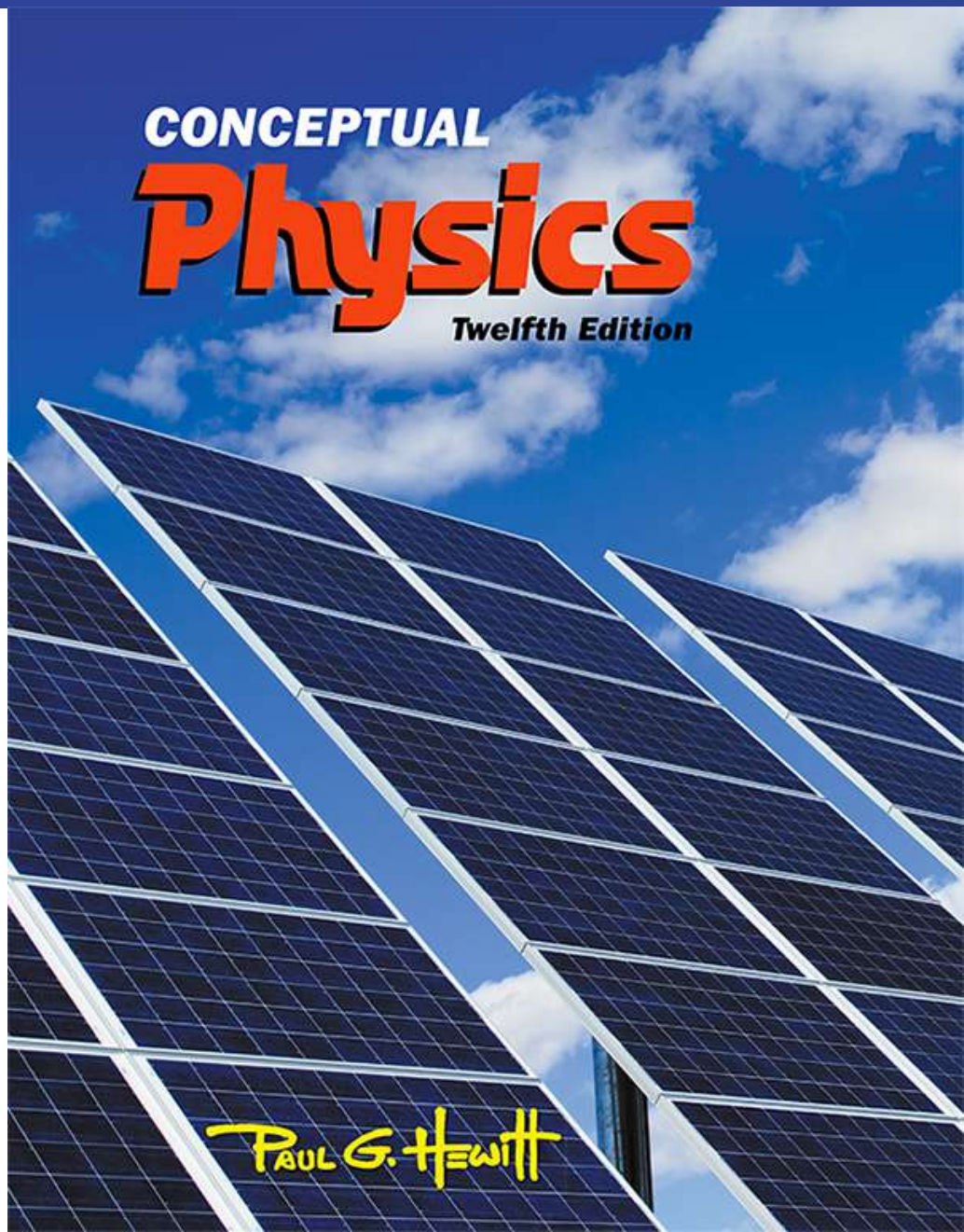
Lecture Outline

Chapter 19: Vibrations And Waves

Part 4 Interference and Resonance



Wave Interference

- **Wave interference** occurs when two or more waves interact with each other because they occur in the same place at the same time.

- **Superposition principle:** The displacement due the interference of waves is determined by adding the disturbances produced by each wave.

Classwork: Answer the question on a new sheet:

15. What is the superposition principle?

Superposition: Result = A + B

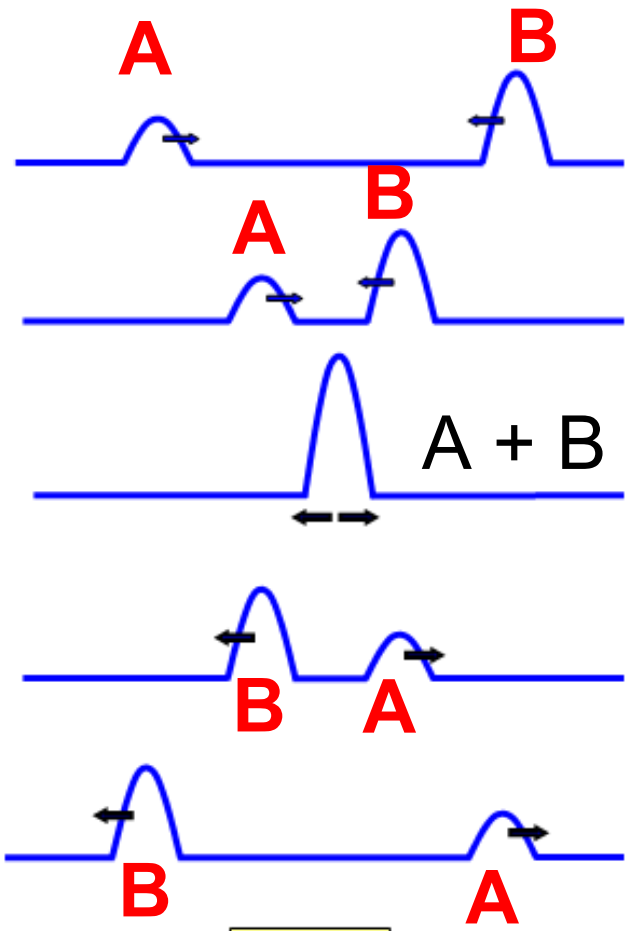


Figure 1(a)

Constructive

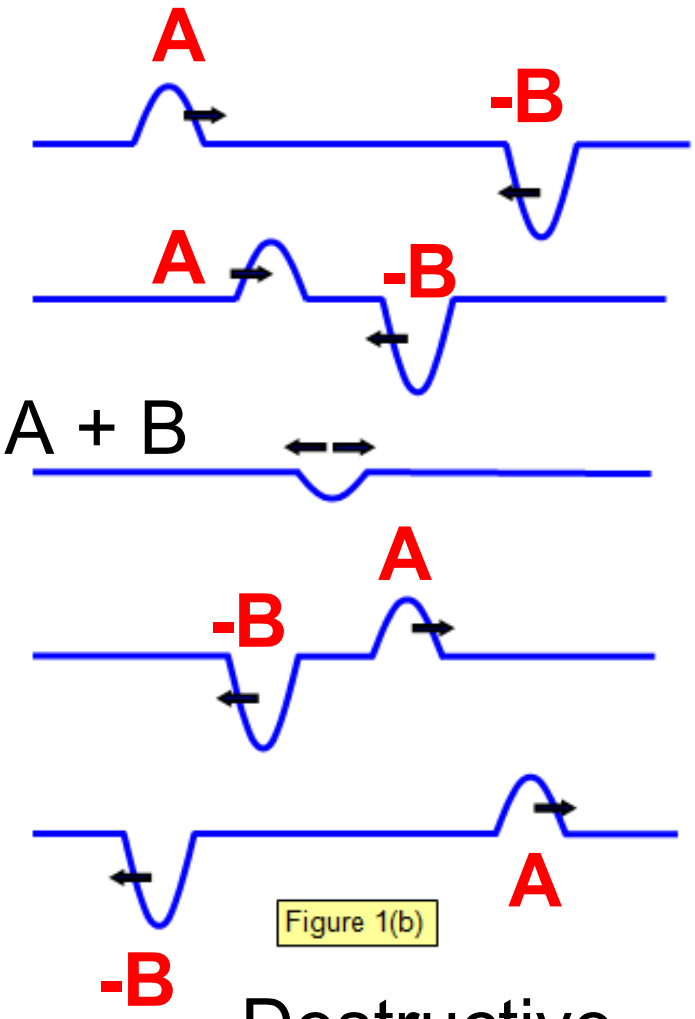


Figure 1(b)

Destructive

Wave Interference, Continued

Constructive interference : When the crest of one wave overlaps the crest of another, their individual effects add together to produce a wave of **increased amplitude.**

Destructive interference: When the crest of one wave overlaps the trough of another, the high part of one wave simply fills in the low part of another. So, their individual effects are **reduced** (or even canceled out).

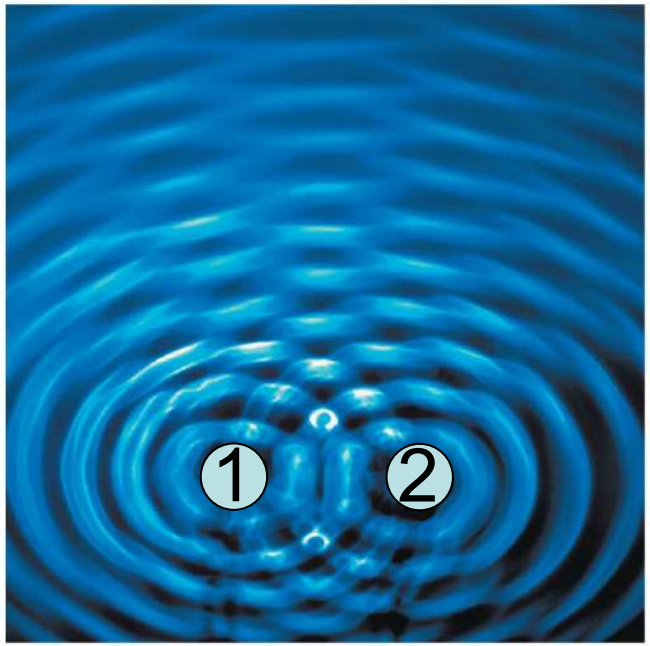
Classwork: Answer the question on a new sheet:

16. Distinguish between constructive interference and destructive interference.

Example:

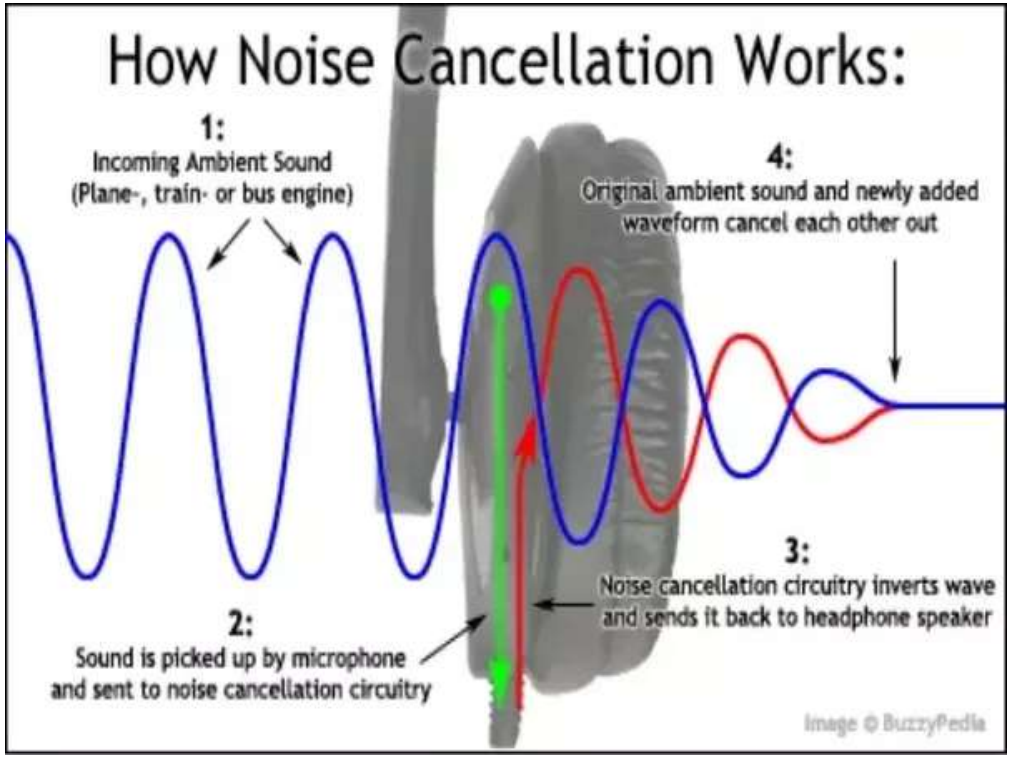
- We see the interference pattern made when two vibrating objects touch the surface of water.
- Where a crest of one wave overlaps the trough of another produces regions of zero amplitude.

At points along these regions, the waves arrive out of step, i.e., *out of phase* with each other, and cancel.



Noise Cancellation Headphones

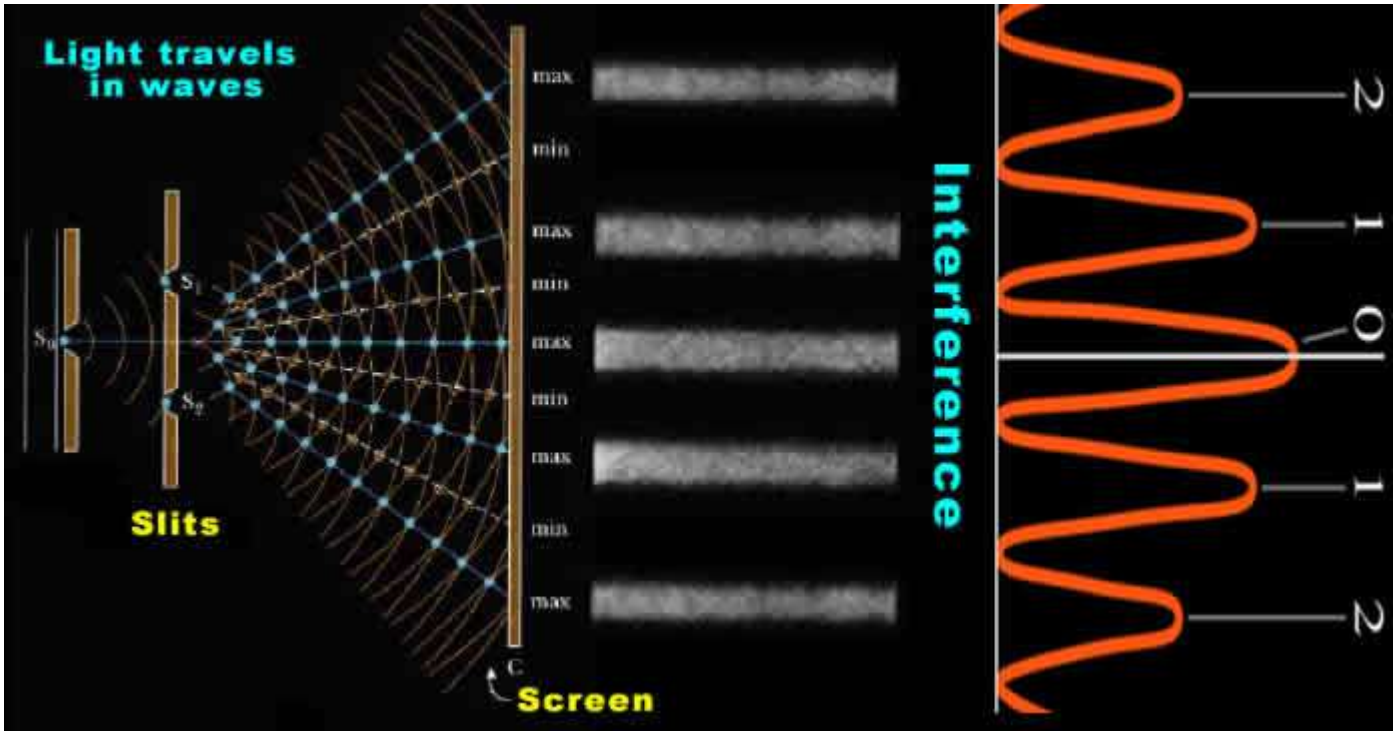
- The protect workers from loud sounds or eliminate distractions.
- How?



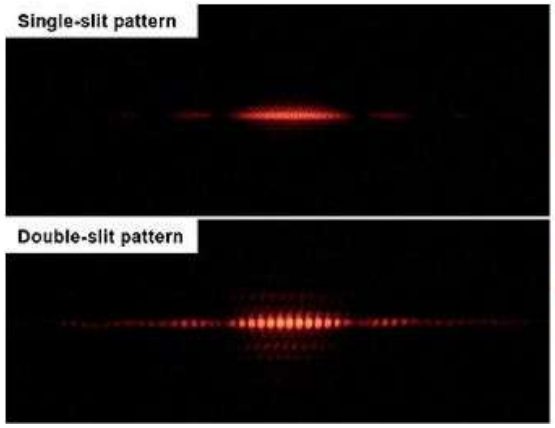
- Headphones create a wave *opposite* to the original wave. The 2 waves interfere and cancel.

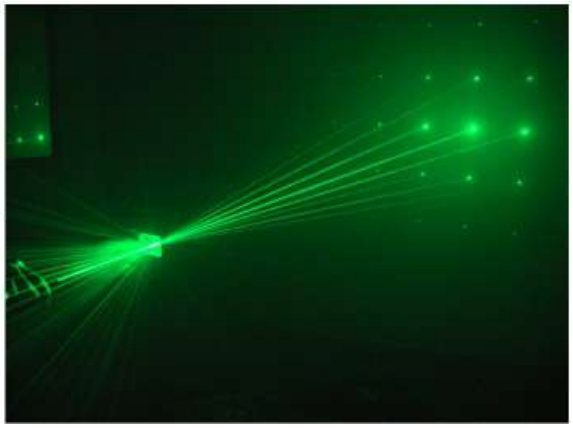
Light waves can interfere:

light passes through 2 slits, which act as 2 sources.



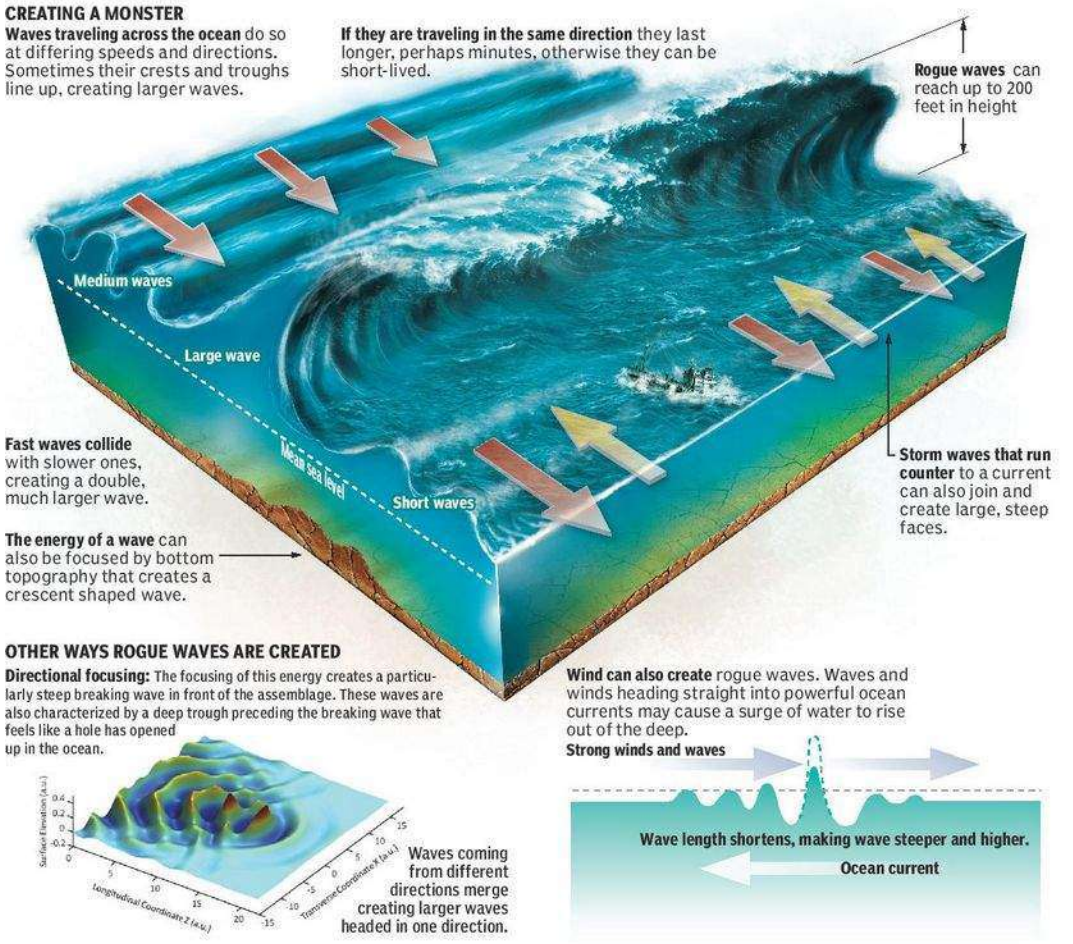
Different patterns are produced by different slits.





Water wave interference:

Rogue waves:



Constructive interference leads to destruction.

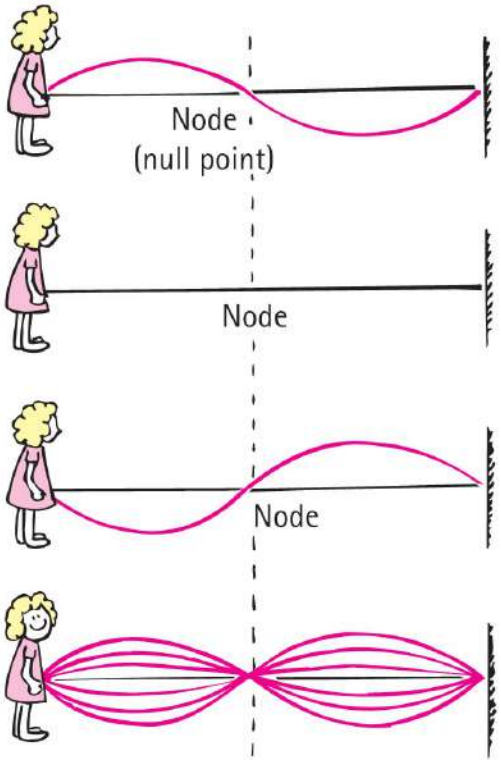
Rogue Wave damage

Classwork:

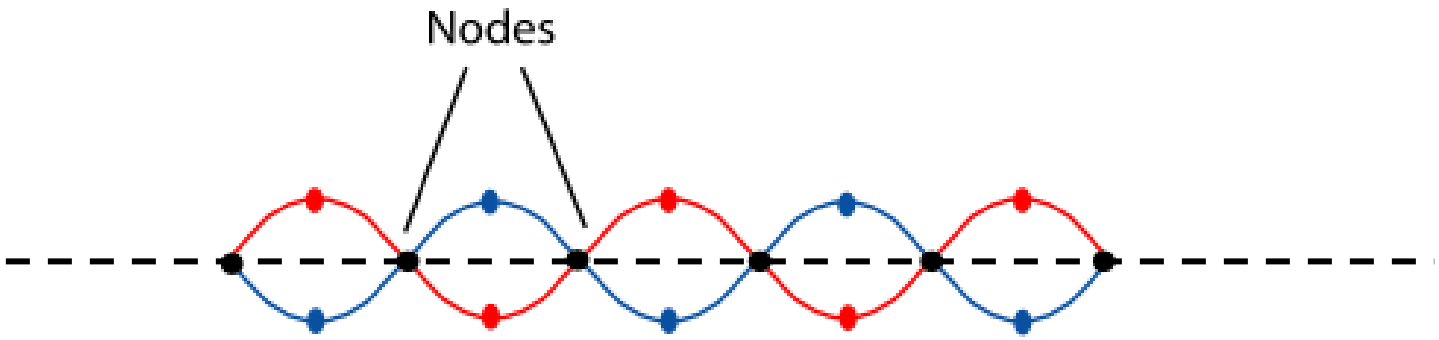
17. What kinds of waves can show interference?

Standing Waves

- If we tie a rope to a wall and shake the free end up and down, we produce a train of waves in the rope.
- The wall is too rigid to shake, so the waves are reflected back along the rope.
- By shaking the rope just right, we can cause the incident and reflected waves to interfere to form a **standing wave.**



- **Nodes** are the regions of minimal or zero displacement, with minimal or zero energy.
- **Antinodes** are the regions of maximum displacement and maximum energy.



- Antinodes and nodes occur equally apart from each other.

Classwork: :

18. What is a node? What is an antinode?

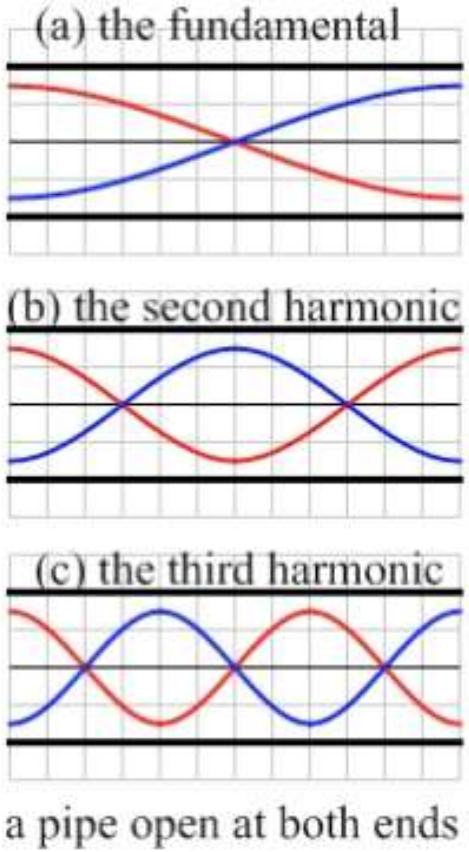
Standing waves of sound

Wind instruments create standing waves of pressure.

The patterns depend on whether one end is open or not.

Standing waves have frequencies that are multiples of the lowest, *fundamental* f.

These are called *harmonics*.



a pipe open at both ends

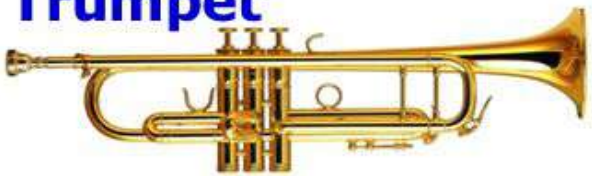
Closed Pipes

- Ends are opposite
- Odd Harmonics

Pan Pipes

Clarinet

Trumpet



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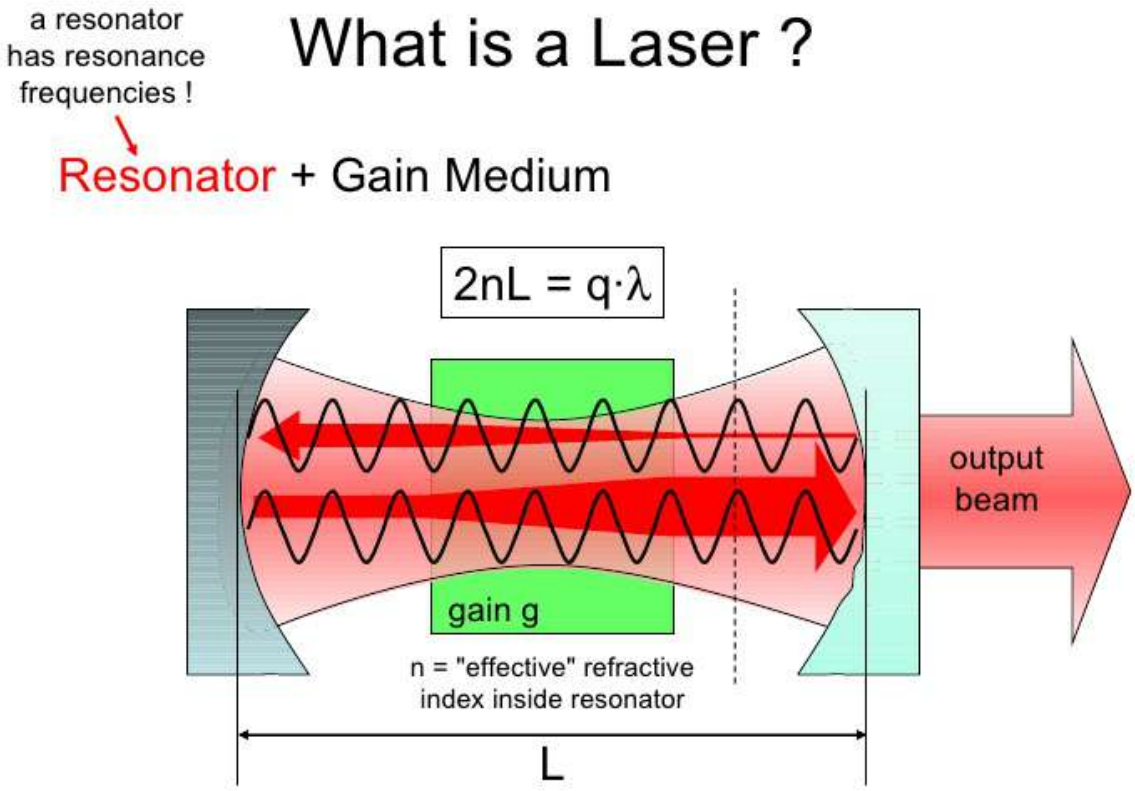
Standing waves of light

Lasers amplify light by creating standing waves of light and releasing the energy from one end.



Classwork:

19. Can standing waves be formed of transverse waves, longitudinal waves, or both?

Standing Waves, Continued-1

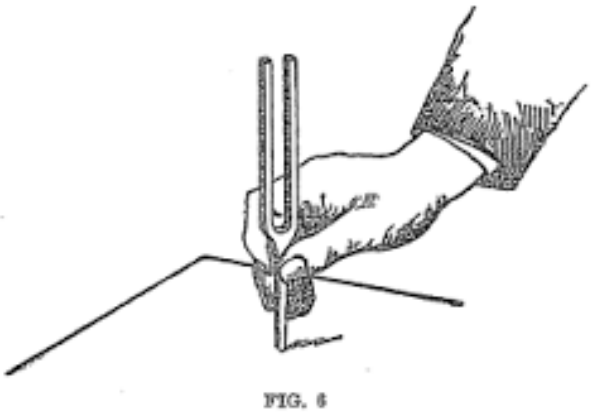
- Tie rubber tubing to a firm support. Shake the tube from side to side with your hand.
- If you shake the tube with the right frequency, you will set up a standing wave.
- If you shake the tube with **twice** the frequency, a standing wave of **half** the wavelength, having **two** loops results.
- If you shake the tube with **three times** the frequency, a standing wave of **one-third** the wavelength, having **three** loops results.

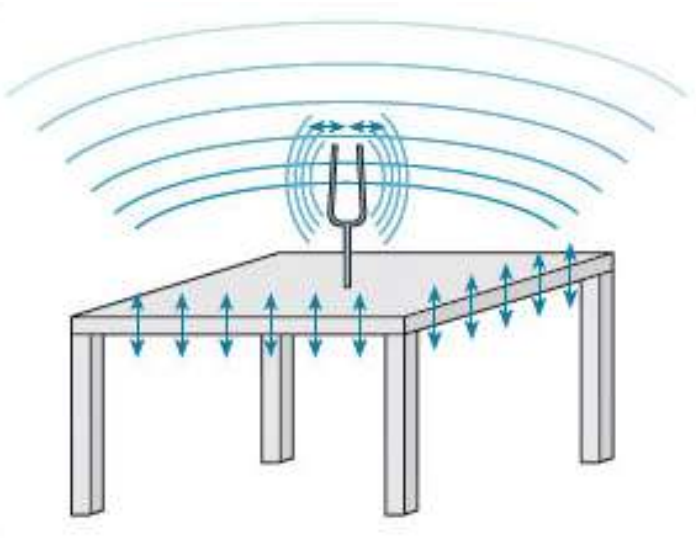
How many nodes N and antinodes A in each?

Standing Waves, Continued-2

- Examples:
  - Waves in a guitar string
  - Sound waves in a trumpet

- **Forced vibration**
  - Setting up of vibrations in an elastic object by a vibrating force
  - Examples:
  - factory floor vibration caused by running of heavy machinery
  - tuning fork forces entire table to vibrate





Classwork:

20. Why does a struck tuning fork sound louder when it is held against a table?

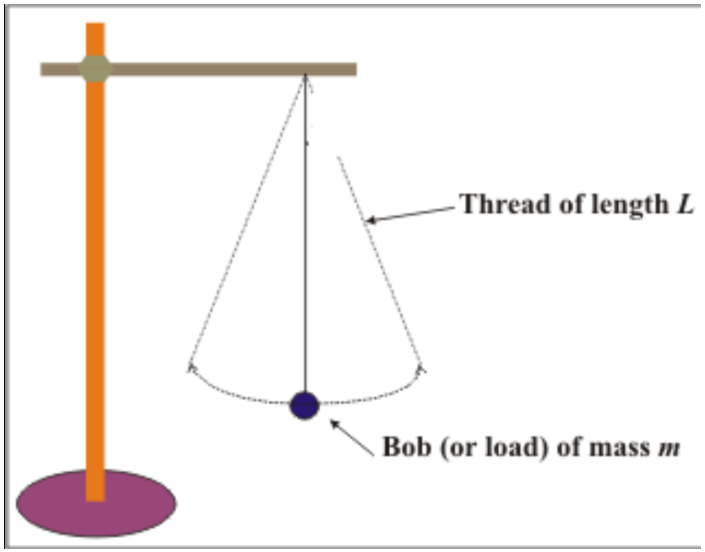
Guitar and violin bodies:

The strings force the body to vibrate.

More air is moved.

Louder sound results.

- Natural frequency
  - Own unique frequency (or set of frequencies) that an object vibrates at most easily
  - Dependent on:
    - elasticity (springiness) of object
    - shape and size of object

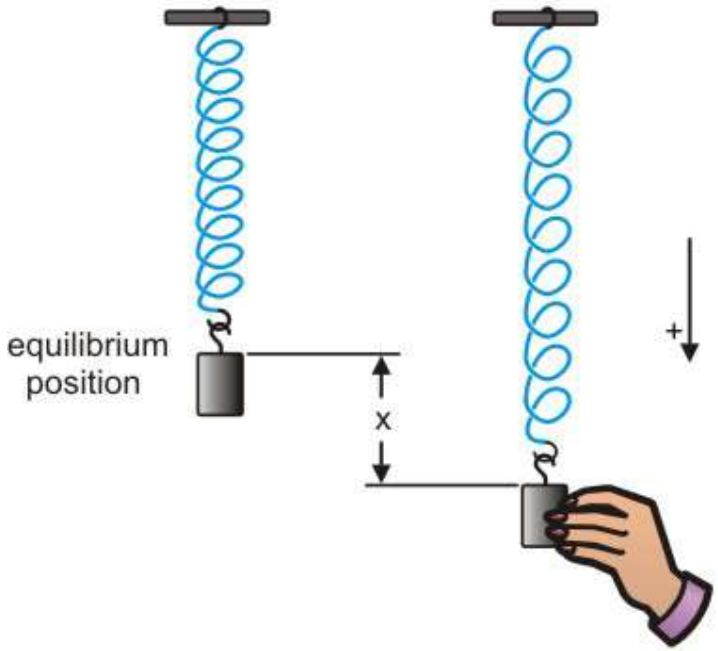


- The natural frequency of a pendulum depends only on its *length* (not mass):
- Longer length → lower frequency

Mass on a spring

The natural frequency of a spring and mass depends on:

1. how stiff the spring is
2. the mass



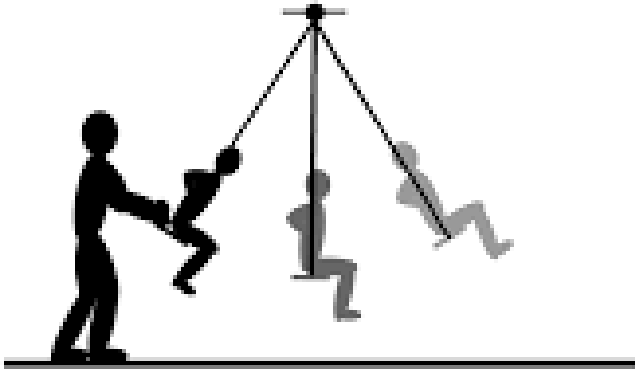
Stiffer spring → higher frequency

More mass → lower frequency

Classwork:

21. Give at least two factors that determine the natural frequency of an object.

Resonance



- A phenomenon in which the frequency of forced vibrations on an object matches the object's natural frequency
- As a result, the amplitude of the vibrations increases dramatically.

Example:
Even small pushes on a swing at the swing's natural frequency can produce large amplitude swings.

Classwork:

22. How do forced vibrations relate to resonance?

Resonance

- Examples:
  - Troops marching in rhythm with the natural frequency of a bridge (a no-no!)
  - Breaking a wine glass by singing the correct note
  - NMR (nuclear magnetic resonance) Electromagnetic waves cause nuclei to resonate
  - Tuning a radio station to the "carrier frequency" of the radio station makes the radio resonate

Classwork:

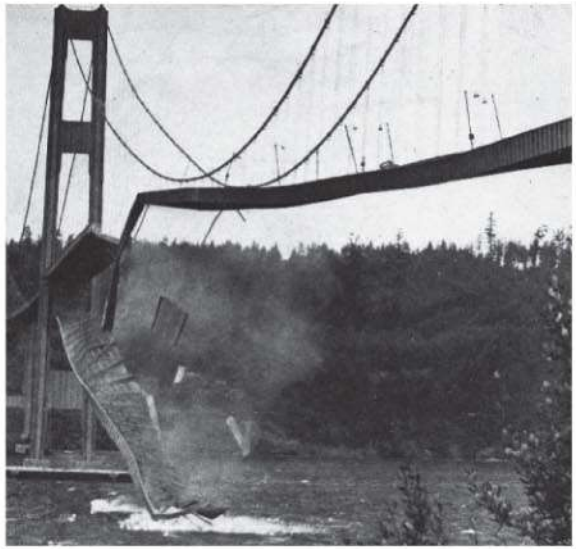
23. When you listen to a radio, why do you hear only one station at a time rather than hearing all stations at once?

24. How did wind-generated resonance affect the Tacoma Narrows Bridge in Washington in 1940?

Resonance, Continued

- Dramatic example of wind-generated resonance





- The bridge was forced to resonate by the wind.
- Large amplitude vibrations destroyed the bridge.

Classwork:

24. How did wind-generated resonance affect the Tacoma Narrows Bridge in Washington in 1940?