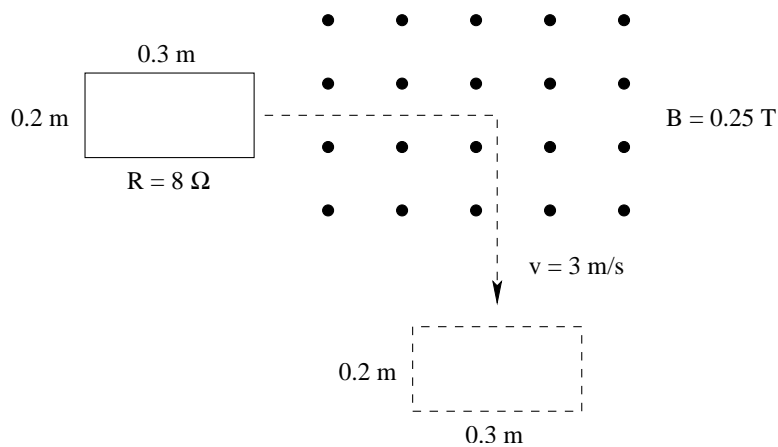


Physics 122  
**Midterm Examination #1**  
March 21, 2007

SOLUTIONS

1. Shown in the figure below is a rectangular loop located to the left of a region with a magnetic field ( $B = 0.25 \text{ Tesla}$ ) pointed out of the paper. The loop is dragged with a constant speed of  $v = 3 \frac{\text{m}}{\text{s}}$  along the path shown by the dashed arrow. The resistance of the loop is  $R = 8 \Omega$ .



- (a) Determine the magnitude **AND** direction (clockwise or counter-clockwise) of the current in the loop during each of the following three conditions:

- i. The loop is entering the field region.

$$\Phi_B = Blx \quad (1)$$

$$\frac{d\Phi_B}{dt} = Bl \frac{dx}{dt} = Blv \quad (2)$$

$$V = Blv \quad (3)$$

$$I = \frac{Blv}{R} = \frac{0.25 \cdot 0.2 \cdot 3}{8} = 0.01875 \text{ A} = 18.75 \text{ mA} \quad (4)$$

$$\text{clockwise} \quad (5)$$

- ii. The loop is completely inside the field region.

$$I = 0 \quad (6)$$

- iii. The loop is leaving the field region.

$$\Phi_B = Blx \quad (7)$$

$$\frac{d\Phi_B}{dt} = Bl \frac{dx}{dt} = Blv \quad (8)$$

$$V = Blv \quad (9)$$

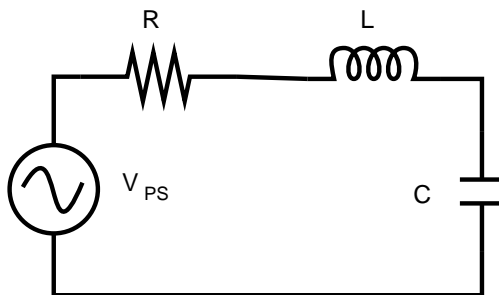
$$I = \frac{Blv}{R} = \frac{0.25 \cdot 0.3 \cdot 3}{8} = 0.0281 \text{ A} = 28.1 \text{ mA} \quad (10)$$

*counter – clockwise* (11)

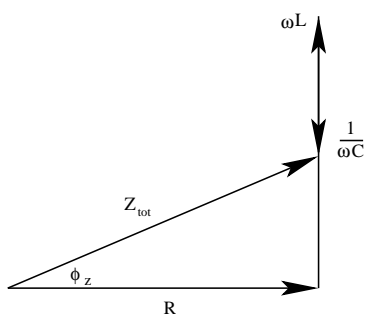
- (b) Determine the magnitude AND direction of the force on the loop as it is exiting the field. Indicate the direction of the force by circling one of the following:
- i. Toward the left of the page.
  - ii. **Toward the top of the page.**
  - iii. Toward the right of the page.
  - iv. Toward the bottom of the page.
  - v. Out of the page.
  - vi. Into the page.

$$F = IlB = 0.0281 \cdot 0.3 \cdot 0.25 = 2.1 \times 10^{-3} \text{ N} \quad (12)$$

2. Shown below is an LRC circuit.



(a) Draw a phaser diagram representing this circuit.



(b) Analyze your phaser diagram to determine the magnitude of the impedance,  $|Z|$ .

$$|Z_{tot}| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \quad (13)$$

(c) Analyze your phaser diagram to determine the phase of the impedance,  $\phi_Z$ .

$$\phi_Z = \tan^{-1} \left( \frac{\omega L - \frac{1}{\omega C}}{R} \right) \quad (14)$$

(d) Let the resistance be  $R = 600 \, \Omega$ , the inductance be  $L = 1.04 \, \mu H$  and the capacitance be  $C = 3 \times 10^{-12} \, F$ . Determine the peak voltage across the resistor if the circuit is driven by an AC power source with  $V_{peak} = 10 \, V$  and  $f = 500 \, MHz$ .

$$|Z_{tot}| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \quad (15)$$

$$\omega L = 2\pi 500 \times 10^6 (1.04 \times 10^{-6}) = 3267\Omega \quad (16)$$

$$\frac{1}{\omega C} = \frac{1}{2\pi 500 \times 10^6 3 \times 10^{-12}} = 106\Omega \quad (17)$$

$$|Z_{tot}| = \sqrt{600^2 + (3267 - 106)^2} \quad (18)$$

$$|Z_{tot}| = 3217\Omega \quad (19)$$

$$V_R = \frac{R}{Z_{tot}} V_p = \frac{600}{3217} 10 = 1.87 V \quad (20)$$

- (e) Clearly, your circuit is not tuned for the  $f = 500 MHz$  signal. Determine the frequency that your circuit **IS** tuned for.

$$\omega = \frac{1}{\sqrt{LC}} \quad (21)$$

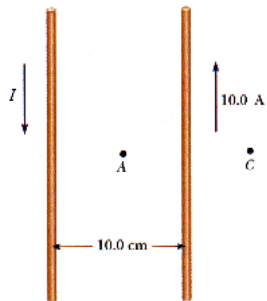
$$\omega = \frac{1}{\sqrt{1.04 \times 10^{-6} 3 \times 10^{-12}}} = 566 \times 10^6 \quad (22)$$

$$f = \frac{\omega}{2\pi} = 90.1 \times 10^6 Hz = 90.1 MHz \quad (23)$$

- (f) **EXTRA CREDIT (1 point):** What are the call letters of this radio station?

WUSB

3. Two parallel conductors carry currents in opposite directions, as shown in the Figure below. One conductor carries a current of 10.0 A. Point A is the midpoint between the wires, and point C is 5.00 cm to the right of the 10.0 A current. I is adjusted so that the magnetic field at C is zero.



- (a) Find the value of the current I.

$$0 = \frac{\mu_0 I}{2\pi 0.15} - \frac{\mu_0 10}{2\pi 0.05} \quad (24)$$

$$\frac{\mu_0 I}{2\pi 0.15} = \frac{\mu_0 10}{2\pi 0.05} \quad (25)$$

$$\frac{I}{0.15} = \frac{10}{0.05} \quad (26)$$

$$I = 30 \text{ Amps} \quad (27)$$

- (b) Find the value of the magnetic field at A.

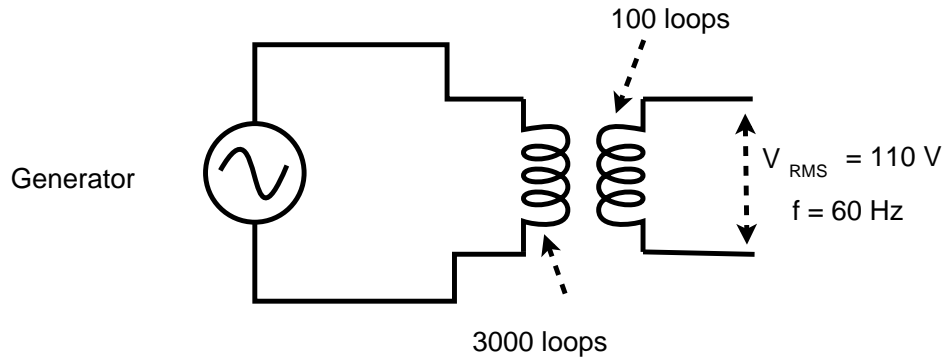
$$B = \frac{\mu_0 30}{2\pi 0.05} + \frac{\mu_0 10}{2\pi 0.05} \quad (28)$$

$$B = \frac{\mu_0 40}{2\pi 0.05} \quad (29)$$

$$B = 0.00016 \text{ Tesla} \quad (30)$$

4. The circuit below shows a generator driving a transformer. The output side of the transformer has an AC voltage whose RMS is  $V_{RMS} = 110\text{ V}$  and whose frequency is  $f = 60\text{ Hz}$ .

The generator is made from a circular coil of wire with  $N = 400\text{ turns}$  whose radius is  $r = 0.2\text{ m}$ . The coil is rotated in a uniform magnetic field,  $B$ .



- (a) Determine the *peak* voltage applied to the input side of the transformer.

$$V_{in}(RMS) = \frac{3000}{100} 110 = 3300 \quad (31)$$

$$V_{in}(peak) = \sqrt{2} V_{in}(RMS) = 4667\text{ Volts} \quad (32)$$

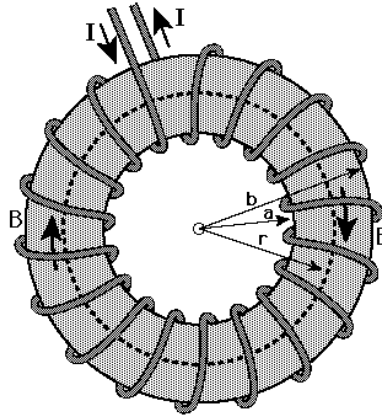
- (b) Determine the magnetic field in the generator.

$$V_{peak} = \omega N B A \quad (33)$$

$$B = \frac{V_{peak}}{\omega N A} = \frac{V_{peak}}{2\pi f N \pi r^2} \quad (34)$$

$$B = \frac{4667}{2\pi 60 (400) \pi 0.2^2} = 0.246\text{ Tesla} \quad (35)$$

5. Shown in the figure below is a toroid. The toroid carries a current  $I$  and has a total of  $N$  turns. Use Ampere's Law to calculate the magnetic field at the radius  $r$  shown in the Figure.



$$\oint \vec{B} \cdot d\vec{L} = \mu_0 I_{in} \quad (36)$$

$$BL = \mu_0 I_{in} \quad (37)$$

$$L = 2\pi r \quad (38)$$

$$I_{in} = NI \quad (39)$$

$$B = \frac{\mu_0 NI}{2\pi r} \quad (40)$$

**HINT:** Think of a toroid as a long solenoid bent into a circular shape.