal{E}_L}{\mathcal{E}_{L,MAX}} = .05 = e^{-t/.0022}$

$\ln .05 = -\frac{t}{.0022}$ $\qquad \boxed{t = .0066\,s}$

2. (30 pts) A single-turn, circular wire loop of radius 3.5 cm is placed in an external magnetic field of 5.0 Tesla pointing into the page and perpendicular to the plane of the loop. The loop has a resistance of 0.045 Ohms.

The loop is rotated in such a way that the top part comes out of the page and the bottom part falls into the page. It is rotated through an angle of 90 degrees in 0.50 seconds.

During this time interval, what is the magnitude and direction of the induced current in the loop? Be sure to fully justify your answer (show work, explain reasoning) for both parts.



$\Phi = X$

$\Delta\Phi$ = decreasing

So $B_{ind} = X$

I_{ind} = CW

$$\mathcal{E}_{ind} = N\frac{\Delta\Phi}{\Delta t} = \frac{(N)BA\Delta\cos\theta}{\Delta t}$$

$$= \frac{(1)(5.0)\pi(.035)^2(1)}{0.50} = .0385$$

$$I_{ind} = \frac{\mathcal{E}_{ind}}{R} = \frac{.0385}{.045} = 0.86\ A$$

3. (40 pts) A power plant generator provides 3.0 million Watts of power along two lines with a voltage difference of 1250 Volts (rms). A transformer is used to step the voltage up to 500,000 Volts (rms) to transmit the power down a line with a resistance of 250 Ohms.

a) If the coil from the generator has 12 turns, how many turns is in the coil providing the output voltage for the power line?

b) What is the percentage of power lost in the line as a result of resistive heating?

c) The voltage is stepped back down to an rms value of 240 Volts. This alternating voltage powers a circuit with a 25 μF capacitor, a 75 mF inductor and a 12 Ohm resistor. If this circuit is driven at a frequency of 60 Hz, what is the power dissipated?

a) $\mathcal{E}_{out} = \frac{N_{out}}{N_{in}} \mathcal{E}_{in}$

$500{,}000 = \frac{N_{out}}{12}(1250)$

$N_{out} = \frac{12(500{,}000)}{1250} = \boxed{4800}$

b) $3.0 \times 10^6 = I_{out}(500{,}000)$

$I_{out} = 6.0\,A$

$P = I^2R = (36)(250) = 9000$

$\%\ loss = 100 \times \frac{9000}{3 \times 10^6} = \boxed{0.30\ \%}$

c) $X_L = 2\pi fL = 28.3$

$X_C = \frac{1}{2\pi fC} = 106.1$

$Z = \sqrt{12^2 + (28.3 - 106.1)^2}$

$= 78.7$

$I_{rms} = \frac{\mathcal{E}_{rms}}{Z} = \frac{240}{78.7} = 3.05\,A$

$P = I^2R = (3.05)^2(12)$

$= \boxed{110\ W}$