

53. Each wire is vibrating in its fundamental mode, so the wavelength is twice the length of the wire ($\lambda = 2L$) and the frequency is

$$f = v/\lambda = (1/2L)\sqrt{\tau/\mu},$$

where $v = \sqrt{\tau/\mu}$ is the wave speed for the wire, τ is the tension in the wire, and μ is the linear mass density of the wire. Suppose the tension in one wire is τ and the oscillation frequency of that wire is f_1 . The tension in the other wire is $\tau + \Delta\tau$ and its frequency is f_2 . You want to calculate $\Delta\tau/\tau$ for $f_1 = 600$ Hz and $f_2 = 606$ Hz. Now, $f_1 = (1/2L)\sqrt{\tau/\mu}$ and $f_2 = (1/2L)\sqrt{(\tau + \Delta\tau)/\mu}$, so

$$f_2/f_1 = \sqrt{(\tau + \Delta\tau)/\tau} = \sqrt{1 + (\Delta\tau/\tau)}.$$

This leads to $\Delta\tau/\tau = (f_2/f_1)^2 - 1 = [(606\text{ Hz})/(600\text{ Hz})]^2 - 1 = 0.020$.

58. We use Eq. 17-47 with $f = 1200$ Hz and $v = 329$ m/s.

(a) In this case, $v_D = 65.8$ m/s and $v_S = 29.9$ m/s, and we choose signs so that f' is larger than f :

$$f' = f \left(\frac{329 \text{ m/s} + 65.8 \text{ m/s}}{329 \text{ m/s} - 29.9 \text{ m/s}} \right) = 1.58 \times 10^3 \text{ Hz.}$$

(b) The wavelength is $\lambda = v/f' = 0.208$ m.

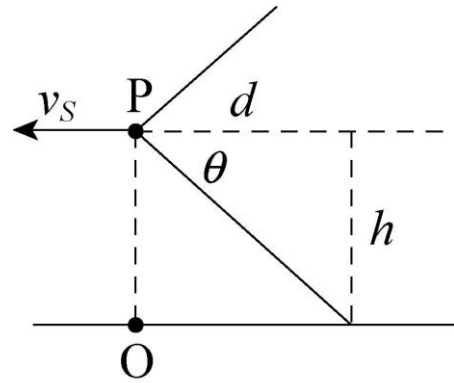
(c) The wave (of frequency f') “emitted” by the moving reflector (now treated as a “source,” so $v_S = 65.8$ m/s) is returned to the detector (now treated as a detector, so $v_D = 29.9$ m/s) and registered as a new frequency f'' :

$$f'' = f' \left(\frac{329 \text{ m/s} + 29.9 \text{ m/s}}{329 \text{ m/s} - 65.8 \text{ m/s}} \right) = 2.16 \times 10^3 \text{ Hz.}$$

(d) This has wavelength $v/f'' = 0.152$ m.

69. (a) The half angle θ of the Mach cone is given by $\sin \theta = v/v_S$, where v is the speed of sound and v_S is the speed of the plane. Since $v_S = 1.5v$, $\sin \theta = v/1.5v = 1/1.5$. This means $\theta = 42^\circ$.

(b) Let h be the altitude of the plane and suppose the Mach cone intersects Earth's surface a distance d behind the plane. The situation is shown on the diagram, with P indicating the plane and O indicating the observer. The cone angle is related to h and d by $\tan \theta = h/d$, so $d = h/\tan \theta$. The shock wave reaches O in the time the plane takes to fly the distance d :



$$t = \frac{d}{v} = \frac{h}{v \tan \theta} = \frac{5000 \text{ m}}{1.5(331 \text{ m/s})\tan 42^\circ} = 11 \text{ s}.$$

23. (a) If point P is infinitely far away, then the small distance d between the two sources is of no consequence (they seem effectively to be the same distance away from P). Thus, there is no perceived phase difference.

(b) Since the sources oscillate in phase, then the situation described in part (a) produces fully constructive interference.

(c) For finite values of x , the difference in source positions becomes significant. The path lengths for waves to travel from S_1 and S_2 become now different. We interpret the question as asking for the behavior of the absolute value of the phase difference $|\Delta\phi|$, in which case any change from zero (the answer for part (a)) is certainly an increase.

The path length difference for waves traveling from S_1 and S_2 is

$$\Delta\ell = \sqrt{d^2 + x^2} - x \quad \text{for } x > 0.$$

The phase difference in “cycles” (in absolute value) is therefore

$$|\Delta\phi| = \frac{\Delta\ell}{\lambda} = \frac{\sqrt{d^2 + x^2} - x}{\lambda}.$$

Thus, in terms of λ , the phase difference is identical to the path length difference: $|\Delta\phi| = \Delta\ell > 0$. Consider $\Delta\ell = \lambda/2$. Then $\sqrt{d^2 + x^2} = x + \lambda/2$. Squaring both sides, rearranging, and solving, we find

$$x = \frac{d^2}{\lambda} - \frac{\lambda}{4}.$$

In general, if $\Delta\ell = \xi\lambda$ for some multiplier $\xi > 0$, we find

$$x = \frac{d^2}{2\xi\lambda} - \frac{1}{2}\xi\lambda = \frac{64.0}{\xi} - \xi$$

where we have used $d = 16.0$ m and $\lambda = 2.00$ m.

(d) For $\Delta\ell = 0.50\lambda$, or $\xi = 0.50$, we have $x = (64.0/0.50 - 0.50)$ m = 127.5 m \approx 128 m.

(e) For $\Delta\ell = 1.00\lambda$, or $\xi = 1.00$, we have $x = (64.0/1.00 - 1.00)$ m = 63.0 m.

(f) For $\Delta\ell = 1.50\lambda$, or $\xi = 1.50$, we have $x = (64.0/1.50 - 1.50)$ m = 41.2 m.

Note that since whole cycle phase differences are equivalent (as far as the wave superposition goes) to zero phase difference, then the $\xi = 1, 2$ cases give constructive interference. A shift of a half-cycle brings “troughs” of one wave in superposition with “crests” of the other, thereby canceling the waves; therefore, the $\xi = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ cases produce destructive interference.

1. (a) The time for the sound to travel from the kicker to a spectator is given by d/v , where d is the distance and v is the speed of sound. The time for light to travel the same distance is given by d/c , where c is the speed of light. The delay between seeing and hearing the kick is $\Delta t = (d/v) - (d/c)$. The speed of light is so much greater than the speed of sound that the delay can be approximated by $\Delta t = d/v$. This means $d = v \Delta t$. The distance from the kicker to spectator A is

$$d_A = v \Delta t_A = (343 \text{ m/s})(0.23 \text{ s}) = 79 \text{ m}.$$

(b) The distance from the kicker to spectator B is $d_B = v \Delta t_B = (343 \text{ m/s})(0.12 \text{ s}) = 41 \text{ m}$.

(c) Lines from the kicker to each spectator and from one spectator to the other form a right triangle with the line joining the spectators as the hypotenuse, so the distance between the spectators is

$$D = \sqrt{d_A^2 + d_B^2} = \sqrt{(79 \text{ m})^2 + (41 \text{ m})^2} = 89 \text{ m}.$$

42. The distance between nodes referred to in the problem means that $\lambda/2 = 3.8$ cm, or $\lambda = 0.076$ m. Therefore, the frequency is

$$f = v/\lambda = (1500 \text{ m/s})/(0.076 \text{ m}) \approx 20 \times 10^3 \text{ Hz.}$$