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Experimental Physics

Experiment-1

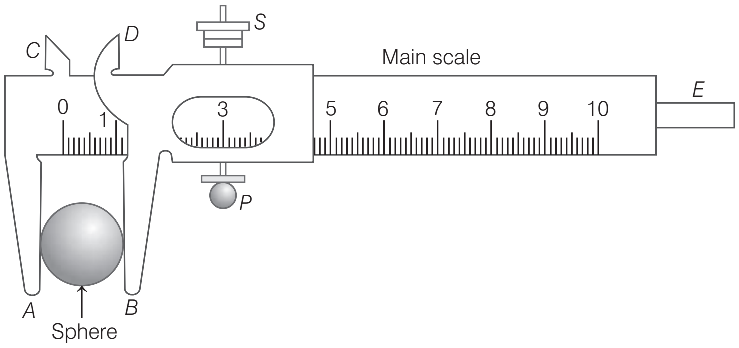
Object

To measure internal and external diameter and depth of a vessel using vernier callipers.

Apparatus

Vernier callipers, a beaker.

Diagram



Theory

If the body is kept between jaws and zero of vernier scale lies ahead of Nth division of the main scale, then MSR (main scale reading) = N.

If nth division of vernier scale coincides with any division of main scale, then vernier scale reading (VSR) = $n \times$ (LC)

where, LC = least count of vernier callipers.

Total reading = MSR + VSR = $N + n \times$ (LC)

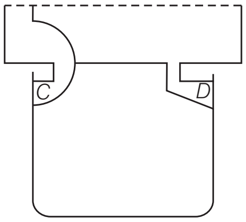
Procedure

(i) **Measurement of external diameter**

- Determine the least count and zero error of the vernier callipers by bringing the movable jaw in contact with the fixed jaw.
- Place the beaker between the jaws and fix the jaw *BD* in such a way that it grips the beaker.
- Record the main scale reading (MSR) and vernier scale reading (VSR).
- Note down 5 readings for different positions of the beaker.
- Find total reading and apply zero correction.
- Take mean of different values of diameter.

(ii) **Measurement of internal diameter**

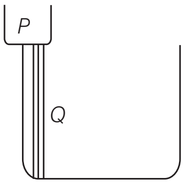
- Put the jaws *C* and *D* inside the vessel and open them till each of them touches the inner wall of the vessel without putting any pressure on the wall.
- Note down the main scale reading and vernier scale reading.



- Rotate the vernier callipers in perpendicular direction and take readings again for its different position.
- Find the total reading, take its mean and apply zero correction.

(iii) **Measurement of depth**

- Keep the right edge of main scale strip *P* on the upper edge of the vessel.



- Start pressing the jaw *BD* downward so that the thin metallic strip *Q* on the backside of *P* moves downward and continue it till the outer edge of *Q* touches the bottoms of the beaker.
- Note down MSR and VSR repeat the previous step for different positions inside the vessel.
- Find the total reading. Take its mean and apply zero correction.

Observations

LC of vernier callipers = …………

Zero error = …………

Table for external diameter of the beaker (***D***)

S.No.	MSR (cm)	VSR = n × LC (cm)	TR (Total reading) = MSR + VSR (cm)	
			Observed	Corrected
1.				D_1
2.				D_2
3.				D_3
4.				D_4
5.				D_5

Table for internal diameter of the beaker (***D′***)

S.No.	MSR (cm)	VSR = n × LC (cm)	TR (Total reading) = MSR + VSR (cm)	
			Observed	Corrected
1.				D'_1
2.				D'_2
3.				D'_3
4.				D'_4
5.				D'_5

Table for depth of the beaker (***d***)

S.No.	MSR (cm)	VSR = n × LC (cm)	TR (Total reading) = MSR + VSR (cm)	
			Observed	Corrected
1.				d_1
2.				d_2
3.				d_3
4.				d_4
5.				d_5

Calculations

(i) Mean corrected external diameter of the beaker

$$= \frac{D_1 + D_2 + D_3 + D_4 + D_5}{5} = \ldots \text{ (cm)}$$

(ii) Mean corrected internal diameter of the beaker

$$= \frac{D'_1 + D'_2 + D'_3 + D'_4 + D'_5}{5} = \ldots \text{ (cm)}$$

(iii) Mean corrected depth of the beaker

$$= \frac{d_1 + d_2 + d_3 + d_4 + d_5}{5} = \ldots \text{ (cm)}$$

Example 1. *A vernier callipers has 1 mm marks on the main scale. It has 20 equal divisions on the vernier scale which match with 16 main scale divisions. For this vernier callipers, the least count is*

(*a*) 0.02 *mm*
(*b*) 0.05 *mm*
(*c*) 0.1 *mm*
(*d*) 0.2 *mm*

Sol. (*d*) $\because$ 20 divisions of vernier scale = 16 divisions of main scale

$$\therefore \quad 1\text{ VSD} = \frac{16}{20}\text{MSD} = 0.8\text{ MSD} = 0.8\text{ mm}$$

We know that, $\text{LC} = 1\text{MSD} - 1\text{VSD}$

$$= 1\text{mm} - 0.8\text{ mm}$$
$$= 0.2\text{ mm}$$

Example 2. *The least count of vernier callipers is* 0.1 *mm. The main scale reading before the zero of the vernier scale is* 10 *and the zeroth division of the vernier scale coincides with the main scale division. Given that each main scale division is* 1 *mm, then the measured value should be equal to*

(a) 1 *cm* (b) 2 *cm* (c) 0.5 *cm* (d) 0.1 *cm*

Sol. (a) Given, least count (LC) = 0.1mm

Vernier scale reading = 0

Main scale reading = 10 mm

Length measured with the vernier callipers = Number of vernier divisions coinciding with any main division + Reading before the zero of vernier scale × Least count

$$= 10\text{ mm} + 0 \times 0.1\text{ mm}$$
$$= 10\text{ mm} = 1\text{ cm}$$

Example 3. 1 *cm on the main scale of vernier callipers is divided into ten equal parts. If* 20 *divisions of vernier scale coincide with* 8 *small divisions of the main scale. What will be the least count of vernier callipers?*

(a) 0.01 *cm* (b) 0.05 *cm*
(c) 0.001 *cm* (d) 0.06 *cm*

Sol. (*d*) $\because$ 20 divisions of vernier scale = 8 divisions of main scale

$$\therefore \quad 1\text{ VSD} = \left(\frac{8}{20}\right)\text{MSD} = \left(\frac{2}{5}\right)\text{MSD}$$

$$\text{LC} = 1\text{MSD} - 1\text{VSD}$$
$$= 1\text{MSD} - \left(\frac{2}{5}\right)\text{MSD} = \left(1 - \frac{2}{5}\right)\text{MSD}$$
$$= \frac{3}{5}\text{MSD} = \frac{3}{5} \times 0.1\text{ cm} = 0.06\text{ cm}$$
$$\left(\because 1\text{MSD} = \frac{1}{10}\text{ cm} = 0.1\text{ cm}\right)$$

Note For objective questions LC = MSD − VSD

$$= \left(\frac{b-a}{b}\right)\text{MSD} = \left(\frac{20-8}{20}\right)\left(\frac{1}{10}\right)\text{cm}$$
$$= \frac{3}{50}\text{ cm} = 0.06\text{ cm}$$

Example 4. *The least count of the main scale of a vernier callipers is* 1 *mm. Its vernier scale is divided into* 10*th division and coincide with* 9*th division of the main scale. When jaws are touching each other, the* 7*th division of vernier scale coincides with a division of main scale and the zero of vernier scale is lying right side of the zero of main scale. When this vernier is used to measure length of a cylinder, the zero of the vernier scale lies between* 3.1 *cm and* 3.2 *cm and* 4*th VSD coincides with a main scale division. The length of the cylinder is (where, VSD = vernier scale division)*

[JEE Main 2020]

(a) 3.2 *cm* (b) 2.99 *cm*
(c) 3.07 *cm* (d) 3.21 *cm*

Sol. (*c*) Given, least count of main scale = 1 main scale division (MSD) = 1 mm

Also, 10 vernier scale divisions = 9 main scale divisions

$$\Rightarrow \text{ 1 vernier scale division (VSD)} = \frac{9}{10}\text{ MSD}$$
$$= 0.9\text{ MSD} = 0.9\text{ mm}$$

Vernier constant or least count of instrument,

$$\text{LC} = 1\text{ MSD} - 1\text{ VSD}$$
$$= 1\text{ MSD} - \frac{9}{10}\text{MSD}$$
$$= \left(\frac{10-9}{10}\right)\text{MSD} = \frac{1}{10}\text{MSD}$$
$$= \frac{1\text{ mm}}{10} = 0.1\text{ mm or } 0.01\text{ cm}$$

The zero of vernier scale lies to the right of main scale, so error is positive.

Zero error = $7 \times \text{LC} = 7 \times 0.01\text{ cm} = 0.07\text{ cm}$

Given, main scale reading = 3.1 cm

Vernier scale reading = 4 divisions

$$\therefore \quad \text{Observed value} = \text{MSR} + \text{VSR} \times \text{LC} - \text{Zero error}$$
$$= 3.1 + 4 \times 0.01 - 0.07$$
$$= 3.14\text{ cm} - 0.07\text{ cm}$$
$$= 3.07\text{ cm}$$

Experiment-2

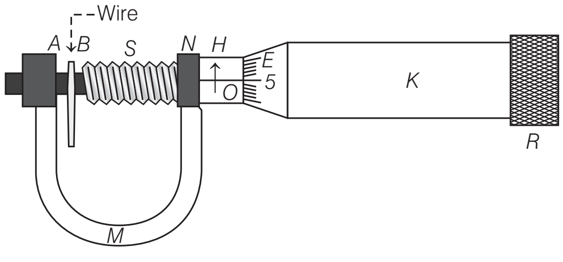
Object

To determine the thickness/diameter of a thin sheet/wire using screw gauge.

Apparatus

Screw gauge, wire/sheet.

Diagram



Theory

When the wire or sheet is kept between plane faces A and B and edge of the cap lies ahead of Nth division of linear scale.

Then, linear scale reading (LSR) = N

If nth division of circular scale lies over reference line.

Then, circular scale reading (CSR) = $n \times$ LC

where, LC = least count of screw gauge.

Procedure

(i) Determine the least count and pitch of the screw gauge.

(ii) Bring the faces A and B in close contact and find zero error if any.

(iii) Place the wire between A and B and move the face B towards A using the head R. Stop when R turns without moving the screw.

(iv) Note down linear scale reading (LSR) and circular scale reading (CSR).

(v) Take five readings for different positions of wire.

(vi) Find total reading, take its mean and apply zero correction.

Observations

Least count of screw gauge = ... mm = ... cm

Zero error = ... mm

Zero correction = ... mm

Table for measuring diameter (***d***)

S.No.	LSR(mm)	CSR = $n \times$ LC (mm)	TR = LSR + CSR(mm)	
			Observed	Corrected
1.				d_1
2.				d_2
3.				d_3
4.				d_4
5.				d_5

Calculations

Mean diameter of the wire

$$= \frac{d_1 + d_2 + d_3 + d_4 + d_5}{5} = \ldots\ldots \text{ mm} = \ldots\ldots \text{ cm}$$

Result

The diameter of the given wire is .... cm.

Precautions

(i) The zero error should be noted carefully with proper sign.

(ii) The screw should move freely without friction.

Example 5. *If the pitch of the screw gauge is thrice the least count of the vernier callipers, then the least count of screw gauge is*

(a) 0.006 *mm* (b) 0.003 *mm*

(c) 0.001 *mm* (d) 0.0001 *mm*

Sol. (b) Pitch = 3 × Least count of vernier callipers

$= 3 \times 0.1$ mm

$= 0.3$ mm

∴ Least count of screw gauge

$$= \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$= \frac{0.3}{100} = 0.003 \text{ mm}$$

Example 6. *Using screw gauge of pitch* 0.1 *cm and* 50 *divisions on its circular scale, the thickness of an object is measured. It should correctly be recorded as* ***[JEE Main 2020]***

(a) 2.121 *cm* (b) 2.124 *cm*

(c) 2.125 *cm* (d) 2.123 *cm*

Sol. (b) Given, pitch = 0.1 cm

Number of divisions on circular scale = 50

Least count of screw gauge

$$= \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$= \frac{0.1}{50} = 0.002 \text{ cm}$$

Now, correctly recorded measurement is an integral multiple of LC.

So, amongst the given options, only 2.124 cm is the integral multiple of LC. Thus, it is the correctly recorded value.

Hence, option (b) is correct.

Experiment-3

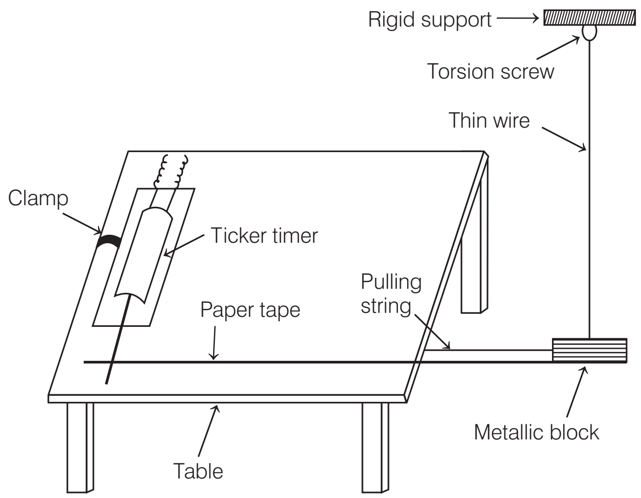
Object

To study dissipation of energy of a simple pendulum by plotting a graph between square of amplitude and time.

Apparatus

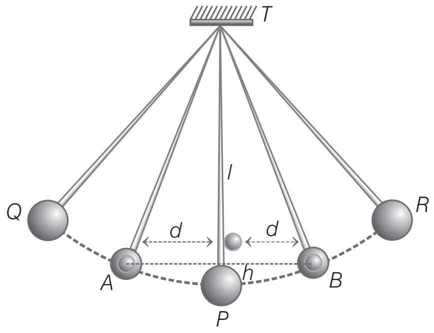
A simple pendulum having for its string a 2 m long thin wire with upper end screwed in a torsion screw fixed to rigid support in ceiling and a 2 kg rectangular metallic block as its bob suspended from its lower end, ticker timer, paper tape, spring balance of range 2.5 kg, meter scale and thread.

Diagram



Theory

When a simple pendulum oscillates, the whole of its energy remains in the form of kinetic energy at mean position P and in the form of potential energy at extreme positions Q and R. If we consider any position between P and Q or P and R, say A and B, total energy is sum of potential and kinetic energies.



At point (A or B)

Kinetic energy of the bob, KE $= \frac{1}{2}mv^2$

Potential energy of the bob, PE $= mgh = \frac{mgd^2}{2l}$

Total energy of the bob, TE $=$ KE $+$ PE $= \frac{1}{2}mv^2 + \frac{mgd^2}{2l}$

Procedure

(i) Using spring balance, find the mass of the metallic block.

(ii) Clamp one end of a thin metallic wire to a torsion screw fixed with a rigid support.

(iii) From lower end of metallic wire, suspend the metallic block.

(iv) Under the carbon disc, pass the paper tape and attach its end to the centre of the bottom of the metallic block.

(v) Tie a thread at the level of its centre of gravity round the metallic block.

(vi) To displacement the block and the wire, pull the thread towards ticker timer.

(vii) Start the ticker timer carefully and leave the pulled thread.

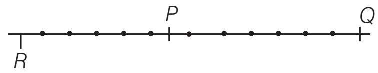
(viii) As metallic block starts oscillating, it pulls the paper tape and dots can be obtained on the tape to record the position of the metallic block.

(ix) Switch off the ticker timer as soon as the metallic block reaches its outer extreme.

(x) Tear off dotted paper. You can observe symmetrical dots about a central dot.

(xi) Mark P as central dot which corresponds to mean position and mark Q and R as extreme dots.

(xii) Measure distances of the different dots from central dot. This gives values of Q.



(xiii) Also note the position of a dot with respect to central dot. This gives instant of time for that distance.

Observations

Least count of spring balance = …… kg

Zero error of spring balance = …… kg

Observed mass of metallic block = …… kg

Corrected mass of metallic block = …… kg

Length of simple pendulum l = …… m

Time period of ticker timer = …… s

Table for d and T

Side from central dot	S. No. of the dot	Distance from central dot d(m)	Time interval T(s)	Velocity v(m/s)	v^2	$h = \frac{d^2}{2l}$(m)	KE $= \frac{1}{2}mv^2$ (J)	TE = KE + PE
Right	1.		0.01					
	2.		0.02					
	3.		0.03					
	4.		0.04					
	5.		0.05					
Left	1.		0.01					
	2.		0.02					
	3.		0.03					
	4.		0.04					
	5.		0.05					

Calculations

(i) Plot a graph between d and T taking T along X-axis and d along Y-axis.

(ii) Find slope of the graph which gives value of velocity

$$h = \frac{d^2}{2l}$$

$$KE = \frac{1}{2}mv^2$$

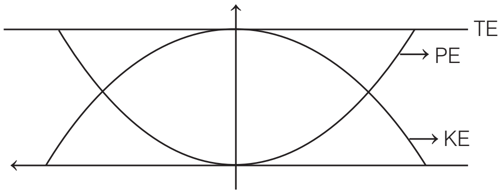
$$PE = \frac{mgd^2}{2l}$$

$$TE = KE + PE$$

[Calculate for each value of d]

(iii) Plot a graph between (d) and $KE = \frac{1}{2}mv^2$. Also plot a graph between d and PE = mgh, taking d along X-axis and mgh along Y-axis.

(vi) Add KE and PE for each value of d and on the same graph as in previous point, plot a graph between d and total energy. The graph comes to be a straight line parallel to X-axis and appears as



Result

At any point, during oscillation of a simple pendulum, the sum of KE and PE is always constant. This verifies the principle of conservation of energy.

Precautions

(i) Pendulum's length should be sufficient say about 2 m.

(ii) The amplitude should be kept small.

Example 7. *Students I, II and III perform an experiment for measuring the acceleration due to gravity using a simple pendulum. They use different lengths of the pendulum and/or record time for different number of oscillations. The observations are shown in the table. Least count for length = 0.1 cm and least count for time = 0.1s.*

Student	Length of the pendulum (cm)	Number of oscillations (n)	Total time for n oscillations (s)	Time period (s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

If E_I, E_{II} and E_{III} are the percentage errors in g, i.e. $\left(\frac{\Delta g}{g} \times 100\right)$, *for students I, II and III respectively.*

(a) $E_I = 0$ (b) E_I is minimum
(c) $E_I = E_{II}$ (d) E_{II} is maximum

Sol. (*b*) Time period $T = 2\pi\sqrt{\frac{l}{g}}$

or $\frac{t}{n} = 2\pi\sqrt{\frac{l}{g}}$

$\therefore$ $g = \frac{(4\pi^2)(n^2)\, l}{t^2}$

% error in g $= \frac{\Delta g}{g} \times 100 = \left(\frac{\Delta l}{l} + \frac{2\Delta t}{t}\right) \times 100$

$$E_I = \left(\frac{0.1}{64} + \frac{2\times 0.1}{128}\right) \times 100 = 0.3125\%,$$

$$E_{II} = \left(\frac{0.1}{64} + \frac{2\times 0.1}{64}\right) \times 100 = 0.46875\%$$

and $$E_{III} = \left(\frac{0.1}{20} + \frac{2\times 0.1}{36}\right) \times 100 = 1.055\%$$

Hence, E_I is minimum.

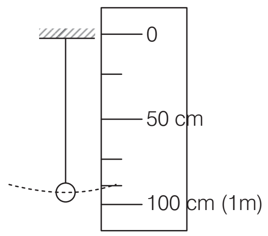
Example 8. *In an experiment to determine acceleration due to gravity, the length of the pendulum is measured as 98 cm by a meter scale of least count of 1 cm. The period of swing/oscillations is measured with the help of a stop watch having a least count of 1s. The time period of 50 oscillations is found to be 98 s. Express value of g with proper error limits.*

(a) $(10.1 \pm 0.5)\, ms^{-2}$ (b) $(10.1 \pm 0.2)\, ms^{-2}$
(c) $(10.1 \pm 0.3)\, ms^{-2}$ (d) $10.1\, ms^{-2}$

Sol. (*c*) As, $T = 2\pi\sqrt{\frac{l}{g}}$ ...(i)

Now, time period of 50 oscillations is 98 s.

$\therefore$ Time period of one oscillation $= \frac{98}{50} = 1.96$ s



$\Rightarrow$ $g = \frac{4\pi^2 l}{T^2}$ [from Eq. (i)]

$= 4 \times (3.14)^2 \times \frac{0.98}{1.96 \times 1.96}$

$= 10.06\ m/s^2$

Now, % error in $g = \frac{\Delta g}{g} \times 100 = \left(\frac{\Delta l}{l} + \frac{2\Delta T}{T}\right) \times 100$

$$\Rightarrow \qquad \Delta g = 10 \times \left(\frac{1}{98} + \frac{2 \times 1}{98}\right)$$

($\because$ least count of meter scale is 1 cm and least count of stop watch is 1s)

$$\therefore \qquad \Delta g = 0.3 \text{ m/s}^2$$

So, final result can be expressed as $(10.1 \pm 0.3)\,\text{ms}^{-2}$.

Experiment-4

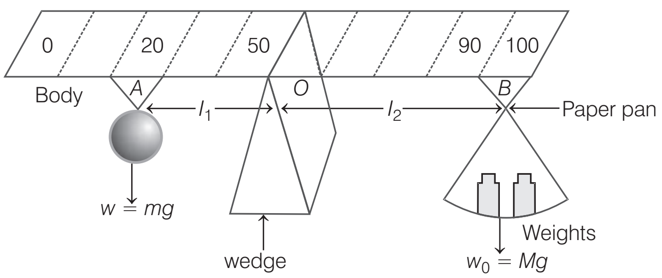
Object

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

Apparatus

A meter scale, a broad heavy wedge with sharp edge, a weight box, a body of unknown mass.

Diagram



Theory

If a body of mass m be suspended at one end A of a meter scale and a body of unknown mass M be suspended at the end B and then position of point O is adjusted, so that the meter scale is in equilibrium.

By the principle of moments,

$$(mg) \times OA = (Mg) \times OB$$

$$OA = l_1 \text{ and } OB = l_2$$

$$mg \times l_1 = Mg \times l_2$$

$$m = M\left(\frac{l_2}{l_1}\right)$$

Procedure

(i) Place the sharp wedge on a wooden block carefully that is placed on the table.

(ii) Place the meter scale on the wedge such that graduated side facing you.

(iii) Find its centre of gravity by balancing it on the edge of the wedge.

(iv) Suspended the known mass on right hand side of the wedge (at point B) and the body of unknown mass (*i.e.* $w = mg$) on the left side of the wedge (at point A) by means of two threads of equal lengths.

(v) Adjust the position of unknown mass at point A to maintain scale in equilibrium.

(vi) Note the position of m, M and centre of gravity O when the meter scale is in equilibrium.

(vii) Repeat the procedure for three more observations changing the positions of m.

Observations

1. Position of centre of gravity O on the scale =...... cm
2. Magnitude of known mass, M = ... g
3. Known weight, $w = Mg$ = ... g-wt

Table for determination of unknown mass

S.No.	Position of mA(cm)	Position of $M\,B$(cm)	$OA = l_1$ (cm)	$OB = l_2$ (cm)	$m = M\left(\frac{l_2}{l_1}\right)$
1.					m_1
2.					m_2
3.					m_3
4.					m_4

Calculation

The mean value of unknown mass,

$$m = \frac{m_1 + m_2 + m_3 + m_4}{4} = \ldots\ldots \text{ g}$$

Result

The value of unknown mass is .... g.

Precautions

(i) Centre of gravity must be determined accurately and after every reading, check that the edge of the wedge remains under this position only.

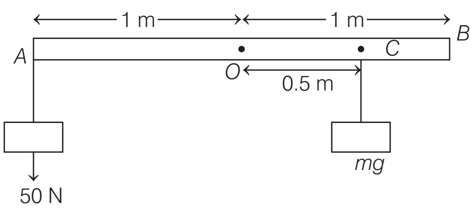
(ii) The meter scale should be made horizontal in equilibrium position.

Example 9. *A meter rule of length 2m is pivoted at its middle point . If a weight of 50N is hanged at a point 1m left from middle point, then amount of mass required to be applied at 0.5m mark on the right side from the middle point to keep it in a balanced position is (Take, $g = 10\ m/s^2$)*

(a) 5 kg (b) 15 kg (c) 10 kg (d) 20 kg

Sol. (c) The given situation is shown below.

If m be the required mass hanging at point C, then according to principle of moments,



$$50 \times OA = mg \times OC$$

$$\Rightarrow \qquad m = \frac{50 \times OA}{g \times OC} = \frac{50 \times 1}{10 \times 0.5} = 10 \text{ kg}$$

Experiment-5

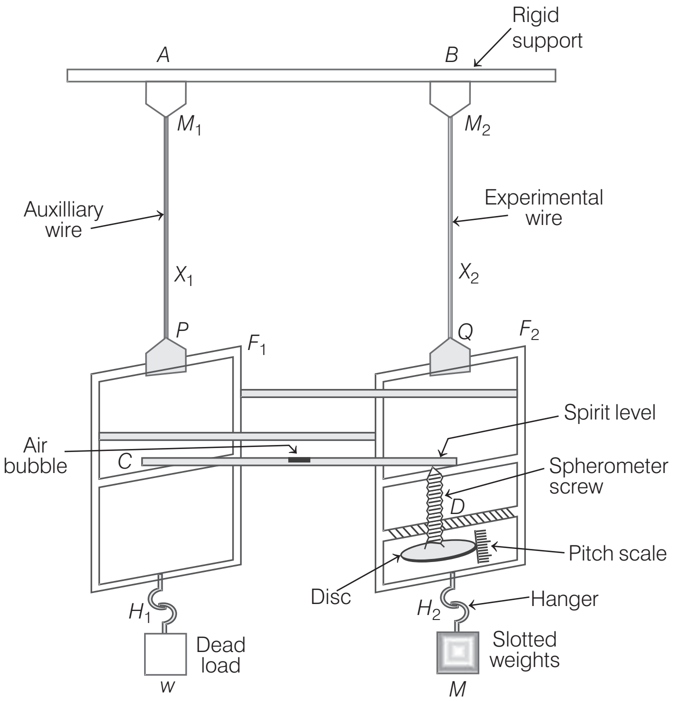
Object

To determine Young's modulus of elasticity of the material of a metallic wire.

Apparatus

Searle's apparatus for Young's modulus, two long wires approximately 2 m length , a (1/2) kg fixed weight, a (1/2) kg hanger along with (1/2) kg slotted weights, a meter scale, a plumb line with long thread, a screw gauge.

Diagram



Theory

Young's modulus is defined as the ratio of longitudinal stress and longitudinal strain.

i.e.
$$Y = \frac{\frac{F}{A}}{\frac{\Delta L}{L}} = \frac{mgL}{\pi r^2 \Delta L}$$

where, ΔL = extension of the wire under load mg,

r = radius of the wire

and L = length of the wire.

Procedure

(i) Straighten the wires by attaching (1/2) kg fixed weight.

(ii) Suspend the plumb line along the suspension wire so that its lower end coincides with binding post P and the upper end of the thread A. Measure lengths AP and BQ and take its mean to find L.

(iii) Measure the diameter of the wire by means of screw gauge.

(iv) Note down the value of breaking stress for the wire from the table of constants multiplying with the area of cross-section of the given wire.

(v) Note down the least count of the micrometer screw attached with the Searle's apparatus.

(vi) Ensure that air bubble in the spirit level should be in middle. If not, adjust it with the help of screw.

(vii) Slip a (1/2) kg weight on the hanger due to which bubble in spirit level will move towards F_1. By raising the tip of the screw, bring it back to the centre.

(viii) Record the height to which the tip of the screw is raised. It gives elongation of the wire under (1/2) kg weight.

(ix) Repeat the same procedure increasing the load in steps of (1/2) kg weight seven more times.

(x) Similarly, unload the wire in steps of (1/2) kg and record the distance to which the tip of the screw is lowered.

Observations

(i) Length of wires, L_1 = …… cm,

L_2 = …… cm

Mean length, $L = \frac{L_1 + L_2}{2}$ = …… cm

= …… m

(ii) Measurement of diameter

- Least count of screw gauge = …… mm
- Zero error = …… mm
- Diameter of the wire, d = …… mm
- Radius, $\frac{d}{2}$ = …… mm
- Area of cross-section of the wire,

  $A = \pi r^2$

  = …… mm^2

(iii) Measurement of extension with load

- Breaking stress for the wire,

  F = …… kgf/mm^2

  Maximum load = $\frac{1}{3} FA$ = …… kgf

- Least count of micrometer screw

  $= \frac{\text{Pitch of micrometer screw}}{\text{Number of division of circular scale}}$

  = …… cm

Table for extension under different loads

S. No.	Load on hanger H_2		Micrometer reading			Extension	Extension for 2 kg weight
	kg-wt	N	Increasing load L (cm)	Decreasing Load L' (cm)	Mean $L_m = \frac{L+L'}{2}$ (cm)	$L_m - L$ (cm)	$L = L_5 - L$ (cm)
1.	0	0				$L = 0$	
2.	0.5	4.9					$L_1 =$
3.	1.0	9.8					$L_2 =$
4.	1.5	14.7					$L_3 =$
5.	2.0	19.6					$L_4 =$
6.	2.5	24.5					
7.	3.0	29.4					
8.	3.5	24.3					

Calculations

(i) Mean extension, $\Delta L = \dfrac{L_1 + L_2 + L_3 + L_4}{4}$

$= \ldots\ldots$ cm $= \ldots\ldots$ m

(ii) $Y = \dfrac{mgL}{\pi r^2 \Delta L} = \ldots\ldots\ldots$

(iii) Draw a graph between load and extension. Calculate slope of the graph.

Result

(i) Young's modulus of the material of given wire is ………Nm^{-2}.

(ii) The load extension graph is a straight line. It verifies the Hooke's law.

Precautions

(i) Wires must be similar in all respects and must be hanged from the same firm and rigid support.

(ii) While changing the weight, wait for 2 min so that wires reach at equilibrium.

(iii) Add and remove the weights gently.

(iv) Do not load the wire beyond maximum allowed load.

Example 10. *In an experiment for measurement of Young's modulus, following readings are taken : Load = 3.00 kg, length = 2.820 m, diameter = 0.041 cm and extension = 0.87. The percentage error in measurement of Y is around*

(a) 6% (b) 8% (c) 1% (d) 3%

Sol. (a) If Y = Young's modulus of wire, M = mass of wire, g = acceleration due to gravity, x = extension in the wire, A = area of cross-section of the wire and l = length of the wire.

$$Y = \frac{Mgx}{Al} \Rightarrow \frac{\Delta Y}{Y} = \frac{\Delta M}{M} + \frac{\Delta x}{x} + \frac{\Delta A}{A} + \frac{\Delta l}{l}$$

$$\Rightarrow \quad \frac{\Delta Y}{Y} = \frac{0.01}{3.00} + \frac{0.01}{0.87} + \frac{2 \times 0.001}{0.041} + \frac{0.001}{2.820}$$

$$= 0.064 \Rightarrow \frac{\Delta Y}{Y} \times 100 = \pm\, 6.4\% \simeq 6\%$$

Experiment-6

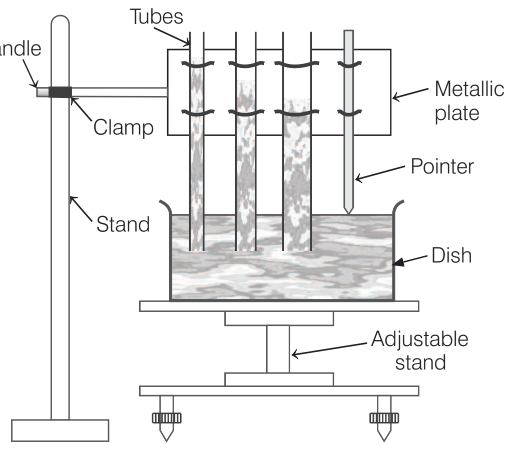
Object

To determine the surface tension of water by capillary rise method.

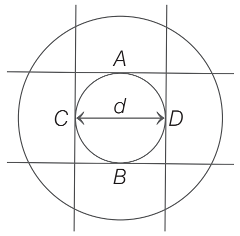
Apparatus

Three glass capillaries having bores of different diameters, adjustable stand, travelling microscope, a petridish, a glass slide, an iron stand with clamp, a thermometer, rubber band, dil HCl and NaOH solution, clean water in a beaker.

Diagram



Measurement of surface tension by capillary rise method,



Theory

When a capillary of radius r is immersed in a liquid of density ρ, the height h to which the liquid rises is given by surface tension T.

$$T = \frac{r\left(h + \frac{r}{3}\right)\rho g}{2\cos\theta}$$

For water, $T = \dfrac{r\left(h + \frac{r}{3}\right)\rho g}{2}$ as θ is small.

Procedure

(i) Clean the tube and petridish first with caustic soda, then with nitric acid and then with water.

(ii) Place the adjustable height stand on the table and make its base horizontal by level.

(iii) Place the petridish containing water on adjustable stand.

(iv) Clamp the capillary tubes of different radii in a metallic plate. Also clamp a pointer after third capillary tube.

(v) Hold the glass plate containing capillaries and pin in the clamp on an iron stand and hold them just above the petridish vertically such that lowest edges of the capillaries are slightly above the water level in the dish.

(vi) Adjust the position of the pointer such that its tip just touches the water surface.

(vii) Record the least count of the microscope for the horizontal scale and the vertical scale.

(viii) Adjust the microscope to a suitable height, keeping its axis horizontal and pointed towards the capillary tube and bring the microscope in front of the first capillary tube.

(ix) Fix the microscope by moving with the help of screw in such a position such that horizontal cross wire is tangential on the meniscus in capillary 1. Record the position of meniscus in capillary 1.

(x) Now move the microscope horizontally and bring it in front of the second capillary tube.

Lower the microscope and repeat the same procedure as in previous step. Similarly, read the position of meniscus in capillary 3.

(xi) Lower the stand so that pointer tip becomes visible.

(xii) Place the first capillary on the stand. Focus the microscope on the end dipped in water. Two concentric circles will be seen.

Observations

Temperature of water (t) = ……°C

Density of water at this temperature = …… gcm^{-3}

Table for internal diameter of the capillary tube

S. No.	Microscope reading for positions				Internal diameter			Internal radius
	A (cm)	B (cm)	C (cm)	D (cm)	Vertical AB (cm)	Horizontal CD (cm)	Mean = $\frac{AB+CD}{2} = d$ (cm)	$\frac{d}{2} = r$ (cm)
1.								
2.								
3.								

Calculations

For first capillary, $T_1 = r\left(h + \frac{r}{3}\right)\rho g$

$= ……$ dyne cm^{-1}

For second capillary, $T_2 = ……$ dyne cm^{-1}

For third capillary, $T_3 = ……$ dyne cm^{-1}

Mean, $T = \dfrac{T_1 + T_2 + T_3}{3}$

$= ……$ dyne cm^{-1}

Result

The surface tension of water at …… °C is ……dyne cm^{-1}.

Precautions

(i) Capillary tube and pin should be set vertical.

(ii) Select capillaries of uniform bore.

Example 11. *A capillary tube whose inside radius is 0.5 mm is dipped in water having surface tension 7.0×10^{-2} Nm^{-1}. To what height is the water raised above the normal water level? Angle of contact of water with glass is 0°. (Take, density of water is 10^3 kg m^{-3} and $g = 9.8$ ms^{-2})*

(a) 3.25 cm (b) 1.25 cm
(c) 2.86 cm (d) 13.76 cm

Sol. (c) Height raised, $h = \dfrac{2T\cos\theta}{r\rho g}$

Substituting the proper values, we have

$$h = \frac{(2)(7.0 \times 10^{-2}) \cos 0°}{(0.5 \times 10^{-3})(10^3)(9.8)}$$
$$= 2.86 \times 10^{-2} \text{ m}$$
$$= 2.86 \text{ cm}$$

Experiment-7

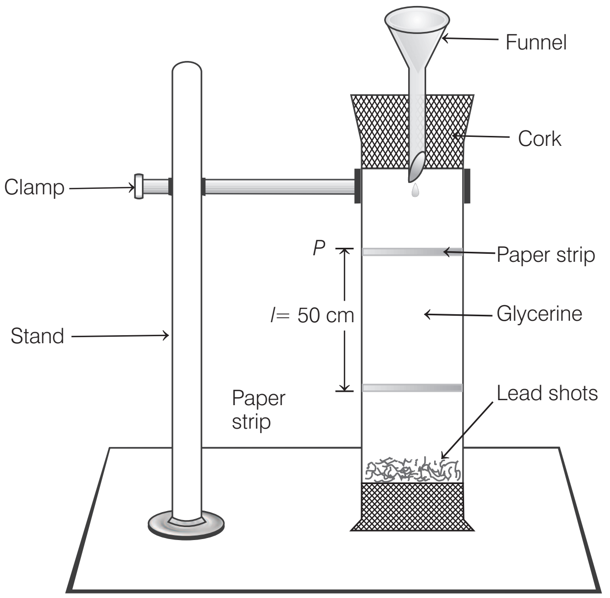
Object

To determine the coefficient of viscosity of a given viscous liquid by measuring terminal velocity of a given spherical body.

Apparatus

An iron stand with clamps, a cylindrical glass pipe, two large cork pieces, a He funnel, experimental liquid (glycerine), meter scale, stop watch, thread, spherical metal balls of different sizes, thermometer and screw gauge.

Diagram



Theory

When a solid falls in a liquid, it experiences a resistive force due to viscosity of the liquid. This is given by

$$F = 6\pi r \eta v$$

where, r = radius of spherical body,

η = coefficient of viscosity of fluid

and v = velocity.

Due to this resistive force, acceleration of the body decreases and after sometime, it attains a constant velocity called terminal velocity which is given by

$$v_t = \frac{2r^2(\rho - \sigma)g}{9\eta}$$

Thus, $$\eta = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{v_t}$$

where, ρ = density of the material of the sphere,

σ = density of fluid and v_t = terminal velocity.

Procedure

(i) Put the cork at one end of glass pipe and seal it leak proof with wax.

(ii) Clamp the pipe vertically in the iron stand such that its open end is at the top fill it up with glycerine.

(iii) Bore a hole at the centre of the cork and in the bore, insert the stem of the He funnel.

(iv) Put the cork in opening of the pipe such that it closes the opening without leakage of glycerine.

(v) Now put some glycerine in the funnel, so that it fills its stem completely.

(vi) Mark two points separated by a distance = 50 cm, nearly in the middle. Tie up two cotton threads around the tube at these points. Measure the distance l between these points A and B.

(vii) Record the temperature of glycerine.

(viii) Choose lead shots of five different sizes taking at least 3 of each size. Measure its radius.

(ix) Place the lead shots gently on glycerine in funnel. Start stop water as it reaches the point A and stop and it passes point B. Record the time.

(x) Repeat the previous step for two more lead shots of the same radius. Calculate terminal velocity for each of them as $v_t = \frac{l}{t}$ cms^{-1}. Calculate mean value of terminal velocity.

(xi) Now take lead shots of different radii and determine corresponding terminal velocity as in previous steps.

(xii) Record the temperature of glycerine at the end of the experiment.

Observations

(i) Least count of thermometer = ……°C

(ii)
- Temperature of glycerine in the beginning of the experiment, θ_1 = ……°C
- Temperature of glycerine at the end of the experiment, θ_2 = ……°C

Mean value of temperature,

$$\theta = \frac{\theta_1 + \theta_2}{2} = \ldots\ldots°C$$

(iii) Density of lead shots = …… gcm^{-3}

(iv) Least count of screw gauge = …… cm

Zero error of screw gauge = …… cm

Table for radius of lead shot

S. No.	Diameter of lead shot			Mean radius $r=\frac{d}{2}$ (cm)	$r^2 = \ldots$ (cm)^2
	Along one diameter d_1 (cm)	Along perpendicular diameter d_2 (cm)	Mean diameter $d=\frac{d_1+d_2}{2}$ (cm)		
1.					
2.					
3.					
4.					
5.					

Table for terminal velocity of lead shot

Distance between A and B l (cm)	Diameter of lead shot				$v_t = \frac{l}{t}$(cm s^{-1})
	Lead shot I t_1 (s)	Lead shot II t_2 (s)	Lead shot III t_3 (s)	Mean $t = \frac{t_1+t_2+t_3}{3}$(s)	
1.					
2.					
3.					
4.					
5.					

Calculations

(i) Plot a graph between r^2 and v_t taking r^2 along X-axis and v_t along Y-axis. It comes out to be a straight line.

(ii) The slope of graph $= \frac{v_t}{r^2} = \ldots\ldots$

(iii) $\eta = \frac{2}{9}\frac{(\rho-\sigma)g}{v_t/r^2} = \ldots\ldots$ poise

Result

(i) The graph between terminal velocity and square of the radius is a straight line, which implies that $v_t \propto r^2$.

(ii) The coefficient of viscosity of glycerine at …… °C is …… poise.

Precautions

(i) Lead shots must be thoroughly immersed in glycerine before dropping in the liquid so that air bubbles are not accumulated.

(ii) The bore in the cork should be exactly at the centre.

(iii) Lead shots should be of uniform diameter.

(iv) Do measure the temperature of glycerine in the beginning and at the end of the experiment.

Example 12. *With what terminal velocity will an air bubble 0.8 mm in diameter rise in a liquid of viscosity 0.15 Ns m^{-2} and specific gravity 0.9. Density of air is 1.293 kg m^{-3}.*

(a) 0.55 cm/s, upward (b) 0.59 cm/s, downward
(c) 0.21 cm/s, downward (d) 0.21 cm/s, upward

Sol. (d) The terminal velocity of the bubble is given by

$$v_t = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$$

Here, $r = 0.4\times 10^{-3}$ m

$\sigma = 0.9\times 10^3$ kgm^{-3}, $\rho = 1.293$ kgm^{-3}

$\eta = 0.15$ Nsm^{-2} and $g = 9.8$ m s^{-2}

Substituting the values, we have

$$v_t = \frac{2}{9}\times\frac{(0.4\times 10^{-3})^2(1.293-0.9\times 10^3)\times 9.8}{0.15}$$

$$= -0.0021 \text{ m s}^{-1} \text{ or } v_t = -0.21 \text{ cms}^{-1}$$

Note Here, negative sign implies that the bubble will rise up.

Example 13. *Two spherical raindrops of equal size are falling vertically through air with a terminal velocity of 1 ms^{-1}. What would be the terminal speed, if these two drops were to coalesce to form a large spherical drop?*

(a) 1.125 m/s (b) 2.225 m/s (c) 1.587 m/s (d) 3.125 m/s

Sol. (c) As, $v_t \propto r^2$ ...(i)

Let r be the radius of small raindrops and R is the radius of large drop.

Equating the volumes, we have

$$\frac{4}{3}\pi R^3 = 2\left(\frac{4}{3}\pi r^3\right)$$

$\therefore$ $$R = (2)^{1/3} \cdot r$$

or $$\frac{R}{r} = (2)^{1/3}$$

$\therefore$ $$\frac{v_t'}{v_t} = \left(\frac{R}{r}\right)^2 = (2)^{2/3}$$

$\therefore$ $$v_t' = (2)^{2/3} v_t = (2)^{2/3}\ (1.0)\ \text{ms}^{-1} = 1.587\ \text{ms}^{-1}$$

Experiment-8

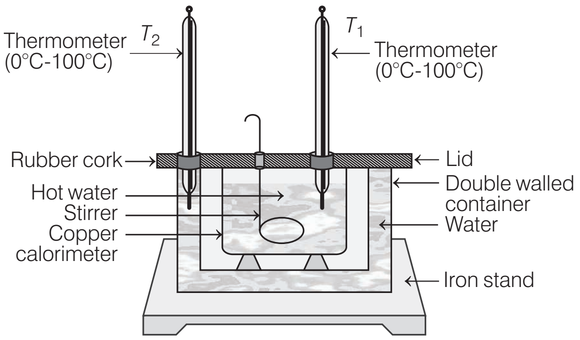
Object

To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

Apparatus

Two celcius thermometers, Newton's law of cooling apparatus, a clamp stand, a stop watch, a beaker, burner, wire gauge, tripod stand and water.

Diagram



Set up of Newton's law of cooling apparatus

Theory

Newton's law of cooling states that rate of cooling of a body is directly proportional to the difference in temperature of the body and its surroundings provided this difference is not very large.

i.e. $$-\frac{d\theta}{dt} \propto (\theta - \theta_0)$$

$\therefore$ $$(\theta - \theta_0) = (\theta_m - \theta_0)e^{-kt}$$

where, θ = temperature of the body,

θ_0 = temperature of surroundings,

and θ_m = temperature of the body at 0°C.

$$\log(\theta - \theta_0) = -kt + c$$

Thus, graph $\log(\theta - \theta_0)$ *versus* t will be a straight line.

Procedure

(i) Clean the apparatus and place it on the table. Fill water between the two walls of the vessel.

(ii) Put the thermometer in water contained in beaker. Mark them as T_1 and T_2, Record the difference of temperature in two thermometers as $(\theta_2 - \theta_1)$.

(iii) Insert thermometer T_1 in calorimeter with the help of clamp stand and insert T_2 in water between double walls.

(iv) Heat water upto 70°C and pour it in the 'calorimeter. Stir it after placing the lid.

(v) Start noting down temperature in T_1 and where it is about 65°C, start stop watch and record the temperature after every 2 min till the temperature reaches 40°C.

(vi) Record the temperature in T_2 at the end of the experiment.

Observations

Temperature of water as recorded by thermometer

$$T_1\ \theta_1 = \ldots\ldots ^\circ\text{C}$$

Temperature of water as recorded by thermometer

$$T_2\ \theta_2 = \ldots\ldots ^\circ\text{C}$$

Correction applied in

$$T_2 = \theta_2 - \theta_1 = \ldots\ldots ^\circ\text{C}$$

Initial corrected temperature between the walls of the apparatus $= \theta_0 = \dfrac{\theta_1' + \theta_2'}{2} = \ldots\ldots ^\circ\text{C}$

Final corrected temperature $= \theta_2' = \ldots\ldots ^\circ\text{C}$

Mean corrected temperature of surroundings of the calorimeter $= \theta_0 = \dfrac{\theta_1' + \theta_2'}{2} = \ldots\ldots ^\circ\text{C}$

Table for measurement of temperature of hot water

S.No.	Time t (min)	Temperature of hot water θ(°C)	$\theta - \theta_0$ (°C)	$\log(\theta - \theta_0)$
1.				
2.				
3.				
4.				
...				
...				
...				
20.				

Calculations

(i) Plot a graph between $(\theta - \theta_0)$ and t taking t along X-axis and $(\theta - \theta_0)$ along Y-axis.

(ii) Plot a graph between $\log(\theta - \theta_0)$ and t taking t along X-axis and $\log(\theta - \theta_0)$ along Y-axis.

Result

(i) The cooling curve for water between $(\theta - \theta_0)$ and t is an exponential curve.

(ii) $\log(\theta - \theta_0)$ *versus* t graph is a straight line. This confirms Newton's law of cooling.

Precautions

(i) The initial temperature of hot water should not be more than 40°C.

(ii) The hot water in the calorimeter should be stirred continuously and gently.

Example 14. *A body cools in 7 min from 60°C to 40°C. What will be its temperature after the next 7 min? The temperature of the surroundings is 10°C.*

(a) 40°C (b) 30°C

(c) 15°C (d) 28°C

Sol. (*d*) In first case, $T_1 = 60°$ C, $T_2 = 40°$ C

$T_0 = 10°$ C, $t = 7$ min $= 420$ s

According to Newton's law of cooling, we get

$$mc\,\frac{T_1 - T_2}{t} = k\left(\frac{T_1 + T_2}{2} - 10\right)$$

$$mc\,\frac{(60-40)}{420} = k\left(\frac{60+40}{2} - 10\right)$$

$$mc \times \frac{20}{420} = k \times 40 \quad \text{...(i)}$$

In second case , $T_1 = 40°$ C, $T_2 = ?$, $T_0 = 10°$ C

and $t = 7$ min $= 420$ s

$$mc \times \frac{40 - T_2}{420} = k\left(\frac{40 + T_2}{2} - 10\right) \quad \text{...(ii)}$$

On dividing Eq. (ii) by Eq. (i), we get

$$\frac{20}{40 - T_2} = \frac{40}{\frac{40 + T_2}{2} - 10}$$

$$20 + \frac{T_2}{2} - 10 = 80 - 2T_2$$

On solving, we get $T_2 = 28°$ C.

Experiment-9

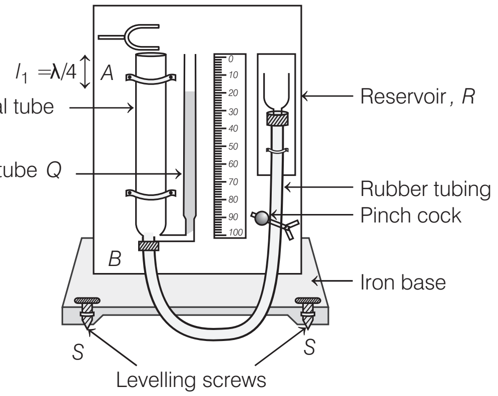
Object

To find the speed of sound in air at room temperature using a resonance tube by two resonance positions.

Apparatus

Resonance tube apparatus, two tuning forks of different frequencies, a rubber pad, a plumb line, water in a beaker, a thermometer and a set square.

Diagram



Theory

Speed of sound in air,

$$v = 2\nu(l_2 - l_1)$$

where, ν = frequency of tuning fork,

l_1 = length of the air column at first resonance

and l_2 = length of the air column in second resonance with tuning fork.

Procedure

(i) Using levelling screws and spirit level, set the resonance tube vertical.

(ii) Fill the sufficient water in the reservoir so that it rises upto the brim in the pipe and doesn't spill.

(iii) For first resonance position, start with zero length of air column in pipe. Strike the tuning fork with the rubber pad, bring it near the opening of the pipe and hear the sound.

(iv) Start lowering the level of the reservoir gradually lowering the level of water in pipe in steps of millimetre till the maximum sound with the tuning fork is heard. Ensure that loudness falls sharply by lowering and raising the level of water by one millimetre.

(v) Record the length y_1 of air column at first resonance.

(vi) Increase the length of air column by few centimetre and repeat the same procedure to find resonating length of air column y_2.

(vii) Increase the length of air column to about three times and find the length of air column corresponding to second resonance.

(viii) Repeat the same procedure with tuning fork of different frequencies.

Observations

(i) • Room temperature in the beginning of the experiment, $\theta_1 = \ldots\ldots {}^\circ C$

• Room temperature at the end of the experiment, $\theta_2 = \ldots\ldots {}^\circ C$

Mean value of room temperature,

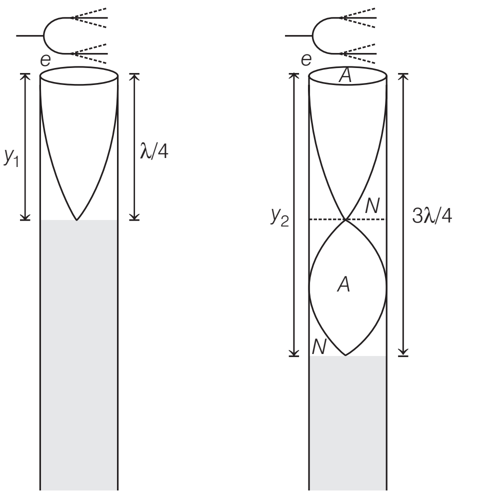
$$\theta = \frac{\theta_1 + \theta_2}{2} = \ldots\ldots {}^\circ C$$

(ii) Position of the top end A of the resonance tube, $y_0 = \ldots\ldots\ldots$ cm

Table for resonating length with different frequencies

Frequency of tuning fork (Hz)	Resonance	Position of water level at resonance			Length of air column $l = y - y_0$ (cm)
		Level falling y_1 (cm)	Level rising y_2 (cm)	Mean $y = \frac{y_1 + y_2}{2}$ (cm)	
$\nu_1 = 480$	Ist				$l_1 =$
	IInd				$l_2 =$
$\nu_2 = 512$	Ist				$l_1' =$
	IInd				$l_2' =$

Calculations



Position of Ist resonance Position of IInd resonance

(i) For tuning fork of 480 Hz

$$v_1 = 2 \times 480\,(l_2 - l_1) = \ldots\ldots\ldots \text{ ms}^{-1}$$

(ii) For tuning fork of 512 Hz

$$v_2 = 2 \times 512\,(l_2' - l_1') = \ldots\ldots\ldots \text{ ms}^{-1}$$

Mean value of velocity of sound in air is

$$\frac{v_1 + v_2}{2} = \ldots\ldots\ldots \text{ ms}^{-1}$$

Result

Velocity of sound in air at ……0°C is…… ms^{-1}.

Precautions

(i) The tuning fork should be struck gently against the rubber pad.

(ii) Ensure that there is no leakage of water from the apparatus.

Example 15. *The internal radius of a 1 m long resonance tube is measured as 3.0 cm. A tuning fork of frequency 2000 Hz is used. The first resonating length is measured as 4.6 cm and the second resonating length is measured as 14.0 cm. Percentage error in calculation of end correction e is*

(a) 100% (b) 80% (c) 94% (d) 75%

Sol. (c) Maximum percentage error in measurement of e, as given by Rayleigh's formula.

(Given, error in measurement of radius is 0.1 cm)

$$\Delta e = 0.6\,\Delta R = 0.6 \times 0.1 = 0.06 \text{ cm}$$

Percentage error is $\frac{\Delta e}{e} \times 100 = \frac{0.06}{0.6 \times 3} \times 100 = 3.33\%$

End correction obtained in the experiment,

$$e = \frac{l_2 - 3l_1}{2}$$

$$= \frac{14.0 - 3 \times 4.6}{2} = 0.1 \text{ cm}$$

So, percentage error in the calculation of e with respect to theoretical value. Percentage error

$$= \frac{0.6 \times 3 - 0.1}{0.6 \times 3} \times 100$$

$$= 94.44\% \simeq 94\%$$

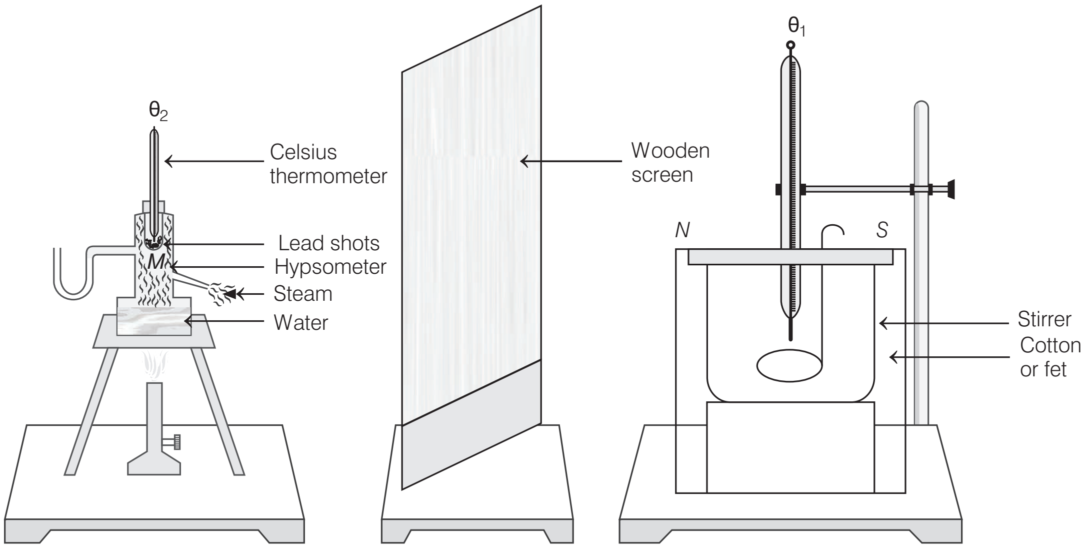
Experiment-10

Object

To determine the specific heat of a given liquid by method of mixtures.

Apparatus

Hypsometer, solid (lead shots), calorimeter with stirrer and lid, celcius thermometers, weight box, heating arrangement, beaker and experimental fluid (turpentine oil).



Heating of lead shot in steam using hypsometer

Calorimeter in jacket containing

Theory

The basis of this method is principle of calorimetry, according to which when two bodies at different temperatures are brought close in contact, heat flows from body at higher temperature to body at lower temperature till both bodies acquire the same temperature, specific heat of a given liquid is defined as the amount of heat required to raise the temperature of 1 kg of liquid through 1°C.

Procedure

(i) Fill the hypsometer's tank with sufficient quantity of water and place it on heating arrangement that is kept on one side of insulating wooden screen.

(ii) Tie a thread around the metal of known specific heat and drop it in tube M of the hypsometer.

(iii) On the other side of screen, place a calorimeter in a wooden box.

(iv) To make the calorimeter thermally insulated, fill the empty space with cotton wool around it.

(v) Weigh the calorimeter taking it out and weigh it along with stirrer. Now fill it with turpentine oil and weight again.

(vi) Now insert thermometer T_1 in calorimeter and T_2 in hypsometer tube M which should be surrounded by lead shots.

(vii) Start heating the water in hypsometer till it boils. Continue heating till thermometer T_2 shows a steady temperature θ_2. Record this value.

(viii) Record the initial temperature of the liquid in calorimeter.

(ix) Now shift gently the metal from tube M into the calorimeter after removing its lid.

(x) After closing the lid, stir well and note the highest temperature attains d by T_1.

(ix) After removing the thermometer, weight the calorimeter again along with stirrer.

Observations

(i) Mass of (empty calorimeter + stirrer), $m_1 = \ldots\ldots\ldots$ g

(ii) Mass of (calorimeter + water + stirrer), $m_2 = \ldots\ldots\ldots$ g

(iii) Mass of (calorimeter + water + stirrer + lead shots), $m_3 = \ldots\ldots\ldots$ g

(iv) Initial temperature of water in calorimeter, $\theta_0 = \ldots\ldots\ldots\,^\circ\mathrm{C}$

(v) Steady temperature of lead shots in hypsometer $\theta_l = \ldots\ldots\ldots\,^\circ\mathrm{C}$

(vi) Final temperature of mixture, $\theta = \ldots\ldots\ldots\,^\circ\mathrm{C}$

(vii) Specific heat of water, $S_1 = 4.2\ \mathrm{Jg^{-1}\text{-}^\circ C^{-1}}$

(viii) Specific heat of material of calorimeter, $S_2 = \mathrm{Jg^{-1}\text{-}^\circ C^{-1}}$

Calculations

(i) Water equivalent of (calorimeter + stirrer),

$$w_1 = \frac{m_1 S_2}{S_1} = \ldots\ldots \text{ g}$$

(ii) Mass of water in calorimeter $= (m_2 - m_1) = \ldots\ldots$ g

(iii) Mass of lead shots $= (m_3 - m_2) = \ldots\ldots$ g

(iv) Rise in temperature of water and calorimeter

$$= (\theta - \theta_0) = \ldots\ldots\,^\circ\mathrm{C}$$

(v) Fall in temperature of lead shots

$$= (\theta_l - \theta) = \ldots\ldots\,^\circ\mathrm{C}$$

According to principle of calorimeter,

Heat lost by lead shots

= heat gained by calorimeter and water

$$(m_3 - m_2) S_L (\theta_l - \theta) = (m_2 - m_1 + w_1) \times 4.2 (\theta - \theta_0)$$

where, S_L = specific heat of given solid.

$$\therefore \quad S_L = \frac{(m_2 - m_1 \times w_1) \times 4.2 \times (\theta - \theta_0)}{(m_3 - m_2)(\theta_l - \theta)}$$
$$= \ldots\ldots \text{ Jg}^{-1}\text{-}^\circ\text{C}^{-1}$$

Example 16. *The temperature of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C, respectively. The temperature when A and B are mixed is 16°C and when B and C are mixed is 23°C. The temperature when A and C are mixed, is*

(a) 18.2°C (b) 22°C
(c) 20.2°C (d) 25.2°C

Sol. (c) By applying calorimetry method, we get

Heat gain = Heat lost

$$c_A (16 - 12) = c_B (19 - 16) \Rightarrow \frac{c_A}{c_B} = \frac{3}{4}$$

and $$c_B (23 - 19) = c_C (28 - 23)$$

$$\Rightarrow \frac{c_B}{c_C} = \frac{5}{4}$$

$$\Rightarrow \frac{c_A}{c_C} = \frac{c_A}{c_B} \times \frac{c_B}{c_C} = \frac{3}{4} \times \frac{5}{4} = \frac{15}{16} \quad \ldots\text{(i)}$$

If θ is the temperature when A and C are mixed, then

$$c_A (\theta - 12) = c_C (28 - \theta)$$

$$\Rightarrow \frac{c_A}{c_C} = \frac{28 - \theta}{\theta - 12} \quad \ldots\text{(ii)}$$

On solving Eqs. (i) and (ii), we have

$$\frac{28 - \theta}{\theta - 12} = \frac{15}{16}$$

$$\Rightarrow 448 - 16\theta = 15\theta - 180$$

$$\therefore \theta = 20.2^\circ \text{ C}$$

Experiment-11

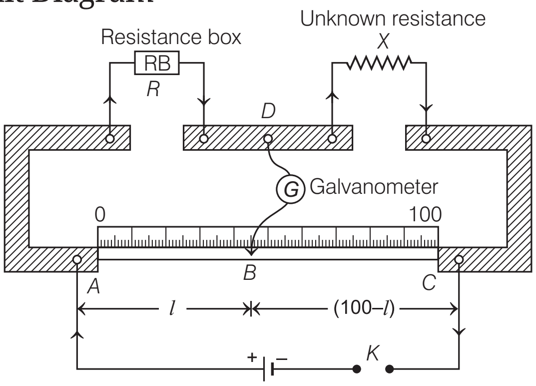
Object

To find resistance of a given wire using meter bridge.

Apparatus

A meter bridge, a galvanometer, a leclanche cell, a resistance box, a jockey, a one way key, a resistance wire, a meter scale and connecting wires.

Circuit Diagram



Description to Meter Bridge The practical form of Wheatstone bridge is the slide wire bridge or meter bridge. Usually, ratio arms of fixed resistance are P and Q, and R is variable resistance of known value. X is an unknown resistance as shown in figure. As the bridge uses 1 m long wire, it is called meter bridge and as the jockey is slided over the wire, it is called slide wire bridge.

Theory

The unknown resistance X is given by

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

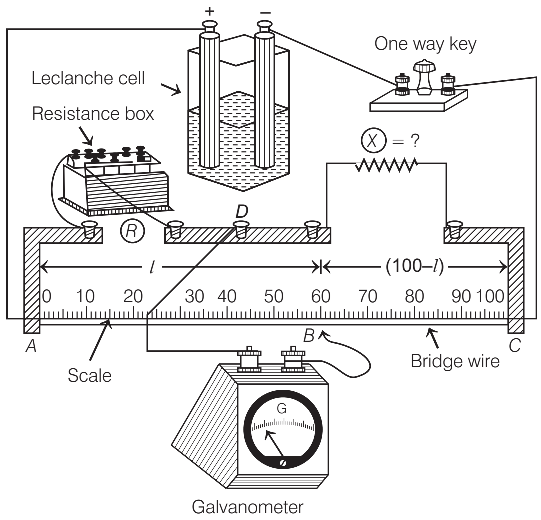
where, R is known resistance placed in the left gap and unknown resistance X in the right gap of the meter bridge, l is the balancing length on the meter bridge wire.

Procedure

(i) Arrange the apparatus according to the arrangement diagram as shown.

(ii) Connect the resistance wire whose resistance is to be determined in the right gap between C and D.

(iii) Connect resistance box of low range in the left hand gap between A and D.



(iv) Take out some resistance (say 4Ω) from the resistance box, plug the key K.

(v) Touch the jockey gently first at left end and then at right end of the bridge wire.

(vi) If the galvanometer shows deflections in opposite directions, the connections are correct.

(vii) Now, move the jockey gently along the wire from left to right till galvanometer shows no deflections. The point where the jockey is touching the wire, when galvanometer shows no deflection is null point B.

(viii) Choose an appropriate value of R from the resistance box such that there is no deflection in the galvanometer when the jockey is nearly in the middle of the wire.

(ix) Take atleast four sets of observations in the same way by changing the value of R by 1Ω in each step.

(x) Record your observations as given ahead in table.

Observations

Table for length (L) and unknown resistance (X)

S. No.	Resistance from the resistance box R (ohm)	Length $AB = l$ (cm)	Length $BC = (100 - l)$ (cm)	Unknown resistance $X = \frac{(100-l)}{l} R$ (ohm)
1.	4	......	......	$X_1 =$ ......
2.	5	......	......	$X_2 =$ ......
3.	6	......	......	$X_3 =$ ......
4.	7	......	......	$X_4 =$ ......

Calculations

(i) From position of B, find l cm and write in table.

(ii) Find length $(100 - l)$ cm and write in table.

(iii) Calculate X by the given formula and write in table.

(iv) Take mean value of X recorded in table.

Mean, $X = \dfrac{X_1 + X_2 + X_3 + X_4 + \ldots + X_R}{n}$

Mean $X =$ .... Ω.

Using formula, $R = \dfrac{\rho l}{A}$.

We can find resistivity also.

Result

The value of unknown resistance, $X =$ ...... Ω.

Precautions

(i) The connections should be tight.

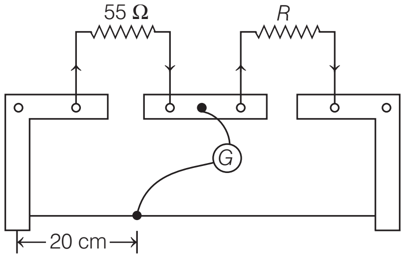
(ii) All the plugs in the resistance box should be tight.

(iii) Move the jockey gently over the bridge wire and do not rub it.

(iv) To save the sensitive galvanometer from high current, introduce a high resistance box in series or a low resistance shunt in parallel with the galvanometer.

(v) Null point should be brought between 40 cm and 60 cm.

Example 17. *The following figure shows a meter bridge set up with null deflection in the galvanometer, the value of the unknown resistance R is*



(a) 13.75 Ω (b) 220 Ω (c) 110 Ω (d) 55 Ω

Sol. (b) From the principle of Wheatstone bridge, we have

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

Putting $P = 55\ \Omega$, $Q =$ unknown resistance $= R$

$R = 20\ \Omega$, $S = 80\ \Omega$, we have

$$\therefore \qquad \frac{55}{R} = \frac{20}{80}$$

$$\Rightarrow \qquad R = 220\ \Omega$$

Example 18. *A meter bridge is used to determine the resistance of an unknown wire by measuring the balance point length l. If the wire is replaced by another wire of same material but with double the length and half the thickness, the balancing point is expected to be*

(a) $\dfrac{1}{8l}$ (b) $\dfrac{1}{4l}$ (c) $8l$ (d) $16\,l$

Sol. (c) In a meter bridge, the ratio of two resistances is

$$\frac{R}{R'} = \frac{l}{l'}$$

where, l and l' are balancing lengths.

Resistance, $R = \dfrac{\rho l}{A} = \dfrac{\rho l}{\pi r^2}$

If material remains same $\rho = \rho'$

Given, $l' = 2\,l$,

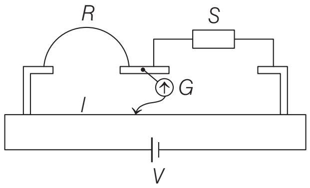
$$r' = \frac{r}{2}$$

$$\because \qquad R' = \frac{\rho l'}{A'} = \frac{\rho 2\,l}{\pi \left(\frac{r}{2}\right)^2} = \frac{8\rho l}{\pi r^2}$$

$$R' = 8R$$

Hence, new balancing point is expected to be $8l$.

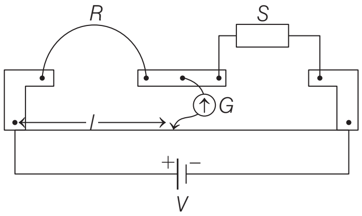
Example 19. *In a meter bridge experiment, S is a standard resistance and R is a resistance wire. It is found that, balancing length is l = 25 cm. If R is replaced by a wire of half length and half diameter that of R of same material, then find the balancing distance l′.*



(a) 20 cm (b) 30 cm

(c) 40 cm (d) 50 cm

Sol. (c)



Given, balance length, $l = 25$ cm

At balance point, $\dfrac{R}{l} = \dfrac{S}{100 - l}$

$$\Rightarrow \quad \frac{R}{25} = \frac{S}{75} \Rightarrow R = \frac{S}{3}\,\Omega \qquad \text{....(i)}$$

When R is replaced by some other resistance of half length and half diameter, then resistance in left gap,

$$R' = \frac{\rho \dfrac{l}{2}}{\dfrac{\pi}{4}\left(\dfrac{d}{2}\right)^2} = 2\left\{\frac{\rho l}{\left(\dfrac{\pi}{4} d^2\right)}\right\}$$

$$\Rightarrow \quad R' = 2R$$

Now, if balance is obtained at length l', then

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

$$\Rightarrow \quad \frac{2R}{l'} = \frac{S}{100 - l'}$$

Substituting the value of S from Eq. (i), we get

$$\frac{2R}{l'} = \frac{3R}{100 - l'}$$

$$\Rightarrow \quad 200 - 2l' = 3l'$$

or $\quad l' = 40$ cm

Experiment-12

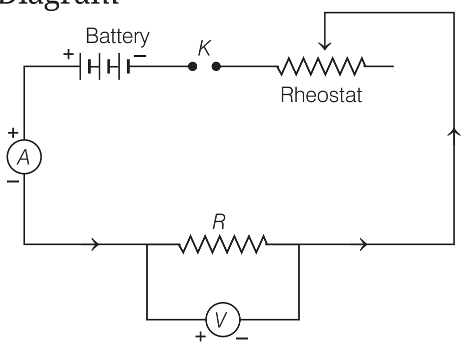
Object

To determine resistance per cm of a given wire using Ohm's law or by plotting a graph of potential difference *versus* current.

Apparatus

A resistance wire, a voltmeter, an ammeter of appropriate range, a rheostat, a meter scale, a battery, one way key and connecting wires.

Circuit Diagram



Theory

If I be the current flowing through a conductor and V be the potential difference across its ends. According to Ohm's law,

$$V \propto I$$

or $\quad V = RI$

where, R is the constant of proportionality. It is known as resistance of the conductor.

or $\quad \dfrac{V}{I} = R$

Procedure

(i) Arrange the apparatus in the same manner as given in arrangement diagram given ahead.

(ii) Make neat, clean and tight connections according to the circuit diagram.

(iii) Determine the least count of voltmeter and ammeter, and also note the zero error, if any.

(iv) Insert the key K, slide the rheostat contact and see that ammeter and voltmeter are working properly.

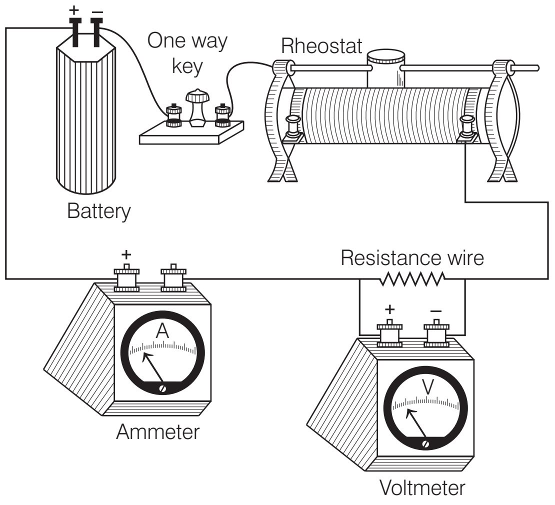
(v) Adjust the sliding contact of the rheostat such that a small current passes through the resistance wire.

(vi) Note down the value of potential difference V from voltmeter and current I from ammeter.

(vii) Shift the rheostat contact slightly so that both ammeter and voltmeter show full division reading and not in fraction.

(viii) Record the readings of the voltmeter and ammeter.

(ix) Take atleast six sets of independent observations.



Experimental setup for verification of Ohm's law

Observations

Table for resistance (R)

S. No.	Ammeter reading I (A)	Voltmeter reading V (V)	$\dfrac{V}{I} = R$ (ohm)
1.	......	......	......
2.	......	......	......
3.	......	......	......
4.	......	......	......
5.	......	......	......
6.	......	......	......

Calculations

(i) Find ratio of V and I for each set of observations.

(ii) Plot a graph between potential difference V and current I taking V along X-axis and I along Y-axis. The graph comes to be a straight line, as shown in figure.

(iii) Constant ratio $\frac{V}{I}$ gives resistance of the wire.

(iv) Resistance of the wire per cm = ... $\Omega\ cm^{-1}$.

Result

Resistance of the wire = ... $\Omega\ cm^{-1}$.

Precautions

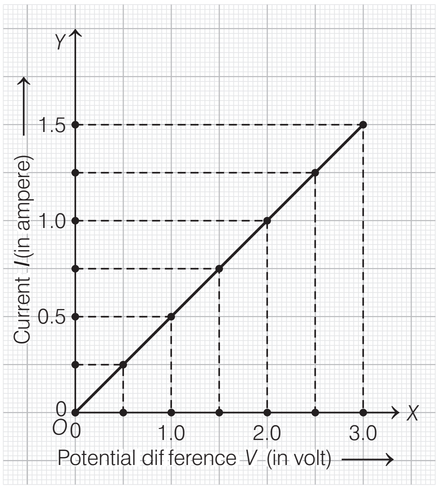
(i) The connections should be neat, clean and tight.

(ii) Voltmeter and ammeter should be of proper range.

(iii) A low resistance rheostat should not be used.

(iv) The unknown resistance should not be too low.

(v) The key should be inserted only while taking observations to avoid heating of wire.



Example 20. *The temperature coefficient of resistance of a wire is* $0.00145°C^{-1}$. *At* 100 °C, *its resistance is* 2 Ω. *At what temperature the resistance of the wire will be* 3 Ω?

(a) 667.8 *K* (b) 567.5 *K*

(c) 928.3 *K* (d) 727.56 *K*

Sol. (a) Using the relation, $R = R_0(1+\alpha T)$

$$R_1 = R_0(1+\alpha t_1)$$

$$\therefore \quad 2 = R_0(1+0.00145\times 100) \quad \text{...(i)}$$

and

$$R_2 = R_0(1+\alpha t_2)$$

$$\therefore \quad 3 = R_0(1+0.00145\times t_2) \quad \text{...(ii)}$$

On dividing Eq. (ii) by Eq. (i), we get

$$\frac{3}{2} = \frac{1+0.00145t_2}{1+0.00145\times 100}$$

or

$$t_2 = 394.8°\ C$$

$$= 667.8K$$

Experiment-13(i)

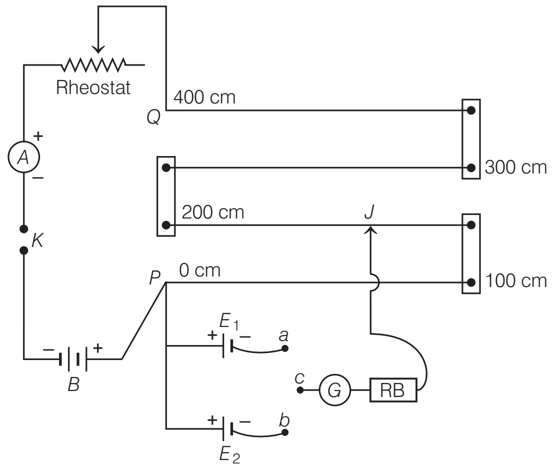
Object

To compare the emf's of two given primary cells using potentiometer.

Apparatus

Two cells (a leclanche cell, a daniel cell), an ammeter, a voltmeter (0 to 5V), a galvanometer, a potentiometer, a battery, a rheostat of low resistance, a resistance box, a one way key, a two way key, a jockey and connecting wires.

Circuit Diagram



Theory

The formula given is $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

where, E_1 and E_2 = the emf's of two given cells and l_1 and l_2 = the corresponding balancing lengths on potentiometer wire.

Procedure

(i) Draw a circuit diagram making connections as in figure.

(ii) Connect the positive pole of the battery (a battery of constant emf to the zero end (P) of the potentiometer and the negative pole through a one way key, an ammeter and a low resistance rheostat to the other end (Q) of the potentiometer.

(iii) Connect the positive poles of the cells E_1 and E_2 to the terminal at the zero end (P) and the negative poles to the terminals a and b of the two way key.

(iv) Connect the common terminal of the two way key through a galvanometer (G) and a resistance box (RB) to the jockey (J).

(v) Take maximum current from the battery making rheostat resistance zero.

(vi) Insert the plug in the one way key and also between the terminals a and c of the two way key to connect cell E_1 with the circuit.

(vii) Take out a 2000 Ω plug from the resistance box (RB).

(viii) The jockey at the zero end and note the direction of deflection in the galvanometer.

(ix) Touch the jockey at the other end of the potentiometer wire. If the direction of deflection is opposite to that in the previous case, the connections are correct.

(x) Slide the jockey along potentiometer wire so as to obtain a point where galvanometer shows no deflection.

(xi) Put the 2000 Ω plug back in the resistance box and obtain the null point position accurately.

(xii) Note the length l_1 of the wire for the cell E_1. Also, note the current as indicated by the ammeter.

(xiii) Disconnect the cell E_1 by removing the plug from gap ac of two way key and connect the cell E_2 by isserting plug into gap bc of two way key.

(xiv) Take out a 2000 Ω plug from resistance box and slide the jockey along potentiometer wire so as to obtain no deflection position. Put the 2000 Ω plug back in the resistance box and obtain accurate position of null point for second cell E_2.

(xv) Note the length l_2 of wire in this position for the cell E_2. However, make sure that ammeter reading is same as in step 12.

(xvi) Increase the current by adjusting the rheostat and obtain at least three sets of similar observations,

Observations

Table for lengths

S. No.	Corrected ammeter reading (A)	Balance point when E_1 (Leclanche cell) in the circuit L_1 (cm)			Balance point when E_2 (Daniel cell) in the circuit L_2 (cm)			$\frac{E_1}{E_2} = \frac{L_1}{L_2}$
		1	2	Mean l_1	1	2	Mean l_2	
1.	…	…	…	…	…	…	…	…
2.	…	…	…	…	…	…	…	…
3.	…	…	…	…	…	…	…	…

(i) Range of voltmeter = 5.0 V
Least count of voltmeter = 0.1 V
Emf of battery (or battery elimination), E = 2.5 V
Emf of leclanche cell, E_1 = 1.4 V
Emf of daniel cell, E_2 = 1.1 V

(ii) Least count of the ammeter = 0.02 A
Zero error of the ammeter = Nil

Calculations

(i) For each observation find mean l_1 and mean l_2 and record in table above.

(ii) Find $\frac{E_1}{E_2}$ for each set.

(iii) Find mean $\frac{E_1}{E_2}$ of all sets.

Result

The ratio of emf's, $\frac{E_1}{E_2} \cong$ …….

Precautions

(i) The plugs should be introduced in the keys only when the observations are to be taken.

(ii) The positive poles of the battery E, E_1 and E_2 should all be connected to the terminal at the zero of the wires.

(iii) The emf of the battery should be greater than the emf's of the either of the two cells.

(iv) The ammeter reading should remain constant for a particular set of observation.

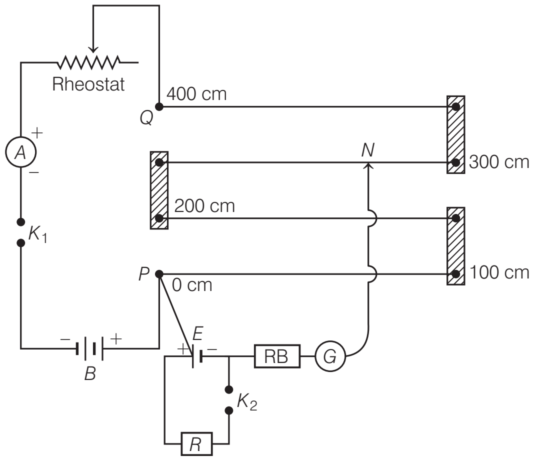
Experiment-13(ii)

Object

To determine the internal resistance of a given primary cell using potentiometer.

Apparatus

A potentiometer, a battery, two one way keys, a rheostat of low resistance, a galvanometer, a high resistance box, an ammeter, a voltmeter (0-5V), a leclanche cell, a jockey and connecting wires.



Theory

The internal resistance of a cell is given by

$$r = \left(\frac{l_1}{l_2} - 1\right)R$$

where, l_1 and l_2 are the balancing lengths without shunt and with shunt, respectively and R is the shunt resistance in parallel with the given cell.

Procedure

(i) Draw the circuit diagram showing the scheme of connections as in figure.

(ii) Tight the plugs of the resistance box.

(iii) Check the emf's of the battery and cell and see that emf of the battery is more than that of the given cell, otherwise null or balance point will not be obtained.

(iv) Take maximum current from the battery, making rheostat resistance zero.

(v) Take out 2000 Ω resistance plug from the resistance box. Place the jockey first at the end P of the wire and then at the end Q. If the galvanometer shows deflection in opposite directions in the two cases, the connections are correct.

(vi) Without inserting the plug in the key (K_2) adjust the rheostat, so that a null point is obtained on the fourth wire of potentiometer.

(vii) Insert the 2000 Ω plug back in its position in resistance box and obtain the null point position.

(viii) Measure the balancing length l_1 between this point and the end P of the wire.

(xi) Take out the 2000 Ω plug again from the resistance box (RB). Introduce the plugs in key (K_1) as well as in key (K_2). Take out a small resistance (1 Ω to 5Ω) from the resistance box (R) connected in parallel with the cell.

(x) Slide the jockey along the potentiometer wire and the obtain null point.

(xi) Insert the 2000 Ω plug back in its position in resistance box and again obtain the null point.

(xii) Measure the balancing length l_2 from end P.

(xiii) Repeat the observations for different values of R repeating each observation twice.

Observations

Range of voltmeter = …… V

Least count of voltmeter = …… V

Emf of battery = …… V

Emf of cell = …… V

Table for Lengths

S.No.	Ammeter reading (A)	Postion of null point (cm)						Shunt resistance R (ohm)	Internal resistance $r=\left(\frac{l_1-l_2}{l_2}\right)R$ (ohm)
		Without shunt R			With shunt R				
		(i)	(ii)	Mean l_1	(i)	(ii)	Mean l_2		
1.	...	...	...	...	...	...	...	...	...
2.	...	...	...	...	...	...	...	...	...
3.	...	...	...	....	...	...	...	...	...
4.	...	...	...	...	...	...	...	...	...
5.	...	...	...	...	...	...	...	...	...
6.	...	...	...	...	...	...	...	...	...

Calculations

(i) For each set of observation, find mean l_1 and l_2.

(ii) Calculate value of r for each set and write it in table.

(iii) Take mean of value of r recorded in table.

Result

The internal resistance of the given cell is ... Ω.

Precautions

(i) The emf of the battery should be greater than that of the cell.

(ii) For one set of observation the ammeter reading should remains constant.

(iii) Current should be passed for short time while finding the null point.

(iv) Cell should not be disturbed during experiment.

To find resistance of a given wire using meter bridge.

Example 21. *The length of a wire of a potentiometer is* 100 *cm, and the emf of its standard cell is E volt. It is employed to measure the emf a battery whose internal resistance is* 0.5 Ω. *If the balance point is obtained at* $l = 30$ *cm from the positive end, then the emf of the battery is*

(a) $\frac{30E}{100}$ (b) $\frac{20}{50}E$

(c) $\frac{100}{30}E$ (d) $\frac{50}{20}E$

Sol. (a) From the formula of potentiometer, we have

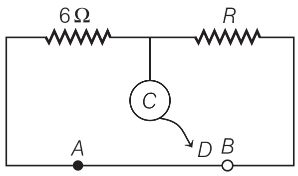
$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

where, E_1 and E_2 are the emf's of two given cells and l_1 and l_2 are the corresponding balancing lengths on potentiometer wire.

Given, $E_1 = E$ volt, $l_2 = 30$ cm, $l_1 = 100$ cm

$$\therefore \quad E_2 = E_1 \cdot \frac{l_2}{l_1} = E \cdot \frac{30}{100}$$

Example 22. *The potentiometer wire AB shown in the figure is 50 cm long. When AD = 30 cm, no deflection occurs in the galvanometer. The resistance R(in Ω) is*



(a) 2 Ω (b) 4 Ω (c) 6 Ω (d) 8 Ω

Sol. (*b*) In case of no deflection, balance condition is achieved, hence we have

$$\frac{R_1}{R_2} = \frac{l_1}{l_2}$$

Given, $R_1 = 6\ \Omega, R_2 = R\ \Omega, l_1 = 30$ cm

$$l_2 = 50 - 30 = 20 \text{ cm}$$

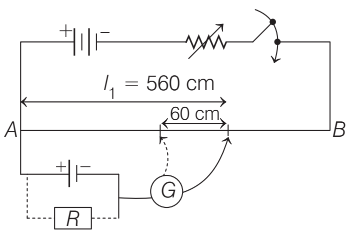
$$\therefore \quad \frac{6}{R} = \frac{30}{20}$$

$$\Rightarrow \quad R = \frac{6 \times 20}{30} = 4\ \Omega$$

Example 23. *The balancing length for a cell is 560 cm in a potentiometer experiment. When an external resistance of 10Ω is connected in parallel to the cell, the balancing length changes by 60 cm. If the internal resistance of the cell is* $\frac{N}{10}$ Ω, *where N is an integer, then find the value of N.*

(a) 2 (b) 7
(c) 10 (d) 12

Sol. (*d*) In experiment of finding internal resistance,



Balancing length with only cell, $l_1 = 560$ cm.

Balancing length with cell and resistance, $l_2 = 560$ cm − 60 cm = 500 cm

External resistance, $R = 10\ \Omega$

Now, using $\quad r = R\left(\frac{E}{V} - 1\right) = R\left(\frac{l_1}{l_2} - 1\right)$, we get

$$r = 10\left(\frac{560}{500} - 1\right) = \frac{6}{5}\ \Omega$$

Now, given $\quad r = \frac{N}{10}$

$$\Rightarrow \quad \frac{6}{5} = \frac{N}{10}$$

$$\Rightarrow \quad N = \frac{60}{5} = 12$$

Experiment-14

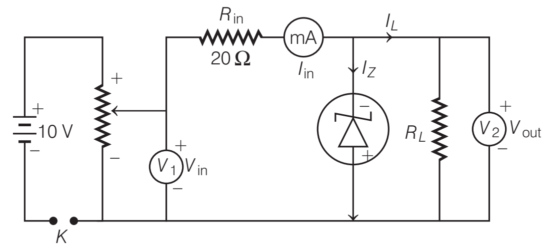
Object

To draw the characteristic curve of a zener diode and to determine its reverse breakdown voltage.

Apparatus

A zener diode, (V_Z = 6V), a 10 V battery, a high resistance rheostat, two (0 – 10V) voltmeters, an (0 – 100 mA) ammeter, a 20 Ω resistance, a one way key and connecting wires.

Diagram



Theory

Zener Diode is a semiconductor diode, having n-type and the p-type sections heavily doped. This heavy doping results in a low value of reverse breakdown voltage.

The reverse breakdown voltage of a zener diode is called zener voltage (V_Z). The reverse current that results after the breakdown, is called zener current (I_Z).

(i) **Relations**

$$I_L = I_{in} - I_Z \qquad \ldots\text{(i)}$$

$$V_{out} = V_{in} - R_{in}I_{in} \qquad \ldots\text{(ii)}$$

$$V_{out} = R_L I_L \qquad \ldots\text{(iii)}$$

Initially, as V_{in} is increased, I_{in} increases a little, then V_{out} increases.

At breakdown, increase of V_{in}, I_{in} increases by large amount, so that $V_{out} = V_{in} - R_{in}I_{in}$ becomes constant.

This constant value of V_{out} which is the reverse breakdown voltage, is called zener voltage.

(ii) **Formula used**

$$V_{out} = V_{in} - R_{in}I_{in}$$

Constant value of V_{out} gives reverse breakdown voltage.

Procedure

(i) Draw circuit diagram as shown in figure.

(ii) Bring moving contact of potential divider (rheostat) near negative end.

(iii) Move the contact a little towards positive end to apply some reverse bias voltage (V_{in}). Milliammeter reading remains zero. Voltmeters give equal readings.

i.e. $\quad V_{out} = V_{in} \qquad (\because I_{in} = 0)$

(iv) As V_{in} is further increased, I_{in} starts flowing. Then V_{out} becomes less than V_{in}. Note the values of V_{in}, I_{in} and V_{out}.

(v) Go on increasing V_{in} in small steps of 0.5 V. Note corresponding values of I_{in} and V_{out} which will be found to have increased.

(vi) At one stage, as V_{in} is increased further, I_{in} increases by large amount and V_{out} does not increase. This is reverse breakdown situation.

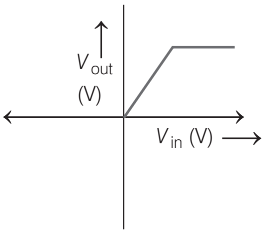
Observations

Table for $\boldsymbol{V}_{in}$, $\boldsymbol{I}_{in}$ and $\boldsymbol{V}_{out}$

S. No.	Input voltage (V_{in})	Input current (I_{in}) (mA)	output voltage (V_{out}) (V)
1.	0	-	0
2.	-	-	-
⋮	…	-	⋮
⋮	…	-	⋮
⋮	…	-	⋮
20.	…	-	

Calculations

Plot a graph between input voltage and output voltage along X-axis and along Y-axis respectively. The graph comes as shown below.



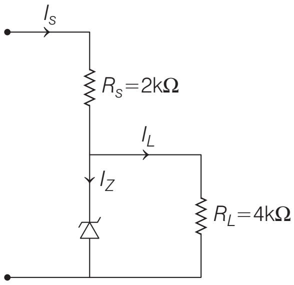
Result

The reverse breakdown voltage of given zener diode is ……V.

Precaution

Key should be used in circuit and opened when the circuit is not being used.

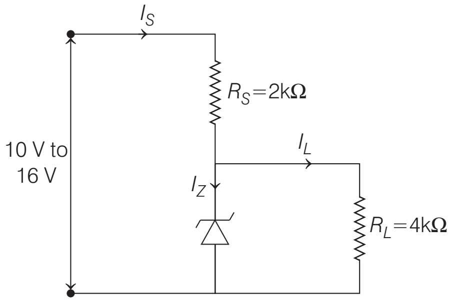
Example 24. *Figure shows a DC voltage regulator circuit, with a Zener diode of breakdown voltage = 6 V. If the unregulated input voltage varies between 10 V to 16 V, then what is the maximum zener current?*



[JEE Main 2019]

(a) 2.5 *mA* *(b)* 1.5 *mA* *(c)* 7.5 *mA* *(d)* 3.5 *mA*

Sol. (*d*) In given voltage regulator circuit, breakdown of zener occurs at 6 V.



After breakdown, voltage across load resistance (R_L = 4kΩ),

$$V = V_Z = 6\text{ V}$$

∴ Load current after breakdown,

$$I_L = \frac{V_Z}{R_L} = \frac{6}{4000} = 1.5 \times 10^{-3}\text{ A}$$

When unregulated supply is of 16 V, potential drop occurring across series resistance (R_S = 2 kΩ),

$$V_S = V - V_Z = 16 - 6 = 10\text{ V}$$

So, current across series resistance,

$$I_S = \frac{V_S}{R_S} = \frac{10}{2 \times 10^3} = 5 \times 10^{-3}\text{ A}$$

So, current across zener diode,

$$\begin{aligned} I_Z &= I_S - I_L = 5 \times 10^{-3} - 1.5 \times 10^{-3} \\ &= 3.5 \times 10^{-3}\text{ A} \\ &= 3.5\text{ mA} \end{aligned}$$

Experiment-15

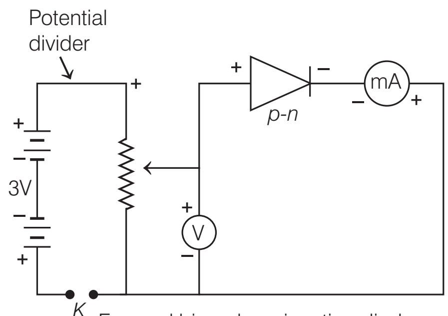
Object

To draw characteristic curves of a *p-n* junction diode in forward bias and reverse bias.

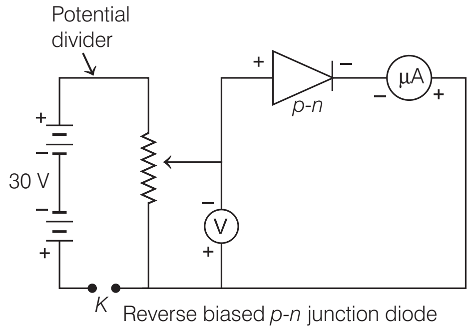
Apparatus

A *p-n* junction diode, a 3 V battery, a 30 V battery, a high resistance rheostat, a (0-3 V) voltmeter, a (0-30 V) voltmeter, an (0-100 mA) ammeter, an (0-100 μA) ammeter, a one way key and connecting wires.

Circuit Diagram



Forward biased *p-n* junction diode



Reverse biased p-n junction diode

Theory

(i) In forward biased p-n junction diode, with increase in bias voltage the forward current increases slowly in the beginning and then rapidly. At about 2.4 V, the current increases suddenly.

(ii) In reverse biased p-n junction diode, in starting no appreciable reverse current flows. At about 5 V, a feeble current starts flowing. With increase in bias voltage, the current slowly increases. At about 25 V, the reverse current increases suddenly.

Procedure

(i) **Forward biased *p-n* junction**

- Make circuit diagram as shown in figure.
- Find least count and zero error of voltmeter (V) and milliammeter (mA).
- Bring contact of potential divider (rheostat) near negative end and insert the key K. Voltmeter (V) and milliammeter (mA) will give zero reading.
- Move the contact a little towards positive end to apply a forward bias voltage of (V_F) of 0.1 V. Current remains zero.
- Increase V_F to 0.4 V. Milliammeter records a small current.
- Increase V_F in steps of 0.2 V and note the corresponding current. Current increases first slowly and then rapidly, till V_F becomes 2 V.
- Make V_F = 2.2 V. The current will rise by large amount.
- Make V_F = 2.4 V. The current increases suddenly representing forward breakdown stage. Note the current and take out the key at once.

(ii) **Reverse biased *p-n* junction**

- Make circuit diagram as shown in figure.
- Note least count and zero error of voltmeter (V) and microammeter (μA).
- Bring contact of potential divider (rheostat) near positive end and insert the key (K). Voltmeter (V) and microammeter (μA). will give zero reading.
- Move the contact towards negative end to apply a reverse bias voltage (V_R) of 0.5 V, a feebly reverse current starts flowing.
- Increase in steps of 0.2 V. Current increases first slowly and then rapidly till V_R becomes 20 V.
- Make V_R = 25 V. The current increases suddenly representing reverse breakdown stage. Note the current and take out the key at once.

Observations

(i) **For forward bias**

Range of voltmeter = 3 V
Least count of voltmeter = 0.1 V
Zero error of voltmeter = Nil
Range of milliammeter = 30 mA
Least count of milliammeter = 0.5 mA
Zero error of milliammeter = Nil

Table for forward bias voltage and forward current

S. No.	Forward bias voltage V_F(V)	Forward current I_F(mA)
1.	...	...
2.	...	...
3.	...	...
4.	...	...
5.	...	...

(ii) **For reverse bias**

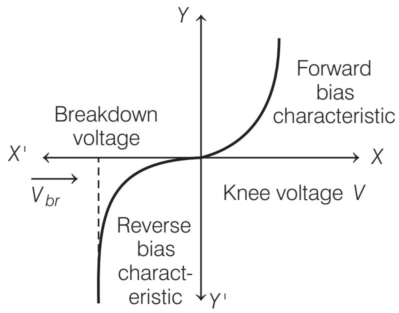
Range of voltmeter = 30 V
Least count of voltmeter = 1 V
Zero error of voltmeter = Nil
Range of microammeter = 30 μA
Least count of microammeter = 0.5 μA
Zero error of microammeter = Nil

Table for reverse bias voltage and reverse current

S. No.	Reverse bias V_R(V)	Reverse current I_R(μA)
1.	...	...
2.	...	...
3.	...	...
4.	...	...
5.	...	...

Calculations

If the voltage is applied along X-axis and current along Y-axis, then it is called a V-I characteristic curve. In the forward region, the voltage where the current starts to increase abruptaly is called knee voltage.



Result

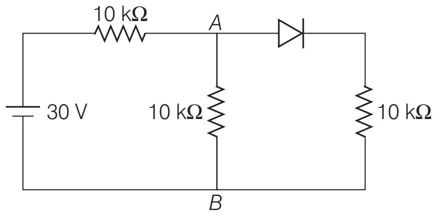
Junction resistance for forward bias $= \dfrac{\Delta V_F}{\Delta I_F} = \ldots \Omega$

Junction resistance for reverse bias $= \dfrac{\Delta V_R}{\Delta I_R} = \ldots \Omega$

Precaution

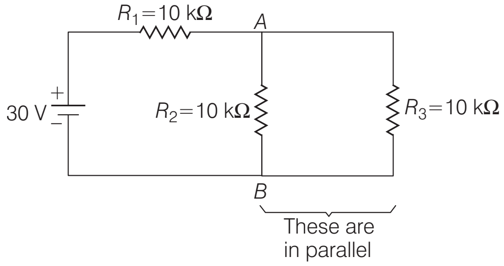
Forward bias and reverse bias voltage should not be applied **beyond breakdown.**

Example 25. *In the figure, potential difference between A and B is* ***[JEE Mlain 2020]***



(a) zero (b) 10 V (c) 5 V (d) 15 V

Sol. () In ideal condition, a forward biased *p-n* junction acts like a conductive path of zero resistance. So, given circuit is equivalent to circuit shown below.



Total resistance of circuit,

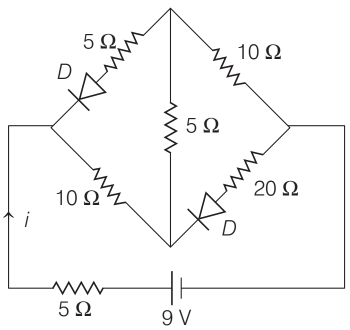
$R = (R_3$ in parallel with $R_2)$ and these are in series with R_1

$$= \frac{10 \times 10}{10 + 10} + 10 = 15 \text{ k}\Omega$$

So, total current in the circuit,

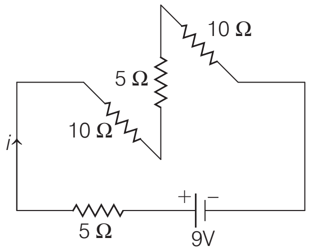
$$I = \frac{V}{R} = \frac{30}{15 \text{ k}\Omega} = 2 \times 10^{-3} \text{ A}$$

Example 26. *The current i in the network is*



(a) 0.2*A* (b) 0 *A* (c) 0.6 *A* (d) 0.3 *A*

Sol. (*d*) As both diodes are in reverse bias, so given circuit is equivalent to the circuit as shown in the figure.



Equivalent resistance of circuit,

$$R = 5 + 10 + 5 + 10 = 30 \Omega$$

$\therefore$ Circuit current, $I = \dfrac{V}{R} = \dfrac{9}{30} = 0.3 \text{A}$

Experiment-16

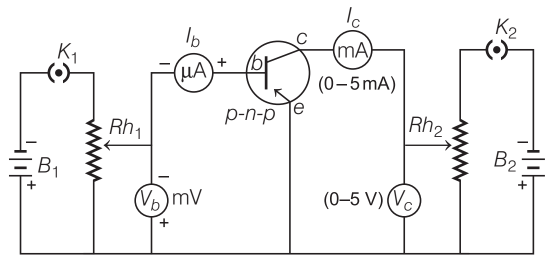
Object

To study the characteristics of a common-emitter *p-n-p* (or *n-p-n*) transistor and to find out the values of current gain and voltage gain.

Apparatus

A *p-n-p* transistor (BC 157 or AC 127), a milliammeter, a microammeter, a voltmeter, a millivoltmeter, two batteries, two rheostats, two one way keys and connecting wires.

Circuit Diagram



Theory

The *p-n-p* transistor consists of a very thin slice of *n*-type semiconductor sandwitched between two small blocks of *p*-type semiconductor. The middle slice is called the base while the left and right blocks are the emitter and the collector respectively. The emitter-base (*p-n*) junction on the left is under forward bias (low resistance), while the base-collector (*n-p*) junction on right is under reverse bias (high resistance).

Characteristics are the graphical form, helpful in understanding the performance of a transistor. The basic parameters of the transistor are emitter voltage (V_e), emitter current (I_e), collector voltage (V_c), collector current (I_c), and base current (I_b).

The relation between input and output currents and voltages may be represented graphically known as characteristic curves. Different characteristic curves are drawn depending upon which of the three transistor points is common. This common point is taken as the reference point and all measurements are taken w.r.t. this point. Thus, the transistor circuits are named as common-base, common-emitter and common-collector depending upon the common point.

In common-emitter arrangement, the following characteristics are drawn

(i) I_c-V_c characteristics Output characteristics are drawn by noting down the collector current (I_c), for different collector voltage (V_c) for a constant base current.

(ii) I_c-I_b characteristics Collector current versus base current graph is plotted for a constant collector voltage.

(iii) I_b-V_b characteristics Input characteristics are drawn by noting down the base current (I_b) for different base voltage (V_b) when the collector voltage is fixed at a particular value.

Formulae Used

Input resistance, $R_{\text{in}} = \dfrac{\Delta V_b}{\Delta I_b}$

Output resistance, $R_{\text{out}} = \dfrac{\Delta V_c}{\Delta I_c}$

Resistance gain, $R_{\text{out}} = \dfrac{R_{\text{out}}}{R_{\text{in}}}$

Current gain, $\beta = \dfrac{\Delta V_c}{\Delta I_b}$

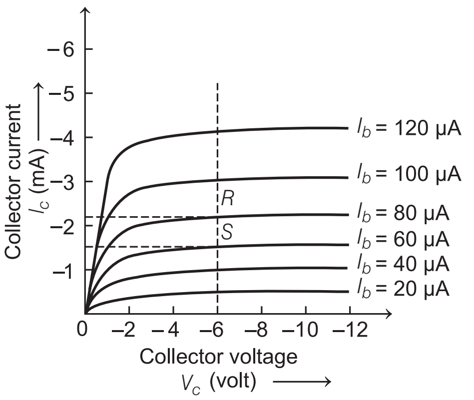
Voltage gain = Current gain × Resistance gain

i.e. $A_V = \beta \cdot \dfrac{R_{\text{out}}}{R_{\text{in}}}$

Procedure

(i) ***I_c-V_c* Characteristics** (output)

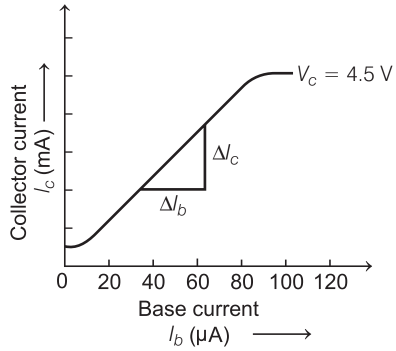
- Make the electrical connections as shown in figure.



- Close the keys K_1 and K_2 adjust the base current (I_b) to 20 μA by means of the rheostat Rh_1 and keep it constant during this part of the experiment.
- Adjust the collector voltage (V_c) to a suitable value (say-8 V) by means of the rheostat Rh_2 and note the corresponding collector current (I_c).
- Increase the collector voltage (V_c) in equal steps of 1 V and note the corresponding collector current (I_c).
- Now, change the base current I_b(≈ 40 μA, 60μA etc.) by means of the rheostat Rh_1 and repeat the above procedure [steps (3) and (4)] for each value of base current.
- Finally, plot the curves between collector current (I_c) and collector voltage (V_c) on a graph paper as shown in figure.

(ii) ***I_c - I_b* Characteristics**

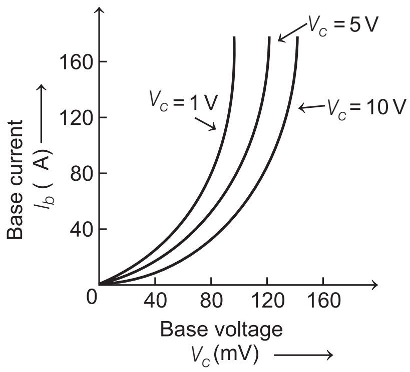
- Make the same electrical connections as shown in figure.



- Adjust the collector voltage (V_c) to −2V with the help of the rheostat Rh_2 and keep it constant throughout the experiment.
- Adjust the base current (I_b) 20 μA by means of the rheostat Rh_1 and note the corresponding collector current (I_c).
- Increase the base current (I_b) in equal steps and note the corresponding collector current (I_c) until it reaches about 5 mA (say).
- Finally, plot the curve between collector current (I_c) against the base current (I_b) as shown in figure.

(iii) **Input characteristics** (I_b-V_b) (Perform this part, if necessary)

- Make the connections as shown in figure. Adjust collector voltage to 5 V by means of rheostat Rh_2 and keep it constant.



- Set the base voltage (V_b) to (say 0 V) by means of the rheostat Rh_1 and note the corresponding base current (I_b).
- Increase the base voltage (V_b) from zero in equal steps of 1 mV (or so) and note the corresponding base current (I_b).
- Now, change the collector voltage (V_c) by means of rheostat Rh_2 and repeat the above procedure [steps (2) and (3)] for each value of collector voltage and plot the curves between base current (I_b) and base voltage (V_b).

Observations

Table for I_c-V_c characteristics (output)

S. No.	Collector Voltage, V_c (V)	Collector current I_c (mA) for constant base current				
		$I_b = 20\,\mu A$	$I_b = 40\,\mu A$	$I_b = 60\,\mu A$	$I_b = 80\,\mu A$	$I_b = 100\,\mu A$
1.	...	...	...	...	...	...
2.	...	...	...	...	...	...
3.	...	...	...	...	...	...
4.	...	...	...	...	...	...
5.	...	...	...	...	...	...

Table for I_c-I_b characteristics

S. No.	Collector voltage $V_c = -2V$		Collector voltage, $V_c = -3V$	
	Base current I_b (μA)	Collector current I_c (mA)	Base current I_b (mA)	Collector current I_c (mA)
1.	...	...	...	...
2.	...	...	...	...
3.	...	...	...	...
4.	...	...	...	...
5.	...	...	...	...
6.	...	...	...	...

Table for I_b-V_b characteristics (input)
(Take these observations if required)

S. No.	Collector voltage $V_c = \dots V$		Collector voltage, $V_c = \dots V$	
	Base voltage V_b (V)	Base current I_b (V)	Base voltage V_b(V)	Base current I_b (μA)
1.	...	...	...	...
2.	...	...	...	...
3.	...	...	...	...
4.	...	...	...	...
5.	...	...	...	...
6.	...	...	...	...
7.	...	...	...	...

Calculations

(i) **Calculation for input resistance** (R_{in})

Plot a graph between base voltage V_b (table 3) and base current I_b (table 3) for zero collector voltage V_c, taking V_b along X-axis and I_b along Y-axis.

Plot graphs for different values of V_c. The graphs come as shown in Fig.(c).

- These graphs are called input characteristics of the transistor.
- The slope of graphs becomes large at the ends.
- The slope given value of $\frac{\Delta I_b}{\Delta V_b}$. Its reciprocal $\frac{\Delta V_b}{\Delta I_b}$ gives input resistance R_{in}. As graphs run parallel near the ends, all gives same value of R_{in}.

(ii) **Calculation for output resistance** (R_{out})

Plot a graph between collector voltage V_c (table 1) and collector current I_c (table 1) for $20\,\mu A$ as current I_b, taking V_c along X-axis and I_c along Y-axis.

Plot graphs for different values of I_b. The graphs come as shown in Fig. (a).

These graphs are called output characteristics of the transistor.

The slope of graphs become almost zero at ends. The slope gives value of $\frac{\Delta I_C}{\Delta V_C}$. Its reciprocal $\frac{\Delta V_C}{\Delta I_C}$ gives output resistance R_{out}. As graphs run parallel near the ends, all give same value of R_{out}.

(iii) **Calculation for current gain** (β)

Plot a graph between base current I_b (table 2) and corresponding collector current I_c for collector voltage V_c, taking I_b along X-axis and I_c along Y-axis. The graph comes to be a straight line as shown in Fig. (b).

The graph is called gain characteristics of the common emitter transistor.

The slope of the straight line gives value of $\frac{\Delta I_c}{\Delta I_b}$ which is the value of the current gain β of the common emitter transistor.

(iv) **Calculation for voltage gain** (A_V)

From relation,

Voltage gain = Current gain × resistance gain

$$A_V = \beta \times \frac{R_{\text{out}}}{R_{\text{in}}}$$

Result

For the given common emitter transistor,

Current gain, β = ……

Voltage gain, A_V = ………

Precautions

(i) Battery with correct polarity should be used in the circuit.

(ii) Overheating of the transistor should be avoided.

(iii) Voltages applied in various parts of the circuit should not exceed the recommended value.

Example 27. *The correct relation between α (ratio of collector current to emitter current) and β (ratio of collector current to base current) of a transistor is*

(a) $\beta = \frac{\alpha}{1+\beta}$ (b) $\alpha = \frac{\beta}{1-\alpha}$

(c) $\beta = \frac{1}{1-\alpha}$ (d) $\alpha = \frac{\beta}{1+\beta}$

Sol. (*d*) We know that, $\alpha = \frac{I_C}{I_E}, \beta = \frac{I_C}{I_B}$

$$I_E = I_B + I_C$$

$$\alpha = \frac{I_C}{I_B + I_C}$$

$$= \frac{1}{\frac{I_B}{I_C} + 1}$$

$$\alpha = \frac{1}{\frac{1}{\beta} + 1}$$

$$\alpha = \frac{\beta}{1+\beta}$$

Exmaple 28. *If I_c = 4 mA and β = 45, then I_E is*

(a) 4.1 *mA* (b) 4.02 *mA*

(c) 4.4 *mA* (d) 0.04 *mA*

Sol. (*b*) For a transistor, emitter current is sum of collector current and base current, hence

$$I_E = I_C + I_B$$

Also, $I_B = \frac{I_C}{\beta} = \frac{4}{95} = 0.042 \text{ mA}$

∴ $I_E = 4 + 0.042$
$= 4.042$

Practice Exercise

1. On measuring the diameter of a spherical body using vernier callipers, main scale reading = 1.3 cm, 5th vernier scale division is coinciding with any main scale division and zero error is – 0.03 cm, what will be corrected reading?

(a)1.38 cm (b)1.32 cm

(c)1.35 cm (d) – 1.38 cm

2. You are given two different vernier callipers A and B having 10 divisions on vernier scale that coincide with 9 divisions on the main scale each. If 1 cm of main scale A is divided into 10 parts and that of B in 20 parts, then least count of A and B are

(a) 0.001 cm and 0.005 cm

(b) 0.01 cm and 0.05 cm

(c) 0.01 cm and 0.005 cm

(d) 0.01 cm and 0.001 cm

3. The vernier scale used for measurement has a positive zero error of 0.2 mm. If while taking a measurement, it was noted that 0 on the vernier scale lies between 8.5 cm and 8.6 cm. Vernier coincidence is 6, then the correct value of measurement is …… cm. (Least count = 0.01 cm) **[JEE Main 2021]**

(a) 8.36 cm (b) 8.54 cm

(c) 8.58 cm (d) 8.56 cm

4. One main scale division of a vernier callipers is a cm and nth division of the vernier scale coincide with $(n-1)$th division of the main scale. The least count of the callipers (in mm) is **[JEE Main 2021]**

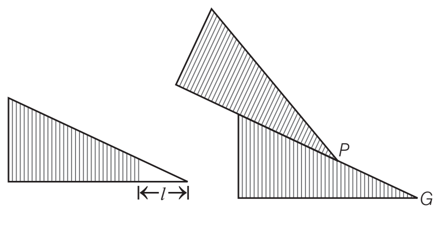
(a) $\frac{10\,na}{(n-1)}$ (b) $\frac{10a}{(n-1)}$ (c) $\left(\frac{n-1}{10n}\right)a$ (d) $\frac{10\,a}{n}$

5. N divisions on the main scale of a vernier callipers coincide with $N+1$ divisions of the vernier scale. If each division of main scale is a units, then least count of the instrument is

(a) $\frac{a}{N+1}$ unit (b) a unit

(c) $\frac{N}{N+1} \times a$ unit (d) $\frac{a}{N}$ unit

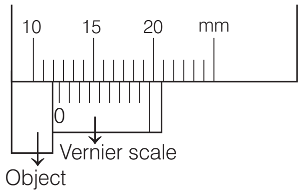
6. A student constructed a vernier callipers as shown. He used two identical inclines and tried to measure the length of line PQ. For this instrument determine the least count.



(a) $\frac{l\,(1-\cos\theta)}{\cos\theta}$ unit (b) $\frac{l}{\cos\theta}$ unit

(c) $l\,(1-\cos\theta)$ unit (d) $\frac{1-\cos\theta}{l}$ unit

7. For the following diagram [used to measure the length of a small metal piece by using vernier callipers], determine the length of the metal piece. [Least count of the vernier callipers is 0.1 mm]



(a) 18 mm (b) 15.7 mm

(c) 12.6 mm (d) None of the above

8. A spectrometer gives the following reading when used to measure the angle of a prism.
Main scale reading : 58.5 degree
Vernier scale reading : 09 divisions
Given that 1 division on main scale corresponds to 0.5 degree. Total divisions on the vernier scale is 30 and match with 29 divisions of the main scale. The angle of the prism from the above data is **[AIEEE 2012]**

(a) 58.59° (b) 58.77° (c) 58.65° (d) 59°

9. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are measured by **[AIEEE 2008]**

(a) vernier scale from microscope
(b) a standard laboratory scale
(c) a meter scale provided on the microscope
(d) a screw gauge provided on the microscope

10. In an experiment the angles are required to be measured using an instrument. 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree (*i.e.* 0.5°), then the least count of the instrument is **[AIEEE 2009]**

(a) one minute (b) half minute

(c) one degree (d) half degree

11. On measuring diameter of a wire with help of screw gauge, main scale reading is 1 mm and 6th division of circular scale lying over reference line. On measuring zero error, it is found that zero of circular scale has advanced from reference line by 3 divisions on circular scale, then corrected diameter is

(a) 1.09 mm (b) 1.06 mm (c) 1.03 mm (d) 1.60 mm

12. Two screw gauges A and B have equal number of divisions on circular scale. A has pitch 1 mm and B has pitch 0.5 mm. Which one is more accurate?

(a) A (b) B

(c) Both (d) Can't say

13. On measuring the thickness of a given sheet using screw gauge, observed readings are

S. No.	LSR (mm)	Circular scale division coinciding
1.	1	4
2.	1	6
3.	1	8

If zero error is + 0.06 mm, then corrected thickness of the sheet (in cm) is

(a) 0.1 (b) 1.0

(c) 0.01 (d) 0.11

14. A screw gauge has 50 divisions on its circular scale. The circular scale is 4 units ahead of the pitch scale marking, prior to use. Upon one complete rotation of the circular scale, a displacement of 0.5 mm is noticed on the pitch scale. The nature of zero error involved and the least count of the screw gauge, are respectively **[JEE Main 2020]**

(a) negative, 2 μm (b) positive, 10 μm

(c) positive, 0.1 mm (d) positive, 0.1 μm

15. If the screw on a screw gauge is given six rotations, it moves by 3 mm on the main scale. If there are 50 divisions on the circular scale, the least count of the screw gauge is **[JEE Main 2020]**

(a) 0.001 cm (b) 0.01 cm

(c) 0.02 cm (d) 0.001 cm

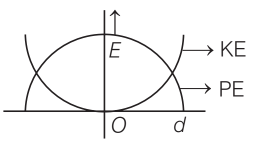
16. A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading : 0 mm
Circular scale reading : 52 divisions
Given that 1 mm on main scale corresponds to 100 divisions of the circular scale.
The diameter of wire from the above data is **[AIEEE 2011]**

(a) 0.052 cm (b) 0.026 cm

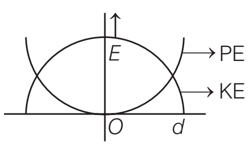
(c) 0.005 cm (d) 0.52 cm

17. For a simple pendulum, when a graph is plotted between displacement d, KE $= \frac{1}{2}mv^2$ and PE $= mgh$, taking d along X-axis and $\frac{1}{2}mv^2$ and mgh along Y-axis, the graph comes as

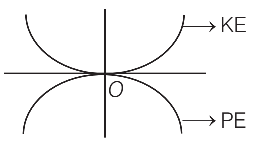
(a)



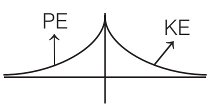
(b)



(c)



(d)



18. The time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$. The measured value of the length of pendulum is 10 cm known to a 1 mm accuracy. The time for 200 oscillations of the pendulum is found to be 100 s using a clock of 1s resolution. The percentage accuracy in the determination of g using this pendulum is x. The value of x to the nearest integer is **[JEE Main 2021]**

(a) 2% (b) 3%
(c) 5% (d) 4%

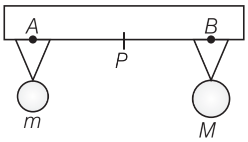
19. A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stop watch with 1s resolution measures the time taken for 40 oscillations to be 50 s. The accuracy in g is **[JEE Main 2020]**

(a) 2.40% (b) 5.40%
(c) 4.40% (d) 3.40%

20. If m and M are the masses of two bodies that are tied at two ends of a meter scale that is balanced on a sharp edge of a heavy broad wedge. If $M = 20$ g, its distance from centre = 30 cm and distance of mass m from centre is 25 cm when metre scale is balanced, then m is

(a) 23 g (b) 24 g (c) 25 g (d) 26 g

21. If two masses M and m are tied to two ends of a meter scale. If a balanced point is obtained at point P and if $M > m$, then



(a) $PA = PB$ (b) $PA > PB$ (c) $PB > PA$ (d) $PA = 3PB$

22. In measurement of mass of a given object by the principle of moments, the meter scale is hung from its mid-point. A known weight of mass 2 kg is hung at one end of meter scale and unknown weight of mass m kg is hung at 20 cm from the centre on other side. The value of m is

(a) 2 kg (b) 5 kg (c) 2.5 kg (d) 0.8 kg

23. In the above question mass of scale is 1 kg and instead of mid-point it is hung at 60 cm from the end where known mass of 2 kg has hung. A mass of 5 kg has to hung at a distance of x cm from pivot to carry out the experiment, then value of x is

(a) 20 cm (b) 10 cm (c) 26 cm (d) 5 cm

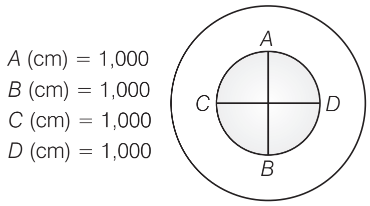
24. In order to determine the Young's modulus of a wire of radius 0.2 cm (measured using a scale of least count = 0.001 cm) and length 1 m (measured using a scale of least count = 1 mm), a weight of mass 1 kg (measured using a scale of least count = 1 g) was hanged to get the elongation of 0.5 cm (measured using a scale of least count 0.001 cm). What will be the fractional error in the value of Young's modulus determined by this experiment? **[JEE Main 2021]**

(a) 0.14% (b) 0.9%
(c) 9% (d) 1.4%

25. Two wires A and B have same lengths and made of the same material but A is thicker than B. Both are subjected to the same extending load. Which will extend more?

(a) A (b) B
(c) Same extension (d) Can't predict

26. In experiment for measuring surface tension by capillary rise method, readings for positions A, B, C and D for internal diameter of capillary tube are given as under. Mean internal radius of capillary is



(a) 0.002 cm (b) 0.003 cm
(c) 0.004 cm (d) 0.005 cm

27. When a glass capillary tube of radius 0.015 cm is dipped in water, the water rises to a height of 15 cm within it. Assuming contact angle between water and glass to be 0°, the surface tension of water is

[$\rho_{water} = 1000 \text{ kg m}^{-3}$, $g = 9.81 \text{ ms}^{-2}$]

(a) 0.11 Nm^{-1} (b) 0.7 Nm^{-1}
(c) 0.072 Nm^{-1} (d) None of these

28. While measuring surface tension of water using capillary rise method, height of the lower meniscus from free surface of water is 3 cm while inner radius of capillary tube is found to be 0.5 cm. Then compute surface tension of water using this data. [Take, contact angle between glass and water as 0° and $g = 9.81\text{ms}^{-2}$]

(a) 0.72 Nm^{-1}
(b) 0.77 Nm^{-1}
(c) 1.67 Nm^{-1}
(d) None of the above

29. In previous question, if we add some detergent to water, then

(a) liquid level in capillary tube is less than 3 cm
(b) liquid level in capillary tube is greater than 3 cm
(c) liquid level in capillary tube is equal to 3 cm
(d) anything may happen

30. While measuring surface tension of water using capillary rise method, the necessary precaution to be taken is/are

(a) capillary tube should be clean while water should have some grease
(b) both capillary tube and water should be clean
(c) no need to take care of temperature of water
(d) None of the above

31. In an experiment for determining coefficient of viscosity, one lead shot A is having radius r_1 and the other B is having $\frac{r_1}{2}$. Which one will fall fast?

(a) A
(b) B
(c) Both with same speed
(d) Can't say

32. In the above question, as air bubble moves up, its radius

(a) remains constant
(b) decreases
(c) increases
(d) can increase or decrease

33. A rain drop of radius 0.2 cm is falling through air with a terminal velocity of 8.7 ms^{-1}. The viscosity of air in SI unit is [Take $\rho_{\text{water}} = 1000 \text{ kg m}^{-3}$ and $\rho_{\text{air}} = 1 \text{ kg m}^{-3}$]

(a) 10^{-4} poise
(b) 1×10^{-3} poise
(c) 8.6×10^{-3} poise
(d) 1.02×10^{-3} poise

34. A wide jar is filled with water, in which a steel ball of radius 0.25 cm has been dropped to measure the viscosity of water by using terminal velocity concept.

(a) This method is appropriate
(b) This method is not appropriate
(c) If we take a jar of length 2 m, it will work
(d) None of the above

35. A wide jar is filled with glycerine having specific gravity 1.26, in this jar, a steel ball of radius 0.25 cm has been dropped. After some time it has been observed that ball is taking equal interval of time (1.8 s) to cover equal successive distances, of 20 cm.
[Take, $\rho_{\text{steel}} = 7.8 \times 10^3 \text{ kg-m}^3$, $g = 9.81 \text{ms}^{-2}$]. The viscosity of glycerine (in N-sm^{-2}) is

(a) 0.802 (b) 1.67
(c) 0.76 (d) 0.963

36. While measuring viscosity of caster oil using terminal velocity concept the following observation table has been taken by a student.
Which one is the first correct reading which he should consider for the computation of terminal velocity?

S.No.	Distance	Time
1.	20 cm	1 s
2.	20 cm	1.4 s
3.	20 cm	1.8 s
4.	20 cm	1.81 s
5.	20 cm	1.82 s

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

37. In an experiment to determine the specific heat of a given liquid by method of mixtures. If room temperature recorded by one thermometer is 29°C and that by second thermometer is 27.5°C. If steady temperature of metal in hypsometer is 62°C, what will be corrected temperature of metal?

(a) 60°C (b) 60.5°C
(c) 61°C (d) 63.5°C

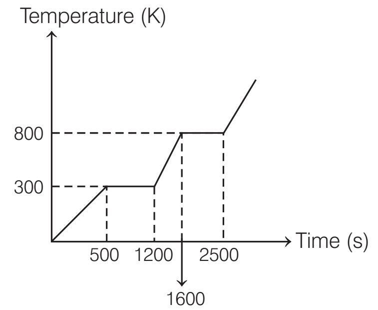
38. In the experiment of measuring speed of sound by resonance tube, it is observed that for tuning fork of frequency $\nu = 480$ Hz, length of air column $l_1 = 30$ cm, $l_2 = 70$ cm, then v_1 is equal to

(a) 338 ms^{-1} (b) 379 ms^{-1}
(c) 384 ms^{-1} (d) 332 ms^{-1}

39 If velocity of sound at room temperature is 35078 cm^{-1}, then velocity of sound at 0°C

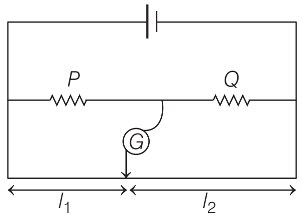
(a) 33200 cms^{-1} (b) 33286 cms^{-1}
(c) 33296 cms^{-1} (d) 33256 cms^{-1}

40. A heating curve has been plotted for a solid object as shown in the figure. If the mass of the object is 200 g, then latent heat of vaporisation for the material of the objects, is (Power supplied to the object is constant and equal to 1 kW)



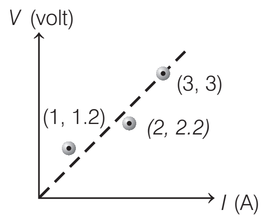
(a) $4.5 \times 10^6 \text{ Jkg}^{-1}$
(b) $4.5 \times 10^6 \text{ calg}^{-1}$
(c) $4.5 \times 10^8 \text{ Jkg}^{-1}$
(d) $4.5 \times 10^4 \text{ calg}^{-1}$

41. The meter bridge shown in the balance position with $\frac{P}{Q}=\frac{l_1}{l_2}$. If we now interchange the positions of galvanometer and cell, will the bridge work?
If yes, that will be the balanced condition?



(a) yes, $\frac{P}{Q}=\frac{l_2-l_1}{l_2+l_1}$ (b) no, no null point
(c) yes, $\frac{P}{Q}=\frac{l_2}{l_1}$ (d) yes, $\frac{P}{Q}=\frac{l_1}{l_2}$

42. In the measurement of resistance of a wire using Ohm's law, the plot between V and I is drawn as shown.

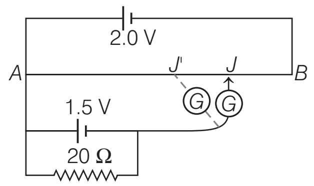


The resistance of the wire is
(a) 0.833 Ω (b) 0.9 Ω
(c) 1 Ω (d) None of these

43. In the experiment of Ohm's law, a potential difference of 5.0 V is applied across the end of a conductor of length 10.0 cm and diameter of 5.00 mm. The measured current in the conductor is 2.00 A. The maximum permissible percentage error in the resistivity of the conductor is **[JEE Main 2021]**
(a) 3.9 (b) 8.4
(c) 7.5 (d) 3.0

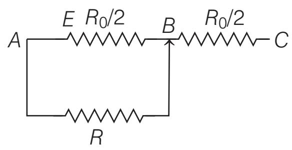
44. In comparison of emf's of two cells using potentiometer, the balanced length for batteries having emfs E_1 and E_2 are 60 cm and 20 cm, respectively. Then
(a) $\frac{E_1}{E_2}=3$ (b) $\frac{E_1}{E_2}=\frac{1}{3}$ (c) $\frac{E_1}{E_2}=60$ (d) $\frac{E_1}{E_2}=20$

45. The figure below shows a 2.0 V potentiometer used for the determination of internal resistance of a 2.5 V cell. The balance point of the cell in the open circuit is 75 cm. When a resistor of 10 Ω is used in the external circuit of the cell, the balance point shifts to 65 cm length of potentiometer wire.
The internal resistance of the cell is **[JEE Main 2018]**



(a) 2.5 Ω (b) 2.0 Ω
(c) 1.54 Ω (d) 1.0 Ω

46. A resistance of R Ω draws current from a potentiometer. Potentiometer has a total resistance R_0 Ω as shown in figure.



A voltage V is supplied to the potentiometer, then for the voltage across R when the sliding contact is in the middle of the potentiometer is
(a) $\frac{2\,VR}{R_0+4R}$ (b) $\frac{2\,VR}{R_0}$
(c) $\frac{4\,VR}{R_0+2\,R}$ (d) $\frac{VR}{R_0+2\,R}$

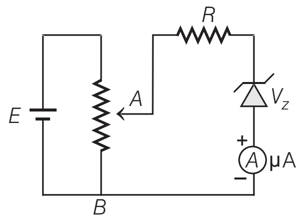
47. The readings corresponding to zener diode are given below in the table. From given table, determine the reverse breakdown voltage of the zener diode.

Forward bias		Reverse bias	
V (volt)	I (mA)	V (volt)	I (μA)
0.5	5	0.5	2.0
0.7	20	1.0	2.0
0.8	40	3.0	2.0
1.0	250	5.0	2.0
		5.5	100.0
		5.5	120.0

(a) It is lying between 1.0 V to 5.0 V
(b) 1.0 V
(c) Approx. 5.3 V
(d) None of the above

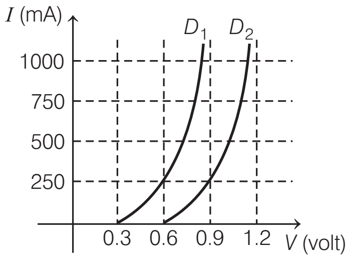
48. The zener diode normally operates under reverse bias condition, the major use of this fact is in the applications where we require
(a) large value of current
(b) a constant voltage
(c) a current that is increasing without any change in applied voltage
(d) All of the above

49. A zener diode is operating in its normal region *i.e.*, the breakdown region for which the circuit diagram is as shown in the figure.
Here, take $V_Z = 7\,\text{V}$ and $R = 10\,\text{k}\Omega$. For potential difference equal to 8 V across AB, what is the current through microammeter?



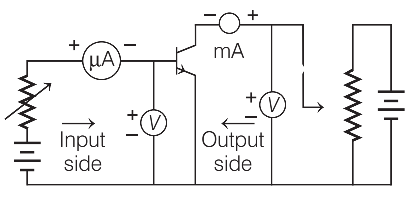
(a) 1000 μA (b) 1 mA
(c) 10 μA (d) 100 μA

50. The forward bias characteristics of two diodes D_1 and D_2 are shown, the knee voltages for D_1 and D_2 are respectively (approx.)



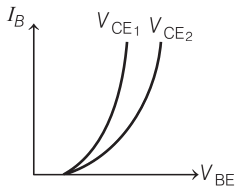
(a) 0.4 V and 0.7 V (b) 0.6 V and 0.9 V
(c) 0.6 V and 0.8 V (d) 0.4 V and 0.9 V

51. The circuit diagram below shows n-p-n transistor in CE configuration. For this configuration, mark the correct statement(s).



(a) The potential divider on input side is used to keep V_{CE} constant while drawing input characteristics
(b) The potential divider on output side is used to keep V_{CE} constant while drawing output characteristics
(c) The potential divider on input side is used to keep base current constant while drawing output characteristics
(d) Both (b) and (c)

52. Input characteristics are shown for CE configuration of n-p-n transistor for different output voltages. Here,

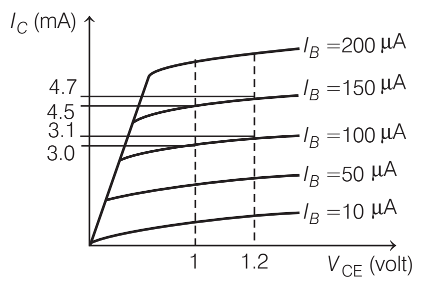


(a) $V_{CE_1} > V_{CE_2}$ (b) V_{CE_1}
(c) $V_{CE_1} < V_{CE_2}$ (d) None of these

53. For CE configuration of a transistor,
(a) input resistance is very small while output resistance is very high
(b) input resistance is very large while output resistance is very small
(c) both input and output resistances are very small
(d) both input and output resistances are very large

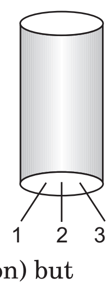
54. Transfer characteristic for a transistor is plotted between
(a) output current *versus* input current keeping output voltage constant
(b) output current *versus* input current keeping input voltage constant
(c) output current *versus* input voltage keeping output voltage constant
(d) input current *versus* output voltage keeping input voltage constant

55. Output characteristic of n-p-n transistor in CE configuration is shown. From the characteristic curve determine the current gain at $V_{CE} = 1\text{V}$.



(a) 30 (b) 32 (c) 28 (d) 40

56. Consider the transistor shown in figure, its terminals are marked as 1, 2 and 3. Using multimeter one try to identify the base of transistor, he proceed in the way as follows



Experiment I He touches the common lead of the multimeter to 2, then on touching other lead of multimeter to 1 he hasn't got any beep (indication of conduction) but when connected to 3 got the beep.
Experiment II He connects the common lead of multimeter to 1 and other lead to 2 and 3 one by one then in this case he got beep for both connections.

From this, we conclude that

(a) 1 is base (b) 2 is base

(c) 3 is base (d) None of these

57. In previous question, the transistor is

(a) *n-p-n*

(b) *p-n-p*

(c) Can't say anything

(d) None of the above

58. To identify whether the transistor is working or not, using multimeter, which statement serves the purpose?

(a) The common lead of multimeter is connected to base and other lead to first emitter and then to collector, only Ist connection shows the continuity

(b) The common lead of multimeter is connected to base and other lead to first emitter and then to collector, both the connections show the continuity

(c) The common lead of multimeter is connected to base and other lead to first emitter and then to collector, none of the connections shows the continuity

(d) All of the above

59. A working transistor with its three legs marked P, Q and R is tested using a multimeter. No conduction is found between P and Q. By connecting the common (– ve) terminal of the multimeter to R and the other (positive) terminal to P or Q, some conduction is seen on the multimeter. Which of the following is true for the transistor? **[AIEEE 2008]**

(a) It is an *n-p-n* transistor with R as base

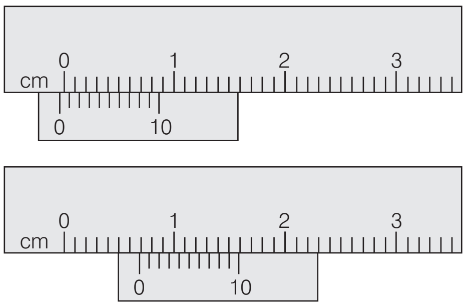
(b) It is an *p-n-p* transistor with R as collection

(c) It is a *p-n-p* transistor with R as emitter

(d) It is an *n-p-n* transistor with R as collector

Numerical Value Questions

60. The main scale of a vernier callipers reads in millimeter and its vernier is divided into 10 divisions which coincides with 9 divisions of the main scale. The reading for shown situation is found to be $(x / 10)$ mm. Find the value of x .



61. An object covers (16.0 ± 0.4) m distance in (4.0 ± 0.2) s. The error in its speed is ± ……… m/s.

62. Students I_1, J_1, J_3 and I_2 perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and record time for different number of oscillations. The observations are shown in the table. Least count for length = 0.1 cm and least count for time = 1 s.

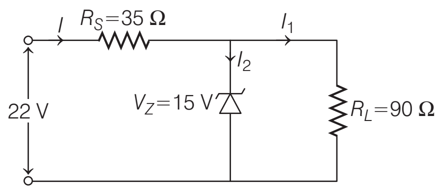
Students	Length of Pendulum (cm)	No. of Oscillations (n)	Time period of Pendulum (s)
I_1	100.0	20	20
J_1	400.0	10	40
J_3	100.0	10	20
I_2	400.0	20	40

If P_1, P_2, P_3 and P_4 are the % error in g for students I_1, J_1, J_3 and I_2 respectively, then find ratio $\frac{P_2}{P_1}$.

63. The length of a cylinder is measured with a meter rod having least count 0.1 cm. Its diameter is measured with vernier callipers having least count 0.01 cm. Given that, the length is 5.0 cm and diameter is 2.00 cm. Find the percentage error in the calculated value of volume.

64. In an experiment to determine an unknown resistance, a 100 cm long resistance wire is used. The unknown resistance is kept in the left gap and a known resistance is put into the right gap. The scale used to measure length has a least count 1 mm. The null point B is obtained at 40.0 cm from the left gap. We shall determine the percentage error in the computation of unknown resistance.

65. The value of power dissipated across the zener diode ($V_Z = 15$ V) connected in the circuit as shown in the figure is $x \times 10^{-1}$ watt.



The value of x, to the nearest integer, is ……… . **[JEE Main 2021]**

Answers

1. (a)	**2.** (c)	**3.** (b)	**4.** (d)	**5.** (a)	**6.** (a)	**7.** (c)	**8.** (c)	**9.** (a)	**10.** (a)
11. (a)	**12.** (b)	**13.** (a)	**14.** (b)	**15.** (a)	**16.** (a)	**17.** (c)	**18.** (b)	**19.** (c)	**20.** (b)
21. (b)	**22.** (b)	**23.** (c)	**24.** (d)	**25.** (b)	**26.** (a)	**27.** (a)	**28.** (b)	**29.** (a)	**30.** (b)
31. (a)	**32.** (c)	**33.** (b)	**34.** (b)	**35.** (a)	**36.** (c)	**37.** (d)	**38.** (c)	**39.** (c)	**40.** (a)
41. (d)	**42.** (c)	**43.** (a)	**44.** (a)	**45.** (c)	**46.** (a)	**47.** (c)	**48.** (b)	**49.** (d)	**50.** (a)
51. (c)	**52.** (a)	**53.** (a)	**54.** (a)	**55.** (a)	**56.** (b)	**57.** (b)	**58.** (d)	**59.** (a)	**60.** 69
61. 0.3	**62.** 0.7	**63.** 3	**64.** 0.42	**65.** 5					

Solutions

1. As, TR = MSR + $n \times$ LC

$$= 1.3 + 5 \times 0.01$$
$$= 1.35 \text{ cm}$$

Zero error = – 0.03 cm

Zero correction = + 0.03 cm

Corrected reading = 1.35 + 0.03 = 1.38 cm

2. Least count of $A = \dfrac{(1/10)}{10} = 0.01$ cm

Least count of $B = \dfrac{(1/20)}{10} = 0.005$ cm

3. Positive zero error = 0.2 mm

Main scale reading = 8.5 cm

Vernier scale reading = $6 \times 0.01 = 0.06$ cm

Final reading = $8.5 + 0.06 - 0.02 = 8.54$ cm

4. $(n-1)a = n(a')$

$$a' = \frac{(n-1)\,a}{n}$$

$\therefore$ LC = 1 MSD – 1 VSD

$$= (a - a') \text{ cm}$$
$$= a - \frac{(n-1)\,a}{n} = \frac{na - na + a}{n} = \frac{a}{n} \text{ cm}$$
$$= \left(\frac{10a}{n}\right) \text{ mm}$$

5. According to question,

N MSD = $(N+1)$ VSD

$\Rightarrow$ 1 VSD = $\dfrac{N}{N+1}$ MSD

Now, LC = 1 MSD – 1 VSD = $\left(1 - \dfrac{N}{N+1}\right)$ 1 MSD

$$= \frac{a}{N+1} \text{ unit}$$

6. Let θ be the angle of incline. Here, the incline kept horizontally is working as main scale while the other incline kept on horizontally placed incline is treated as vernier scale.

From the given figure, it is clear that,

1 MSD = $\dfrac{l}{\cos\theta}$ unit and 1 VSD = l unit,

So, LC of instrument, DC = 1MSD – 1 VSD

$$= \left(\frac{l}{\cos\theta} - l\right) = \frac{l\,(1-\cos\theta)}{\cos\theta} \text{ unit}$$

7. As, 6th VSD is coinciding with one of the MSD, so reading of the vernier callipers is

$$12 + 6 \times 0.1 = 12.6 \text{ mm}$$

8. 1 Vernier scale division = $\dfrac{29}{30}$ main scale division

$$\Rightarrow \quad 1 \text{ VSD} = \frac{29}{30} \times 0.5^\circ = \left(\frac{29}{60}\right)^\circ$$

$\therefore$ The least count = 1 MSD – 1 VSD

$$= \left(\frac{1}{2}\right)^\circ - \left(\frac{29}{60}\right)^\circ = \left(\frac{1}{60}\right)^\circ$$

So, reading = main scale reading + vernier scale reading

$$= \text{MSR} + n \times \text{LC}$$
$$= 58.5^\circ + 9 \times \left(\frac{1}{60}\right)^\circ = 58.65^\circ$$

9. During the experiment performed by travelling microscope of measurement of refractive index, distances are measured by vernier scale from microscope.

10. As, least count = $\dfrac{\text{value of main scale division}}{\text{number of divisions on vernier scale}}$

$$= \frac{1}{30} \text{ MSD} = \frac{1}{30} \times \frac{1^\circ}{2} = \frac{1^\circ}{60} = 1 \text{ min}$$

11. Observed reading = 1 mm + 6×0.01 mm

$$= 1.06 \text{ mm}$$

Zero error = – 0.03 mm

Zero correction = + 0.03 mm

Corrected reading = 1.06 + 0.03 = 1.09 mm

12. B's least count is half that of A, hence it is more accurate.

13. Corrected thickness of the sheet

$$= \frac{(0.14 - 0.06) + (0.16 - 0.06) + (0.18 - 0.06)}{3}$$

$$= \frac{0.08 + 0.10 + 0.12}{3}$$

$$= \frac{0.30}{3} = 0.10 \text{ cm}$$

14. Given that, number of divisions on circular scale $= 50$

Pitch $= 0.5 \text{ mm} = 5 \times 10^{-4}$ m

Least count of screw gauge

$$= \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$= \frac{5 \times 10^{-4}}{50} = 1 \times 10^{-5} \text{ m} = 10\,\mu\text{m}$$

Since, circular scale is 4 units ahead of the pitch scale marking which means screw gauge has positive zero error.

15. Pitch of screw of a screw gauge

$$= \frac{\text{Distance moved by screw}}{\text{Number of rotations}}$$

$$= \frac{3 \text{ mm}}{6} = 0.5 \text{ mm}$$

and least count of screw gauge

$$= \frac{\text{Pitch}}{\text{Number of circular scale divisions}}$$

$$= \frac{0.5 \text{ mm}}{50} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

16. Diameter of wire,

$$d = \text{MSR} + \text{CSR} \times \text{LC}$$

$$= 0 + 52 \times \frac{1}{100} = 0.52 \text{ mm} = 0.052 \text{ cm}$$

17. For a simple pendulum, KE is maximum at mean position and PE is maximum at extreme position. Therefore, curve (c) is correct.

18. $g = \frac{4\pi^2 l}{T^2}$

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T} = \frac{0.1}{10} + 2\left(\frac{\frac{1}{200}}{0.5}\right)$$

$$\frac{\Delta g}{g} = \frac{1}{100} + \frac{1}{50}$$

$$\frac{\Delta g}{g} \times 100 = 3\%$$

19. Given, length of pendulum, $l = 25.0$ cm So, there is an uncertainty of 0.1 cm in measurement of length.

Resolution of stop watch is 1s, so uncertainty in measurement of time is 1s.

Now using, $T = 2\pi\sqrt{\frac{l}{g}}$ or $g = \frac{4\pi^2 l}{T^2}$

We have, $\frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$

$$\Rightarrow \quad \frac{\Delta g}{g} \times 100\% = \left(\frac{\Delta l}{l} + \frac{2\Delta T}{T}\right) \times 100\%$$

Accuracy in measurement of g is

$$\frac{\Delta g}{g} \times 100\% = \left(\frac{0.1}{25} + \frac{2 \times 1}{50}\right) \times 100\%$$

$$= (0.004 + 0.04) \times 100\,\% = 4.40\%$$

20. As, $ma = MA$ [principle of moments]

$$\Rightarrow \quad m \times 25 = 20 \times 30$$

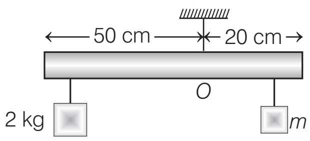
$$m = \frac{20 \times 30}{25} = 24 \text{ g}$$

21. In equilibrium, $m \times PA = M \times PB$

$$\frac{PA}{PB} = \frac{M}{m} > 1$$

$$\therefore \quad PA > PB$$

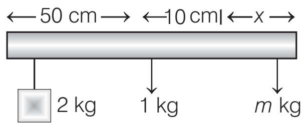
22. Taking moments about the point O.



$$2g \times 0.5 = mg \times 0.2$$

$$\Rightarrow \quad m = 5 \text{ kg}$$

23. Taking torque about hanging point.



$$2g \times 60 + 1g \times 10 = mg \times x$$

$$\Rightarrow \quad x = \frac{2 \times 60 + 1 \times 10}{5} = 26 \text{ cm}$$

24. $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{FL}{Al} = \frac{mg.L}{\pi R^2. l}$

$$\frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta L}{L} + 2 \cdot \frac{\Delta R}{R} + \frac{\Delta l}{l}$$

$$\frac{\Delta Y}{Y} \times 100 = 100\left[\frac{1}{1000} + \frac{1}{1000} + 2\left(\frac{0.001}{0.2}\right) + \frac{0.001}{0.5}\right]$$

$$= \frac{1}{10} + \frac{1}{10} + 1 + \frac{1}{5} = \frac{14}{10} = 1.4\%$$

25. As, Young's modulus, $Y = \frac{F \cdot l}{A\Delta l} \Rightarrow \Delta l = \frac{F \cdot l}{YA}$

$$\Rightarrow \quad \Delta l \propto \frac{1}{A}$$

$$\therefore \quad \frac{\Delta l_A}{\Delta l_B} = \frac{A_B}{A_A}$$

As, $\quad A_A > A_B \quad \therefore \quad \Delta l_B > \Delta l_A$

26. Here, $AB = 1.009 - 1.006 = 0.003$ cm

and $CD = 1.009 - 1.004 = 0.005$ cm

$$\therefore \quad d = \frac{AB + CD}{2} = \frac{0.008}{2} = 0.004 \text{ cm}$$

$$r = d/2 = 0.002 \text{ cm}$$

27. For the liquid of meniscus, $2\pi r \times T \cos\theta = \pi r^2 h\rho g$

$$\Rightarrow \quad T = \frac{rh\rho g}{2}$$

$$= \frac{0.015 \times 10^{-2} \times 15 \times 10^{-2} \times 1000 \times 9.8}{2}$$

$$= 0.11 \text{ Nm}^{-1}$$

28. As, $T = \dfrac{r\left(h + \dfrac{r}{3}\right)\rho g}{2\cos\theta}$

$$= \frac{0.5 \times 10^{-2}\left(3 + \dfrac{0.5}{3}\right) \times 10^{-2} \times 10^3 \times 9.81}{2}$$

$$= 0.77 \text{ Nm}^{-1}$$

29. As, detergent is added to water, its surface tension decreases and hence height of water level falls in capillary tube.

30. In the experiment of capillary action, both capillary tube and water should be clean.

31. For lead shot, $v_t \propto r^2$

Hence, A will fall faster.

32. As, air bubble moves up, pressure outside the liquid decreases. As, there is excess of pressure inside the bubble expands due to surface tension.

33. We have, $\eta = \dfrac{2gr^2(\rho - \sigma)}{9v}$

where, η = coefficient of viscocity.

Here, $\rho = \rho_{\text{water}}$ and $\sigma = \rho_{\text{air}}$

$$= \frac{2 \times 9.81 \times (0.2 \times 10^{-2})^2 \times 999}{9 \times 8.7}$$

$$= 1 \times 10^{-3} \text{ poise}$$

34. As, water is having low viscosity, the terminal velocity will not be acquired by steel ball very soon, so to serve the purpose a very long jar of approximately 1000 m, is needed which is not suitable to perform the experiment.

35. From the expression,

$$\eta = \frac{2r^2(\rho_{\text{steel}} - \rho_{\text{glycerine}})}{9 \times v} \times g$$

where, v is terminal speed.

Here, $v = \dfrac{0.2}{1.8}$ ms^{-1}

$$\therefore \quad \eta = \frac{2 \times (0.25 \times 10^{-2})^2 \times (7.8 - 1.26) \times 10^3 \times 9.81}{9 \times \dfrac{0.2}{1.8}}$$

$$= 0.802 \text{ N-sm}^{-2}$$

36. After 2nd reading, *i.e.* from 3rd reading the velocity of the ball is almost constant, so this is the first correct reading which shows that terminal speed has been acquired by ball.

37. Corrected temperature of metal

$$= 62°\text{C} + (29°\text{C} - 27.5°\text{C}) = 63.5°\text{C}$$

38. $v = 2\nu(l_2 - l_1)$

$$= 2 \times 480 \times \frac{(70 - 30)}{100} \quad \text{(Convert cm in m)}$$

$$= 2 \times 480 \frac{40}{100} = 384 \text{ ms}^{-1}$$

39. As, $v_0 = v\sqrt{\dfrac{273}{273 + t}}$

$$= 33296 \text{ cms}^{-1} \quad (\text{where, } t = 273 + 25 = 298)$$

40. As, $\displaystyle\int_{1600}^{2500} P\,dt = mL_v$

where, P = power developed,

m = mass

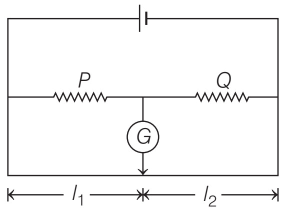
and L_v = latent heat of vaporisation.

$\Rightarrow 10^3 \times 900 = 0.2 \times L_v$

($\because$ time duration is 1600 s to 2500 s)

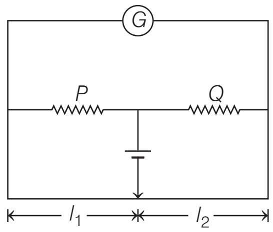
$$\Rightarrow \quad L_v = 4.5 \times 10^6 \text{ Jkg}^{-1}$$

41. For balanced position in a meter bridge.



$$\frac{P}{Q} = \frac{l_1}{l_2}$$

Now, if position of G and cell is interchanged,



The balance condition still remains the same, if the jockey points at the same point as given in the initial condition, for which there is no deflection in the galvanometer or no current will be drawn from the cell. Thus, the bridge will work as usual and balance condition remains same, *i.e.* $P/Q = l_1/l_2$.

42. We know that, V-I curve for a linear device is a straight line passing through origin. Due to some errors/carelessness on the part of experiment all points may not come on the same line. In this situation, we draw the most appropriate curve.

From the diagram, $R = \frac{3}{3} = 1\ \Omega$.

43. $R = \frac{\rho l}{A} = \frac{V}{I}$

$$\rho = \frac{AV}{Il} = \frac{\pi d^2 V}{4Il} \qquad \left(A = \frac{\pi d^2}{4}\right)$$

$$\therefore \quad \frac{\Delta\rho}{\rho} = \frac{2\Delta d}{d} + \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta l}{l}$$

$$\frac{\Delta\rho}{\rho} = 2\left(\frac{0.01}{5.00}\right) + \frac{0.1}{5.0} + \frac{0.01}{2.00} + \frac{0.1}{10.0}$$

$$\frac{\Delta\rho}{\rho} = 0.004 + 0.02 + 0.005 + 0.01$$

$$\frac{\Delta\rho}{\rho} = 0.039$$

$$\%\ \text{error} = \frac{\Delta\rho}{\rho} \times 100 = 0.039 \times 100 = 3.90\%$$

44. As, for potentiometer, $E \propto l$

where, l is the balanced length of the potentiometer wire.

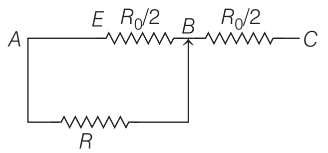
So, $$\frac{E_1}{E_2} = \frac{60}{20} = 3$$

45. For a potentiometer, the internal resistance r is given by $r = R\left(\frac{l_1}{l_2} - 1\right)$

Given, $R = 10\ \Omega$, $l_1 = 75$ cm, $l_2 = 65$ cm

$$\therefore \quad r = 10\left(\frac{75}{65} - 1\right) = 10 \times 0.154 = 1.54\ \Omega$$

46. The circuit can be drawn as



Equivalent resistance across AB,

$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{(R_0/2)}$$

$$\Rightarrow \quad R_1 = \frac{R_0 R}{R_0 + 2R} \qquad \ldots\text{(i)}$$

The total resistance between A & C will be the sum of resistances between A & B and B & C, *i.e.* $R_1 + R_0/2$.

So, the current flowing through the potentiometer will be

$$I = \frac{V}{R_1 + R_0/2} = \frac{2V}{2R_1 + R_0}$$

The voltage V_1 taken from the potentiometer will be the product of current I and resistance R_1,

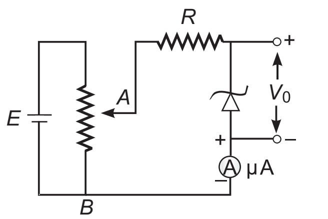
$$V_1 = IR_1 = \left(\frac{2V}{2R_1 + R_0}\right) \times R_1$$

$$= \frac{2V}{2\left(\frac{R_0 R}{R_0 + 2R}\right) + R_0} \times \frac{R_0 R}{R_0 + 2R}$$

$$\Rightarrow \quad V_1 = \frac{2VR}{R_0 + 4R} \qquad \text{[using Eq. (i)]}$$

47. Current changes by large amount when we change reverse bias voltage from 5 V to 5.5 V, so reverse breakdown voltage is somewhere there only and thereafter current increases even though no change in voltage occurs.

48. The circuit used for working zener diode is shown. Once the diode attains the breakdown voltage, then there is no change in voltage across the diode even if we change the current in circuit by changing the position of rheostat and that is why the voltage across zener diode is constant.



49. Write KVL equation,

$$-V_{BA} + IR + V_Z = 0$$

[As diode is operating in breakdown region]

$$\Rightarrow \quad IR = V_{BA} - V_Z = 8 - 7$$

$$\text{or,} \quad I = \frac{1\text{V}}{10\ \text{k}\Omega} = 100\ \mu\text{A}$$

50. The forward voltage when current in circuit starts increasing abruptly, is the knee voltage.

51. Input characteristic is plotted between I_B *versus* V_{BE} for different values of V_{CE}.
Output characteristic is plotted between I_C *versus* I_{CE} for different values of I_B.

52. Clearly, $V_{CE_1} > V_{CE_2}$

53. As, input resistance,

$$R_i = \frac{\Delta V_{BE}}{\Delta I_C} = \frac{1}{\text{Slope of input characteristic curve}}$$

and output resistance,

$$R_o = \frac{\Delta V_{CB}}{\Delta I_C} = \frac{1}{\text{Slope of output characteristic curve}}$$

So, R_i is very small while R_o is very large.

54. Output current *versus* input current keeps the output voltage constant.

55. Current gain is defined as $\beta = \dfrac{\Delta I_C}{\Delta I_B}$ at constant V_{CE}

$\therefore$ Current gain at $V_{\text{CE}} = 1$ V is $\dfrac{(4.5-3)\text{ mA}}{(50)\ \mu\text{A}}$

$$= \frac{1.5 \times 10^3}{50} = 30$$

56. To identify the base of transistor, the multimeter has to show conduction between emitter and base as well as between collector and base keeping one lead of the multimeter common in both cases, then the terminal of the transistor to which the lead of multimeter is common is the base of transistor.

57. If common lead of the multimeter is connected to base and then it shows conduction for other two connections as mentioned in above question, the transistor is *p-n-p* otherwise *n-p-n*.

58. Option (a) tells that transistor is not working, as there is no connection between base and collector *i.e.*, there is some fault in this part of the transistor.

Option (b) tells that transistor is having no open circuit fault, *i.e.* it is having the continuity. Option (c) tells that transistor is faulty.

59. Since, no conduction in found when multimeter is connected across P and Q, it means either one of P and Q are n-type or p-type. So, it means R is zero. When R is connected to common terminal and conductor is seen when other terminal is connected to P or Q, so it mean transistor is *n-p-n* with R as the base.

60. Least count $= \dfrac{1\text{ mm}}{10} = 0.1$ mm

Zero error $= -(10-6) \times 0.1 = -0.4$ mm

Reading $= 6 + 5 \times (0.1) - (-0.4) = 6.9$ mm

$$\Rightarrow \quad 6.9 = \frac{x}{10} \text{ (given)}$$

$$x = 6.9 \times 10 = 69$$

61. Speed, $v = \dfrac{\text{Distance}}{\text{Time}} = \dfrac{16.0}{4.0} = 4.0$ m/s

Error in speed, $\Delta v = \pm\left(\dfrac{\Delta s}{s} + \dfrac{\Delta t}{t}\right)v$

$$= \left(\frac{0.4}{16.0} + \frac{0.2}{4.0}\right)(4.0)$$

$$= \pm 0.3 \text{ m/s}$$

62. $\therefore T = 2\pi\sqrt{\dfrac{l}{g}}$

So, $\dfrac{\Delta g}{g} = \dfrac{\Delta l}{l} + \dfrac{2\Delta T}{T}$

Therefore, $P = \left(\dfrac{\Delta l}{l} + \dfrac{2\Delta T}{T}\right) \times 100$

$$\Rightarrow \quad P_1 = \left(\frac{0.1}{100} + \frac{2(1)}{400}\right) \times 100 = 0.6\%,$$

$$P_2 = \left(\frac{0.1}{400} + \frac{2(1)}{400}\right) \times 100 = 0.42\%$$

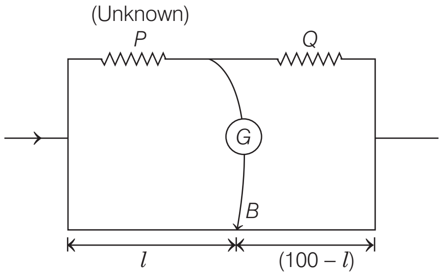
$$\therefore \quad \frac{P_2}{P_1} = \frac{0.42}{0.6} = 0.7$$

63. $V = \pi r^2 h = \dfrac{\pi D^2 h}{4}$

$$\Rightarrow \quad \frac{\Delta V}{V} = \frac{2\Delta D}{D} + \frac{\Delta h}{h}$$

$$\Rightarrow \quad \frac{\Delta V}{V} \times 100 = \left[2 \times \left(\frac{0.01}{2.00}\right) + \left(\frac{0.1}{5.0}\right)\right] \times 100 = 3\%$$

64. As shown in the figure, $\dfrac{P}{Q} = \dfrac{l}{100-l}$, $P \propto \dfrac{l}{100-l}$



$$\Rightarrow \quad \frac{\Delta P}{P} = \frac{\Delta l}{l} + \frac{\Delta(100-l)}{100-l}$$

$$= \frac{\Delta l}{l} + \frac{\Delta l}{100-l} = \frac{0.1}{40.0} + \frac{0.1}{60.0}$$

$$\Rightarrow \quad \frac{\Delta P}{P} \times 100 = 0.42\%$$

65. From given figure,

Voltage across $R_S = 22 - 15 = 7$ V

Current through R_S, $I = \dfrac{7}{35} = \dfrac{1}{5}$ A

Current through 90 Ω, $I_2 = \dfrac{15}{90} = \dfrac{1}{6}$ A

Current through zener $= \dfrac{1}{5} - \dfrac{1}{6} = \dfrac{1}{30}$ A

Power through zener diode,

$$P = VI$$

$$P = 15 \times \frac{1}{30} = 0.5 \text{ W}$$

$$P = 5 \times 10^{-1} \text{ W}$$

$\because \quad P = x \times 10^{-1}$ W (given)

$\therefore \quad x = 5$