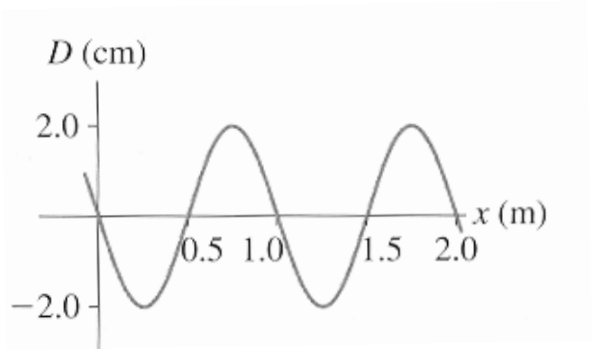
Problem Session

1. A wave has an angular frequency of 30 rad/s and a wavelength of 2.0 m. What are its wave number and wave speed?

2. The displacement of a wave traveling in the negative y-direction is $D(y,t) = (5.2\text{ cm})\sin(5.5y + 72t)$, where y is in m and t in s. What are the frequency, wavelength, and propagation speed of this wave?

3. The figure below is a waveform at t = 1/4 s of the wave function $D(x,t) = (2.0\text{ cm})\sin(2\pi x - 4\pi t)$, where x is in m and t in s.
   a) Reproduce this graph on your page, then use a ***dotted line*** to show the waveform at t = 0 s, and a ***dashed line*** to show the waveform at t = 1/8 s.
   b) What is the speed of this wave?



4. Two sinusoidal waves in a string are defined by the functions
$$y_1 = (2.00\text{ cm})\sin(20.0x - 32.0t)$$
$$y_2 = (2.00\text{ cm})\sin(25.0x - 40.0t)$$
where y and x are in centimeters and t is in seconds.
   a) What is the phase difference between these two waves at the point x = 5.00 cm at t = 2.00 s?
   b) What is the positive x value closest to the origin where the two waves add to zero at t = 2.00 s?

5. A sound source is located somewhere along the x-axis. Experiments show that the same wave front reaches listeners at x = -7.0 m and x = 3.0 m.
   a) What is the x-coordinate of the source?
   b) A third listener is positioned along the positive y-axis. What is her y-coordinate if the same wave front reaches her at the same instant it does the first two listeners?

6. A sound wave with intensity 2.0×10^{-3} W/m^2 is perceived to be modestly loud. Your eardrum is 6.0 mm in diameter. How much energy will be transferred to your eardrum while listening to this sound for 1.0 minute?

7. The sound intensity from a jack hammer breaking concrete is 2.0 W/m^2 at a distance of 2.0 m from the point of impact. This is sufficiently loud to cause permanent hearing damage if the operator doesn't wear ear protection. What is the sound intensity for a person watching from 50 m away? Give your answers in W/m^2 and in dB.

8. An earthquake emits both S-waves and P-waves which travel at different speeds through the Earth. A P-wave travels at 9000 m/s and an S-wave travels at 5000 m/s. If P-waves are received at a seismic station 1.00 minute before an S-wave arrives, how far away is the earthquake center?

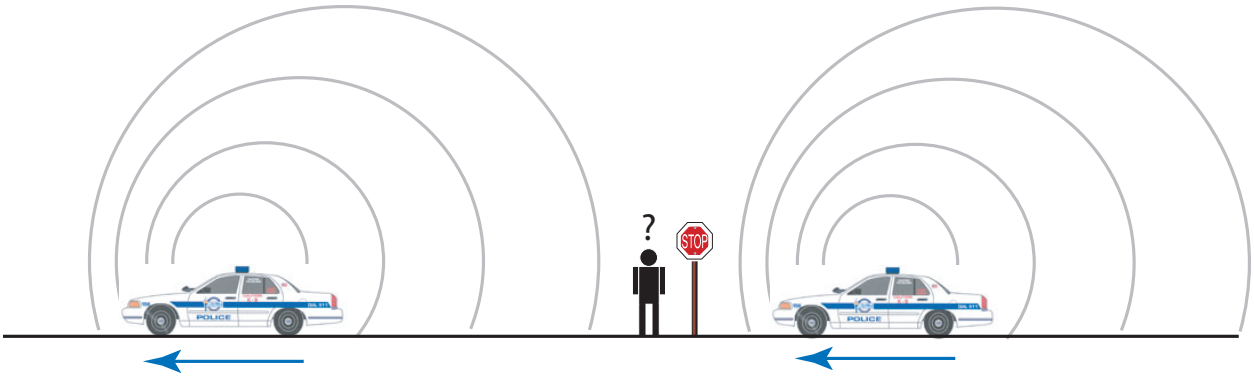
9. A physics professor demonstrates the Doppler effect by tying a 600 Hz sound generator to a 1.0-m-long rope and whirling it around his head in a horizontal circle at 100 rpm. What are the highest and lowest frequencies heard by a student in the classroom?

10. A string with linear density 2.0 g/m is stretched along the positive x-axis with tension 20 N. One end of the string, at x = 0 m, is tied to a hook that oscillates up and down at a frequency of 100 Hz with a maximum displacement of 1.0 mm. At t = 0 s, the hook is at its lowest point.
    a) What are the wave speed on the string and the wavelength?
    b) What are the amplitude and phase constant of the wave?
    c) Write the equation $y = (x,t)$ for the traveling wave.
    d) What is the string's displacement at x = 0.50 m and t = 15 ms?

11. Two radio antennas are 100-m apart along a north-south line. They broadcast identical radio waves at a frequency of 3.0 MHz. Your job is to monitor the signal strength with a handheld receiver. To get your first measuring point, you walk 800 m east from the midpoint between the antennas then 600 m north.
    a) What is the phase difference between the waves at this point?
    b) Is the interference at this point maximum constructive, perfect destructive or somewhat in between? Explain.
    c) If you now begin to walk farther north, does the signal strength increase, decrease or stay the same? Explain.

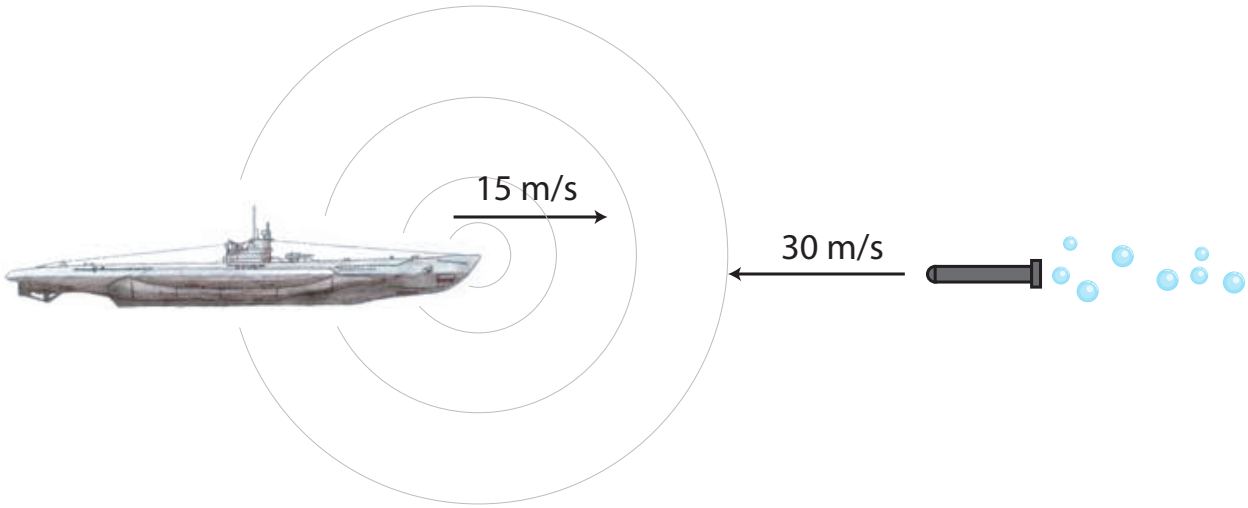
12. Astronauts visiting Planet X have a 2.5-m-long string whose mass is 5.0 g. They tie the string to a support, stretch it horizontally over a pulley 2.0 m away, and hang a 1.0 kg mass on the free end. Then the astronauts begin to excite standing waves on the string. Their data show that standing waves exist at frequencies of 64 Hz and 80 Hz, but at no frequencies in between. What is the value of g, the acceleration due to gravity on Planet X?

13. The police are busy on the day that you hear two police cars sounding their one-note sirens as you wait at a stop sign. The police cars are moving at 30 m/s and their drivers hear their own sirens emitting at a frequency of 650 Hz. One police car passes you while the other is still approaching. What is the beat frequency of the sound from the sirens?



14. You're helping with an experiment in which a vertical cylinder will rotate about its axis by a very small angle. You need to devise a way to measure this angle. You decide to use what is called an optical lever. You begin by mounting a small mirror on top of the cylinder. A laser beam 5.0 m away shoots a laser beam at the mirror. Before the experiment starts, the mirror is adjusted to reflect the laser beam directly back to the laser. Later, you measure that the reflected laser beam, when it returns to the laser, has been deflected sideways by 2.0 mm. How many degrees has the cylinder rotated?

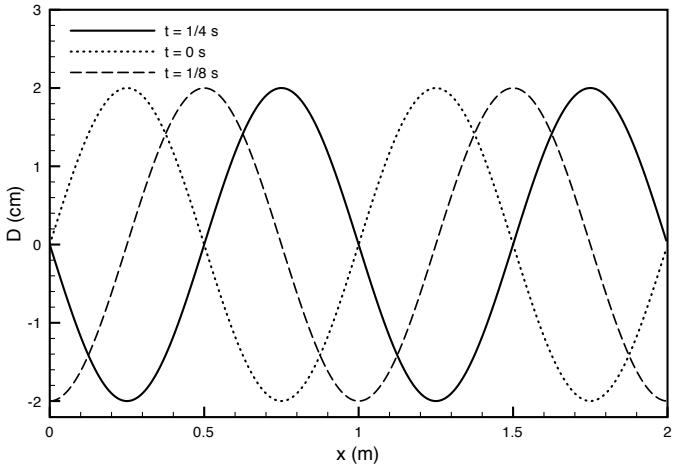
15. A submarine with a cruising speed of 15.0 m/s uses a sonar (**SO**und **NA**vigation and **R**anging) operating at 15 000 Hz. The speed of sound in sea water at the submarine's depth is 1551 m/s. Calculate the frequency of the echo, a sonar operator would receive, from a torpedo incoming directly toward the submarine at a speed of 30.0 m/s.



Answers

1. Wavenumber: $k = \pi$ rad/m, wavespeed: $v = 9.55$ m/s

2. $f = 11.46$ Hz, $\lambda = 1.14$ m, $v = 13.1$ m/s



3. propagation speed: 2 m/s

4. a) 9 rads, b) $x = 0.0584$ cm

5. a) $x = -2$ m, b) $y = 4.58$ m

6. $E = 3.39$ μJ

7. $I = 3.20 \times 10^{-3}$ W/m^2, $\beta = 95.05$ dB

8. 675 km

9. $f_{max} = 618.89$ Hz, $f_{min} = 582.23$ Hz

10. $v = 100$ m/s, $\lambda = 1$ m, $A = 1.0$ mm, $\varphi = \pi$, $y(x,t) = (1.0 \text{ mm}) \cos(2\pi x - 200\pi t + \pi)$, $y(0.5 \text{ m}, 15 \text{ ms}) = 9.98 \times 10^{-1}$ mm.

11. a) $\Delta r = 59.8$ m, $\Delta\phi = 3.757$ rads b) Conditions for max constructive: $\Delta\phi = 2n\pi$, condition for perfect destructive: $\Delta\phi = (2n+1)\pi$, (n=0,1,2,...). Neither are satisfied, so interference is in between. c) when $\Delta r = 50$ m, perfectly destructive, as Δr increases as one walks north, the signal also increases until $\Delta r = 100$ m.

12. $g = 8.19$ m/s^2

13. Beat frequency = 114 Hz

14. $\Delta\theta = 1.15 \times 10^{-2}$ degrees

15. 15 896 Hz