Physics I

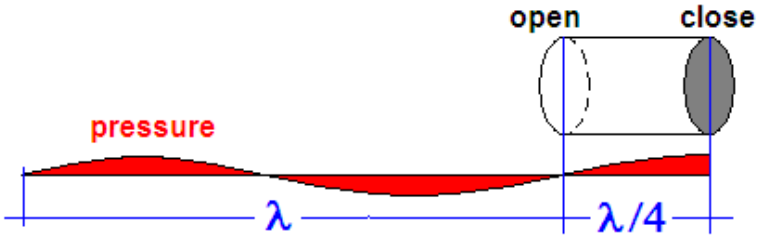
Sound Generation

Standing frequency in a pipe open on both sides: $f = n\frac{v_{sound}}{2L}$, $n = 1,2,3...$

Standing frequency in a pipe open on one side: $f = n\frac{v_{sound}}{4L}$, $n = 1,3,5...$

Problem 1.- Consider the human ear canal as a 2.4 cm pipe open at one end and closed at the other. At what frequencies are the fundamental and the first overtone resonances?

Solution: For a pipe open at one end the first resonance occurs when the length of the pipe is equal to one quarter of a wavelength:

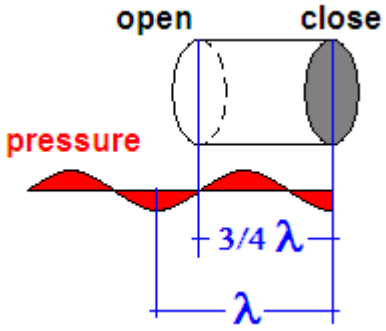


This is so because the pressure at the open end must be equal to the outside pressure if there is going to be a standing wave. The displacement of air at the closed end must be zero because the particles have nowhere to go, so the pressure is a maximum or minimum at the closed end.

Consequently, the first resonance corresponds to

$$\lambda/4 = 2.4\text{cm} \rightarrow \lambda = 9.6\text{cm} = 0.096\text{m} \rightarrow f = \frac{v_{sound}}{\lambda} = \frac{343\text{m/s}}{0.096\text{m}} = \mathbf{3{,}570\ Hz}$$

The first overtone will happen when the length of the pipe is equal to ¾ of a wavelength as shown below:



So, in this case:

$$3/4\lambda = 2.4\text{cm} \rightarrow \lambda = 3.2\text{cm} = 0.032\text{m} \rightarrow f = \frac{v_{sound}}{\lambda} = \frac{343\text{m/s}}{0.032\text{m}} = \mathbf{10{,}720\ Hz}$$

Problem 2.- Consider a chimney to be an open tube (both ends open). If the fundamental frequency heard is 25Hz, how long is the chimney?

Solution: The wavelength is $\lambda = \frac{v}{f} = \frac{343}{25} = 13.72m$

The length of the chimney is then $\lambda / 2 = \mathbf{6.86m}$

Problem 3.- At 20ºC, when the speed of sound is 343 m/s, a pipe open at both ends resonates at a frequency of 440 hertz. At what frequency does the same pipe resonate on a particularly cold day when the speed of sound is 322.8 m/s?

Solution:

In the first condition $\lambda = \frac{343}{440} = 0.78m$

In the second condition $f = \frac{322.8}{0.78} = \mathbf{414\ Hz}$

Problem 4.- Two horns produce sounds with wavelength 6.5 m and 7.5 m respectively. What beat frequency is heard when both horns emit sound simultaneously?
Take the speed of sound as 343 m/s

Solution: The beats will happen at the difference in frequency

$$f_{beats} = \frac{343}{6.5} - \frac{343}{7.5} = \mathbf{7.0\ Hz}$$