11 PHYSICS

Unit 4: Waves

Booklet ~~2~~ 3

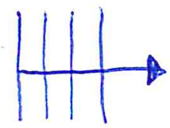
May 26th - June 2nd

NAME: Answers.

U4:L5 Diffraction

When periodic waves are produced in a ripple tank, they travel in a straight line if the water level in the tank remains uniform.

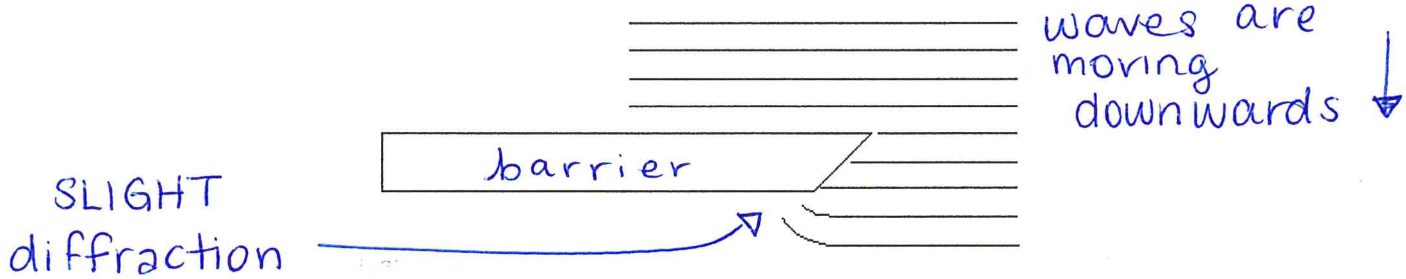
The direction of motion of the wavefront is indicated by a wave ray drawn at right angles to the wavefront.



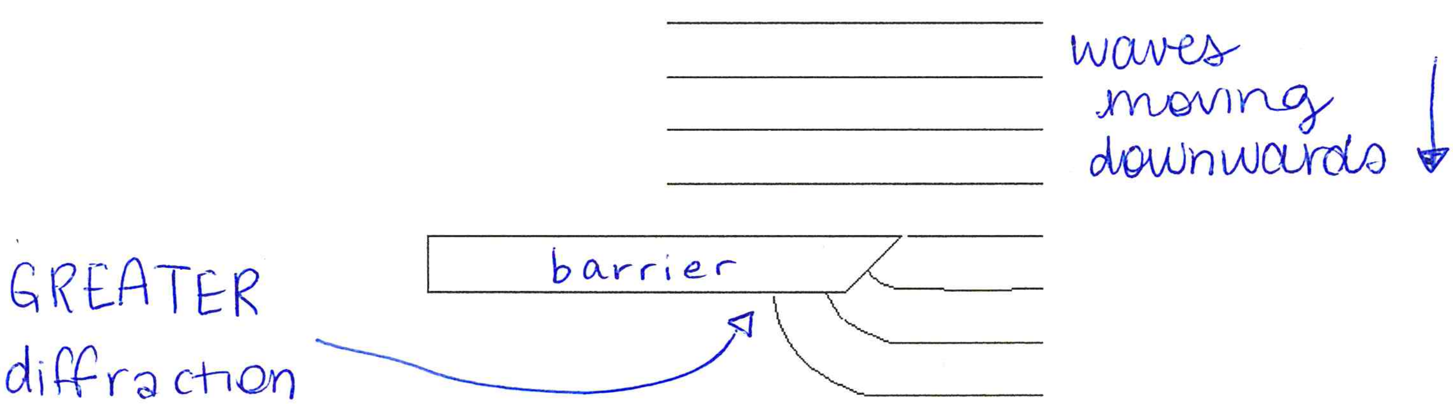
If the waves encounter an obstacle, they are blocked and may be reflected.

But if the waves are allowed to pass by the sharp edge of an obstacle, or if they pass through a small opening in the obstacle, they will bend. This bending is called **diffraction.**

The diagram below shows waves with a relatively short wavelength approaching the sharp edge of a barrier. At they pass the edge of the barrier, they bend (diffraction). They are diffracted only slightly.



The next diagram shows the same barrier. But this time waves with longer wavelengths are approaching the barrier. They are diffracted to a greater extent.



(λ)

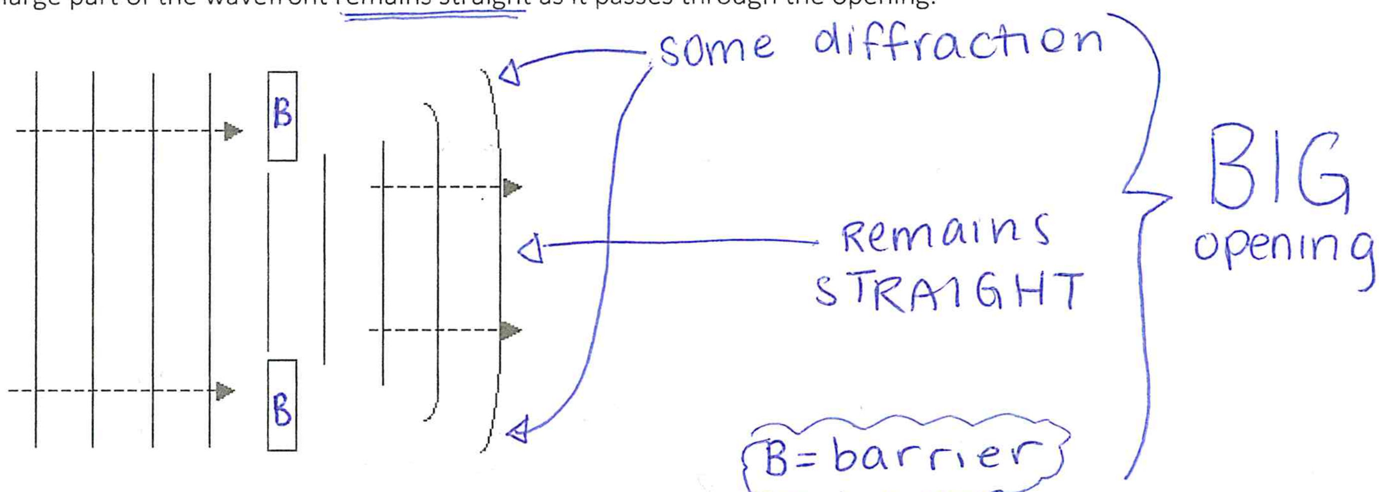
The larger the wavelength of the waves approaching a barrier, the greater will be the diffraction.

Diffraction Through an Opening

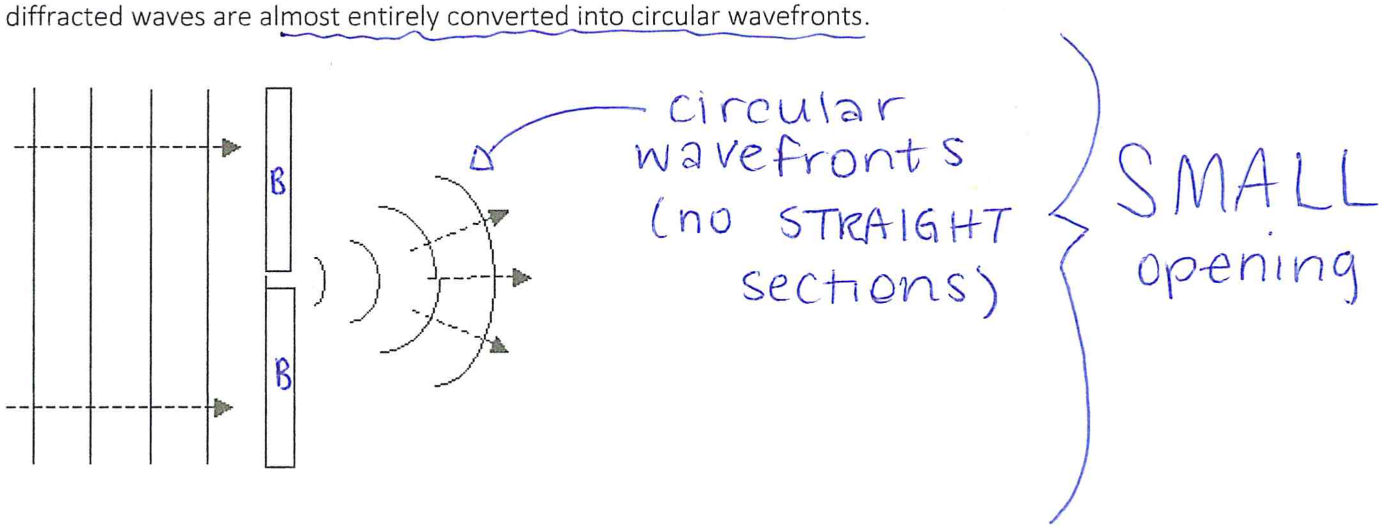
In the case of diffraction through an opening, **the amount of diffraction will vary depending on the size of the opening.**

In the first diagram below, incident waves are passing through an opening that is large relative to the wavelength of the waves.

There is some diffraction near the edges of the waves after they pass through the opening. But a large part of the wavefront remains straight as it passes through the opening.

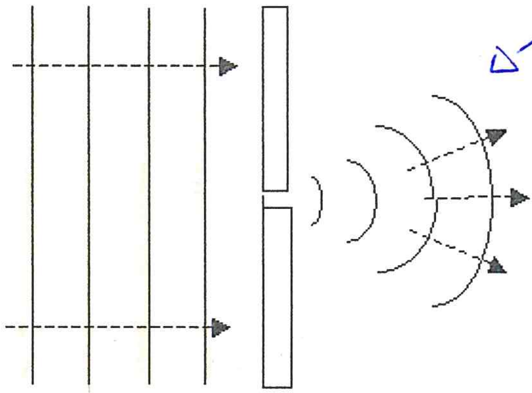


In the next diagram the size of the opening is much smaller than before. In this case, the diffracted waves are almost entirely converted into circular wavefronts.



The smaller the opening relative to the wavelength, the greater is the diffraction.

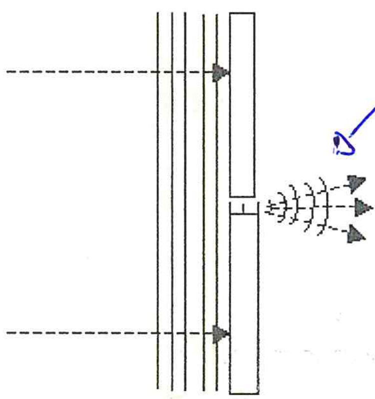
In the previous section we saw this diagram.



circular diffraction

BIG wavelength (λ)

If we keep the size of the opening the same but **decrease the wavelength** of the incident waves, we can see that there will be **less diffraction.**



LESS diffraction

SMALL wavelength (λ)

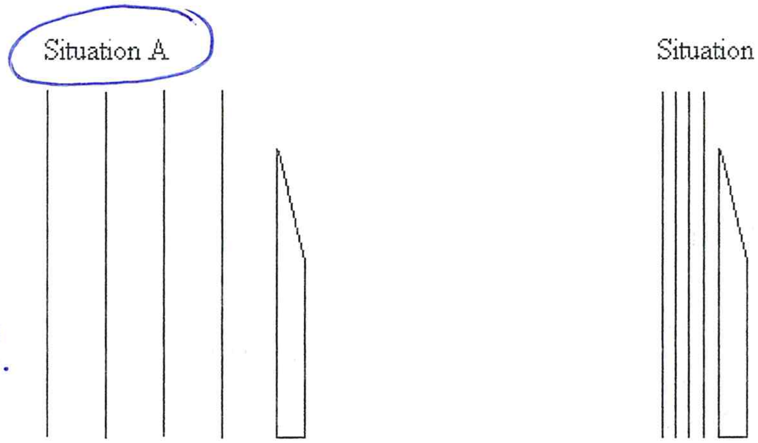
If the wavelength is very small, a narrow opening is required to produce any significant diffraction.

In general for any obvious diffraction to occur, the wavelength of the incident waves must be large compared to the size of the opening.

If λ represents the wavelength and w represents the size of the opening, then the ratio $\boxed{\lambda / w}$ should be about 1 or greater for any significant diffraction to be apparent.

Examples:

1. The diagram below shows two different types of water waves approaching a sharp edge. Which type of wave will show the greatest diffraction, the waves in situation A or the waves in situation B?



$\lambda A > \lambda B$

so

diffraction A > diff. B

2. Ocean waves are approaching an opening into a harbour. The opening is 100 m wide. For which wavelength of ocean waves would there be the greater diffraction, those with a wavelength of 50 m or those with a wavelength of 200 m?

$\lambda \Rightarrow 50m < 200m$

$\uparrow\lambda = \uparrow$ diffraction

so, 200m wave will have greater diffraction.

3. A D note in music has a frequency of 294 Hz. A G note has a frequency of 392 Hz. If music was playing in a hallway around the corner, what frequency of sound could you most clearly hear?

$f \propto \frac{1}{\lambda} \Rightarrow \uparrow f = \downarrow \lambda$ so... $\underset{(\lambda)}{294\,Hz} > \underset{(\lambda)}{392\,Hz}$

You would hear 294 Hz more clearly.

4. Light of wavelength 470 nm is blue in colour, and 610 nm light is orange. If these colours of light pass through a 500 nm hole, which colour of light will show the greatest diffraction?

$470nm\,(\lambda) < 610\,nm\,(\lambda)$

so... 470 diffraction < 610 diffraction

∴ 610nm (orange) will show greater diffraction

U4:L6 2D Wave Interference

In the previous lesson, we discussed constructive and destructive interference in one dimension. Such interference also occurs in the two dimensional situation. In this section we will study wave interference in two dimensions when the waves have the same frequency (wavelength) and amplitude, and when they are vibrating at the same time (in phase).

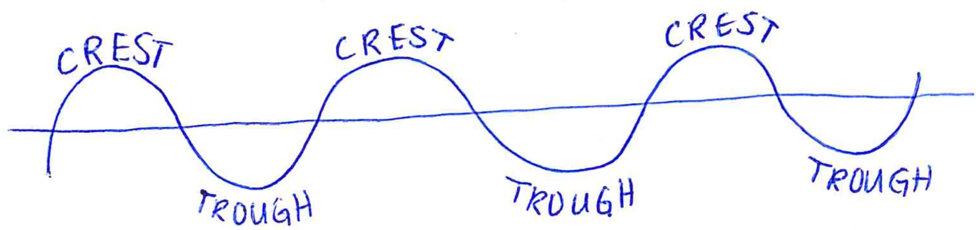
The diagram below shows wave crests (solid lines) and troughs (dashed lines) produced by two vibrating point sources that are attached to the same generator and thus have identical frequencies and amplitudes.

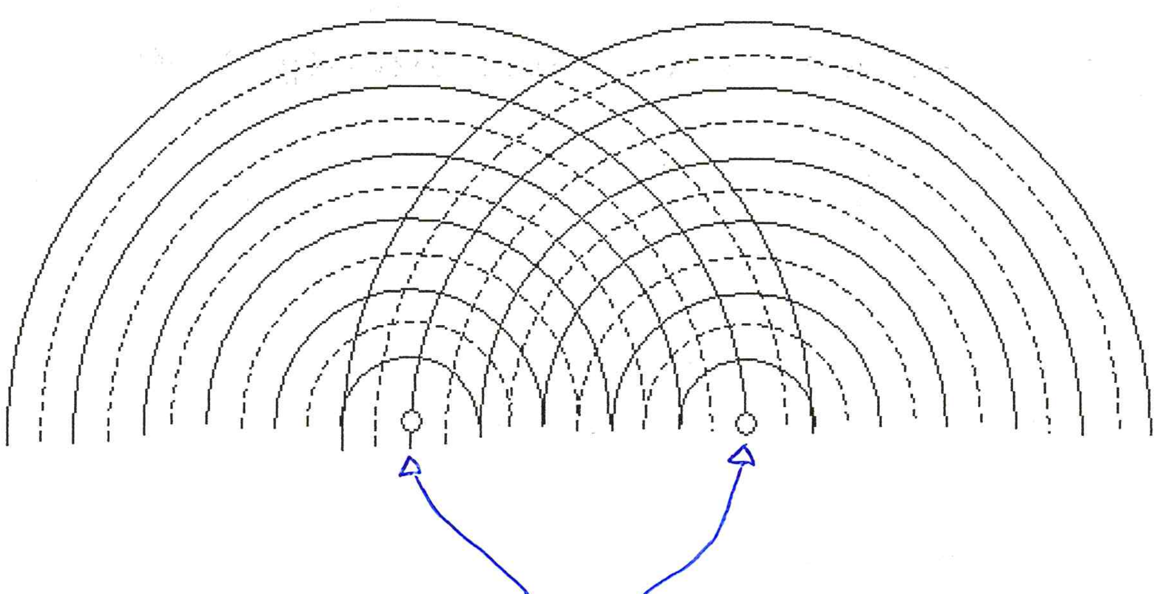
They are also vibrating up and down at the same time so they are in phase.

As was the case in the one dimensional medium, the waves pass through one another unchanged.

But as the crests and troughs travel out from each point source, they interfere with each other, this can be:

- crest on crest
- trough on trough
- crest on trough



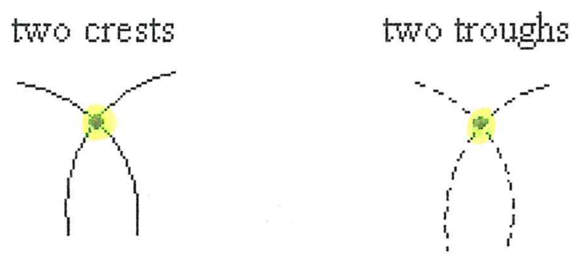


Constructive Interference

There are two kinds of constructive interference. One occurs when two crests meet, and other when two troughs meet.

In the diagram below, the crests are indicated by solid lines. The troughs are shown by dashed lines.

We will indicate these areas of **constructive interference** by a **solid dot**.



Deconstructive Interference

Destructive interference occurs when a crest and a trough meet. Areas of **destructive interference** will be indicated by an **open dot**.

Nodal Lines

The diagram below shows what happens when two identical waves, produced by two point sources, interfere with each other.

As the successive crests and troughs travel out from each of the two sources, S_1 and S_2, they interfere with each other, sometimes crest on crest, sometimes trough on trough, and sometimes crest on trough.

So, areas of constructive and destructive interference are produced.

These areas move out from the sources in symmetrical patterns producing areas of destructive interference called **nodal lines**, and areas of constructive interference as shown below.

When illuminated from above in a ripple tank, the nodal lines appear as stationary grey areas.

Between the nodal lines are areas of constructive interference that appear as alternating bright (double-crest) and dark (double-trough) lines of constructive interference.

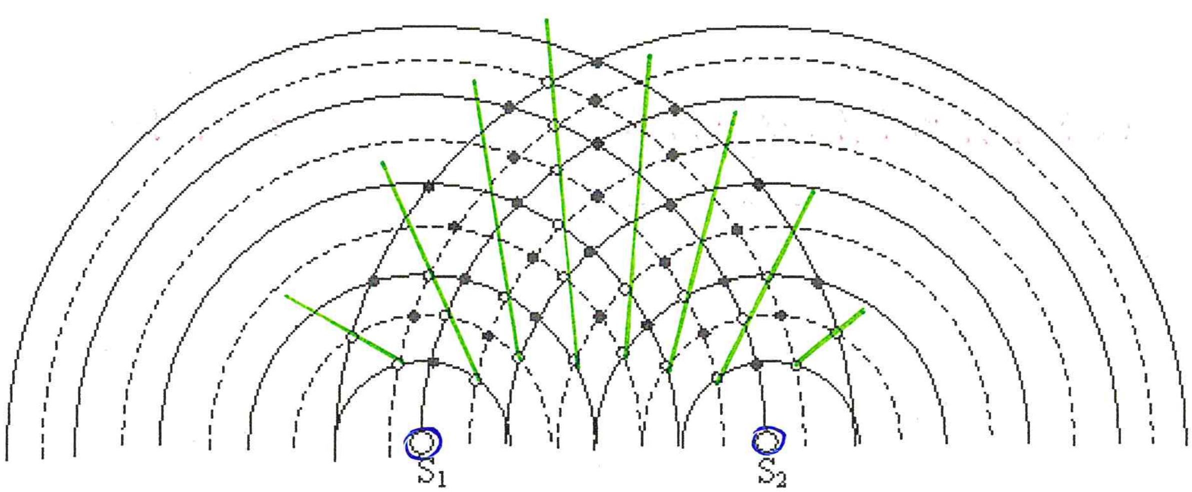
Although the nodal lines below may appear to be straight, their paths are actually curved lines called hyperbolae.

GREEN :)

In the diagram below, the nodal lines are grey in color. They represent areas of destructive interference where troughs and crests meet.

The areas with the shaded in circles represent areas of constructive interference and appear alternately bright and dark on a ripple tank.

(dark circles)



This symmetrical interference pattern will remain stationary (not move) if three factors do not change:

- the frequency of the two sources
- the distance between the sources
- the phase of the sources

$f\uparrow = \lambda\downarrow = \uparrow$ NODAL LINES

If the frequency of the two sources is increased, the wavelength decreases resulting in the nodal lines being closer together and therefore increasing their number.

$\uparrow$ N. LINES $= d\uparrow$

The number of nodal lines will also increase if the distance between the two sources increases.

Neither of these two factors will change the symmetry of the pattern.

shown by highlighted line (middle)

There will be an equal number of nodal lines on either side of the perpendicular bisector between the sources if they are in phase, and an area of constructive interference runs along the bisector.

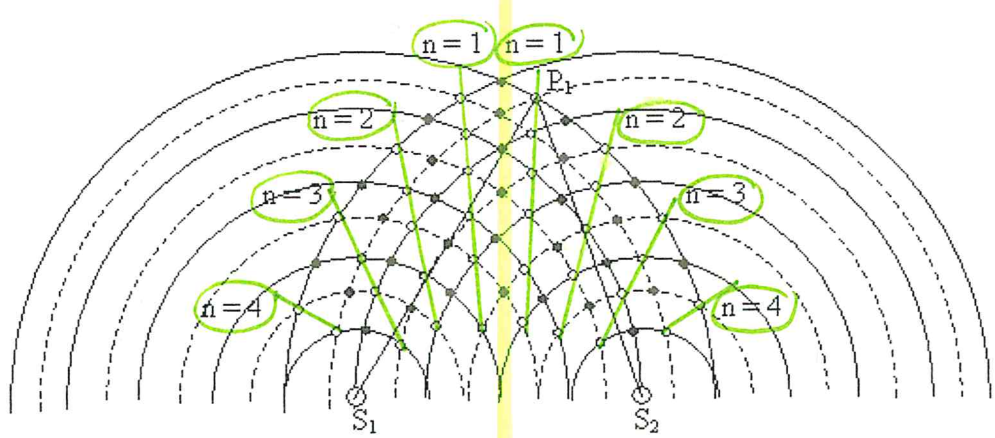
If the two sources are not vibrating at the same time (relative phase is not the same) then the number of nodal lines will remain the same, but the pattern will shift so that the area of constructive interference may not run along the bisector.

does NOT MOVE.

The interference pattern produced by two in phase point sources is relatively stationary. The nodal lines remain in the same position as long as the two sources are vibrating.

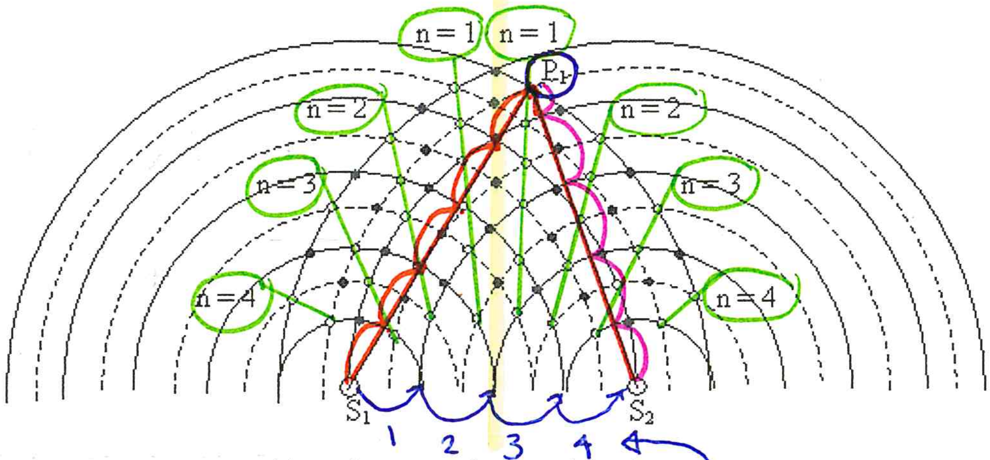
This stationary pattern makes it possible for us to measure the wavelength of the waves producing this pattern.

This is similar to the situation of the standing wave pattern from the last booklet where relatively stable nodal points allow us to measure the distance between them and then calculate the wavelength.



4 Nodal lines on Left Side.

4 nodal lines on Right Side



The two sources are separated by a distance of 4 wavelengths.

There are 4 nodal lines on each side of the perpendicular bisector (middle). The lines are numbered 1, 2, 3, 4 on both sides of the bisector. This means that there are two lines labelled n = 1, the first line on either side of the bisector, and so on with the other values of "n."

A point P_1 is placed on one of the first nodal lines. It is connected to the two sources by drawing the lines $\overline{P_1S_1}$ and $\overline{P_2S_2}$

By counting the number of wavelengths between P_1 and S_1, you can see that there are 5 wavelengths. The distance between P_1 and S_2 is 4.5 wavelengths. The difference between these two distances is the difference in path length.

It is $\boxed{|P_1S_1 - P_1S_2| = \frac{1}{2}\lambda}$ "Difference between the two lines is 1/2 of a wavelength"

This relationship holds for any point on the first nodal line on either side of the bisector.

The difference in path length for any point P_2 on a second nodal line from the center can be measured in the same way and the relationship is $\boxed{|P_2S_1 - P_2S_2| = \frac{3}{2}\lambda}$

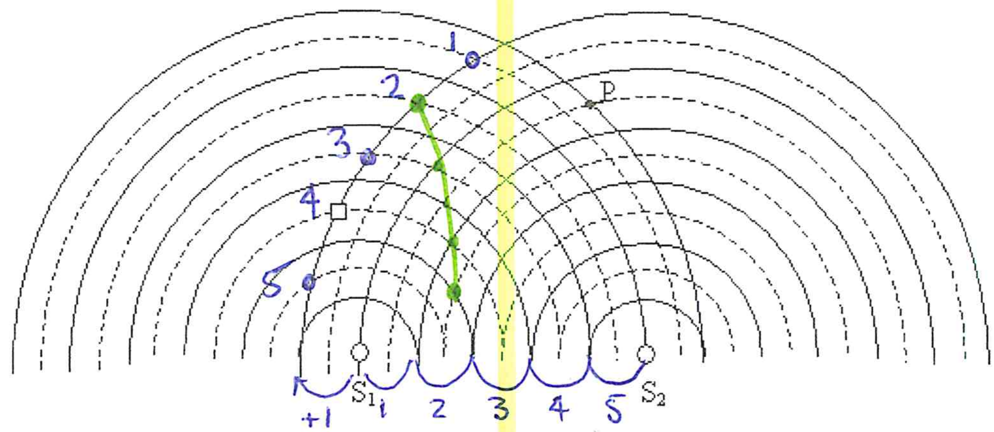
Continuing this procedure, we can arrive at the general relationship for any point P on the nth nodal line as

$$\boxed{|P_nS_1 - P_nS_2| = (n - \frac{1}{2})\lambda}$$

To use this equation to calculate the wavelength, simply locate a point on a specific nodal line, measure the path lengths, and substitute in the above equation.

Examples:

1. Two point sources are generating waves at the same frequency and phase. The pattern is shown below. The solid lines represent the crests and the dashed lines represent the troughs.



   a. Draw the second nodal line to the left of the perpendicular bisector.
   b. What kind of interference, constructive or destructive, is occurring at the location of the square?

crest + trough meet = DECONSTRUCTIVE

   c. On which nodal line would the square located?

4th Nodal Line

   d. What would be the distance between the square and the source S_2 if the wavelength of the waves is 4.0 cm?

□ is 6λ away from S_2

$6 \times 4cm = 24cm$

2. Two point sources are generating waves in a ripple tank causing the waves to interfere. The two point sources are 10.0 cm apart, and the frequency of the waves is 4.0 Hz. A point on the first nodal line is located 16.0 cm away from one source and 15.0 cm away from the other.

   a. What is the wavelength of the waves?

$[P_1S_1 - P_2S_2] = (n - \frac{1}{2})\lambda \Rightarrow [16cm - 15cm] = (1 - \frac{1}{2})\lambda$

$\frac{1}{0.5} = \lambda$

$2cm = \lambda$

   b. What is the speed of the waves?

$V = f\lambda$

$V = (4\,Hz)(2cm)$

$V = 8cm/s$

$8cm/s$

OR $\Rightarrow$ $\frac{8cm}{1s} \times \frac{1m}{100cm} = 0.08\,m/s$