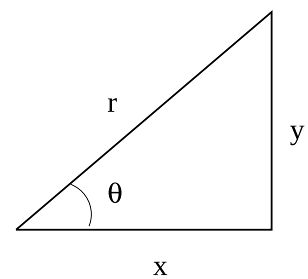
Physics 241 – Exam #2

March 30 **2006**

This exam consists of 13 problems on 9 pages. **Please check that you have them all.** Each problem is worth 12 points unless otherwise noted.

All of the formulas that you will need are given below. You may also use a calculator.

$\sin\theta = y/r$ $\cos\theta = x/r$ $\tan\theta = y/x$



$e = 1.6\times10^{-19}$ C $k = 9.0\times10^{9}\ \mathrm{N\cdot m^2/C^2}$ $\epsilon_0 = 8.9\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$

$$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\epsilon_0 r^2} \qquad E = \frac{kq}{r^2} \qquad \Phi = \int \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0} \qquad \text{charged plane}: E = \frac{\sigma}{2\epsilon_0}$$

$$\Delta V = \frac{\Delta U_E}{q} = -\int \vec{E}\cdot d\vec{l} \qquad dV = -\vec{E}\cdot d\vec{l} \qquad \text{point charge}: V = \frac{kq}{r} \qquad U_E = q_0V = \frac{kqq_0}{r}$$

$$E_x = -\frac{\partial V}{\partial x} \qquad 1\ \text{Volt} = 1\ \text{J / C} \qquad 1\ \text{Volt/m} = 1\ \text{N / C} \qquad U_E = \frac{1}{2}qV \qquad C = \frac{q}{V}$$

$$\text{Surface area(sphere)} = 4\pi R^2 \qquad \text{capacitor}: U_E = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}qV = \frac{1}{2}CV^2 \qquad u_E = \frac{1}{2}\epsilon_0E^2$$

$$\text{parallel plate capacitor}: C = \frac{\epsilon_0 A}{d} \qquad \text{isolated spherical capacitor}: C = 4\pi\epsilon_0 R$$

$$\text{capacitors in parallel}: C = C_1 + C_2 + C_3... \qquad \text{capacitors in series}: \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}...$$

$$C = \kappa C_0 \qquad I = \frac{\Delta q}{\Delta t} \qquad R = \frac{V}{I} \qquad R = \rho\frac{L}{A} \qquad V = IR$$

$$P = IV = I^2R = \frac{V^2}{R} \qquad P = \mathcal{E}I \qquad \text{resistors in series}: R = R_1 + R_2 + R_3...$$

$$\text{resistors in parallel}: \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}... \qquad q(t) = q_0 e^{-t/(RC)} = q_0 e^{-t/\tau}$$

$$I(t) = \frac{V}{R} e^{-t/(RC)} = I_0 e^{-t/\tau} \qquad \tau = RC$$

$$q(t) = C\mathcal{E}(1 - e^{-t/(RC)}) = q_0(1 - e^{-t/\tau}) \qquad I(t) = \frac{\mathcal{E}}{R} e^{-t/(RC)} = I_0 e^{-t/\tau}$$

$$\vec{F_B} = q\vec{v} \times \vec{B} \qquad \vec{F_B} = I\vec{L} \times \vec{B} \qquad \vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2} \qquad \Phi_B = BA\cos\theta$$

$$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A} \qquad d\vec{B} = \frac{\mu_0}{4\pi}\frac{I d\vec{\ell} \times \hat{r}}{r^2} \qquad \int \vec{B} \cdot d\vec{\ell} = \mu_0 I \qquad B(\text{center of circular loop}) = \frac{\mu_0 I}{2R}$$

$$B(\text{wire}) = \mu_0 I/(2\pi r) \qquad B(\text{solenoid}) = \mu_0 n I \qquad \mathcal{E} = -\frac{d\Phi_B}{dt} \qquad U_L = \frac{1}{2}LI^2$$

$$V_L = -L\frac{dI}{dt} \qquad L = \mu_0 n^2 A\ell \qquad U_B = \frac{1}{2\mu_0}B^2(Vol) \qquad u_B = \frac{1}{2\mu_0}B^2$$

$$I = \frac{V}{R}(1 - e^{(-t/\tau)}) \qquad |V_L| = Ve^{(-t/\tau)} \qquad \tau = L/R$$

$$\omega = 2\pi f \qquad X_C = \frac{1}{\omega C} \qquad X_L = \omega L \qquad \omega_{resonance} = \frac{1}{\sqrt{LC}}$$

$$I_{rms} = \frac{1}{\sqrt{2}}I_{peak} \qquad I_{rms} = \frac{V_{rms}}{R} \qquad I_{rms} = \frac{V_{rms}}{X_C} \qquad I_{rms} = \frac{V_{rms}}{X_L} \qquad P_{ave} = I_{rms}^2 R$$

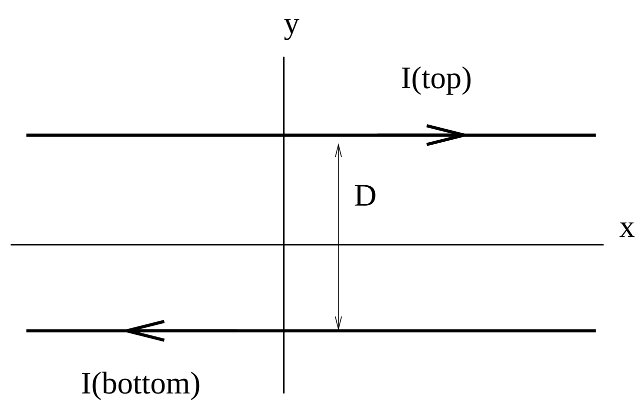
$$I_{peak} = \frac{V_{peak}}{R} \qquad I_{peak} = \frac{V_{peak}}{X_C} \qquad I_{peak} = \frac{V_{peak}}{X_L}$$

1. An electron has a velocity along the $-z$ direction, in a region where the magnetic field is along $-y$. What is the direction of the magnetic force on the electron?

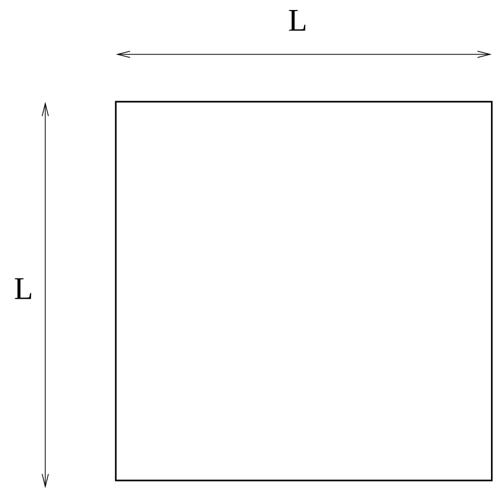
   (a) The force is zero
   (b) The force is along the $+x$ direction
   (c) The force is along the $-x$ direction
   (d) The force is along the $+y$ direction
   (e) The force is along the $-y$ direction

2. A very long straight wire carries a current $I(top) = 8.5$ A to the right as shown below. A parallel wire (also very long and straight) carries a current $I(bottom) = 3.5$ A to the left. The wires are separated by a distance $D = 0.55$ m. What is the magnitude of the magnetic force on a 2.5 m long section of the top wire?

   (a) 270 N
   (b) 3.1×10^{-7} N
   (c) 1.7×10^{-4} N
   (d) 2.7×10^{-5} N
   (e) 1.1×10^{-5} N

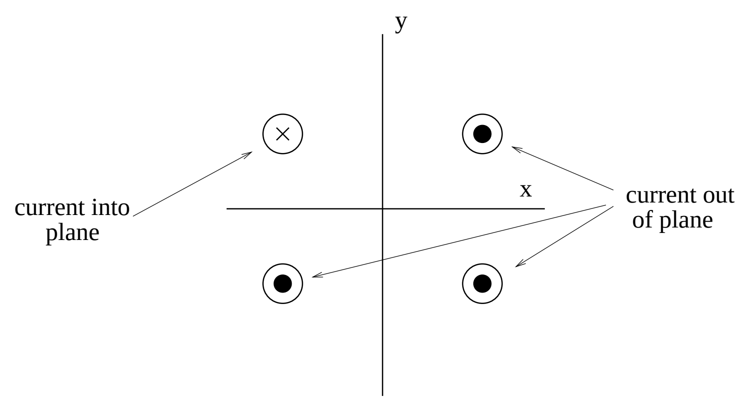


3. Four wires, each of length $L = 2.5$ m, are connected to form a square metal loop as shown. Each wire has a resistance $R = 750\ \Omega$. A magnetic field of magnitude B is directed perpendicular to the plane of the loop, and into the plane of the drawing. This field varies with time as $B = 0.65 - 1.5t$ where the field is measured in tesla and time in seconds. What is the magnitude of the force on one of the straight sections of the loop at $t = 0$?



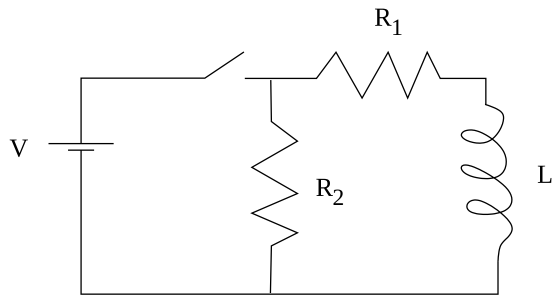
(a) 6.1 N
(b) 0.85 N
(c) 15 N
(d) 2.1 N
(e) 0.0051 N

4. Four very long straight wires are directed perpendicular to the plane of the drawing below. The points where these wires cross the plane of the drawing form a square of edge length $L = 40$ cm. Each wire carries a current of magnitude 2.5 A. Find the magnetic field (direction and magnitude) at the center of the square.



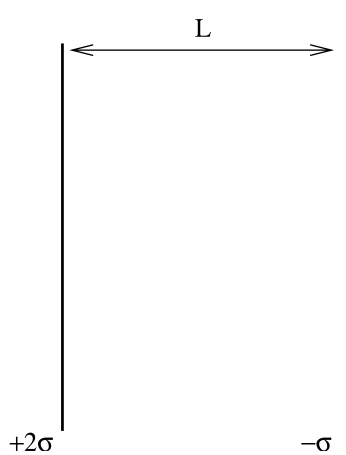
(a) 7.0×10^{-6} T directed towards the bottom of the figure.
(b) 2.5×10^{-6} T directed towards the lower left of the figure.
(c) 1.7×10^{-6} T directed towards the lower left of the figure.
(d) zero
(e) 3.5×10^{-6} T directed towards the lower left of the figure.

5. Consider the circuit shown below with $V = 9.0$ V, $R_1 = 3000\ \Omega$, $R_2 = 7000\ \Omega$, and $L = 7.7$ mH. This switch is closed for a very long time. What is the energy stored in the inductor?



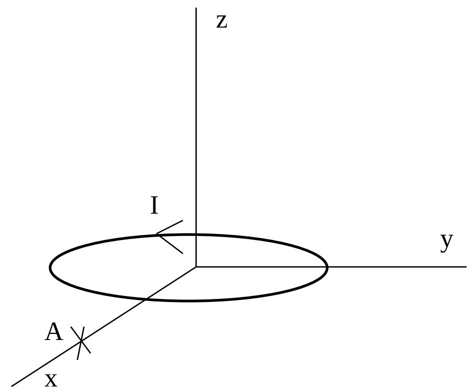
(a) zero
(b) 6.9×10^{-8} J
(c) 1.2×10^{-5} J
(d) 3.0×10^{-3} J
(e) 3.5×10^{-8} J

6. Two infinite uniformly charged planes are separated by a distance L. The plane on the left has a charge per unit area of $+2\sigma$, and is at $V = 0$. The plane on the right has a charge per unit area $-\sigma$. What is the potential of the plane on the right?



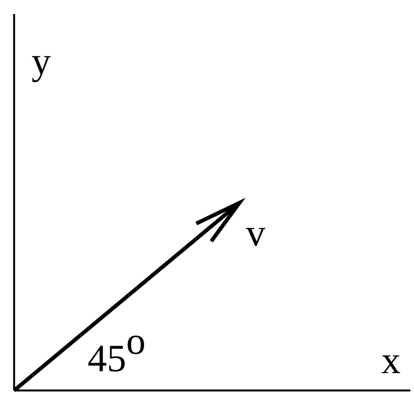
(a) $-3\sigma L/(2\epsilon_0)$
(b) $\sigma L/(2\epsilon_0)$
(c) $+3\sigma L/(2\epsilon_0)$
(d) $-\sigma L/(2\epsilon_0)$
(e) $-\sigma L/\epsilon_0$

7. A loop of wire lies in the $x-y$ plane. This loop has a current I that circulates counter-clockwise as viewed from above (along $+z$). What is the direction of the magnetic field at point A on the x axis?



(a) $+y$
(b) $-y$
(c) $+z$
(d) $-z$
(e) $+x$

8. A proton (charge $= +e = +1.6 \times 10^{-19}$ C) travels in the $x-y$ plane as shown below with a speed of 250 m/s. There is a magnetic field of magnitude 2.5 T along the $+x$ direction. What is the direction and magnitude of the magnetic force on the proton? Note that the $+z$ direction is out of the plane of the drawing, toward you.



(a) 1.0×10^{-16} N along the $+z$ direction
(b) 1.0×10^{-16} N along the $-z$ direction
(c) zero
(d) 7.1×10^{-17} N along the $+z$ direction
(e) 7.1×10^{-17} N along the $-z$ direction

9. The axis of a current loop is parallel to the z axis, and the loop is centered at the origin. A very long straight wire runs parallel to the x axis and lies in the $x-y$ plane as shown. The current in the wire is in the $+x$ direction, and is decreasing with time. What is the direction of the induced current in the loop?

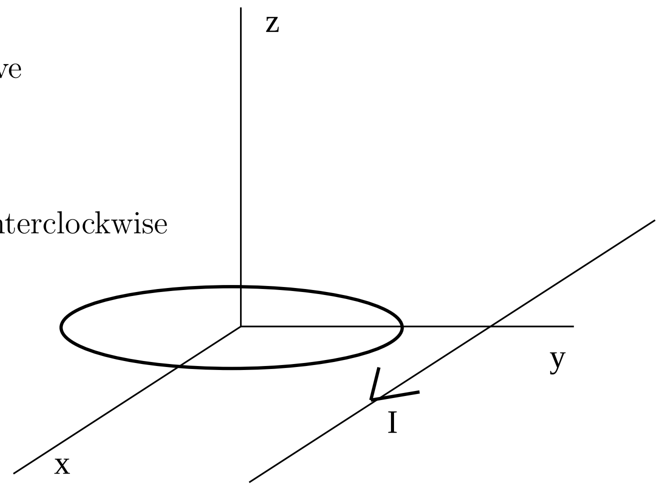
(a) counterclockwise as viewed from above

(b) clockwise as viewed from above

(c) zero - there is no induced current

(d) oscillates between clockwise and counterclockwise

(e) not enough information to tell



10. An $L-C$ circuit contains a single inductor in parallel with a single capacitor. The inductor has an inductance of 0.55 mH and the circuit has a resonant frequency of 250 kHz. What is the capacitance of the capacitor?

(a) 2.9×10^{-8} F

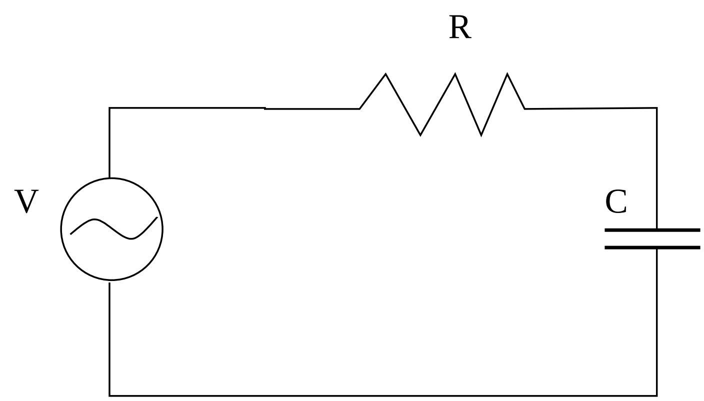
(b) 1.7×10^{-4} F

(c) 7.4×10^{-10} F

(d) 1.5×10^{-9} F

(e) 5.5×10^{-8} F

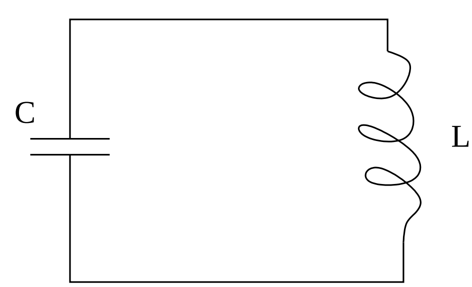
11. Consider the AC circuit shown below. The AC voltage has an amplitude of $V_0 = 1.5$ V; i.e., $V = V_0 sin(2\pi f t)$ where f is very very high. If the amplitude of the current in the circuit is 5.7 mA, what is the resistance R of the resistor?



(a) 860 Ω
(b) 3.8×10^{-3} Ω
(c) 260 Ω
(d) 170 Ω
(e) 3600 Ω

12. Consider the LC circuit shown below with $L = 2.5$ mH and $C = 7.5 \times 10^{-9}$ F. At $t = 0$ the current is 45 mA while the charge on the capacitor is zero. A short time later the current is zero; what is the charge on the capacitor at that moment?

(a) 1.9×10^{-7} C
(b) 8.4×10^{-10} C
(c) 4.5×10^{-2} C
(d) 7.3×10^{-6} C
(e) zero



Note: Problem 13 is worth 6 points.

13. Which fundamental law of electromagnetism explains how a generator produces an AC electric potential difference?

    (a) Ampere's law
    (b) Coulomb's law
    (c) Faraday's law
    (d) Gauss' law
    (e) Biot-Savart law

The End