Nautral Frequency, Forced Vibration, and Resonance
Lesson Notes

Learning Outcomes
- How can the natural frequency of an object be controlled?
- What is resonance and when does it occur?

Natural Frequency
- **Natural Frequency**: the frequency (or set of frequencies) at which an object vibrates when struck, plucked, strummed, or otherwise disturbed.
- The **timbre** (quality) of a sound is dependent upon the mixtures of frequencies at which the source naturally vibrates.

Dropped Pencil	Flute	Tuba
197 Hz	200 Hz	200 Hz
211 Hz	(pure tone)	400 Hz
217 Hz		600 Hz
289 Hz		800 Hz
329 Hz		1000 Hz
(noisy)		(rich sounding)

Factors Affecting Natural Frequency 1
The frequency (**f**) at which an object vibrates is dependent on the speed (**v**) at which vibrations travel through it and the wavelength (**λ**) established in it.

$$f = v / \lambda$$

Dependence on Speed:

Guitar Strings

(tension and density)

Singing Water Goblet

(mass of water)

Source: YouTube

Vocal Folds

(tension and density)

Source: Wikimedia Commons

Factors Affecting Natural Frequency 2
The dimensions (e.g., length) of an object affect its frequency since larger objects vibrate with longer wavelengths.
For many vibrating objects, the **vibrational frequency** (and pitch) is inversely proportional to the object's **length**.

$$f = v / \lambda$$

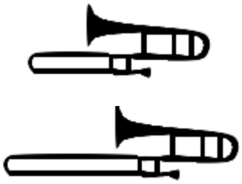
Dependence on Length:

Guitar Strings

(*fingering* a string)

Trombone

(extending the slide)



Recorder

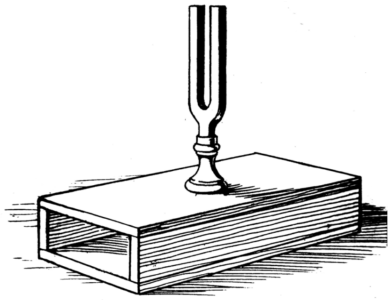
(fingering the holes)

The Straw

(cut length)

Force Vibration

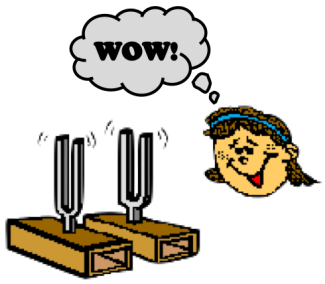
Forced Vibration: when one vibrating object forces another *connected* object into vibrational motion.



Vibrating guitar strings and tuning forks do not produce loud sounds; but when mounted on a sound box, the sound is amplified. The vibrations of the sound box force more air particles into vibration.

Resonance

Resonance: when one vibrating object forces a second object to begin vibrating at the same natural frequency.



Resonating Tuning Forks

Resonance can be demonstrated with 3 sets of inverted pendula having varying length and natural frequencies.

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