$\bar{x} = 86$
$s = 8$

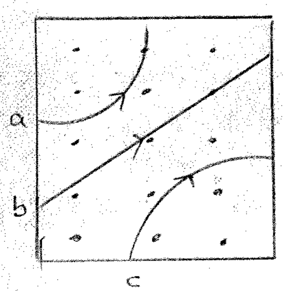
PHYSICS 203 **EXAM #1** NAME KEY
15 October 2008

General Instructions: For each problem your solution must be readable and your logic followable. Put a box around any numerical answers. Show your work.

PART I - SHORT ANSWER QUESTIONS.

Do the **five** short questions/problems. Worth 8 points each.

1. Three particles travel through a region of uniform magnetic field which is directed up out of the page as shown. They follow the paths labeled a, b, and c. Indicate whether the charge on each particle is positive, negative, or zero. Explain your reasoning.



$\vec{F} = q\vec{v}\times\vec{B}$ & provides the centripetal force. If $\vec{v}\times\vec{B}$ points to center of circle, $q > 0$. If opp. $q < 0$. If straight line $q = 0$.

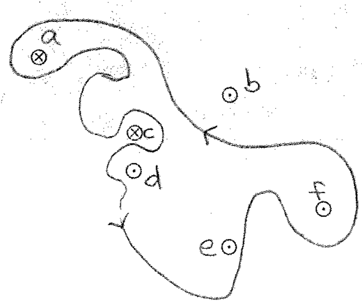
Using RHR:

q_a is $-$

$q_b = 0$

q_c is $+$

2. Several currents go into (indicated with an x) or come out of (indicated with a dot) the page. The currents have the values: $i_a = 1.0$ A, $i_b = 2.0$ A, $i_c = 3.0$ A, $i_d = 4.0$ A, $i_e = 5.0$ A, and $i_f = 6.0$ A. What is the value of integral $\oint$ **B**·d**A** for the loop shown, evaluated in the direction indicated by the arrow?



$\oint \vec{B}\cdot d\vec{s} = \mu_0 i_{enc}$.

Using RHR $i > 0$ if out of paper for integration direction shown & $i < 0$ for current into paper.

So looking at what's enclosed:

$\oint \vec{B}\cdot d\vec{A} = \mu_0(-i_a + i_d + i_e + i_f)$

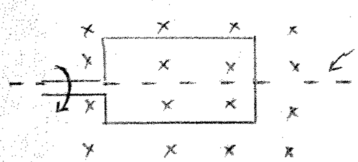
$= \mu_0(-1.0A + 4.0A + 5.0A + 6.0A)$

$= \mu_0(14.0A)$

$= 1.26\times10^{-6}\frac{Tm}{A}(14.0A)$

$\boxed{\oint \vec{B}\cdot d\vec{A} = 1.76\times10^{-5}\ Tm}$

3. A uniform magnetic field is directed into the page, as shown. A single loop of wire (shown at an instant when it is in the plane of the page) is caused to rotate with an angular speed of ω. Show that a sinusoidally time varying voltage is produced.



$\mathcal{E} = -\frac{d\Phi_B}{dt}$ for a single turn

$+ \Phi_B = \vec{B}\cdot\vec{A}$ for a uniform field

$= BA\cos\phi$) ϕ varies as ωt

$= BA\cos\omega t$

$\mathcal{E} = -\frac{d\Phi_B}{dt} = -BA\frac{d}{dt}\cos\omega t = \underline{+BA\omega\sin\omega t}$

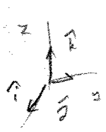
4. Is the way Michael Faraday viewed the relationship between his religious faith and his scientific work the same as the way Fischer (author of **God Did it, But How?**) describes as the appropriate way to relate these? Explain.

No   Faraday separate areas of life

Fischer are related

5. A straight wire carries a current of 2.50 A in the +y direction. It lies in a uniform magnetic field given by $\vec{B} = (2.00\text{ mT})\hat{\mathbf{j}} + (3.00\text{ mT})\hat{\mathbf{k}}$. In unit-vector notation, what is the force on a 0.500 m long segment of this wire?

$\vec{F} = I\vec{L}\times\vec{B}$



$= (2.50\,A)(0.500\,m)\hat{j} \times [2.00\,mT\,\hat{j} + 3.00\,mT\,\hat{k}]$

$\hat{j}\times\hat{j} = 0 \qquad \hat{j}\times\hat{k} = \hat{i}$

so $\vec{F} = (2.50\,A)(0.500\,m)(3.00\,mT)\,\hat{i}$

$$\boxed{\vec{F} = 3.75\,mN\,\hat{i}}$$

Part II - Problems.

Do all three. Worth 20 points each. Show and explain your work.

7. An RLC series circuit has L = ~~100 μH~~ 0.100 H (m), C = ~~100 pF~~ 10.0 nF, and R = 10.0 Ω. It is driven by a variable frequency AC generator that puts out a signal of (5.00 V)sin(ω_d t).

a) At what value of ω_d will the rms current have its maximum value?

-4 if missed → For each of the parts below, assume that the driving frequency is twice that found in part a).

b) What rms current flows?

c) What is the phase difference between the current and driving voltage?

d) Is the circuit more capacitive or inductive? How do you know?

pts e) What is the average power provided by the generator?

3 a) if $w_d = \frac{1}{\sqrt{LC}}$ get max $\quad W_d = \frac{1}{\sqrt{(0.100H)(10.0\times10^{-9}F)}} = 1.0\times10^{3}s^{-1}$

b) at $w_d = 2.0\times10^{3}s^{-1}$

$i_m = \frac{\mathcal{E}_m}{Z} = \frac{\mathcal{E}_m}{\sqrt{R^2+(X_L-X_C)^2}}$

$X_L = w_d L = 2.0\times10^{3}s^{-1}\cdot 0.100 H = 200\,\Omega$

$X_C = \frac{1}{w_d C} = \frac{1}{2.0\times10^{3}s^{-1}(10.0\times10^{-9}F)} = 50.0\,\Omega$

8 so $i_m = \frac{5.00\,V}{\sqrt{(10.0\,\Omega)^2+(200\,\Omega-50\,\Omega)^2}}$

$= 3.33\,mA$

$i_{rms} = i_m/\sqrt{2} = \boxed{2.36\,mA}$

3 c) $\phi = \tan^{-1}\frac{X_L - X_C}{R} = \tan^{-1}\frac{200\,\Omega-50\,\Omega}{10\,\Omega} = \boxed{86.2^\circ} = 1.50$ rad

4 d) $\boxed{\text{inductive}}$ i lags ε by almost 90° (or $X_L > X_C$)

3 e) $P = i_{rms}\,\mathcal{E}_{rms}\cos\phi = (2.36\,mA)\left(\frac{5.00V}{\sqrt{2}}\right)\cos 86.2^\circ = \boxed{5.55\,mW}$

8. A solenoid is circular in cross section and has a length of 45.0 cm, and diameter of 1.00 cm. It has a total of 600 turns and a current of 2.50 A is flowing through it.
a) What is the magnetic field produced inside the solenoid?
b) What is energy density stored in the magnetic field?
c) What is the total energy stored in the field?
d) What is the self inductance of the solenoid?
e) If the current flowing through the solenoid is now reduced at the rate of 0.030 A/s, what emf is induced?

a) $B = \mu_0 i n = 1.26\times10^{-6}\,\frac{Tm}{A}\,(2.50A)\left(\frac{600\text{ turns}}{0.45m}\right) = \boxed{4.20\,mT}$

b) $u_B = \frac{1}{2\mu_0}B^2 = \frac{(4.20\times10^{-3}T)^2}{2(1.26\times10^{-6}Tm/A)} = \boxed{7.00\,J/m^3}$

c) $U_{B\,tot} = u_B \cdot Vol = \left(7.00\,\frac{J}{m^3}\right)\pi\left(\frac{.010m}{2}\right)^2(0.450m)$

$\boxed{= 2.47\times10^{-4}\,J}$

4pts each

d) $L = \mu_0 n^2 A l = 1.26\times10^{-6}\,\frac{Tm}{A}\cdot\left(\frac{600}{0.45m}\right)^2(\pi)\left(\frac{.010m}{2}\right)^2(.450m)$

$= 7.92\times10^{-5}H$

or (easier) use $U_{B\,tot} = \frac{1}{2}Li^2$

e) $\mathcal{E} = -L\frac{di}{dt} = -(7.92\times10^{-5}H)(-0.030A/s)$

$\boxed{= 2.38\,\mu V}$

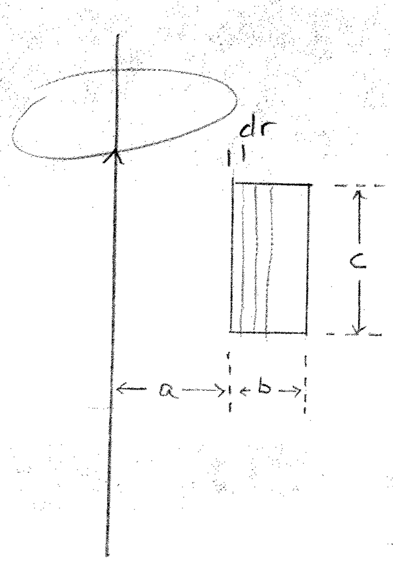
9. A long straight wire carries a time varying current i that is given by $i = I_0 e^{-kt}$ where t is the time and k is a constant. Near this wire is a rectangular loop of wire with the dimensions shown and having resistance R.

3 a) At a distance r (along a perpendicular from the long wire) what is the magnetic field produced by the long wire?

4 b) What is the magnetic flux through the rectangular loop?

4 c) What current flows in the rectangular loop?

5 d) What is the direction of current flow in the rectangular loop? Explain.



a) From Amperes law

$$\oint \vec{B} \cdot d\vec{r} = \mu_0 i_{enc}$$

$$B \cdot 2\pi r = \mu_0 I_0 e^{-kt}$$

$$\boxed{B = \frac{\mu_0 I_0 e^{-kt}}{2\pi r}}$$

b) $\Phi = \int \vec{B} \cdot d\vec{A}$ here $\vec{B} \parallel d\vec{A}$

so $\Phi = \int B\, dA$

$$dA = c\, dr$$

so $$\Phi_B = \int_a^{a+b} \frac{\mu_0 I_0 e^{-kt}}{2\pi r} c\, dr$$

$$\boxed{\Phi_B = \frac{\mu_0 I_0 e^{-kt} c \ln\left(\frac{b+a}{a}\right)}{2\pi}}$$

c) $$\mathcal{E}_{ind} = -\frac{d\Phi_B}{dt} = +\frac{\mu_0 I_0 e^{-kt} k c \ln\left(\frac{b+a}{a}\right)}{2\pi}$$

$$i = \frac{\mathcal{E}_{ind}}{R} = \boxed{\frac{\mu_0 I_0 e^{-kt} k c \ln\left(\frac{b+a}{a}\right)}{2\pi R}}$$

d) $\vec{B}$ from long wire points into the page & decreases in time. Lenz's law says this change is opposed, so $B_{induced}$ is also into page. $\boxed{\text{clockwise}}$ current flow will accomplish this.