# Waves in pipe and string

**Logitudinal Stationary wave**

| Open Pipe | Close Pipe |
|---|---|
| $f, 2f, 3f, 4f, \ldots$ | $f, 3f, 5f, 7f, \ldots$ |
| Fundamental frequency: $f = \frac{V}{2l_o}$ (Without end correction) | Fundamental frequency: $f = \frac{V}{4l_c}$ (Without end correction) |
| $f = \frac{V}{2(l_o + 2e)}$ (With end correction) | $f = \frac{V}{2(l_c + e)}$ (With end correction) |
| Frequency of $n^{th}$ mode: $f_n = nf \mid n = 1,2,3\ldots$ | Frequency of $n^{th}$ mode: $f_n = (2n-1)f \mid n = 1,2,3\ldots$ |

end correction: $e = 0.3d = 0.6r$

**Transverse Stationary wave**

**String**

$f, 2f, 3f, 4f, \ldots$

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

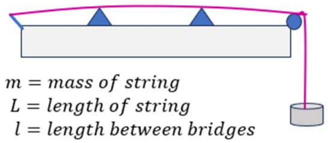
Fundamental frequency: $f = \frac{V}{2l} = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

Frequency of $n^{th}$ mode: $f_n = nf \mid n = 1,2,3\ldots$

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

$\mu = A \times \rho$ → $f = \frac{1}{2l}\sqrt{\frac{Y \times strain}{\rho}}$

$\mu = \frac{\pi d^2}{4} \times \rho$ → $f = \frac{1}{ld}\sqrt{\frac{T}{\pi \rho}}$



$m$ = mass of string
$L$ = length of string
$l$ = length between bridges = resonating length
$M$ = mass of suspended load
$\rho$ = density of string
$\mu$ = mass per unit length

$\mu = \frac{m}{L}$ | $T = Mg$

$\mu = A \times \rho$ | $T$ = Tension on string

$\mu = \frac{\pi d^2}{4} \times \rho$

1.a. What is close organ pipe? Discuss various modes of vibration of the air column in close organ pipe and hence write the expression for the frequency of $n^{th}$ mode.[3]

b. What is standing wave? How and what type of standing wave is formed in close organ pipe. [2]

c. Determine the length of the pipe closed at one end in which the air column will vibrate with fundamental frequency of 160 Hz taking the speed of sound in air to be 340m/s. Also find the frequency of third overtone. [**0.53m, 1120Hz**] [3]

d. A close pipe is 0.5m long. What is the fundamental frequency and third Harmonics if velocity of sound is 350 m/s? [**175Hz, 525Hz**] [2]

e. Draw the waveform for third harmonics in close organ pipe. If the fundamental frequency is $f$, what is the frequency of third overtone in open pipe? [2]

2. a. What is resonance? Explain why soldiers are ordered to break steps while crossing a bridge. [2]

b. The frequency of fundamental note of a closed organ pipe and that of open organ pipe are the same. What is the ratio of their length? [2]

c. An open organ pipe of length 30cm sounding at third harmonics is in unison with a close organ pipe sounding at third overtone. Find the length of close pipe. [2]

d. Determine the length of a closed pipe and an open pipe that will resonate in the air at with a minimum frequency of 175 vibrations per second.

[Velocity of sound $= 330m/s$.] [**0.47m,0.94m**] [2]

e. What is end correction? How is end correction related to radius of pipe? [1]

f. Two open pipes of same length produce sounds of different frequencies if their diameters are different. Why? [2]

3. a. What type of wave is generated in a stretched string when plucked?

b. Discuss various modes of vibration in a stretched string and hence write the expression for the frequency of $n^{th}$ mode. [3]

c. What happens to the frequency of vibration of a string under tension if, i) Thickness of the string is doubled? ii) Tension on the string is doubled? [2]

d. Calculate the velocity of a transverse wave travelling in a copper wire of radius $1mm$ stretched under a load of $1.4Kg$. (Density of copper= $8.8gm/cm^3$). [**22.4m/s**] [2]

4. a. A guitar consists of several strings of different thickness. Why it is made so? Explain. [2]

b. A wire of diameter $0.04cm$ and made of steel of density $8000kg/m^3$ is under a constant tension of 80N. What length of this wire should be plucked to cause it to vibrate with a fundamental frequency of 840Hz? [**0.168m**] [2]

c. A string $1.5m$ long is made of steel (density $7.7 \times 10^3\ Kg/m^3$ and Young's modulus $2 \times 10^{11} Pa$). It is maintained at a tension that it produces a strain of 1% in the string. What is the fundamental frequency of the transverse vibration of the string? [2]

## Acoustics

**Pressure** amplitude: $\Delta P_{max} = BaK = v^2 \rho\ a\ k$

**Intensity:** $I = \frac{E/t}{A} = \frac{P}{A}$   $\omega = 2\pi f$, $k = 2\pi/\lambda$

$I = 2\, v\, \rho\, \pi^2 f^2 a^2$

$I = \frac{1}{2}\frac{(\Delta P_{max})^2}{v\ \rho}$   $\therefore \frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2$

**Inverse** square law: $\frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2$

**Intensity level,** $\beta = 10\ log\left(\frac{I}{I_o}\right)$ [in decibel]

$\beta_1 - \beta_2 = 10\log\left(\frac{I_1}{I_2}\right)$ | $\beta_2 - \beta_1 = 10\log\left(\frac{I_2}{I_1}\right)$

$\beta_1 - \beta_2 = 20\log\left(\frac{a_1}{a_2}\right)$ | $\beta_2 - \beta_1 = 20\log\left(\frac{a_2}{a_1}\right)$

$\beta_1 - \beta_2 = 10\log\left(\frac{d_2}{d_1}\right)$ | $\beta_2 - \beta_1 = 10\log\left(\frac{d_1}{d_2}\right)$

**Dopplers Effect:**

$f' = \frac{v \pm v_o}{v \pm v_s} \times f$

- **When the source approaches and passes the stationary observer** (Overtaking problem)

**Approaches**: $f' = \frac{v}{v - v_s} \times f$

Passes: $f'' = \frac{v}{v + v_s} \times f$

- Doppler Effect in sound is asymmetric.
- Doppler's effect is independent of distance between source and observer.
- Doppler's effect is not observed if both source and observer are at rest.

1. a. Define pressure amplitude. [1]

b. Write the mathematical form of pressure amplitude. [1]

c. The displacement node is called as pressure antinode. Explain. [2]