Experimental Physics

Experiment 1

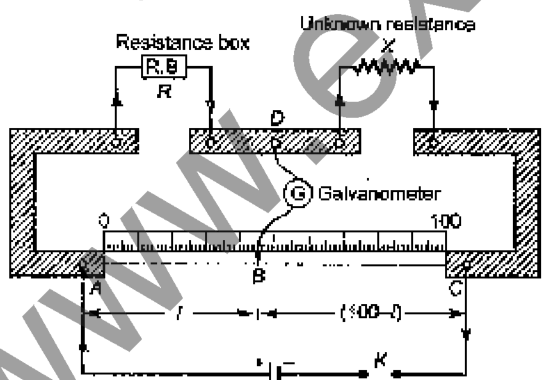
Object

To find resistance of a given wire using metre bridge.

Apparatus

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

Circuit Diagram

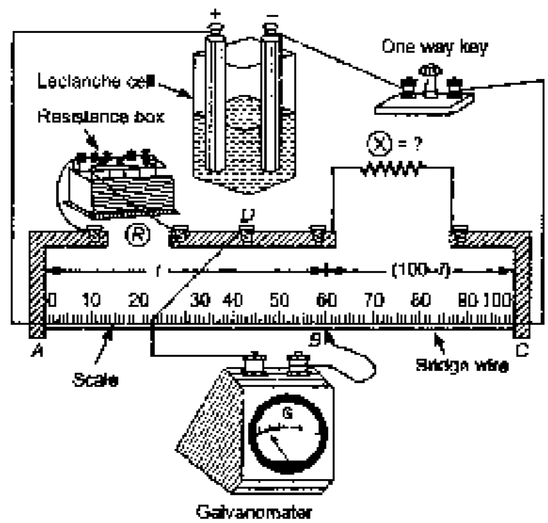


Description to Metre Bridge

The practical form of Wheatstone bridge is the slide wire bridge or metre bridge. Usually, ratio arms of fixed resistance are P and Q, and R is a 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 metre bridge and as the jockey is slided over the wire, it is called slide wire bridge.

Procedure

1. Arrange the apparatus according to the arrangement diagram as shown.
2. Connect the resistance wire whose resistance is to be determined in the right gap between C and D.
3. Connect resistance box of low range in the left hand gap between A and D.



4. Take out some resistance (say 4 Ω) from the resistance box, plug the key K.
5. Touch the jockey gently first at left end and then at right end of the bridge wire.

8. 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.
9. Take at least four sets of observations in the same way by changing the value of R by one ohm in each step.
10. Record your observations as given ahead in table.

Observations

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

S.N.	Resistance from the resistance box R (ohm)	Length AB = l (cm)	Length BC = (100 − l) (cm)	Unknown resistance X (ohm)
1.	4			$X_1 = \dots$
2.	5			$X_2 = \dots$
3.	6			$X_3 = \dots$
4.	7			$X_4 = \dots$

Calculations

1. From position of B, find l cm and write in table.
2. Find length $(100 - l)$ cm and write in table.
3. Calculate X by the given formula and write in table.
4. Take mean value of X recorded in table.

$$\text{where Mean } X = \frac{X_1 + X_2 + X_3 + X_4 + \dots + X_n}{n}$$

$$\text{Mean } X = \dots\dots\ \Omega.$$

Result

The value of unknown resistance, $X = \dots\dots\ \Omega$

Precautions

1. The connections should be **tight.**
2. All the **plugs** in the resistance box should be **tight.**
3. Move the jockey **gently** over the **bridge** wire and do not rub it.
4. 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.
5. Null point should be brought between **40 cm** and **60 cm.**

Experiment 2

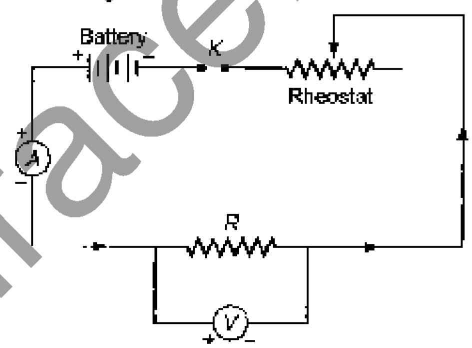
Object

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 metre 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, then according to Ohm's law,

$$V \propto I$$

or $$V = RI$$

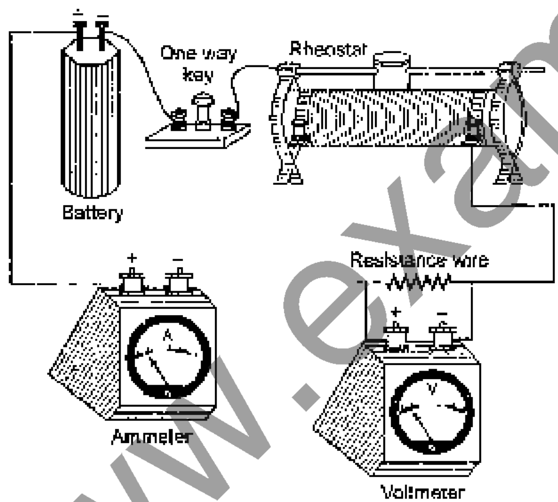
where R is the constant of proportionality. It is known as resistance of the conductor.

or $$\frac{V}{I} = R$$

Procedure

1. Arrange the apparatus in the same manner as given in arrangement diagram given below.
2. Make neat, clean and tight connections according to the circuit diagram.
3. Determine the least count of voltmeter and ammeter, and also note the zero error, if any.
4. Insert the key K, slide the rheostat contact and see that ammeter and voltmeter are working properly.

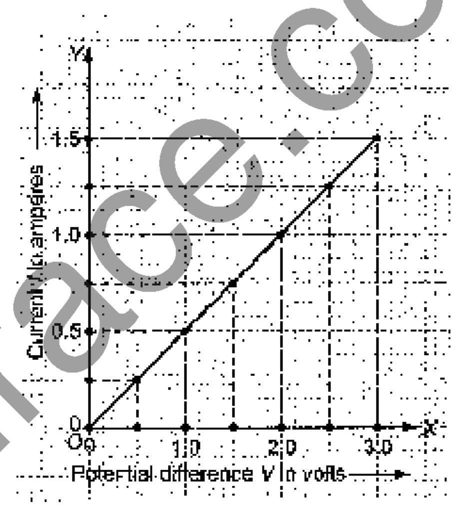
5. Adjust the sliding contact of the rheostat such that a small current passes through the resistance wire.
6. Note down the value of potential difference V from voltmeter and current I from ammeter.
7. Shift the rheostat contact slightly so that both ammeter and voltmeter show full divisions readings and not in fraction.
8. Record the readings of the voltmeter and ammeter.
9. Take at least six sets of independent observations.



Observations

Table for resistance (R)

S.N.	Ammeter reading (A)	Voltmeter reading (V)	R (ohm)
1.			
2.			
3.			
4.			
5.			



3. Constant ratio $\frac{V}{I}$ gives resistance of the wire.
4. Resistance of the wire per cm = ... $\Omega\ cm^{-1}$.

Result

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

Precautions

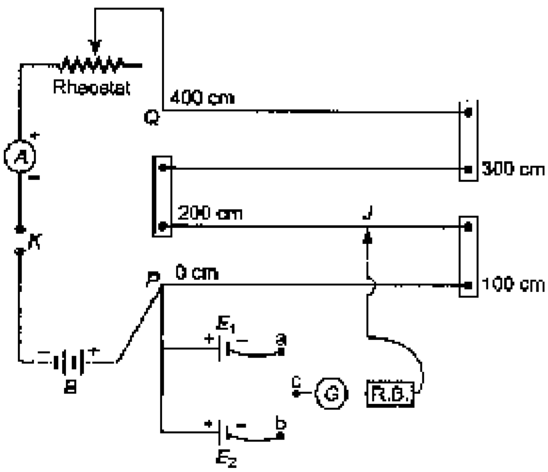
1. The connections should be **neat, clean** and **tight**.
2. Voltmeter and ammeter should be of **proper range.**
3. **A low resistance** rheostat should not be used.
4. The unknown resistance should not be too low.
5. The key should be inserted only while taking observations to avoid heating of wire.

Experiment 3

Object

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

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

1. Draw a circuit diagram making connections as in figure.
2. 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.
3. 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.
4. Connect the common terminal of the two way key through a galvanometer (G) and a resistance box (RB) to the jockey J.
5. Take maximum current from the battery making rheostat resistance zero.
6. 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.
7. Take out a 2000 Ω plug from the resistance box (RB).
8. The jockey at the zero end and note the direction of deflection in the galvanometer.
9. 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.
10. Slide the jockey along potentiometer wire so as to obtain a point where glavanometer shows no deflection.
11. Put the 2000 Ω plug back in the resistance box and obtain the null point position accurately.
12. Note the length l_1 of the wire for the cell E_1. Also, note the current as indicated by the ammeter.
13. Disconnect the cell E_1 by removing the plug from gap ac of two way key and connect the cell E_2 by inserting plug into gap b-c of two way key.
14. 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.
15. 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 step12.
16. Increase the current by adjusting the rheostat and obtain at least three sets of similar observations.

Observations

1. 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
2. Least count of the ammeter = 0.02 A

   Zero error of the ammeter Nil

3. **Table for lengths**

S. N.	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.								

Calculations

1. For each observation find mean l_1 and mean l_2 and record in table above.
2. Find $\frac{E_1}{E_2}$ for each set.
3. Find mean $\frac{E_1}{E_2}$ of all sets.

Result

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

Precautions

1. The plugs should be introduced in the keys only when the observations are to be taken.
2. The positive poles of the battery E and E_1 and E_2 should all be connected to the terminal at

Experiment 4

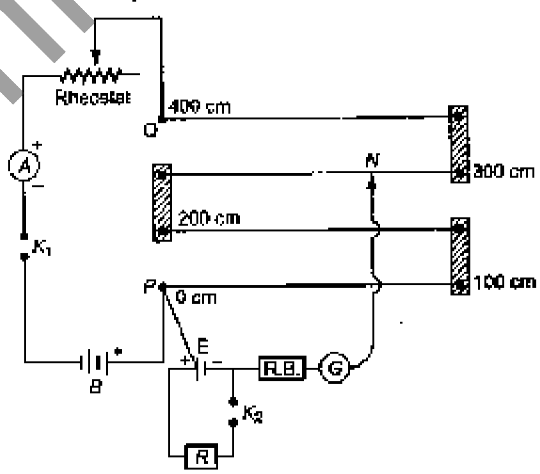
Object

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 (0–5 V), a Leclanche cell, a jockey and connecting wires.

Circuit Diagram



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

1. Draw the circuit diagram showing the scheme of connections as in figure.

5. 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.
6. 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.
7. Insert the 2000 Ω plug back in its position in resistance box and obtain the null point position.
8. Measure the balancing length l_1 between this point and the end P of the wire.
9. 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 (1–5 Ω) from the resistance box R connected in parallel with the cell.
10. Slide the jockey along the potentiometer wire and the obtain null point.
11. Insert the 2000 Ω plug back in its position in resistance box and again obtain the null ooint.
12. Measure the balancing length l_2 from end P.
13. Repeat the observations for different values of R repeating each observation twice.

Observations

1. Range of voltmeter = ... V
   Least count of voltmeter = ... V
   emf of battery = ... V
   emf of cell = ... V.

2. **Table for lengths**

S. No.	Ammeter reading (A)	Position of null point (cm)						[illegible]	Internal resistance
		Without shunt			With shunt R				
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1.									
2.									
3.									
4.									
5.									
6.									

Calculations

1. For each set of observation find mean l_1 and l_2.
2. Calculate value of r for each set and write it in table.
3. Take mean of value of r recorded in table.

Result

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

Precautions

1. The emf of the battery should be **greater than** that of the cell.
2. For one set of observation the ammeter reading should remain **constant.**
3. Current should be passed for **short time** while finding the null point.
4. Cell should not be **disturbed** during experiment.

Experiment 5

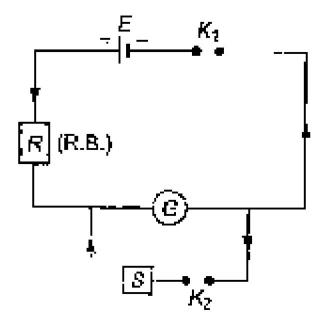
Object

To determine the resistance of a galvanometer by half deflection method and to find its figure of merit.

Apparatus

A galvanometer, a voltmeter, a battery of two cells, two resistance boxes, two one way keys, a rheostat, an ammeter of given range and connecting wires.

Circuit Diagrams



Half deflection method

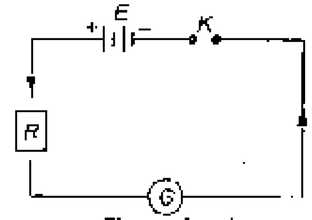


Figure of merit

Theory

1. The resistance of the galvanometer as found by half deflection method is

$$G = \frac{RS}{R - S} \qquad \ldots(i)$$

where R = resistance connected in series with the galvanometer and S = shunt resistance.

2. The figure of merit,

$$k = \frac{E}{(R + G)\theta} \qquad \ldots(ii)$$

where E = emf of the cell

and θ = deflection produced with resistance R.

3. The maximum current that can pass through the galvanometer is,

$$I_g = nk \qquad \ldots(iii)$$

where n = total number of divisions on the galvanometer scale on either side of zero.

4. The shunt resistance required for conversion, is

$$S' = \frac{I_g \cdot G}{I - I_g} \qquad \ldots(iv)$$

where I = range of conversion.

5. The length of the shunt wire required for conversion is

$$l = \frac{\pi r^2 S'}{\rho} \qquad \ldots(v)$$

where r is the radius of the wire and ρ is the specific resistance or resistivity of the material of the wire used for conversion.

Procedure

(i) Resistance of galvanometer by half deflection method

1. Draw the circuit diagram and make the
3. Adjust the value of R so that deflection is maximum, even in number and within the scale.
4. Note the deflection θ.
5. Insert the key K_2 and without changing the value of R, adjust the value of S, such that deflection in the galvanometer reduces to exactly half the value obtained in previous step.
6. Note the value of resistance S.
7. Repeat steps taking out different values of R and adjusting S every time.

(ii) Figure of merit

8. Find emf (E) of the cell by a voltmeter by connecting +ve of the voltmeter with −ve of the cell and −ve of voltmeter with −ve of the cell.
9. Make connections as in circuit diagram.
10. Adjust the value of R to obtain a certain deflection θ when the circuit is closed.
11. Note the values of resistance R and deflection θ. Now change the value R and note the galvanometer deflection again.
12. Find the figure of merit k using the formula.

Observations

Number of division in the galvanometer scale, n = ...

Table 1. Resistance of the galvanometer by half deflection method

S. No.	Resistance R (ohm)	Deflection in the galvanometer θ	Shunt resistance S (ohm)	Half deflection $\theta/2$	Galvanometer resistance $G = \frac{RS}{R-S}$ (ohm)

Table 2. Figure of merit

SN	Number of cells	Emf of the cells E(V)	Resistance from RB R(ohm)	Deflection θ(div.)	Figure of merit $k = \frac{E}{(R+G)\theta}$ (amp./division)
1.	One				
2.	One				
3.	Two				
4.	Two				

Calculations

1. **Calculation for G**

   (a) Calculate G, using formula, $G = \frac{RS}{R - S}$ and write it in Table 1.

   (b) Take mean of value of G recorded in Table 1.

2. **Calculation for k**

   (a) Calculate k, using formula, $k = \frac{E}{(R+G)\theta}$ and write it in Table 2.

   (b) Take mean of value of k recorded in Table 2.

Precautions

1. All the plugs in resistance boxes should be **tight**.
2. The emf of cell or battery should be **constant**.
3. Initially, a **high resistance** from the resistance box should be introduced in the circuit.

Experiment 6

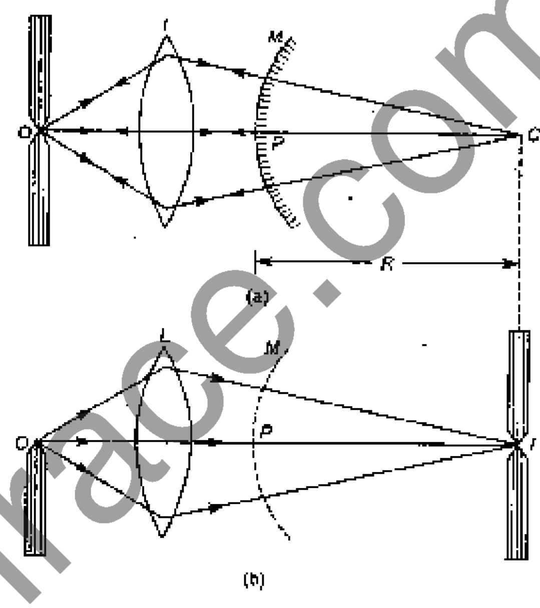
Object

To find the focal length of a convex mirror using a convex lens.

Apparatus

An optical bench, convex lens (20 cm focal length), convex mirror, a lens holder, a mirror holder, two optical needles, (one thick, one thin) and a half metre scale.

Ray Diagram



Theory

Focal length of a convex mirror, $f = \frac{R}{2}$

where R = radius of curvature of the mirror.

Procedure

1. Clamp the holder with lens in a fixed upright such that len's surface is vertical and perpendicular to the length of the optical bench.
2. Take the **thin** optical needle as object needle (O). Mount it in outer laterally moveable upright near zero end.
3. Move the object needle upright and clamp it at a distance (in full cms) nearly 1.5 times the focal length of the lens.
4. Adjust height of the object needle to make its tip lie on horizontal line through the optical centre of the lens.
5. Clamp the holder with convex mirror near the lens upright, keeping reflecting surface of the mirror towards lens.

6. Adjust the height of the mirror to make its pole lie on horizontal line through the optical centre of the lens.
7. Make the mirror surface vertical and perpendicular to the length of the optical bench.
8. Move towards zero end of the optical bench (where object needle is mounted). Keep open only right eye about 30 cm away from the tip of the object needle.
9. See the inverted image of the object needle (formed by reflection from the convex mirror).
10. Adjust the height of the needle so that the two tips are seen in one line with right open eye. Move the eye towards right. The tips will get separated. The tips have parallax.
11. Move the convex mirror back and forth till tip to tip parallax is removed and note the position.
12. Remove the convex mirror, keeping upright in its position.
13. See with the right open eye from the other end of the optical bench. An inverted and enlarged image of the object needle will be seen. Tip of the image must lie in the middle of the lens.
14. Mount the thick optical needle (image needle) in the fourth upright near the other end of the optical bench.
15. Adjust the height of the image needle so that its tip is seen in line with the tip of the image when seen with right open eye.
16. Move the eye towards right. The tips will get separated. The image tip and the image needle tip have parallax. Remove the parallax tip to tip and note the position.
17. Move object needle upright away from/towards lens, to get more observations.

Observations

Table for focal length of convex mirror

SN	Position of convex mirror P (cm)	Position of image needle (cm)	Radius of curvature (R) Observed PI (cm)	Focal length $f = \frac{R}{2}$ (cm)
1.				
2.				
3.				
4.				

Calculations

Find mean of values of f recorded in last column of table.

Result

The focal length of the given convex mirror = ... cm.

Precautions

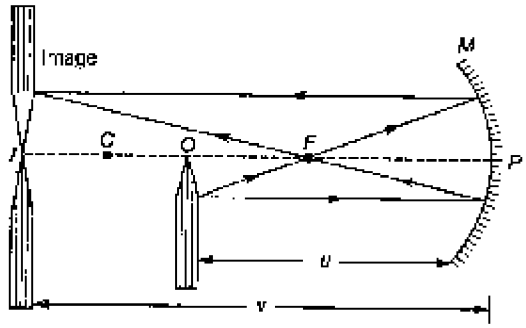
1. **Principal axis of the lens should be horizontal and parallel** to the central line of the **optical bench.**
2. The tip of the needle, centre of the mirror and centre of the lens should be at the **same height.**
3. While removing the parallax, the eye should be kept at a **minimum distance** of 30 cm from the needle.
4. The convex mirror should be placed **close** to the convex lens.

Experiment 7

Object

To find the focal length of a concave mirror by

Ray Diagram



Theory

From mirror formula, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

or $$f = \frac{uv}{u+v}$$

where f – focal length of concave mirror.

u – distance of object needle from pole of the mirror.

v = distance of image needle from pole of the mirror.

Procedure

1. A needle O which serves as an object is placed infront of the concave mirror such that its tip is at the centre of mirror and its inverted image is seen in the mirror.
2. Then the other needle I which is called the image needle is moved to and fro till there is no parallax between it and the inverted image of the object pin. This determines position of image.
3. The distance u of the object pin O and the distance v of the image pin I from the mirror are measured. Thus $PO = u$, $PI = v$
4. The focal length is calculated by substituting the values of u and v in the following relation (u and v both are –ve, so f is also –ve)
$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$
5. The process is repeated for different values of u and v and average values of f is calculated.

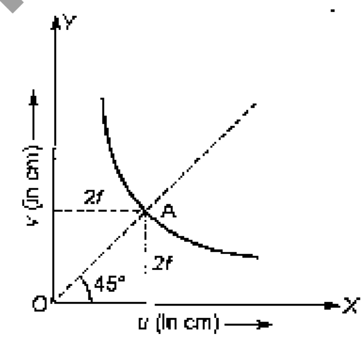
Observations

Table for focal length of concave mirror

S. No.	Position of mirror (cm)	Position of object needle (cm)	Position of image needle (cm)	Observed distance PO (u)	Observed distance PI (v)
1.					
2.					
3.					
4.					
5.					
6.					

Graphical Calculations

Knowing the values of v corresponding to different values of u, if a graph is plotted between u and v, taking v on Y-axis and u on X-axis with same scale on either axes, we get a rectangular hyperbola as shown in figure. If a line is drawn at 45° with the



X-axis (or 45° with the Y-axis) passing through origin, the point A where the line meets the curve will have coordinates $(2f, 2f)$. The values of u and v are read, corresponding to the point of intersection A of the curve and the line. Taking averge of it, half of it gives the focal length f.

Result

The focal length of the given concave mirror = ... cm

Precautions

1. The mirror should be neat and clean.

2. Principal axis of the mirror should be **horizontal and parallel** to the central line of the **optical bench**.
3. The uprights should be **sharp** and **vertical**.
4. **Tip to tip parallax** should be removed between the needle I and image of the needle O.
5. To locate the position of the image the eye should be at least **30 cm** away from the needle.
6. Tips of the object and image needles should lie at the **same height** as that of pole of the concave mirror.

Experiment 8

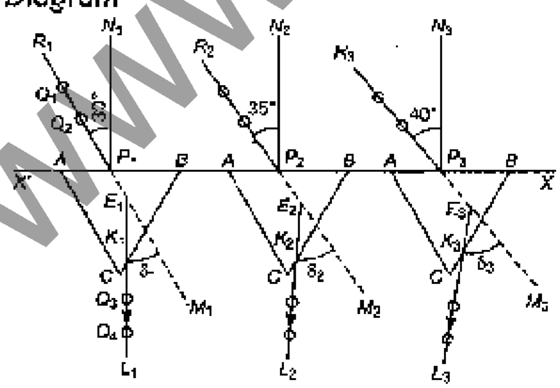
Object

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

Apparatus

Triangular prism, drawing board, a white sheet of paper, drawing pins, pencil, half metre scale, graph paper and a protector.

Diagram



Theory

Procedure

1. Fix a white sheet of paper on the drawing board.
2. Draw a horizontal line XX' in the middle of the paper as shown in figure.
3. At distances of about 7 cm mark points P_1, P_2, P_3 on XX'.
4. Draw normals N_1P_1, N_2P_2, N_3P_3 and straight lines R_1P_1, R_2P_2, R_3P_3 as shown so that the angles are 30°, 35° and 40°.
5. Take prism as ABC and place as in figure.
6. Fix two pins Q_1 and Q_2 on line R_1P_1 at sufficient distance.
7. Look the images of points Q_1 and Q_2 through face BC and fix two pins Q_3 and Q_4 vertical.
8. Encircle pins by pencils and remove them and prism.
9. Repeat step 5 to 8 for 35° and 40° angles.
10. Now, draw straight lines through points Q_3 and Q_4 to obtain emergent rays K_1L_1, K_2L_2, K_3L_3. Find points E_1, E_2 and E_3 as shown.
11. Measure angles $M_1E_1K_1$, $M_2E_2K_2$, $M_3E_3K_3$. Note angles $\delta_1, \delta_2, \delta_3$.
12. Measure angle ABC in the boundary of the prism as angle A.

Observations

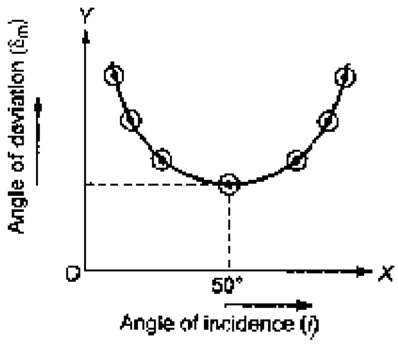
Angle of prism A =

Table for angle of incidence ($\angle i$) and angle of deviation ($\angle D$)

S.N.	Angle of incidence $\angle i$	Angle of deviation $\angle D$
1.	30°	
2.	35°	
3.	40°	

Calculations

The value of angle of minimum deviation δ_m = ------



Result

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

Precautions

1. The angle of incidence should lie between 30°–60°.
2. The pins should be fixed vertical.
3. The distance between the two pins should not be less than 10 cm.
4. The same angle of prism should be used for all the observations.

Experiment 9

Object

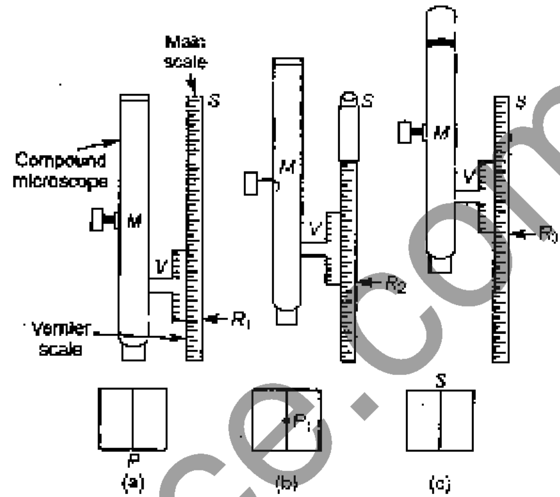
To find refractive index of a glass slab, using a travelling microscope

Apparatus

A travelling microscope, lycopodium powder, three glass slabs of same material but different thickness.

Diagram

The diagram for the apparatus is shown in figure.



Description to Travelling Microscope

It is a compound microscope fitted on a vertical scale and can move up and down, carrying a vernier scale moving along the main scale.

The reading is the result of main scale and vernier scale measurements.

Theory

Refractive index of glass

$$\mu = \frac{\text{real thickness of slab}}{\text{apparent thickness of slab}}$$

Procedure

1. Put the microscope on the table near a window for getting sufficient light.
2. To have the base of the microscope horizontal, adjust the horizontal screws.
3. Adjust the position of the eyepiece so that the cross wires are clearly visible.
4. Determine the vernier constant of the vertical scale of the microscope.
5. Now make the cross-mark as point P on the base of the microscope.
6. To avoid any parallax between the cross-wires and image of mark P, adjust the microscope vertical and focus it on the cross at P.
7. Note down the main scale and the vernier scale readings (R_1) on the vertical scale.
8. Move the microscope further upward and focus it on the image P_1 of the cross-mark.

9. Note down the reading (R_2) on the vertical scale.
10. Sprinkle a few particles of lycopodium powder on the surface of the slab.
11. Move the microscope and focus it on the particle near S and note down the reading (R_3) on the vertical scale.

Observations and Calculations

Vernier constant (least count) for vertical scale of microscope = ... cm.

Table for microscope readings

S. N.	Reading on vertical scale when microscope is focused on			Real thickness $(R_3 - R_1)$ (cm)	Apparent thickness $(R_3 - R_2)$ (cm)	Refractive index $\mu = \frac{R_3 - R_1}{R_3 - R_2}$
	Cross-mark without slab R_1 (cm)	Cross-mark with slab R_2 (cm)	Lycopodium powder R_3 (cm)			
1.						
2.						
3.						

$$\text{Mean, } \mu = \frac{\mu_1 + \mu_2 + \mu_3}{3}$$

Result

From the table the ratio $\frac{R_3 - R_1}{R_3 - R_2}$ is constant.

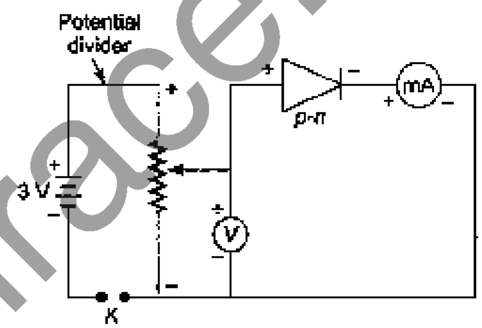
It gives refractive index of the material of the glass slab.

Precautions

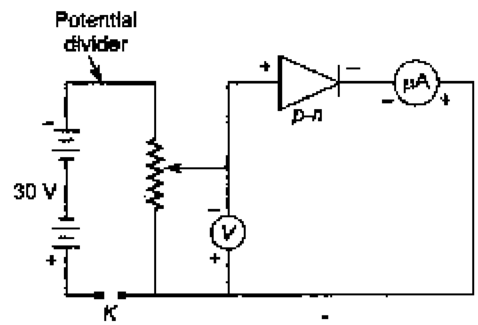
1. In microscope, the **parallax** should be properly removed.
2. The microscope should be moved in **upper direction** only to avoid backlash error.

(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 bias 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 bias 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.

Voltmeter V and milli-ammeter mA will give zero reading.

4. Move the contact a little towards positive end to apply a forward bias voltage (V_F) of 0.1 V. Current remains zero.
5. Increase V_F to 0.4 V. Milliammeter records a small current.
6. 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.
7. Make $V_F = 2.2$ V. The current will rise by large amount.
8. 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 bias *p-n* junction

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

Observations

(a) 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 1. For forward bias voltage and forward current

SN	Forward bias voltage V_F (V)	Forward current I_F (mA)
1.		
2.		
3.		
4.		
5.		

(b) For reverse bias

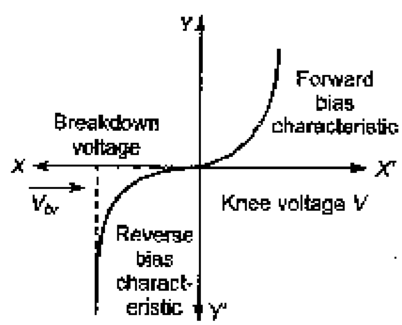
Range of voltmeter	= 30 V
Least count of voltmeter	= 1 V
Zero error of voltmeter	= Nil
Range of microammeter	= 30 μA
Least count of microammeter	= 0.5 μA
Zero error of microammeter	= Nil

Table 2. For reverse bias voltage and reverse current

SN	Reverse bias voltage V_R (V)	Reverse current I_R (mA)
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 rapidly is called knee voltage.



Result

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

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.**

Experiment 11

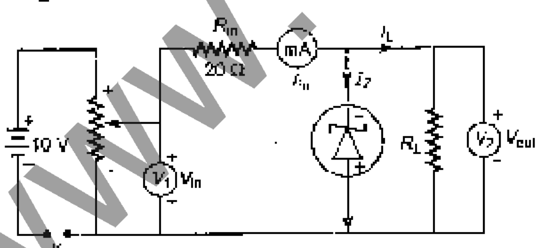
Object

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

Apparatus

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

Diagram



Theory

Zener Diode It 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

At breakdown, increase of V_{in} increases I_{in} 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

1. Draw circuit diagram as shown in figure.
2. Bring moving contact of potential divider (rheostat) near negative end.
3. 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., $V_{out} = V_{in} \quad \because \quad I_{in} = 0$
4. 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}.
5. 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.
6. 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 V_{in}, I_{in} and V_{out}

[illegible]	[illegible]	[illegible]	[illegible]
1.	0	0	0
2.			

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

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

Experiment 12

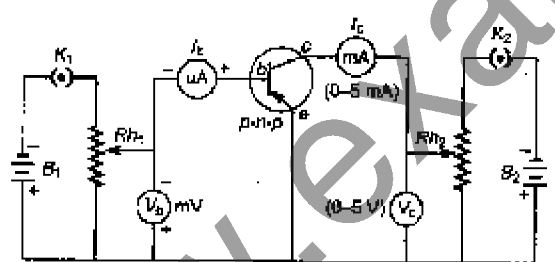
Object

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 sandwiched 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 the 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 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.

Formula Used

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

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

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

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

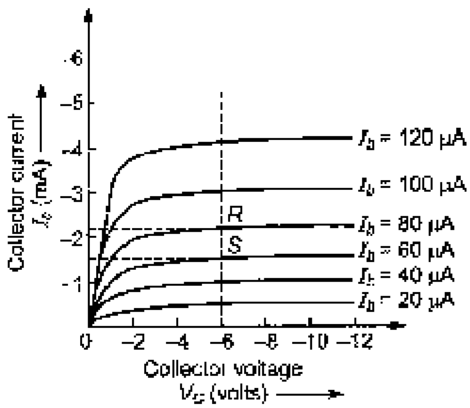
Voltage gain = Current gain × Resistance gain

ie, $$A_v = \beta \cdot \frac{R_{out}}{R_{in}}$$

Procedure

(i) $I_c - V_c$ Characteristics (Output)

1. Make the electrical connections as shown in figure.



(a) $I_c - V_c$ characteristic (output)

2. 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.
3. Adjust the collector voltage (V_c) to a suitable value (say − 8V) by means of the rheostat Rh_2 and note the corresponding collector current (I_c).
4. Increase the collector voltage (V_c) in equal steps of 1 V and note the corresponding collector current (I_c).
5. Now, change the base current I_b (≈ 40 µA, 60 µA etc) by means of the rheostat Rh_1 and repeat the above procedure [steps (3) and (4)] for each value of base current.
6. Finally, plot the curves between collector current (I_c) and collector voltage (V_c) on a graph paper as shown in figure.

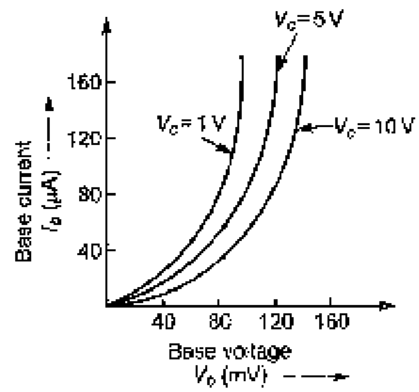
(ii) $I_c - I_b$ Characteristics

1. Make the same electrical connections as shown in figure.

2. Adjust the collector voltage (V_c) to −2 V with the help of the rheostat Rh_2 and keep it constant throughout the experiment.
3. Adjust the base current (I_b) to 20 µA by means of the rheostat Rh_1 and note the corresponding collector current (I_c).
4. Increase the base current (I_b) in equal steps and note the corresponding collector current (I_c) until it reaches about 5 mA (say).
5. 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)

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



(c) $I_b - V_b$ characteristic (input)

2. 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).
3. Increase the base voltage (V_b) from zero in equal steps of 1 mV (or so) and note the corresponding base current (I_b).

Observations

Table 1. $I_c - V_c$ Characteristics (output)

S.No.	Collector Voltage V_c (V)	Collector current I_c (mA) for constant base current				
		[illegible]	[illegible]	[illegible]	80 µA	[illegible]
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

Table 2. $I_c - I_b$ Characteristics

S.No.	Collector voltage V_c = ... V		Collector voltage V_c = ... V	
	Base current I_b (µA)	Collector current I_c (mA)	Base current I_b (µA)	Collector current I_c (mA)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

Table 3. $I_b - V_b$ Characteristics (input)
(Take these observations if required)

S.No.	Collector voltage V_c = ... V		Collector voltage V_c = ... V	
	Base voltage V_b (V)	Base current I_b (µA)	Base voltage V_b (V)	Base current I_b (µA)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

Calculations

1. **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 gives 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 give same value of R_{in}.

2. **Calcualtion for output resistance (R_{out})**

   Plot a graph between collector voltage V_c (table 1) and collector current I_c (table 1) for 20 µA 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 becomes 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}.

3. **Calcualtion 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 figure (b). The graph is called current gain characteristic 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 current gain β of the common emitter transistor.

4. **Calculation for voltage gain (A_v)**

From relation, Voltage gain = Current gain × Resistance gain

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

Result

For the given common emitter transistor,

Current gain, β = ...

Voltage gain, A_V = ...

Precautions

1. Battery with **correct polarity** should be used in the circuit.
2. **Overheating** of the transistor should be avoided.
3. Voltages applied in various parts of the circuit should not exceed the recommended value.

Practical Based Questions

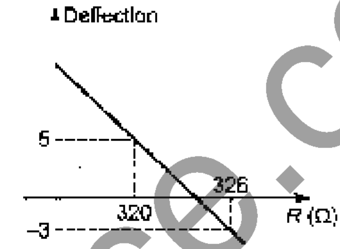
1. N divisions on the main scale of a vernier callipers coincide with $N+1$ divisions of the vernier scale. If each division of main scale is a units, then least count of the instrument is
   (a) $\frac{a}{N+1}$ (b) a
   (c) $\frac{N}{N+1} \times a$ (d) $\frac{a}{N}$

2. The pitch of a screw gauge is 0.5 mm and there are 50 divisions on circular scale. When there is nothing between the two ends (studs) of screw gauge, 45^{th} division of circular scale is coinciding with screw gauge, and in this situation zero of main scale is not visible. When a wire is placed between the studs, the linear scale reads 2 divisions and 20^{th} division of circular scale coincides with reference line. For this situation mark the correct statement(s).
   (a) Least count of the instrument is 0.01 mm.
   (b) Zero correction for the instrument is + 0.45 mm.
   (c) Thickness of wire is 1.65 mm.
   (d) All of the above

3. The main scale of a vernier calipers reads in millimeter and its vernier is divided into 10 divisions which coincide with 9 divisions of the main scale. When there is nothing between the jaws of the vernier calipers, the 7^{th} division of vernier scale coincides with a division of main scale and in this case zero of vernier scale is lying on right side of the zero of main scale. When a cylinder is tightly placed along its length between the jaws, the zero of the vernier scale is slightly left to he 3.1 cm and 4^{th} VSD coincides with a scale division. The length of the cylinder is
   (a) 3.2 cm (b) 3.07 cm
   (c) 3.21 cm (d) 2.99 cm

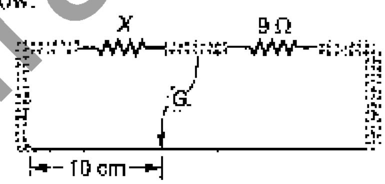
4. In a meter bridge apparatus, the bridge wire should possess
   (a) high resistivity and low temperature coefficient
   (b) high resistivity and high temperature coefficient
   (c) low resistivity and high temperature coefficient
   (d) low resistivity and low temperature coefficient

5. In post office box, the graph of galvanometer deflection *versus* resistance R (pulled out of resistance box) for the ratio 100 : 1 is given as shown (due to unsuitable values of R, galvanometer shows deflection). The two consecutive values of R are shown in the figure.



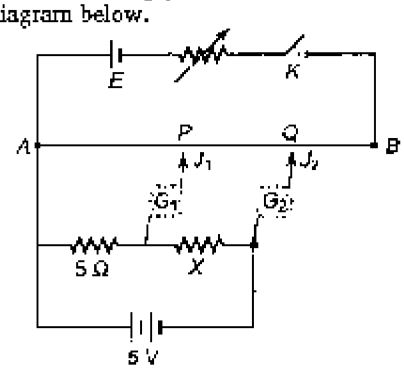
The value of unknown resistance would be
   (a) 3.2 Ω (b) 3.24 Ω
   (c) 3.206 Ω (d) 3.2375 Ω

6. Consider the meter bridge shown in the figure below.



The resistance X has temperature coefficient α_1 and from resistance box [9 Ω shown] has α_2. For shown situation, balance point is at 10 cm from left end, if temperature of system increases by ΔT due to Joule heating, then the shift in the balance point is [Assume that only the resistance of X and resistance box changes due to change in temperature and there is no other effect]
   (a) $9(\alpha_1 - \alpha_2)\Delta T$ (b) $9(\alpha_1 + \alpha_2)\Delta T$
   (c) $\frac{1}{9}(\alpha_1 + \alpha_2)\Delta T$ (d) $\frac{1}{9}(\alpha_1 - \alpha_2)\Delta T$

7. A person tries to find the value of unknown resistance using potentiometer as shown in the diagram below.



He uses a resistance of 5 Ω, unknown resistance X and a battery of 5 V in secondary circuit. He touches the jockey J_1 on potentiometer wire to get the point P, so that there is no deflection in G_1, then he locates the point Q so that G_2 shows zero deflection. It is found that $AP = \frac{AQ}{3}$. Value of X is

(a) 5 Ω
(b) 15 Ω
(c) 10 Ω
(d) This method won't works

8. The length of the string of a simple pendulum is measured with a meter scale to be 92.0 cm. the radius of the bob plus the hook is measured with the help of vernier caliper to be 2.17 cm. Mark out the correct statement(s).
(a) Least count of meter scale is 0.1 cm.
(b) Least count of vernier caliper is 0.01 cm.
(c) Effective length of simple pendulum is 94.2 cm.
(d) All of the above

Codes

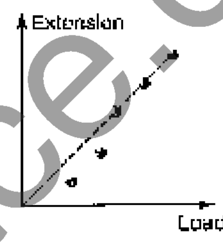
In the questions that follow two statements are given. Statement II is purported to be the explanation for Statement I. Study both the statements carefully and then mark your answers, according to the codes given below.

Mark your answer as

(a) If Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I.
(b) If Statement I is true, Statement II is true; Statement II is not a correct explanation for Statement I.
(c) If Statement I is true; Statement II is false.
(d) If Statement I is false; Statement II is true.

9. **Statement I :** While operating Wheatstone bridge [PO box], in starting, the key of the battery is closed first and the key of the galvanometer is closed later and when the circuit is to be switched off then switches are released in the reverse order.

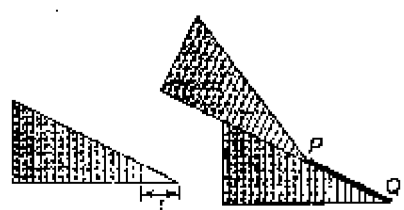
the first two readings are not lying on the straight line.



Statement II : Experiment is performed incorrectly.

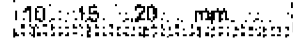
12. **Statement I :** In the measurement of specific heat of a liquid using calorimeter, while performing the experiment we keep the value of current constant by adjusting rheostat.
Statement II : Changing current damages the heating coil (heater).

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



(a) $\frac{l(1-\cos\theta)}{\cos\theta}$ units (b) $\frac{l}{\cos\theta}$ units
(c) $l(1-\cos\theta)$ units (d) $\frac{1-\cos\theta}{l}$ units

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

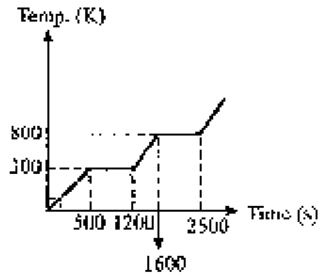


of air in SI units is [Take $\rho_{water} = 1000\,kg/m^3$ and $\rho_{air} = 1\,kg/m^3$]

(a) 10^{-4} Poise (b) 1×10^{-3} Poise

(c) 8.6×10^{-3} Poise (d) 1.02×10^{-3} Poise

16. 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 vapourization for the material of the objects, is [Power supplied to the object is constant and equal to 1 kW]



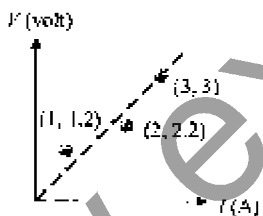
(a) 4.5×10^6 J/kg

(b) 4.5×10^6 cal/g

(c) 4.5×10^4 J/kg

(d) 4.5×10^4 cal/g

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

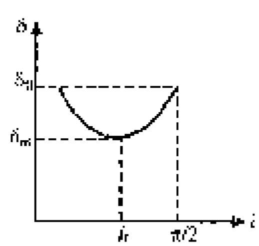


The resistance of the wire is

(a) $0.833\,\Omega$ (b) $0.9\,\Omega$

(c) $1\,\Omega$ (d) None of these

18. In the diagram, a plot between δ (deviation) *versus* i (angle of incidence) for a triangular prism is given. From the observed plot, some conclusions can be drawn. Mark out the correct conclusions.



(a) The range of deviation for which two angles of incidence are possible for same deviation is $\delta_0 - \delta_m$

(b) The curve is unsymmetrical about i_0

(c) For a given δ, i is unique

(d) Both (a) and (b) are correct

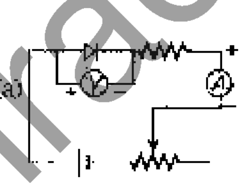
19. In comparison of emf's of two cells using potentiometer, the balanced length for batteries having emf E_1 and E_2 are 60 cm and 20 cm, respectively. Then

(a) $\frac{E_1}{E_2} = 3$ (b) $\frac{E_1}{E_2} = \frac{1}{3}$

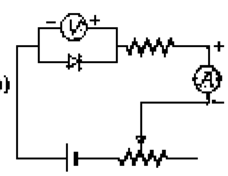
(c) $\frac{E_1}{E_2} = 60$ (d) $\frac{E_1}{E_2} = 20$

20. The circuit arrangement to plot characteristic curves of diode in forward bias mode is best represented by

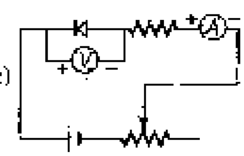
(a)



(b)



(c)



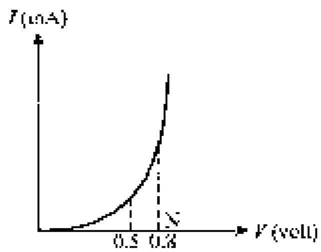
(d) None of these

21. In determination of refractive index of glass slab using travelling microscope, first of all we take a reading when the microscope is focussed on a mark. This reading comes out to be s_1, then we place a glass slab on the surface covering the mark. Now, the microscope is re-adjusted to focus the mark through the slab and this time reading comes out to be s_2. Then, we place an opaque object on the glass slab and adjust the microscope to focus on opaque object, this time the reading of microscope is s_3. The refractive index of the glass slab is

(a) $\frac{s_3 - s_1}{s_2 - s_1}$ (b) $\frac{s_3 - s_2}{s_2 - s_1}$

(c) $\frac{s_3 - s_1}{s_3 - s_2}$ (d) $\frac{s_3}{s_3 - s_2}$

22. The characteristic curve for a diode is shown in the figure for forward bias mode. The cut-off voltage for this diode is approximately



(a) 0.5 V (b) 0.8 V
(c) 1 V (d) >1 V

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

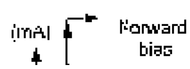
Forward Bias		Reverse Bias	
V (volt)	I (mA)	V (volt)	I (mA)
0.5	5	0.5	2.0
0.7	20	1.0	2.0
0.8	40	3.0	2.0
1.0	250	5.0	2.0
		5.5	100
		5.5	120

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

24. 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 [$\rho_{water} = 1000\ kg/m^3$, $g = 9.81\ m/s^2$]

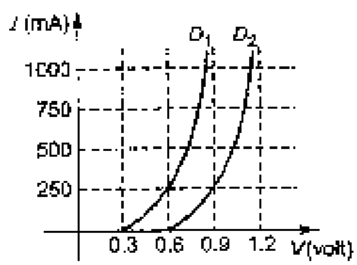
(a) 0.11 N/m (b) 0.7 N/m
(c) 0.072 N/m (d) None of these

25. The V-I characteristic for a p-n junction diode is plotted as shown in the figure. From the plot we can conclude that



(a) the forward bias resistance of diode is very high; almost infinity for small values of V and after a certain value it becomes very low
(b) the reverse bias resistance of diode is very high in the beginning upto breakdown voltage is not achieved
(c) both forward and reverse bias resistances are same for all voltages
(d) Both (a) and (b) are correct

26. 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]

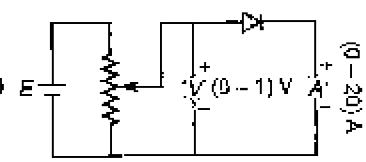


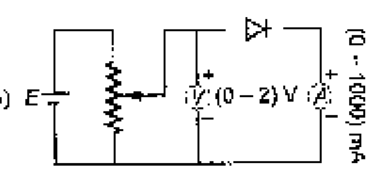
(a) 0.4 V and 0.7 V (b) 0.6 V and 0.9 V
(c) 0.6 V and 0.8 V (d) 0.4 V and 0.9 V

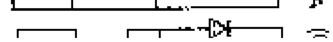
27. The reverse bias voltage for a p-n junction diode is approximately of the order of

(a) 0.3 V (b) 0.7 V
(c) 3 V (d) 20 V

28. To plot forward characteristic of p-n junction diode, the correct circuit diagram is

(a) 

(b) 

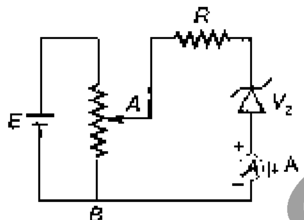


In bracket the range of measuring instruments are measured.

29. 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

30. In zener diode, the n-type and p-type sections are heavily doped as compared to normal p-n junction diode, this is made to ensure
   (a) constant reverse breakdown voltage
   (b) low value of reverse breakdown voltage
   (c) high value of reverse breakdown voltage
   (d) All the above statements are wrong

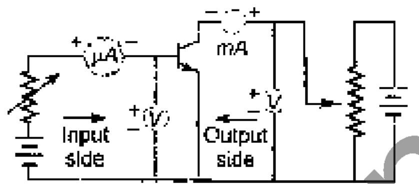
31. A zener diode is operating in its normal region ie, the breakdown region for which the circuit diagram is as shown in the figure.



Here take $V_Z = 7$ V and $R = 10$ kΩ. 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

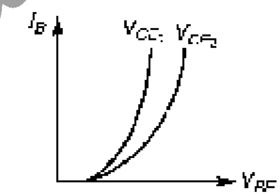
32. For CE configuration of a transistor, mark the correct statement(s).
   (a) Input characteristic is plotted between base current and base to emitter voltage keeping collector current constant.
   (b) Input characteristic is plotted between base current and base to emitter voltage keeping collector to emitter voltage constant.
   (c) Input characteristic is plotted between emitter current and base to emitter voltage keeping collector to emitter voltage constant.
   (d) Any of the above may be correct.

33. 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) are correct.

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

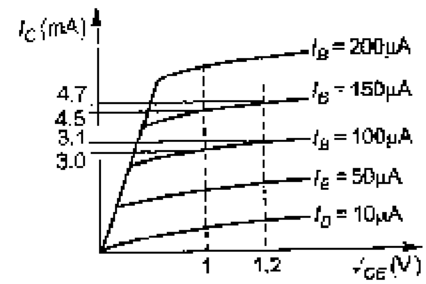


   (a) $V_{CE_1} > V_{CE_2}$ (b) $V_{CE_1} = V_{CE_2}$
   (c) $V_{CE_1} < V_{CE_2}$ (d) None of these

35. 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

36. 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

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



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

38. Mark the correct statement(s).
(a) Diode, LED and transistor are two leg devices.
(b) Diode, LED and resistor are two leg devices.
(c) Transistor and IC are 3 leg devices.
(d) IC and transistor are having same number of legs but not three.

39. 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 procee 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 turn by turn 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

40. In previous question the transistor is
(a) n-p-n
(b) p-n-p

(b) When p side of diode is connected to negative lead of multimeter and n-side to positive lead, then a beap is obtained
(c) When one leg of diode is connected to negative lead of multimeter and other leg to positive lead, then no beap is obtained
(d) Both (a) and (b) are correct

42. 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 1st 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

43. 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 metre 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

44. 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) None of these

45. In above question the minimum value of unknown mass which we can measure is
(a) 2 kg (b) 3.25 kg

(a) 0.72 N/m (b) 0.77 N/m
(c) 1.67 N/m (d) None of these

47. 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

48. 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

49. 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

50. 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 $\rho_{steel} = 7.8 \times 10^3$ kg/m^3, $g = 9.81$ m/s^2]. The viscosity of glycerine is [in N-s/m^2]
(a) 0.802 (b) 1.67
(c) 0.76 (d) 0.963

51. 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.N	Distance	Time
[illegible]	[illegible]	[illegible]

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

52. Assertion: While measuring viscosity of a liquid using terminal velocity concept we start taking the reading after the ball has covered some distance.
Reason: Ball takes some time to acquire terminal velocity
(a) Both Assertion and Reason are true and Reason is explaining the Assertion
(b) Both Assertion and Reason are true but Reason is not explaining the Assertion
(c) Assertion is true and Reason is false
(d) Both Assertion and Reason are false

53. In resonance tube experimental apparatus length of air column for 1st and 2nd resonances are 10 cm and 42 cm respectively. When it is vibrating with a tuning fork of frequency 512 Hz, the speed of sound in air would be calculated as
(a) 340 m/s (b) 332 m/s
(c) 328 m/s (d) 320 m/s

54. While performing resonance tube experimental apparatus one should keep in mind that
(a) prongs of tuning fork should be kept in horizontal plane
(b) prongs of tuning fork should be kept in vertical plane
(c) resonance tube must be kept vertical
(d) Both (b) and (c) are correct

55. While drawing cooling curve between the temperature of hot water and time we should stir the water uniformly, this has been done to ensure that
(a) temperature of water in the calorimeter is same at all places
(b) cooling will occur fast to save the time of experiments
(c) we can stir water non-uniformly also
(d) None of the above

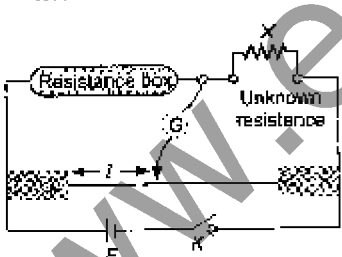
56. An aluminium vessel of mass 0.5 kg contains 0.2 kg of water at 20°C. A block of iron of mass 0.2 kg at 100°C is gently put into the water. The equilibrium temperature of the mixture is found to be 25°C. The specific heat capacity of iron would be [$s_{aluminium} = 910$ J/kg-K; $s_{water} = 4200$ J/kg-K]
(a) 470 J/kg-K (b) 431.7 J/kg-K
(c) 480 J/kg-K (d) None of these

57. A piece of iron of mass 0.1 kg is kept inside a furnace for a long time and then put into a calorimeter of water equivalent 10 g containing 0.25 kg of water at 20°C. The final equilibrium temperature is found to be 60°C. Take $s_{iron} = 470$ J/kg-K, $s_{water} = 4200$ J/kg-K. The temperature of the furnace would be

(a) 100°C
(b) 354°C
(c) 953.6°C
(d) 893.6°C

58. In meter bridge experiment the observation table and circuit diagram are shown in figure.

[illegible]	[illegible]	[illegible]
1.	1000	60 cm
2.	100	13 cm
3.	10	1.5 cm
4.	1	1.0 cm



Which of the readings is not taken correctly?

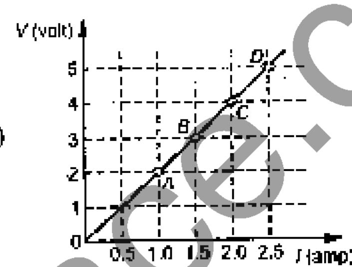
(a) 1 (b) 2
(c) 3 (d) 4

59. In above question the value of unknown resistance is

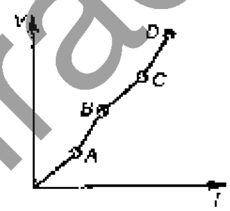
(a) $664\,\Omega$
(b) $100\,\Omega$
(c) $348\,\Omega$
(d) $864\,\Omega$

60. The reading of an experiment (to determine the resistance of a given wire using Ohm's law) are as given below

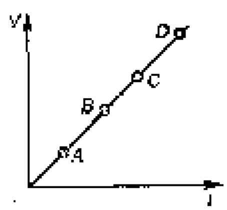
(a)



(b)



(c)



(d) None of the above

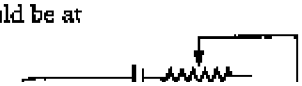
61. In previous question resistance of wire would be

(a) $2\,\Omega$ (b) $2.14\,\Omega$
(c) $1.90\,\Omega$ (d) $2.02\,\Omega$

62. In question number 60, the variations in reading may be due to

(a) heating of wire due to thermal effects of current
(b) the concentration may become somewhat loose in between
(c) may be experimentor error
(d) All of the above

63. In the potentiometer circuit shown, if for cell $E_1 = 5$ V the balanced point is at 40 cm from A, then for another battery $E_2 = 10$ V the balanced point would be at



64. If length of potentiometer wire is 300 cm and in its primary circuit a standard cell of emf 2 V and a rheostat having resistance setting at $4\,\Omega$ is connected, the resistance per unit length of potentiometer wire is $2\,\Omega/m$. If a battery of emf 1 V and internal resistance $0.5\,\Omega$ is connected in secondary, then null point will be obtained at

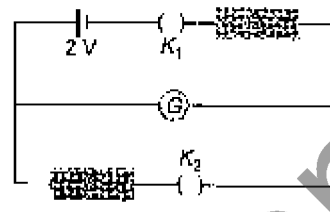
(a) 250 cm
(b) 200 cm
(c) 150 cm
(d) 100 cm

65. In previous question the maximum emf of a particular battery which we can measure is

(a) 1 V (b) 2 V
(c) 1.2 V (d) 3 V

66. In determining resistance of galvanometer by using half deflection method, the following readings are noted down.

S. N.	Resistance of (ohm)	Deflection (div) θ	Shunt for $\frac{\theta}{2}$
1.	200	80	$40\,\Omega$
2.	280	60	$42\,\Omega$
3.	300	50	$43\,\Omega$
4.	450	40	$45\,\Omega$
5.	620	30	$46.3\,\Omega$



The circuit diagram is also shown for reference. Galvanometer has total 100 divisions and it can measure current upto 10 mA. The least count of galvanometer is

(a) 10 mA
(b) 1 mA
(c) 0.1 mA
(d) Information is insufficient

67. For previous question, the approximate value of resistance of galvanometer is

(a) $50\,\Omega$ (b) $40\,\Omega$
(c) $53\,\Omega$ (d) None of these

68. In above question which reading does not seems to be correct?

(a) 1 (b) 2
(c) 3 (d) None of these

69. In previous question, figure of merit of galvanometer is

(a) 3×10^{-4} (b) 1.03×10^{-4}
(c) 4×10^{-4} (d) 3×10^{-7}

ANSWERS

1. (a)	**2.** (d)	**3.** (b)	**4.** (d)	**5.** (b)	**6.** (a)	**7.** (c)	**8.** (d)	**9.** (a)	**10.** (c)
11. (c)	**12.** (c)	**13.** (a)	**14.** (c)	**15.** (b)	**16.** (a)	**17.** (c)	**18.** (d)	**19.** (a)	**20.** (a)
21. (c)	**22.** (a)	**23.** (c)	**24.** (a)	**25.** (d)	**26.** (a)	**27.** (d)	**28.** (b)	**29.** (c)	**30.** (b)
31. (d)	**32.** (b)	**33.** (c)	**34.** (a)	**35.** (a)	**36.** (a)	**37.** (a)	**38.** (b)	**39.** (a)	**40.** (b)
41. (a)	**42.** (c)	**43.** (b)	**44.** (c)	**45.** (b)	**46.** (b)	**47.** (a)	**48.** (b)	**49.** (b)	**50.** (a)
51. (c)	**52.** (a)	**53.** (c)	**54.** (d)	**55.** (a)	**56.** (b)	**57.** (c)	**58.** (c)	**59.** (a)	**60.** (a)
61. (a)	**62.** (d)	**63.** (b)	**64.** (a)	**65.** (c)	**66.** (c)	**67.** (a)	**68.** (d)	**69.** (b)	

HINTS & SOLUTIONS

1. N MSD = $(N-1)$ VSD

$$1\text{ VSD} = \frac{N}{N+1}\text{ MSD}$$

$$LC = 1\text{MSD} - 1\text{VSD} = \left(1 - \frac{N}{N+1}\right)1\text{ MSD}$$

$$= \frac{a}{N+1}\text{ units.}$$

2. Least count, $LC = \dfrac{\text{pitch}}{\text{divisions on circular scale}}$

$$= \frac{0.5}{50} = 0.01\text{ mm}$$

Zero error is negative in nature and is given by,
$e = -45 \times LC = -0.45$ mm
Zero correction = – Zero error = 0.45 mm.

Reading of the screw gauge,

$d = 2 \times 0.5 + 20 \times 0.01 +$ zero correction

$= 1.65\,\text{mm}$.

3. Least count of instrument,

$$\text{LC} = 1\,\text{MSD} - 1\,\text{VSD}$$
$$= 1\,\text{MSD} - \frac{9}{10}\,\text{MSD}$$
$$= \frac{1}{10} \times 1\,\text{MSD}$$
$$= 0.1\,\text{mm} = 0.01\,\text{cm}$$

As zero of vernier scale lies to the right of zero of main scale when there is nothing between the jaws of vernier calipers, zero error is present in the instrument and zero error is positive in nature.

Length of the cylinder,

$l = [3.1 + 4(0.01) - (7 \times 0.01)]$ cm

$l = 3.1 + 0.04 - 0.07 = 3.07$ cm zero error term

4. The meter bridge wire should have low temperature coefficient of resistivity so that with rise in temperature (due to Joule heating) the resistivity won't change appreciably so that change in resistivity (error) due to above mentioned reason is small.

5. For post office box (Wheatstone bridge), under balanced conditions

$\frac{P}{Q} = \frac{R}{S}$ where $S \rightarrow$ unknown resistance

$$S = \frac{Q}{P} \times R \quad \left[\text{Here, } \frac{P}{Q} = 100, \text{ given}\right]$$

From the given graph the galvanometer shows zero deflection at

$R = 323.75 = 324\,\Omega$ [upto 3 significant digits]

So, $S = 3.24\,\Omega$

6. From the balance condition, $\frac{X}{Y} = \frac{l}{100 - l}$

For the given situation, $Y = 9\,\Omega$ and $l = 10$ cm.

$$\frac{dX}{X} - \frac{dY}{Y} = \frac{dl}{l} + \frac{dl}{100 - l}$$

As error sign is known or we can say these are systematic errors, we will substitute them with sign.

Similarly, $(5 + X)l \propto AQ$

$$\Rightarrow \quad \frac{5 + X}{5} = \frac{AQ}{AP} = 3$$

$$\Rightarrow \quad X = 10\,\Omega$$

8. Effective length of the pendulum is, $(92.0 + 2.17)$ cm $= 94.2$ cm after rounding off to 3 significant digits.

9. If the switch of galvanometer is pressed before the battery switch, while switching on the circuit, then a large sparking takes place at the battery switch.

While disconnecting if we open the battery switch before the galvanometer switch, then we can observe induced current in the circuit till the galvanometer switch is not opened.

10. Here, Statement I is true but Statement II is false, the correct reason for Statement I is that we have to give some time to wire so that it can acquire its desired change in length due to loading and as a result vertical oscillations get subsidised.

For statement II, in the beginning of the experiment the wire is not free from kinks but at later stage it gets straight and becomes free of kinks.

11. Here, first two readings are not lying on straight line due to initial kinks in the wire.

12. Here, Statement I is correct but Statement II is wrong. The correct reason for Statement I is, in calculation we are using the concept that electrical energy supplied by heater is used to increase the temperature of liquid and calorimeter *ie*,

$$VIt = m_l s_l \Delta\theta + m_c s_c \Delta\theta$$

If I changes with time, then to compute LHS of above equation, we have to know its variation with time which is a tedious task.

13. 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 figure, it is clear that, $1\,\text{MSD} = \frac{l}{\cos\theta}$ unit and $1\,\text{VSD} = l$ unit, so LC of instrument is,

15. We have, $\Rightarrow \eta = \dfrac{2gr^2(\rho - \sigma)}{9v}$

where $\rho \to \rho_{water}$ and $\sigma \to \rho_{air}$

$$= \frac{2 \times 9.81 \times (0.2 \times 10^{-2})^2 \times 999}{9 \times 8.7}$$

$$= 1 \times 10^{-3} \text{ Poise}$$

16. $\int_{1600}^{2500} P dt = mL_v$

$\Rightarrow \quad 10^3 \times 900 = 0.2 \times L_v$

$\Rightarrow \quad L_v = 4.5 \times 10^6$ J/kg

17. 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 experimentor, all points may not come on the same line, in this situation, we draw the most appropriate curve.

From the diagram, $R = \dfrac{3}{3} = 1\,\Omega$

19. $E \propto l$

where l is the balanced length of the potentiometer wire.

So, $\dfrac{E_1}{E_2} = \dfrac{60}{20} = 3$

20. Directly from the experimental set-up.

21. $s_3 - s_1$ corresponds to thickness of slab or actual depth of the mark while $s_3 - s_2$ corresponds to the apparent depth of the object.

Now, $\mu = \dfrac{\text{Actual depth}}{\text{Apparent depth}} = \dfrac{s_3 - s_1}{s_3 - s_2}$

22. Cut-off voltage is the voltage applied across diode in forward bias mode to overcome the potential barrier region. Upto this, forward bias voltage current through diode is approximately zero.

23. Current changes by large amount when we change reverse bias voltage from 5 to 5.5 V, so reverse breakdown voltage is somewhere there only and thereafter current increases even though no change in voltage occurs.

24. $2\pi r \times T \cos 0 = \pi r^2 h\rho g$

$\Rightarrow T = \dfrac{rh\rho g}{2} = \dfrac{0.015 \times 10^{-2} \times 15 \times 10^{-2} \times 1000 \times 98}{2}$

$= 0.11$ N/m

25. The resistance (dynamic or AC) is given by,

$$r = \frac{\Delta V}{\Delta I}$$

From graph the situation is very clear.

For forward bias mode

Upto knee voltage, $r = \dfrac{\Delta V}{\Delta I}$ is very high as a particular change in V is not causing appreciable change in current, but afterwards a small change in V causes a large change in I.

For reverse bias mode

Upto breakdown voltage, the current is hardly changed if we change the applied voltage but once breakdown voltage is achieved, the current increases even if there is almost no change in the voltage.

26. The forward voltage when current in circuit starts increasing rapidly is the knee voltage.

27. Factual.

28. For forward bias mode the p-side of diode has to be at higher potential than n-side. The meters used are DC, so we have to be careful while connecting them *w.r.t.* polarity.

Last point is to decide the range of meters, the range of meters has to be in such a way that we can have the readings which leads to plot on realistic scale. If we take 0–20 A ammeter then reading we read from this is tending to 0 to 5 divisions which is not fruit ful.

29. 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's why the voltage across zener diode is constant.

30. Factual.

31. Write KVL equation.

$$-V_{BA} + IR + V_Z = 0$$

[As diode is operating in breakdown region]

$\Rightarrow \quad IR = V_{BA} - V_Z = 8 - 7$

$\Rightarrow \quad I = \dfrac{1\text{ V}}{10\text{ k}\Omega} = 100\,\mu\text{A}$

33. Input characteristic is plotted between I_B *versus* V_{BE} for different values of V_{CE}.

Output characteristic is plotted between I_C *versus* V_{CE} for different values of I_B.

34. $V_{CE_1} > V_{CE_2}$

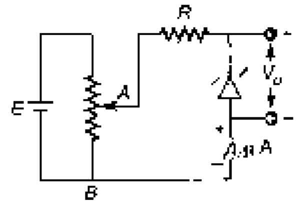
35. Input resistance,

$$R_i = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{1}{\text{Slope of input characteristic curve}}$$

Output resistance,

$$R_o = \frac{\Delta V_{CE}}{\Delta I_C} = \frac{1}{\text{Slope of output characteristic curve}}$$

36. Output current *versus* input current keeps the output voltage constant.



37. Current gain is defined as, $\frac{\Delta I_C}{\Delta I_B}\Big|$ constant V_{CE}

Current gain at $V_{CE} = 1$ V is $\frac{(4.5-3)\text{ mA}}{(50)\,\mu\text{A}}$

$$= \frac{1.5\times10^3}{50} = 30$$

38. **Diode** Diode is a two terminal device and offers very high resistance when in reverse bias and very low resistance when forward biased.

LED It is a two terminal device and nothing but p-n junction diode, operates in forward bias mode and emits light. Its negative leg is longer than positive.

Capacitor and **resistor** both are two terminal devices. Transistor is a three legged device, it is of two types n-p-n and p-n-p.

IC (Integrated circuits) It is a device with many thousands to millions of transistors packed in a slice of semiconductor. These have any number of pins greater than 3.

39. 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.

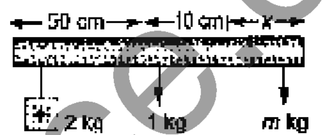
40. If common lead of the multimeter is connected to base and then it shows conduction for other two connections as mentioned in above question the transistor is p-n-p otherwise n-p-n.

42. Option (a) tells that transistor is not working, as there is no connection between base and collector *ie*, there is some fault in this part of the transistor. Option (b) tells that transistor is having no open

$$2g\times0.5 = mg\times0.2$$

$$\Rightarrow \quad m = 5\text{ kg}$$

44. Taking torque about hanging point.



$$2g\times60 + 1g\times10 = mg\times x$$

$$\Rightarrow \quad x = \frac{2\times60+1\times10}{5} = 26\text{ cm}$$

45. For minimum value of m, the value of x has to be maximum, *ie*, $x = 40$ cm.

So, $2g\times60 + 1g\times10 = mg\times40$

$$m = \frac{120+10}{40} = 3.25\text{ kg}$$

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

$$= \frac{0.5\times10^{-2}\left[3+\frac{0.5}{3}\right]\times10^{-2}\times10^3\times9.81}{2}$$

$= 0.77$ N/m

47. As detergent is added to water, its surface tension decreases and hence, height of water level falls in capillary tube.

48. Factual.

49. As water is having low viscosity, the terminal velocity won't be acquired by steel ball very soon, so to serve the purpose a very long jar is needed approximately 1000 of metres, which is not suitable to perform the experiment.

50. From the expression

$$\eta = \frac{2r^2(\rho_{steel}-\rho_{glycerine})g}{9\times v}$$

where v is terminal speed.

Here, $v = \frac{0.2}{1.8}$ m/s

$$\eta = \frac{2\times(0.25\times10^{-2})^2\times(7.8-1.26)\times10^3\times9.81}{9\times\frac{0.2}{1.8}}$$

$\Rightarrow \qquad \lambda = 2(l_2 - l_1) = 2 \times 0.32\,\text{m}$

$v = f\lambda = 2 \times 0.32 \times 512$

$= 327.68 \cong 328\ \text{m/s}$

56. $m_{iron}\, s_{iron} \times (100 - 25)$

$= m_{Al} s_{Al} \times (25 - 20) + m_{water}\, s_{water}\ (25 - 20)$

$\Rightarrow 0.2 \times s_{iron} \times 75 = 0.5 \times 910 \times 5 + 0.2 \times 4200 \times 5$

$\Rightarrow \qquad s_{iron} = 431.7\ \text{J/kg-K}$

57. Temperature of furnace would be same as that of iron piece initially, let it be T °C.

$0.1\,(T - 60) \times 470 = 0.25 \times 4200 \times (60 - 20)$

$\Rightarrow \qquad T = 953.6°\text{C}$

58. From 1,

$$X = 1000 \times \frac{100 - 60}{60} = \frac{2000}{3}\,\Omega = 666.67\,\Omega$$

From 2, $X = 100 \times \dfrac{100 - 13}{13} = 669.23\,\Omega$

From 3, $X = 10 \times \dfrac{100 - 1.5}{1.5} = 656.66\,\Omega$

From 4, $X = 1 \times \dfrac{100 - 1}{1} = 99\,\Omega$

4^{th} reading is far away from other readings so most probably it would be wrong.

59. $X = \dfrac{666.67 + 669.23 + 656.66}{3} = 664\,\Omega$

60. While plotting a curve we have to draw according to the actual shape, although all readings may not lie on the required curve.

61. R = Slope of V-I curve drawn in previous question.

63. From theory $E_1 \propto l_1$ and $E_2 \propto l_2$ where l_1 and l_2 are balancing lengths

Then $\qquad \dfrac{E_1}{E_2} = \dfrac{l_1}{l_2}$

$\Rightarrow \qquad l_2 = 80\ \text{cm}$

64. Current in primary circuit is,

$$I = \frac{2}{4 + 2 \times 3} = 0.2\,\text{A}$$

For 1 V let us say balancing length is x metre, then

$$I \times (2\,\Omega/\text{m}) \times x = 1\,\text{V}$$

$$\Rightarrow \quad x = \frac{1}{2 \times 0.2} = \frac{5}{2} = 2.5\,\text{m} = 250\,\text{cm}$$

65. Potential drop across entire potential wire

$= I \times 6 = 1.2\,\text{V}$

So, maximum emf of battery which can be determined is 1.2 V.

66. Least count of galvanometer is the current it can measure when the galvanometer needle deflects by 1 division.

$$\text{LC} = \frac{10\ \text{mA}}{100} = 0.1\ \text{mA}$$

67. When key K_1 is closed, the current in the galvanometer is

$$I_g = \frac{E}{R + G} = k\theta$$

where k is figure of merit of galvanometer and θ is the deflection shown by galvanometer.

When key K_2 is also closed, current through galvanometer is

$$I_g' = \frac{E}{R + \dfrac{GS}{G + S}} \times \frac{S}{G + S}$$

For half deflection the value of S is determined by equation, $I_g' = \dfrac{k\theta}{2}$

$$\Rightarrow \qquad \frac{E}{R + G} = \frac{E \times S}{R(G + S) + GS}$$

$$\Rightarrow \qquad G = \frac{RS}{R - S}$$

For 1^{st} reading $\rightarrow G = \dfrac{200 \times 40}{160} = 50\,\Omega$

2^{nd} reading $\rightarrow G = \dfrac{280 \times 42}{238} = 49.41$

3^{rd} reading $\rightarrow G = \dfrac{300 \times 43}{257} = 50.19$

4^{th} reading $\rightarrow G = \dfrac{450 \times 45}{405} = 50\,\Omega$

5^{th} reading $\rightarrow G = \dfrac{620 \times 46.3}{573.7} = 50.03$

Average of observed readings for G $= 49.926\,\Omega$

$\approx 50\,\Omega$

68. Here, all the readings are very close to each other and hence are in agreement with each other so we can say all readings are upto the mark.

69. Figure of merit is given by

$$k = \frac{E}{(R + G)\theta}$$

$\Rightarrow$ For 1^{st} reading $\rightarrow k = 1 \times 10^{-4}$

2^{nd} reading $\rightarrow k = 1.01 \times 10^{-4}$

3^{rd} reading $\rightarrow k = 1.14 \times 10^{-4}$

4^{th} reading $\rightarrow k = 1 \times 10^{-4}$

5^{th} reading $\rightarrow k = 0.995 \times 10^{-4}$

Average value $= 1.03 \times 10^{-4}$