DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
Bangladesh University of Business and Technology
Rupnagar, Mirpur-2, Dhaka-1216, Bangladesh
Phone: PABX-9024266, 9024277, 9015397, 9020132-4, Fax: 9024399
E-mail: info@bubt.edu.bd, Website: www.bubt.edu.bd

LAB MANUAL

(Hardware Based)

Program	**: B.Sc. in EEE**
Course Code	**: PHY 104 (Combined)**
Course Title	**: Physics Lab I**
Course Credit	**: 1.50**
Contact Hours	**: 3 hrs**

Introduction

This course will mainly focus on Waves and Oscillations (Compound pendulum, Katter's pendulum, Spring-Mass system), Properties of Matter (Modulus of rigidity, Young's Modulus, Surface Tension), Physical Optics (Refractive Index), Electricity (Specific resistance of a wire, emf of one cell and compare e.m.f. of two cell, verify the laws of resistance by P.O. Box), , Physical Optics (Newton's ring, Specific rotation of sugar solution, wavelength of various spectral lines).

1. Course Objectives

This course will provide practical knowledge by applying the experimental methods to correlate with the Physics theory and the ideas of different measuring devices and meters to record the data with precision.

2. Course Outcomes

Upon completion of this course students will be able to:

CO1: To apply the basic laws and theories of classical physics to characterize physical properties of various states of materials and mediums

CO2: Design and develop the experimental setup to evaluate simple pendulum, etc.

CO3: Select and use modern hardware and software tools and devices

CO4: Assess societal, health, safety, legal and cultural issues involved with the mini project

CO5: Realize the impact of societal, environmental and sustainable development issues for the design solution of mini project.

CO6: Apply professional ethics and responsibilities in the implementation of mini project.

CO7: Work individually and in a team

CO8: Communicate and share knowledge, data, information, results etc. with others

CO9: Apply engineering project management knowledge and skill to implement the mini project.

CO10: Gather and apply knowledge, data and information from various multidisciplinary sources to analyze, design and implement the mini project

3. Course Outcomes (COs), Program Outcomes (POs) and Assessment:

CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
Upon completion this experiment, students will be able to: CO1: To apply the basic laws and theories of classical physics to characterize physical properties of various states of materials and mediums	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☑ Project show & project presentation
CO2: Design and develop the experimental setup to evaluate simple pendulum, etc	**PO9–- Team Work**	**Psychomotor**		
CO3: Select and use modern hardware and software tools and devices	**PO10- Communication**	**Affective domain/ Psychomotor**		
CO4: Assess societal, health, safety, legal and cultural issues involved with the mini project	**PO6- The engineer and society**	**Affective domain/ Psychomotor**		☐ Lab tests ☐ Lab reports ☐ Final lab test ☐ Open ended lab
CO5: Realize the impact of societal, environmental and sustainable development issues for the design solution of mini project.	**PO7- Environment and Sustainability**	**Affective domain/ Psychomotor**		

CO6: Apply professional ethics and responsibilities in the implementation of mini project.	**PO8- Ethics**	**Psychomotor**		☑ Project show & project presentation ☑ Continuous lab performance
CO7: Work individually and in a team	**PO9-Individual work and teamwork**	**Affective domain**		
CO8: Communicate and share knowledge, data, information, results etc. with others	**PO10-Communication**	**Affective domain**		☑ Project show & project presentation
CO9: Apply engineering project management knowledge and skill to implement the mini project.	**PO11-Project management and finance**	**Affective domain/ Psychomotor**		☑ Project show & project presentation
CO10: Gather and apply knowledge, data and information from various multidisciplinary sources to analyze, design and implement the mini project	**PO12-Life-long learning**	**Affective domain/ Psychomotor**		☑ Project show & project presentation

4. Text Book

1. Practical Physics", Dr. Giasudin Ahmad and Md. Shahabuddin

5. Reference

1. Physics I Lab Manual, EEE Department, BUBT

2. Practical Physics, R.K. Shukla and Anchal Srivastava

6. Weekly Schedule

Expt. No.	Name of the Experiment	No. of Week
01	Familiarization with Vernier Calipers and Screw Gauge by measuring various samples	Week1
02	To determine the value of g, acceleration due to gravity, by means of a compound pendulum	Week2
03	To determine the spring constant and effective mass of a given spiral spring	Week3
04	To determine the Young's modulus by the flexure of a beam	Week4
05	To determine the modulus of rigidity of a wire by Statical method.	Week5
06	To determine the modulus of rigidity of a wire by method of oscillations (dynamic method).	Week7
	Mid Examination	Week6
07	To determine the refractive index of the material of a prism.	Week8
08	To calibrate a polarimeter and hence to determine the specific rotation of a sugar solution by means of a polarimeter.	Week9
09	To determine the moment of inertia of a fly-wheel about its axis of rotation.	Week10
10	To determine the specific resistance of a wire by using a meter bridge.	Week11
11	To determine the e.m.f of a cell with a potentiometer of known resistance.	Week12
12	To determine the value of unknown resistance and verify the laws of series and parallel resistance by Post Office Box.	Week13
	Final Examination	

Experiment No.: 01

Name of the Experiment:

Familiarization with Vernier Calipers and Screw Gauge by measuring various samples

Objectives of the Experiment:

- To know the use of the Vernier Calipers and Screw Gauge.
- To measure the length, width and height of the given rectangular block and then measuring the volume of the sample
- To measure the diameter of a small spherical body and then measuring volume of the sample.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Correspon ding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
01	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation

Theory:

Vernier Calipers:

A Vernier calipers is a device used to measure the distance between two opposing sides of an object. It can be as simple as a compass with inward or outward-facing points. First the tips of the calipers are adjusted to fit across the points to be measured and the calipers is then removed and the distance between the tips is measured using a ruler. The modern Vernier calipers was invented by Joseph R. Brown in 1851. It was the first practical tool for exact measurements that could be sold at an affordable price to ordinary machinists. The Vernier Calipers consists of a main scale fitted with a jaw at one end. Another jaw, containing the Vernier scale, moves over the main scale. When the two jaws are in contact, the zero of the main scale and the zero of the Vernier scale should coincide. If both the zeros do not coincide, there will be a positive or negative zero error.

Parts of a Vernier Calipers:

1.Main Scale

The main scale consists of a steel metallic strip graduated in centimeters at one edge and in inches at the other edge. It carries the inner and outer measuring jaws. When the two jaws are in contact, the zero of the main scale and the zero of the Vernier scale should coincide. If both the zeros do not coincide, there will be a positive or negative zero error.

2. Vernier Scale
A Vernier scale slides on the strip. It can be fixed in any position by the retainer. On the Vernier scale, 0.9 cm is divided into ten equal parts.

3. Outer Measuring Jaws
The outer measuring jaws helps to take the outer dimension of an object

4. Inner Measuring Jaws
The inner measuring jaws helps to take the inner dimension of an object.

5. Retainer
The retainer helps to retain the object within the jaws of the Vernier calipers.

6. Depth Measuring Prong
The depth measuring prong helps to measure the depth of an object.

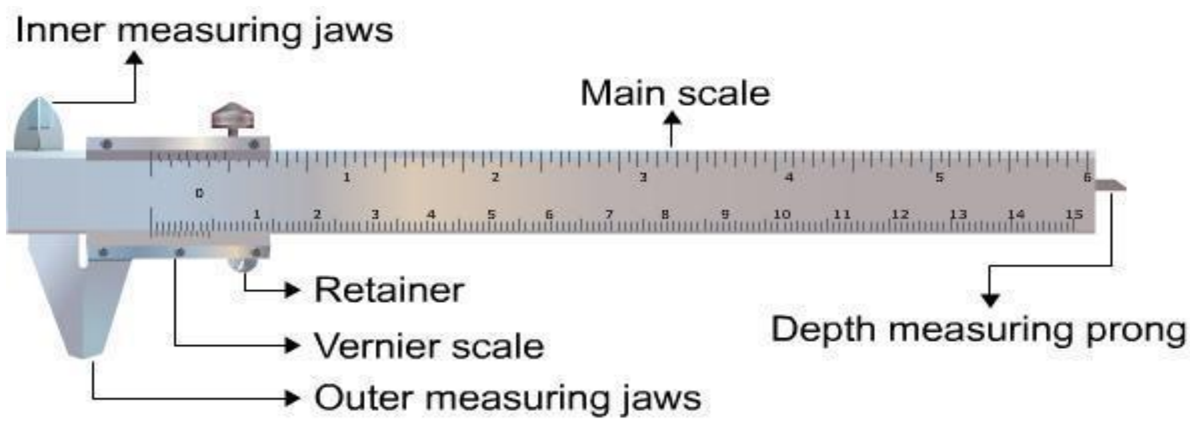


Figure-1

<u>Vernier Constant (V.C.) calculation:</u>

Vernier constant is a measure of the difference in length of a scale division and a Vernier division in the unit of the scale division.

Let the value of one small division of the main scale = 1 mm and let 10 Vernier division be equal to 9 scale division.

10 Vernier division = 9 scale division

I Vernier division = $\frac{9}{10}$ scale division.

Vernier constant (V.C.) = 1 s. d. - I v. d.

= I s.d - $\frac{9}{10}$ s.d. =.d.= $\frac{1}{10} \times 1$ mm

= 0.1 mm = 0.01 cm.

Instrumental Error/Zero error of Vernier Calipers:

When the Vernier zero does not coincide with the main scale zero, there is an instrumental error or zero error. In such a case, the actual reading of the scale does not give the true length of the body. There may be two types of zero errors:

(a) The zero of the Vernier may be in advance of the zero line of the main scale by an amount x mm. This means that in place of zero reading the instrument is giving a reading +x mm. On placing the body between the jaws if the scale reading be y mm, then the actual length of the body is (y - x) mm. In this case the instrumental error is + ve and must always be subtracted.

(b) When Vernier zero is behind that of the main scale by an amount -x mm, the instrumental error is - ve and must be added to the actual reading to get true length of the body. On placing the body between the jaws if the scale reading be y mm, then the actual length of the body is (y + x) mm

Calculating the Reading of Iron Block

When a body is between the jaws of the Vernier Caliper; If the zero of the Vernier scale lies ahead of the Nth division of the main scale, then the main scale reading (MSR) is;

$\mathrm{M.S.R.} = \mathrm{N}$

If nth division of Vernier scale coincides with any division of the main scale, then the Vernier scale reading (VSR) is;

$\mathrm{V.S.R.} = \mathrm{n} \times \mathrm{V.C.}$ (Vernier Constant of Vernier Calipers)…………….(1)

Total reading,

$\mathrm{TR} = \mathrm{M.S.R.} + \mathrm{V.S.R.} = \mathrm{N} + (\mathrm{n} \times \mathrm{V.C.})$…………………(2)

Volume of a Rectangular Block

$V = l \times b \times h$……………………………..(3)

where 'l' is length of the block, 'b' the breadth and 'h' the height of the block.

Screw Gauge:

The screw gauge is an instrument used for measuring accurately the diameter of a thin wire or the thickness of a sheet of metal. It consists of a U-shaped frame fitted with a screwed spindle which is attached to a thimble.

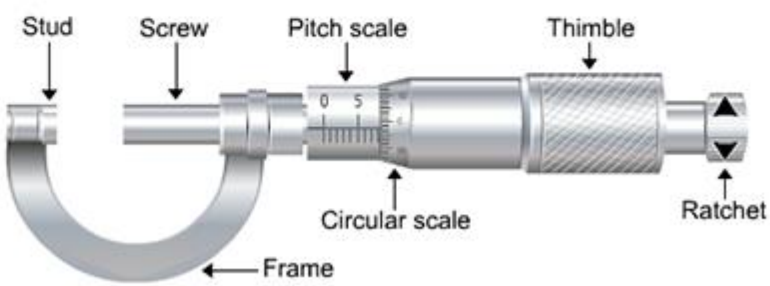


Figure-2

Parallel to the axis of the thimble, a scale graduated in mm is engraved. This is called pitch scale. A sleeve is attached to the head of the screw.

The head of the screw has a ratchet which avoids undue tightening of the screw. On the thimble there is a circular scale known as head scale which is divided into 50 or 100 equal parts. When the screw is worked, the sleeve moves over the pitch scale.

A stud with a plane end surface called the anvil is fixed on the ‘U’ frame exactly opposite to the tip of the screw. When the tip of the screw is in contact with the anvil, usually, the zero of the head scale coincides with the zero of the pitch scale.

<u>Pitch of the Screw Gauge</u> :The pitch of the screw is the distance moved by the spindle per revolution. To find this, the distance advanced by the head scale over the pitch scale for a definite number of complete rotation of the screw is determined.

The pitch can be represented as;

$$\text{Pitch of the screw} = \frac{\text{Distance moved by screw}}{\text{No.Of full rotations given}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

<u>Least Count of the Screw Gauge</u>

The Least count (L.C.) is the distance moved by the tip of the screw, when the screw is turned through 1 division of the head scale.

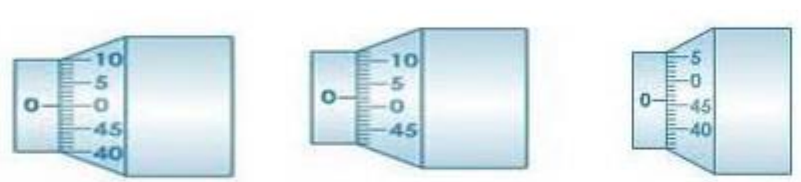
The least count can be calculated using the formula;

$$\text{Least Count (L.C.)} = \frac{\text{Pitch}}{\text{Total nubmer of divisions onthe Circular Scale}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

<u>Zero Error and Zero Correction of Screw Gauge:</u>

To get the correct measurement, the zero error must be taken into account. For this purpose, the screw is rotated forward till the screw just touches the anvil and the edge of cap is on the zero mark of the pitch scale. The Screw gauge is held keeping the pitch scale vertical with its zero down wards. When this is done, anyone of the following three situations can arise (Figure-3):

1. The zero mark of the circular scale comes on the reference line. In this case, the zero error and the zero correction, both are nil.
2. The zero mark of the circular scale remains above the reference line and does not cross it. In this case, the zero error is positive and the zero correction is negative depending on how many divisions it is above the reference line.
3. The zero mark of the head scale is below the reference line. In this case, the zero error is negative and the zero correction is positive depending on how many divisions it is below the reference line.



Zero error nil Case 1 | zero error positive Case 2 | Zero error negative Case 3

Figure-3

To find the diameter of the lead shot:

With the lead shot between the screw and anvil, if the edge of the cap lies ahead of the N^{th} division of the linear scale.

Then, linear scale reading (L.S.R.) = N

If nth division of circular scale lies over reference line,

Then, circular scale reading (C.S.R.) = n x (L.C.) (L.C. is least count of screw gauge)

Total reading (T.R.) = L.S.R. + corrected C.S.R. = N + (n x L.C.)………………(6)

If D be the mean diameter of lead shot,

Then, volume of the lead shot,

$V = \frac{4}{3}\pi(\frac{D}{2})^3$………………………(7)

Apparatus:

1. Vernier calipers.
2. A small rectangular metallic block
3. Screw Gauge
4. Lead shot

Experimental Procedures:

1. We'll first determine the Vernier constant (VC), which is the least count (L.C) of the Vernier caliper and record it stepwise as in the equation, L.C = 1 MSD - 1 VSD.
2. Now, bring the movable jaw in close contact with the fixed jaw and find the zero error. Do this three times and record the values. If there is no zero error, then record 'zero error nil'.
3. Open the jaws of the Vernier Caliper and place the sphere or cylinder between the two jaws and adjust the movable jaw, such that it gently grips the body without any undue pressure on it. That done, tighten the screw attached to the Vernier scale.
4. Note the position of the zero mark of the Vernier scale on the main scale. Record the main scale reading just before the zero mark of the Vernier scale. This reading (N) is called main scale reading (MSR).
5. Note the number (n) of the Vernier scale division which coincides with the division of the main scale.
6. You'll have to repeat steps 5 and 6 after rotating the body by 90^o for measuring the diameter in a perpendicular direction.
7. Repeat steps 4 to 7 for three different positions and record the observations.
8. Now find total reading using the equation, TR = MSR+VSR = N+(n x L.C) and apply the zero correction.
9. Take the mean of the different values of the diameter and show that in the result with the proper unit.

For Screw Gauge:

1. Determine the pitch and least count of the screw gauge using the equations (1) and (2) respectively.
2. Bring the anvil and screw in contact with each other and find the zero error. Do it three times and record them. If there is no zero error, then record ‘zero error nil’.
3. Move the screw away from the anvil and place the lead shot and move the screw towards the anvil using the ratchet head. Stop when the ratchet slips without moving the screw.
4. Note the number of divisions on the pitch scale that is visible and uncovered by the edge of the cap. The reading N is called the pitch scale reading(PSR)
5. Note the number (n) of the division of the circular scale lying over the reference line.
6. Repeat steps 4 and 5 after rotating the lead shot by 900 for measuring the diameter in a perpendicular direction. Record the observations in the tabular column.
7. Find total reading using the equation 3 and apply zero correction in each case.
8. Take the mean of different values.

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. Do not perform unauthorized experiments. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Data Table- 1: Reading for Measurement of the length of the sample (Iron block) (using slide Calipers)

Dimension to be measured	No. of obs.	Main scale reading (M.S.R) cm	Vernier scale divisions (V.S.D)	Vernier constant (V.C) cm	Vernier scale reading (V.S.R) = V.S.D X V.C cm	Total length/breadth/ Thickness, l/b/h Cm (MSR+ VSR)	Average	Volume of the Iron block (V) cm^3
Length of Iron block	1							
	2							
	3							
Breadth of Iron block	1							
	2							
	3							
Thickness of Iron block	1							
	2							
	3							

Table- 2: Reading for Measurement of the radius of the sample (Lead Shot) (using Screw Gauge)

No. of obs.	Liner scale reading (L.S.R) cm	Circular scale divisions (C.S.D)	Least count (L.C) cm	Circular scale reading (C.S.R) = (CSD * L.C)	Total diameter D Cm (LSR + CSR)	Mean diameter D cm	Volume of the Lead Shot (V) cm^3
1							
2							
3							

Calculation:

Vernier Calipers:
Zero Error Calculation:
Zero error, C= 0 cm

Volume of the sample (Iron Block): $V = l \times b \times h = \quad \boldsymbol{cm^3}$

Screw Gauge:
Zero Error Calculation:
Zero error, C= -2 × 0.001= -0.002 cm
Volume of the sample (Lead shot): $V = \frac{4}{3}\pi(\frac{D}{2})^3 = \boldsymbol{cm^3}$

Results and Discussions:

Volume of the sample (Iron Block) using Vernier Calipers: $\boldsymbol{cm^3}$

Volume of the sample (Lead shot) using Screw Gauge: $\boldsymbol{cm^3}$

Conclusion:
Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1. **Practical Physics:** Dr. Giasuddin Ahmad and Md. Shahabuddin
2. Practical physics: R.K. Shukla, Anchal Srivatsava
3. Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is Vernier Calipers?
2. What is Screw Gauge?

Post-Lab Questions:

1. What is Vernier constant?
2. What is least count?
3. What is pitch of a Screw Gauge?

Experiment No.: 02

Name of the Experiment:

To determine the value of g, acceleration due to gravity, by means of a Compound Pendulum

Objectives of the Experiment:

- To study the motion of a compound pendulum,
- To study simple harmonic motion,
- To determine the acceleration due to gravity using the theory, results, and analysis of this experiment.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
02	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: To select and use modern hardware and software tools and devices	**PO5- select & use modern tools**	**Affective domain/ Psychomotor**	**CO3:** To select and use modern hardware and software tools and devices	
	CO8: To Communicate and share knowledge, data, information, results etc. with others	**PO10–Communication**	**Affective domain**		☑ Lab reports ☑ Project show & project

Theory:

A simple pendulum consists of a small body called a "bob" (usually a sphere) attached to the end of a string the length of which is great compared with the dimensions of the bob and the mass of which is negligible in comparison with that of the bob. Under these conditions the mass of the bob may be regarded as concentrated at its center of gravity, and the length of the pendulum is the distance of this point from the axis of suspension. When the dimensions of the suspended body are not negligible in comparison with the distance from the axis of suspension to the center of gravity, the pendulum is called a compound, or physical, pendulum. A rigid body mounted upon a horizontal axis so as to vibrate under the force of gravity is a compound pendulum. Compound pendulum is a rigid body of any shape free to turn about a horizontal axis. In Eigure-1, G is the center of gravity of the pendulum of mass M, which performs oscillations about a horizontal axis through O.

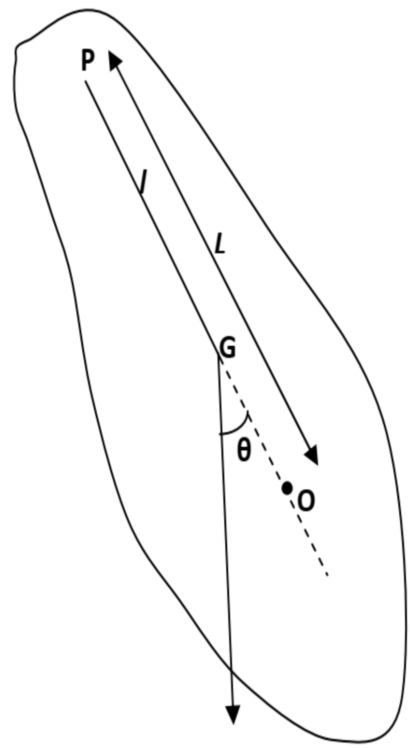


Figure-1

In Fig.1 a body of irregular shape is pivoted about a horizontal frictionless axis through P and is displaced from its equilibrium position by an angle θ. In the equilibrium position the center of gravity G of the body is vertically below P. The distance GP is l and the mass of the body is m. The restoring torque for an angular displacement θ is

$\tau = -mglsin\,\theta$………………………(1)

For small amplitudes ($\theta \approx 0$),

$\tau = -mgl\,\theta$…………………………..(2)

And $\tau = I\,\frac{d^2\theta}{dt}$…………………………(3)

From equation (2) and (3),

$I\,\frac{d^2\theta}{dt} = -mgl\,\theta$……………………….(4)

Where, I is the moment of inertia of the body through the axis P. Eq. (4) represents a simple harmonic motion and hence the time period of oscillation is given by

$T = 2\pi\sqrt{\frac{I}{mgl}}$…………………………(5)

Now, $I = I_G + ml^2$, where I_G is the moment of inertia of the body about an axis parallel with axis of oscillation and passing through the center of gravity G.

$I_G = mk^2$……………………………..(6)

Where, K is the radius of gyration about the axis passing through G. Thus,

$T = 2\pi\sqrt{\frac{mk^2+ml^2}{mgl}} = 2\pi\sqrt{\frac{\frac{k^2}{l}+l}{g}}$……......(7)

The time period of a simple pendulum of length L, is given by

$\mathrm{T} = 2\pi\sqrt{\frac{\mathrm{l}}{\mathrm{g}}}$ ……………………………..(8)

Comparing with Eq. (7) we get

$L = \frac{k^2}{l} + l$…………………………..(9)

This is the length of "equivalent simple pendulum". If all the mass of the body were concentrated at a point O (See Figure-1) such that $OP = \frac{k^2}{l} + l$, we would have a simple pendulum with the same time period. The point O is called the 'Centre of Oscillation'. Now from Eq. (9)

$l^2 - lL + k^2 = 0$……………………..(10)

i.e. a quadratic equation in l. Equation 10 has two roots l_1 and l_2 such that

$l_1 + l_2 = L$

And, $l_1 l_2 = K^2$……………………….(11)

Thus both l_1 *and* l_2 are positive. This means that on one side of C.G there are two positions of the center of suspension about which the time periods are the same. Similarly, there will be a pair of positions of the center of suspension on the other side of the C.G about which the time periods will be the same. Thus there are four positions of the centers of suspension, two on either side of the C.G, about which the time periods of the pendulum would be the same. The distance between two such positions of the centers of suspension, asymmetrically located on either side of C.G, is the length L of the simple equivalent pendulum. Thus, if the body was supported on a parallel axis through the point O (see Figure-1), it would oscillate with the same time period T as when supported at P. Now it is evident that on either side of G, there are infinite numbers of such pair of points satisfying Eq. (11). If the body is supported by an axis through G, the time period of oscillation would be infinite. From any other axis in the body the time period is given by Eq. (7). From Equation (8) and (11), the value of g and K are given by

$\mathrm{g} = \frac{4\pi^2 \mathrm{L}}{\mathrm{T}^2}$…………………………(12)

and $K = \sqrt{l_1 l_2}$…………………(13)

By determining L, $l_1$and l_2 graphically for a particular value of T, the acceleration due to gravity g at that place and the radius of gyration K of the compound pendulum can be determined.

<u>Apparatus:</u>

1. A Compound Pendulum (metallic rectangular bar with hole in each 5cm distance).
2. A small metallic wedge
3. A holder in fixed point
4. Stop watch

<u>Description of the apparatus (Compound Pendulum):</u>

The apparatus ordinarily used in the laboratory is a rectangular bar AB of brass about 1-meter long. A series of circular holes is drilled along the bar at intervals of 5 cm (Figure-2). The bar is suspended from a horizontal knife-edge passing through any of the holes (Figure-2). By inserting the metal wedge S in one of the holes and placing the wedge on the support S_1S_2, the bar may be made to oscillate. The real picture of compound pendulum is shown in Figure-3.

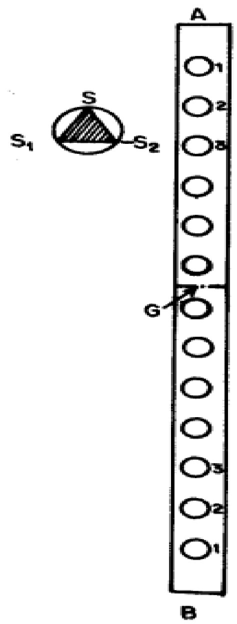


Figure-2: Compound pendulum

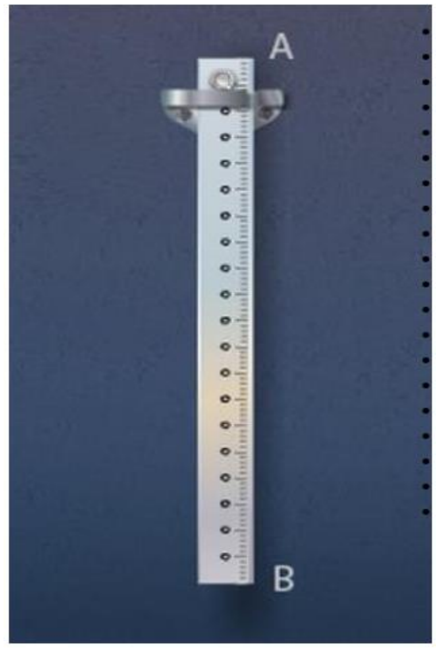


Figure-3: Compound pendulum

Experimental Procedures:

1. The compound bar pendulum AB is suspended by passing a knife edge through the first hole at the end A. The pendulum is pulled aside through a small angle and released, whereupon it oscillates in a vertical plane with small amplitude. The time for 10 oscillations is measured. From this the period *T* of oscillation of the pendulum is determined.
2. In a similar manner, periods of oscillation are determined by suspending the pendulum through the remaining holes on the same side of the centre of mass G of the bar. The bar is then inverted and periods of oscillation are determined by suspending the pendulum through all the holes on the opposite side of G. The distances *d* of the top edges of different holes from the end A of the bar are measured for each hole. The position of the centre of mass of the bar is found by balancing the bar horizontally on a knife edge. The mass *M* of the pendulum is determined by weighing the bar with an accurate scale or balance.
3. A graph is drawn with the distance *d* of the various holes from the end A along the X-axis and the period *T* of the pendulum at these holes along the Y-axis. The graph has two branches, which are symmetrical about G. To determine the length of the equivalent simple pendulum corresponding to any period, a straight line is drawn parallel to the X- axis from a given period *T* on the Y- axis, cutting the graph at four points A, B, C, D. The distances AC and BD, determined from the graph, are equal to the corresponding length *l*. The average length l = (AC+BD)/2 and l/T^2 are calculated. In a similar way, l/T^2 is calculated for different periods by drawing lines parallel to the X-axis from the corresponding values of *T* along the Y- axis. L/T^2 should be

constant over all periods T, so the average over all suspension points is taken. Finally, the acceleration due to gravity is calculated from the equation $g = 4\pi^2(l/T^2)$.

4. T_{min} is where the tangent EF to the two branches of the graph crosses the Y-axis. At T_{min}, the distance EF = l = $2k_G$ can be determined, which gives us k_G, the radius of gyration of the pendulum about its centre of mass, and one more value of g, from $g = 4\pi^2(2k_G/T_{min}^2)$.
5. k_G can also be determined as follows. A line is drawn parallel to the Y -axis from the point G corresponding to the centre of mass on the X-axis, crossing the line ABCD at P. The distances AP = PD = AD/2 = h and BP = PC = BC/2 = h' are obtained from the graph. The radius of gyration k_G about the centre of mass of the bar is then determined by equation (4). The average value of k_G over the different measured periods T is taken, and the moment of inertia of the bar about a perpendicular axis through its centre of mass is calculated using the equation $I_G = Mk_G^2$.

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Table 1: Data for time period

Starting direction	Hole no.	Distance from Top (cm)	Time for 10 oscillations (sec)	Mean Time, t (sec)	Mean Time Period, T (sec)
Forward	1	5	(i) (ii)		
	2	10	(i) (ii)		
	3	15	(i) (ii)		
	4	20	(i) (ii)		
	5	25	(i) (ii)		
	6	30	(i) (ii)		
	7	35	(i) (ii)		
	8	40	(i) (ii)		
	9	45	(i) (ii)		
Reverse	1	55	(i) (ii)		
	2	60	(i) (ii)		
	3	65	(i) (ii)		
	4	70	(i) (ii)		
	5	75	(i) (ii)		
	6	80	(i) (ii)		
	7	85	(i) (ii)		
	8	90	(i) (ii)		
	9	95	(i) (ii)		

Graph:

Draw a graph by plotting distance from the top, d along the X-axis and time period, T along the Y-axis. The graph will be drawn with the center of gravity of the bar at the origin which is put at the middle of the paper along the abscissa. Put the length measured in the forward direction to the left and that measured in reverse direction to the right of the origin. A line ABCD will be drawn parallel to the abscissa intersects the two curves at A, B, C and D to get the value of time period, T. The average of the lengths of AC and BC will be the measurement of L. The schematic graph is shown in figure-4.

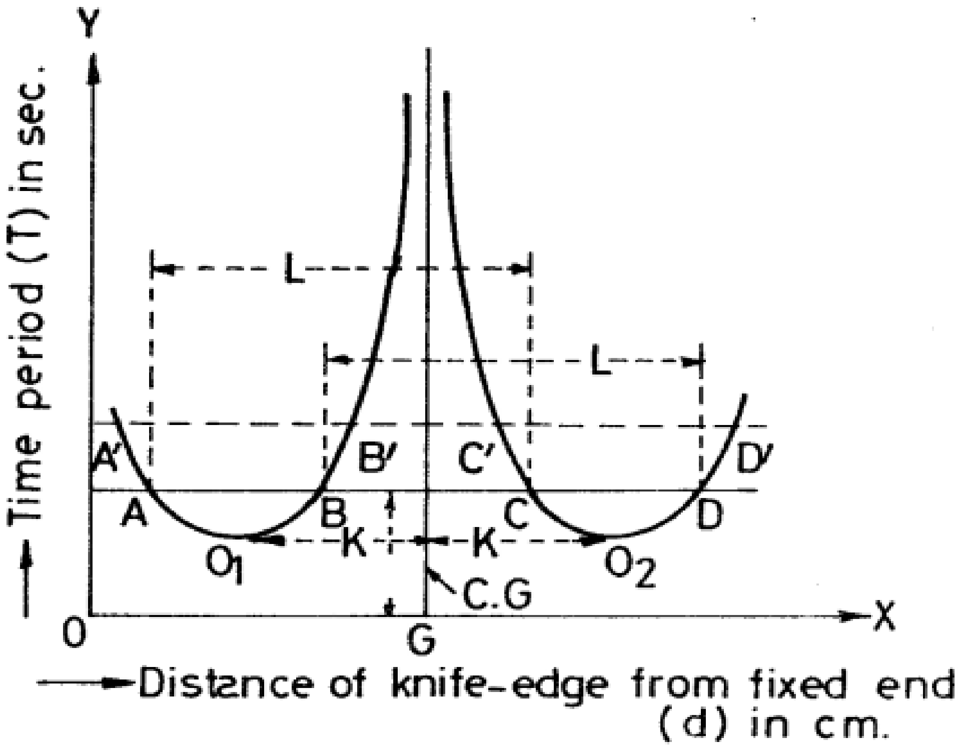


Figure-4

Calculation:

From the graph,

Length L=$\frac{AC+BD}{2}$ cm = cm and

Time period, T = Sec

Therefore, g = $\frac{4\pi^2 L}{T^2}$ cm/sec^2 = cm/sec^2

% of error calculation = $\left|\frac{Experimental\ value - Actual\ value}{Actual\ Value}\right| \times 100\%$

=

Results and Discussions:

The acceleration due to gravity, g =   cm/sec^2

Conclusion:

Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1. **Practical Physics:** Dr. Giasuddin Ahmad and Md. Shahabuddin
2. Practical physics: R.K. Shukla, Anchal Srivatsava
3. Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is gravitational acceleration?
2. What is compound pendulum?

Post-Lab Questions:

1. How does g vary?
2. What factors do affect on the variation of g?

Experiment No: 03

Name of the Experiment:

To determine the spring constant and effective mass of a given spiral spring

Objectives:

a) To Determine the spring constant of a given spiral spring.

b) To calculate the effective mass of a given spiral spring.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Correspon ding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
03	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: To select and use modern hardware and software tools and devices	**PO5- select & use modern tools**	**Psychomotor**	**CO3:** To select and use modern hardware and software tools and devices	
	CO8: To Communicate and share knowledge, data, information, results etc. with others	**PO10–Communication**	**Affective domain**		☑ Lab reports ☑ Project show & project

Theory:

In this experiment a spring is suspended vertically from a clamp attached to a rigid frame work of heavy metal rods. At the bottom end (which is the free end) of the spring a load of mass, m_0 is suspended. So the force acting on the spring is the weight m_0g of the load which acts vertically downward and the spring gets extended. Due to the elastic property of the spring, it tries to regain its initial size, hence applies a counter force on the load, which is called the restoring force of the spring.

According to Hooke's law, magnitude of restoring force is directly proportional to the extension of the spring and the direction of this restoring force is always towards the equilibrium position. If k is the spring constant of the spring and l is the extension of the spring, then

Restoring force = $-kl$

Let, the spring is in equilibrium with mass m attached as in figure and so we can write

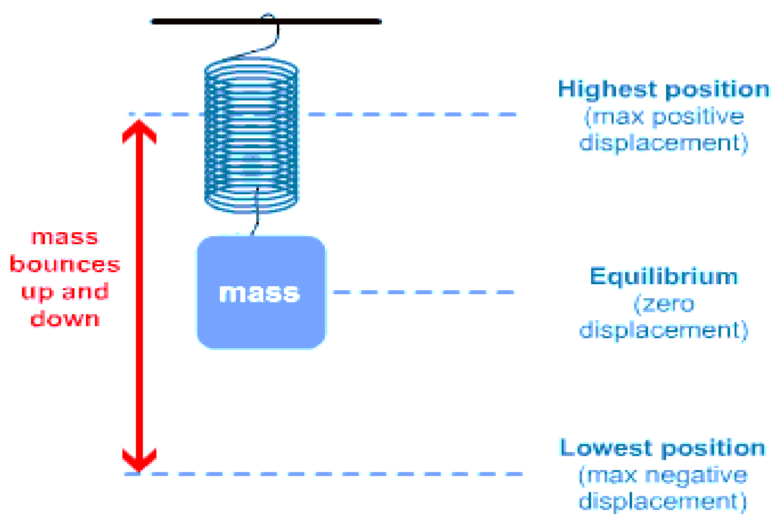
$$m\,g = k\,l$$

⇨ $k = \frac{m}{l} x g$

⇨ $l = m_0 \frac{g}{k}$-- (i)

Here k is the spring constant and g is the acceleration due to gravity. From equation (i) and equation of straight line, slope of this line is given by-

Slope = $\frac{g}{k}$



$\Rightarrow$ $k = \frac{g}{\text{slope}}$ ---.(ii)

We can plot l vs. m_0 graph and determine its slope to determine k.

As you know, if the mass of the spring were negligible then the period of oscillation would be given by

$$T = 2\,\pi\sqrt{\frac{m_o}{k}} - - - - - - - - - - - - - - (iii)$$

Due to the mass, m of the spring an extra term m' will be added with the mass of the load m_o in the above mentioned equation. So, the period of oscillation is,

$$T = 2\pi\sqrt{\frac{m_o + m'}{k}} - - - - - - - - - - - - (iv)$$

m' is called the effective mass of the spring. It can be showed that m' is related with the mass of the spring by following equation,

$$m' = \frac{m}{3}$$

From equation (iv) →

$$T^2 = \frac{4\pi^2}{k} m_0 + \frac{4\pi^2}{k}\ m'$$

$$\therefore 0 = \frac{4\pi^2}{k} m_0 + \frac{4\pi^2}{k}\ m'$$

For different mass, m_0 of the load we find different periods of oscillation, T. If we draw a graph by plotting m_0 along X axis and corresponding T^2 along Y axis, it will be a straight line. The point where the line intersects the X axis, its y-coordinate is 0, i.e., $T^2 = 0$ there. We can find the X coordinate of the point, (i.e. the value of m_0 at that point) by putting $T^2 = 0$ in the above mentioned equation.

⇨ $m_0 = -m'$

That means x coordinate of the point is equal to the negative value of the effective mass. So, if we draw a T^2 vs. m_0 graph, it will be a straight line and its x-interception gives us the effective mass of the spring.

Apparatus:

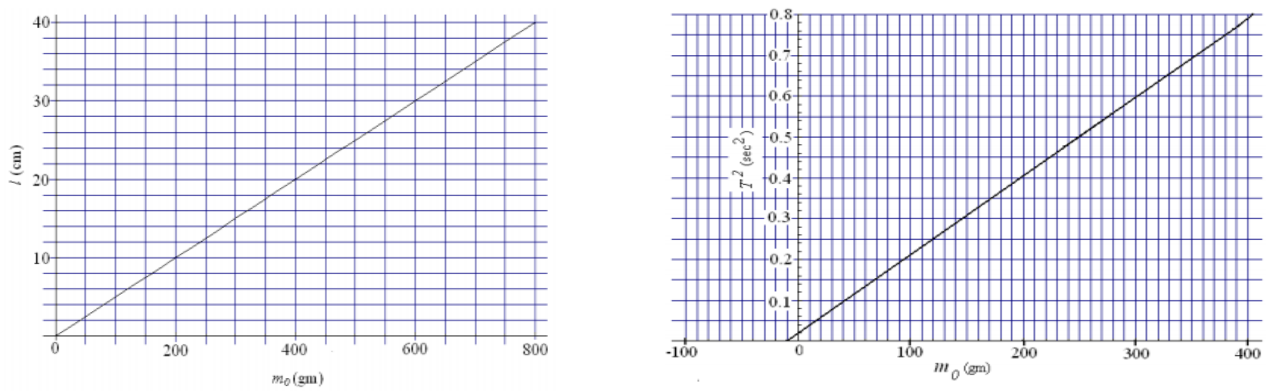
1. A spiral spring,
2. convenient masses with hanging arrangement,
3. a hook attached to a rigid framework of heavy metal rods,
4. weighing balance,
5. stop watch and
6. scale.

Procedure:

1. The helical spring is suspended vertically from a rigid support.A pointer is attached horizontally at the free end of the spring.
2. A meter scale is kept vertically in such a way that the tip of the pointer is over the divisions of the scale, but does not touch the scale.
3. A dead weight, w_0 g-wt is suspended by the weight hanger to keep the spring vertical. The reading of the pointer on the meter scale is noted.
4. Now, gently add a suitable load of 50 g slotted weights to the hanger and the reading of the pointer is noted.
5. The weights are added one by one till the maximum load is reached. In each case, the reading of the pointer is noted.
6. The weights are then removed one by one and the reading of the pointer is noted in each case of unloading.
7. The average of the readings for each load during loading and unloading is calculated in each case. Let z0, z1, z2, z3…etc.., be the average readings of the pointer for the loads w0, (w0+50), (w0+100), (w0+150) etc.

8. From this, extension, l (in m) for the loads (w0+50), (w0+100), (w0+150) etc. , are calculated as (z1-z0), (z2-z0), (z3-z0) respectively.
9. In each case, k =mg/l is calculated. The average value of k gives the spring constant in N/m.
10. A graph is drawn with load M in kg wt along X axis and extension, l in metre along the Y axis. The graph is a straight line. The reciprocal of the slope of the graph is determined. It gives spring constant in kg wt/m. The spring constant in N/m is obtained by multiplying this with $g=9.8\ m/s^2$.
11. Draw graphs with added loads m_0 in grams (abscissa) against the extensions of the spring in cm (ordinate) and with T^2 as a function of m_0. Draw lines of best fit through the points.

An l vs. m_0 and a T^2 vs. m_0 graphs are shown below. Work out the spring constant and effective mass.



12. From the first graph determine the slope of the line. Find out the spring constant of the spring by equation (ii).
13. Draw a graph of T^2 vs. m_0, which should be a straight line and does not pass through the origin owing to the mass of the spring which has not been considered in drawing it. The intercept of the resulting line on the mass-axis give m′ the effective mass of the spring.
14. Measure the mass m of the spring with a weight meter and find the effective mass m′ i.e. $m' = \frac{m}{3}$, also compare the value of m′ what you deduced in (viii)

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.

7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Table 1: Data of time period for different masses

No. of obs.	Loads m_0 gm	Extension l cm	Times for 10 oscillation		Total Period $T = \frac{t}{10}$ (Sec.)		Mean T Sec	T^2
			t_1	t_2				
1								
2								
3								
4								
5								
6								

Calculation:

a) Length of the spring, L = ……………cm.

b) Measurement of the mass of the spring,
M = Slope $= \frac{y_2 - y_1}{x_2 - x_1} =$ ……… gm.

c) Determinations of extension and time period:

d) A graph is attached in 1st left page about added loads against the extension of the spring.

e) Calculation of k, the spring constant and $m'$the effective mass of the spring.

From fig, Slope = $\frac{g}{k} =$ ………

$k = \frac{g}{slope} =$ gm-wt/cm

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

Now, $k = \frac{g}{slope} =$ gm-wt/cm

Spring constant, k =………… dynes/cm

f) (i) Theoretical: the effective mass of Spring, $m' = \frac{M}{3}$ =…………… gm.

(ii) Experimental: From the graph, the effective mass of Spring, $m' =$………… gm

Results and Discussions:

1. Spring Constant, k =…………………… dyne/cm.
2. Theoretical effective mass, m′=…………………….. gm.
3. Experimental effective mass, m′=…………………….. gm.

Conclusion:

Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1. **Practical Physics:** Dr. Giasuddin Ahmad and Md. Shahabuddin
2. Practical physics: R.K. Shukla, Anchal Srivatsava
3. Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is spring constant?
2. What are strain and stress?
3. What is effective mass of a spring?

Post-Lab Questions:

1. State Hooke’s law of elasticity.
2. What is the modulus of rigidity?

Experiment No.: 04

Name of the Experiment:
Determination of the Young's Modulus by the flexure of a beam

Objectives:

a) To determine Young's modulus by the flexure of a beam
b) To determine the intrinsic property of the given material

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
04	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: To select and use modern hardware and software tools and devices	**PO5- select & use modern tools**	**Psychomotor**	**CO3:** To select and use modern hardware and software tools and devices	
	CO8: To Communicate and share knowledge, data, information, results etc. with others	**PO10– Communication**	**Affective domain**		☑ Lab reports ☑ Project show & project

Theory:

Provided the distortion of a body is not too great it has been found that the amount of distortion is directly proportional to the magnitude of the forces producing the distortion. This fact is known as "Hooke's" law. If a wire of natural length l is stretched or compressed a distance x by a force F, experiment reveals that
F = kx---------------------------- (1)
Where, k is a constant whose value will depend on the material, the dimension of the wire and the units used for measurement. In practice it is very desirable that the value of the constant should depend only on the material of the specimen and not on its dimension. Experiment shows that such a constant exists-it is called Young's modulus of elasticity for the material-symbol Y.

If a force F be applied normally to a cross-sectional area A of the material in the form of a wire, then $\frac{F}{A}$ is called the tensile stress.

Young's modulus Y is then defined as the ratio of the tensile stress to tensile strain.

$$Y = \frac{tensile\ stress}{tensile\ strain} = \frac{\frac{F}{A}}{\frac{x}{l}}$$

$$= \frac{mg}{\pi r^2} \times \frac{l}{x} \text{ dynes/ cm}^2$$

Where m is the mass of the load, g is the acceleration due to gravity and r is the radius of the wire. Let x be the increase in length produced in an original length l as a result of this force, then $\frac{x}{l}$, is called the tensile strain.

If a rectangular beam of breadth b and thickness d is supported near its two ends by two knife edges separated by a distance l and if a mass m acting at a point of the beam equidistant from the knife edges produces a depression x, then the Young's modulus of the material is given by $Y= \frac{mgl^3}{4bd^3x}$

As stress is a force per unit area, it must be expressed in dynes per sq. cm or other units of similar dimensions. A strain is a ratio and has no dimension. Young's modulus is, therefore, expressed in the same units as those used for stress.

Apparatus:

1. Pin and microscope,
2. meter scale,
3. suitable weights,
4. screw gauge and
5. A long wooden stick.

Experimental Procedure:

1. Put two suitable weights (say 1 to 2 kg) on the hook and scale pane to make the wires straight (dead load).
2. By means of a screw gauge measure the diameter of the experimental wire W at several regions (say 5 regions) with two perpendicular readings at each region. Calculate the mean diameter and the area of cross-section of the wire in sq. cm.
3. Multiply the area of cross-section of the wire in sq. cm by the breaking stress of the particular material given in the Appendix. This is the breaking load for the wire. The wire must not be loaded with more than half this breaking load.
4. To find the least count of the micro-meter screw attached to the frame, determine the value of the smallest division of the vertical scale. Give the circular scale a complete rotation and observe the linear distance through which the edge of the disc moves. The distance covered is the pitch of the screw. Divide the pitch by the number of circular divisions. This gives the least count of the micrometer.
5. Rotate the micrometer screw so that air bubble in the spirit level goes to the other end of it. Then rotate the micrometer screw in the opposite direction, until the air bubble is at the centre of the spirit level. From now on the micrometer should always be turned in the same direction. Take the readings of the linear scale R and circular scale S.

6. Place load (say half kg) on the scale pan. Owing to elongation the level will be disturbed. After waiting for about a minute adjust the micrometer screw till the bubble is brought back to the center. Note the reading of the micrometer. The difference of the two readings will give the elongation due to the load added.

7. In this way put equal loads by a few installments and take the corresponding Readings. These are readings with the loads increasing on the pan.
8. When half the breaking load is reached, take out the load one by one from the pan and obtain another set of readings for loads decreasing, taking care to rotate the micrometer screw in the same direction. At each installment of decreasing the load, wait for about a minute before taking the reading.
9. Measure the length of the experimental wire from the point of suspension to the point where it is clamped to the apparatus
10. Calculate the elongation for each load increasing and decreasing. Take the mean. Draw the load versus mean elongation graph with load along abscissa and elongation along ordinate.

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

(A) Vernier constant of the microscope:

50 Vernier divisions= 49 main scale divisions

1 ....= $\frac{49}{50}$

Vernier constant = 1 m.s.d. – 1 v.s.d. = (1- $\frac{49}{50}$)×0.5 mm = $\frac{1}{50} \times 0.5mm$= 0.01 mm =0.001 cm

(B) Length of the beam, l = …. cm

Table 1: Data for load versus elongation

Additional Load on hanger (kg)	Readings for the elongation, x										Average depression x (cm)
	Load increasing					Load decreasing					
	MSR x (cm)	VSD N	VC (cm)	VSR y = N × $L.C.$ (cm)	Total Reading = x + y cm	MSR x (cm)	VSD N	VC (cm)	VSR y = N × LC (cm)	Total Reading = x + y cm	

Table 2: Measure the breadth, (b) of beam

No. of obs.	Main scale reading (M.S.R) cm	Vernier scale divisions (V.S.D)	Vernier constant (V.C) cm	Vernier scale reading (V.S.R) = (V.S.D X V.C) cm	Total breadth b (cm)	Mean Breadth b (cm)
1						
2						
3						

Table 3: Measure the depth, (d) of beam

No. of obs.	Main scale reading (M.S.R) cm	Vernier scale divisions (V.S.D)	Vernier constant (V.C) cm	Vernier scale reading (V.S.R) = (V.S.D X V.C) cm	Total depth d (cm)	Mean depth d (cm)
1						
2						
3						

Calculation:

For the mass of ………………..gm

Young's modulus of the material, Y= $\frac{mgl^3}{4bd^3x}$ = dyne/cm^2

Results and Discussion:

Young's modulus of the given material is ....dyne/cm^2

Conclusion:

Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1.**Practical Physics:** Dr. Giasuddin Ahmad and Md. Shahabuddin

2.Practical physics: R.K. Shukla, Anchal Srivatsava

3.Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is Young's modulus of materials?

2. What are strain and stress?

Post-Lab Questions:

1.State Hooke's law of elasticity.

Experiment No.: 05

Name of the Experiment:

To determine the modulus of rigidity of a wire by Statical method using Barton's apparatus

Objectives of the Experiment:

- To determine the modulus of rigidity of a wire by Statical method

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Correspon ding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
05	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: To select and use modern hardware and software tools and devices	**PO5- select & use modern tools**	**Psychomotor**	**CO3:** To select and use modern hardware and software tools and devices	
	CO8: To Communicate and share knowledge, data, information, results etc. with others	**PO10– Communication**	**Affective domain**		☑ Lab reports ☑ Project show & project

Theory:

The following formula is used for the determination of modulus of rigidity (**η**).

$$\eta = \frac{360\, l\, g\, D}{\pi^2 r^4}\ x\ \frac{M}{(\varphi_2{}^\circ - \varphi_1{}^\circ)}\ \textbf{dynes/cm}^2$$

Where M = load suspended on each cord, g: acceleration due to gravity,

D = Diameter of heavy cylinder, r: radius of experimental rod,

l = ($l_1 - l_2$) = Distance between two circular scales,

$\varphi = \varphi_2{}^\circ - \varphi_1{}^\circ)$ = Difference between deflections measured in circular scales g = acceleration due to gravity,

And r = radius of experimental rod

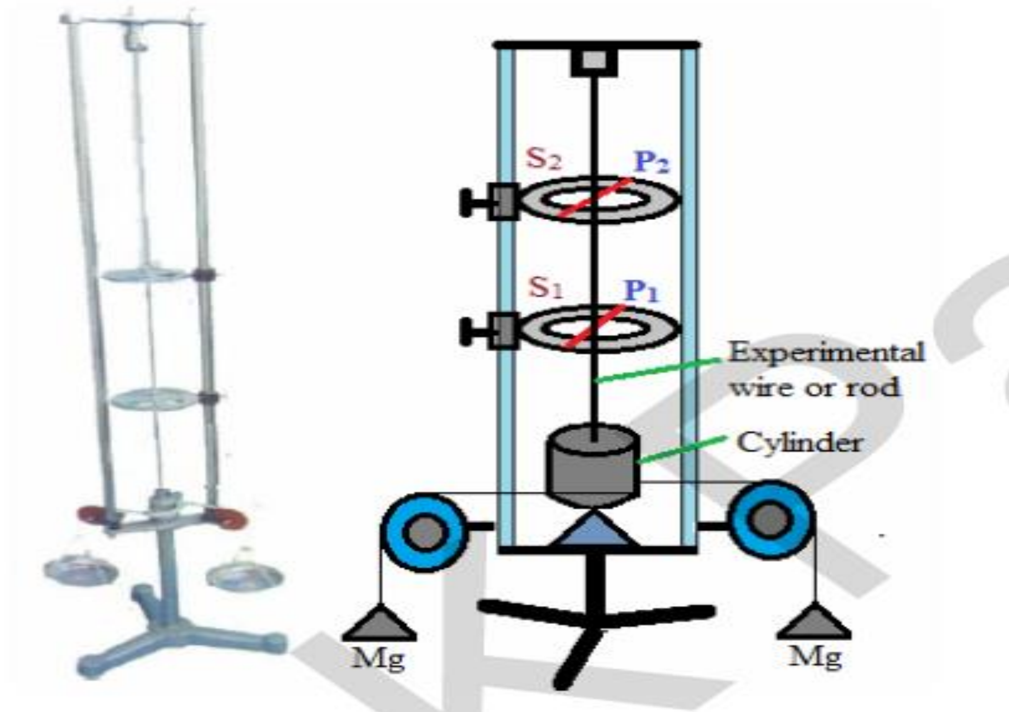


Figure-1: Diagram of Barton's Apparatus

Apparatus:

Barton's apparatus, 500 gm weights, screw Gauge, Vernier Calipers and meter scale.

Procedures:

1. Fix the both scales and pointers at different places such that pointers should indicate 0-0 on scales in absence of load (note: at least pointer on one side must indicate zero). Now measure distance between scales. This will provide the value of (l_1-l_2).
2. Place equal masses (start from 0gm in interval of 500gm) on each pan and read deflection on both scale and on both side. The scale which is nearer to cylinder will provide θ1 value while other will give θ2 value.
3. Go on increasing masses on each pan by equal amounts (from 0 to 2.5kg in interval of 0.5kg) and note the corresponding deflections on both scales on both sides.
4. Go on increasing masses on each pan by equal amounts (from 0 to 2.5kg in interval of 0.5kg) and note the corresponding deflections on both scales on both sides.
5. Now decreases the masses on pans in the same interval and note the corresponding readings on scales for the case of load decreasing.

6. Take mean of all four readings of θ1 which is noted for the case of load increasing and decreasing. Similarly, do it also for θ2.
7. After it, calculate θ_1-θ_2 for each mass. Using these values, find the angle of twist (θ_1-θ_2) for 1.5kg (it can be obtained by taking difference between 1st & 4th, 2nd &5th and 3rd &6th).
8. Find out the least count of screw gauge and zero error in it. Using screw gauge, measure the diameter of wire. Its half will provide the value of radius (*r*) of wire/experimental rod.
9. Find out the least count and zero error of Vernier calipers. Using Vernier calipers, measure the diameter of cylinder (*D*).
10. Put all the values in the formula and calculate it by log method.

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Table:

Table 1: **Diameter of the fly-wheel (heavy cylinder)**

No. of obs.	Main scale reading (M.S.R) cm	Vernier scale divisions (V.S.D)	Vernier constant (V.C) cm	Vernier scale reading (V.S.R) = (V.S.D X V.C) cm	Total Diameter d (cm)	Mean Diameter d (cm)
1						
2						
3						

Table 2: Radius of the wire (using screw gauge)

No. of obs.	Liner scale reading (L.S.R) cm	Circular scale divisions (C.S.D)	Least count (L.C) cm	Circular scale reading (C.S.R) = (CSD X L.C)	Total diameter D cm	Mean diameter D cm	Mean radius r=D/2 cm
1							
2							
3							

Table 3: Reading for load-twist graph

No. of Obs.	**Load in each hanger (gm)**	**Pointer reading in degrees**				**Mean pointer reading**		**Mean twist $(\varphi 2^{\circ} - \varphi 1^{\circ})$**
		Scale S_1		**Scale S_2**		**S_1 $(\varphi 1^{\circ})$**	**S_2 $(\varphi 2^{\circ})$**	
		Load increasing	**Load decreasing**	**Load increasing**	**Load decreasing**			
1	**500**							
2	**1000**							
3	**1500**							
4	**2000**							
5	**2500**							
6	**3000**							

Calculations:

$$n = \frac{360\, l\, g\, d}{\pi^2 r^4}\ x\ \frac{m}{(\varphi_2{}^\circ - \varphi_1{}^\circ)}$$

Results and Discussions:

The rigidity modulus of the wire is ....…… dynes/cm^2

Conclusion:

Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1. **Practical Physics:** Dr. Giasuddin Ahmad and Md. Shahabuddin
2. Practical physics: R.K. Shukla, Anchal Srivatsava
3. Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is rigidity modulus of materials?
2. What are strain and stress?

Post-Lab Questions:

1. State Hooke's law of elasticity.

Experiment No. 06

Name of the Experiment:

To determine the modulus of rigidity of a wire by method of oscillations (dynamic method)

Objectives:

- To determine the rigidity modulus of the material of a wire by dynamical method.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Correspon ding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
06	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: To select and use modern hardware and software tools and devices	**PO5- select & use modern tools**	**Psychomotor**	**CO3:** To select and use modern hardware and software tools and devices	
	CO8: To Communicate and share knowledge, data, information, results etc. with others	**PO10–Communication**	**Affective domain**		☑ Lab reports ☑ Project show & project

Theory:

Within the elastic limit of a body, the ratio of tangential stress to the shearing strain is called **rigidity modulus** of elasticity. The period (***T***) with which the bob of a torsion pendulum oscillates with its suspension wire as axis, is given by

$$T = 2\pi\sqrt{\frac{I}{C}}$$

$$\Rightarrow C = \frac{4\pi^2 I}{T^2} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where, C is the couple per unit twist of the wire.

Where, I is the moment of inertia of the suspended cylinder about its own axis and is given by

$$I = \frac{1}{2} \times Mass \times Radius^2 \text{ …….. } (2)$$

Here ***C*** represents the restoring couple exerted by the suspension wire of length l for one radian twist at its free end and is given by,

$$C = \frac{n\,\pi r^4}{2l} \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

Where n is the rigidity of the material of the wire, while l and r are respectively the length and radius of the suspension wire.

From (1) and (3) we get

$$\frac{n\,\pi r^4}{2l} = \frac{4\pi^2 I}{T^2}$$

$$\Rightarrow n = \frac{8\pi I l}{r^4 T^2} \ldots \ldots \ldots . (4)$$

Calculating *I* from the relation (2) and by measuring *l*, *r* and *T* experimentally, we can find the rigidity (*n)* of the wire by employing the relation (4). If *l* and *r* are put in meters, *I* in kg.m^2 then ***n*** will be in N/m^2.

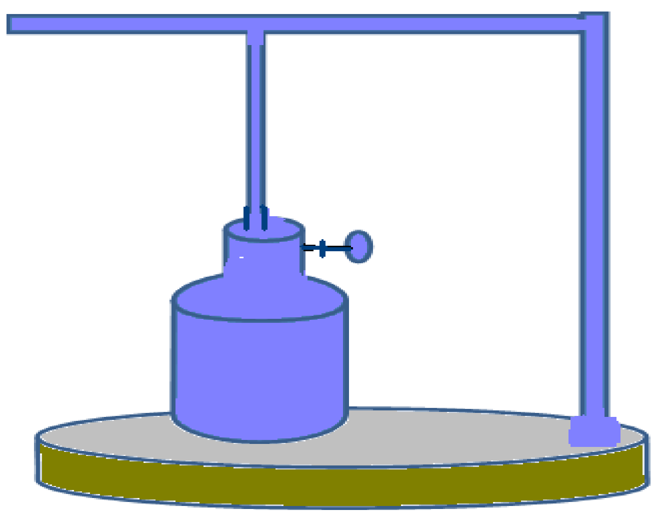


Fig. 1: Schematic diagram of Rigidity modulus experimental set-up

Apparatus:

A screw gauge, measuring tape, stop watch, slide calipers, rigidity modulus experimental set-up etc.

Experimental Procedure:

(i) If the cylinder is detachable from the suspension wire, then it should be detached from the suspension wire and its mass (***M)*** is to be found out either by a rough balance or by a spring balance, [if this cylinder is not detachable from the suspension wire then its mass (***M)*** should be supplied].

(ii) The diameter ***D*** of the cylinder is to be determined by a slide calipers at least in six different places and at each place, the diameter in two perpendicular directions should be found out. The mean of these diameters when halved we get the radius (***R***) of the cylinder. Thus ***R=D/2***. Knowing the mass ***M*** and the radius ***R*** of the cylinder, its moment of inertia ***I*** about its own axis is calculated by using the formulae $I = MR^2/12$

(iii) The cylinder is then attached to the lower end of the suspension wire (provided the cylinder is detachable from the suspension wire) and the length ***l*** of wire, from its point of suspension to the point where the cylinder is attached, is measured by a scale thrice and its mean value is found out.

(iv) The diameter of the suspension wire is measured by a screw gauge at least in eight different places and at each place this diameter is found out in two perpendicular directions. When the mean of these diameters (***d***) is halved and corrected for the instrumental error of the screw gauge we get the mean corrected radius ***r = d/2*** of the suspension wire.

(v) To find the time period ***T*** of a chalk-mark is given on the circular scale just below the pointer when the cylinder is at rest. (if there is no pointer, a vertical line N is marked on the cylinder and is focused by a telescope from a distance such that the line coincides with the vertical cross-wire of the telescope). The cylinder is then twisted by a certain angle and is released to perform torsional oscillations about the vertical axis. The pendulum linear oscillation (if any) should be stopped by leveling the base of the pendulum stand. When the pointer is going towards right by crossing the chalk mark (or when the vertical line of the cross-wire of the telescope) a stop-clock is started and note the total time for 30 complete oscillations. The time for 30 complete oscillations is noted thrice independently and the mean of this time when divided by 30, we get the period (***T***) of oscillation of the cylinder.

(vi) The value of the rigidity ***n*** is then calculated by putting the values of ***I, l, r*** and ***T*** in the relation (4)

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.

12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

Table 1: Readings for the Radius of the cylinder, R (using slide calipers)

No. of obs.	Main scale reading (M.S.R) cm	Vernier scale divisions (V.S.D)	Vernier constant (V.C) cm	Vernier scale reading (V.S.R) = (V.S.D * V.C) cm	Total diameter D (cm)	Mean diameter D (cm)	Mean radius R= D/2 (cm)
1							
2							
3							

Table 2: Radius of the wire, r (Using screw gauge)

No. of obs.	Liner scale reading (L.S.R) cm	Circular scale divisions (C.S.D)	Least count (L.C) cm	Circular scale reading (C.S.R) = (CSD * L.C)	Total diameter D cm	Mean diameter D cm	Mean radius r=D/2 cm
1							
2							
3							

Table 3: Reading for the time period T.

No. of obs.	Time for 30 oscillations (see)	Period of oscillation t(sec)	Mean T. (sec)
1			
2			
3			

Calculations:

1. $I = \frac{1}{2}\, m\, R^2$

2. $\mathbf{n} = \frac{8\pi IL}{T^2 r^4}$ **dynes/cm^2**

Results and Discussions:

The modulus of rigidity of the wire is ………………… ………. dynes/cm^2

Conclusion:

Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1.Practical Physics: Dr. Giasuddin Ahmad and Md. Shahabuddin

2.Practical physics: R.K. Shukla, Anchal Srivatsava

3.Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is Young's modulus of materials?
2. What are strain and stress?

Post-Lab Questions:

1. State Hooke's law of elasticity.

Experiment No.: **07**

Experiment Name: To determine the refractive index of the material of a prism

Objectives of the Experiment:

a) To observe the refraction of light;

b) To determine the refractive index of the material of a prism.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	**CO Statement**	**Corresponding PO**	**Domain / level of learning taxonomy**	**Delivery methods and activities**		**Assessment tools**
07	Upon completion this experiment, students will be able to: **CO1:** Apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial		☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: To select and use modern hardware and software tools and devices	**PO5- select & use modern tools**	**Psychomotor**	**CO3:** To select and use modern hardware and software tools and devices		
	CO8: To Communicate and share knowledge, data, information, results etc. with others	**PO10–Communication**	**Affective domain**			☑ Lab reports ☑ Project show & project

Theory:

When a beam of light strikes on the surface of transparent material (Glass, water, quartz crystal, etc.), the portion of the light is transmitted and other portion is reflected. The transmitted light ray has small deviation of the path from the incident angle. This is called refraction.

Refraction is due to the change in speed of light while passing through the medium. It is given by Snell's Law.

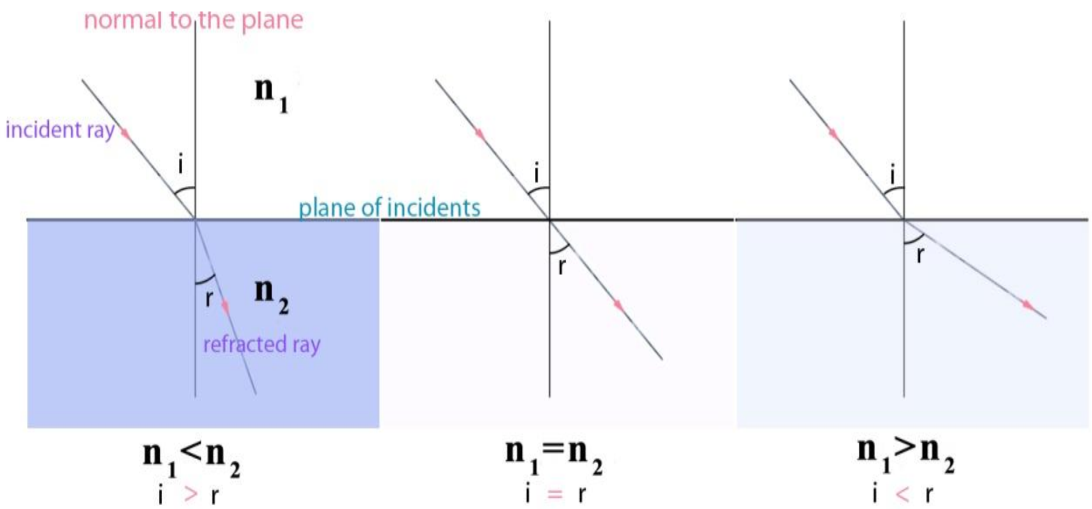
$$\frac{\sin(i)}{\sin(r)} = \frac{n_2}{n_1} \quad \dots\dots\dots \ (1)$$

Where, i is the angle of incident and r is the angle of refraction. And n_1 is the refractive index of the first face and n_2 is the refractive index of the second face.

$$\frac{C_1}{C_2} = \frac{n_2}{n_1} \quad \dots\dots\dots\dots\dots \quad (2)$$

And the speed of light on both faces is related to the equation

C_1 is the velocity of wave in first face and C_2 is the velocity of wave in second face .



The above figure illustrates the change in refracted angle with respect to the refractive index.

Refractive index of the material of prism

The refractive index of the material of the prism can be calculated by the equation.

$$\mu = \frac{sin\frac{A+\delta m}{2}}{sin\frac{A}{2}} \quad \dots\dots\dots\dots\dots..(3)$$

Where, D is the angle of minimum deviation, here δ_m is different for different color.

Apparatus: Spectrometer, Prism, prism clamp, sodium vapour lamp, lens etc.

Description of Apparatus:

Spectrometer has application in a wide range of areas including determining the constituents of stars, to investigate the structure of the atom. You will use a simple but high precision student spectrometer similar to the picture shown in Fig. 1, which consists of three basic components: a collimator, a diffraction grating, and a telescope.

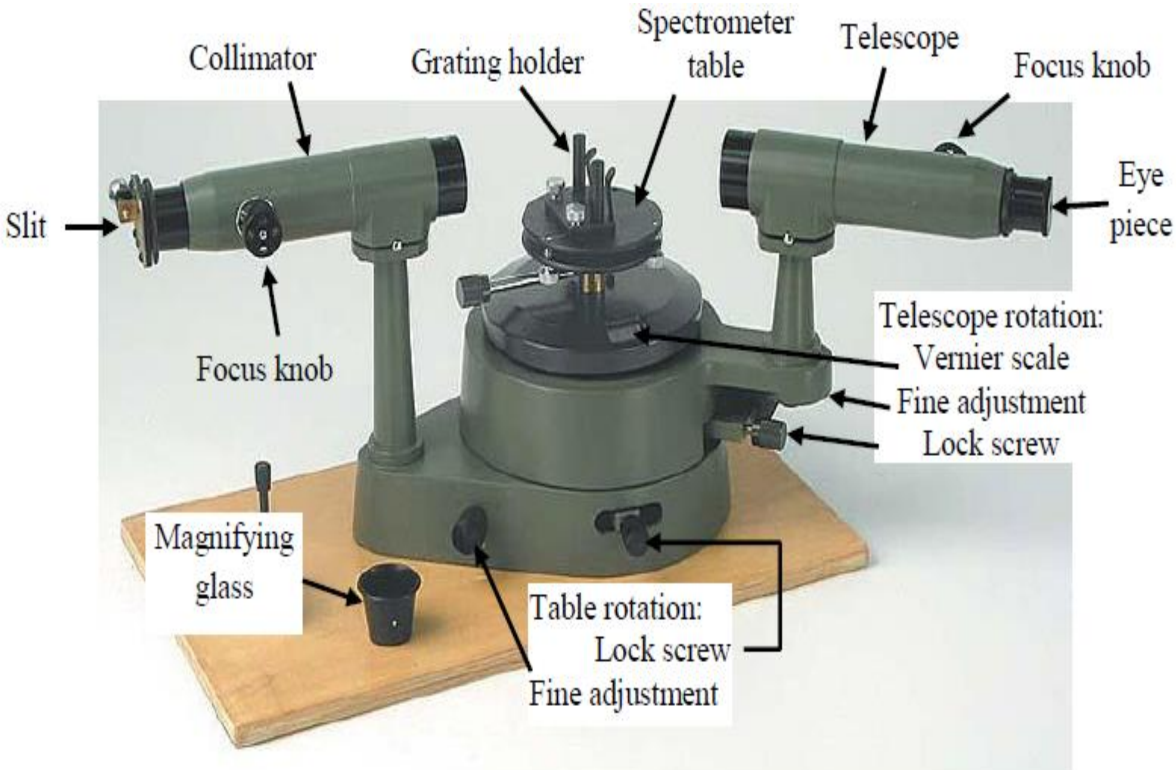


Fig. 1: Spectrometer and its components.

Light enters through a narrow slit positioned at the focal point of the collimating lens. The light leaving the collimator is therefore a thin, parallel beam, which ensures that all the light from the slit strikes the diffraction grating at the same angle of incidence. The grating diffracts the light of different color light at different angles. The telescope is focused at infinity to collect the parallel diffracted beam of light and can be rotated at very precisely measured angles. There are two Vernier readings on two opposite sides on the table, Vernier A and B. You can treat these two reading as measured by two different scales. The Vernier reading has least count of 1' [$(1/60)^0$]. To aid viewing the Vernier scale reading a magnifying glass is provided. The table and the telescope can be fine adjusted by tightening the lock screw and rotating the fine adjustment knobs.

<u>Experimental Procedures:</u>

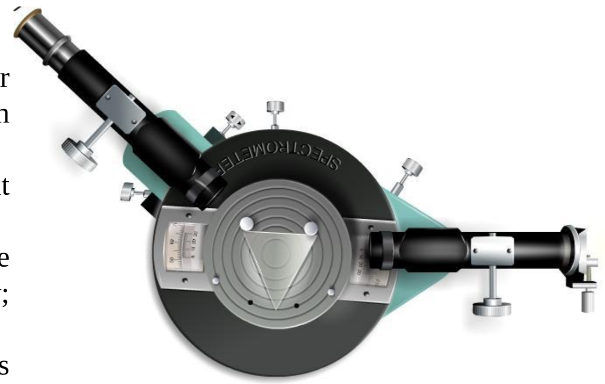
<u>Preliminary adjustments:</u>

1. Turn the telescope towards the white wall or screen and looking through eye-piece, adjust its position till the cross wires are clearly seen.
2. Turn the telescope towards window; focus the telescope to a long distant object.
3. Place the telescope parallel to collimator.
4. Place the collimator directed towards sodium vapor lamb. Switch on the lamp.
5. Focus collimator slit using collimator focusing adjustment.
6. Adjust the collimator slit width.
7. Place prism table, note that the surface of the table is just below the level of telescope and collimator.
8. Place spirit level on prism table. Adjust the base leveling screw till the bubble come at the center of spirit level.
9. Clamp the prism holder.
10. Clamp the prism in which the sharp edge is facing towards the collimator, and base of the prism is at the clamp.

<u>To determine the angle of the Prism:</u>

1. Prism table is rotated in which the sharp edge of the prism is facing towards the collimator.
2. Rotate the telescope in one direction up to which the reflected ray is shown through the telescope.
3. Note corresponding main scale and Vernier scale reading in both Vernier (Vernier I and Vernier II).
4. Rotate the telescope in opposite direction to view the reflected image of the collimator from the second face of prism.
5. Note corresponding main scale and Vernier scale reading in both Vernier (Vernier I and Vernier II).
6. Find the difference between two readings, i.e.θ
7. Angle of prism, A=θ/2

<u>To determine the Angle of minimum deviation:</u>



1. Rotate the Vernier table so that the light from the collimator falling on one of the face of the prism and emerges through the other face.
2. The telescope is turned to view the refracted image of the slit on the other face.
3. The Vernier table is slowly turned in such a direction that the image of slit is move directed towards the directed ray; ie., in the direction of decreasing angle of deviation.
4. It will be found that at a certain position, the image is stationary for some moment. Vernier table is fixed at the position where the image remains stationary.
5. Note the readings on main scale and Vernier scale.
6. Carefully remove the prism from the prism table.
7. Turn the telescope parallel to collimator, and note the direct ray readings.
8. Find the difference between the direct ray readings and deviated readings. This angle is called angle of minimum deviation (D). Refractive index of the material of the prism is determined by using equation (3)

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.

11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

<u>Data Collection:</u>

Table 1: Determination of angle of Prism

<table>
<tr><th rowspan="2">No. of obs.</th><th colspan="5">Readings for image in the face AB of the prism</th><th colspan="5">Readings for image in the face AC of the prism</th><th rowspan="2">Difference in readings at the two face (θ=M-N)</th><th rowspan="2">Mean (θ) of the two venires</th><th rowspan="2">Angle of the prism A=θ/2</th></tr>
<tr><th>M.S.R</th><th>V.S.D</th><th>V.C</th><th>Value of V.S.R</th><th>Total Reading N</th><th>M.S.R</th><th>V.S.D</th><th>V.C</th><th>Value of V.S.R</th><th>Total Reading M</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 2: Determination of angle of minimum deviation

<table>
<tr><th rowspan="2">No. of obs.</th><th colspan="5">Readings for the minimum deviation position</th><th colspan="5">Readings for the direct position</th><th rowspan="2">Angle of minimum deviation (δm)=(M-N)</th><th rowspan="2">Mean (δm)</th></tr>
<tr><th>M.S.R</th><th>V.S.D</th><th>V.C</th><th>Value of V.S.R</th><th>Total Reading N</th><th>M.S.R</th><th>V.S.D</th><th>V.C</th><th>Value of V.S.R</th><th>Total Reading M</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<u>Calculation:</u>

The refractive index of the material of Prism is

$$\mu = \frac{\sin\frac{A+\delta m}{2}}{\sin\frac{A}{2}} =$$

Results and Discussions:

The refractive index of the material of Prism is ………………

Conclusion:

Summarize the experiment and discuss whether the objective were fulfilled or not within a short paragraph.

References:

1.**Practical Physics:** Dr. Giasuddin Ahmad and Md. Shahabuddin

2.Practical physics: R.K. Shukla, Anchal Srivatsava

3.Kenneth. E. Jesse, American Journal of Physics, Vol. 48, Issue 9, pp.785 (1980)

Knowledge Test Questions:

Pre-lab Questions:

1. What is refractive index?

Post-Lab Questions:

1. State the laws of reflection.
2. State the laws of refraction.

Experiment No: 08

Name of the Experiment: To calibrate a Polarimeter and hence to determine the specific rotation of a sugar solution by means of a Polarimeter.

Objectives:

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
08	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using ammeter voltmeter for finding the specific resistance.	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-Communication**	**Affective domain**		

Theory:

The angle of rotation produced to the plane of vibration by an optically active substance, in solution is proportional to

(i) The thickness of the medium (solution)
(ii) The concentration of the solution or the density of the active substance in the solvent and
(iii) The nature of the substance.

Thus, $\theta \infty$ l.c or, θ =slc, or, s = $\frac{\theta}{lc}$

Where θ is the angle of rotation produced, l is the length of the substance in decimeters, c is the concentration in gm/cm^3 of the solution and s is a constant called specific rotation and depends upon the nature of the substance.

If l = 1 decimeter and c = 1 gm/cm^3 then specific rotation may be defined as the rotation produced while traversing a path of one decimeter (10 cm) length in the solution containing 1 gm of the optically active substance per cm^3 of the solution. Then,

Specific rotation = $\frac{\text{Rotation produced by 1 decimetre length of the solution}}{\text{density of the solution in gm per c.c.}} = \frac{\theta}{l/_{10}} \div c = \frac{10\theta}{lc}$

Where the length *l* is expressed in centimeters.

The amount of rotation also depends upon (a) the *temperature* and (b) the wavelength of the light used. So for a given temperature and a given wavelength

$(s_\lambda^t) = \frac{10\theta}{lc}$…………..(1)

The specific rotation of dextro-rotatory substance is taken as positive while that of a laevo-rotatory substance is considered negative.

Now, the angles of rotation (θ) for different values of known concentrations (c) of a solution can be measured with the help of a polarimeter. If a graph is plotted with θ against c, then the graph will be a straight line. The polarimeter is thus calibrated. Taking then the solution of an unknown concentration, the rotation of the plane of polarization produced by the solution can be measured and from the graphs, its concentration can be determined.

Again, using eqn (1), the value of the specific rotation of the solution can also be determined.

Required equipment and devices:

1. A polarimeter or saccharimeter,
2. sodium lamp,
3. sugar,
4. balance,
5. Graduated cylinder and thermometer.

Procedures:

(i) Examine the circular scale in contact with the analyzer and find its Vernier constant. Obtain the zero reading of the instrument.

(ii) Carefully weigh out 20 gm of sugar in a water glass; dissolve it in about 50 or 60 cc of distilled water. Make up the solution up to 100 cc so that you may have a 20 percent solution. During dissolving, do not apply heat; just pour the solution from one vessel to another so that the solution has a uniform concentration.

(iii) Carefully measure the length of the tube. Clean the tube as well as the glass plates used to close its ends. Filter some distilled water so that it becomes free from dust and fill the tube with it. Take care so that no air bubble is introduced. Close the tube.

(iv) Place the tube with its contents horizontally on two V supports between the analyzer and polarizer so that it is coaxial with the telescope. Focus the eye-piece of the telescope so that on the field of view of the polarizer any line dividing it may be seen clearly. Rotate the analyzer so that the field of view is completely and uniformly dark i.e. both halves are equally dark. Read the position of the analyzer on the circular scale. Use the Vernier. Repeat the operations for at least three times ad take the mean of these three readings. Call this reading P.

(v) Remove the tube, empty it and rinse it with a little of the prepared solution. Carefully fill the tube completely with the solution. Take care not to have any air bubble inside the tube. Clean the ends, replace the tube in position and allow it to stand there for sometime so that the temperature becomes uniform. Note the temperature by placing a thermometer by its side. See through the telescope, the two halves are no longer completely and equally dark. Rotate the analyzer till the two halves get equally and completely dark as before. Take the reading. Repeat the operation for at least three times and take the mean of these three readings. Call it Q. (Q~P) is the angle through which the plane of polarization has been rotated. Calculate the specific rotation.

(vi) Next repeat the operation described in (v) with 10 percent, 5 percent and 2.5 percent solution. Find out (Q~P) in each case. Always take care that the temperature remains constant. Calculate specific rotation in each case.

(vii) Repeat the entire experiment with different tubes having different lengths.

(viii) Draw a graph between the percentages of the solution and the corresponding angle of rotations. This should be a straight line. Take a point P on the graph and find the values of θ and c corresponding to this point. Calculate the specific rotation of the solution using equation (1)

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.

2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.

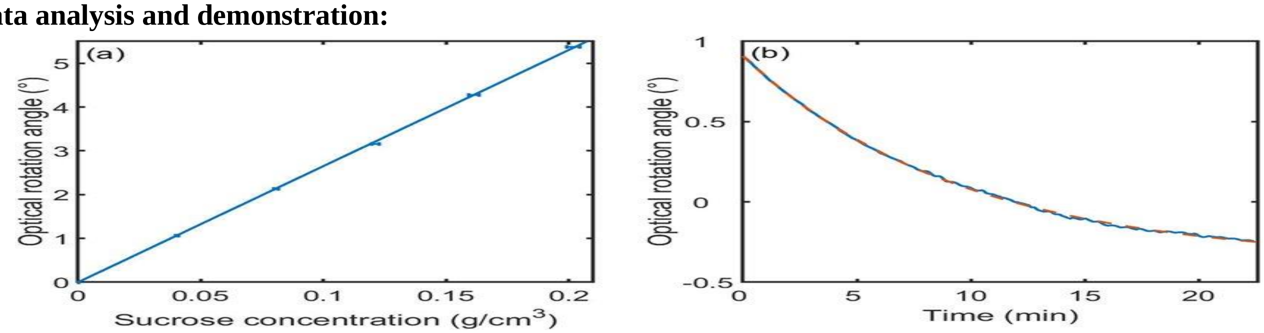
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Table for angular rotation

Strength of sugar solution (%)	No. of obs	First reading with water (P)	Second reading with solution (Q)	Angular rotation (Q~P)	Mean angular rotation	Specific rotation (s)
20	1.					
	2.					
	3					
10						

Data analysis and demonstration:



Weight of empty glass, m_1= …….gm

Weight of watch glass + sugar, m_2= ……..gm

Weight of sugar = m_2- m_1= ………gm

Length of the tube = …………..cm

Vernier constant of the circular scale =

Calculation:

So for 20% solution, specific rotation (s)= $\frac{10\theta\times100}{l\times20}$= …….

From graph, angle of rotation at point P, θ = …..

Concentration of the solution, c = ……… mass/cc

specific rotation (s)= $\frac{10\theta\times100}{l\times c}$= …….

Results and Discussion:

The specific rotation of sugar solution, s= …………

Conclusion:

In this experiment the specific rotation of sugar solution is calculated

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md.Shahabuddin
2. http://vlab.amrita.edu/?sub=1&brch=189&sim=335&cnt=4

Knowledge Test

Pre-lab viva sample Question

15. Are light waves of transverse nature?
16. Do you believe electromagnetic waves are light waves?
17. What do you mean by plane of polarization?

Post-lab viva sample question

1. What are polaroids?
2. What are the uses of Nicol prism?
3. If two prisms are placed co-axially, can you see the polarized light from the second one?

Experiment No: 09

Experiment Name: Determination of moment of inertia of a flywheel about its axis of rotation.

Objectives:

c) To measure the angular velocity of a flywheel and conservation of energy for calculate its moment of inertia.

d) To determine intrinsic property of material.

e) To learn the use of rotation to measure moment of inertia.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
09	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques to determine moment of inertia of fly wheel.	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10- Team Work**	**Psychomotor**		

Theory:

Fig.1 (a) shows a mass M, attached by means of a string to the axle, radius r, of a fly-wheel the moment of inertia of which about its axis of rotation is I. The length of the string is such that it becomes detached from the axle when the mass strikes the floor. In falling a distance h, the potential energy of the mass has been converted into kinetic rotational and transnational energy. If ω be the maximum angular velocity of the Wheel and F be the amount of work done against friction per revolution and n_1 be the revolutions made while the mass falls the distance h,

Then, the loss in P.E. of M= Gain in K.E. of M + Gain in K. E of fly-wheel + work done against friction

So, $Mgh = \frac{1}{2} Mr^{2\omega^2} + \frac{1}{2} I\omega^2 + n_1F$…………………………………………….… (1)

After the mass strikes the ground the wheel executes a further n_2 revolutions and the angular velocity gradually decreases to zero.

The rotational kinetic energy $\frac{1}{2} I\omega^2$ have been used up in overcoming frictional forces, hence

$Fn_2 = \frac{1}{2} I\omega^2$ ……………………………………………………..….. (2)

If n_2 revolutions take a time t, then the average angular velocity $\omega_a = \frac{2\pi n_2}{t}$

Since the angular velocity decreases uniformly from a maximum ω to a minimum of zero, the average angular velocity is also given by, $\omega_a = \frac{\omega+0}{2} = \frac{\omega}{2}$

Also the motion is uniform. Hence $\frac{\omega}{2} = \frac{2\pi n_2}{t}$

i.e. $\omega = \frac{4\pi n_2}{t}$ ………………………………………………………… (3)

From equations (1) (2) and (3) it follows that

I = $\frac{2mgh - m\ \omega^2 r^2}{\omega^2 (1+\frac{n_1}{n_2})}$ ………………………………………………..….(4)

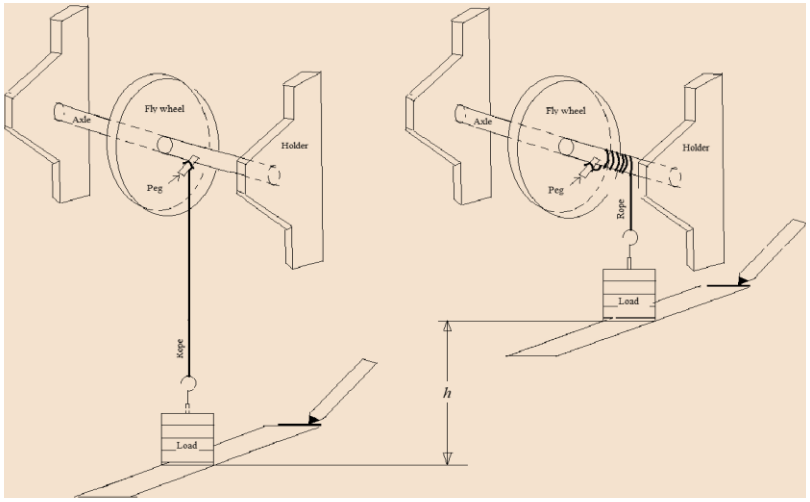


Fig.: 1(a) Flywheel when the rope and load is about to be detached from the axle. (b) The same flywheel after rotating it for n_1 number of times. There is a small peg on the axle, as shown in figure. We make a loop on one end of a rope round this peg. A load of mass, M, is connected to the other end of the rope. hold the flywheel in such a way that the load is about to be detached from the axle.

Required equipment and devices:

1. Fly-wheel,
2. weights,
3. cord,
4. stop-watch,
5. setsquare,
6. meter scale
7. calipers

Procedures:

1. The length of the cord is carefully adjusted, so that when the weight-hanger just touches the ground, the loop slips off the peg.
2. A suitable weight is placed in the weight hanger
3. A chalk mark is made on the rim so that it is against the pointer when the weight hanger just touches the ground.
4. The other end of the cord is loosely looped around the peg keeping the weight hanger just touching the ground.

5. The flywheel is given a suitable number (n) of rotation so that the cord is wound round the axle without overlapping.
6. The height (h) of the weight hanger from the ground is measured.
7. The flywheel is released.
8. The weight hanger descends and the flywheel rotates.
9. The cord slips off from the peg when the weight hanger just touches the ground. By this time the flywheel would have made n rotations.
10. A stop clock is started just when the weight hanger touches the ground.
11. The time taken by the flywheel to come to a stop is determined as t seconds.
12. The number of rotations (N) made by the flywheel during this interval is counted.
13. The experiment is repeated by changing the value of n and m.
14. From these values the moment of inertia of the flywheel is calculated using equation $I = \frac{Nm}{N+n}\left[\frac{2gh}{\omega^2} - r^2\right]$.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it

Data Collection:

Table 1: Determination of n_1, n_2 and t:

Mass M Gm	Height h Cm	No. of Revolutions n_1	No. of Revolutions n_2	Average n_2	Time t in sec	Average t Sec

Table 2**:** Determination of the radius of the axle: We got from simulator software **r= 1 cm.**

LSR (X) (cm)	VSD	VC (cm)	VSR Y =(VSD×VC) (cm)	Total Reading = X+Y Cm	Average Diameter cm	Radius r cm

Data analysis and demonstration:

- For the mass of 200.gm

$\omega = \frac{4\pi n_2}{t}$ = 10.71

Formula for determination of moment of inertia:

For the mass of 200.gm

I = $\frac{2mgh - m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})}$ = 1.28×10^4 gmcm^2

- For the mass of 400.gm

$\omega = \frac{4\pi n_2}{t}$ = 10.71

Formula for determination of moment of inertia:

For the mass of 600.gm

$$I = \frac{2mgh - m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})} = 1.28\times10^4 \text{ gmcm}^2$$

- For the mass of 600.gm

$\omega = \frac{4\pi n_2}{t}$ = 10.71

Formula for determination of moment of inertia:

For the mass of 200.gm

$$I = \frac{2mgh - m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})} = 1.28\times10^4 \text{ gmcm}^2$$

Results and Discussions:

The moment of inertia of the given fly-wheel is

1. ………………………………………

Conclusion:

The angular velocity of a flywheel can be measured and the moment of inertia of fly wheel for different mass can be determined.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. http://phy-sc22-au.vlabs.ac.in/mechanics/Moment_of_Inertia_of_Flywheel/

Knowledge Test

Pre-lab viva sample Question

1. What is a fly-wheel? Why is its mass mostly concentrated in its rim?
2. What is moment inertia of a body? Is it a constant for a body?
3. What is the physical significance of the moment of inertia? What is the unit of moment of inertia?
4. What is the radius of gyration?

Post-lab viva sample question

1. What type of difficulties did you face while counting the number of revolutions of the flywheel? Please mention.
2. What will happen if the rope were too thick? [hint: could you write v= ωr]
3. Name the forces acting on the descending in the mass.
4. What happens to the potential energy lost by the mass?
5. Describe a practical application of Fly wheel

Experiment Number: 10

Name of the Experiment: To determine the Specific resistance of a wire using a Meter Bridge

Objectives:
To find the resistance of a given wire using a meter bridge and hence determine the specific resistance of its materials.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

<table>
<tr><th>Expt. No.</th><th>CO Statement</th><th>Correspon ding PO</th><th>Domain / level of learning taxonomy</th><th>Delivery methods and activities</th><th>Assessment tools</th></tr>
<tr><td rowspan="2">10</td><td>Upon completion this experiment, students will be able to:
CO1: use the various procedures and techniques for using ammeter voltmeter for finding the specific resistance.</td><td>PO1–Engineering knowledge</td><td>Affective domain/ analyzing level</td><td rowspan="2">☐ Simulation
☑ Experiment
☑ Practice lab
☑ Group discussion
☐ Tutorial</td><td rowspan="2">☑ Lab tests
☑ Lab reports
☑ Final lab test
☐ Open ended lab
☐ Project show & project presentation</td></tr>
<tr><td>CO3: learn the writing techniques of lab report in a systematic way.</td><td>PO10-Communication</td><td>Affective domain</td></tr>
</table>

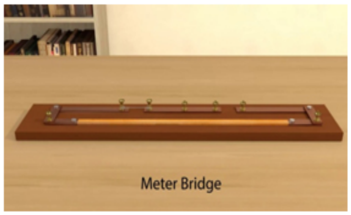
Theory:

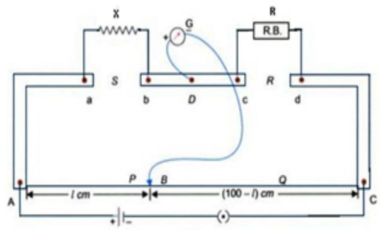
The metre bridge is operates under Wheatstone's principle. Here, four resistors P, Q, R, and S are connected to form the network ABCD. The terminals A and C are connected to a battery, and the terminals C and D are connected to a galvanometer through keys K1 and K2 respectively. In the balancing condition, there is no deflection on the galvanometer. Then,

$$\frac{P}{Q} = \frac{R}{S}$$

Metre Bridge apparatus

The metre bridge, also known as the slide wire bridge consists of a one metre long wire of uniform cross sectional area, fixed on a wooden block. A scale is attached to the block. Two gaps are formed on it by using thick metal strips in order to make the Wheat stone's bridge. The terminal B between the gaps is used to connect galvanometer and jockey.





A resistance wire is introduced in gap S and the resistance box is in gap R. One end of the galvanometer is connected to terminal D and its other end is connected to a jockey. As the jockey slides over the wire AC, it shows zero deflection at the balancing point (null point).

If the length AB is l , then the length BC is (100-l).

Then, according to Wheatstone's principle;

$$\frac{X}{R} = \frac{l}{(100 - l)}$$

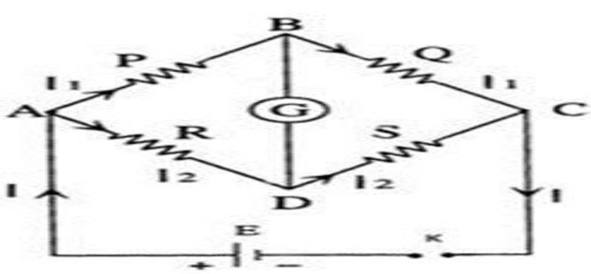
Now, the unknown resistance can be calculated as,

$$X = R\frac{l}{(100 - l)}$$

The specific resistance or resistivity of the material of the wire can be then calculated by using the relation,

$$\rho = \frac{\pi r^2 X}{L}$$; Where L be the length of the wire and r be its radius.

Circuit Diagram:



Required equipment and devices:

1. Metre bridge (slide wire bridge)
2. Leclanche cell or Battery eliminator
3. Galvanometer
4. Resistance box

5. Jockey
6. One way key
7. A resistance wire
8. Screw gauge
9. Metre scale
10. Connecting wires

Procedures:

(i) Make connections as shown in figure. Before putting in, fold one cm of the specimen wire at each end at right angles to the rest of it and put the folded portion within the binding screws of the left gap. Insert 1 ohm resistance in the right gap. With 100 ohms or higher in the rheostat, move the sliding contact first to the left end and then to the right end of the bridge wire. If the deflections are on the opposite directions, the connections have been correctly made.

(ii) Move the sliding contact along the bridge wire until the galvanometer deflection is almost zero. Null point is being approached.

(iii) If the balance point seems to be far from the middle of the bridge wire, change the value of the resistance ® in the right gap until the null point is brought very near the middle of the wire. Remove the galvanometer shunt by unplugging the key K' and find the null point accurately and note it. Reverse the current by changing the commutator plug and note the null point again. Take the mean of the two readings, thus eliminating thermo-electric effects. Now interchanging the positins of X and R with R in the left gap. Find out the null point. Reverse the current and gain find out the null point.Then

- You can calculate the unknown resistance of the resistance wire by using the relation,

$$X = R\frac{l}{(100 - l)}$$

- If L is the length and r is the readius of the wire, the specific resistance (resistivity) of the given resistance wire can be calculated using the relation,

$$\rho = \frac{\pi r^2 X}{L}$$

(iv) With two or more knows resistances, repeat the operations, every time reversing the current. Then calculate the mean value of X.

(v) Carefully determine the length L of the wire between bends with a metre scale

(vi) Measure the diameter (d) of the wire with a screw gauge.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.

3. when instructed to do so.

6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection: Table 1: Reading for the balance point.

No. of observation	**Value of resistance, R(Ω)**	**Length, l cm**	**$(100 - l)$ cm**	**X=$\frac{Rl}{(100-l)}$(Ω)**	**Mean X (Ω)**
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					

Table 2: Reading for the radius of the experimental wire. (Using Slide Calipers)

No. of obs.	Liner scale reading (L.S.R) cm	Circular scale divisions (C.S.D)	Least count (L.C) cm	Circular scale reading (C.S.R) = (CSD x L.C) cm	Total diameter D Cm	Mean diameter D cm	Mean radius r=D/2 cm
1							
2							
3							

Data analysis and demonstration:

Length of the wire, L = ...cm

Resistance of the wire, X = ... Ω

Resistivity (specific resistance) of the wire,

$$\rho = \frac{\pi r^2 X}{L}$$

= ....Ω m

Result and Discussions

The specific resistance (resistivity) of the given resistance wire, ρ = ……...... Ω m

1.
2.
3.

Conclusion: From the experiment, unknown resistance and specific resistance can be measured.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. http://amrita.olabs.edu.in/?sub=1&brch=6&sim=146&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. Why is Metre Bridge called so?
2. What is null point?

Post-lab viva sample question

1. Why is bridge method better than Ohms law of measurement?
2. What is the range of measurement of resistance using a Wheatstone bridge?
3. How a Wheatstone bridge can be used for the measurement of physical parameters?

Experiment Number. 11

Name of the Experiment: To determine the e.m.f of a cell with a potentiometer of known resistance

Objectives:

c) Determination of the e.m.f of a cell with a potentiometer of known resistance

d) Comparison of the e.m.f of two cells with a potentiometer

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
11	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using potentiometer for finding e.m.f of a cell	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-Communication**	**Affective domain**		

Theory:

Potentiometer: Potentiometer is a device used to determine the e.m.f. (electromotive force) of a cell, to measure the internal resistance of a cell, and potential difference across a resistor. It consists of a long wire of uniform cross-sectional area and of 10 m in length. The material of wire should have a high resistivity and low temperature coefficient. The wires are stretched parallel to each other on a wooden board. The wires are joined in series by using thick copper strips. A meter scale is also attached on the wooden board. The potentiometer works on the principle that when a constant current flows through a wire of uniform cross-sectional area, potential difference between its two points is directly proportional to the length of the wire between the two points.

If i be the current in milliamperes flowing through a potentiometer wire of length L cm and resistance R ohms then the potential drop across the ends of the wire is

$$V = \frac{iR}{1000}\ volts$$

Hence the potential drop per unit length, L of the wire is

$$\rho = \frac{V}{L}$$

$$\Rightarrow \rho = \frac{iR}{1000\ L}\ volts/cm$$

If a cell of e.m.f $\acute{E}$ be balanced on a length l of the potentiometer wire then

$$\acute{E} = \rho l = \frac{iRl}{1000\,L}$$

Circuit Diagram:

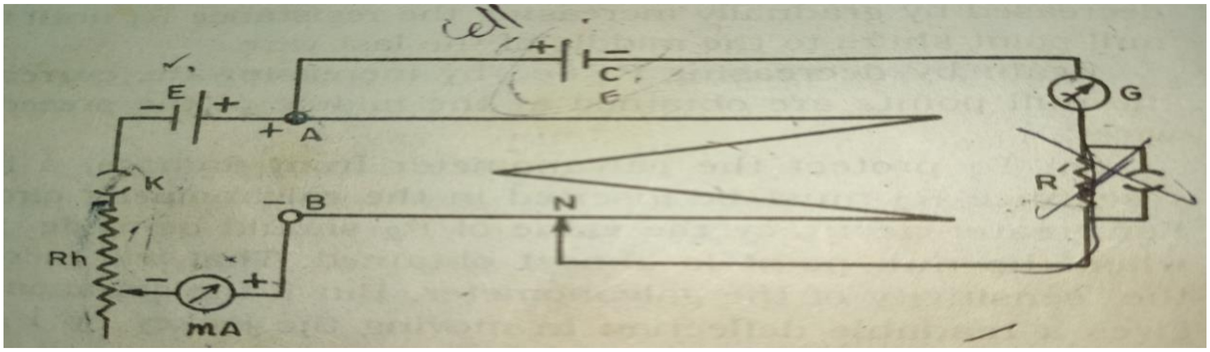


Fig: circuit diagram for determine the emf using potentiometer

Required equipment and devices:
Potentiometer, storage cell, the experimental cell, zero-center galvanometer, milli-ammeter, rheostat Rh, plug keys, a high resistance.

Procedure:

i. Connect the positive terminal of the battery E to the binding screw A of the potentiometer and the negative terminal of the battery through Rh and the key K_1 to the binding screw B of the potentiometer (Fig.). Join the positive terminal of the cell E_1 whose internal resistance is to be determined, to the binding screw A of the potentiometer and its negative terminal through the galvanometer G to the jockey J. Also connect the resistance box R.B through the key K_2 to the two terminals of the cell 81. It is better to put a shunt across the galvanometer.

ii. Adjust a small resistance in the rheostat Rh and close the key K_1. Keep the key K_2 open and press the jockey first near the end A and then near the end B of the potentiometer wire. If the galvanometer deflection are in the same direction, then either the resistance in Rh is too great or e.m.f. of E is too small. Decrease the resistance in Rh until the opposite deflections are obtained at the above two contact points. If necessary increase the number of cells in the battery E. Adjustment of Rh should be such as to get a null point on the fifth or sixth wire.

iii. Remove the shunt of the galvanometer (if any) and find out the balance point accurately. Open the key K_1 and calculate the distance l_1 of the balance point from the end A of the potentiometer wire Determine l_1 three times and calculate the mean value of l_1.

iv. Close the key K_2 without changing Rh and take out a resistance 10 ohms from the RB and determine the balance point and calculate the distance l_2 of the balance point from A. Then remove 20,30,40,50 ohms from R and determine the value of [2 in each case]

v. Calculate the value of b from the relation (2) for each value of R and then calculate the mean value of b.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

<u>Data collection:</u>

(A) Resistance of the potentiometer wire, R = ……………Ω ohms

(B) Total length of the potentiometer, L= ………………………..cm.

Table-1: Determination of the electromotive force

No. of obs.	Milliammeter readings = i	Null points		Total length for balance l cm	e.m.f of the cell $E=\frac{iRl}{1000L}$ Volts.	Mean E' Volts.
		On wire no.	Scale readings in cm.			
1		**10th**				
2		**9th**				
3		**8th**				
4		**7th**				
5		**6th**				

Data analysis and demnstration:

Result and discussion: The e.m.f of the cell….

i. …………………………….

ii. ………………………………

iii. ………………………………….

Conclusion: The e.m.f of any cell can be measured by using potentiometer.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. https://amrita.olabs.edu.in/?sub=1&brch=6&sim=231&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. Define E.M.F
2. Define internal resistance
3. What is potentiometer

Post-lab viva sample question

1. What do you understand by the internal resistance of a cell?
2. On what factor does internal resistance of cell depend?
3. Name cells of high and low internal resistance
4. Show a relation between the e.m.f.(E) and internal resistance of the cell. Is the internal resistance of a cell?

Experiment No: 12

Name of the Experiment: To determine the value of unknown resistance and verify the laws of series and parallel resistance by Post Office Box.

Objectives:

a) Determination the value of unknown resistance
b) Verification the laws of series and parallel resistance

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Correspon ding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
12	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using ammeter voltmeter for verification of Ohm's law.	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

a) Determination the value of unknown resistance:

Theory: If P and Q are the known resistances in the ratio arms and R that in the third arm (see Figs. Z.2g and 7. 3O). the unknown resistance S in the fourth arm is obtained, when there is no deflection of the galvanometer, from the relation

$$\frac{P}{Q} = \frac{R}{S}$$

Or, $S = \frac{RQ}{P}$

Circuit Diagram:

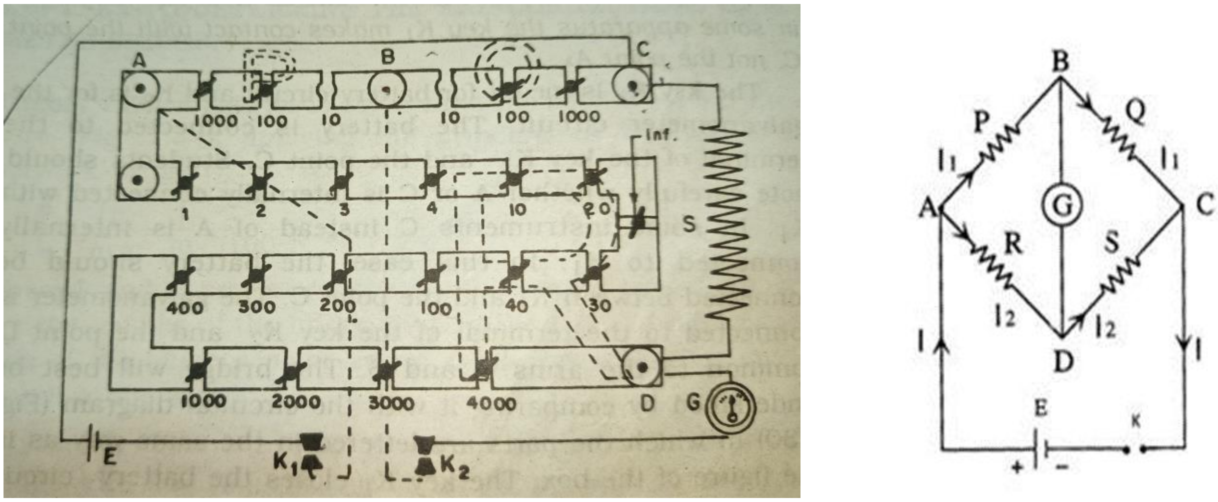


Fig. Circuit diagram of a P.O. Box to determine unknown resistance

Required equipment and devices:

1. PO box unknown resistance
2. zero-center galvanometer,
3. Cell,
4. commutator,
5. connecting wires.

Procedure:

1) Connect the terminals of the galvanometer between D and K_2 of the P.O. box, K_2 being internally connected to the point B. Connect the poles of the cell E through a rheostat Rh to the point K_1 and C, K_1 being internally connected to A. Connect the terminals of unknown resistance S to the points C and D.
2) Take out resistances 10 and 10 from the ratio arms BA and BC. See that alt other plugs in the box are tight. This means zero resistance in the third arm. Put the maximum resistance in the rheostat. Press the battery key K_1 and then press the galvanometer key K_2. Observe the direction of the deflection in the galvanometer. Next take out the infinity plug from the third arm and press the keys as done before. If opposite deflection is obtained then the connection is correct. If not check the connections again.
3) Then go on gradually reducing the resistance in the third arm until a resistance, say R_1, is found for which there is no deflection in the galvanometer when the circuit is closed. Then the unknown resistance S is given by $S = \frac{10}{10} R_1 = R_1$(say 5 ohms).
4) If instead of null point, there is a deflection in one direction with R_1 and an opposite deflection with (R_1 + l) in the third arm, the unknown resistance is partly integral and partly fractional i.e., it lies between 5 and 6 ohms.
5) Now take out the resistance of 100 ohms in the arms P (BA) keeping 10 ohms in the arm Q (BC) so that the ratio is now $\frac{P}{Q} = \frac{10}{100} = \frac{1}{10}$. Hence the null point should occur when the resistance in the third arm is of some value between $10R_1$ and 10 (R_1+1) i.e., between 50 and 6O (if R_1 =5);.

Observe the opposite deflection and as before narrow down the range to obtain the null point at R_2 = 53 (say).Then S = $\frac{53}{10}$= 5.3 ohms. In that case, the resistance is found correct to one decimal Place.

6) (If the null point cannot be obtained at this stage also i.e.., if opposite deflections are observed for R_2 and R_2 + 1 (viz. for 53 and 54) in the third arm, it ties between 5.3 and 5.4 ohms. Repeat the observations with 1000 ohms in P arm and 1O ohms in Q arm. The resistance in the third arm should be between 530 and 540 for which opposite deflections will be obtained. Narrow down the range to obtain a null point at R_3 = 535 (say).

   Then S = R/10 = 5.35 ohms (say). The resistance is now correct to two decimal Place.

7) If even at this stage there are opposite deflections for a change of resistance of I ohm in the third arm, the unknown resistance can be determined to the third decimal place by proportional parts. But it is futile to expect that much accuracy from the P.O. box. However, if it is desired to go further, proceed as follows: Count the number of divisions for which the galvanometer is deflected when R_3 is put in the third arm. Suppose it is d_1 divisions to the left. If now for (R_3 + l) in the third arm, the deflection is d_2 to the right, then for a change of t ohm in the third arm, the pointer moves through $d_1 + d_2$ divisions. Hence to bring the pointer to zero of the scale (i.e., for no deflection) a resistance $R_3 + \frac{d_1+d_2}{d_1}$ is to be inserted in the third arm. Hence the value of the unknown resistance S is given by S=1/100 ($R_3 + \frac{d_1+d_2}{d_1}$)

8) While taking the final reading with the ratio 1000: 10, reverse the current and take mean value of S.

Data collection:

Table 1: Reading for the Unknown resistance.

Value of P (Ω)	**Value of Q (Ω)**	**Value of R (Ω)**	**Value of S = $\frac{QxR}{P}$(Ω)**	**Mean , S(Ω)**
10	10			
100	10			
1000	100			
10	100			
100	1000			

Data analysis and demonstration:

The unknown resistance, $S = \frac{RQ}{P}$ = ………

Results and Discussions:

The unknown resistance is ……….. Ω

b) To verify the laws of series and parallel resistance by PO box

Theory: Resistance S are said to be connected in series when they are connected with the end of one joined to the beginning of the next and so on as shown in Fig. 7 34 [a].The equivalent resistance to a number of resistances connected in series is equal to the sum of the individual resistances, i.e.,

$R= R_1+R_2+R_3+R_4$ …………………..(l)

If ,then resistances are arranged with their respective ends connected to common terminals, they are said to be connected in parallel as shown in Fig. 7.34 (b) The reciprocal of equivalent resistance to a number of resistances connected in parallel is equal to the sum of the

$R= \frac{1}{R1+R2+R3+R4}$ ………………… (2)

Measuring R_1, R_2,R_3 etc. separately and the equivalent resistance R by connecting them in series and in parallel' the relation (l) and (2) may be verified.

Circuit Diagram:

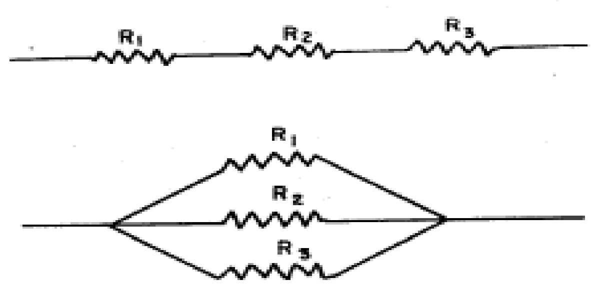


Fig. 7.34

Procedure:

1) Measure the resistances, R1, R2, resistances separately by means of a P.O. Box.
2) Join the resistance R_1, R_2, R_3 etc. in series as in Fig7.34 (a) and determine the equivalent resistance of the series combination by means of the P.O. Box' Show that relation (1) holds good.
3) [iii) Connect the resistances R_1, R_2, R_3 etc.in parallel as in Fig 7.34 (b] and determine the equivalent resistance of the parallel combination as before. Show that relation (2) holds good.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.

4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

Table 2: Reading for the series resistance, S_s

Value of P (Ω)	**Value of Q (Ω)**	**Value of R (Ω)**	**Series resistance, $S_s=\frac{QxR}{P}$(Ω)**	**Mean S_s(Ω)**
10	10			
100	10			
1000	100			

Table 3: Reading for the parallel resistance, S

Value of P (Ω)	**Value of Q (Ω)**	**Value of R (Ω)**	**Parallel resistance $S_p=\frac{QxR}{P}$(Ω)**	**Mean, S_p(Ω)**
10	10			
100	10			
1000	100			

Data analysis and demonstration:

Record data for R_1, R_2, R_3 etc. and for the combination.

Results and Discussions:

From the observed and calculated values of the equivalent resistances, show that they are equal. This verifies the laws of series and parallel

Conclusion:

The laws of series and parallel resistance is verified.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. https://cdac.olabs.edu.in/?sub=74&brch=9&sim=75&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. What is a P.O. Box and why is it so called?
2. What is the principle on which it works?

Post-lab viva sample question

1. Principle of Wheatstone's bridge, is it suitable for measuring very high or Low resistance?
2. If the resistance coils of the box be calibrated at 20; will they give the same value at other temperatures?