

13. Let L_1 be the distance from the closer speaker to the listener. The distance from the other speaker to the listener is $L_2 = \sqrt{L_1^2 + d^2}$, where d is the distance between the speakers. The phase difference at the listener is $\phi = 2\pi(L_2 - L_1)/\lambda$, where λ is the wavelength.

- (a) For a minimum in intensity at the listener, $\phi = (2n + 1)\pi$, where n is an integer. Thus $\lambda = 2(L_2 - L_1)/(2n + 1)$. The frequency is

$$f = \frac{v}{\lambda} = \frac{(2n + 1)v}{2(\sqrt{L_1^2 + d^2} - L_1)} = \frac{(2n + 1)(343 \text{ m/s})}{2(\sqrt{(3.75 \text{ m})^2 + (2.00 \text{ m})^2} - 3.75 \text{ m})} = (2n + 1)(343 \text{ Hz}) .$$

Now $20,000/343 = 58.3$, so $2n + 1$ must range from 0 to 57 for the frequency to be in the audible range. This means n ranges from 1 to 28 and $f = 1029, 1715, \dots, 19550 \text{ Hz}$.

- (b) For a maximum in intensity at the listener, $\phi = 2n\pi$, where n is any positive integer. Thus $\lambda = (1/n)(\sqrt{L_1^2 + d^2} - L_1)$ and

$$f = \frac{v}{\lambda} = \frac{nv}{\sqrt{L_1^2 + d^2} - L_1} = \frac{n(343 \text{ m/s})}{\sqrt{(3.75 \text{ m})^2 + (2.00 \text{ m})^2} - 3.75 \text{ m}} = n(686 \text{ Hz}) .$$

Since $20,000/686 = 29.2$, n must be in the range from 1 to 29 for the frequency to be audible and $f = 686, 1372, \dots, 19890 \text{ Hz}$.