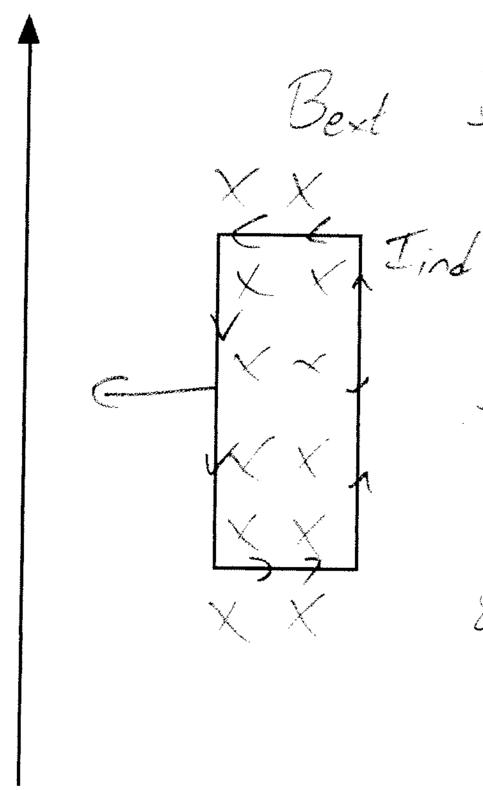
Physics 10164 - Exam 3A

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 long straight wire carries a current toward the top of the page as shown. The rectangular loop near the wire has dimensions 15 cm x 42 cm. The center of the loop moves toward the straight wire during a time interval of 0.33 seconds, and during this time the magnitude of the magnetic field in the loop due to the long straight wire increases from 7.5 T to 17 T.

If the loop has a resistance of 0.22 Ohms, determine the magnitude and direction of the induced current in the loop during this time.



B_{ext}

$\Phi_i = BA\cos\theta$

$= (7.5)(.15)(.42)(1)$

$= 0.4725$

$\Phi_f = (17)(.15)(.42)(1)$

$= 1.071$

$\mathcal{E}_{ind} = \frac{\Delta\Phi_B}{\Delta t} = \frac{1.071 - .473}{0.33}$

$= 1.81$ Volts

$I_{ind} = \frac{1.81}{.22} = \boxed{8.2\ A}$

$\Phi = \times$, increasing

$\Rightarrow B_{ind} = \odot$

$\Rightarrow \boxed{I_{ind} = CCW}$

2. (30 pts) A series circuit contains a 12 Volt battery, a 5.0 Ohm resistor, and a 0.250 H inductor. A switch is closed at t=0, connecting the circuit.

a) What is the voltage drop across the inductor just after the switch is closed?

b) At what time after the switch is closed is the voltage drop across the inductor equal to the voltage drop across the resistor?

c) After three time constants have passed, what is the voltage drop across the inductor?

a) At $t = 0$, $\Delta V_L = \Delta V_{max} = \mathcal{E} = \boxed{12\,V}$

since $\frac{\Delta I}{\Delta t} = max$

b) When $\Delta V_L = \Delta V_R$, both are 6 Volts

$\Delta V_L = \Delta V_{max} e^{-t/\tau}$

$6 = 12 e^{-t/\tau}$ $\qquad \tau = \frac{L}{R} = .05\,s$

$0.5 = e^{-t/.05}$

$-0.693 = -\frac{t}{.05}$ $\qquad \boxed{t = .035\,s}$

c) $\Delta V_L = 12 e^{-3} = \boxed{0.60 \text{ Volts}}$

3. (40 pts) A series AC circuit contains a 120 Volt rms source, a 2.0 Ohm resistor and a 120 μF capacitor. A blank page has been added to the end of the exam if you need extra room for this one.

a) What is the rms current for this circuit if it is operated at a frequency of 75 Hz?

b) When the current is zero, what is the voltage drop across the resistor, the power source and the capacitor? Explain your reasoning for each, briefly.

c) If a 0.25 Henry inductor is added to the circuit, what is the average power delivered by the source to this circuit if the circuit is operating at its resonant frequency?

d) If the frequency is increased by 25% over the resonant frequency, what is the average power delivered by the source to this circuit?

a) $X_C = \frac{1}{2\pi f C} = 17.68\ \Omega$

$Z = \sqrt{2^2 + (17.68)^2} = 17.8\ \Omega$

$I_{rms} = \frac{\mathcal{E}_{rms}}{Z} = \frac{120}{17.8} = \boxed{6.7\ A}$

b) $I_{max} = \frac{6.7}{.707} = 9.5\ A$ $\quad \Delta V_{C,MAX} = I_{max} X_C$

$= 168.6$ Volts

When $I = 0$, $\Delta V_R = 0$ (no current)

$\frac{\Delta I}{\Delta t}$ is max, so $\Delta V_C = 168.6\ V = \boxed{170\ V}$

Loop rule says $\Delta V_{source} = \boxed{170\ V}$

c) At resonance $Z = R = 2.0\ \Omega$

$I_{rms} = \frac{\mathcal{E}_{rms}}{Z} = 60\ A \quad P = I\mathcal{E} = (60)(120) = \boxed{7200\ W}$

d) $f = \frac{1}{2\pi\sqrt{LC}} = 29.06 \Rightarrow X_L = 57.05$

$f_{new} = 36.32 \qquad X_C = 36.52$

$\Rightarrow Z = \sqrt{2^2 + (20.53)^2} = 20.6$

$I_{rms} = \frac{120}{20.6} = 5.82\ A$

$P = I\mathcal{E} = \boxed{700\ W}$