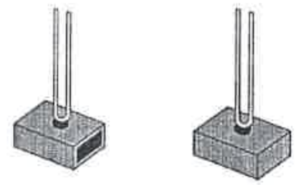
Natural Frequency and Resonance

Natural frequency: The frequency at which an object naturally vibrates due to its physical properties.

Resonance: The amplification of a vibration if the frequency of the applied force matches the natural frequency of the system.

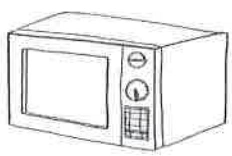
Explain the results of the tuning fork demonstration

Sound energy is transferred from one tuning fork to the other if they have the same natural frequency (i.e. 2nd tuningfork is resonating with the first)



Other examples of resonance:

1. Two instruments
2. Swings
3. Wine glasses
4. Bridges
5. Buildings in earthquakes
6. Microwave ovens
7. MRI (Magnetic Resonance Imaging)

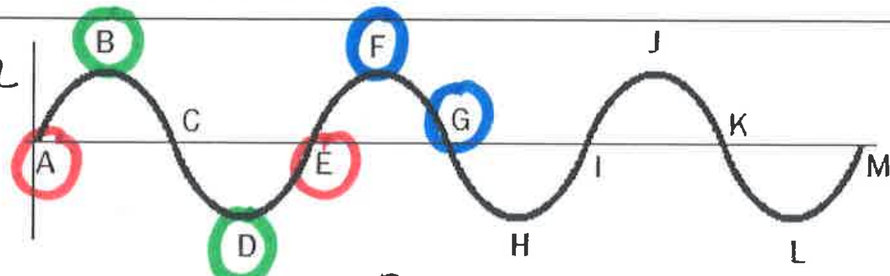


The Tacoma Narrows Bridge (Nov. 7, 1940)

Galloping Gertie's final moments

Phase and Reflections

Phase: relative position



Inspect the labeled graph at right and name points that are:

a) in phase A, E

b) out of phase by 180° B

c) out of phase by 90° F, G

Fixed End Reflection (Hard Reflection): Reflected pulse is . . . out of phase by 180°

Free End Reflection (Soft Reflection): Reflected pulse is . . . in phase

Waves Crossing Boundaries

In general, whenever a wave (or pulse) reaches a boundary between two media . . .

part is reflected
part is transmitted

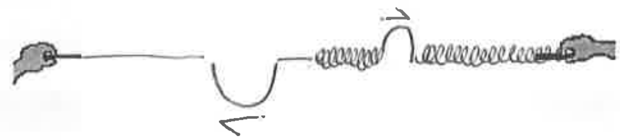
Before

After

1. When a pulse travels from a less dense to a more dense medium reflected out of phase

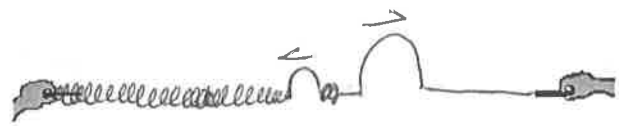
Before

After



2. When a pulse travels from a more dense to a less dense medium reflected in phase

Before



http://surendranath.tripod.com/Applets.html

3. When a wave crosses a boundary

What characteristic(s) of a wave must remain the same as the wave crosses a boundary between two different media? Explain. frequency (or period) remain the same

Compare the characteristics of the wave in the two media

$V = \lambda f$

Thick rope

Thin rope

$f = \frac{V}{\lambda}$) change

same

Light Crossing a Boundary

A swimmer underwater looks up to see the Sun.
Compare the light wave in air and water.

in water, light slows down
shorter wavelength
ray is bent toward normal

$f = \frac{V\downarrow}{\lambda\downarrow}$
same

Sound Crossing a Boundary

A swimmer underwater hears a boat's engine.
Compare the sound wave in air and water.

in water - speed up
longer wavelength

$f = \frac{V\uparrow}{\lambda\uparrow}$
same

One Medium

When a wave travels in a single medium, what is the control variable?

same speed (constant)

$V = \lambda f$ or λf
same $\uparrow\downarrow$ $\downarrow\uparrow$

Two Media

When a wave crosses a boundary between two media, what is the control variable?

same frequency (constant)

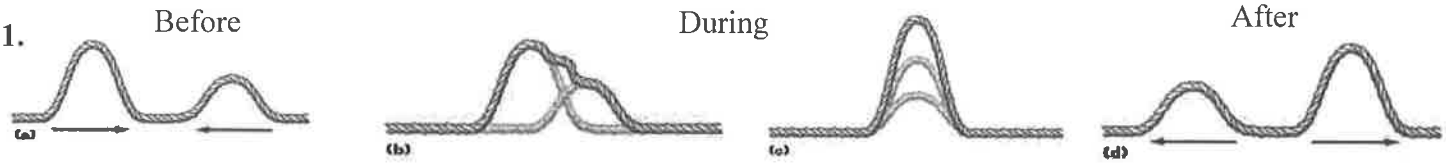
$f = \frac{V\uparrow}{\lambda\uparrow}$ or $\frac{V\downarrow}{\lambda\downarrow}$

Superposition and Interference

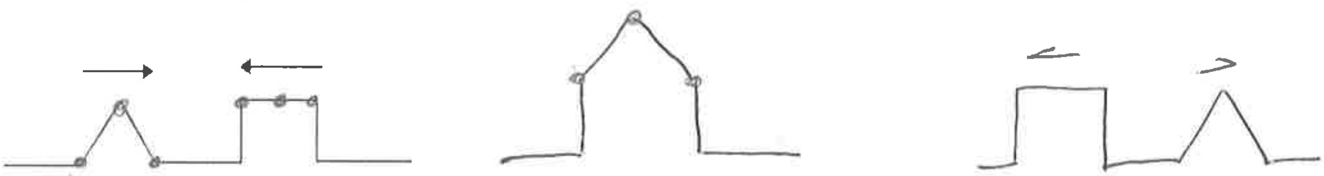
The Principle of Superposition: When two or more waves meet, the resultant displacement is the vector sum of the displacements of the individual component waves.

Constructive Interference:

1. Before — During — After



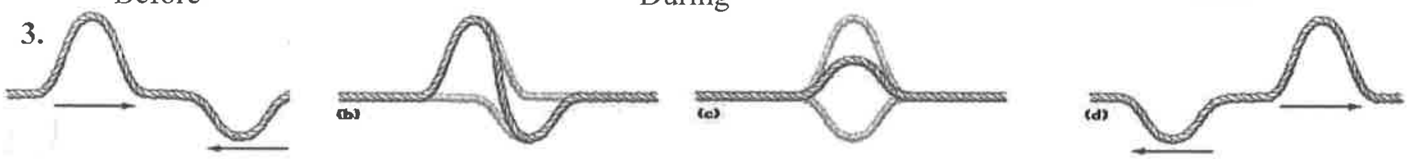
2.



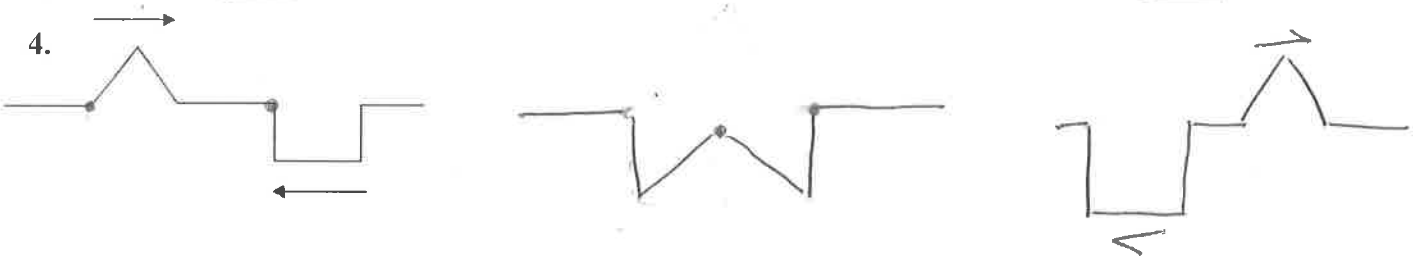
Destructive Interference:

Before — During — After

3.



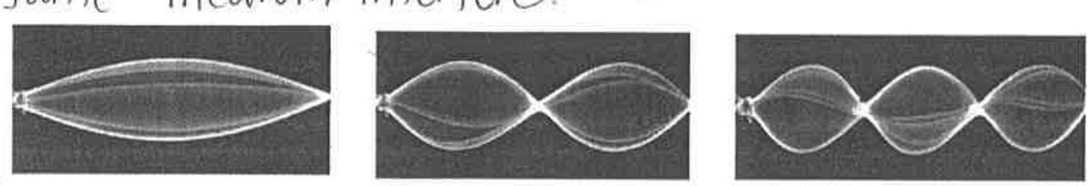
4.



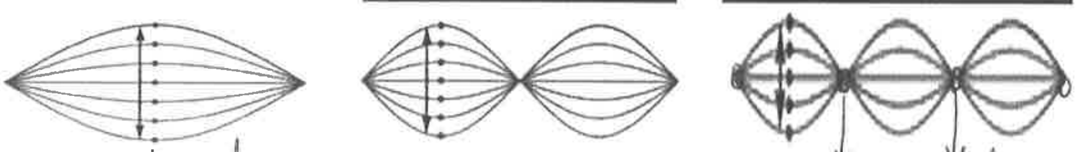
Standing Waves

Traveling Wave: a series of pulses or oscillations that move through a medium

Standing Wave: resultant wave formed when two waves of equal amplitude + frequency traveling in opposite directions in the same medium interfere.



Time elapsed photographs of three possible standing waves on a string



antinode = max. constructive interference

node node = max destructive interference

Harmonic series: a series of frequencies that includes the fundamental frequency and integral multiples of that fundamental frequency.

Node:
location of constant maximum destructive interference

Anti-node:
location of constant maximum constructive interference

	Sound	Light
Node	silent	dark
Anti-node	loud	bright

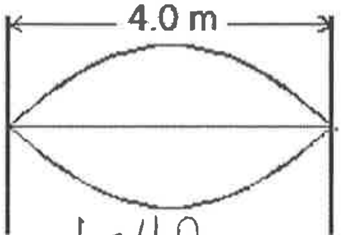
n = # of the harmonic

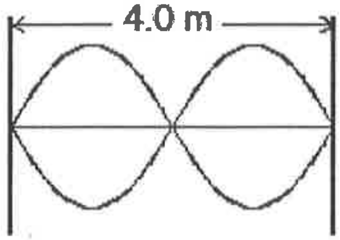
For the standing waves shown below, sketch them in the spaces provided and determine their characteristics. The speed of the component waves making up these standing waves is 12 m/s.

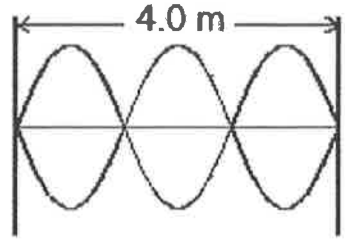
Name: fundamental
1st harmonic n=1

Name: 2nd harmonic
n=2

Name: 3rd harmonic
n=3







$L = 4.0\,m$

$\lambda = \left(\frac{2L}{n}\right)$ substitute → $v = \lambda f$

so $v = \left(\frac{2L}{n}\right) f$

and $f = \frac{nv}{2L}$

Wavelength	
Node(s)	
Antinode(s)	
Frequency	

Wavelength	
Node(s)	
Antinode(s)	
Frequency	

Wavelength	
Node(s)	
Antinode(s)	
Frequency	

How do the frequencies of the harmonic waves compare to the frequency of the fundamental wave?

What wave phenomena are responsible for the occurrence of standing waves?