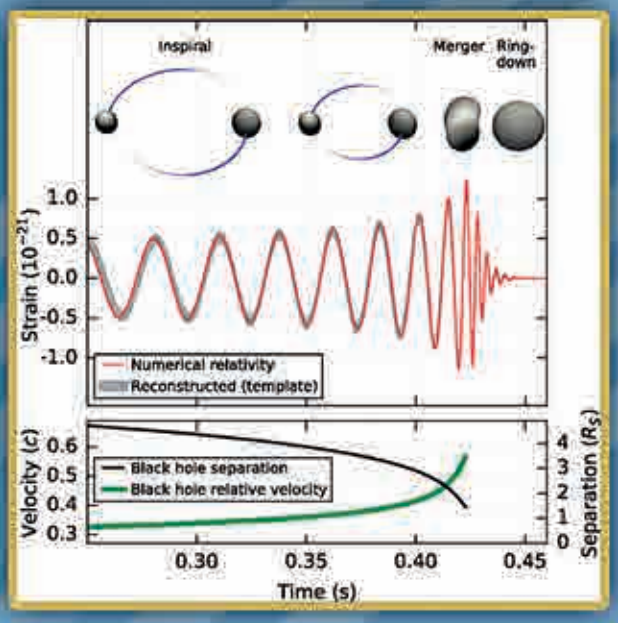
PHYSICS PRACTICAL NOTEBOOK STANDARD XI



PHYSICS

Standard XI

Practical Notebook

Name of the students : _____

Name of the Junior college: _____

_____

_____

Class : _____ Division : _____ Roll No. : _____

E5D3S1

Audio - Visual study material about practicals can be obtained through DIKSHA APP on your smartphone by using Q.R.Code.

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Foreward

Dear Friends,

The National Curriculum Framework (NCF) 2005 and State Curriculum Frame (SCF) 2010, recommends that children's life at school must be linked to their daily life. That is why a new educational system linking school, society and family is forming instead of bookish education. While the boundaries of different subjects are becoming gray, it has become very much necessary to develop skills of respective subjects, to reach the fundamental concepts and content and to enrich the taste for the concerned subject. In science stream you are going to study different subjects like Physics, Chemistry, Biology, etc.

Physics is a core subject of science, that must be learnt through experiments and observations. Laboratory is a place where students have opportunities for clarification of concepts, they are introduced in the theory course under different units like Units and Mathematical, Tools Motion and Gravitation, Properties of Matter, Sound and Optics, etc. While performing experiments related to instrumental work e.g., vernier calliper, screw guage, etc. The students must estimate the errors in their measurements, thereby realizing the accuracy and precision of their results. Various parts have been covered in the notebook, thereby facilitating teachers in the proper evaluation of the students in the laboratory. An opportunity to verify the theoretical part in the textbook is obtained through the experimental work. All these points are taken into account in this notebook. It will be possible to evaluate the students with respect to basics of experimental skills, observational methods and skills, calculation abilities.

A detailed procedure is given for the practicals included as per the syllabus in the textbook. In addition, thought provoking questions based on the practicals are given. All these should be used not only for the practical examination, but it is expected to be used also for science education through experimental skill. This notebook could be used as good supplimentary material for learning physics. QR code is given on first page, by using QR code you can get additional audio-visual information regarding experiments and activities.

We are sure, you all will welcome this physics practical notebook prepared with due concern and care. Also taking this note, we wish you all the best for your educational career.

(Dr. Sunil Magar)
Director
Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune 411 004.

Pune
Date : 20 June 2019
Bharatiya Saur: 30 Jyeshtha 1941

Physics Laboratory Apparatus

1. Collect the information about different instruments, apparatus and other material in your laboratories.
2. Read the books on Scientists and their discoveries.

PHYSICS LABORATORY MANUAL

In a broad sense, Science means to know (the nature). Development of Science usually involves following steps: Observe everything around, try to find relationship/hypothesis/theory/ law, perform controlled experiments to verify these, and use it for the mankind (benefit of the world). Obviously, proper experimentation is the backbone of Science.

There are four major requirements during scientific experimentation: Procedural understanding, recording the observations, processing those and working upon errors for betterment.

1. **Procedural understanding:** This involves scientific planning of an experiment that includes (i) What all we need for that experiment (ii) What should the least count and ranges of the instruments to be used (iii) Which and how many observations are to be recorded. For example, for a simple pendulum experiment to determine g, how should the bob be, what should the lengths of the thread be, stop clock of which least count to be used, how to record the periodic time, how many oscillations to be counted, etc.
2. **Recording the observations:** This is the actual process of data collection. It should be worked out as carefully and as meticulously as possible. Taking care for various types errors is part of it.
3. **Data analysis:** Processing the observations with various calculations, approximations (rounding off), graph/s and arriving at the result or conclusions refers to analysis part of an experiment.
4. **Error analysis:** Even after taking utmost care, there is/are always some errors involved in the recorded data. It is necessary to analyse the data by using statistical methods to know how much uncertainty (variation) is possible. Accordingly, the result is to be submitted along with the possible uncertainty. If the uncertainty is on higher side, quite often the experiment should be repeated with proper modifications.

We have suggested some extensions to the experiments. Make it a point to work upon those. The geometrical optics part needs more skills. Whenever you come across any measuring instrument, always try to know its least count, range and any systematic error – if there. Always take care of the safety measures, especially for electrical and heat experiments.

EVALUATION SCHME OF PRACTICAL EXAMINATION IN PHYSICS

GENERAL INSTRUCTION

1. **Complete minimum 10 experiments in academic year .**
2. **Complete minimum 6 Activities s in academic year.**
3. **After the experiment is alloted to you, read the backgound of the experiment.**
4. **Get familiar with the apparatus.**
5. **Draw the circuit diagram whenever required and assemble the circuit using necessary components.**
6. **Properly note the readings so as to minimize parallax.**
7. **After you finish performing the experiment, turn off all the nobs of experiment.**
8. **Calculate the results with significant figures and also calculate the error in the result.**
9. **Students have to complete the figures, labling of the figures, observation tables, calculations and conclusions / results themselves under the guidance of the teacher.**
10. **Answers to the multiple choice and open ended questions should be written only in the space provided examination. The multiple choice and open ended questions are important for written examinations.**

FIRST TERMEND PRACTICAL EXAMINATION (STD. XI ONLY)

TIME : TWO HOURS **TOTAL MARKS : 20** **(PASSING MARKS : 07)**

A	**Any one experiment (1 hour 30 minutes)**		**10 marks**
	I	Circuit diagram /Ray diagram /Experimental diagram	1 mark
	II	Setting of apparatus /circuit connections	1 mark
	III	Formula with explanation/law	1 mark
	IV	Performance with proper recording of observations	3 marks
	V	Graph /calculation or both	2 marks
	VI	Result with proper unit /conclusions	2 marks
B	**Any one Activity (30 minutes)**		**5 marks**
	I	Performance of activity with proper recording of observations	3 marks
	II	Write-up of activity	1 mark
	III	Result with proper unit/conclusions	1 mark
C	**Viva based on experiment/activities performed during the term.**		
	(viva should be taken while experiment /activity is being performed)		**5 marks**

ANNUAL PRACTICAL EXAMINATION (STD XI AND XII)

TIME THREE HOURS **TOTAL MARKS : 30** **(PASSING MARKS : 11)**

A	**One long experiment (1hour 30 minutes)**		**10 marks**
	I	Circuit diagram /Ray diagram /Experimental diagram	1 mark
	Ii	Setting of apparatus /circuit connections	1 mark
	Iii	Formula with explanation/law	1 mark
	Iv	Performance with proper recording of observations	3 marks
	V	Graph /calculation or both	2 marks
	Vi	Result with proper unit /conclusions	2 marks
B	**One short experiment (45 minutes)**		**5 marks**
	I	Circuit diagram /Ray diagram /Experimental diagram	1 mark
	Ii	Performance with proper recording of observations	2 marks
	Iii	Graph /calculation or both	1 marks
	Iv	Result with proper unit /conclusions	1marks
C	**Any one Activity (30 minutes)**		**5 marks**
	I	Performance of activity with proper recording of observations	3 marks
	Ii	Write-up of activity	1 mark
	Iii	Result with proper unit/conclusions	1 mark
D	**Viva based on experiments/activities performed during the year. (15minutes)**		**5 marks**
E	**Certified journal**		**5 marks**

For better reliability in assessment, the above is a suggestive distribution of marks for different aspects of practicals in physics.The exact value point distribution of marks will depend on the particular experiment/ activity being performed.Hence care should be taken to select actual marks for each aspect/value point out of the range of marks suggested.

INDEX

EXPERIMENT No. 1
USE OF VERNIER CALLIPERS

Aim: To determine volume of a solid sphere and a hollow cylinder by using Vernier callipers.

Apparatus: Vernier callipers, solid sphere, hollow cylinder

Diagram:

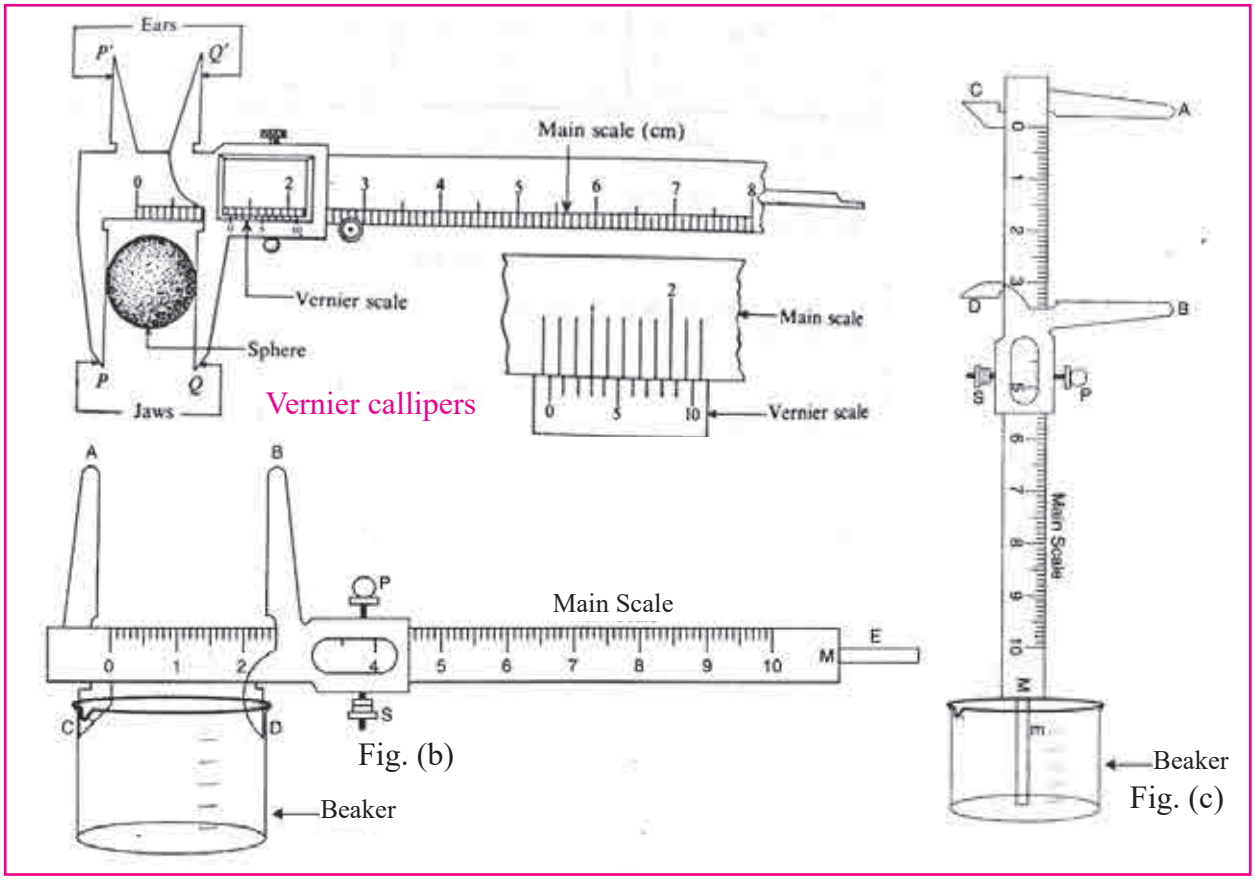


Fig.1.1 Vernier calliper

Formula:

1. Least count (L.C.) = $\frac{\text{(Smallest division on the main scale of vernier callipers)}}{\text{(Total number of divisions on vernier scale)}}$

2. Volume of solid sphere = $\frac{4}{3}\pi R^3$,
   Where R – Radius of sphere

3. Volume of hollow cylinder = $\pi r^2 h$, Where r- Radius of Cylinder, h- Height of Cylinder

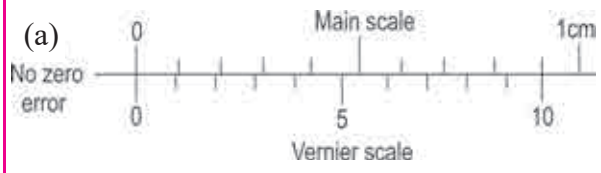
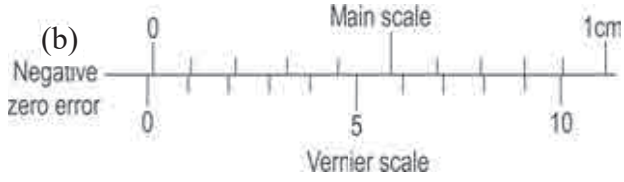
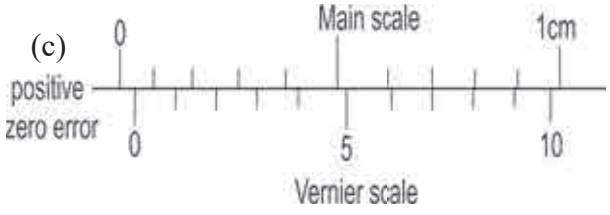
Observations:

Least count of Vernier calliper :

1. Smallest division on main scale = S = ……cm.
2. Total number of divisions on Vernier scale = N = …….
3. Least count = L.C. = $\frac{S}{N}$ = ……..cm.

I. To find the zero error :

Bring the two jaws of Vernier callipers in contact. Observe and conclude according to the following given conditions.

Position of main Scale	Observation	Conclusion
(a) No zero error 	If zero division of the main scale coincides with zero division of Vernier scale	There is no zero error
(b) Negative zero error 	If zero division of the Vernier scale is on right side of zero division of main scale and if m^{th} division of Vernier scale coincides with same division of main scale.	Zero error = m x L.C. From fig (b), Z =9 div = 0.09 cm.
(c) positive zero error 	If zero division of Vernier scale is on left side of zero division of main scale and if mth division of Vernier scale coincides with same division on main scale.	Zero error = - (N-m) x L.C. From fig (c), Z = - 7 div = -0.07 cm.

So, Zero error Z = ……..cm.

II. To determine volume of sphere:

1. Hold the given solid sphere between the lower jaws of Vernier callipers. as shown in fig (1).
2. Note the position of zero mark of Vernier scale on the main scale. Let the reading be 'A'.
3. Note the Vernier division (B) that coincides with some division on the main scale.
4. Then calculate the total reading (T) with formula T = A + (B X L.C.)
5. Take at least three independent reading for different positions of sphere.
6. Apply correction according to zero error (T+ Z) and find the mean value of diameter (D) and calculate radius of sphere = $r = \frac{D}{2}$.

III. To find the inner diameter and length of the hollow cylinder. (Use upper jaws for measuring inner diameter)

Observation Table:

Object	Sr. No.	Dimensions	Main Scale Reading A (cm)	Coin-cident Vernier Scale division B	Vernier scale reading C = B X L.C. (cm)	Total Read-ing T = A + C (cm)	Cor-rected Reading = T+Z (cm)	Mean Reading (cm)
Sphere	1	Diameter (D)						
	2							
	3							
Cylinder	1	Inner Diameter (d)						
	2							
	3							
Cylinder	1	Depth/Length (h)						
	2							
	3							

Calculations:

1. Radius of sphere $(R) = \frac{D}{2}$ = ……..cm.

2. Volume of sphere $(V) = \frac{4}{3}\ \pi R^3$ = ……..cm^3.

3. Radius of Cylinder $(r) = \frac{d}{2}$ =……cm.

4. Volume of cylinder $V = \pi R^2 h$ = ……cm^3.

Result :

1. Volume of sphere = ……..cm^3.
2. Volume of cylinder = …… cm^3.

Precautions:

1. Hold the object tightly between the jaws; do not press the jaws too hard.
2. Take observations for diameter at different positions of the object.
3. Eye should be exactly perpendicular to the Vernier scale while observing reading.

Additional Experiment you can do:

Procedure : Take a small mug or cylindrical glass having thick bottom. Measure its inner diameter by using upper ends of the jaws. Measure depth by using depth measurement strip. Hence, calculate capacity (inner volume) of the mug or glass.

Multiple-choice Questions

1. If smallest division on the main scale of Vernier Callipers is 0.05cm and number of division on the Vernier scale is 25, the L.C. of Vernier Callipers is ……

   a) 0.0002 cm b) 0.002 cm c) 0.001cm d) 0.01cm

2. Upper jaws are used to find .....

   a) outer diameter b) inner diameter c) length d) thickness

Questions

1. What is zero error?

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2. How do you apply the correction due to zero error?

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Remark and sign of teacher: .....
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FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT No. 2
USE OF MICROMETER SCREW GAUGE

Aim: To measure

1. The diameter of a given wire and calculate its area of cross section
2. Thickness of glass plate.

Apparatus: Screw gauge, Wire, glass plate

Diagram :

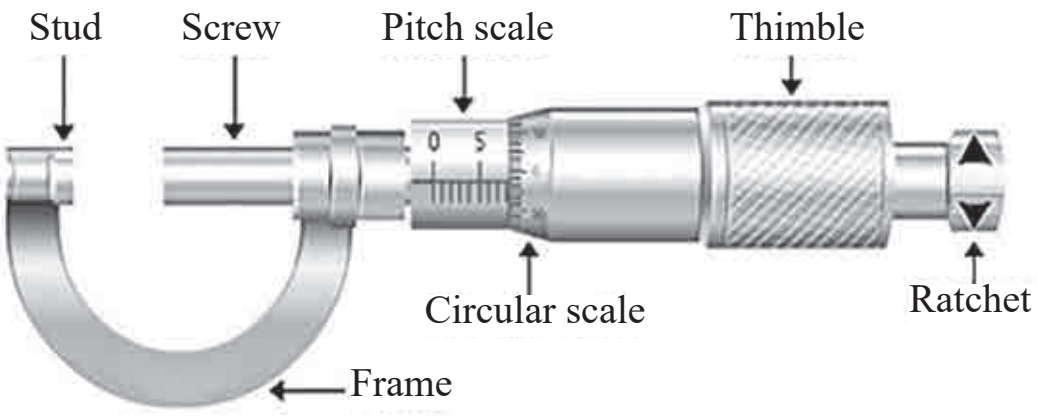


Fig. 2.1 Micrometer Screw gauge

Formula :

1. Least Count of the Screw Gauge

$$\text{Least Count} = \frac{\text{Pitch}}{\text{Total number of division on the circular scale}}$$

2. Area of cross section of wire :
   $A = \pi r^2$ ------ Where r is radius.

Zero Error and Zero Correction

To get the correct measurement the zero error must be taken into account. For this purpose, the screw is rotated forward, until 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:

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.

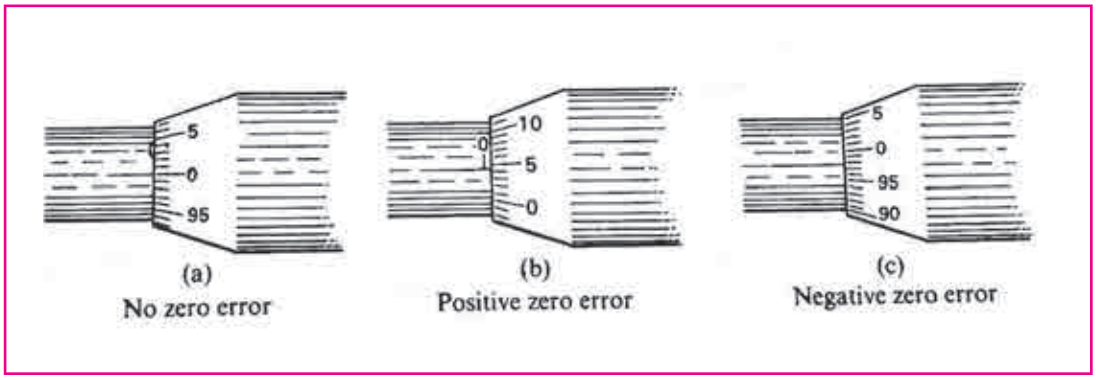


Fig. 2.2 Zero error

Procedure :

1. Determine the pitch and least count of the screw gauge using the formula.
2. Bring the anvil and screw in contact with each other and find the zero error. If there is no zero error, then record 'zero error nil'.
3. Move the screw away from the anvil and place the wire 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 main scale that is visible and uncovered by the edge of the cap. The reading A is called the main scale reading.
5. Note the number (B) of the division on the circular scale lying over the reference line.
6. Repeat steps 4 and 5 for two different positions of the wire. Record the observations in the tabular column.
7. Find total reading using the formula and apply zero correction in each case.
8. Take the mean of different values.

Note: Place the other objects like wire, glass plate etc. between the screw and the anvil and follow the above procedure to find the measurement.

Observations :

1. Determination of Least Count of the Screw Gauge

a) Smallest division on main scale, S = 1 mm.

b) Number of full rotations given to screw, n = 4

c) Distance moved by the screw on main scale, D = 4 mm.

d) Hence, pitch $p = \frac{D}{n} = \frac{(4\text{ mm})}{4} = 1$ mm.

e) Number of divisions on circular scale, N = 100

f) Hence, least count, L.C.$= \frac{p}{N} = \frac{(1\text{ mm})}{100} =$ 0.01 mm = 0.001 cm.

2. Zero Error

Zero error = Z = ----------mm = ----------cm

Object	Obs No.	Main Scale Reaing (A) (cm)	Coincident divisions on circular scale (B)	circular Scale Reading C = (B x L.C) (cm)	Total Reading		
					Observed $D_o = A + C$ (cm)	Corrected $D = D_0 + Z$ (cm)	Mean
Wire	1						cm.
	2						
	3						
Glass Plate	1						cm.
	2						
	3						

Calculations :

1. Mean Diameter of the wire, D =---------cm.
2. Radius of wire, $r = \frac{D}{2}$ = ---------cm.
3. Area of cross section of the wire, $A = \pi r^2$ = ----------cm^2.
4. Thickness of the glass plate, t = --------cm.

Result:

1. Diameter of the wire, D = ---------- cm.
2. The area of cross section of the given wire is, A =……cm^2.
3. Thickness of the glass plate, t = ---------- cm.

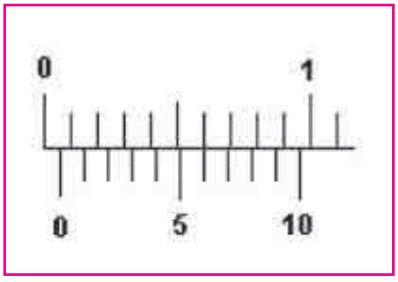
Precautions :

1. Rotate the screw in one direction to avoid backlash error.
2. Do not apply undue pressure while turning the micrometer screw.

Additional Experiment you can do : Find the volume of the small ball bearing/ metal sphere.

Multiple-choice Questions:

1. What is the zero error as shown in the figure?



   a) 0.6 mm b) 0.06 mm c) 6mm d) 60 mm

2. Precision of micrometer screw gauge is----------.

   a) 0.1 cm b) 0.01 mm c) 0.1 mm d) 0.01 m

Questions

1. Define the terms pitch and least count.

2. What is the backlash error? How do you reduce it?

Remark and sign of teacher: .....

FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 3
USE OF SPHEROMETER

Aim: To determine the radius of curvature of a spherical surface using a spherometer.

Apparatus: A spherometer, a plane glass plate/mirror spherical mirror or lens or curved glass.

Diagram:

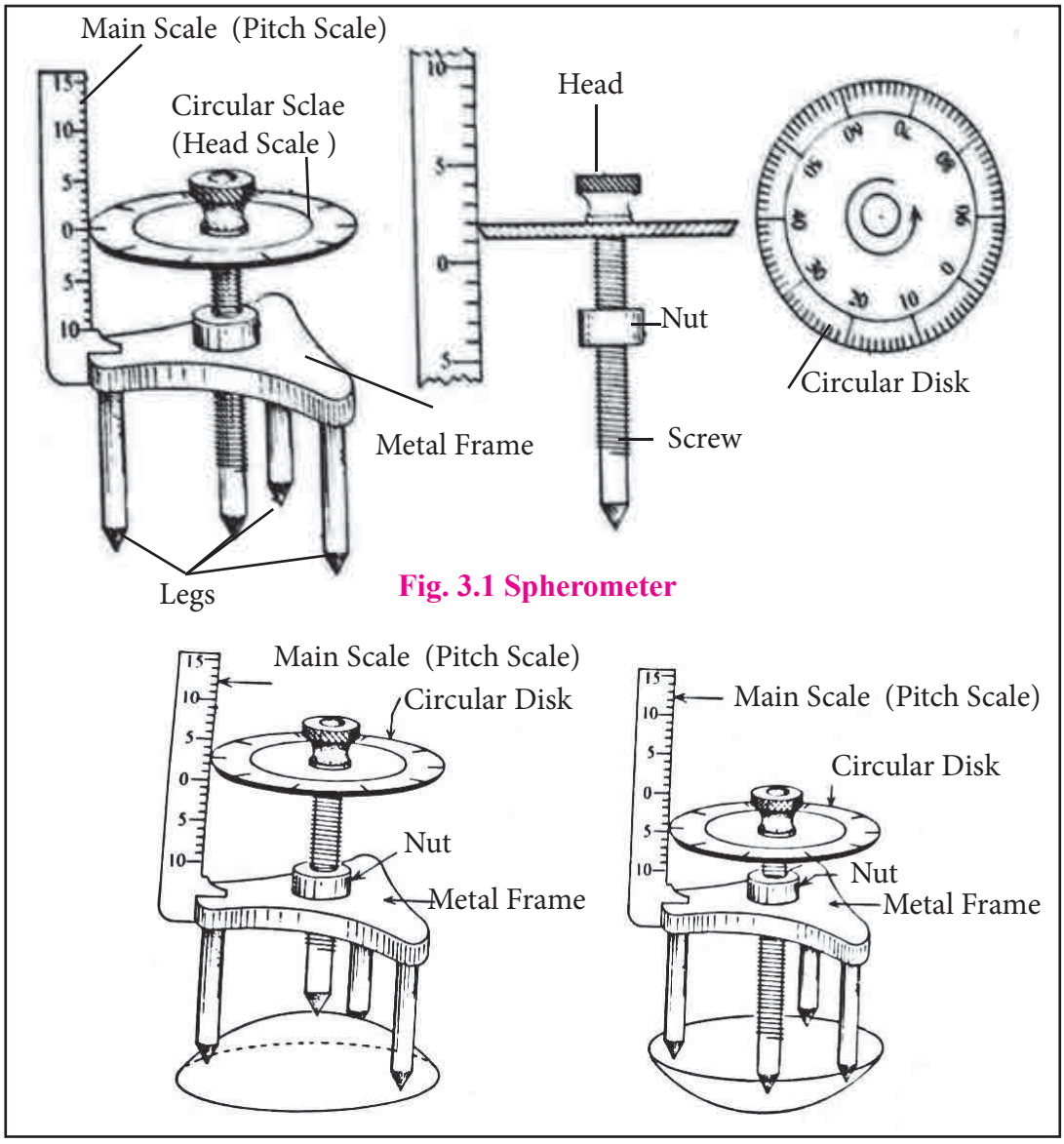


Fig. 3.1 Spherometer

Fig. 3.2 Determination of the radius of curvature of a spherical surface

Formula:

Radius of curvature of the spherical surface. , $R = \frac{a^2}{6h} + \frac{h}{2}$

Procedure:

1. Determine the L.C. of spherometer
2. Record the average distance between three legs of spherometer by taking their impressions on a plane paper.
3. Keep the spherometer on the plane glass plate/mirror and rotate the screw till its tip just touches the plane surface. Note the spherometer reading. Repeat the same once more at a different location.

4. Keep the spherometer on the spherical surface kept on the plane mirror. Adjust the spherometer screw so that its tip just touches the center of spherical surface. Note the spherometer reading. Repeat the same once at a different central location.

Observations:

I. To find average distance between the legs

a_1 = ---------- cm, a_2 = ---------- cm, a_3 = ---------- cm,

$a = \frac{(a_1 + a_2 + a_3)}{3}$ = ... cm.

II. To find the L.C. of spherometer

1. Value of one division on the main scale, S = ...cm.
2. Number of divisions on the circular scale, N= .....
3. Distance through which the screw advances on the main scale in n rotations of the circular scale = D = ...cm.
4. n = number of rotations given to the circular scale = ----------
5. Pitch of the screw = P = $\frac{D}{n}$ =..... cm.
6. Least Count of spherometer = $\frac{P}{N}$ = ... cm.

Surface	Obs. no.	Main scale reading A (cm)	Coincident divisions on circular scale B	Circular scale reading (cm) C= (B + L.C.)	Total reading = A+C (cm)	Mean reading (cm)
Plane Mirror	1					X =
	2					
Convex surface	1					Y =
	2					

III. To find sagitta (h) :

Sagitta of the spherical surface = h= | X-Y | = ...cm

Calculations:

For radius of curvature.

$$R = \frac{a^2}{6h} + \frac{h}{2}$$

Result: Radius of curvature of spherical surface = ... cm.

Precautions:

1. While taking reading with spherometer consider the lowest division on the main scale as zero.
2. Rotate the screw in one direction to avoid backlash error.
3. Take care that tip of the screw and tip of three legs just touch the surface.

Additional Experiment you can do:

Determine the sagita by placing the spherometer on the concave surface. Hence, determine the Radius of curvature.

Multiple-choice Questions

1. The radius of curvature of a flat surface is …… cm

   a) 0 b) infinity c) 1 d) 100

2. If the number of divisions on the circular scale are 50 then the L. C. of the spherometer whose pitch is 0.5cm, will be …… cm

   a) 0.001 b) 0.01 c) 0.05 d).005

Questions

1. How do you determine the pitch of a spherometer?

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2. What is radius of curvature of the lens?

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What is sagita of a spherometer?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and Notes

EXPERIMENT NO. 4
PARALLELOGRAM LAW OF VECTORS

Aim: To Verify parallelogram law and find the weight of a given body.

Apparatus: Parallelogram Law of Forces apparatus (Gravesand's apparatus), two hangers with slotted weights, a body (a wooden block) whose weight is to be determined, thin strong thread, white drawing paper sheet, drawing pins, mirror strip , sharp pencil , half meter scale, set squares, protractor.

Diagram :

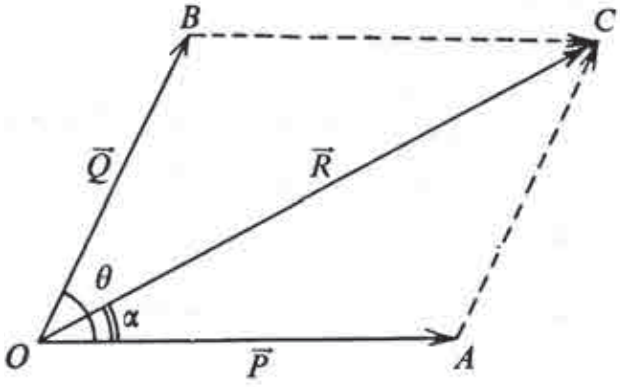


Fig 4.1 Parallelogram of forces

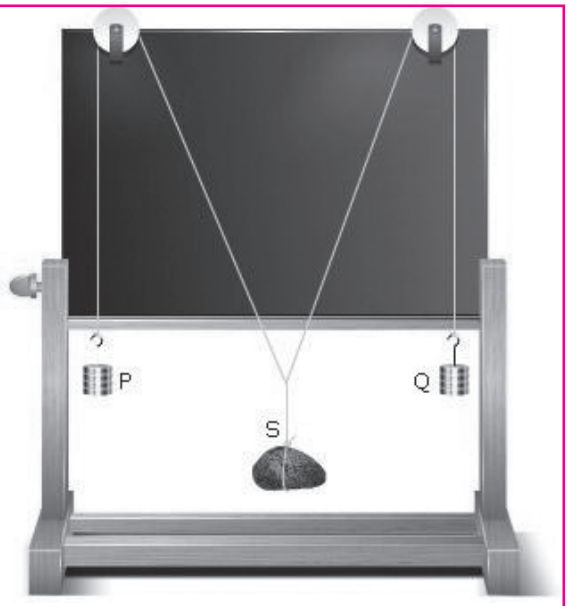
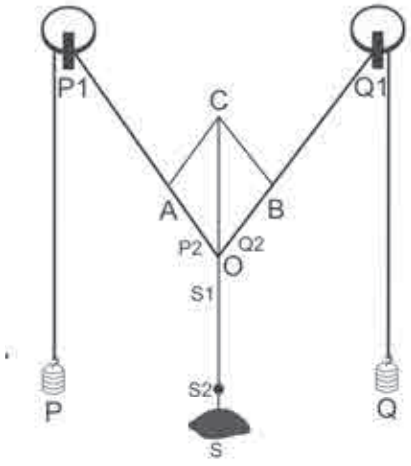
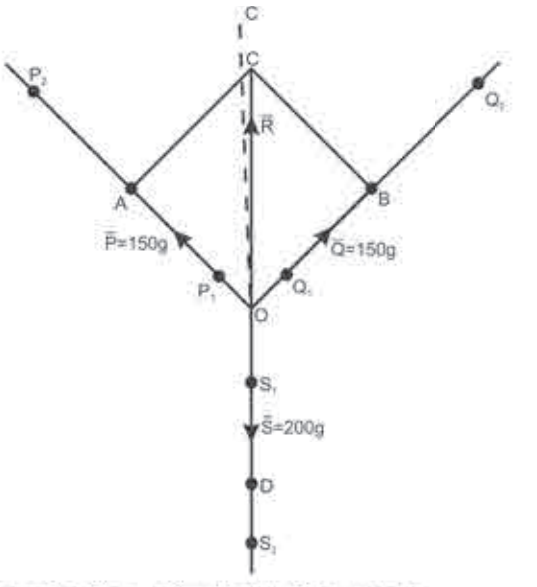


Fig. 4.2 Actual set up of parallelogram law of forces





Determination of weight of a wooden block

Fig. 4.3 Determination of weight of a wooden block

Formula :

1. $R = \sqrt{P^2 + Q^2 + 2PQ\cos\Theta}$, $\Theta < 90^0$

2. $R = \sqrt{P^2 + Q^2 - 2PQ\sin(\theta - 90)}$, $\Theta > 90^0$

3. $R = \sqrt{P^2 + Q^2}$, $\Theta = 90^0$

Where R is resultant vector, P and Q are two vectors, and Θ is the angle between P and Q vectors.

Procedure:

1. Fix the wooden board in a vertical position as shown in figure. Clamp the pulleys on the wooden board. Fix the white paper on the drawing board with the help of drawing pins.
2. Pass a long string over the pulleys and a hanger at each end. Tie another string at the centre of the first string. Tie a hanger to the free end of this string as shown in figure.
3. Add suitable weights to the hangers so that the system is in equilibrium and the common point O is near the centre of the board.
4. Note the forces P, Q and S from diagram it can be seen that $p = w_1$,$Q = w_2$ and $S = w_3$ where w denotes the numerical value or magnitude of the total weight in each case .
5. Hold the plane mirror on the paper behind the string. Mark two points on the paper at the ends of the mirror such that string and its image in the plane mirror coincide. The line joining the points gives the line of action of the corresponding forces (P,Q or Q).Determine the lines of action of all three forces in this manner .
6. Remove the white paper from the board. Draw the lines through the points and produce them to meet at the common point O.
7. With a suitable scale(for e.g. Let 20 g = 1 cm) mark the points A and B such that the lengths OA and OB represent the magnitude of the forces P and Q respectively.
8. Complete the parallelogram OACB . Draw the diagonal OC . Measure the length OC and determine the magnitude of R using the scale chosen.
9. Measure the angle AOB (Θ) between the forces P and Q . Calculate R using the formula. Compare it with the value obtained by calculation .
10. Take two readings by changing the weights added to the hangers. Replace w_3 by the object (unknown) whose weight is to be found. Adjust w_1 and w_2 such that the system is in equilibrium and the common point O is near the centre of the board.
11. For unknown weight, following the earlier procedure complete the parallelogram. Find the weight of the body by measuring the length of the diagonal passing through the point O and using the scale chosen.

Observations:

I. To find the actual weight of the unknown mass, R unknown.

1. Least count of spring balance = ... g.

2. Zero error of spring balance = ... g.

3. Weight of unknown body by spring balance, R= unknown = ... g.

II. To verify parallelogram law of vectors

Obs. no.	P (w_1) gwt	Q (w_2) gwt	Angle between P and Q Θ^0	Resultant R (gwt)		
				Observed (w_3)	From the diagram	Calculated using the formula
1						
2						
3						

III. To find the weight of the unknown mass using parallelogram law of vectors Scale.

Obs. no	P (w_1) gwt	Q (w_2) gwt	Angle between P and Q. Θ^0	R by measurement from the diagram (diagonal × scale) gwt	R by calculation using the formula gwt
1				=	
2					
3					

Calculation : $R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta}$

1.

2.

3.

1. Mean value of unknown weight R (using diagonal) = ---------- gwt.

2. Mean value of unknown weight, R (using angle Θ) = --------- gwt.

Result :

The unknown weight of given body = ---------- gwt.

The result shows the error is within limits of the experiment error.

Precautions:

Use frictionless pulleys. Hanger and pulley should not touch the board. Sufficient length of string is preferred.

Additional Experiment you can do:

1. If scale pan or spring balance is available in laboratory student can compare weight of unknown object with calculated weight of unknown weight.

2. To determine the direction of resultant vector R as follows:
   Measure the angle AOC (α) between P and R. 'α' gives the direction of resultant vector.

Multiple-choice Questions

1. In the experiment, on finding the weight of a given body by the parallelogram law of vectors, the student needs to use :

   a) Three pulleys and two weights in all
   b) Two pulleys and two weights in all
   c) Two pulleys and three weights in all
   d) Three pulleys and two weights in all

2. In above diagram if P = 5gwt, Q =7gwt, Θ = 45^0, then α = ……..

   a.) 26.40 with direction of P
   b) 26.40 with direction of Q
   c) 450 with direction of P
   d) 18.30 with direction of P

Questions

1. What are the main sources of error in the experiment using Gravesand's apparatus ?

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2. State the law of Parallelogram of forces?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 5
COEFFICIENT OF STATIC FRICTION

Aim: To study the relationship between force of limiting and normal reaction and to find coefficient of friction between a block and a horizontal surface.

Apparatus: Horizontal plane with a pulley, Wooden block with a hook, string, weight box, scale pan etc.

Formula: $\mu_s = \frac{P}{W}$

Where μ_s = Coefficient of static friction between two surfaces.
P = Horizontal force required just to slide the block (or effort)
W = Weight of the block (or load)

Diagram:

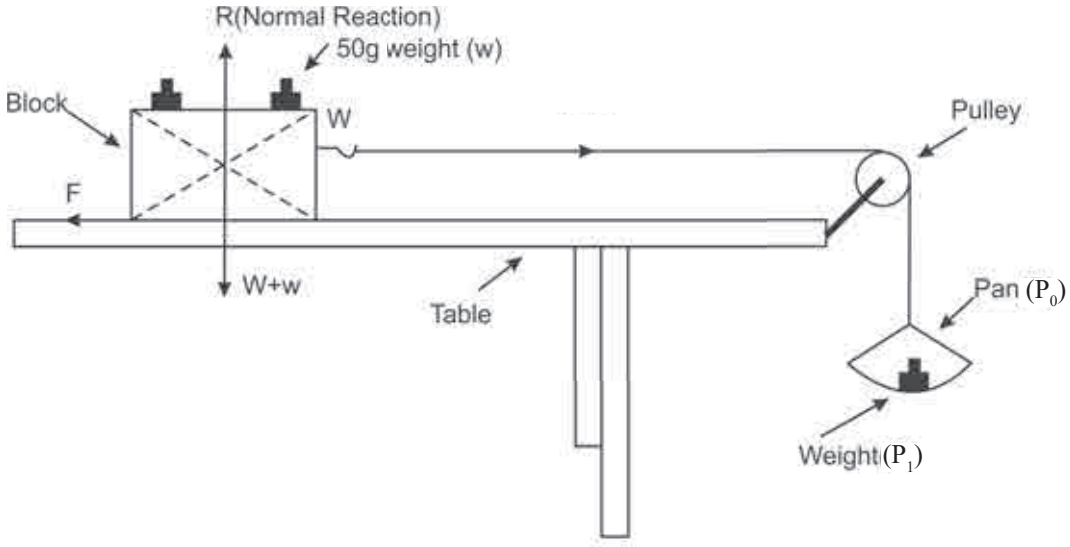


Fig. 5.1 Study for force of sliding friction

Procedure:

1. Measure the weight of block and pan separately (respective masses in g.wt).
2. Clean the surface of block and horizontal plane with the clean cloth every time.
3. Tie one end of the string to the hook of block, pass it over the pulley, and attach the scale pan to the other end.
4. Keep same weight on the block, which is kept on horizontal surface. Add suitable weights in the scale pan so that the block just starts moving and note down the reading.
5. Repeat the same procedure for different values of loads and measure the corresponding efforts.

Observations :

Least count of spring balance = _____ g Zero error of spring balance = _____ g.

1. Mass of the block = W_0 = ... gwt.

2. Mass of the pan = P_0 = ...gwt.

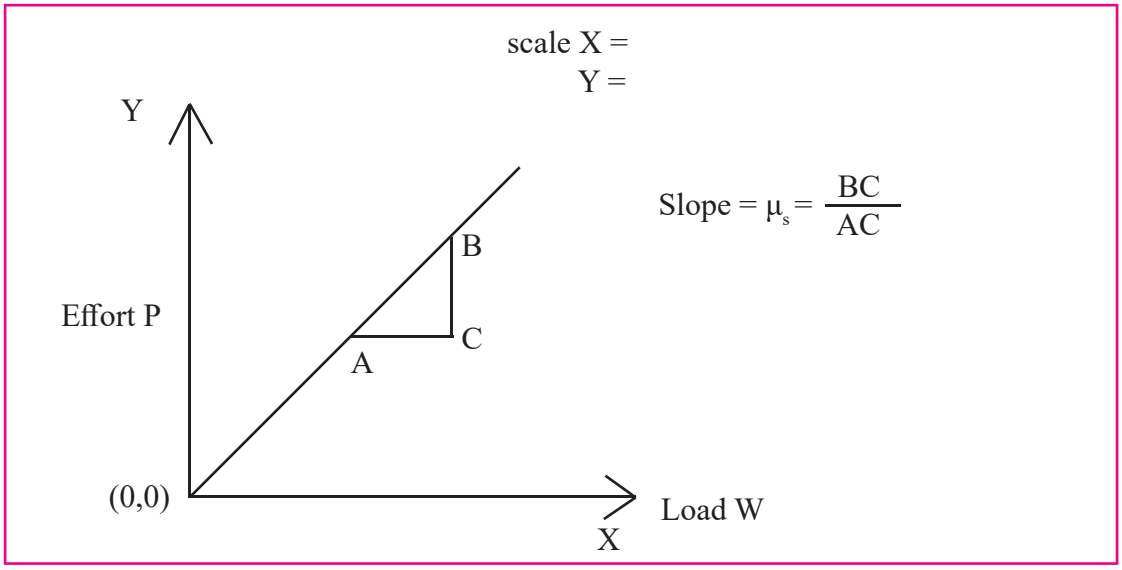
Observation Table:

Sr No.	Mass on the block W_1 gwt	Total load $W=(W_0+W_1)$ gwt	Mass in the pan P_1 gwt	Total Effort $P=(P_0+P_1)$ gwt	$\mu_s = \frac{P}{W}$	Mean μ_s

Calculations : $\mu_s = \frac{P}{W}$

Graph :

Plot a graph between load W (on X-axis) against effort P(on Y- axis) and find the slop of the graph.



Result :

1. Coefficient of static friction between the two surfaces by calculation = μ_s = ……
2. Coefficient of static friction between the two surfaces by graph = μ_s = …….

Precautions :

1. Two surface in contact should be dry and clean.
2. Reading must be taken for the weight for which block just start moving.
3. Pan and string should not touch the table.
4. String should be parallel to the horizontal surface.

Additional Experiment you can do :

Place the empty block (without pan) on the plane surface. Now gradually increase the angle of inclination of the plan surface such that the block just begins to slide down the plane. The minimum angle of inclination of the plane at which the body kept on the plane just begins to slide down is known as the angle of repose (Q_r). Determine this angle. Than $\mu_s = \tan Q_r$

Multiple-choice Questions

1. The value of coefficient of static friction is …….

   a) Greater than 1 b) less than 1 c) equal to 1 d) zero

2. …….. is the force of friction which comes into play when a body does not slide on the surface of another body under the effect of an applied force.

   a) Rolling friction b) Kinetic friction c) static friction d) dynamic friction

Questions

1. How can you say the force of friction is a self adjusting force?

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2. On which factor the force of friction depends?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 6
TRAVELLING MICROSCOPE

Aim: To determine the refractive index of glass and water by using a travelling microscope.

Apparatus: A travelling microscope, a glass slab, a beaker, water, lycopodium powder or saw dust.

Figure:

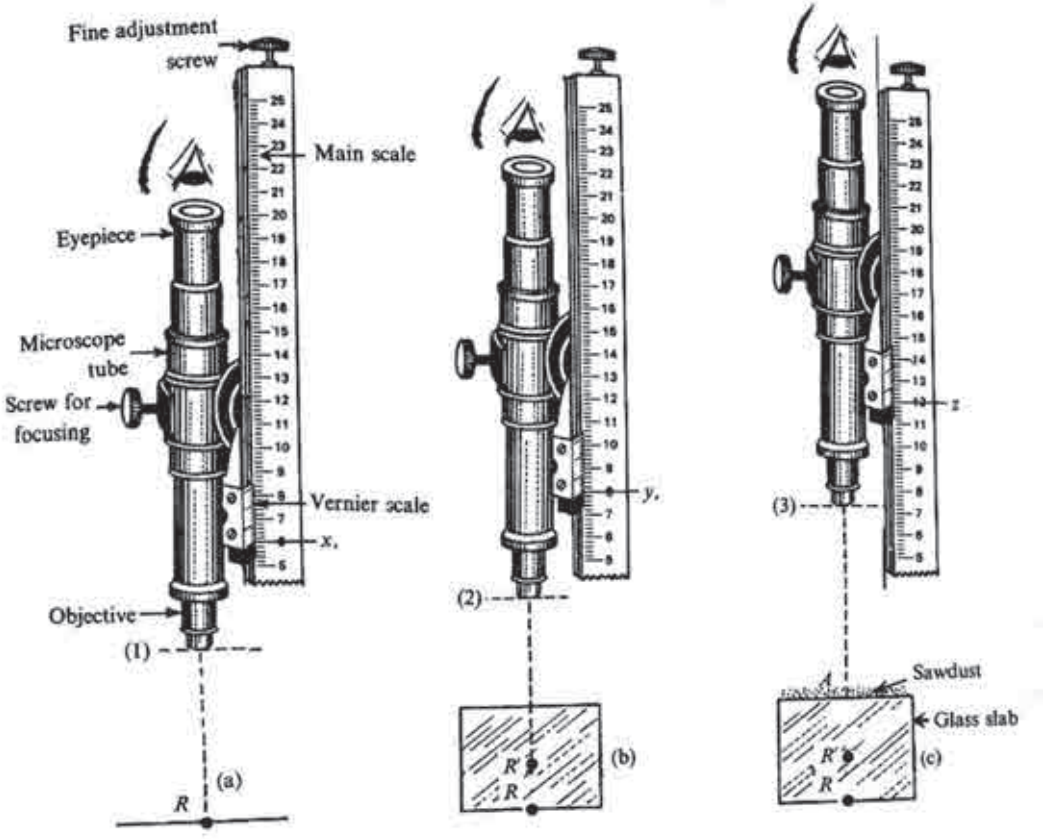


Fig 6.1 Travelling microscope focusing

Theory:

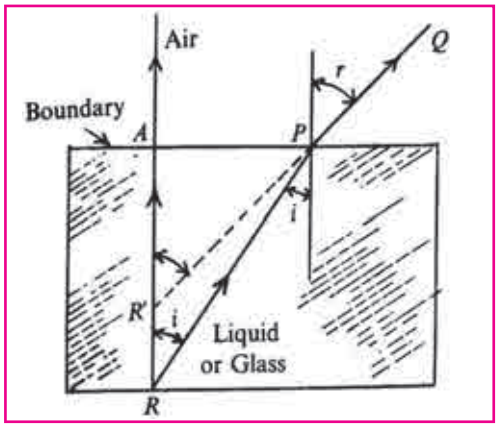
A travelling microscope essentially consists of a compound microscope fit with a Vernier calipers. By using the Vernier calipers, the displacement of the microscope tube can be recorded when it is successively focused at different locations, (say x, y and z) as shown in the figure above.

For small angles of incidence, the refractive index of certain thickness of a medium can be approximately related as,

$$n = \frac{\text{(Real depth)}}{\text{(Apparent depth)}}$$

Thus,as per the earlier and following figures,

$$n = \frac{AR}{AR^{l}} = \frac{(z-x)}{(z-y)}$$



To record AR and AR^1, we need to focus the microscope at the levels A, R and R.

For level (R), we make a cross mark (×) on a plane paper and focus the microscope on it.

For locating level (R), the glass slab (or the thin walled transparent beaker containing water) is kept on the cross mark and apparent position of the cross mark is focused as R.

To locate the topmost position (A), some lycopodium powder or saw dust is to be spread on the top surface and microscope should be focused on the powder particles (smallest possible).

Differences between the corresponding microscope readings give us AR and AR'. Thus, refractive index n can be calculated.

Remarks:

(A) Doubtful Vernier reading: Quite often the Vernier divisions of a travelling microscope are so close that it is difficult to locate the exact coinciding division. In such cases, restrict your doubt to three divisions and use the middle one as the coinciding division (Figures II and III).

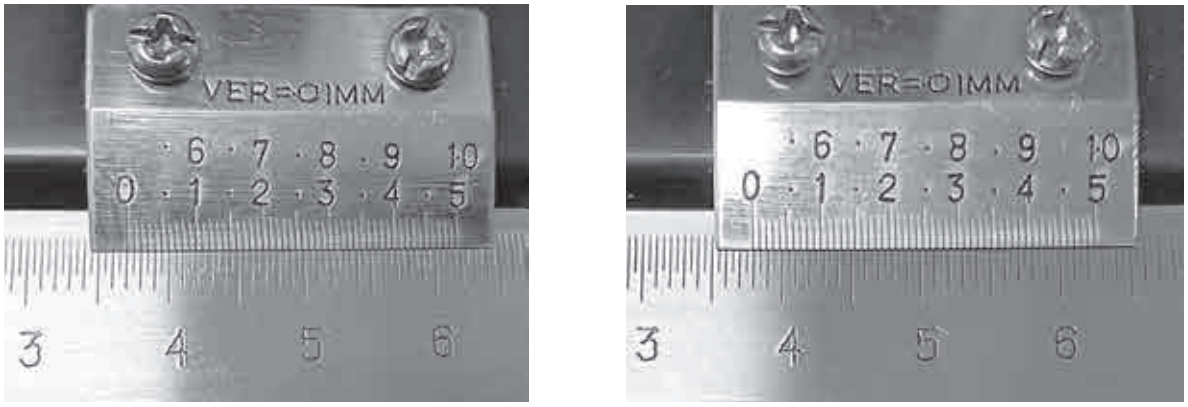
(B) Doubtful main scale reading: If zero of the Vernier scale is close to a division on the main scale, it may be difficult to make out whether that main scale division is complete or not. In such cases, first record the coinciding Vernier scale division. If it is within first 10, the apparent main scale division is complete (Figure II). If the coinciding division is in last 10 (in forties), the apparent main scale division is not complete, i.e., Vernier zero is just before that. In this case, the previous division is to be recorded. (Figure III).

(II) Just after the main scale division:

Main scale reading = 3.70 cm
Coinciding division = 4
Vernier scale reading = 0.004 cm
Total reading = 3.704 cm

(III) Just before the main scale division:

Main scale reading = 3.75 cm
Coinciding division = 45
Vernier scale reading = 0.045 cm
Total reading = 3.795 cm



Procedure:

1. Determine least count (L.C.) of the travelling microscope.
2. Focus the travelling microscope on the cross mark (×) on a plane paper and record the reading as x.
3. Initially use glass slab as the transparent material. Keep the glass slab on the cross mark and look for the apparent position of the cross mark. Focus the microscope on the apparent position and record the reading as y.
4. Spread some saw dust on the top surface. Record the reading as z by focusing the microscope on the smallest saw-dust particles.
5. Repeat the steps 3 and 4 for water and record corresponding values of y and z for water.
6. Separately calculate the refractive indices of glass and water.

Observations:

1. Least count of the travelling microscope (For vertical scale).
2. L.C. = (Length of one main scale division) – (Length of one Vernier scale division)

   = (…….. cm) – (……. cm) = …….. cm.
3. 50 division of Main Scale = 25 mm.
4. 50 division of Vernier Scale = 24.5 mm.
5. Difference between 50 division of M.S. and V.S. = 0.5 mm.
6. Difference between each division = $\frac{0.5}{50}$ = 0.01mm.

---------- or ----------

1. L.C. = $\frac{\text{(Length of one main scale division)}}{\text{(Total number of divisions on the vernier scale)}}$ = $\frac{(\ldots\ldots\text{cm})}{(\ldots\ldots\ldots..)}$ = …….. cm.
2. Abbreviations used: M.S.R. = Main Scale Reading.
3. V.S.R. = Vernier Scale Reading = Coinciding division 'n'×Least count.
4. T.R. = Total Reading = M.S.R. + V.S.R.
5. Obs. No. = Observation number.

Observation table:

Obs. No.	Micrometer readings								
	x			y			z		
	M.S.R. cm	V.S.R. cm	T.R. cm	M.S.R. cm	V.S.R. cm	T.R. cm	M.S.R. cm	V.S.R. cm	T.R. cm
For glass slab									
1									
2									
3									
For water									
4									
5									
6									

Calculation table :

Obs. No.	Real depth R= z-x	Apparent depth A= y-x	Refractive index $n = \frac{(z-x)}{(z-y)}$	Mean refractive Index, n
For glass slab				
1				n_g = _____
2				
3				
For water				
4				n_w = _____
5				
6				

Calculations:

Refractive index : $n = \frac{(z-x)}{(z-y)}$

Results:

n_g = _____ n_w = _____

Precautions:

1. The axis of the microscope tube should be vertical.
2. The microscope tube should be in the lowest possible position when the microscope is focused on the point on the paper or on the paint mark on the inner surface of the bottom of the beaker (when the beaker is empty).
3. The focusing screw should not be touched while raising the microscope tube.
4. The quantity of sawdust or lycopodium power added should be small. It should not form a thick layer on the surface of the glass slab or liquid.

Additional Experiment you can do :

1. Calculate the apparent shift due to refraction for glass and for water.
2. Measure sizes of very small objects such as thickness of needle, width of the bore of a capillary.

Multiple-choice Questions

1. Least count of travelling microscope (when smallest division on main scale is 0.1cm and number of divisions on Vernier scale is 100) is …….

a) 0.001cm b) 0.001m c) 0.01cm d)0.01m

Questions

1. Why should the focusing screw not disturbed after noting the reading X ?

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2. What are the factors on which the refractive index depends?

3. Can you use this method of determining refractive index of a highly volatile liquid? Explain.

Remark and sign of teacher: .....

FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 7
FOCAL LENGTH OF CONVEX LENS BY DISPLACEMENT METHOD

Aim: To determine focal length of a lens by displacement method.

Apparatus: A convex lens, lens stand, a screen with graph paper on it, Extended source of light (Most preferable a filament bulb, else an illuminated slit) metre scale.

Diagram:

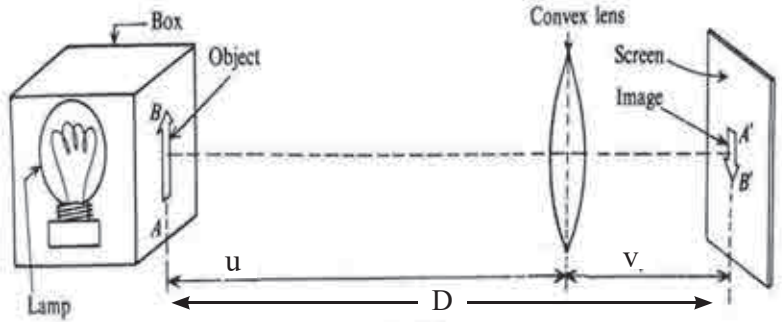

Fig. 7.1 experimental arrangement for displacement method

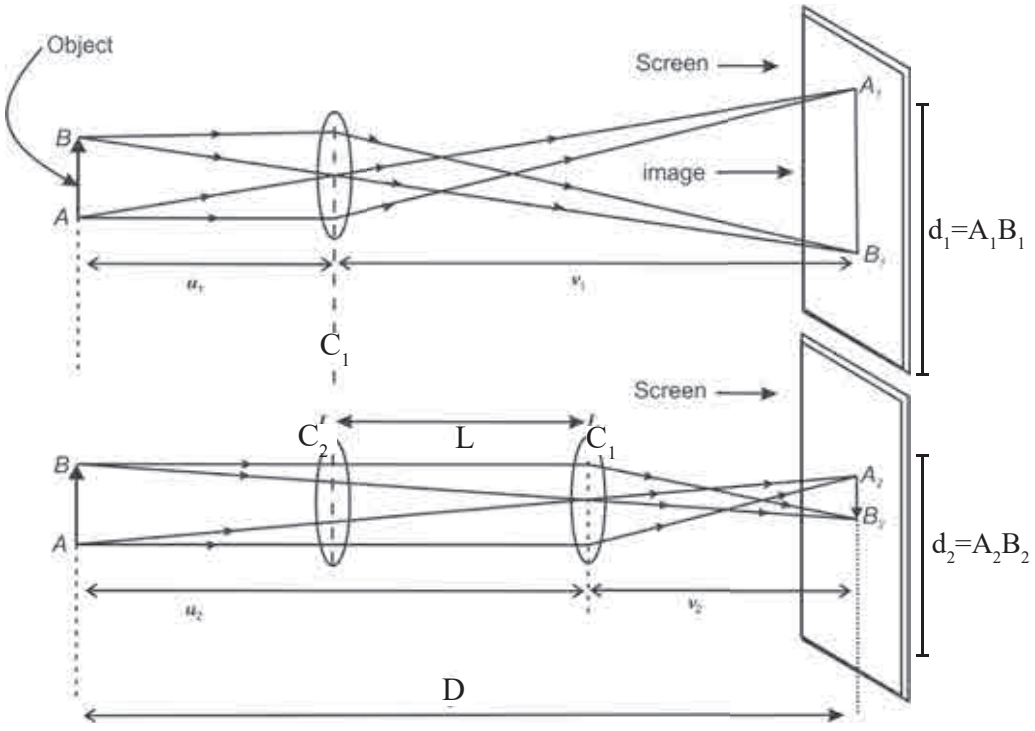

Fig.7.2 Ray diagram for displacement method

Theory:

For a convex lens, if the object is at 2*f*, its real image is also at 2*f*. In this case, the separation between object and the image is minimum and it is 4f. Thus, for obtaining a real image, the screen must be at a distance greater than 4*f*. Let this distance be *D*. As shown in the figures above, there are two positions of the lens when real image is obtained at the same distance $D > 4f$ from the object. These two positions are called conjugate foci separated by a distance L. (For $D = 4f$, these two positions coincide). From the principle of reversibility of light, it can be easily understood that the distances u and v should just interchange.

$\therefore\ u + v = D$ and $v - u = L \quad \therefore\ 2u = D + L$ and $2v = D - L$

$\therefore$ Using u negative, $\frac{1}{f} = \frac{1}{u} - \frac{1}{(-u)}$

$\therefore$ $f = \frac{uv}{(u+v)} = \frac{D^2 - L^2}{4D}$

Let d be the size of the object. Sizes of magnified and diminished images are d_1 and d_2 respectively.

$\therefore \frac{v}{u} = \frac{d_1}{d}$ and $\frac{v}{u} = \frac{d_2}{d}$

By multiplying these equations and solving,

we get $d = \sqrt{d_1 d_2}$

as the size of the object (filament). In standard XII, you will be using this method and this formula for obtaining the distance between two coherent sources in the topic of interference of light.

Procedure:

1. Illuminate the source/filament bulb and keep it more than a metre away from the screen.
2. Adjust the height of the lens stand so that centre of the lens and filament are at the same height.
3. Adjust the position of the lens (closer to the object) to obtain a clear magnified image on the screen (Fig 1). Record size of the image on the screen as d_1, and distance between object and the screen as D. Mark the position of the lens as C_1.
4. Without disturbing positions of the object and the screen, shift the lens towards the screen to obtain a clear and diminished image on the screen (Fig 2). Record the image size as d_2 and mark position of the lens as C_2. Record the distance between C_1 and C_2 as L.
5. Repeat steps (3) and (4) for six more values of D.

Obs. No.	Distance between source and screen D … cm	Distance between positions of lens L … cm	Size of magnified image d_1 … cm	Size of diminished image d_2 … cm
1				
2				
3				
4				
5				

Observation table:

Obs. No.	D^2	L^2	$D^2 - L^2$	$4D$	$f = \frac{D^2 - L^2}{4D}$	$d_1 d_2$	$d = \sqrt{d_1 d_2}$
1							
2							
3							
4							
5							

Calculations :

Results:

Mean f = ……. cm Mean d = ……. cm.

Precautions:

1. Keep the distance between object and the screen constant
2. The distance L should be greater than 4f

Additional Experiment you can do :

1. Try to determine size of the flame of a candle.

2. Measure u, determine $v = D - u$. Calculate focal length for one or two readings and verify if it matches with that calculated by using D

Multiple-choice Questions

1. In above experiment if u=30cm and v= 65 cm then linear magnification m = …….

   a) 2.17 b) 21.7 c) 35cm d) 0.35m

Questions

1. Can the above method be used for determining focal length of a) concave lens b) plano concave lens?

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2. What is conjugate foci?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 8
R.I. OF A LIQUID BY CONCAVE MIRROR

Aim: To determine the refractive index of a liquid by using a concave mirror.

Apparatus: A concave mirror, index pin, Retort stand, liquid, meter scale.

Diagram:

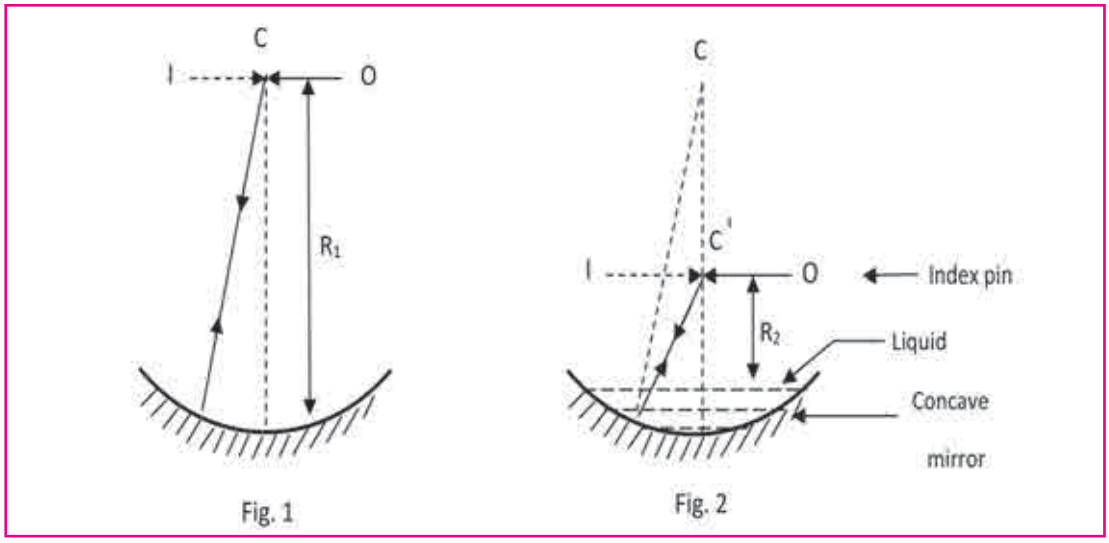

Fig. 1 Fig. 2

Formula: $\mu = \frac{R_1}{R_2}$

Where, μ= R. I. of the liquid

R_1 = Distance between the mirror and the pin

R_2 = Distance between the pin and surface of liquid

Procedure:

1. Keep the concave mirror on a horizontal surface.
2. Clamp the index pin horizontally in the retort stand in such a way that the tip of the pin is on the principal axis of the mirror.
3. Look from above the pin and adjust the position of the pin either by raising or by lowering it so that it coincides with its own inverted image formed by reflection in the mirror, without parallax. (You will have to lower down the object pin if image appears thinner than the object pin and raise the object pin if the image appears thicker than the object pin).
4. Measure the distance (R_1) of the pin from the pole of the mirror with a scale. This distance is equal to the radius of curvature of the mirror. Repeat these two more times and take the mean value of R_1 (as shown in fig. 1)
5. Pour a quantity of the given liquid on the concave mirror such that it covers more than half the surface.
6. Lower the pin and adjust its position again so that it coincides with its own image without parallax. (Use the same judgement).
7. Measure the distance R_2 of the pin from the surface of liquid (as shown in fig. 2)
8. Repeat these two more times.

Observations:

Sr. No.	Distance between pin and the surface of the mirror: R_1 cm	Mean R_1 cm	Distance between pin and the surface of the liquid: R_2 cm	Mean R_2 cm
1				
2				
3				

Formula: $\mu = \dfrac{R_1 \ (mean)}{R_2 \ (mean\ )}$

Calculations:

Result: Refractive index of given liquid = μ = _____

Precautions :

1. There should be no parallax between the pin and its image.
2. The pin should be horizontal.
3. The quantity of the liquid added to the mirror should not be very small.
4. The part of the upper surface of the liquid in contact with the mirror is slightly curved. Hence, consider the central part of the liquid while determining "R"

Additional Experiment you can do :

Repeat the above experiment by using kerosene and sop water instead of water.

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Multiple-choice Questions

1. Which one of the following is the refractive index of water:
   a) 1.333 b)1.545 c) 1.723 d) 2.891

2. The bending of a ray of light as it travels from one medium to another is called.....
   a) Deflection b) total internal reflection c) refraction d) reflection

Questions

1. State Snell's law of refraction.

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2. What is the merit of the method described in this experiment?

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3. Is the any other method to determine the refractive index of a liquid?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and NOTES.

EXPERIMENT NO. 9
REFRACTIVE INDEX OF PRISM

Aim: To determine angle of minimum deviation for a given prism by plotting a graph between angle of incidence and the angle of deviation.

Apparatus: Drawing board, a white sheet of paper, prism, drawing pins, pencil, half-metre scale, office pins, graph paper and a protractor.

Formula:

The refractive index of the material of the prism is given by,

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where, δm angle of minimum deviation and A angle of the prism.

Diagram:

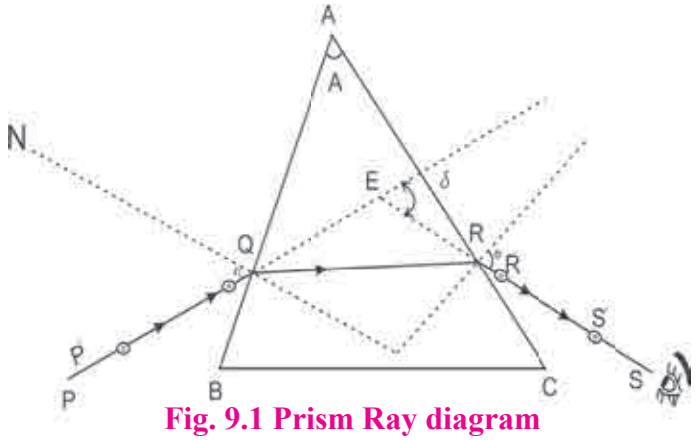


Fig. 9.1 Prism Ray diagram

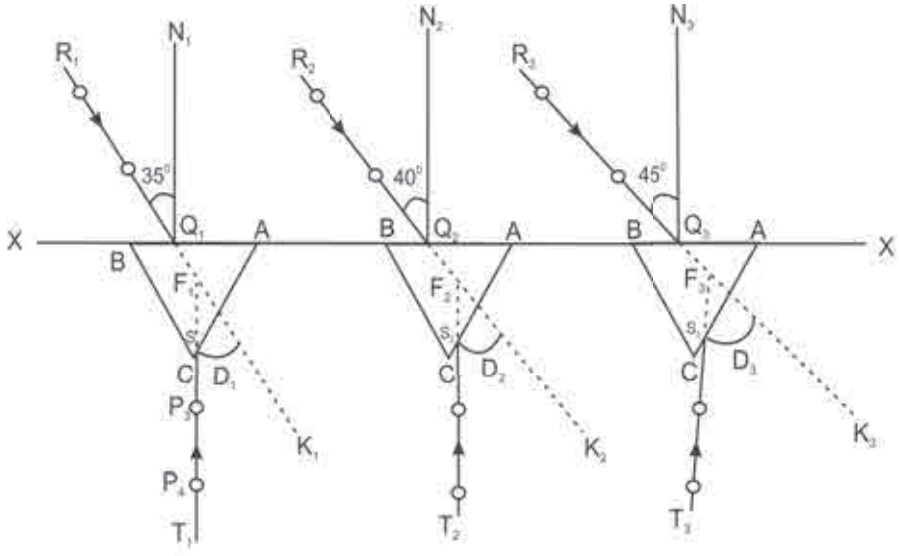


Fig. 9.2 Prism experiment

Procedure:

1. Fix a white sheet of paper on the drawing board with the help of drawing pins or tape.
2. Draw a straight line XX' parallel to the length of the paper nearly in the middle of the paper.
3. Mark points Q_1, Q_2, Q_3,… on the straight line XX' at suitable distances of about 5 cm.
4. Draw normal N_1Q_1, N_2Q_2, N_3Q_3,… on points Q_1, Q_2, Q_3,… as shown in diagram.

5. Draw straight lines R_1Q_1, R_2Q_2, R_3Q_3,… making angles of 35°, 40°, … 60° (write value of the angles on the paper) respectively with the normal.
6. Mark one corner of the prism as A and take it as the edge of the prism for all the observations.
7. Put prism with its refracting face AB on the line XX' and point Q_1 in the middle of AB.
8. Mark the boundary of the prism.
9. Fix two or more office pin P_1 and P_2 vertically on the line R_1Q_1. The distance between the pins should be 10 mm or more.
10. Look the images of point P_1 and P_2 through face AC.
11. Close your left eye and bring open right eye in line with the two images.
12. Fix two office pins P_3 and P_4 vertically, and 10 cm apart such that the open right eye sees pins P_4 and P_3 and images of P_2 and P_1 in one straight line.
13. Remove pins P_3 and P_4 and encircle their pricks on the paper.
14. Repeat steps 7 to 13 with points Q_2, Q_3,… for i = 40°,…, 60°.

To measure δ in different cases

1. Draw straight lines through points P_4 and P_3 (pin pricks) to obtain emergent rays S_1T_1, S_2T_2, S_3T_3,……
2. Produce T_1S_1, T_2S_2, T_3S_3, … inward in the boundary of the prism to meet produced incident rays R_1Q_1, R_2Q_2, R_3Q_3,… at points F_1, F_2, F_3,…
3. Measure angles $K_1F_1S_1$, $K_2F_2S_2$, $K_3F_3S_3$, …….. These give angle of deviation δ1, δ2, δ3,….
4. Write values of these angles on the paper.

To measure A

1. Measure angle BAC in the boundary of the prism. This gives angle A.
2. Record your observations.

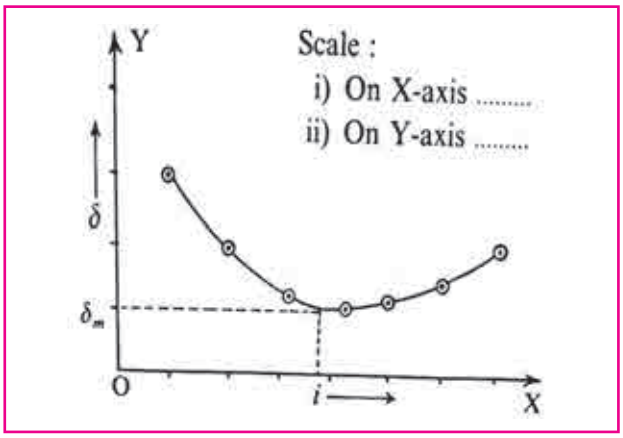
Observation table :

Angle of prism A = ...

Sr no.	Angle of incidence i in degree	Angle of deviation δ in degree
1	35	
2	40	
3	45	
4	50	
5	55	
6	60	
7	65	

Graph:

Plot a graph between angle of incidence ∠i and angle of deviation ∠δ by taking ∠i along X-axis and ∠δ along Y-axis. From this graph, find the value of single of minimum deviation δm corresponding to the lowest point of the graph.



Calculations:

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Result:

1. i-δ graph indicates that as the angle of incidence (i) increases, the angle of deviation (δ) first decreases, attains a minimum value (δm) and then starts increasing for further increase in angle of incidence.
2. Angle of minimum deviation, δm = ……..
3. Refractive index of the material of the prism, μ = …….

Precautions:

1. The angle of incidence should lie between 35°-60°.
2. The pins should be fixed vertical.

3. The distance between the two pins should not be less than 10 mm
4. Arrow heads should be marked to represent the incident and emergent rays.
5. The same angle of prism should be used for all the observations.

Sources of error:

1. Pin pricks may be thick.
2. Measurement of angles may be wrong.

Additional experiment :

Repeat the same experiment by using laser beam instead of pin.

Multiple-choice Questions

1. Which of the following Colour suffers maximum deviation in a prism?

   a) Red b)violet c)yellow d) orange

2. How many refractions occur when a ray of light passes through a triangular prism?

   a) 1 b) 3 c) 4 d) 2.

Questions

1. On which factors does refractive index depend?

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2. State Snell's law of refraction.

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Remark and sign of teacher: .....
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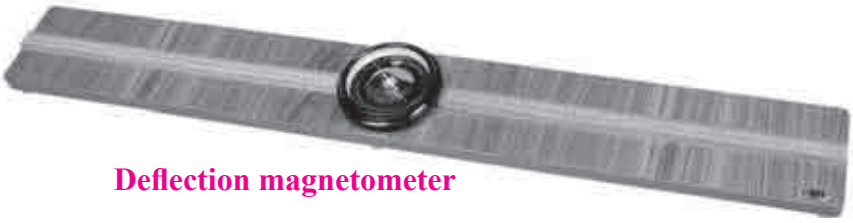
FOR ADDITIONAL EXPERIMENT and NOTES.

EXPERIMENT NO. 10
DETERMINATION OF MAGNETIC MOMENT OF A SHORT BAR MAGNET (DIPOLE) USING A DEFLECTION MAGNETOMETER

Aim: To calculate the magnetic moment of a given magnet using the deflection magnetometer.
Apparatus: Deflection magnetometer, bar magnets, meter scale.

Diagram:



Deflection magnetometer

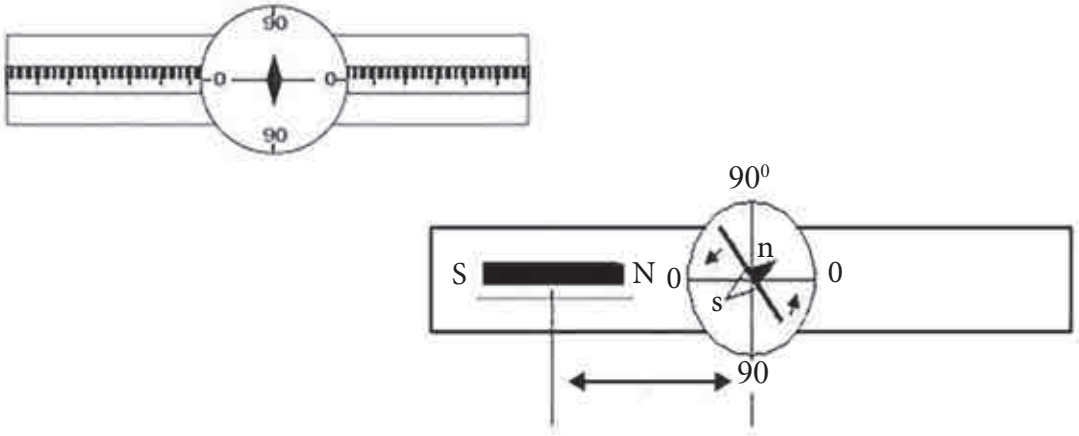


Fig 10.1 For tan A position

Theory:

Tangent law:

Consider a bar magnet(dipole) with magnetic moment M in a region where there are two perpendicular horizontal magnetic fields, an external field B and the horizontal component of the earth's field BH . If no external field B is present, the bar magnet will align along B_H. Due to field B the magnet experiences a torque, which deflects it from its original position by an angle θ. Then we have the relation $B = B_H \tan \theta$.

Deflection Magnetometer:

It consists of large compass, with a small magnetic needle pivoted at the centre of a circular scale so that the needle is free to rotate in a horizontal plane. A large aluminium pointer is rigidly fixed perpendicular to the magnetic needle. The circular scale is graduated in degrees ($0^0 – 0^0$) and ($90^0 – 90^0$) readings are marked at the ends of two perpendicular diameters. The compass box is placed at the centre of a wooden board one meter long. The wooden board has a millimetre scale along its axis such that the zero of the scale is at the centre of the compass box.

Tan A position

In Tan-A position (figure 10.1), prior to placement of magnet, the compass box rotated so that the ($0^0– 0^0$) line is parallel to the arm of the magnetometer. Then the magnetometer as a whole is rotated till pointer reads ($0^0 – 0^0$).The bar magnet is placed horizontally on the arm of the deflection magnetometer (parallel to the arm) so that the deflection on the aluminium pointer is θ^0

Since the magnet is a dipole and placed on the axis its magnetic induction B at a distance 'd' from the centre of the magnetometer ($0^0 - 0^0$) to the centre of the dipole is given as

$$B_{axis} = \frac{\mu_o}{4\pi} \frac{2md}{(d^2 - l^2)^2}$$

Where $2l$ is the length of the magnet.
For a short magnetic dipole

$l << d$

$$B_{axis} = \frac{\mu_o}{4\pi} \frac{2M}{d^3}$$

By Tangent Law

$$B_{axis} = B_H \tan\theta \quad , \quad B_H \tan\theta = \frac{\mu_o}{4\pi} \frac{2M}{d^3}$$

$$M = \frac{B_H \tan\theta}{\frac{2\mu_o}{4\pi}} d^3 \quad \text{since } \frac{\mu_o}{4\pi} = 10^{-7}$$

$$M = \frac{B_H \tan\theta}{2 \times 10^{-7}} d^3$$

Procedure :

1. The bar magnet is placed at the same height as the magnetic needle is tan A position.
2. The other magnetic materials should be kept as far away as possible from the magnetometer.
3. The distance of the magnet should be adjusted so that the pointer points at 45^0-45^0.
4. The distance should be noted as d_1.
5. The same magnet should be placed by reversing its position (that means if it was N-S previously it should now be placed as S-N and vice versa). The distance should be noted as d_2.
6. The experiment should be repeated with another bar magnet.

Observation table:
Calculations :

Obs. No.	Magnet no	Distance d_1	Distance d_2	Mean d	$M = \frac{B_H \tan\theta}{2 \times 10^{-7}} d^3$
1	M1				
2	M2				

Result :

1. Magnetic moment of Magnet 1 = _____
2. Magnetic moment of Magnet 2 = _____

Precautions :

Check that setting of magnetometer in TanA position is properly done before keeping magnet on its arms.

Additional Experiment you can do :

Tan B position

In this position (figure below), prior to placement of the magnet, the compass box alone is rotated so that the (90^0-90^0) line is parallel to the arm of the magnetometer. Then the magnetometer as whole is rotated so that the pointer reads (0^0-0^0). Finally the, magnet is placed horizontally, perpendicular to the arm of the magnetometer and distance'd' is adjusted to get a reading θ on the pointer.

Diagram :

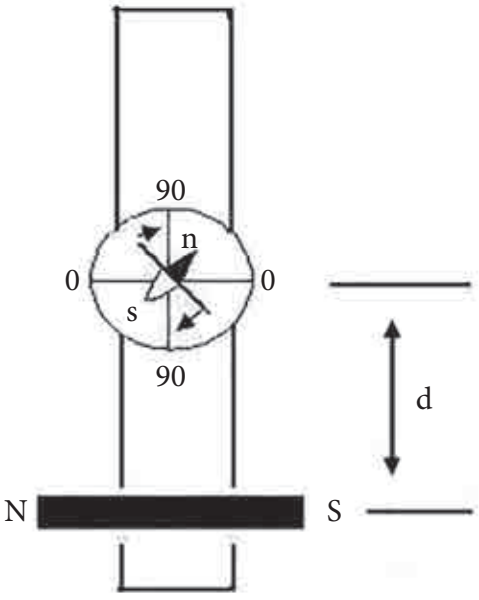


Fig 10.2 For tan B position

In this case

$$Beq = \frac{\mu_0}{4\pi} \frac{M}{d^3}$$

$$Beq = B_H \tan\theta$$

$$M = \frac{B_H \tan\theta}{10^{-7}} d^3$$

Procedure:

Repeat the above procedure for Tan B position.

Observation table:

Obs. No.	Magnet no	Distance d_1	Distance d_2	Mean d	$M = \frac{B_H \tan\theta}{10^{-7}} d^3$
1	M1				
2	M2				

Calculations :

Result :

1. Magnetic moment of Magnet 1 = _____
2. Magnetic moment of Magnet 2 = _____

Multiple-choice Questions

1. Magnetic pole strength of a short magnetic dipole of length 4 cm and magnetic moment 10 Am^2 is …….

   0.125 Am b)2.5 Am c) 0.025Am d)1.25Am

Questions

1. Explain what is Tan A and Tan B position of Deflection magnetometer.

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2. How will you measure the reading of θ in a deflection magnetometer if the pointer is adjusted to 90-90 instead of 0-0 while doing initial adjustment?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 11
THERMISTOR

Aim : To study the characteristics of a Thermistor.

Apparatus : Thermometer (0 - 100 oC), Bead type Thermistor, Battery Eliminator (0 - 5 V), mill ammeter, connecting wires.

Theory:

A thermistor is a thermal resistor having a large temperature coefficient of resistance. Thermistor works in a temperature range such that its resistance decreases rapidly with a rise in temperature. A thermistor is a composite semiconductor consisting of cobalt, nickel, manganese, copper, titanium, sintered oxides of iron etc. Thermistors are used for temperature measurement and in electronic circuits and devices such as fire alarms in industries.

Formulae : $R_{T1} = R_{T2}\,\beta \left[\frac{1}{T_1} - \frac{1}{T_2} \right]$

Diagram:

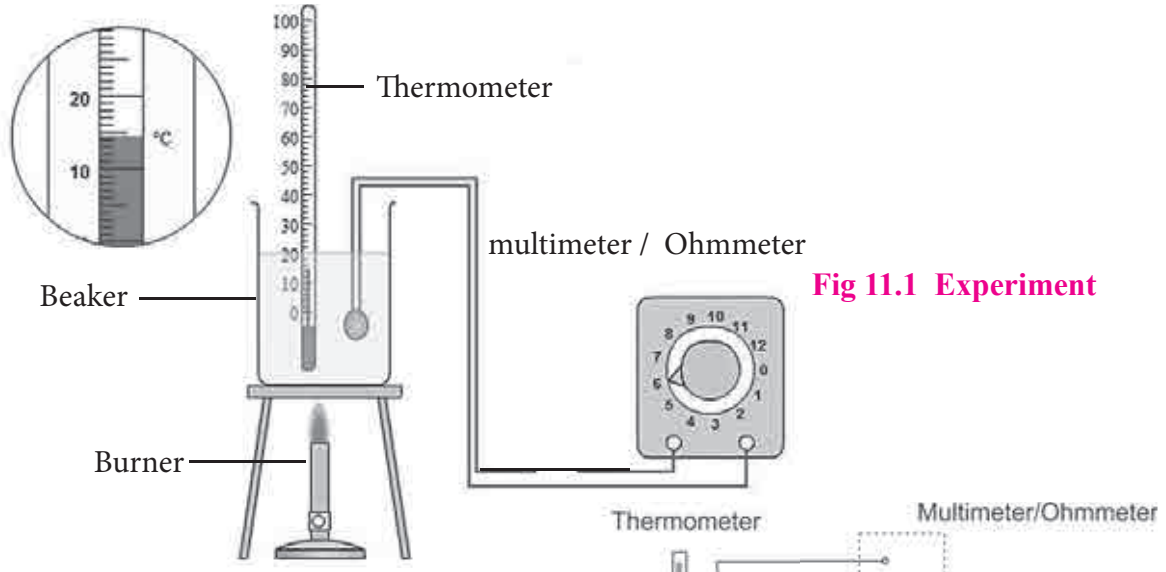


Fig 11.1 Experiment

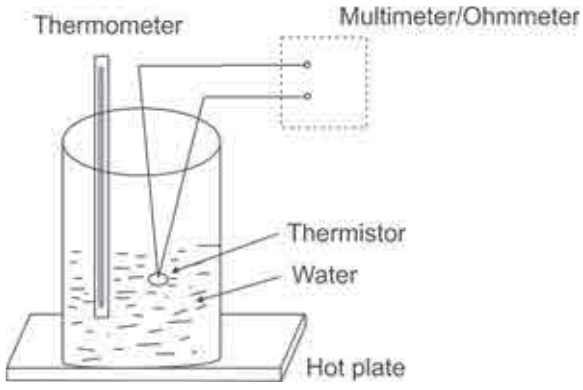


Fig 11.2 Experiment Setup (Laboratory)

Procedure:

1. Make the electrical connections as shown in figure.
2. Note down the least count of the thermometer.
3. Note down the temperature and corresponding resistance of the thermistor with the help of digital multimeter at room temperature.
4. Increase the temperature of water in step of 10° C with the help of hot plate or gas burner.
5. Note down the temperaure and corresponding resistance of the thermistor with the help of digital multimeter for every increase in temperature, in the steps of 10° C.
6. Plot the graph of resistance of thermistor against temperature.

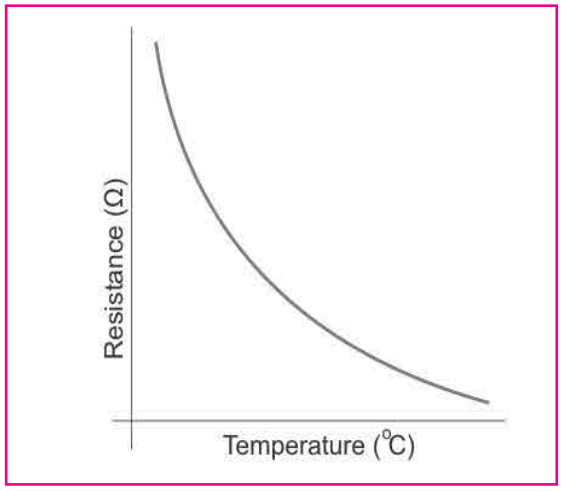
Observations:

Least count of Thermometer = °C.

Sr. No.	Temperature (°C)	Resistance (Ω)
1	30	
2	40	
3	50	
4	60	
5	70	
6	80	

Graph :

Plot the graph of Resistance R (on Y axis) and Temperature T (°C) (on axis)



Calculation of β:

Θ_1 = ...°C Θ_2 = ...°C

R_{T_1} = ... Ω R_{T_2} = ... Ω

$$R_{T_1} = R_{T_2} \beta \left[\frac{1}{T_1} - \frac{1}{T_2} \right]$$

Result :

1. Temperature coefficient of resistance at = --------- Ω.

2. Give your opinion about the nature of the graph.

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Precautions:

1. Thermistor should be immersed completely in water.
2. Bulb of the thermometer should not touch the sides of the contender.

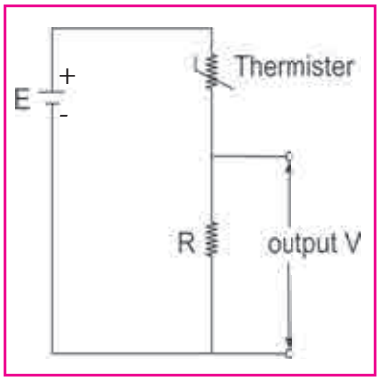
Additional Experiment you can do :

Try to use another thermistor with PTC characteristics and do the same experiment and compare the graph of Resistance V/s Temperature of this experiment with the previous one.

Try to plot the graph of resistance of thermistor with temperature while cooling.

Multiple Choice Question:

1. Thermistors _____
   a) sense only positive changes in temperature
   b) cannot sense any change in temperature
   c) sense only negative changes in temperature
   d) sense positive and negative changes in temperature
2. When temperature rises, resistance of negative temperature coefficient thermistor
   a) Increases b) decreases c) zero d) infinity
3. A student designs a circuit to give a decreasing voltage output as the temperature increases. He builds the circuit in the diagram, but finds that the output voltage increases with increasing temperature.
   Four of his friends suggest four possible changes to the circuit. Which change would produce the effect he wanted?
   a) Replace the resistor with one of the higher resistance.
   b) Replace the resistor with one of the lower resistance.
   c) Reverse the polarity of the battery
   d) Swap the position of the thermistor and resistor



Questions

1. What is thermistor? Why is it so called?

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2. What does a thermistor consist of?

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Remark and sign of teacher: .....
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FOR ADDITIONAL EXPERIMENT and NOTES

EXPERIMENT NO. 12
DIODE CHARACTERISTICS

Aim : To draw the I-V characteristics curves of a P-N junction diode in forward and reverse bias.

Apparatus : D.C. power supply, Milliammeter (0-250mA), Microammeter, Voltmeter (0-5v,L.C. 0.1V), Silicon diode (IN4007) Rheostat, plug key and connecting wires.

Circuit Diagram:

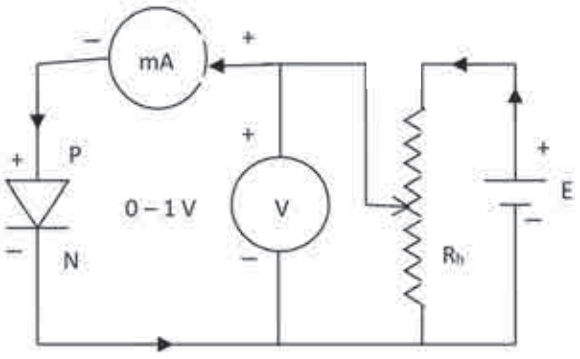


Fig 12.1 Forward characteristics

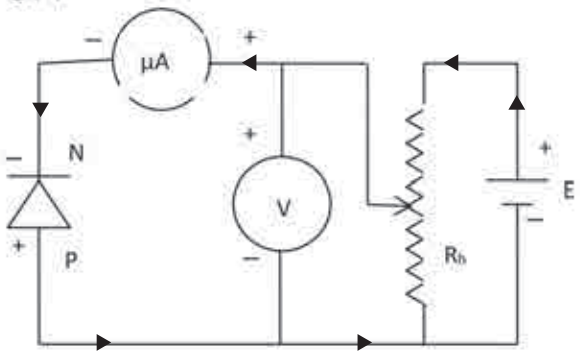


Fig 12.2 Reverse characteristics

Observation:

1. L.C. of Voltmeter: =_____ volt.
2. L. C. of Milliammeter : =_____ mA.
3. L. C. of Microammeter: =_____ μA.

Procedure :

A. Forward characteristics

1. Connect the circuit as shown in fig. 12.1
2. Voltage is increased from zero in steps of 0.1 V and corresponding current are recorded by the milliammeter.
3. For small value of the forward biased voltage (below 0.6 V), the forward biased current is zero. When applied voltage is less than V_K, a small current flows. Beyond Vk, a small increase in voltage produces a large increase in current. V_K, the voltage at which current start to increase rapidly, is called knee voltage or cut-in voltage. This voltage is equal to the barrier potential.
4. Plot the forward characteristics graph for diode (i.e. I-V curve) and find knee voltage V_K.
5. Calculate Static and dynamic resistance.

B. Reverse characteristics

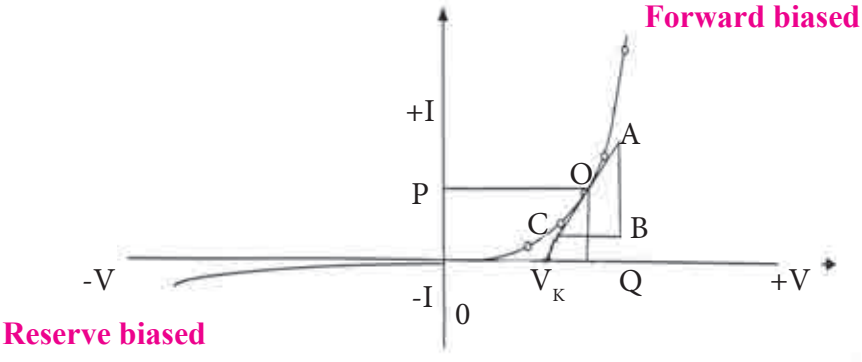
1. Connect the circuit as shown in fig. 12.2.
2. The reverse biased voltage is increased from zero in suitable steps and corresponding reverse biased current is measured by using microammeter.
3. As reverse voltage is increased from zero, reverse current increases and is equal to reverse saturation current (I_0).
4. When reverse voltage is increased further, at a particular voltage, the current may increase rapidly. This is called breakdown voltage. When reverse voltage is less than breakdown voltage, the p-n junction diode offers a high resistance.
5. Plot the reverse biased characteristics graph for diode.

Observation table :

Forward Bias			Reverse Bias		
Sr. No.	Voltage (V)	Current (mA)	Sr. No.	Voltage (V)	Current (μA)
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		
11			11		
12			12		
13			13		
14			14		
15			15		

Calculations :

Graph:



$$R_d = \frac{BC}{AB}$$

$$R_S = \frac{OQ}{OP}$$

Result:

The forward and reverse characteristics of diode were studied.

1. Knee Voltage = V_K =_____ volt.
2. R_d = _____Ω.
3. R_S = _____ Ω.

Precautions:

1. Check the polarities of the milliammeter/ Microammeter/Ammeter/Voltmeter before passing current.
2. Use milliammeter/ Microammeter/Ammeter and voltmeter of proper least count.

Additional Experiment you can do :

Determine voltage when Red, Yellow, green and blue LEDs, just start glowing (crossing knee voltage).

Multiple Choice Question

1. The d.c. resistance of a diode is ……..
   a) the same as it's a.c. resistance b) more than as it's a.c. resistance
   c) less than as it's a.c. resistance d) zero
2. The knee voltage of a crystal diode is approximately equal to …….
   a) applied voltage b) breakdown voltage
   c) forward voltage d) barrier potential

Questions

1. When is a junction diode said to be a) Forward biased b) reverse biased ?

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2. When does a junction diode offer very high resistance? Why?

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Remark and sign of teacher: .....

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FOR ADDITIONAL EXPERIMENT and NOTES

ACTIVITY NO.1
REFRACTIVE INDEX OF CONVEX LENS USING SPHEROMETER AND AUTO COLLIMATION METHOD

Aim: To determine refractive index of the material of given convex lens.

Apparatus: A spherometer, a double convex lens, a plane mirror, an index pin, a retort stand, a metre scale.

Diagram:

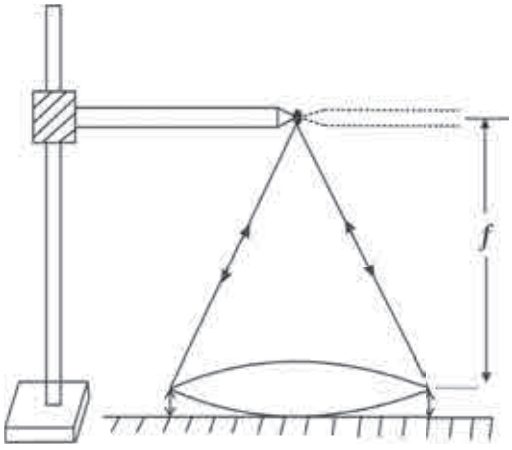

Fig. Auto Collimation

Formula: For a lens,

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Where, f = focal length of the lens

n = Refractive index of material of the lens

R_1 and R_2 = Radii of curvature of the lens.

According to Cartesian sign convention, R_1 & f are positive and R_2 is negative for a convex lens.

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$ …numerically.

Procedure:

1. Determine the radii of curvature R_1 & R_2 of both the surfaces of the given double convex lens. (Use the values which have been determined in spherometer experiment)
2. Keep the lens on the plane mirror.
3. Hold the pin horizontal in the retort stand holder and adjust its position so that its tip is along the principal axis of the lens.
4. Look from above the pin and adjust the position of the pin either by raising or lowering it so that it coincides with its own inverted image formed by reflection in the mirror, without parallax. (You will have to lower down the object pin if image appears thinner than the object pin and raise the object pin if the image appears thicker than the object pin). This method is called auto collimation method.
5. Record the distance of the tip of the pin from the centre of the lens. This distance is focal length of the lens f.
6. Calculate refractive index of the material of the lens.

Observations:

R_1 = ... cm. R_2 = ... cm. *f* = ... cm.

Calculations:

$$n = 1 + \frac{(R_1 R_2)}{f(R_1+R_2)} = \text{.....}$$

Result:

Refractive index of material of the lens, n = ……

Precaution:

Use the same lens which we have used in spherometer experiment.

FOR NOTES

Remark and sign of teacher: .....

ACTIVITY No. 2
LAW OF MOMENTS

Aim: To determine the mass of a given body using a meter scale by principle of moments.

Apparatus: A meter scale suspended at C.G., hanger with slotted weights, a body of unknown mass.

Diagram:

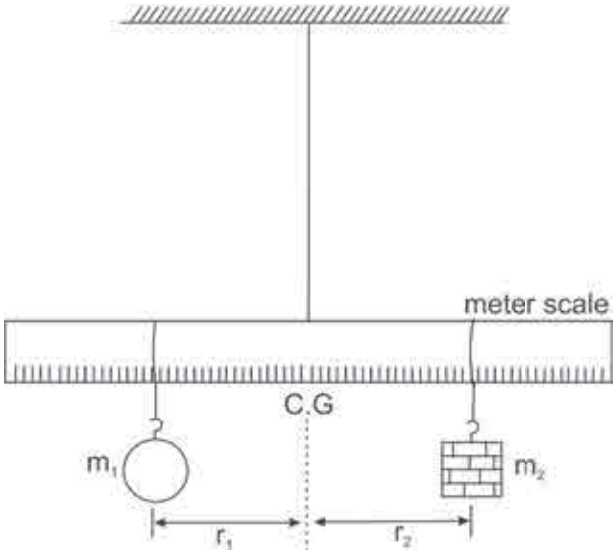

Fig . Experiment Setup

Formula:

$$m_1 r_1 = m_2 r_2$$

$$\therefore\ m_1 = \frac{m_2 r_2}{r_1}$$

Procedure:

1. Balance the meter scale carefully at its C.G. and note down the position of the C.G.
2. Suspend the body of unknown mass (m_1) at a fixed distance (r_1) from C.G. as shown in the figure.
3. Suspend the hanger with slotted masses (m_2) at some distance from C.G. to the other side as shown in the figure.
4. Adjust the distance (r_2) in such a way that, the meter scale becomes horizontal.
5. Repeat the steps 3 and 4 by changing the slotted weights (m_2) and note down the corresponding distance (r_2) in each case for three times.

Observations :

Fixed distance of unknown mas from C.G. = r_1 = ——— cm.

Sr. No.	Mass suspended with hanger (m_2) g	Distance of hanger from C.G. at balance (r_2) cm	$m_2 r_2$ gcm	Unknown (m_1) mass g
1				
2				
3				

Mean mass = ———

Result : The unknown mass of a body (m_1) = ———————— g.

Precaution: Find centre of gravity of scale using knife edge.

FOR NOTES

Remark and sign of teacher: .....

Activity NO. 3
ROLLING FRICTION

Aim : To determine the force of limiting friction for rolling of a roller on a horizontal plane.

Apparatus : A wheel base wooden / metal block(or trolley), weight box , friction less pulley, a plane horizontal plane, a balance a pan and a thread.

Theory: Rolling friction is that force of friction which comes into play when a body is rolling on the surface of another body.

Magnitude of the rolling friction is proportional to the normal reaction

$F_r \alpha N$

$F_r = \mu_r N$

$\mu_r = \frac{F_r}{W}$

Where μ_r = Coefficient of rolling friction

F_r = Magnitude of force of rolling friction

N = Normal reaction.

Diagram :

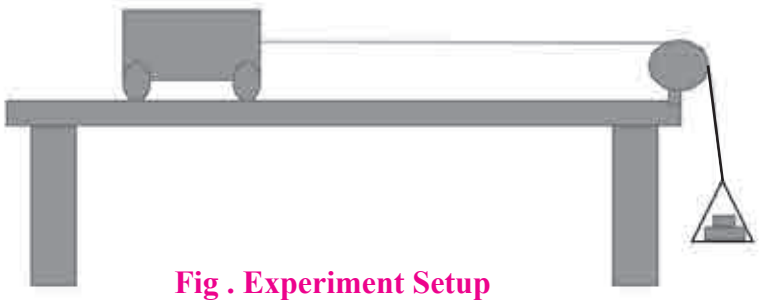

Fig . Experiment Setup

Procedure :

1. Measure the weight of wooden roller block (W_o) by using balance.
2. Measure the weight of Pan (P_o) by using balance.
3. Place wooden roller block on the horizontal plane plank. The one end of thread to block and other to the pan by passing it over the pulley. Pan should be freely suspended in air and thread between pulley and block should be horizontal.
4. Add weights in the plan gradually till the roller just starts rolling.
5. Note that minimum weight in the pan for which roller just start rolling.
6. Repeat the experiment by putting weights in the step of 50g on the wooden block.
7. In each case find the force of limiting friction (F_r)

Observations :

1. Weight of empty wooden block roller (W_o) = ……..g.
2. Weight of empty scale pan (P_o) = …….g.

Observation Table :

Sr. No.	Mass on the block W_1 g.wt	Total load $W = (W_0+W_1)$ g.wt	Mass in the pan P_1 g.wt	Total Effort $Fr = (P_0+P_1)$ g.wt	$\mu_r = \frac{F_r}{W}$	Mean μ_r
1						
2						
3						
4						
5						

Calculation :

$$\mu_r = \frac{F_r}{W}$$

Result :

1. Coefficient of rolling friction for the given surface μ_r = ……..
2. As the weight of pulley increases the effort increases.

Precautions :

1. Table top should be horizontal.
2. Pulley should be frictionless.
3. Weight in the pan should be increased in small steps.
4. Table top should be top gently.

FOR NOTES

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Remark and sign of teacher: .....

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ACTIVITY NO. 4
COEFFICIENT OF RESTITUTION

Aim : To determine the coefficient of restitution.

Apparatus : Rubber balls of different sizes (preferably same material), wooden board, meter scale, retort stand.

Formula:

$$e = \sqrt{\frac{h_2}{h_1}}$$

Diagram :

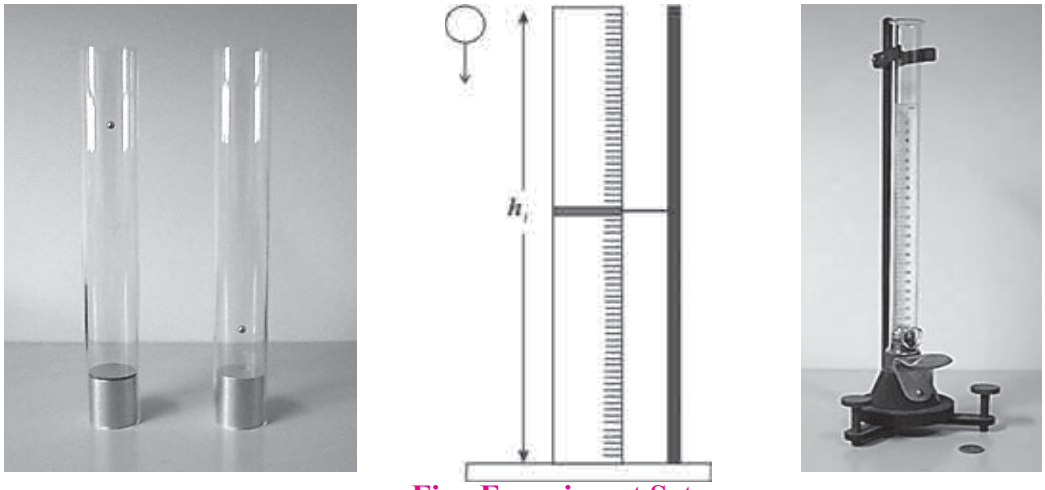

Fig . Experiment Setup

Procedure :

1. Measure the mass of each rubber ball.
2. Arrange the set up as shown in the figure.
3. Leave a ball vertically downward from the fixed height (may be 1 m).
4. Measure and record the height reached by the ball after the first bounce from the rigid floor of the laboratory.
5. Repeat the same for each ball one at a time and record the height reached.
6. Now the same experiment needs to be repeated with floor changed to wooden board.

Observations :

1. Mass of Ball (M_1) = …… g.
2. Mass of Ball (M_2) = …… g.
3. Mass of Ball (M_3) = …….. g.

Height of the ball initially = h_1 = ------- cm.

Observation table :

Ball	Height of bounce of ball from Rigid Floor Surface (h_2)	Height of bounce of ball from Wooden Board surface (h_2)
1		
2		
3		

Calculations:

1. Calculation of coefficient of restitution (for rigid floor surface).

Ball Number	$e = \sqrt{\frac{h_2}{h_1}}$
1	
2	
3	

2. Calculation of coefficient of restitution (for wooden floor surface).

Ball Number	$e = \sqrt{\frac{h_2}{h_1}}$
1	
2	
3	

Conclusion:

Compare the value of 'e' for different ball for same surface and draw your conclusion.

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Precautions : Use thread and scale method to measure vertical height.

FOR NOTES

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Remark and sign of teacher: .....

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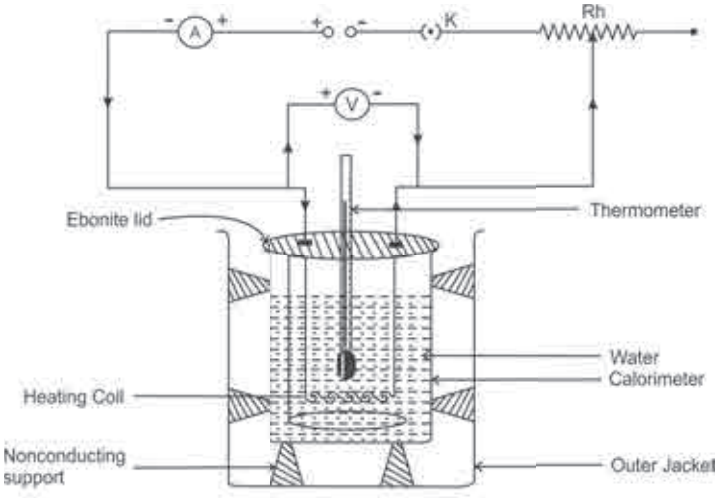
ACTIVITY NO. 5
'J' BY ELECTRICAL METHOD

Aim : ' J' by electrical method.

Apparatus : Calorimeter with stirrer, heating coil, DC Power supply, ammeter ,voltmeter, rheostat, thermometer, stopwatch, weight box, connecting wires etc.

Circuit Diagram :



E : D.C. Power supply, K : Plug key,
Rh: Rheostat, A : Ammeter, V : Voltmeter,
S : Stirrer

Formula:

1. Work done, W = V I t
2. Heat gained by the calorimeter with stirrer and water, H = $(m_c c_c + m_w c_w)\ (\Theta_2 - \Theta_1)$
3. Mechanical equivalent of heat, $J = \frac{W}{H} = \frac{V I t}{(m_c c_c + m_w c_w)(\Theta_2 - \Theta_1)}$

Procedure:

1. Weigh the empty calorimeter with stirrer.
2. Fill the calorimeter to about two-thirds of its volume with water and weigh it again.
3. Immerse the coil into the water in the calorimeter. Insert the thermometer, stirrer through the slots provided in the lid, into the calorimeter. Place the calorimeter on the non conducting supports inside the outer jacket.
4. Connect the circuit as shown in the figure above. Adjust the rheostat to position of maximum resistance.
5. Note the initial temperature (Θ_1) of the water in the calorimeter.
6. Pass current in the circuit and adjust the rheostat so that desired current (I) passes in the coil.
7. Note the potential difference , (V) across the coil.
8. Pass a steady current I through the coil for time t so that the temperature of the water rises by 10^{o} C.
9. Note the final temperature (Θ_2) of the water.

Observations :

1. Mass of the empty calorimeter with stirrer, m_C=……. g.
2. Mass of the calorimeter with stirrer and water, m=…….. g.
3. Hence mass of water = m_w = m – mc = ……g.
4. Initial temperature of the water, Θ_1 = ---------- °C.
5. Final temperature of the water, Θ_2 = ---------- °C.
6. Potential difference across the coil, V = ……. Volts.
7. Current through the coil, I = …….. A.

8. Specific heat of material of calorimeter and stirrer, C_c = ... $\frac{cal}{gram\ 0_C}$ (given)

9. Specific heat of water , C_w = ... $\frac{cal}{gram\ 0_C}$ (given)

Calculations:

$$J = \frac{W}{H} = \frac{V I t}{(m_c c_c + m_w c_w)(\Theta_2 - \Theta_1)}$$

Result : Mechanical equivalent of heat, J = ... J/cal =..... J/Kcal.

Precautions :

1. Keep the current in the circuit constant throughout the experiment by adjusting the rheostat as required.
2. The bulb of the thermometer should be well immersed in the water.
3. The bulb of the thermometer should touch the coil.
4. Stir the water in the calorimeter gently throughout the experiment for uniformity of temperature.

FOR NOTES

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Remark and sign of teacher: .....

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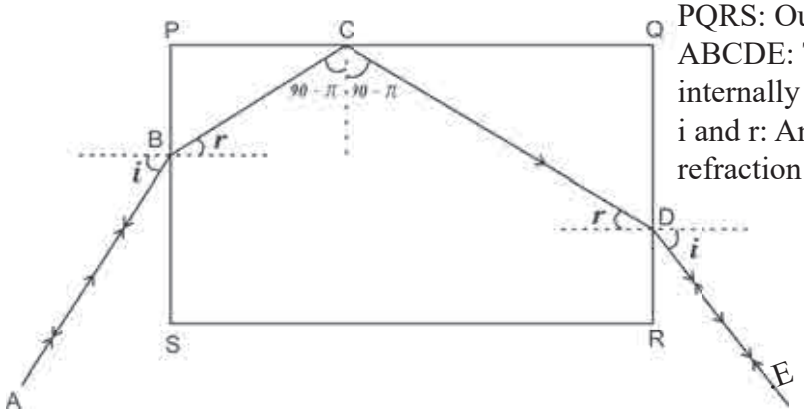
ACTIVITY NO. 6
REFRACTIVE INDEX OF GLASS BY TOTAL INTERNAL REFLECTION

Aim : To determine refractive index of glass by total internal refraction.

Apparatus : Glass slab, plain white paper, laser pointer, geometrical instrument box.

Diagram:



PQRS: Outline of glass slab
ABCDE: Trajectory of light, total internally reflected at point C
i and r: Angles of incidence and refraction at A (Same at D, by symmetry)

Theory:

At B, $i < 90°$

$\therefore r < i_C$

$\therefore$ At C, $(90-r) > i_C$

Thus, at point C, there will always be total internal reflection. Then at D, we get same angles, by symmetry.

Procedure:

1. Place the glass slab on white paper fixed the wooden drawing board.
2. Hold the laser pointer very close (touching the glass slab) along the width side (shorter side of glass slab) of it.
3. Initially place the laser beam perpendicular to the glass surface (angle of incidence 0 degree) at the point B such that PB is lesser than half the width of the glass slab.
4. Observe the refracted beam
5. Vary the angle of incidence by just changing the angle made by laser pointer with respect to the surface of glass slab.
6. Note the intensity of light refracted to air medium from surface PQ of glass slab and intensity of light reflected back in to the glass slab.
7. Find the position of the laser pointer (minimum angle of incidence) at which the light incident on the surface PQ is reflected back it to glass slab. (i_C).
8. Mark the position of laser pointer using pencil and draw the incident ray and measure the angle of incidence. Complete the ray diagram as shown in figure to get the path BCD. Draw the direction of emergent ray as same as that of incident ray following the path of the emergent laser beam. Measure the angle of incidence at the surface PQ. (for condition noted in point 6).
9. Calculate the refractive index of glass slab.

Observation Table :

Obs. No.	Angle of incidence i_C	$\mu = \frac{1}{\sin i_C}$

Result:

Value of refractive index n= …….

Precations:

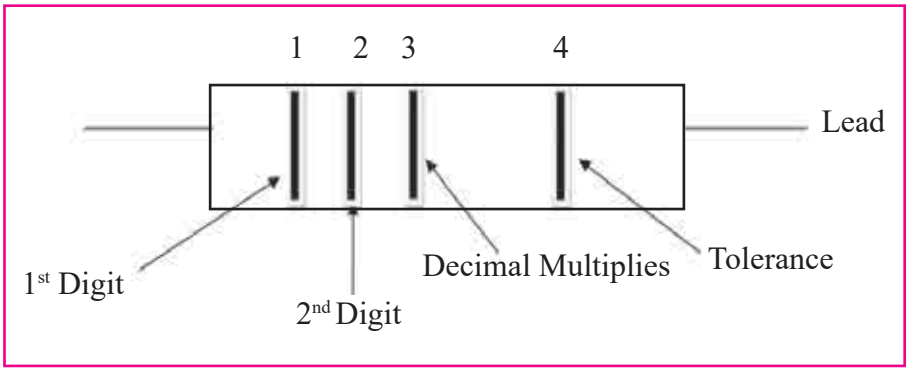
1. Use laser properly.
2. Mark points properly on the reflected ray laser beam.

FOR NOTES

Remark and sign of teacher: .....

ACTIVITY NO. 7
STUDY OF RESISTORS USING COLOR CODE

Aim : To learn how to calculate the value of resistor with help of colour code.
Apparatus : 5 Resistors of different values, multimeter.
Diagram :



Generally, standard value carbon resistors are colour coded to indicate their value. From left to right, the first band gives the first digit, the second band gives the second digit, the third band gives the decimal multiple [no. of zero's after first two digits] . The fourth band gives the tolerance of the resistor in percentage. In some cases there is no fourth band.In this case resistor should be hold in such a way that the gap on the left side is smaller.

Procedure:

1. Calculate the value of the first resistor alongwith its tolerance using the colour code marked on the resistor. The values of colour code are given in the table below.
2. Take a multimeter and adjust it to the suitable resistance range. Measure the value of the first resistor using the multimeter.
3. Repeat the same procedure for 4 other resistors.

Resistor colour code chart :

Colour	Digit	Multiplier	Tolerance
Black	0	10^0	--
Brown	1	10^1	± 1 %
Red	2	10^2	± 2 %
Orange	3	10^3	--
Yellow	4	10^4	--
Green	5	10^5	--
Blue	6	10^6	--
Violet	7	10^7	--
Grey	8	10^8	--
White	9	10^9	--
Golden	--	10^{-1}	± 5 %
Silver	--	10^{-2}	± 10 %
No Colour	--	--	± 20 %

Observation table :

Sr. No.	Colour code on Resistor	Band -I	Band -II	Band -III	Band -IV	Value Ω	Tolerance Ω	Calculated value of Resistor with tolerance in Ω	Reading on multimeter in Ω
1									
2									
3									
4									
5									

Result :

We study the method of finding the value of resistor from colour code and verify the value using a multimeter.

Precautions :

Use multimeter with proper range for measuring resistance.

FOR NOTES

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Remark and sign of teacher: .....

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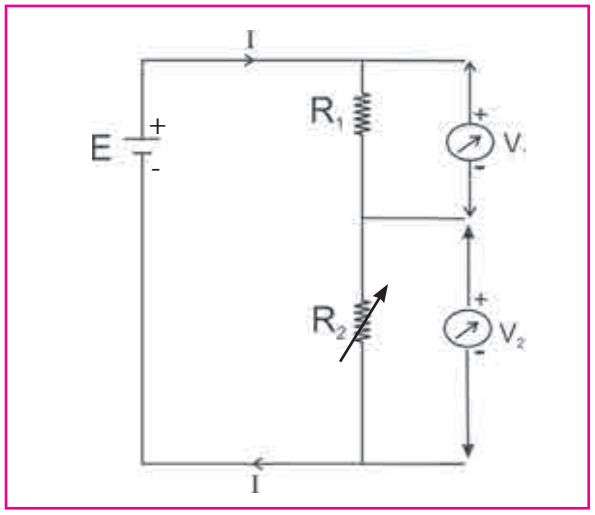
ACTIVITY NO. 8
STUDY OF POTENTIAL DIVIDER CIRCUIT

Aim: To study a potential divider circuit

Apparatus : 5 volts d.c. power supply with least count 0.1volt, 100 Ω, carbon resistor (1⁄4 watt ± 20% tolarence) and standard variable resistance box.

Circuit Diagram :



Theory:

The current in the above circuit is

$$I = \frac{E}{(R_1+R_2)}$$

Potential difference across resistor R_1 (100 Ω) is given as

$$V_1 = IR_1 = \frac{(E\ R_1)}{(R_1+R_2)}$$

Potential difference across the variable resistor is,

$$V_2 = IR_2 = \frac{(E\ R_2)}{(R_1+R_2)}$$

(R_2 is suitable resistance from resistance box)

Procedure :

1. Initially the resistance in the resistance box (R_2) is kept 0.
2. The voltmeter is connected across R_1 (100 Ω)and potential difference V_1 is noted.
3. The voltmeter is then connected across R_2 and potential difference V_2 is noted.
4. The steps (2) & (3) are repeated for 2 more values of R_2 (preferably 20 Ω and 40 Ω)

Observation :

R_1 = _____Ω

Observation table :

Obs. no.	Resistor R_2 Ω	Theoretical value of P.D.		Observed value of P.D.	
		Across $R_1 = \frac{(E\ R_1)}{(R_1+R_2)}$	Across $R_2 = \frac{(E\ R_2)}{(R_1+R_2)}$	Across R_1	Across R_2

Result : Theoretical and actually measured values of V_1 and V_2 nearly same.
Study of potential divider circuit is done.

Precautions:

Check that positive terminal connection of voltmeter with positive terminal of battery.

FOR NOTES

Remark and sign of teacher: .....

NOTES /CALCULATIONS /ROUGH WORK

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SLIPS FOR PRACTICAL EXAMINATION
PHYSICS

LONG EXPERIMENTS

1. Vernier Callipers

Determine the least count of vemier callipers. Find the diameter of the given sphere using vernier callipers. Take 3 independent readings. Calculate the volume of the sphere.

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2. Vernier Callipers

Determine the least count of vemier callipers. Find the inner diameter and depth of the hollow cylinder. Take 3 readings in each case. Calculate the volume of the hollow cylinder.

---

3. Micrometer Screw Gauge

Determine the least count and zero error of the micrometer-screw gauge. Measure the diameter of the given wire. Take three readings. Calculate the cross - sectional area of the wire.

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4. Micrometer Screw Gauge

Find out the pitch, least count and Zero error of a given micrometer screw gauze. Hence determine the thickness of given glass plate. Take three readings

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5. Spherometer

Determine the least count of the spherometer. Determine the radius of curvature of the given curved surface.

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6. Law of Parallelogram of Forces

Determine the unknown weight using the law of parallelogram of forces. Verify the same by calculation of resultant force.

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7. Law of Parallelogram of Forces

Verify law of parallelogram of forces for

a) P = Q b) P > Q Where P and Q are applied forces along two adjacent sides of a paral lelogram.

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8. Coefficient of Static Friction

Determine the coefficient of static friction between wooden block and horizontal surface. Take four independent sets of readings.

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9. Coefficient of Static Friction

You are given plane surface wooden box and a pan. For four different values of load 'L' find the effort 'P' required to just move the wooden box over the plane surface. Plot a graph of 'P' vs. 'L', hence find coefficient of static friction

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10. R.I. of glass using Travelling microscope

Determine the refractive index of the given glass slab using travelling microscope. Take one set of readings.

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11. R.I. of glass using Travelling microscope

Determine the refractive index of the given liquid using travelling microscope. Take one set of readings.

12. Focal length of convex lens

For four different values of object distance measure corresponding image distance: Hence find the focal length of a given convex lens using suitable formula.

13. R.I. of Liquid

Determine the Refractive Index of a given liquid by using concave mirror. Take four readings.

14. Prism

You are given drawingboard, pins, white paper, and prism. For four different angles of incidence (i) find angle of deviation 'δ'and angle of emergence e. Hence Verify A+ δ = i + e

15. Prism

You are given Prism, white paper, Drawing board, and pins. For four different angle of incidence (i) find angle of deviation'δ'. Plot a graph of δ agaist i. Hence find R.I. of material of Prism. Given A=600.

16. Prism

You are given prism, white paper, Drawing board, pins. For four different angle of incidence (i) measure angle of deviation δ. Plot a graph of δ against i. Find angle of minimum deviation from graph. Draw your conclusion from graph.

17. Deflection Magnetometer

Calculate the magnetic moment of a short bar magnet by using deflection magnetometer in Tan A / Tan B position. Repeat for one more magnet.

18. Characteristics of Thermistor

You are given a thermistor Dip it in the liquid. Increase the temperature of the liquid gradually. Note the resistance of the thermistor for five different temperatures. Plot the graph resistance verses temperature. Find the value of β.

19. Characteristics of Thermistor

You are given a thermistor dip it in the liquid. Increase the temperature of the liquid gradually. Note the resistance of the thermistor for five different temperatures. Plot the graph resistance verses temperature. Draw your conclusion from graph.

20. PN Junction diode

Draw the characteristics of PN junction diode when the diode is used in forward bias. Find knee voltage.

22. PN Junction diode

Draw the characteristics of PN junction diode when the diode is used in forward bias. Find dynamic and static resistance.

SHORT EXPERIMENTS

1. Vernier Callipers

Determine the least count of vemier callipers. Find the diameter of the given sphere using vernier callipers. Take 2 independent readings.

2. Vernier Callipers

Determine the least count of vemier callipers. Find the inner diameter of the hollow cylinder. Take 2 readings.

3. Micrometer Screw Gauge

Determine the least count and zero error of the micrometer-screw gauge. Measure the diameter of the given wire of given plate. Take 2 readings.

4. Micrometer Screw Gauge

Determine the least count and zero error of the micrometer-screw gauge. Measure the thickness of the given glass plate. Take 2 readings.

5. Spherometer

Determine the least count of the spherometer. Calculate sagita for any one surface of the convex surface.

6. Law of Parallelogram of Forces

Verify the Law of Parallelogram by using given data (one reading) P = --- Q = ----

7. Law of Parallelogram of Forces

Draw vector diagram using given data of P=----,Q=--- and Θ = --- Measure the diagonal (R), also determine R by using formula .

8. Coefficient of Static Friction

Determine the coefficient of static friction between wooden block and horizontal surface. Take two independent sets of readings.

9. R.I. of glass using Travelling microscope

Determine the thickness of glass slab using travelling microscope. (Least count of travelling microscope = 0.001cm)

10. R.I. of glass using Travelling microscope

Determine the apparent depth of glass slab using travelling microscope. (Least count of travelling microscope = 0.001cm)

11. Focal length of convex lens by displacement method

Determine size of diminished and magnified images of an object for two different positions of source and screen. Hence find "d".

12. R.I. of Liquid

Measure the distance of index pin from concave mirror by removing parallax with water.

13. R.I. of Liquid

Measure the distance of index pin from concave mirror by removing parallax.

14. Prism

For given angle of incidence i = --- use the given prism and find the value of angle of deviation δ. Repeat for i = ---

15. Deflection Magnetometer

Arrange the deflection magnetometer in Tan A / Tan B position and measure distance of magnet for $\Theta = 45^0$ .Hence calculate magnetic moment of the magnet.

16. Characteristics of Thermistor

You are given a thermistor Dip it in the liquid. Increase the temperature of the liquid gradually. Note the resistance of the thermistor for three different temperatures.

17. Characteristics of Thermistor

Measure the resistance of the given thermistor at room temperature . Repeat the same by holding the thermistor in the closed palm.

Using β = _____ , correlate the temperatures of the body with that of the thermistor.

18. PN junction diode

Measure the current through the forward biased junction diode for different values of voltages .Hence find the value of knee voltage.

ACTIVITIES

1. Total internal reflection

You are given a glass slab. Pass the laser beam through the width of the slab and preasure the angle of incidence for which total external reflection takes place.

2. Law of moments

You are given a meter scale, Slotted weights, and a body of Unknown mass. Keeping un known mass at a fix distance from C.G., adjust the distance of slotted weight on the other side of C.G. so that meter scale remains perfectly horizontal. Hence determine the mass of a give body. Repeat for one more unknown mass.

3. Rolling friction

Determine the force of limiting friction for rolling of a roller on a horizontal plane.

4. Coefficient of restitutions

Determine the coefficient of restitution by using rubber balls of different size.

5. 'J' by electrical method

Pass suitable current in the coil for time t = --- s. Measure current I and potential V. Measure the required temperatures and determine J.

6. Colour code resistor

Measure the value of given resistance by using multimeter. Hence write its colour code .

Tolerance of the resistance is _____

7. Potential divider circuit

E = _____ R_1 = _____ find the value of resistance R_2 for which potential difference is equal to……. Verify it using multimeter.

8. Refractive Index by Auto collimation method

You are given a convex lens having R_1 =_____ and R_2 =_____

Using auto collimation method find the refractive index of the lens.

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No of experements performed ☐ No of activities performed ☐

Subject Teacher Examiner Principal

Stamp

LOGARITHMS

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1887	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	5879	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3679	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	4	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	4	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	2	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7502	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

LOGARITHMS

	0		2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7881	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8066	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	862	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8245	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8315	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	5	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	2	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9531	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9641	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	4	4

ANTILOGARITHMS

	0		2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	2
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	3	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	3	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
.33	2138	2143	2148	2153	2058	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
.34	2188	2193	2098	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	5	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3536	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	6	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3980	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5356	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5683	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	8715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6526	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6981	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	13	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7960	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	11	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	11	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	11	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	11	15	17	19
.96	9120	9141	9165	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9551	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

NATURAL SINES

Degrees	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	Mean Differences				
	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°	1′	2′	3′	4′	5′
0°	.0000	0017	0035	0052	0070	0087	0105	0122	0140	0157	3	6	9	12	15
1	.0175	0192	0209	0227	0244	0262	0279	0297	0314	0332	3	6	9	12	15
2	.0349	0366	0384	0401	0419	0436	0454	0471	0488	0506	3	6	9	12	15
3	.0523	0541	0558	0576	0593	0610	0628	0645	0663	0680	3	6	9	12	15
4	.0698	0715	0732	0750	0767	0785	0802	0819	0837	0854	3	6	9	12	14
5	.0872	0889	0906	0924	0941	0958	0976	0993	1011	1028	3	6	9	12	14
6	.1045	1063	1080	1097	1115	1132	1149	1167	1184	1201	3	6	9	12	14
7	.1219	1236	1253	1271	1288	1305	1323	1340	1357	1374	3	6	9	12	14
8	.1392	1409	1426	1444	1461	1478	1495	1513	1530	1547	3	6	9	12	14
9	.1564	1582	1599	1616	1633	1650	1668	1685	1702	1719	3	6	9	12	14
10°	.1736	1754	1771	1788	1805	1822	1840	1857	1874	1891	3	6	9	11	14
11	.1908	1925	1942	1959	1977	1994	2011	2028	2045	2062	3	6	9	11	14
12	.2079	2096	2113	2130	2147	2164	2181	2198	2215	2233	3	6	9	11	14
13	.2250	2267	2284	2300	2317	2334	2351	2368	2385	2402	3	6	8	11	14
14	.2419	2436	2453	2470	2487	2504	2521	2538	2554	2571	3	6	8	11	14
15	.2588	2603	2622	3639	2656	2672	2689	2706	2723	2740	3	6	8	11	14
16	.2756	2773	2790	2807	2823	2840	2857	2874	2890	2907	3	6	8	11	14
17	.2924	2940	2957	2974	2990	3007	3024	3040	3057	3074	3	6	8	11	14
18	.3090	3107	3123	3140	3156	3173	3190	3206	3223	3239	3	6	8	11	14
19	.3256	3272	3289	3305	3322	3338	3355	3371	3387	3404	3	5	8	11	14
20°	.3420	3437	3453	3469	3486	3502	3518	3535	3551	3567	3	5	8	11	14
21	.3584	3600	3616	3633	3649	3665	3681	3697	3714	3730	3	5	8	11	14
22	.3746	3762	3778	3795	3811	3827	3843	3859	3875	3891	3	5	8	11	14
23	.3907	3923	3939	3955	3971	2987	4003	4019	4035	4051	3	5	8	11	14
24	.4067	4083	4099	4115	4131	4147	4163	4179	4195	4210	3	5	8	11	13
25	.4226	4242	4258	4274	4289	4305	4321	4337	4352	4368	3	5	8	11	13
26	.4384	4399	4415	4431	4446	4462	4478	4493	4509	4524	3	5	8	10	13
27	.4540	4555	4571	4586	4602	4617	4633	4648	4664	4679	3	5	8	10	13
28	.4695	4710	4726	4741	4756	4772	4787	4802	4818	4833	3	5	8	10	13
29	.4848	4863	4879	4894	4909	4924	4939	4955	4970	4935	3	5	8	10	13
30°	.5000	5015	5030	5054	5060	5075	5090	5105	5120	5135	3	5	8	10	13
31	.5150	5165	5180	5195	5210	5225	5240	5255	5270	5284	2	5	7	10	12
32	.5299	5314	5329	5344	5358	5373	5388	5402	5417	5432	2	5	7	10	12
33	.5446	5461	5476	5490	5505	5519	5534	5548	5563	5577	2	5	7	10	12
34	.5592	5606	5621	5635	5650	5664	5678	5693	5707	5721	2	5	7	10	12
35	.5736	5750	5764	5779	5793	5807	5821	5835	5850	5864	2	5	7	10	12
36	.5878	5892	5906	5920	5934	5948	5962	5976	5990	6004	2	5	7	9	12
37	.6018	6032	6046	6060	6074	6088	6101	6115	6129	6143	2	5	7	9	12
38	.6157	6170	6184	6198	6211	6225	6239	6252	6266	6280	2	5	7	9	11
39	.6293	6307	6320	6334	6347	6361	6374	6388	6401	6414	2	5	7	9	11
40°	.6428	6441	6455	6468	6481	6494	6508	6521	6534	6547	2	5	7	9	11
41	.6561	6574	6587	6600	6613	6626	6639	6652	6665	6678	2	4	7	9	11
42	.6691	6704	9717	6730	6743	6756	6769	6782	6794	6807	2	4	6	9	11

43	.6820	6833	6845	6858	6871	6884	6896	6909	6921	6934	2	4	6	8	11
44	.6947	6959	6972	6984	6997	7009	7022	7034	7046	7059	2	4	6	8	10

NATURAL SINES

Degrees	0' 0.0°	6' 0.1°	12' 0.2°	18' 0.3°	24' 0.4°	30' 0.5°	36' 0.6°	42' 0.7°	48' 0.8°	54' 0.9°	Mean Differences				
											1'	2'	3'	4'	5'
45°	.7071	7083	7096	7108	7120	7133	7145	7157	7169	7181	2	4	6	8	10
46	.7193	7206	7218	7230	1242	7254	7266	7278	7290	7302	2	4	6	8	10
47	.7314	7325	7337	7349	7361	7373	7385	7396	7408	7420	2	4	6	8	10
48	.7431	7443	7455	7466	7478	7490	7501	7513	7524	7536	2	4	6	8	10
49	.7547	7559	7570	7581	7593	7604	7615	7627	7638	7649	2	4	6	8	9
50°	.7660	7672	7683	7694	7705	7716	7727	7738	7749	7760	2	4	6	7	9
51	.7771	7782	7793	7804	7815	7826	7837	7848	7859	7869	2	4	5	7	9
52	.7880	7891	7902	7912	7923	7934	7944	7955	7965	7976	2	4	5	7	9
53	.7686	7997	8007	8018	8028	8039	8049	8059	8070	8080	2	3	5	7	9
54	.8090	8100	8111	8121	8131	8141	8151	8161	8171	8181	2	3	5	7	8
55	.8192	8202	8211	8221	8231	8241	8251	8261	8271	8281	2	3	5	7	8
56	.8290	8300	8310	8320	8329	8339	8348	8358	8368	8377	2	3	5	6	8
57	.8387	8396	8406	8415	8425	8434	8443	8453	8462	8471	2	3	5	6	8
58	.8480	8490	8499	8508	8517	8526	8536	8545	8554	8563	2	3	5	6	8
59	.8572	8581	8590	8599	8607	8616	8625	8634	8643	8652	1	3	4	6	7
60°	.8660	8669	8678	8686	8695	8704	8712	8721	8729	8738	1	3	4	6	7
61	.8746	8755	8763	8771	8780	8788	8796	8805	8813	8821	1	3	4	6	7
62	.8829	8838	8846	8854	8862	8870	8878	8886	8894	8902	1	3	4	5	7
63	.8910	8918	8926	8934	8942	8949	8957	8965	8973	8980	1	3	4	5	6
64	.8988	8996	9003	9011	9018	9026	9033	9041	9048	9056	1	3	4	5	6
65	.9063	9070	9078	9085	9092	9100	9107	9114	9121	9128	1	2	4	5	6
66	.9135	9143	9150	9157	9164	9171	9178	9184	9191	9198	1	2	3	5	6
67	.9205	9212	9219	9225	9232	9239	9245	9252	9259	9265	1	2	3	5	6
68	.9272	9278	9285	9291	9298	9304	9311	9317	9223	9330	1	2	3	5	5
69	.9336	9342	9348	9354	9361	9367	9373	9379	9385	9391	1	2	3	5	5
70	.9397	9403	9409	9415	9421	9426	9432	9438	9444	9449	1	2	3	5	5
71	.9455	9461	9466	9472	9478	9483	9489	9494	9500	9505	1	2	3	4	5
72	.9511	9516	9521	9527	9532	9537	9542	9548	9553	9558	1	2	3	3	4
73	.9563	9568	9573	9578	9583	9588	9593	9598	9603	9608	1	2	2	3	4
74	.9613	9517	9622	9627	9632	9636	9641	9646	9650	9655	1	2	2	3	4
75	.9659	9664	9668	9673	9677	9681	9686	9690	9694	9699	1	1	2	3	4
76	.9503	9707	9711	9715	9720	9724	9728	9732	9736	9740	1	1	2	3	3
77	.9744	9748	9751	9755	9759	9763	9767	9770	9774	9778	1	1	2	3	3
78	.9781	9785	9789	9792	9796	9799	9803	9806	9810	9813	1	1	2	2	3
79	.9816	9820	9823	9826	9829	9833	9836	9839	9842	9845	1	1	2	2	3
80°	.9848	9851	9854	9857	9860	9863	9866	9869	9871	9874	0	1	1	2	2
81	.9877	9880	9882	9885	9888	9890	9893	9895	9898	9900	0	1	1	2	2
82	.9903	9905	9907	9910	9912	9914	9917	9919	9921	9923	0	1	1	2	2
83	.9925	9928	9930	9932	9934	9936	9938	9940	9942	9943	0	1	1	1	2
84	.9945	9947	9949	9951	9952	9954	9956	9957	9959	9960	0	1	1	1	2
85	.9962	9963	9965	9966	9968	9969	9971	9972	9973	9974	0	0	1	1	1
86	.9976	9977	9978	9979	9980	9981	9982	9983	9984	9985	0	0	1	1	1
87	.9986	9987	9988	9989	9990	9990	9991	9992	9993	9993	0	0	0	1	1
88	.9994	9995	9995	9996	9996	9997	9997	9997	9998	9998	0	0	0	0	0
89	.9998	9999	9999	9999	9999	1.000	1.000	1.000	1.000	1.000	0	0	0	0	0

NATURAL COSINES

Degrees	0′ 0.0°	6′ 0.1°	12′ 0.2°	18′ 0.3°	24′ 0.4°	30′ 0.5°	36′ 0.6°	42′ 0.7°	48′ 0.8°	54′ 0.9°	Mean Differences SUBTRACT				
											1′	2′	3′	4′	5′
0	1.000	1.000	1.000	1.000	1.000	1.000	9999	9999	9999	9999	0	0	0	0	0
1	.9998	9998	9998	9997	9997	9997	9996	9996	9995	9995	0	0	0	0	0
2	.9994	9993	9993	9992	9991	9990	9990	9989	9988	9987	0	0	0	1	1
3	.9986	9985	9984	9983	9982	9981	9980	9979	9978	9977	0	0	1	1	1
4	.9976	9974	9973	9972	9971	9969	9968	9966	9965	9963	0	0	1	1	1
5	.9962	9960	9959	9957	9956	9954	9952	9951	9949	9947	0	1	1	1	2
6	.9945	9943	9942	9940	9938	9936	9934	9932	9930	9928	0	1	1	1	2
7	.9925	9923	9921	9919	9917	9914	9912	9910	9907	9905	0	1	1	2	2
8	.9903	9900	9898	9895	9893	9890	9888	9885	9882	9880	0	1	1	2	2
9	.9877	9874	9871	9869	9866	9863	9860	9857	9854	9851	0	1	1	2	2
10	.9848	9845	9842	9839	9836	9833	9829	9826	9823	9820	1	1	2	2	3
11	.9816	9813	9810	9806	9803	9799	9796	9792	9789	9785	1	1	2	2	3
12	.9781	9778	9774	9770	9767	9763	9759	9755	9751	9748	1	1	2	3	3
13	.9744	9740	9736	9732	9728	9724	9720	9715	9711	9707	1	1	2	3	3
14	.9703	9699	9694	9690	9686	9681	9677	9673	9668	9664	1	1	2	3	4
15	.9659	9655	9650	9646	9641	9636	9632	9627	9622	9617	1	2	2	3	4
16	.9613	9603	9603	9598	9593	9588	9583	9578	9573	9568	1	2	2	3	4
17	.9563	9558	9553	9548	9542	9537	9532	9527	9521	9516	1	2	3	3	4
18	.9511	9505	9500	9494	9489	9483	9478	9472	9466	9461	1	2	3	4	5
19	.9455	9449	9444	9438	9432	9426	9421	9415	9409	9403	1	2	3	4	5
20	.9397	9391	9385	9379	9373	9367	9361	9354	9348	9342	1	2	3	4	5
21	.9336	9330	9323	9317	9311	9304	9298	9291	9285	9278	1	2	3	4	5
22	.9272	9265	9559	9252	9245	9239	9232	9225	9219	9212	1	2	3	4	6
23	.9205	9198	9191	9184	9178	9171	9164	9157	9150	9143	1	2	3	5	6
24	.9135	9128	9121	9114	9107	9100	9092	9085	9078	9070	1	2	4	5	6
25	.9063	9056	9048	9041	9033	9026	9018	9011	9003	8996	1	3	4	5	6
26	.8988	8980	8973	8965	8957	8949	8942	8934	8926	8918	1	3	4	5	6
27	.8910	8902	8894	8886	8878	8870	8862	8854	8846	8838	1	3	4	5	7
28	.8829	8821	8813	8805	8796	8788	8780	8771	8763	8755	1	3	4	6	7
29	.8746	8738	8729	8721	8712	8704	8695	8686	8678	8669	1	3	4	6	7
30	.9660	8652	8643	8634	8625	8616	8607	8599	8590	8581	1	3	4	6	7
31	.8572	8563	8554	8545	8536	8526	8517	8508	8499	8490	2	3	5	6	8
32	.8480	8471	8462	8453	8443	8434	8425	8415	8406	8396	2	3	5	6	8
33	.8387	8377	8368	8358	8348	8339	8329	8320	8310	8300	2	3	5	6	8
34	.8290	8281	8271	8261	8251	8241	8231	8221	8211	8202	2	3	5	7	8
35	.8192	8181	8171	8161	8151	8141	8131	8121	8111	8100	2	3	5	7	8
36	.8090	8080	8070	8059	8049	8039	8028	8018	8007	7997	2	3	5	7	9
37	.7986	7976	7965	7955	7944	7934	7923	7912	7902	7891	2	4	5	7	9
38	.7880	7869	7859	7848	7837	7826	7815	7804	7793	7782	2	4	5	7	9
39	.7771	7760	7749	7738	7727	7716	7705	7694	7683	7672	2	4	6	7	9
40	.7660	7649	7638	7627	7615	7604	7593	7581	7570	7559	2	4	6	8	9
41	.7547	7536	7524	7513	7501	7490	7478	7466	7455	7443	2	4	6	8	10
42	.7431	7420	7408	7396	7385	7373	7361	7349	7337	7325	2	4	6	8	10
43	.7314	7302	7290	7278	7266	7254	7242	7230	7218	7206	2	4	6	8	10
44	.7193	7181	7169	7157	7145	7133	7120	7108	7096	7083	2	4	6	8	10

NATURAL COSINES

Degrees	0′ 0.0°	6′ 0.1°	12′ 0.2°	18′ 0.3°	24′ 0.4°	30′ 0.5°	36′ 0.6°	42′ 0.7°	48′ 0.8°	54′ 0.9°	Mean Differences SUBTRACT				
											1′	2′	3′	4′	5′
45°	.7071	7059	7046	7034	7022	7009	6997	6984	6972	6959	2	4	6	8	10
46	.6947	6934	6921	6906	6896	6884	6871	6858	6845	6833	2	4	6	9	11
47	.6820	6807	6794	6782	6769	6756	6743	6730	6717	6704	2	4	6	9	11
48	.6691	6678	6665	6652	6639	6626	6613	6600	6587	6574	2	4	7	9	11
49	.6561	6547	6534	6521	6508	6494	6481	6468	6455	6441	2	4	7	9	11
50°	.6428	6414	6401	6388	6374	6361	6347	6334	6320	6307	2	4	7	9	11
51	.6293	6280	6266	6252	6239	6225	6211	6198	6184	6170	2	5	7	9	11
52	.6157	6143	6129	6115	6101	6088	6074	6060	6046	6032	2	5	7	9	12
53	.6018	6004	5990	5976	5962	5948	5934	5920	5906	5892	2	5	7	9	12
54	.5878	5864	5850	5835	5821	5807	5793	5779	5764	5750	2	5	7	9	12
55	.5736	5721	5707	5693	5678	5664	5650	5635	5621	5606	2	5	7	10	12
56	.5592	5577	5563	5548	5534	5519	5505	5490	5476	5461	2	5	7	10	12
57	.5446	5432	5417	5402	5388	5373	5358	5344	5329	5314	2	5	7	10	12
58	.5299	5284	5270	5255	5240	5225	5210	5195	5180	5165	2	5	7	10	12
59	.5150	5135	5120	5105	5090	5075	5060	5045	5030	5015	3	5	8	10	13
60°	.5000	4985	4970	4955	4939	4924	4909	4894	4879	4863	3	5	8	10	13
61	.4848	4833	4818	4802	4787	4772	4756	4741	4726	4710	3	5	8	10	13
62	.4695	4679	4664	4648	4633	4617	4602	4586	4571	4555	3	5	8	10	13
63	.4540	4524	4509	4493	4478	4462	4446	4431	4415	4399	3	5	8	10	13
64	.4384	4368	4352	4337	4321	4305	4289	4274	4258	4242	3	5	8	11	13
65	.4226	4210	4195	4179	4163	4147	4131	4115	4099	4083	3	5	8	11	13
66	.4067	4051	4035	4019	4003	3987	3971	3955	3939	3923	3	5	8	11	14
67	.3907	3891	3875	3859	3843	3827	3811	3795	3778	3762	3	5	8	11	14
68	.3746	3730	3714	3697	3681	3665	3649	3633	3616	3600	3	5	8	11	14
69	.3584	3567	3551	3535	3518	3502	3486	3469	3453	3437	3	5	8	11	14
70°	.3420	3404	3387	3371	3355	3338	3322	3305	3289	3272	3	5	8	11	14
71	.3256	3239	3223	3206	3190	3173	3156	3140	3123	3107	3	6	8	11	14
72	.3090	3074	3057	3040	3024	3007	2990	2974	2957	2940	3	6	8	11	14
73	.2924	2907	2890	2874	2857	2840	2823	2807	2790	2773	3	6	8	11	14
74	.2756	2740	2723	2706	2689	2672	2656	2639	2622	2605	3	6	8	11	14
75	.2588	2571	2554	2538	2521	2504	2487	2470	2453	2436	3	6	8	11	14
76	.2419	2402	2385	2368	2351	2334	2317	2300	2284	2267	3	6	8	11	14
77	.2250	2233	2215	2198	2181	2164	2147	2130	2113	2096	3	6	9	11	14
78	.2079	2062	2045	2028	2011	1994	1977	1959	1942	1925	3	6	9	11	14
79	.1908	1891	1874	1857	1640	1822	1805	1788	1771	1754	3	6	9	11	14
80°	.1736	1719	1702	1685	1668	1650	1633	1616	1599	1582	3	6	9	12	14
81	.1564	1547	1530	1513	1495	1478	1461	1444	1426	1409	3	6	9	12	14
82	.1392	1374	1357	1340	1323	1305	1288	1271	1253	1236	3	6	9	12	14
83	.1219	1201	1184	1167	1149	1132	1115	1097	1080	1063	3	6	9	12	14
84	.1045	1028	1011	0993	0976	0958	0941	0924	0906	0889	3	6	9	12	14
85	.0872	0854	0837	0819	0802	0785	0767	0750	0732	0715	3	6	9	12	14
86	.0698	0680	0663	0645	0628	0610	0593	0576	0558	0541	3	6	9	12	15
87	.0523	0506	0488	0471	0454	0436	0419	0401	0384	0366	3	6	9	12	15
88	.0349	0332	0314	0297	0279	0262	0244	0227	0209	0192	3	6	9	12	15
89	.0175	0157	0140	0122	0105	0087	0070	0052	0035	0017	3	6	9	12	15

RECIPROCALS OF FOUR – FIGURE NUMBERS

	0	1	2	3	4	5	6	7	8	9	Mean Differences SUBTRACT								
											1	2	3	4	5	6	7	8	9
1.0	1.0000	9901	9804	9709	9615	9524	9434	9346	9259	9174	9	18	28	37	46	55	64	74	83
1.1	.9091	9009	8929	8850	8772	8696	8621	8547	8475	8403	8	15	23	31	38	46	53	61	69
1.2	.8333	8264	8197	8130	8065	8000	7937	7874	7813	7752	7	13	20	26	33	39	46	52	59
1.3	.7692	7634	7576	7519	7463	7407	7353	7299	7246	7194	6	11	17	22	28	33	39	44	50
1.4	.7143	7092	7042	6993	6944	6897	6849	6803	6757	6711	5	10	14	19	24	29	33	38	43
1.5	.6667	6623	6579	6536	6494	6452	6410	6369	6329	6289	4	8	13	17	21	25	29	33	38
1.6	.6250	6211	6173	6135	6098	6061	6024	5988	5952	5917	4	7	11	15	18	22	26	29	33
1.7	.5882	5848	5814	5780	5747	5714	5682	5650	5618	5587	3	7	10	13	16	20	23	26	29
1.8	.5556	5525	5495	5464	5435	5405	5376	5348	5319	5291	3	6	9	12	15	17	20	23	26
1.9	.5263	5236	5208	5181	5155	5128	5102	5076	5051	5025	3	5	8	11	13	16	18	21	24
2.0	.5000	4975	4950	4926	4902	4878	4854	4831	4808	4785	2	5	7	10	12	14	17	19	21
2.1	.4762	4739	4717	4695	4673	4651	4630	4698	4587	4566	2	4	7	9	11	13	15	17	19
2.2	.4545	4525	4505	4484	4464	4444	4425	4405	4386	4367	2	4	6	8	10	12	14	16	18
2.3	.4348	4329	4310	4292	4274	4255	4237	4219	4202	4184	2	4	5	7	9	11	13	14	16
2.4	.4167	4149	4132	4115	4098	4082	4065	4049	4032	4016	2	3	5	7	8	10	12	13	15
2.5	.4000	3984	3968	3953	3937	3922	3906	3891	3876	3861	2	3	5	6	8	9	11	12	14
2.6	.3846	3831	3817	3802	3788	3774	3759	3745	3731	3717	1	3	4	6	7	9	10	11	13
2.7	.3704	3690	3676	3663	3650	3636	3623	3610	3597	3584	1	3	4	5	7	8	9	11	12
2.8	.3571	3559	3546	3534	3521	3509	3497	3484	3472	3460	1	2	4	5	6	7	9	10	11
2.9	.3448	3436	3425	3413	3401	3390	3378	3367	3356	3344	1	2	3	5	6	7	8	9	10
3.0	.3333	3322	3311	3300	3289	3279	3268	3257	3247	3236	1	2	3	4	5	6	7	9	10
3.1	.3226	3215	3205	3195	3185	3175	3165	3155	3145	3135	1	2	3	4	5	6	7	8	9
3.2	.3125	3115	3106	3096	3086	3077	3067	3058	3049	3040	1	2	3	4	5	6	7	8	9
3.3	.3030	3021	3012	3003	2994	2985	2976	2967	2959	2950	1	2	3	4	4	5	6	7	8
3.4	.2941	2933	2924	2915	2907	2899	2890	2882	2874	2865	1	2	3	3	4	5	6	7	8
3.5	.2857	2849	2811	2833	2825	2817	2809	2801	2793	2786	1	2	2	3	4	5	6	6	7
3.6	.2778	2770	2762	2755	2747	2740	2732	2725	2717	2710	1	2	2	3	4	5	5	6	7
3.7	.2703	2695	2688	2681	2674	2667	2660	2653	2646	2639	1	1	2	3	4	4	5	6	6
3.8	.2632	2625	2618	2611	2604	2597	2591	2584	2577	2571	1	1	2	3	3	4	5	5	6
3.9	.2564	2558	2551	2545	2538	2532	2525	2519	2513	2506	1	1	2	3	3	4	4	5	6
4.0	.2500	2494	2488	2481	2475	2469	2463	2457	2451	2445	1	1	2	2	3	4	4	5	5
4.1	.2439	2433	2427	2421	2415	2410	2404	2398	2392	2387	1	1	2	2	3	3	4	5	5
4.2	.2381	2375	2370	2364	2358	2353	2347	2342	2336	2331	1	1	2	2	3	3	4	4	5
4.3	.2326	2320	2315	2309	2304	2299	2294	2288	2283	2278	1	1	2	2	3	3	4	4	5
4.4	.2273	2268	2262	2257	2252	2247	2242	2237	2232	2227	1	1	2	2	3	3	4	4	5
4.5	.2222	2217	2212	2208	2203	2198	2193	2188	2183	2179	0	1	1	2	2	3	3	4	4
4.6	.2174	2169	2165	2160	2155	2151	2146	2141	2137	2132	0	1	1	2	2	3	3	4	4
4.7	.2128	2123	2119	2114	2110	2105	2101	2096	2092	2088	0	1	1	2	2	3	3	4	4
4.8	.2083	2079	2075	2070	2066	2062	2058	2053	2049	2045	0	1	1	2	2	3	3	3	4
4.9	.2041	2037	2033	2028	2024	2020	2016	2012	2008	2004	0	1	1	2	2	2	3	3	4
5.0	.2000	1996	1992	1988	1984	1980	1976	1972	1969	1965	0	1	1	2	2	2	3	3	4
5.1	.1961	1957	1953	1949	1946	1942	1938	1934	1931	1927	0	1	1	2	2	2	3	3	3
5.2	.1923	1919	1916	1912	1908	1905	1901	1898	1894	1890	0	1	1	1	2	2	3	3	3
5.3	.1887	1883	1880	1876	1873	1869	1866	1862	1859	1855	0	1	1	1	2	2	2	3	3
5.4	.1852	1848	1845	1842	1838	1835	1832	1828	1825	1821	0	1	1	1	2	2	2	3	3

RECIPROCALS OF FOUR – FIGURE NUMBERS

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
5.5	.1818	1815	1812	1808	1805	1802	1799	1795	1792	1789	0	1	1	1	2	2	2	3	3
5.6	.1786	1783	1779	1776	1773	1770	1767	1764	1761	1757	0	1	1	1	2	2	2	3	3
5.7	.1754	1751	1748	1745	1742	1739	1736	1733	1730	1727	0	1	1	1	1	2	2	2	3
5.8	.1724	1721	1718	1715	1712	1709	1706	1704	1701	1698	0	1	1	1	1	2	2	2	3
5.9	.1695	1692	1689	1686	1684	1681	1678	1675	1672	1669	0	1	1	1	1	2	2	2	3
6.0	.1667	1664	1661	1658	1656	1653	1650	1647	1645	1642	0	1	1	1	1	2	2	2	3
6.1	.1639	1637	1634	1631	1629	1626	1623	1621	1618	1616	0	1	1	1	1	2	2	2	2
6.2	.1613	1610	1608	1605	1603	1600	1597	1595	1592	1590	0	1	1	1	1	2	2	2	2
6.3	.1587	1585	1582	1580	1577	1575	1572	1570	1567	1565	0	0	1	1	1	1	2	2	2
6.4	.1562	1560	1558	1555	1553	1550	1548	1546	1543	1541	0	0	1	1	1	1	2	2	2
6.5	.1538	1536	1534	1531	1529	1527	1524	1522	1520	1517	0	0	1	1	1	1	2	2	2
6.6	.1515	1513	1511	1508	1506	1504	1502	1499	1497	1495	0	0	1	1	1	1	2	2	2
6.7	.1493	1490	1488	1486	1484	1481	1479	1477	1475	1473	0	0	1	1	1	1	2	2	2
6.8	.1471	1468	1466	1464	1462	1460	1458	1456	1453	1451	0	0	1	1	1	1	2	2	2
6.9	.1449	1447	1445	1443	1441	1439	1437	1435	1433	1431	0	0	1	1	1	1	2	2	2
7.0	.1429	1427	1425	1422	1420	1418	1416	1414	1412	1410	0	0	1	1	1	1	1	2	2
7.1	.1408	1406	1404	1403	1401	1399	1397	1395	1393	1391	0	0	1	1	1	1	1	2	2
7.2	.1389	1387	1385	1383	1381	1379	1377	1376	1374	1372	0	0	1	1	1	1	1	2	2
7.3	.1370	1368	1366	1364	1362	1361	1359	1357	1355	1353	0	0	1	1	1	1	1	2	2
7.4	.1351	1350	1348	1346	1344	1342	1340	1339	1337	1335	0	0	1	1	1	1	1	1	2
7.5	.1333	1332	1330	1328	1326	1325	1323	1321	1319	1318	0	0	1	1	1	1	1	1	2
7.6	.1316	1314	1312	1311	1309	1307	1305	1304	1302	1300	0	0	1	1	1	1	1	1	2
7.7	.1299	1297	1295	1294	1292	1290	1289	1287	1285	1284	0	0	0	1	1	1	1	1	1
7.8	.1282	1280	1279	1277	1276	1274	1272	1271	1269	1267	0	0	0	1	1	1	1	1	1
7.9	.1266	1264	1263	1261	1259	1258	1256	1255	1253	1252	0	0	0	1	1	1	1	1	1
8.0	.1250	1248	1247	1245	1244	1242	1241	1239	1238	1236	0	0	0	1	1	1	1	1	1
8.1	.1235	1233	1232	1230	1229	1227	1225	1224	1222	1221	0	0	0	1	1	1	1	1	1
8.2	.1220	1218	1217	1215	1214	1212	1211	1209	1208	1206	0	0	0	1	1	1	1	1	1
8.3	.1205	1203	1202	1200	1199	1198	1196	1195	1193	1192	0	0	0	1	1	1	1	1	1
8.4	.1190	1189	1188	1186	1185	1183	1182	1181	1179	1178	0	0	0	1	1	1	1	1	1
8.5	.1176	1175	1174	1172	1171	1170	1168	1167	1166	1164	0	0	0	1	1	1	1	1	1
8.6	.1163	1161	1160	1159	1157	1156	1155	1153	1152	1151	0	0	0	1	1	1	1	1	1
8.7	.1149	1148	1147	1145	1144	1143	1142	1140	1139	1138	0	0	0	1	1	1	1	1	1
8.8	.1136	1135	1134	1133	1131	1130	1129	1127	1126	1125	0	0	0	1	1	1	1	1	1
8.9	.1124	1122	1121	1120	1119	1117	1116	1115	1114	1112	0	0	0	1	1	1	1	1	1
9.0	.1111	1110	1109	1107	1106	1105	1104	1103	1101	1100	0	0	0	1	1	1	1	1	1
9.1	.1099	1098	1096	1095	1094	1093	1092	1090	1089	1088	0	0	0	0	1	1	1	1	1
9.2	.1087	1086	1085	1083	1082	1081	1080	1079	1078	1076	0	0	0	0	1	1	1	1	1
9.3	.1075	1074	1073	1072	1071	1070	1068	1067	1066	1065	0	0	0	0	1	1	1	1	1
9.4	.1064	1063	1062	1060	1059	1058	1057	1056	1055	1054	0	0	0	0	1	1	1	1	1
9.5	.1053	1052	1050	1049	1048	1047	1046	1045	1044	1043	0	0	0	0	1	1	1	1	1
9.6	.1042	1041	1039	1038	1037	1036	1035	1034	1033	1032	0	0	0	0	1	1	1	1	1
9.7	.1031	1030	1029	1028	1027	1026	1025	1024	1022	1021	0	0	0	0	1	1	1	1	1
9.8	.1020	1019	1018	1017	1016	1015	1014	1013	1012	1011	0	0	0	0	1	1	1	1	1
9.9	.1010	1009	1008	1007	1006	1005	1004	1003	1002	1001	0	0	0	0	0	1	1	1	1

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