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 102**
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), Heat & Thermodynamics (Thermal conductivity, Pressure coefficient), Properties of Matter (Modulus of rigidity, Young's Modulus, Surface Tension), Physical Optics (Refractive Index).

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 ☑ Project show & project presentation ☑ Continuous lab performance
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**		
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 surface tension of water by capillary tube method	Week5
06	To determine the modulus of rigidity of a wire by Statical method.	Week7
	Mid Examination	Week6
07	To determine the modulus of rigidity of a wire by method of oscillations (dynamic method)	Week8
08	To determine the presser co-efficient of a gas at constant volume by constant volume air thermometer	Week9
09	To determine the refractive index of the material of a prism.	Week10
10	To determine the thermal conductivity of a bad conductor by Lees and Charlton's method	Week11
11	To verify the Newton's law of cooling of different materials and different liquids.	Week12
12	To determine the value of g, acceleration due to gravity, by means of Katter's Pendulum	Week13
	Final Examination	Week14

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.

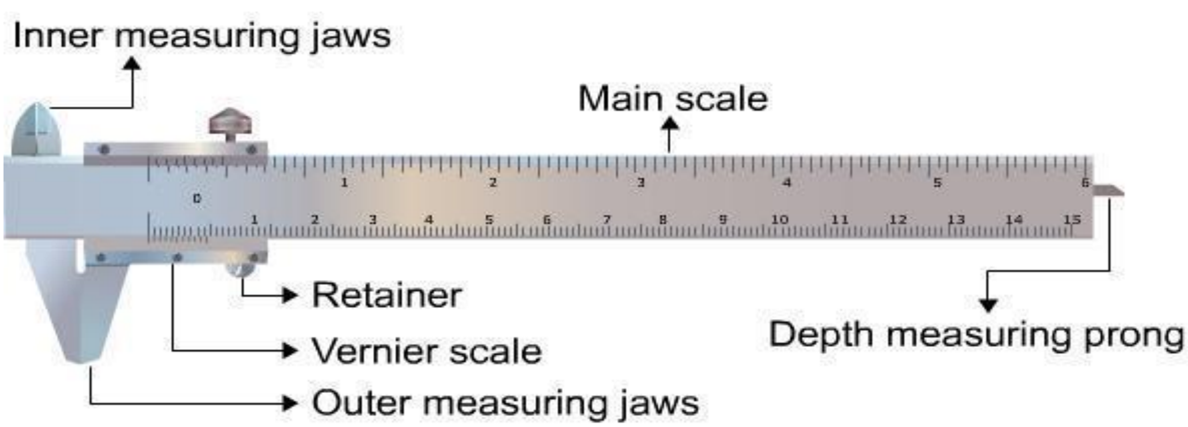


Figure-1

Vernier Constant (V.C.) calculation:

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

$\mathrm{V} = \mathrm{l} \times \mathrm{b} \times \mathrm{h}$……………………………..(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.

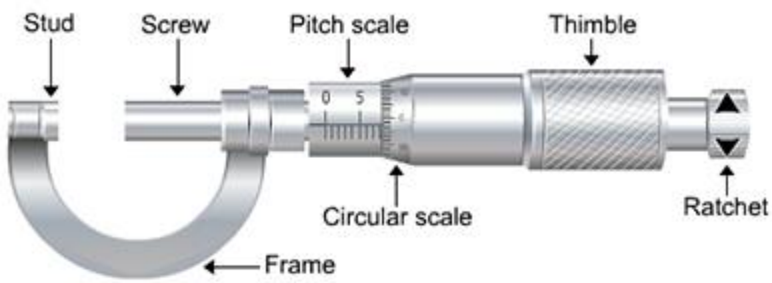


Figure-2

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.

Pitch of the Screw Gauge :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;

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

Least Count of the Screw Gauge

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;

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

Zero Error and Zero Correction of Screw Gauge:

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.

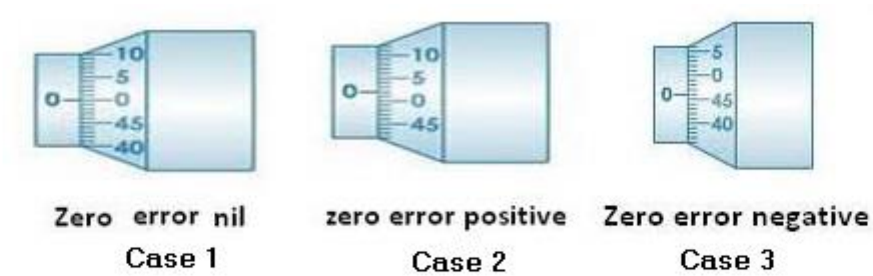


Figure-3

<u>To find the diameter of the lead shot:</u>

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)

<u>Apparatus:</u>

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.

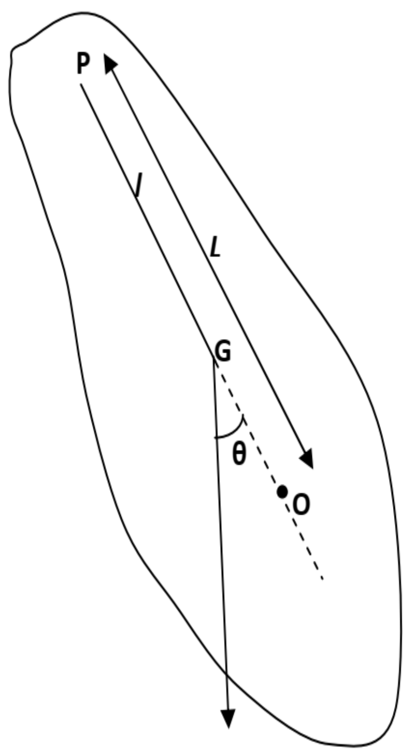


Figure-1

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 (θ ≈ 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

$g = \frac{4\pi^2 L}{T^2}$…………………………(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.

Apparatus:

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

Description of the apparatus (Compound Pendulum):

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.

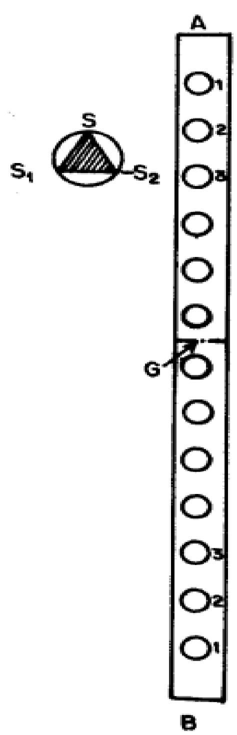


Figure-2: Compound pendulum

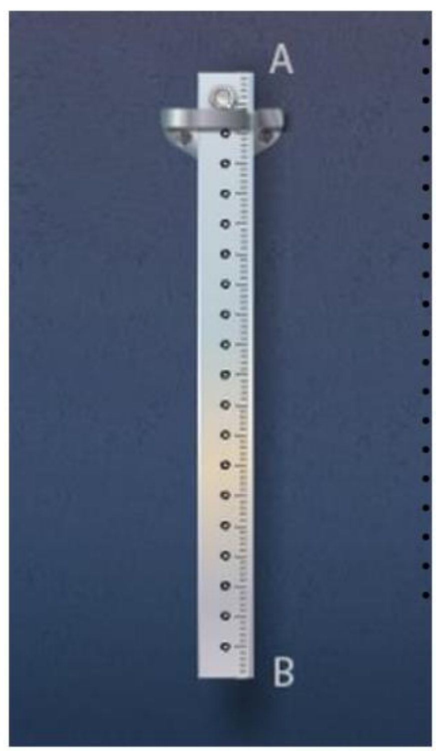


Figure-3: Compound pendulum

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.

<u>Table 1</u>: 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.

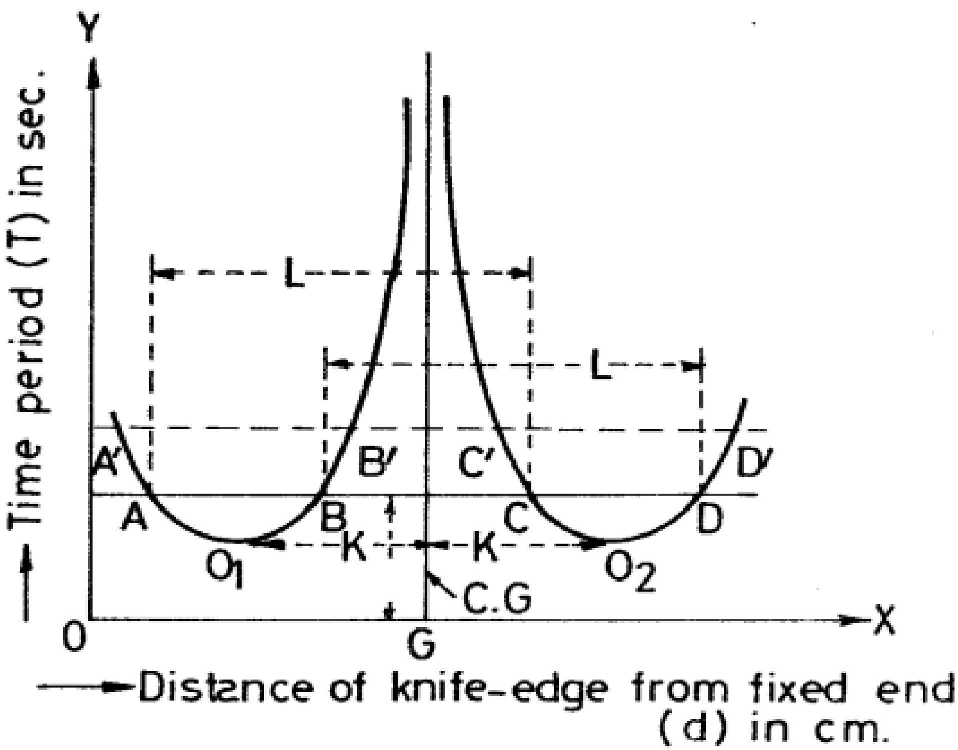


Figure-4

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

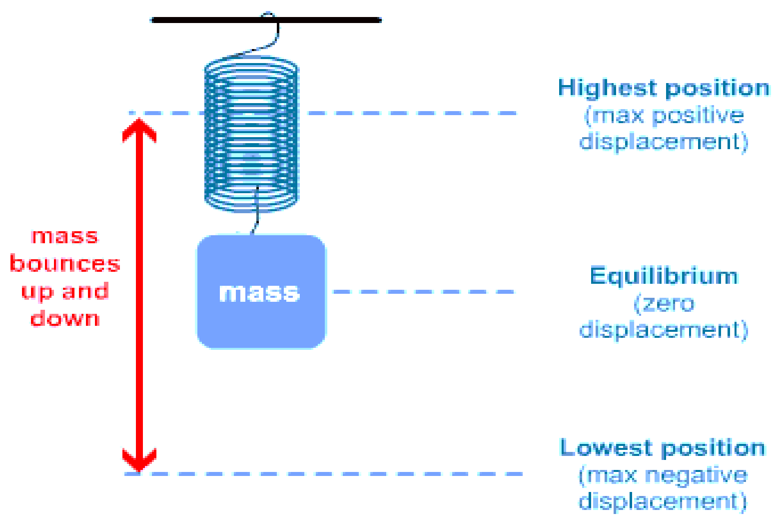
$$m\,g = k\,l$$

$$\Rightarrow \quad k = \frac{m}{l} x g$$

$$\Rightarrow \quad l = m_0\,\frac{g}{k} \text{---} \text{(i)}$$

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-

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



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

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

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

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,

$$T = 2\pi\sqrt{\frac{m_0 + m'}{k}} - - - - - - - - - - - - - (iv)$$

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:

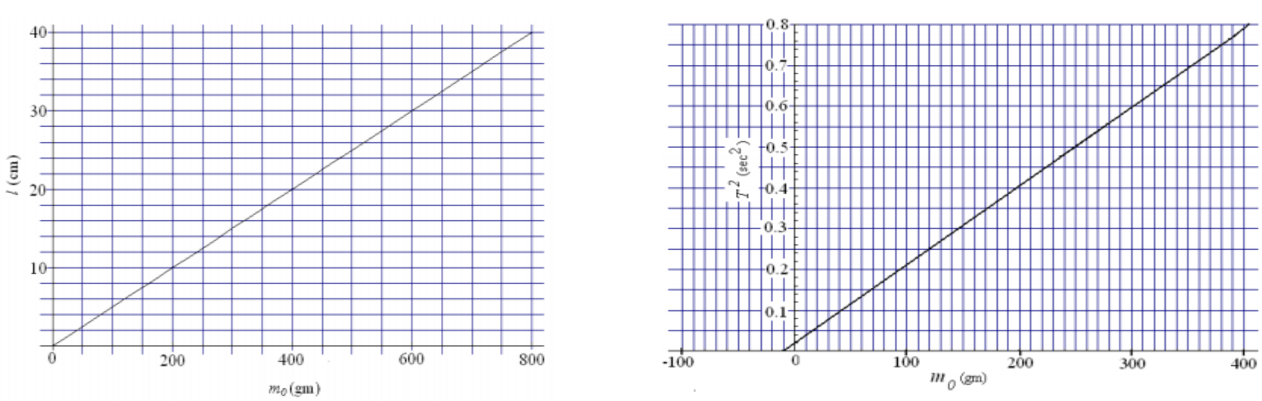
1. A spiral spring,
2. convenient masses with hanging arrangement,
3. a hook attached to a rigid framework of heavy metal rods,
4. weighing balance,
5. stop watch and
6. scale.

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	Extension l	Times for 10 oscillation	Total Period $T = \frac{t}{10}$	Mean T Sec	T^2

	m_0 gm	cm	t_1	t_2	(Sec.)			
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	Correspon ding 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:
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6. Use equipment with care for the purpose for which it is intended.
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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) 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. = $(1-\frac{49}{50})\times 0.5$ 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 $y = N \times L.C.$ (cm)	Total Reading = x + y cm	MSR x (cm)	VSD N	VC (cm)	VSR $y = N \times LC$ (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.

<u>Experiment No.</u> 05

<u>Name of the Experiment:</u>
To determine the surface tension of water by capillary tube method

<u>Objectives:</u>

- To determine the height of the column of water.
- To determine the diameter of the capillary tube.
- To determine surface tension of the water.

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
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:

When glass is dipped into a liquid like water, it becomes wet. When a clean fine bore glass capillary is dipped into such a liquid it is found to rise in it, until the top of the column of water is at a vertical height ‘*h*’ above the free surface of the liquid outside the capillary. The reason for this rise is the surface tension, which is due to the attractive forces between the molecules of the liquid. Such forces called cohesive forces try to make the surface of the liquid as small as possible. This is why a drop of liquid is of spherical shape.
Since the surface tension tries to reduce the surface of a liquid we can define it as follows. If an imaginary line of unit length is drawn on the surface of a liquid, then the force on one side of the line in a direction, which is perpendicular to the line and tangential to the surface, is called surface tension.

When the liquid is in contact with the glass then on the line of contact the cohesive forces (or surface tension) try to pull the liquid molecules towards the liquid surface and the adhesive forces *i.e.* the forces between the molecules of the glass and the liquid try to pull the liquid molecules towards the glass surface. Equilibrium results when the two forces balance each other.

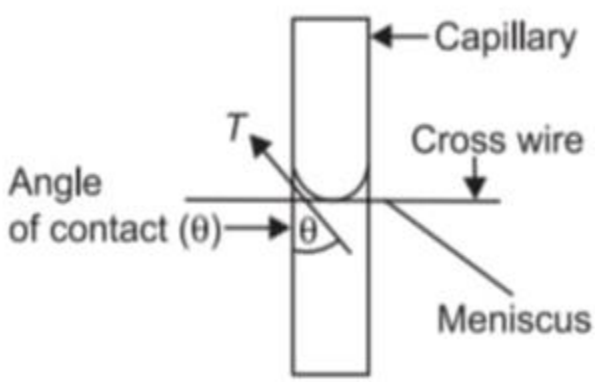

Fig. 1: Magnified view of the meniscus in the capillary tube

Such equilibrium arises after the water has risen in the capillary to a height of ‘*h*’. This column has weight equal to *mg* where *m* is the mass of the water in the column. This balances the upward force due to the surface tension which can be calculated as follows:
The length of the line of contact in the capillary between the surface of the water and the glass is $2\pi r$

where 'r' is the radius of the capillary. As seen from Fig.1, the surface tension T acts in the direction shown and θ is called the angle of contact. The upward component of T is given by $T\cos\theta$ and therefore, recalling that T is the force per unit length, we get the total upward force equal to $2\pi rT\ \cos\theta$. This must balance the weight mg and we have

$$mg = 2\pi rT\ \cos\theta$$

For water-glass contact = 0° and so cosθ = 1

Therefore, $mg = 2\pi rT$ (1)

Now $m = \rho V$ (2)

Where ρ is the density of the liquid and V is the Volume of the column of water

Since radius of the capillary is 'r'

$$V = \pi r^2 h \text{ + volume in meniscus}$$

and the volume of liquid in the meniscus = volume of cylinder radius 'r' & height 'r' – volume of hemisphere of radius 'r'

i.e. volume in meniscus = $\pi r^3 - 2/3\ \pi r^3 = 1/3\ \pi r^3$

Therefore $V = \pi r^2 h + 1/3\ \pi r^3$

$$= \pi r^2 \left(h + \frac{1}{3}r\right) \quad (3)$$

Substituting the value of V from Eq. (3) in Eq. (2) we obtain

$$m = \rho\ \pi r^2 \left(h + \frac{1}{3}r\right)$$

For water and so, Eq. (1) becomes

$$2\pi rT = \rho\ \pi r^2 \left(h + \frac{1}{3}r\right)g$$

$$T = ½\ \rho g r\left(h + \frac{1}{3}r\right) \qquad \text{in C.G.S. units,}$$

ρ = 1 and we finally obtain the formula for a glass capillary dipping in water to be

$$T = ½\ g r\left(h + \frac{1}{3}r\right) \qquad \text{dynes/c.m. at......°c}$$

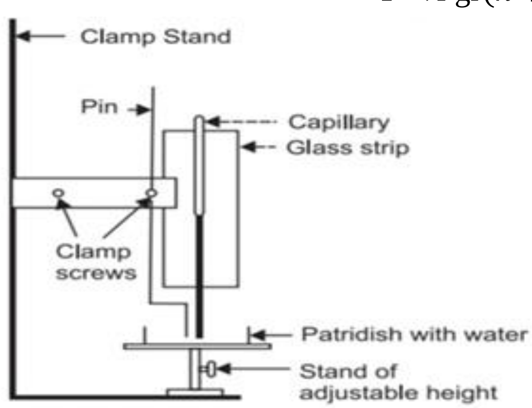

Fig.2: Setup for the observing capillary rising

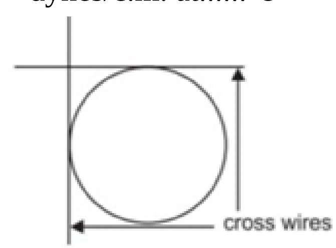

Fig. 3: Measurement of the capillary radius

Apparatus:

1. A clean and dry capillary tube,
2. A tipped pointer,
3. A beaker containing water,
4. A travelling microscope,
5. Adjustable wooden stand,

6. Clamps and stand.

Experimental Procedure:

To set up the apparatus:

- Place the adjustable height stand on the table and make its base horizontal by leveling the screws.
- Fix the capillary tube and the pointer in a cork, and clamp it in a rigid stand so that the capillary tubes and the pointer become vertical.
- Adjust the height of the vertical stand, so that the capillary tubes dip in the water in an open beaker.
- Adjust the position of the pointer, such that its tip just touches the water surface.

To find the capillary rise:

- Find the least count of the travelling microscope for the horizontal and the vertical scale.
- Make the axis of the microscope horizontal.
- Adjust the height of the microscope using the height adjusting screw.
- Bring the microscope in front of the capillary tube and clamp it when the capillary rise becomes visible.
- Make the horizontal cross wire just touch the central part of the concave meniscus.
- Note the reading of the position of the microscope on the vertical scale.
- Now, carefully remove the beaker containing water
- Move the microscope horizontally and bring it in front of the pointer.
- Lower the microscope and make the horizontal cross wire touch the tip of the pointer.
- Corresponding vertical scale readings are noted.
- The difference in the two readings (i.e., height of water meniscus and height of the tip of pointer) will give the capillary rise of the given liquid.
- We can repeat the experiment by changing the height of the wooden stand.

To find the internal diameter of the capillary tube:

- Place the capillary tube horizontally on the adjustable stand.
- Focus the microscope on the end dipped in water.
- Make the horizontal cross- wire touch the inner circle at A (fig i). Note microscope reading on the vertical scale.
- Raise the microscope to make the horizontal cross wire touch the circle at B (fig ii). Note the vertical scale reading.
- The difference between the two readings will give the vertical internal diameter (AB) of the tube.

- Move the microscope on the horizontal scale and make the vertical cross wire touch the inner circle at C (fig iii). Note microscope reading on the horizontal scale.
- Move the microscope to the right to make the vertical cross wire touch the circle at D (fig iv). Note the horizontal scale reading.
- The difference between the two readings will give the horizontal internal diameter (CD) of the tube.

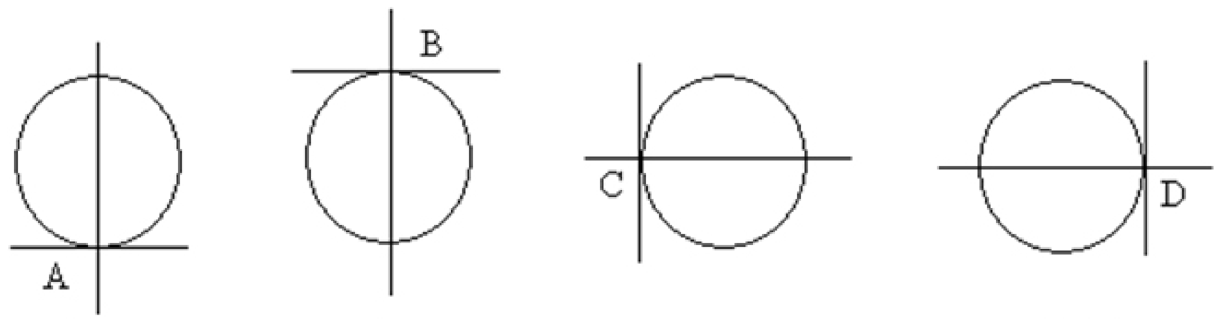

fig (i) fig (ii) fig (iii) fig (iv)

- We can calculate the diameter of the tube by calculating the mean of the vertical and horizontal internal diameters. Half of the diameter will give the radius of the capillary tube.

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:

1. Least count of the travelling microscope = Value of one MSD / Number of divisions on the Vernier

=0.5mm/50 = 0.01 mm = 0.001 cm

Table 1: Measurement of inside radius (r) of the tubes

Tube no.	Readings in cm for the bore										Difference diameter $D=X_2 \sim X_1$ (cm)	Radius $r = D/2$ (cm)
	Left side (X_2)					Right side (X_1)						
	M.S.R (cm)	V.S. D	V.C (cm)	V.S.R (cm)	Total Reading (x_1) cm	M.S.R (cm)	V.S. D	V.C (cm)	V.S.R (cm)	Total Reading (x_2) cm		
A												
B												

Table 2: Determination of the height of the column of water ‘h’:

No. of observation	Radius of the water meniscus					Reading at the tip of pointer					Height, h = h_1-h_2 cm
	MSR x (cm)	VSD N	LC (cm)	CSR y = N × L.C. (cm)	Total Reading = x + y h_1 cm	MSR x (cm)	VSD N	LC (cm)	CSR y = N × L.C. (cm)	Total Reading = x + y h_2 cm	
1											
2											
3											
4											
5											

Calculation: The surface tension of water at room temperature,

$$T = \frac{1}{2}\rho g r\left(h + \frac{1}{3}r\right) \quad \text{dynes/cm}$$

Here, cos θ = 1 and density, =1

h= in cm

r= in cm

Results and Discussions:

The surface tension of water is = dynes/cm.

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 capillarity?

2. What are the cohesive and adhesive forces?

3. What is surface tension?

Post-Lab Questions:

1.State what factors effect on surface tension

<u>Experiment No.:</u> 06

<u>Name of the Experiment:</u>

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

<u>Objectives of the Experiment:</u>

- 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**

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:

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

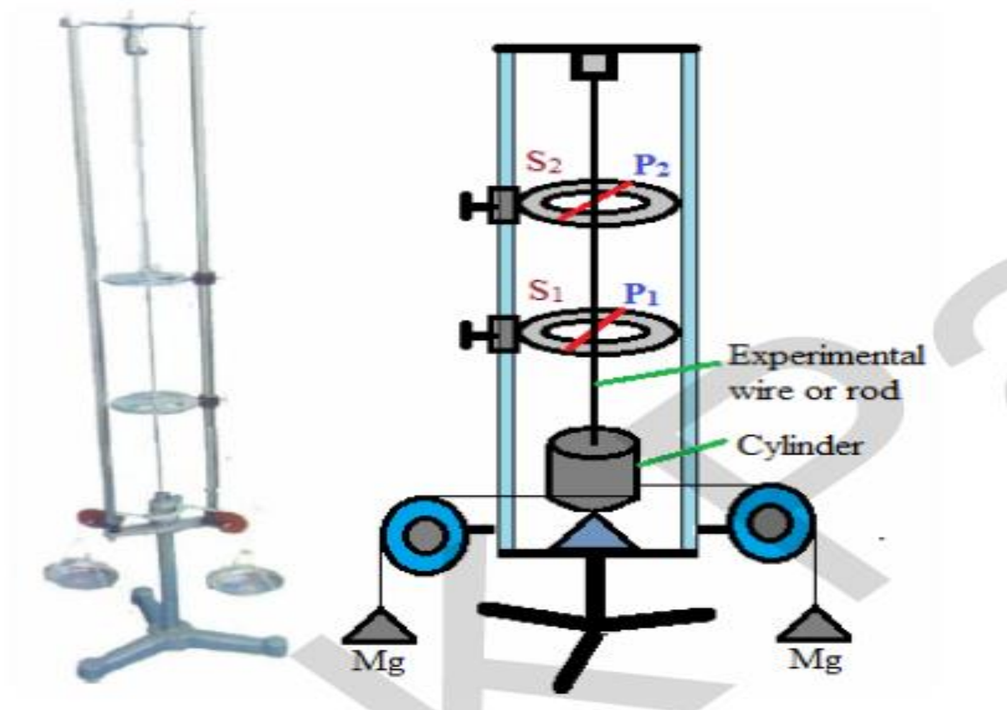

Figure-1: Diagram of Barton's Apparatus

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.

<u>Data Table:</u>

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. 07

<u>Name of the Experiment:</u>

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

<u>Objectives:</u>

- 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
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

<u>Theory:</u>

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

$$I = \frac{1}{2} \times Mass\ \times Radius^2\ \ldots\ldots\ (2)$$

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.

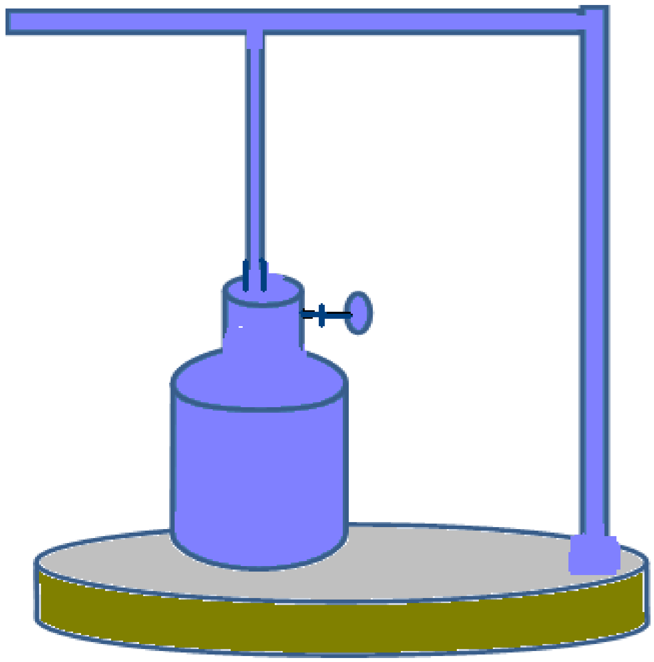

Fig. 1: Schematic diagram of Rigidity modulus experimental set-up

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.
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5. Use goggles:
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    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. 08

Name of the Experiment:

Determination of the presser co-efficient of a gas at constant volume by constant volume air thermometer

Objectives:

To determine the presser co-efficient of a gas at constant volume by constant volume air

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
08	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:

According to Charles law, If V_t and Vo be the volumes of a gas at t° C and O°C respectively and α_p be the Co-efficient of expansion of gas, then

$V_t = V_o\,(1+\alpha_p t)$ …………. (1)

Or $\alpha_p = \frac{Vt-Vo}{Vot}$………..(2)

Pressure remain constant.

Now gases, such as carefully dried air, behave approximately as ideal gas, for which boyle's law is strictly valid. Hench if T and T_o are absolute temperatures corresponding to the temperature t° C and O°C respectively and n the number of moles of gas used, then

$PV_t = nRT$

$PV_o = nRT_o$ ………………..(3)

$\therefore \frac{Vt-Vo}{Vo} = \frac{T-\mathbf{To}}{To} = \frac{t}{To}$…………(4)

But, by definition, the co-efficient of increase of volume at constant pressure

$\alpha_p = \frac{Vt-Vo}{Vot}$

Hence $\alpha_p = \frac{Vt-Vo}{Vot} = \frac{1}{To}$ ……………………..(5)

Therefore, if the volumes V_t and V_o of a gas can be determined at any temperature at t° C and O°C respectively, α_p can be obtained from equation (2) which should be equal

$t_o = \frac{1}{To}$

Apparatus:

1. The constant pressure air thermometer
2. Steam boiler
3. Thermometer

Experimental Procedure:

1. Suspend a thermometer, reading to a tenth of degree, in the bath so that its bulb is very close to bulb B. Adjust the level of acid in the two arms to the same height. carefully note down the temperature of water in the jar and find out the volume of enclosed air from graduations on the stem below B.

2. Now allow steam from a boiler to pass through the tube . E unit the temperature of the bath is raised by about 5°C . Maintain this temperature steady for at least five minutes by carefully stirring the bath . it may also be necessary to regulate the steam supply by intern mitten heating of the boiler .As a result of the increase of temperature ,air in the bulb B will expand and will push down the acid which rises in other limb. Again adjust the level of the acid in the arm to same height by allowing the acid to drip out through the cock C. Note Down the steady temperature and the corresponding volume of air.

3. Repeat the process several times, each time raising the temperature in steps of about 5°C so that at least 8-10 sets of reading are obtained for drawing the graph . However, the maximum temperature o the bath should be below 80°C . Otherwise the increase in volume of gas would be so much that a portion of the gas escape the closed limb.

4. Note down the barometric pressure before and after the experiment.

5. Plot a graph with temperature as the abscissa and volume as the ordinate . IT should be straight line which when proceed backwards will cut the volume –axis at a certain height . this is the required volume V_o of the gas at O°C.
   Use this value of V_o an d the volume V_t at fairly high temperate ,which should be obtained from the graph ,to calculate α_p from the equation (2) .See whether the value of α_p thus obtained . corresponds to equation (5).

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: Data for pressure - temperature record

No. of observation	**Temperature in °C**	**Reading in cm of the mercury level in the**		**Difference of two levels in cm** $H=R_1 \sim R_2$	**Pressure of gas in cm of mercury** $P= P_o \pm h$
		Open limb (R_1)	**Closed limb constant level at** (R_2)		
1.					
2.					
3.					
4.					
5.					
6.					

7.					
8.					
9.					
10.					

Calculation:

$$\alpha_V = \frac{P_t - P_o}{P_o\, t} \quad \text{per } ^\circ\text{C}$$

Results and Discussions:

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 thermal Equilibrium?
2. What is pressure co-efficient?

Post-Lab Questions:

1. How can you find it?

Experiment No.: **9**

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	Correspon ding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools

09	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.

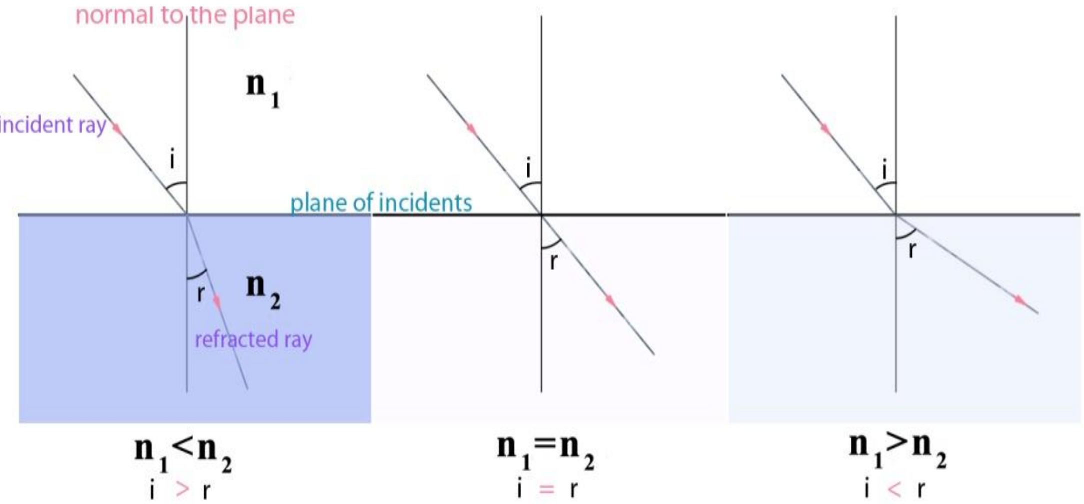
$$\frac{\sin(i)}{\sin(r)} = \frac{n_2}{n_1} \quad \dots\dots\dots \ (1)$$

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.

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

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.

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

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

<u>**Apparatus:**</u> Spectrometer, Prism, prism clamp, sodium vapour lamp, lens etc.

<u>**Description of Apparatus:**</u>

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.

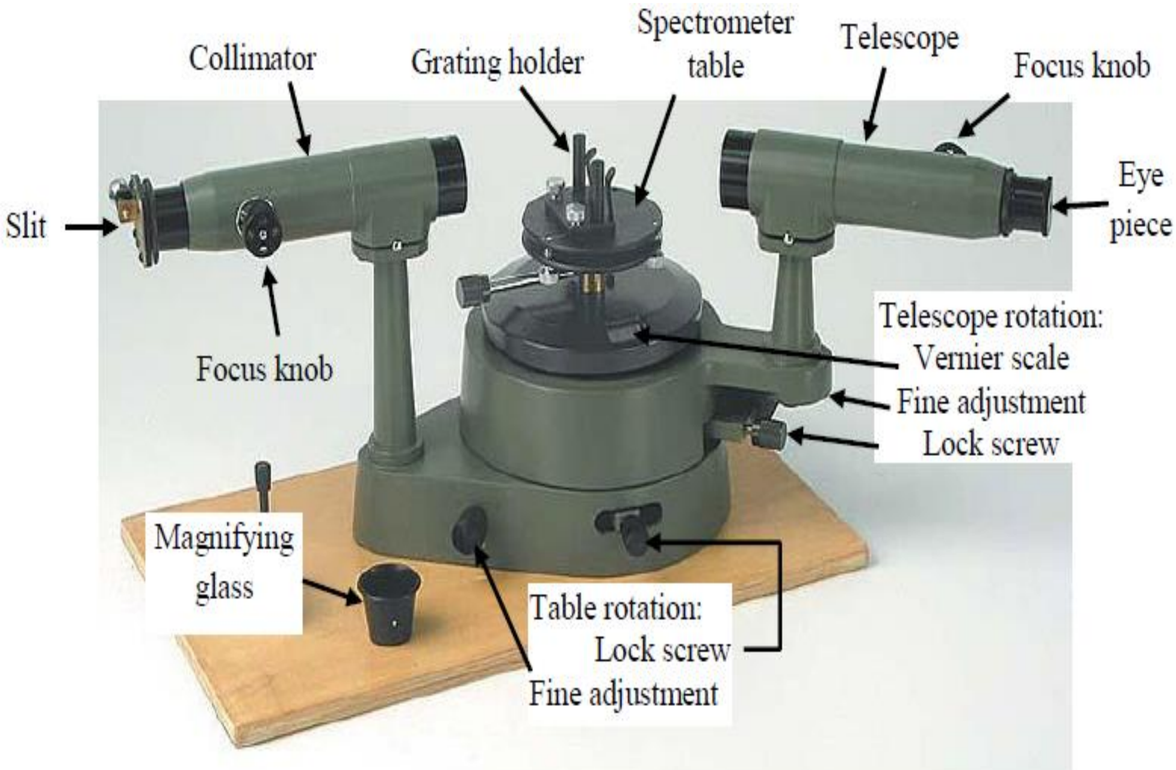


Fig. 1: Spectrometer and its components.

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.

Experimental Procedures:

Preliminary adjustments:

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.

To determine the angle of the Prism:

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, $A=\theta/2$

To determine the Angle of minimum deviation:

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.

Data Collection:

Table 1: Determination of angle of Prism

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

Table 2: Determination of angle of minimum deviation

No. of obs.	Readings for the minimum deviation position					Readings for the direct position					Angle of minimum deviation (δm)=(M-N)	Mean (δm)
	M.S.R	V.S.D	V.C	Value of V.S.R	Total Reading N	M.S.R	V.S.D	V.C	Value of V.S.R	Total Reading M		
1												
2												
3												

<u>Calculation:</u>

The refractive index of the material of Prism is

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

<u>Results and Discussions:</u>

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

<u>Conclusion:</u>

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

<u>References:</u>

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.: 10

Experiment Name: To determine the thermal conductivity of a bad conductor by Lees and Chorltons method.

Objectives of the Experiment:

To determine the thermal conductivity of a bad conductor

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
10	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 Lee's Disc experiment determines an approximate value for the thermal conductivity k of a poor conductor like glass, cardboard, etc. The procedure is to place a disc made of the poor conductor, radius r and thickness x, between a steam chamber and two good conductivity metal discs (of the same metal) and allow the setup to come to equilibrium, so that the heat lost by the lower disc to convection is the same as the heat flow through the poorly conducting disc. The upper disc temperature T_2 and the lower disc temperature T_1 are recorded. The poor conductor is removed and the lower metal disc is allowed to heat up to the upper disc temperature T_2. Finally, the steam chamber and upper disc are removed and replaced by a disc made of a good insulator. The metal disc is then allowed to cool through $T_1 < T_2$ and toward room temperature T_0. The temperature of the metal disc is recorded as it cools so a cooling curve can be plotted. Then the slope s1 $=\Delta T/\Delta t$ of the cooling curve is measured graphically where the curve passes through temperature T_1.

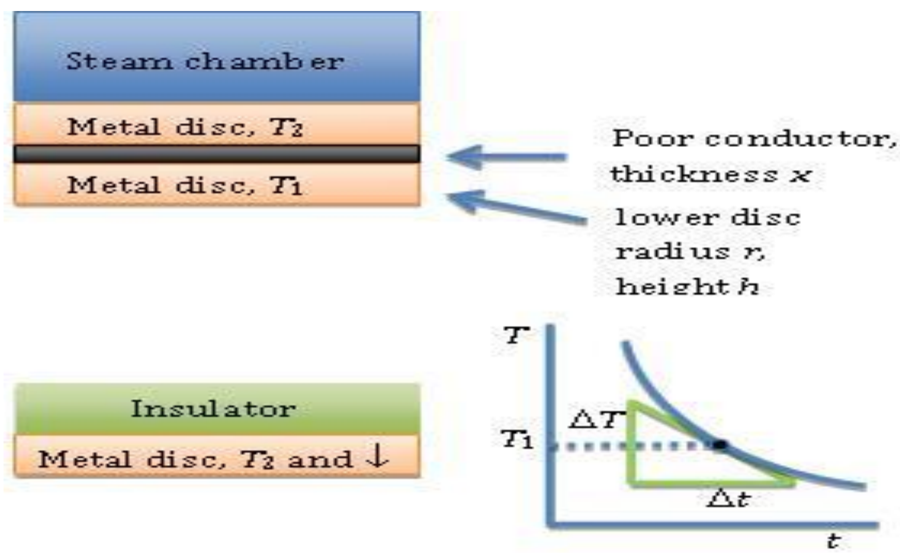


Fig. 1: Lee’s disc arrangement

At the steady state, rate of heat transfer (H) by conduction is given by;

$$H = kA\left[\frac{T_2 - T_1}{x}\right]$$

Where,

K is Thermal conductivity of the sample;

A is Cross sectional area;

T_2 - T_1 is Temperature difference across the sample;

x is Thickness of the bad conductor (see figure 1)

The sample is an insulator. It is in the form of a thin disc with large cross sectional area ($A = \pi r^2$) compared to the area exposed at the edge ($a = 2\pi rx$) in order to reduce the energy loss. Rate of energy transfer across the sample can be increased by keeping 'x 'small and 'A 'large. Keeping x small means the apparatus will reach a steady state quickly.

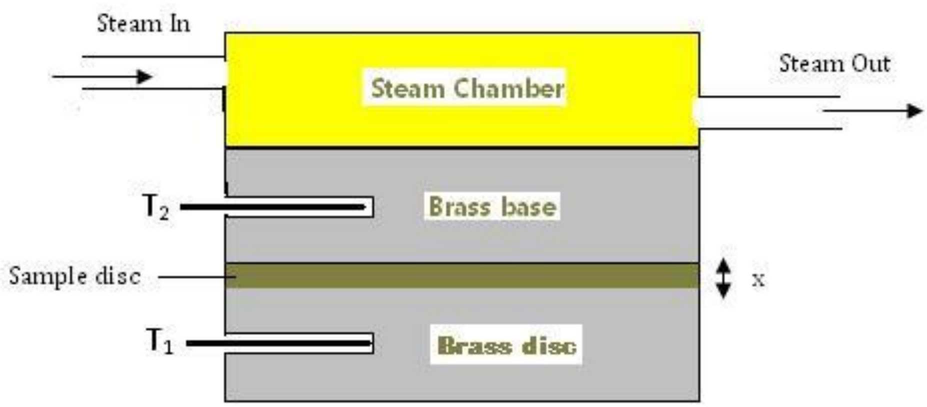


Fig. 2: Experimental Arrangement

The thin sample of disc is sandwiched between the brass disc and brass base of the steam chamber (see figure 2). The temperature of the brass disc is measured by thermometer T_1 and the temperature of the brass base is measured by thermometer T_2. In this way the temperature difference across such a thin disc of sample can be accurately measured.

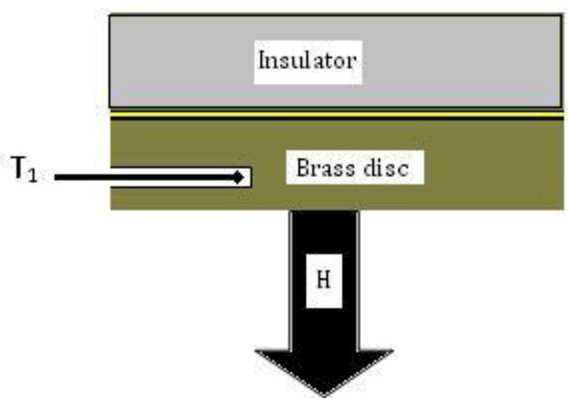


Fig. 3:

The temperatures T_1 and T_2 are constant when the apparatus is in steady state. Then the rate of heat conducted through the brass disc must be equal to the rate of heat loss due to cooling from the bottom of the brass disc by air convection. By measuring how fast the brass disc cools at the steady state temperature T_1, the rate of heat loss can be determined.

It is shown in figure 3. If the disc cools down at a rate, $\frac{dT}{dt}$ then the rate of heat loss is given by:

$$H = mc\frac{dT}{dt}$$

Where,

m- Mass of the brass disc

c - Specific heat capacity of brass.

At steady state, heat conducted through the bad conductor per second will be equal to heat radiated per second from the exposed portion of the metallic disc.

$$kA\left[\frac{T_2 - T_1}{x}\right] = mc\frac{dT}{dt}$$

$$k = \frac{mc\frac{dT}{dt}}{A\frac{(T_2 - T_1)}{x}}$$

Where,

k - Coefficient of thermal conductivity of the sample,

A - Area of the sample in contact with the metallic disc,

x - Thickness of the sample,

T_2- T_1 -Temperature difference across the sample thickness,

m - Mass of the metallic disc,

c - The Heat capacity of the metallic disc,

$\frac{dT}{dt}$ - Rate of cooling of the metallic disc at T_2.

Apparatus: Specimen of a bad conductor, two metallic disks, Heat source, Thermometers etc.

Experimental Procedures:

1. Determine the mean thickness of metal disc and bad conductor with a screw gauge.
2. Determine the diameter of metal disc and bad conductor with Vernier calipers.
3. Find the mass M of the metal disc by a balance.

4. Keep the bad conductor between metal disc and steam chamber.
5. Introduce thermometers through holes in the steam chamber and in the metal disc.
6. Pass steam through the chamber until the temperature indicated by thermometers become steady and note the steady temperature.
7. Remove the bad conductor.
8. Remove the steam chamber when the temperature of the metal disc is $10\,^{0}$C above its steady temperature.
9. Start a stop clock and take time-temperature observation till the temperature of the disc is $10\,^{0}$C below its steady state.
10. Plot a time-temperature graph.

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:
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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: Diameter of the Specimen disc.

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: Thickness of the disc shaped specimen.

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							

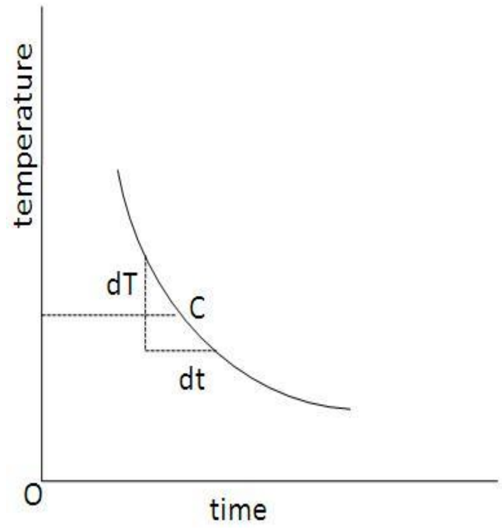
Table 3: Time temperature record of B and A

Time in minutes	0	5	10	15	20	25	30	35	40	45	50
θ_1											
θ_2											

Table 5=4: Time temperature record of A during cooling

Time in minutes		0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
Temperature in °C θ_2											
5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9	$9\frac{1}{2}$	10	$10\frac{1}{2}$

Calculation:

From the graph, dT =..........^{0}C dt=............s dT/dt=.........^{0}Cs^{-1} Specific heat capacity of the metal disc c =...........JKg^{-1}K^{-1} Coefficient of thermal conductivity of the given material, $k = \frac{mc(\frac{dT}{dt})x}{\pi r^2 (T_2 - T_1)} \times \left[\frac{r + 2h}{2(r + h)}\right]$ **⇒ K = …………….**	

Results and Discussion:

The Coefficient of thermal conductivity of the given material, k =.....................Wm^{-1}K^{-1}

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 thermal conductivity?
2. What is oscillation?
3. What is time period?

Post-Lab Questions:

1. Mention some names of bad conductor?

Experiment Number: 11
Name of the Experiment:

To verify the Newton's law of cooling of different materials and different liquids

Objectives:

- The aim of the experiment is to verify Newton's Law of Cooling of different materials and different liquids.
- To draw the cooling curve.

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:** 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:

Temperatures difference in any situation results from energy flow into a system or energy flow from a system to surroundings. The former leads to heating, whereas latter leads to cooling of an object. Newton's Law of Cooling states that the rate of temperature of the body is proportional to the difference between the temperature of the body and that of the surrounding medium. This statement leads to the classic equation of exponential decline over time which can be applied to many phenomena in science and engineering, including the discharge of a capacitor and the decay in radioactivity.

Newton's Law of Cooling is useful for studying water heating because it can tell us how fast the hot water in pipes cools off. A practical application is that it can tell us how fast a water heater cools down if you turn off the breaker when you go on vacation.

Suppose that a body with initial temperature T_1°C, is allowed to cool in air which is maintained at a constant temperature T_2°C.

Let the temperature of the body be T °C at time t. Then by Newton's Law of Cooling,

$\frac{dT}{dt} = -k\ (T - T_2)$…………………..(1)

Where k is a positive proportionality constant. Since the temperature of the body is higher than the temperature of the surroundings then $T\text{-}T_2$ is positive. Also the temperature of the body is decreasing i.e. it is cooling down and rate of change of temperature is negative.

$\frac{dT}{dt} < 0$

The constant 'k' depends upon the surface properties of the material being cooled.

Initial condition is given by $T{=}T_1$ at t = 0

Solving Eq. (1)

$-kt = \log(T - T_2) + \log C$

Or, $T - T_2 = Ce^{-kt}$…………………..(2)

Applying initial conditions;

, $C = T_1 - T_2$

Substituting the value of C in equation (2) gives

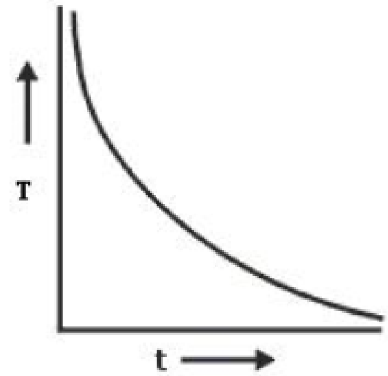
$T = T_2 + (T_1 - T_2)e^{-kt}$

This equation represents Newton's law of cooling.

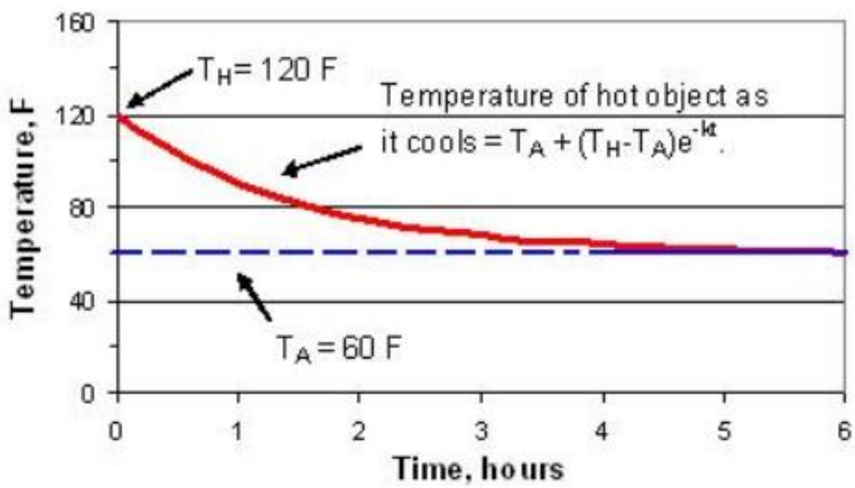
If $k < 0, \lim t \to \infty, e^{-kt} = 0\ and\ T = T_2$

Or we can say that the temperature of the body approaches that of its surroundings as time goes.

The graph drawn between the temperature of the body and time is known as cooling curve. The slope of the tangent to the curve at any point gives the rate of fall of temperature.

In general, $T\ (t) = T_A + (T_H - T_A)e^{-kt}$ where, T(t) = Temperature at time t, T_A = Ambient temperature (temp of surroundings), T_H = Temperature of hot object at time 0, k = positive constant and t = time.	

Example of Newton's Law of Cooling:

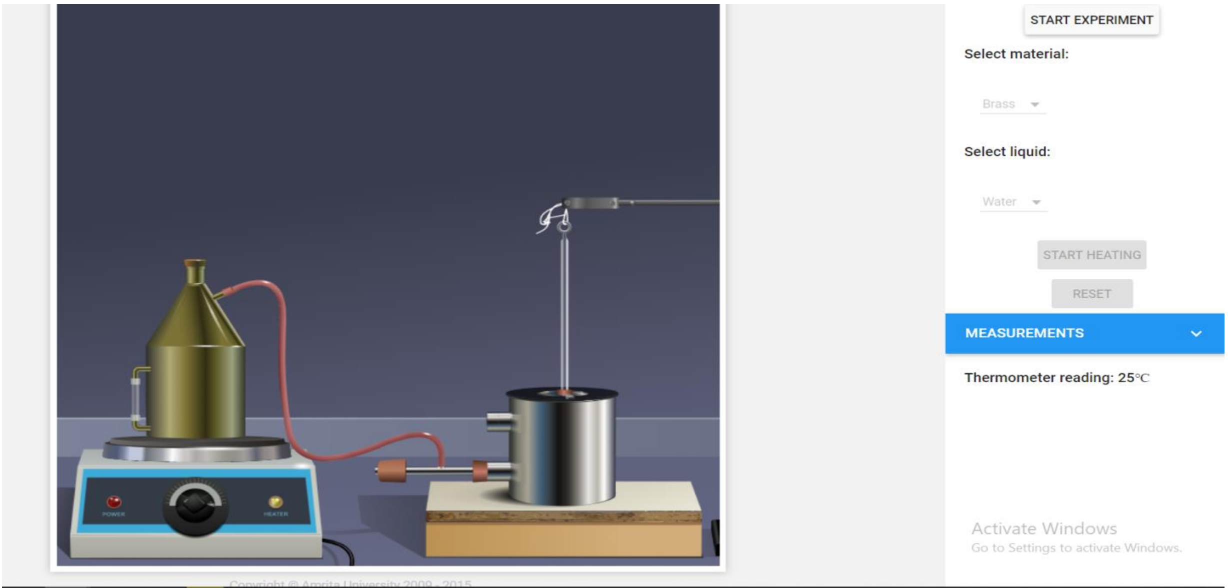


This kind of cooling data can be measured and plotted and the results can be used to compute the unknown parameter k. The parameter can sometimes also be derived mathematically.

Apparatus: Calorie meter, heat source, thermometers

Experimental Procedure:

The calorie meter is filled $2/3^{rd}$ with the given liquid and is heated to a temperature of 80°C. This liquid will act as a hot body which is subjected to cooling. The thermometer is inserted in to the calorimeter. When the temperature reading is 70°C the stopwatch is started. The time readings are noted for every 5° fall of temperature up to the room temperature. The readings are tabulated. A graph is drawn with temperature θ along Y axis and time (t) along X axis, dθ/dt is found by taking slopes to tangents drawn at various temperatures on the cooling curve. Hence Newton's law of cooling is verified.



Precautions:

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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:
   i) when heating anything.
   ii) when using any type of projectile.
   iii) when instructed to do so.
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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.

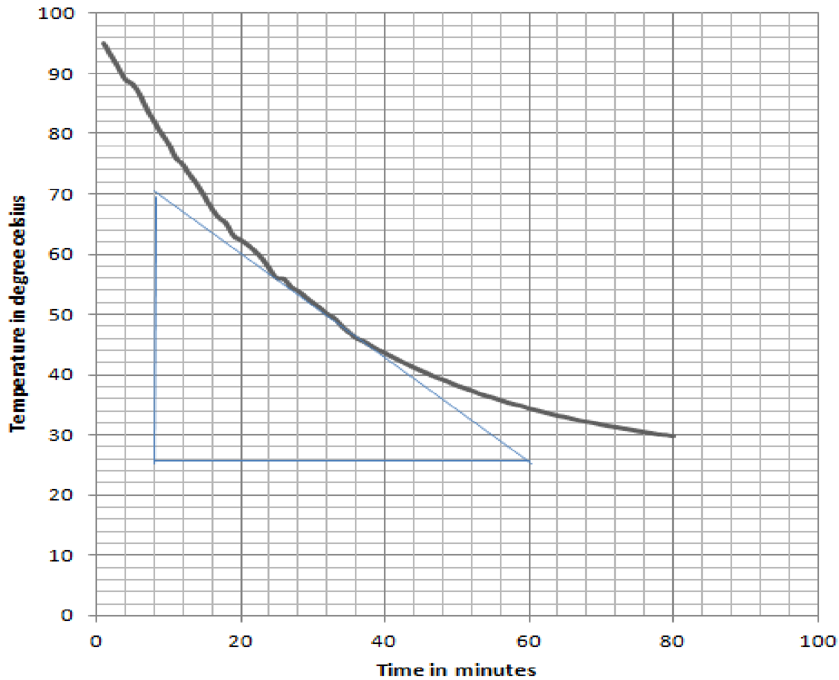
Table: Data for time and Temperature

Time (Sec)	Temperature (℃)		Time (Sec)	Temperature (℃)
1			41	
2			42	
3			43	
4			44	
5			45	
6			46	
7			47	
8			48	
9			49	
10			50	
11			51	
12			52	
13			53	
14			54	
15			55	
16			56	
17			57	
18			58	
19			59	
20			60	
21			61	
22			62	
23			63	
24			64	
25			65	
26			66	
27			67	
28			68	
29			69	
30			70	
31			71	
32			72	
33			73	
34			74	
35			75	

36			76	
37			77	
38			78	
39			79	
40			80	

Calculations:

Cooling Curve:



Calculations:

Slope, $\frac{dT}{dt} = \frac{T_2 - T_1}{t_2 - t_1} = . \ldots \ldots \ldots \ldots degree/sec$

Results and Discussions:

Newton's Law of Cooling is verified.

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 thermal Equilibrium?

Post-Lab Questions:

1. State Newton's Law of Cooling.

<u>Experiment No.:</u> 12

<u>Name of the Experiment:</u>

To determine the value of g, acceleration due to gravity, by means of Kater's Pendulum

<u>Objectives of the Experiment:</u>

- To study the motion of Katter's 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	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:** 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:

Kater's pendulum, shown in Fig. 1, is a physical pendulum composed of a metal rod 1.20 m in length, upon which are mounted a sliding metal weight W_1, a sliding wooden weight W_2, a small sliding metal cylinder w, and two sliding knife edges K_1 and K_2 that face each other. Each of the sliding objects can be clamped in place on the rod. The pendulum can be suspended and set swinging by resting either knife edge on a flat, level surface. The wooden weight W_2 is the same size and shape as the metal weight W_1. Its function is to provide as near equal air resistance to swinging as possible in either suspension, which happens if W_1 and W_2, and separately K_1 and K_2, are constrained to be equidistant from the ends of the metal rod. The centre of mass G can be located by balancing the pendulum on an external knife edge. Due to the difference in mass between the metal and wooden weights W_1 and W_2, G is not at the centre of the rod, and the distances h_1 and h_2 from G to the suspension points O_1 and O_2 at the knife edges K_1 and K_2 are not equal. Fine adjustments in the position of G, and thus in h_1 and h_2, can be made by moving the small metal cylinder w.

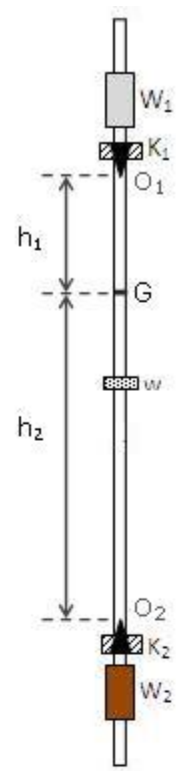


Figure 1

In Fig. 1, we consider the force of gravity to be acting at G. If h_i is the distance to G from the suspension point O_i at the knife edge K_i, the equation of motion of the pendulum is

$$I_i\ddot{\theta} = -Mgh_i \sin\theta$$

And the equation of motion of the simple pendulum

$$\ddot{x} = -\frac{g}{l_i}x$$

We see that the two equations of motion are the same if we take

$$\frac{Mgh_i}{I_i} = \frac{g}{l_i} \dots\dots\dots \quad (1)$$

It is convenient to define the radius of gyration of a compound pendulum such that if all its mass M were at a distance from Oi, the moment of inertia about Oi would be Ii , which we do by writing

$$I_i = Mk_i^2$$

Inserting this definition into equation (1) shows that

$$k_i^2 = h_i l_i \text{ ………….. (2)}$$

If I_G is the moment of inertia of the pendulum about its centre of mass G, we can also define the radius of gyration about the centre of mass by writing

$$l_G = Mk_G^2$$

The parallel axis theorem gives us

$$k_i^2 = h_i^2 + k_G^2$$

o that, using (2), we have

$$l_i = \frac{h_i^2 + k_G^2}{h_i}$$

The period of the pendulum from either suspension point is then

$$T_i = 2\pi\sqrt{\frac{l_i}{g}}$$

$$T_i = 2\pi\sqrt{\frac{h_i^2 + k_G^2}{gh_i}} \text{ … … … … (3)}$$

Squaring (3), one can show that

$$h_1T_1^2 - h_2T_2^2 = \frac{4\pi^2}{g}\,(h_1^2 - h_2^2)$$

and in turn,

$$\frac{4\pi^2}{g} = \frac{h_1T_1^2 - h_2T_2^2}{(h_1^2 - h_2^2)} = \frac{h_1T_1^2 - h_2T_2^2}{(h_1 + h_2)(h_1 - h_2)} = \frac{T_1^2 + T_2^2}{2(h_1 + h_2)} + \frac{T_1^2 - T_2^2}{2(h_1 - h_2)}$$

$$\therefore g = 8\pi^2\left[\frac{T_1^2 + T_2^2}{(h_1 + h_2)} + \frac{T_1^2 - T_2^2}{(h_1 - h_2)}\right]^{-1}$$

Apparatus:

1. A Kater's Pendulum
2. A small metallic wedge
3. A holder in fixed point
4. Stop watch

Experimental Procedure:

1. Shift the weight W_1 to one end of katers pendulum and fix it. Fix the knife edge K_1 just below it.
2. Keep the knife edge K_2 at the other end and fix the wooden weight W_2 symmetrical to other end. Keep the small weight 'w' near to centre.
3. Suspend the pendulum about the knife edge 1 and take the time for about 10 oscillations. Note down the time t_1 using a stopwatch and calculate its time period using equation $T_1=t_1/10$.
4. Now suspend about knife edge K_2 by inverting the pendulum and note the time t_2 for 10 oscillations. Calculate T_2 also.
5. If $T_2 \neq T_1$ adjust the position of knife edge K_2 so that $T_2 \approx T_1$
6. Balance the pendulum on a sharp wedge and mark the position of its centre of gravity. Measure the distance of the knife-edge K_1 as h_1 and that of K_2 as h_2 from the centre of gravity.

Precautions:

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14. Leave your lab area cleaner than you found it.

Data Collection:

1. Distance between K_1 and CG (l_1)=……..cm
2. Distance between K_2 and CG (l_2)=……..cm
3. Table for time period T_1 (oscillation about K_1)

No. of Observation	Number of Oscillation, n	Time of Oscillation t_1 (sec)	Time Period $T_1 = t_1/n$ (sec)	Mean Time T_1(sec)
1				
2				
3				

4				
5				

4. Table for time period T_2 (oscillation about K_1)

No. of Observation	Number of Oscillation, n	Time of Oscillation t_1 (sec)	Time Period $T_2 = t_1/n$ (sec)	Mean Time T_2(sec)
1				
2				
3				
4				
5				

Calculation:

$$g = 8\pi^2 \left[\frac{T_1^2 + T_2^2}{(h_1 + h_2)} + \frac{T_1^2 - T_2^2}{(h_1 - h_2)}\right]^{-1}$$

Results and Discussions:

The acceleration due to gravity, g = …….. cm/s^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 acceleration due to gravity?
2. What is oscillation?
3. What is time period?

Post-Lab Questions:

1. What is Kater's Pendulum?
2. What is centre of gravity?
3. How does g vary?