Section 9.1: Properties of Waves and Light

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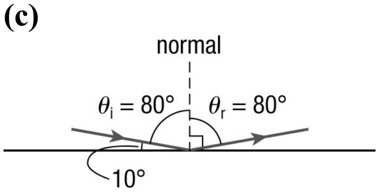
1. The frequency of a wave is determined by the frequency of the wave's source.
2. The speed of a wave is determined by the medium in which it travels.
3. The amplitude of a wave is determined partly by its source and partly by the conditions of the medium in which it travels.
4. The wavelength of a wave is determined by both the wave speed and the frequency. This mathematical relationship is called the universal wave equation.
5. (a) Given: incident ray makes an angle of 10° with the surface
Required: angle of incidence, θ_i
Analysis: The angle of incidence is measured with respect to the normal. Therefore $\theta_i = 90° - 10°$.
Solution: $\theta_i = 90° - 10°$

$\theta_i = 80°$

Statement: The angle of incidence is 80°.
(b) The angle of reflection, θ_r, equals the angle of incidence. Therefore $\theta_r = 80°$.
(c)



6. Given: sketch of a wave; $f = 40$ Hz
Required: v
Analysis: The wavelength is the length of one complete wave. Measure the length of several complete waves on the sketch, and calculate an average value for λ. Then use the universal wave equation $v = f\lambda$ to determine v.
Solution: The wave first crosses the x-axis at approximately 0.1 cm. Three cycles later it crosses the x-axis at 4.0 cm.

$$\lambda = \frac{4.0 \text{ cm} - 0.1 \text{ cm}}{3}$$

$\lambda = 1.3$ cm

$$v = f\lambda$$
$$= \left(40 \ \frac{1}{\text{s}}\right)(1.3 \text{ cm})$$

$v = 50$ cm/s

Statement: The wave speed is 50 cm/s, or 0.5 m/s.
7. Given: $\Delta d = 0.3$ m; $\Delta t = 3.5$ s; $f = 4.6$ Hz
Required: λ
Analysis: Use the distance and time information to calculate the wave speed, $v = \frac{\Delta d}{\Delta t}$. Then rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for wavelength.

$v = f\lambda$

$\lambda = \frac{v}{f}$

Solution: $v = \frac{\Delta d}{\Delta t}$

$= \frac{0.3 \text{ m}}{3.5 \text{ s}}$

$v = 0.0857$ m/s (two extra digits carried)

$\lambda = \frac{v}{f}$

$= \frac{0.0857 \text{ m/}\cancel{\text{s}}}{4.6 \ \frac{1}{\cancel{\text{s}}}}$

$\lambda = 2 \times 10^{-2}$ m

Statement: The wavelength is 2×10^{-2} m.

8. Given: $T = 0.05$ s

Required: f

Analysis: Frequency is the inverse of period, $f = \frac{1}{T}$.

Solution: $f = \frac{1}{T}$

$= \frac{1}{0.05 \text{ s}}$

$f = 20$ Hz

Statement: The frequency is 20 Hz.

9. Given: $v = 3.0 \times 10^{8}$ m/s; $f = 5.0 \times 10^{14}$ Hz

Required: λ

Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for wavelength.

$v = f\lambda$

$\lambda = \frac{v}{f}$

Solution: $\lambda = \frac{v}{f}$

$= \frac{3.0 \times 10^{8} \text{ m/}\cancel{\text{s}}}{5.0 \times 10^{14} \ \frac{1}{\cancel{\text{s}}}}$

$\lambda = 6.0 \times 10^{-7}$ m

Statement: The wavelength of the light is 6.0×10^{-7} m.

10. Given: $v = 3.0 \times 10^8$ m/s; $\lambda = 750$ nm $= 7.5 \times 10^{-9}$ m
Required: f
Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for frequency.

$$v = f\lambda$$

$$f = \frac{v}{\lambda}$$

Solution: $f = \frac{v}{\lambda}$

$$= \frac{3.0 \times 10^8 \ \cancel{\text{m}}/\text{s}}{7.5 \times 10^{-7} \ \cancel{\text{m}}}$$

$$f = 4.0 \times 10^{14} \text{ Hz}$$

Statement: The frequency of the red light waves is 4.0×10^{14} Hz.

11. Given: $c = 3.0 \times 10^8$ m/s; $f = 6.0 \times 10^{14}$ Hz
Required: λ
Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for wavelength.

$$v = f\lambda$$

$$\lambda = \frac{v}{f}$$

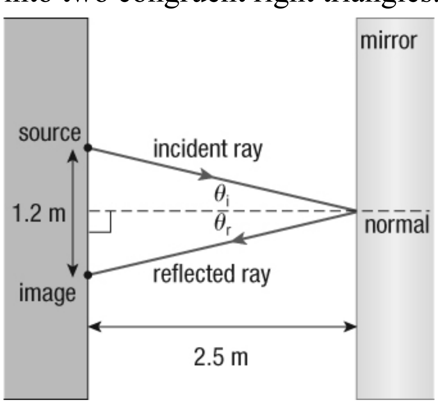
Solution: $\lambda = \frac{v}{f}$

$$= \frac{3.0 \times 10^8 \ \text{m}/\cancel{\text{s}}}{6.0 \times 10^{14} \ \frac{1}{\cancel{\text{s}}}}$$

$$\lambda = 5.0 \times 10^{-7} \text{ m}$$

Statement: The wavelength of the violet light is 5.0×10^{-7} m.

12. Given: distance to mirror = 2.5 m;
distance between source and reflected ray at source wall = 1.2 m
Required: θ_i
Analysis: $\theta_i = \theta_r$; sketch the situation. The normal at the point of incidence divides the triangle into two congruent right triangles. Use the tangent ratio to determine θ_i.



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Solution: $\theta_i = \tan^{-1}\left(\frac{0.6\ \text{m}}{2.5\ \text{m}}\right)$

$\theta_i = 13°$

Statement: The angle of incidence is 13°.

13. Given: $v = 1.5 \times 10^3$ m/s; $f = 4.4 \times 10^2$ Hz

Required: λ

Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for wavelength.

$v = f\lambda$

$\lambda = \frac{v}{f}$

Solution: $\lambda = \frac{v}{f}$

$= \frac{1.5 \times 10^3\ \text{m/s}}{4.4 \times 10^2\ \frac{1}{\text{s}}}$

$\lambda = 3.4$ m

Statement: The wavelength of this frequency of sound in water is 3.4 m.

14. Given: $v = 20.0$ m/s; $\lambda = 2.0$ m

Required: f

Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for frequency.

$v = f\lambda$

$f = \frac{v}{\lambda}$

Solution: $f = \frac{v}{\lambda}$

$= \frac{20.0\ \text{m/s}}{2.0\ \text{m}}$

$f = 10$ Hz

Statement: The frequency of the wave is 10 Hz.

15. Given: $f = 3.1$ kHz $= 3.1 \times 10^3$ Hz; $\lambda = 0.13$ m

Required: v

Analysis: $v = f\lambda$

Solution: $v = f\lambda$

$= \left(3.1 \times 10^3\ \frac{1}{\text{s}}\right)(0.13\ \text{m})$

$v = 4.0 \times 10^2$ m/s

Statement: The speed of the wave is 4.0×10^2 m/s.

16. Given: $f = 7.9 \times 10^{14}$ Hz; $v = 3.0 \times 10^8$ m/s

Required: λ

Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for wavelength.

$$v = f\lambda$$

$$\lambda = \frac{v}{f}$$

Solution: $\lambda = \dfrac{v}{f}$

$$= \frac{3.0\times10^{8}\ \text{m/}\cancel{\text{s}}}{7.9\times10^{14}\ \dfrac{1}{\cancel{\text{s}}}}$$

$$\lambda = 3.8\times10^{-7}\ \text{m}$$

Statement: The wavelength of the radiation is 3.8×10^{-7} m.

17. Given: f = 310 MHz = 3.1×10^{8} Hz; $v = 3.0 \times 10^{8}$ m/s

Required: λ

Analysis: Rearrange the universal wave equation, $v = f\lambda$, to isolate and solve for wavelength.

$$v = f\lambda$$

$$\lambda = \frac{v}{f}$$

Solution: $\lambda = \dfrac{v}{f}$

$$= \frac{3.0\times10^{8}\ \text{m/s}}{3.1\times10^{8}\ \text{Hz}}$$

$$\lambda = 0.97\ \text{m}$$

Statement: The wavelength of the microwaves is 0.97 m.

18. Sample answer: Mirrors can reflect images because they have a smooth reflecting surface. When several incident light rays strike the mirror, they are reflected in the same direction, which creates a clear image to an observer. This is called specular reflection.

19. Answers may vary. Sample answers:

Method 1: Using proportional reasoning. Frequency and wavelength are related by the universal wave equation $v = f\lambda$. For fixed wave speed, wavelength is inversely proportional to frequency. If one frequency is a factor of three larger than another, its corresponding wavelength is one-third of the other wavelength.

Method 2: Using algebra. $v = f_1\lambda_1$ and $v = f_2\lambda_2$; $f_2 = 3f_1$. Set the two values for v equal to each other.

$$f_2\lambda_2 = f_1\lambda_1$$

$$\frac{\lambda_2}{\lambda_1} = \frac{f_1}{f_2}$$

$$= \frac{\cancel{f_1}}{3\cancel{f_1}}$$

$$\frac{\lambda_2}{\lambda_1} = \frac{1}{3}$$

$$\lambda_2 = \frac{\lambda_1}{3}$$

The ratio of the second wavelength to the first wavelength is 3 : 1.

20. Given: f_1 = 0.13 Hz; λ_1 = 0.56 m; f_2 = 0.45 Hz

Required: λ_2

Analysis: Use the universal wave equation, $v = f\lambda$, to calculate the wave speed. Then use the wave speed and f_2 to determine λ_2.

Solution:

$$v = f\lambda$$
$$= (0.83 \text{ Hz})(0.56 \text{ m})$$
$$v = 0.4648 \text{ m/s} \text{ (two extra digits carried)}$$

$$\lambda_2 = \frac{v}{f_2}$$
$$= \frac{0.4648 \text{ m/}\cancel{\text{s}}}{0.45 \frac{1}{\cancel{\text{s}}}}$$
$$\lambda_2 = 1.0 \text{ m}$$

Statement: When the frequency is 0.45 Hz, the new wavelength is 1.0 m.

21. (a) Sample answer: A flat mirror causes *specular* reflection because its surface is smooth and regular and reflects the rays of a parallel beam of light in one direction.

(b) Sample answer: A piece of notebook paper causes *diffuse* reflection because the paper fibres have many orientations and reflect the rays of a parallel beam of light in many different directions.

(c) Sample answer: The surface of a puddle on a calm day causes *specular* reflection because it is smooth and regular and reflects the rays of a parallel beam of light in one direction.

(d) Sample answer: The surface of a lake on a windy day causes *diffuse* reflection because the rough waves reflect the rays of a parallel beam of light in many directions.

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