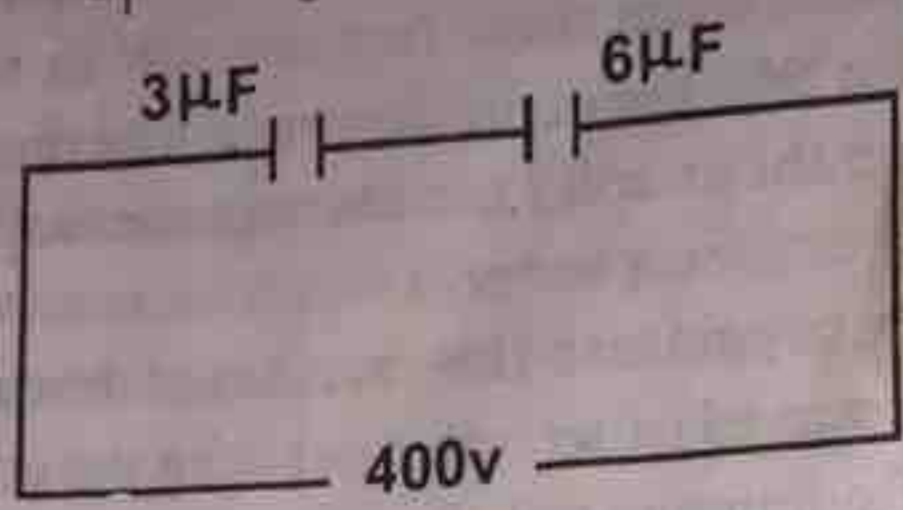
Given $V = 400V$, $C_1 = 3\mu F$, $C_2 = 6\mu F$

Connected in a series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$



$$C_T = \frac{C_1 \times C_2}{C_1 + C_2} = \frac{3 \times 6}{3 + 6}$$

$$= \frac{18}{9} = 2\mu F$$

Since they are in series, the charge must be the same. $Q = CV$

$$= 2 \times 10^{-6} \times 400$$

$$= 0.0008C$$

$Q = 8 \times 10^{-4}C$ which is the charge stored in each capacitor.

$$\text{Energy} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{(8 \times 10^{-4})^2}{3 \times 10^{-6}} = \frac{1}{2} \times \frac{64 \times 10^{-8}}{3 \times 10^{-6}}$$

$$= \frac{32 \times 10^{-8+6}}{3}$$

$$= 10.67 \times 10^{-2}J$$

$$\text{Energy} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{(8 \times 10^{-4})^2}{6 \times 10^{-6}} = \frac{1}{2} \times \frac{64 \times 10^{-8}}{6 \times 10^{-6}}$$

$$= \frac{32 \times 10^{-8+6}}{6}$$

$$= 5.33 \times 10^{-2}J$$

The potential difference across $3\mu F$

$$V = \frac{Q}{C_1} = \frac{8 \times 10^{-4}}{3 \times 10^{-6}}$$

$$= \frac{8 \times 10^{-4\times6}}{3}$$

$$= 2.67 \times 10^{2}$$

$$= 267V$$

the p.d across $6\mu F$

$$V = \frac{Q}{C_2} = \frac{8 \times 10^{-4}}{6 \times 10^{-6}}$$

$$= \frac{8}{6} \times 10^{-4+6}$$

$$= 1.33 \times 10^{2}$$

$$= 133.3V$$

Worked example 7.3

A capacitor has capacitance $10\mu F$ and the charge on the plate is $10^{-5}C$. Calculate the energy stored by the capacitor.

Solution

Given that $C = 10\mu F$

$$Q = 10^{-5}C$$

$$\text{Since energy} = \frac{1}{2}\frac{Q^2}{C}$$

$$= \frac{1}{2} \times \frac{(10^{-5})^2}{10 \times 10^{-6}}$$

$$\frac{1}{2} \times \frac{10^{-10}}{10 \times 10^{-6}} = \frac{1}{20} \times 10^{-10+6}$$

$$= \frac{1}{20} \times 10^{-4}$$

$$= 5 \times 10^{-6}J$$

Worked example 7.4

Calculate the workdone on a capacitor of capacitance of $200\mu F$, when a potential difference of $1000V$ is applied.

Solution

Given that $C = 200\mu F$

$$V = 1000V$$

$$W = ?$$

$$\text{Since workdone} = \tfrac{1}{2}QV$$

$$= \tfrac{1}{2}(CV)V = \tfrac{1}{2}CV^2$$

$$= \tfrac{1}{2} \times 200 \times 10^{-6} \times (1000)^2$$

$$= 100J$$

Revision exercise

1. State how electric charges can be produced.
2. What is an electrostatic induction? Explain using a neutral body.
3. Define a gold leaf electroscope and explain how it works.
4. State two methods of charging a neutral body
5. What is meant by the statement: *The*

8. ELECTRIC CURRENT

8.1 Electric Current

Electric current through a conductor is the rate of flow of charges (electrons). This can also be referred to as the charge that flows per unit time.

The unit of current is ampere (Amp, A). It is denoted by I and is a vector quantity. Electric current is measured with the aid of an ammeter. The continuous flow of current is known as *electricity.*

hence, $I = \frac{Q}{t}$

$\therefore Q = It$

Q = Quantity of charge, t = time.

Worked example 8.1

A 20μc charge flows through a conductor in 10ns. Determine the current flowing in the circuit.

Solution

$Q = 20\mu c = 20 \times 10^{-6}c$

$t = 10ns = 10 \times 10^{-9}s$

$I = \frac{Q}{t} = \frac{20 \times 10^{-6}}{10 \times 10^{-9}}$

$= \frac{20}{10} \times 10^{-6+9}$

$= 2 \times 10^{3}$ A

$= 2KA.$

Effects of electric current

The effects of electric current are:

(i) magnetic effect, e.g. electromagnet

(ii) heating effect, e.g. electric iron or gas cooker

(iii) chemical effect, e.g. charging battery or electroplating.

8.2 Potential Difference

Potential difference is the amount of work done in moving a unit positive charge from a point to another, mostly from a point of lower potential to the point of higher potential. It is denoted by p.d and measured in volts (v) with the aid of a voltmeter.

Thus, $V = \frac{W}{Q}$

$\therefore W = QV$

Worked example 8.2

A 50μc charge flows through a conductor. If the p.d between its ends is 20mV, find the work-done by the charge.

Solution

$Q = 50\mu c = 50 \times 10^{-6}c,$

$V = 20mV = 20 \times 10^{-3}V$

$W = QV$

$= 50 \times 10^{-6} \times 20 \times 10^{-3}$

$= 1000 \times 10^{-9}$

$= 1 \times 10^{-6}J$

$= 1 J$

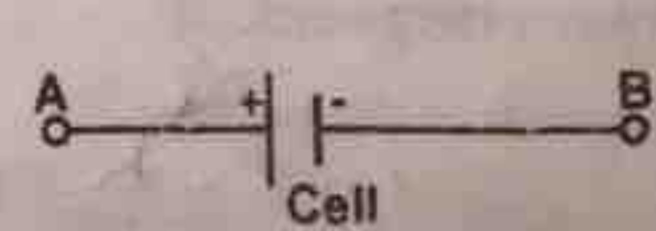
Voltage: Voltage is the potential difference between two points in a given electric circuit.
It is denoted by v and measured in volts (v).

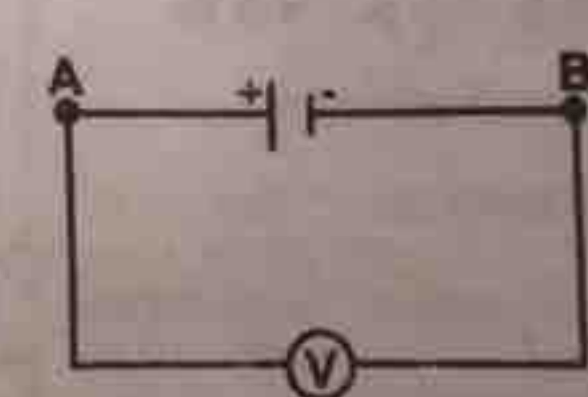
8.3 Electric Circuits

An electrical circuit is a representation of how current moves from the source of the current (e.g. a battery or a cell) through resistors and other devices before entering the source.

There are two important types of electrical circuit, the open and the closed circuit.

Open Circuit: A circuit is said to be open if the source of electricity, such as the battery or the cell, is not connected to any external conductor (or resistance (R)). In this situation any voltmeter or an avometer, connected across the terminal of the cell (or the source) measures the total driving force (electrical pressure) of the cell.





This voltage is what is measured by the voltmeter or avometer connected across the battery.

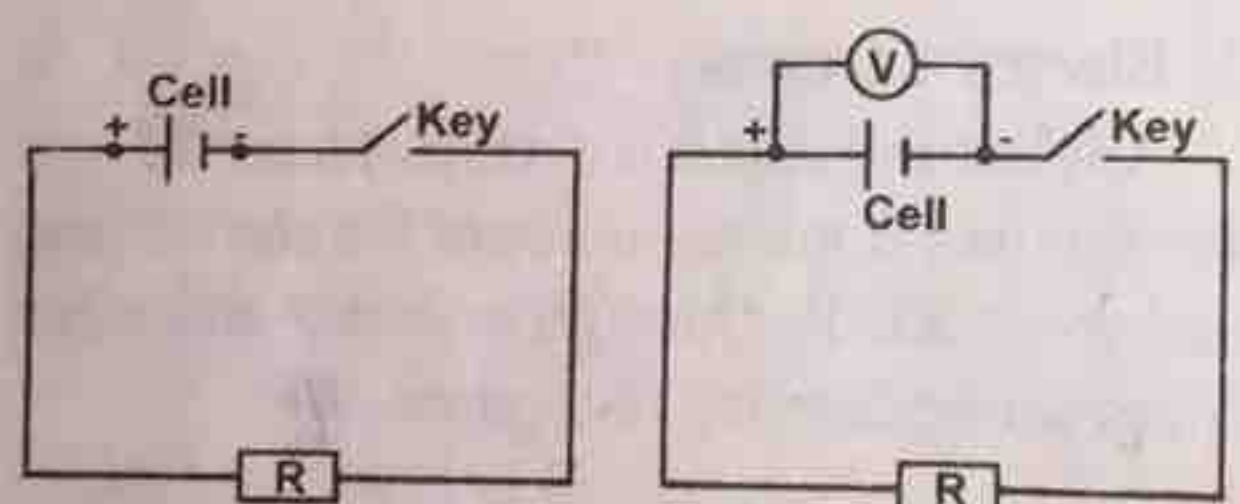
Closed Circuit: A circuit is said to be closed if the source of electricity (e.g. a cell or battery) is connected to an external conductor through which current is passed. The reading of the avometer or voltmeter across the terminals of the cell is a measure of the potential differences or voltage drop, across the external conductor. Here, part of the total driving force of the source is used to drive current through the external resistance and the difference is used to overcome the internal resistance of the battery.

If P.d. across the conductor is V volts and the battery of internal resistance r ohms has an e.m.f. of E volts, the equation

$E = V + Ir$ holds

$E = IR + Ir = I(R + r)$

Where I is the current in the circuit, and Ir is voltage used to overcome the internal resistance of the battery.



Closed circuit

8.4 Differences between Ammeter and Voltmeter.

Ammeter	Voltmeter
1. It has low resistance galvanometer.	It has a high resistance galvanometer.
2. It is connected in a series.	It is connected in parallel between the points.
3. It measures the current of the circuit in ampere.	It measures the voltage between two points in volts.

8.5 Resistance

Resistance is the amount of opposition given to the flow of electric current through a conductor of electricity. It can also be defined as the ratio of voltage to current (electric). Resistance is denoted by R, measured in ohms (Ω)

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

$\therefore V = IR$

Factors of resistance

(i) temperature (ii) cross-sectional area (iii) length of the conductor (iv) resistivity.

Effects of rise in temperature on resistance

The rise in temperature on resistance can be brought about by the following ways:

(i) with pure metals, the resistance increases.

(ii) with non-metals, carbon and semi-conductors the resistance is constant.

(iii) with alloys, the resistance is constant and so standard resistors are made of alloys such as constantan.

Measurement of resistance

The methods of measuring resistance are:

(i) voltmeter-ammeter method
(ii) wheatstone-bridge
(iii) metre-bridge
(iv) potentiometer

8.6 Voltmeter - Ammeter method

In 1826, Simeon Ohms investigated the relationship between voltage (v) and current (I).

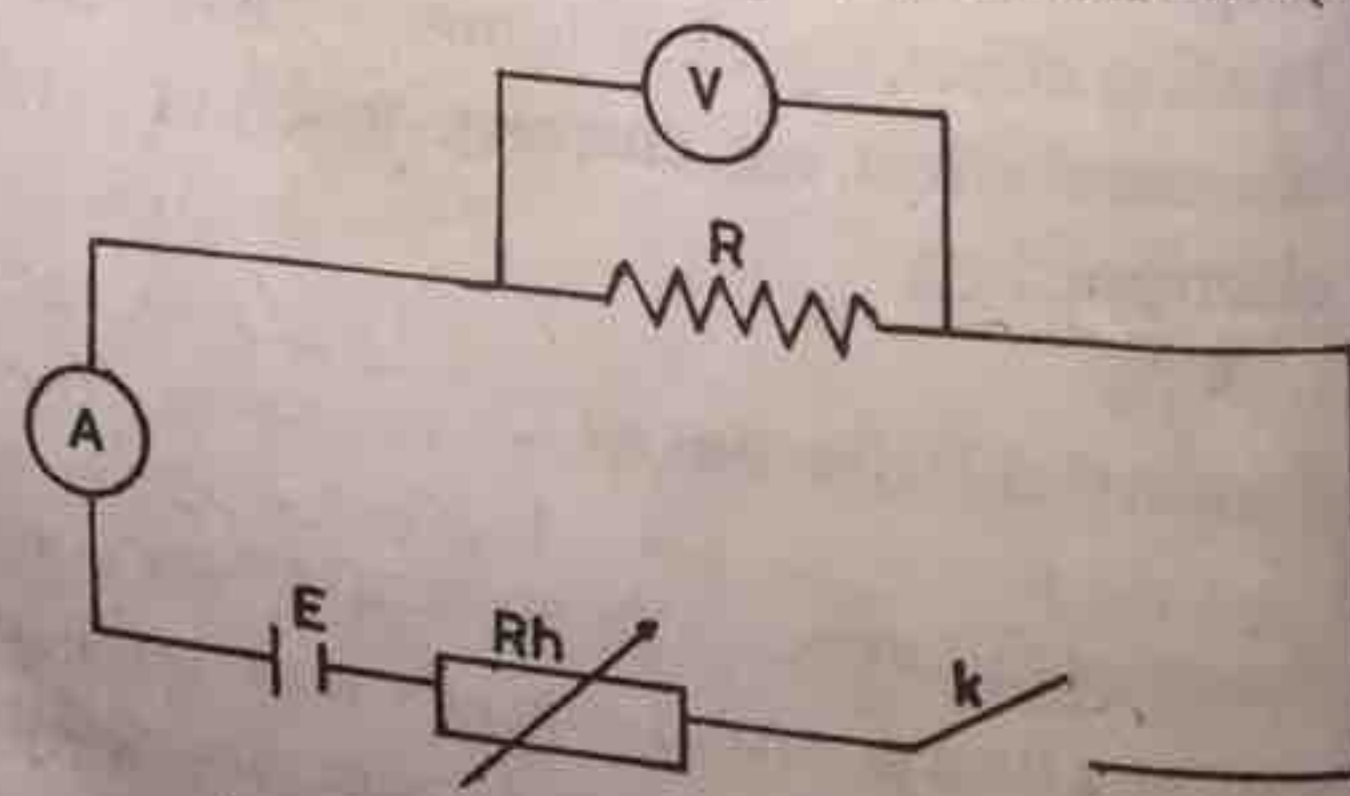


Fig. 8.1 Voltmeter - ammeter method

NB: V = voltmeter, A = ammeter
R = resistance, E = cell or battery
Rh = rheostat, K = key

By adjusting or varying the rheostat, different values of the voltage were obtained as shown in figure 33.1 above.

S/N	I(A)	V(volts)
1	I_1	V_1
2	I_2	V_2
3	:	:
:	:	:
:	:	:
n	n_n	V_n

A graph of V(volts) against I (Amp) was plotted as shown in Figure 8.2 below.

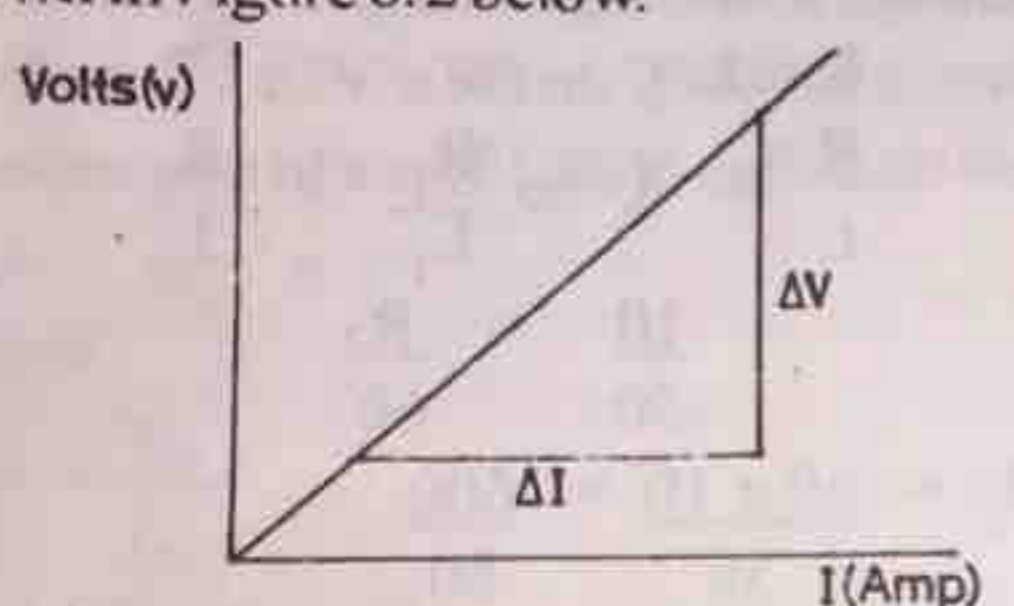


Fig. 8.2 Graph of V against I

Slope/gradient of the graph $= \dfrac{\Delta V}{\Delta I} = $ Constant

This constant is what is regarded or considered as *resistance.*

8.7 Wheatstone-bridge

Wheatstone-bridge is an instrument used in getting accurate resistance. This consists of four resistors of resistance R_1, R_2, R_3 and R_4, connected side by side together to form a close circuit. The current flowing in the circuit divides into two branches. Varying the resistances, a stage is reached when no current flows through the galvanometer placed at the centre indicating zero.

The points B and D are at the same potential difference, as shown in Figure 8.3 below.

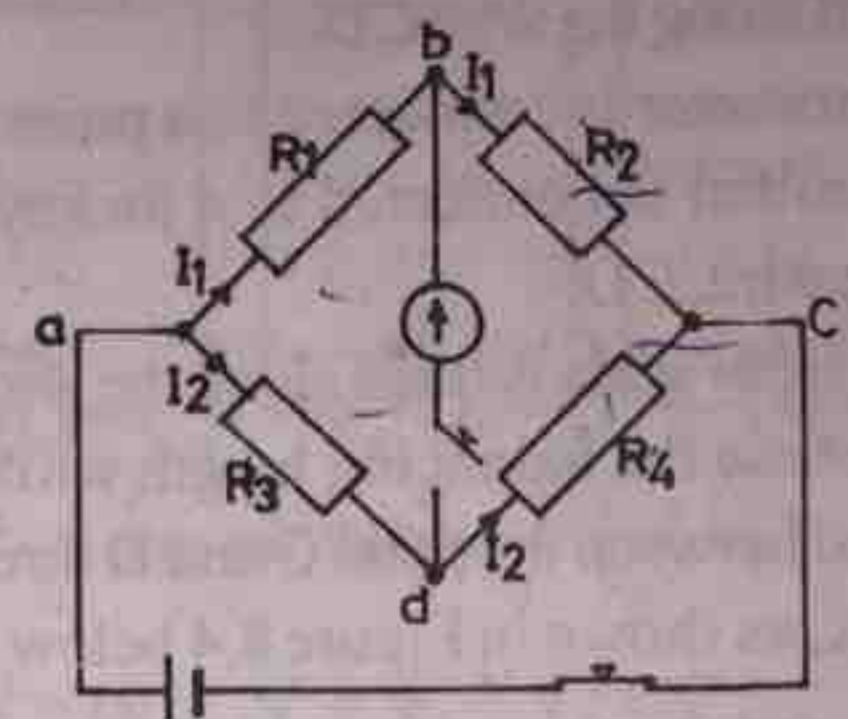


Fig. 8.3 Wheatstone-bridge

$I_1R_1 = I_2R_3$ .... (i)

At the same time, the p.d between A and C.

$I_1R_2 = I_2R_4$ ....(ii)

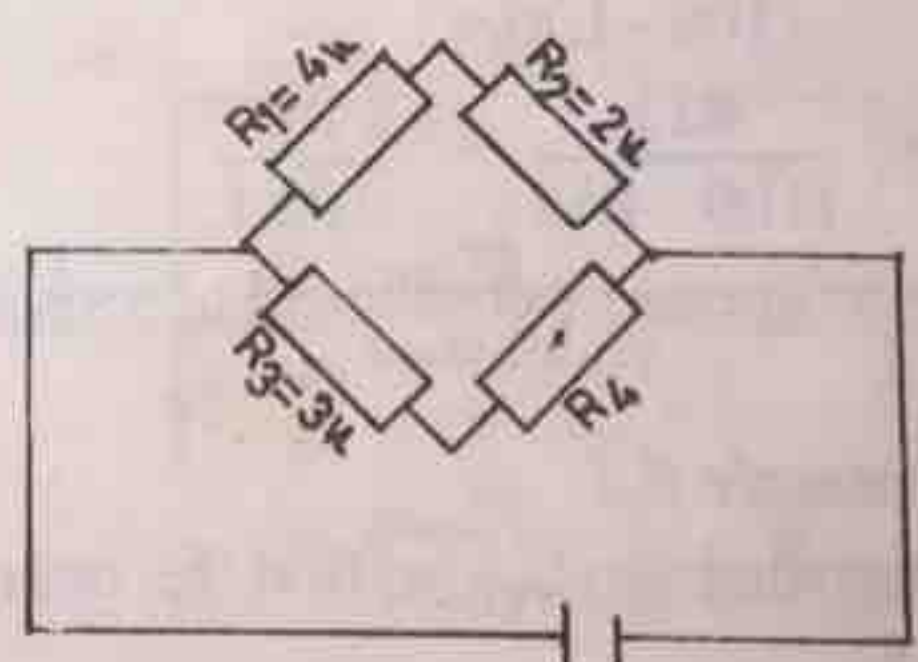
Dividing through the two equations

$$\frac{I_1R_1}{I_1R_2} = \frac{I_2R_3}{I_2R_4}$$

$$\therefore \frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{R_1}{R_3} = \frac{R_2}{R_4}$$

Worked example 8.3

From the diagram below, find the value of the R_4 resistor



Solution

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$\frac{4}{2} = \frac{3}{R_4}$$

$$\therefore R_4 = \frac{3 \times 2}{4} = 1.5\Omega$$

8.8 Metre-bridge

Metre-bridge is a bridge with low temperature coefficient and length, 100cm or 1m. An unknown resistance x and the standard (known) resistance are placed along the wire CD.

A galvanometer is connected to a point and the other terminal is connected to a jockey placed along the wire, CD.

The meter scale is fixed along the wire AC so as to increase the balancing length while cell is connected between the point C and D through the top key, k, as shown in Figure 8.4 below.

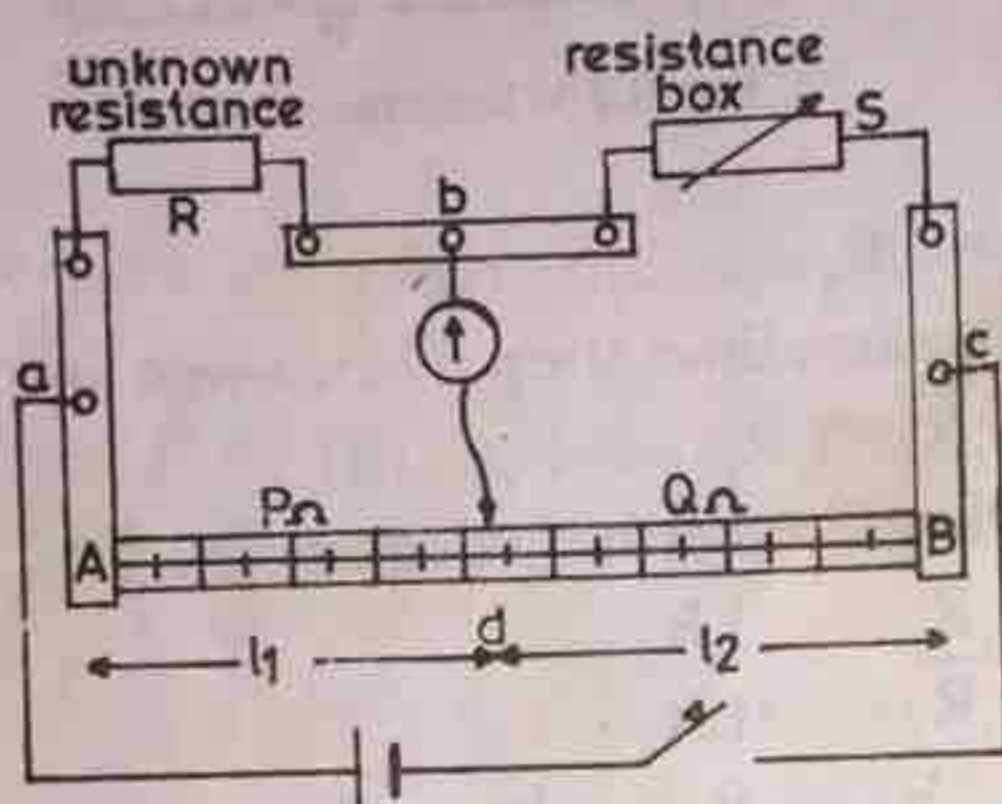


Fig. 8.4 Metre-bridge

Neglecting the resistance of the connected wires and copper.

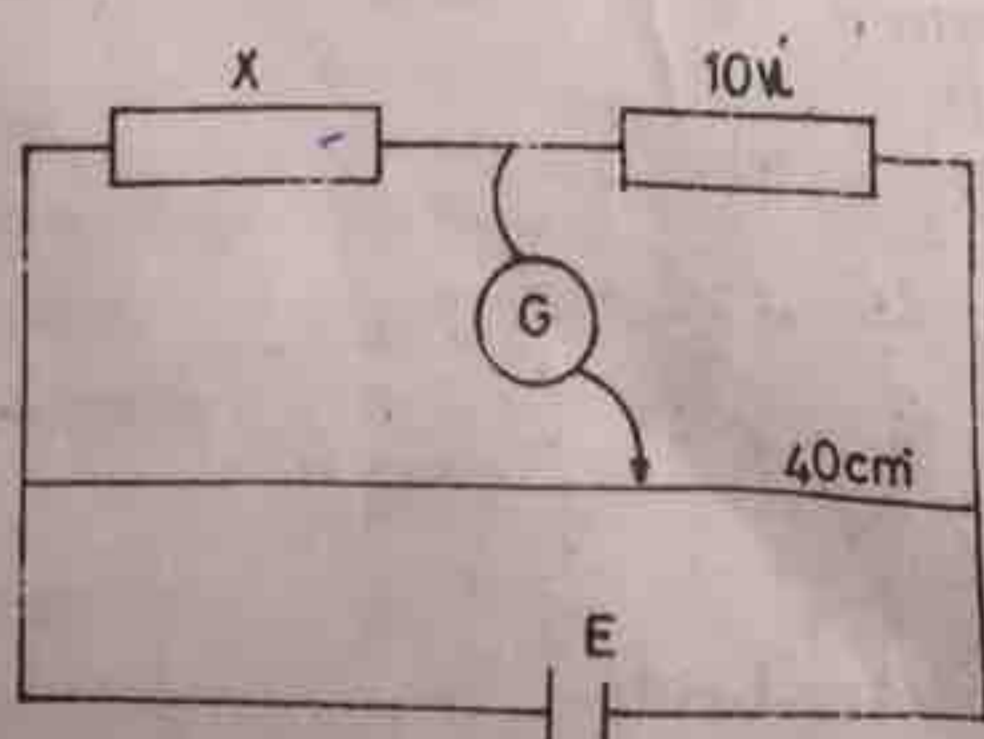
$$\frac{x}{L\alpha} = \frac{R}{(100 - L)\alpha}$$

$$x = \frac{RL\alpha}{(100 - L)\alpha} = \frac{RL}{100\text{-}L}$$

Where α = temperature coefficient of resistance

Worked example 8.4

From the diagram below, find the unknown resistance X.



Solution

$$\frac{X}{R} = \frac{L}{100\text{-}L}$$

$$\frac{X}{10} = \frac{40}{100\text{-}40}$$

$$\frac{X}{10} = \frac{40}{60}$$

$$X = \frac{40 \times 10}{60} = \frac{400}{60}$$

$$x = 6.67\Omega$$

Worked example 8.5

The balance length on a meter-bridge for two resistances P and Q are 50cm and 60cm respectively. If P is 10Ω, calculate the value of Q.

Solution

$$R \propto L$$

$$\frac{R}{L} = K \Rightarrow \frac{R_1}{L_1} = \frac{R_2}{L_2}$$

$$\frac{10}{50} = \frac{R_2}{60}$$

$$R_2 = \frac{60 \times 10}{50} = \frac{600}{50}$$

$$R_2 = 12\Omega$$

8.9 Potentiometer

Potentiometer is a device used to measure potential difference. It consists of uniform wire AB of length usually 100cm (1.0m) stretched on a wooden board by the side of a metre-rule. The wire used is at a low temperature coefficient of resistance.

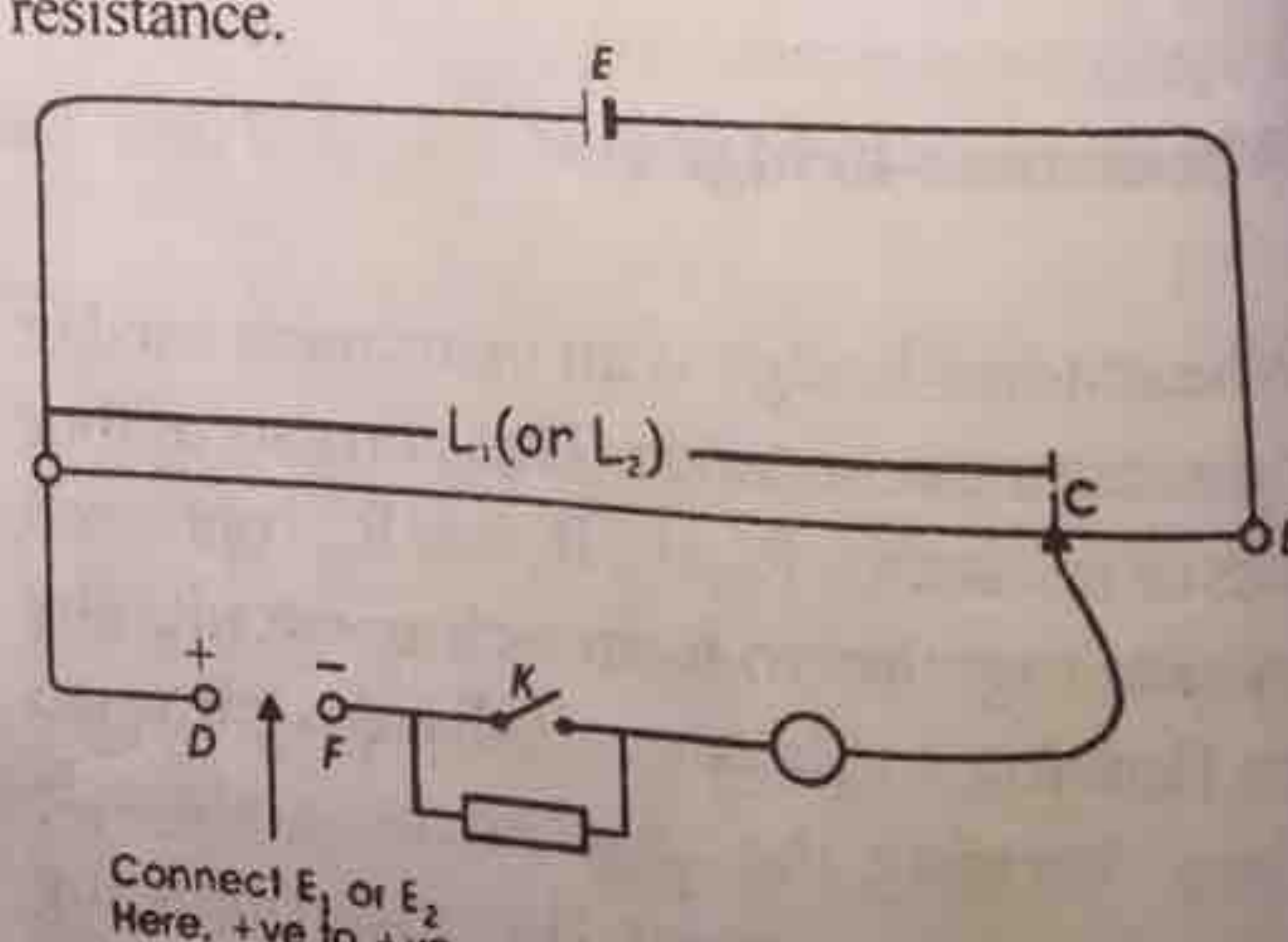


Fig. 8.5 Potentiometer