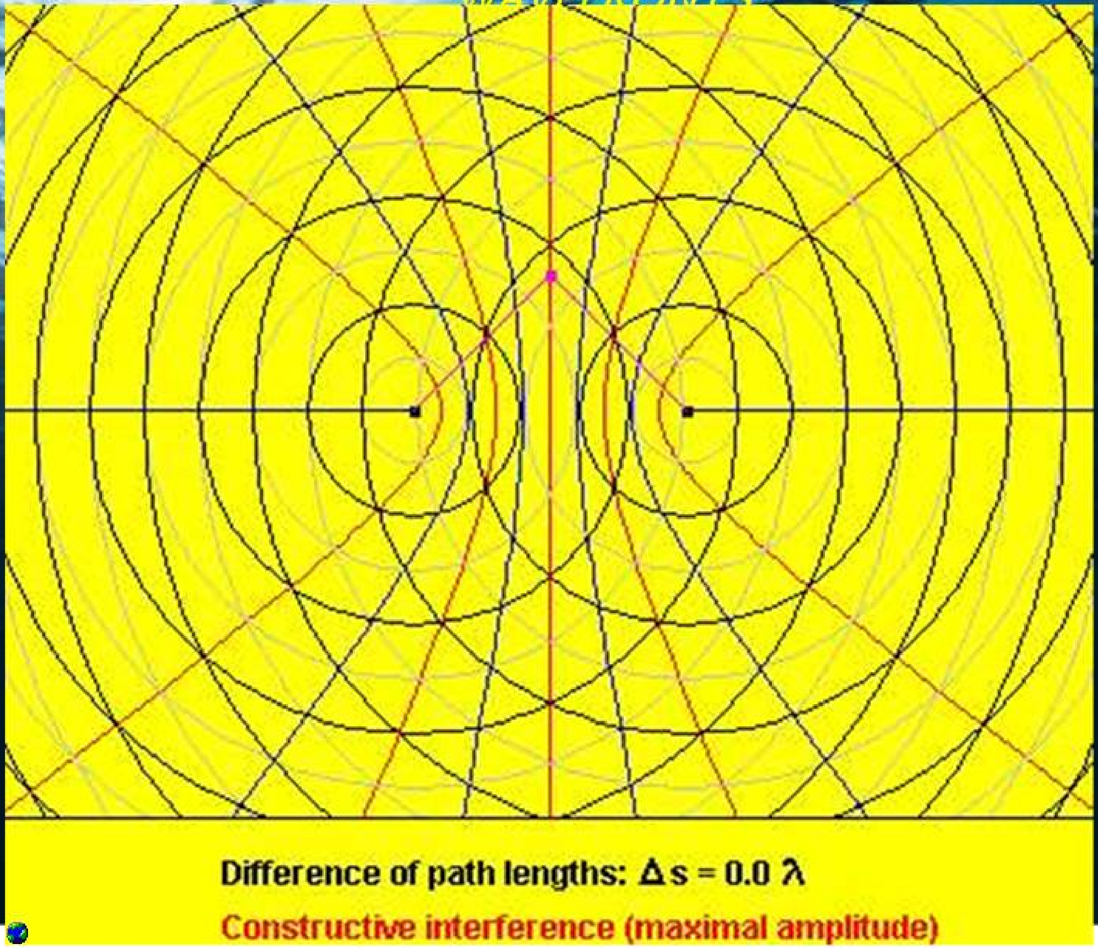
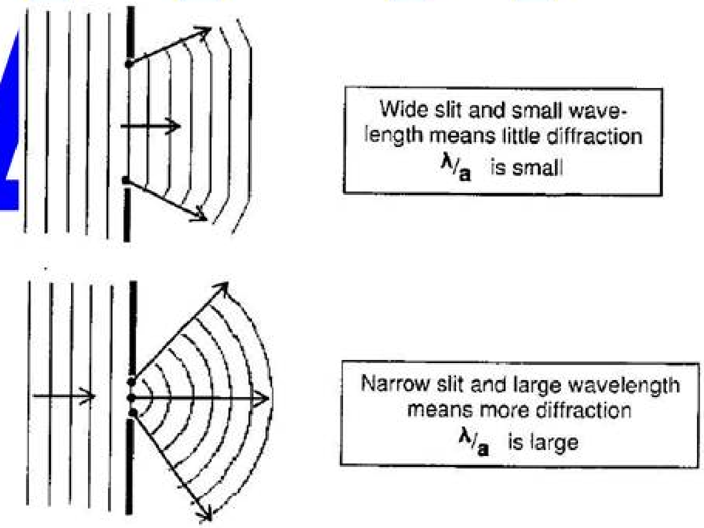
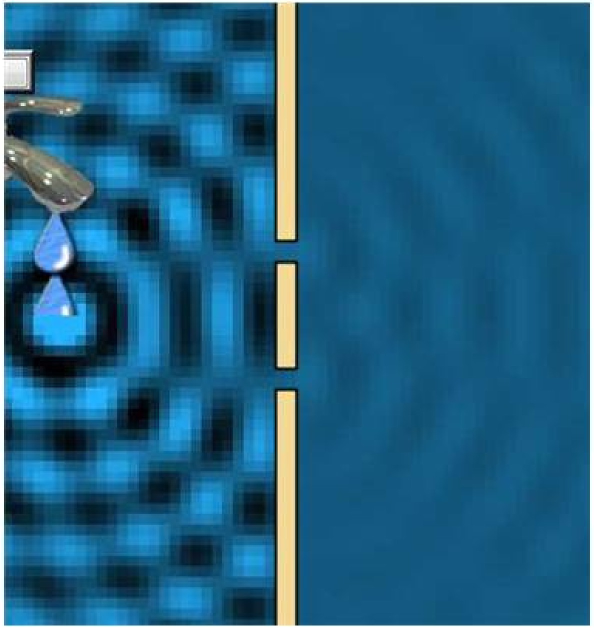
2D AND 3D WAVEFRONTS



Diffra





- The angle through which the direction of a wave-front is changed depends on the ratio $\lambda/\mathbf{a}$ where **a** is the width of the slit.
- For this effect to be noticeable the opening must be about the same size as the wavelength of the wave. The smaller the opening the larger the ratio $\lambda/\mathbf{a}$ and the greater the degree of diffraction.

The Huygens principle

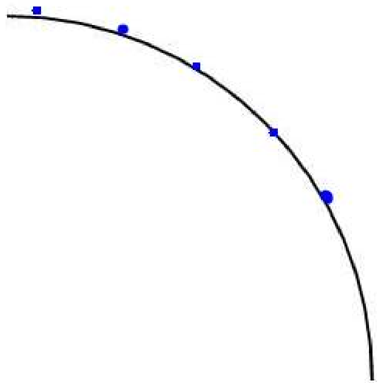
Christiaan Huygens described how to determine the path of waves through a medium.

Definition 1: *The Huygens Principle*

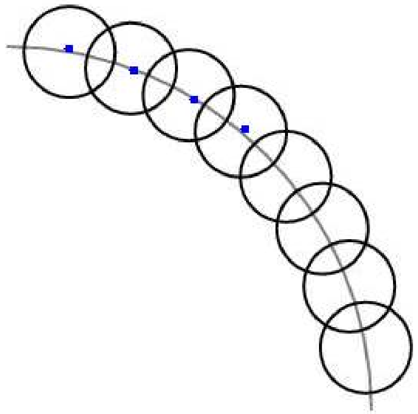
Each point on a wavefront acts like a point source of circular waves. The waves emitted from these point sources interfere to form another wavefront.

Wavefr

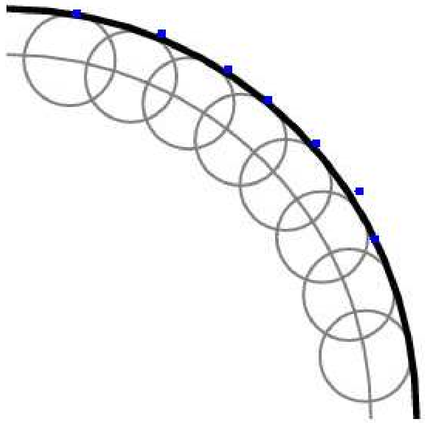
Given the wavefront,



Draw circles at various points along the given wavefront



Join the circle crests to get the wavefront at a later time

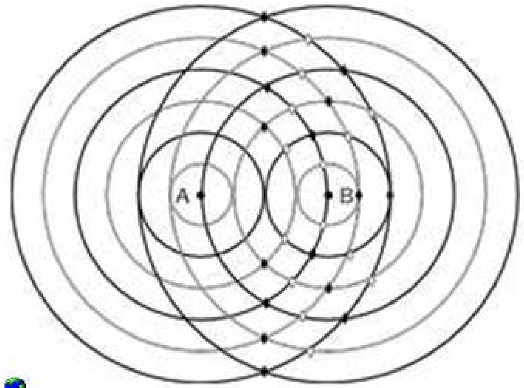


Wave

Interference

Interference occurs when two identical waves pass through the same region of space at the same time resulting in a superposition of waves. There are two types of interference which is of interest: **constructive** interference and **destructive** interference.

On half the picture below, we have marked the constructive interference with a solid black diamond and the destructive interference with a hollow diamond.



When they are coherent sources meaning that two sources must vibrate at the same frequency or the waves of a single source must pass through two narrow slits.

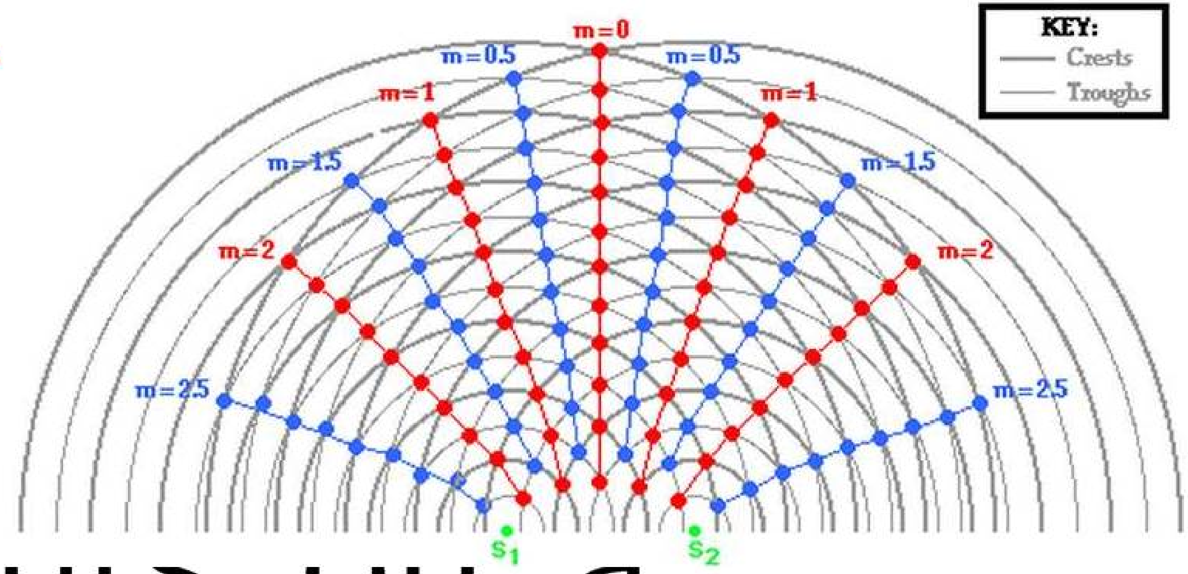
Way

(Note the path difference or PD is the difference in distance traveled by the two waves from their respective sources to a given point on the pattern.)

The

Nodes:

Anti

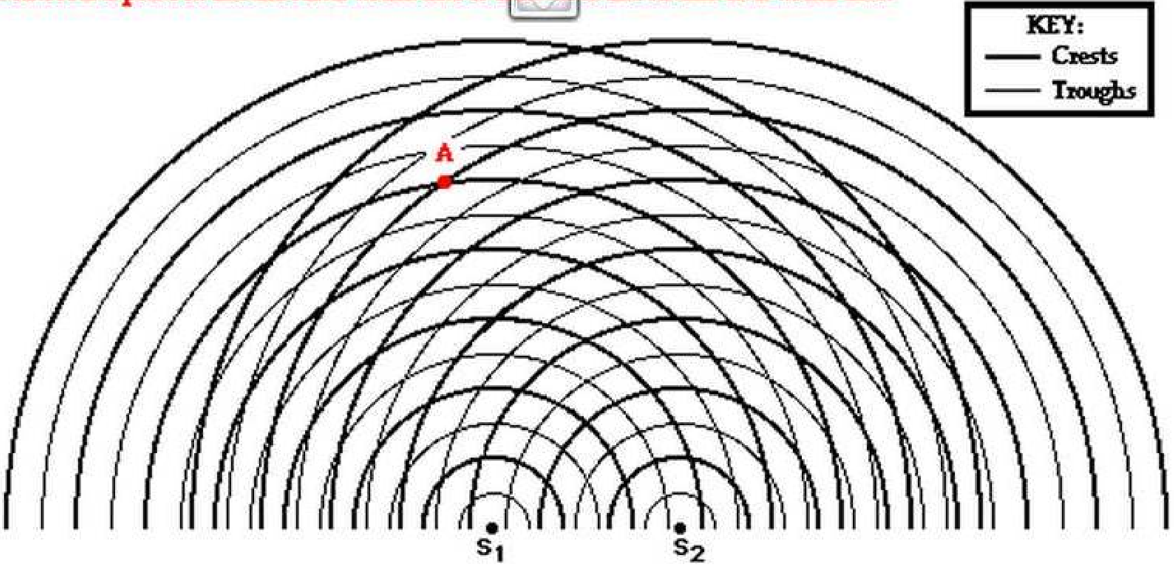


Pat

Points on a

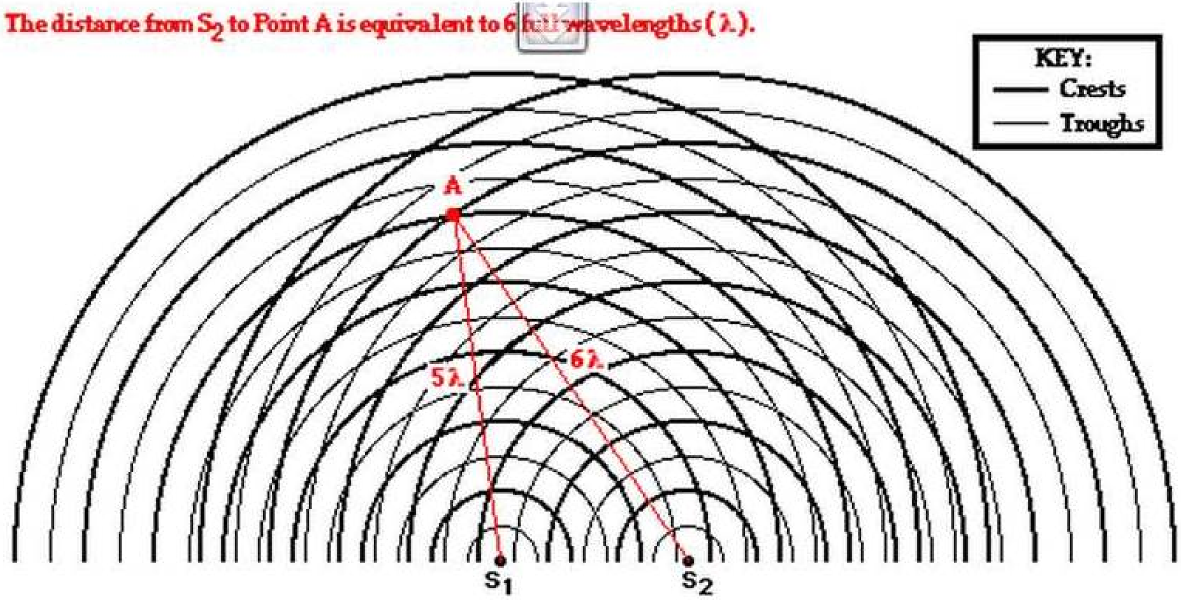
Points on a

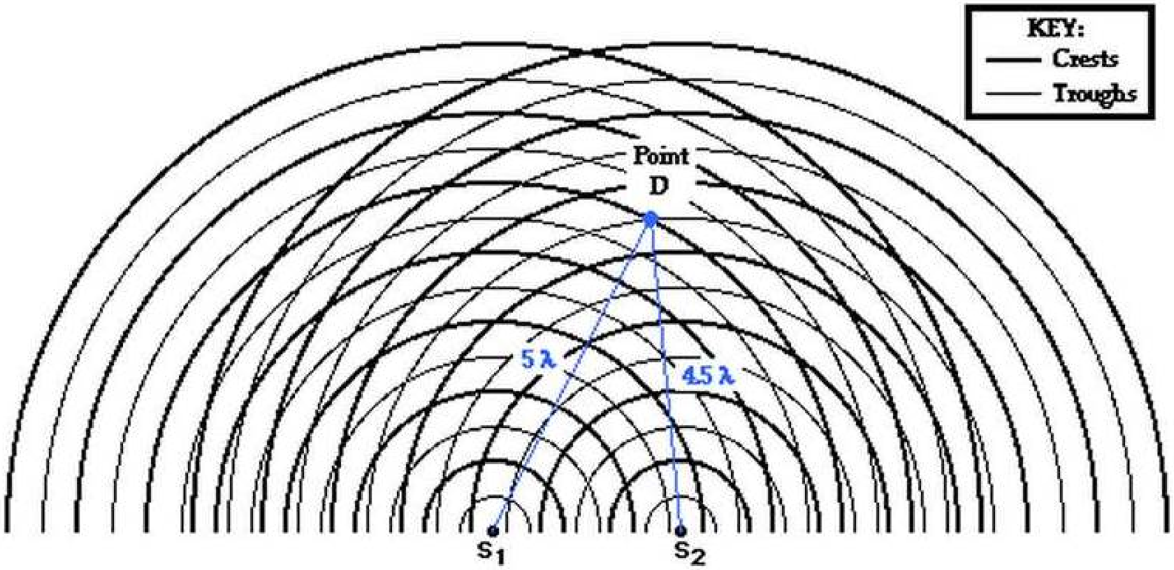
Point A is a point on the first anti-nodal line to the left of the central anti-nodal line.



$$PD = | S_1A - S_2A | = | 5\lambda - 6\lambda | = 1\lambda$$

(Note the path difference or PD is the difference in distance traveled by the two waves from their respective sources to a given point on the pattern.)

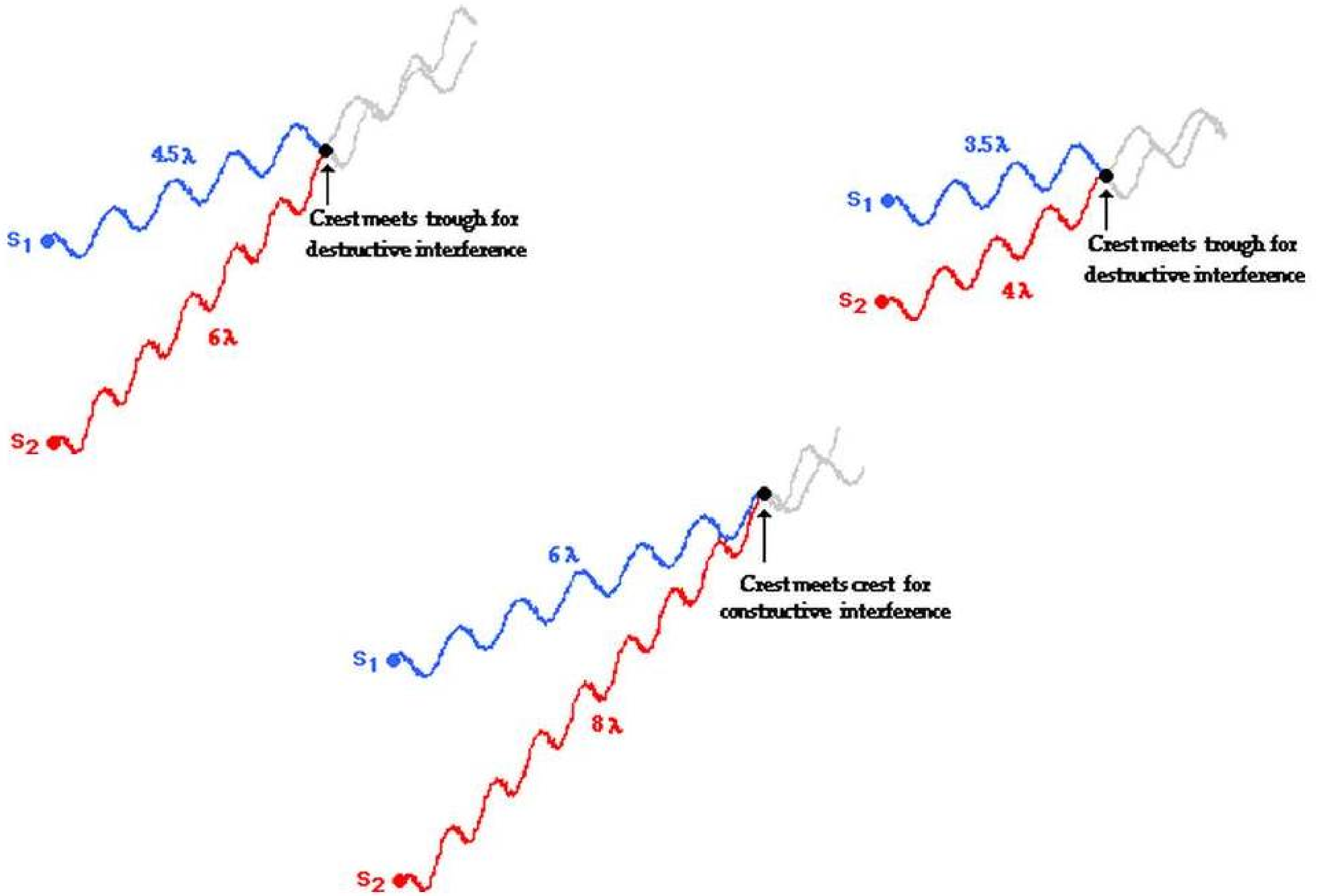




$PD = | S_1D - S_2D | = | 5\lambda - 4.5\lambda | = 0.5\lambda$

Summary of the Path Difference Analysis

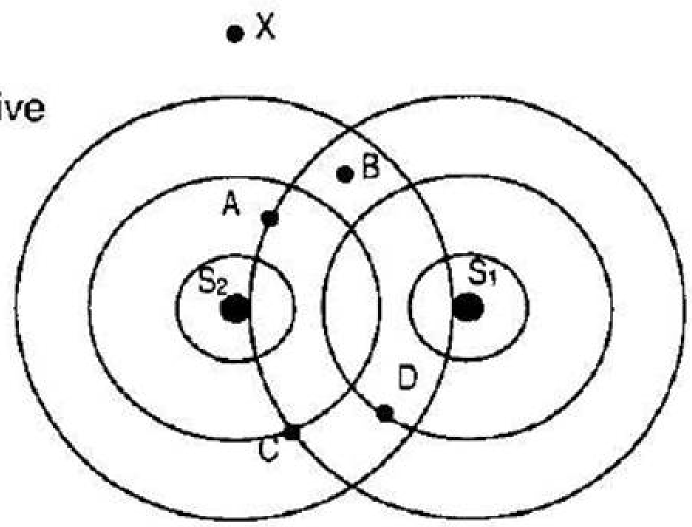
Point	antinode or Node?	Order # (m)	Distance from S_1 (in λ)	Distance from S_2 (in λ)	Path Difference (in λ)
A	Antinode	1	5 λ	6 λ	1 λ
B	Antinode	1	3 λ	4 λ	1 λ
C	Antinode	2	4 λ	6 λ	2 λ
D	Node	0.5	5 λ	4.5 λ	0.5 λ
E	Node	1.5	3.5 λ	5 λ	1.5 λ
F	Node	2.5	2 λ	4.5 λ	2.5 λ
G	Antinode	2	4.5 λ	6.5 λ	2 λ
H	Node	1.5	2.5 λ	4 λ	1.5 λ
I	Antinode	1	3.5 λ	4.5 λ	1 λ
J	Node	0.5	2.5 λ	3 λ	0.5 λ
K	Antinode	0	6 λ	6 λ	0 λ
L	Node	0.5	5 λ	4.5 λ	0.5 λ
M	Antinode	1	3 λ	2 λ	1 λ
N	Node	1.5	6 λ	4.5 λ	1.5 λ
O	Antinode	2	6 λ	4 λ	2 λ
P	Node	2.5	4 λ	1.5 λ	2.5 λ



4.5λ
S1
6λ
S2
Crest meets trough for
destructive interference
3.5λ
S1
4λ
S2
Crest meets trough for
destructive interference
6λ
S1
8λ
S2
Crest meets crest for
constructive interference

Type
Whole
Decim

8 The arcs or circles shown in the diagram represent the crests of two waves produced by two coherent sources.



8.1 What is meant by coherent?

8.2 Which of the points A, B, C, and D will have constructive interference?

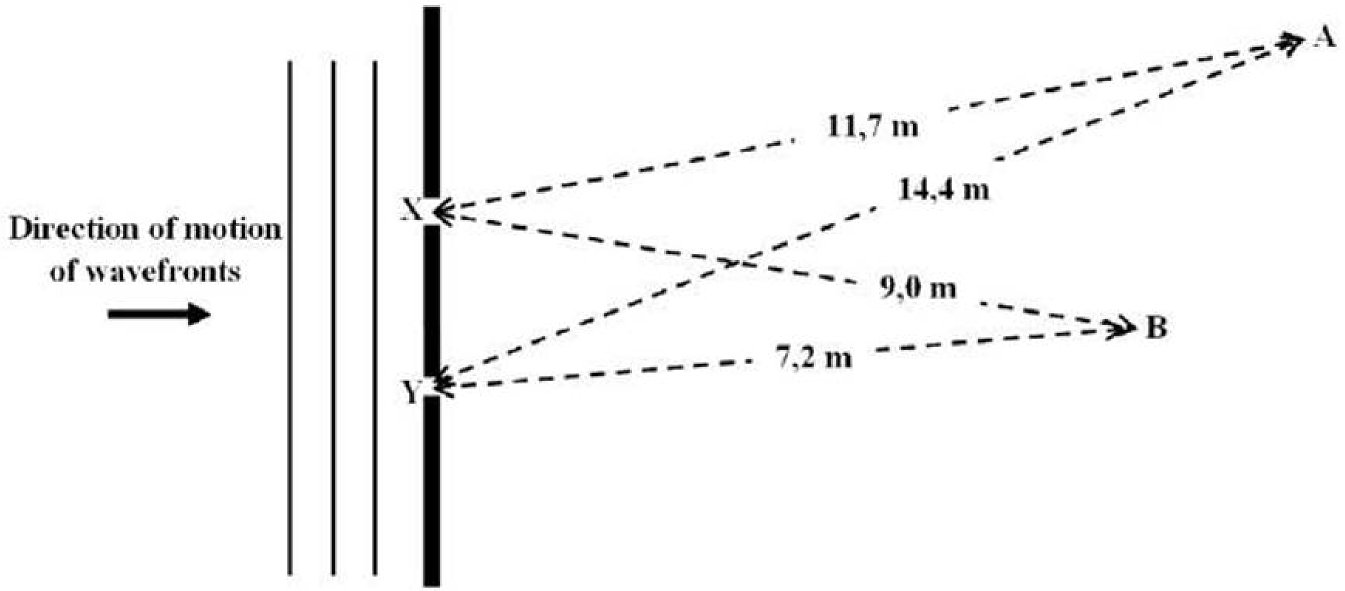
8.3 Which of these points will lie on nodal lines?

8.4 The waves have an amplitude of 0,5 cm and a wavelength of 4 cm. Draw diagrams to show the resultant wave at A, B, C, and D

8.5 Point X is 11 cm from S_2 and 13 cm from S_1.

8.5.1 Will these waves be in phase or out of phase at X?

8.5.2 Will the waves interfere constructively or destructively at X?



5.1 What is a wavefront? (2)

5.2 An observer on the banks of the pool notices that one of the boats is in a region of calm water while the other boat is undergoing large changes in vertical displacement as it bobs up and down in the water. By means of suitable calculations explain what type of interference is experienced by the water waves arriving:

5.2.1 at A and (3)

5.2.2 at B. (3)

5.3 Which boat will undergo large changes in vertical displacement, bobbing up and down in the water? (2)

[10]

5.1 A wavefront is an imaginary line that connects points on a wave that are in phase. (2)

5.2 5.2.1 No. of waves arriving at A from $X = \frac{11,7}{1,8} = 6,5$ (half number of waves)

No. of waves arriving at A from $Y = \frac{14,4}{1,8} = 8,0$ (whole number of waves)

Therefore waves will arrive at A **out of phase (crest meets trough)** and will undergo **destructive** interference. (3)

OR

Path difference between waves arriving at A from X and waves arriving at A from Y

$= (14,4 - 11,7) = 2,7$ m

No. of waves $= = \frac{2,7}{1,8} = 1,5$ →

Since the path difference corresponds to a **half number of waves (1,5 waves)** then they will arrive at A **out of phase** and will experience **destructive** interference.

5.2.2 No. of waves arriving at B from $X = \frac{9,0}{1,8} = 5,0$ (whole number of waves)

No. of waves arriving at B from $Y = \frac{7,2}{1,8} = 4,0$ (whole number of waves)

Therefore waves will arrive at B **in phase (trough meets trough or crest meets crest)** and will undergo **constructive** interference. (3)

OR

Path difference between waves arriving at B from X and waves arriving at B from Y

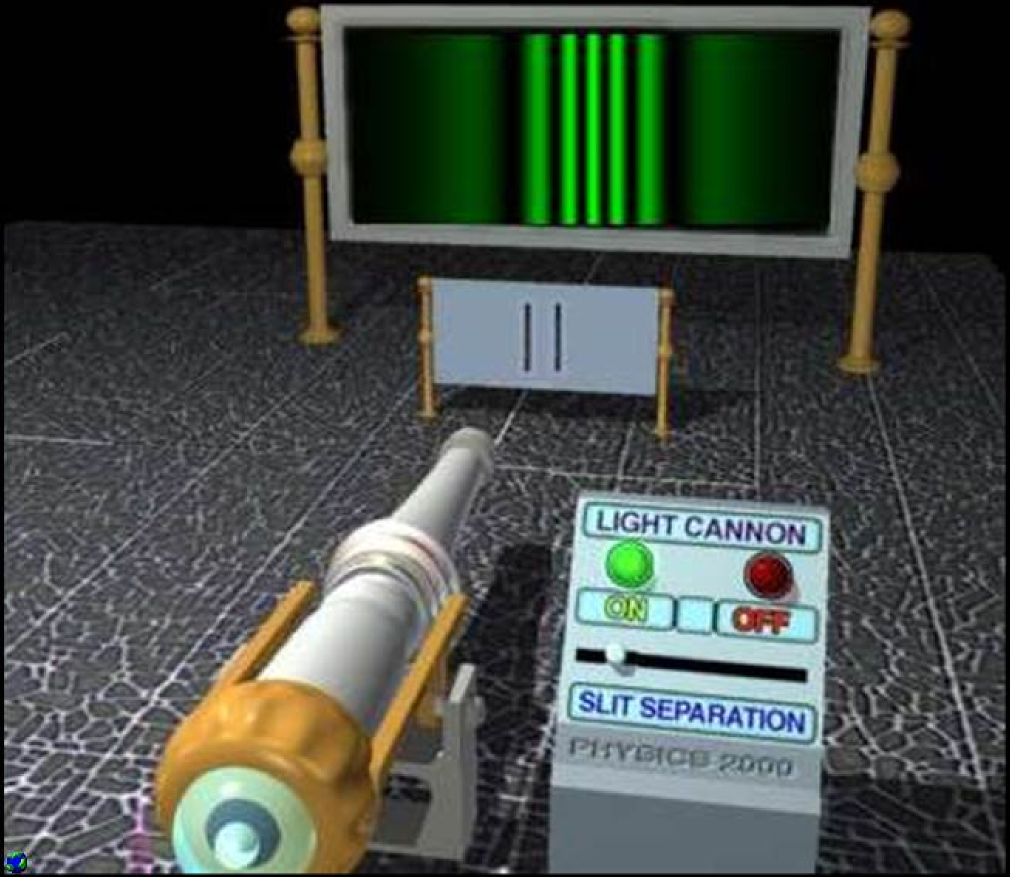
$= (9,0 - 7,2) = 1,8$ m

No. of waves $= \frac{1,8}{1,8} = 1,0$ →

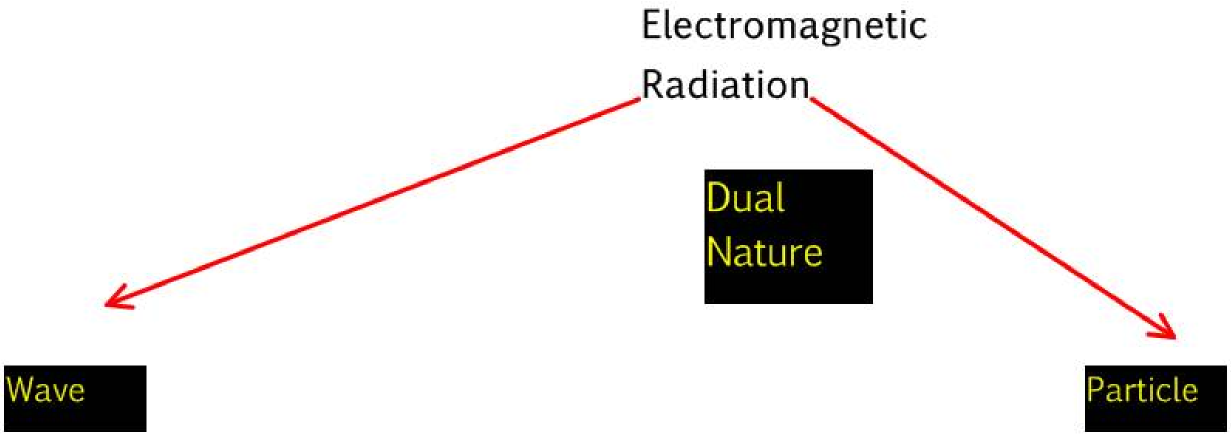
Since the path difference corresponds to a **whole number of waves (1,0 wave)** then they will arrive at B **in phase** and will experience **constructive** interference.

5.3 B (c.o.e. must agree with Question 5.2) (2)

[10]



Simulation web


Electromagnetic Radiation
Dual Nature
Wave
Particle

Characteristics of electromagnetic waves

- They are produced by oscillating charges.

- An oscillating electric field is at right angles
to an oscillating magnetic field.

- The two fields are in phase with each other.

- Electromagnetic waves are transverse waves.

- Electromagnetic waves do not need a physical medium to travel in.

- All electromagnetic waves travel at a speed of 3 X 108 m/s
(c).

- c = f . »

- Electromagnetic waves have a particle nature as well and the energy of the photons   E = h.

f

Electromagnetic waves and energy

- c = f . » and because c is a constant value, when f increases » decreases .
- E = hf , where h is Plancks constant. The higher the frequency of an electromagnetic wave, the higher the energy of the photons.

Proving that light (an electromagnetic wave) is also a transverse wave

Polaroid sheets have crystals of quinine iodosulphate deposited on them.

These crystals are needle-like in shape and have their axes parallel to each other.

The crystals transmit light vibrating in the same plane as the crystal axis and absorb light vibrating at right angles to this plane.