Measurement of Resistance

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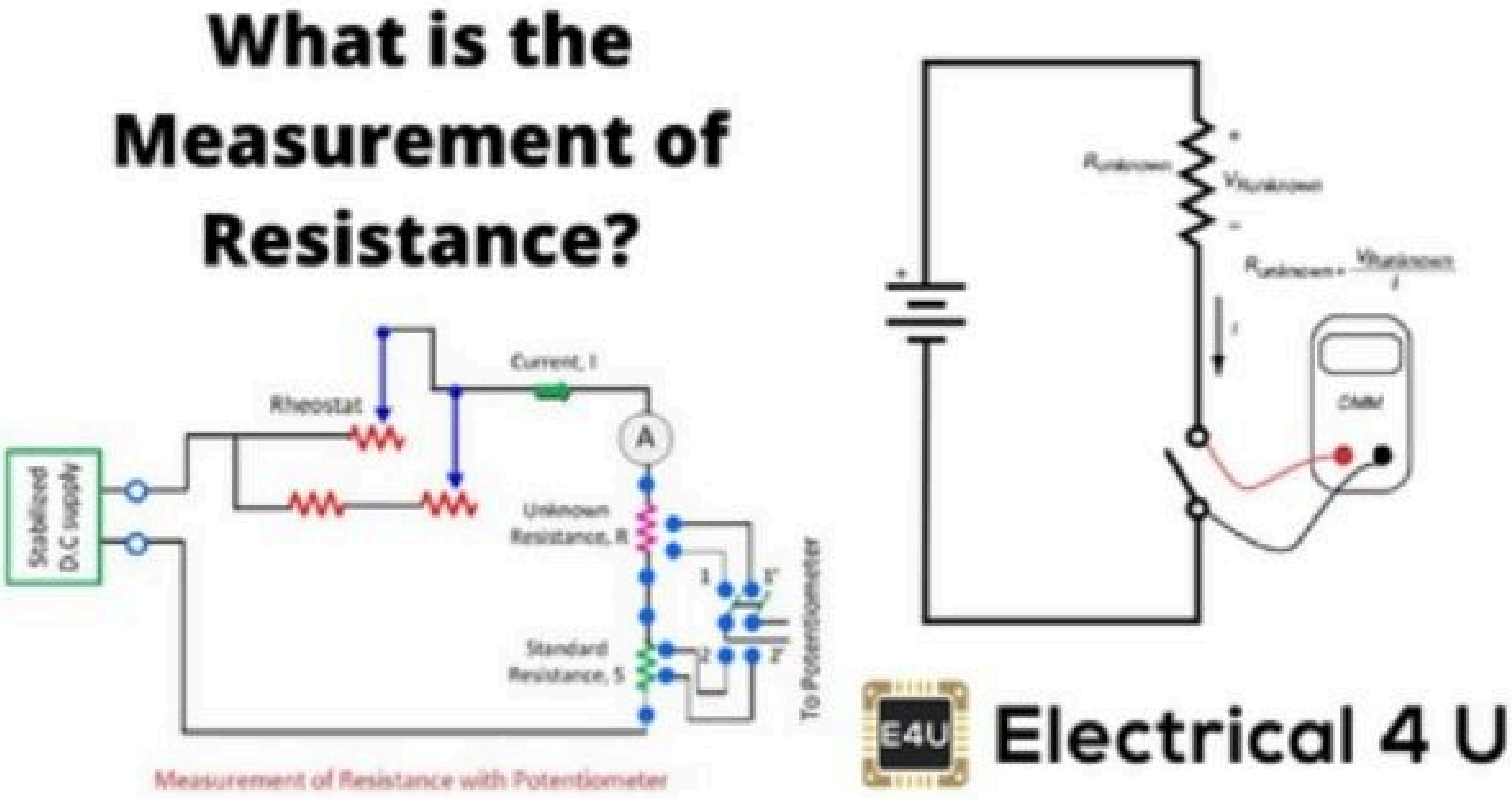
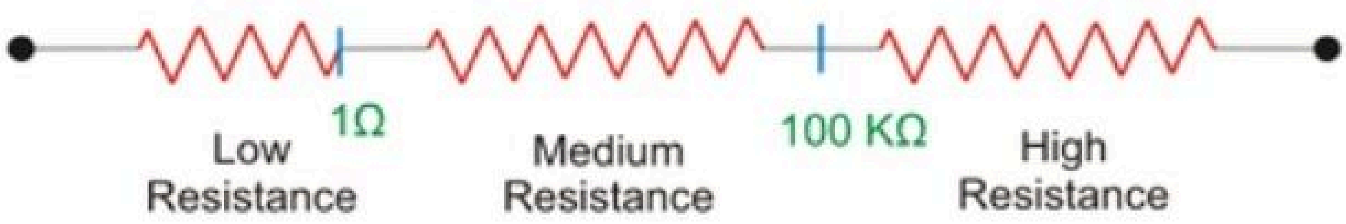
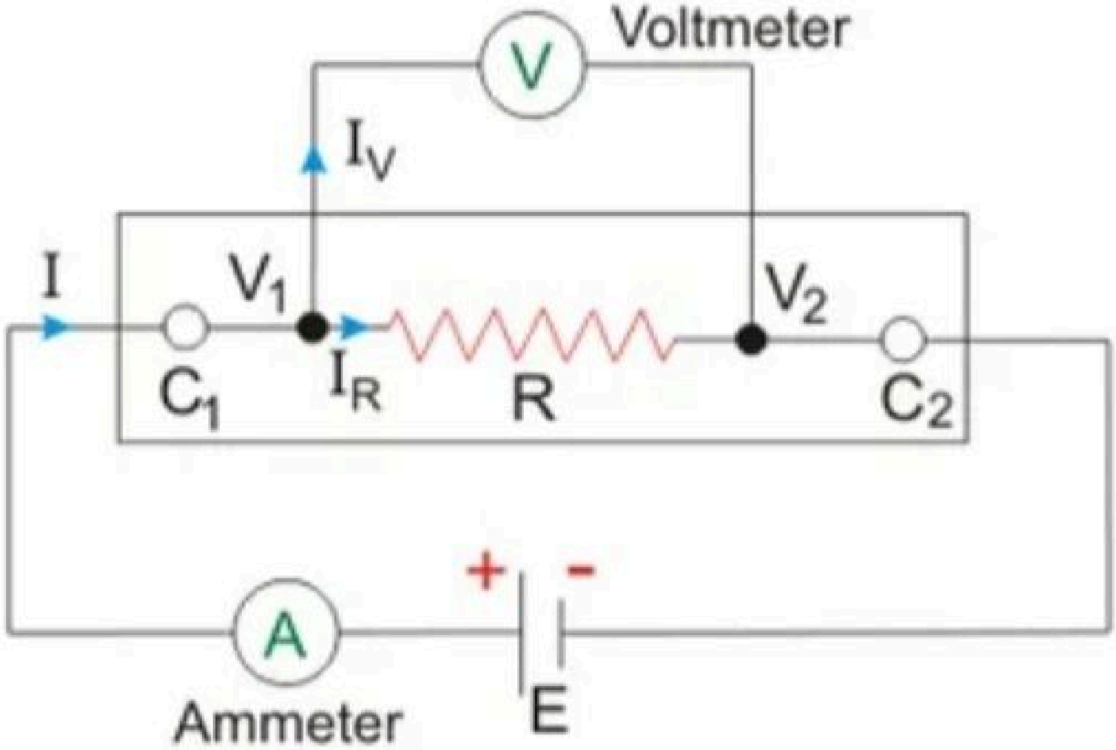


Resistance is one of the most basic elements encountered in electrical and electronics engineering. The value of resistance in engineering varies from very small value like, resistance of a transformer winding, to very high values like, insulation resistance of that same transformer winding. Although a multimeter works quite well if we need a rough value of resistance, but for accurate values and that too at very low and very high values we need specific methods. In this article we will discuss various methods of **resistance measurement**. For this purpose we categories the resistance into three classes-



Measurement of Low Resistance (<1Ω)

The major problem in **measurement of low resistance** values is the contact resistance or lead resistance of the measuring instruments, though being small in value is comparable to the resistance being measured and hence causes serious error.
Thus to eliminate this issue small valued resistance are constructed with four terminals. Two terminals are current terminals and other two are potential terminals.
Figure below shows the construction of low resistance.



Low Resistance

The current is flown through current terminals C_1 and C_2 while the potential drop is measured across potential terminals V_1 and V_2. Hence we can find out the value of resistance under experiment in terms of V and I as indicated in the above figure. This method helps us to exclude the contact resistance due to current terminals and though contact resistance of potential terminals still comes into picture, it is very small fraction of high resistance potential circuit and hence induces negligible error.

The methods employed for measurement of low resistances are:-

- Kelvin’s Double Bridge Method
- Potentiometer Method
- Ducter Ohmmeter.

Kelvin’s Double Bridge

Kelvin’s double bridge is a modification of simple Wheatstone bridge. Figure below shows the circuit diagram of Kelvin’s double bridge.

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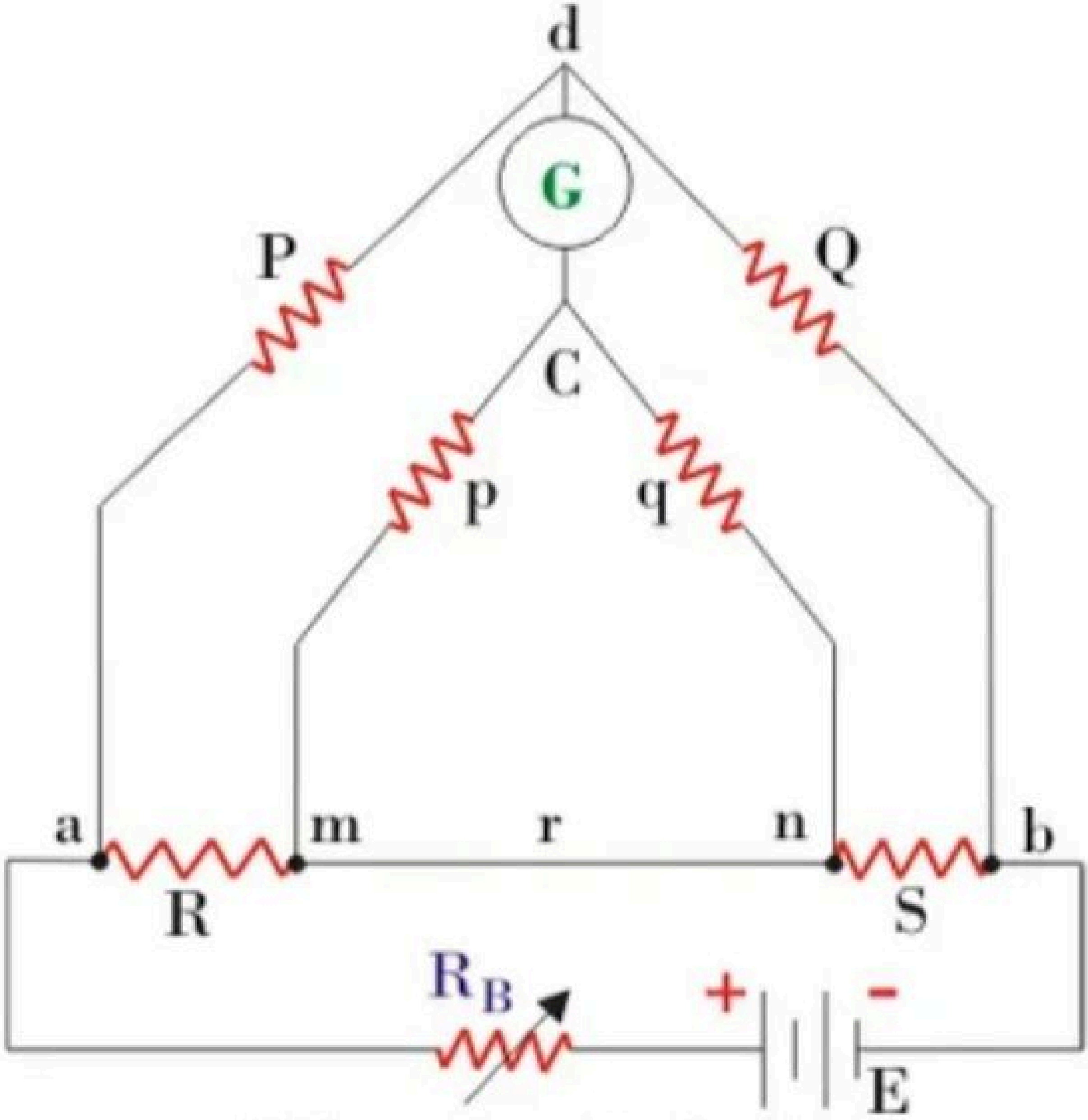

Kelvin Double Bridge

As we can see in the above figure there are two sets of arms, one with resistances P and Q and other with resistances p and q. R is the unknown low resistance and S is a standard resistance. Here r represents the contact resistance between the unknown resistance and the standard resistance, whose effect we need to eliminate. For measurement we make the ratio P/Q equal to p/q and hence a balanced Wheatstone bridge is formed leading to null deflection in the galvanometer. Hence for a balanced bridge we can write

$$E_{ad} = E_{amc}$$

$$Or,\ \left\{\frac{P}{P+Q}\right\} E_{ab} = I\left[R + \frac{p}{p+q}\left\{\frac{r(p+q)}{p+q+r}\right\}\right] \ \ldots\ldots(1)$$

$$Where,\ E_{ab} = I\left[R + S + \frac{p}{p+q}\left\{\frac{r(p+q)}{p+q+r}\right\}\right] \ \ldots\ldots(2)$$

Putting eqn 2 in 1 and solving and using P/Q = p/q, we get-

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

$$E_{ad} = E_{amc}$$

$$Or, \left\{\frac{P}{P+Q}\right\} E_{ab} = I\left[R + \frac{p}{p+q}\left\{\frac{r(p+q)}{p+q+r}\right\}\right] \ldots\ldots(1)$$

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Putting eqn 2 in 1 and solving and using P/Q = p/q, we get-

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

Hence we see that by using balanced double arms we can eliminate the contact resistance completely and hence error due to it. To eliminate another error caused due to thermo-electric emf, we take another reading with battery connection reversed and finally take average of the two readings. This bridge is useful for resistances in range of 0.1μΩ to 1.0 Ω.

Now here we are going to discuss **measurement of low resistance** by Ammeter-Voltmeter Method.

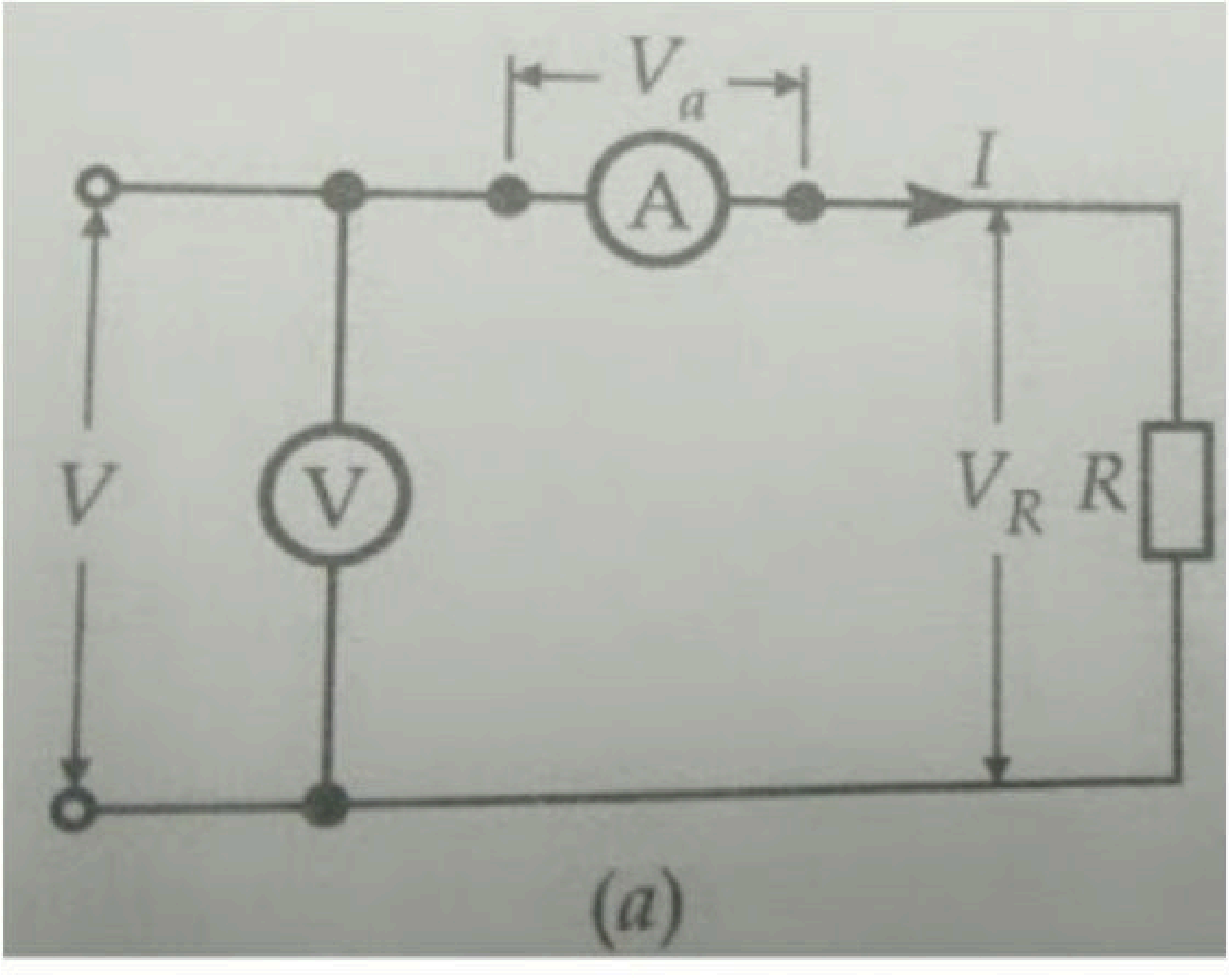
Ammeter-Voltmeter Method :

This **resistance measurement** method is very popular since the instruments required for this test are usually available in the laboratory. The two types of connections employed for ammeter voltmeter method are shown in below figure. In both the cases, is readings of ammeter and voltmeter are taken, then the measured value of resistance is given by :

$$R_m = \frac{voltmeter\ reading}{ammeter\ reading} = \frac{V}{I}$$

The measured value of resistance R_m, would be equal to the true value,R,if the ammeter resistance is zero and the voltmeter resistance is infinite so that the conditions in the circuit are not disturbed. However, in practice this is not possible and hence both the methods give inaccurate results.

Consider circuit (a): In this circuit the ammeter measures the true value of the current through the resistance but the voltmeter does not measure the true voltage across the resistance. The voltmeter indicates the sum of the voltages across the ammeter and the measured resistance.



(a)

$$R_{m1} = \frac{V}{I} = \frac{V_R + V_a}{I} = \frac{IR + IR_a}{I} = R + R_a$$

True value of resistance,

$$R = R_{m1} - R_a$$

$$= R_{m1}\left(1 - \frac{R_a}{R_{m1}}\right)$$

Thus the measured value of resistance is higher than the true value. It is also clear from above that the true value is equal to the measured only if the ammeter resistance, R_a, is zero.

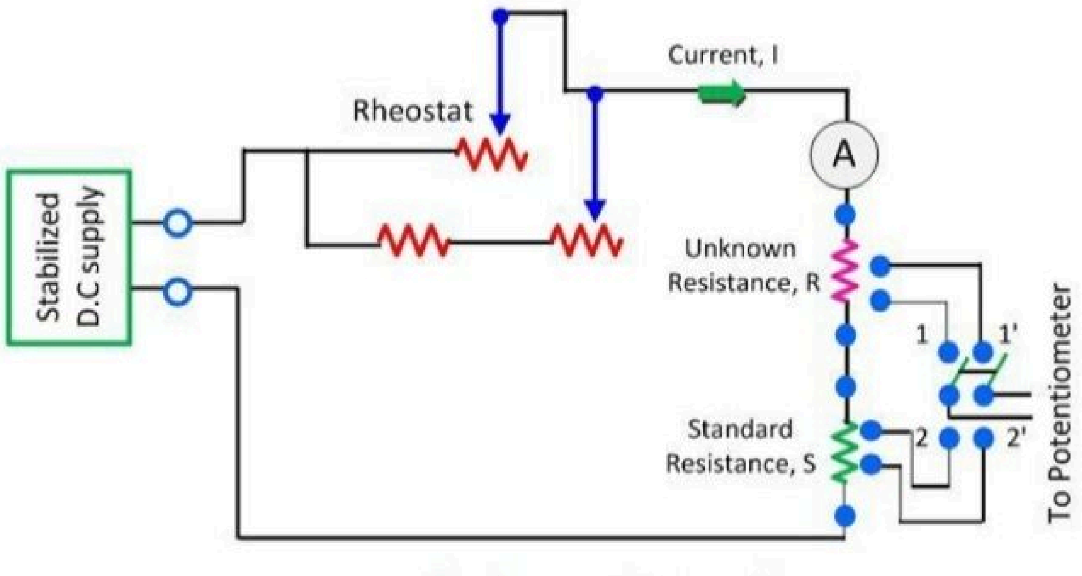
Relative error,

$$E_r = \frac{R_{m1} - R}{R} = \frac{R_a}{R}$$

Measurement of Resistance using Potentiometer

The DC potentiometer method of measurement of resistance is used for measuring the unknown resistance of low value. This can be done by comparing the unknown resistance with the standard resistance. The voltage drop across the known and unknown resistance is measured and by comparison the value of known resistance is determined.

Let understand this with the help of the circuit diagram. The R is the unknown resistance whose value is needed to be measured. The S is the standard resistance from which the value of unknown resistance is compared. The rheostat is used for controlling the magnitude of current into the circuit.



Measurement of Resistance with Potentiometer

The double pole double throw switch is used in the circuit. The switch, when moves to position 1, 1 the unknown resistance connects to the circuit, and when it moves to position 2, 2 the standard resistance connects to the circuit.

Consider that when the switch is in position 1,1 the voltage drop across the unknown resistance is V_r

$$V_R = IR$$

and when it is in 2, 2 the voltage drop across the resistance is V_s

$$V_S = IS$$

On equating the equation (1) and (2), we get

$$\frac{V_R}{V_S} = \frac{IR}{IS}$$

$$\frac{V_R}{V_S} = \frac{R}{S}$$

$$R = \frac{V_R}{V_S}.S$$

The accuracy of unknown resistance depends on the value of standard resistance.

The accuracy of the unknown resistance also depends on the magnitude of the current at the time of the readings. If the magnitude of current remains same, the circuit gives the accurate result. The ammeter is used in the circuit for determining the magnitude of current passing through resistor during the reading.

The magnitude of the current is adjusted in such a way that the voltage drop across the resistance is equal to 1 volt.