بسم الله الرحمن الرحيم

Faculty of Computers and Information

Fayoum University

Standing Waves

The student will be able to:

- Define the standing wave.
- Describe the formation of standing waves.
- Describe the characteristics of standing waves.

Objectives:

the student will be able to:

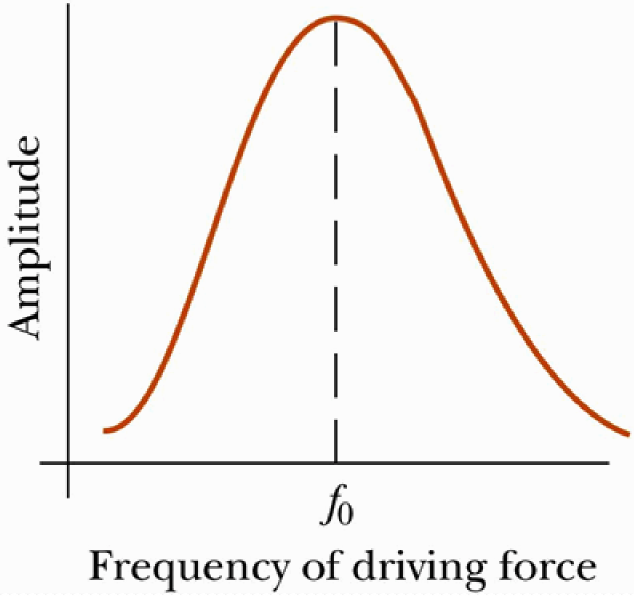
- Define the resonance phenomena.

- Define the standing wave in air columns.

4 - Resonance

- A system is capable of oscillating in ***one or more normal modes***

- If a **periodic force** is applied to such a system, **the amplitude** of the resulting motion is **greatest** when the ***frequency*** of the applied force ***is equal to one of the natural frequencies*** of the system



Resonance,

- Because an oscillating system exhibits a **large amplitude** when driven at any of its natural frequencies, these frequencies are referred to as ***resonance frequencies!!!***

- The **resonance frequency** is symbolized by f_o

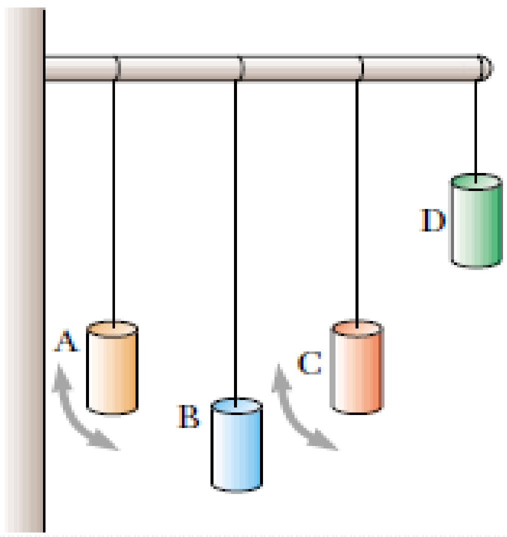
- The **maximum amplitude** is **limited by friction** in the system

Example:

An example of resonance.

If pendulum A is set into oscillation, only pendulum C, whose length matches that of A, eventually oscillates with large amplitude, or resonates.

The arrows indicate motion in a plane perpendicular to the page



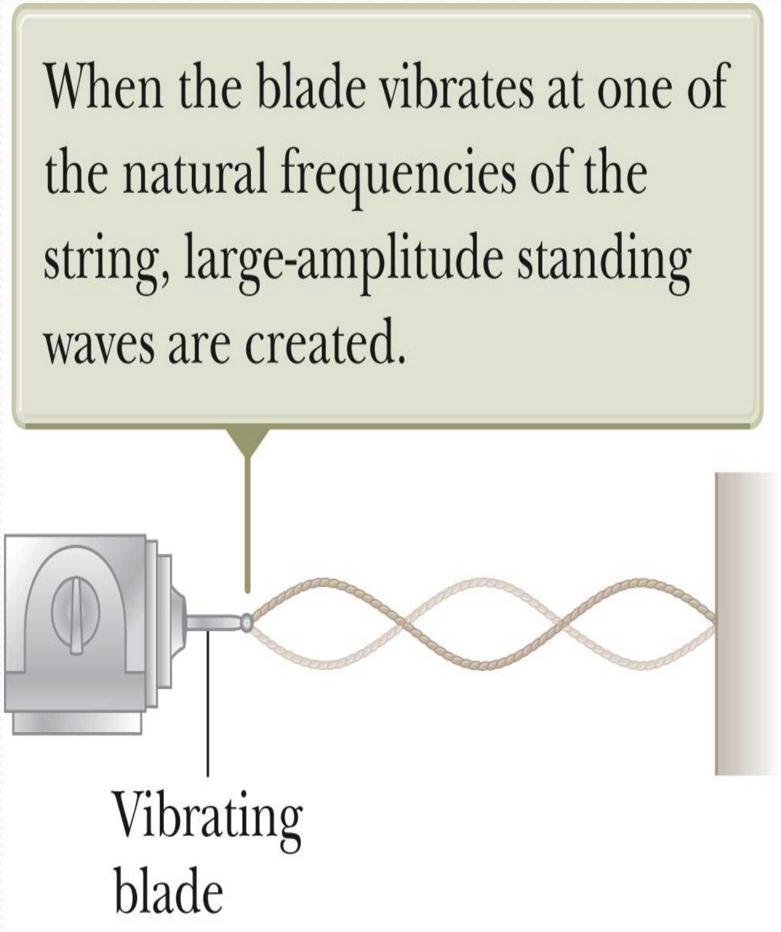
Resonance

A system is capable of oscillating in one or more normal modes.

Assume we drive a string with a vibrating blade.

If a periodic force is applied to such a system, the amplitude of the resulting motion of the string is greatest when the frequency of **the applied force is equal to one of the natural frequencies of the system.**

This phenomena is called **resonance.**



Standing Waves in Air Columns

- Standing waves can be set up in air columns as the result of interference between longitudinal sound waves traveling in opposite directions.
- The phase relationship between the incident and reflected waves depends upon whether the end of the pipe is opened or closed.

Waves under boundary conditions model can be applied.

Standing Waves in Air Columns, Closed End

A closed end of a pipe is a displacement node in the standing wave.

- The rigid barrier at this end will not allow longitudinal motion in the air.

The closed end corresponds with a pressure antinode.

- It is a point of maximum pressure variations.
- **The pressure wave is 90° out of phase with the displacement wave.**

1-Standing Waves in a Tube Closed at One End

The closed end is a displacement node.

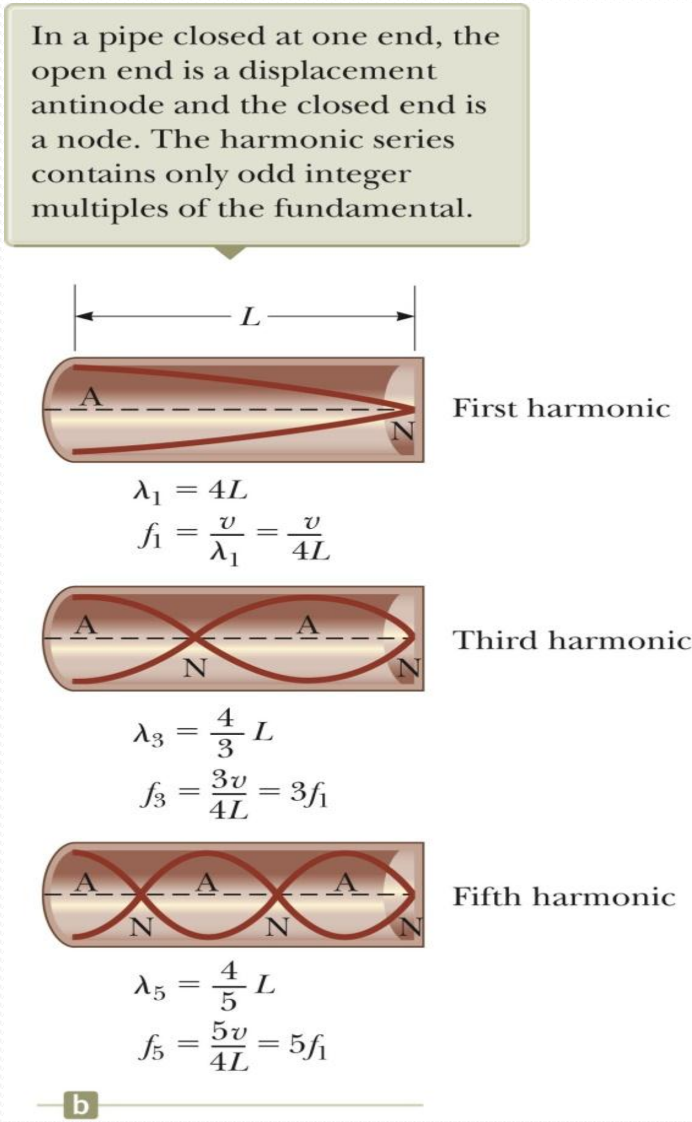
The open end is a displacement antinode.

The fundamental corresponds to $\frac{1}{4}\lambda$.

The frequencies are $f_n = nf = n\,(v/4L)$

where $n = 1, 3, 5, \ldots$

In a pipe closed at one end, the natural frequencies of oscillation form a harmonic series that includes only **odd integral multiples of the fundamental frequency.**



Standing Waves in Air Columns, Open End

The open end of a pipe is a **displacement antinode** in the standing wave.

- As the compression region of the wave exits the open end of the pipe, the constraint of the pipe is removed and the compressed air is free to expand into the atmosphere.

The open end corresponds with a **pressure node**.

- It is a point of no pressure variation.

2- Standing Waves in an Open Tube

<u>Both ends</u> are displacement <u>antinodes.</u>

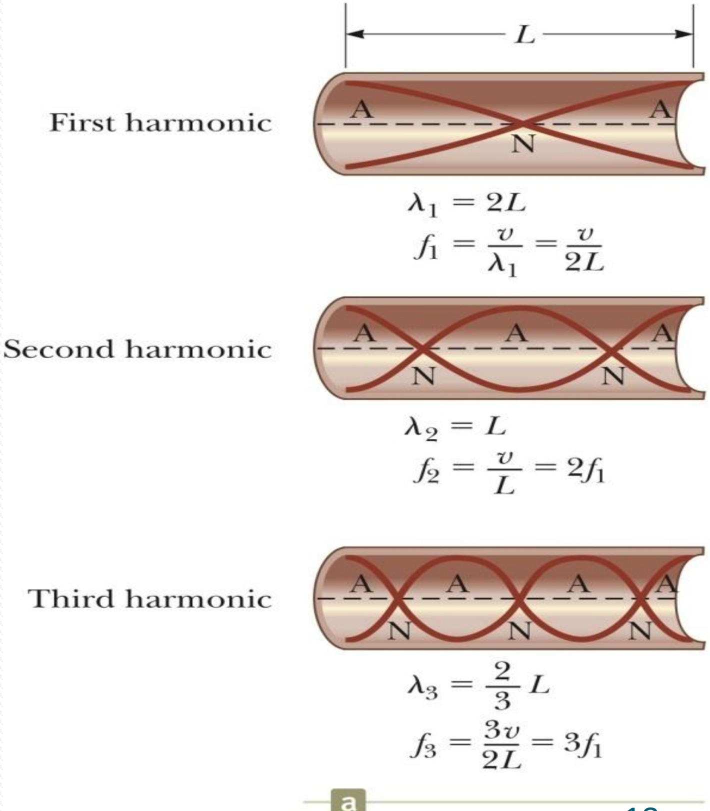
<u>The fundamental frequency is $v/2L$.</u>

- This corresponds to the first diagram.

The higher harmonics are $f_n = nf_1 = n(v/2L)$ **where n = 1, 2, 3, …**

<u>In a pipe open at both ends</u>, the natural frequencies of oscillation form a harmonic series that <u>**includes all integral multiples of the fundamental frequency**</u>.

In a pipe open at both ends, the ends are displacement antinodes and the harmonic series contains all integer multiples of the fundamental.



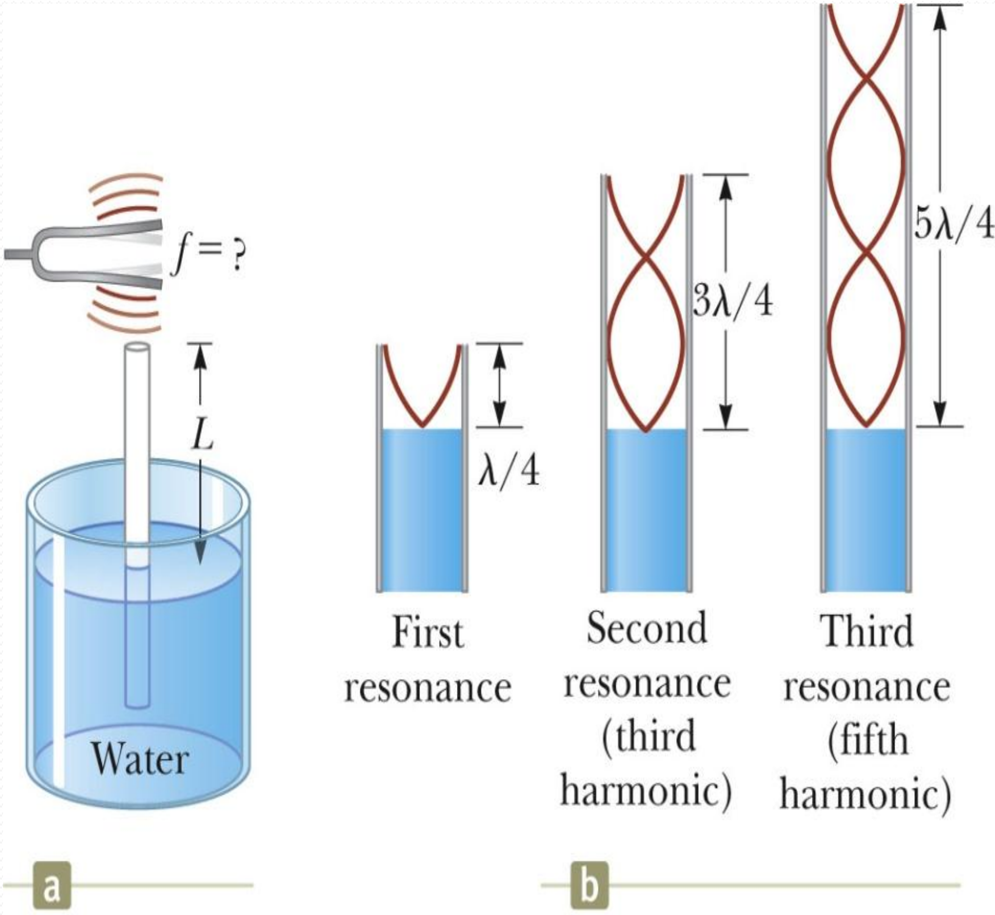
Resonance in Air Columns, Example

A tuning fork is placed near the top of the tube.

When *L* corresponds to a resonance frequency of the pipe, the sound is louder.

The water acts as a closed end of a tube.

The wavelengths can be calculated from the lengths where resonance occurs.



Summary:

1- When two traveling waves having equal amplitudes and frequencies superimpose , the resultant waves has an amplitude that depends on the phase angle φ between the resultant wave has an amplitude that depends on the two waves are in phase , two waves . **Constructive interference** occurs when the two waves are in phase, corresponding to $\emptyset = 0.2\pi, 4\pi, \ldots$ rad, **Destructive interference** occurs when the two waves are 180° out of phase, corresponding to $\emptyset = \pi.3\pi, 5\pi, \ldots$ rad.

2- Standing waves are formed from the superposition of two sinusoidal waves having the same frequency , amplitude , and wavelength but traveling in opposite directions . the resultant standing wave is described by $y = (2A\sin kx)\cos\omega t$

3- The natural frequencies of vibration of a string of length L and fixed at both ends are quantized and are given by

$$f_n = \frac{n}{2l}\sqrt{\frac{T}{\mu}} \qquad n = 1,2,3,\ldots\ldots$$

Where T is the tension in the string and μ is its linear mass density .The natural frequencies of vibration f_1, f_2,f_3,…… form a **harmonic series**.

4- Standing waves can be produces in a column of air inside a pipe. If the pipe is open at both ends, all harmonics are present and the natural frequencies of oscillation are

$$fn = n\frac{v}{2L} \qquad n = 1,2,3,\ldots$$

If the pipe is open at one end and closed at the other, only the odd harmonics are present, and the natural frequencies of oscillation are

$$fN = n\frac{v}{4L} \qquad n = 1,3,5, \ldots$$

5- An oscillating system is in **resonance** with some driving force whenever the frequency of the driving force matches one of the natural frequencies of the system. When the system is resonating, it responds by oscillating with a relatively large amplitude.