ÇANKAYA UNIVERSITY

PHYS 132 – PHYSICS II

CHAPTER 31

ELECTROMAGNETIC OSCILLATIONS AND ALTERNATING CURRENT

PROBLEM SET

1) A heater coil connected to a 240-V_{rms} ac line has a resistance of 44 Ω (*a*) What is the average power used? (*b*) What are the maximum and minimum values of the instantaneous power? **[Answer: a) 1300 W, b) Maximum = 2600 W, minimum = 0]**

2) *** For a time-dependent voltage $V(t)$, which is periodic with period T, the rms voltage is defined to be

$$V_{\text{rms}} = \left[\frac{1}{T}\int_0^T V^2 dt\right]^{1/2}$$

Use this definition to determine V_{rms} (in terms of the peak voltage V_0) for (a) a sinusoidal voltage, i.e., $V(t)$ equals

$$V_0 \sin\frac{2\pi t}{T}$$

for $0 \leq t \leq T$; and (b) a positive square-wave voltage, i.e.,

$$V(t) = \begin{cases} V_0 & 0 \leq t \leq \frac{T}{2} \\ 0 & \frac{T}{2} \leq t \leq T \end{cases}$$

[Answer: a) $\frac{V_0}{\sqrt{2}}$, b) $\frac{V_0}{\sqrt{2}}$]

3) Compare the oscillations of an *LRC* circuit to the vibration of a mass *m* on a spring. What do *L* and *C* correspond to in the mechanical system?

[Answer: L corresponds to *m*, and C corresponds to $1/k$]

4) In some experiments, short distances are measured by using capacitance. Consider forming an *LC* circuit using a parallel-plate capacitor with plate area *A*, and a known inductance *L*. (*a*) If charge is found to oscillate in this circuit at frequency $f = \omega/2\pi$ when the capacitor plates are separated by distance *x*, show that

$$x = \boxed{4\pi^2 A\varepsilon_0 f^2 L}$$

(*b*) When the plate separation is changed by Δx, the circuit's oscillation frequency will change by Δf. Show that

$$\frac{\Delta x}{x} \approx \frac{2\Delta f}{f}$$

(*c*) If f is on the order of 1 MHz and can be measured to a precision of $\Delta f = 1$ Hz with what percent accuracy can *x* be determined? Assume fringing effects at the capacitor's edges can be neglected. **[Answer: 0.0002 %]**

5) (*a*) What is the reactance of a 0.086-μF capacitor connected to a 22-kV (rms), 660-Hz line? (*b*) Determine the frequency and the peak value of the current.

[Answer: a) 2800 Ω, b) 11 A at 660 Hz]

6) *** (*a*) What is the rms current in a series *RC* circuit if R = 3.8 kΩ, $C = 0.80\ \mu F$ and the rms applied voltage is 120 V at 60.0 Hz? (*b*) What is the phase angle between voltage and current? (*c*) What is the power dissipated by the circuit? (*d*) What are the voltmeter readings across *R* and *C*?

[Answer: a) 2.4×10^{-2} A, b) -41^0, c) 2.2 W, d)90 V across R and 79 V across C]

7) An ac voltage source is connected in series with a 1.0-μF capacitor and a 750-Ω resistor. Using a digital ac voltmeter, the amplitude of the voltage source is measured to be 4.0 V rms, while the voltages across the resistor and across the capacitor are found to be 3.0 V rms and 2.7 V rms, respectively. Determine the frequency of the ac voltage source. Why is the voltage measured across the voltage source not equal to the sum of the voltages measured across the resistor and across the capacitor?

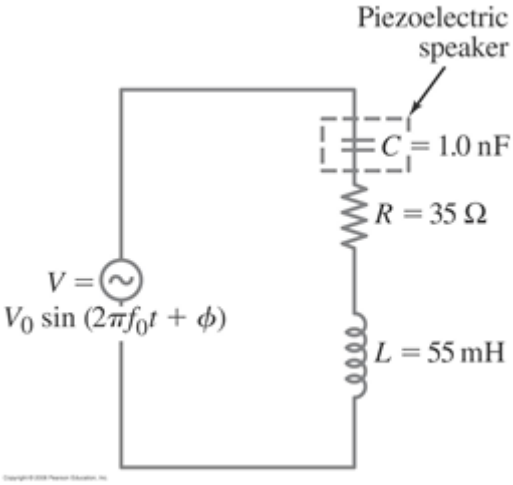
[Answer: 240 Hz, Since the voltages in the resistor and capacitor are not in phase, the rms voltage across the power source will not be the sum of their rms voltages.]

8) A 3800-pF capacitor is connected in series to a 26.0-mH coil of resistance 2.00 Ω. What is the resonant frequency of this circuit?

[Answer: 5.1×10^5 Hz]

9) Capacitors made from piezoelectric materials are commonly used as sound transducers ("speakers"). They often require a large operating voltage. One method for providing the required voltage is to include the speaker as part of an *LRC* circuit as shown in Fig. 30–29, where the speaker is modeled electrically as the capacitance $C = 1.0\,\text{nF}$. Take R=35 Ω and $L = 55\,\text{mH}$. (*a*) What is the resonant frequency f_0 for this circuit? (*b*) If the voltage source has peak amplitude $V_0 = 2.0\,\text{V}$ at frequency $f = f_0$, find the peak voltage V_{C0} across the speaker (i.e., the capacitor *C*). (*c*) Determine the ratio V_{C0}/V_0.

[Answer: a) 21 kHz, b) 420 V, c) 210]



10) *** In our analysis of a series *LRC* circuit, Fig. 30–19, suppose we chose $V = V_0 sin\omega t$. (*a*) Construct a phasor diagram, like that of Fig. 30–21, for this case. (*b*) Write a formula for the current *I*, defining all terms. **[Answer: a) figure below,**

b)

$$\frac{V_0}{\sqrt{R^2 + (\omega L - 1/\omega C)^2}} \sin(\omega t - \phi)$$

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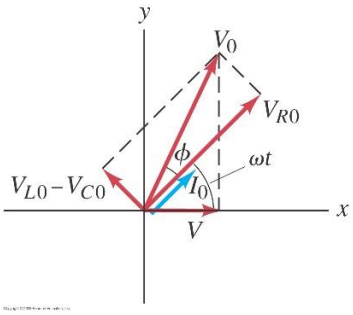
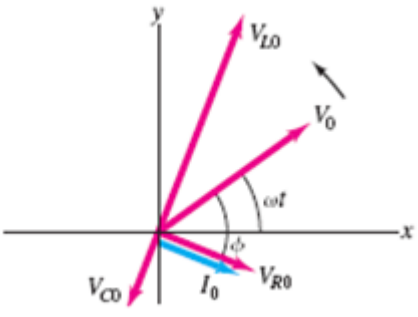


Fig. 30–21



Answer for a)

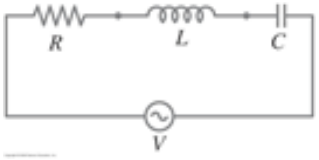


Fig. 30–19