Physics 116b Test 3 October 22, 2008

Name:__________________

This is a 75 minute, closed book examination. Put answers in the boxes provided (if any). If numerical answers are needed, you must include units. Any work needed to justify the answer must be shown in the space provided, or as indicated on a separate piece of paper or elsewhere on the test. A correct answer without the necessary justifying work may not receive any credit. **DO NOT** tear the formula sheet off the back of the exam.

Total points for each problem will appear in the table below and in ( ) beside each problem number. Do what is easiest first. AVOID glancing at anyone else's paper during the exam. No means of communication between other students or outside parties is allowed. **The honor code is in effect.**

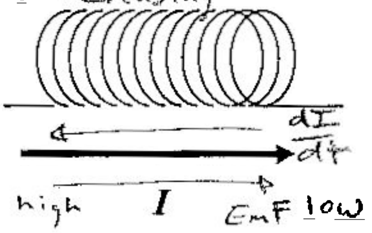
You must do all the problems on this test.

Problem	Description	Max Score	Score
1	Multi-Choice & Short Answer	37	
Total		37	

Multi-Choice & Short Answer (20 points)(Show Your Work!)

a) If the current flowing through the solenoid as shown below is decreasing, indicate the direction of ~~increasing~~ decreasing EMF on the solenoid (Explain) (3 pts).

drop



or less B in I direction, need more I to make more B, need to apply Emf as shown to get "more I"

b) An inductor is in series with a 1.0 Ohm resistor. By checking the value of the current through the resistor every 0.2 seconds after a battery is placed in series with the resistor and the inductor, you notice that it takes about 6s for the current in the resistor to reach a steady value of 1.0A on your amp-meter. Since this amp-meter is accurate to about 100mA, the current will read as 1.0 A on the amp-meter after the real current reaches about 0.95 A!) *Choose the best estimate* for the value of the inductance in the circuit, and briefly explain your reasoning. (4 pts)

I) 0.08 H
II) 12.0 H
III) 6.0 H
IV) 0.17 H
[✓ V) 2.0 H]

about 6s to get to 95% of max

$\sim 3\tau$ 3 time constants

$1 - e^{-3} = 0.95$

$3 \times 2s = 6s \quad \tau = \frac{L}{R} \Rightarrow L = (2H) = 2\Omega s$

$= \frac{L}{1\Omega}$

c) What is the self-inductance of a solenoid of length 30.0 cm, area 1.0 cm^2 and 300 turns of wire? (2 pts) Which will increase the inductance the most *for the same length of wire* : 1) doubling the turns/length OR 2) Doubling the area of each turn? (be sure to justify your answer mathematically!) (4 pts)

$L = \mu_0 n^2 A \ell$

$= \mu_0 \frac{N^2}{\ell} A = \left(4\pi \times 10^{-7} \frac{Tm}{A}\right) \frac{300^2}{.30m} 1cm^2 \left(\frac{1m}{100cm}\right)^2$

$= 120\pi \times 10^{-7} H = 3.77 \times 10^{-5} H$

$\boxed{L = 3.77 \times 10^{-5} H}$

Double the n

(N/ℓ same)

$\text{double}\left(\frac{n}{\ell}\right)$, same N but $\ell \Rightarrow \frac{\ell}{2}$

$\left(\frac{N}{(\ell/2)}\right)^2 A \frac{\ell}{2} = 2L_{orig}$

$\frac{1}{n} \quad \frac{\ell}{2\pi r_{old}\sqrt{2}} = \left(\frac{\ell}{\sqrt{2}}\right)$

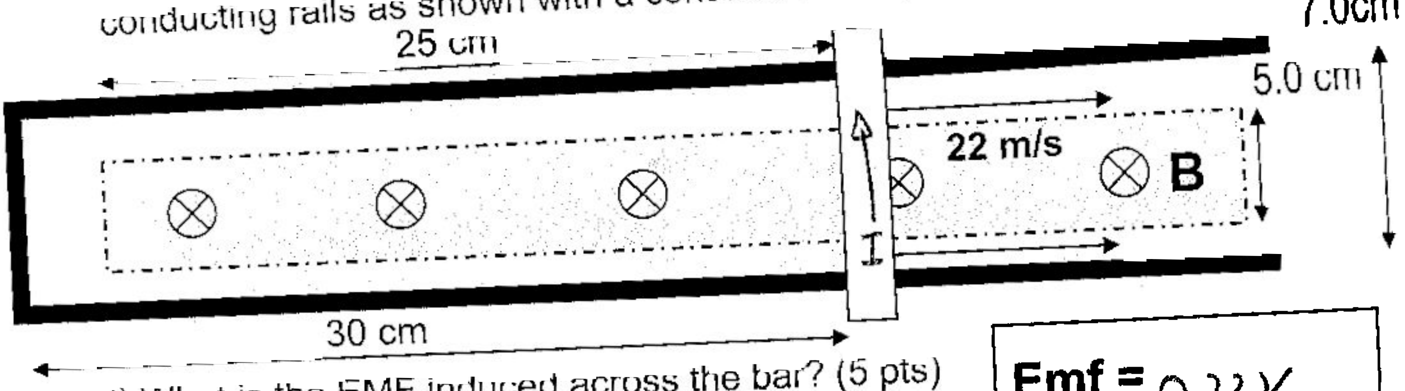
$A \Rightarrow 2A \quad L_{new} = \sqrt{2} L_{old}$

double A means increase radius by $\sqrt{2}$, circumference $= 2\pi r$

ℓ = length of wire = $N(2\pi r)$ $\quad N = (\ell / 2\pi\sqrt{2} r_{old}) \quad \ell = \left(\frac{\ell}{N}\right)_{old} N =$

Multi & Short Answer cont'd (Show Your Work!)

The B Field inside the dashed area shown below has a magnitude of 0.20T. Due to a constant applied force F, a conducting bar moves frictionlessly on conducting rails as shown with a constant velocity of 22 m/s.



d) What is the EMF induced across the bar? (5 pts)

Emf = 0.22V

$$\mathcal{E} = -\frac{d\phi_B}{dt} = -B(.05m)22m/s$$
$$= 0.20T(.05m)22m/s$$
$$= .22V$$

e) Indicate the direction current flows *through the bar* due to the induced emf. (Draw an arrow on the bar.) Explain. (3 pts)

opposes the change

- produces a force to the left
- trys to make less B by making B out of the page

f) Suppose the B field was not perpendicular to the page, but was, say, 10 degrees from being perpendicular and into the page. Assuming the bar continued along on the rail at a constant velocity (due to the same constant applied force F), would the bar have a constant speed that is faster, slower or the same? (3 pts) Explain.

- makes an angle

$F_B = I\ell B\sin\theta = F$ for constant v

so $I\uparrow$, $I\uparrow$ means $\mathcal{E}\uparrow$

$\mathcal{E} \propto v$ so v goes up too!

even worse since $\cos\theta$ term for flux

Multi-Choice & Short Answer contd (Show Your Work!)

g) A 0.2 Ohm resistance, a 1.5 mH inductor and a 2.6 mF capacitor are in series in a circuit being driven by a sinusoidally varying voltage. What is the resonance frequency of this RLC combo? (3 pts)

$$\omega^2 = \frac{1}{LC} = (2\pi f)^2$$

$\boxed{f = 81\ Hz}$

$$f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} = \frac{1}{2\pi}\frac{1}{\sqrt{0.0015\frac{s}{\Omega}\,0.0026\Omega s}} = 80.59\ /s$$

h) Above the resonance frequency, will the current through the series combination Lead or Lag the voltage supplied to the whole circuit by the driving voltage? Explain (3 pts)

series, all I same

current lags (more inductive reactance)

above $\omega L > \frac{1}{\omega C}$

i) What is the average power supplied by the voltage source at a frequency that is 10% lower than the resonance frequency? (5 pts) (Assume $V_{max} = 10V$)

$W_{res} = 506.37$ rad/s

$9\, w_{res} = 455.73$ rad/s

$$P_{avg} = \frac{V_{max}^2}{2Z}\frac{R}{Z} = \frac{10V^2}{2(0.256\Omega)^2}0.2\Omega = 152.58$$

$\boxed{P_{avg} = 152.6\ W}$

$$Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$$

$$= \sqrt{(0.2\Omega)^2 + \left((455.73\tfrac{rad}{s})(0.0015\Omega s) - \frac{1}{(455.73\frac{rad}{s} \cdot 0.0026 s/\Omega)}\right)^2} = 0.256\Omega$$

j) What is the value of the impedance when the average power drops to half of its maximum (resonance) value? (3 pts)

$\boxed{Z = 0.282\ \Omega}$

$$P_{max}\ @\ res = \frac{V_{max}^2}{2R}$$

$$P_{max} @ \frac{1}{2} P_{max} = \frac{V_{max}^2}{2Z^2} R$$

$$\frac{1}{2} = \frac{\frac{V_{max}^2}{2Z^2} R}{\frac{V_{max}}{2R}} = \frac{R^2}{Z^2}$$

$$Z^2 = 2R^2$$

$$Z = \sqrt{2}R = .282\Omega$$

Multi-Choice & Short Answer contd (Show Your Work!)

g) A 0.2 Ohm resistance, a 1.5 mH inductor and a 2.6 mF capacitor are in series in a circuit being driven by a sinusoidally varying voltage. What is the resonance frequency of this RLC combo? (3 pts)

f =

h) Above the resonance frequency, will the current through the series combination Lead or Lag the voltage supplied to the whole circuit by the driving voltage? Explain (3 pts)

i) What is the average power supplied by the voltage source (assume Vmax = 10.0V) at a frequency that is 10% lower than the resonance frequency? (5 pts)

P_{avg}=

j) What is the value of the impedance when the average power drops to half of its maximum (resonance) value? (3 pts)

Z =

k) What are the values of the frequency in part j) where this occurs? (2 pts) (note: the binomial theorem may be useful)

f = 91.9 hz, 70.7 hz

2 ways
an use φ from
revious & then
$an\phi = \frac{\omega L - \frac{1}{\omega C}}{R}$

$$\overset{Z^2}{0.282\Omega^2} = \overset{R^2}{0.2\Omega^2} + \left(\omega L - \frac{1}{\omega C}\right)^2$$

$$\Rightarrow \underbrace{\sqrt{Z^2-R^2} = \pm\left(\omega L - \frac{1}{\omega C}\right)}_{\text{can be either}} \overset{\text{choose}}{\Rightarrow} \omega \underbrace{\sqrt{Z^2-R^2}}_{y} = \left(\omega^2 L - \frac{1}{C}\right)$$

$$\omega^2 L - \omega y - \frac{1}{C} = 0$$

$$y = \sqrt{0.282^2 - 0.2^2} = 0.2\Omega! \quad Z^2 = 2R^2$$

$$y/2L = 66.66$$

$$\omega = \frac{y \pm \sqrt{y^2 + 4L/C}}{2L}$$

$$= \frac{y}{2L} \pm \sqrt{\left(\frac{y}{2L}\right)^2 + \frac{1}{LC}} = 66.66 \pm \sqrt{(66.66)^2 + (506.4)^2}$$

$$= 66.66 \pm 510.73 \quad (f \text{ must be} > 0!)$$

$$= \frac{1}{2\pi}(66.66 + 519.73) = 91.9/s$$

$$\frac{1}{2\pi}\left|(66.66 - 510.73)\right| = 70.7/s$$

Physics 116b Test 3 October 23, 2008

Name: Key

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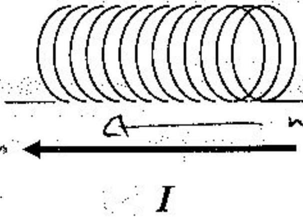
1	Multi-Choice & Short Answer	39	
Total		39	

Multi-Choice & Short Answer (Show Your Work!)

a) If the current flowing through the solenoid as shown below is decreasing, indicate the direction of decreasing EMF on the solenoid (Explain) (3 pts).

← poor word choice



drop

your explanation is where the points are ⇒

need more I this way to fight decreasing I, EMF should point this way too, so, I suppose decreasing EMF points the other way

b) An inductor is in series with a 0.50 Ohm resistor. By checking the value of the current through the resistor every 0.2 seconds after a battery is placed in series with the resistor and the inductor, you notice that it takes about 12s for the current in the resistor to reach a steady value of 1.0A on your amp-meter. Since this amp-meter is accurate to about 100mA, the current will read as 1.0 A on the amp-meter after the real current reaches about 0.95 A!) *Choose the best estimate* for the value of the inductance in the circuit, and briefly explain your reasoning. (4 pts)

[✓ I) 2.0 H]
II) 0.17 H
III) 6.0 H
IV) 12.0 H
V) 0.08 H

so, get to ~0.95A in 12s

$.95 = 1 - e^{-12/\tau}$

$\approx 1 - e^{-3}$

$3 = 12/\tau$

$\tau \sim 4 = \frac{L}{.5\Omega}$

$L \approx 2$ H

c) What is the self-inductance of a solenoid of length 20.0 cm, area 2.0 cm² and 200 turns of wire? (2 pts) Which will increase the inductance the least *for the same length of wire* : 1) doubling the turns/length OR 2) Doubling the area of each turn? (be sure to justify your answer mathematically!) (4 pts)

$L = \mu_0 n^2 A l = 4\pi \times 10^{-7} \frac{Tm}{A} \left(\frac{200}{.2m}\right)^2 (2.0cm^2) \left(\frac{1m}{100cm}\right)^2 .0.2m = 5.03 \times 10^{-5} H$

$\boxed{L = 5.03 \times 10^{-5} H}$

Double the Area

units of L are Ωs

B are $\left(\frac{V \cdot s}{m^2}\right)$ or T from $\mathcal{E} \propto \frac{BA}{time}$

w/a set length of wire $N = \frac{length}{(2\pi r)}$

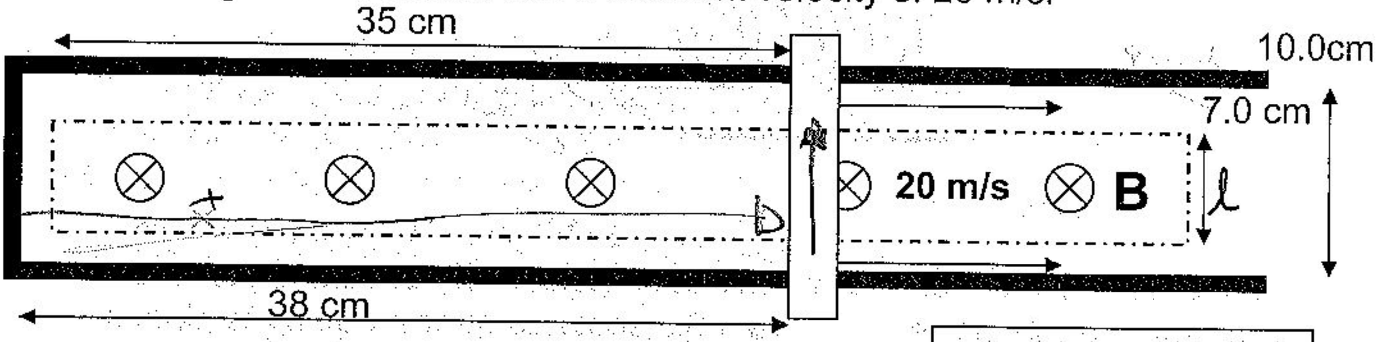
can double n by having same N in $\frac{1}{2} l$ $L_{new} \Rightarrow \mu_0 (2n_0)^2 A_0 \frac{l_0}{2} = 2 L_{orig}$

If double A, then $r \Rightarrow \sqrt{2} r$ & $N \Rightarrow N_0/\sqrt{2}$ $L_{new} \Rightarrow \mu_0 (n_0)^2 2 A_0 \frac{l}{\sqrt{2}} = \sqrt{2} L_0$

but n/l stays same since $l \Rightarrow l/\sqrt{2}$, so

Multi & Short Answer cont'd (Show Your Work!)

The B Field inside the dashed area shown below has a magnitude of 0.10T. Due to a constant applied force F, a conducting bar moves frictionlessly on conducting rails as shown with a constant velocity of 20 m/s.



d) What is the EMF induced across the bar? (5 pts)

Emf = 0.14V

$BA = B\ell x$

$\frac{d}{dt} BA = |B\ell v| = |\mathcal{E}| = 0.1 \frac{Vs}{m^2} (0.07m)(20m/s) = 0.14V$

e) Indicate the direction current flows *through the bar* due to the induced emf. (Draw an arrow on the bar.) Explain. (3 pts)

① Current Flows to oppose the change
I up gives F left

② getting more flux down, try to create some Flux up by having current flow CCW

f) Suppose the B field was not perpendicular to the page, but was, say, 10 degrees from being perpendicular and into the page. Assuming the bar continued along on the rail at a constant velocity (due to the same constant applied force F), would the bar have a constant speed that is faster, slower or the same? (3 pts) Explain.

In order to get Forces to balance (constant v) more I needs to flow since B ⊥ to bar is reduced

$F = I\ell B \sin 80°$ Before $I = \frac{F}{B\ell}$ now $I = \frac{F}{BL\sin 80°}$

more I more $\mathcal{E}_{new} \overset{?}{=} B\ell(\cos 10°)v$ $v = \frac{\mathcal{E}_{new}}{B\ell \underbrace{\cos 10°}_{<1}}$ so v is faster

Multi-Choice & Short Answer contd (Show Your Work!)

Note:The RLC values in part g) are to be used for parts g)-k)

g) A 0.2 Ohm resistance, a 2.5 mH inductor and a 2.6 mF capacitor are in series in a circuit being driven by a sinusoidally varying voltage. What is the resonance frequency of this RLC combo? (3 pts)

at resonance $\omega L = \frac{1}{\omega C}$ $\omega^2 = \frac{1}{LC}$

$(\omega = 392.2 \text{rad/s})$

or $f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} = \frac{1}{2\pi}\frac{1}{\sqrt{0.0025\,\Omega s \cdot 0.0026\,s/\Omega}} = 62.4/s$

f = 62.4 hz

h) Below the resonance frequency, will the current through the series combination [✓ Lead] or Lag the voltage supplied to the whole circuit by the driving voltage? Explain (3 pts)

$\omega < \omega_0$ $\frac{1}{\omega C}$ gets bigger than ωL, capacitance dominates. Current leads voltage for capacitance

i) What is the average power supplied by the voltage source (assume Vmax = 10.0V) at a frequency that is 10% higher than the resonance frequency? (5 pts) $\Rightarrow \omega = 431.45$

$Z = \sqrt{(0.2\Omega)^2 \left(\frac{431.45}{s}(.0025\Omega s) - \frac{1}{\frac{431.45}{s}\cdot 0.0026 s/\Omega}\right)^2}$

$= (0.2\Omega)^2 + (0.187\Omega)^2$

$= .274\Omega$

$P_{avg} = \frac{1}{2}\frac{(10V)^2}{(.274\Omega)}\frac{0.2\Omega}{0.274\Omega} = 133W$

P_{avg} = 133W

j) What is the value of the impedance when the average power drops to half of its maximum average value? (Hint: Maximum average Power occurs at resonance) (3 pts)

$P_{avg} = \frac{1}{2}\frac{V^2}{Z}\frac{R}{Z}$ @ res $P_{avg} = \frac{1}{2}\frac{V^2}{R}$

$\frac{P_{avg}}{P_{avg@res}} = \frac{1}{2} = \frac{\frac{1}{2}\frac{V^2 R}{Z^2}}{\frac{1}{2}V^2/R} = \frac{R^2}{Z^2}$

$\frac{1}{2} = \frac{R^2}{Z^2}$

$Z^2 = 2R^2$

$Z = \sqrt{2}R$

Z = $\sqrt{2}$R

$= 0.283\Omega$

k) What are the values of the frequency in part j) where this occurs? (2 pts) (note: the binomial theorem may be useful)

Occurs @ $R^2 + (\omega L - \frac{1}{\omega C})^2 = 2R^2$ or $R^2 = (\omega L - \frac{1}{\omega C})^2$

$R = \omega L - \frac{1}{\omega C}$ & $R = \frac{1}{\omega C} - \omega L$

$\omega R = \omega^2 L - \frac{1}{C}$ $\omega R = \frac{1}{C} - \omega^2 L$

$\omega^2 L - \omega R - \frac{1}{C} = 0$ $\omega^2 L + \omega R - \frac{1}{C} = 0$

only + sol only + solution

$\frac{R \pm \sqrt{R^2 + 4L/C}}{2L}$ ⓐ $\frac{-R \pm \sqrt{R^2 + 4L/C}}{2L}$ ⓑ

$\frac{1}{2}\left(\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + 4\omega_{res}^2}\right)$, $\frac{1}{2}\left(-\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + 4\omega_{res}^2}\right)$

ⓐ $\left(\frac{R}{L} = \frac{0.2\Omega}{0.0025\Omega s} = 80 \text{rad/s}\right)$

$\frac{1}{2\pi}\left(\frac{1}{2}\left(80 + \sqrt{80^2 + 4(392.2)^2}\right)\right) = \frac{434/s}{2\pi} = 69.$

b) $\frac{1}{2\pi}\left(\frac{1}{2}\left(-80 + \sqrt{80^2 + 4(392.2)^2}\right)\right) = \frac{354/s}{2\pi} = 56.3$

f = 69.1/s, 56.3/s