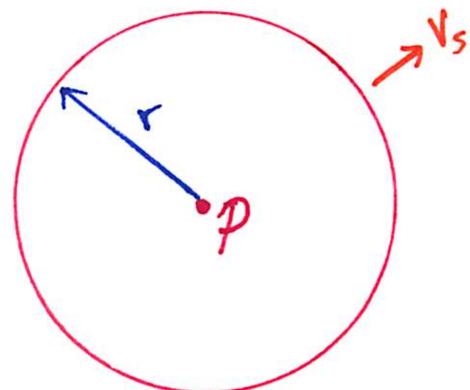
SPEED OF SOUND:

$$v_s = \sqrt{B/\rho} \text{ or } v_s = \sqrt{Y/\rho}.$$

Note that since B and ρ depend on temperature, the speed of sound has a strong temperature dependence.

Sound waves propagate in all directions in an open system, so the intensity of the wave in Watts/m^2 goes like

$$I = \mathcal{P}/A = \mathcal{P}/(4\pi r^2).$$



Sound level:

$$\beta = [10 \text{ dB}] \log[I/I_0] \text{ where } I_0 \text{ is } 10^{-12} \text{ W/m}^2.$$

DOPPLER EFFECT: Moving detector D:

$$f = f_s[1 \pm (V_D/v_p)]$$

v_p is the phase speed of sound in air

Moving source S:

$$f = f_s[1 \mp (V_s/v_p)]^{-1}.$$

GENERAL RESULT:

$$f = f_s\left[\frac{1 \pm (V_D/v_p)}{1 \mp (V_s/v_p)}\right].$$

• A car horn emits a sound which at your location has an intensity of 10^{-6} W/m^2. What is the sound level? If 100 cars at about the same distance with identical horns are blowing their horns at once, how does the sound level change?

• If the intensity is 10^{-5} W/m^2 at 1 km from a sound source, what is the average power of the source?

• An emergency vehicle has a siren that produces a sound of 2000 Hz. On a day when the speed of sound is 340 m/s, you are standing on the street as the vehicle approaches you at 30 m/s. What frequency do you hear? [2193 Hz.]

What frequency would you hear if you were running down the street away from the ambulance at 5 m/s as it approaches at 30 m/s? [All speeds measured relative to the street.] [2160 Hz.]

• A glass hooting tube, as seen in class, has a length of 1 m. If the speed of sound in the hot air in the tube is 350 m/s, what is the fundamental frequency? [175 Hz.]

Standing waves in air-pipes:

Count half-wavelengths. It is easiest to visualize pressure waves $\Delta p(x,t)$ in the pipe. A closed end is a maximum-minimum of the wave since air can be compressed against a wall. An open end is a zero of the wave since the pressure becomes normal as you come out of the pipe. [If a Quest problem shows the displacement wave $s(x,t)$, once again just count half-wavelengths. For s the maximum-minimum and nodal points are switched around but this does not affect the count.]

Beats:

When two sound waves of about the same amplitude but slightly different frequencies arrive at the same point, a pattern of alternating constructive and destructive interference produces a throbbing noise with a frequency $f = |f_1 - f_2|$.

Resonance:

The standing waves are of course the resonant frequencies of one-, two-, and three-dimensional oscillating systems. Classic examples: Chladni Plates, singing aluminum rods, hooting tubes, bloogles.