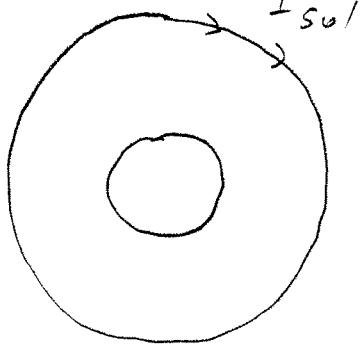
Physics 10164 - Exam 3

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. (20 pts) A single-turn circular wire loop of diameter 10 cm is oriented coaxially with a 300 turn solenoid, so the cross-sectional areas of the loop and solenoid are parallel. The solenoid is 30 cm in length and carries a current of 5.0 Amps in a clockwise direction, and the wire loop is completely within the solenoid.

The current in the solenoid drops to zero in 0.25 seconds. Determine the magnitude of the average induced EMF in the wire loop and the direction of the induced current in the wire loop during this time interval.



$$B_{sol} = \frac{\mu_0 N I}{L} = \frac{(4\pi \times 10^{-7})(300)(5)}{0.30}$$

$$= .0063\,T$$

$$\Delta B = .0063$$

$$|\mathcal{E}_{ind}| = N \frac{\Delta \Phi_B}{\Delta t}$$

$$= (1)\left(\frac{(.0063)\pi(.05)^2}{0.25}\right)$$

$$= \boxed{1.98 \times 10^{-4}\ \text{Volts}}$$

Since I_{sol} is cw, Φ_B initially is (⊗)

$\Delta \Phi_B$ is ⊗ decreasing

So B_{ind} will be (⊗)

and I_{ind} will be clockwise

2. (30 pts) A circuit contains a 12 Volt DC battery, a 3.0 Ohm resistor and an inductor, initially with no current flowing. At t = 0, a switch is closed, and current begins to flow. After 1.2 seconds, the voltage drop across the resistor is measured to be 5.0 Volts.

a) What is the inductance, L, of the inductor?

b) What is the voltage drop across the inductor at t = 1.2 sec?

If $\Delta V_R = 5.0\ V$, then $\boxed{\Delta V_L = 7.0\ V}$ (loop rule)

$$\Delta V_L = \mathcal{E}_{max} e^{-t/\tau}$$

$$7.0 = 12\, e^{-t/\tau}$$

$$\ln .583 = -\frac{1.2}{\tau}$$

$$\tau = 2.23 = \frac{L}{R}$$

$$L = 2.23R = \boxed{6.7\ H}$$

3. (20 pts) A series RLC circuit has R = 12 Ohms, L = 0.25 H and C = 45 μF. The maximum voltage provided by the AC power source is 310 Volts.

a) Find the resonant frequency of this circuit.

b) Determine the power dissipated by the resistor when the circuit is operated at the resonant frequency.

c) Determine the power dissipated by the resistor when the circuit is operated at one half the resonant frequency.

a) $f_0 = \frac{1}{2\pi\sqrt{LC}} = 47.45\ Hz$ or **47 Hz**

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b) $\mathcal{E}_{rms} = .707\,\mathcal{E}_{max} = 219\ V$

$I_{rms} = \frac{\mathcal{E}_{rms}}{Z} = \frac{219}{12}$ ← $Z = R$ at resonance

$= 18.26\ A$

$P = I_{rms}^2 R =$ **4000 Watts**

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c) $f = 23.73\ Hz$

$X_L = 2\pi(.25)(23.73) = 37.3\ \Omega$

$X_C = \frac{1}{2\pi(23.73)(45\times10^{-6})} = 149\ \Omega$

$Z = \sqrt{12^2 + (112)^2} = 112.4\ \Omega$

$I_{rms} = \frac{219}{112.4} = 1.95\ A$

$P = I_{rms}^2 R =$ **46 Watts**

4. (30 pts) A circuit contains an AC voltage source operating at 60 Hz with maximum voltage of 170 Volts. It is connected in series with a 75 Ohm resistor and a 0.45 H inductor.

a) What is the maximum value of the current in this circuit?

b) When the current is at its maximum value, determine the voltage drop across the resistor, the inductor and the power source.

a) $I_{max} = \frac{\mathcal{E}_{max}}{Z}$ $\quad Z = \sqrt{75^2 + X_L^2}$

$X_L = 2\pi(60)(.45) = 170\ \Omega$

so $Z = 185.5\ \Omega$

$I_{max} = \frac{170}{185.5} = \boxed{0.917\ A}$

b) $\Delta V_R = I_{max} R = \boxed{68.7\ \Omega}$

$\boxed{\Delta V_L = 0}$ when $I = I_{max}$,

$\frac{\Delta I}{\Delta t} = 0$, so $\mathcal{E}_{ind} = 0$

$\boxed{\Delta V_{\mathcal{E}} = 68.7\ \Omega}$ (loop rule)