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:

\[
\Delta t = \frac{d}{c} = \frac{4.5 \times 10^7 \text{ m}}{3.00 \times 10^8 \text{ m/s}} = 1.5 \times 10^{-1} \text{ s}
\]

**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:

\[
f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{9.0 \times 10^{-6} \text{ m}} = 3.3 \times 10^{13} \text{ Hz}
\]

2. (b) This frequency falls in the **infrared range** (10^{12} Hz to 4.3 \times 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:

\[
E_{\text{rms}} = \frac{E_{\text{max}}}{\sqrt{2}} = \frac{65 \text{ V/m}}{\sqrt{2}} = 46 \text{ V/m}
\]

**Insight**: The rms magnetic field for this wave is 1.5 \times 10^{-7} \text{ 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 \(E_{\text{max}}\):

\[
E_{\text{max}} = \frac{I_{\text{max}}}{c \varepsilon_0} = \sqrt{\frac{5.00 \text{ W/m}^2}{(3.00 \times 10^8 \text{ m/s})(8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2)}} = 43.4 \text{ V/m}
\]

**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 \(I_\nu = \frac{P_\nu}{A} = \frac{75 \text{ W}}{4\pi (3.50 \text{ m})^2} = 0.4872 \text{ W/m}^2}\)
2. Calculate the electric field: 
\[ I_{av} = \frac{c\varepsilon_0 E^2}{A} \]
\[ E_{rms} = \sqrt{\frac{I_{av}}{c\varepsilon_0}} = \sqrt{\frac{0.4872 \text{ W/m}^2}{(3.00 \times 10^8 \text{ m/s})(8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2)}} = 13.5 \text{ V/m} \]

3. Find the magnetic field: 
\[ B_{rms} = \frac{E_{rms}}{c} = \frac{13.55 \text{ V/m}}{3.00 \times 10^8 \text{ m/s}} = 45.2 \text{ nT} \]

**Insight:** The magnetic field could also have been calculated using \( I_{av} = \frac{c}{\mu_0} B_{rms}^2 \) (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:
\[ E_{rms} = \sqrt{\frac{P_{av}}{c\varepsilon_0}} = \sqrt{\frac{2.8 \times 10^{-3} \text{ W}}{\pi (1.2 \times 10^{-3} \text{ m})^2 (3.00 \times 10^8 \text{ m/s})(8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2)}} = 0.48 \text{ kV/m} \]

**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:
\[ \frac{I_2}{I_0} = \frac{1}{2} \cos^2 30.0^\circ = 0.375 \]

**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:

   \[ I = \frac{1}{2} I_0 \]

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

   \[ I = \left( \frac{1}{2} I_0 \right) \cos^2 30.0^\circ = 0.375I_0 \]

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

   \[ I = (0.375I_0) \cos^2 (90.0^\circ - 30.0^\circ) = 0.0938I_0 \]

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

   \[ I = \left( \frac{1}{2} I_0 \right) \cos^2 90.0^\circ = 0 \]

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