Specific Resistance by Carey Foster's Bridge

Experiment No. 8

Object : To determine the specific resistance of the material of a given wire using Carey Foster's bridge.

Apparatus : *Carey Foster's bridge, Leclanche cell, A resistance box in decimal range (decimal ohm box), A sensitive galvanometer, plug key, Thick copper strip, A sliding rheostat of nearly 10 ohms resistance, Screw Gauge, Meter scale, Jockey, Experimental wire, connection wires and a piece of sand paper.*

Description of the Apparatus and Circuit : A Carey Foster bridge is the modified form of a meter bridge (A meter bridge or slide-wire bridge is a sensitive device based on the principle of Wheatstone's bridge, having two gaps and is used to measure the unknown resistance of a wire) having two addition gaps as shown in fig. 8.1. It is used to measure very small resistances. A Carey Foster bridge consists of a meter long wire of uniform cross-section stretched along a wooden board and runs parallel to a meter

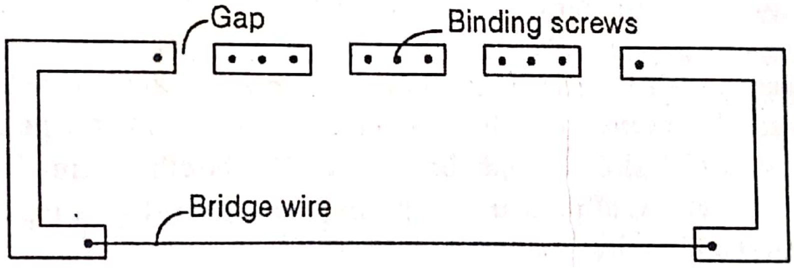


Fig. 8.1

scale (not shown). The wire is of the material of high specific resistance and of low temperature coefficient, such as ureka or manganin. The ends of the wire are soldered to two L-shaped brass strips. The three brass strips running parallel to the wire are firmly attached on the board between the two L-shaped strips as shown in fig. 8.1. These five strips constitute four gaps. Terminals with binding screws are provided on each strip for making necessary connections. The working of a Carey Foster bridge depends on the principle of Wheatston's bridge, as is clear from figs. 8.2 and 8.3.

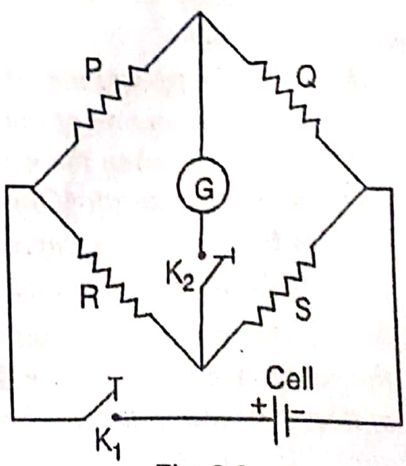


Fig. 8.2

The circuit arrangements for the determination of specific resistance of the material of a wire is shown in fig. 8.3. In this arrangement two nearly equal and small resistances P and Q are connected in the inner gaps of the bridge. These resistances serve as a ratio arms of the Wheatstone bridge. Of the two outer gaps one is short circuited by connecting a thick copper strip across its ends, and to the other outer gap a fractional resistance box

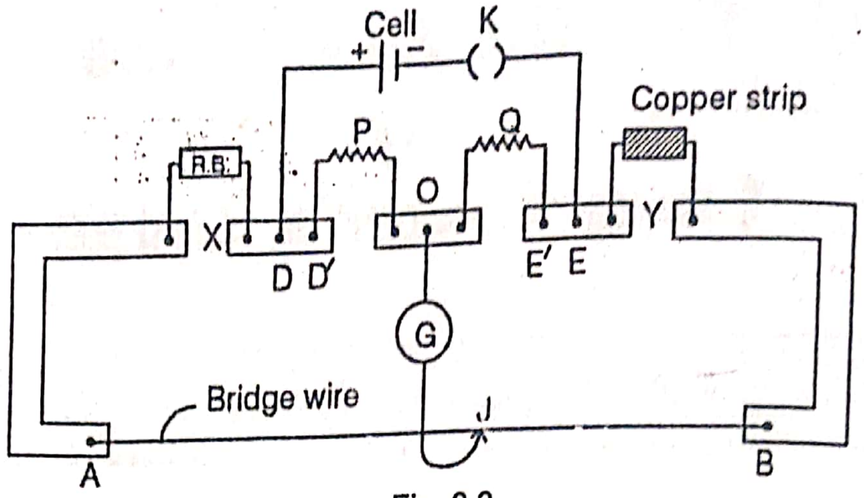


Fig. 8.3

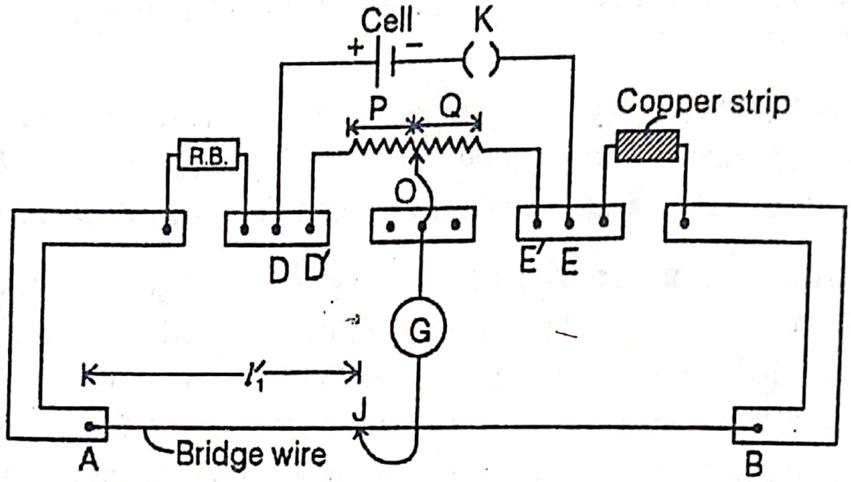


Fig. 8.4

is connected. A Leclanche cell in series with a key K is connected to the terminals D and E of the two middle strips. One end of the sensitive galvanometer G is connected to the point O of the central strip and other to the Jockey J which slides over the bridge wire AB. The other form of circuit diagram is shown in fig. 8.4. For the measurement of resistance of a wire, the copper strip is replaced by the wire whose resistance is to be measured.

Formula Used

The unknown resistance Y of the experimental wire whose specific resistance K is to be determined, is obtained by the formula

$$Y = X - \rho(l_2 - l_1) \text{ ohms} \qquad \text{.......(1)}$$

where X is the resistance introduced in the decimal ohm box (R.B.), Y the resistance of the experimental wire connected in one of the outer gaps of the Carey Foster bridge, l_1 the length of the balance point on the bridge wire when the resistance box (R.B.) is in the left outer gap or unknown resistance is in right outer gap, l_2 the length of the balance point on the bridge wire when the resistance box R.B. (or resistance X) is in the right outer gap of the bridge or unknown resistance is in left outer gap and ρ the resistance per unit length of the bridge wire (between A and B).

The resistance per unit length (ρ) of the bridge wire is determined by using known resistance R (in the resistance box R.B.) for X and a thick copper strip for Y (it makes $Y = 0$). In this case if the distance of the balance point on the bridge wire from the left-hand be l_1' when the copper strip is in the right outer gap or R.B. is in the left outer gap and l_2' (It is also measured from left hand side) that when the copper strip is the left outer gap or R.B. is in the right outer gap, then

$$\rho = \frac{R}{(l_2' - l_1')} \; ohm/cm \qquad ....(2)$$

The specific resistance, K of the material of the wire is calculated by using the formula

$$K = \frac{\pi r^2 Y}{l} \; ohm\text{-}cm \qquad ....(3)$$

where r is the radius and l the length of the experimental wire.

Thus the determination of specific resistance K involves the measurement of resistance per unit length (ρ), unknown resistance Y and the radius r of the experimental wire.

Procedure : The whole experiment is essentially performed in the following three steps

(A) Measurement of the resistance per unit length (ρ) of the bridge wire

1. First of all the ends of the connection wires are cleaned with sand paper and the electric connections are made in accordance to the diagram shown in fig. 8.3 or fig. 8.4. Initially the copper strip is connected to the right outer gap and fractional resistance box (*R.B.*)to the left outer gap.
2. The ratio arms *P* and *Q* can be obtained either by connecting two separate nearly equal resistance *P* and *Q* in the inner gaps (Fig. 8.3) or by using a rheostat (Fig. 8.4). When we use rheostat its lower terminals are connected to the points *D'* and *E'* of the two strips and its upper terminal (which is connected to the sliding contact) to the point *O* of the central strip and then finally to the jockey *J* through the galvanometer *G* as shown in fig. 8.4. The slider or sliding contact should be adjusted in the middle so that the resistances *P* and *Q* are nearly equal.

When the resistances in the ratio arms are exactly equal, that is, when P = Q, it is not possible to take more sets for l_1 and l_2 because these values will always remain nearly same. To avoid this situation, a rheostat is used instead of two resistances P and Q as shown in fig. 8.4. In this case for the same values of X and Y, a number of different sets for l_1 and l_2 can be obtained by varying the resistances in the two parts (or P and Q) of the rheostat. Hence, it is preferable.

3. To check the correctness of the connections close the plug key *K*. Now touch the Jockey *J* on the left end *A* of the bridge wire and note the direction of deflection in the galvanometer. Now touch the jockey on the right end *B* of the bridge wire and again note the direction of deflection. If the directions of deflection in the two cases are opposite, then the connections may be considered correct. If it is not so, then check the connections as well as the emf of cell.
4. Now to perform the actual experiment introduce a resistance *R* (say 0.5 Ω) in the resistance box *R.B.* and find out the position of null point by sliding the Jocky on the bridge wire (**The null point is the point on the bridge wire at which on touching the jockey no deflection in the galvanometer is observed**). Note down the distance l_1' of this null point from the left end *A* of the bridge wire. Now interchange the positions of the copper strip and the decimal ohm box *R.B.* in the outer gaps and again find the position of null point on the bridge wire for the same resistance (0.5 Ω) in the decimal ohm box. This time the balance point may lie near the right end of the bridge wire. Now again note down the position l_2' of the null point, from the same left end of the bridge wire (Fig. 8.3).
5. Obtain different sets of observations by repeating the above procedure (step no. 4) for at least five different values of *R*. The different values of *R* are obtained by changing the value of *R* slightly

(say 0.6, 0.7, 0.8, 0.9 ohms) in the decimal ohm box. Note all these reading systematically in the observation table (A) and then calculate the values of resistance per unit length (ρ) of the bridge wire separately for each set of observations by using the formula represented by equation (2) $\left[\text{that is, } \rho = \frac{R}{(l_2' - l_1')}\right]$. Finally, find the mean value of ρ.

(B) Measurement of the unknown resistance Y of the experimental wire

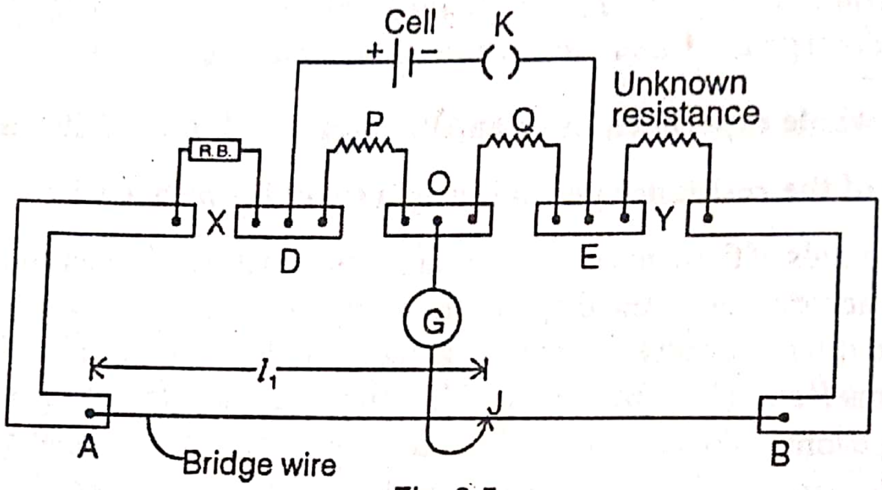


Fig. 8.5

(*i*) To measure the unknown resistance *Y* of the given experimental wire, remove the thick copper strip from the right outer gap and in its place connect the given experimental wire as shown in fig. 8.5. Keep the other connections same as in the previous case.

(*ii*) Introduce a suitable resistance, *X* ohm (say 1 Ω) in decimal ohm box attached to the left outer gap and obtain the null point by sliding the jockey *J* along the bridge wire. Note down its distance l_1 from the left end *A* of the bridge wire. Now interchange the positions of the decimal ohm box *R.B.* and the experimental wire in the outer gaps (**the length of the experimental wire between the screws should remain the same throughout the experiment**). Again obtain the position of null point for the same value of resistance and note down its distance l_2 from the left end *A* of the bridge wire. (**It should be noted that if the null point is not obtained anywhere on the bridge wire, change the value of *X* till the null point is obtained**).

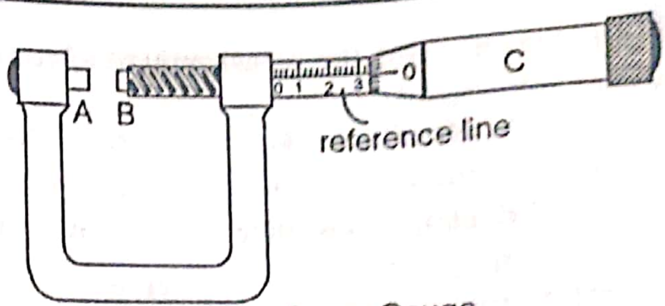
(*iii*) Obtain different sets of observations by repeating the above procedure [no. (*ii*)] for at least five different values of *X* obtained by changing the value of resistance in decimal resistance box. Note all these readings systematically in the observation table (B) and then calculate the values of unknown resistance *Y* of the experimental wire separately for each set of observation by using the formula represented by equation (1) $[Y = X - \rho(l_2 - l_1)]$. Finally find the mean value of the resistance *Y* of the given experimental wire.

(C) Measurement of specific resistance K of the material of experimental wire

1. Before measuring the actual diameter or radius of the experimental wire with the help of screw gauge, we first measure the pitch, least count and zero error of the screw gauge in the following manner :

(a) To determine the pitch of the screw gauge (Fig. 8.6) rotate the cap of the screw till the zero mark of the circular scale coincide with the reference line. Note this reading on the linear scale.

Now give four or five complete rotations to the circular scale and note the reading on the linear scale. The difference of the two reading on the linear scale gives the linear distance moved when a certain number of rotations to the circular scale has been given. Calculate the pitch of the screw gauge by the formula.



Screw Gauge
Fig. 8.6

$$\text{Pitch} = \frac{\text{The distance moved along the linear scale}}{\text{No. of complete rotations given to the circlar scale}}$$

Least count of the screw gauge is obtained by the relation,

$$\text{Least Count} = \frac{\text{Pitch}}{\text{Total no. of divisions on the circular scale}}$$

(b) To measure the zero correction, move the screw so that A just touches B. Use the ratchet stop to avoid any under pressure between them. If zero of the circular scale coincides with the zero of the liner scale, there is no zero error and hence no correction is needed. If zero of the circular scale does not coincide with the zero of the liner scale, then note down the number of the circular scale division by which the zero of the circular scale goes ahead or lags behind the reference line. Let it be n.

If the zero of the circular scale goes ahead of the reference line, zero correction is positive and is obtained by multiplying n with the least count and if it lags behind, the magnitude ($n \times$ least count) is negative.

2. Measure the diameter of the experimental wire at various places in two mutually perpendicular directions by using screw gauge. Note all these readings systematically in the observation table (C) and then calculate the mean value of radius r of the experimental wire.
3. Measure the length of the given experimental wire between two terminals A and B by means of a meter scale.
4. Calculate the value of specific resistance K of the material of the wire by substituting the measured values of Y, l and r in equation (3) $[K = \pi r^2 Y/l]$.

Observations

(a) Table (A) : For the measurement of resistance per unit length (ρ) of the bridge wire

S.No.	Resistance, R introduced in decimal resistance box R.B. (in ohm)	Position of Null point or distance of balance point from left end A of the bridge wire when R.B. is in		$(l_2' - l_1')$ (in cm)	$\rho = \frac{R}{(l_2' - l_1')}$ (in ohm/cm)
		Left gap l_1' (cm)	Right gap l_2' (cm)		
1.	...	...	...	...	...
2.	...	...	...	...	...
3.	...	...	...	...	...
4.	...	...	...	...	...
5.	...	...	...	...	...
				Mean value of ρ	... ohm/cm

(b) **Table (B) : For the measurement of resistance (Y) of the given experimental wire :**

S.No.	Resistance, R introduced in decimal resistance box R.B. X (ohm)	Position of Null point or distance of balance point from left end A of the bridge wire when R.B. is in		$(l_2 - l_1)$ (in cm)	$Y = X - \rho(l_2 - l_1)$ (in ohm/cm)
		Left gap l_1 (cm)	Right gap l_2 (cm)		
1.	...	...	...	...	...
2.	...	...	...	...	...
3.	...	...	...	...	...
4.	...	...	...	...	...
5.	...	...	...	...	...
				Mean value of Y	... ohm

(c) **Table (C) : For the measurement of radius (r) of the experimental wire**

$$\textit{Least count of the screw gauge} = \frac{\textit{Pitch}}{\textit{Total no. of divisions on the circular scale}}$$

$$= \frac{\ldots\ldots \textit{ mm}}{\ldots\ldots \textit{ div}} = \ldots\ldots \textit{ cm}$$

$$\textit{Pitch} = \frac{\textit{The distance moved along the linear scale}}{\textit{No. of complete rotations given to the circular scale}} = \frac{\ldots\ldots \textit{ mm}}{\ldots\ldots \textit{ div}} = \ldots\ldots \textit{ cm}$$

Zero correction of the screw gauge $= \pm \ldots$ *cm*

S.No.	Screw gauge reading along any direction			Screw gauge reading in per perpendicular direction			Dia-meter $D = \frac{a+b}{2}$ (cm)	Diameter corrected from zero error (cm)	radius $r = \frac{D}{2}$ (cm)
	Main scale reading M.S.	No. of circular scale divisions coinciding with reference line (n)	Total observed diameter (M.S. + n × least count) (a) (cm)	Main scale reading M.S.	No. of circular scale divisions coinciding with reference line (n)	Total observed diameter (M.S. + n × least count) (b) (cm)			
1.	...	...	...	...	...	...	...	...	...
2.	...	...	...	...	...	...	...	...	...
3.	...	...	...	...	...	...	...	...	...
4.	...	...	...	...	...	...	...	...	...
								Mean radius r	... cm

(D) The length (l) of the experimental wire between the two terminals = ... cm

Calculations

(i) *The resistance per unit length* (ρ) *of the bridge wire is calculated separately for each set of observations, given in table A, with the help of the formula*

$$\rho = \frac{R}{(l_2' - l_1')}$$

and then its mean value is obtained.

(ii) *The resistance* (Y) *of the experimental wire is calculated separately for each set of observations recorded in table B, with the help of the relation* $Y = X - \rho(l_2 - l_1) = \ldots$ *ohm and then its mean value is determined*

(iii) *By measuring the radius* (r) *of the experimental wire accurately, the specific resistance K of the material of the experimental wire is calculated by using the formula*

$$K = \frac{\pi r^2 Y}{l} = \ldots \text{ ohm-cm}$$

(iv) *The percentage error in the experimental result is calculated by the following formula,*

$$\text{Percentage error} = \frac{\text{Standard value} \sim \text{Calculated value}}{\text{Standard value}} \times 100$$

$$= \ldots \%$$

Result : *The specific resistance of the material of the given wire* = ... *ohm-cm*

Standard Result : *The standard value of the specific resistance for the material of the given wire* = ... *ohm-cm*

Percentage Error : *The percentage error* (%) = ... %

Precautions and Sources of Error

1. *The connection wire should be thick and their ends should be properly cleaned with sand paper before use. All the connections to the binding terminals should be tightly made.*
2. *The decimal ohm box should be connected to the bridge gap by short and thick copper wires.*
3. *The plug key connected in the cell circuit should be closed only when observations are to be taken.*
4. *The jockey should be pressed, on the bridge wire gently and momentarily. It should never be kept pressed during the search of null point on the bridge wire, otherwise the uniformity of the bridge wire will lost.*
5. *First the plug key of the cell circuit should be closed and then jockey should be pressed gently on the bridge wire.*
6. *To avoid the excessive deflection in the sensitive galvanometer, the galvanometer should be shunted by a wire of low resistivity which should be removed as one reach near the balance point.*
7. *While determining the resistance per unit length* (ρ) *of the bridge wire, the resistance introduced in the decimal ohm box R.B. should be smaller then the resistance of the bridge wire, otherwise null point would not be obtained and deflection in galvanometer will appear only in one direction.*

Viva-Voce

Q. 1. What are you doing ?

Ans : Sir, I am determining specific resistance of this wire (a given) with the help of a Carey Foster's bridge.

Q. 2. What do you mean by specific resistance ?

Ans : The specific resistance of the material of a wire is defined as the resistance of one cm cube of the material or the resistance of one cm length of a wire whose area of cross-section is one square centimetre.

Q. 3. What is resistance ?

Ans : When a potential difference of V volts is applied across the ends of a conductor, an electric current of I amp. flows through it. The ratio of the potential difference to the current, that is, V/I is called electric resistance, R. In fact the resistance opposes the flow of current in a conductor. Higher the resistance, higher will be the opposition to the flow of current.

Q. 4. What are the factors which affect the resistance of a conductor ?

Ans : The resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross-section ($R \propto l/a$).

Q. 5. If the length or radius of a wire is increased, whether the specific resistance will change ?

Ans : No, because the specific resistance is independent of length or radius of the wire, it depends only on the material of a wire.

Q. 6. What is this ? (Indicating towards the resistance box)

Ans : This is a decimal ohm resistance box.

Q. 7. What is a resistance box ?

Ans : A resistance box has a number of resistance coils of different resistances, all are connected in series and mounted inside a box (Fig. 8.7).

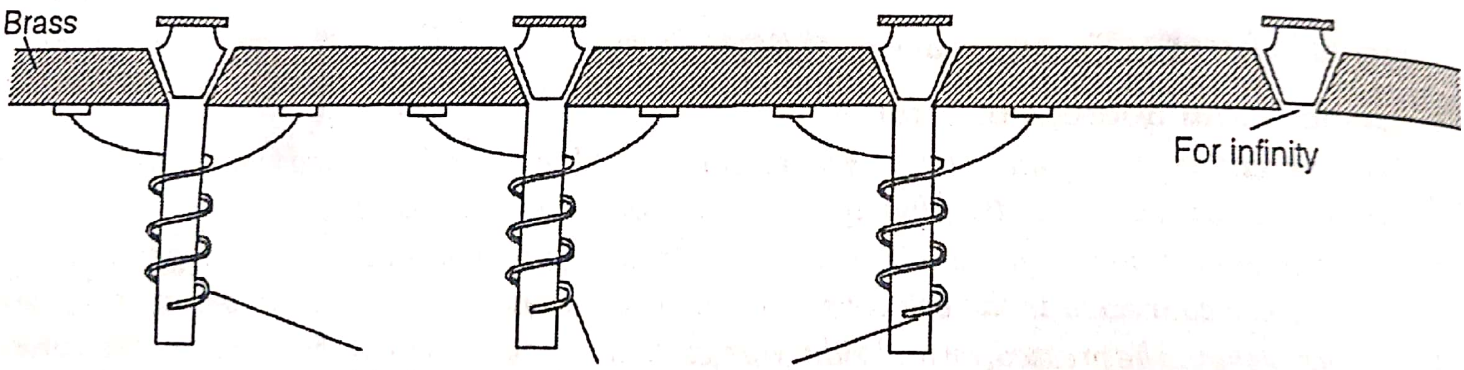


Fig. 8.7

Q. 8. How are the resistance coils placed inside the box ?

Ans : In resistance coils, insulated wires of suitable lengths of manganin (material) are taken. Each wire say PQR is doubled on itself and then it is wound in a bobbin of a non-conducting material (Fig. 8.8). The free ends P and Q of the wire are soldered to the piece of brass at the top.

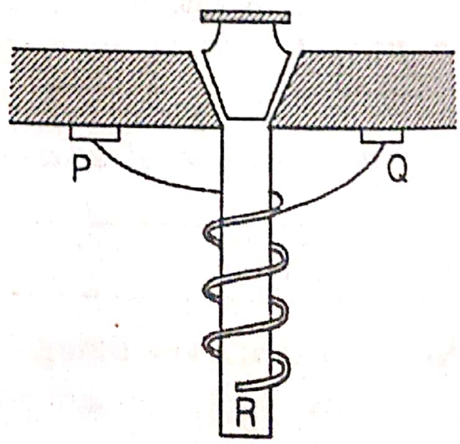


Fig. 8.8

Q. 9. Why is the wire doubled before winding over the bobbin ?

Ans : This is done to avoid the inductive effects. When the current passes through the coil, its direction of flow in one wire is opposite to that in the other wire so that the magnetic flux produced by one wire is equal and opposite to the flux produced by the other wire. Hence the total flux is always zero.

Q. 10. How is that a particular resistance in the circuit gets introduced when a plug is removed, although all the resistances are connected in series ?

Ans : When the plug is taken out of a particular gap or resistance the current passes through the coil of that particular resistance. In all the remaining resistances the current pass through the path of minimum resistance and thus flows through the brass pieces and the brass portion of the plugs without passing through the coils.

Q. 11. Is the resistance of the coil below the brass pieces marked INF is infinity ?

Ans : There is no coil below the pieces of brass marked INF. When the plug is removed from the gap, the circuit is broken and the gap so produced offered an infinite resistance between the brass pieces.

Q. 12. What type of wire is used in making the resistance coils ?

Ans : In the preparation of resistance coils, the constantan or manganin alloys are used. The constantan (Cu 60% and Ni 40%) or manganin (Cu 84%, Ni 4%, Mn 12%) wires are doubly insulated by means of silk thread.

Q. 13. Why are resistances usually made of constantan or manganin wires ?

Ans : Because these materials have a high resistivity (resistance per unit length) and very low temperature coefficient of resistance which is desirable.

Q. 14. What is the working principle of a Carey Foster's bridge ?

Ans : When the resistances connected to the outer gaps of the Carey Foster bridge are interchanged the position of the null points changes. The difference in the value of resistances (X-Y) is equal to the resistance of that much of the bridge wire $[(\rho(l_2 - l_1)]$ by which the null point has shifted.

Q. 15. What is the principle on which the Carey Foster bridge is based ?

Ans : Carey Foster's bridge is based on the principle of Wheatstone's bridge.

Q. 16. What is the principle of Wheatstone's bridge ?

Ans : When the resistances P, Q, R and S in the four arms of a Wheatstone bridge (Fig. 8.2) are such that the galvanometer gives no deflection on closing the cell key K_1 first and then galvanometer key K_2, or when bridge is balanced then

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

Q. 17. When does the bridge most sensitive ?

Ans : The bridge is most sensitive when all the four resistances P, Q, R and S are equal or at least of the same order.

Q. 18. How the radius of the resistance wire is determined ?

Ans : The radius of the resistance wire is determined by means of a screw gauge in two mutually perpendicular directions at a number of places and then mean is taken.

Q. 19. What do you mean by the least count of a screw gauge ?

Ans : Least count is the least reading which can be measured accurately with a screw gauge. It is the distance moved along the linear scale, when circular scale moves through one division.

Q. 20. What do you mean by zero correction of the screw gauge ?

Ans : When the two jaws of the screw gauge are brought in contact with each other, the zero of the circular scale should coincide the reference line. If they do not coincide, an error exist and is called zero error. Zero error is equal to the reading on the screw gauge when the two jaws are brought in contact with each other. Zero correction is equal in magnitude to zero error but opposite in sign.

Q. 21. When does the zero correction of the screw gauge positive ?

Ans : When the two jaws are brought in contact with each other, the zero of the circular scale goes ahead of the reference line, the zero correction is positive. If zero goes ahead of reference line by n divisions, then, the zero correction = n × least count.

Q. 22. What is the advantage in interchanging the positions of resistance box (R.B.) and unknown resistance in this Carey Foster's bridge experiment ?

Ans : By interchanging the positions of resistance box and unknown resistance, the error due to resistance at the ends caused by soldering etc., is eliminated.

Q. 23. Why the resistance of inner gaps (ratio arms) should be of same value ? If not, what is the harm?

Ans : By taking equal resistance in the inner gaps the sensitivity and accuracy of the bridge is increased.

Q. 24. What will happen if the two resistances in the inner gaps are not equal ?

Ans : If the two resistances in the inner gaps are unequal, the sensitivity of the bridge will be reduced and the null point will be shifted toward one end. Thus the percentage error in measuring the length will increase. If the difference between the resistances is very small, the null point will appear very near to the middle point of the bridge wire.

Q. 25. What is the maximum value of the difference in the two resistances which you can measure with it ?

Ans : The maximum value of the difference in two resistances which can be measure by Carey Foster's bridge is equal to the total resistance of the bridge wire.

Q. 26. What is the minimum difference in resistance that you can measure with this bridge wire ?

Ans : The resistance of one millimeter length of the bridge wire is the minimum difference that can me measured by it.

Q. 27. What precaution are you taking in regard to the use of jockey ?

Ans : The jockey should not be pressed hard on the bridge wire nor should it be slipped over it, otherwise the diameter of the wire may not remain uniform.

Q. 28. In Post office box what is the function of the brass plugs and why are they made in tapper ?

Ans : When the brass plug is inserted inside the air gap between the two brass blocks, the resistance connected across the gap is short circuited and current flows through the brass plug, not through the resistance coil connected inside. Conversely, when the plug is taken away, the current will flow through the resistance coil (connected inside), not through the gap. The brass plugs are made tappered in shape to ensure a good contact.

Q. 29. Why is the top of the resistance box made of ebonite ?

Ans : Because the ebonite is a bad conductor of electricity, therefore it avoids the short circuiting of the two ends of the wire connected to the blocks of brass.

Q. 30. Is the specific resistance same for all substances ?

Ans : No, it is different for different substances.