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<th>Form C</th>
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Physics 116B – Exam #3 (Wednesday) – Fall 2008

Only calculators and pens/pencils are allowed on your desk. No cell phones, music players, or additional scrap paper. You have 75 minutes to complete the exam.

Name __________________________________________

Section (Circle):  3  Helms  TR 8:10-9:25

1  Helms  TR 11:00-12:15

If you are in Prof. Johns’s class, you’re in the wrong room!

I pledge my honor that I have neither given nor received aid on this work.

Signed __________________________________________
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) In Fig. 29.1, a wire and a 10-Ω resistor are used to form a circuit in the shape of a square, 20 cm by 20 cm. A uniform but nonsteady magnetic field is directed into the plane of the circuit. The magnitude of the magnetic field is decreased from 1.50 T to 0.50 T in a time interval of 32 ms. The average induced current and its direction through the resistor, in this time interval, are closest to:

A) 75 mA, from a to b
B) 75 mA, from b to a
C) 190 mA, from a to b
D) 30 mA, from b to a
E) 130 mA, from a to b

\[
|\mathcal{E}| = \left| \frac{d\Phi}{dt} \right| = A \frac{d\Phi}{dt} = (20 \text{ cm})^2 \frac{1.5 \text{ T} - 0.5 \text{ T}}{32 \text{ ms}} = 1.25 \text{ V}
\]

\[
I = \frac{\mathcal{E}}{R} = \frac{1.25 \text{ V}}{10 \text{ Ω}} = 0.125 \text{ A}
\]

If the external field is decreasing into the page, then by Lenz's law, the induced current opposes that change, i.e., it produces a field into the page.
2) In Fig. 29.8, the inner loop carries a current $I$ that is increasing. The resistor $R$ is in the outer loop. The induced current through the resistor $R$ is:

A) zero  

B) from $a$ to $b$  

C) from $b$ to $a$

The inner current produces a field that is increasing into the page. The outer current must produce a field that is out of the page.
3) An R-L circuit has a 60-V battery, a 51-H inductor, a 21-Ω resistor, and a switch S, in series, as shown. Initially, the switch is open, and there is no magnetic flux in the inductor. At time \( t = 0 \) s, the switch is closed. In Fig. 30.1c, when the resistor voltage is equal to the inductor voltage, the current in the circuit is closest to:

A) 1.4 A  
B) 0.57 A  
C) 0.86 A  
D) 1.7 A  
E) 1.1 A

By Kirchhoff’s Loop Rule:

\[ V_R + V_L = 60 \text{ V} \]

If \( V_R = V_L \)

\[ 2V_R = 60 \text{ V} \]

\[ V_R = 30 \text{ V} \]

By Ohm’s Law:

\[ I = \frac{V}{R} = \frac{30 \text{ V}}{21 \Omega} = 1.43 \text{ A} \]

The current in the resistor is

The current in the whole circuit.

4) In Fig. 30.3, the instant after closing the switch, the current through the 60.0-Ω resistor is closest to:

A) 1.43 A  
B) 0.00 A  
C) 2.50 A  
D) 3.33 A  
E) 10.0 A

Right after closing the switch, the inductors look like open circuits with no current in them.

\[ I = \frac{V}{R_{\text{tot}}} = \frac{100 \text{ V}}{60 + 10} = 1.43 \text{ A} \]
5) In Fig. 30.5, the potential drop across the 70.0-µF capacitor after the switch has been closed for a very long time is closest to:

A) 101 V  B) 33 V  C) 200.0 V  D) 0.00 V  E) 80.0 V

After a long time, the circuit looks like:

\[ V = \frac{200 V}{75 \Omega} = 2.67 A \]

\[ V_D = V_{tot} + (2.67 A)(50 \Omega) = 138 V \]

6) The 60-Hz ac source of a series circuit has a voltage amplitude of 120 V. The capacitive and inductive reactances are 790 Ω and 270 Ω, respectively. The resistance is 500 Ω. In Fig. 31.1a, the capacitance, in µF, is closest to:

A) 20  B) 3.4  C) 9.7  D) 13  E) 6.5

\[ X_C = \frac{1}{C \omega} = \frac{1}{C 2\pi f} \]

\[ C = \frac{1}{X_C 2\pi f} = \frac{1}{(790 \Omega)2\pi(60)} = 3.4 \times 10^{-6} F = 3.4 \mu F \]
7) If the voltage amplitude across an 8.50-pF capacitor is equal to 12.0 V when the current amplitude through it is 3.33 mA, the frequency is closest to:

A) 32.6 Hz  B) 5.20 MHz  C) 32.6 kHz  D) 5.20 kHz  E) 32.6 MHz

\[ V = i \times C \quad \Rightarrow \quad \frac{i}{C} = \frac{i}{\omega C} = \frac{i}{2\pi f C} \]

\[ f = \frac{1}{2\pi C} = \frac{3.33 \times 10^{-3} A}{2\pi \left( 8.5 \times 10^{-12} \text{F} \times 12 \text{V} \right)} = 5.2 \times 10^6 \text{ Hz} = 5.2 \text{ MHz} \]

8) An L-R-C series circuit consists of an 85.0-Ω resistor, a 14.0-µF capacitor, a 1.50-mH inductor, and a variable frequency ac source of voltage amplitude 13.25 V. The angular frequency at which the inductive reactance will be 4.00 times as large as the capacitive reactance is closest to:

A) 2.20 \times 10^3 \text{ rad/s}  B) 3.8 \times 10^4 \text{ rad/s}  C) 6.90 \times 10^3 \text{ rad/s}  D) 3.45 \times 10^3 \text{ rad/s}  E) 1.10 \times 10^3 \text{ rad/s}

\[ X_L = \frac{1}{\omega} \quad \Rightarrow \quad L \omega = \frac{1}{C} \]

\[ \omega^2 = \frac{1}{LC} \]

\[ \omega = \frac{2}{\sqrt{LC}} = \frac{2}{\sqrt{\left( 1.5 \times 10^{-3} \text{H} \times 14 \times 10^{-6} \text{F} \right)}} = 13800 \frac{\text{rad}}{\text{s}} = 1.38 \times 10^4 \frac{\text{rad}}{\text{s}} \]
Physics 116B – Exam #3 (Thursday) – Fall 2008

Only calculators and pens/pencils are allowed on your desk. No cell phones, music players, or additional scrap paper. You have 75 minutes to complete the exam.

Name _________________________________

Section (Circle): 3 Helms TR 8:10-9:25

1 Helms TR 11:00-12:15

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_I pledge my honor that I have neither given nor received aid on this work._

Signed _________________________________

__________________________
1) In Fig. 29.9, a bar magnet moves away from the solenoid. The induced current through the resistor $R$ is:

A) zero  
B) from a to b  
C) from b to a

As the magnet is pulled away, the coil must produce a magnetic field to the left.

2) A small square coil is located inside an ideal solenoid at the center with its plane oriented perpendicular to the axis of the solenoid. The resistance of this coil is 2.00 Ω and each side is 4.00 cm long. The solenoid has 125 windings per centimeter of length. If the current in the solenoid is increasing at a constant rate of 1.50 A/s, the current in the square coil is:

A) decreasing at 1.50 A/s  
B) initially equal at 18.8 μA but is increasing  
C) increasing at 1.50 A/s  
D) steady at 18.8 μA  
E) zero

If $I$ changes at a constant rate, then $rac{dB}{dt}$ is constant. Then $rac{dE}{dt}$ is constant, so $E$ is constant, so the current in the square loop is constant. D is the only answer.

But if you want to calculate it:

\[
I_{\text{loop}} = \frac{E}{R} = \frac{-1}{R} \frac{dE}{dt} = \frac{-1}{R} \frac{d}{dt} (BA) = -\frac{A}{R} \frac{dI}{dt}
\]

For a solenoid $B = \mu_0 n I$ so

\[
I_{\text{loop}} = -\frac{A}{R} \mu_0 n \frac{dI}{dt}
\]

\[
= -\left(\frac{0.4 m}{2}\right)^2 (4 \pi \times 10^{-7} \text{ T m/A}) \frac{12500 \text{ m}}{1.5 \text{ A}} \times 1.5 \text{ A} \times 3
\]

\[
= -18.8 \mu A
\]

A-1
3) An R-L circuit has a 60-V battery, a 45-H inductor, a 25-Ω resistor, and a switch S, in series, as shown. Initially, the switch is open, and there is no magnetic flux in the inductor. At time $t = 0$ s, the switch is closed. In Fig. 30.1d, the rate of change of the current when the current is 1.5 A is closest to:

A) 0.67 A/s  
B) 0.83 A/s  
C) 0.75 A/s  
D) 0.58 A/s  
E) 0.50 A/s

$$I(t) = I_0 (1 - e^{-t/\tau})$$

$$I_0 = \frac{V}{R} = \frac{60V}{25\Omega} = 2.4A$$

$$\tau = \frac{L}{R} = \frac{45H}{25\Omega} = 1.8s$$

$$1.5A = (2.4A)(1 - e^{-t_0/1.8})$$

$$\frac{dI}{dt} = \frac{I_0}{\tau} e^{-t/\tau}$$

$$2.4A - 1.775e^{-1.8s}$$

$$e^{-t_0/1.8} = 1 - \frac{1.5}{2.4} = 0.375$$

$$-\frac{t_0}{\tau} = \ln(0.375)$$

$$t_0 = -\tau \ln(0.375) = 1.775s$$

4) In Fig. 30.3, after the switch has been closed and left closed for a very long time, the potential drop across the 60.0-Ω resistor is closest to:

A) 0.00 V  
B) 85.7 V  
C) 66.7 V  
D) 100.0 V  
E) 90.0 V

After a long time, the 40mH inductor acts like a short across the 60Ω resistor. Therefore, no current flows through the resistor and the potential drop across it is zero.
5) In Fig. 30.5, the potential drop across the 15.0-mH inductor just after closing the switch is closest to: 5)  
A) 0.00 V  
B) 150.0 V  
C) 50.0 V  
D) 200.0 V  
E) 100.0 V

Initially, the capacitors look like shorts and the inductors look like open circuits.

\[ V = \text{the drop across the } 75 \Omega \text{ resistor} \]

\[ I_{\text{tot}} = \frac{V}{R_{\text{tot}}} = \frac{200 \text{ V}}{100 \Omega} = 2 \text{ A} \]

\[ V_{25} = I_{\text{tot}} R = 2 \text{ A}(75 \Omega) = 150 \text{ V} \]
6) The 60–Hz ac source of a series circuit has a voltage amplitude of 120 V. The capacitive and inductive reactances are 710 Ω and 320 Ω, respectively. The resistance is 490 Ω. In Fig. 31.1b, the inductance, in mH, is closest to:

A) 1900  B) 850  C) 3200  D) 4000  E) 5300

\[ X_L = L \omega = 2\pi f L \]

\[ L = \frac{X_L}{2\pi f} = \frac{320\text{Ω}}{2\pi(60\text{Hz})} = 850\text{H} = 850\text{mH} \]

7) The inductor in a radio receiver carries a current of amplitude 200 mA when a voltage of amplitude 2.4 V is across it at a frequency of 1400 kHz. What is the value of the inductance?

A) 1.97 mH  B) 1.43 mH  C) 4.42 mH  D) 9.20 mH  E) 1.36 mH

\[ V = i X_L = i L \omega \]

\[ L = \frac{V}{i \omega} = \frac{V}{2\pi f i} = \frac{2.4\text{V}}{2\pi(1400\times10^3)(0.200\text{A})} = 1.36\times10^{-6}\text{H} = 1.36\mu\text{H} \]
8) A series $L$-$R$-$C$ circuit consists of a 175-Ω resistor, a 10.0-mH inductor, a 2.50-µF capacitor, and an ac source of amplitude 15.0 V and variable frequency. If the voltage source is set to 3.00 times the resonance frequency, the impedance of this circuit is closest to:

(A) 243 Ω  
(B) 386 Ω  
(C) 525 Ω  
(D) 344 Ω  
(E) 175 Ω

\[ \omega_0 = \frac{1}{\sqrt{LC}}; \quad \omega = 3 \omega_0 \]

\[ X_L = L \omega = 3L \omega_0 = 3 \frac{\sqrt{L}}{\sqrt{C}} \omega_0 \]

\[ X_C = \frac{1}{C \omega} = \frac{1}{3C \omega_0} = \frac{\sqrt{L}}{3\sqrt{C}} \omega_0 \]

\[ Z = \sqrt{R^2 + (X_L - X_C)^2} \]

\[ = \sqrt{R^2 + \left(3 \frac{\sqrt{L}}{\sqrt{C}} - \frac{\sqrt{L}}{3\sqrt{C}}\right)^2} \]

\[ = \sqrt{R^2 + \frac{L}{C} \left(3 - \frac{1}{3}\right)^2} \]

\[ = \sqrt{R^2 + \left(\frac{8}{3}\right)^2 \frac{L}{C}} = 243 \Omega \]

A-5
FREE RESPONSE. Write your final answer for each part in the box provided. Partial credit will only be given if you show your work and it is clear.

9) A rectangular loop with width $L$ and a slide wire with mass $m$ are shown in the figure below. A uniform magnetic field $B$ is directed perpendicular to the plane of the loop, into the page. The slide wire is given an initial speed $v_0$ and then released. The resistance of the loop is negligible and the resistance of the slide wire is $R$. There is no friction between the loop and the slide wire.

(a) Calculate the magnitude of the emf induced in the loop enclosed by the fixed wire and the slide wire. (Your answer should depend on $v$).

$$ |\mathcal{E}| = \frac{d\Phi}{dt} = \frac{d}{dt}(BA) = B \frac{dA}{dt} = BLv $$

$$ \mathcal{E}(v) = BLv \quad (4) $$

(b) Calculate the current in the loop and indicate its direction.

$$ I = \frac{\mathcal{E}}{R} = \frac{BLv}{R} $$

Since the field points into the page and the flux is increasing, Lenz's law says that the induced current produces a field to oppose that change, or, a field out of the page.

$$ I = \frac{BLv}{R} \text{ ccw} \quad (4) $$
(c) Calculate the magnetic force on the slide wire.

\[ F = ILB = \frac{B^2L^2v}{R} \]

(d) From your last answer, show that the velocity of the slide wire as a function of time is given by \( v(t) = v_0 e^{-\frac{B^2L^2}{mR} t} \). \( 4 \)

\[ \frac{dv}{dt} = \frac{-B^2L^2}{mR} v \]

\[ v(t) = v_0 e^{-\frac{B^2L^2}{mR} t} \]

(e) Calculate the total distance traveled by the slide wire from the point where it was released.

\[ d = \frac{v_0 mR}{B^2L^2} \] \( 4 \)