Chapter 17 Sound Waves

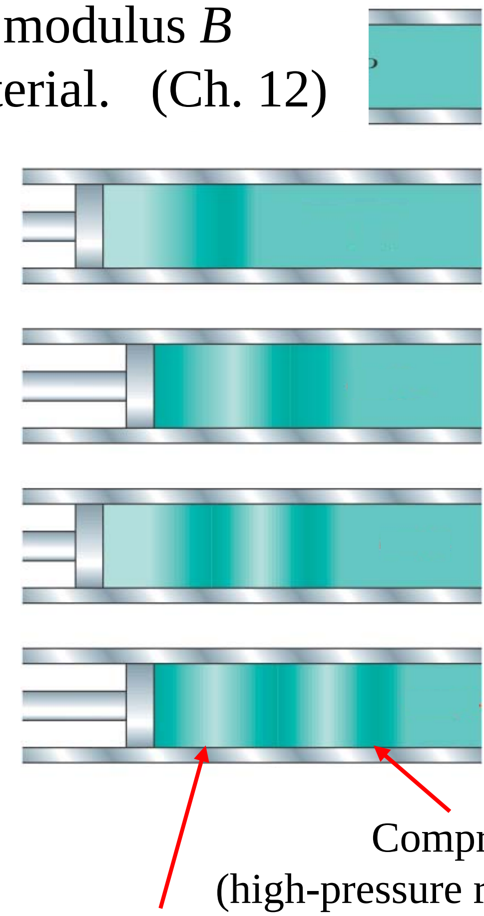
17.1 Speed of Sound Waves

- The speed of all mechanical waves follows a general form :

$$v = \sqrt{\frac{\text{elastic property}}{\text{inertia property}}}$$

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

with bulk modulus B of the material. (Ch. 12)



Recall

Bulk modulus : Volume elasticity

Bulk modulus characterizes the response of an object to changes in a force of uniform magnitude applied over the entire surface of the object.

$$B \equiv -\frac{\Delta P}{\Delta V / V_o}$$

- Derivation of speed of sound wave :

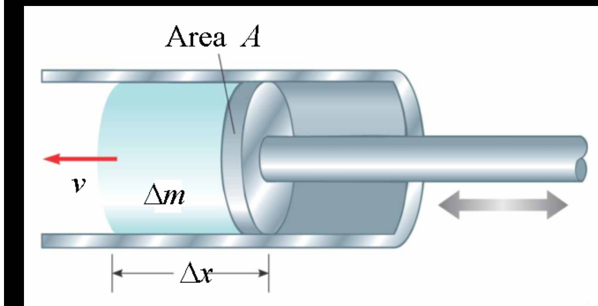
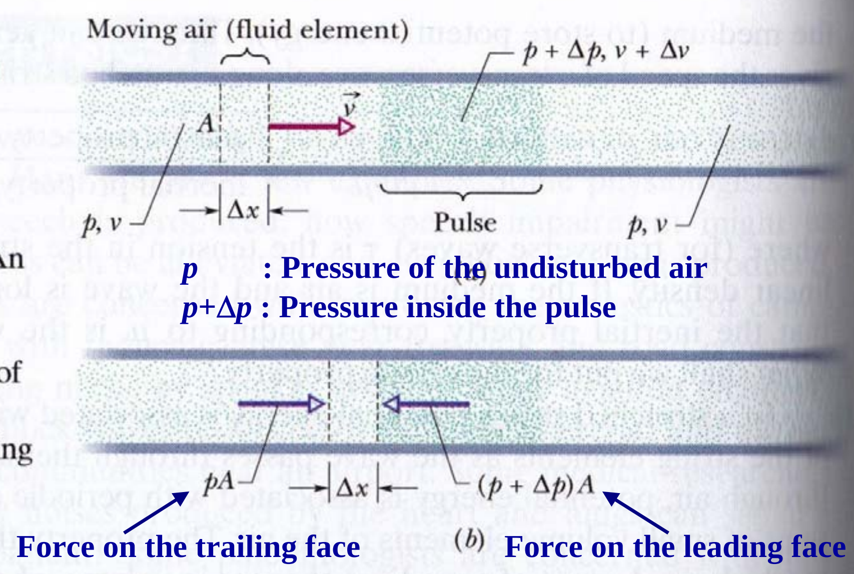


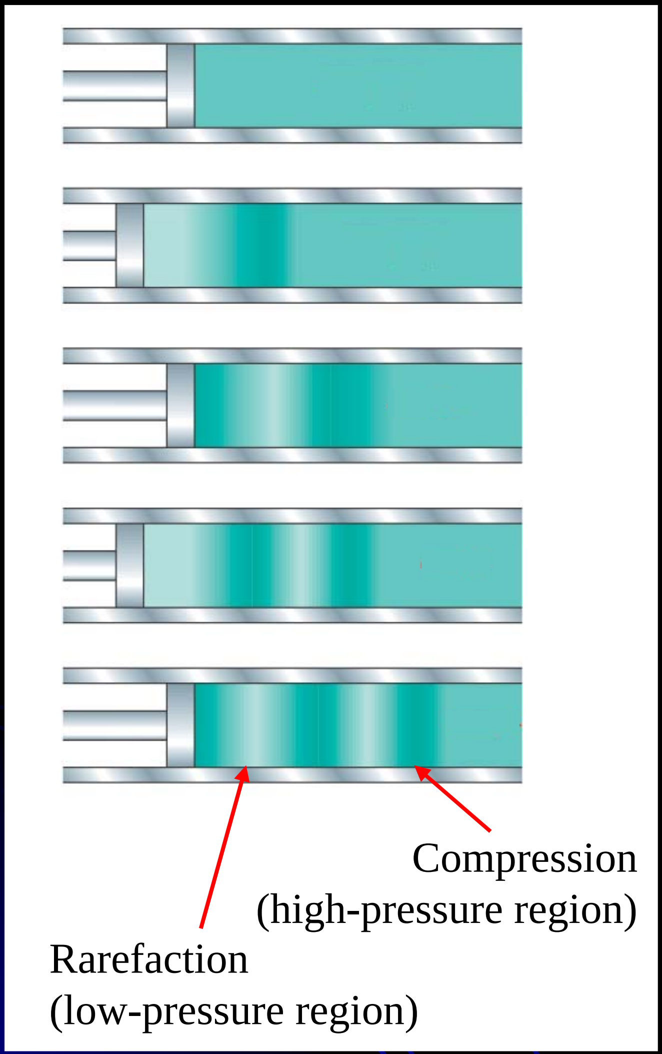
FIG. 17-3 A compression pulse is sent from right to left down a long air-filled tube. The reference frame of the figure is chosen so that the pulse is at rest and the air moves from left to right. (*a*) An element of air of width Δx moves toward the pulse with speed v. (*b*) The leading face of the element enters the pulse. The forces acting on the leading and trailing faces (due to air pressure) are shown.



- For air, the relationship between the speed and temperature is :

$$v = (331\ \text{m/s})\sqrt{1 + \frac{T_C}{273^\circ\ \text{C}}}$$

17.2 Periodic Sound Waves



- The source of the wave is an oscillating piston.
- A longitudinal wave is propagating through a gas-filled tube.
- The distance between two successive compressions (or rarefactions) is the wavelength λ.

$$\boxed{v = \lambda f}$$

- Looking in detail at the displacements and pressure variations of sound wave
- Displacement amplitude :

$$s(x,t) = s_{max} \cos(kx - \omega t)$$

→ The small element of the medium moves with SHM parallel to the direction of the wave.

- Variation in pressure :

$$\Delta P(x,t) = \Delta P_{max} \sin(kx - \omega t)$$

→ The variation in pressure, ΔP, is also periodic.

- The pressure wave is 90º out of phase with the displacement wave.