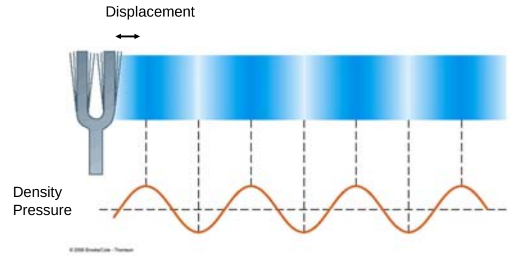
1.4 Sound

Producing sound waves
Speed of sound
Energy and Intensity
Spherical and Plane waves.

Producing sound waves



- Sound waves are longitudinal
- Produced by compression and rarefaction of media (air) resulting in displacement in the direction of propagation.
- The displacements result in oscillations in density and pressure.

Frequencies of sound wave

infra-sonic | Audible Sound | ultra- sonic

10 | 20,000

Frequency (Hz) →

30 | 0.015

Wavelength (m) in air

Speed of sound

Speed of sound in a fluid

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

$$B = -\frac{\Delta P}{\Delta V / V}$$ Bulk modulus

$$\rho = \frac{m}{V}$$ Density

Similarity to speed of a transverse wave on a string

$$v = \sqrt{\frac{elastic\_property}{intertial\_property}}$$

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

Density is higher in water than in air.
Why is the speed of sound higher in water than in air?

TABLE 14.1
Speeds of Sound in Various Media

Medium	v (m/s)
Gases	
Air (0°C)	331
Air (100°C)	386
Hydrogen (0°C)	1 290
Oxygen (0°C)	317
Helium (0°C)	972
Liquids at 25°C	
Water	1 490
Methyl alcohol	1 140
Sea water	1 530
Solids	
Aluminum	5 100
Copper	3 560
Iron	5 130
Lead	1 320
Vulcanized rubber	54

Speed of sound in air

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

γ is a constant that depends on the nature of the gas
γ =7/5 for air

P - Pressure
ρ - Density

Since P is proportional to the absolute temperature T by the ideal gas law.
PV=nRT

$$v = 331\sqrt{\frac{T}{273}}$$ (m/s)

Find the speed of sound in air at 20º C.

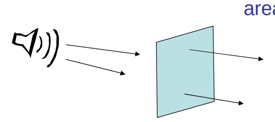
$$v = 331\sqrt{\frac{T}{273}}$$

$$v = 331\sqrt{\frac{273+20}{273}} = 343 m/s$$

For calculations use v=340 m/s

Energy and Intensity of sound waves

power $P = \frac{energy}{time}$



intensity $I = \frac{power}{area} = \frac{P}{A}$ (units W/m^2)

Sound intensity level

The decibel is a measure of the sound intensity level

$$\beta = 10\log\left(\frac{I}{I_o}\right)$$ decibels

$I_o = 10^{-12}$ W/m^2 the threshold of hearing

note- decibel is a logarithmic unit. covers a wide range of intensities.

The ear is capable of distinguishing a wide range of sound intensities.

What is the intensity of sound at a rock concert? (W/m^2)

TABLE 14.2

Intensity Levels in Decibels for Different Sources

Source of Sound	β(dB)
Nearby jet airplane	150
Jackhammer, machine gun	130
Siren, rock concert	120
Subway, power mower	100
Busy traffic	80
Vacuum cleaner	70
Normal conversation	50
Mosquito buzzing	40
Whisper	30
Rustling leaves	10
Threshold of hearing	0

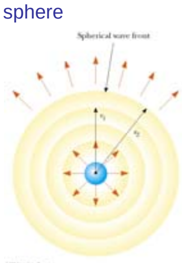
Spherical and plane waves

$A = 4\pi r^2$ area of sphere

Power passes through larger areas.

$P = I_1A_1 = I_2A_2$

$$\frac{I_2}{I_1} = \frac{A_1}{A_2} = \frac{r_1^2}{r_2^2}$$



As sound spreads out uniformly from a point source the intensity decreases as $1/r^2$

Suppose you are standing near a loudspeaker that can is blasting away with 100 W of audio power. How far away from the speaker should you stand if you want to hear a sound level of 120 dB. (assume that the sound is emitted uniformly in all directions.)