

## CHAPTER 18 -- RADIO

### QUESTION & PROBLEM SOLUTIONS

**18.1)** Solutions not provided (they are research questions).

**18.2)** Solutions not provided (they are research questions).

**18.3)** An RLC circuit incorporates a 12 ohm resistor, a 60 mH inductor, and a 12  $\mu$ f capacitor hooked in series across a power supply whose time-dependent voltage is  $140 \sin(1100 t)$ .

**a.)** Determine the frequency of the power supply's signal.

Solution: The angular frequency  $\omega$  of the oscillating power source is 1100 radians per second (look to see where that information is found in the *time dependent voltage* function). As angular frequency is related to frequency

$$\text{by } \omega = 2\pi\nu, \text{ we can write } \nu = \frac{\omega}{2\pi} = \frac{1100}{2\pi} = 175 \text{ Hertz.}$$

**b.)** Determine the capacitive reactance at this frequency.

Solution: The *capacitive reactance* is the frequency dependent resistive nature of the capacitor. Numerically, this is

$$X_C = \frac{1}{2\pi\nu C} = \frac{1}{2\pi(175 \text{ Hz})(12 \times 10^{-6} \text{ F})} = 75.8 \ \Omega.$$

**c.)** Determine the inductive reactance at this frequency.

Solution: The *inductive reactance* is the frequency dependent resistive nature of the inductor (i.e., the coil). Numerically, this is

$$X_L = 2\pi\nu L = 2\pi(175 \text{ Hz})(60 \times 10^{-3} \text{ H}) = 66.0 \text{ ohms.}$$

**d.)** Determine the impedance of the circuit at this frequency.

Solution: The *impedance* is the net resistive nature due to both the fixed resistance and frequency dependent contributions of any inductors and/or capacitors in a circuit. Numerically, this is

$$Z = \left[ R_{net}^2 + (X_L - X_C)^2 \right]^{1/2} = \left[ R_{net}^2 + \left( 2\pi\nu L - \frac{1}{2\pi\nu C} \right)^2 \right]^{1/2} = \left[ (12)^2 + (66 - 75.8)^2 \right]^{1/2} = 15.5 \text{ ohms.}$$

Notice that the resistive nature of both the inductor at 66 ohms and the capacitor at 75.8 ohms are larger than the overall circuit resistance at 15.5 ohms. How can this be? It turns out that the capacitor's contribution to the resistive nature and the inductor's contribution to the resistive nature *fight* one another. That is why the two are subtracted from one another in the impedance relationship.

**e.)** Determine the phase shift at this frequency. Is the voltage leading or lagging the current?

Solution: The phase shift is determined by the relationship

$$\phi = \tan^{-1} \left( \frac{X_L}{X_C} \right).$$

In this instance, that numeric value is

$$\phi = \tan^{-1} \left( \frac{66}{75.8} \right) = 41.0^\circ = .716 \text{ radians.}$$

As for the relationship between voltage and current, if  $X_L - X_C$  is positive, the inductor holds sway and the voltage *leads* the current. If  $X_L - X_C$  is negative, the capacitor holds sway and the voltage *lags* the current. In this case, the capacitive reactance is dominant and the voltage *lags* the current by .716 radians.

**f.)** Determine the power supply's RMS voltage.

Solution: The RMS value for the voltage is numerically equal to  $.707V_{\text{peak}}$ . In this case, that is  $.707(140) = 99.0$  volts.

**g.)** Determine the RMS current in the circuit at this frequency.

Solution: To get the RMS current, we need to use Ohm's Law. As the resistive nature of the circuit is what limits the current, we write Ohm's Law as  $V_{RMS} = i_{RMS}Z$ . That means the RMS current will be

$$i_{RMS} = \frac{V_{RMS}}{Z} = \frac{99.0 \text{ volts}}{15.5 \Omega} = 6.39 \text{ amps.}$$

**h.)** Determine the resonance frequency for this circuit.

Solution: The resonant frequency happens when the inductor's frequency dependent resistive effect and the capacitor's frequency dependent resistive effect cancels one another out. That is, when  $X_L - X_C = 0$ .

Manipulating the math leads to the expression

$$\nu_{res} = \frac{1}{2\pi} \sqrt{\frac{1}{LC}} = \frac{1}{2\pi} \sqrt{\frac{1}{(60 \times 10^{-3})(12 \times 10^{-6})}} = 188 \text{ Hz.}$$

**18.4)** You have an old, analog radio (i.e., not electronic) in which there exists a fixed 25 mH inductor. Unfortunately, the little arrow thingie that points to the station numbers on the face of the radio has broken off, so you can't just turn the dial until it points to the station number you want. You do, though, have access to the guts of the radio, and you have an impedance bridge (i.e., a meter that measures inductance or capacitance or resistance). You would *like* to listen to KFWB, channel 98 (x10 kHz). To get that station, what must you do. Be complete, and include any numerical values needed to execute your plan.

Solution: You know the resonance frequency of the tuning circuit in the radio has to match the sending frequency of the station you want to listen to. In other words,

$v_{res} = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$  has to equal  $98 \times 10^4$  Hz (that is, 980,000 Hz). Knowing that the fixed inductor in the tuning circuit is  $L = 25$  mH, you could work backwards to determine the correct capacitor value to make the resonance frequency 980,000 Hz.

Writing  $v_{res} = 980,000 = \frac{1}{2\pi} \sqrt{\frac{1}{(25 \times 10^{-3})(C)}}$  yields a capacitance value of  $C =$

$1.05 \times 10^{-12}$  f (i.e., 1.05 pf). By using the impedance bridge to set the variable capacitor in your tuning circuit to the correct value, voila, KFWB will come through.

**18.5)** A circuit driven at 240 hertz has 27 ohms of impedance when a 12 ohm resistor is connected in series with an inductor whose internal resistor-like resistance is 8 ohms and a 25  $\mu$ f capacitor. The circuit's power source provides 70 volts RMS.

a.) What is the inductive reactance at this frequency?

Solution: This problem is designed to make you think (I know, I know, I should be ashamed of myself). What do you know? You know you have a total resistor-like resistance in the circuit of 20  $\Omega$  (that's 12  $\Omega$  from a resistor and 8  $\Omega$  from the coil). You know that the capacitor's capacitance is  $C = 25 \times 10^{-6}$  farads. And you know that  $V_{RMS} = 70$  volts. You know that the circuit's impedance is  $Z = 27$   $\Omega$  when the power supply's frequency is  $v = 240$  Hz. As the impedance relationship has  $X_L$  (i.e., the inductive reactance) as one of its members, we should be able to use the impedance relationship to determine  $X_L$ . Doing so yields

$$Z = 27 \Omega = \left[ R_{net}^2 + (X_L - X_C)^2 \right]^{1/2} = \left[ (20)^2 + \left( X_L - \frac{1}{2\pi(240)(25 \times 10^{-6})} \right)^2 \right]^{1/2}.$$

Solving this is a little bit icky, but if you do it you get  $X_L = 44.6$  ohms.

b.) Determine the circuit's impedance at 1000 hertz.

Solution: We need the inductor's inductance. We know that  $X_L = 2\pi\nu L$ , and we know from the previous problem that when the frequency is 240 Hz,  $X_L = 44.6 \text{ ohms}$ . Using this, we get an inductance of

$$L = \frac{X_L}{2\pi\nu} = \frac{44.6}{2\pi(240)} = 2.96 \times 10^{-2} \text{ Henrys (i.e., 29.6 mH).}$$

With the inductance, we can use the impedance relationship

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

to determine the circuit's impedance at 1000 Hz. Doing that yields

$$Z = \left[ (20)^2 + \left( 2\pi(1000)(2.96 \times 10^{-2} H) - \frac{1}{2\pi(1000)(25 \times 10^{-6} f)} \right)^2 \right]^{1/2} = 180.7 \Omega.$$

c.) Determine the circuit's RMS current at 1000 hertz.

Solution: As noted in a previous problem,  $i_{RMS} = \frac{V_{RMS}}{Z}$ . As such, we can

$$\text{write } i_{RMS} = \frac{V_{RMS}}{Z} = \frac{70 \text{ volts}}{180.7 \Omega} = .387 \text{ amps.}$$

d.) What is the resonant frequency for this circuit?

Solution: Resonance occurs when

$$\nu_{res} = \frac{1}{2\pi} \sqrt{\frac{1}{LC}} = \frac{1}{2\pi} \sqrt{\frac{1}{(2.96 \times 10^{-2} H)(25 \times 10^{-6} f)}} = 185 \text{ Hz.}$$

**18.6)** Use the breadboard provided (next page) to show how you would wire the amplified radio circuit pictured in Figure 18.24.

Solution: There are so many ways to do this, I couldn't possibly do justice to the problem with a solution. As such, if you can't figure it out, come in and talk to me.