B. Sc. Physics Lab Manual

Department of Physics

Ramakrishna Mission Vivekananda Centenary College
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Title of the Experiment

To determine the dispersive power, Cauchy constants and $\frac{d\mu}{d\lambda}$ (at a given λ)of the material of a prism using known source

Theory :

Refractive index (μ) of the material of a prism is not constant; it depends on the wavelength (λ) of the light passing through it. The phenomena of dependence of refractive index of a medium with wavelength is known as *dispersion* and the medium is called *dispersive medium*. If μ(λ) is the wavelength dependent refractive index of the material of a prism, then, in the visible range it follows *Cauchy's relation*;

$$\mu(\lambda) = a + \frac{b}{\lambda^2} \tag{1}$$

where, a and b are two constants (depends on the medium) are called *Cauchy's constants*. The plot of $\mu(\lambda)$ vs $1/\lambda^2$ will give a straight line; in which a can be obtained by taking the intercept at μ axis and b can be obtained as the slope of the straight line.

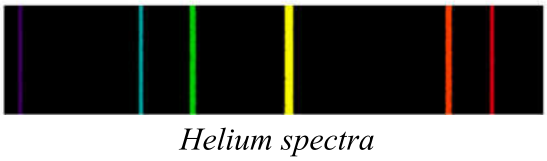
Dispersive power of prism between two specified colours having refractive indices μ_1 and μ_2 respectively is defined as;

$$\omega = \frac{\mu_1 \sim \mu_2}{\mu_0 - 1} = \frac{\delta\mu}{\mu_0 - 1} \tag{2}$$

where, $\mu_0 = (\mu_1 + \mu_2)/2$

If, prism angle is A and minimum deviation angle is δ_m then, refractive index can be measured from the relation,

$$\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}} \tag{3}$$



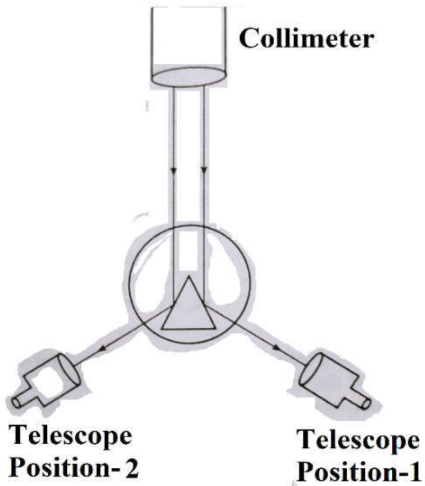
Helium spectra

Apparatus :

i) Spectrometer
ii) Prism
iii) Spirit level
iv) Sodium light source
v) Source with known wavelengths (Mercury / Helium etc.)

Procedure :

1. Adjustment of the spectrometer (as discussed in a separate note entitled 'Spectrometer.pdf') using sodium yellow light.
    a) Levelling of telescope
    b) Levelling of collimator
    c) Mechanical levelling of prism table
    d) Crosswire focusing
    e) Optical levelling of prism
    f) Focussing for parallel ray by *Schuster's method*
2. Determine the vernier constant of the circular scale of the spectrometer.
3. **Part – 1 :** Finding the prism angle:
    a) Place the prism on prism table as depicted in following figure.
    b) See the images of the slit formed due to reflection from both refracting surfaces of the prism. Record the scale reading for both two images at two different position of the telescope (Position-1 and Position-2).



4. **Part-2 :** Finding the minimum deviation angles for known source of light:
    a) Replace the sodium light by the known source. Move the source to get sharp and intense spectral lines. Do not disturb the focusing and alignment of the telescope.
    b) Adjust for minimum deviation angle for red spectral line and record both vernier reading.
    c) Repeat (b) for other observed spectral lines and record the vernier readings.
    d) Remove the prism without disturbing the prism table. Move telescope to get direct light from the collimator. Record both vernier reading as *direct reading*.

Experimental results :

- **Determination of vernier constant :**

  1 smallest division in main scale = $20'$

  60 vernier divisions = 59 main scale divisions = $59 \times 20'$

  1 vernier divisions = $\frac{59\times20'}{60}$

  Therefore,

  Vernier constant = 1 main scale division – 1 vernier division = $\left(20' - \frac{59\times20'}{60}\right) = 20''$

- **Table – 1 : To determine the prism angle**

Vernier Nos.	Obs. No.	Telescope position – 1				Telescope position – 2				Difference $a_1 \sim a_2$	Mean difference (C)	Prism angle $\frac{C}{2}$
		Main scale	Vernier	Total	Mean a_1	Main scale	Vernier	Total	Mean a_2			
1st	1 #	56^0 0′	10	56^0 03′ 20″	56^0 15′ 00″	176^0 40′	40	176^0 53′ 20″	176^0 53′ 20″	120^0 38′ 20″	120^0 31′ 30″	60^0 15′ 45″
	2	56^0 20′	20	56^0 26′ 40″		176^0 40′	40	176^0 53′ 20″				
2nd	1	236^0 0′	40	236^0 13′ 20″	236^0 23′ 20″	356^0 40′	20	356^0 46′ 40″	356^0 48′ 00″	120^0 24′ 40″		
	2	236^0 20′	40	236^0 33′ 20″		356^0 40′	28	356^0 49′ 20″				

Obtained value of angle of the prism = **60^0 15′ 45″**

Sample calculation :

Total = Main scale + (vernier scale reading X vernier constant)

= 56^0 0′ + 10 X 20″

= 56^0 0′ + 200″

= 56^0 0′ + 3′20″ (since, 60″ = 1′ So, 200″ = 3′20″)

= 56^0 03′20″

- **Table – 2 : Telescope reading at the minimum deviation position**

Colour with wavelength (in *nm*)	Vernier No.	Obs. No.	Main scale	Vernier	Total	Mean
Red 667.8	1st	1	67° 40′	42	67° 54′ 00″	67° 53′ 30″
		2	67° 40	39	67° 53′ 00″	
	2nd	1	247° 40′	46	247° 55′ 20″	247° 54′ 40″
		2	247° 40	42	247° 54′ 00″	
Yellow 587.6	1st	1	67° 00′	35	67° 11′ 40″	67° 10′ 50″
		2	67° 00′	30	67° 10′ 00″	
	2nd	1	247° 00′	44	247° 14′ 40″	247° 15′ 00″
		2	247° 00′	46	247° 15′ 20″	
Green 501.6	1st	1	65° 40′	45	65° 55′ 00″	65° 55′ 50″
		2	65° 40′	50	65° 56′ 40″	
	2nd	1	245° 40′	41	245° 53′ 40″	245° 53′ 00″
		2	245° 40′	37	245° 52′ 20″	
Blue - I 492.2	1st	1	65° 40′	18	65° 46′ 00″	65° 45′ 30″
		2	65° 40′	15	65° 45′ 00″	
	2nd	1	245° 40′	26	245° 48′ 40″	245° 48′ 20″
		2	245° 40′	24	245° 48′ 00″	
Blue - II 447.1	1st	1	64° 40′	13	64° 44′ 20″	64° 44′ 40″
		2	64° 40′	15	64° 45′ 00″	
	2nd	1	244° 40′	25	244° 48′ 20″	244° 48′ 40″
		2	244° 40′	27	244° 49′ 00″	

- **Table – 3 : Direct reading of the telescope :**

Vernier No.	Obs. No.	Main scale	Vernier	Total	Mean
1st	1	118^0 40′	15	118^0 45′ 00″	118^0 45′ 20″
	2	118^0 40′	17	118^0 45′ 40″	
2nd	1	298^0 40′	27	298^0 49′ 00″	298^0 48′ 30″
	2	298^0 40′	24	298^0 48′ 00″	

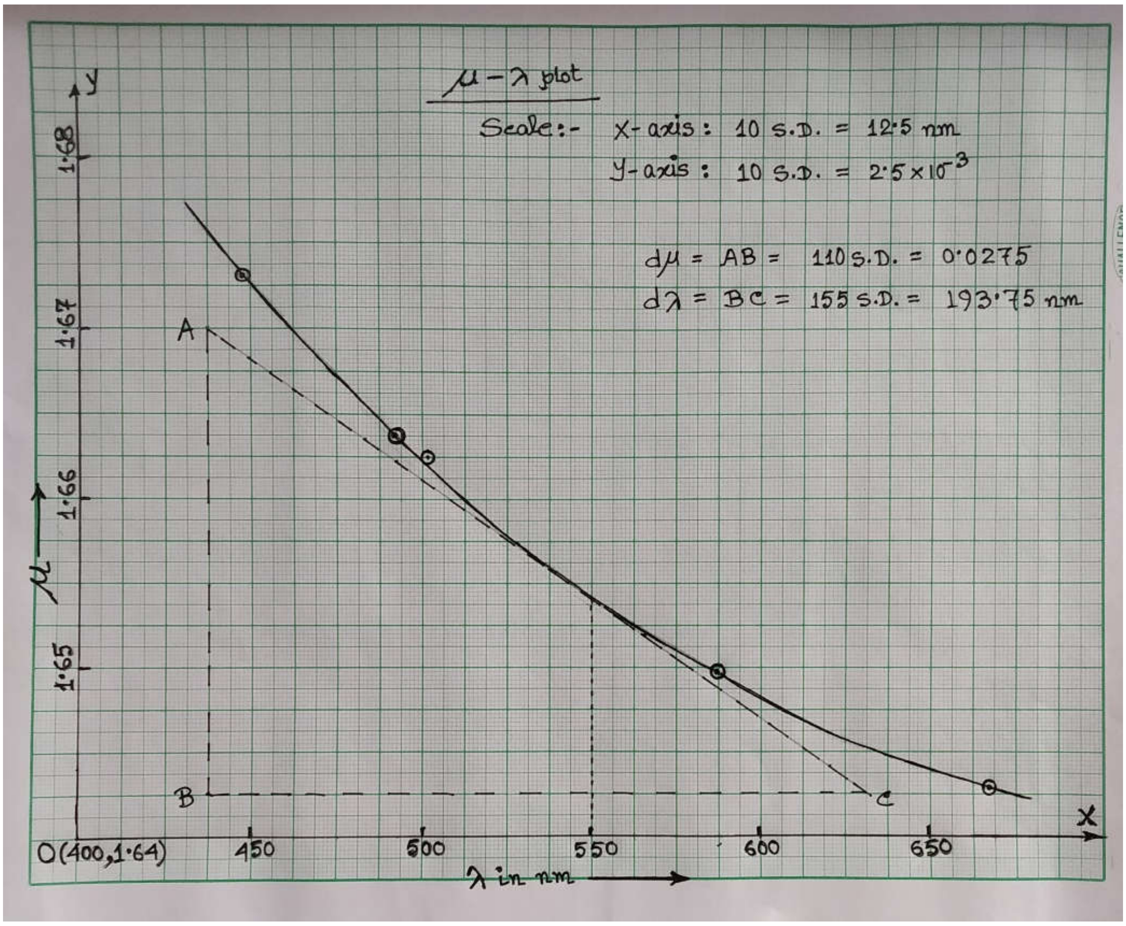
- **Table – 4 : Determination of the angle of minimum deviation and refractive index :**

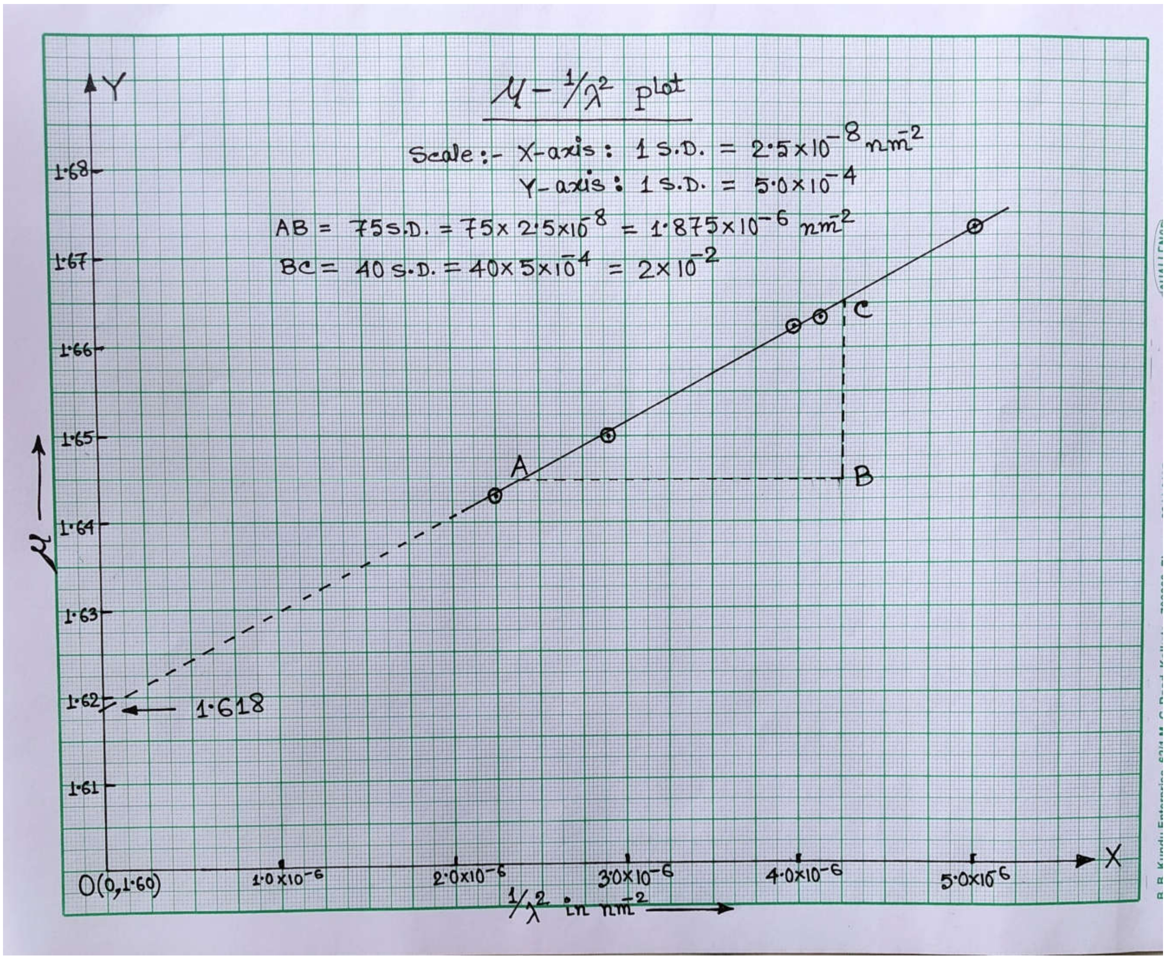
Prism angle found out : $A = 60^0\, 15' \,45''$

Colour with wavelength (in *nm*)	Vernier No.	Direct ray reading (a)	Telescope reading at minimum deviation (b)	Minimum deviation angle ($a \sim b$)	Mean minimum deviation angle (δ_m)	$\mu = \dfrac{sin\,\frac{A+\delta_m}{2}}{sin\,\frac{A}{2}}$
Red 667.8	1st	118^0 45′ 20″	67° 53′ 30″	50^0 51′ 50″	50^0 52′ 50″	1.64315
	2nd	298^0 48′ 30″	247° 54′ 40″	50^0 53′ 50″		
Yellow 587.6	1st	118^0 45′ 20″	67° 10′ 50″	51^0 34′ 30″	51^0 34′ 00″	1.64987
	2nd	298^0 48′ 30″	247° 15′ 00″	51^0 33′ 30″		
Green 501.6	1st	118^0 45′ 20″	65° 55′ 50″	52^0 49′ 30″	52^0 52′ 30″	1.66251
	2nd	298^0 48′ 30″	245° 53′ 00″	52^0 55′ 30″		
Blue - I 492.2	1st	118^0 45′ 20″	65° 45′ 30″	52^0 59′ 50″	53^0 00′ 00″	1.66370
	2nd	298^0 48′ 30″	245° 48′ 20″	53^0 00′ 10″		
Blue - II 447.1	1st	118^0 45′ 20″	64° 44′ 40″	54^0 00′ 40″	54^0 00′ 15″	1.67324
	2nd	298^0 48′ 30″	244° 48′ 40″	53^0 59′ 50″		

- **Table – 5 : To plot $\mu - \lambda$ and $\mu - \frac{1}{\lambda^2}$ curve :**

λ in nm	$\frac{1}{\lambda^2}$ in nm^{-2}	μ
667.8 (Red)	2.24237 X 10^{-6}	1.64315
587.6 (Yellow)	2.89625 X 10^{-6}	1.64987
501.6 (Green)	3.97452 X 10^{-6}	1.66251
492.2 (Blue - I)	4.12778 X 10^{-6}	1.66370
447.1 (Blue - II)	5.00254 X 10^{-6}	1.67324


μ − λ plot
Scale:- X-axis : 10 S.D. = 12·5 nm
Y-axis : 10 S.D. = 2·5 × 10⁻³
dμ = AB = 110 S.D. = 0·0275
dλ = BC = 155 S.D. = 193·75 nm
A
B
C
Y
X
1·68
1·67
1·66
1·65
μ
O(400, 1·64)
450
500
550
600
650
λ in nm


μ − 1/λ² plot
Scale:- X-axis : 1 S.D. = 2·5×10⁻⁸ nm⁻²
Y-axis : 1 S.D. = 5·0×10⁻⁴
AB = 75 S.D. = 75× 2·5×10⁻⁸ = 1·875×10⁻⁶ nm⁻²
BC = 40 S.D. = 40× 5×10⁻⁴ = 2×10⁻²
A
B
C
Y
X
1·68
1·67
1·66
1·65
1·64
1·63
1·62
1·61
1·618
μ
O(0, 1·60)
1·0×10⁻⁶
2·0×10⁻⁶
3·0×10⁻⁶
4·0×10⁻⁶
5·0×10⁻⁶
1/λ² in nm⁻²

Calculations :

- **Dispersive power calculation (using table - 5) :**

Colour and wavelength in nm	μ	$\mu_0 = (\mu_1 + \mu_2)/2$	$\omega = \frac{\mu_1 \sim \mu_2}{\mu_0 - 1}$
667.8 (Red)	$\mu_1 = 1.64315$	1.6582	0.0457
447.1 (Blue - II)	$\mu_2 = 1.67324$		

- $\boldsymbol{\frac{d\mu}{d\lambda}}$ **from** $\boldsymbol{\mu - \lambda}$ **plot :**

$$\left(\frac{d\mu}{d\lambda}\right)_{\lambda=550\ nm} = \frac{AB}{BC} = \frac{0.0275}{193.75} = 1.424 \times 10^{-4}\ \ nm^{-1}$$

- **Cauchy constants from** $\boldsymbol{\mu - \frac{1}{\lambda^2}}$ **plot :**

$a =$ intercept at Y-axis = 1.618

$b =$ slope of $\mu - \frac{1}{\lambda^2}$ curve (straight line) $= \frac{BC}{AB} = \frac{0.02}{1.875\times10^{-6}} = 10666\ \ nm^2$

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Title of the Experiment

To determine wavelength of sodium light using Newton's rings

Brief theory :

Newton's rings are basically circular interference pattern produced due to interference by division of amplitude. The ray diagram for the formation of Newton's ring is shown in the Fig. 1a and corresponding interference pattern (alternate dark and bright concentric rings) is shown in Fig. 1b.

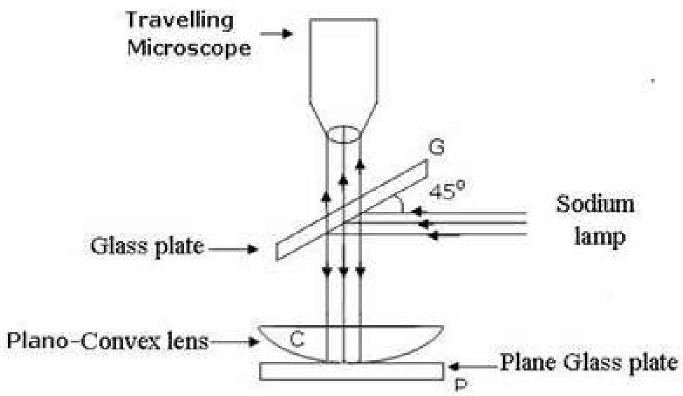


Figure : 1a

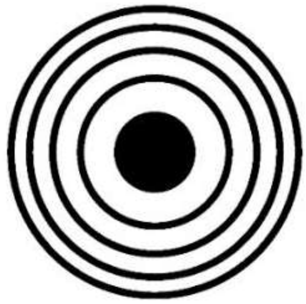


Figure : 1b

Monochromatic light of wavelength λ from sodium source is falling on half-reflecting glass plate (G). A part of which is reflected towards the system of plano-convex lens mounted on a plane glass plate. The incident ray on the system of lens and plate gets reflected from two different surfaces:

i) From the convex (lower portion) surface of the lens

ii) From the top surface of the glass plate

These two reflected light waves are monochromatic and coherent. However they posses a path difference produced due to small special gap between glass plate and the convex surface of the lense. Due to thid path difference, theses reflected light beams produce a stable interference pattern which is localized at the lower convex surface of the plano-convex lens.

Here, in the experiment, by measuring the diameter of Newtons ring i.e. the circular interference pattern (Fig. 1b) we can measure the wavelength of the source if the radius of the plano-convex lens is provided. Let us get the formula for this purpose.

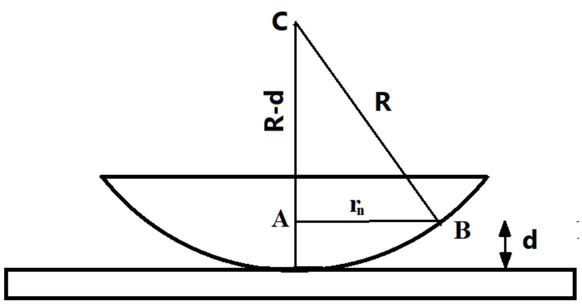


Figure : 2

Consider Fig. 2, in which we have depicted the magnified part of the lens-glass plate system.

Let n-th circular ring is produced at B point of radius r_n.

The air film thickness at this point $=d$

Then path difference at this point = $2d$
From the geometry of Fig. 2 we can write down,

$$AB^2 + AC^2 = BC^2$$

Or,

$$r_n^2 + (R - d)^2 = R^2$$

In the limit $d \ll R$, we get,

$$2d = \frac{r_n^2}{R} \tag{1}$$

One of the interfering rays is reflected from rarer medium (convex surface to air film interface) and another one from denser medium (air film to glass plate interface). Therefore, two interfering waves already have a phase shift by amount of π; that means equivalent path difference of λ/2.

Hence, the condition to get n-th bright ring,

$$\text{Path difference } = 2d = (2n + 1)\frac{\lambda}{2} \tag{2}$$

and the condition to get n-th dark ring,

$$\text{Path difference } = 2d = 2n\frac{\lambda}{2}$$

Now if we consider the bright rings, then, from equation (1) and (2) we get,

$$\text{Path difference } = 2d = \frac{r_n^2}{R} = (2n + 1)\frac{\lambda}{2}$$

Or,

$$\frac{r_n^2}{R} = (2n + 1)\frac{\lambda}{2} \tag{3}$$

If D_n be the diameter of the n-th bright ring, then, from equation (3),

$$\boldsymbol{\frac{D_n^2}{4R} = (2n + 1)\frac{\lambda}{2}} \tag{4}$$

This relation (4) is used to measure the wavelength of the source.

Theory and working formula (for experiment) :

If a monochromatic beam of light of wavelength λ produces Newton's ring pattern within the air film of plane glass plate and plano-convex lens of radius R then diameter of the n-th bright ring is given by,

$$\frac{D_n^2}{4R} = (2n + 1)\frac{\lambda}{2}$$

The same for *(n+m)*-th bright ring will be,

$$\frac{D_{n+m}^2}{4R} = (2n + 2m + 1)\frac{\lambda}{2}$$

From these two relations we obtain,

$$\boldsymbol{\lambda = \frac{D_{n+m}^2 - D_n^2}{4mR}} \qquad (\mathbf{5})$$

This is the working formula to determine wavelength of monochromatic light using Newton's rings.

Apparatus :

Newton's ring apparatus have two parts; in one of these parts, interference pattern is formed and another part is used to observe and measure the ring diameter. A typical Newton's ring apparatus is depicted in Fig. 3.

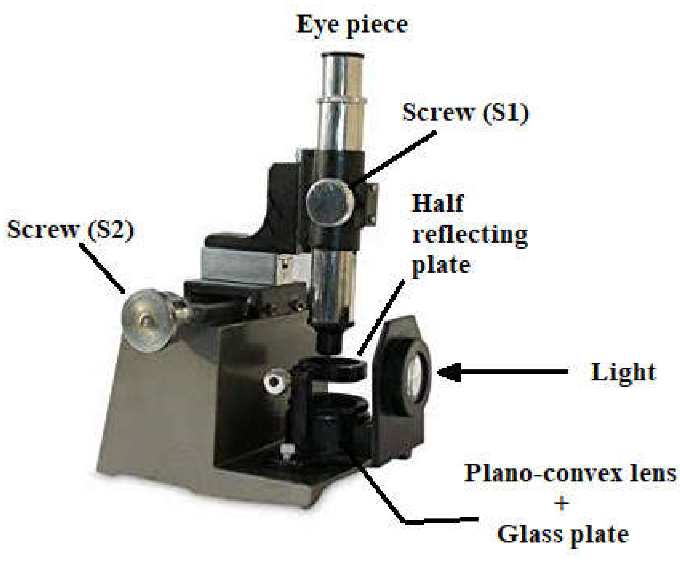


Figure : 3

Procedure (in brief) :

1. The followings are adjusted with attached screws attached with the parts respectively to get sharp concentric Newton's rings with dark spot at the centre.
   a) System of plano-convex lens and glass plate are adjusted by pressure screws attached with this part.
   b) Half reflecting glass plate is rotated about horizontal axis by a 45^0 with the attached screw with it.
   c) Screw S1 is rotated for sharp focusing on the rings while viewed through the eyepiece.
2. Rotation of screw S2 gives rise to horizontal movement of microscope over a linear scale graduated in millimetre. S2 is attached with a circular scale (in some case there exist vernier scale instead of circular scale). Typically, 100 uniform circular divisions present on the circular scale. A complete rotation of circular scale produces 1 mm translation of linear scale. S2 is rotated to focus crosswire on the central dark spot of the rings.
3. After focusing on the central dark spot, rotate S2 such that the crosswire moves along the direction from left to right ($L \rightarrow R$). Count the bright rings and focus crosswire on 25-th bright ring.
4. Now, rotate S2 in opposite direction so that the cross wire moves along $R \rightarrow L$. Focus crosswire on right edge of 20-th bright ring. Take main scale and circular scale reading in Tab. 1. This is the reading at right edge of 20-th bright ring for crosswire motion $R \rightarrow L$ (see Fig. 4).
5. Rotate S2 in the same direction of procedure-4 and focus crosswire on right edges of 19-th, 18-th, 17-th .... up to (say) 5-th bright rings successively. Note down both linear and circular scale reading for these. These are the readings at right edges of bright ring for crosswire motion $R \rightarrow L$.
6. Rotate S2 in the same direction but do not take readings for initial 4 rings from centre. Focus crosswire on the left edge of 5-th ring. Take reading as left edge for crosswire motion $R \rightarrow L$.
7. Follow step-6 for 6-th, 7-th, ... up to 20-th bright ring. Take linear and circular scale reading for left edges with crosswire motion $R \rightarrow L$.
8. Focus, on 25-th ring but do not record data for 21st to 25th rings.
9. Start rotating S2 such that crosswire moves along $L \rightarrow R$.
10. Focus crosswire on left edge of 20-th bright ring. Take main scale and circular scale reading. This is the reading at left edge of 20-th bright ring for crosswire motion $L \rightarrow R$.
11. Focus crosswire on left edges of 19th, 18th, 17th, ... up to 5th bright rings successively. Take main scale and circular scale reading. This are the readings at left edges for crosswire motion $L \rightarrow R$.
12. Avoid data collection for 4 rings in the central region either sides.
13. Focus crosswire on right edges of 5th, 6th, 7th, ... up to 20th bright rings successively. Take main scale and circular scale reading. This are the readings at right edges for crosswire motion $L \rightarrow R$.
14. Now, determine the diameter of any n-th ring by taking difference between left edge and right edge reading of that particular ring.

15. Fig. 4 pictorially shows how the field of view appears through eyepiece. The crosswire is indicated by red cross (it appears black in the experiment).

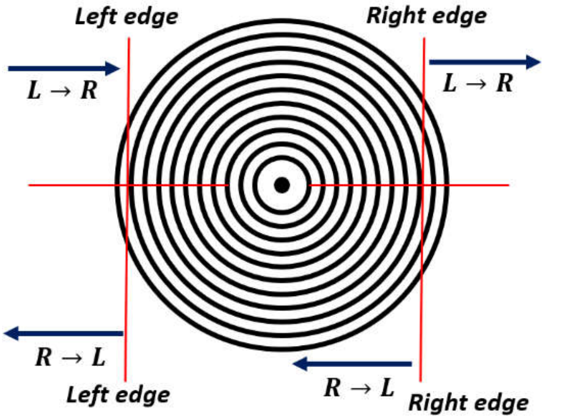


Figure : 4

16. Plot ring number (n)vs square of the corresponding ring diameter(D_n^2). It will give a straight line. From this graph take any p-th and (p+m)-th ring and determine D_p^2 and D_{p+m}^2 then, use equation (5) to determine wavelength.

Data recording :

- Given that radius of the plano-convex lens =90 cm
- **Determination of least count of circular scale:**

  100 circular scale divisions equivalent to one main scale division = 1 mm

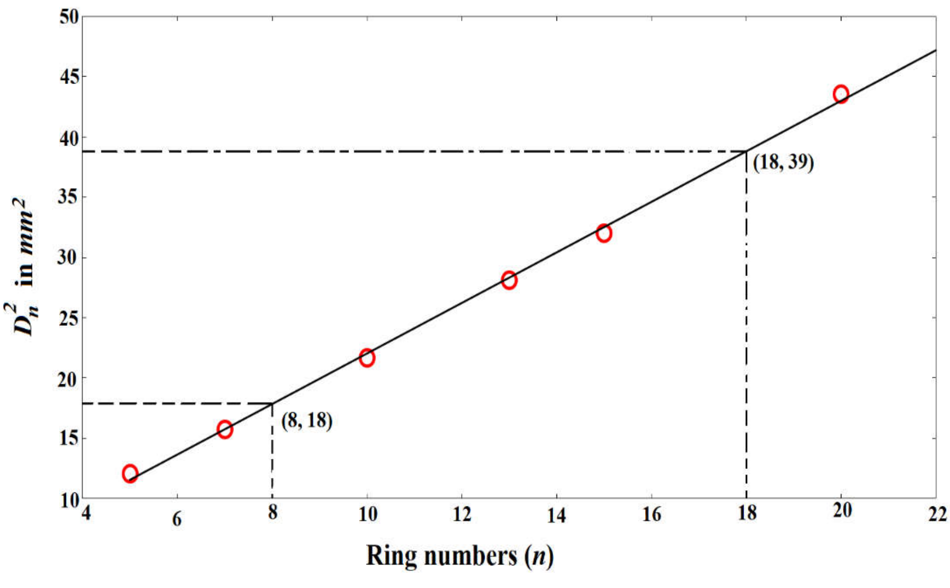
  Therefore, Least count $= \frac{1}{100} = 0.01\ mm$
- **Table for recording of microscope reading to determine ring diameter**

  (Here we give few data to understand the graph and further calculations)

Ring No. (n)	Crosswire movement	Right edge reading			Left edge reading			D_n (mm)	MeanD_n (mm)	D_n^2 (mm²)
		Main scale (mm)	Circular scale	Total (mm)	Main scale (mm)	Circular scale	Total (mm)			
20	$L \to R$	45	61	45.61	52	34	52.34	6.73	6.60	43.56
	$R \to L$	45	33	45.33	51	80	51.80	6.47		
19	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	--		
18	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
17	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
16	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
15	$L \to R$	46	03	46.03	51	75	51.75	5.72	5.66	32.03
	$R \to L$	45	70	45.70	51	30	51.30	5.60		
14	$L \to R$	--	--	--	--	--	--	---	--	--

	$R \to L$	--	--	--	--	--	--	---		
13	$L \to R$	46	22	46.22	51	56	51.56	5.34	5.30	28.09
	$R \to L$	45	89	45.89	51	15	51.15	5.26		
12	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
11	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
10	$L \to R$	46	49	46.49	51	17	51.17	4.68	4.655	21.67
	$R \to L$	46	20	46.20	50	83	50.83	4.63		
9	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
8	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
7	$L \to R$	46	86	46.86	50	83	50.83	3.97	3.965	15.72
	$R \to L$	46	54	46.54	50	50	50.50	3.96		
6	$L \to R$	--	--	--	--	--	--	---	--	--
	$R \to L$	--	--	--	--	--	--	---		
5	$L \to R$	47	10	47.10	50	59	50.59	3.49	3.47	12.04
	$R \to L$	46	78	46.78	50	23	50.23	3.45		

Calculations and results :



The above figure shows variation of D_n^2 with ring number n; which is a straight line.

- **Table for calculation of λ from graph :**

p	D_p^2 (mm^2)	m	$p+m$	D_{p+m}^2 (mm^2)	R (mm)	$\lambda = \frac{D_{p+m}^2 - D_p^2}{4mR}$
8	18.0	10	18	39.0	900	$\frac{39-18}{4\times10\times900}\ mm$ $= 583\times10^{-6}\ mm$ $= 583$ nm

Therefore, wavelength of the light coming from the source $= \mathbf{583\ \ nm}$

Discussions :

1. First few rings in the central region are deformed, so, data should not be taken for these rings
2. During the experiment the system of glass plate and plano-convex lens must not be disturbed.

Appendix: Support manual for prism spectrometer

In some of the optics experiments, we will use a spectrometer. The spectrometer is an instrument for studying the optical spectra. Light coming from a source is usually dispersed into its various constituent wavelengths by a dispersive element (prism or grating) and then the resulting spectrum is studied. A schematic diagram of a prism spectrometer is shown in Fig. 1. It consists of a collimator, a telescope, a circular prism table and a graduated circular scale along with two verniers. The collimator holds an aperture at one end that limits the light coming from the source to a narrow rectangular slit. A lens at the other end focuses the image of the slit onto the face of the prism. The telescope magnifies the light dispersed by the prism (the dispersive element for your experiments) and focuses it onto the eyepiece. The angle between the collimator and telescope are read off by the circular scale. The detail description of each part of the spectrometer is given below.

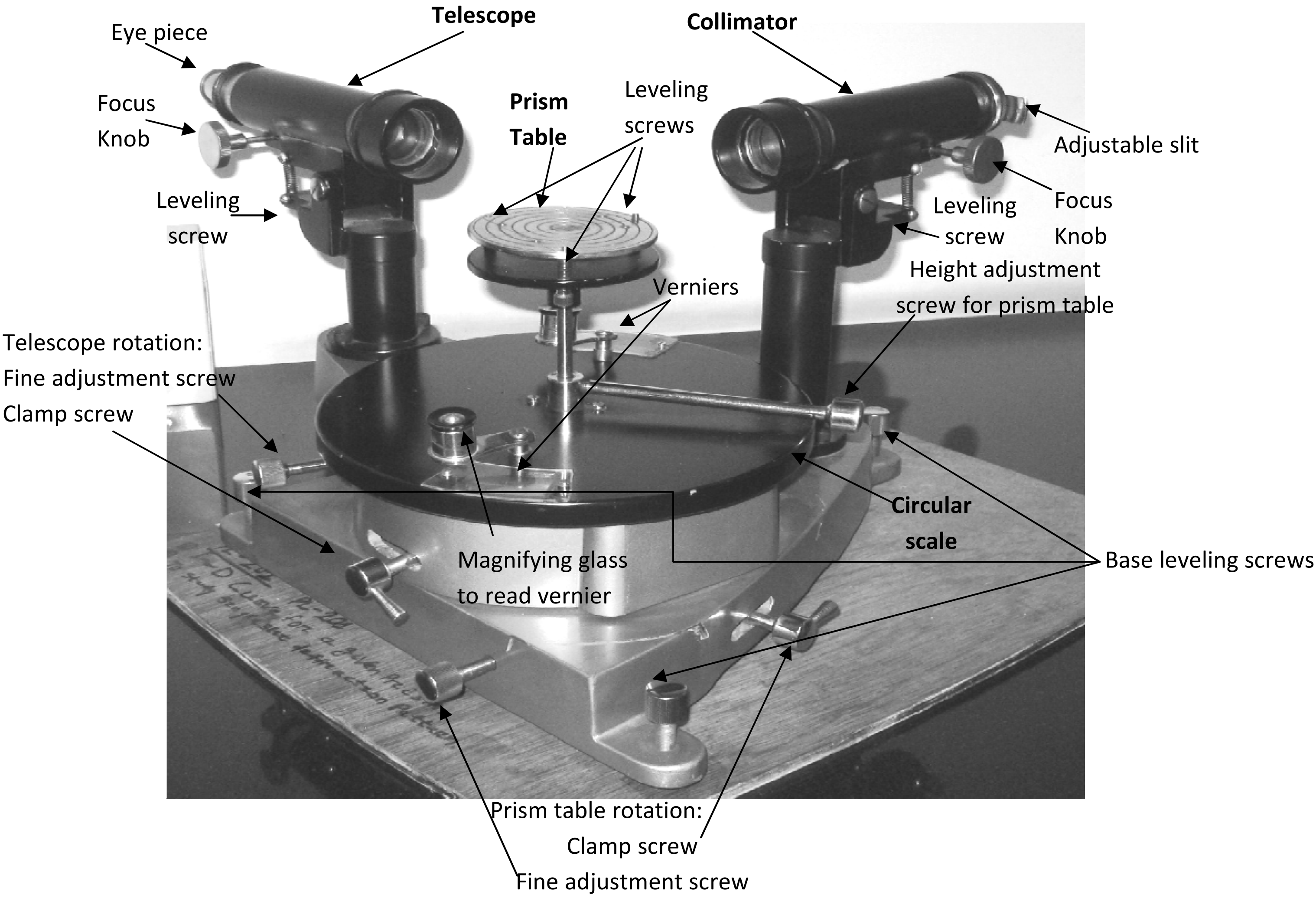


Fig. 1: Different parts of spectrometer

(i) **Collimator (*C*):** It consists of a horizontal tube with a converging achromatic lens at one end of the tube and a vertical slit of adjustable width at the other end. The slit can be moved in or out of the tube by a rack and pinion arrangement using the focus knob and its width can be adjusted by turning the screw attached to it. The collimator is rigidly fixed to the main part of the instrument and can be made exactly horizontal by adjusting the leveling screw provided below it. When properly focused, the slit lies in the focal plane of the lens. Thus the collimator provides a parallel beam of light.

(*ii*) **Prism table (*P*):** It is a small circular table and capable of rotation about a vertical axis. It is provided with three leveling screws. On the surface of the prism table, a set of parallel, equidistant lines parallel to the line joining two of the leveling screws, is ruled. Also, a series of concentric circles with the centre of the table as their common centre is ruled on the surface. A screw attached to the axis of the prism table fixes it with the two verniers and also keep it at a desired height. These two verniers rotate with the table over a circular scale graduated in fraction of a degree. The angle of rotation of the prism table can be recorded by these two verniers. A clamp and a fine adjustment screw are provided for the rotation of the prism table. It should be noted that a fine adjustment screw functions only after the corresponding fixing screw is tightened.

(*iii*) **Telescope (*T*):** It is a small astronomical telescope with an achromatic doublet as the objective and the Ramsden type eye-piece. The eye-piece is fitted with cross-wires and slides in a tube which carries the cross-wires. The tube carrying the cross wires in turn, slides in another tube which carries the objective. The distance between the objective and the cross-wires can be adjusted by a rack and pinion arrangement using the focus knob. The Telescope can be made exactly horizontal by the leveling screws. It can be rotated about the vertical axis of the instrument and may be fixed at a given position by means of the clamp screw and slow motion can be imparted to the telescope by the fine adjustment screw.

(*iv*) **Circular Scale (*C.S.*):** It is graduated in degrees and coaxial with the axis of rotation of the prism table and the telescope. The circular scale is rigidly attached to the telescope and turned with it. A separated circular plate mounted coaxially with the circular scale carries two verniers, V_1 and V_2, 180° apart. When the prism table is clamped to the spindle of this circular plate, the prism table and the verniers turn together. The whole instrument is supported on a base provided with three leveling screws. One of these is situated below the collimator.

Adjustment of Spectrometer: The following essential adjustments are to be made step by step in a spectrometer experiment: Leveling the apparatus means making (*a*) the axis of rotation of the telescope vertical, (*b*) the axis of the telescope and that of the collimator horizontal, and (*c*) the top of the prism table horizontal. The following operations are performed for the purpose.

(*i*) Leveling of telescope: Place a spirit level on the telescope tube making its axis parallel to that of the telescope. Bring the air bubble of the spirit level halfway towards the centre by first turning the two base leveling screws (i.e. leaving the base leveling screw below collimator) and then turning the telescope leveling screw. Now rotate the telescope through 180° and adjust the base and telescope leveling screws. Repeat the operations several times so that the bubble remains at the centre for both positions of the telescope. Next place the telescope in the line with the collimator and bring the air bubble of the spirit level at the centre by turning the base leveling screw below the collimator. Again check the first adjustment for the previous orientations of telescope. The axis of the rotation of the telescope has thus become vertical and the axis of the telescope has become horizontal.

(*ii*) Leveling of collimator: Remove the spirit level from the telescope. Place it on the collimator along its length. Bring the air bubble of the spirit level at the centre by adjusting the collimator leveling screw provided below the collimator. This makes the axis of the collimator horizontal.

(*iii*) Leveling of the prism table: Place a spirit level at the centre of the prism table and parallel to the line joining two of the leveling screws of the prism table. Bring the air bubble of the spirit level at the centre by turning these two screws in the opposite directions. Now place the spirit level perpendicular to the line joining the two screws and bring the bubble at the centre by adjusting the third screw. This makes the top of the prism table horizontal.

(iv) Adjusting cross wires and focusing image

Rotate the telescope towards any illuminated background. On looking through the eye-piece, you will probably find the cross-wires appear blurred. Move the eye-piece inwards or outwards until the cross-wire appears distinct.

Place the telescope in line with the collimator. Look into the eye-piece without any accommodation in the eyes. The image of the slit may appear blurred. Make the image very sharp by turning the focusing knob of the telescope and of the collimator, if necessary. If the image does not appear vertical, make it vertical by turning the slit in its own plane. Adjust the width of the slit to get an image of desired intensity.

(v) Optical leveling of a prism: The leveling of a prism makes the refracting faces of the prism vertical only when the bottom face of the prism, which is placed on the prism table, is perpendicular to its three edges. But if the bottom face is not exactly perpendicular to the edges, which is actually the case, the prism should be leveled by the optical method, as described below:

(a) Illuminate the slit by sodium light and place the telescope with its axis making an angle of about 90° with that of the collimator.

(b) Place the prism on the prism table with its vertex coinciding with that of the table and with one of its faces (faces *AB* in Fig. 2) perpendicular to the line joining two of the leveling screws of the prism table.

(c) Rotate the prism table till the light reflected from this face *AB* of the prism enters the telescope. Look through the telescope and bring the image at the centre of the field of the telescope by turning the two screws equally in the opposite directions.

(d) Next rotate the prism table till the light reflected from the other face *AC* of the prism enters the telescope, and bring the image at the centre of the field by turning the third screw of the prism table.

(vi) Focusing for Parallel rays by Schuster's method*:* This is the best method of focusing the telescope and the collimator for parallel rays within the space available in the dark room. In order to focus the telescope parallel light rays are required and this in turn requires a properly adjusted collimator. For this reason the adjustment of the telescope and the collimator are usually done together.

Schuster's method is based on the fact that the effect of the prism on the divergence of the beam is different on opposite sides of this minimum deviation position (see Fig. 2). The emergent beam will be less divergent (or more divergent) than the incident beam as the angle of incidence is increased (or decreased) from the minimum deviation value (i.e. as the apex A in Fig.2 is rotated towards, or away from, the telescope). This property of the prism can be used to obtain an accurately collimated beam. The method is explained below:

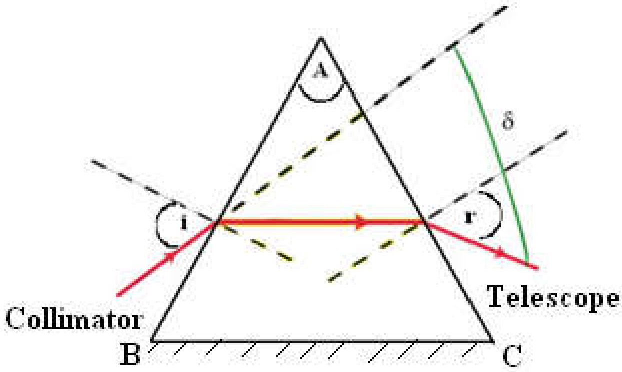


Fig. 2: Minimum deviation of light ray

(a) Place the prism on the spectrometer table as shown in Fig.2.
(b) For your prism the angle of minimum deviation is around 50° so set the telescope at an angle a few degrees greater than this (~55°).
(c) Illuminate the slit of the spectrometer with light from a sodium lamp. Rotate the prism table and observe the images of the slit through the telescope as it passes through the minimum deviation position.
(d) Lock the telescope at an angle a few degrees greater than this position.
(e) Turn the prism table away from its minimum deviation position so that apex A moves towards the telescope and a spectral line is brought into the centre of the field of view of the telescope. Adjust the focus of the telescope until this line image is as sharp as possible.
(f) Turn the prism table to the other side of the minimum deviation position until the same spectral line is again at the centre of the telescopes field of view. Now adjust the focus of the collimator until a sharp image is once more obtained.
(g) Repeat this process until no further adjustment is required. If the same line image is sharply focused when viewed on either side of the minimum deviation position then the light beam through the prism is properly collimated.

B. Sc. Physics Lab Manual

Department of Physics

Ramakrishna Mission Vivekananda Centenary College
Rahara, Kolkata – 700118

Title of the Experiment

Measurement of spring constant (k) and acceleration due to gravity (g)

Theory:

Time period of oscillation of a spring-mass system is given by,

$$T = 2\pi\sqrt{\frac{m_p + m}{k}} \qquad (1)$$

where,

m_p = Mass of the pan attached to the end of vertically suspended spring

m = Mass of the loads placed on the pan

k = Spring constant

According to (1), T^2 vs m gives a straight line and slope of this straight line is equal to $4\pi^2/k$. Therefore, measuring this slope from experimental data we can get the value of k.

Within elastic limit, elongation of a spring due to load m is given by,

$$l = \frac{mg}{k} \qquad (2)$$

Hence, l vs m gives an origin passing straight line. Slope of this line is equal to g/k.
Therefore, measuring this slope from experimental data we can get the value of g with the help of previously calculated value of k.

Data recording:

1) **Data for spring constant:**

Sl. Nos.	m (in gm)	Nos. of oscillations	Time taken (sec)	Time period (T in sec)	Average T (in sec)	T^2 (in sec^2)

2) **Data for g:**

Sl. Nos.	m (in gm)	l (in cm)	Average l (in cm)

<u>B. Sc. Physics Lab Manual</u>

Department of Physics

Ramakrishna Mission Vivekananda Centenary College
Rahara, Kolkata – 700118

Title of the Experiment

Measurement of acceleration due to gravity (g) by a bar pendulum

Theory:

Time period of oscillation of a bar pendulum is given by,

$$T = 2\pi\sqrt{\frac{I}{mgl}} \tag{1}$$

where,

I = Moment of inertia of the bar pendulum about the axis of rotation.

l = Distance of the axis of rotation from the center of mass of the bar

m = Mass of the bar pendulum

g = Acceleration due to gravity

Let, I_G is the moment of inertia of the bar pendulum about an axis passing through the center of mass, then, according to parallel axis theorem,

$$I = I_G + ml^2 \tag{2}$$

Therefore, combining (1) and (2), we get,

$$T = 2\pi\sqrt{\frac{I_G + ml^2}{mgl}} \tag{3}$$

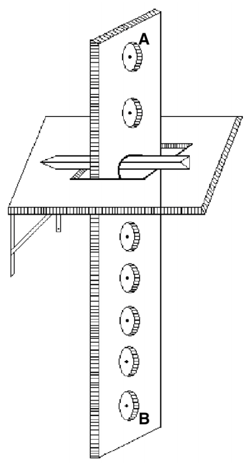
It gives a quadratic equation of l,

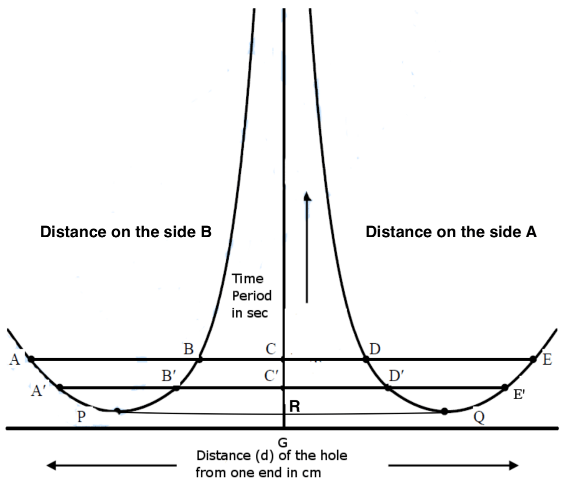
$$l^2 - \frac{gT^2}{4\pi^2}l + \frac{I_G}{m} = 0 \tag{4}$$

Let, l_1 and l_2 be two roots associated with the above quadratic equation, then,

$$l_1 + l_2 = \frac{gT^2}{4\pi^2} \tag{5}$$

From experiment, $T - l$ curve is obtained and from this curve we can identify T and $l_1 + l_2$. Then from (5), the value of g can be estimated.





Data recording:

Sl. Nos.	l (in cm)	Nos. of oscillations	Time taken (sec)	Time period (T in sec)	Average T (in sec)

Calculation of g from $T - l$ curve:

l_1 (in cm)	l_2 (in cm)	T (in sec)	g (in cm/s^2)

B. Sc. Physics Lab Manual

Department of Physics

Ramakrishna Mission Vivekananda Centenary College
Rahara, Kolkata – 700118

Title of the Experiment

To determine wavelength of sodium light using Fresnel's Biprism

Theory :

Formation of interference pattern by Fresnel's biprism is depicted in Fig. 1. Monochromatic light of wavelength λ emanating from slit S splits into two parts and forms two virtual sources S_1 and S_2 separated by distance d. These two virtual sources (slits) form the alternate dark and bright parallel band of interference fringes at the eyepiece field of view located D distance apart from the slit S.

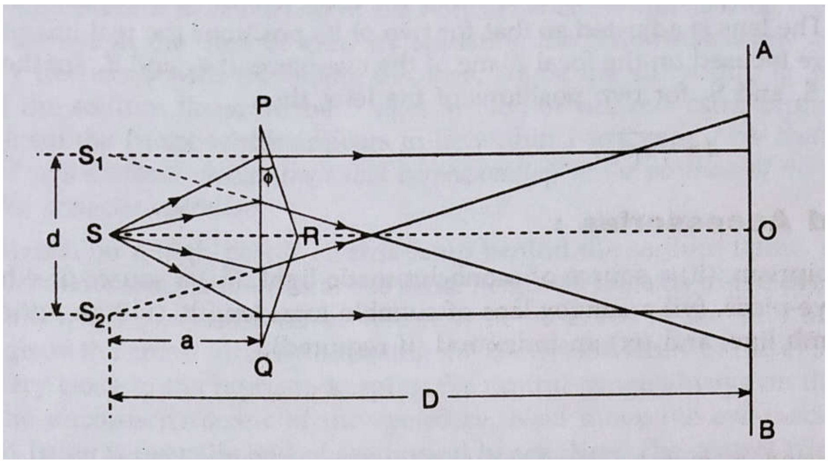


Fig. 1 : *Interference pattern formation by Fresnel's biprism*

Fringe width is given by,

$$\beta = \frac{\lambda D}{d} \tag{1}$$

If D_1 and D_2 are two different positions of eyepiece and let β_1 and β_2 are corresponding fringe width, then, from equation (1) it can be shown,

$$\lambda = \left(\frac{\beta_1 - \beta_2}{D_1 - D_2}\right) \times d \tag{2}$$

This is the working formula to determine unknown wavelength of a monochromatic source by using Fresnel's biprism.

The separation between virtual sources (i.e; d) can be obtained by measuring the separation of the image of these virtual slits formed by convex lens at two different positions between biprism and eyepiece. If d_1 and d_2 are the separation of slit images then,

$$d = \sqrt{d_1 d_2} \tag{3}$$

Apparatus :

1. Fresnel's biprism
2. Optical bench
3. Convex lens
4. Sodium light source
5. Micro-meter eyepiece

Procedure :

Part – A: Adjustments

1. Mount the slit stand near zero of the optical bench. Make the slit vertical and very narrow. Bring the slit at the middle of the optical bench using adjustment screw.
2. Mount the biprism on its stand facing its plane face towards the slit (see Fig. 1). Bring its central line parallel to slit and at the same height of the slit. Move its stand to touch the slit stand.
3. Place the sodium source at its position behind the slit. Look through the biprism towards the slit and adjust the transverse screw of the biprism to show that the common base of the biprism moves across the slit.Place biprism common base in the same line of the slit as well as middle of the optical bench.
4. Place the eyepiece to see the fringe pattern. If there is no pattern at all, adjust transverse screw of the biprism to move it lateral direction of optical bench. After getting fringe pattern, adjust tangent screw of the biprism slowly (rotates the biprism) to attain sharp fringe pattern.
5. Move the eyepiece away from the slit more than five times a distance of focal length of the given convex lens. During this process move the eyepiece away from the prism steadily and see through it, if fringe pattern goes out side the field of view, then, move biprism perpendicular to optical bench by adjusting transverse screw.
6. Place an intense white source behind the slit without moving the sodium source (just shut down the light exit window of the sodium source). Adjust transverse screw of the eyepiece to bring the crosswire at the white central bright fringe of the coloured fringe pattern due to white source. Move the eyepiece very close to the biprism and obtain the central white fringe on the cross wire of the eyepiece by adjusting eyepiece screws. Move eyepiece steadily away from the slit and adjust biprism transverse screw to get central white fringe on the crosswire. Repeat this operation several times to ensure that cross wire always remain on the white central fringe for all position of the eyepiece.
7. After doing this remove the white light source and open sodium source window.

Part – B :Measurements

8. Illuminate the slit by sodium light. Fix the eyepiece more than five times of the focal length of the given convex lens.
9. Take micrometre readings by succession of three fringe width. Repeat this process at least twice while cross wire moves from $L \rightarrow R$and$R \rightarrow L$.
10. Perform step 9 for two another positions of eyepiece.
11. Mount the convex lens in between biprism and eyepiece and adjust its height accordingly. Move the lens over the optical bench. For two different position of the lens sharp image of the virtual slits will be observed through the eye piece. Measure image slit width by micrometer screw attached with the eyepiece.

Experimental results :

- **Vernier constant of the optical bench**

1 main scale division = 1 mm

10 vernier division = 9 main scale division = 9 mm

Vernier constant = 1 main scale division - 1 vernier scale division

= 0.1 mm

= 0.01 cm

- **Least count of the micrometer screw of the eyepiece**

50 circular divisions = 0.5 mm

Least count = 0.5/50 = 0.01 mm= 0.001 cm

- **Table – 1 : Fringe width measurement**

Slit to eyepiece distance (cm)	Fringe Nos.	Eyepiece direction :$L \rightarrow R$				Eyepiece direction :$R \rightarrow L$				Mean gap between three fringes 3β (mm)	Fringe width β (mm)
		Main scale (mm)	Circular scale	Total (mm)	Gap between three fringes (mm)	Main scale (mm)	Circular scale	Total (mm)	Gap between three fringes (mm)		
120	1	1.5	3	1.53	1.11	1.5	7	1.57	1.13	1.068	0.356
	4	2.5	14	2.64	1.00	2.5	20	2.70	0.98		
	7	3.5	14	3.64	1.12	3.5	18	3.68	1.13		
	10	4.5	26	4.76	1.05	4.5	31	4.81	1.03		
	13	5.5	31	5.81	1.07	5.5	34	5.84	1.06		
	16	6.5	38	6.88	---	6.5	40	6.90	---		
100	1	1.5	21	1.71	0.96	1.5	25	1.75	0.95	0.914	0.305
	4	2.5	17	2.67	0.87	2.5	20	2.70	0.88		
	7	3.5	4	3.54	0.93	3.5	8	3.58	0.95		
	10	4.0	47	4.47	0.90	4.0	53	4.53	0.88		
	13	5.0	37	5.37	0.91	5.0	41	5.41	0.91		
	16	6.0	28	6.28	---	6.0	32	6.32	---		
80	1	1.0	5	1.05	0.75	1.0	10	1.10	0.74	0.715	0.238
	4	1.8	0	1.80	0.70	1.8	4	1.84	0.72		
	7	2.5	0	2.50	0.68	2.5	6	2.56	0.67		
	10	3.0	18	3.18	0.74	3.0	23	3.23	0.74		
	13	3.9	2	3.92	0.71	3.9	7	3.97	0.70		
	16	4.5	13	4.63	---	4.5	17	4.67	---		

- **Table – 2 : Slit width measurement**

Slit to eyepiece distance = 100 cm

Lens position	Eyepiece direction	Left image reading x_1			Right image reading x_2			Distance between slitimage $x_1 \sim x_2$ (mm)	Mean distance (mm)	Slit separation $d = \sqrt{d_1 d_2}$ (mm)
		Main scale (mm)	Circular scale	Total (mm)	Main scale (mm)	Circular scale	Total (mm)			
1st	$L \rightarrow R$	1.0	31	1.31	6.5	6	6.56	5.25	5.227 (d_1)	1.984
	$R \rightarrow L$	1.0	39	1.39	6.5	10	6.60	5.21		
	$L \rightarrow R$	1.0	35	1.35	6.5	8	6.58	5.23		
	$R \rightarrow L$	1.0	41	1.41	6.5	13	6.63	5.22		
2nd	$L \rightarrow R$	1.0	2	1.02	1.5	27	1.77	0.75	0.753 (d_2)	
	$R \rightarrow L$	1.0	4	1.04	1.5	32	1.82	0.78		
	$L \rightarrow R$	0.5	48	0.98	1.5	23	1.73	0.75		
	$R \rightarrow L$	1.0	3	1.03	1.5	26	1.76	0.73		

Calculation :

d (mm)	D_1 (mm)	β_1 (mm)	D_2 (mm)	β_2 (mm)	$\lambda = \left(\frac{\beta_1 - \beta_2}{D_1 - D_2}\right) \times d$ (mm)	Meanλ (nm)
1.984	1200	0.356	1000	0.305	$5.059 \text{ X}10^{-4}$	585.3
	1000	0.305	800	0.238	$6.646 \text{ X}10^{-4}$	
	1200	0.356	800	0.238	$5.853 \text{ X}10^{-4}$	

Calculated value of the wavelength of sodium light = 585.3 nm

B. Sc. Physics Lab Manual

Department of Physics

Ramakrishna Mission Vivekananda Centenary College
Rahara, Kolkata – 700118

Title of the Experiment

To determine grating constant from known source and then spectral lines of unknown source using plane diffraction grating

Theory and working formula :

Plane transmission grating is an optical instrument which is capable of forming diffraction spectrum of visible light (depicted in Fig. 1). It is a system of uniform parallel lines of openings and opaques arranged alternatively. If the width of opening is a and opaque is b, then, the grating constant is defined as (a+b). Number of rulings per unit length of a transmission grating is,

$$N = \frac{1}{a+b} \tag{1}$$

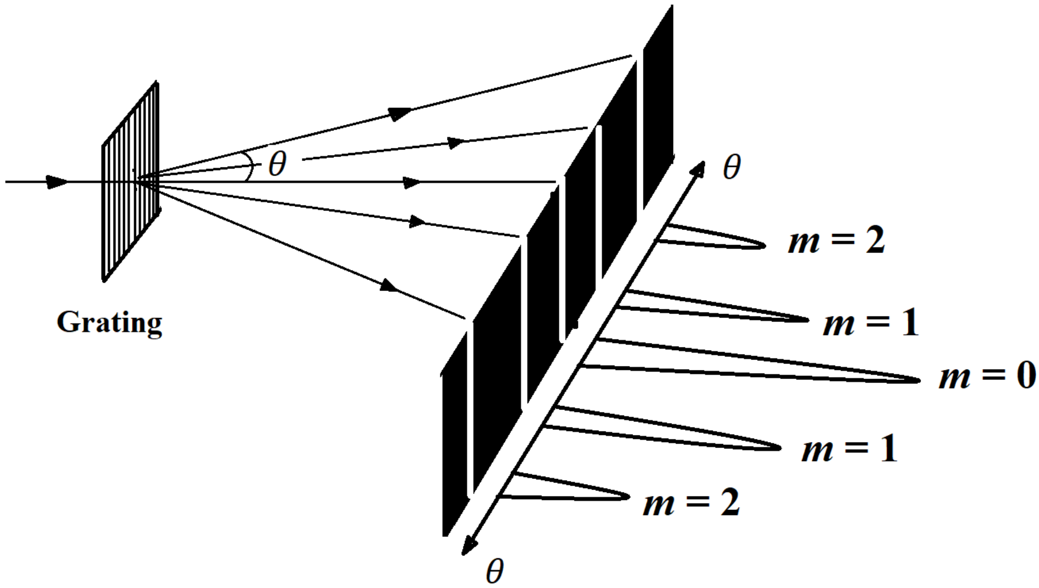


***Fig. 1 :** Pictorial representation of plane transmission grating diffraction spectrum and associated intensitydistribution.*

Parallel beam of light passing through plane transmission grating forms diffraction pattern on the other side. If θ be the angular position (with respect to incident beam direction) of m-th bright diffraction band then,

$$(a+b)sin\theta = m\lambda \tag{2}$$

$$or, \qquad \lambda = \frac{sin\theta}{mN} \tag{3}$$

Using a known source one can determine grating constant$(a+b)$ and using this value unknown wavelengths can be determined.

Apparatus :

1. Spectrometer
2. Prism
3. Transmission grating
4. Spirit level
5. Sodium light source
6. Unknown source

Procedure (in brief) :

1. **1.** Adjustment of the spectrometer (as discussed in a separate note entitled 'Spectrometer.pdf') using sodium yellow light.
   a) Levelling of telescope
   b) Levelling of collimator
   c) Mechanical levelling of prism table
   d) Crosswire focusing
   e) Optical levelling of prism
   f) Focussing for parallel ray by *Schuster's method*
2. **2.** Determine the vernier constant of the circular scale of the spectrometer.
3. **3.** Adjustment of grating :
   i) Keep sodium light at its position.
   ii) First bring the telescope to receive the direct ray from collimator and then rotate the telescope by 90^0.
   iii) Mount the grating on the prism table along its diameter and such that the grating plane is approximately normal to incident light from collimator. The grating lines is to be parallel to the slit.
   iv) Rotate the prism table to see the slit as reflected image from grating surface through the telescope. Reflection from unruled surface is brighter than reflection from ruled surface. Rotate prism table to receive reflected light from unruled surface of grating. Coincide cross wire with reflected slit image. This sets the grating to receive light at 45^0 incident angle.
   v) Rotate the prism table by 45^0 such that grating unruled surface faces the collimator.
   vi) Adjust the appropriate prism table screw such that grating rotate on its own plane to make the diffraction lines aligned properly, not up and down.

Experimental results :

- **Determination of vernier constant :**

1 smallest division in main scale = $20'$

60 vernier divisions = 59 main scale divisions = $59 \times 20'$

1 vernier divisions = $\frac{59\times 20'}{60}$

Therefore,

Vernier constant = 1 main scale division – 1 vernier division = $\left(20' - \frac{59\times 20'}{60}\right) = 20''$

- **Table – 1 : To determine diffraction angle of known wavelength ($\lambda = 589.3\ nm$)**

Order No	Vernier No	Left side reading: Main scale	Ver. scale	Total	Mean (a)	Right side reading: Main scale	Ver. scale	Total	Mean (b)	$a{\sim}b$	Mean difference (2θ)	Diffraction angle (θ)
1	I	206^{0} 00’	8	206^{0} 02’ 40”	206^{0} 02’ 10”	199^{0} 20’	2	199^{0} 20’ 40”	199^{0} 20’ 20”	6^{0} 41’ 50”	6^{0} 42’ 50”	3^{0} 21’ 55”
		206^{0} 00’	5	206^{0} 01’ 40”		199^{0} 20’	0	199^{0} 20’ 00”				
	II	26^{0} 00’	11	26^{0} 03’ 40”	26^{0} 04’ 00”	19^{0} 20’	0	19^{0} 20’ 00”	19^{0} 20’ 10”	6^{0} 43’ 50”		
		26^{0} 00’	13	26^{0} 04’ 20”		19^{0} 20’	1	19^{0} 20’ 20”				
2	I	209^{0} 20’	18	209^{0} 26’ 00”	209^{0} 25’ 40”	195^{0} 40’	25	195^{0} 48’ 20”	195^{0} 48’ 30”	13^{0} 37’ 10”	13^{0} 37’ 00”	6^{0} 48’ 30”
		209^{0} 20’	16	209^{0} 25’ 20”		195^{0} 40’	26	195^{0} 48’ 40”				
	II	29^{0} 20’	19	29^{0} 26’ 20"	29^{0} 26’ 50"	15^{0} 40’	28	15^{0} 49’ 20”	15^{0} 50’ 00”	13^{0} 36’ 50”		
		29^{0} 20’	22	29^{0} 27’ 20”		15^{0} 40’	32	15^{0} 50’ 40”				
3	I	212^{0} 40’	31	212^{0} 50’ 20”	212^{0} 49’ 50”	192^{0} 20’	18	192^{0} 26’ 00”	192^{0} 26’ 10”	20^{0} 23’ 40”	20^{0} 22’ 30”	10^{0} 11’ 15”
		212^{0} 40’	28	212^{0} 49’ 20”		192^{0} 20’	19	192^{0} 26’ 20”				
	II	32^{0} 40’	24	32^{0} 48’ 00”	32^{0} 48’ 20”	12^{0} 20’	22	12^{0} 27’ 40”	12^{0} 27’ 00”	20^{0} 21’ 20”		
		32^{0} 40’	26	32^{0} 48’ 40”		12^{0} 20’	19	12^{0} 26’ 20”				

- **Table – 2 : To determine diffraction angle for unknown wavelength**

Order No	Vernier No	Left side reading				Right side reading				$a \sim b$	Mean difference (2θ)	Diffraction angle (θ)
		Main scale	Ver. scale	Total	Mean (a)	Main scale	Ver. scale	Total	Mean (b)			
1	I	202° 20’	10	202° 23’20”	202° 23’ 00”	196° 00’	18	196° 06’ 00”	196° 06’ 20”	6° 16’ 40”	6° 17’ 00”	3° 08’ 30”
		202° 20’	7	202° 22’ 40”		196° 00’	20	196° 06’ 40”				
	II	22° 20’	14	22° 24’ 40”	22° 24’ 10”	16° 00’	20	16° 06’ 40”	16° 06’ 50”	6° 17’ 20”		
		22° 20’	11	22° 23’ 40”		16° 00’	21	16° 07’ 00”				
2	I	205° 20’	18	205° 26’ 00”	205° 25’40 ”	193° 00’	3	193° 01’ 00”	193° 00’ 40”	12° 25’ 00”	12° 25’ 50”	6° 12’ 55”
		205° 20’	16	205° 25’ 20”		193° 00’	1	193° 00’ 20”				
	II	25° 20’	19	25° 26’ 20”	25° 26’50 ”	13° 00’	0	13° 00’ 00”	13° 00’ 10”	12° 26’ 40”		
		25° 20’	22	25° 27’ 20”		13° 00’	2	13° 00’ 40”				
3	I	208° 40’	5	208° 41’ 40”	208° 41’ 40”	189° 40’	25	189° 48’ 20”	189° 47’ 50”	18° 53’ 50”	18° 54’ 10”	9° 27’ 05”
		208° 40’	5	208° 41’ 40”		189° 40’	22	189° 47’ 20”				
	II	28° 40’	10	28° 43’ 20”	28° 43’ 10”	9° 40’	27	9°49’ 00”	9° 48’ 40”	18° 54’ 30”		
		28° 40’	9	28° 43’ 00”		9° 40’	25	9°48’ 20”				

Calculations and results :

- **Table – 3 : To determine number of grating rulings using known source (Table – 1)**

Known wavelength λ (cm)	Order No. m	Diffraction angle θ	Nos. of rulings per unit length $N = \frac{sin\theta}{m\lambda}$ (cm^{-1})	Mean N (cm^{-1})
589.3×10^{-7}	1	3^0 21' 55"	996	1000
	2	6^0 48' 30"	1006	
	3	10^0 11' 15"	1000	

- **Table – 4 : To determine unknown wavelength (Table – 2, 3)**

Nos. of rulings per unit length N (cm^{-1})	Order No. m	Diffraction angle θ	Wavelength $\lambda = \frac{sin\theta}{mN}$ (cm)	Mean λ (nm)
1000	1	3^0 08' 30"	548.05×10^{-7}	545.6
	2	6^0 12' 55"	541.32×10^{-7}	
	3	9^0 27' 05"	547.37×10^{-7}	

Obtained value of the wavelength of the unknown source = 545.6 nm