

Light and Reflection

Problem A**ELECTROMAGNETIC WAVES PROBLEM**

The atoms in an HCl molecule vibrate like two charged balls attached to the ends of a spring. If the wavelength of the emitted electromagnetic wave is $3.75\ \mu\text{m}$, what is the frequency of the vibrations?

SOLUTION

Given: $\lambda = 3.75 \times 10^{-6}\ \text{m}$

$$c = 3.00 \times 10^8\ \text{m/s}$$

Unknown: $f = ?$

Use the wave speed equation, and solve for λ .

$$c = f\lambda$$

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8\ \text{m/s}}{3.75 \times 10^{-6}\ \text{m}} = 8.00 \times 10^{13}\ \text{Hz}$$

ADDITIONAL PRACTICE

1. New-generation cordless phones use a $9.00 \times 10^2\ \text{MHz}$ frequency and can be operated up to $60.0\ \text{m}$ from their base. How many wavelengths of the electromagnetic waves can fit between your ear and a base $60.0\ \text{m}$ away?
2. The highest *directly* measured frequency is $5.20 \times 10^{14}\ \text{Hz}$, corresponding to one of the transitions in iodine-127. How many wavelengths of electromagnetic waves with this frequency could fit across a dot on a book page? Assume the dot is $2.00 \times 10^{-4}\ \text{m}$ in diameter.
3. Commercial trucks cause about 18 000 lane-change and merging accidents per year in the United States. To prevent many of them, a warning system covering blind spots is being developed. The system uses electromagnetic waves of frequency $2.40 \times 10^{10}\ \text{Hz}$. What is the wavelength of these waves?
4. A typical compact disc stores information in tiny pits on the disc's surface. A typical pit size is $1.2\ \mu\text{m}$. What is the frequency of electromagnetic waves that have a wavelength equal to the typical CD pit size?
5. A new antiterrorist technique detects the differences in electromagnetic waves emitted by humans and by weapons made of metal, plastic, or ceramic. One possible range of wavelengths used with this technique is from $2.0\ \text{mm}$ to $5.0\ \text{mm}$. Calculate the associated range of frequencies.
6. The U.S. Army's loudest loudspeaker is almost $17\ \text{m}$ across and is transported on a special trailer. The sound is produced by an electromagnetic coil that can generate a minimum frequency of $10.0\ \text{Hz}$. What is the wavelength of these electromagnetic waves?

ELECTROMAGNETIC WAVES PROBLEM

How fast does light with a frequency of 5.4999×10^{14} Hz and a wavelength of 545.00 nm travel?

SOLUTION

Given: $\lambda = 5.4500 \times 10^{-7}$ m $f = 5.4999 \times 10^{14}$ Hz

Unknown: $c = ?$

Choose the equation(s) or situation:

Use the wave speed equation for electromagnetic waves.

$$c = f\lambda = (5.4999 \times 10^{14} \text{ s}^{-1}) (5.4500 \times 10^{-7} \text{ m}) = \boxed{2.9974 \times 10^8 \text{ m/s}}$$

ADDITIONAL PRACTICE

1. Shortwave radio is broadcast between 3.50 and 29.7 MHz. To what range of wavelengths does this correspond? Why do you suppose this part of the spectrum is called shortwave radio?
2. What is the frequency of an electromagnetic wave if it has a wavelength of 1.0 km?
3. Scientists at Lucent Bell Labs use high-resolution microscopes to make images of tiny organisms that provide a lot of information. By using 3.2 nm x-rays on human tissue, images can be made showing microtubules in the nuclei of cells. What is the frequency of these x-rays?
4. In order to see objects, the wavelength of the light must be smaller than the object. The Bohr radius of a hydrogen atom is $5.291\,770 \times 10^{-11}$ m.
 - a. What is the lowest frequency that can be used to locate a hydrogen atom?
 - b. The visible part of the spectrum ranges from 400 nm to 700 nm. Why aren't individual atoms visible?
5. Your skin tans when melanin within the skin oxidizes. Your skin sunburns when it receives more ultraviolet radiation than the protection provided by the melanin. Generally, ultraviolet (UV) radiation has been divided into two classes: UVA and UVB. You are more likely to be sunburned if you are exposed to radiation in the UVB range (280 nm–320 nm) than in the UVA range (320 nm–400 nm). To what range of frequencies do these wavelength ranges correspond?
6. Suppose you must decide whether a pre-Columbian mask is genuine before buying it for a museum. It looks genuine, but to ensure its authenticity, you shine X rays of wavelength 1.67×10^{-10} m on it to see if a certain element is present. What is the frequency of this radiation?
7. Suppose you use ultraviolet light of frequency 9.5×10^{14} Hz to determine whether a mineral is fluorescent. To what wavelength does this correspond?

8. Meteorologists use Doppler radar to watch the movement of storms. If a weather station uses electromagnetic waves with a frequency of 2.85×10^9 Hz, what is the length of the wave?
9. PCS cellular phones have antennas that use radio frequencies from 1800–2000 MHz. What range of wavelengths corresponds to these frequencies?
10. Suppose the microwaves in your microwave oven have a frequency of 2.5×10^{10} Hz.
- What is the wavelength of these microwaves?
 - The holes in the door of a microwave oven have a radius of 1.2 mm. Why don't microwaves pass through these holes?
 - Visible light has a wavelength that ranges from 400 nm to 700 nm. Would visible light be able to pass through the holes? Why or why not?