Experimental Physics - II
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Lecture – 34
Bi – Prism

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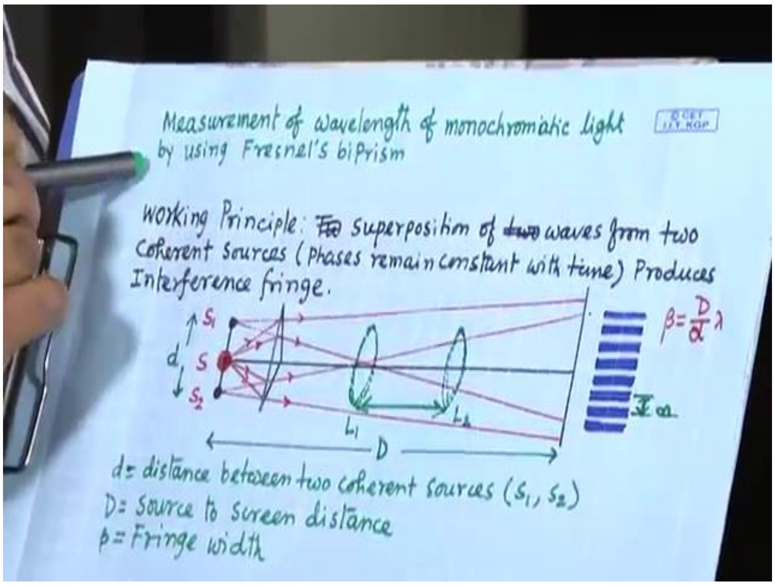

Measurement of wavelength of monochromatic light by using Fresnel's biPrism

Working Principle: superposition of ~~two~~ waves from two coherent sources (phases remain constant with time) Produces Interference fringe.

d = distance between two coherent sources (S_1, S_2)
D = Source to Screen distance
β = Fringe width

today we will demonstrate how to measure the wavelength of monochromatic light by using Fresnel's bi Prism. actually you know this for this is the experiment for interference. for interference we need two coherent source from this two coherent source, when waves will come out from this source and they will super impose with each other. super position of this two waves coherent waves we will form the; will interfere and form the fringe pattern bright dark bright dark this type of fringe pattern this type of fringe pattern only form,

now this fringe pattern carries lot of information measuring the fringe width and other parameters one can find out the wavelength of the light which is used for the experiment. two individual source if you use they are not coherent. to get the coherent source from single source we have to produce two source that is the Young's double slit experiment; Young's double slit experiment in that experiment you know that from a single source this light is coming then in front of that source this two Fresnel two hole was used. from these two hole this light was coming. this two hole this two source and it is generated from the same source. these two are coherent.

to observe the interference from a single source we have to produce two source and light from these two source will interfere will super impose and we will see the interference to produce two source there are different method. one of them is the bi-prism here you can see this is the bi prism; this is the bi prism this two prism is their base are attached and this angle is merely 180 degree it is a 179.5 degree given and this is also very thin, bi prism; that means two prisms are there.

in front of this bi prism if you have a source S; if you have a source S now from source S this light will fall on the bi prism. from upper half this is the refracted light; this is the refracted light now if you. they are diverging if you extend backside. they will meet here. as if this light is coming from this S 1this is the virtual source and light from the lower half of this prism bi prism. again the same way; refracted light is diverging light and they are if you extend back side they are meeting here this is another virtual source.

that from two prism bi prism we can generate from same source, we can generate two virtual source S 1 and S 2. this is the use of bi prism to produce the virtual source; produce the virtual source two source S 1 and S 2. if the distance between these two source, now we can say that this is the S 1 and S 2 our source the distance between these two source is the and now this rays coming from the S 1 and S 2, S 1 is to a coherent source. this light will interfere and will get the interference fringe, interference pattern. where we will see? We will see on a screen.

this is the screen, this is the screen on the screen you will see the interference pattern fringe. this type of fringe you will see on the screen. dark bright dark bright dark b this type of fringe you will see here really for this geometry we will get straight line it is a nothing, but this image of this source you know. this source is lead source. you will see this linear; bright lines and between two bright lines there will be dark region. bright lines are separated by dark lines.

there is a bright lines we tell this constructive interference and dark lines we tell that is the destructive conference interfere. if the fringe width; fringe width separation of this two dark lines or separation of two bright lines, there is the fringe width, if this fringe width is beta and the source and screen distance is capital D; it is capital D then the relation is that fringe width beta equal to this capital D divided by small d into lambda; what is lambda? Lambda is the wavelength of light from this source.

using the bi prism we are fulfilling the condition for interference, we are getting two source, we are deriving two source from the same source they are coherent; we will see the interference on a scale Now if we can measure the fringe width and the distance between the source and the screen capital D and then small d that is the distance between the two source in this case the virtual source. we can find out we can calculate the wavelength lambda.

to determine to measure the wave length of this monochromatic light, monochromatic light means it has one single wavelength by using Fresnel's Bi prism. you need this arrangement and in that arrangement you should be able to measure the fringe width and this is the from optical table itself there is a scale from there. virtual source it will be on the same plane of the actual source, actual source that slit where ever I put

that distance also you can get easily and on screen you will see the fringe and that fringe width also you can measure that is not difficult task. Now difficult task is to measure the small d distance between the two source virtual source, since they are virtual we cannot see them how to measure this d?

for this you; we use convex lens convex lens Now you know that convex lens if I put here. this light is coming this light are coming; they; these two from virtual this two source will get real image of this two source on a screen real image of the source of the source virtual source on a screen.

Now, if screen and the source distance is greater than 4 f of this focal length of this lens, then you know that for two position; for two position of the lens we will see the we will see the image real image on the screen. we will fix the screen at a distance from the source greater than 4 f, now we will use this convex lens and move it to get two position of this lens; to get two position of this lens to see the image; real image for the source for each position of the lens.

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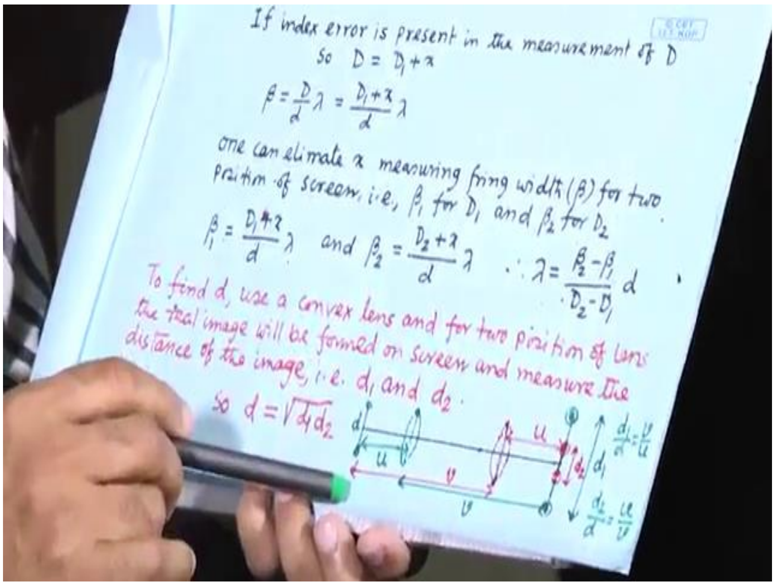

If index error is present in the measurement of D

So $D = D_1 + x$

$$\beta = \frac{D}{d}\lambda = \frac{D_1 + x}{d}\lambda$$

one can elimate x measuring fring width (β) for two position of screen, i.e., β_1 for D_1 and β_2 for D_2

$$\beta_1 = \frac{D_1 + x}{d}\lambda \quad \text{and} \quad \beta_2 = \frac{D_2 + x}{d}\lambda \quad \therefore \lambda = \frac{\beta_2 - \beta_1}{D_2 - D_1} d$$

To find d, use a convex lens and for two position of lens the real image will be formed on screen and measure the distance of the image, i.e. d_1 and d_2.

So $d = \sqrt{d_1 d_2}$

I have described here this method; I have described here this method this is the source two source and now this is the screen. this is the lens for this position of lens you will get image virtual real image of the source on the screen. on the screen you will see this real image; you will see this real image you can measure the distance between these two real image.

if it is d 1 and for second position of the lens if that distance it will be smaller; the size of the image or distance between this two source that will be smaller if it is that distance is d 2, then d this d equal to square root of d 1 d 2. how it comes?

actually this is the u for first position of the lens this is the; if this is u and this other one is v for second position of the lens; when you are getting image. this will be u actually this is the [vocalized-noise] object distance but magnitude will be equal object distance this now this magnitude will be equal to v whatever for first position of the lens whatever the image distance was there. it will just reversed this distance will be v, we are writing v, but it is actually u, but in magnitude vise this equal to this v. v and this will be distance of the image that magnitude will be u.

you know magnification; of the object is if this is the height d 1 and actual height is d d 1 by d equal to v by u similarly d 2 by d equal to just it will be just opposite u by v, image distance divided by object distance. for this position it just magnitude wise it is a reverse. if you multiply this two; d 1 into d 2 by d square equal to v by u into u by v equal to 1. d square equal to d 1 into d 2 d equal to square root of d 1 d 2. using this method we have to find out d.

small d we can we could find out and then capital D that is the easy to find out and also we have to measure beta fringe width. then if you consider that there is a index error present in the measurement. we can actually in the measurement of D. actually we can eliminate this error’s this way D is equal to D 1 plus x. this is the correction for index error.

beta equal to we know d capital D by small d lambda equal to D 1 plus x by small d lambda, this is the D is distance between the source and screen. if we measure the fringe width for two distance D 1 and D 2, for D 1 and D 2. beta 1 equal to this and beta 2 will be equal to this

if you subtract this two; beta 2 minus beta 1 will be equal to D 2 minus D 1 and then d is there x will be eliminated. then you will get lambda equal to beta 2 minus beta 1 divided by D 2 minus D 1 into d. this will take as a working formula beta 2 minus beta 1 divided by D 2 minus D 1 into this d and what is this d small d. that is square root of d 1 d 2, ok; how to find that I explain.

we need the arrangement for this experiment as from working principle we could see, this is the working formula and how it has come that we know. for that we have to arrange the experiment and you need experimental data recording.

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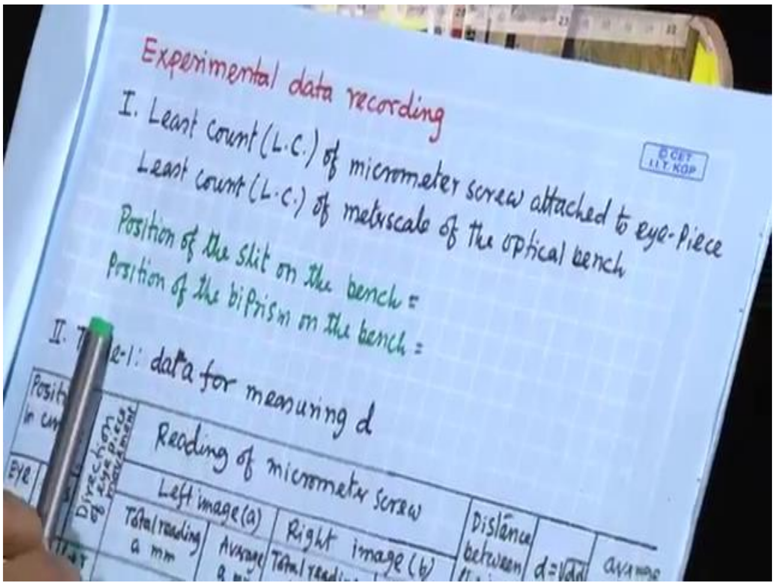

Experimental data recording

I. Least count (L.C.) of micrometer screw attached to eye-piece

Least count (L.C.) of meterscale of the optical bench

Position of the slit on the bench =

Position of the biprism on the bench =

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II. T e-1: data for measuring d

Posit in cm		Direction of eye piece movement	Reading of micrometer screw				Distance between	d=√dd	average
			Left image (a)		Right image (b)				
Eye			Total reading a mm	Average	Total readi				

you have to measure the fringe width right; they are we will use micrometer of attached with the eye piece. least count of the micrometers screw attached with the eye piece. that least count we have to note down also you have to measure the capital D, least count of the meter scale of the optical bench that we have to note down then position of the slit on the bench that we have to note down. Then position of the bi prism on the bench that we have to note down because these two when we fixed these two really will not change. just we will note down this.

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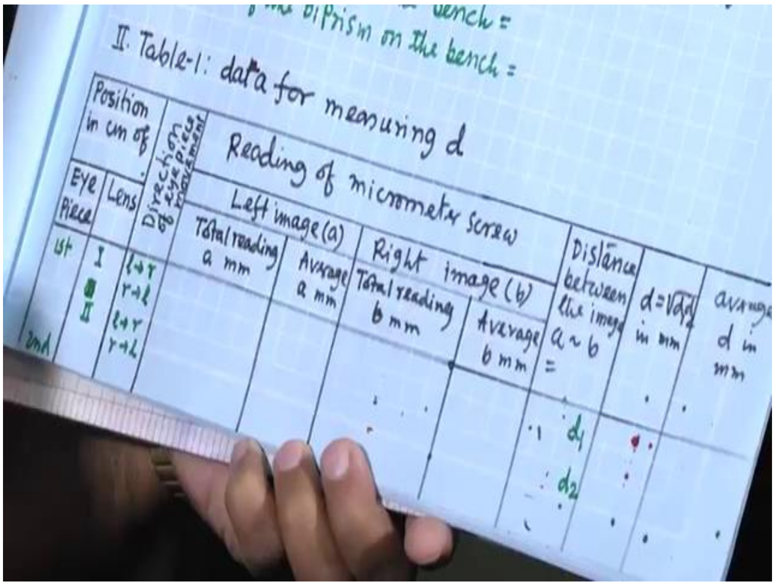

biprism on the bench =

II. Table-1: data for measuring d

Position in cm of		Direction of eye piece movement	Reading of micrometer screw				Distance between the image a ~ b =	$d=\sqrt{d_1 d_2}$ in mm	average d in mm
			Left image (a)		Right image (b)				
Eye Piece	Lens		Total reading a mm	Average a mm	Total reading b mm	Average b mm			
1st	I	l→r					d_1		
		r→l							
	II	l→r					d_2		
2nd		r→l							

Then we have to; what we have to measure? We have to measure small d, we have to measure bets ok, beta 1 beta 2 for two different position of screen and d 1 d 2 we have to measure,

this is the table for recording the data for measurement of d. why I am discussing this table? From table itself you can understand that is in which step we should follow position in centimeter of eye piece, we will use eye piece and lens position. eye piece is screen, what about I discussed? there whatever I told screen. that is eye piece with the eye piece there is a cross wire. that cross wire is at the focal point of this eye piece.

that cross wire, that focal plane will act as a screen. here position of eye piece then means screen then lens position; lens position for position I and positon II and here we have written direction of eye piece because this fringe width generally or this image this length it is very small.

direction of eye piece movement means we will take; we will see the image. we will move the eye piece from left to right and during that we will take reading and again we will move to right to left then again we will take reading and then we will take the average of the reading that is the idea. for lens position 1 left to right, what is the reading right to left what is the reading. we will note down then we will find out the average. And then this is a for the left we will see the image, two image right real image of virtual source.

for image 1 or image 2 or left image or right image reading of the micrometer screw; that is a reading of this left image a and reading of the right image b. both reading we will take twice when we will move the micrometer from left to right and again right to left, and we will find out the average. that is reading a and b for position of the left image and right image.

distance between the image will be difference of this two reading a and b. that is for position of the lens 1 that will be d 1 and for the position of the lens 2 that will be d 2. you can calculate this d is square root of d 1 and d 2. then now you go for the second position of the eye piece means screen.

that is that d 1 distance; d 1 distance for first position and d 2 distance for second position, It is not necessary that d 1; these d 1 and d 2 is for the we will use same d 1 d 2 for this fringe measurement that can be different, but for second position of the screen. Again we will repeat the measurement this is for the averaging mores sets of data for second position for third position of the screen just keeping without disturbing the slit position and the bi prism position, only changing the distance of the screen means eye piece,

for different distance between the source and the screen we can repeat the experiment and then we can find out the average small d. for finding out the small d this table we have to follow and then next we will go for the second table; that data for fringe width.

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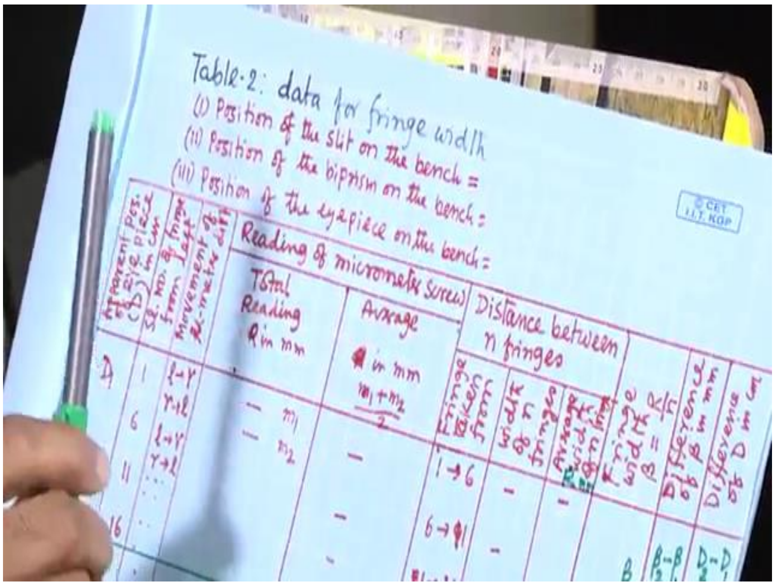

Table-2: data for fringe width
(i) Position of the slit on the bench =
(ii) Position of the biprism on the bench =
(iii) Position of the eyepiece on the bench =

Apparent pos. of eye piece (D) in cm	Sl. No. of fringe	Movement of micrometer from left	Reading of micrometer screw: Total Reading R in mm	Reading of micrometer screw: Average in mm $\frac{m_1+m_2}{2}$	Distance between n fringes: Fringe taken from	Distance between n fringes: width of n fringes	Distance between n fringes: Average width of n fringes	Fringe width β = R/n	Difference of β in mm	Difference of D in cm
D	1	l→r	— m_1							
	6	r→l	— m_2	—	1→6	—	—			
	11	l→r								
	16	r→l		—	6→11	—		β	$\beta_2-\beta_1$	D_2-D_1

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here again position of the slit on the bench position of the bi prism on the bench will note down, but that will not disturb, because for that position only if we found the small d we cannot disturb this one. only position of the eye piece means screen for a particular position of the screen we will do the experiment. now we do not need the lens we will remove the convex lens, now we know from convex lens experiment. we have we know that there are two sources what is the distance between these two source that is known to us.

Now, for this two coherent source, we will get the interference and that interference pattern we will see on the screen that is on the eye piece. Now we have to take we have to measure the fringe width. for that this table will use.

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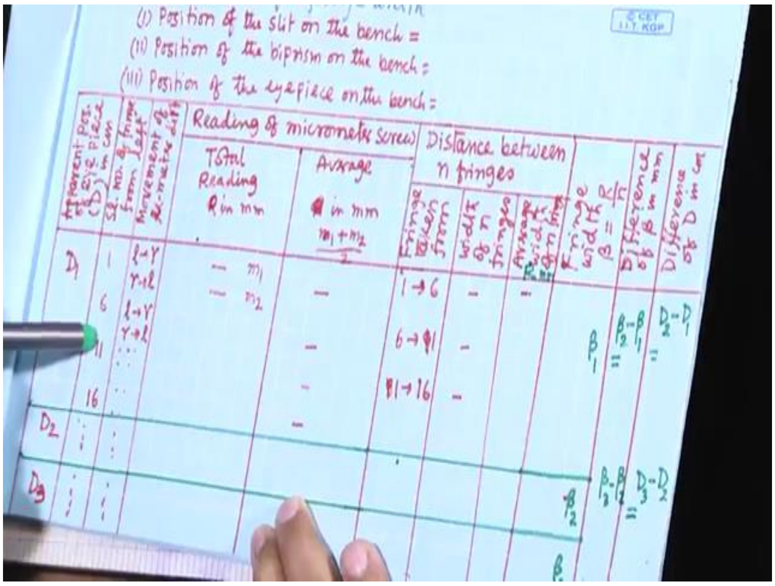

(i) Position of the slit on the bench =
(ii) Position of the biprism on the bench =
(iii) Position of the eyepiece on the bench =

Apparent pos. of eye piece (D) in cm	Sl. No. of fringe from left	Movement of micrometer	Reading of micrometer screw: Total Reading R in mm	Average in mm $\frac{m_1+m_2}{2}$	Distance between n fringes: Fringe taken from	width of n fringes	Average width of n fringes	Fringe width $\beta =$	Difference of β in mm	Difference of D in cm
D_1	1	l→r	— m_1							
		r→l	— m_2	—	1→6	—	—			
	6	l→r r→l								
	11	⋮		—	6→11	—		β_1 =	$\beta_2-\beta_1$ =	D_2-D_1 =
	16	⋮		—	11→16	—				
				—						
D_2	⋮	⋮								
D_3	⋮	⋮						β_2	$\beta_3-\beta_2$ =	D_3-D_2
								β_3		

again this position of the eye piece say D1 we will keep the eye piece at a position particular position. that distance from the source of this eye piece is d 1 and for that we will measure we will see the fringe on the eye piece; we will see the fringe on the eye piece

now what we will do? We will just serial number of the fringe from the left. what about the visible fringe so on the left? On the left we will fix the crosswire with a fringe from left side and then we will move from left to right; we will move from left to you can take the reading of fringe if first one is 1, then 2, 3, 4, 5 that way, but generally I prefer to take; generally I prefer to take this fringe one and then 2, 3, 4, 5 then 6th one I will take reading of the 6th one then again 11th one then 16th one.

this way I will take reading when I am moving the cross wire from left to right From left to right, left to right this reading first I will note down then from right to left again I will move I will come back. when I am coming back then I will take reading. right to left right to left.

then we will take the average of this left to right and right to left this reading we will take the average one of average 1 here m 1 plus m 2 divided by 2 for left to right and right to left and then we will calculate the fringe width for that distance between n fringes. I have reading for first fringe and then 6th 11. reading difference between this first and 6th one that is the width of n fringe in this case n is 5. I will note down and then I will note down for the second one 6 to 11, what is the difference of this two reading that I will take that is how our five fringe whatever the width.

I will note down and then next five fringe, I will note down I will find out this width of n fringes means in this case five fringes. And then I will take the average of this. from there if this is r; it is r fringe width will be R by n, n in this case is 5 I will get the beta 1.

similarly I will repeat the experiment for second position of the eye piece means; for second position of the screen. if it is D 2 this position this distance between the source and the screen that is eye piece if it is D 2 for that I will repeat the experiment. fringe width will be different that is d 2 for the third position of the eye piece means screen I will repeat the experiment I will get beta 3 different fringe width.

Now, beta 2 minus beta 1 this is one set I will get for D 2 minus D 1 for this distance of the difference of D in centimeter. this is D 2 minus D 1 beta 2 minus beta 1 I will get and second set I will get beta 3 minus beta 2 equal to D 3 minus D 2. So; that means, what about the working formula was there lambda equal to beta 2 minus beta 1 divided by D 2 minus D 1 into small d Small d already we know and from this table we know beta 2 minus beta 1 and d 2 minus d 1. we can calculate lambda.

and then for second set we will get another lambda. we will take average of this two or you can do more you can take average of them that will be the your wavelength of the light whatever we have used in the experiment.

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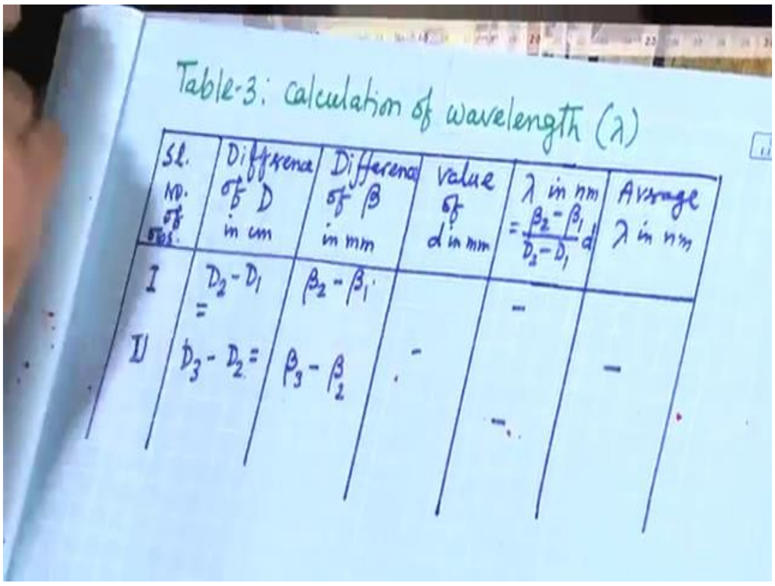

Table-3: calculation of wavelength (λ)

Sl. No. of obs.	Difference of D in cm	Difference of β in mm	value of d in mm	λ in nm $= \frac{\beta_2 - \beta_1}{D_2 - D_1} d$	Average λ in nm
I	$D_2 - D_1 =$	$\beta_2 - \beta_1$		–	
II	$D_3 - D_2 =$	$\beta_3 - \beta_2$	–	–	–

calculation of the wavelength as I mentioned you; D or D 2 minus D 1 and beta 2 minus beta 1 value of d is from first table lambda you are calculating average lambda we will get.

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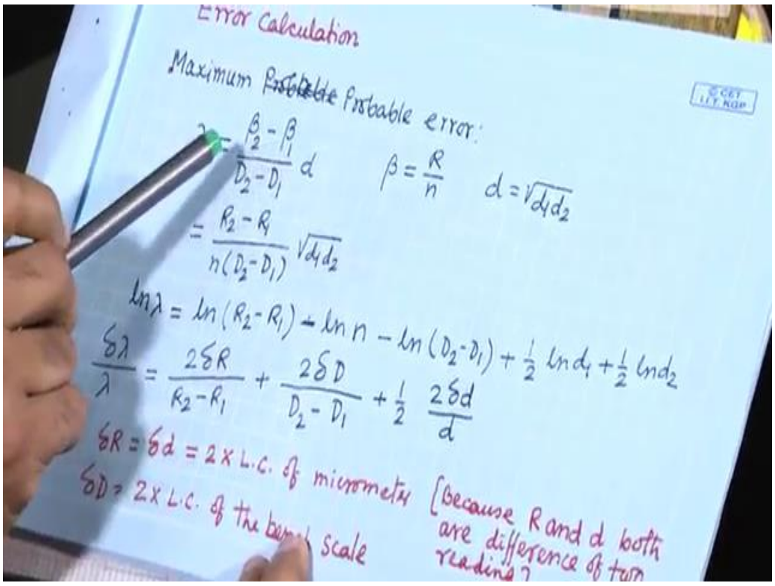

Error Calculation

Maximum ~~Probable~~ Probable error:

$$\lambda = \frac{\beta_2 - \beta_1}{D_2 - D_1} d \qquad \beta = \frac{R}{n} \qquad d = \sqrt{d_1 d_2}$$

$$= \frac{R_2 - R_1}{n(D_2 - D_1)} \sqrt{d_1 d_2}$$

$$\ln\lambda = \ln(R_2 - R_1) - \ln n - \ln(D_2 - D_1) + \frac{1}{2}\ln d_1 + \frac{1}{2}\ln d_2$$

$$\frac{\delta\lambda}{\lambda} = \frac{2\delta R}{R_2 - R_1} + \frac{2\delta D}{D_2 - D_1} + \frac{1}{2}\frac{2\delta d}{d}$$

$\delta R = \delta d = 2 \times$ L.C. of micrometer [Because R and d both are difference of two reading]

$\delta D = 2 \times$ L.C. of the bench scale

then you have to do error calculation, let me tell you. this is your working formula where even not measuring the sum parameter directly. actually what is beta you related with the measurement? that is equal to R by n; what is R? R is the fringe r width of the total width of the n fringe. for one fringe what will be the width R by n. we have measured not beta directly, we have measured R and n and for small d also we have not measured d directly it is calculated. actually we have measured d 1 and d 2.

this lambda is equal to then if you put the parameter which we have measured directly. that is R 2 minus R 1 divided by n into D 2 minus D 1 into square root of d 1 d 2. just take log of it. log n equal to log R 2 minus R 1 minus log n minus log D 2 minus D 1 plus half log d 1 plus half log d 2, then differentiate del lambda by lambda equal to. error in both case is the same and error is additive.

delta R 2 plus delta R; 1 by R 2 minus R 1 and then delta R 2 plus delta R 1. it is a since the error are same least count are same for both cases. we have written 2 delta R similarly plus since error are additive; that is why we have to add them. minus we cannot write here minus. why you know we have find out maximum probable error. that is why all will be added.

in this case again 2 del D by D 2 minus D 1, again same logic why we have written 2 del D plus half 2; this 2 del d by d. del R equal; del R and del d that is least count of the micro meter and this each reading R and d when we are finding out then we are taking difference of two reading. error will be twice. that is why two into least count of micrometer.

Similarly, del capital D this is the least count of the optical scale meter scale of the optical table. again this d capital D that is also difference of two reading. that is why least count will be 2 into least count of the del scale. from data one can actually calculate the error in the measurement of wavelength. I will stop here. in next class I will demonstrate this experiment based on this discussion here.

Thank you for your attention.