PHYSICS 232 – CHAPTER 16: SOUND

Sound consists of longitudinal waves in a medium. A sinusoidal wave of wavenumber \( k = \frac{2\pi}{\lambda} \) and amplitude \( A \) has pressure amplitude

\[
p_{\text{max}} = BkA,
\]

where \( B \) is the bulk modulus of the wave medium.

Speed:

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

Intensity (time-average power per unit area):

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

Sound intensity level:

\[
\beta = (10dB) \log \frac{I}{I_0},
\]

where \( I_0 = 10^{-12} W/m^2 \).

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

\[
f_n = \frac{nv}{2L} \quad (n = 1, 2, 3, \ldots)
\]

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

\[
f_n = \frac{nv}{4L} \quad (n = 1, 3, 5, \ldots)
\]

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

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

Beat frequency \((f_a > f_b)\):

\[
f_{\text{beat}} = f_a - f_b
\]

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 \( \alpha \):

\[
\sin \alpha = \frac{v}{v_S}
\]