A LAB BOOK
OF
Applied Physics Lab-I (ETPH -151)

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PREFACE

We feel great pleasure in bringing out this Lab Book for the Physics Lab Course ETPH-151 of B.Tech (First Semester) of GGSIP University. The high lights of this Lab Book are:

(a) The coloured photographs of the actual apparatus used in AIT Physics Lab have been included. Normally, the apparatus shown in the Practical Physics books are different from those available in the Lab. This not only creates confusion but also poses difficulties to the students. I am sure that the actual pictures will not only enhance the interest of the students in doing the Lab work but also help in better and quicker understanding.
(b) An introduction to the apparatus used and the theory behind each experiment has been written in a very concise way so that the students can read and understand the gist of the experiment. There are no unnecessary details, which are normally available in the Practical Books.
(c) The precautions have not only been given in the end, but also included in the procedure wherever it is necessary.
(d) The recording of observations in tabular form has been encouraged in all experiments so that various readings can be compared at a glance
(e) The SI units of the quantities to be calculated are written, to avoid any confusion.
(f) The standard value of the quantity to be calculated is also given so that error analysis can be carried out easily.

It is hoped that the Lab Manual with all these features will prove very useful in enhancing learning of the students.

Any suggestions towards further improvement will be thankfully acknowledged and incorporated in it in the next edition.

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A Note To Students

The objective of Lab Experiments along with the theory classes is to understand the basic concepts clearly. The experiments are designed to illustrate important phenomena in different areas of Physics and to expose you to different measuring instruments and techniques. **The importance of labs can hardly be overemphasized as many eminent scientists have made important discoveries in home made laboratories.** In view of this, you are advised to conduct the experiments with interest and an aptitude of learning. In order to make full use of Lab periods, you are requested to adhere to the following requirements:

(i) You must come well prepared for the experiment.

(ii) Work quietly and carefully and share your work with your experiment partners.

(iii) **Be honest in recording your data. Never cook up the readings to get desired/ expected results. You never know that you might be heading towards an important discovery**.

(iv) Presentation of observations in tables/ graphs and calculations should be done neatly and carefully. Always label your graph properly. Be very clear to write the proper units.

(v) Bring your Lab book daily. If you finish with your experiment early, spend the remaining time to do your calculation work. Therefore it is essential that you come equipped with calculator, scale, pencil etc.

(vi) Don’t fiddle with the apparatus. Handle instruments with care. Report any breakage to the instructor. Return all the equipments that you have taken from the Lab Assistant/ faculty for the purpose of your experiment before leaving the Lab.

Paper Code: ETPH-151 **P C**
Paper: Applied Physics Lab –I **2 1**

LIST OF EXPERIMENTS

Experiment No. 1: Use of measuring instruments
(a)To find the volume of a cylinder and volume of a cube by using vernier calipers
(b) To find the diameter of a wire using a screw gauge
(c) To find the radius of curvature of a convex lens with the help of a spherometer
Page No. 4-18

Experiment No. 2: To determine the value of acceleration due to gravity at a place with the help of Kater's pendulum. Page No. 19-23

Experiment No. 3: To plot a graph between the distance of the knife-edges from the center of gravity and the time period of a bar pendulum. From the graph, find
(a) The acceleration due to gravity.
(b) The radius of gyration and the moment of inertia of the bar about an axis.
Page No. 24-29

Experiment No. 4: To find the moment of inertia of a flywheel about its axis of rotation. Page No. 30-34

Experiment No. 5: To determine the frequency of AC mains using a sonometer and an electro-magnet. Page No. 35-38

Experiment No. 6: To determine the refractive index of the material of a prism using spectrometer and a sodium lamp. Page No, 39-43

Experiment No. 7: To study the variation of the refractive index with wave length of spectral lines of mercury and to determine the dispersive pwer of the material of the prism. Page No. 44-47

Experiment No. 8: To determine the wavelength of sodium light by Newton's Rings Method. Page No. 48-55

Experiment No. 9: To determine the wavelength of sodium light by using diffraction grating. Page No. 56-61

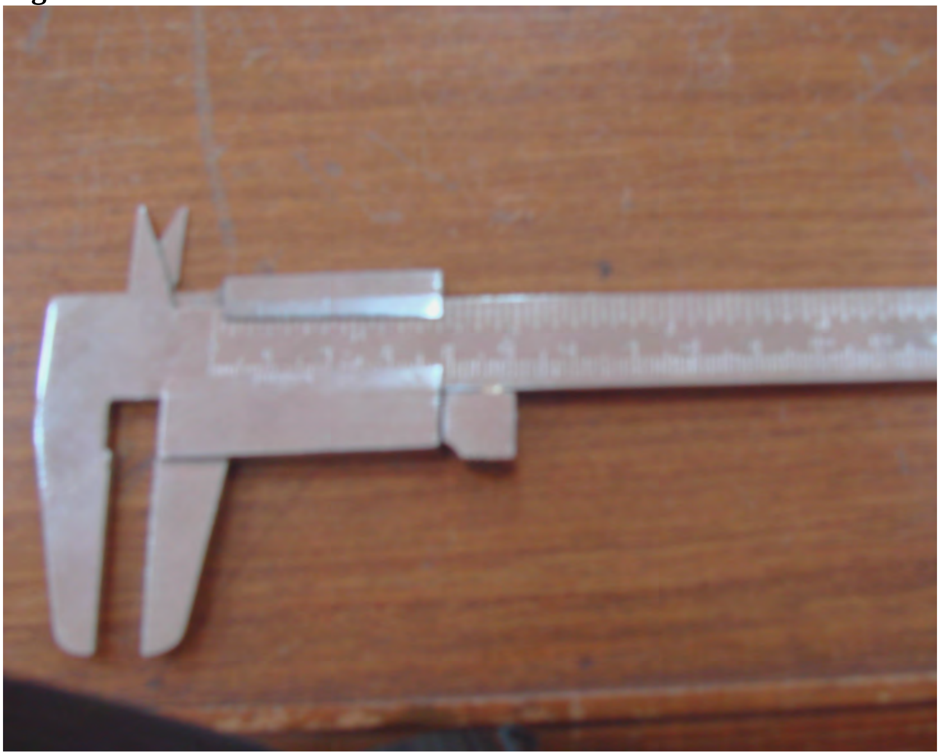
Experiment No. 10: To find the specific rotation of cane sugar solution using polarimeter. Page No. 62-68

Exp. 1(a)

Aim- To find the volume of a cylinder and volume of a cube by using vernier calipers

Apparatus – Vernier Callipers, a cylinder, a cube

Figure-



Formula-

Volume of cylinder = $\pi r^2 h$

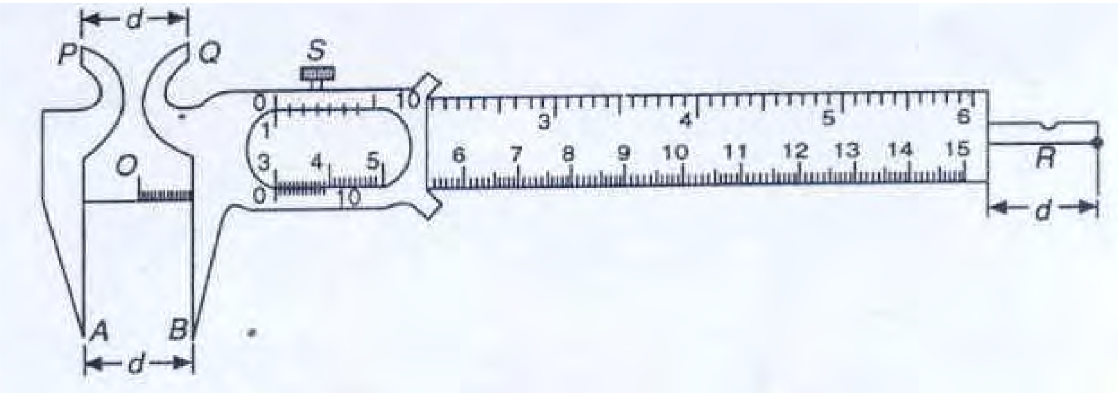
Volume of cube = l^3

Theory -

About Vernier calipers- It is a device to measure the length or width of any small object with greater precision than with a normal mm scale. While the least count of a mm scale is one mm, the least count of vernier calipers is normally 0.1 mm or even lesser. Different vernier calipers have different least counts.

Vernier calipers consist of a rectangular steel bar graduated in inches on one side and centimeters on the other side. This is known as the main scale. Over this scale slides another small scale called vernier scale (see figure). The instrument has two jaws A and B. The jaw A is fixed at the end of the main scale, while the jaw B is movable. It is a part of the sliding vernier scale. Each jaw is at right angles to the main scale. Usually when

the two jaws are touching each other, the zero of the vernier scale coincides with the zero of the main scale. If it is not so then the instrument has a zero error.
In some forms of the instrument , the jaws protrude upwards as P and Q. These projecting jaws are used to measure the internal diameter of the tubes. The movable jaw also carries a thin rectangular rod R that is used to measure the depth of a vessel.
As shown in Fig. AB=PQ=R=d



Vernier constant or Least Count- In order to understand how the fraction of the smallest scale division on the main scale (mm) can be read, consider a vernier scale having 10 vernier divisions**. Let these 10 vernier scale divisions coincide with 9 main scale divisions.**

1 V.D = 9/10 M.S.D

1 M.S.D- 1V.D = 1/10 M.S.D = 0.1 M.S.D = 0.1 mm

The difference between one main scale division and one vernier division is called vernier constant or least count of the vernier calipers.

In order to measure the length of a cylinder, hold it between the jaws and note the position of the zero of the vernier against the main scale. Say it lies between 1.2 cm and 1.3 cm on the main scale. This means that the length of the cylinder is more than 1.2 cm and less than 1.3 cm. In order to find the fraction of mm, note which division on vernier scale coincides with the main scale division. For example, in Fig. 6^{th} vernier division coincides with main scale division. If we denote fraction after 1.2 cm by x, then

1.2 + x + 6 V.D = 1.2 + 6 M.S.D

x = 6 (M.S.D – V.D)

x = 6 × Vernier constant

x = . 6 M.S.D

x = . 6 mm or .06 cm

Therefore the length of the cylinder is equal to 1.2 cm + .06 cm or 1.26 cm

<u>Zero error</u>- when the two jaws are pressed together, then the zero line of the vernier scale should coincide with the zero line of the main scale. If it is not so, then the instrument has a zero error. To find the zero correction, note the division, which coincides with the main scale division. Multiply that number with the vernier constant. This is the zero correction. It is positive if the zero of the vernier scale lies ahead of the zero of the main scale; and it is negative, if the zero of the vernier lies behind the zero of the main scale.

Procedure-

(1) Hold the cylinder length wise between the jaws of the vernier calipers tightly and note the reading on main scale and also note which division of vernier scale coincides with main scale division.
(2) Repeat the procedure at least four times by changing the positions of the jaws on the two cross sections of the cylinder.
(3) Hold the cylinder diameter wise between the jaws of the vernier calipers tightly. Note the reading on main scale and also note which division of vernier scale coincides with main scale division.
(4) Repeat the procedure at least four times by changing the position of the jaws to measure different diameters. Find the mean value. Apply correction**.**
(5) Calculate the volume of the cylinder by using the formula for volume.
(6) Hold the cube between the jaws of the vernier calipers and measure its length, breadth and height. Take at least four readings for each dimension.
(7) Calculate the volume of the cube by using the formula.

Observations-

Vernier constant = 1 M.S.D – 1V. D
=

Zero correction =

<u>Measurement of length</u>

<u>Sl. No</u>	Reading on the main scale (m)	The division on the vernier which coincides with the main scale division (x)	Measured length= m×MSD + x× vernier const	Mean value of h

Correct value of h = measured value of h + zero correction
Value of h after applying correction = mean value of h + zero correction
=

Measurement of diameter

Sl. No	Reading on the main scale (m)	The division on the vernier which coincides with the main scale division (x)	Measured length= m×MSD + x× vernier const	Mean value of diameter (d)

Correct value of diameter d= measured value d + zero correction
=
radius r =

Measurement of the sides of the cube

Sl. No	Reading on the main scale (m)	The division on the vernier which coincides with the main scale division (x)	Measured length= m×MSD + x× vernier const	Mean value of l

Mean value of measured l=
Corrected value of l = measured vale l + zero correction
=

Calculations:
Volume of the cylinder =
Volume of the cube =

Precautions-

1. Calculate the least count carefully.
2. Note the zero correction carefully.
3. Take the readings carefully.
4. Find the diameter at least at four different places along the length. Also at each place, find the diameter along two perpendicular directions.

SPACE FOR STUDENTS WORK AREA

Exp.1(b)
Aim- To find the diameter of a wire using a screw gauge

Apparatus- A screw gauge, a piece of wire
Figure-

Theory-
<u>About Screw Gauge</u>- It is an instrument designed to have a least count .01 mm or even smaller. It is used to measure the thickness of very thin objects such a thin sheet, a wire or a hair etc. It is based upon the principle of a screw. It consists of a U- shaped frame, which has a fixed end at A. A fine and an accurately cut screw of uniform pitch passes through the other end of the frame. A cap fits on to the screw and carries on its inner edge 100 or 50 equal division marks. This is called the circular scale (H) and is used to measure the fraction of a revolution. There is another linear scale graduated on the nut parallel to the axis of the screw. This is called pitch scale (S). When the screw is rotated, the number of complete rotations can be read on the pitch scale, while the fraction of

rotation can be read from the circular scale. In some screw gauges, the screw head is provided with a ratchet arrangement R (See Fig.). When the studs A and C are in contact with each other or with some other object placed in between, the ratchet slips over the screw without moving the screw forward. This helps in avoiding undue pressure between the studs or on the object for accurate measurements.

To find the least count of the screw gauge

Pitch The distance between two consecutive threads taken parallel to its axis is called the pitch of the screw. It is measured as the distance through which the screw moves forward or backward when one full rotation is given to the screw cap.

$$\text{Pitch} = \frac{\text{Distance traveled on the pitch scale}}{\text{Number of rotations}}$$

Normally the pitch is either 0.5 mm or 1.0 mm

Least Count of a screw gauge is defined as the distance through which the screw moves (on the pitch scale) when the cap of the screw is rotated through one division on the circular scale**.**

$$\textbf{Least Count} = \frac{\textbf{Number of full rotations of the circular scale}}{\textbf{Distance moved on the pitch scale}}$$

Usually, the least count of a screw gauge is 0.01 mm.

Zero Error – when we bring the studs A and C in contact without applying an undue pressure (one click on the ratchet), the zero of the circular scale should coincide with the reference line on the pitch scale. If it is not so; then the instrument has zero error. In some instruments, the zero of the circular scale goes beyond the reference line; while in other instruments, it is left behind. To find the zero correction, count the number of divisions on the circular scale by which the zero of the circular scale has gone beyond or left behind the reference line. Multiply this number with the least count of the instrument. This is the correction. **If the zero of the circular scale lies beyond the reference line, then the correction is positive and if the zero of the circular scale lies behind the reference line, then the correction is negative.**

Procedure-

(1) Hold the wire between the studs A and C of the jaws just tight, without undue pressure (with one click on the ratchet).
(2) Note the reading on the circular scale against the reference line on the pitch scale. Multiply it with the least count and add it to the number of complete divisions visible on the main scale. **If the pitch is 0.5 mm , then care should be taken to note the reading on the pitch scale correct to 0.5 mm** .
(3) Turn the wire through 90° and again take the reading as in step (2).
(4) Repeat the procedure by holding the wire at least three different places.
(5) Find the mean value of different readings.
(6) Obtain the correct value of the diameter by applying correction.

Observations-

Zero correction

Diameter of the wire

Sl. No	Reading on Pitch scale(m)	Circular scale reading (x)	Measured diameter= $m\times$ pitch + $x\times$least count	Mean value of diameter

Mean value of measured diameter=

Precautions-

1. The circular scale should be rotated in the same direction to avoid backlash error.
2. There should be no undue pressure on the wire. Rotate the circular scale and stop when one click is heard on the ratchet arrangement.
3. Measure diameter in two perpendicular directions by turning the wire by 90^0. Take such measurements at least at four different places along the length of the wire.

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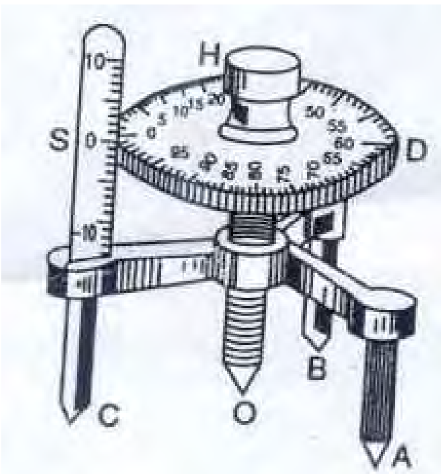
Exp. 1(c)
Aim – To find the radius of curvature of a convex lens with the help of a spherometer

Apparatus – A spherometer, a plane glass slab, a convex lens of appropriate diameter (about 8cm to 10 cm), a vernier calipers and wooden blocks for supporting the lens

Formula-

Radius of curvature of the lens R $= \frac{l^2}{6h} + \frac{h}{2}$

Figure-



Theory –

About spherometer –

It is a device to measure the thickness of a thin plate and the radius of curvature of any spherical surface (concave /convex mirror or a lens). It carries a small vertical scale usually divided into millimeters. The body of the instrument is supported on three legs whose lower tips form an equilateral triangle and lie in one plane. A screw which carries a circular scale (having 100 or 50 divisions) at its top is so supported that the tip of this screw is at circum- centre of the triangle formed by the tips of the legs. The distance through which the screw advances along the vertical scale in one full rotation is called pitch of the spherometer. It is usually 1 mm or 0.5 mm. If the pitch is 1 mm and the circular scale has 100 divisions, then this means that when the circular scale is rotated by 100 divisions, the screw moves through distance 1mm. Therefore when rotated through one division, it moves through .01 mm. This is the least count of the instrument.

Zero Error- If the instrument is correct, then the zero of the circular scale should coincide with the zero of the vertical scale when the tip of the screw is in the plane of the tips of the legs. This is seldom so and hence the instrument has initial error called zero error. The correction whether positive or negative depends upon the final reading whether taken by moving the screw downward or upward. **It is not quite necessary to find the zero error if the number of divisions through which the circular scale is rotated is measured correctly and carefully.**

To determine the radius of curvature of a spherical surface-

The formula for calculating R can be easily derived.

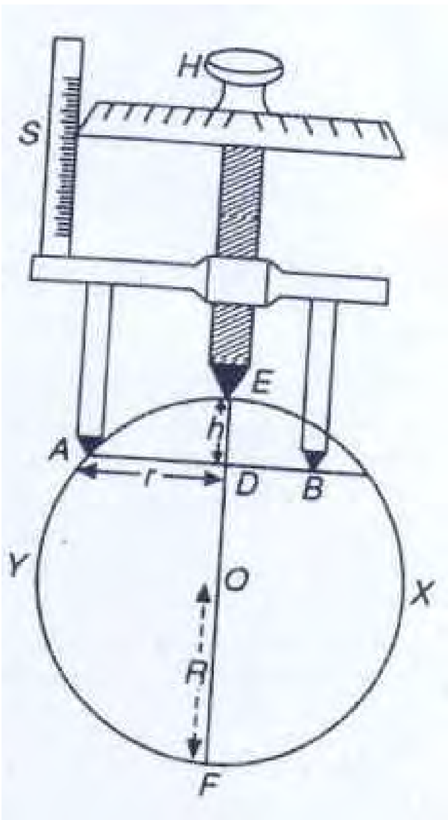


Fig 1

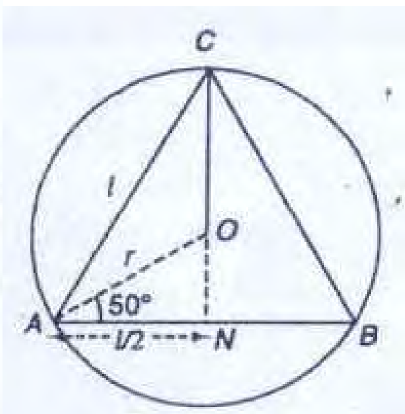


Fig 2

From the geometry of the circle (Fig 1), we have

AD^2= ED. DF
or $r^2 = h(2R-h)$
or $2Rh = r^2 + h^2$
or $R = r^2/2h + h/2$
If l is the length of each side of the equilateral triangle ABC formed by joining the tips of the three outer legs, then as shown in Fig 2,
$l/2 = r\cos\theta = r\sqrt{3}/2$
Substituting $r = l/\sqrt{3}$, we have $R = \frac{l^2}{6h} + \frac{h}{2}$

Procedure –

(1) Find the least count of the spherometer.
(2) Raise the screw by tuning its head so that it may be above the plane containing the tips of the three legs. Place the spherometer on the page of your notebook on which experiment is to be done. Press the spherometer to get the impression of the tips of three legs. Mark the position of each of the three points by drawing a small circle round each point. Measure the length of each side of the triangle formed by joining these points and let the mean value. Let the mean length be l cm.
(3) Set the convex lens firmly on a horizontal surface (table).Place the spherometer on the surface of convex lens after raising its central leg through four or five complete rotations of the circular scale. Turn the screw so that the central leg while moving downwards touches the surface of the lens. Note the circular scale reading against the edge of the vertical scale. Repeat this step three times
(4) Place the spherometer on the surface of the plane glass slab or a table. **Turn the screw in the same directions** as in the previous step till tip of the central leg just touches the plane surface. Count the number of complete rotations and the additional number of circular divisions moved.
(5) Repeat the step three times by moving the central leg every time in the upward direction through a sufficient large distance as compared to the value of 'h'.

Observations
Distance moved by the screw in 4 complete rotations =
Pitch of the screw =
Total number of divisions on circular scale (n) =
Least count of the spherometer = Pitch/ n
=
Mean distance between the legs l =

Measurement of h

Sl. No.	No. of complete rotations (m)	No. of additional circular divisions moved (x)	h = m× pitch + x×least count	Mean value of h in meters

Radius of curvature of the lens R $= \frac{l^2}{6h} + \frac{h}{2}$

Precautions

(1) l should be measured accurately with the help of vernier calipers because we use l^2 in calculations. Measure l by use of projecting jaws P and Q of the vernier calipers correct to a fraction of a millimeter or with the help of a traveling microscope.

(2) The lens must be in perfectly stable position when readings are being taken.

(3) There should be no play between the screw and the nut in which it rotates

SPACE FOR STUDENTS WORK AREA

Exp. 2

Aim – To determine the value of acceleration due to gravity at a place with Kater's pendulum.

Apparatus – Kater's pendulum, a stop watch and a metre rod

Formula-

$$g = \frac{8\pi^2}{(t_1^2 + t_2^2)/(l_1 + l_2) + (t_1^2 - t_2^2)/(l_1 - l_2)}$$

Here,

t_1, and t_2 are the time periods of the oscillating pendulum from knife-edge K_1 and K_2 respectively;

l_1 and l_2 are the distances of the knife-edges K_1 and K_2 from CG of the pendulum respectively (obtained without disturbing the steel and wooden weights).

When t_1 and t_2 are very close to each other (difference less than 1 percent), the simplified formula is :

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

Here $(l_1 + l_2)$ is the distance between the two knife-edges (In this case, we need not find the CG of the pendulum) and t is the mean value of t_1 and t_2.

Figure-

THEORY: It is a pendulum designed on the principle that the centre of oscillation and the centre of suspension are interchangeable. It is also called reversible compound pendulum. The basic principle is to find the two points on it that are not equidistant from the centre of gravity and such that the time periods of the pendulum are almost equal when the pendulum is suspended from either of these points**.** The difference in the time periods should be around .01 second. This means that the time for 50 oscillations should differ by about .5 second. The pendulum can be used to obtain the value of acceleration due to gravity very accurately.

It consists of a steel or brass bar capable of oscillating about two adjustable knife-edges K_1 and K_2 facing each other. Two metal weights W and w and two wooden weights W_1 and w_1 (which are exactly similar to W and w respectively) can be made to slide, along the length of the bar and can be clamped in any position. The bigger metal weight W is fixed at one end and the wooden weight W_1 is kept symmetrically at the other end of the bar as shown. The smaller weights w and w_1 are placed symmetrically between the two knife-edges. **The symmetry in the positions of the weights W and W_1 and in the positions of w and w_1 is required because the pendulum motion has extra air mass associated with these blocks, which needs to be identical for the two configurations; otherwise the kinetic energies are not equal. In this position the centre of gravity lies in between and near one of the knife-edges.** The poison of the two knife-edges and the weight w and w1 are so adjusted that the time periods of the pendulum about the two knife- edges are nearly equal. In such a case one knife-edge is at the centre of oscillation with respect to the other position as the centre of suspension. Therefore the distance between these knife-edges then is equal to the length of an equivalent simple pendulum L.

$L = l_1 + l_2$; where l_1 is the distance of the knife-edge K_1 from centre of gravity and l_2 the distance of K_2 from the centre of gravity**. If t_1 and t_2 are nearly equal and l_1 and l_2 differ by a fairly large amount, we need not find l_1 and l_2 separately because the formula**

$$g = \frac{8\pi^2}{(t_1^2 + t_2^2)/(l_1 + l_2) + (t_1^2 - t_2^2)/(l_1 - l_2)}$$

is simplified to:

$$g = \frac{4\pi^2 (l_1 + l_2)}{t^2}$$, where t^2 is the mean value of $(t_1^2 + t_2^2)$.

Procedure-

(1) Fix the weights W and W_1 near the two ends of Kater's pendulum and the knife-edges K_1 and K_2 close to W and W1 respectively. The smaller weights w and w1 should be fixed symmetrically between the knife-edges (see Fig.)

(2) Suspend the pendulum about the knife-edge K_1 and set it into vibrations with small amplitude. Start the stopwatch when the pendulum is just passing through its equilibrium position and count zero. Count one when the pendulum again passes

(3) through its equilibrium position in the same direction and so on. Note the time taken for 20 vibrations.
(4) Now suspend the pendulum about the knife-edge K_2 and find the time for 20 vibrations again. Adjust the positions of w and w_1 so that time period of the pendulum about K_2 is very nearly the same as that about the knife- edge K_1.
(5) Again suspend the pendulum about the knife-edge K_1 and note the time for 20 vibrations. The time period about K_1 will be different from the time period found in step 3 It is because the position of C.G has shifted due to the change in position of the knife-edge K_2. Again adjust the positions of w and w1, so that the new time period is close to that in step 3.
(6) Again suspend the pendulum about the knife-edge K_2 and adjust its position very slightly till the new time period about K_2 is as nearly equal to the time period about K_1 as far as possible.
Now find the time for 100 vibrations about K_1 first and then about K_2 three times. The two time periods may differ by 1% but no more. For accurate measurements, we may need to see the vibrations with the help of a telescope.
(7) Balance the pendulum on a sharp wedge and mark the position of its centre of gravity. Measure the distance of the knife-edge K_1 as well as that of K_2 from the centre of gravity.

Observations -

SL. No.	Knife Edge	Time for 100 Vibrations				Time Period
		(i)	(ii)	(iii)	Mean	

Calculations-

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

=

Standard value of g=

Percentage error =

Precautions-

1. The heavy weight should be placed at one end so that the C.G lies near one of the knife-edges and wooden weight W symmetrically at the other end to avoid error due to air drag
2. The two knife-edges should be parallel to each other

3. The amplitude of vibration should be small so that the motion of the pendulum satisfies the condition $\sin\theta = \theta$
4. To avoid any irregularity of motion the time period should be noted after the pendulum has made a few vibrations and the vibrations have become irregular.
5. For final observation the time of at least 100 vibrations must be taken with an accurate stopwatch

Sources Of Error-

1. Slight error is introduced due to resistance of air
2. Slight error is introduced due to curvature of the knife-edges, because they are not sharp
3. The support may be yielding slightly.
4. The amplitude of oscillation cannot be very small as desirable.

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Exp. 3

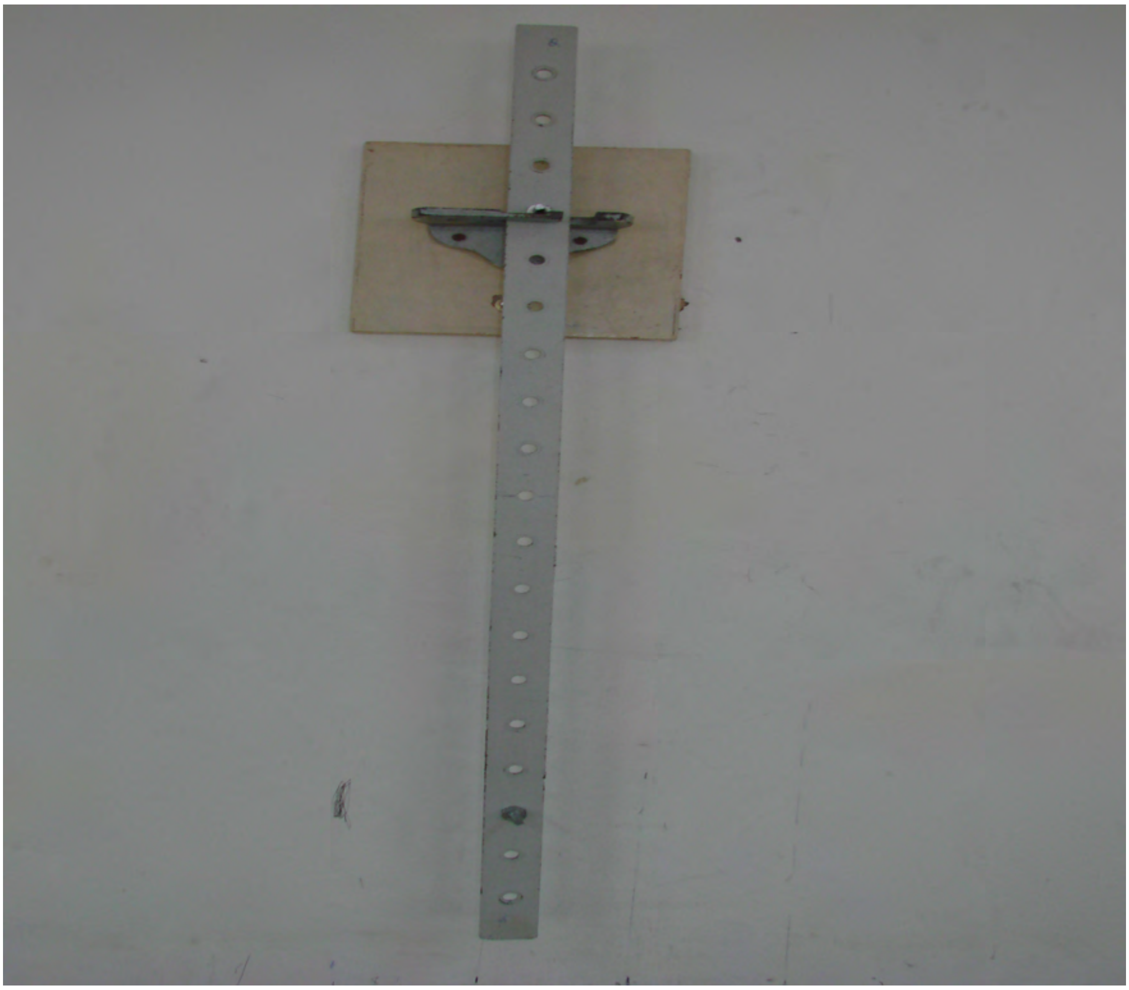
Aim – To plot a graph between the distance of the knife-edges from the centre of gravity and the time period of a bar pendulum. From the graph find acceleration due to gravity.

Apparatus – A compound pendulum, a wedge, a spirit level, a telescope, a stop watch , a meter rod , a spring balance and a graph paper

Formula-

$$g = \frac{4\pi^2 L}{t^2}$$

Figure-



Theory-

A bar pendulum is a compound pendulum in the form of a metal bar with a number of holes equally spaced along the length of the bar. A knife-edge can be inserted in any of the holes and then the bar pendulum can be oscillated by putting the knife-edge on a fixed support. We find the time periods of the pendulum by inserting the knife-edges in different holes.). It will be observed that as the middle hole of the bar (CG of the bar) is approached, the time period first decreases, acquires a minimum value and then increases until it becomes infinite at the CG itself.

A graph ABD is plotted between the time period (T) along y-axis and the distance of the corresponding point of suspension (knife's inner edge) from the centre of gravity of the bar pendulum. The experiment is then repeated by fixing the knife-edge in the holes on the other side of the CG of the pendulum and a similar EFH drawn along side the first. This graph (EFH) will be a mirror image of the first (ABD. The basic principle is to find the two points on it that are not equidistant from the centre of gravity and such that the time periods of the pendulum are equal when the pendulum is suspended from either of these points. In fact we can find out from the graphs that there are four points of suspension on the bar pendulum which correspond to the same time period. Any one pair of points that are on different sides of the centre of gravity (CG) and which are not equidistant from the CG will correspond to centre of suspension and the corresponding centre of oscillation. The distance between these two points will be equal to the length of the equivalent simple pendulum = L. In the Fig. A line parallel to x- axis is drawn which cuts the two curves in points A, B, D and E. Then the time periods for all these points are same =OC in Fig. given below:

Therefore L=AD or BE

Or L= (AD+BE)/2

The graph obtained will be as given below:

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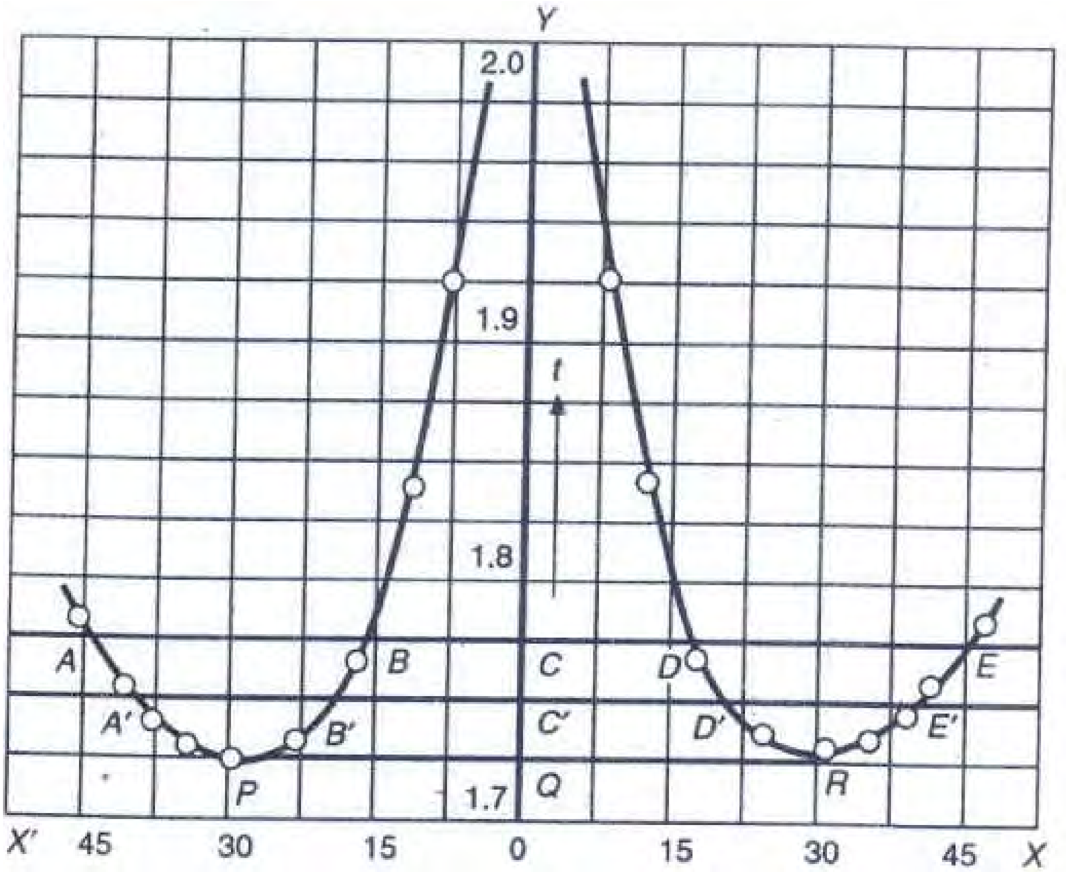


After finding L, we find the value of g as following:

g= $\frac{4\pi^2 L}{t^2}$

Procedure-

1. Paste a small piece of paper on either end of the compound pendulum as shown.
2. Mark on one side 'A' (knife-edge K_1) and on other side 'B' (knife-edge K_2). Place the knife edges such that their sharp edges are pointing towards the centre of gravity.
3. Place a spirit level on glass plates fixed on the bracket in the wall meant for suspending the pendulum and see that the upper surfaces of the glass plates are in the same level.
4. Suspend the pendulum from the knife-edge K_1 fixed in the first hole on the side A so that knife-edge is perpendicular to the edge of slot and the pendulum is hanging parallel to the wall. The knife-edge K_2 should be fixed in the first hole on the side B.
5. Set the pendulum into vibration with small amplitude of about 5° and allow it to make a few vibrations so that these become regular.
6. Start the stopwatch and count zero when the pendulum is at its one extreme position. Count one when pendulum is passing through same position in same direction and so on. Note the time taken for 20 vibrations. Repeat again and take mean.
7. Remove the pendulum from the support and find its CG and then find distance of the CG from the inner edge of the knife.
8. Now suspend the pendulum on the knife-edge K_2 on the side B and repeat the steps 5 to 7.
9. Repeat the observations with the knife-edges in the 2nd, 3rd, 4th etc. holes on either side.
10. **Plot the graphs APB and DRE between distances of holes from the CG along x- axis and the time period (T) along y-axis. The graph APB is for the holes on one side of the CG (say side A), while the graph DRE is for the holes on the other side of the CG (say side B).**

Observations-

Sl. No.	Side A					Side B				
	Time for 20 vibrations			Time period (t) sec	Distance from CG (m)	Time for 20 vibrations			Time period (t) sec	Distance from CG (m)
	1	2	Mean			1	2	Mean		
1										
2										
3										
…										
…										
…										

Length of Equivalent simple pendulum from the graph

AD =
BE =
A_1D_1=
B_1E_1=

Sl. No	Length of Equivalent Simple pendulum			Time period (t) s from the graph	L/t^2
	(i)	(ii)	Mean (L)		
1	AD=	BE=			
2	A_1D_1=	B_1E_1=			

Mean value of L/t^2 =

Calculations-

$$g = \frac{4\pi^2 L}{t^2} =$$

Precautions-
1.The knife-edges should be horizontal and the bar pendulum parallel to the wall.
2.Amplitude should be small.
3.The time period should be noted after the pendulum has made a few vibrations and the vibrations have become regular.
4.The two knife-edges should always lie symmetrically with respect to the C.G
5.The distances should be measured from the knife-edges.

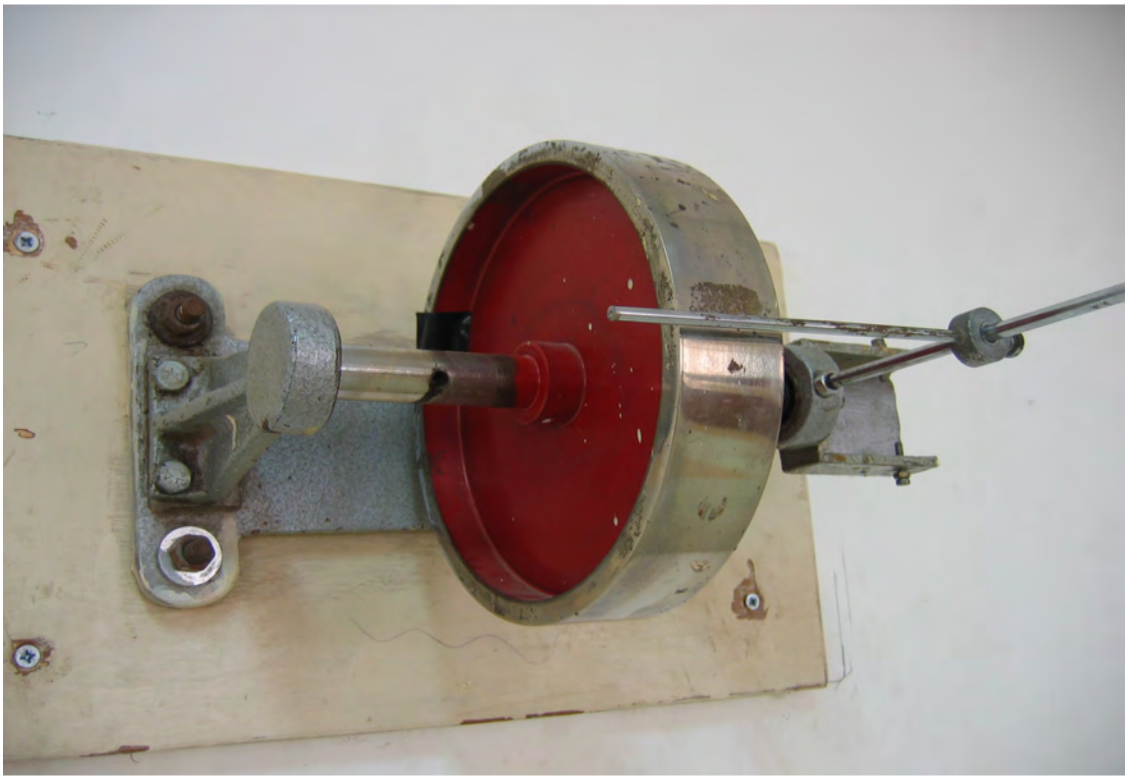
Sources of error
Slight error is introduced due to
1. Resistance of air
2. Curvature of knife-edges
3.Yielding of support
4. Finite amplitude

SPACE FOR STUDENTS WORK AREA

Exp. 4

Aim –To find the moment of inertia of a flywheel about its own axis of rotation.
Apparatus- A flywheel, a few different masses and a hook, a strong and thin string, a stop watch, a meter rod, a vernier calipers and a piece of chalk.
Formula-

$$I = \frac{2mgh - mr^2 w^2}{w^2 (1 + n/n_1)}$$



Theory-

A flywheel is simply a heavy wheel with a long axle supported in bearings such that it can rest in any position; that is, its CG lies on the axis of rotation. To find its moment of inertia, a mass m is attached to the axle of the wheel by a cord, which is wrapped several times around the axle. One end of the string is in the form of a loop so that it can be easily attached or detached from a pin projecting from the axle. The length of the string is so adjusted that it gets detached from the axle as soon as the bottom of the mass is just to touch the floor. When the mass is allowed to fall, its potential energy is partly converted into the kinetic energy due to the velocity gained by it and partly into the energy of rotation of the flywheel. Let w be the angular velocity of the wheel at the moment the mass m is detached. After the mass is detached from the wheel, the wheel continues to revolve for some time. The angular velocity decreases due to friction and finally comes to rest. If n_1 is the number of revolutions that the wheel makes in time t before coming to rest, then

$$\text{Average Angular Velocity} = \frac{2\pi n_1}{t}$$

If the frictional force is constant then the rotation of the wheel is uniformly retarded. It begins with angular velocity w and its final velocity is zero; so that the initial velocity w is double the average velocity.

$$\text{Or} \qquad w = \frac{2 \times 2\pi n_1}{t} = \frac{4\pi n_1}{t}$$

According to the principle of conservation of energy, when the string is detached
PE of mass m = KE of mass m + KE of wheel + work done against friction
If the mass m falls through height h, then PE of the mass = mgh
Linear velocity of the mass at the moment it is detached = r w, where r is the radius of the axle. **Therefore the KE of the mass = ½ m(r*w*)^2.**
And the KE of the wheel is = ½ I w^2.
If the energy dissipated during each revolution of the wheel = F, then the energy used against friction during the descent of the mass m = n F, where n is the number of revolutions the wheel makes during the descent of the mass (n= no. of turns of the string wound on the axle).
Therefore

$$mgh = \tfrac{1}{2} mr^2w^2 + 1/2\, I w^2 + nF \qquad (1)$$

Also the KE possessed by the wheel is dissipated due to friction. As the wheel comes to rest after making n_1 revolutions,

$$n_1F = \tfrac{1}{2} I w^2 \qquad (2)$$

By eliminating F from Eq. (1) and (2), we get

$$I = \frac{2mgh - mr^2w^2}{w^2(1 + n/n_1)}$$

Procedure-

(1). Examine the wheel and if needed oil the bearings.
(2). Measure the diameter of the axle with a vernier calipers at different points and find the mean diameter. Also measure the circumference of the wheel with a thread.
(3). Take a strong and thin string whose length is less than the height of the axle from the floor. Make a loop at its one end and slip it on the pin on the axle. Tie a suitable mass on the other end of the string. Suspend the mass by means of the string so that the loop is just on the point of slipping from the pin. Make a chalk mark (or stick tape) on the wheel behind the pointer in this position. Also note the position of the lower surface of the mass on a scale fixed behind on the wall.
(4). Now rotate the wheel and wrap the string uniformly around the axle so that the mass m is slightly below the rim of the wheel and chalk mark is opposite to the pointer. Again note the position of the lower surface of the mass on the scale fixed on the wall. Let the difference in the two positions of the lower surface of the mass = h and let the number of turns of the string round the axle = n. The wheel will then make n revolutions before the thread is detached.
(5). Hold the stopwatch in your hand and allow the mass to descend. As soon as the sound of the mass hitting the ground is heard, start the stopwatch. Count the number of revolutions n_1 made by the wheel before coming to rest with reference to the chalk mark and note the time t taken for this purpose. Note the fraction of revolution if any. Repeat three times for the same load and height.
(6). Repeat the experiment with three different masses and suitable heights.

Observations-

Vernier Constant =
Diameter of the wheel = (i) (ii) (iii)
Mean Diameter =
Radius of the axle r = m
Circumference of the wheel S= m
Mass m= kg
Height h= m
Number of turns wound on the whee n=

Finding n_1

Sl. No.	No. of revolutions made by the wheel = x	Distance of chalk mark from the pointer=d	Fraction of revolution d/S=y	Number of revolutions n= x+y	Time = t
1					
2					
3					

Mean time t =

Mean $n_1 =$

Therefore Angular Velocity $w = 4\pi n_1/t$

Moment of Inertia of the fly wheel $I = \dfrac{2mgh - mr^2w^2}{w^2(1+n/n_1)}$ kg-m^2

Record Observations as above for different masses and corresponding heights and obtain the corresponding values of I.

Mean Moment of inertia I = kg-m^2

Precautions-

(1). There should be least possible friction.
(2). The length of the string should be less than the height of the axle of the flywheel from the floor.
(3). The loop slipped over the pin should be loose enough to be detached easily.
(4). The string should be strong and thin and should be wound evenly.
(5). The stopwatch should be started just when the string is detached.

Sources of Error-

(1). The angular velocity *w* has been calculated on the assumption that the friction remains constant when the angular velocity decreases from initial value to zero. Actually, it is not correct.
(2). The instant at which the string is detached can not be found correctly.

SPACE FOR STUDENTS WORK AREA

Exp. 5

Aim – To determine the frequency of AC mains using a sonometer and an electro-magnet

Apparatus – Sonometer with steel wire, an electro magnet, a step down transformer, balance, weight box and a clamp stand

Formula-

f= (1/4l) $\sqrt{T/m}$, where

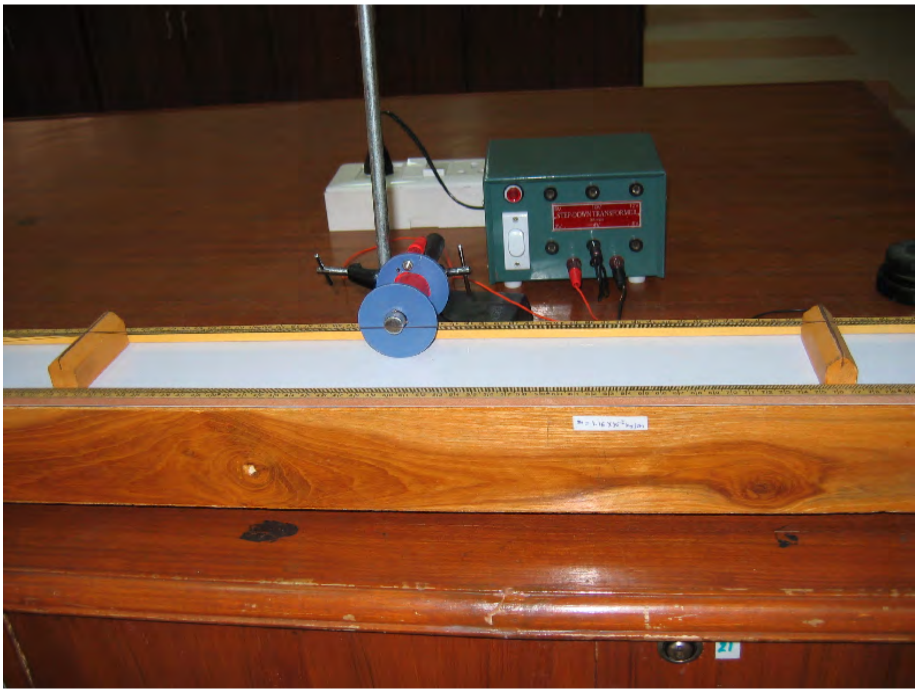
f is the frequency of the mains A.C

l is the length of the wire vibrating in resonance with A.C oscillations,

m is the mass of wire per unit length,

T is the tension in the wire = M g, here M is the mass hung from the wire

Figure



Theory –

If a sonometer wire of mass per unit length m, of length l stretched between two knife-edges under a tension T is once plucked and then released, it executes transverse vibrations of fundamental frequency given by

n=(1/2l) $\sqrt{T/m}$. Here n is called its natural frequency of the vibrating wire.

To find the frequency of A.C. mains using an electromagnet and a sonometer, the A.c. is passed through the primary of a step-down transformer (220-240 V to 4-6 V). The two ends of the secondary coil of the step-down transformer are connected to the two ends of the windings of the electro-magnet. The electro-magnet gets magnetized twice in each cycle, first with its face as North pole and then with the same face as South pole. The electro-magnet is kept close to and vertically above the steel wire of the sonometer. Now the wire is pulled by the electro-magnet twice in each cycle- once when its end near the wire is north-pole and again when it is a south- pole. Thus the wire starts vibrating with frequency twice the frequency of the A.C. When the natural frequency of the wire becomes equal to this frequency, resonance is produced and the vibrations produce large sound. Therefore the frequency of the A.C.(f) is given by:

$2f = n = (1/2l)\sqrt{T/m}$

or

$f = (1/4l)\sqrt{T/m}$,

Here T = Mg

Where M= mass hung from one end of the wire

m= mass of unit length of the wire

l= length of the wire between the two knife-edges when resonance is observed

Procedure-

1. Set up the sonometer apparatus.
2. Arrange the electro magnet in a clamp stand and hold it 2-3 mm vertically above the centre of the steel wire of sonometer. Connect the electromagnet to the secondary of the step down transformer. Switch on the A.C mains and test the magnetization of the electromagnet with the help of an iron needle.
3. Cut a V shaped light paper rider about one cm long and 2mm wide. Bring the two knife-edges close to each other and place the paper ride on the wire in between the knife-edges. See that the pole of electromagnet is just above the centre of sonometer wire. Now gradually increase the distance between the two knife-edges till the rider begins to flutter. The wire is now in resonance with the frequency of AC mains supply. Measure the length of the wire.
4. Increase the distance between the two knife-edges by a few centimeters. Repeat the above process by decreasing slowly the distance between the two knife-edges till the rider again flies off. Measure the length of the wire between the two knife-edges again. The mean of the two lengths is true resonant length.
5. Weigh the weights suspended including the hanger with trip scale balance.
6. Increase the weight by half a kilogram and repeat the observation to find the length of wire vibrating in resonance with AC mains supply

Take such four sets of observations by changing the load by ½ kg each time.

7. Switch off the AC mains and remove the electromagnet. To find the mass per unit length of wire, adjust the distance between the two knife-edges to be exactly 50 cm apart.

Mark with ink a point on the wire at the position of each knife-edge and cut the wire at these points. Find the weight by a sensitive balance. **Or obtain the value of mass per unit length from the Lab Assistant/ Faculty.**

Observations-

Length of wire = cm = m

Mass of wire = g = kg

Mass per unit length (m) =

Sl. No.	Load in kg including the mass of hanger (M)	Tension T =Mg	Length of the wire in meter at resonance			$f = \frac{1}{4l}\sqrt{\frac{T}{m}}$
			Length increasing l_1	Length decreasing l_2	Mean length l (in meter)	
1						
2						
3						
4						
5						

Mean frequency of A.C. = Hz

Standard value of frequency of A.C. mains = 50 Hz

Percentage error =

Precautions

1. The magnetization of electromagnet should be checked with an iron needle before starting the experiment.
2. The electro magnet should be clamped close (2-3 mm) and vertically above the centre of vibrating segment of the wire.
3. The sonometer wire should be made of steel so that it is attracted by the electromagnet.
4. Sufficient load should be put on the wire so that it becomes tight.
5. For each load, the resonant length of the wire should be taken at least twice.

SPACE FOR STUDENTS WORK AREA

Exp.6

AIM : Determination of refractive index of material of a prism by spectrometer.

APPARATUS USED : A Sodium lamp, Spectrometer, a spectrometer prism, a spirit level, magnifying glass, a table lamp etc.

PROCEDURE :

1. Cross wires of the telescope are adjusted properly and then the telescope is focused on a distant object. A clear and sharp image is got in telescope with the proper adjustment of the telescope screws. This will make the telescope, set for parallel rays.
2. The telescope is now turned to a position where the axis of telescope and collimator are in the same line. The slit of collimator is adjustment so that a fine and sharp image of the sodium lamp that illuminates the slit is obtained in the telescope. Now slit is at focus of telescope wire and is adjusted for parallel rays.
3. Determination of angle of prism. To find the angle of prism, the prism is paced at centre of prism table with its base perpendicular to the axis of collimator and the edge towards collimator. Parallel rays from collimator will be incident on refracting surface AB and AC are reflected by reach face.

   The telescope is now turned to receive the light reflected from face AB and its position is so adjusted that the image of slit is at the centre of vertical cross-wires of telescope. The position of both venires of telescope is recorded.

   The telescope is then turned and it receives the light reflected from face AC. Then it is adjusted till the image of both slit of collimator coincides with the center of vertical cr4oss wires of telescope. The position of both the venires is again recorded.

   The mean difference of these two reading gives the angle 2A, and half of this angle of prism A.

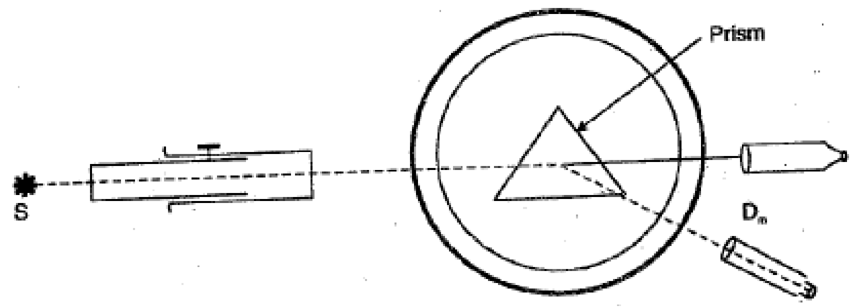
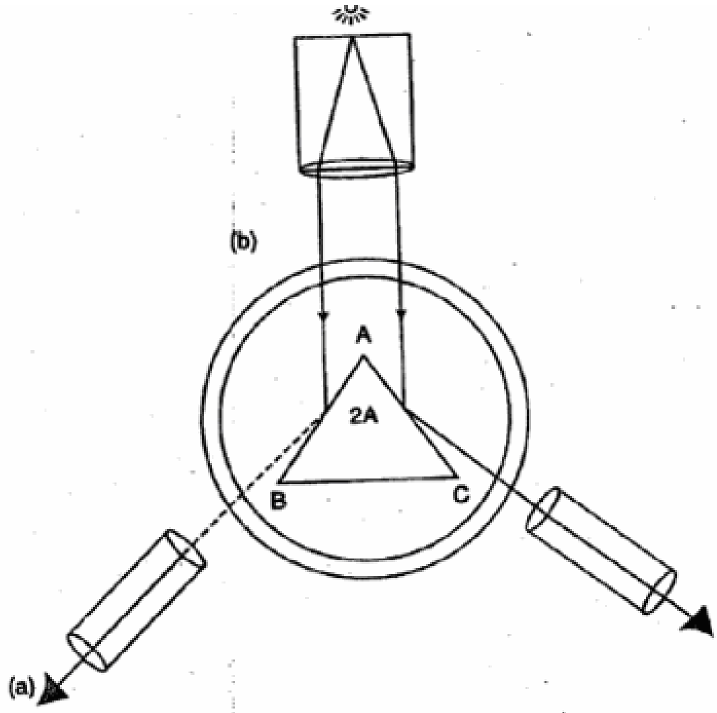


Figure 1

4. Determination of D_m. The prism is placed on the centre of prism table; and the height of the table is adjusted. On one of the refracting faces of prism the parallel rays of monochromatic light from collimator are incident with oblique angle.
5. The image is seen through opposite refracting face through the prism. The prism table is turned in a particular direction till the image of slit becomes stationary and on further



turning of prism table, it moves back. The position of the prism table where the image stops moving is position of minimum deviation. If the prism table is turned in any direction from position of minimum deviation the image of the moving slit moves back. The position of telescope is ready by two verniers to minimize the errors.

Prism is removed and telescope is brought in line with collimator. The image of slit is focused at the centre of cross wire.

And the position of telescope is also read on two verniers.

The difference between the corresponding reading for two position of telescope given the angle minimum deviation D_m.

The experiment is repeated 3 to 4 times to minimize the error.

OBSERVATIONS

Vernier constant of spectrometer = …………

S.No.	Vanier V_1 Position of telescope			Vanier V_2 Position of telescope		
	Face AB	Face AC	Difference θ	Face AB	Face AC	Difference θ
1. 2. 3.						

Mean value of θ = ……………………………

Angle of prism A = θ/2 = …………………….

Table : Angle of minimum deviation

S.No.	Vanier V_1 Position of telescope			Vanier V_2 Position of telescope		Difference
	Min. Deviation	Direct	Difference D_m	Min. Difference	Direct	Difference D_m
1. 2. 3.						

Mean D_m = …………………

Calculations

$$\mu = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin A/2}$$

Result : **Refractive index on material of prism =**

Actual value from tables =

% Error: =

Precautions

1. Proper leveling of the various parts should be done with spirit level.
2. The slit should be adjusted so that a narrow and fine image is obtained in the telescope.
3. The centre of the prism table, centre of collimator and centre of telescope should be adjustable to be in the same line.
4. Tangent screw provided at the base of the spectrometer should be used for fine adjustment.

Sources of error

1. Prism may not be placed I the exact minimum deviation position.
2. There may be some error in taking the readings of the cross wire if the telescope is not adjusted in vertical position.

Exercise : To find the refractive index of a liquid using spectrometer.

SPACE FOR STUDENTS WORK AREA

Exp. 7

AIM : To study the variation of the refractive index with wavelength of spectral lines of mercury and to determine the dispersive power of the material of the prism.

APPARATUS USED: A spectrometer, a prism (dense flint glass), a mercury lamp, spirit level, a magnifier and a table lamp.

THEORY : Dispersive power is the ability of a material to produce separation in different colours. It is defined as the ratio of angular dispersion of the composite light to the mean deviation produced by the prism.

Or dispersive power $\infty = \dfrac{Angular \quad dispersion \quad (\theta)}{Mean \quad deviation}$

Angular dispersion $\theta = (\mu_v - \mu_r) A$

And $D = (\mu - 1)A$

Where $\mu_v \rightarrow$ refractive index for violet colour

$\mu_r \rightarrow$ refractive index for red colour

$\mu \rightarrow$ refractive index for the middle (yellow) colour

$\therefore$ $$\omega = \frac{\mu_v - \nu_r}{\mu - 1}$$

In the case of mercury $\mu = \mu_g \rightarrow$ refractive index for green colour.

$$\omega = \frac{\mu_v - \nu_r}{\mu_g - 1}$$

And $$\mu = \frac{\sin \frac{A + D_m}{2}}{\sin \frac{A}{2}}$$

PROCEDURE :

1. Find the vernier constant of the spectrometer.
2. Switch on the mercury light and find out the angle of the prism as in the previous experiment.
3. Put the prism on the middle of the prism table and find out the angles of minimum deviation for red, green and violet colours as explained in the previous experiment.
4. Using the angle of prism and angles of minimum deviation calculate μ_r, μ_v, and μ_g. Substitute these in the equation.

$$\omega = \frac{\mu_v - \nu_r}{\mu_g - 1}$$ and find the dispersive power

Observations

Vernier constant of spectrometer = …………………

Direct reading of telescope with vernier V_1 (Direct) = …………………

Direct reading of telescope with vernier V_2 (Direct) = …………………

Table for angle of the prism : Same as in the previous experiment.

Table for wavelength (I) and minimum deviation.

No. of obs.	Colour	Telescope Reading (Min. Position		Angle of Min. Dev.			
		Vernier V_1	Vernier V_2	With V_1	With V_2		Mean D_m
				$V_1 - V_1$ Direct	$V_2 - V_2$ Direct		
1.	Red						
2.	Green						
3.	Violet						

CALCULATION :

$$\mu_r = \frac{\sin\frac{A+D_r}{2}}{\sin\frac{A}{2}}$$

$$\mu_g = \frac{\sin\frac{A+D_g}{2}}{\sin\frac{A}{2}}$$

Spectrometer Experiments

$$\mu_v = \frac{\sin\frac{A+D_v}{2}}{\sin\frac{A}{2}}$$

$$\omega = \frac{\mu_v - \nu_r}{\mu_g - 1} =$$

Result : ω = ……………

Actual value = …………

Percentage error = …………..

SPACE FOR STUDENTS WORK AREA

Exp. 8

AIM : Determination of wavelength of sodium light by Newton Rings.

APPARATUS USED : A sodium lamp, Newton ring apparatus (consisting of a traveling microscope, a plano convex lens filled on a plane glass plate and a glass plate inclined at an angle of 45°, spherometer, magnifying glass etc.

Theory of experiment

Introduction: Circular interference fringes can be observed if a very thin film of air or some other transparent medium of varying thickness is enclosed between a plane glass plate and plano-convex lens of large focal length. Such fringes were first observed by Newton and so are called Newton's Rings.

Experimental Arrangement: Light from monochromatic source S is rendered parallel by a convex lens L and then it is made to fall on a glass plate G inclined at a angle of 45° to the incident beam. This beam is reflected normally on to a plano-convex lens placed on a glass plate P as shown in Figure 1.

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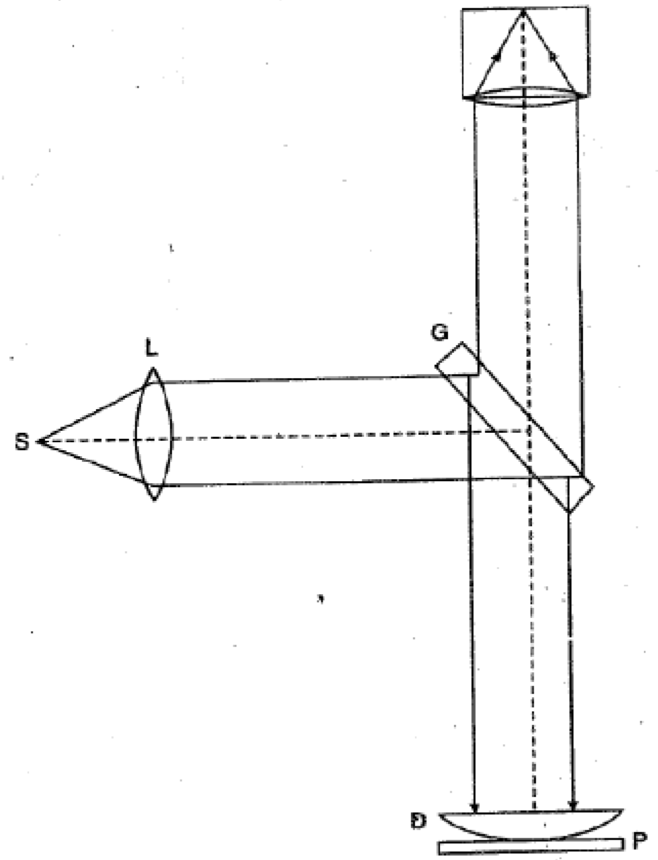

Figure 1

Light rays reflected from the top and bottom surfaces of the air film formed between the lens O and glass plate P superimpose upon each other and depending upon the path difference between these rays, circular bright and dark rings are observed with a monochromatic light. The fringes are circular because the air film is symmetrical about the point of contact of the lens O and the plane glass plate P. These fringes can be observed by a traveling microscope which can also measure the diameter of the various rings.

Theory of Newton's rings. Let CME be the vertical section of the lens surface and let R be the radius of curvature of the lens. The lens is contact with plat at M in such a way that the film thickness at CL and EN is equal, i.e., CL = CN = *t*.

Now from the geometry of the circle, we have .

$$CD \times DE = AD \times DM$$

$$= (AM - DM) \times DM$$

$= (2R - t) \times t$

$= 2Rt - t^2$

Since air film thickness is very small, so t^2 can be neglected as compared. $2Rt$

It dm be the diameter of some (say nth) ring, then

$$\frac{dn^2}{4} = 2Rt$$

Or $$2t = \frac{dn^2}{4R} \qquad \text{..........(1)}$$

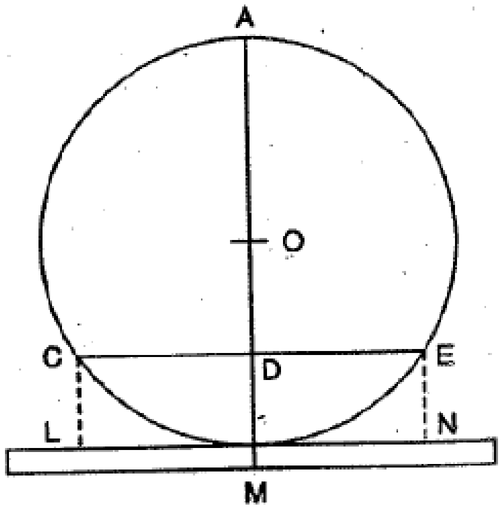

FIG 2

Now the path difference between the two rays, one reflected from C and other from L = $2\mu t$

$\cos r = 2\mu r$ [$\therefore$ incidence is normal so r = 0 and cos 0° = 1]

As one of the rays travels from denser to rarer medium, so an additional path difference of $\frac{\lambda}{2}$ is introduced.

$\therefore$ Total path diff. $= 2\mu t + \frac{\lambda}{2}$

Condition for getting a bright ring is

$$2\mu t + \frac{\lambda}{2} = n\lambda$$

Or $$2\mu t = (2n-1)\frac{\lambda}{2} \qquad \text{.......(2)}$$

Similarly condition for a dark ring is

$$2\mu t + \frac{\lambda}{2} = (2n-1)\frac{\lambda}{2}$$

$$2\mu t = n\lambda$$

Putting the values of 2t from (1) in (2) and (3), we get for nth bright ringh

$$\frac{dn^2}{4R\mu} = (2n-1)\frac{\lambda}{2}$$

Or $$\frac{dn^2}{4R} = (2n-1)\frac{\lambda}{2}$$ [for air μ = 1]

$\therefore\ dn \alpha \sqrt{\left(n-\frac{1}{2}\right)}$ for a bright ring. ….. (4)

And for nth dark ring in air

$$\frac{dn^2}{4R} = n\lambda \qquad \text{…..(5)}$$

$\therefore\ dn \alpha \sqrt{n}$ for a dark ring.

Formula for determination of λ. Considering the condition for nth dark ring.

$$\frac{dn^2}{4R} = n\lambda \qquad \text{…..(i)}$$

And corresponding to mth dark ring, we have

$$\frac{dm^2}{4R} = m\lambda \qquad \text{…..(ii)}$$

For (i) and (ii)

$$\frac{{d_m}^2 - {d_n}^2}{4R} = (m-n)\lambda$$

$$\lambda = \frac{{d_m}^2 - {d_n}^2}{4R(m-n)} \qquad \text{…….(iii)}$$

Similar results can be obtained by taking bright rings.

PROCEDURE :

1. Level the microscope and find the vernier constant of the horizontal scale of microscope.
2. Put the Newton ring apparatus in position place the arrangement in front of a sodium lamp so that the height of the centre of the glass plat4e G is the same as that of the centre of the sodium lamp.
3. Focus the microscope so that it lies vertically above the centre of the lens D and alternate dark and bright rings are clearly visible.
4. Adjust the position of the microscope so that the point of intersection of the cross – wire coincides with the centre of the ring system and one of the cross-wires is perpendicular to the horizontal scale.
5. Move the microscope to the left so that the cross-wires lies tangentially along the 25^{th} dark ring. Note the reading on the vernier scale of the microscope. Move the microscope backward with the help of the slow motion screw and note the reading when the cross-wires lies tangentially at the center of the 20^{th}, 15^{th}, 10^{th}, 5^{th} dark rings respectively. Keeping on sliding the microscope to the right and note the reading when the cross-wire again lies tangentially at the 5^{th}, 10^{th}, 15^{th}, 20^{th}, 25^{th} dark rings.

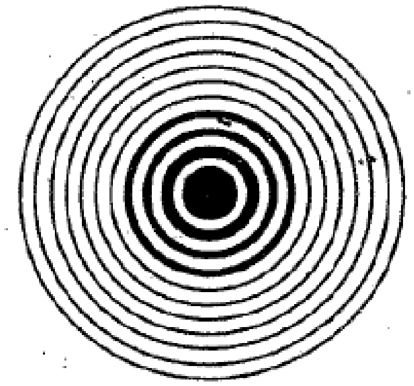

Figure 3

6. After reaching the 25^{th} ring move the microscope backwards and again not the readings corresponding to the same rings on the right and then on the left of the centre of the ring system.
7. Remove the lens D and find the radius of curvature of the surface of the lens in contact with the glass plate P with the help of a spherometer.

Observations

Vernier constant = …………….. cms

	Mircoscope reading			Mircoscope reading			
			Diameter of the ring	Right	Left	Diameter of the ringh	Mean Diameter of the ring
25							
20							
15							
10							
5							

Pith of the spherometer = mm

No. of divisions on circular scale = ………n

Least count = $\frac{Pitch}{n}$

Distance between the two legs of spherometer = 1 …. 2…. 3

Spherometer reading on

No.	Convex surface	Plane surface	H
1			
2			
3			

Mean h = …..cms

Radius of curvature of convex surface R = $\frac{l^2}{6h} + \frac{h}{2}$

= cms.

∴ Wavelength $$l = \frac{D_n^{\ 2} - D_m^{\ 2}}{4(n-m)R}$$

Find the value of λ by taking the various combinations of n and as m as for example, (25, 15), (20, 10), (20, 10), (15, 5)

1 = 1. .2.. 3.

Mean wavelength of sodium light λ = cms.

Actual value of λ = 5893 A°, % error =

Precautions

1. The lens and the glass plate should be cleaned properly.
2. Lens of a large focal length should be used.
3. The point of intersection of the cross-wires should coincide tangentially with a particular ring.
4. The micrometer screw should always be moved in the same direction to avoid back lash error.
5. The radius of curvature of the surface of the lens is contact with the glass plate should be measure accurately in formula since

   R = $\frac{l^2}{6h} + \frac{h}{2}$, so l and h should be measured very carefully.
6. The amount of light for the source should be adjusted for maxima visibility of the rings and good contrast between dark and bright ring.

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Exp. 9

AIM : To determine the wavelength of sodium light using diffraction grating.

Apparatus. A spectrometer, table lamp, Spirit level, Sodium lamp, magnifying glass, diffraction grating etc.

Theory

PLANE TRANSMISSION GRATING

The diffraction grating as stated above consists of a large no. of fine equidistant lines of large number (between 12000 LPI to 30,000 LPI) marked on a polished glass plate. The spaces between the lines act as transparency and opacity be 'a' and 'b' respectively the distance (a + b) is called grating constant or grating element. The points between adjoining transparencies separated by distance, (a + b) are known as corresponding points. In figure 4, ABC….. represents the section of a plane transmission grating having N number of clear space placed $\perp$ to the plane of paper. Let a parallel beam of monochromatic light of wavelength λ be incident normally on the grating surface. Most of the light from the spaces go straight, but a part of it is diffracted in various direction. This light is converged by convex lens L on the screen where alternate dark and bright bands are formed on both sides of the central maximum.

All the rays starting from AH reach O in phase with each other and so reinforce each other producing an image of the slits corresponding to central maximum. The rays which are diffracted at an angle θ with the normal reach PL on passing through the lens indifferent phases. If AK is drawn $\perp$ to the diffracted lights from the corresponding points A and C at an angle θ.

So path difference $\quad CN = AC \sin\theta = (a + b)\sin\theta$

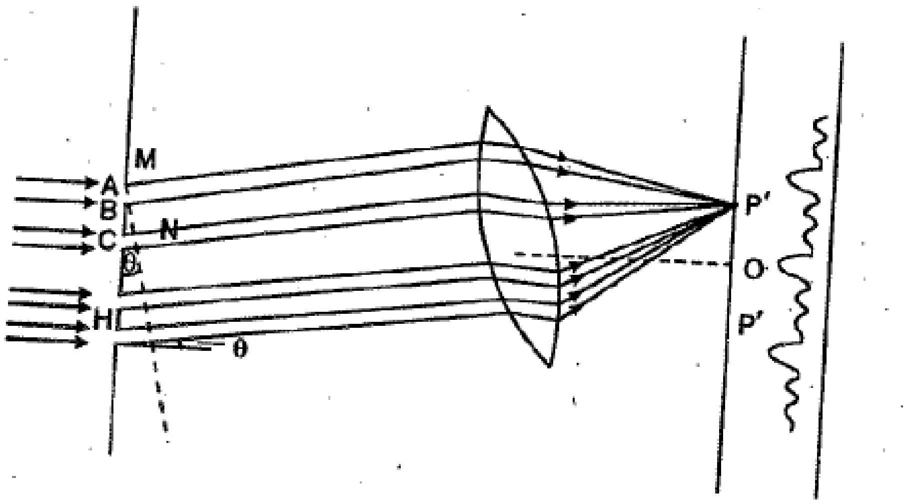


Figure 4

Now the condition of maxima

$$(a + b) \sin \theta = n \lambda$$

And condition for minima is

$$(a + b) \sin \theta = (2n - 1) \lambda/2$$

Where $n = 0, 1, 2, 3 \ldots\ldots.$

So the diffracted rays from any pair of corresponding points of the slits will produce constructive or destructive interference at a point P according as the path difference is an even or an old multiple of $\lambda/2$. This condition holds for all the pair of rays from the corresponding poits of the total grating surface.

For $n = 0$, $\theta = 0$, $(a + b) \sin \theta = 0$

Which corresponds to the central maxima at 0.

For $n = 1$, $(a + b) \sin\theta = \lambda$

This gives the position of the second order principal maxima at P_1' and P_2" a on either side of 0.

Also for $n = 0$, $(a + b) \sin \theta = \lambda/2$, which will corresponds to the first order minima on either side of 0.

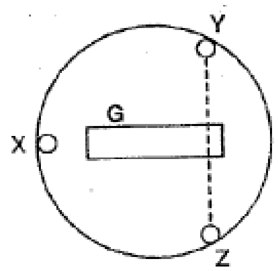
For $n = 1$, $(a + b) \sin 3\lambda/2$, we get positions of second order minima on either side of point O. So we get alternate bright and dark bands.

PROCEDURE :

1. The initial adjustment are made as usual in the case of spectrometer, however, in this case, since a grating is to used instead of a prism, so final adjustment and leveling should be done with grating on prism table.
2. Adjustments of grating. The surface of the grating should be set up on the prism table so that it is normal to the incident light and the lines of gratings are parallel to the axis about which telescopes rotates.

   The grating is put on its stand fixed with screws on the prism table so that the ruled surface is just over the centre of the circle and parallel to the line joining two leveling screws Y, Z.

   The grating is put on its stand and is mounted on the prism table so that the ruled surface is just over the centre of the circle and parallel to the line joining the two leveling screws XY. The telescope is fixed roughly and table is rotated until the light reflected from the grating surface is received by the telescope. If the image of the slit is not located at the centre of the field of view, the screw Y and Z are adjusted to bring the centre of the cross wire to the centre of the image. Next rotate either the grating or the telescope so that the reflected image from the other surface appears in the field of view. The screw X is now adjusted to get the image again to the centre of the cross-wire (Figure 4)



3. Now the telescope is turned to view the direct image of the slit and the corresponding reading x is noted. It is then turned through exactly 90° to a reading x + 90° and fixed so that the axis are at right angles to the direction of the rays proceedings from the collimator. Now the grating is rotated till the image, which is simply reflected from the ruled surface of the grating (not diffracted) coincides with the centre of the cross-wire of the telescope. The reading of the vernier attached to the prism table is noted. The plane of the grating now makes an angle 45° with the incident light. The prism table is turned through 45° from the above position so that the plane of the grating becomes exactly normal to the direction of the incident light.
4. In order to find the grating element "N:, the sodium light is taken as the standard source since its wavelength λ known (mean λ = 5893 A°). The slit is illuminated

5. by the sodium lamp. As the telescope is moved from the direct position to one side or the other the first and second order images of the slit are seen on both sides. Taking the first order spectrum the angle of diffraction θ is given by the difference between the telescope reading in the deviated position and the direct position. So N is calculated by the relation.

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

Observation

Vernier Constant of spectrometer = ………….

No. of lines / inch on grating = N =

Grating element (a + b) = 2.54 N =

S.No.	Order of Spectrum	Reading of Telescope						Mean θ
		Vernier V_1			Vernier V_2			
		Left	Direct	Right	Left	Direct	Right	
1.	1^{st} order							
2.								
3.								
1.	2^{nd} Order							
2.								
3.								

Calculations

Wavelength from Ist order

$$\lambda = (a+b)\sin\theta_1 = A°$$

Wavelength from 2^{nd} order

$$\lambda = \frac{(a+b)\sin\theta_2}{2} = A°$$

Mean Wavelength =

Actual value = 5893 A°

[Θ Sodium has to spectral lines $D_1 = 5896$ A°

$D_2 = 5890$ A°

Mean = 5893 A°

% error = ……….

Precautions

1. The ruled surface of the grating must face the telescope.
2. The slit should be made very fine and bright.
3. The grating surface should not be touched.
4. While setting the grating, two images are seen, the telescope should be focused on the brighter one.
5. When observations are to be made the prism table should be clamped.

Exercise

1. **To find the number of lines per cm. of the grating.**

The experiment is done on the same lines as the above. In order to find the No. of lines per cm of the grating, we use the relation

$(a + b) \sin\theta = n\lambda$

Also $$(a+b) = \frac{2.54}{N}$$

∴ $$\frac{2.54}{N}\sin\theta_1 = 1\lambda$$ For Ist order spectrum

And $$\frac{2.54}{N}\sin\theta_2 = 2\lambda$$ For 2nd order spectrum

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Exp. 10

AIM : To find the specific rotation of cane sugar solution using polarimeter.

Apparatus : Polarimeter, graduated cylinder, common balance, weight box, beaker, a wall glass, magnifying glass, sodium or mercury lamp, electric lamp, magnifying glass, filter pap tunnel, glass rod, sugar.

THEORY

SPECIFIC ROTATION

The term specific rotation is used to bring rotation of all optically active substances in a comparable form.

Specific rotation for a given temperature t °C and for a light of given wavelength λ is defined as the rotation (in degrees) produced by a path of one decimeter length in a substance of unit density.

It θ is the rotation produced by decimeter length of a solution of density dlec; then specific rotation S corresponding to some temperature t and light of wavelength λ is given by

$$S_\lambda = \frac{\theta}{l \times d}$$

$$= \frac{\text{Rotation in degrees}}{\text{Length in decimeter} \times \text{concentration in g/cc}}$$

Sugar is the most commonly used optically active substance and the instruments used for measuring the optical rotation produced by substance are called polarimeters or saccharimeters. Basically, they consists of two Nicol Prism capable of rotation about the incident beam as axis. The optically active substance is placed between the two nicol prism. Generally, it is very difficult to locate the position of analyzing nicol when no light is received but with the used of Laurent’s half shade device, this difficulty is overcome.

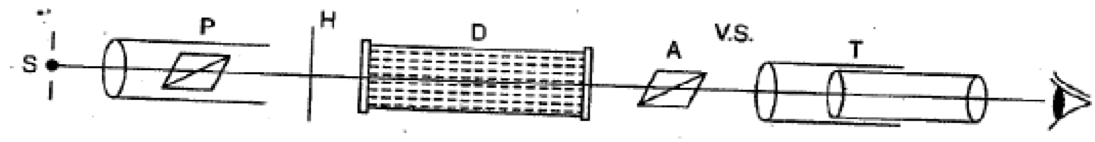
Ansal Institute of Technology

LAURENT's POLARIMETER

It is an instrument used for finding optical rotation of certain solutions whenused for finding specific rotation ofr sugar, it is called a saccharimeter. Also if the specific rotation of sugar is known the concentration of the solution can be found.

Construction: It consiss of two Nicol Prisms P and A mounted in brass tube and capable of rotation about a common axis. A glass tube D containing optically active solution is placed in between the two nicols as shown Fig. 6.2. All the tubes are in line. Monochromatic light from a source is rendered parallel by a convex lens L and is made to fall on polarizing prisms P which renders the light plane polarized with its vibrations in the principal plane of the nicol prism. This polarized light is then made to pass through half shade device H and the tube D containing the active solution and then in passes through analyzing Nicol prism A.

The emergent light is viewed through telescope T. The analyzing nicol A can be rotated about its axis and the rotation can be measured on a graduated circular scale in terms of degrees with the use of Vernier Scale (V.S.).



LAURENT'S HALF SHADE DEVICE

It consists of two semicircular plates, one made of glass and other of quartz. Both glass and quartz are connected together as shown in Figure 5.

The quartz plane is cut parallel to its axis which being || to the line joining two plates Y Y' quartz plate is made as a half wave plate, [i.e. its thickness is so adjusted that it introduces a path difference of $\lambda/2$ between E-ray on O-ray for sodium light. In other words, in passing through the Quartz plate. O ray gains $\lambda/2$ on E-ray. Thickness of glass plate is so adjusted that it transmits the same amount of right as the quartz plate

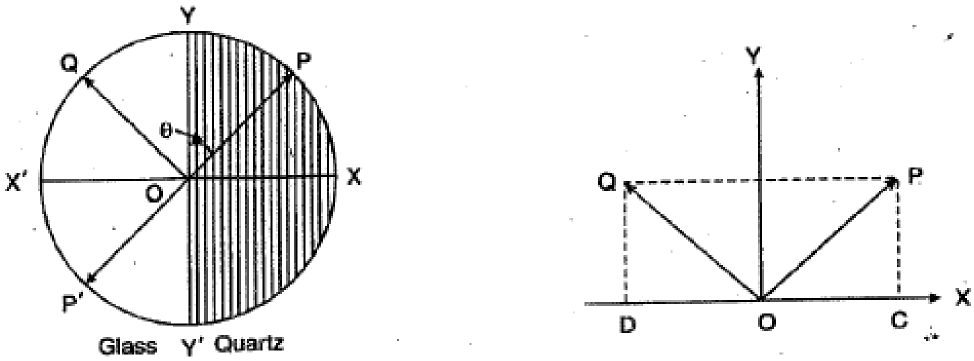


Figure 5

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Let the light after passing through the polarized P be incident normally on half shade plate and has vibrations along OP, but on passing through the glass half, the vibration will remain along OP, but on passing through the quartz half of these will split E and O components. The vibration of E-component are along OY and those of O-component along OX.

On passing through the quartz plate a phase different of a π or path difference of $\lambda/2$ is introduced between the two vibrations. The O-vibrations will advance in phase by π and will appear along OX instead of OX' on emergence. So the resultant vibration after emerging from the quartz plate will be along OQ, such that

$\angle POY = \angle YOQ$

In the analyzing Nicol is placed with its principal plane parallel to OP, the plane polarize light through glass half will pass and hence it will appear brighter than the quartz half from which light will be practically obstructed.

If the principal plane of Nicol is parallel (II) of OQ, the quartz half will appear brighter this glass due to the above reason.

When the principal plane of analyzing Nicol is parallel (II) to OQ, the two halves will appear equally bright. It is because the two vibrations coming out off the two halves are equally inclined to its principal plane and so the two components will have equal intensity.

Again if the principal plane of the analyzer is $\perp$ to YOY', we will have components of C and OQ equal. The two halves are again equally illuminated but since the intensity of the tv components passing through its small as compares to that in the first case, the two halves a equally dark. Since the eye can easily detect the change when the two halves are equally dark the readings are taken for this position.

Procedure

1. Weight a watch glass and put 20 gm sugar on the watch glass, weigh accurately a dissolve the 20 gm sugar thus weighted slowly in distilled water in a beaker putting above 40 cc of distilled water. Put the solution thus obtained in a graduated cylinder and ri. The beaker slowly and number of times using about 20 cc of distilled water each time that the volume of the solution in cylinder is 100 cc. Filter the solution. This is 20% sugar solution.
2. Remove one of the caps of the polarimeter tube and put distilled water in the tube after cleaning it and the caps thoroughly. See that there is no air bubble in the tube Screw the cap gently without undue pressure on the glass windows of the tube. Place the tube in position in polarimeter and see that no air bubble is present in the path of light through the polarimeter. Also note the vernier constant of the polarmieter.
3. illuminate the circular aperture of polarimeter with sodiumlamp (in case Bi quartz is used, then mercury lamp may be used). Adjust the eye piece of the telescope, so that circular image is clearly visible. Adjust the position of analyzer for equal darkness of the two image seen through the field of view of telescope.

   Note the reading at the vernier. Turn analyzer through 180° and again set if for equal darkness of the two images. Take the reading at the vernier.
4. Fill the tube the Sugar solution prepared above and repeat the observations as stated in 3rd step.
5. Now make the concentration of the sodium 15%. It can be done by taking 75 CC of the above solution and diluting it to 100 CC

$$\left(\frac{20\times 75}{100}=15\%\right)$$

The above experiment may be repeated for 15% strength.

6. Again take the observations for 10%, 7.5%, 5% of sugar solution.
7. Take the length of the polarmieter tube and also measure the room temperature.

Observations and Calculations

Vernier constant =

Mass of the watch glass = m_1, gm

Mass of watch glass + sugar = m_2 gm

Mass of sugar m = $(m_2 - m_1)$ = ………….. gm

Length of thetube in decimeter = ……………………

Room temperature t = ° C = ………….

Wavelength of light used

For sodium $\lambda = 5893$ A °

For Hg $\lambda = 6000$ A°

Strength of solution		PolarImeter reading		Rotation in degrees		Mean θ	θ/d
%	gm/c.c. (d)	Ist Position	2^{nd} Position	Ist Position	2^{nd} Position		
0	0						
20	0.20						
15	0.15						
10	0.10						
5	0.05						
2.5	0.025						

θ/c can be got by plotting a curve between θ and c.

Specific rotation

Specific rotation at t ° s = $\dfrac{\theta}{I-d}$ = …………

Actual value of S 9from tables) = …………..

% error

Precautions

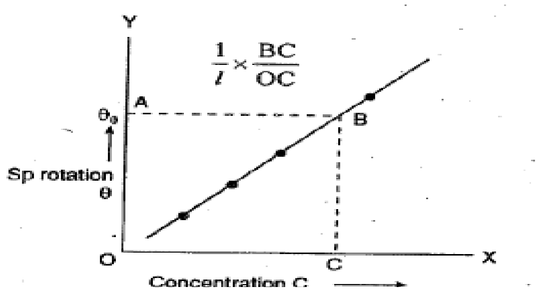
1. There should not be an air bubble in the polarimeter tube and the polarimeter tube along with its caps should be thoroughly cleaned.
2. Caps must be put on the tube tightly.
3. Positions of equal darkness must be got for each observations.
4. Sugar must be dust free and distilled water should be used for making the solution.

5. Since specific rotation depends on room temperature and wavelength of light used, so the result must be given for the temperature of the room and the wavelength of thelight used.

Exercise : To find (a) the concentration of a given sugar solution 9b) specific rotation.

Hint:

Plot a graph between concentration and specific rotation. It will be straight line. From slope of curve, get the value θ/c for particular value of θ.



Slope of graph = $\frac{BC}{0} = \frac{\theta}{d}$

Length of polarimeter tube – 1 decimeter

Specific rotation = $\frac{1}{l} \times \frac{\theta}{d}$

$= \quad \frac{1}{l} \times \frac{BC}{OC}$

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