Physics
Lab Manual
1-2

FIGURE NO.__________

Heaven's Light is our Guide
Department of Physics
Rajshahi University of Engineering & Technology

Experiment Name (1st Year Even Semester CE / IPE / GCE)

1. DETERMINATION OF THE RADIUS OF CURVATURE OF A PLANO CONVEX LENS BY NEWTONS RING METHOD.

2. DETERMINATION OF THE REFRACTIVE INDEX OF THE MATERIAL OF A PRISM BY A SPECTROMETER

3. DETERMINATION OF THE SPECIFIC ROTATION OF SUGAR SOLUTION BY MEANS OF POLARIMETER.

4. DETERMINATION OF THE FOCAL LENGTH OF A CONCAVE LENS BY AN AUXILLIARY CONVEX LENS.

5. DETERMINATION OF THE VALUE OF ACCELERATION DUE TO GRAVITY (g) BY MEANS OF A COMPOUND PENDULUM.

6. DETERMINATION OF THE WAVELENGTH OF SODIUM LIGHT BY A PLANE DIFFRACTION GRATTING WITH THE HELP OF A SPECTROMETER.

N.B.

1. Students must have to do at least four (04) of the above experiments.
2. Make a rough loose sheet for each experiment.
3. Students are advised to write (a) Name, (b) Theory with figure, (c) Required Apparatus and (d) Data Table of the assigned experiment in the rough loose sheet before coming into the lab. Otherwise they will not be allowed to enter into the lab.
4. Keep preparation for Table Viva everyday. This may be your final lab viva.
5. Make a fair note book for your final examination and complete it regularly. In fair note book write down the followings: (a) Name of the experiment with date, (b) Theory with figure, (c) Required Apparatus, (d) Procedure,(e) Data Table, (f) Calculations, (g) Result and (h) Precautions and Discussion.
6. Always keep some graph papers (8.5 inch x 11.5 inch) with you
7. Cell phone are not allowed during sessional class.(Cell phone must be in swtiched off mode. Keep it within your own bag in your own responsibility)

DETERMINATION OF THE REFRACTIVE INDEX OF THE MATERIAL OF A PRISM BY SPECTROMETER.*

Theory

Let a ray PQ be the incident on the first face AB of a prism and then after passing through the prism, finally emerges out through the other face AC in the direction RS. Let i_1 and r_1 be the respective angles of incidence and refraction at the first face of the prism and r_2 and i_2 be the corresponding quantities for the second face. Now the deviation of the ray is given by the angle $\angle SOT$,

$$\delta = (i_1 - r_1) + (i_2 - r_2) \ldots\ldots\ldots (1)$$

But in the minimum deviation position, the ray passes symmetrically through the prism so that $i_1 = i_2$ and $r_1 = r_2$. Therefore the angle of the minimum deviation

$$\delta_m = 2(i_1 - r_1) \ldots\ldots\ldots (2)$$

But

$$\angle LMR = r_1 + r_2 = 2r_1 = A \ldots\ldots\ldots (3)$$

i.e.

$$r_1 = \frac{A}{2}$$

where A = angle of prism

From Equations (2) and (3), we get $i_1 = \frac{A+\delta_m}{2}$.

Hence the refractive index of the material of the prism (for a particular color) is given by

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

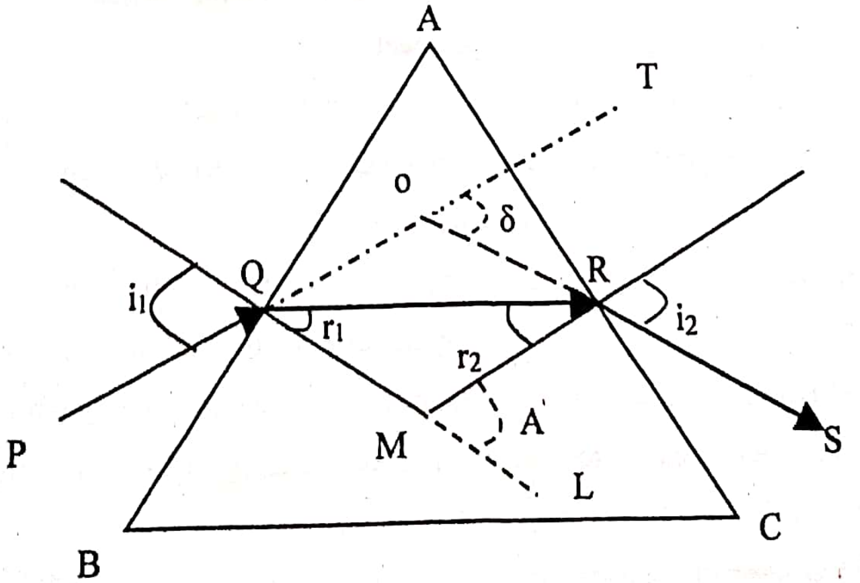

Fig.1: Refraction mechanism through the prism.

* This manual is just a guideline for students. For details, please go through books and other references. Students can draw only the data table from manual. Please write detail theory from textbook. Procedure, precautions and discussion must be written with past tense and passive form.

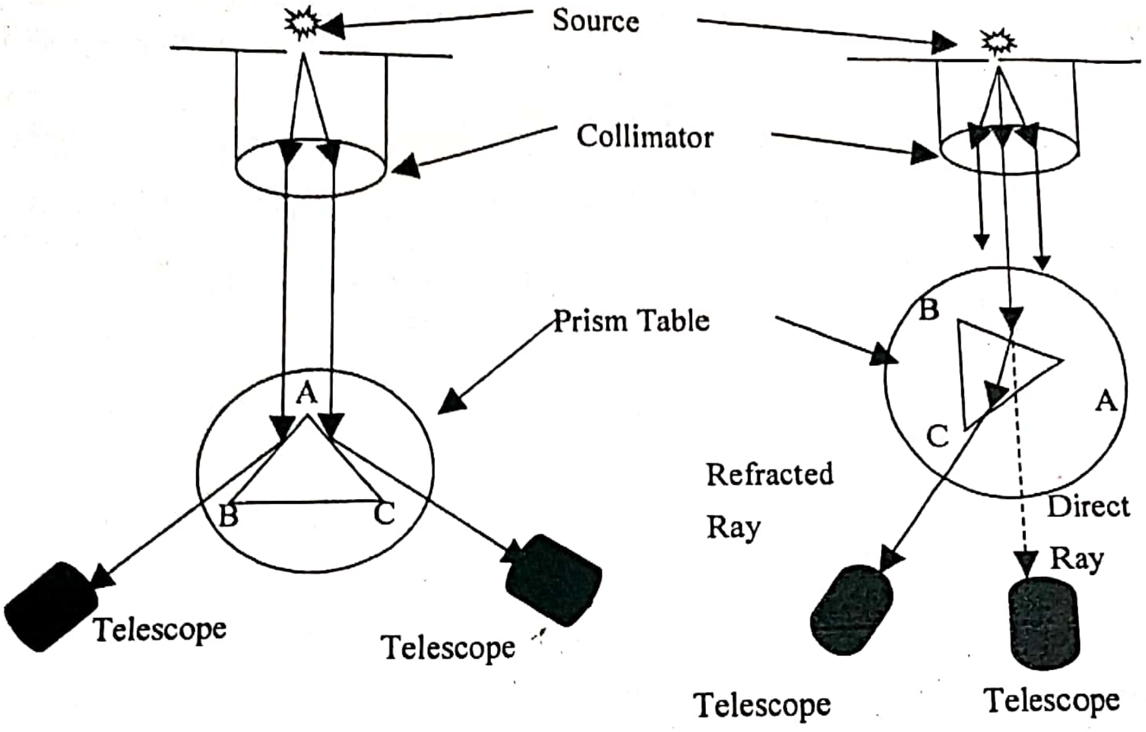

Fig.2: Measurement of the prism angle, A.

Fig.3: Measurement of the angle of minimum deviation, δ_m.

Required Apparatus

Spectrometer, prism, spirit level, Na light, etc.

Procedure

Write yourself (past tense with passive voice).

Experimental Data

Table 1: Data for the angle of prism *A*.

Vernier constant (VC) = ⋯ deg.

No. of obs.	Vernier no.	Readings of the reflected images: Left side: MSR M (deg)	VSD D (div)	VSR $V = (D \times VC)$ (deg)	TR $P = (M + V)$ (deg)	Right side: MSR M (deg)	VSD D (div)	VSR $V = (D \times VC)$ (deg)	TR $Q = (M + V)$ (deg)	$A = \left(\frac{P \sim Q}{2}\right)$ (deg)	Mean A (deg)
1	Scale A										
	Scale B										
2	Scale A										
	Scale B										

[NB: MSR = main scale reading, VSD = vernier scale division, VSR = vernier scale reading, TR= total reading.]

Table 2: Data for the angle of minimum deviation δ_m.

No. of obs.	Vernier no.	Reading at minimum deviation position				Direct reading				$\delta_m =$ $(P \sim Q)$ (deg)	Mean δ_m (deg)
		MSR M (deg)	VSD D (div)	VSR $V =$ $(D \times \text{VC})$ (deg)	TR $P =$ $(M + V)$ (deg)	MSR M (deg)	VSD D (div)	VSR $V =$ $(D \times \text{VC})$ (deg)	TR $Q =$ $(M + V)$ (deg)		
1	Scale A										
	Scale B										
2	Scale A										
	Scale B										

Calculations

Results

$\mu = \cdots$

Percentage of error =

Precautions and Discussion

1. The source should be kept in front of the collimator to make the image bright.
2. The cross-wire should be made coincident with the same edge of the slit image.
3. Parallax error should be avoided.
4. The telescope should be rotated in the same direction to avoid backlash error.
5. The width of the slit image should be made as narrow as possible.
6. Readings should be taken carefully to ascertain whether the zero of the main scale crossed from one position to the other.

DETERMINATION OF THE VALUE OF ACCELERATION DUE TO GRAVITY, g BY MEANS OF A COMPOUND PENDULUM.*

Theory

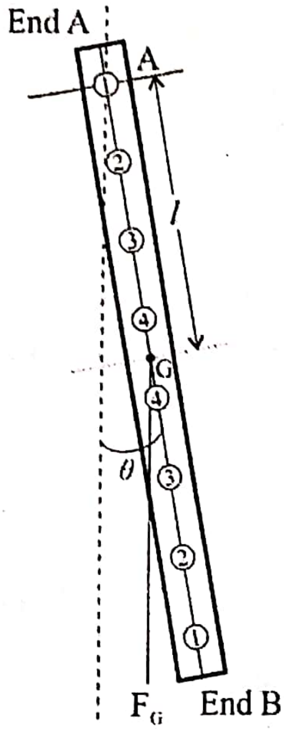

Fig. 1: Compound pendulum.

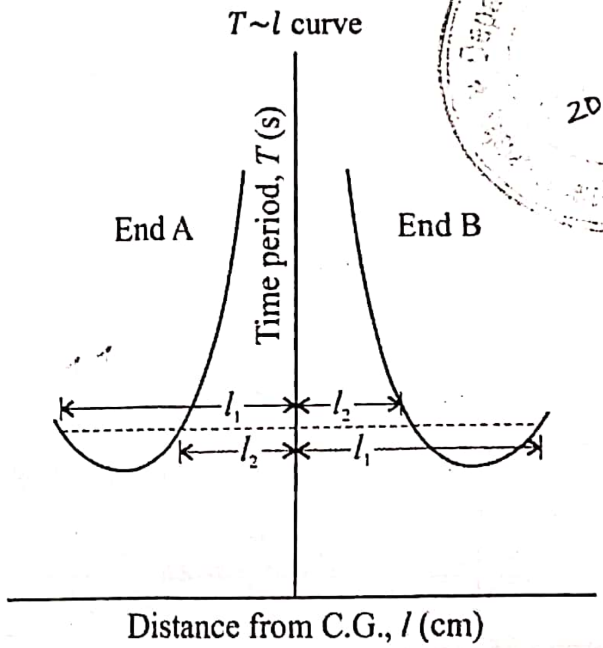

Fig. 2: $T \sim l$ curve.

Compound pendulum is a rigid body of any shape free to turn about a horizontal axis. The center of gravity at distance l from A is denoted by G. The pendulum experiences a restoring angular momentum. At an angle θ from the mean position, the restoring angular momentum is

$$M = mgl \sin\theta \text{ .... } (1)$$

Here, mg is force and $l \sin\theta$ is the distance from the axis of rotation.

From the Newton's law of motion for a rotary motion,

$$\text{torque} = \text{moment of inertia} \times \text{angular acceleration}$$

$$-mgl \sin\theta = I_A \alpha \text{ .... } (2)$$

where I_A is the moment of inertia relative to axis of rotation and α is the angular acceleration.

In a compound pendulum, there are two axes. One is point of suspension and another is center of gravity of a pendulum. So from parallel axis theorem, we can write

$$I_A = I_G + ml^2 \text{ .... } (3)$$

I_G corresponds to the moment of inertia relative to the axis at the center of gravity G.

$$I_G = mk^2 \text{ .... } (4)$$

where k is called the radius of gyration.

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Equation (3) can be written as

$$I_A = mk^2 + ml^2$$

or

$$I_A = m(k^2 + l^2) \dots\dots\dots (5)$$

A simple solution of the differential Equation (1) exist only for small amplitude θ, where $\sin\theta \approx \theta$. Equation (1) is then equal to an equation of oscillation.

$$\alpha = \frac{mgl}{I_A}\theta \dots\dots\dots (6)$$

with the following solution

$$\theta(t) = \theta_0(t)\cos(\omega t + \gamma) \dots\dots\dots (7)$$

Here, $\theta_0(t)$ = initial amplitude and $\theta(t)$ = amplitude at time t.

This describes a harmonic oscillation with amplitude θ_0 and angular velocity

$$\omega = \sqrt{\frac{mgl}{I_A}} = \sqrt{\frac{gl}{I_A}} \dots\dots\dots (8)$$

The corresponding oscillation Time period is given by

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{k^2 + l^2}{gl}} \dots\dots\dots (9)$$

The time period of oscillation of a compound pendulum is given by,

$$T = 2\pi\sqrt{\frac{l^2 + k^2}{lg}} \dots\dots\dots (10)$$

Equation (10) can be written in the quadratic form as

$$l^2 - \frac{T^2 g}{4\pi^2} l + k^2 = 0 \dots\dots\dots (11)$$

If l_1 and l_2 are the distances i.e. the roots of Equation (11) for the same time period T, then we can write

$$l_1 + l_2 = \frac{T^2 g}{4\pi^2} \dots\dots\dots (12)$$

and

$$l_1 l_2 = k^2 \dots\dots\dots (13)$$

Equation (12) can be rearranged to the form

$$g = \frac{4\pi^2(l_1 + l_2)}{T^2} \dots\dots\dots (14)$$

By measuring the values of $L = (l_1 + l_2)$ and T graphically, g may be calculated from Equation (14).

Required Apparatus

A compound pendulum, stopwatch, meter scale, knife-edge, etc.

Procedure

1. The center of gravity of the pendulum was determined.
2. The distance of each of the holes from the center of gravity was measured.
3. Time for 20 oscillations, t was recorded twice for each of the holes used as point of suspension.
4. A graph of T versus L was plotted (Fig. 2). The values of l_1 and l_2 taken for the same T.

Experimental Data

Table 1: Data for time period.

End	No. of holes	Distance between point of suspension and center of gravity l (cm)	Time for ... oscillations (s)			Time period T (s)
			t_1	t_2	Mean t	
A	1					
	2					
	...					
	10					
B	1					
	2					
	...					
	10					

Results

$g = \cdots \text{ m/s}^2$

Percentage of error =

Precautions and Discussion

1. Amplitude of oscillation was kept within 4°.
2. The knife-edge was made horizontal for every reading.
3. Error due to the curved knife-edge, yielding the support and resistance of air were avoided as far as possible.
4. Stopwatch was used to measure time.
5. Distances between the point of suspension and CG were measured carefully.

DETERMINATION OF THE RADIUS OF CURVATURE OF A PLANO-CONVEX LENS BY NEWTON'S RING APPARATUS.*

Theory

When a parallel beam of monochromatic light of wavelength λ is incident on a combination of P and C as shown in Fig.1, a part of it is reflected from the lower surface of the lens, and a part after refraction through the film between P and C is reflected back from the glass plate P. when the refracted ray strikes the glass plate, it undergoes a phase change of 180^0 on reflection. After reflection, the two rays of 1 and 2 are obtained. These rays interfere each other producing alternate bright and dark rings around the point of contact. At the point of contact, the thickness of air film is zero. As a $\lambda/2$ path difference occurs, they cancel each other and a dark ring is obtained at the Centre. These rings were first discovered by Newton, that's why they are called Newton's rings.

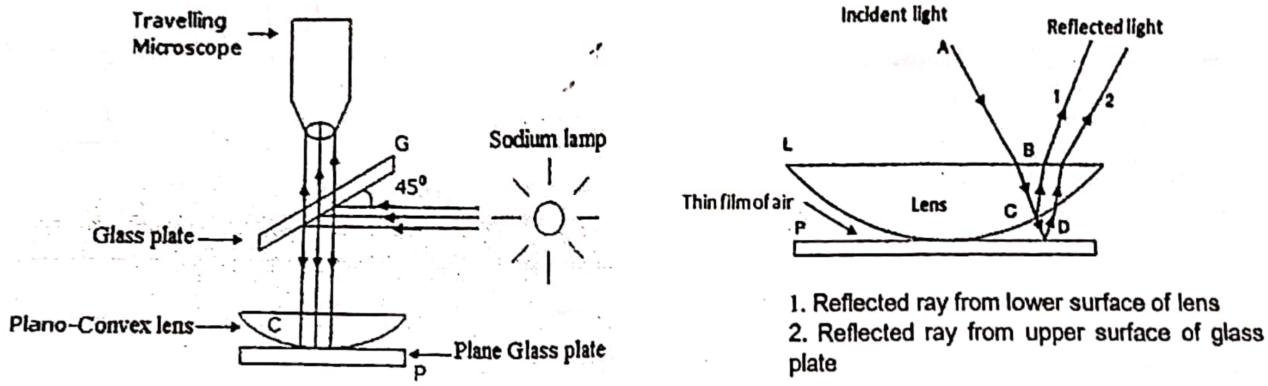

Fig. 1: Experimental setup to find Newton's Ring

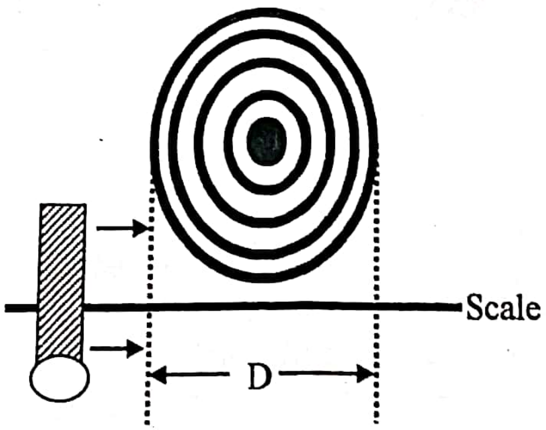

Fig. 2: Observed Newton's Rings. Center is dark because of π phase change during reflection at glass plate.

Let D_n and D_{n+p} be the diameters of the n^{th} and $(n+p)^{th}$ bright or dark rings for normal incidence.

Diameter of the n^{th} dark ring is

$$D_n = \sqrt{4n\lambda R} \ldots\ldots\ldots (1)$$

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And diameter of the $(n+p)^{th}$ dark ring is

$$D_{n+p} = \sqrt{4(n+p)\lambda R} \;\ldots\ldots\ldots (2)$$

By subtracting Equation (1) from (2) the wavelength λ of the incident monochromatic light is given by the equation

$$R = \frac{D_{n+p}^2 - D_n^2}{4p\lambda} \;\ldots\ldots\ldots (3)$$

where λ is known (for Na-light, $\lambda \approx 5893$ Å). Then by measuring the diameter D_n and D_{n+p} of the n^{th} and $(n+p)^{th}$ bright or dark rings, the value of R can be determined.

Required Apparatus

Plano-convex lens, plane glass sheets, travelling microscope, wooden box, sodium flame arrangement, etc.

Procedure

Write yourself (past tense with passive voice).†

Experimental Data

Table 1: Readings for diameters of the rings.

Least count (LC) = ⋯ cm.

Ring no.	Readings of the microscope								Diameter $D = (L - R)$ (cm)	D^2 (cm^2)
	Left side				Right side					
	MSR S (cm)	CSD D (div)	CSR $C = (D \times \text{LC})$ (cm)	TR $L = (S + C)$ (cm)	MSR S (cm)	CSD D (div)	CSR $C = (D \times \text{LC})$ (cm)	TR $R = (S + V)$ (cm)		
1										
2										
3										
…										

[NB: MSR = main scale reading, CSD = circular scale division, CSR = circular scale reading, TR= total reading.]

Calculations

From data:

Consider diameters of any two arbitrary rings

For example, n^{th} ring is 3rd ring and $(n+p)^{th}$ ring is 5th ring, then $p = (5 - 3) = 2$

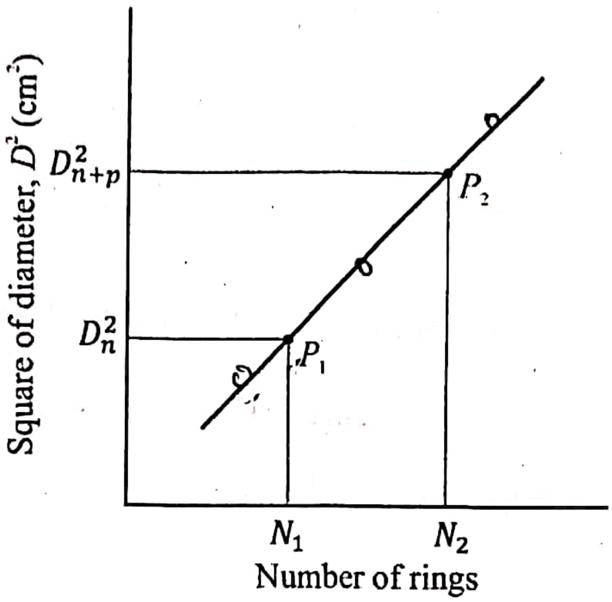
$$R = \frac{D_{n+p}^2 - D_n^2}{4p\lambda}$$

† Ref: Advanced Practical Physics by K Din, and Practical Physics by Giasuddin Ahmad

Putting the values of D, p and λ, the radius of curvature R can be determined.

From graph:

Equation (3) can be written as $D_{n+p}^2 - D_n^2 = (4\lambda R)p$, this equation is comparable with $y = mx + c$. Here, $y = D_{n+p}^2 - D_n^2$, $4R\lambda = m$, $p = x$ and $c = 0$.



But, Equation (3) can be written as

$$R = \frac{m}{4\lambda} \ldots\ldots\ldots (4)$$

where slope $m = \frac{P_2N_2 - P_1N_1}{N_1N_2} = \frac{D_{n+p}^2 - D_n^2}{p}$

Finding P_2N_2, P_1N_1 and N_1N_2 from the graph, the value of R can be determined from Equation (4).

Results

$R = \cdots$ cm (from calculations)

$R = \cdots$ cm (from graph)

Precautions and Discussion

1. Backlash error should be avoided.
2. Diameter should be measured very carefully.
3. The cross wire of travelling microscope should be set mid-way between the outer and inner edges of a ring to avoid error.

DETERMINATION OF THE WAVELENGTH OF SODIUM LIGHT BY PLANE DIFFRACTION GRATING.*

Theory

A parallel beam of light of wavelength λ, coming out from a collimator falls normally on a plane diffraction grating. The grating is placed vertically on a prism table, a series of diffracted images of the collimator slit will be observed on both sides of the direct image.

The equation of interference maxima (that is the grating equation) can be written as,

$$(a+b)\sin\theta = n\lambda \text{ ……… (1)}$$

Here, θ = angle of deviation; $(a+b)$ = grating element, and n = order number $(0,1,2,3,\ldots)$.

Since $(a+b) = \frac{1}{N}$, where N is the grating constant i.e. number of lines or ruling or grooves or scratches per cm of the grating surface

$$\sin\theta = nN\lambda$$

or

$$N = \frac{\sin\theta}{n\lambda}$$

or

$$\lambda = \frac{\sin\theta}{nN} \text{ ……… (2)}$$

The wavelength λ can be determined from Equation (2) by the known values of N, the order (n) and the diffraction angle (θ).

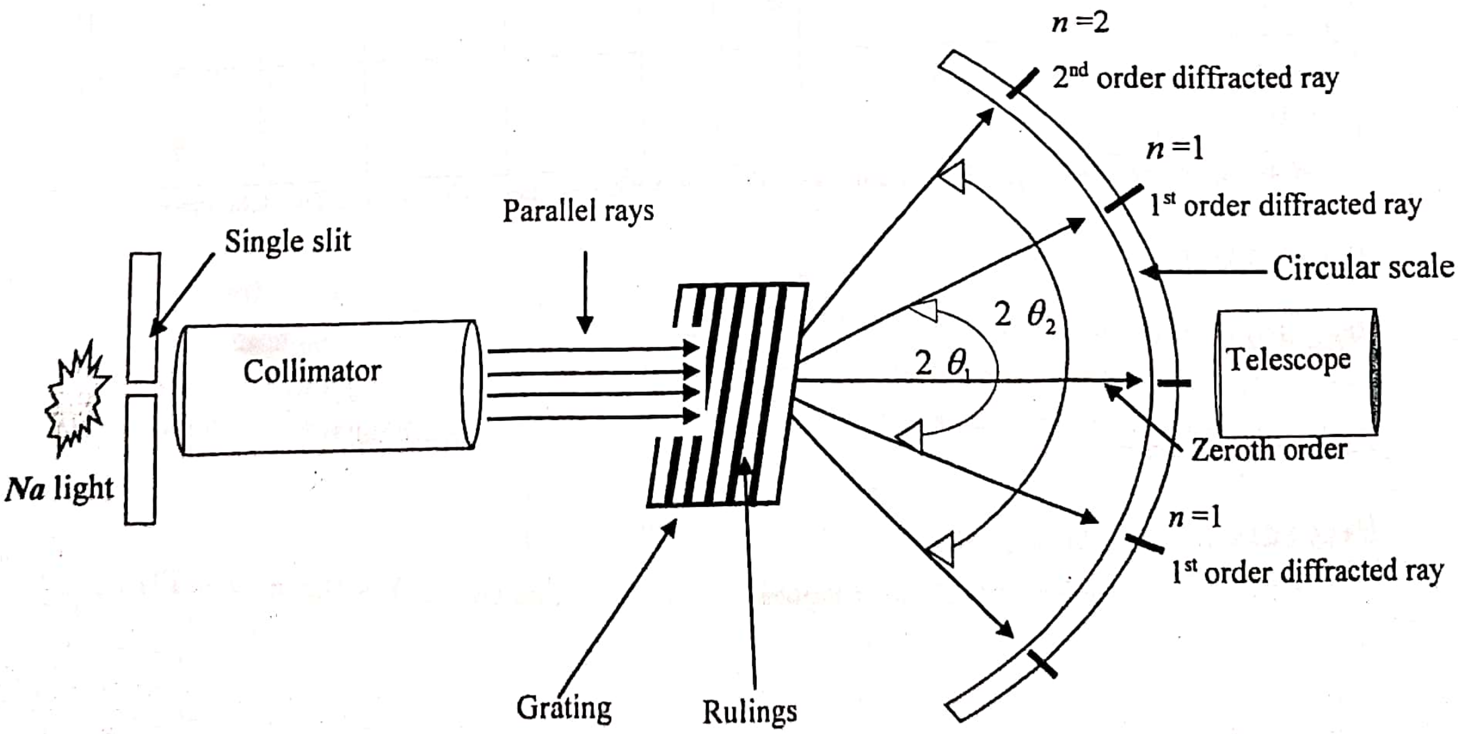


Fig. 1: Diffraction mechanism through grating.

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Required Apparatus
Spectrometer, Na light, grating, spirit level, etc.

Procedure
Write yourself (past tense with passive voice).

Experimental Data

Table 1: Data for the angle of diffraction.
Vernier constant (VC) = ⋯ deg.

Order no.	Vernier	Readings for the diffracted images								$2\theta =$ $(P \sim Q)$ (deg)	θ (deg)	Mean θ (deg)
		Left side				Right side						
		MSR M (deg)	VSD D (div)	VSR $V =$ $(D \times \text{VC})$ (deg)	TR $P =$ $(M + V)$ (deg)	MSR M (deg)	VSD D (div)	VSR $V =$ $(D \times \text{VC})$ (deg)	TR $Q =$ $(M + V)$ (deg)			
1	scale A											
	scale B											
2	scale A											
	scale B											

MSR = main scale reading, VSD = vernier scale division, VSR = vernier scale reading, TR= total reading

Calculations

Results
$\lambda = \cdots$ Å

Percentage of error = ⋯

Precautions and Discussion
Write yourself (past tense with passive voice).

DETERMINATION OF THE SPECIFIC ROTATION OF SUGAR SOLUTION BY USING A POLARIMETER.*

Theory

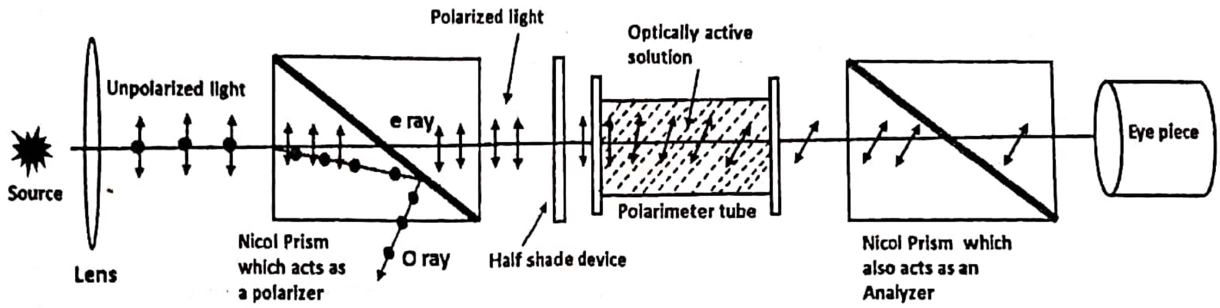

Fig. 1: Laurent's half shade polarimeter.

The specific rotation of a solution is a characteristic physical property of a given optically active molecules. If the specific rotation of a compound is positive, the compound is said to be dextrorotatory, if negative, it is referred to as levorotatory. The substances that rotate the plane of vibration to the right are called right-handed or dextrorotatory and the substances that rotate the plane of vibration to the left are called left-handed or levorotatory. The angle of rotation produced to the plane of vibration by an optically active substance in solution is proportional to

1. the thickness of the solution
2. the concentration of the solution or the density of the active substance in the solvent and
3. the nature of the substance.

Thus we can write

$$\theta \propto lc$$

or

$$\theta = Slc$$

or

$$S = \frac{\theta}{lc}$$

where θ is the angle of rotation produced, l is the length of the solution in decimeters, c is the concentration of the solution and $c = \frac{m}{V}$ gm/cm^3, where m is the mass of sugar in grams dissolved in water, V is the volume of sugar solution, S is a constant called specific rotation and depends upon the nature of the solution.

If l is in decimeter then, $S = \frac{\theta}{lc}$.

If $l = 1$ decimeter ($10\ cm$) and $c = 1$ gm/cm^3 then $S = \theta$.

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In our experiment, usually we measure l in cm and the concentration of the sugar solution is not unit concentration. In that case,

$$\text{Specific rotation} = \frac{\text{Rotation produced by 1 decimeter length of the solution}}{\text{Density of the solution in gm/cm}^3} = \frac{\theta/\left(\frac{l}{10}\right)}{c}$$

$$= \frac{10\theta}{lc}$$

where l is the length expressed in centimeters.

> If l is in centimeter then $S = \frac{10\theta}{lc}$.

Now the angles of rotation, θ for different values of known concentrations, c of a solution can be measured with the help of a polarimeter. If a graph is plotted with θ against c, then the graph will be a straight line. The polarimeter is thus calibrated.

Required Apparatus

Polarimeter, balance, measuring cylinder, sugar, beaker, thermometer and a source of light.

Procedure

Write yourself (past tense with passive voice).

Experimental Data

Weight of empty watch glass, $m_1 = \cdots$ gm

Weight of watch glass and sugar, $m_2 = \cdots$ gm

Weight of sugar, $(m_2 - m_1) = \cdots$ gm

Length of the sugar solution, $l = \cdots$ cm

[NB: Students should note that vernier scale is divided into 20 divisions.]

Table 1: Data for determining angular rotation.

No. of obs.	Strength of the solution (%)	Concentration of sugar solution (gm/cm³)	Reading with water P (deg)					Reading with solution Q (deg)					Angular rotation $(Q-P)$ (deg)	Mean angular rotation (deg)	Specific rotation S (deg)
				MSR (deg)	VSD (div)	VSR (deg)	TR (deg)		MSR (deg)	VSD (div)	VSR (deg)	TR (deg)			
			Scale A					Scale A							
			Scale B					Scale B							
			Same reading					Scale A							
								Scale B							
								Scale A							
								Scale B							
								Scale A							
								Scale B							

[NB: MSR = main scale reading, VSD = Vernier scale division, VSR = Vernier scale reading, TR= total reading.]

Calculations

Length of the sugar solution, $l = \cdots$ cm

[NB: l is the length of the sugar solution, it is not the length of the tube.]

$$\text{Concentration} = \frac{mass}{volume} = \cdots \text{gm/cm}^3$$

So for a 20% solution, Specific rotation, $S = \frac{10\theta}{lc} =$

For 15% solution, —

For 10% solution, —

For 5% solution, —, etc.

Calculate in a similar manner the specific rotation from θ and corresponding to point of the graph.

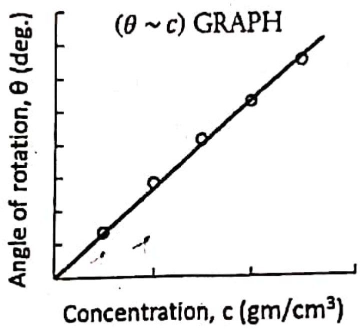

Fig. 2: $(\theta \sim c)$ graph.

[NB: Students should plot angle of rotation versus concentration (not strength) curve.]

Results

$S = \cdots$ (from graph)

$S = \cdots$ (from calculation)

Precautions and Discussion

1. The polarimeter tube should be well cleaned.
2. Water used should be dust free.
3. Whenever a solution is changed, rinse the tube with the new solution under examination.
4. There should be no air bubble inside the tube.
5. Reading should be taken when halves of the field of view becomes equally illuminated.
6. The temperature of the solutions should be maintained constant during the experiment since the rotation depends on the temperature of the solution.
7. The rotation also depends on the wavelength. Hence Na-light of wavelength $\lambda =$ 5893 Å is to be employed to find the rotation.

FIGURE NO...

DETERMINATION OF THE FOCAL LENGTH OF A CONCAVE LENS WITH THE HELP OF AN AUXILIARY CONVEX LENS.*

Theory

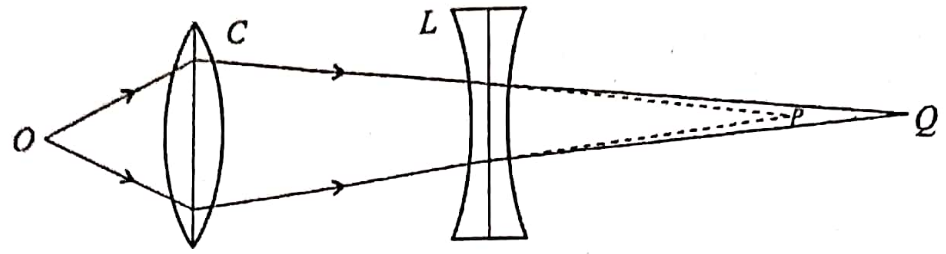

Fig.1. Image with convex lens and concave lens.

A concave lens cannot produce a real image of a real object; but if a virtual object is placed within its focus, it can produce a real image of the virtual object. This principle is utilized in determining the focal length of a concave lens. At first a real image of a real object is produced with the help of a convex lens. Then a concave lens is interposed between the convex lens and its real image falls within the focus of the concave lens. The real image then acts as the virtual object for the concave lens. This method has the advantage that the focal length of the convex lens need not necessarily be less than that of the concave lens and is therefore suitable for any pair of concave and convex lenses. However, for greater accuracy of measurement, it is desirable that the focal length of the convex lens should be neither too large nor too small as compared to that of the concave lens.

Referring to Fig.1, it can be seen that the convex lens C forms at P a real image of the object O. Now if the concave lens L be so placed that the distance LP is less than that its focal length, then the image at P will act as a virtual object for the concave lens and as a result a real image will be formed at the point Q. Here the object distance LP = u and the image distance LQ = v. According to sign convention both are positive. Hence f, the focal length may be determined from the relation,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \ldots\ldots\ldots (1)$$

Equation (1) can be written as

$$f=\frac{uv}{u-v} \quad \ldots\ldots\ldots (2)$$

Since $v > u$, f will be negative.

Required Apparatus

Optical bench, convex lens, concave lens, screen, index rod, light source, etc.

Procedure

Write yourself (past tense with passive voice).

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FIGURE NO...

Experimental Data

Table 1. Data for focal length.

No. of obs.	Position of the convex lens C (cm)	Position of the concave lens L (cm)	Image P (cm)	Image Q (cm)	LP = $u = (P - L)$ (cm)	LQ = $v = (Q - L)$ (cm)	Focal length f (cm)	Mean focal length f (cm)
1								
2								
3								
4								
5								

Result

$f = \cdots$ cm

Precautions and Discussion

1. The convex lens C was placed at a distance from the object more than the focal length of the lens C so that a real image was formed on the screen.
2. The image formed by the concave lens was focused on the screen by shifting the positions of the concave lens and not by moving the screen. This was necessary because the focused condition of the image would not change within an appreciable range of the movement of the screen.
3. When LP was equal to the focal length of the concave lens, then the light emerged from the concave lens was parallel to the axis and consequently no image was found.