Physics 201 Name KEY

Exam 3 – Electrodynamics

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April 23, 2009

This is a closed book examination. You may use a large card on which you have written helpful information during this exam. There is extra scratch paper available. Please explain your answers. Your explanation is worth 3/4 of the points on multiple-choice questions.

1) [4 PTS] A charged object moves in a straight line through a region of space with a strong magnetic field, $\vec{B}$. What must be true?
   - a) The object must be traveling very quickly (close to 3×10^8 m/s).
   - b) The object is traveling perpendicular to $\vec{B}$.
   - [✓ c)] The object is traveling parallel to $\vec{B}$.
   - d) There is an electric field perpendicular to $\vec{B}$.
   - e) traveling very slowly
   - f) none of the above

$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$

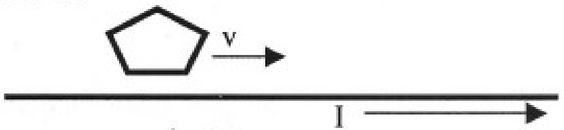
Force from magnetic field is ⊥ to $\vec{v}$ unless $v \times B = 0$ and there is no force

2) [4 PTS] The more rapidly a magnet approaches a coil of wire, the
   - a) lower the current in the coil
   - b) greater the resistance of the coil
   - c) more it is attracted to the coil
   - [✓ d)] greater the induced voltage across the coil
   - e) none of the above

$V_{emf} = -\frac{d}{dt}\Phi_m \quad \Phi_m = \int \vec{B} \cdot d\vec{A}$

travel faster and $\frac{d}{dt}\Phi_m$ is larger! and V_{emf} is larger

3) [4 PTS] A closed loop moves at a constant speed parallel to a long straight current-carrying wire. The loop moves in the same direction as the current in the wire.
   - a) The induced current in the loop will progress clockwise
   - b) The induced current in the loop will progress counterclockwise
   - [✓ c)] There will be no induced current
   - d) The induced current will vary with the speed at which the loop moves
   - e) None of the above



$V_{emf} = -\frac{d}{dt}\Phi_m$ but Φ_m is constant

$I = \frac{V}{R}$

*magnetic field strength doesn't change

4) [4 PTS] When the instantaneous voltage and current in *any* AC circuit (think LCR circuits) are in-phase, we know
   - a) the capacitive reactance is zero
   - b) the inductive reactance is zero
   - [✓ c)] the total reactance is zero
   - d) the resistance is zero
   - e) the impedance is zero
   - f) none of these

$Z = \left[R^2 + (X_L - X_C)^2\right]^{1/2}$

Condition to be in-phase is that $X_L = X_C \;\therefore\; \omega_0^2 = \frac{1}{LC}$

$X = 0$ @ resonance

(Note: there can still be a resistance and hence impedance)

5) [4 PTS] You have a 12V car battery and a transformer (N_p=1000 and N_s=10). What should you do if you want to shock your "friends" with 1200 Volts?
   a) Connect the battery to the side with 1000 windings.
   b) Connect the battery to the side with 10 windings.
   c) Get a different transformer.
   [✓ d)] Get a different battery.

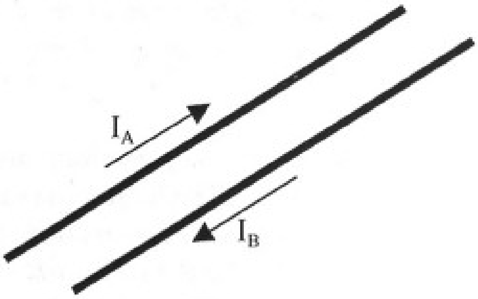
Only works w/ AC will not work if voltage is constant

$$\frac{V_p}{N_p} = \frac{V_s}{N_s}$$ so hooking an AC voltage source of 12 V_{rms} to the 10 turn side would produce 1200 V_{rms} in the secondary –

6) 4 PTS] A capacitor and resistor are connected in series to an AC voltage source. If you double the frequency of the voltage the effect on the capacitor is to
   a) double its reactance
   b) increase its reactance by a factor of four
   c) leave its reactance unchanged
   [✓ d)] halve its reactance
   e) decrease its reactance by a factor of four

$$X_c = \frac{1}{\omega C}$$ $\omega\uparrow \; X_c\downarrow$

7) [10 PT] Two very long wires are hung parallel to each other a distance of 10 cm apart. Current flows down each wire in opposite directions. Wire A has a current of 100 mA and wire B has a current of 400 mA.
   a) Do the wires move? If so in what direction?
   b) What is the force per unit length on wire B?
   c) What is the force per unit length on wire A?
   d) What is the magnetic field 10 meters away from the two wires?

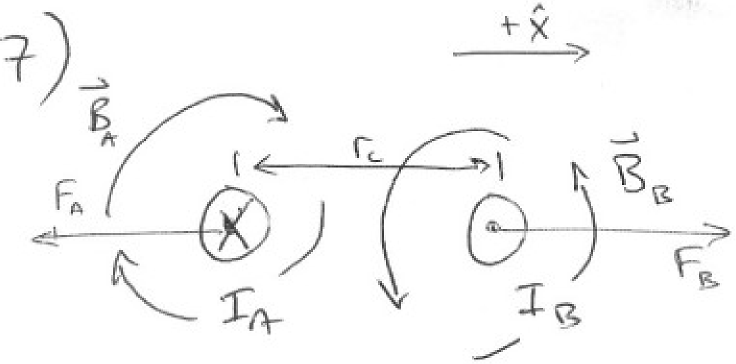


8) [10 PT] You have connected an inductor (L=500 mH), a capacitor (C=0.6μF) and resistor (R=1400Ω) in series. You connect your LCR circuit to a function generator that is producing a time varying voltage signal with V_{rms}=0.71 volts.
   a) What is the resonant frequency for this circuit?
   b) What is the impedance of this LCR circuit when it is at resonance?
   c) What is the peak current passing through the resistor for a frequency of 2 kHz?

Useful mathematical (trigonometric) relationships:

$$\sin^2(\theta) + \cos^2(\theta) = 1$$
$$\cos(2\theta) = \cos^2(\theta) - \sin^2(\theta) = 2\cos^2(\theta) - 1 = 1 - 2\sin^2(\theta)$$
$$\sin(2\theta) = 2\sin(\theta)\cos(\theta)$$

7)



$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$

$\vec{F} = q\,\vec{v}\times\vec{B}$

$\vec{F} = l\,\vec{I}\times\vec{B}$

$\frac{\vec{F}}{l} = \vec{I}\times\vec{B}$

(a) Wires move $\vec{I}_A \times \vec{B}_B = \frac{\vec{F}_A}{l}$ and $\vec{I}_B \times \vec{B}_A = \frac{\vec{F}_B}{l}$

Force in $-\hat{x}$ Force in $+\hat{x}$

$\boxed{\text{They repel}}$

(b) $\frac{F_B}{l} = I_B \times B_A$ $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$ $B_A = \frac{\mu_0 I_A}{2\pi r}$

$= \frac{\mu_0 I_B I_A}{2\pi r_c}$

$r_c = 10\,cm = 0.1\,m$

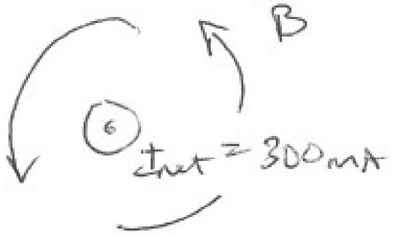
$I_A = 100\,mA = 0.1\,A$

$\mu_0 = 4\pi \times 10^{-7}\,\frac{Tm}{A}$

$\boxed{= 80\,\frac{nN}{m}\,\hat{x}}$

(c) $\left|\frac{F_B}{l}\right| = \left|\frac{F_A}{l}\right|$ but opposite $\boxed{-80\,\frac{nN}{m}\,\hat{x}}$

(d) $\vec{B}(10\,cm)$ treat two wires as one current source

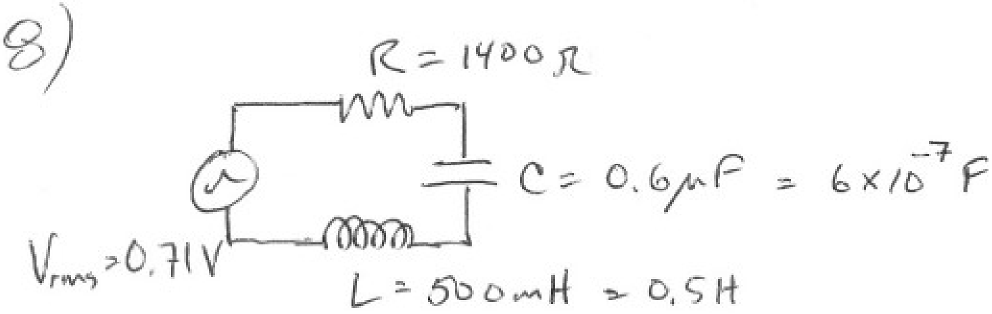


$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$

$\vec{B} = \frac{\mu_0 I_{enc}}{2\pi r}\,\hat{\theta}$

$\boxed{|\vec{B}| = 6\,nT}$

8)



(a) Resonant Frequency $\omega_0 = \frac{1}{\sqrt{LC}}$ $f_0 = \frac{\omega_0}{2\pi}$

$$\boxed{\omega_0 = 1826 \frac{rad}{sec} \qquad f_0 = 291 Hz}$$

(b) $Z = \left(R^2 + (X_L - X_C)^2\right)^{1/2}$

$X_L = \omega L = 913\Omega$

$X_C = \frac{1}{\omega_0 C} = 913\Omega$

$\therefore X_L - X_C = 0$

@ $\omega = \omega_0$ $X = 0$

$$\boxed{Z = R = 1400\Omega}$$

(c) $I_{peak} = \frac{V_{peak}}{Z(\omega)}$

$V_{peak} = \sqrt{2} V_{rms} = 1.0 V$
or $2.0 V = V_{peak to peak}$

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

$\omega = 2\pi \cdot 2kHz = 12,566$ rad/sec

$X = \omega L - \frac{1}{\omega C} = 6150\Omega$

$Z = 6308\Omega$

$I_{peak} = \frac{1.0 V}{6308\Omega}$

$= 0.00016 A$

$$\boxed{I_p = 0.16 mA}$$