Solutions to Problems : Chapter 25
Problems appeared on the end of chapter 25 of the Textbook

(Problem 16, 30, 42, 44, 58, 60, 66, 72)

16. **Picture the Problem**: Radio signals travel from Earth to a distant spacecraft.

Strategy: Divide the distance by the speed of light to calculate the time for the signal to reach the craft.

Solution: Calculate the time: $$\Delta t = \frac{d}{c} = \frac{4.5\times10^{12}\text{ m}}{3.00\times10^{8}\text{ m/s}} = \boxed{1.5\times10^{4}\text{ s}}$$

Insight: This time delay is 4 hours and 10 minutes. When NASA sends a signal to the craft it takes 8 hours and 20 minutes for NASA to receive a confirmation from the satellite.

30. **Picture the Problem**: The radiation emitted by humans has a wavelength of about 9.0 μm.

Strategy: Solve equation 25-4 to calculate the frequency. Then compare the frequencies to the ranges given in section 25-3 of the text.

Solution: 1. (a) Calculate the frequency: $$f = \frac{c}{\lambda} = \frac{3.00\times10^{8}\text{ m/s}}{9.0\times10^{-6}\text{ m}} = \boxed{3.3\times10^{13}\text{ Hz}}$$

2. (b) This frequency falls in the $\boxed{\text{infrared}}$ range (10^{12} Hz to 4.3×10^{14} Hz).

42. **Picture the Problem**: A sinusoidal electric field has a maximum value of 65 V/m.

Strategy: Divide the peak electric field by the square root of two to calculate the rms magnitude of the electric field.

Solution: Calculate the rms electric field: $$E_{\text{rms}} = \frac{E_{\text{max}}}{\sqrt{2}} = \frac{65\text{ V/m}}{\sqrt{2}} = \boxed{46\text{ V/m}}$$

Insight: The rms magnetic field for this wave is 1.5×10^{-7} T.

44. **Picture the Problem**: A given electromagnetic wave has a maximum intensity of 5.00 W/m^2.

Strategy: Solve equation 25-10 for the maximum electric field.

Solution: Calculate E_{max}:

$$I_{\text{max}} = c\varepsilon_0 E_{\text{max}}^2$$

$$E_{\text{max}} = \sqrt{\frac{I_{\text{max}}}{c\varepsilon_0}} = \sqrt{\frac{5.00\text{ W/m}^2}{\left(3.00\times10^{8}\text{ m/s}\right)\left(8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2\right)}} = \boxed{43.4\text{ V/m}}$$

Insight: Verify for yourself that the maximum magnetic field for this wave is 0.145 μT.

58. **Picture the Problem**: A 75.0-W lightbulb emits electromagnetic waves uniformly in all directions.

Strategy: Use equation 14-7 to calculate the intensity of the light 3.5 m from the source. Insert the intensity into equation 25-10 to calculate the rms electric field, and then solve equation 25-9 for the magnetic field.

Solution: 1. Divide the power by area: $$I_{\text{av}} = \frac{P_{\text{av}}}{A} = \frac{75\text{ W}}{4\pi\left(3.50\text{ m}\right)^2} = 0.4872\text{ W/m}^2$$

2. Calculate the electric field:

$$I_{av} = c\varepsilon_0 E_{rms}^2$$

$$E_{rms} = \sqrt{\frac{I_{av}}{c\varepsilon_0}} = \sqrt{\frac{0.4872\ \text{W/m}^2}{(3.00\times10^8\ \text{m/s})(8.85\times10^{-12}\ \text{C}^2/\text{Nm}^2)}} = \boxed{13.5\ \text{V/m}}$$

3. Find the magnetic field:

$$B_{rms} = \frac{E_{rms}}{c} = \frac{13.55\ \text{V/m}}{3.00\times10^8\ \text{m/s}} = \boxed{45.2\ \text{nT}}$$

Insight: The magnetic field could also have been calculated using $I_{av} = \dfrac{c}{\mu_0} B_{rms}^2$ (equation 25-10).

60. **Picture the Problem**: A 2.8-mW laser beam has a diameter of 2.4 mm.

Strategy: Write the intensity as the average power divided by the area of the beam. Write the intensity in terms of the rms electric field using equation 25-10 and solve for the electric field.

Solution: 1. Write I_{av} in terms of E_{rms}:

$$I_{av} = \frac{P_{av}}{A} = c\varepsilon_0 E_{rms}^2$$

2. Solve for the electric field:

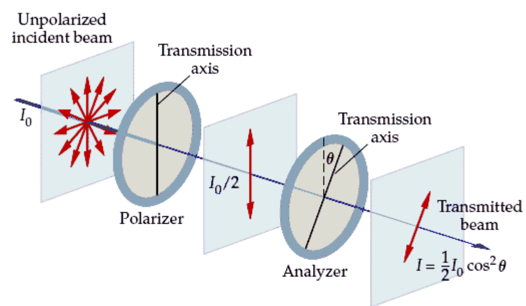
$$E_{rms} = \sqrt{\frac{P_{av}}{Ac\varepsilon_0}}$$

$$= \sqrt{\frac{2.8\times10^{-3}\ \text{W}}{\pi(1.2\times10^{-3}\ \text{m})^2(3.00\times10^8\ \text{m/s})(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2)}}$$

$$E_{rms} = \boxed{0.48\ \text{kV/m}}$$

Insight: Note that the electric field is inversely proportional to the beam diameter. If the diameter is doubled to 4.8 mm, the electric field will drop to 240 V/m.

66. **Picture the Problem**: The image shows unpolarized light incident upon two polarizers, the transmission axes of which are oriented at some angle with respect to each other.



Strategy: Set the intensity after the first polarizer equal to half
the intensity before (equation 25-14). Use Malus' Law (equation 25-13) to calculate the intensity after the second polarizer. Divide the result by the initial intensity to determine the relative intensity.

Solution: 1. Calculate the intensity after the first polarizer:

$$I_1 = \frac{1}{2}I_0$$

2. Calculate the intensity after the second polarizer:

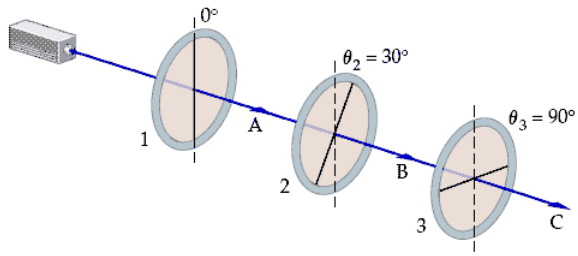
$$I_2 = I_1\cos^2\theta = \frac{1}{2}I_0\cos^2\theta$$

3. Divide the final intensity by the initial:

$$\frac{I_2}{I_0} = \frac{1}{2}\cos^2 30.0° = \boxed{0.375}$$

Insight: The exact orientation of the two polarizers is not important, only the relative orientation of their transmission axes.

72. **Picture the Problem**: The image shows unpolarized laser light passing through three polarizers.



Strategy: Use equation 25-14 to calculate the intensity after the first polarizer. Then use Malus's Law (equation 25-13) to calculate the intensity as the light passes through each of the other polarizers.

Solution: 1. (a) Use equation 25-14 to calculate *I* at point A:

$$I = \boxed{\frac{1}{2}I_0}$$

2. (b) Use Malus's Law to calculate the intensity at point B:

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

3. (c) Use Malus's Law to calculate the intensity at point C:

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

4. (d) Use Malus's Law to calculate the intensity at point C, with the second polarizer removed:

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

Insight: The second filter rotates the polarization so that some light can pass through the third filter.