ID CODE: A

Physics 202 Midterm Exam 3
April 18, 2010

Name: ................................................ Student ID: .........................
Section: .........................

TA (please circle):
Zach Billy  Scott Douglass  Peter Dudley  Weiwei Hu  Ang Li
Hyungjun Lim  Andrew Long  Nicole Vaash  Hojin Yoo

Instructions:

1. Don’t forget to write down your name, student ID#, and section number. You need to do this on (this page of) your test book AND on your Scantron sheet.

2. Answer all multiple choice questions in this test book by indicating the best answer among choices. You must do this both on your test book and on your Scantron sheet. Follow instructions on the Scantron sheet on how to mark valid answers.

3. When you finish, you need to turn in both this test book and the Scantron sheet.

4. Use the blank side of question pages as additional draft spaces. An extra blank sheet is provided at the end of the test book.

5. Only one answer is allowed per problem/question. All problems have equal weight.

Constants: \( \mu_0 = 4\pi \times 10^{-7} \text{Tm/A} \)

Speed of light: \( c = 3.0 \times 10^8 \text{m/s} \)

Please be very careful with the first question even though the answer will not count towards your grade:

1. ENTER THE ID CODE ABOVE IN THE UPPER RIGHT CORNER OF THE PAGE
   A. ID Code A
   B. ID Code B
   C. ID Code C
   D. ID Code D
Phys 202, Exam 3, Spring 2011

Multiple Choice

Identify the choice that best completes the statement or answers the question.

2. A coil is wrapped with 300 turns of wire on the perimeter of a circular frame (radius = 8.0 cm). Each turn has the same area, equal to that of the frame. A uniform magnetic field is turned on perpendicular to the plane of the coil. This field changes at a constant rate from 20 to 80 mT in a time of 20 ms. What is the magnitude of the induced emf in the coil at the instant the magnetic field has a magnitude of 50 mT?
   \[ \frac{dB}{dt} = \frac{(80 - 20) \text{ mT}}{20 \text{ ms}} = 3 \text{ T/s} \]
   a. 24V
   b. **18 V**
   c. 15 V
   d. 10 V
   e. 30 V

3. A bar \((L = 80 \text{ cm})\) moves on two frictionless rails, as shown, in a region where the magnetic field is uniform \((B = 0.30 \text{ T})\) and into the paper. If \(v = 50 \text{ cm/s}\) and \(R = 60 \text{ m}\Omega\), what is the induced current across \(R\)?

\[ E = -BLv \]
\[ = -(0.3)(0.8)(0.5) = -0.12 \text{ V} \]
\[ I = \frac{E}{R} = \frac{0.12 \text{ V}}{0.06 \Omega} = 2 \text{ A} \]

   a. 1.3 A counter-clockwise
   b. 2.0 A counter-clockwise
   c. 1.3 A clockwise
   d. 2.0 A clockwise
   e. None of the above

4. In the same setting as above (problem 2), what is the magnetic force on the moving bar?

\[ F = I \ell \times B \]
\[ F = (2A)(0.8 \text{ m})(0.3 \text{ T}) \]
\[ = 0.48 \text{ N} \]

In direction that opposes \(\frac{dB}{dt}\), i.e. left.
5. A long solenoid has a radius $r_1$ of 4.0 cm and has 800 turns/m. If the current in the solenoid is increasing at the rate of 3.0 A/s, what is the magnitude of the induced electric field at a point 2.2 cm from the axis of the solenoid? (hint: the strength of the magnetic field inside a solenoid is $B = \mu_0 n I$ where $n$ is the number of turns/unit length)

$$B = \mu_0 n I$$

$$\frac{dB}{dt} = \mu_0 n \frac{dI}{dt} = \left(4\pi \cdot 10^{-7} \text{T} \cdot \text{m/A}\right) \left(800 \text{ m}^{-1}\right) \left(\frac{3A}{s}\right)$$

$$\oint E \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\frac{d\Phi_B}{dt} = A \frac{dB}{dt} = \pi r_2^2 \frac{dB}{dt}$$

$$E = \frac{(4\pi \cdot 10^{-7} \text{T} \cdot \text{m/A}) (800 \text{ m}^{-1}) (3\text{A/s}) \pi (0.022 \text{m})^2}{2\pi (0.022 \text{m})}$$

$$E = 3.3 \times 10^{-5} \text{ V/m}$$

6. Starting outside the region with the magnetic field, a single square coil of wire enters, moves across, and then leaves the region with a uniform magnetic field $\vec{B}$ perpendicular to the page so that the graph shown below represents the induced emf. The loop moves at constant velocity $\vec{v}$. As seen from above, a counterclockwise emf is regarded as positive. In which direction did the loop move over the plane of the page?

a. The loop moved from bottom to top.
b. The loop moved from top to bottom.
c. The loop moved from left to right.
d. The loop moved from right to left.

e. All of these directions of motion will produce the graph of emf vs $t$.  

**2**
7. The figure shows an RL circuit with a switch and a 240-volt battery. At the instant the switch is closed the current in the circuit and the potential difference between points a and b, \( V_{ab} \), are

\[
I = \frac{E}{IR} \left(1 - e^{-\frac{t}{RC}}\right)
\]

at \( t=0 \), \( I = 0 \)

With \( I = 0 \), all of \( \Delta V \) of 240 V is across the inductor since \( \Delta V \) across R is zero. Potential at a is higher than at b as indicated by the battery \( \frac{t^+}{t^-} \rightarrow V_{ab} = 240 \text{V} \)

- a. 0 A, 0 V
- b. 0 A, -240 V
- c. 0 A, +240 V
- d. 0.024 A, 0 V
- e. 0.024 A, +240 V

8. A series LC circuit contains a 100 mH inductor, a 36.0 mF capacitor and a 12 V battery. The angular frequency of the electromagnetic oscillations in the circuit is

\[
\omega = \sqrt{\frac{1}{LC}} = \sqrt{\frac{1}{(100 \times 10^{-3} \text{H})(36 \times 10^{-3} \text{F})}} = 16.7 \text{ rad/s}
\]

- a. \( 36.0 \times 10^{-4} \text{ rad/s} \)
- b. \( 6.00 \times 10^{-2} \text{ rad/s} \)
- c. 2.78 rad/s
- d. 16.7 rad/s
- e. 277 rad/s

9. An inductor produces a back emf in a DC series RL circuit when a switch connecting the battery to the circuit is closed. We can explain this by

- a. Lenz’s law.
- b. increasing magnetic flux within the coils of the inductor.
- c. increasing current in the coils of the inductor.
- d. all of the above.
- e. only (a) and (c) above.
10. Before the switch is closed in the figure, the potential across the capacitor is 200 V. What is the maximum current? (hint: you may need Q = CV)

\[ I = -\omega Q_{\text{max}} \sin(\omega t + \phi) \]

\[ \phi = 0 \text{ if we set } t = 0 \]

When the switch is closed,

\[ I_{\text{max}} = \omega Q_{\text{max}} \]

\[ = \frac{1}{\sqrt{LC}} \left( CV_{\text{max}} \right) = \frac{1}{\sqrt{[0.2H][4 \times 10^{-4}F]}} \left( 4 \times 10^{4} \frac{\text{V}}{\text{A}} \right) \]

\[ = 0.89 \text{ A} \]

a. 40 A
b. 0.89 A
c. 0.70 A
d. 0.031 A
e. 1.3 A

11. When a switch is closed, completing an LR series circuit, the time needed for the current to reach one half its maximum value is ___ time constants.

\[ I = \frac{E}{R} (1 - e^{-t/\tau}) \]

\[ \frac{1}{2} = 1 - e^{-t/\tau} \]

\[ e^{-\frac{t}{\tau}} = \frac{1}{2} \]

\[ \frac{t}{\tau} = \ln(2) \]

\[ = 0.693 \]

a. 0.250
b. 0.500
c. 0.693
(d. 1.00
e. 1.44

12. A high-voltage powerline operates at 500 000 V-rms and carries an rms current of 500 A. If the resistance of the cable is 0.050Ω/km, what is the resistive power loss in 200 km of the powerline?

\[ P = I_{\text{rms}}^2 R \]

\[ = \left( 500 \frac{\text{A}}{} \right)^2 \left( 0.05 \frac{\Omega}{\text{km}} \right)(200 \text{ km}) \]

\[ = 2.5 \times 10^6 \text{ W} \]

a. 250 kW
b. 500 kW
c. 1 Megawatt
d. 2.5 Megawatts
(e. 250 Megawatts
13. A 2.0-μF capacitor in series with a 2.0-kΩ resistor is connected to a 60-Hz ac source. Calculate the impedance of the circuit.

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

\[ \omega = 2\pi f \]

\[ X_C = \frac{1}{(2\pi f)(10^6)(2 \times 10^{-6} F)} \]

\[ X_L = 0 \]

\[ Z = \sqrt{(2000 - 12)^2 + (1326 - 52)^2} \]

\[ = 2400 \Omega \]

14. (The circuit on the figure below refers to the next two questions)

In the circuit below, what is the rms current for the RLC circuit?

\[ V_{\text{max}} = 140 \text{ V} \]

\[ V_{\text{rms}} = \frac{140}{\sqrt{2}} = 99 \text{ V} \]

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

\[ = \sqrt{(10^3)^2 + [(500)(\omega) - \frac{1}{(500)(10^6)}]^2} \]

\[ = 1803.5 \Omega \]

\[ I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} \]

\[ = \frac{99V}{1803.5} = 55 \times 10^{-3} \text{ A} \]

15. What is the rms voltage drop across the inductor in the RLC circuit drawn above?

\[ V_{\text{rms}} = I_{\text{rms}} \cdot X_L \]

\[ = (55 \text{ mA})(500 \Omega) \]

\[ = 27.5 \text{ V} \]
16. An LC circuit is to have resonant oscillations at 5.0 MHz. Find the value of a capacitor which will work with a 1.0-mH inductor.

\[
\omega_0 = \frac{1}{\sqrt{LC}} \quad \Rightarrow \quad C = \frac{1}{\omega_0^2} = \frac{1}{(10^{-3} \text{H})(5 \times 10^8 \text{s} \cdot 2\pi)^2} = 1 \times 10^{-12} \text{F}
\]

a. 2.0 mF
b. 1.0 \mu F
c. 0.020 \mu F
d. 1.0 pF
e. 40 pF

17. If the radiant energy from the sun comes in as a plane EM wave of intensity 1340 W/m², calculate the peak values of E and B.

\[ S_{avg} = \frac{E_{max}}{2\mu_0 c} \]

\[ E = \left[ S_{avg} \cdot 2\mu_0 c \right]^\frac{1}{2} = \left[ \frac{(1340 \text{W/m}^2)}{(2)(4\pi \cdot 10^{-7} \text{T} \cdot \text{m/Hz})(3 \times 10^8 \text{m/s})} \right]^\frac{1}{2} = 1000 \text{ V/m} \] (check: B = E/c)

a. 300 V/m, 10⁻⁴ T
b. 1000 V/m, 3.35 x 10⁻⁴ T
c. 225 V/m, 1.60 x 10⁻³ T
d. 111 V/m, 3.00 x 10⁻⁵ T
e. 711 V/m, 2.37 x 10⁻⁶ T

18. Find the force exerted by reflecting sunlight off a reflecting aluminum sheet in space if the area normal to the sunlight is 10 000 m² and the solar intensity is 1340 W/m².

\[ F = S/c \cdot \frac{2}{r} \text{ reflected} \]

\[ F = 2PA = 2 \frac{SA}{c} = 2 \frac{(1340)(10^4)}{3 \times 10^8} = 0.09 \text{ N} \]

a. 0.72 N
b. 0.09 N
c. 9 N
d. 45 N
e. 0.18 N

19. An FM radio station broadcasts at 98.6 MHz. What is the wavelength of the radiowaves?

\[ \lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{m/s}}{98.6 \times 10^6 \text{Hz}} = 3.04 \text{ m} \]

a. 60.8 m
b. 6.08 m
c. 3.04 m
d. 0.314 m
e. 0.33 cm
20. What is the average value of the magnitude of the Poynting vector $\mathbf{S}$ at 1 meter from a 100-watt lightbulb radiating in all directions?
   a. 1 W/m²
   b. 4 W/m²
   c. 2 W/m²
   d. 8 W/m²
   e. 12 W/m²

\[
\text{S at 1m} = \frac{100 \text{ W}}{4\pi (1 \text{ m})^2} = \frac{100 \text{ W}}{4\pi} (1 \text{ m})^2 = 7.96 \text{ W/m}^2 \rightarrow 8 \text{ W/m}^2
\]

21. What should be the height of a dipole antenna (of dimensions 1/4 wavelength) if it is to transmit 1200 kHz radio waves?
   a. 11.4 m
   b. 60 cm
   c. 1.12 m
   d. 62.5 m
   e. 250 m

\[
\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{1200 \times 10^3 \text{ /s}} = 250 \text{ m}
\]

\[
\frac{\lambda}{4} = 62.5 \text{ m}
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