B. Tech. - I Year

Physics Laboratory – PHIR12

(Lab Manual 2019-20)

DEPARTMENT OF PHYSICS

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I have no satisfaction in formulae,

unless I feel their numerical magnitude.

- Lord Kelvin

Measurement and Error

Measurement is a fundamental activity of any scientific endeavour. Measurement can range from mundate activitiy of measuring our body temperature to measuring distance between two stars. For any physical quantity we define

$$\text{Error} = \text{True Value} - \text{Approxmiate value} .$$

It is also useful to define

$$\text{Relative Error} = \frac{|\text{Error}|}{|\text{True Value}|}$$

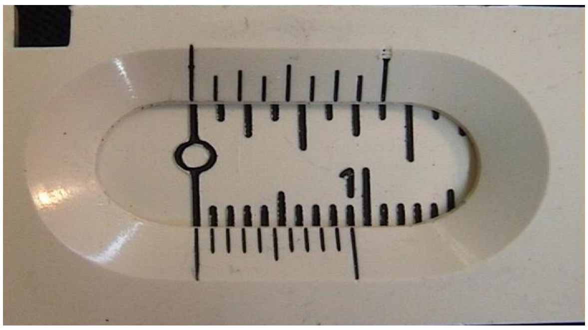
for further analysis of error. Error, which is inherent and so inevitable in all problems, araises from

- statement of the problem
- simplfied assumptions in mathematical formulation of the problem
- physical measurements.

In what follows we demonstate the possiblity of reducing error in simple measurement devices.

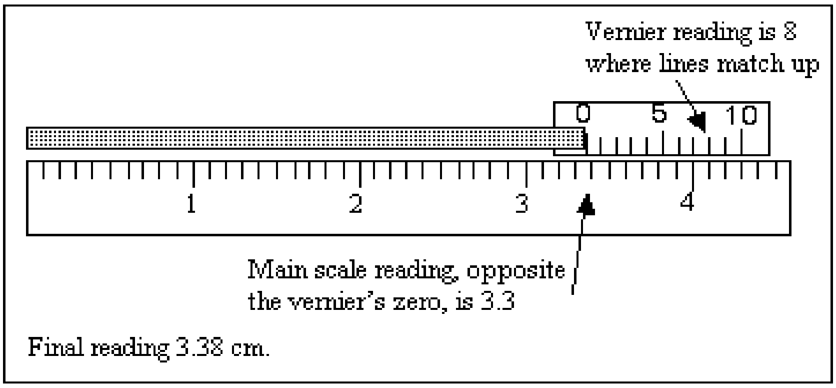
We all know that the smallest value that can be measured accurately with a metre scale is 1mm. This quantity is called as *Least Count (LC)* which signifies the accuracy of length measurement using metre scale. LC can be reduced by a combination of two scales one on top of the other. A clever design of a small extra (vernier) scale, which dates back to 1631 by a French mathematician Pierre Vernier, improves the precision in length measurement. This is demonstrated using a typical vernier caliper as shown below.

Vernier Caliper



Main scale and vernier scale

In the above diagram, vernier scale has 10 divisions such that they equal 9 divisions of main scale. If $1\ Main\ Scale\ Division\ (MSD) = 1mm$ and $10\ Vernier\ Scale\ Division\ (VSD) = 9\ MSD$, then $1\ VSD = 0.9\ MSD = 0.9mm$. Then, the LC of vernier caliper can be defined as $LC = 1MSD - 1VSD = 0.1mm$. In other words, vernier scale improves accuracy of the main scale by 10 times.



Measurement using Vernier caliper

Measuring length of a rod using vernier caliper is shown here. From the mail scale reading (MSR) and vernier scale reading (VSR), the length can be calculated as follows:

$$Length = MSR + (VSR \times LC) = 33 + (8 \times 0.1)mm = 33.8mm.$$

Measurement principle of travelling microcscope is similar to the above. The only difference is that the vernier scale has 50 divisions which equal 49 divisions of the main scale, and $1MSD = 0.5mm$. That is, $50\ VSD = 49\ MSD$, or $1\ VSD = \frac{49}{50}\ MSD$. Then the LC of travelling micrscope $LC = 1MSD - 1VSD = 0.01mm$. In other words, the accuracy of microscope is 10 times more than that of the vernier caliper.

Same principle is being followed in spectrometer to measure the angle. In a typical spectrometer, $1MSD = 0.5^0 = 30'$ (30 minutes) and $30\ VSD = 29\ MSD$, or $1\ VSD = \frac{29}{30}\ MSD$. With this, $LC = 1MSD - 1VSD = 1'$. In other words, spectrometer can measure an angle to the accuracy of $1'$ (one minute).

With this, particular position x of micrsoscope (or) spectrometer can be calculated as

$$x = MSR + (VSR \times LC).$$

1. TORSIONAL PENDULUM WITH RING

Aim

To determine the rigidity modulus of the material of a wire and moment of inertia of annular ring.

Apparatus required

Screw gauge, stop clock, torsional pendulum, symmetric masses and weighing balance.

Formulae

Rigidity modulus of wire, $G = \frac{1}{a^4} 8\pi m R^2 \left(\frac{l}{T_{rd}^2 - T_d^2}\right)$ *Nm*$^{-2}$ *(Pascal).*

Moment of Inertia of annular ring, $I_r = I_d \left[\left(\frac{T_{rd}}{T_d}\right)^2 - 1\right]$, *kg m*^{2}

where $I_d = \frac{1}{2} M R^2$ is the moment of inertia (theoretical) of the circular disc of mass M and radius R.

Moment of inertia of annular ring (theoretical), $I_r = \frac{1}{2} m(R_1^2 + R_2^2)$ *kg m*^{2}.

Other symbols in the formulae have the following meaning:

m	-	mass of the annular ring (*kg*)
a	-	radius of the wire (*m*)
l	-	length of the wire from the disc top *(m)*
T_{rd}, T_d	-	mean period with ring and without ring (*sec*)
R_1, R_2	-	inner and outer radii of the ring *(m).*

Procedure

Torsional pendulum consists of an iron disc of known mass M hanging by a wire (*Fig. 1.1*). From the oscillations of the disc, rigidity modulus of the wire as well the moment of inertia of the disc can be calculated as follows. Measure the length of the wire (l) from the bottom of the binding screw to the top of the chunk nut. Determine thickness of the wire at different positions using screw gauge and hence find the average radius a.

Rotate the disc, through a small angle, hold it in this position for a moment and then release it. The pendulum will perform torsional oscillations of small amplitude. Leave one or two oscillations and then determine the time taken for 10, 20 and 30 oscillations and tabulate the same. From the time of oscillation, calculate the average period as T_d. Place a circular ring, with inner and outer radii R_1 and R_2 respectively, on the disc and determine the corresponding period of oscillations T_{rd} as before. Then calculate radius of the disc and ring by measuring its circumference. Using the above formulae, rigidity modulus of the wire and moment of inertia of the disc can be calculated. Calculated moment of inertia can then be compared with the theoretical value.

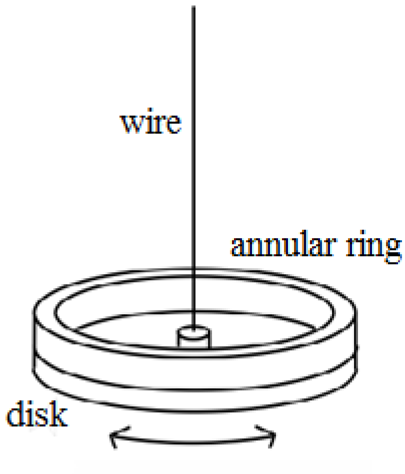


Fig. 1.1: Torsional Pendulum with annular ring

Length of the wire	$l = \ldots\ldots\ldots\ldots\ m$
Mass of the annular ring	$m = \ldots\ldots\ldots\ldots\ kg$
Mass of the circular disc	$M = \ldots\ldots\ldots\ldots\ kg$
Radius of the disc	$R = \ldots\ldots\ldots\ldots\ m$
Inner radius of the annular ring	$R_1 = \ldots\ldots\ldots\ldots\ m$
Outer radius of the annular ring	$R_2 = \ldots\ldots\ldots\ldots\ m$

Table 1.1: To find the thickness of wire

Least count (LC) = … *mm*, Zero error (ZE) = ….. *mm*, Zero Correction (ZC)= ….. *mm*

S. No.	PSR (*mm*)	HSR (*div*)	Observed Reading OR = PSR + (HSR × LC) (*mm*)	Corrected Reading CR = OR + ZC (*mm*)

Thickness, $2a = \ldots\ldots\ldots\ldots\ m$

Table 1.2: To find the period of oscillation of torsional pendulum

S. No.	Pendulum	Number of oscillations	Time (*sec*)	Period (*sec*)	Mean Period (*sec*)
1	Without ring	10			$T_d =$
2		20			
3		30			
1	With ring	10			$T_{rd} =$
2		20			
3		30			

Result

Rigidity modulus of the wire $G =$ ………….. Nm^{-2}
Moment of inertia of the ring (experimental) $I_r =$ …………. $kg\ m^2$
Moment of inertia of the ring (theoretical) $I_r =$ ………….. $kg\ m^2$.

2. NUMERICAL APERTURE OF AN OPTICAL FIBER

Aim

To determine the numerical aperture (measure of light carrying capacity) of a fiber cable.

Apparatus required

Optical fiber cable, photo detector and light source.

Formula

Numerical Aperture (experimental),

$$N.A. = \text{Sin } \theta_{max} = \frac{W}{\sqrt{4L^2 + W^2}}$$

where

θ_{max} – acceptance angle (*deg*)
L – distance of the screen/detector from the fiber end (*m*)
W – is the diameter of the spot (*m*).

Procedure

Optical fiber is a thin co-axial cable of two transparent materials. The inner one is called the *core* with refractive index n_1 and the outer one is called the *cladding* with refractive index n_2, such that $n_1 > n_2$. *Acceptance angle* of an optical fiber is the maximum incident angle of the light ray that enters and propagates through the fiber by total internal reflection. We may note that the light ray emerging from other end of the fiber will make the same angle with the fiber axis as that of the incident ray. *Numerical aperture* of an optical fiber is defined as the sine of the acceptance angle, which is theoretically given as $N.A. = \sqrt{n_1^2 - n_2^2}$. Refractive indices of the optical fiber we use are n_1 = 1.492 and n_2 = 1.402. Numerical aperture can also be calculated experimentally for a given fiber by measuring width of the light spot comes out from the fiber as shown in *Fig. 2.1*.

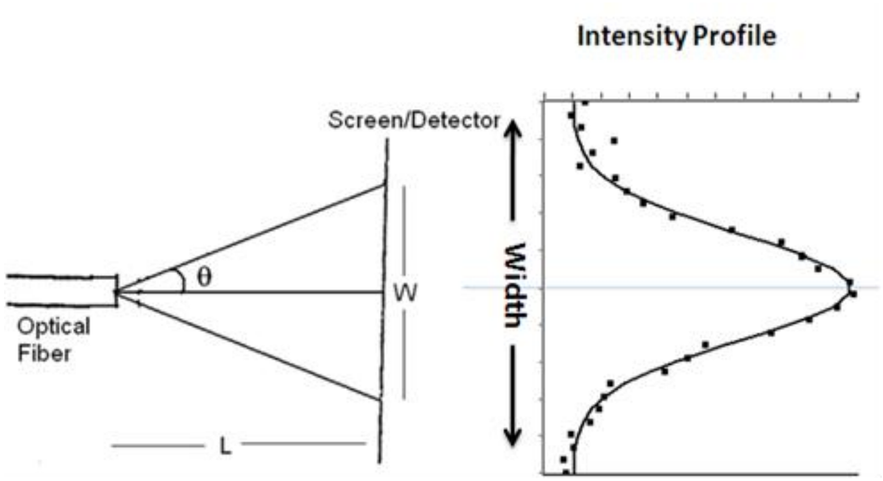


Fig. 2.1: Intensity profile and width of the light spot

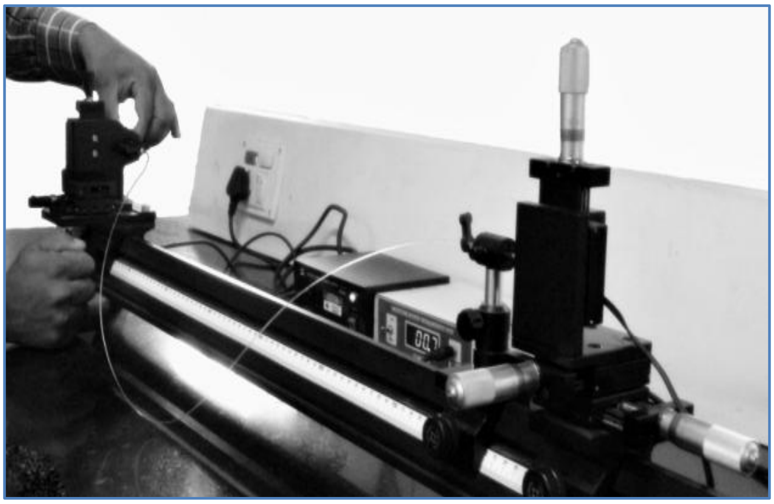


Fig. 2.2 Optical fiber setup

Experimental setup is as shown in *Fig. 2.2*. One end of the one metre fiber cable is connected to the PO of light source (laser) and the other end to the photo detector. Adjust the fiber such that the light appear at the other end of the fiber and allow it to fall on the photo detector. Intensity of the laser light is adjusted to a maximum value using the knob provided. As the PO knob is turned clockwise or anticlockwise the intensity varies. Intensity of the light emerging from the fiber can be measured in terms of photo-current using the detector.

Let *L* be the distance of the detector from other end of the cable. If the detector is moved laterally, the intensity will be maximum when the detector is along the axis of the fiber. Intensity will decrease as the detector is moved on either side of the fiber axis. For a fixed *L*, the lateral distance of the detector and the corresponding intensities (min – max – min) are noted. A graph between the lateral distance and the intensity will result to a Gaussian shaped curve, which is the typical intensity profile of the light emerging out of the fiber. The width of the Gaussian curve *W* is the diameter of the light spot. From this, the numerical aperture of the given fiber can be calculated using the above formula. The same procedure is repeated for different *L* and the results can be compared with the theoretical value.

Table 2.1: To find the intensity profile across the axis of fiber

L = …….. (*m*)	
Distance (*mm*)	Intensity (*mA or mV*)

L = …….. (*m*)	
Distance (*mm*)	Intensity (*mA or mV*)

Table 2.2: To find the acceptance angle

S. No.	Distance L (m)	Diameter of the spot W (mm)	$N.A. = \frac{W}{\sqrt{4L^2 + W^2}}$	θ_{max} (deg)

Result

Numerical aperture of the fiber *N.A.* (theoretical) = ………

Numerical aperture of the fiber *N.A.* (experimental) = ……….

Acceptance angle, θ_{max} = ………. *deg*

3. CALIBRATION OF VOLTMETER – POTENTIOMETER

Aim

To calibrate the high range voltmeter using a potentiometer and a standard cell.

Apparatus required

Potentiometer, rheostat, voltmeter, galvanometer, high resistance, d.c. power source, connecting wires and standard cell (Daniel cell).

Formula

Voltage measured using potentiometer,

$$V' = 1.08\left(\frac{l}{l_0}\right)\frac{P+Q}{P} \quad Volts$$

where

l_0 - balancing length of the potentiometer wire (*m*)
P, Q – resistance boxes (Ω)
l – balancing length against the different ratio of [P + Q] (*m*).

Procedure

(1) To standardize the potentiometer

For standardizing the potentiometer, firstly we apply a constant d.c. voltage across the two ends of the potentiometer. For this we can use a 2V accumulator or a 2V stabilized power supply. If a stabilized power supply of 6V is available we have to use a potential divider arrangement with a rheostat and voltmeter to tap 2V. With this, we drop 2V across the 10m length of potentiometer wire.

Further, for standardization we use a standard cell of constant emf (here, Daniel cell of 1.08V). The polarity of Daniel cell is such that the outer copper vessel is positive and the zinc rod is negative. Make the circuit as shown in *Fig. 3.1,* wherein care must be taken to connect the positive end of potentiometer wire to the positive of the Daniel cell.

Remove the plug in the high resistance (H.R) and press the jockey J on the potentiometer wire near the end A and note the direction of deflection in the galvanometer G. Press the jockey near the other end B, and now the deflection in G must be opposite to the earlier deflection. If so the connections are correct, otherwise connections need to be checked.

Now find the approximate balancing length (for which the deflection in G is zero). Keeping the jockey near the approximate balancing length, H.R. can now be bypassed by putting its key. This results to more deflection in G, and now by adjusting the position of J, more accurate balancing length l_0 can be found. In other words, the potential across A and J is equal to the potential of Daniel cell (i.e., 1.08V). Then, the potential corresponding to 1m length of potentiometer wire is $\frac{1.08}{l_0}$ Vm^{-1}.

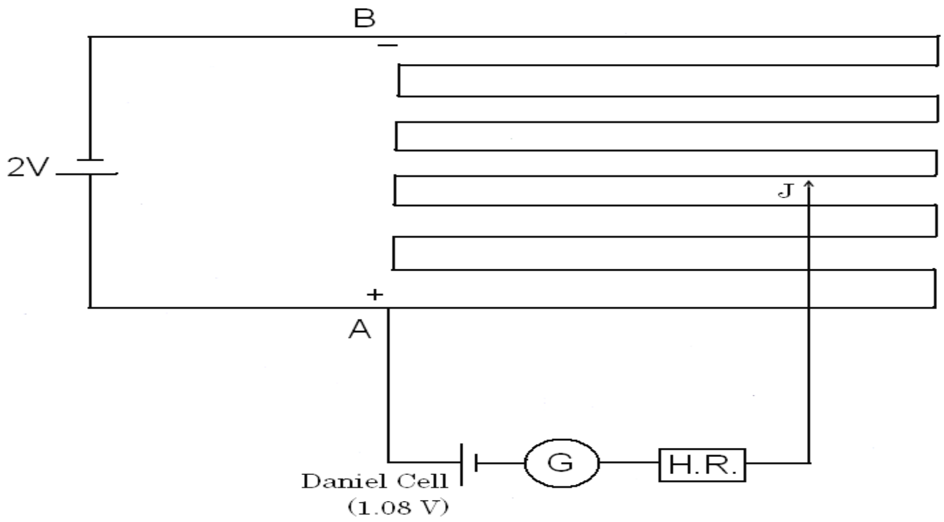


Fig. 3.1: Standardizing potentiometer

(2) To calibrate the voltmeter

Without disturbing the primary (earlier) circuit, disconnect the Daniel cell and make the new circuit as shown in *Fig. 3.2*. Make sure that the polarities are maintained correctly at each point.

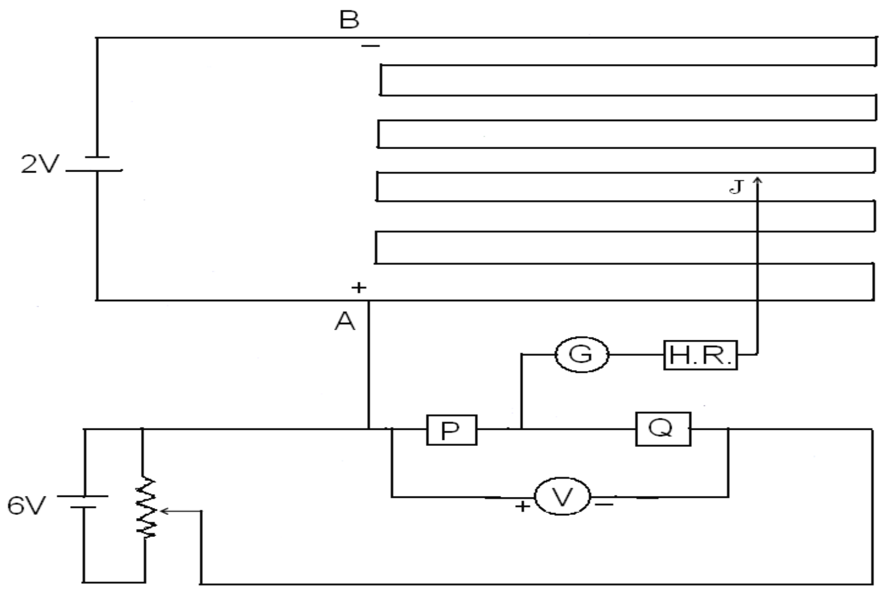


Fig. 3.2: Measuring voltages

Adjust the rheostat in the secondary circuit so that the voltmeter reads 1V. The resistances *P* and *Q* must be such that the potential difference across *P* is less than 2V, since the voltage between A and B are 2V. Now find the balancing length *l*, which corresponds to the potential across *P*. If V_P is the voltage across *P*, then $V_P = l\left(\frac{1.08}{l_0}\right)$. With this we shall now find the voltage across (*P* + *Q*), as shown below, and can be compared with the voltmeter reading. If *V´* is the voltage across (*P* +*Q*), then from *Fig. 3.3* we have

$$I = \frac{V_P}{P} = \frac{V'}{(P+Q)}.$$

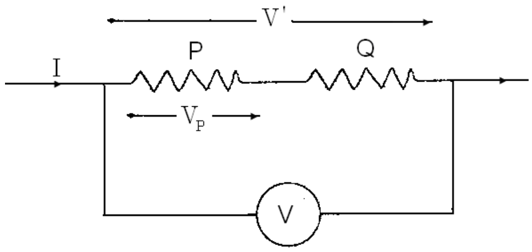


Fig. 3.3: Diagram for V'

In other words,

$$V_P = \frac{V'P}{(P+Q)} = 1.08\left(\frac{l}{l_0}\right) \quad \text{(or)} \quad V' = 1.08\left(\frac{l}{l_0}\right)\left(\frac{P+Q}{P}\right).$$

Repeat the experiment for different voltmeter readings (e.g. 1V - 5V in steps of 0.5V), by either keeping the resistances *P* and *Q* the same or varying them each time suitably, if necessary. Tabulate the observations as follows and draw the calibration graph between the voltmeter reading and correction.

Table 3.1: To find the correction in voltage measurement

S. No.	Voltmeter Reading *V* (*Volts*)	Balancing length *l* (*m*)	Calculated voltage across (*P*+*Q*) *V´* (*Volts*)	Correction *V´* - *V* (*Volts*)

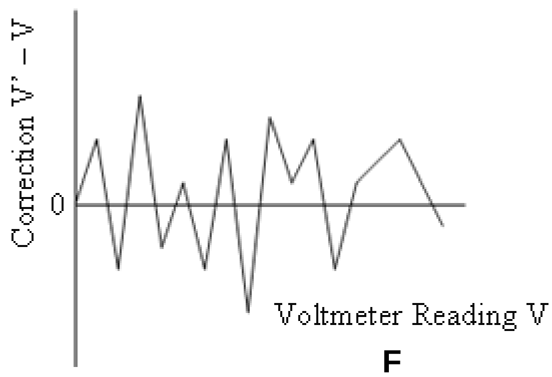


Fig. 3.4: Voltmeter reading .vs. Correction

Result

Potentiometer is standardized, and with this given voltmeter is calibrated.
Maximum value of $|V' - V| =$………… *Volts*

4. FIELD ALONG THE AXIS OF A CIRCULAR COIL

Aim

To determine the horizontal component of earth's magnetic induction B and magnetic moment of a bar magnet using field along the axis of a current carrying coil apparatus with deflection magnetometer.

Apparatus required

Field along the axis of coil apparatus, deflection galvanometer (compass box), bar magnet, 6V battery, rheostat, commutator, ammeter and connecting wires.

Formulae

Magnetic field produced along the axis of a coil at a distance x from the centre,

$$B_C = \frac{\mu_0 n a^2 I}{2(a^2 + x^2)^{3/2}} \quad \textit{Tesla}$$

where

$\mu_0 = 4\pi \times 10^{-7}$ Henry/metre, permeability of free space

n – number of turns in the circular coil

a – radius of circular coil (m)

I – current passed through the coil (A)

x – distance between centre of the coil and center of magnetic needle (m).

The field due to the circular coil is in east-west direction, which is perpendicular to the horizontal component of earth's magnetic field B. Then if θ is the mean deflection in magnetometer due to both these fields, tangent law of magnetism implies that $B_C = B \tan\theta$. Then the earth's magnetic field,

$$B = \frac{B_C}{\tan\theta} \quad \textit{Tesla}$$

where θ is mean deflection produced in the deflection magnetometer (*deg*).

Magnetic moment of the bar magnet is given by,

$$M = \frac{2\pi B_C (d^2 - l^2)^2}{\mu_0 d} \quad A\,m^2$$

where

d – distance of the center of the bar magnet from the centre of the compass box (m)

l – semi-length of the bar magnet (m).

Procedure

Remove magnetic materials, if any, from the vicinity of the apparatus. The wooden platform, with circular coil fixed in the middle, is kept in magnetic east-west direction and the plane of coil in the magnetic meridian. A compass box is placed with its centre coinciding with the centre of the coil, and adjusted so that its aluminum pointer reads zero-zero. The apparatus is now in

Tan A position. A circuit is made as shown in *Fig. 4.1*. Rheostat and ammeter should be kept sufficiently away from the circular coil.

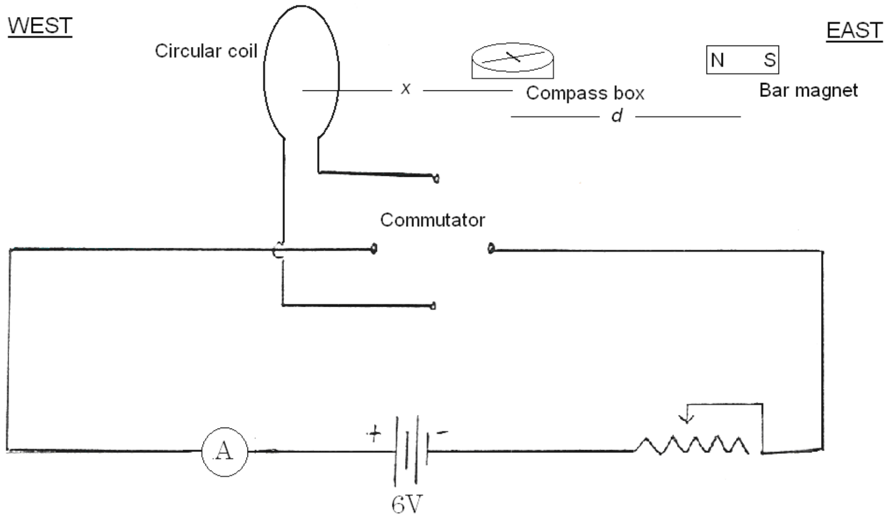


Fig 4.1: Field along the axis setup

Without disturbing the apparatus, move the compass box slowly and keep it at a distance x from the centre of the coil on one side, say east. The rheostat is adjusted to pass a suitable current I amps through the coil such that deflection in the compass box is between 30° and 60°. Let the deflections, as read by the aluminum pointer, be θ_1 and θ_2. Keep the given bar magnet on eastern side of the compass box on the platform with its axis along the axis of the coil. The position of the magnet is adjusted until the deflection in the compass box becomes zero. Note this distance as d_1.

The current in the coil is now reversed using commutator and the deflections without the magnet in vicinity are noted as θ_3 and θ_4. The magnet is reversed end-to-end and the distance corresponding to zero deflection is noted as d_2. The experiment is repeated by keeping the compass box and bar magnet on the western side of the coil. The mean deflection θ and the mean distance d are obtained. Similarly, repeat the experiment by keeping the compass box at various distances from the centre of the coil. The radius of the coil a is found from it circumference using a thread. The horizontal component of earth magnetic induction B_H and the magnetic moment of the bar magnet M are calculated using the above formulae.

Table 4.1: To determine B

Distance x *(m)*	East				West				Mean θ *(deg)*	$B_C = \frac{\mu_0 n a^2 I}{2(a^2+x^2)^{3/2}}$ (*Tesla*)	$B = \frac{B_C}{\tan\theta}$ (*Tesla*)
	Direct		Reversed		Direct		Reversed				
	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8			

Table 4.2: To determine M

Distance x (m)	Distance of the magnet (m)				Mean d (m)	$B_C = \frac{\mu_0 n a^2 I}{2(a^2 + x^2)^{3/2}}$ (*Tesla*)	$M = \frac{2\pi B_C (d^2 - l^2)^2}{\mu_0 d}$ ($A\ m^2$)
	d_1	d_2	d_3	d_4			

Result

Horizontal component of earth’s magnetic induction, B = ……… *Tesla*
Magnetic moment of the bar magnet, M = ……… $A\ m^2$

5. WAVELENGTH OF A LASER USING DIFFRACTION GRATING

Aim

To determine the wavelength of the laser light from the principle of diffraction.

Apparatus required

Laser, diffraction grating, screen and meter scale.

Formula

$$\lambda = \frac{Sin\theta}{nN} \quad m$$

where

λ – wavelength of the laser (m)
N – number of lines/m in the grating (N = 15000 lines/inch); (1 inch = 2.54 cm)
n – order of diffraction
θ - angle of diffraction (*deg*).

Procedure

The experimental setup consists of a laser, whose wavelength to calculated, and laser the beam is allowed to fall normally on a diffraction grating. A white screen is kept at a distance L from the grating as shown in *Fig. 5.1*. The directed ray of the laser beam will appear as a small dot in the middle of the screen. In addition, diffracted spots will appear at equal distance on either side of the centre spot (corresponding to direct ray). If D is the distance of the diffracted spot from the centre spot, then the angle of diffraction satisfies the relation, $\tan\theta = \frac{D}{L}$. From this we can calculate *sin θ*. The experiment is repeated for different L. Then using the above formula, the wavelength λ of the laser is calculated.

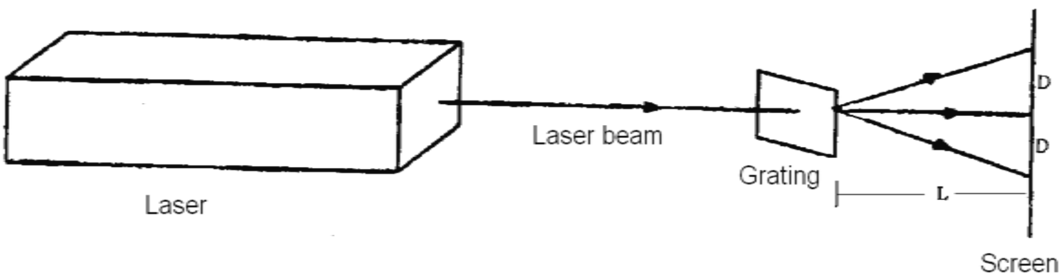


Fig. 5.1: Laser diffraction setup

Table 5.1: To find the angle of diffraction of first order (n = 1)

Distance between grating and screen *L* (*cm*)	Distance between centre spot and spot on left side D_1 (*cm*)	Distance between centre spot and spot on right side D_2 (*cm*)	Mean *D* (*cm*)	*Tan θ*	*Sin θ*

Table 5.2: To find the angle of diffraction of second order (n = 2)

Distance between grating and screen *L* (*cm*)	Distance between centre spot and spot on left side D_1 (*cm*)	Distance between centre spot and spot on right side D_2 (*cm*)	Mean *D* (*cm*)	*Tan θ*	*Sin θ*

Result

Wavelength of the laser, λ = ……… *m*

6. DISPERSIVE POWER OF A PRISM – SPECTROMETER

Aim

To determine the refractive index of material of the prism using mercury light source and hence to determine the dispersive power of the prism.

Apparatus required

Spectrometer, prism, mercury light source and spirit level.

Formulae

Refractive index of the prism, $\mu = \dfrac{Sin\left(\dfrac{A+D}{2}\right)}{Sin\left(\dfrac{A}{2}\right)}$

Dispersive power of the prism, $\delta = \dfrac{\mu_v - \mu_r}{\dfrac{\mu_v + \mu_r}{2} - 1}$

where

A – angle of the prism (*deg*)
D – angle of minimum deviation (*deg*)
μ_v – refractive index of the prism for violet
μ_r – refractive index of the prism for red.

Procedure

(1) Initial adjustments of spectrometer

1. *Eye-piece adjustment:* Eye-piece is adjusted until the cross wires are clearly seen when viewed through the telescope.
2. *Telescope adjustment:* Telescope is adjusted until a clear, well defined inverted image of a distant object is seen through the eye-piece.
3. *Slit adjustment:* Slit is made narrow with the help of the screw.
4. *Collimator adjustment:* The slit is illuminated by a source of light and the telescope is brought on line with collimator. If the image of the slit appears blurred, then the screw of the collimator is adjusted until a clear image is seen when viewed through the telescope. Now the rays of light emerging from the collimator will be rendered parallel.
5. *Prism table adjustment:* A spirit level is placed on the prism table, parallel to the line joining any two leveling screws. The air bubble in the spirit level is brought to the centre by adjusting the two levelling screws. It is then placed in a perpendicular direction and the air bubble is brought at the centre by adjusting the third screw. Now the prism table is horizontal.
6. *Spectrometer base:* The base of the spectrometer is adjusted to the horizontal with the help of the three leveling screws.

(2) To find the angle of prism

Mount the prism on the prism table and orient it in such a way that the refracting edge of the prism almost bisects the collimating lens. Turn the telescope to receive the reflected image of the slit (illuminated by the mercury light source) from the face AB as shown in *Fig. 6.1*. Using the tangential screw of the telescope make the vertical cross wire to coincide with the image of the slit. Note down the readings of both the verniers. Then turn the telescope to receive the rays reflected from the face AC and note down the readings as earlier. The difference between the two readings of both the vernier is 2θ, twice the angle of the prism.

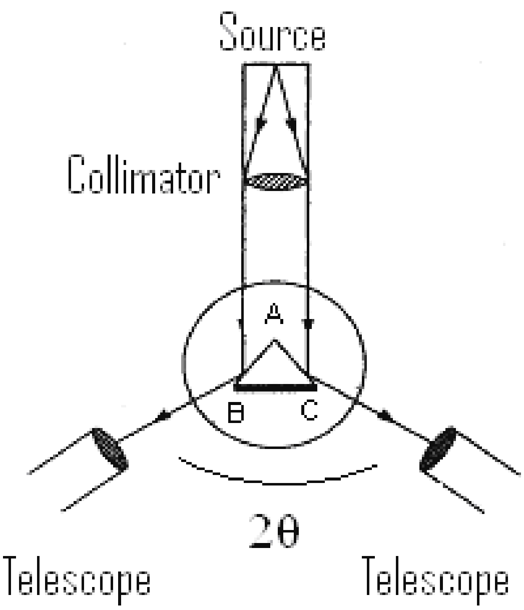


Fig. 6.1: Angle of Prism

Table 6.1: To find the angle of prism

Least Count (LC) = ……

Ray	Telescope Readings					
	Vernier A (*deg*)			Vernier B (*deg*)		
	MSR	VSR	TR	MSR	VSR	TR
Reflected from face AB						
Reflected from face AC						

2A = *2A* =

(3) To find the angle of minimum deviation and dispersive power

The prism is mounted as shown in *Fig. 6.2* such that light emerging from the collimator is incident on one of the refracting faces of the prism. The telescope is slowly rotated to catch the refracted image of the slit (say, green) emerges from other face of the prism. Now by viewing through the telescope, the prism table is slightly rotated in such a way that the green image moves towards the direct ray and at a particular position it retraces its original path. This position is called the *minimum deviation position*.

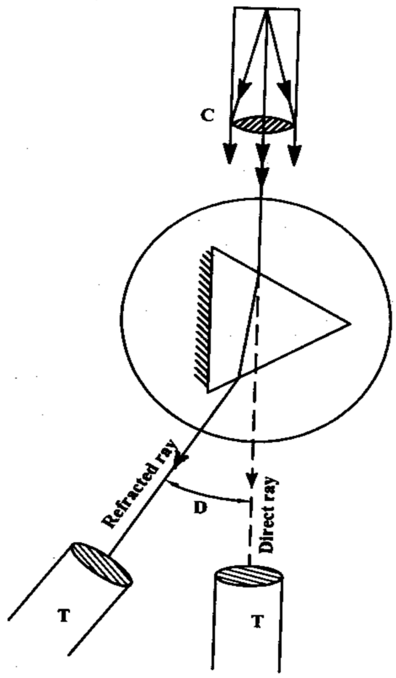


Fig. 6.2: Angle of minimum deviation

The prism table is fixed and now all the prism is set into minimum deviation position. The tangential screw is adjusted so that each colour of the slit coincides with vertical cross wire and the readings are tabulated. The prism is removed and direct ray reading is noted. Difference between the direct ray and the refracted ray readings for each colour gives the angle of minimum deviation (D) for the respective colour. By substituting the values of D and A in the above formula, refractive indices of the prism for each colour can be calculated.

From the refractive indices for a pair of colours (say, violet and red) dispersive of the prism can be calculated using the above formula.

Table 6.2: To find the angle of deviation and refractive index

Least Count (LC) = ……… Angle of prism *A* = ………. *deg*

Direct ray reading: Ver A = ……… *deg*, Ver B = ………. *deg*

Spectral lines	Vernier A (*deg*)			Vernier B (*deg*)			*D* (*deg*)		μ
	MSR	VSR	TR	MSR	VSR	TR	V_A	V_B	
Violet I									
Voilet II									
Blue									
Bluish Green									
Green									
Yellow									
Orange									
Red									

Result

Angle of the given prism, *A* = ……… *deg*
Refractive index of the prism (for yellow), μ = ……..
Dispersive power of the prism, δ = …….

7. WAVELENGTH OF MERCURY SPECTRUM – SPECTROMETER

Aim

To determine the wavelengths of mercury (Hg) spectrum by using plane transmission grating.

Apparatus required

Spectrometer, plane transmission grating, sodium vapour lamp, mercury vapour lamp and spirit level.

Formula

Number of lines drawn on the grating per meter is given by

$$N = \frac{Sin\theta}{n\lambda} \ lines/m.$$

Wavelength of prominent lines of the mercury spectrum is given by

$$\lambda = \frac{Sin\theta}{nN} \ \ m$$

where

n – order of the spectrum
λ - wavelength of the sodium vapour lamp ($\mathring{A}$)
θ - angle of diffraction (*deg*).

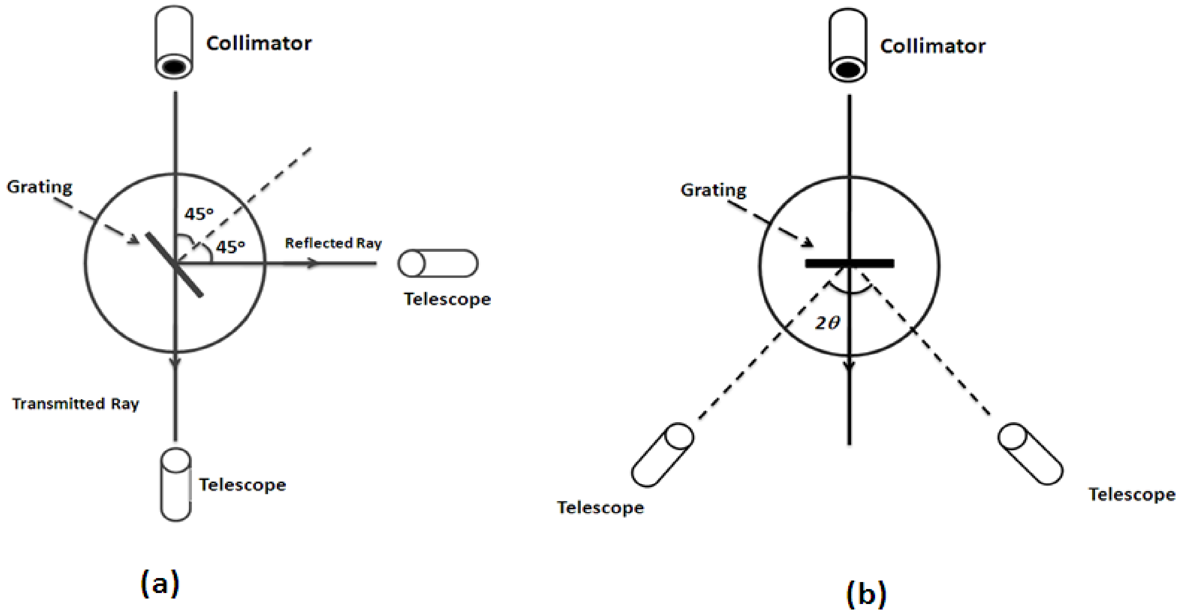


Fig. 7.1: Spectrometer with grating

Procedure

(1) Adjustment of grating for normal incidence

Preliminary adjustments of the spectrometer are made. The grating G is mounted on the grating table with its ruled surface facing the collimator. The slit is illuminated by a source of light (sodium vapour lamp) and is made to coincide with the vertical cross wire of the eye-piece. For this directed ray, the vernier scales are adjusted to read 0° and 180°. The telescope is rotated through an angle 90° and is fixed. The grating table is adjusted such that the reflected image of the slit coincides with the vertical cross wire. Now the grating table is fixed at this position, wherein the normal to the grating makes an angle of 45º to both the incident and the reflected rays as shown in *Fig. 7.1(a)*.

Rotate the vernier table through 45° in the same direction in which the telescope has been previously rotated, so that the grating will now be normal (perpendicular) to the incident ray from the collimator. This is seen in *Fig. 7.1(b)*. The telescope is released and is brought on line with the direct image of the slit and now the grating is said to be in the normal incidence position.

(2) Standardization of grating (to find the number of lines per meter)

The telescope is released to get the diffracted image of the first order on the left side of the central direct image. The readings are tabulated from the two verniers. Similarly readings are taken for the right side of the central direct image. The difference between the two readings gives 2θ, where θ is the angle of first order diffraction. The number of lines per metre (N) of the grating is calculated using the given formula. The experiment is repeated for the second order and the readings are tabulated.

(3) Determination of wavelength of the mercury spectrum

The sodium vapour lamp is now replaced by mercury vapour lamp. The diffracted images of the first order are seen on either side of the central direct image. As before the readings are tabulated by coinciding the vertical cross wire with the prominent lines namely violet, blue, bluish-green, green, yellow, orange and red of the mercury spectrum. The difference between the readings gives 2θ, and from this θ is obtained. The wavelength of each spectral line is calculated using the above formula.

Table 7.1: To find the number of lines per metre of the grating (N)

Least Count (LC) = …….., $n = 1$, $\lambda =$ ……….. m

Diffracted Ray fringes	Vernier A (*deg*)			Vernier B (*deg*)			2θ (*deg*)		Mean θ (*deg*)	$N = \frac{Sin\theta}{n\lambda}$ (*lines/m*)
	MSR	VSR	TR	MSR	VSR	TR	Ver A	Ver B		
Left Side										
Right Side										

Table 7.2: Determination of wavelength (λ) of the mercury spectrum

Least Count (LC) = …….., $n = 1$, N = ………… *lines/m*

Spectral lines of mercury light	Diffracted ray reading (*deg*)				Difference 2θ (*deg*)		Mean θ (*deg*)	$\lambda = \frac{Sin\theta}{nN}$ (*m*)
	Left		Right					
	Ver A	Ver B	Ver A	Ver B	Ver A	Ver B		
Violet I								
Violet II								
Blue								
Bluish Green								
Green								
Yellow								
Red								

Result

Number of lines in the grating , N = ……… *lines/m*

Wavelengths of the spectral lines are

Violet I = ………… *m*

Violet II = ………… *m*

Blue = ………… *m*

Bluish Green = ………… *m*

Green = ………… *m*

Yellow = ………… *m*

Orange = ………… *m*

Red = ………… *m*

8. RADIUS OF CURVATURE OF LENS – NEWTON'S RING

Aim

To determine the radius of curvature of a given lens by forming Newton's rings.

Apparatus required

Newton's ring apparatus, long focus convex lens, sodium vapour lamp, condensing lens, traveling microscope.

Formula

Radius of curvature,

$$R = \frac{r_{n+15}^2 - r_n^2}{15\lambda} \quad m$$

where
λ – wavelength of sodium light (5893 Å)
r_n - radius of n^{th} ring (m).

Experimental Setup

Light from sodium vapour lamp S is rendered parallel by a condensing lens L. The parallel beam is incident on a plane glass plate G, inclined at an angle 45^o to the horizontal, and gets reflected. The reflected light is incident normally on the convex lens glass plate system. The interference pattern is viewed through a microscope M (*Fig. 8.1*). The microscope is moved up and down until alternate bright and dark circular rings are observed. These rings are called *Newton's rings*. In this system, the central ring will be a dark ring. For want of proper curvature in the convex lens, the central ring and a few rings at the centre will not be well defined. Hence that dark ring which appears as a perfect circle is taken as the n^{th} ring.

Procedure

To find the diameter of n^{th} dark ring, vertical cross wire of the microscope is made tangential to the left and right sides of the ring and readings are taken. The difference between the two readings gives the diameter from which the radius can be calculated. Similarly, the radius of other rings can be found. But this process involves movement of the microscope in opposite directions which will result in an error in the reading known as the back lash error. Further, since the rings get closer as we go away from the central ring system, it may be difficult to find the diameter for each ring. Both these difficulties are overcome by the following procedure.

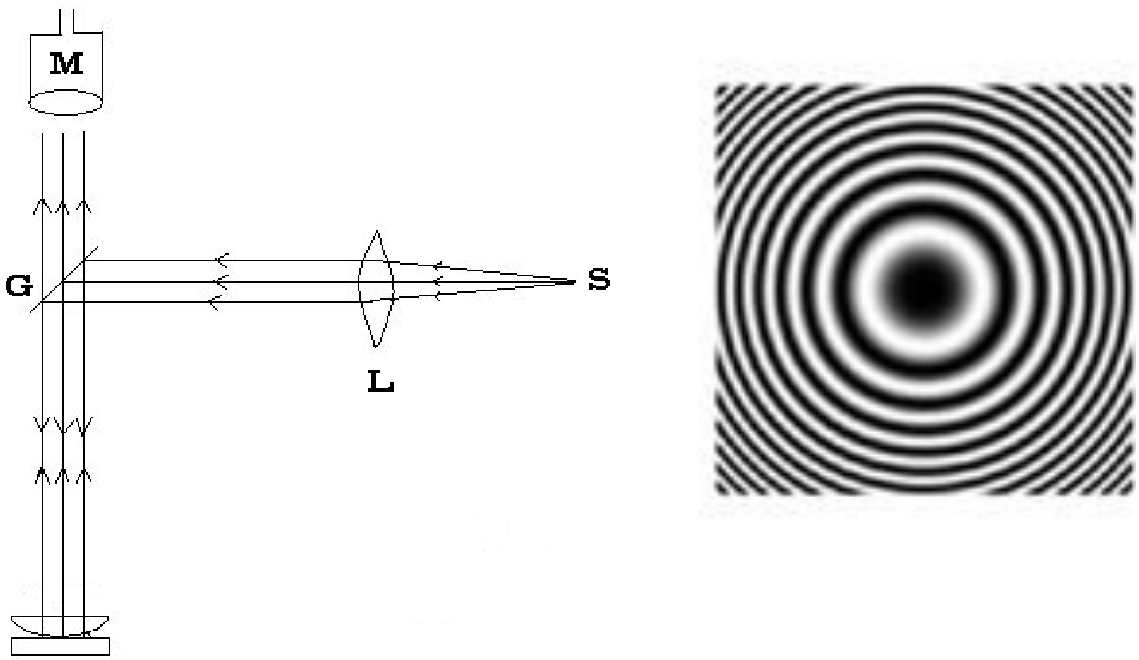


Fig. 8.1: Newton's set-up and ring pattern

Table 8.1: To determine the radius of curvature of convex lens

Least count (LC) = ….. *mm*

Order of rings	Microscope reading (m)		Diameter $2r$ (m)	r (m)	r^2 (m^2)	$r_{n+15}^2 - r_n^2$ (m^2)
	Left	Right				
n						
$n + 3$						
$n + 6$						
$n + 9$						
$n + 12$						
$n + 15$						
$n + 18$						
$n + 21$						
$n + 24$						
$n + 27$						

Mean =

Microscope is moved until vertical cross wire is tangential to the $(n+27)^{th}$ ring on left side and reading is taken. Similarly, readings are taken for $(n+24)^{th}$, $(n+21)^{st}$… n^{th} rings on the left side. Then microscope is moved in the same direction to the right side of ring pattern, and readings are taken by keeing the vertical cross wire tangential to the n^{th}, $(n+3)^{rd}$, … $(n+27)^{th}$ rings. From the above readings, diameter and hence the radii r of all the rings are calculated. Readings are entered in a tabular column, wherein values in the last column will be a constant. Radius of curvature of the lens R can then be calculated using the above formula.

Results

Radius of curvature of the lens, R = ……….. *m*

9. CONVERSION OF GALVANOMETER INTO AMMETER AND VOLTMETER

Aim

To convert a given galvanometer into ammeter and voltmeter.

Apparatus Required

Ammeter, voltmeter, galvanometer, rheostat, shunt wire, resistance box and power supply.

Procedure

(1) Conversion of galvanometer into ammeter

Conversion of galvanometer into ammeter is usually employed to measure small current of the order of micro ampere. For measuring large currents, a shunt is usually connected in parallel with the galvanometer as shown in *Fig. 9.1,* so that only a fraction of the total current passes through the galvanometer and the rest of the current passes through the shunt. This instrument is calibrated so as to read the total current directly in amperes and then it can be used as an ammeter.

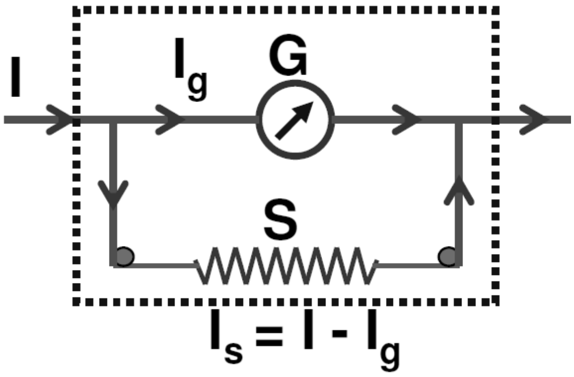


Fig. 9.1: Conversion of galvanometer into ammeter

Let *S* and *G* are the resistances of shunt and galvanometer respectively. Then, the above circuit implies that

$$I_g G = (I - I_g)S \quad \text{(or)} \quad I_g = I\left(\frac{S}{S+G}\right).$$

To study the performance of this unit, connect it in series with an ammeter, a battery and a rheostat as shown in *Fig. 9.2.* Adjust the rheostat for different currents and take the readings of the galvanometer and hence calculate the current. Suppose $I = 1.5\ A$, $G = 30\ \Omega$ and $I_g = 600\ \mu A$, then the shunt resistance can be calculated by using the above equations as $S = 0.012\ \Omega$. If suppose for current $I = 1.5\ A$ the galvanometer with this shunt *S* shows full deflection (30 divisions), then the current/division (current sensitivity) is 1.5/30 = 0.05 *A/div*. Hence, by multiplying the readings of galvanometer by current sensitivity, the current can be obtained.

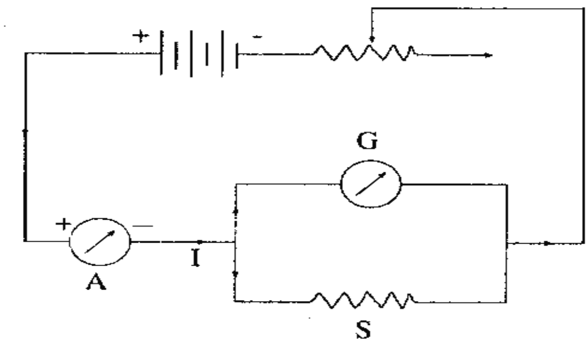


Fig. 9.2: Calibration of galvanometer to measure current

Table 9.1: To calibrate the galvanometer to measure current

Current Sensitivity = ……. *A/div*

Ammeter reading (*A*)	Deflection in galvanometer (*div*)	Current (*A*)

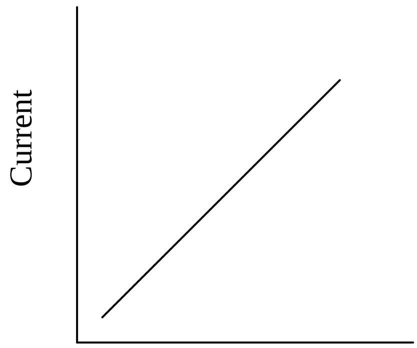


Fig. 9.3: Ammeter reading .vs. Current

(2) Conversion of galvanometer into voltmeter

Suppose a galvanometer has a resistance of G ohms and that it makes a current of I_g amperes for full scale, then the maximum potential difference that the galvanometer can measure is I_gG volts. If we want this galvanometer to be used to measure up to a voltage of, say V volts, we have to add a resistance R in series with G such that

$$(R+G)\, I_g = V \quad \text{(or)} \quad R = \left(\frac{V}{I_g}\right) - G\,.$$

Suppose V = *1.5 Volts*, G = 30 Ω and I_g = 600 μA, then the resistance to be connected in series with G can be calculated as R = 2470 Ω. Now the galvanometer with this resistance in series becomes the voltmeter of desired range.

To study the performance of this unit take a standard voltmeter and make a circuit as shown in *Fig. 9.4*. Adjusting the potential divider for various voltages as indicated by the voltmeter and take the readings of the converted galvanometer. If the galvanometer has 30 divisions for the voltage 1.5 *V*, then we the voltage sensitivity is 1.5/30 = 0.05 *V/div*. Hence, by multiplying the readings of galvanometer by voltage sensitivity, the voltage can be measured.

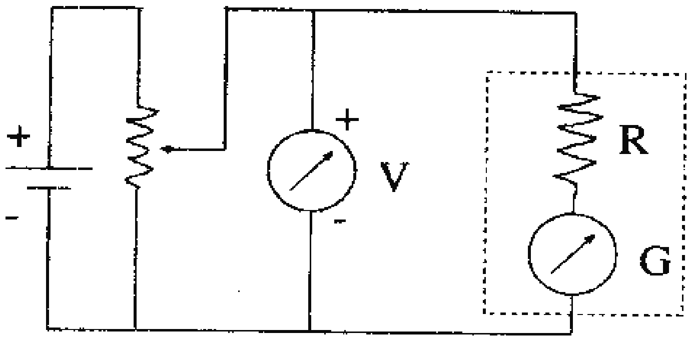


Fig. 9.4: Calibration of galvanometer to measure voltage

Table 9.2: To calibrate the galvanometer to measure voltage

Voltage Sensitivity = …….. *V/div*

Voltmeter reading (*volts*)	Deflection in galvanometer (*div*)	Voltage (*volts*)

Result

Galvanometer is converted into an ammeter and a voltmeter.

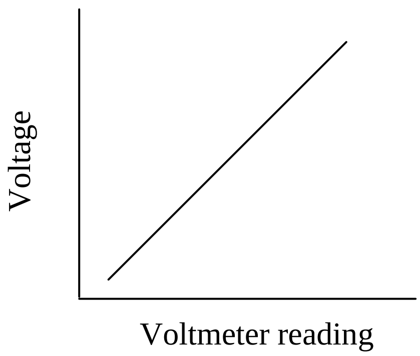


Fig. 9.5: Voltmeter reading .vs. Voltage

10. SPECIFIC ROTATION OF A LIQUID – HALF SHADE POLARIMETER

Aim

To determine the specific rotation of an optically active substance.

Apparatus required

Cane sugar/sugar solution (with different concentrations), polarimeter and solution tubes.

Formula

Specific rotation, $S = \frac{\theta}{LC}$ *deg cc/g dm*

where

θ – angle of rotation (*deg*)
L – length of polarimeter tube containing the sugar solution (*dm*)
C – concentration of sugar solution (*g/cc*).

Experimental Setup

Polarimeter is an instrument which determines the angular rotation of plane of polarization of light by an optically active solution. The angle through which the plane polarized light is rotated depends on the thickness of the medium, concentration of solution, wavelength of light and temperature. Here we perform the experiment with sodium light at room temperature.

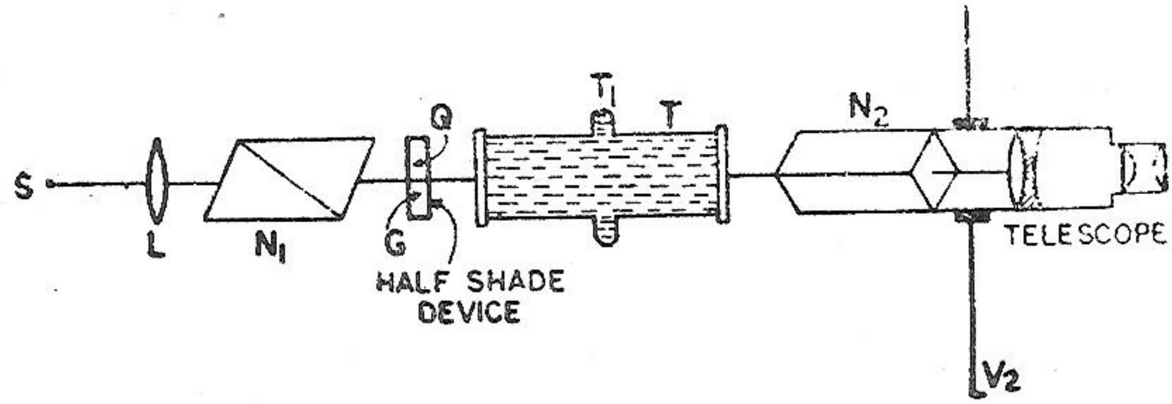


Fig. 10.1: Polarimeter

Polarimeter consists of two prisms, a polarizer and an analyzer. Just behind the polarizer is the half wave plate of quartz and the other half wave plate of glass. Both the halves of the plate together give the full field of view. As shown in *Fig. 10.1*, the light from lens L passes through the polarizer N_1. The plane polarized light falls on the wave plate where one half of the light passes through the quartz Q and the other half passes through the glass plate G. The vibrations of beam emerging out of glass will be along CD and the vibrations of beam emerging out of quartz will be along AB as shown in *Fig. 10.2*

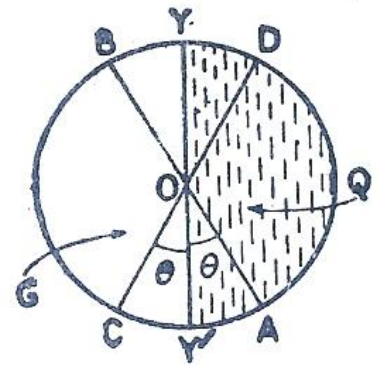


Fig. 10.2: Principle of specific rotation

At this position, the field of view will be bright. If you further rotate the circular scale (with the vernier) clockwise, the plate on the right would become brighter increasingly with the rotation and the plate on the left would become darker in proportion respectively to the other plate. If you rotate the vernier anti-clockwise, the plate on the left would become brighter increasingly and the plate on the right would become darker in proportion respectively to the other plate.

Procedure

After completing the initial adjustments in the polarimeter instrument, adjust the vernier such that both the halves namely quartz and glass plates, remain equally bright. Measure the reading for this position as V_1. Now a hollow glass tube of length 20 *cm* (2 *dm*) having a large diameter in the middle is filled with a sugar solution of known concentration and placed in between the polarizer N_1 and the analyzer N_2. The sugar solution in the cell, which is an optically active medium, would rotate the plane of vibration to the right (dextro-rotatory). When seen through the eye-piece, brightness in both the halves will not be same due to the rotation of plane of vibration caused by the sugar solution.

The analyzer N_2 is adjusted by rotating the vernier clockwise till the brightness in both the halves of the plates (full field of view) are equal. Note the reading in the vernier in this new position V_2. The angle through which the analyzer is rotated gives the angle through which the plane of vibration of the incident beam has been rotated by the sugar solution. The experiment is repeated for various concentrations of sugar solution and the corresponding angles of rotation are determined. A graph is plotted between the concentration C and the angle of rotation θ, as in *Fig. 10.3.* Straight line of the graph indicates that the angle of rotation increases linearly with the concentration of sugar solution. From the tabulation the average specific rotation of the sugar solution is obtained.

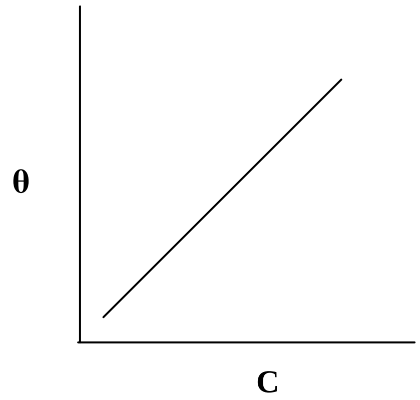


Fig. 10.3: Concentration .vs. angle of rotation

Table 10.1: To find the specific rotation

Least Count (LC) = ……. V_1 = ……..

S. No	Concentration of sugar solution (*gm/cc*)	V_2 (*deg*)	$\theta = V_2 \sim V_1$ (*deg*)	$S = \dfrac{\theta}{LC}$ (*deg cc/g dm*)

Mean S = …… *deg cc/g dm*

Result

Specific rotation of the sugar solution, S = ……….. *deg cc/g dm*

* * * * *