Physics 10164 - Exam 3B

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 and remember to include correct units and significant figures.

1. (30 pts) A direct current circuit contains a 12 Volt battery, a resistor and a 0.14 H inductor. At t = 0, a switch is closed, connecting the circuit.

a) After 0.040 seconds have passed, the voltage drop across the resistor is 5.0 Volts. What is the resistance of the resistor?

b) When the current is changing at a rate ($\Delta I/\Delta t$) of 25 A/s, what is the voltage drop across the inductor?

c) What is the voltage drop across the resistor at this time?

d) At what time is $\Delta I/\Delta t$ equal to 25 A/s?

a) $\Delta V_R = \mathcal{E}(1 - e^{-t/\tau})$

$5 = 12(1 - e^{-.04/\tau})$

$0.417 = 1 - e^{-.04/\tau}$

$-.583 = e^{-.04/\tau}$

$-.540 = -\frac{.04}{\tau}$

$\tau = .074 = \frac{L}{R}$

$R = \frac{.14}{.074} = \boxed{1.9\,\Omega}$

b) $\Delta V_L = L\frac{\Delta I}{\Delta t}$

$= (.14)(25) = \boxed{3.5\ V}$

c) $\boxed{\Delta V_R = 8.5\ V}$ due to loop rule

d) $\Delta V_L = \mathcal{E} e^{-t/\tau}$

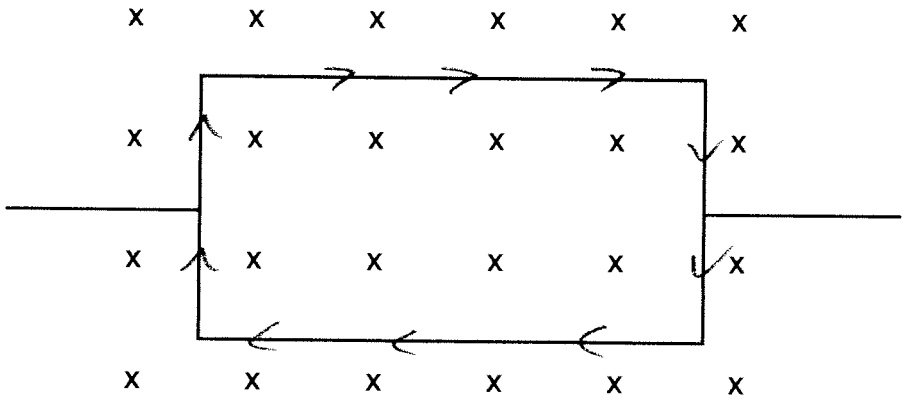
$3.5 = 12\, e^{-t/.074}$

$0.292 = e^{-t/.074}$

$-1.23 = -\frac{t}{.074}$

$\boxed{t = .091\ s}$

2. (30 pts) A rectangular loop measuring 25 cm by 42 cm has 850 turns and is in an external 1.5 Tesla magnetic field. The angular speed of the loop is 24 rad/sec. The initial position of the loop with respect to the external field is shown below.



a) In the first 0.065 seconds of its motion, the loop rotates so that the top of the loop comes out of the page toward you and the bottom of the loop goes into the page. During this time, what is the magnitude of the induced emf in the loop and the direction of the induced current in the loop? Explain your direction choice.

b) What is the rms value of the induced EMF in the loop as it rotates through a complete cycle?

a) $T = \frac{2\pi}{24} = 0.262$ sec

0.065 sec is $\frac{1}{4}$ cycle, so $\cos\theta$ goes from $1 \rightarrow 0$

$N\Phi_i = NBA\cos\theta = (850)(1.5)(.25)(.42)(1) = 134$

$N\Phi_f = 0$

$\mathcal{E}_{ind} = \frac{N\Delta\Phi}{\Delta t} = \frac{134}{.065} = \boxed{2060\ V}$ or $\boxed{2100\ V}$

$\Phi = \times$, decreasing, so $\mathcal{B}_{ind} = \times$ $\boxed{I_{ind} = cw}$

b) $\mathcal{E}_{max} = NBA\omega$

$= (850)(1.5)(.25)(.42)(24) = 3213\ V$

$\mathcal{E}_{rms} = .707\mathcal{E}_{max} = \boxed{2270\ V}$

3. (40 pts) A series AC circuit contains a 150 Volt rms source, a 5.0 Ohm resistor and a 1.4 H inductor. A blank page has been added to the end of the exam if you need extra room for this one.

a) What is the maximum current for this circuit if it is operated at a frequency of 22 Hz?

b) When the current is equal to this maximum value, what is the voltage drop across the resistor, the power source and the inductor? Explain your reasoning for each, briefly.

c) If a 95 mF capacitor is added to the circuit, what is the rms current if the circuit is operated at its resonant frequency?

d) If the frequency is reduced to a value equal to 85% of the resonant frequency, what is the new rms current?

a) $X_L = 2\pi f L = 193.5\ \Omega$

$Z = \sqrt{5^2 + 193.5^2} = 193.6\ \Omega$

$I_{rms} = \frac{\mathcal{E}_{rms}}{Z} = 0.77\ A$

$I_{max} = \frac{I_{rms}}{.707} = \boxed{1.1\ A}$

b) When $I = I_{max}$

$\Delta V_R = (1.1)(R) = \boxed{5.5\ V}$

$\boxed{\Delta V_L = 0}$ because $\frac{\Delta I}{\Delta t} = 0$

Loop rule says $\Delta V_{source} = \boxed{5.5\ V}$

c) At resonance, $Z = R$

$I_{rms} = \frac{150}{5} = \boxed{30\ A}$

d) $f = \frac{1}{2\pi\sqrt{LC}} = 0.436\ Hz$

$f_{new} = 0.371\ Hz$

$X_L = 2\pi f L = 3.26\ \Omega$

$X_C = \frac{1}{2\pi f C} = 4.52\ \Omega$

$Z = \sqrt{5^2 + (3.26 - 4.52)^2}$

$= 5.155$

$I_{rms} = \frac{150}{5.155} = \boxed{29\ A}$