(For Counsellor's use only)

Grade . . . . Name . . . .

Evaluated by . . . . Enrolment Number . . . . .

EXPERIMENT 9

INTERFERENCE OF LIGHT - YOUNG'S EXPERIMENT

Structure

9.1 INTRODUCTION

Knowing about the nature of light will be helpful to us in many ways. In fact the knowledge of its behaviour helped us to use it in technology, medicine, industry, communication, cinematography, photography and in quite a number of useful areas.

Interestingly, people thought in the early days that light travels in straight lines only. Newton proposed the corpuscular theory of light which was found to be inadequate later.

It was Young who performed a very simple experiment but very significant one. That suggests that light is propogated by means of waves. Anyone, including you, can perform what Young did.

Since you are a science student you might have observed the fact that soap bubbles and also thin films of oil spread over water surface appear to be coloured. Later you would know that the reason for the above is due to interference of light which is the subject of this experiment, You will realise how simple is the Youngs experiment from the following description. It is shown in Fig.9.1

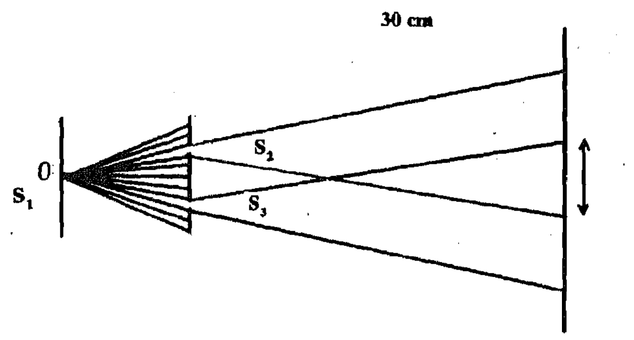

Fig 9.1

S is a source of light having single colour (called monohromaticsource). S_1, S_2 and S_3 are narrow rectangular parallel slits of width order of magnitute .03mm to .02mm. Light from each of the slits spreads out, and light from sources S_2 and S_3 overlap in the region X on the screen. In this interfering region one finds alternate bright and dark parallel bands of equal width, the bands being perpendicular to the plane of the figure and parallel to the slit opening. It is shown in Fig 9.7. This observation formed the basis for the wave theory of light.

Objectives

After performing the experiment you will be able to:

* Explain the phenonienon of interference.
* Measure the wave length of any given monochromatic source, using a Young's two-slit interference experiment.

9.2 APPARATUS

A monochromatic source like sodium vapour lamp.

A travelling microscope.

Glass plates 1mm or 2mm thick.

Kerosene lamp or any other lamp that could be used to smoke the glass surfaces.

Sharp edge like the tip of a shaving blade.

Meter scale.

9.3 BACKGROUND MATERIAL

YOUNG'S EXPERIMENT.

Assume two waves of equal frequency travelling inapproximately in the samedirection, having nearly equal intensities and having a phase difference that remains constant with time. Such waves combine so that their energy is not distributed uniformly in space but is a maximum at certain pointsand minimurnatother points. Young was able to measure the wave length of light from such an experiment.

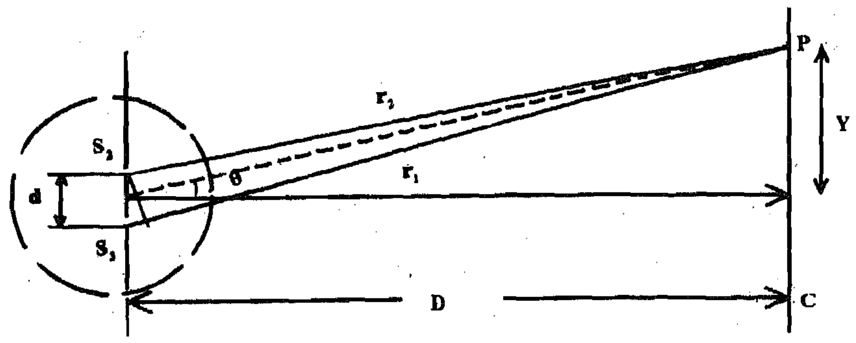

Fig 9.2

In Fig 9.2, S_3 and S_2 represent the narrow parallel slits separated from each other by a distance d. P is any point on the screen C. P is at distances r_1 and r_2 from the narrow slits S_3 and S_2 respectively. Draw a line from S_2 to b in such a way that the lines PS_2 and Pb are equal.' If the distance between the slits S_3 and S_2 is much smaller than the distance D then S_2b is almost perpendicular to both r_1 and r_2. This means that angle S_3S_2b is almost equal to angle Pao., in the Fig 9.2.

The two rays arriving at P from S_3 and S_2 are coherent since both are derived from same source S_1. Because the rays have different optical path lengths, they arrive at P with a constant phase difference. The number of wavelengths contained in S_3 b, which is the path difference, determines the nature of the interference at P i.e. whether it is a maximum intensity or minimum intensity at P.

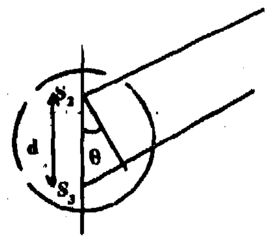

Fig.9.3

'To have **maximum** at P: (See Fig. 9.3)

S_3b = d sin θ - must contain an integral number of wave lengths (*mL*)

$S_3b = mL$ $m = 0, 1, 2, 3, ...$

Which can be written as

$d * \sin\theta \approx m * L$ $m = 0, 1, 2, 3, ...$ (1)

Note that each maximum above O in the' Fig.7.2, has a **symmetrically** located **maximum below** O.

The central maximum occurs at O for m = 0.

For minimum intensity to occur at P:

S_3b d sin 8 - must contain a half integral number of wave lengths. **i.e.**

$d * \sin 8 - = (m+1/2) * L$ m = 0, 1, 2, 3,.......(2)

From Fig. 9.2 if θ is small **enough** we can use the **following** approximation.

$\sin\theta - = \tan\theta - = \theta -$

We see that $\tan\theta - = \theta - = y/D$

Substituting this eqn in **Eqn.(1)** we get

$d\theta - = mL$
$dy/D = mL$
$y = mLD/d \quad m = 0, 1, 2, 3,..,$ (for maximum)

This positions of any two adjacent maxima are given by

$$Y_m = mL\,D/d \quad .... (3)$$

$$Y_{m+1} = (m+1)\,LD/d = (m+1)\,LD/d \quad .... (4)$$

Their separation W that is **the** width of a single fringe or band **is** obtained by subtracting equation (3) from eqn (4).

$$W = Y_{m+1} - Y_m = LD/d \quad .... (5)$$

From the above eqn L is given by

$$L = dW/D \quad .... (6)$$

9.4 PRECAUTIONS

Care should be taken to keep the centre slits S,, S_2 **and** S_3 and the eye piece in **the** travelling microscope are almost ina straight line. The **slits** S_1, S_2 and S, must all be parallel. Care **should** be taken to locate the eye piece in the region where light **from** S_2 and S, overlap. To do this, take out the eyepiece also, and look through **the microscope** tube. Move it. until both slits show **light.** Replace the eyepiece-fringes appear!

9.5 EXPERIMEN'E

AIM: To set up Young's Double slit Experiment and to measure the wave length **of** the monochromatic source (Sodium light)

9.5.1 Procedure

MAKING THE SLITS

First you should make rectangular slits of your own. Take two ordinary **transperent glass** plates (approximately) 3cm * **5cm** of **0.2** cm thick or any convenient dimensions. Using a kerosene lamp, smoke the two glass plates (one side only) to a convenient area so that the glass plate becomes completely opaque as shown in the Fig **9.4.a.**

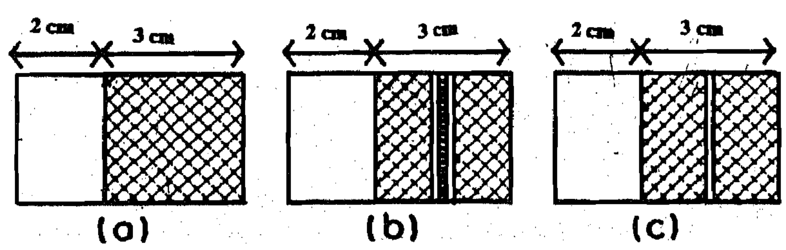

Fig 9.4

Take any two wooden strips of 5mm or 6mm thick. Place them apart on a plane table sufficiently apart-in order to place the smoked glass plate in between them. Place the scale over the two wooden blocks, then with a pointed tip (which could be the tip of a ball point pen or a blunt needle or blunt edge of a shaving blade) scratch the smoked surface by drawing a straight line with the help of the scale. This arrangement is shown in the Fig. 9.5. The transparent scratch mark acts as a rectangular slit. you draw two close-by lines. This acts as a double slit. As shown in Fig 9.4.b and 9.4.c, make a single slit and a double slit.

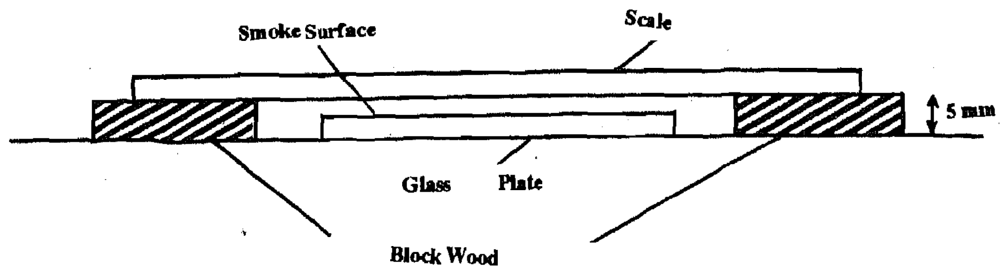

Fig 9.5

For performing Young's Experiment, we need a single slit a double slit and an eye piece. The widths of the slits should be as narrow as possible, say of the order of 0.02 mm. The length of the slit shall be about 2 cm. The distance between the centres of the closely spaced double slits shall be of the order of 0.05 mm. You can use the eye piece attached to any travelling microscope by removing the objective lens.

ADJUSTMENT TO GET INTERFERENCE FRINGES

Place the single slit in a clamp close to the sodium light (about 10 to 20 cms). Then place tbe double slit, you made, about 20-25 cms away from the single slit. The experimental set up is shown in the Fig 9.6.

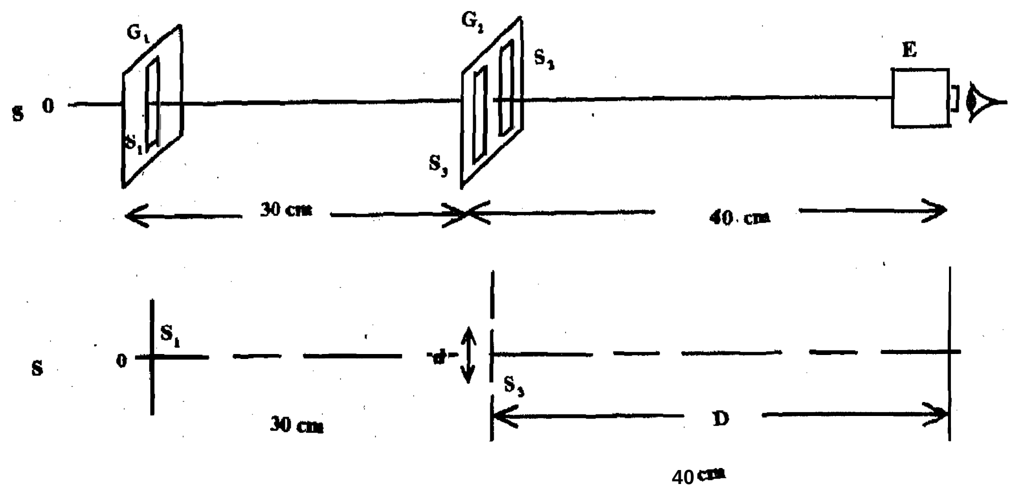

Fig 9.6

Place the eye piece of a travelling microscope (you can just remove the objective lens temporarily). So that S,, the mid point of S_2 and S_3 are in a line. You probably see the interference pattern of alternate bright and dark bands. If not rotate slightly either G, or G_2 about an axis perpendicular to the plane of the glass plates G, and G_2 while looking through the eye piece, until you get the interference pattern. In order to get sharp interference bands it is necessary that slit S_1 must be parallel to slits S_2 and S_3 and the widths of the slits shall be as narrow as possible.

9.5.2 Measurements and Tabulations

The wave length of light of the given source (monochromatic) is given by the equation (6)

$$L = dW/D \qquad \text{..... (6)}$$

Where: d is the distance between the centres of the double slits S_2 and S,.

D is the distance between the glass plate G,. (which is the plane which carries the double slit S_2 and S_3) and the position of the crosswire of the eye piece E.
W is the width of the band (either dark or bright).

MEASUREMENT OF 'd' THE DISTANCE BETWEEN THE CENTRES OF THE TWO SLITS S2 AND S3;

The travelling microscope with the objective lens (replaced back), could be used for measuring d. The glass plates G, is held with the help of a stand and clamp such that the plane of the glass plate, G_2 is vertical which contains the slits S_2 and S_3. The axis of the microscope is kept in the horizontal position. The microscope is focussed on the slit S_2. Its position on the horizontal scale is noted. Again the microscope is focussed on the slit S,. Its position on the horizontal scale is noted. The difference between the two positions give the distance between the two slits S_2 and S_3 and that is d. Tabulate the observations in the tabular form I.

TABLE I

MEASUREMENT OF THE DISTANCE d BETWEEN THE TWO SOURCES S_2 AND S_3.

Position of the Microscope when the vertical cross wire coincides with the centre of the		The distance between centres of the two slits S_2 and S_3
Slit S_2 cm	Slit S_3 cm	d cm

The mean value of d = cm.

MEASUREMENT OF W AND L

Again remove the objective lens from the microscope, and observe the interference "fringes".

Make the vertical cross-wire of the eye piece to coincide with the centre of any of the dark or bright fringe. Consider it as the mth order fringe (band). See Fig 9.7

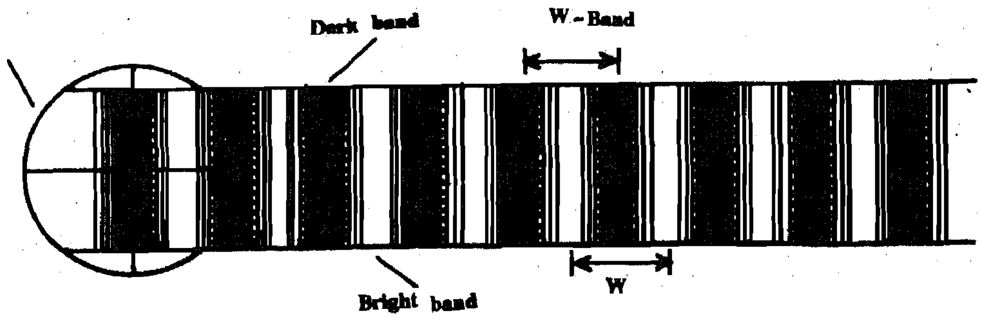

Fig 9.7

Note the initial position of the eye piece reading of the microscope. Then move the eye piece lateral to the direction of light rays from the slits such that the alternate bright and dark bands cross the field of view. Count them by watching the number of fringes shifted. Then make the cross wire to coincide with the $(m+n)$, fringe, n could be 10 or 11. Note the reading on the travelling microscope which gives the final positions of the eye piece corresponding to the (m $+n$), fringe. The difference between the initial and final positions of the eye piece will give the width of n fringes. Hence calculate the width of one fringe W. Tabulate the readings. The tabular form is shown in Table II.

D - The distance between G_2 (containing sources S_2 and S_3) and the position of the crosswire in the eye piece.

P_1 - The position of the eye piece in the horizontal scale of the travelling microscope when the vertical crosswire coincides with the mth order bright fringe.

P_2 - The position of the eye piece in the horizontal scale of the travelling microscope when the vertical crosswire coincides with the $(m+n)_{th}$ order of the bright fringe.

n - The number of fringes that has shifted in the field of view when the position of the eye piece is shifted from P, to P_2.

W_s - Widtb of the fringes

W - Widtb of one fringe.

L - The wave length of the source light [L = $(d/D)*W$]

TABLE II

MEASUREMENT OF THE WIDTH OF THE FRINGE W AND THE WAVE LENGTH L

D cms	P_1 cms	P_2 cms	n	W_s cms	W cms	L nm

Mean value of L = nm
The standard deviation = nm
The wave length of the source of light =

What will happen to the widths of the fringes if d the distance between the two slits S_2 and S_3 is increased or decreased? Find slits of other students which have a different separation, and observe the figures. Answer the question, and explain.

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SAQ's

1. Why do the fringes in **Young's** experiment have equal width?

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2. Suggest' any other method to produce interference of light waves.

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3. **Can** interference be **observed for** (a) sound waves? (b) **radio** waves? Give reason.

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4. If the sodium light is replaced by a filament **bulb what** will you observe on the screen? Try, and verify your idea. Record here What you find.

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9.6 CONCLUSIONS

The alternate bright and dark bands obtained due to two closely spaced slits suggest that the light propagates by means of waves. This method helps to **determine** the wave length of a given monochromatic source.