Summary

Sound Pressure

When sound passes through a medium (fluid), there is a change in volume as follows:

$$\begin{aligned} \frac{dv}{V} &= \lim_{\Delta x \to 0} \frac{S(y(x+\Delta x, t) - y(x,t))}{S\Delta x} \\ \frac{dv}{V} &= \frac{\delta y(x,t)}{\delta x} \end{aligned}$$

Note that the bulk modulus B is represented in terms of pressure and change in volume:

$$B = \frac{-p(x,t)}{\frac{dv}{V}}$$

These two equations can then be combined and rearranged to get the pressure equation:

$$p(x,t) = BkA\sin(kx - \omega t)$$

where B is the bulk modulus.

The maximum pressure can then be found through:

$$p_{\max} = BkA \tag{of a sinusoidal sound wave}$$

Sound Velocity

We can express velocity in terms of the Bulk or Young's Modulus.

For liquids

$$v = \sqrt{\frac{B}{\rho}}$$

For solids

$$v = \sqrt{\frac{B}{\rho}}$$

We can also find the velocity in gas in terms of the heat capacity ration γ:

$$v = \sqrt{\frac{\gamma RT}{M}}$$

where:

- T = absolute temperature (K)
- M = molar mass
- R = gas constant, 8.314 J/mole-K
- γ = heat capacity ratio

Sound Intensity

The intensity of a sound wave can be expressed as follows:

$$I = \frac{1}{2}\sqrt{\rho B}\omega^2 A^2$$

$$I = \frac{p_{\max}^2}{2\rho v} = \frac{p_{\max}^2}{2\sqrt{\rho B}}$$

Then to get the sound intensity level in decibels:

$$\beta = (10dB)\log\frac{I}{I_0}$$

where $I_0 = 1 \times 10^{-12} W/m^2$

Standing Sound Wave

Open Pipe (Open both sides)

$$f_n = n\frac{v}{2L} \text{ (n} = 1, 2, 3, ...)$$

Stopped Pipe (Closed one side)

$$f_n = n\frac{v}{4L} \text{ (n} = 1, 3, 5, ...)$$

Their fundamental frequencies would then be:

$$f_1 = \frac{v}{2L} \qquad \text{(for an open pipe)}$$
$$f_1 = \frac{v}{4L} \qquad \text{(for a closed pipe)}$$

Beat Frequency

The frequency of a "beat" is:

$$f_{\text{beat}} = |f_2 - f_1|$$

Doppler Effect & Shock Wave

Doppler Effect

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$$

where the sign of v_L and v_s depends on the direction of the movement of the listener and source.

Shock Wave

$$\sin\alpha = \frac{vt}{v_s t} = \frac{v}{v_s}$$