* Chapter 9

- Sound waves:- a compression or strain waves transmitted through a medium that have sufficient intensity and area of freq that can be detected as sound.

* for the human ear to hear
→ waves with freq too high (ultrasonic)
→ " " " " low (infrasonic)
→ waves that the human ear can detect called (sonic)

- pressure waves in Gases

a moving disturbance of the molecules of the air, where the molecules are closer together are called comparessions

the area where the molecules become more sparse are called rarefractions

→ the sound wave known as longitudinal waves?

Since the direction of the air molecules are displaced in the same direction of the wave pulse propagates.

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→ So, the sounds waves travels when it hit's the particle of the element which lead the the compartssion and ranefaction in Gases medium

es in Solid and liquids:.

→ So we can conclude that the speed of sound would be higer in solid and liquid than in gases, since it's easy for the vibration to hit the next particle,

→ So, the mor densety the particles are arranged, the faster sound travels.

→ Sound waves transmitted through liquids and Solids by oscillation of the molecules of the medium.

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-waves speed :-

the speed of waves depend on the temp of the medium.

$T \uparrow$ the K.E $\uparrow$

in gases if T increase the particles will colid more, so the sound move faster

→ and has the same relation with pressure

$$\boxed{v_{air} = 331 + 0.6T}$$

$V_{air} = 331 \frac{m}{s}$ when ($0 C°$, 1 atm)

$= 343 \frac{m}{s}$ when ($20 C°$, 1)

$$C_{sound} = \sqrt{\frac{B}{\rho}}$$

B ← Bulk modulus

ρ ← density

Bulk modulus: the resistance of the subst to bulk compression

- Acoustic Impedance :-

- it's a crucial parameter in determining how waves will reflect and transmit at a boundry between media.

$$Z = \rho \, C_{sound}$$

→ if the first medium has Z_1 and Z_2 for the second medium.

where the wave propagates from medium 1 to the medium 2, then the propotions of the wave intensity reflected and transmitted depends on

$$r = \frac{Z_1}{Z_2}$$ ~~transmitted~~ ~~proportion~~

proportion reflected. $$r' = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2} = \frac{(1 - r)^2}{(1 + r)^2}$$

so

proportion transmitted = 1 − proportion reflected

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* Loudness and pitch:

refers to sensation in the Consciousness
(by human brain)

→ Those two determine by it's own physical quintity

Intensity: determine the Loudness of the sound waves
"rate of energy per area

Freq: determines the pitch

high freq → high pitch

→ audible freq: a range of freq values that the human brain can received.

(20 Hz — 20 kHz)

infrasonic < 20 Hz

ultrasonic > 20 kHz

→ The upper end of the range decreases with age, and maybe as high as 40 kHz in Children.

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Freq and pitch :

pitch : ~~is how "high" or "Low" it Sounds~~
~~or~~ where the Sound lies on a musical scale
is determined by the wave freq

high freq ↑ higher pitch ↑ (shrill)
شديد , حاد

freq : refers to an objectively measurable
wave property

pitch : describe the subjective psychological
impression.

both have the unit of Hz (Cycle per
unit time)

see example 9.2

→ lion roaring is a Low-pitched Sound
where a bird produced a high-pitched Sound

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Intensity of Sound:

physical quantity that tells us how much power a wave has per some given area.

$$I = \frac{Watt}{m^2} = \frac{P}{Area}$$

recall $I \propto A^2$ amplitude.

→ if we double the amplitude ∴ I doubled

∴ then the sound wave would be louder

$$\boxed{I \propto \text{Loudness}}$$

→ The human ear can detect an extremely wide range of intensities.

$(1 \times 10^{-12}\ W/m^2$ to $1\ W/m^2)$

$$I = \frac{\rho C A^2 (2\pi f)^2}{2}$$

ρ: density   C: the speed of the wave

f: freq   A: amplitude

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$$I = \frac{P^2}{2Z}$$

intensity in terms of pressure fluctuations (P)

Z: acoustic impedance.

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The Sound level:

Because of the wide range of intensity and the relationship between loudness and intensity, sound intensity is specified using a logarithmic sacal called the sound level.
(non linear scale)

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

[unit of sound is a bel
$1 \text{ bel} = 10 \text{ dB}$
decibel

I_0 = reference intensity (min intensity audible to humans)

I = intensity of some given sound wave

note: for sound wave with $I = I_0$ the sound level 0 dB

dB (decibel): Used to compare sound intensities

let the reference intensity $= I_0 = 10^{-12} \frac{W}{m^2}$

$$L_1 = 10 \log_{10} \frac{I}{10^{-12} W \cdot m^{-2}}$$

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Normal Breathing	10 dB
Soft whisper	≈ 30 dB
Normal Conversation	60dB
Traffic	70dB
average factory	80 dB

Becomes noise to human ears.

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* Resonance and Sound Generation :

- Mode of vibration of a string:

a wave which is repeatedly reflected between two parallel reflecting boundaries will form a standing wave.

the string has fixed places that must have zero vibrational amplitude [nodes]

there are limited places on the standing waves that can be formed, and so only wavelengths that have nodes at the fixed ends will keep bouncing back and forth.

* fundamental mode of vibration: (fixed Ends)

the Longest wavelength pattern has λ twice the length of the string, the freq is called "fundamental freq" or "first harmonic"

* first overtone or "second harmonic" :- λ equal to the string length and so has freq that is twice that of the fundamental

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→ The next possibility has a $\lambda = \frac{2}{3}$ of the length which is $\frac{1}{3}$ of the λ of the fundamental and its three times its freq.

→ The overtones all have freq which are integer multiples of the fundamental.

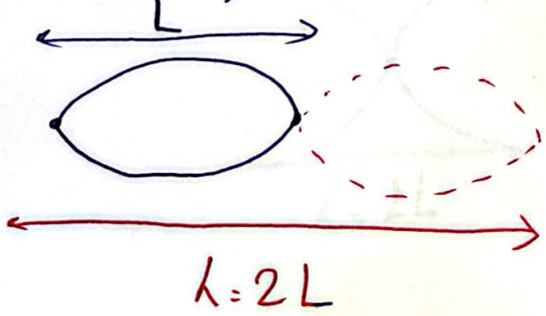
$$f_n = n\frac{c}{2L} = nf_1 \quad n = 1, 2, 3 \ldots$$

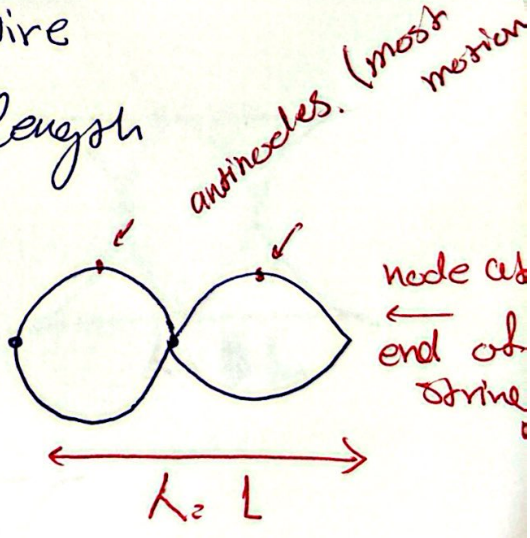
→ the speed of a wave along a wire such as a guitar string.

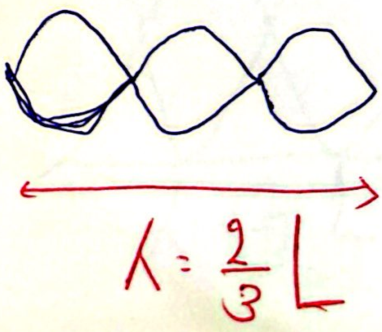
$$v = \sqrt{\frac{T}{\mu}}$$

T: tension in the wire

μ: mass per unit length







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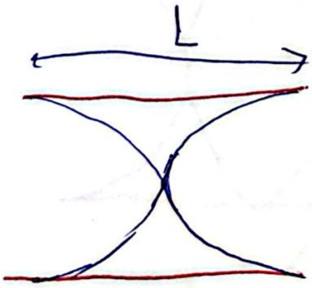
Modes of vibration of an open pipe :

- An open pipe acts in very similar way to a string with both fixed ends.
- in this situation, the sound waves in the pipe reflect off the open ends and form a standing wave pattern, where the constraint this time is the pressure at each end must be that of outside the pipe.

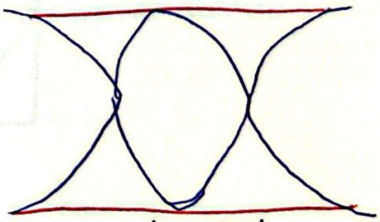
"So the ends are nodes in terms of pressure"

$$f_n = n \frac{C}{2L} \qquad n = 1, 2, 3 .$$

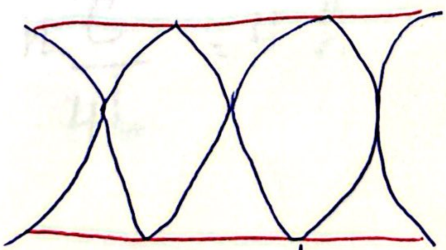
see figure 9.4



$\lambda = 2L$



$\lambda = L$



$\lambda = \frac{2}{3} L$

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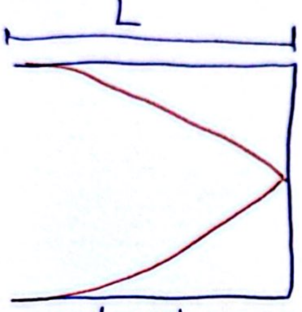
Modes of vibration of a half-open pipe:

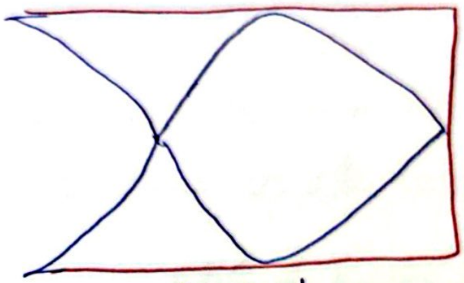
- in this Case, the open end is a pressure node and the Closed one is a displacement node.

- the max displacement will be in the pressure node

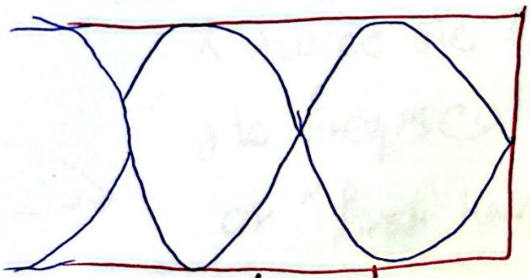
- the min " " " " " the pressure antinode



$\lambda = 4L$



$\lambda = \frac{4}{3} L$



$\lambda = \frac{4}{5} L$

$$f_n = n \frac{C}{4L} = 4 f_1 \qquad n = 1, 3, 5$$

ee example 9.3

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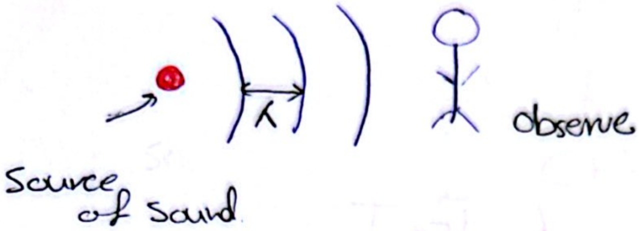
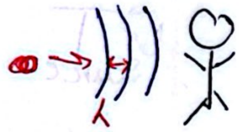
The Doppler effect:

* A stationary source creating sound will emit sound waves that travel outward.



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

→ if this source of sound start moving toward the stationary observer., the freq will change



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

$\lambda \downarrow \therefore f \uparrow$

- Doppler effect:-

the change in freq of a wave that is heard by an observer, when there is relative motion between the source of sound waves and the observer.

v: depend on the medium which remain the same in both cases since it's the same medium.

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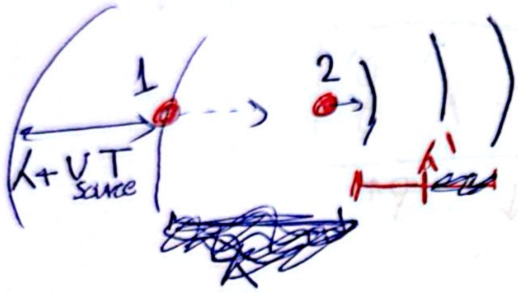
* How to calculate the freq shift.

if stationary source:-

$$T = \frac{1}{f} = \frac{\lambda}{v_{sound}} \quad \therefore \lambda = \vec{v}_{sound} T$$

$\boxed{\text{Case 1:}}$ moving source, stationary observer



$$\lambda' = \lambda - \vec{v}_{source} T$$

$$= \lambda - \vec{v}_{source}\left(\frac{\lambda}{\vec{v}_{sound}}\right)$$

$$\lambda' = \lambda\left(1 - \frac{v_{source}}{\vec{v}_{sound}}\right)$$

$$\rightarrow f' = \frac{V_{sound}}{\lambda'}$$

$$\boxed{f' = \frac{f}{\left(1 - \frac{V_{source}}{v_{sound}}\right)}}$$

$$f' = f \frac{c}{c \pm v_s}$$

(−) approaching sound sou

(+) retreating source

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→ fixed Source, moving observer: Case 2

$$T = \frac{\lambda}{c}$$

$$T' = \frac{\lambda}{c + v_D}$$ ← observer speed

$$\therefore f' = \frac{1}{T'} = \frac{c + v_D}{\lambda}$$

$$\boxed{\therefore f' = \frac{c \pm v_D}{c} f}$$

(+): approaching observer

(−): retreating observer

* The General Case:

$$\boxed{f' = \frac{c \pm v_D}{c \pm v_S} f}$$

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