PHYSICS 232 – CHAPTER 16: SOUND

Sound consists of longitudinal waves in a medium. A sinusoidal wave of wavenumber $k = 2\pi/\lambda$ and amplitude A has pressure amplitude

$$p_{max} = BkA,$$

where B is the bulk modulus of the wave medium.

Speed:

$$v = \sqrt{\frac{B}{\rho}} \text{ (fluid)}, \quad \sqrt{\frac{Y}{\rho}} \text{ (solid rod)}, \quad \sqrt{\frac{\gamma p}{\rho}} = \sqrt{\frac{\gamma RT}{M}} \text{ (ideal gas)}$$

Intensity (time-average power per unit area):

$$I = \frac{1}{2}\sqrt{\rho B}\omega^2 A^2 = \frac{p_{max}^2}{2\rho v} = \frac{p_{max}^2}{2\sqrt{\rho B}} = \frac{\text{total power}}{4\pi r^2}$$

Sound intensity level:

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

where $I_o = 10^{-12}\ W/m^2$.

For a pipe open at both ends, the normal-mode frequencies are

$$f_n = \frac{nv}{2L} \quad (n = 1, 2, 3, \dots)$$

For a pipe open at one end and closed at the other (stopped pipe), the normal-mode frequencies are

$$f_n = \frac{nv}{4L} \quad (n = 1, 3, 5, \dots)$$

Interference at a point at distances d_1 and d_2 from two sources oscillating in phase

$$d_1 - d_2 = n\lambda \quad \text{(constructive)} \qquad d_1 - d_2 = \left(n + \frac{1}{2}\right)\lambda \quad \text{(destructive)}$$

Beat frequency ($f_a > f_b$):

$$f_{beat} = f_a - f_b$$

The Doppler effect (S: source, L: listener):

$$f_L = \frac{v + v_L}{v + v_S} f_S$$

A source moving with speed $v_S > v$ creates a cone of angle α:

$$\sin \alpha = \frac{v}{v_S}$$