Experiment Name / No.: Activity No-1:- Units, errors and graphs

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1) Units

Every physical quantities requires the measurement of one or more quantities. There are 3 fundamental units → length, mass and time

The systems of fundamentals units in common are :-

(i) The MKS system - The unit of lengths, mass and time on this system are metre, kilogram & second respt

(ii) The CGS system - The units of length, mass and time on this system are centimetre, gram & second resp

1 cm = 1/100 m ; 1 g = 1/1000 Kg

S.I units of 6 fundamentals :-

a) Unit of length - m
b) Mass - Kg
c) Time - sec
d) Current - A
e) Thermodynamics Temp - K
f) Luminous intensity - cand (cd)

2) Errors

There is some error ~~or~~ in every measurement.

i) Errors due to known reason :-

a) Due to temp
b) Due to buoyancy of air
c) Error in watching time if watch running slow / fast
d) Error due to radiation loss or gain in calorimetric experiment
e) Zero error

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ii) Errors due to unknown reasons :- When a large no. of observations are taken, there are chances that the taken value may have observation greater or lesser than the correct value.
Thats why we should take arithmetic mean of the observations

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

o Avg deviation :- The average value of the deviation of all the individual measurements from the AM is known as average deviation $(\bar{d})$

$$\bar{d} = \frac{(x_1 - \bar{x}) + (x_2 - \bar{x}) \ldots + (x_n - \bar{x})}{n} = \frac{\delta_1 + \delta_2 \ldots + \delta_n}{n} = \frac{\sum_{i=1}^{n} \delta_i}{n}$$

o Standard deviation :- The square root of the mean square deviation for an infinite of measuments is known as standard deviations

$$\sigma = \sqrt{\frac{\delta_1^2 + \delta_2^2 \ldots \delta_n^2}{n-1}} = \sqrt{\frac{S}{n-1}}$$

o Standard error - The quantity $\frac{\sigma}{\sqrt{n}}$ is known as standard error

$$\sigma_m = \sqrt{\frac{\delta_1^2 + \delta_2^2 \ldots \delta_n^2}{n(n-1)}}$$

o Probable error - The probable error is a quantity e.

such that it is an even chance whether true value of the quantity measured differs from the mean value by a amount greater or less than e.

$$\text{Probable error} = \pm 0.6745 \sqrt{\frac{S}{n(n-1)}}$$

o Degree of accuracy-: All observation must be taken to same "degree of accuracy". It is no use to take some observation to a much higher degree of accuracy than the rest, as it will not make result more accurate

o Percentage error-: The ratio of diff b/w observed and accurate measurent with accurate measurement multiplied by 100

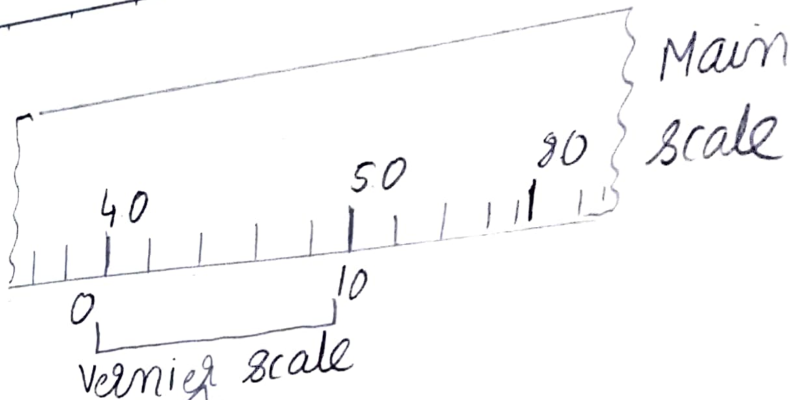
$$\% = \frac{A - A_0}{A} \times 100$$

o Significant figures - The no. of significant figures to which the final result of an experiment should be stated depends upon the nature of the exp. & the accuracy with which the various measurements have been made.

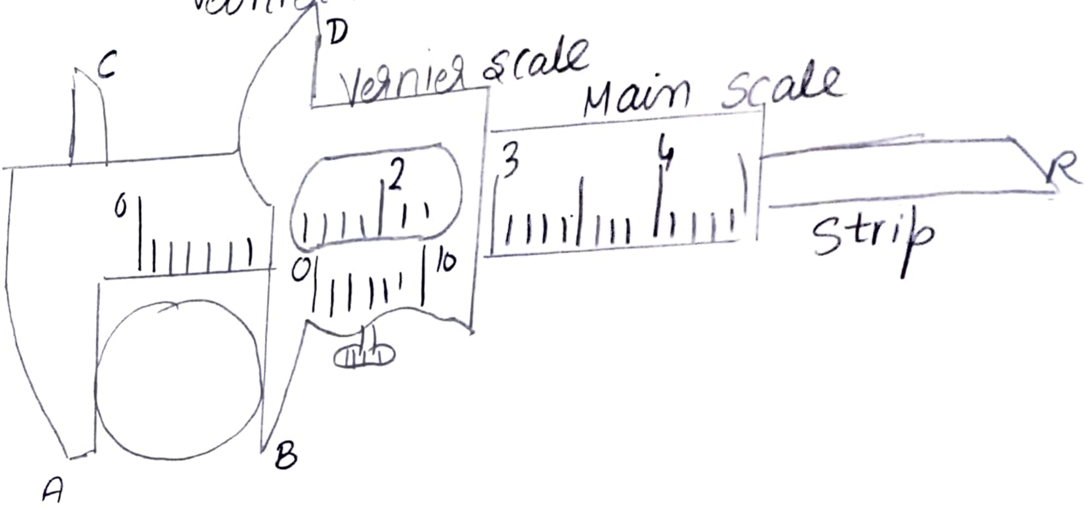
3) **Graphs**

Physical laws express relationship b/w various physical quantities.

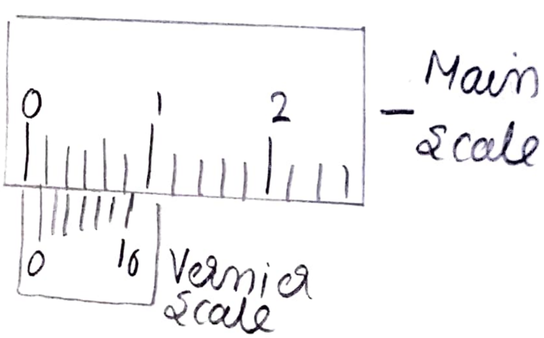
o Scale - Its the measurement of graph. Should not be taken narrow or wide.



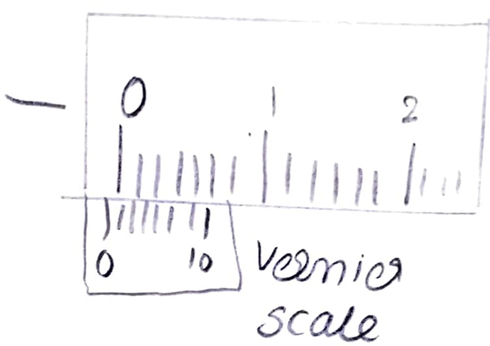
Main scale
40
50
80
0
10
Vernier scale



C
D
Vernier scale
Main scale
2
3
4
0
0
10
R
Strip
A
B



0
1
2
0
10
Vernier scale
Main scale



0
1
2
0
10
Vernier scale

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- Origin:- It is the relation b/w the two variables begins from zero

(4) Calculations

(a) Vernier Calliper:-

(i) Vernier constant (VC) - It is the least count of vernier calliper.

$$VC = \text{Value of } 1MSD - \text{Value of } 1VSD$$

$$10VSD = 9MSD = 9mm$$

$$1VSD = \frac{9}{10} mm = 0.9mm$$

$$VC = 1mm - 0.9mm = 0.1mm = 0.01cm$$

VC of vernier calliper is equal to the ratio of value of 1MSD to total no. of divisions on vernier scale

$$VC = \frac{\text{Value of one MSD}}{\text{Total No. of divisions}}$$

(ii) Zero error - If zero doesn't coincide with the main scale it is known as zero error.

$$\text{Zero error} = \text{No. of divisions} \times VC$$

(iii) Zero correction - It is the value that must be added or subtracted for correction.

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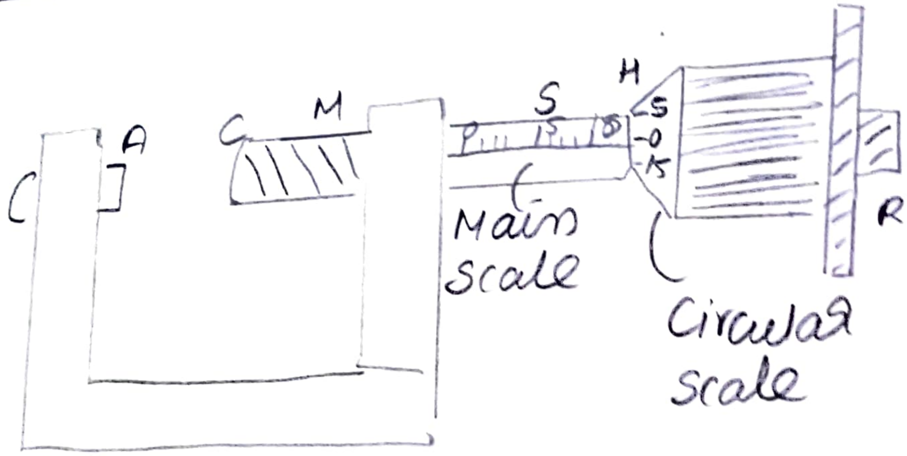
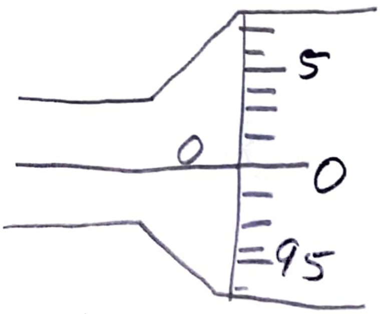
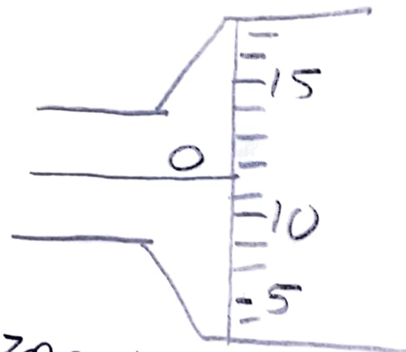
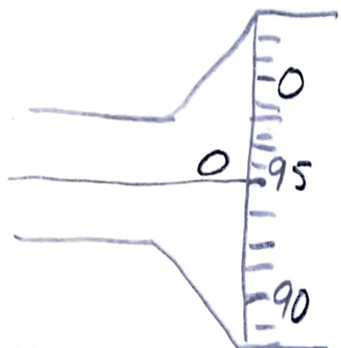




Nil error
(a)



Zero +ve error
(b)



Zero -ve error
(c)

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(b) Screw Gauge

Pitch = Rotate the instrument and note down the linear distance covered.

Pitch = linear dist / no. of rotations

least count = $\dfrac{\text{Pitch}}{\text{Total no. of divisions on circular scale}}$

Zero error = $\left\{ \begin{pmatrix}\text{No. of circular scale} \\ \text{divisions coinciding} \\ \text{with reference line}\end{pmatrix} - \begin{pmatrix}\text{Total no. of} \\ \text{circular} \\ \text{scale divisions}\end{pmatrix} \right\} \times \left\{ \begin{matrix}\text{least} \\ \text{count}\end{matrix} \right)$

Zero correction: It is always equal to negative of zero error.

Backlash error: The error due to lag b/w rotatory motion given to the head screw & the linear motion along the reference line is known as backlash error.

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Experiment-2

Aim-

To determine the wavelength of Sodium light by Newton's rings.

Apparatus Required-

A plano-convex lens of large radius of curvature, optical arrangement for Newton's rings, plane glass plate, Sodium lamp and travelling microscope.

Theory-

- Light from a monochromatic source (sodium lamp) is allowed to fall on the convex lens through a broad slit which renders it into a nearly parallel beam.
- ~~A~~ A film is said to be thin when its thickness is about the order of one wavelength of visible light.

Rings are fringes of equal thickness. They are observed when light is reflected from a plano-convex lens of a long focal length placed in contact with a plane glass plate. A thin air film is formed b/w the plate and the lens. The thickness of the air film varies from 0 at the pt of contact to some value t. When the system is illuminated with monochromatic light, concentric bright and dark interference rings are observed. Rings get closer as the order increases

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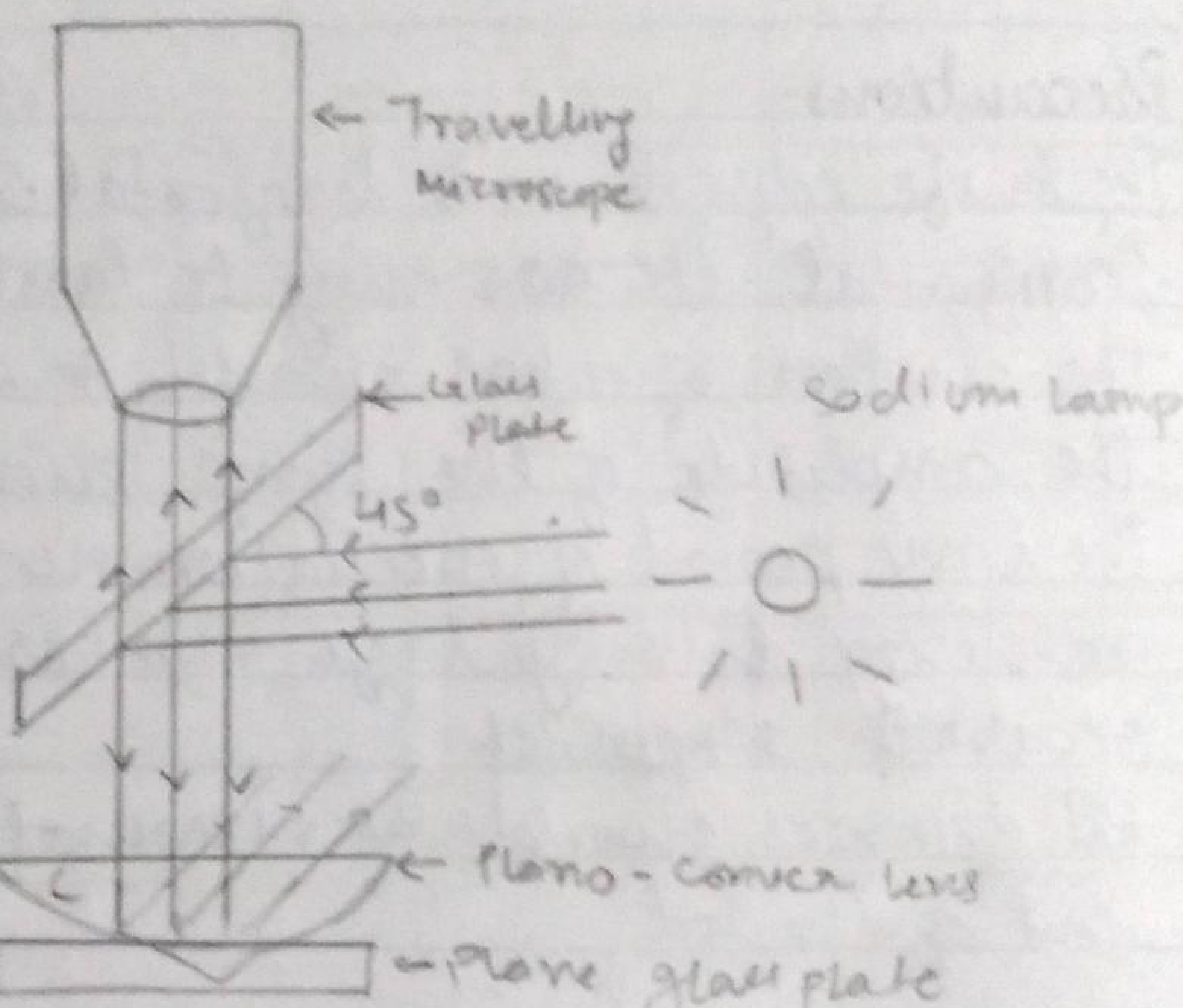
Aim-

To determine the wavelength of Sodium light by Newton's ring



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The wavelength of monochromatic light can be determined as

$$\lambda = \frac{D_{m+p}^2 - D_m^2}{4pR}$$

where D_{m+p} is the diameter of $m+p^{th}$ rings, D_m is the diameter of mth ring. R is the radius of curvature of lens.

Procedure -

1. After the experimental arrangement, the glass plate is inclined at an angle 45° to the horizontal. The glass plate reflects light from the source vertically downwards and falls normally on the convex lens
2. Newton's rings are seen using a long focus microscope focussed on the air film. The cross-wire microscope is made tangential to the 1st ring on the left side of the centre. The readings of main scale and vernier scale of the microsope are noted.
3. Then it is seen through the right side from the centre and observation are taken. Similarly readings for 2nd, 3rd, 4th .. etc rings are taken from both left and right side.
4. The Diameter of the ring is found out by subtracting readings on the left and right sides. The square of diameter and hence D_n^2 + D_{n+m}^2 are found out. Wavelength for individual ring is calculated and their mean wavelength is found.

~~Result~~
~~R~~

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Observations-

L.C of vernier scale - 0.01 cm

radius of curvature of lens = 75 cm $\quad$ $p = 2$

Order of ring	Microscopic Reading (cm)		Diameter D (cm)	D^2 (cm²)	$D^2_{m+p} - D^2_m$
	Left	Right			
1	2.50014	2.47041	0.02973	0.0008838	0.03139
2	2.55047	2.40015	0.15032	0.0225961	0.02360
3	2.55014	2.37047	0.17967	0.0322813	0.04611
4	2.55526	2.35032	0.21494	0.0461992	0.03802
5	2.57283	2.32006	0.27999	0.0783944	0.03767
6	2.60005	2.34021	0.29021	0.0842218	0.04890
7	2.62010	2.27941	0.34069	0.1160696	-
8	2.63020	2.2534	0.36486	0.1331228	-

Calculations-

Mean value of $D^2_{m+p} - D^2_m = \dfrac{0.22569}{6} = 0.037615$

Wavelength of light $\lambda = \dfrac{(D^2_{m+p} - D^2_m)}{4pR} = \dfrac{0.037615}{4 \times 2 \times 75}$

$= 6.2691 \times 10^{-7}$ m

$= 626.91$ nm

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Result:-

The wavelength of the given light source is 626.91 nm

Precautions-

1. Glass plate and lens should be cleaned thoroughly.
2. The lens used should be of large radius of curvature
3. The source of light used should be an extended one.
4. Before measuring the diameter of rings, the range of microscope should be adjusted properly.
5. Crosswire should be focused on a bright ring tangentially.
6. Radius of curvature should be measured accuratly.

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Experiment-3

Aim-

To find the numerical appreture of a given optic fibre and hence to find its acceptance angle

Material required-

Optical fiber cable, emitter, output unit, detector, fibre stand, concentrator

Theory-

Optical fibres are fine transparent glass or plastic fibres which can propogate light. They work under the principle of total internal reflection. ~~The core transmit~~ It consist of a core, surrounded cladding made up of silica glass or plastic. The core transmits an optical signal while the cladding guides the light with the core.

light enter the core at a point A, and travells till it reaches the cladding boundary at B. If the light ray intersects the core-cladding boundary at an angle greater the critical angle of the wire, it gets internally reflected to point C.

If the light ray enter the core with an angle less than a particular angle called acceptance angle, it will be guided by cladding.

consider an optical fibre of refractive index n_1 & cladding n_2, incident angle (i), angle of reflection (θ)

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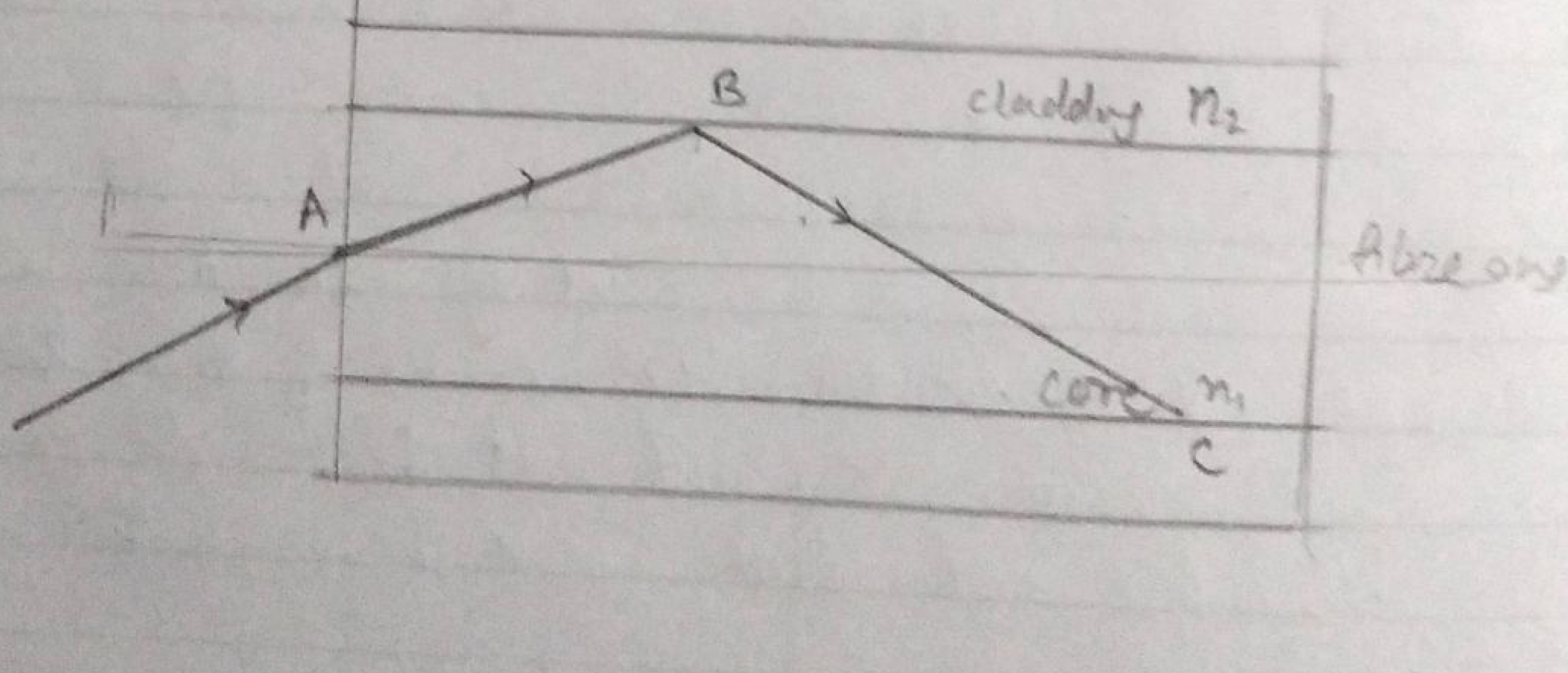
B
cladding n_2
A
I
Fibre axis
core
n_1
C

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$\theta' = (90-\theta)$ — (1)

$n_0 \sin i = n_1 \sin\theta$ — (2) (Snell's law)

$n_0 = 1$ (air)

for light travelling from core to cladding

$n_1 \sin\theta'_c = n_2 \sin 90$

$\sin\theta'_c = \frac{n_2}{n_1}$ — (3)

let maximum value of i be i_m, it is called maximum angle of acceptance & $n_0 \sin i_m$ is numerical aperture (NA)

from eq (2) $NA = n_0 \sin i_m = n_1 \sin\theta$

$NA = n_1 (\sin(90-\theta)) = n_1 \cos\theta'_c$

$NA = n_1 \sqrt{1-\sin^2\theta'_c}$

$NA = n_1 \sqrt{1 - \frac{n_2^2}{n_1^2}}$ from (3)

$NA = \sqrt{n_1^2 - n_2^2}$

let the spot size of beam at a distance d and spot radius (r)

$\therefore \sin\theta = \frac{r}{\sqrt{r^2+d^2}}$

$NA = \sin\theta_a$, angle of acceptance $\theta_a = \sin^{-1} NA$

Procedure-

1. Set the detector distance Z.
2. Vary the detector distance X by an order of 0.5 mm, using the screw gauge.
3. Measure the detector reading from output unit and tabulate it.

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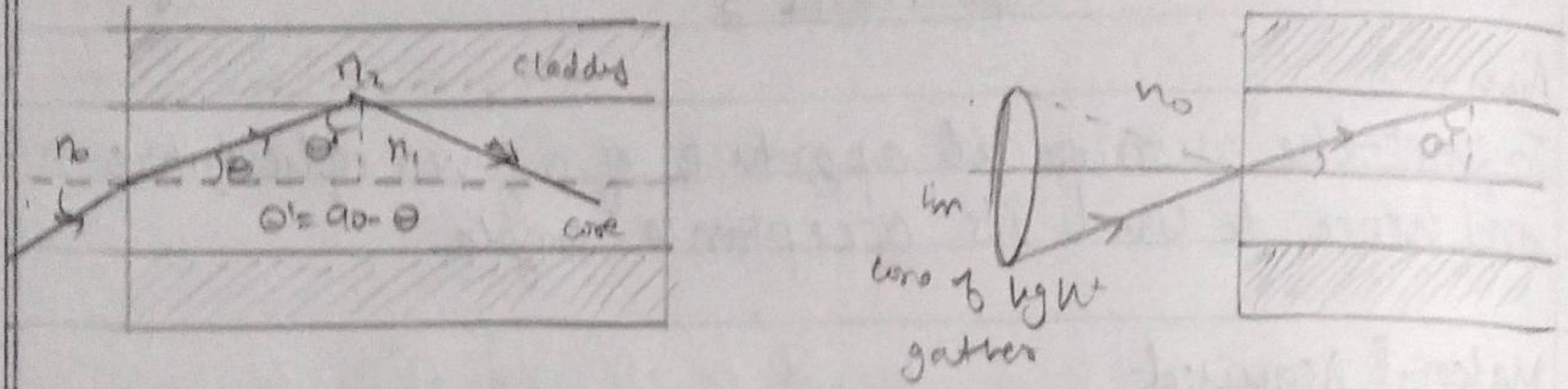

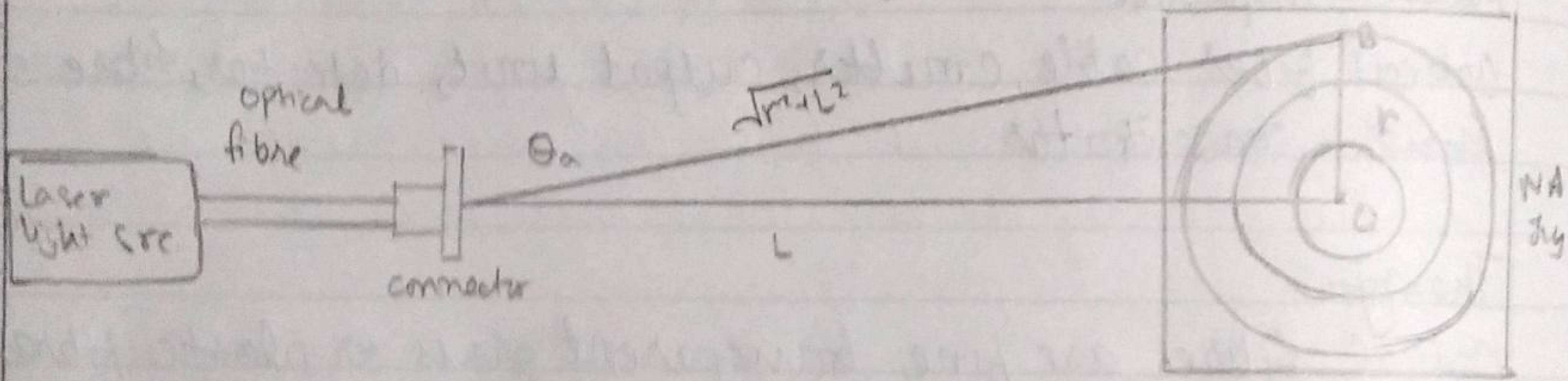

Observation -

S.No	Screw Gauge Reading (mm) M.S.R.	(mm) C.S.R	Distance (mm) (X)	Current (µA)
1	3.0	0.44	3.44	0.0022245
2	4.0	0.18	4.18	0.0220427
3	4.0	0.36	4.36	0.0680603
4	4.0	0.47	4.47	0.1120356
5	4.5	0.13	4.63	0.2108090
6	4.5	0.33	4.83	0.2457037
7	4.5	0.45	4.95	0.2317784
8	5	0.1	5.1	0.1735473
9	5	0.5	5.5	0.0318217
10	6	0.2	6.2	0.0007187

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4. Plot the graph between X in x-axis and output readings in Y-axis.

5. Find the radius of the spot r, which is corresponding to $I_{max}/2$.

6. Find the numerical aperture of optic fibre.

Result-

Numerical aperture of the optic fibre = 0.227

Acceptance angle of the optic fibre = 13.12°

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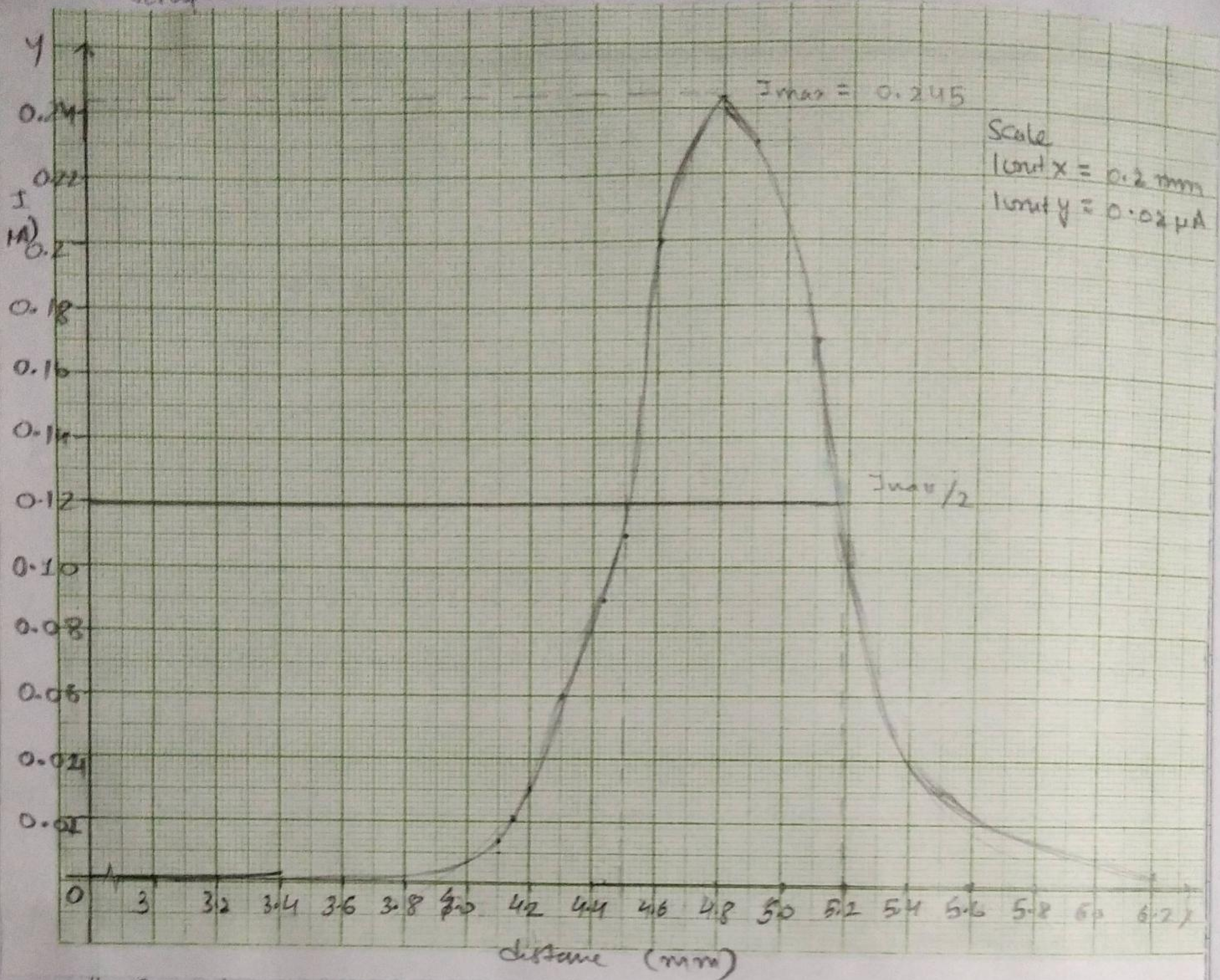
Graph -



Calculations -

Distance between the fiber end the detector, d = 3 mm

Radius of the spot, r = 0.7 mm

Numerical Apeature of the optic fibre, $\sin(\theta) = \frac{r}{\sqrt{r^2+d^2}} = 0.227$

acceptance angle, $\theta = \sin^{-1}\left(\frac{r}{\sqrt{r^2+d^2}}\right) = 13.12^\circ$

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Experiment-4

Aim- To determine the value of g, the acceleration due to gravity at a particular location using Kater's pendulum

Apparatus required-
Kater's pendulum, stopwatch, meter scale, weights, wooden and metal knife edges

Theory-
Kater's pendulum is composed of a metal rod 1-2 m in length, upon which are mounted a sliding metal weight W_1, a sliding wooden weight W_2, a small sliding metal cylinder w, two sliding knife edges K_1 & K_2. The pendulum can suspended and set swinging by resting either knife edge on flat surface. The wooden weight W_2 is the same size and shape as W_1. Its function is to provide as near equal air resistance to swing by resting on either suspension. The centre of mass G can be located by balancing the pendulum on an external knife. Fine adjustments in G, & thus h_1 & h_2 can be made by small cylinder w.

We consider the force of gravity to be acting at G. If h_i is the distance to G from the suspension point O_i at the knife edge K_i . $I_i \ddot{\theta} = -Mgh_i \sin\theta$

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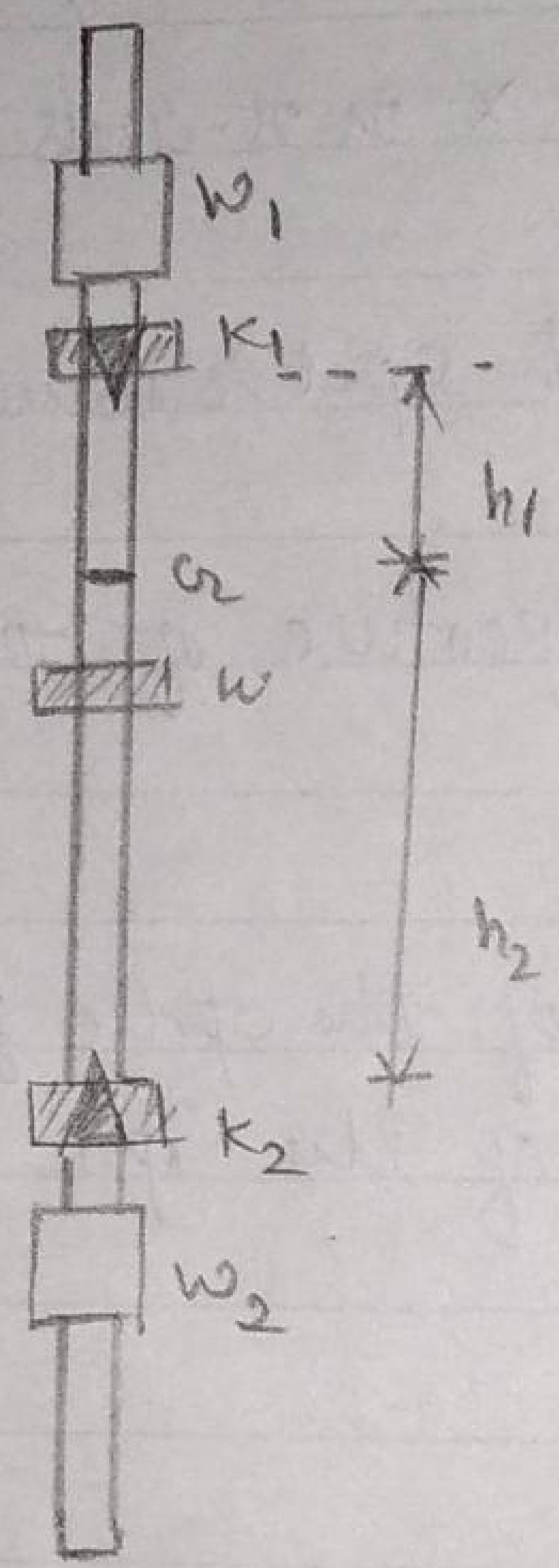
Aim - To determine the value of g at a particular location using Kater's pendulum



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where I_1 is moment of inertia

Comparing to the motion of simple pendulum eq:-

$$MJ_1^2\ddot{\theta} = -Mgl_1 \sin\theta$$

$$Mgh_1/L_1 = g/l_1 \quad -(1)$$

$$I_1 = Mk_1^2$$

$$k_1^2 = h_1 l_1 \quad -(2)$$

If I_g is the moment of inertia of the pendulum about G, radius of gyration is $I_g = Mk_g^2$

$$l_1 = \frac{h_1^2 + k_g^2}{h_1} \quad \text{using (2)}$$

time period $$T_1 = 2\pi\sqrt{\frac{l_1}{g}} = 2\pi\sqrt{\frac{h_1^2 + k_G^2}{gh_1}} \quad -(3)$$

Squaring (3) and calculating g

$$g = 8\pi^2\left[\frac{T_1^2 + T_2^2}{h_1 + h_2} + \frac{T_1^2 - T_2^2}{h_1 - h_2}\right]^{-1}$$

Procedure-

1. Choose a desired environment for pendulum.
2. Shift the weight W_1 to one end of Katers pendulum and fix it. Fix the knife edge K_1 just below it.
3. Keep the knife edge K_2 at the other end and fix the wooden weight W_2 symmetrical to other end. Keep the small weight 'w' near to centre.
4. Suspend the pendulum about the knife edge 1 and take the time for about 10 oscillations. Note down the time t_1

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using a stopwatch and calculate its time period using $T_1 = t_1/10$.

5. Now suspend about knife edge K_2 by inverting the pendulum and note the time t_2 for 10 oscillations. Calculate T_2.

6. If $T_2 \neq T_1$ adjust the position of knife edge K_2 so that $T_2 \approx T_1$.

7. Balance the pendulum on a sharp wedge and mark the position of its centre of gravity. Measure the distance of the knife-edge K_1 as h_1 and that of K_2 as h_2 from G.

Result -

The acceleration due to gravity at a given place is found to be = 9.78 ms^{-2}

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Observation

S No	for W_1 — Time period for 10 osc				for W_2 — Time Period for 10 osc				distance from G		$T_2 - T_1$ s
	t_{11}	t_{12}	t_{1mean}	T_1	t_{21}	t_{22}	t_{2mean}	T_2	h_1	h_2	
1	17.49	18.48	17.98	1.798	20.541	20.43	20.49	2.049	63.8[illegible]	16.02	0.251
2	20.25	20.28	20.27	2.027	20.46	20.38	20.4	2.040	68.52	31.48	0.013

Calculation -

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{h_1 + h_2} + \frac{T_1^2 - T_2^2}{h_1 - h_2}} = \frac{78.95}{\frac{4.108 + 4.161}{68.52 + 31.48} + \frac{4.108 - 4.161}{68.52 - 31.48}}$$

$$= \frac{78.95}{0.0826 + (-0.00143)}$$

$$= 9.78 \ ms^{-2}$$

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Experiment-5

Aim-

1. To determine the number of lines per millimeter of the grating using the green line of mercury spectrum and to calculate the wavelength of the other prominent lines of mercury by normal incidence method.

Apparatus-

Spectrometer, diffraction grating element and mercury vapour lamp

Theory-

When waves pass through a gap, which is about as wide as the wavelength they spread out into the region beyond the gap. Huygens considered each point along wavefront as a source of secondary wave front forming semicircular wavelets. Diffraction is due to superposition of secondary wavelets. Consider a slit of width 'a', let angle θ, the path diff. b/w the top and bottom of the slit is wavelength (λ), causing destructive interference

$$\Delta S = a\sin\theta \quad (1) \qquad \text{(minimum intensity)}$$

$$a\sin\theta = n\lambda \quad (2)$$

intensity, $I = I_0 \dfrac{\sin^2\left(\frac{N\delta}{2}\right)}{\left(\frac{\delta}{2}\right)^2}$ (3) where δ is total phase angle

$$\delta = \frac{2\pi a \sin\theta}{\lambda} \quad (4)$$

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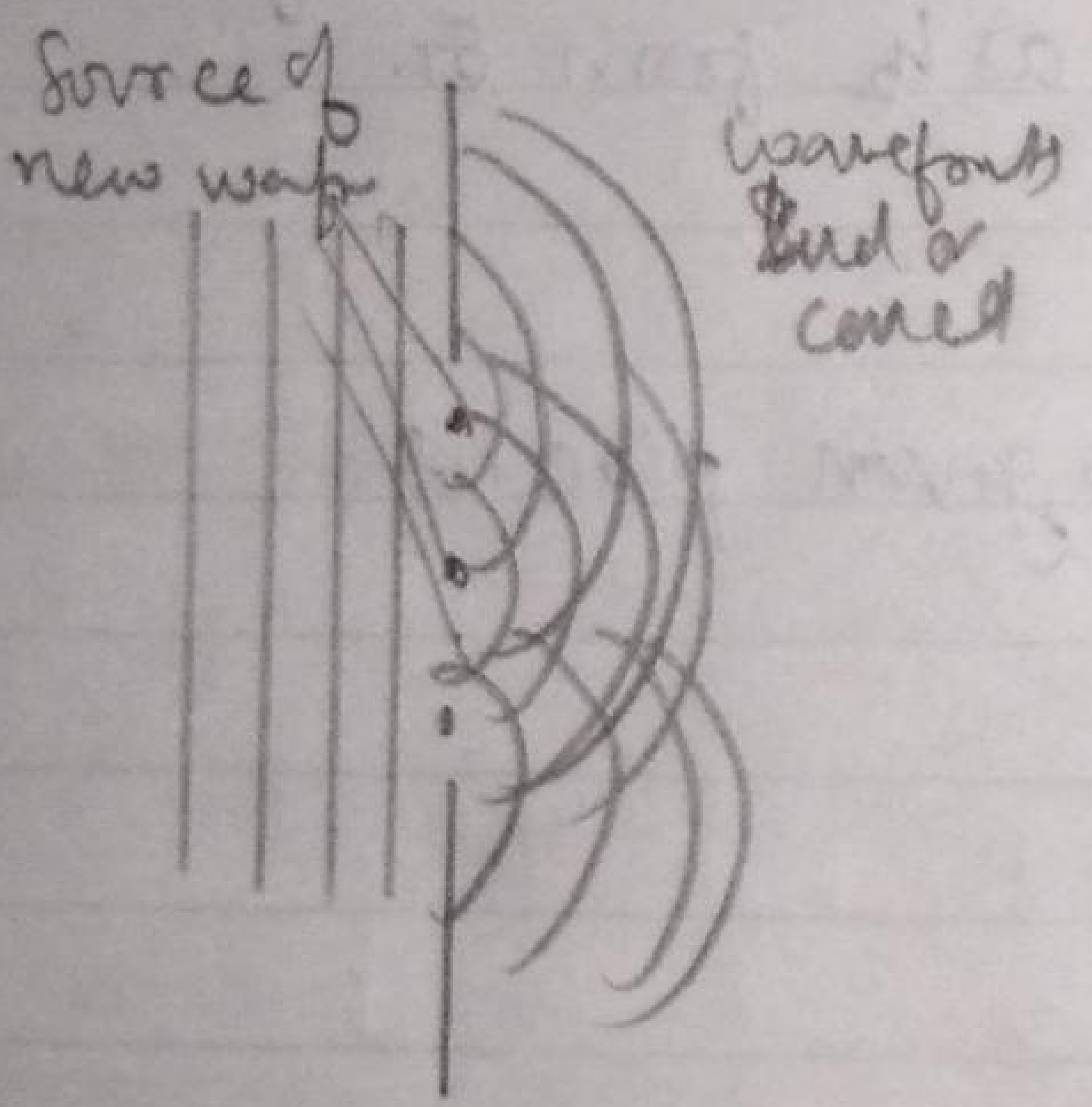
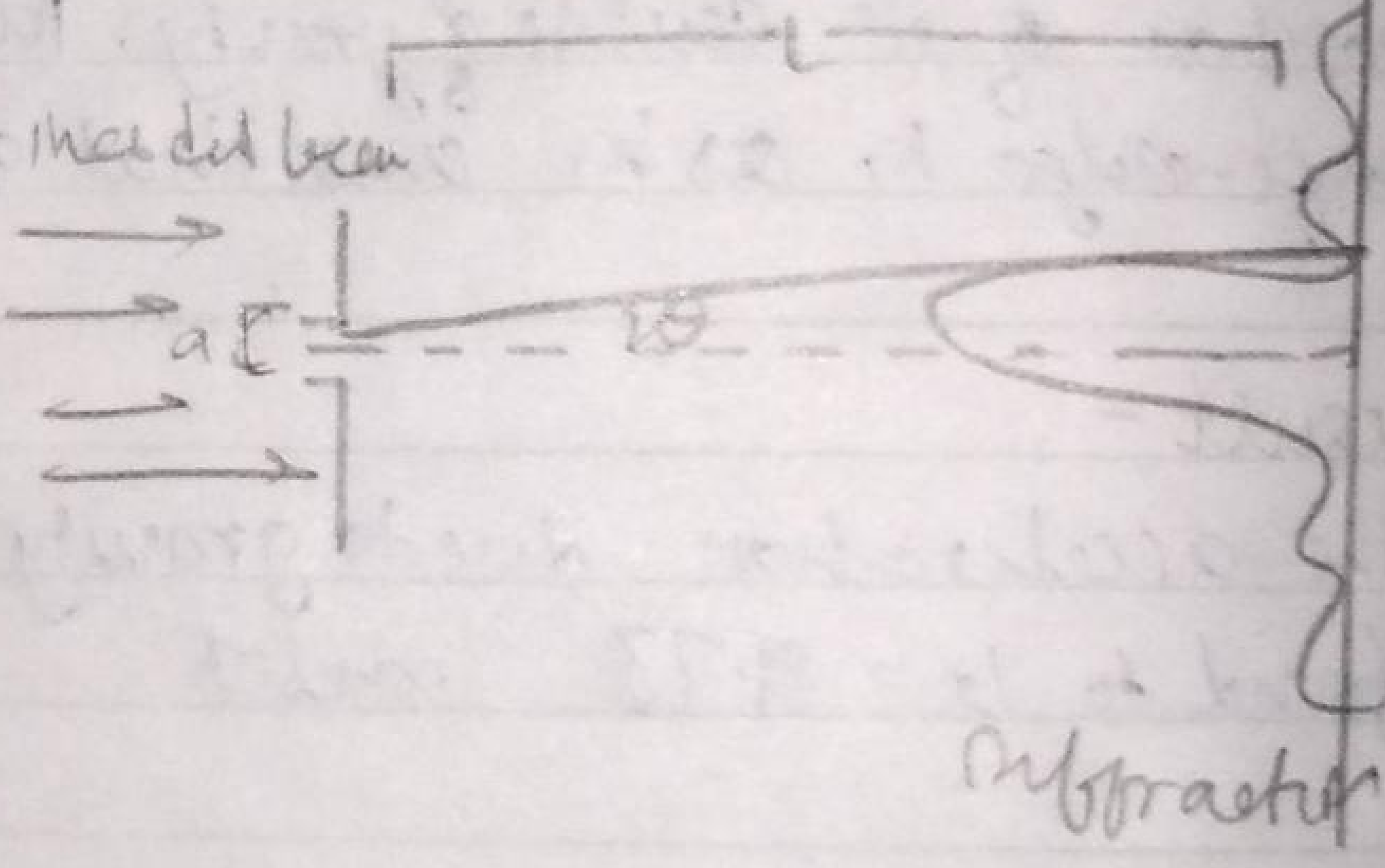

Source of
new wave
wavefronts
Bend or
curved


Incident beam
a
2θ
Diffraction

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Diffraction grating is an optical component having a periodic structure which can split and diffract light to several beams. This depends on the spacing of the grating and λ of light

$$\sin\theta = Nn\lambda$$

N → no. of lines / unit length

Procedure-

1 Prelimary adjust for spectrometer was made, The grating is set at normal incidence. The slit is illuminated by mercury lamp. The telescope is brought in a line with collimator and the direct image of slit is made coincide with vertical cross wire.

2 The readings of one vernier are noted. The vernier table is clamped. The telescope is rotated exactly through 90° and is fixed in this position. The grating is mounted vertically on the prism table with its ruled surface facing the collimator. The vernier table is released and rotated till image coincides with crosswire.

3 ~~Set~~ the telescope crosswire ~~is~~ coincides with narrow line. Record the readings of verniers from left and similarly from right

4 The difference between the readings on the left and right on the same vernier is determined for each line The mean value of this difference gives 2θ - twice the

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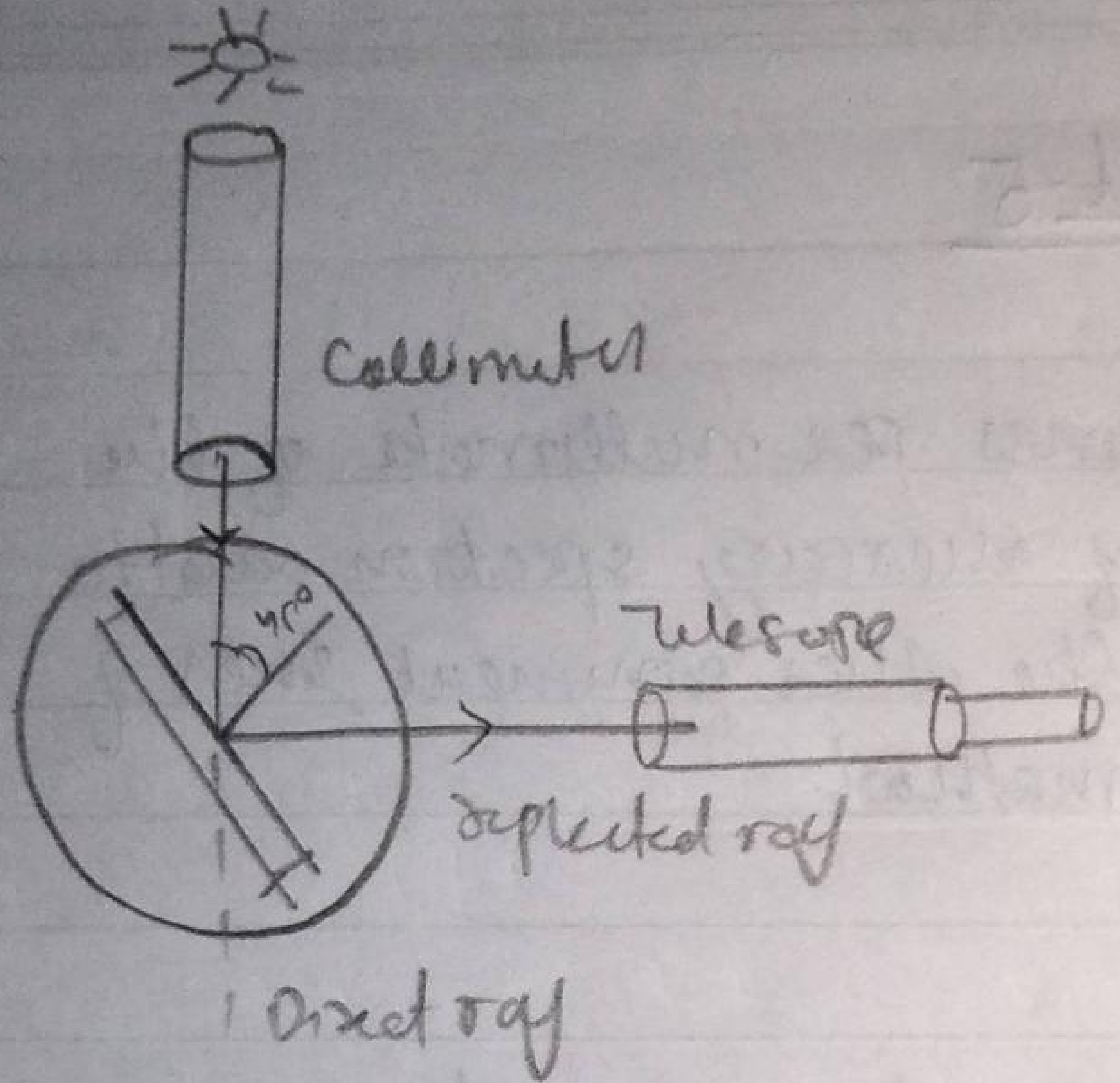
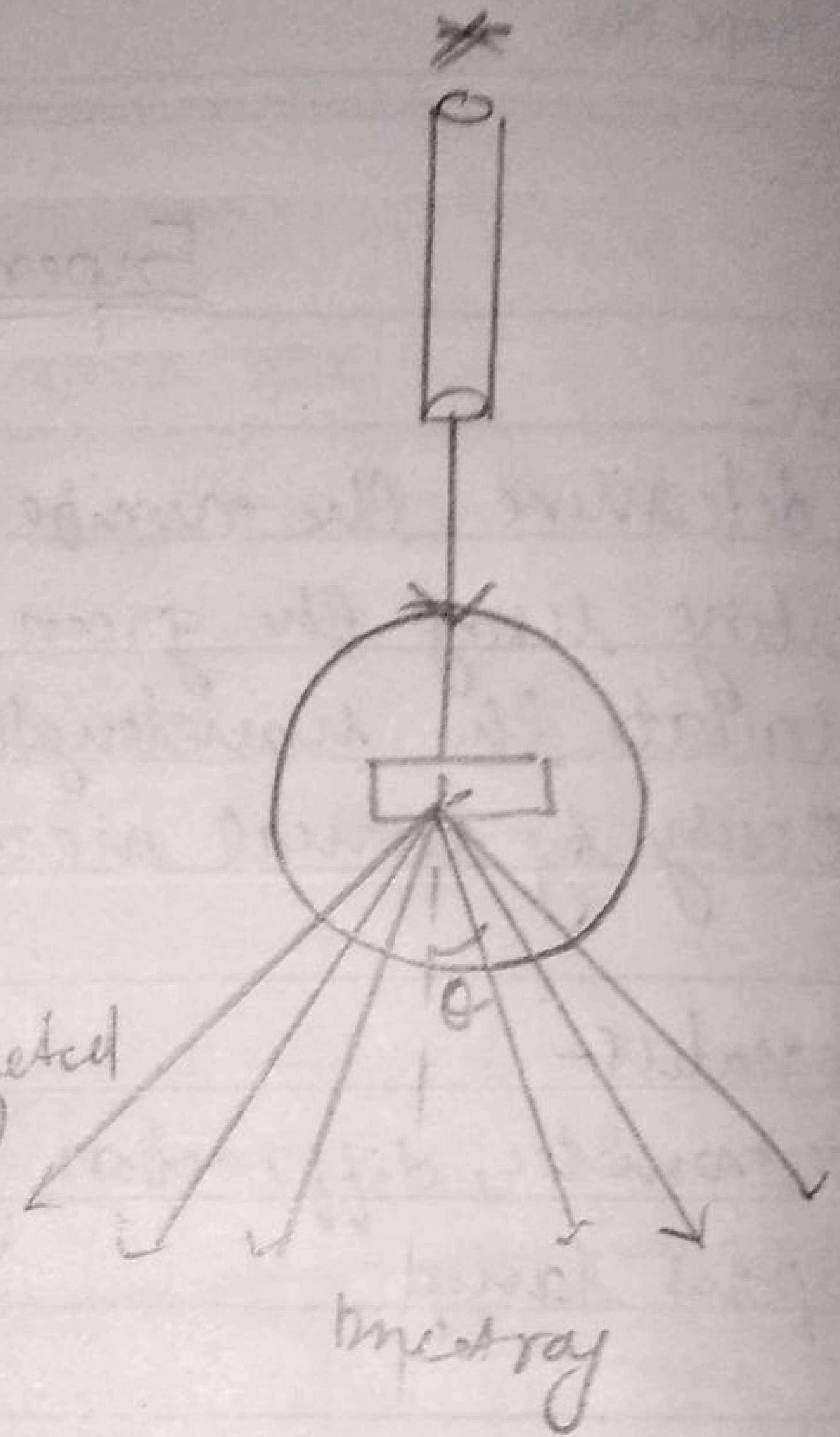

Collimator
45°
Telescope
Reflected ray
Direct ray


θ
Diffracted rays
Direct ray

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angle of diffraction. Thus θ is defined, $\lambda_g = 5461 \times 10^{-9}$ m Number of lines per grating is calculated. Using N, λ of prominent lines are calculated.

Results-

The Wavelength of: Yellow I = 563.84 nm
Yellow II = 490.8 nm
Blue green = 478.94 nm
Violet I = 380.15 nm
Violet II = 361.26 nm

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Observations

Determination of grating per mm

Green λ (nm)	Left		Right		Difference (R-L) readings (2θ)		Mean θ	$N = \frac{\sin\theta}{n\lambda}$
	Ver I	Ver II	Ver I	Ver II	Ver I	Ver II		
546.1	19°0'	199°0'	340.25°	160.5°	321.5	38.5	141.5	0.00113993

Determination of wavelengths –

Colours	Left		Right		diff read		Mean θ	$\lambda = \frac{\sin\theta}{nN}$
	V I	V II	V I	V II	V I	V II		
Yellow I	20°	204°7'	340°	164°9'	320°	39.98°	140.01°	563.84
Yellow II	47° 18'	21° 16'	320° 2'	140° 2'	272.13°	120	140°	490.8
Blue Green	29° 18'	203° 13'	346.5° 8'	179.5° 16'	317.33°	23.45	146.94°	478.94
Violet I	26° 24'	200° 11'	357.5° 6'	177.5° 7'	331.2°	22.56	154.32°	380.15
Violet II	36° 10'	224.5° 29'	345° 8'	165° 8'	308.96°	59.85	124.55°	361.26