Wavefronts

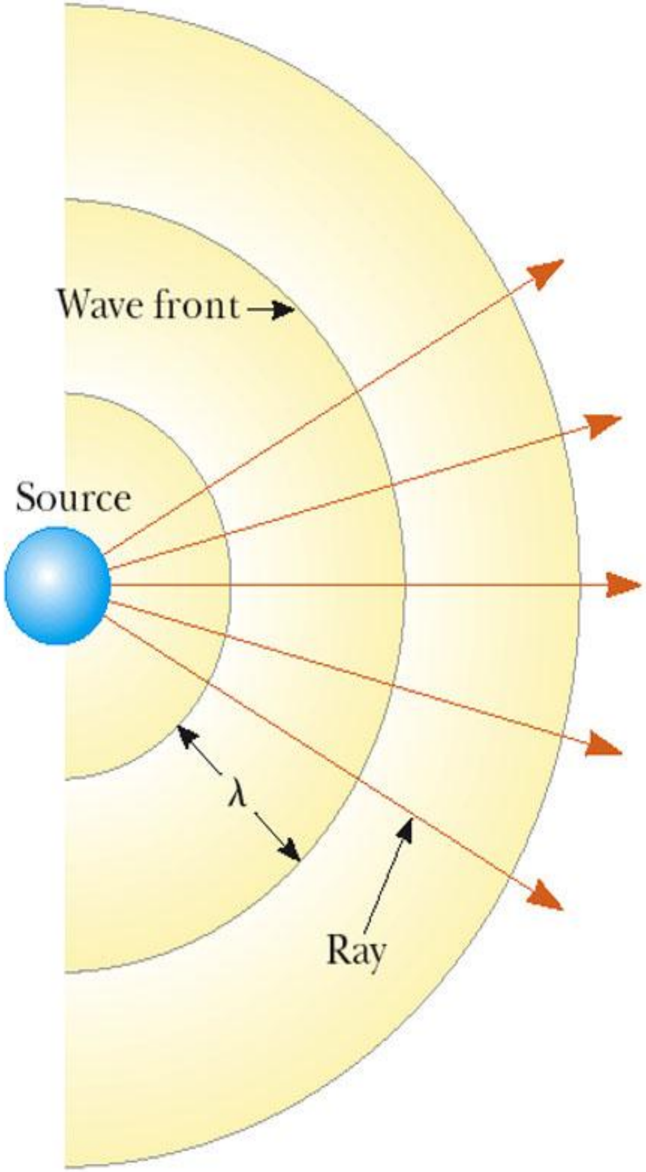
A **wave front** *is a line or plane on which the vibrations of every points on it are* **in phase** *and are at the same distance from the source of the wave*

- Define and explain the term wavefront. Ans. Such a surface on which all the points have the same phase of vibration is called wavefront.
- The distance between two consecutive wavefronts is one wavelength . A line normal to the wavefront which gives the direction of motion of the wave is called a ray. Ray is always perpendicular to the wavefront. Q
- Spherical wavefront: The source in which the waves propagate in spherical form, with the source at the center of sphere, is called spherical wavefront. Plane wavefront: The wavefront, in which the rays of the waves are parallel, is called plane wavefront. At very large distance from the source, a small portion of the spherical wavefront is nearly plane and is called plane wavefront.

Wave Fronts

- Waves that travel in all directions from a source can be represented by wave fronts.
- Wave fronts are concentric circles that spread out in all directions from the source.
- The distance between successive wave fronts is equal to wavelength (λ)

Circular Wave fronts

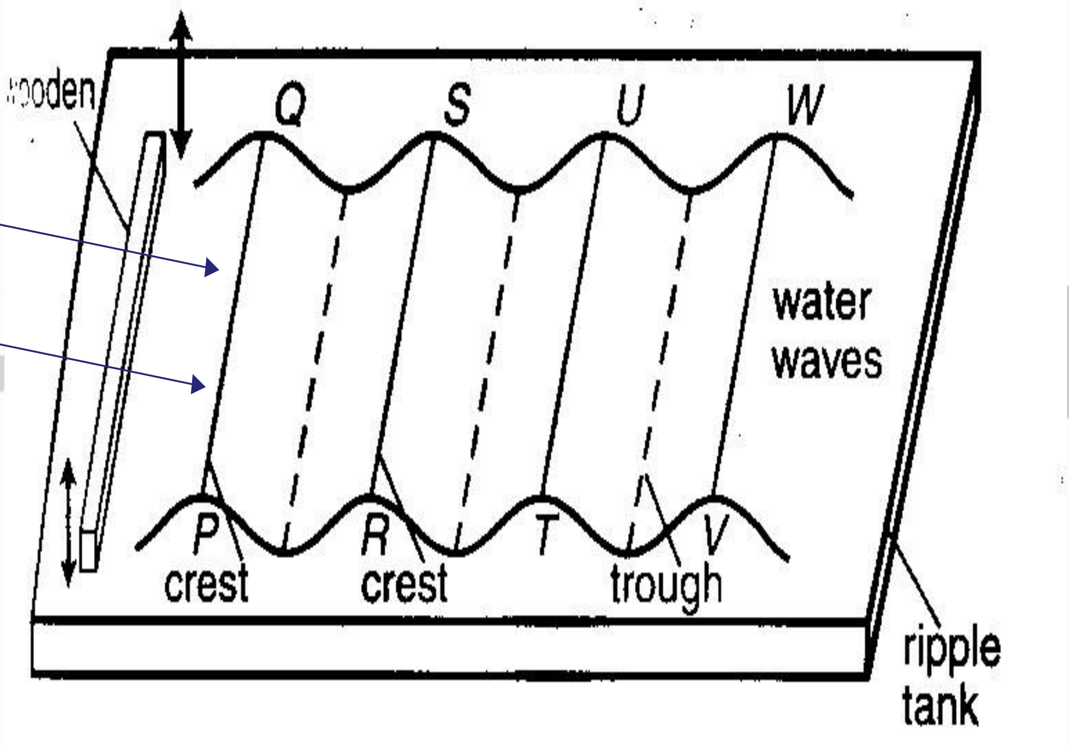


Plane Wave fronts

Lines PQ, RS, TU and VW are straight lines along the respective crests of the waves. These lines are called **wave fronts**.

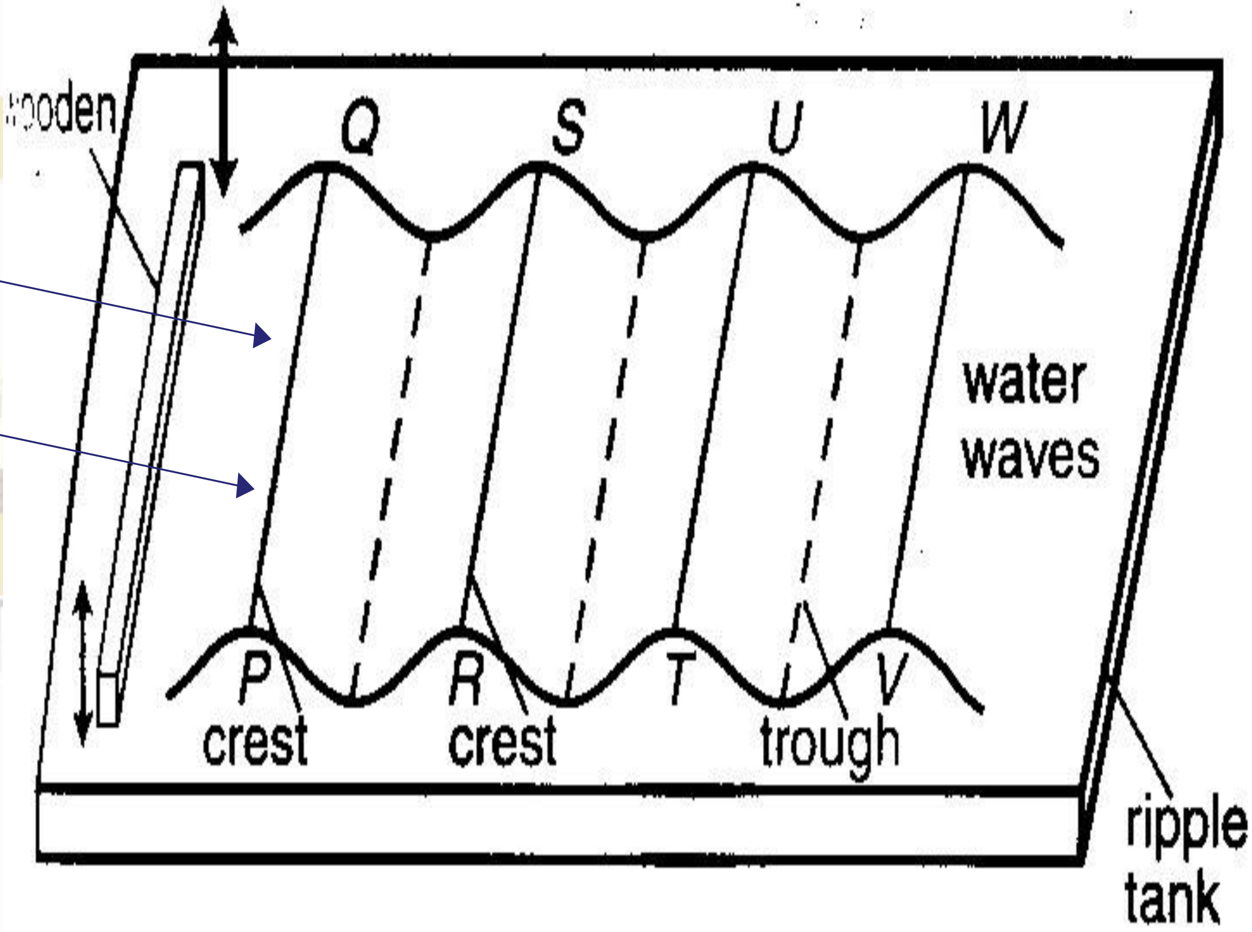
•

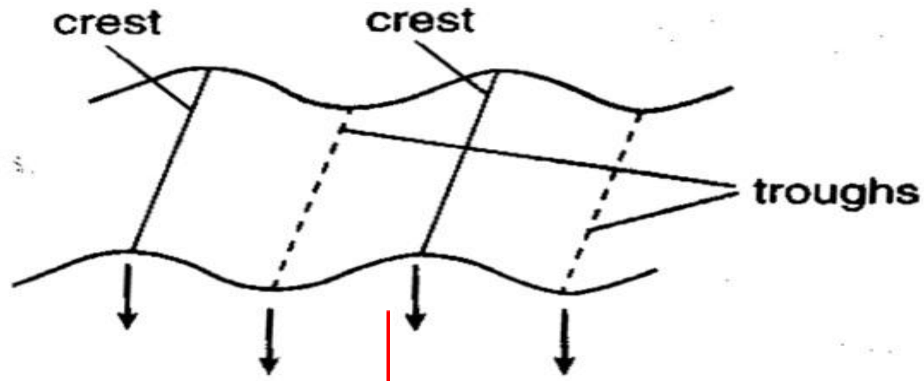
Same Phase



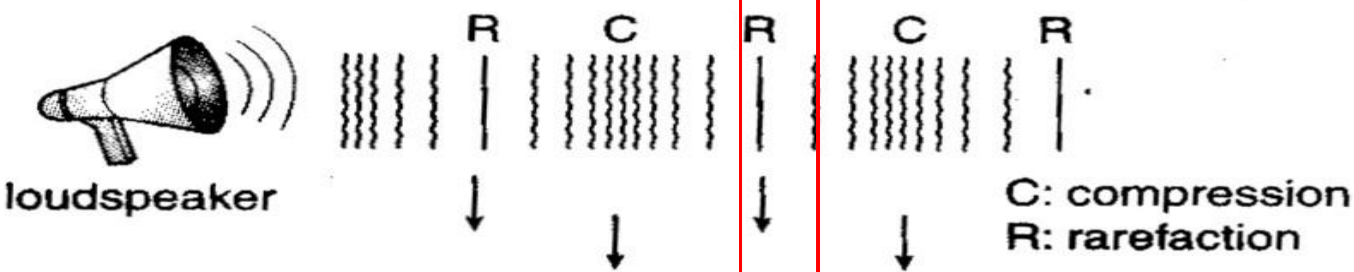
Same

displacement

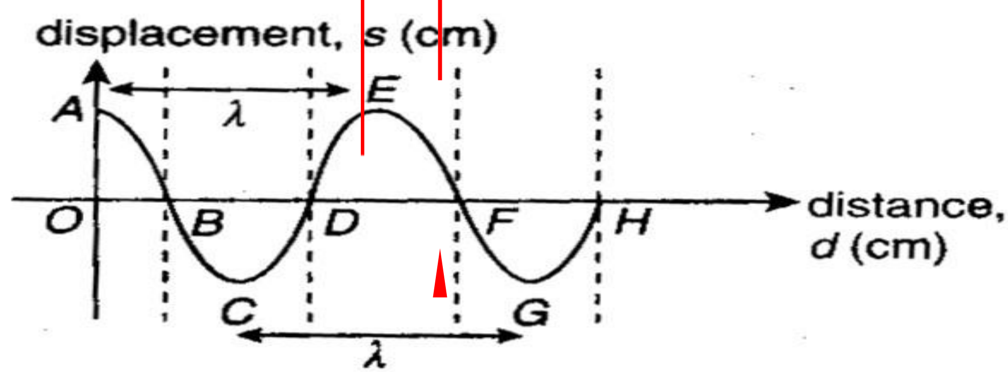




(a) Water wave



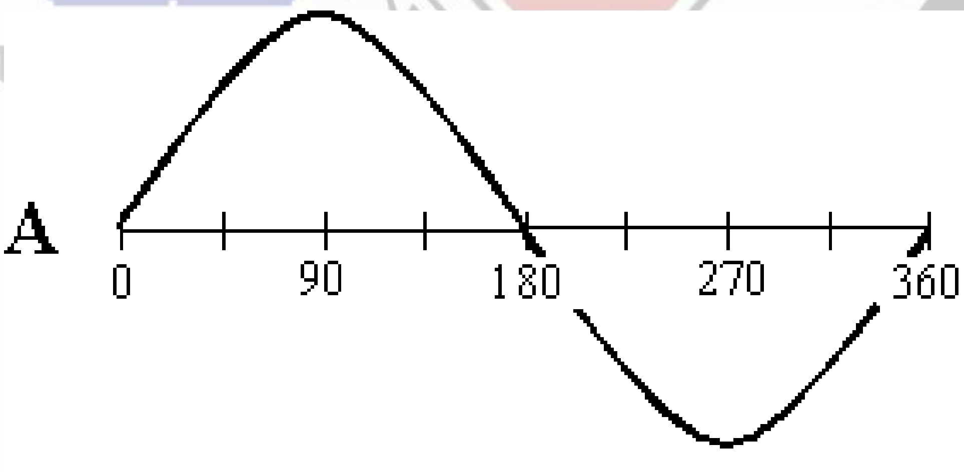
(b) Sound wave



(c) Displacement-distance graph

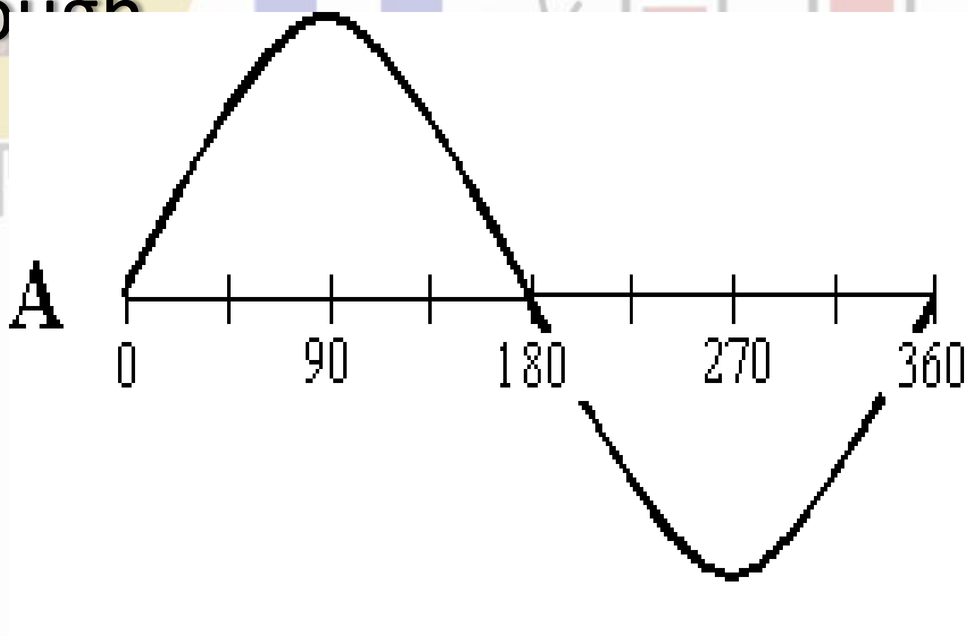
Wave Phase

- The state of motion (for instant speed and direction) of a particle on the wave is known as the phase of that wave and is represented by the symbol θ and is known as the phase angle.
- Phase is a reference to the portion of the wave passing through a location in a medium.



Wave Phase

- At 0°,180°, & 360° degrees the medium is at equilibrium.
- At 90° the medium is at its crest.
- At 270° the medium is at its trough.



Phase can be measured in distance, time, or degrees. If the peaks of two signals with the same frequency are in exact alignment at the same time, they are said to be in phase. Conversely, if the peaks of two signals with the same frequency are not in exact alignment at the same time, they are said to be out of phase.” -

Points in phase

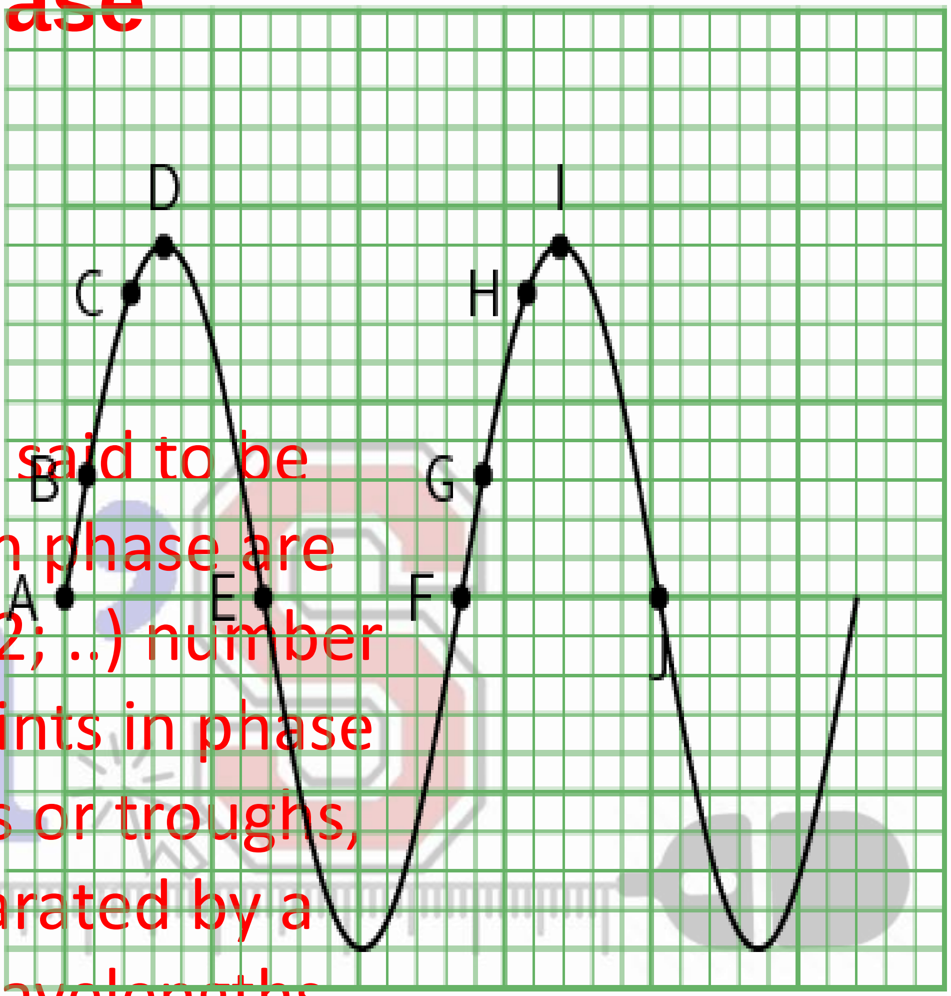
A & F

B & G

C & H

D & I

E & J

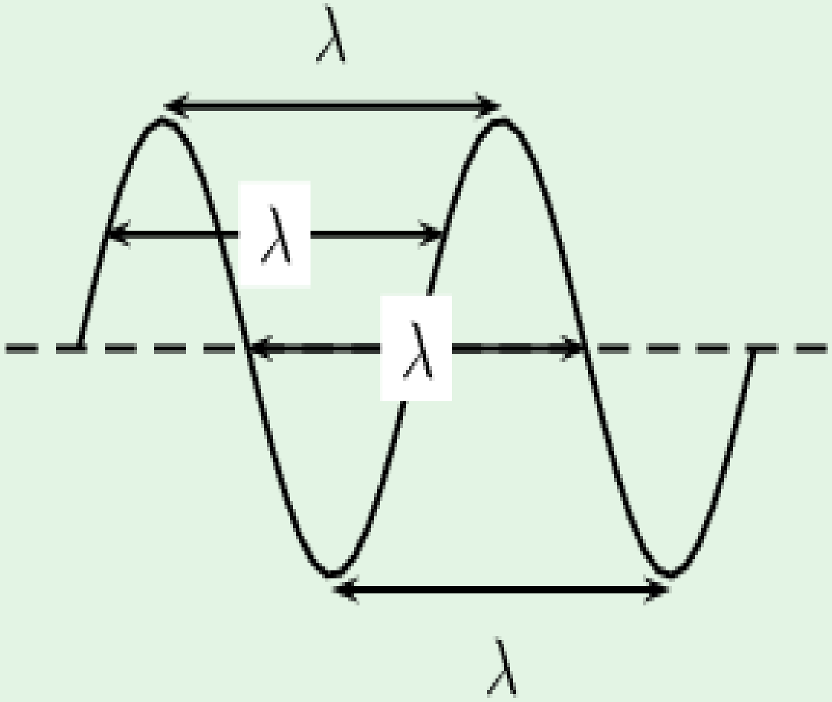


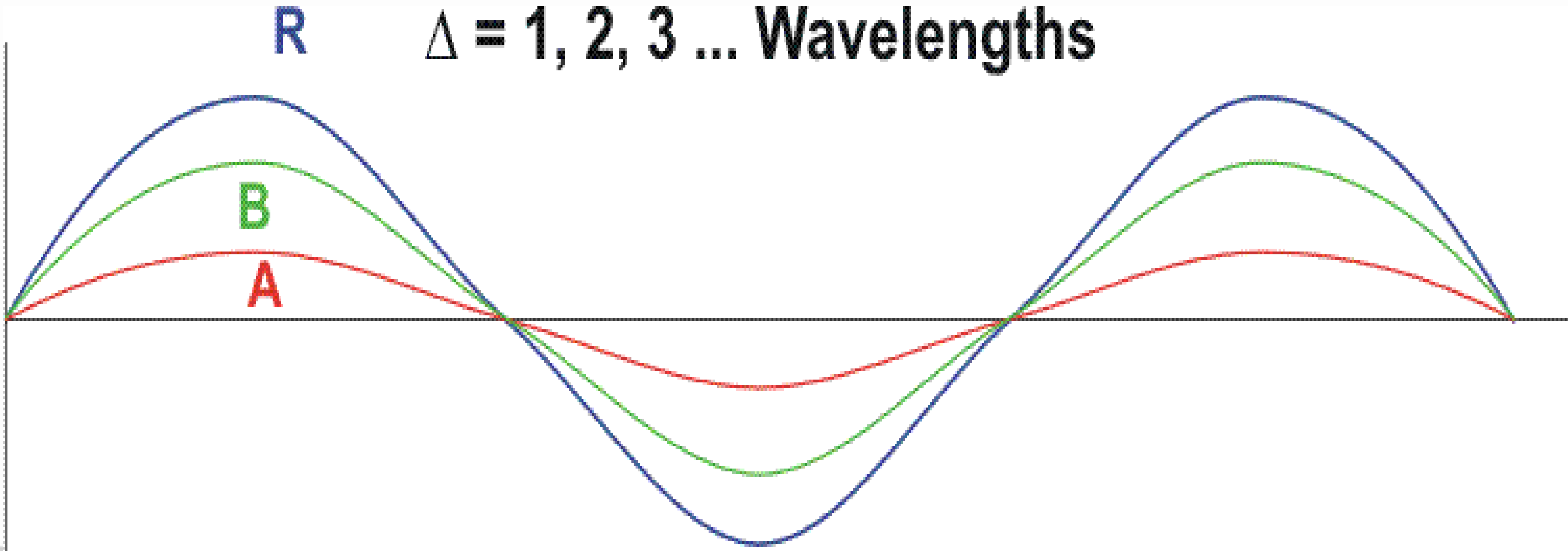
These points are then said to be in phase. Two points in phase are separate by a whole (1; 2; ..) number of wavelengths. The points in phase do not have to be crests or troughs, but they must be separated by a complete number of wavelengths.

Points that are not in phase, those that are not separated by a complete number of wavelengths, are called out of phase. (A and C, or D and E, or B and H).

Def - Wavelength

The wavelength of a wave is the distance between any two adjacent points that are in phase.



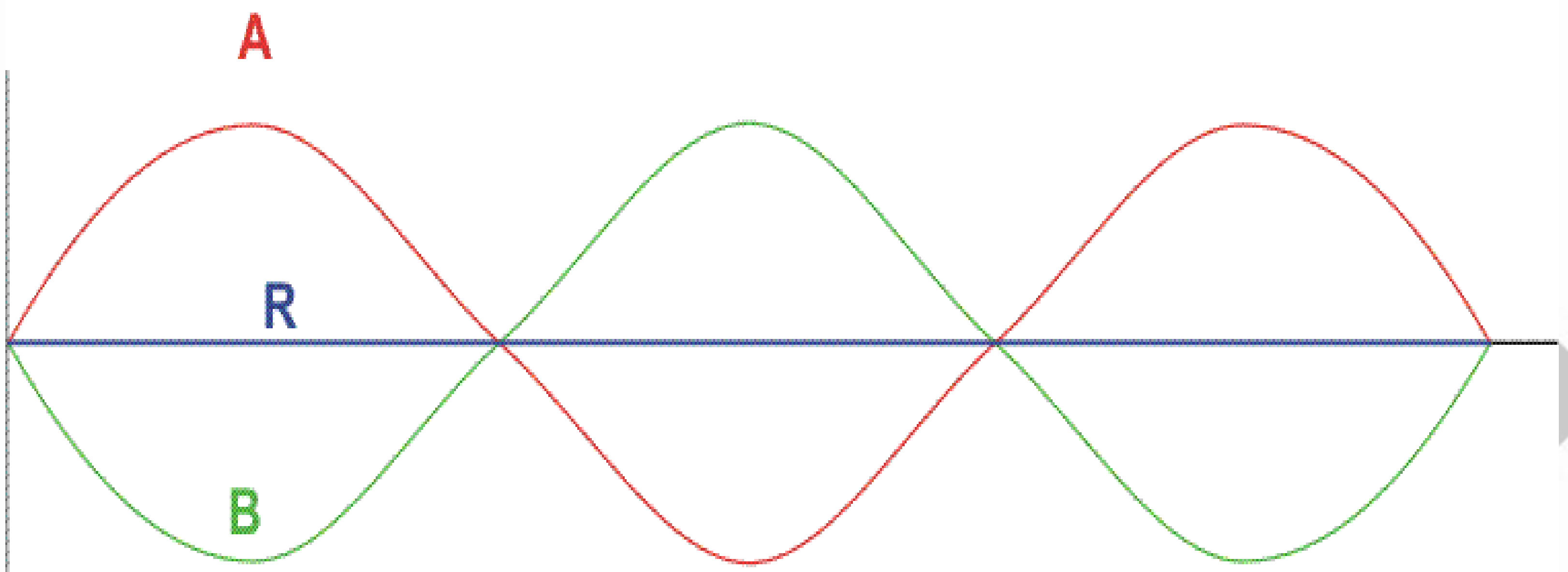


Waves **A** and **B** are **IN PHASE** ($\Delta = i\lambda$), so that the waves constructively interfere and produce the resultant wave (**R**).

the sum of wave **A** and **B**.

When λ is = ½, 1½, 2½ . . . Wavelengths, the two waves are **OUT OF PHASE** they destructively interfere, cancelling each other out, producing the resultant wave (**R**), which has no amplitude or wavelength.

Δ = 1/2, 1 1/2, 2 1/2 ... Wavelengths



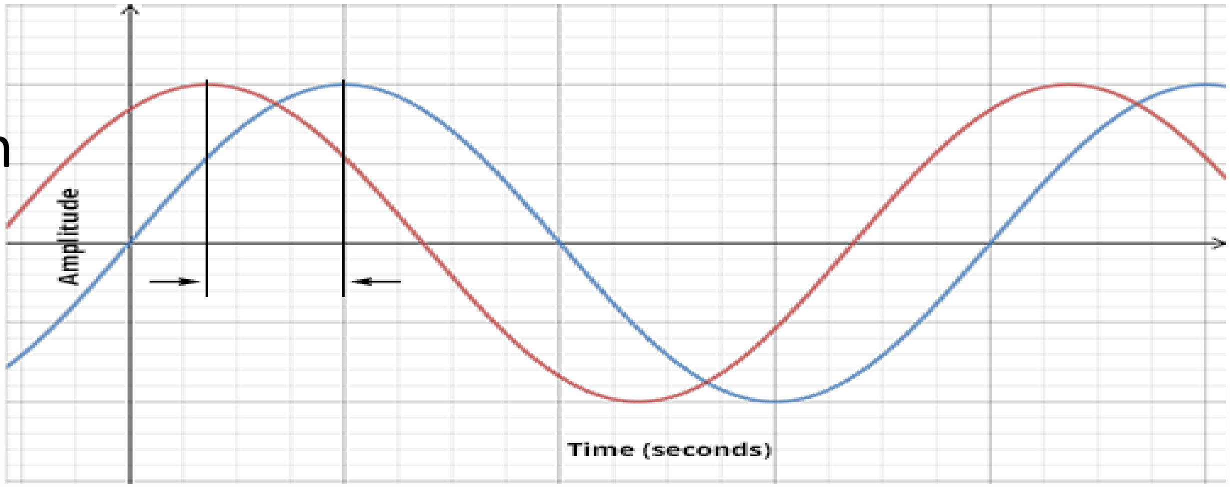
Waves A and B are **OUT OF PHASE** {Δ =(i + 1/2) λ}. The amplitudes of waves A and B are equal, but opposite, they cancel (destructive interference) each other and the resultant wave (R) has zero amplitude.

the phase. Phase specifies the location of a point within a wave cycle of a repetitive waveform. When two waves combine, thedifference between the phases of the two waves is important in determining the resulting waveform.

The phase difference between two waves of the same frequency moving past a fixed location is given by the phase difference between the same positions within the wave cycles of the two waves, expressed as a fraction of one wave cycle in θ

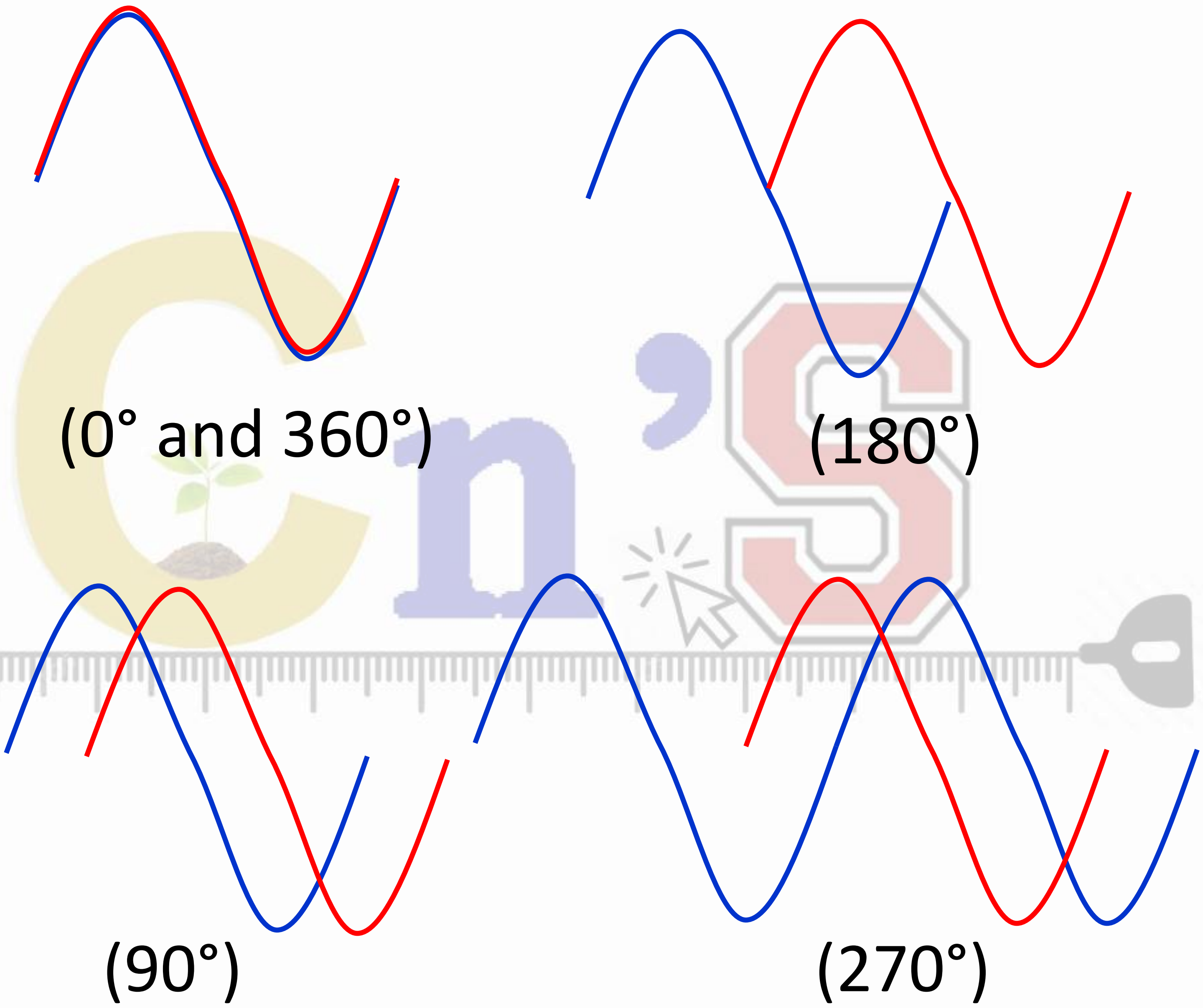
or λ

.Two waveforms with an arbitrary phase difference

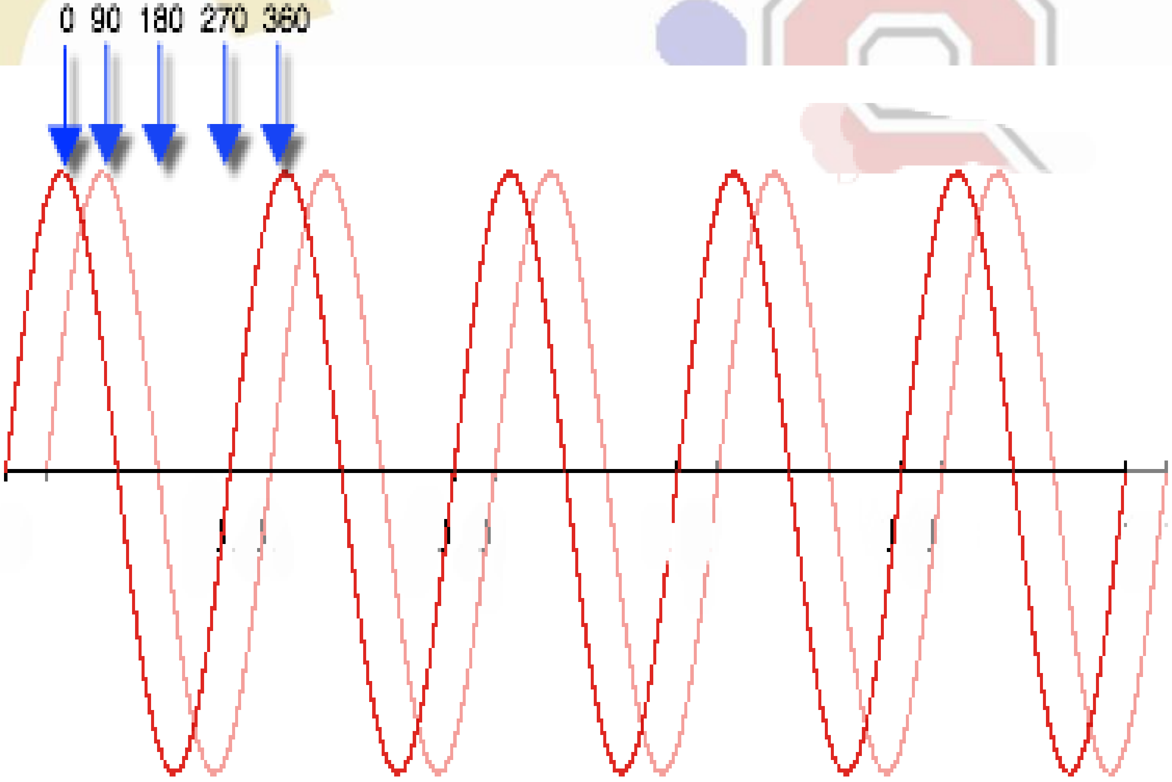


Phase difference & Path difference

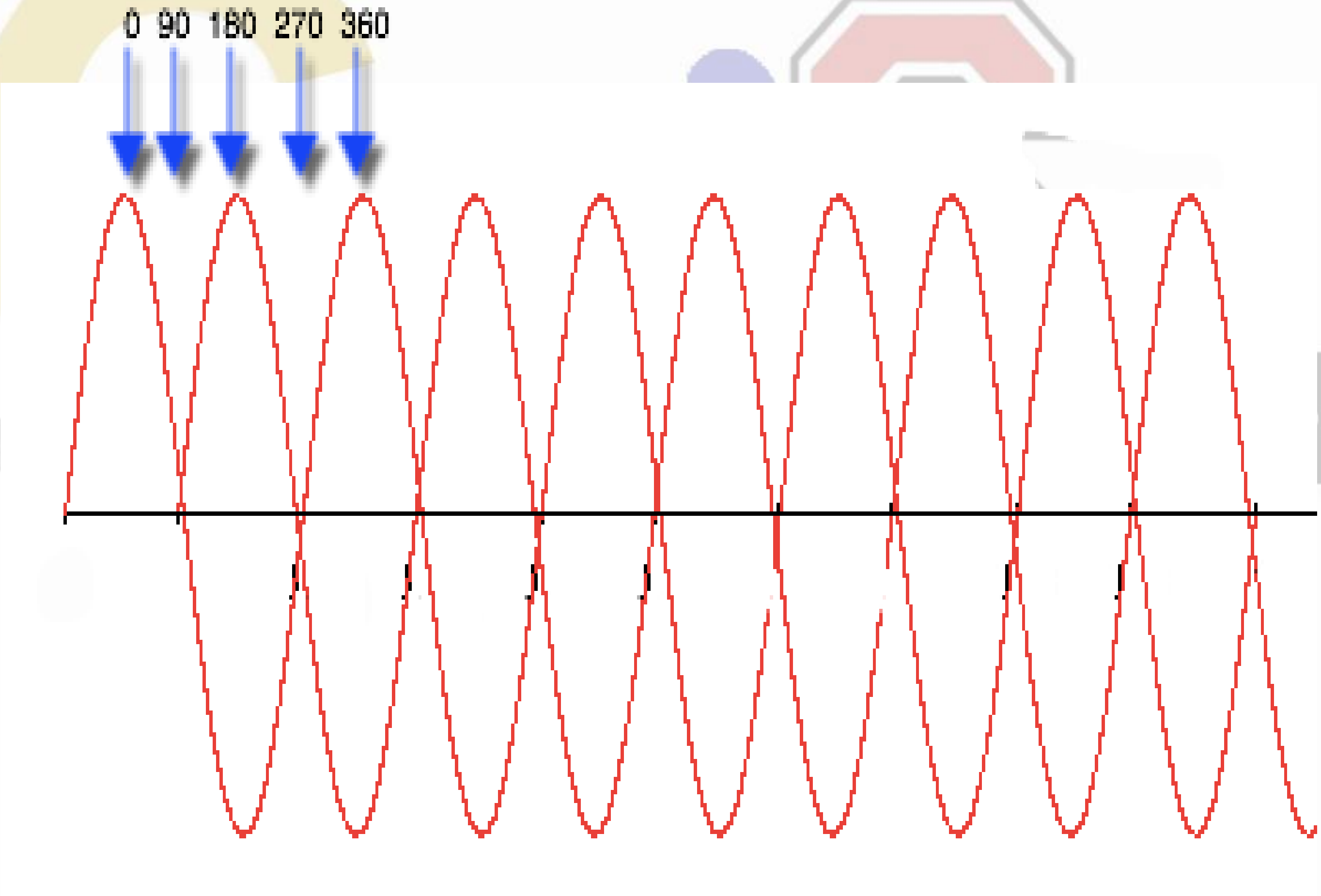
- Phase difference between two consecutive points in phase is 2π rad or 360 degrees
- So Path difference (wave length distance)between two consecutive points of a wave which are in the same phase is λ
- Phase difference between two


(0° and 360°)
(180°)
(90°)
(270°)

An example of 2 wave forms 90 degree out of pl

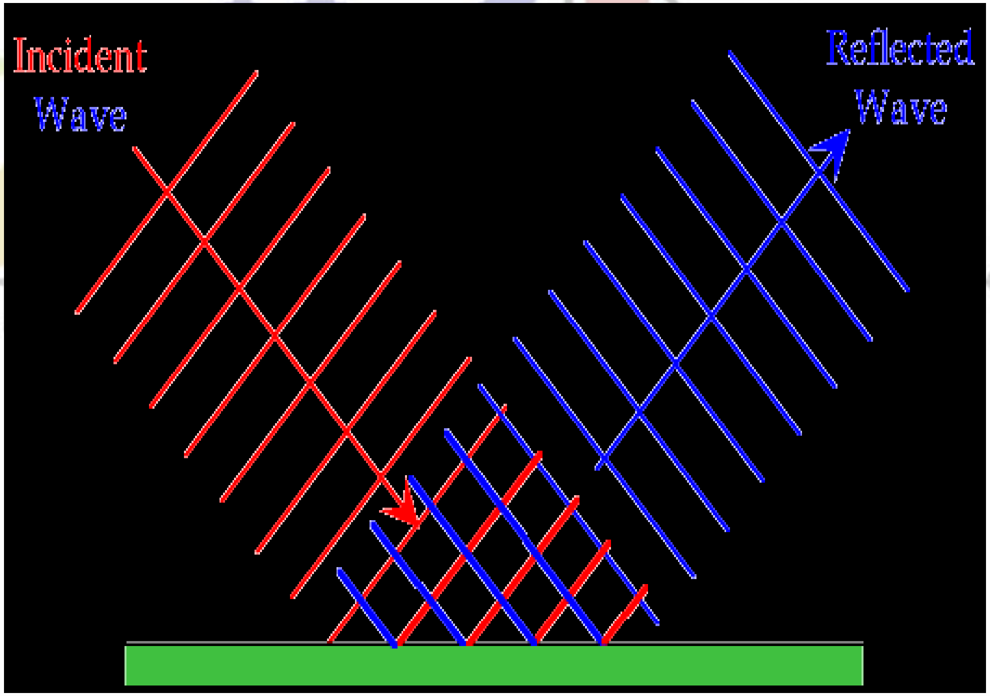


An example of 2 wave forms 180 degree out of phase.

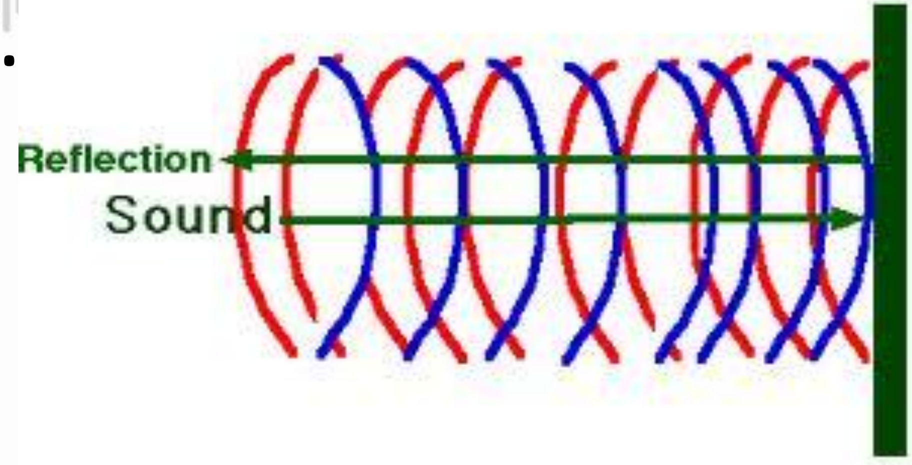


Properties of waves

- **1. Reflection:**
  Reflection is the bouncing of a wave off an object.



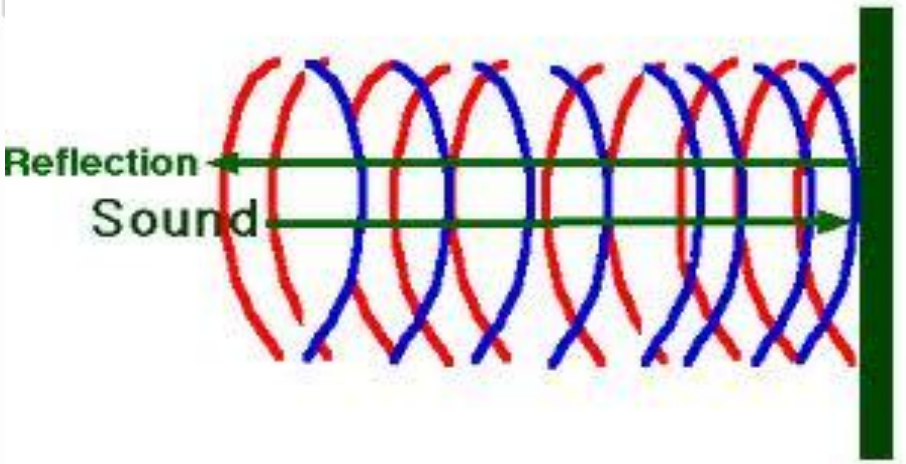
- **Reflection** – The reversing of direction of a propagating wave at the boundary of a medium.
  – A boundary is any intersection of two different medium such as air and a stone wall.



Reflection

- **Echo** – The observation of a reflected sound wave.

- **Sonar** – The use of reflected sound waves to detect objects and boundaries.



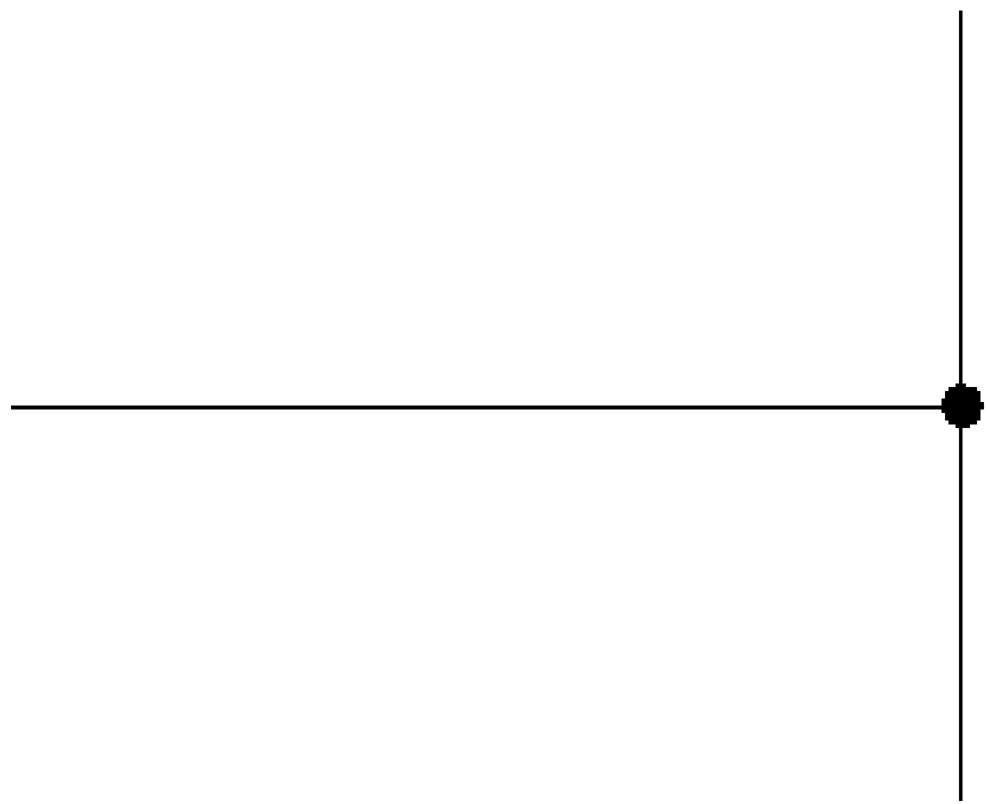
Properties of wave reflection.

- Reflection occur according to laws of reflection.
- Frequency, wave length and velocity of waves do not change during reflection of waves.
- If reflecting surface is rigid the phase change occur during reflection.
- If the reflecting surface is soft phase change does not occur during reflection.

Reflection from a HARD boundary

- The animation at left shows a wave pulse on a string moving from left to right towards the end which is rigidly clamped. As the wave pulse approaches the fixed end, the internal restoring forces which allow the wave to propagate exert an upward force on the end of the string. But, since the end is clamped, it cannot move. According to Newton's third law, the wall must be exerting an equal downward force on the end of the string. This new force creates a wave pulse that propagates from right to left, with the same speed and amplitude as the incident wave, but with opposite polarity (upside down).

at a fixed (hard) boundary, the displacement remains zero and the reflected wave changes its polarity (undergoes a 180o phase change)



Reflection from a SOFT boundary

The animation at left shows a wave pulse on a string moving from left to right towards the end which is free to move vertically (*imagine the string tied to a massless ring which slides frictionlessly up and down a vertical pole*). The net vertical force at the free end must be zero. This boundary condition is mathematically equivalent to requiring that the slope of the string displacement be zero at the free end (look closely at the movie to verify that this is true). The reflected wave pulse propagates from right to left, with the same speed and amplitude as the incident wave, and with the same polarity (right-side up).

At a free (soft) boundary, the restoring force is zero and the reflected wave has the same polarity (no phase change) as the incident wave

Properties of waves

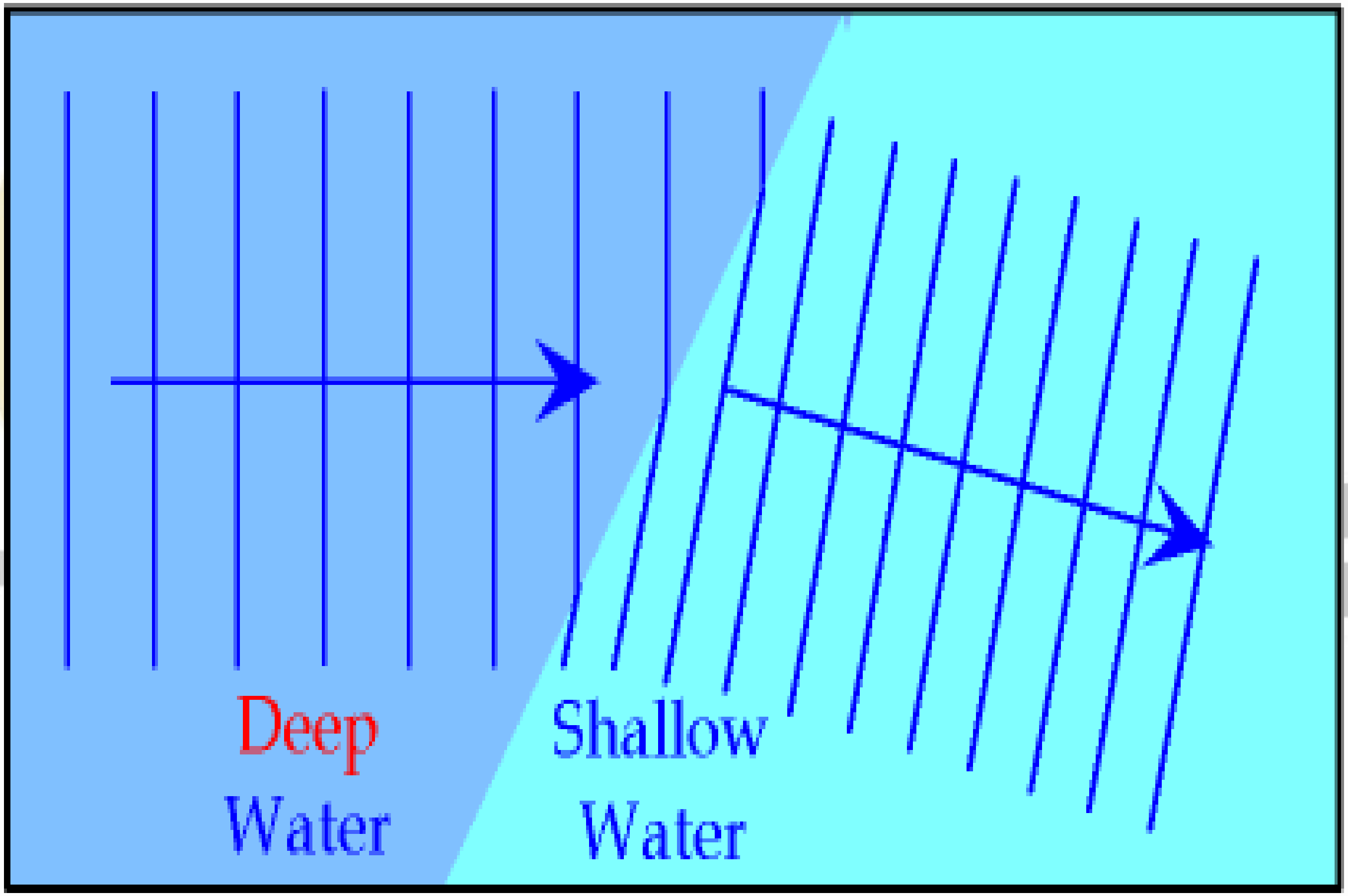
2 - Refraction of Waves

Refraction is the bending of a wave as it travels from one medium to another. Note that when a wave travels from one medium to another

Refraction

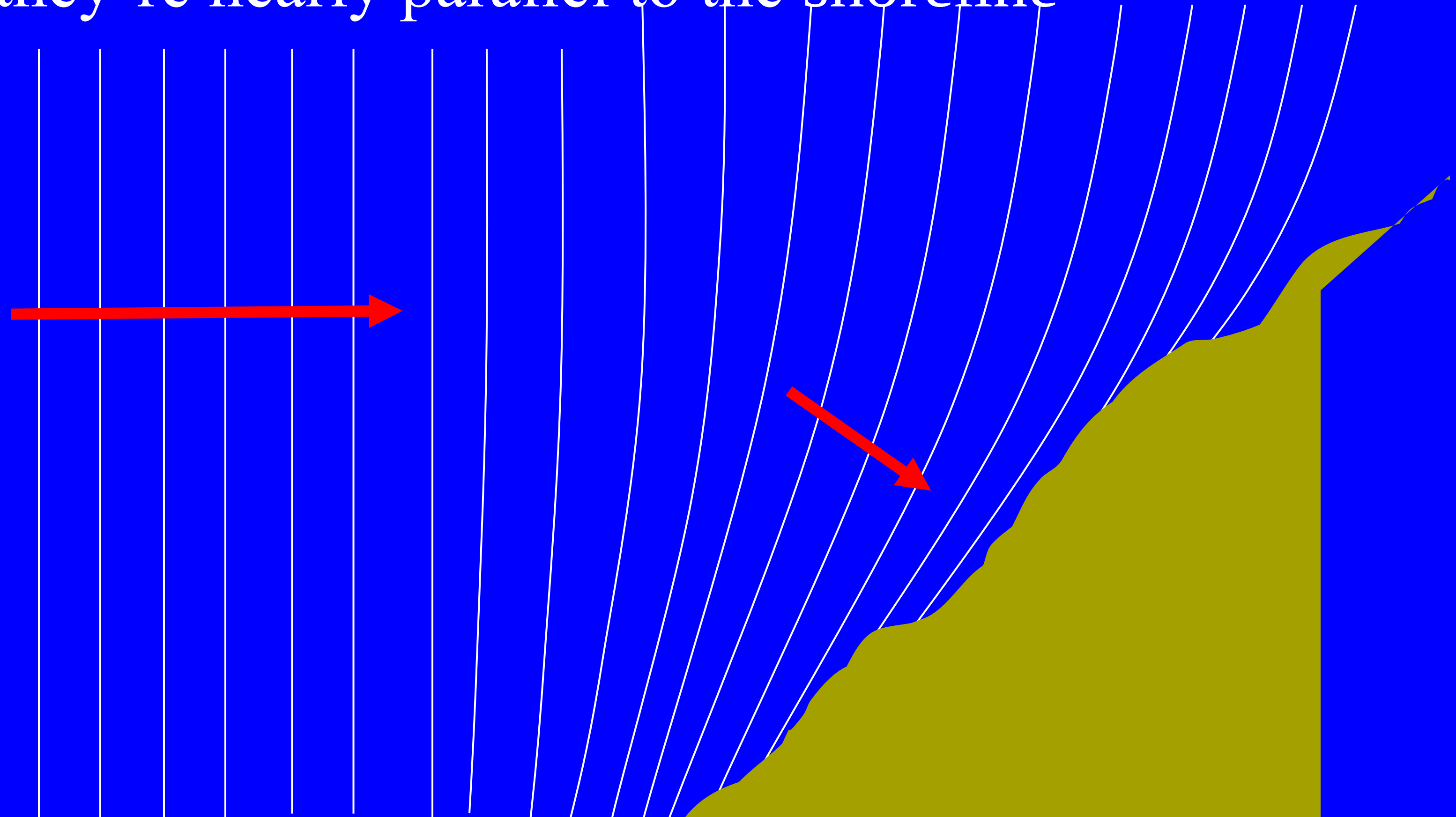
We've seen that when a wave reaches an interface (a change from one medium to another), part of the wave can be transmitted, and part can be reflected back. This is refraction—the bending of a wave as it passes from one medium to another. The most well know type of refraction is that of light bending as it passes from air to glass or water.

As ocean waves approach the shore at an angle, the part of the wave closer to shore begins to slow down because the water is shallower. This causes refraction, and the waves bend so that it the wave fronts (crests) come in nearly parallel with the shore


Deep
Water
Shallow
Water

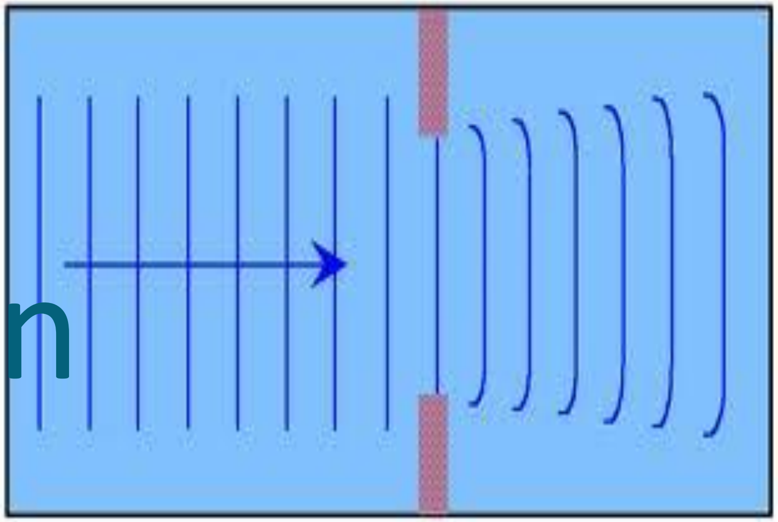
Refraction of Ocean Waves

Wave fronts are shown in white heading toward the beach. The water gets shallow at the bottom first, which causes the waves to slow down and bend, and the wavelength to decrease. By the time the waves reach shore, they're nearly parallel to the shoreline



Properties o

3- Diffraction

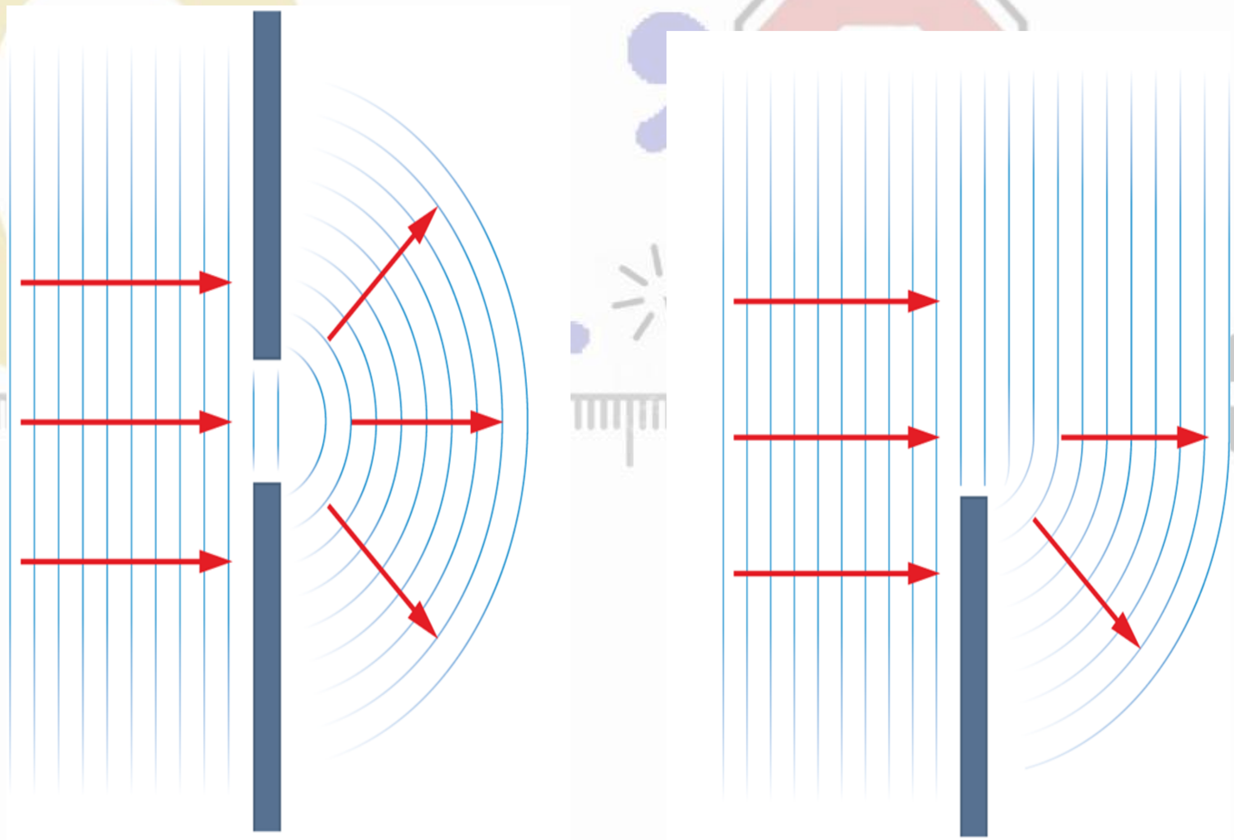


Diffraction is the spreading of waves around a slit or an obstacle.

- This effect is only significantly noticeable if the slit width is approximately the same size as the wavelength of the waves.
- Refraction involves a change in wave speed and wavelength; but diffraction doesn't.
- These effects happen for <u>any</u> type of wave: water; sound; light; seismic waves, etc.

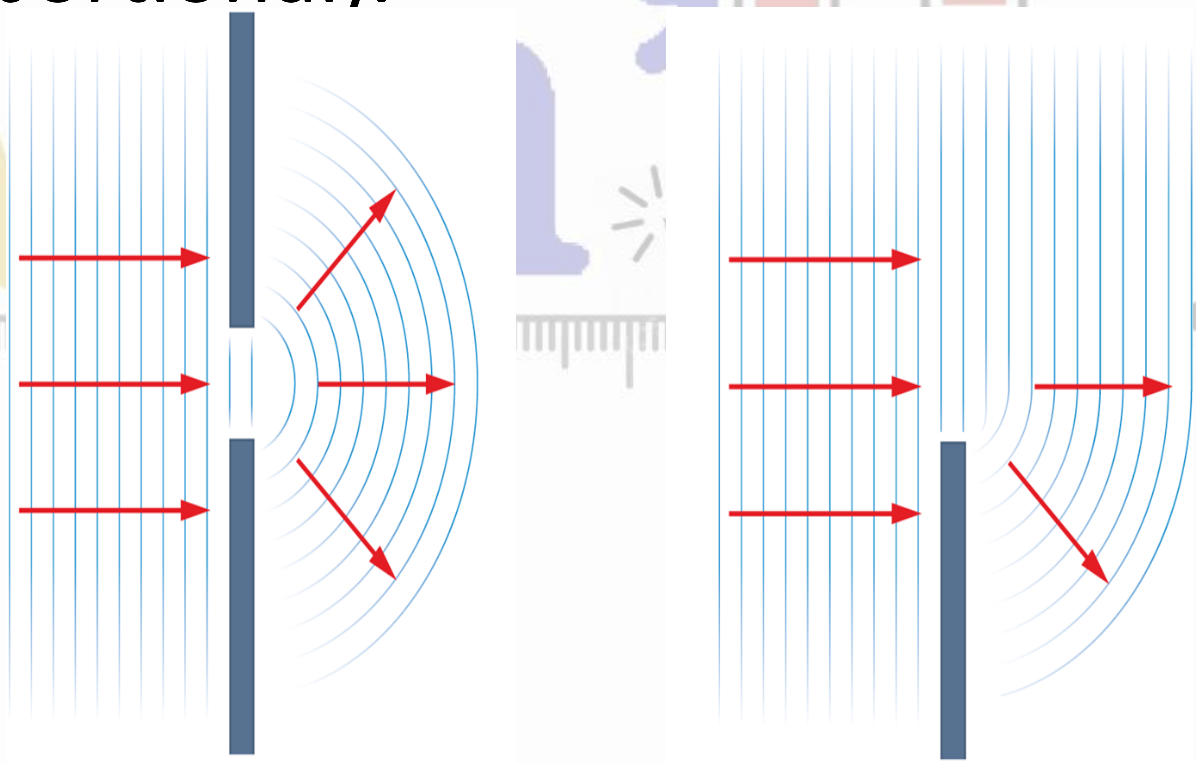
Diffraction

- **Diffraction** – The bending of waves around obstructions.



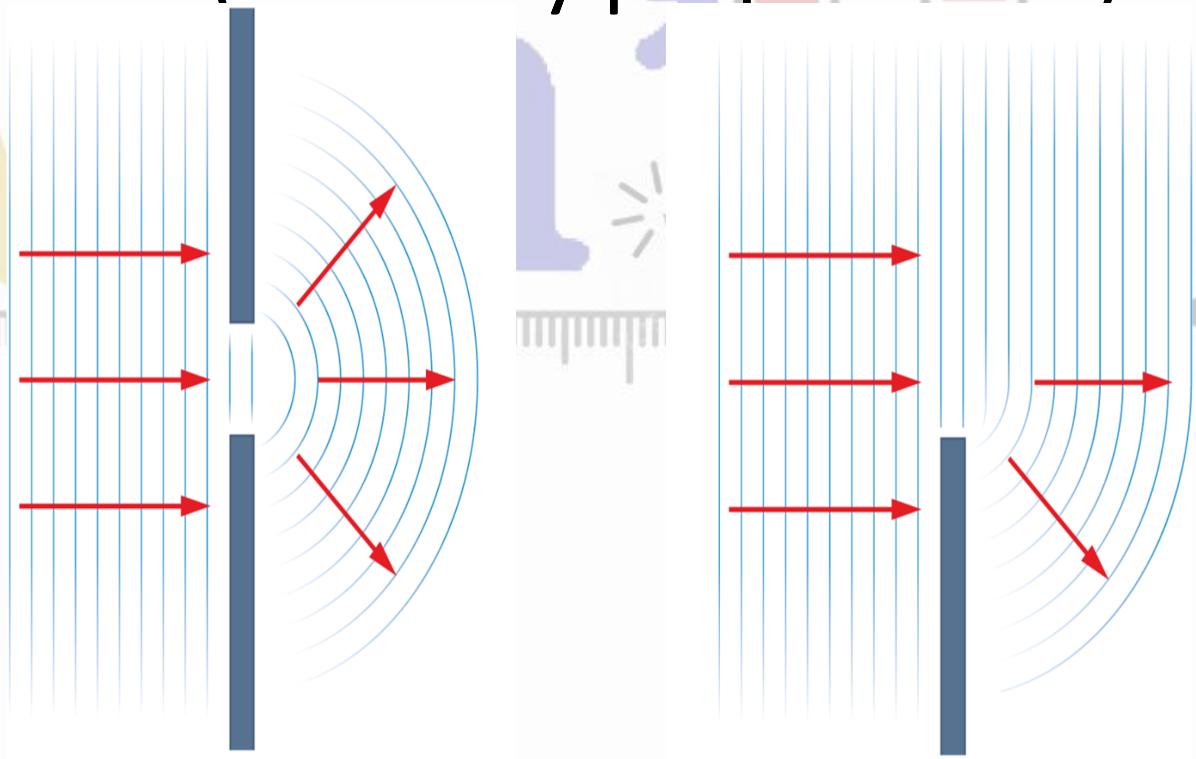
Diffraction

– Wavelength – Diffraction increases as wavelength decreases (Inversely proportional).



Diffraction

– Barrier size / Barrier Opening - Diffraction increases as barrier size or opening decreases (Inversely proportional).



Diffraction & Bats

Bats use ultrasonic sound waves (a frequency too high for humans to hear) to hunt moths. The reason they use ultrasound is because at lower frequencies much of the sound waves would have a wavelength close to the size of a moth, which means much of the sound would diffract around it.

Bats hunt by echolocation—bouncing sound waves off of prey and listening for the echoes, so they need to emit sound with a wavelength smaller that the typical moth, which means a high frequency is required. High frequency sound waves reflect off the moths rather than diffracting around them. If bats hunted bigger prey, we might have emitted sounds that we could hear.

The sound waves from an owl's hoot (beep) travel a greater distance in the forest than a song bird's call, because a low pitch owl hoot has a longer wavelength than a high pitch

Properties of waves

4 – Wave Interference

Interference occurs when two or more waves overlap to produce a wave of different amplitude. When this occurs, the total wave at any point at any time is governed by the Principle of Superposition

Principle of Superposition

- When two or more waves overlap, the resultant displacement at any point & at any instant is found by adding the instantaneous displacements that would be produced at the point by the individual waves if each were present alone.

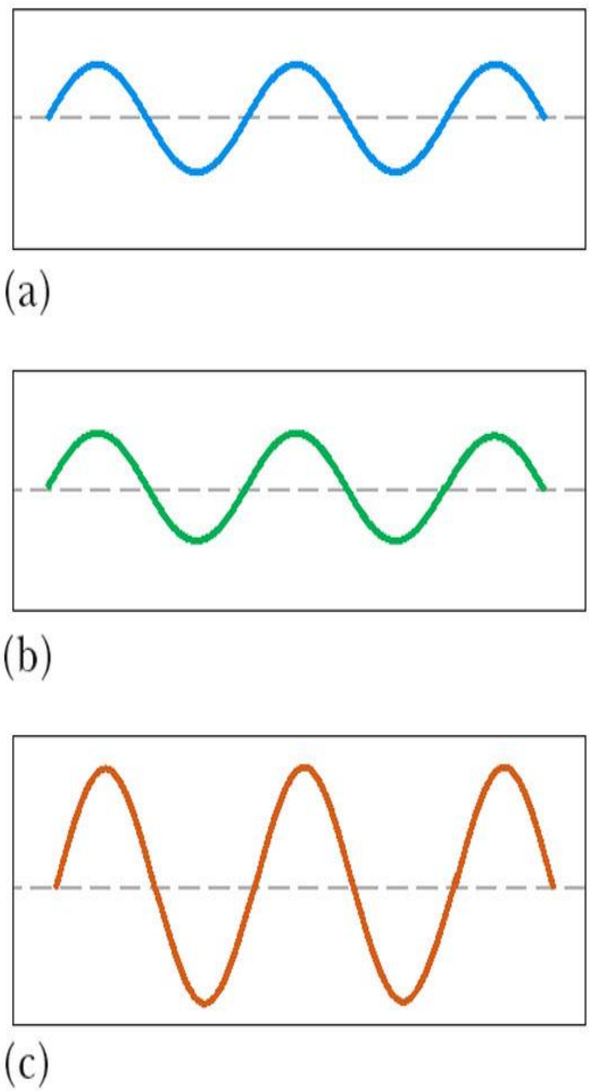
- So the resulting superimposed wave is found by adding the vector amplitudes of each individual wave.
- Superposition applies even when the waves are not identical.
- Superposition can involve both constructive and destructive interference at the same time (but at different points in the medium).

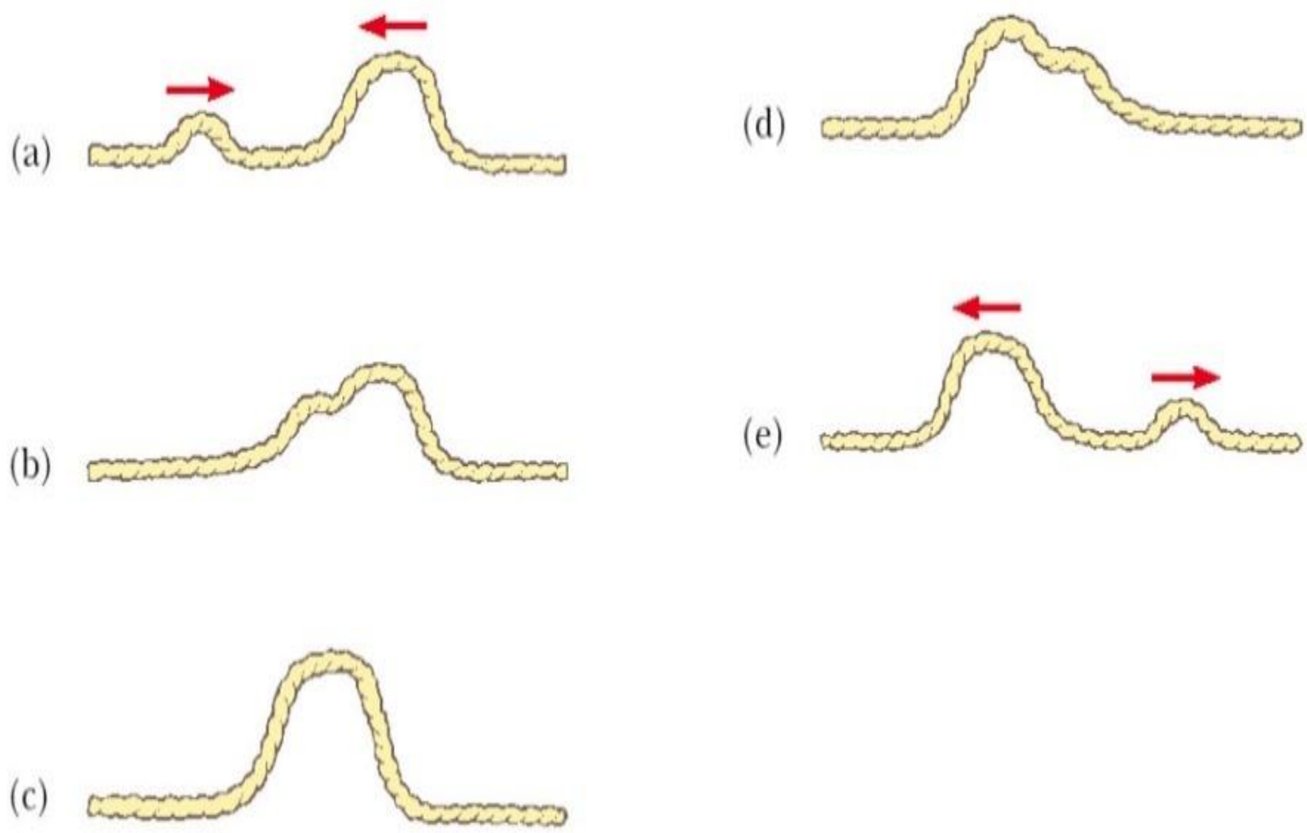
Constructive Interference

- When two waves of identical frequency arrive at the same point in a medium with identical phases, constructive interference occurs.

Constructive Interference

- Two waves, a and b, have the same frequency and phase.
- The crests and troughs of both waves line up.
- The combined wave, c, has the same frequency and a maximum amplitude.



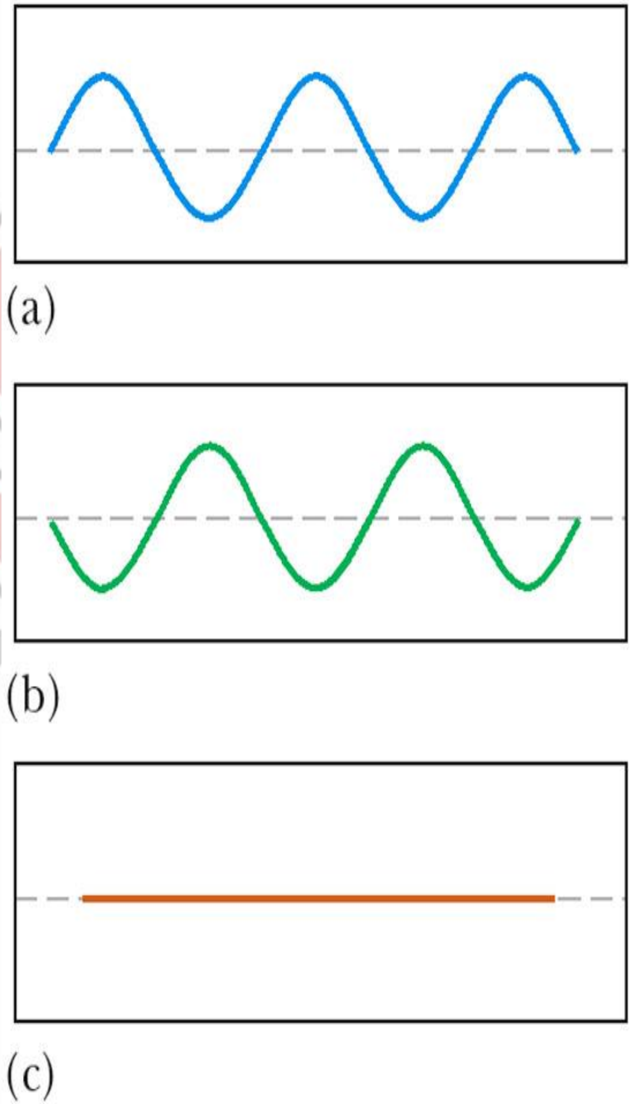

(a)
(b)
(c)
(d)
(e)

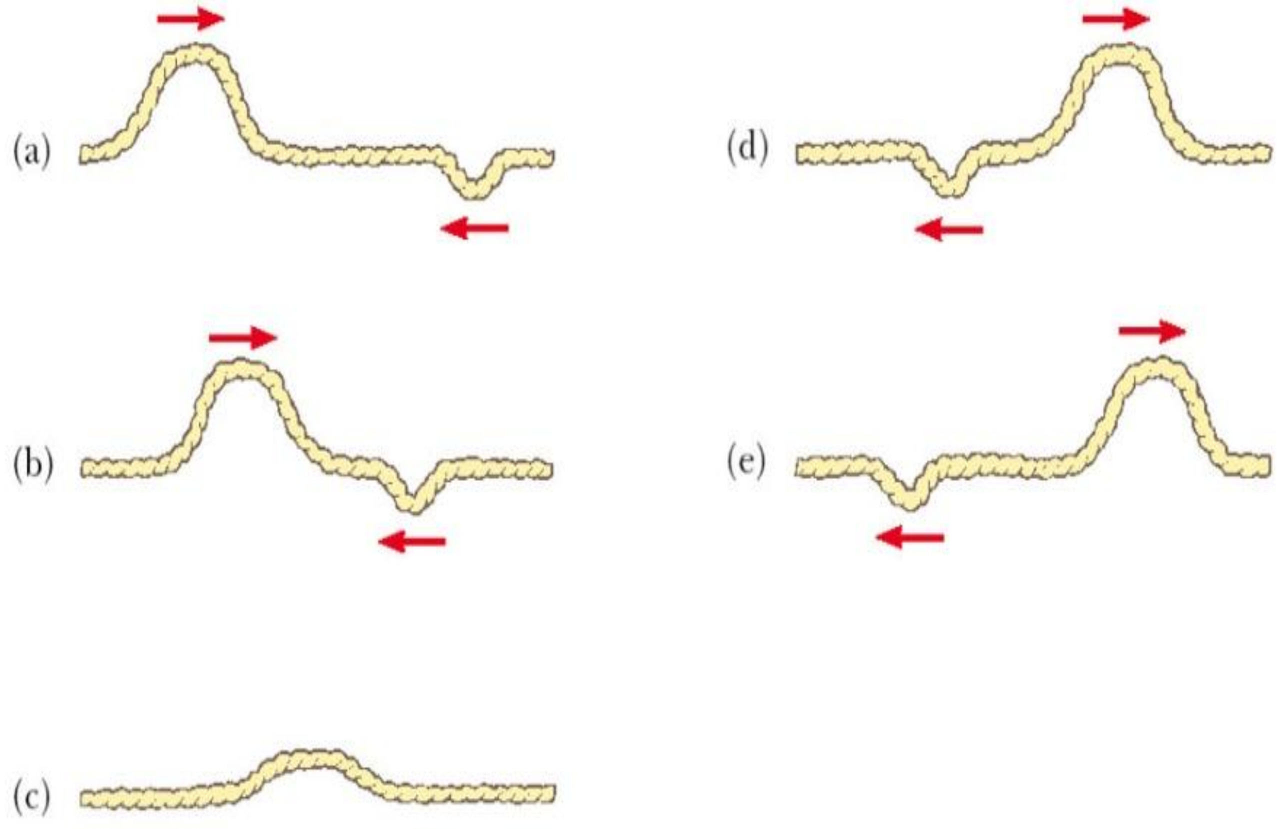
Destructive Interference

- When two waves of identical frequency arrive at the same point in a medium with 180° out of phase, destructive interference occurs.

Destructive Interference

- Two waves, a and b, have the same frequency, but are out of phase.
- The crests of wave a line up with the troughs of wave b.
- In the combined wave, c, the waves cancel out and a minimum amplitude occurs.




(a)
(d)
(b)
(e)
(c)

Question

You are standing at a point where the signals from two radio antennas cancel exactly.

The towers broadcast at 1000 kHz.

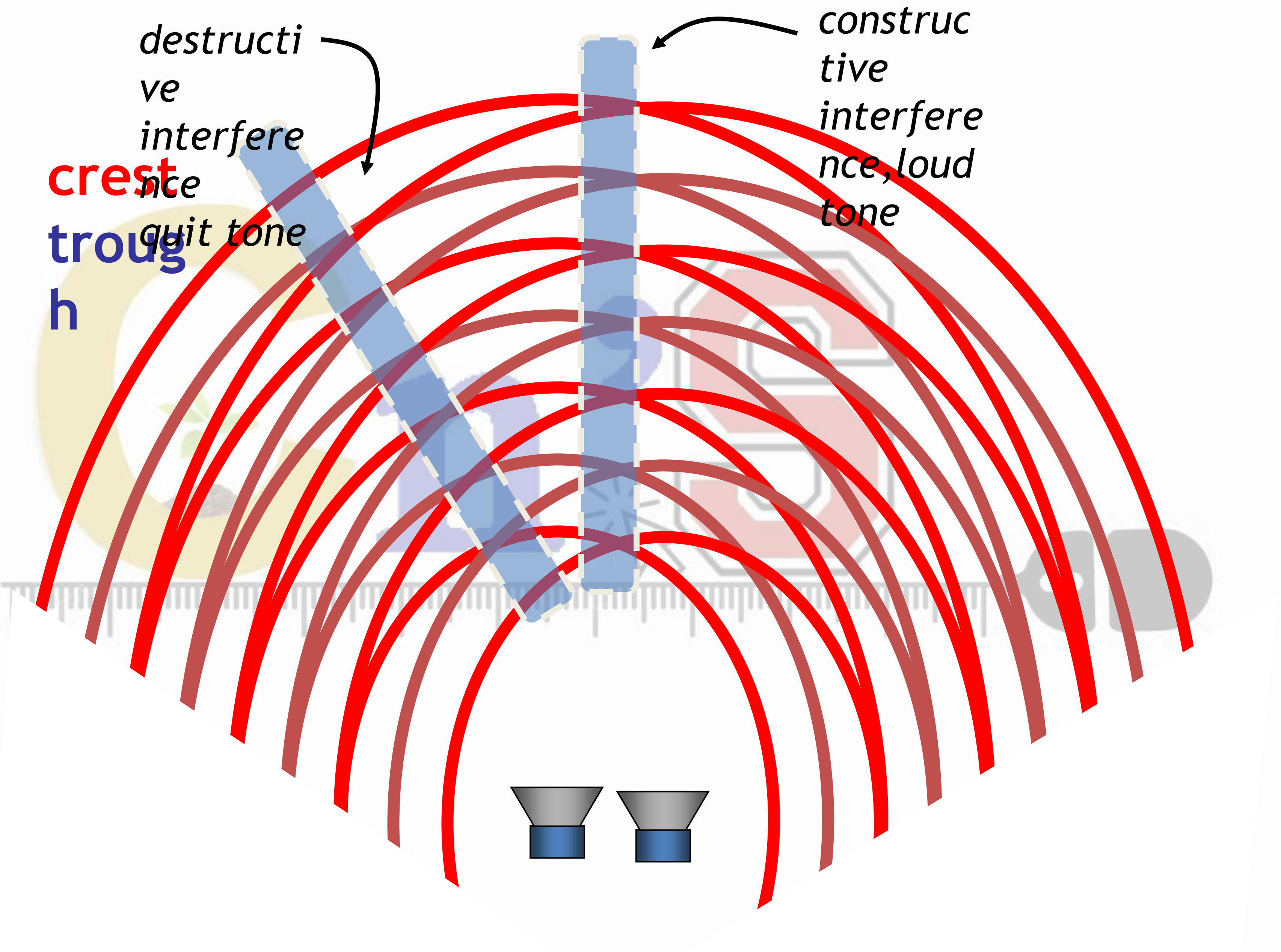
You walk around with a constant distance from tower 1. How much closer to tower 2 do you need to go to get full constructive interference (strong radio signal)? Speed of sound: 340m/s

A. 300 meters

B. 150 meters

C. 75 meters

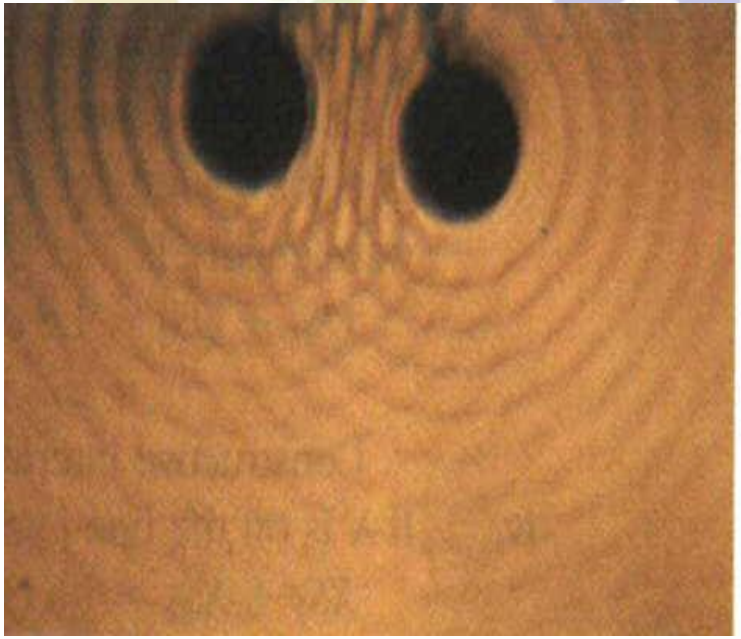
Interference of 2 speakers

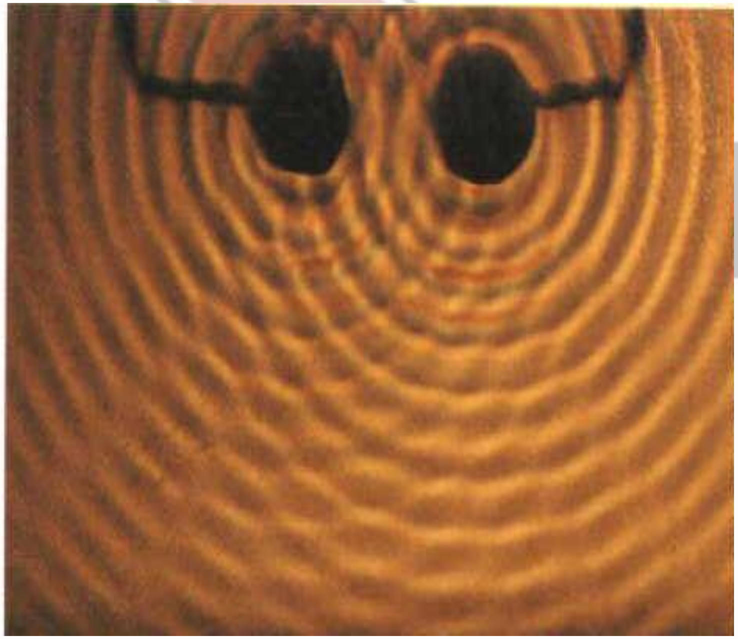


Interference of Waves

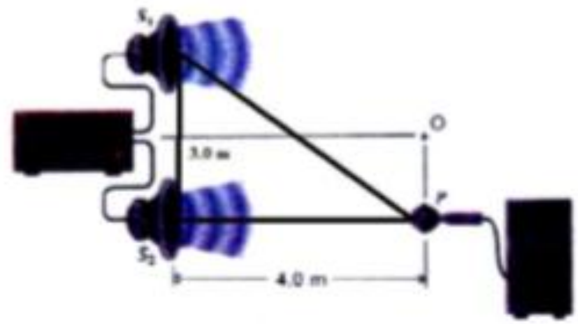
When two or more waves propagating in the same medium
meet at the same point, **interference** is said to occur.

A stable interference pattern can be observed when two w
waves of same frequency meet one another in a ripple ta





Q # 2. Two speakers are arranged as shown in Fig. The distance between them is 3 m and they emit a constant tone of 344 Hz. A microphone P is moved along a line parallel to and 4.00 m from the line connecting the two speakers. It is found that tone of maximum loudness is heard and displayed on the CRO when microphone is on the center of the line and directly opposite each speakers. Calculate the speed of sound.



Given Data: Distance between speakers $S_1S_2 = 3\ m$, Frequency $f = 344\ Hz$, Distance between speakers and microphone $S_2P = 4\ m$
To Determine: Speed of sound $v = ?$
Calculations: As $v = f\lambda \quad ---- \quad (1)$, Here $\lambda = ?$ From condition of constructive interference: Path Difference = Integral Multiple of λ $\Rightarrow \lvert S_1P\rvert - \lvert S_2P\rvert = \lambda \quad ---- \quad (2)$, For First Maxima $n = 1$, Here $S_1P = ?$ In right triangle S_1S_2P: $\lvert S_1P\rvert^2 = \lvert S_1S_2\rvert^2 + \lvert S_2P\rvert^2 \Rightarrow \lvert S_1P\rvert = \sqrt{\lvert S_1S_2\rvert^2 + \lvert S_2P\rvert^2}$ $\Rightarrow \lvert S_1P\rvert = \sqrt{(3)^2 + (4)^2} = \sqrt{9+16} = \sqrt{25} = 5$ Equation (2) becomes: $\lambda = \lvert S_1P\rvert - \lvert S_2P\rvert = 5 - 4 = 1\ m$ Putting values in (1): $v = f\lambda = 344 \times 1 = 344\ ms^{-1}$