Physics 6C, Summer 2006
Homework 2 Solutions

All problems are from the 2nd edition of Walker. Numerical values are different for each student.

Chapter 23 Problems

22. Figure 23-30 below shows a circuit containing a resistor R. To the right of the circuit is a current-carrying wire.

VERSION A: the current in the wire on the right is travelling up.
VERSION B: the current in the wire on the right is travelling down.

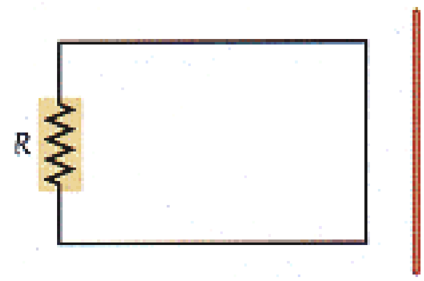


Figure 23-30

(a) If the current in the wire is constant, what is the induced current in the circuit?
(b) If the current in the wire increases, what is the induced current in the circuit?

Solution:

(a) Since the current in the wire is constant, the magnetic field through the circuit does not vary with time. This means the magnetic flux through the circuit is not changing, so the induced current is zero.

(b) Since the current in the wire is increasing, its magnetic field (and therefore the flux through the circuit) is increasing. By the right hand rule, the wire's magnetic field that penetrates the circuit is directed out of the page for **version A** and into the page for **version B**. By Faraday's law, there will be an induced current in the circuit (to oppose the increasing magnetic flux) whose magnetic field opposes the wire's increasing magnetic field. Thus the magnetic field produced by the circuit is into the page for **version A** and out of the page for **version B**. By the righthand rule for a current loop, this means the current in the circuit flows clockwise for **version A** and counterclockwise for **version B**.

Chapter 24 Problems

6. A "75 watt" light bulb uses an average power of 50 W when connected to an rms voltage of 120 V.
(a) What is the resistance of the light bulb?
(b) What is the maximum current in the bulb?
(c) What is the maximum power used by the bulb?

Solution:

(a) $R = \frac{V_{\text{rms}}^2}{P_{\text{av}}} = \frac{(120\text{ V})^2}{75\text{ W}} = \boxed{190\ \Omega}$

(b) $I_{\text{max}} = \frac{V_{\text{max}}}{R} = \frac{\sqrt{2}V_{\text{rms}}}{R} = \frac{\sqrt{2}(120\text{ V})}{192\ \Omega} = \boxed{0.88\ \text{A}}$

(c) $P_{\text{max}} = 2P_{\text{av}} = 2(75\text{ W}) = \boxed{150\text{ W}}$

28. An inductor has a reactance of 56.5 Ω at 75.0 Hz. What is its reactance at 60.0 Hz?

Solution: $L = \dfrac{X_L}{\omega}$

$$X_L{}' = \omega' L = \omega'\left(\frac{X_L}{\omega}\right) = \frac{\omega'}{\omega} X_L = \frac{2\pi(60.0\text{ Hz})}{2\pi(75.0\text{ Hz})}(56.5\ \Omega) = \boxed{45.2\ \Omega}$$

45. Consider the circuit shown in Figure 24-29. The ac generator in this circuit has an rms voltage of 65 V. The circuit-element values are R = 15 Ω and C = 41 μF.

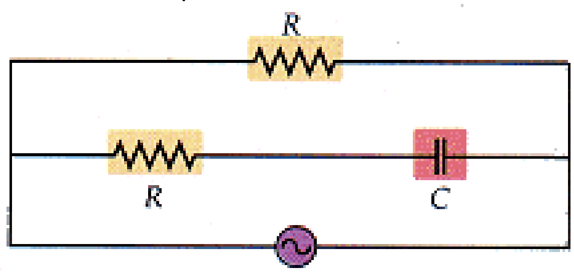


Figure 24-29

(a) Find the rms current in this circuit in the limit of high frequency.
(b) Find the rms current in this circuit in the limit of low frequency.

Solution:

(a) In the limit of high frequency, the reactance of the capacitor approaches zero. So, the current flows through each resistor equally. Since the two resistors are in parallel,

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$$

Thus,

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{R_{\text{eq}}} = \frac{2V_{\text{rms}}}{R} = \frac{2(65\text{ V})}{15\ \Omega} = \boxed{8.7\text{ A}}$$

(b) In the limit of low frequency, the capacitor behaves like a very large resistor. So, nearly all of the current flows through the circuit with the lone resistor.

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{65\text{ V}}{15\ \Omega} = \boxed{4.3\text{ A}}$$

49. An ac voltmeter, which displays the rms voltage between the two points touched by its leads, is used to measure voltages in the circuit shown in Figure 24-32. In this circuit, the ac generator has an rms voltage of 6.00 V and a frequency of 60.0 kHz. The inductance in the circuit is 0.300 mH, the capacitance is 0.100 μF, and the resistance is 2.50 Ω.

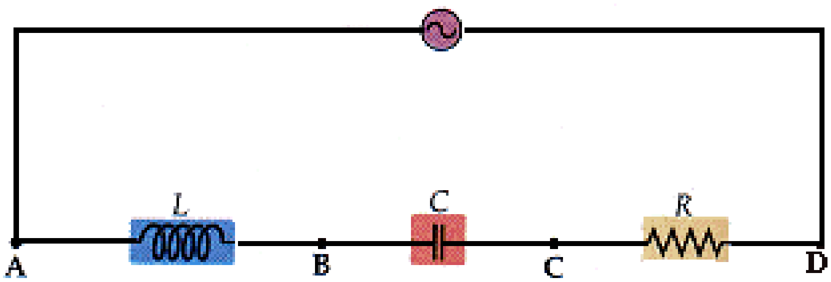


Figure 24-32

(a) Calculate the rms voltage across the resistor, R
(b) Calculate the voltage across the inductor, L.
(c) Calculate the voltage across the capacitor, C.
(d) The sum of the rms voltages in parts (a), (b), and (c) is not equal to 6.00 V due to which of the following phase differences? Select all that apply:

☐ the voltage across *C* is out of phase with the current

☐ the voltage across *L* is out of phase with the current

☐ the voltage across *R* is out of phase with the current

Solution:

First find the rms current I_{rms}.

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} = \frac{V_{\text{rms}}}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

$$= \frac{6.00\text{ V}}{\sqrt{(2.50\ \Omega)^2 + \left[2\pi(60.0\times10^3\text{ s}^{-1})(0.300\times10^{-3}\text{ H}) - \frac{1}{2\pi(60.0\times10^3\text{ s}^{-1})(0.100\times10^{-6}\text{ F})}\right]^2}}$$

$$= 69.3\text{ mA}$$

(a) $V_{\text{rms},R} = I_{\text{rms}}R = (69.3\text{ mA})(2.50\ \Omega) = \boxed{0.173\text{ V}}$

(b) $V_{\text{rms},L} = I_{\text{rms}}\omega L = (69.3\text{ mA})2\pi(60.0\times10^3\text{ s}^{-1})(0.300\times10^{-3}\text{ H}) = \boxed{7.84\text{ V}}$

(c) $V_{\text{rms},C} = \frac{I_{\text{rms}}}{\omega C} = \frac{69.3\text{ mA}}{2\pi(60.0\times10^3\text{ s}^{-1})(0.100\times10^{-6}\text{ F})} = \boxed{1.84\text{ V}}$

(d) In an AC circuit, a capacitor's voltage lags behind the current and an inductor's voltage leads the current, and a resistor's voltage is always in phase with the current. So the voltage across C and the voltage across L are both out of phase with the current.

Chapter 24 Conceptual Questions

14. In the analogy between an RLC circuit and a mass on a spring, what is the analog of the current in the circuit?

Answer: velocity. The full analogy is:

circuit:	mass-spring system:
Q (charge)	position
I (current)	velocity
ΔI/Δt	acceleration
$\mathcal{E}$ (voltage)	force
L (inductance)	mass
R (resistance)	friction or shock absorber
1/C (inverse capacitance)	spring constant
$\mathcal{E}$ = L ΔI/Δt	F = m Δv/Δt (Newton's 2nd Law)

26. The resistance in an RLC circuit is doubled. Does the resonance frequency increase, decrease, or stay the same? Does the maximum current in the circuit increase, decrease, or stay the same?

Solution: The value of the resistance does not affect the resonance frequency, as can be seen from Equation 24-18, so the resonance frequency does not change. The maximum current in the circuit does change, however since it is inversely proportional to the resistance (the maximum current will be reduced by a factor of two in this case).

Chapter 24 Problems

75. An RLC circuit with R = 25.0 Ω, L = 325 mH, and C = 45.2 μF is connected to an ac generator with an rms voltage of 24 V. Determine the average power delivered to this circuit when the frequency of the generator is (a) equal to the resonance frequency, and when it is (b) twice the resonance frequency.

Solution: The key equations are: $\omega = \dfrac{1}{\sqrt{LC}} = 2\pi f$

$$P_{\text{av}} = \frac{V_{\text{rms}}^2}{Z^2} R$$

(a) At resonance, $Z = R$. Thus:

$$P_{\text{av}} = \frac{V_{\text{rms}}{}^2 R}{R^2} = \frac{V_{\text{rms}}{}^2}{R} = \frac{(24\text{ V})^2}{25.0\ \Omega} = \boxed{23\text{ W}}$$

(b) Using $\omega = 2/\sqrt{LC}$ gives:

$$P_{\text{av}} = \frac{V_{\text{rms}}{}^2 R}{Z^2}$$

$$= \frac{V_{\text{rms}}{}^2 R}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \frac{V_{\text{rms}}{}^2 R}{R^2 + \left[\left(\frac{2}{\sqrt{LC}}\right)L - \left(\frac{\sqrt{LC}}{2}\right)\frac{1}{C}\right]^2}$$

$$= \frac{V_{\text{rms}}{}^2 R}{R^2 + \left(2\sqrt{\frac{L}{C}} - \frac{1}{2}\sqrt{\frac{L}{C}}\right)^2}$$

$$= \frac{(24\text{ V})^2 (25.0\ \Omega)}{(25.0\ \Omega)^2 + \frac{9(0.325\text{ H})}{4(45.2\times 10^{-6}\text{ F})}}$$

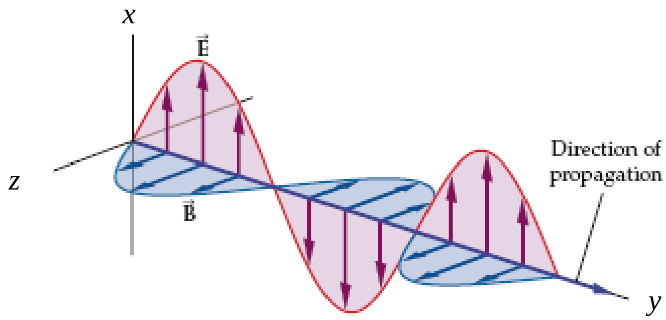
$$= \boxed{0.86\text{ W}}$$

Chapter 25 Problems

2. An electric charge oscillates sinusoidally in the +x and -x directions about the origin. A distant observer is located at a point on the +y axis.

(a) In what direction(s) is an electric field oscillating at the observer's location?
(b) In what direction(s) is a magnetic field oscillating at the observer's location?
(c) In what direction(s) is an electromagnetic wave propagating at the observer's location?

Solution:



(a) The electric field propagates parallel to the oscillation and hence it oscillates in the +x and –x directions.

(b) The magnetic field oscillates in the plane perpendicular to the electric field and is also perpendicular to the direction of propagation. The only direction perpendicular to the x and y directions is the z direction. So the magnetic field oscillates in the +z and –z directions.

(c) The electromagnetic wave propagates in the +y direction, since to reach the observer it must have traveled from the origin to a point on the +y axis. Since light travels in straight lines, it will continue to propagate in the +y direction after it reaches the observer.

29. A cell phone transmits at a frequency of 1.25 x 10^8 Hz. What is the wavelength of the electromagnetic wave used by this phone?

Solution: $\lambda = \dfrac{c}{f} = \dfrac{3.00\times 10^8\ \frac{\text{m}}{\text{s}}}{1.25\times 10^8\ \text{Hz}} = \boxed{2.40\ \text{m}}$

75. A typical medical X-ray has a frequency of 1.50 x 10^{19} Hz. What is the wavelength of such an X-ray?

Solution: $\lambda = \dfrac{c}{f} = \dfrac{3.00\times 10^8\ \frac{\text{m}}{\text{s}}}{1.50\times 10^{19}\ \text{Hz}} = \boxed{2.00\times 10^{-11}\ \text{m}}$

43. The magnetic field in an electromagnetic wave has a peak value given by B = 2.7 μT. For this wave, find:

(a) the peak electric field strength
(b) the peak intensity
(c) the average intensity

Solution: **(a)** $E = cB = \left(3.00\times 10^8\ \dfrac{\text{m}}{\text{s}}\right)(2.7\times 10^{-6}\ \text{T}) = \boxed{810\ \text{V/m}}$

(b) $I = \dfrac{c}{\mu_0}B^2 = \dfrac{3.00\times 10^8\ \frac{\text{m}}{\text{s}}}{4\pi\times 10^{-7}\ \frac{\text{T}\cdot\text{m}}{\text{A}}}(2.7\times 10^{-6}\ \text{T})^2 = \boxed{1.7\ \text{kW/m}^2}$

(c) Use the given value $B = B_{\text{max}}$ and $B_{rms} = \dfrac{B_{\text{max}}}{\sqrt{2}}$:

$$I_{\text{av}} = \frac{c}{\mu_0}B_{\text{rms}}^{\ 2} = \frac{3.00\times 10^8\ \frac{\text{m}}{\text{s}}}{4\pi\times 10^{-7}\ \frac{\text{T}\cdot\text{m}}{\text{A}}}\left(\frac{2.7\times 10^{-6}\ \text{T}}{\sqrt{2}}\right)^2 = \boxed{870\ \text{W/m}^2}$$

19. Most of the galaxies in the universe are observed to be moving away from Earth. Suppose a particular galaxy emits orange light with a frequency of 5.000 x 10^{14} Hz. If the galaxy is receding from Earth with a speed of 3025 km/s, what is the frequency of the light when it reaches Earth? (Enter your answer to 4 significant figures.)

Solution: Since the galaxy is receding from the Earth, we must chose the – sign in the Doppler formula:

$$f' = f\left(1-\frac{u}{c}\right) = (5.000\times10^{14}\text{ Hz})\left(1-\frac{3025\times10^{3}\ \frac{\text{m}}{\text{s}}}{3.00\times10^{8}\ \frac{\text{m}}{\text{s}}}\right) = \boxed{4.950\times10^{14}\text{ Hz}}$$

89. A light bulb emits light uniformly in all directions. If the rms electric field of this light is 18.0 N/C at a distance of 1.85 m from the bulb, what is the average total power radiated by the bulb?

Solution:

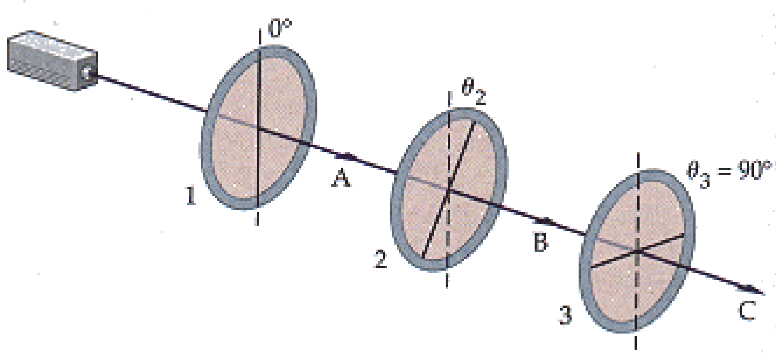
$$P_{\text{av}} = I_{\text{av}}A = c\varepsilon_0 E_{\text{rms}}{}^2 A = \left(3.00\times10^{8}\ \frac{\text{m}}{\text{s}}\right)\left(8.85\times10^{-12}\ \frac{\text{C}^2}{\text{N}\cdot\text{m}^2}\right)\left(18.0\ \frac{\text{N}}{\text{C}}\right)^2 4\pi(1.85\text{ m})^2 = \boxed{37.0\text{ W}}$$

53. After filtering through the atmosphere, the Sun's radiation illuminates Earth's surface with an average intensity of 1.0 kW/m^2. Assuming this radiation strikes the 15 m x 45 m black, flat roof of a building at normal incidence, calculate the average force the radiation exerts on the roof.

Solution:

$$F_{\text{av}} = P_{\text{av}}A = \frac{I_{\text{av}}A}{c} = \frac{\left(1.0\times10^{3}\ \frac{\text{W}}{\text{m}^2}\right)(15\text{ m})(45\text{ m})}{3.00\times10^{8}\ \frac{\text{m}}{\text{s}}} = \boxed{2.3\text{ mN}}$$

72. A helium-neon laser emits a beam of unpolarized light that passes through three Polaroid filters, as shown in Figure 25-29, where $\theta_2 = 30°$. The intensity of the laser beam is I_0.



(a) What is the intensity of the beam at point A?
(b) What is the intensity of the beam at point B?
(c) What is the intensity of the beam at point C?
(d) If filter 2 is removed, what is the intensity of the beam at point C?

Solution: **(a)** $I = \boxed{\frac{1}{2}I_0}$

(b) $I = \frac{1}{2}I_0\cos^2 30.0° = \boxed{0.375I_0}$

(c) $I = 0.375I_0\cos^2(90.0° - 30.0°) = \boxed{0.0938I_0}$

(d) $I = \frac{1}{2}I_0\cos^2 90.0° = \boxed{0}$