L2 Physics: Problems on waves

The speed of sound is $340\,\mathrm{m\,s^{-1}}$ in air. See also the final page for useful formulae.

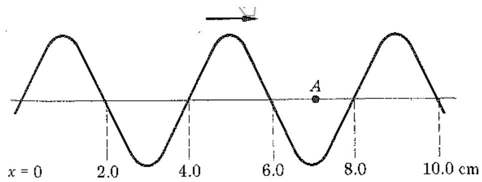
Sections 1.1-1.2

1. A radio station sends out radio waves with frequency 750 kHz. All radio waves travel with a speed of $3.0 \times 10^8\,\mathrm{m\,s^{-1}}$. How far apart are the crests of the wave sent out by the station?

2. A television station sends out radio waves with frequency 750 MHz. All radio waves travel with a speed of $3.0 \times 10^8\,\mathrm{m\,s^{-1}}$. How far apart are the crests of the wave sent out by the station?

3. A wave has wavelength 2 cm; at a given point, 25 wave crests per second are observed. Calculate (a) the frequency of the wave; (b) the speed of the wave; (c) the time between observed wave crests.

4. The wave shown below is travelling to the right with a speed of $2.00\,\mathrm{m\,s^{-1}}$. How long after the instant shown will the crest on the left have moved to the position of the crest on the right?

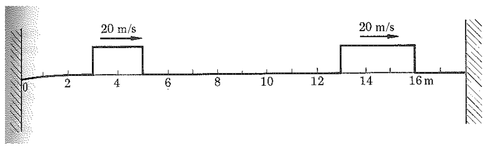


5. If the same wave is slowed so that it is moving at a speed of $100\,\mathrm{cm\,s^{-1}}$, how many crests per second will pass point A?

6. What frequency must a sound source have if the wavelength of its sound is to be 3.0 cm?

Sections 1.3-1.4

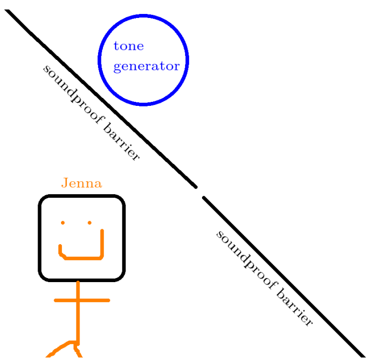
1. The two pulses in the igure are moving down the string at $2.0\,\mathrm{m\,s^{-1}}$ each. Sketch the position of the string (a) after 0.40 s; (b) after 0.20 s.



2. Two waves moving in opposite directions can interfere with each other in such a way that no net movement is seen; this is called an *standing wave*. Give a simple example of an experiment you could set up to show this.

3. Describe a water-wave experiment which illustrates the phenomenon of diffraction.

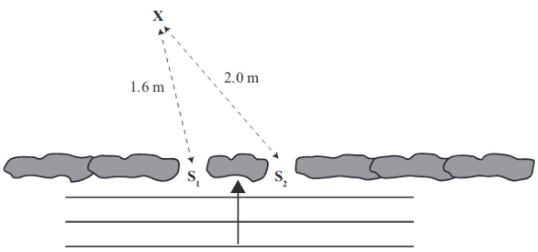
4. Jenna is conducting an experiment; she places a tone generator (a machine that generates a particular frequency of wave) on the other side of a narrow slit in a sound-proof barrier. She notices that, if the generator is placed around the corner as in the following diagram, the sound of the generator is much louder when it is set to a lower frequency. Explain this observation.



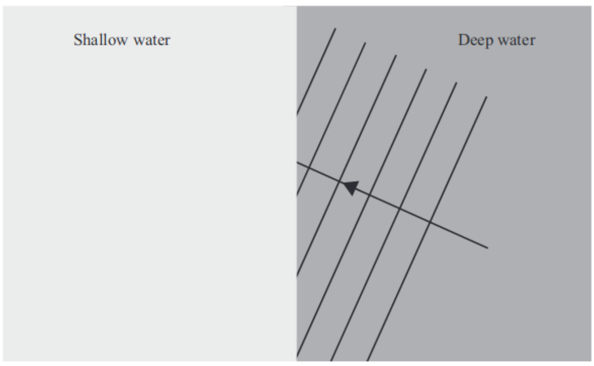
5. Two identical sound sources are at the coordinate origin and send 70 cm wavelength waves out. One source is now moved slowly to the left (to negative x–values). For an observer at point $x = 20\,\mathrm{m}$ on the x–axis, what positions of the moving source give rise to (a) the loudest and (b) the quietest observed sound? (Assume the sources are in phase.)

6. Two identical sources with unknown wavelength are on the x–axis some distance apart. One of the sources is moved away from the observer (who is also on the x–axis, but some way away).
   (a) Draw a diagram and annotate it to explain why the observer hears alternating loud and weak sounds.
   (b) If the source moves 30 cm between observed loud sounds, what is the wavelength of the sound?

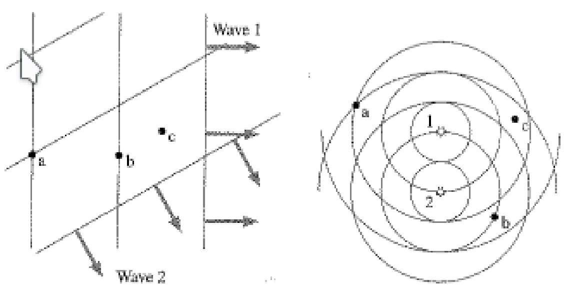
7. At a given place there are two gaps, labelled S_1 and S_2, in a line of rocks. A set of waves passes through the rocks, creating an interference pattern. The difference between the distance between points S_1 and X, and the distance between S_2 and X, is 0.40 m. The wave speed is $0.80\,\mathrm{m\,s^{-1}}$, and one reaches the wall each second. Is X at a node or an antinode? Explain your answer.



8. Water waves travel from deep to shallow water. The wave-fronts of the wave hit the boundary between the depths at a shallow angle. Draw a diagram showing the relation of the wavefronts leaving the boundary to those reaching it. Which phenomenon does your diagram illustrate?



9. Consider the following systems of waves.



   (a) In the left-hand system, both waves have an amplitude of 2.0 mm and the same wavelength. What is the net displacement of the medium at points a, b, and c?
   (b) In the right-hand system, both circular waves are in phase. Are a, b, and c points of maximum constructive interference, points of maximum destructive interference, or in between?

10. A water wave initially of wavelength 3.0 cm and period 0.50 s enters water of a different depth where its speed is $2.0\,\mathrm{cm\,s^{-1}}$. Calculate the changed wavelength.

11. Which of the following waves is diffracted most by an open square window of width 0.5 m?
    (a) Microwaves of frequency 10 GHz and speed $3.0 \times 10^8\,\mathrm{m\,s^{-1}}$
    (b) Light waves of wavelength 650 nm
    (c) Sound waves of frequency 1050 Hz and speed $350\,\mathrm{m\,s^{-1}}$

12. Noise-cancelling headphones are an application of destructive interference. Each side of the headphones uses a microphone to pick up noise, delays it slightly, and then rebroadcasts it to your ear where it can interfere with the incoming sound wave of the noise. Suppose you are sitting 1.5 m from an annoying 120 Hz buzzing sound. What is the minimum headphone delay, in milliseconds, that will cancel this noise?

Section 1.5

1. A boy 1.5 m tall whose eyes are 1.4 m from the floor when he stands straight can just see his complete image in a wall mirror.
    (a) What is the smallest length of the mirror that allows the boy to see his full length?
    (b) How high off the ground is the mirror's bottom edge?

2. An object 1.5 cm high is placed 2.5 cm in front of a concave mirror with a focal length of 5.0 cm. Draw a ray diagram, and identify the nature of the image formed.

3. An object 2.0 cm high is placed 12 cm in front of a concave mirror. The image formed is 1 cm high. How far away from the mirror is the image formed?

4. How far should an object be placed in front of a concave mirror with a radius of curvature 36 cm in order to form a real image 1 9 of its size?

5. It is possible to produce an image with a magnification of 2 when an object is 12 cm away from the mirror. Find the focal length of the mirror if the image is virtual.

6. A beam of light strikes a pool of water at a angle of incidence of 60.0°. Some light is reflected, and some is refracted. Find the directions of both the reflected and refracted rays, given that the index of refraction of water is $n_w = 1.33$.

7. A beam of light moves from an unknown substance with a refractive index of $n_1 = 1.33$ into air. Supposing that the speed of light in air is $2.99 \times 10^8\,\mathrm{m\,s^{-1}}$, what is the speed of light in the unknown substance?

8. Recall that the critical angle is the angle at which light is totally reflected back into the originating medium when it meets the boundary.
    (a) Give the condition(s) needed for total internal reflection to occur.
    (b) If the exact critical angle for red light travelling from water into air is 48.70°, calculate the refractive index of water for red light.

9. A person of height 1.7 m is standing 2 m from a concave mirror with a focal length of 20 m. State the nature of the image formed, and give the magnification.

10. A beam of light travels from a ruby ($n = 1.76$) into ice ($n = 1.31$).
    (a) The initial angle of incidence is 30°. If some light is refracted and some is reflected, find the angles of refraction and reflection.
    (b) The angle of incidence is gradually increased. At what angle does light cease being refracted and totally reflect?

11. A person of height 1.7 m is standing 2 m from a concave mirror with a focal length of 20 m. State the nature of the image formed, and give the magnification.

12. A beam of light travels from a ruby ($n = 1.76$) into ice ($n = 1.31$).
   (a) The initial angle of incidence is $30°$. If some light is refracted and some is reflected, find the angles of refraction and reflection.
   (b) The angle of incidence is gradually increased. At what angle does light cease being refracted and totally reflect?
13. Large convex mirrors are often used in shops to improve security. Tracey is looking at herself in a convex security mirror of focal length 2.0 m. Tracey is 4.0 m away from the mirror, and is 1.5 m tall. Draw a ray diagram and use it to calculate:
   (a) The position of Tracey's image.
   (b) The size of Tracey's image.
14. Find the position of the image of a candle flame located 40 cm in front of a concave spherical mirror of radius of curvature 64 cm, and describe the type of image formed.
15. An object and its image in a mirror are the same height when the object is 36 cm from the mirror. What type of mirror is used, and what is its focal length?
16. A ray of light passes from glass ($n = 1.5$) to air ($n = 1.0$).
   (a) Is the ray deflected towards the normal, or away from the normal?
   (b) If the angle of incidence is $50°$, what is the angle of refraction?
17. A layer of oil ($n = 1.45$) floats on water ($n = 1.33$). A ray of light shines into the oil with an angle of incidence of $40.0°$.
   (a) Draw a diagram of the system, and label the angle of refraction θ of the light in the water.
   (b) Calculate the value of θ.
18. The refractive index of diamond is $n = 2.42$.
   (a) Can total internal reflection occur if light is passes from air into the diamond? Explain.
   (b) What is the critical angle for light passing from diamond to air?
19. By ray diagram or otherwise, find the position and magnification of the image formed by a convex lens of focal length 100.0 cm, when the object is
   (a) 150.0 cm from the lens.
   (b) 75.0 cm from the lens.

Formulae

91170 Demonstrate understanding of waves

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \text{or} \quad s_i s_o = f^2$$

$$m = \frac{d_i}{d_o} = \frac{h_i}{h_o} \quad \text{or} \quad m = \frac{f}{s_o} = \frac{s_i}{f}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \frac{n_1}{n_2} = \frac{v_2}{v_1} = \frac{\lambda_2}{\lambda_1}$$

$$v = f\lambda \qquad f = \frac{1}{T} \qquad v = \frac{d}{t}$$

Speed of light in a vacuum $= 3.00 \times 10^8 \text{ m s}^{-1}$