Kirchoff's network law:-

If the circuit contains more than one source of emf and more than one loop then it is very difficult to apply ohm's law to determine current & voltage in the circuit. To solve such a problem, we use Kirchoff's network law.

First law:

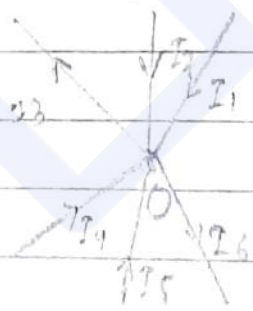
S.Q Kirchoff's current law:-

Statement:

It states that algebric sum of the current meeting at a point in an electrical circuit is equal to zero.

Sign conventions:

The currents moving towards a point are taken as positive & the current moving away from the point are taken as negative.



consider the current I_1, I_2, I_3, I_4, I_5 & I_6 meeting at point O. Here the current I_1, I_2 & I_4 are moving towards the point O. So, they are taken as positive & simplarly the current I_3, I_5 & I_6 are moving away from the points so they are taken as negative.

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A/c to Krichoff's 1st law we have,

$(I_1 + I_2 + (I_3) + I_4 + (-I_5) + (-I_6) = 0$

$I_1 + I_2 + I_4 = I_3 + I_5 + I_6$

Hence, the sum of the current moving towards the point is equal to the sum of the currents moving away from the point.

Second law.

S.Q) Krichoff's Voltage law

Statement:

It states that for any closed loop in an electrical circuit, algebric sum of emf's & p.d is equal to zero.

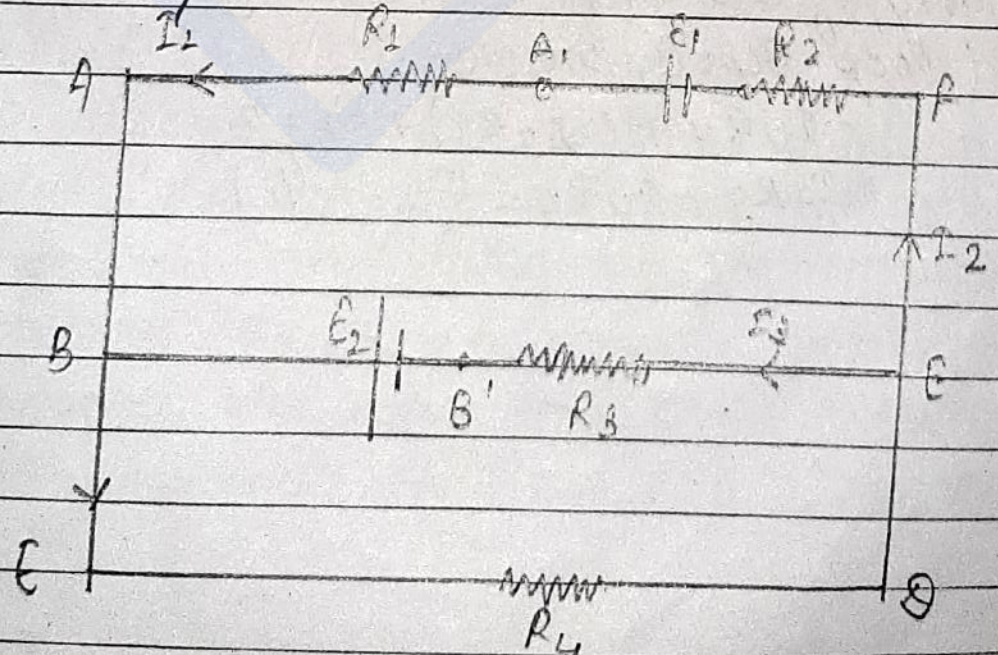
Sign convention.

Rise in potential should be taken as '+ve' & fall in potential should be taken as '-ve'

Rise in PE = (-) to (+) = +ve
= low to high = high

Fall in PE = (+) to (-) = -ve
= high to low = low

Explanation



To explain kirchoff's voltage law, consider a circuit consists of two loops having two sources of Emf 'E_1' & 'E_2' and four resistance R_1, R_2, R_3 & R_4 as shown in fig. above

In the closed loop ABEFA

From A to B, there is no pd. From B to B', the charge has to cross emf 'E_2' and it moves from high potential to low potential. Hence, E_2 is taken as '-ve'. From B' to E, the charge has to cross the pd of R_3 i.e I_3R_3. Here, current moves from E to B' i.e high potential to low potential but the charge moves from low potential to high. So the pd across R_3 is taken to be +ve. From E to F, there is no pd. From F to F', the charge has to move from high to low potential. So I_2R_2 is taken as '-ve'. From F' to A the charge has to move from low to high potential so it is taken as '+ve'. From A' to A, the charge has to move from high potential to low. So I_1R_1 is taken as '-ve'. In closed loop ABEFA,

Hence,

$$-E_2 + I_3R_3 + (-I_2R_2) + E_1(-I_1R_1) = 0$$

$$\Rightarrow I_3R_3 - I_2R_2 - I_1R_1 = E_2 - E_1 \quad \text{--- (i)}$$

Similarly, if we apply the same sign convection in the closed loop BCDEB, we get.

$$-I_4R_4 + (-I_3R_3) + E_2 = 0$$

$$I_3R_3 + I_4R_4 = E_2 \quad \text{--- (ii)}$$

Wheatstone Bridge (Circuit draw of balanced condition 2 marks (2077))

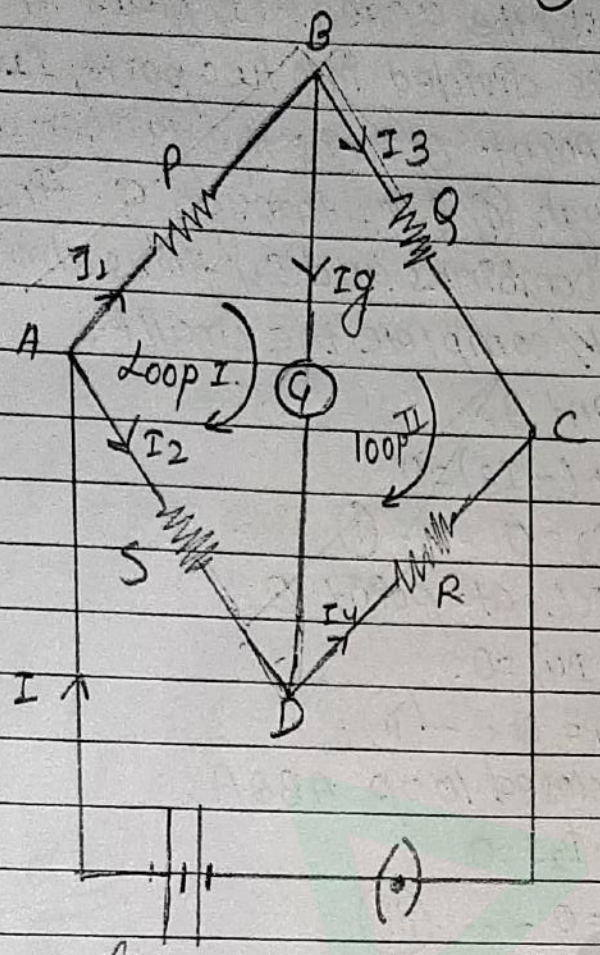


fig:- Wheatstone Bridge.

Wheatstone Bridge is an accurate device which is used to measure unknown resistance. It consists of 4 resistance P, Q, R & S which are arranged in the form of quilateral. Here, P & Q is called ratio arms, R is variable resistance & S is unknown resistance which is to be measured. Between point B & D, a highly ~~resistance which is to be measured. Between point~~ sensitive galvonometer is connected & between A & C, a battery of emf (ε) and key (k) is connected. the value of R is so adjusted that galvonometer shows null deflection ($I_g = 0$). In this condition we have

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

This is called balanced condition of resistance Bridge.

Proof:-

When key is closed, the current (I) flows in the circuit & at point A, it is divided into two parts; I_1 through P & I_2 through S. At point B, I_1 is the further divided into two parts, I_g through (G) & I_3 through Q. Finally, at point D, I_2 & I_g combines and I_4 flows through R. In this way, current complete the circuit.

Applying KCL at point B,

$$I_1 + (-I_g) + (-I_3) = 0$$

$$\Rightarrow I_1 - I_g - I_3 = 0 \quad \cdots \text{(i)}$$

Similarly applying KCL at point D

$$I_2 + I_g + (-I_4) = 0.$$

$$\Rightarrow I_2 + I_g - I_4 = 0 \quad \text{— (ii)}$$

Applying KVL in the closed loop ABDA,

$$-I_1 P + (-I_g G) + I_2 S = 0$$

$$-I_1 P - I_g G + I_2 S = 0 \quad \cdots \text{(iii)}$$

Similarly, applying KVL in the closed loop BCDB

$$-I_3 Q + I_4 R + I_g G = 0 \quad \text{— (iv)}$$

The value of R is so adjusted such that the galvonometer shows null deflection. At null deflection condition no current flows through (G) i.e $I_g = 0$.

From eqn (i), $I_1 - I_3 = I_g$

$$I_1 - I_3 = 0$$

$$\Rightarrow I_1 = I_3 \quad \text{— (v)}$$

From eqn (ii), $I_2 - I_4 = 0$

$$I_2 = I_4 \quad \text{— (vi)}$$

From eqn (iii) $-I_1 P + I_2 S = 0$

$\Rightarrow \cancel{I_1 P = I_2 S} \Rightarrow I_1 P = I_2 S$ — (vii)

From eqn (iv) $\cancel{-I_3 Q + I_4 R + I_2 S = 0}$

$-I_3 Q + I_4 R + I_g G = 0$

$\Rightarrow I_3 Q = I_4 R$ — (viii)

Dividing eqn (vii) by (viii)

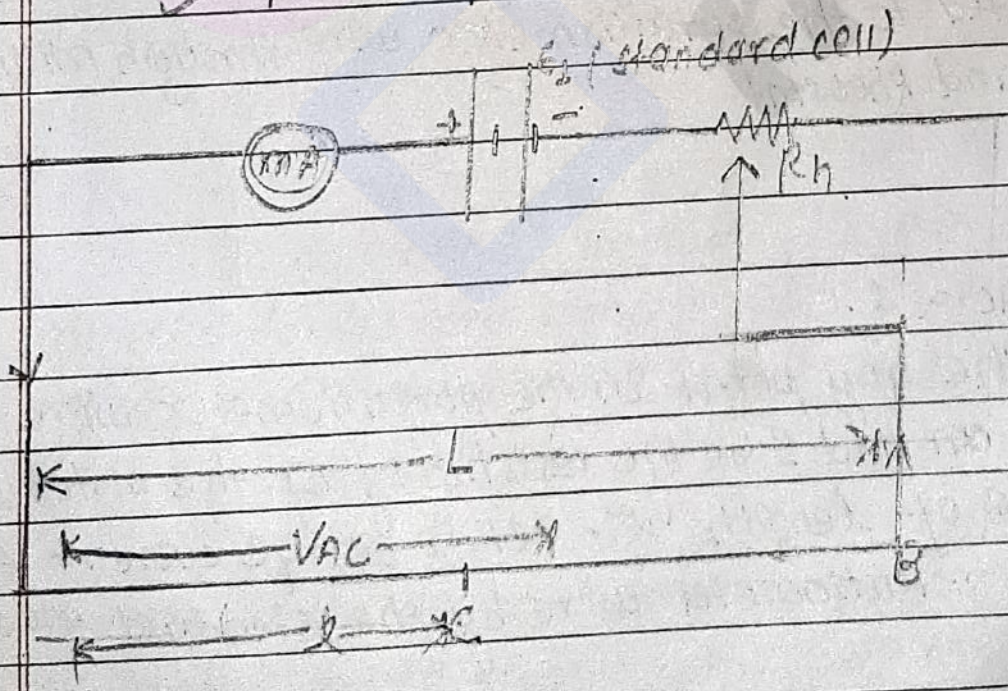
we get,

$$\frac{I_1 P}{I_3 Q} = \frac{I_2 S}{I_4 R}$$

$$\therefore \frac{P}{Q} = \frac{S}{R} \quad \text{— (ix)} \quad [\because I_1 = I_3 \ \& \ I_2 = I_4]$$

Prooved.

Potentiometer



Ans :- Potentiometer

from eqn (iii) $-I_1 P + I_2 S = 0$

$$\Rightarrow \cancel{I_1 P = I_2 S} \Rightarrow I_1 P = I_2 S \quad \text{— (vii)}$$

from eqn (iv) $\cancel{-I_3 Q + I_4 R + I_2 S = 0}$

$$-I_3 Q + I_4 R + I_g G = 0$$

$$\Rightarrow I_3 Q = I_4 R \quad \text{— (viii)}$$

Dividing eqn (vii) by (viii)
we get,

$$\frac{I_1 P}{I_3 Q} = \frac{I_2 S}{I_4 R}$$

$$\therefore \frac{P}{Q} = \frac{S}{R} \quad \text{— (ix)} \quad [\because I_1 = I_3 \ \& \ I_2 = I_4]$$

Prooved

Potentiometer

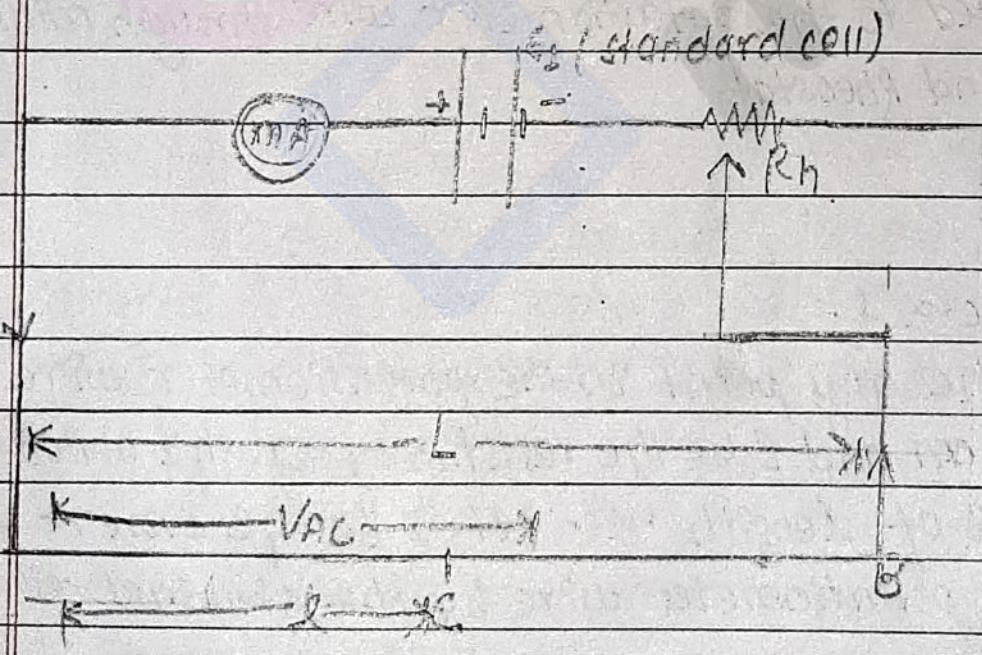


fig :- Potentiometer

A potentiometer is an accurate device which is used to measure emf and p.d across the resistors.

Imp

Principal of Potentiometer

If a steady current is passed through the wire of uniform cross sectional area then pd across any section of the wire is directly proportional to the length of that section.

Let ~~VAC~~ V_{AC} be the pd across the section AC of the wire such that $AC = l$ cm. Then acc to principle of potentiometer

$$V_{AC} \propto l.$$

Construction:

It consist of wire AB of length 'α' having uniform crosssectional area and which is attached over a wooden board. A cell of emf ($\mathcal{E}'$) called standard cell is connected to the potentiometer wire through milliometer (mA) and Rheostat.

Proof:-

$$V_{AC} \propto l.$$

Let C be the any point in the potentiometer wire such that $AC = l$ cm and ρ be the resistivity of the material of the wire AB of length 'α'. Let I be the current flowing in the potentiometer wire by the standard cell of emf ($\mathcal{E}'$)

Then,

$$R_{AB} = \frac{\rho L}{A} \quad \ldots (1)$$

Total current in the circuit $(I) = \frac{\mathcal{E}'}{R_{AB}}$ $\left(\frac{\text{total emf}}{\text{total resistance}}\right)$

$= \frac{E'}{\frac{\rho L}{A}}$ (from (i))

$\Rightarrow \frac{E' A}{\rho L}$ — (ii)

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~~Also resistance of the wire of section AC is $R_{AC} = \frac{\rho l}{A}$~~

$\therefore$ Pd across the section AC is,

$$V_{AC} = I R_{AC}$$

$$\Rightarrow V_{AC} = \frac{E' A}{\rho L} \times \frac{\rho l}{A}$$

$$\Rightarrow V_{AC} = \left(\frac{E'}{L}\right) l$$

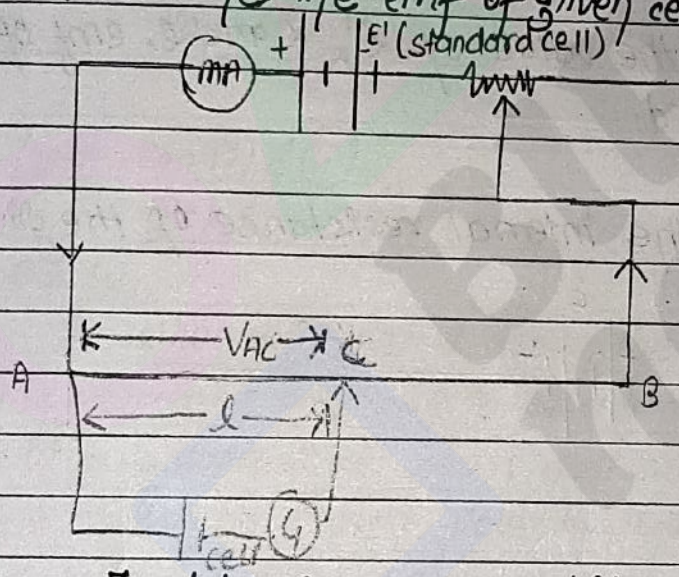
$$V_{AC} = k l$$

where $k = E'$ is constant called constant of potentiometer wire

$\therefore V_{AC} \propto l$ which is called principle of potentiometer

Application of potentiometer

I. To determine the emf of given cell.



To determine the emf 'E' of the given cell, the cell is connected to the potentiometer wire AB as shown in figure where G is galvonometer & J is jockey or slider which can be slide over the wire AB.

If jockey touches the wire AB at point A, the galvonometer shows the deflection towards right & if it touches left it means there exists a point betn the wire A and B at which galvonometer shows null deflection. Let C be the point at which galvonometer shows null deflection such that, AC = l cm. At null deflection condition no current flows through galv

onometer and hence through the cell of emf 'E'. Hence, the pd across the section AC i.e V_{AC} gives the emf of a cell.

$$E = V_{AC} \quad -(i)$$

Acc to principle of potentiometer

$$V_{AC} = kl \quad \text{where } k = \frac{E'}{L}$$

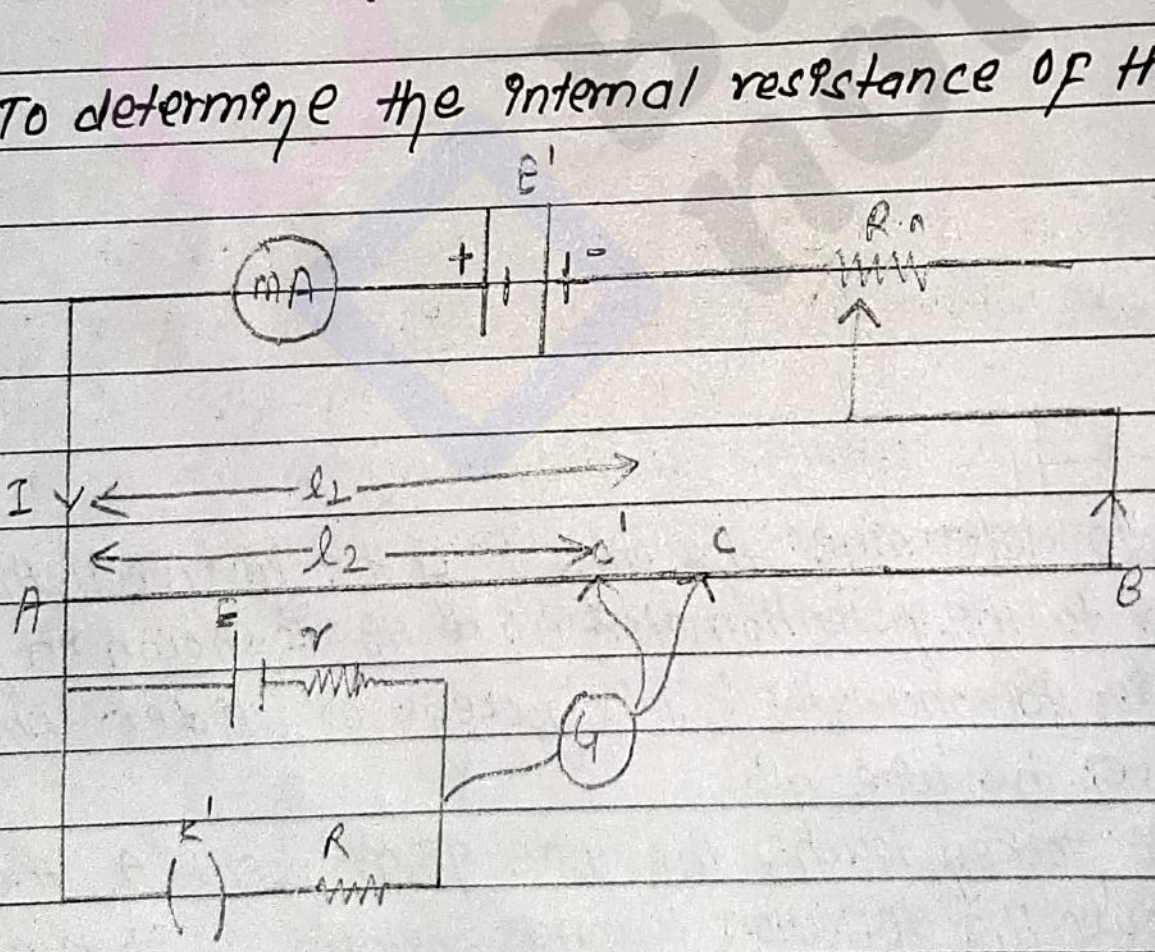
$$\therefore V_{AC} = \left(\frac{E'}{L}\right) l \quad -(ii)$$

From eqn (i) & (ii)

$$E = \left(\frac{E'}{L}\right) l \quad -(iii)$$

By knowing the value of E', L and l, emf of a cell can be determined.

To determine the internal resistance of the given cell.



To determine the internal resistance of the given c
of emf (E) along with resistance (R) is connected to the pot
ntiometer as shown in fig above. Here, AB is potentiomet
wire, E is emf of standard cell, J is jockey (G) is galvonom
ter and 'K' is key. To determine the internal resistance of the
given cell, following procedures are adopted.

When K is opened, the posn of null deflection in the galvonometer is to be determined. Let c be the point at which galvonometer shows null deflection such that, AC = l_1 cm. Here the pd betn two points A & C gives the emf 'E' of the cell i.e

$V_{AC} = E$ ---- (i)

A/c to principle of potentiometer

$V_{AC} = k l_1$ ..... (ii) where $k = \left(\frac{E}{L}\right)$

From eqn (i) & (ii)

$E = k l_1$ ... (iii)

Similarly,

When K is closed again the posn of null deflection in the galvonometer is to be determined. Let (c') be the posn at which galvonometer shows null deflection such that, AC' = l_2 cm. Here no current flows through the galvonometer but current flow through the cell of emf (E) because the resistance (R) is introduced. So the pd betn two points A and C' gives the terminal pd i.e

$V_{AC'} = V$ --- (iv)

But, $V_{AC'} = k l_2$ ... (v)

From eqn (iv) & (v)

$V = k l_2$ --- (vi)

We know, circuit formula

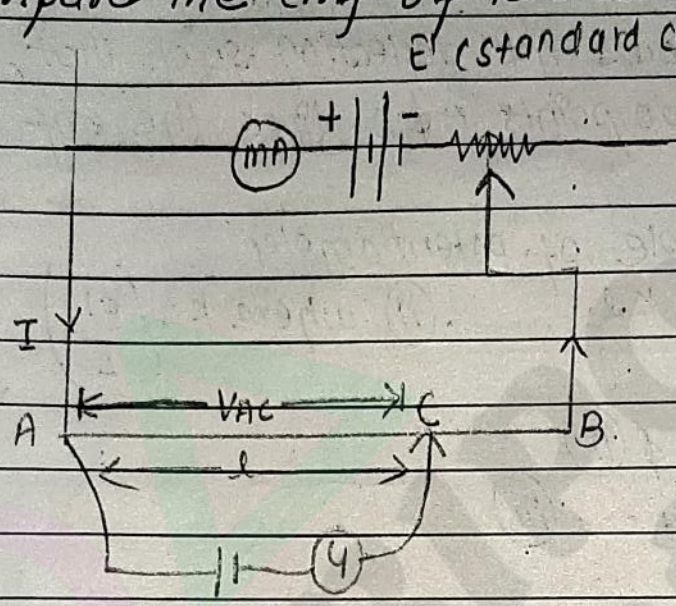
$r = \left(\frac{E}{V} - 1\right) R$

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

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

By knowing the value of l_1, l_2 & R, internal resistance of the cell can be determined.

III. To compare the emf of two cells.



To compare the emf of two cells, consider two cells of emf 'E_1' & 'E_2' and they are connected with potentiometer. An anode of cell 'E_1' and 'E_2' are connected to a point A of the potentiometer of wire 'AB' and cathodes of the cells are connected to the two side screws of two way key. At the middle of two way key, a highly sensitive galvonometer along with jockey is connected.

To compare the emf of two cells initially the plug is inserted in k_1 position. In doing so, the cell of emf 'E_1' comes into the cell circuit and position of null deflection in the galvonometer is to be determined. Let C be the point at which galvonometer shows null deflection such that AC = l_1 cm. Here, the pd betn the poi

nts A and C gives the emf E_1 of the cell i.e.

$$V_{AC} = E_1 \quad \ldots (i)$$

But, $V_{AC} = k l_1 \quad \ldots (ii)$ where $k = \left(\frac{E'}{L}\right)$

From eqn (i) & (ii)

$$E_1 = k l_1 \quad \ldots (iii)$$

Now,

The plug is taken out from K_1 position and inserted into K_2 position. In doing the cell of emf 'E_2' comes in to the cell circuit and position of null deflection is to be determined. Let D be the point at which galvanometer shows null deflection such that $AD = l_2$ cm. Here, the pd betn the point A and D gives the emf 'E_2' of the cell. i.e

$$V_{AD} = E_2 \quad \ldots (iv)$$

But, $V_{AD} = k l_2 \quad \ldots (v)$

From eqn (i) & (ii)

$$E_2 = k l_2 \quad \ldots (vi)$$

Dividing equation (iii) by (vi)

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} \quad \ldots (iii)$$

Knowing the value of l_1 & l_2 we can compare the emf of two cell.

Thermoelectric series

Seeback found that the value of thermo emf produced in a thermocouple depends upon nature of thermocouple used & tempn difference betn two junctions. He arranged different metals in series on the basis of their electron density such that any two of which can be used to form a thermocouple.

Hence, arrangement of metals in series on the basis of their electron density such that any two of which can be used to form a thermocouple is called thermoelectric series. A/c to seebeck thermoelectric series is given as

Sb, As, Fe, Zn, Ag, Au, Mo, Cr, Sn, Pb, Hg, Mn, Cu Pt, Co, Ni, Bi. It is formed that more the gap betn two metals in thermoelectric series, more will be the thermo emf becomes there will be large difference in electron density betn two metals. Due to these reason, Sb-Bi thermocouple is preffered than Fe-Cu thermocouple.

Meter - Bridge

Meter Bridge is an accurate device which is used to measure unknown resistance. It is based on principle of wheatstone Bridge. It consist of a wire AC of 1m long having uniform cross sectional area stretched over a wooden board provided with meter scale. At point A & C, two L-shaped copper strips are connected & at the middle.

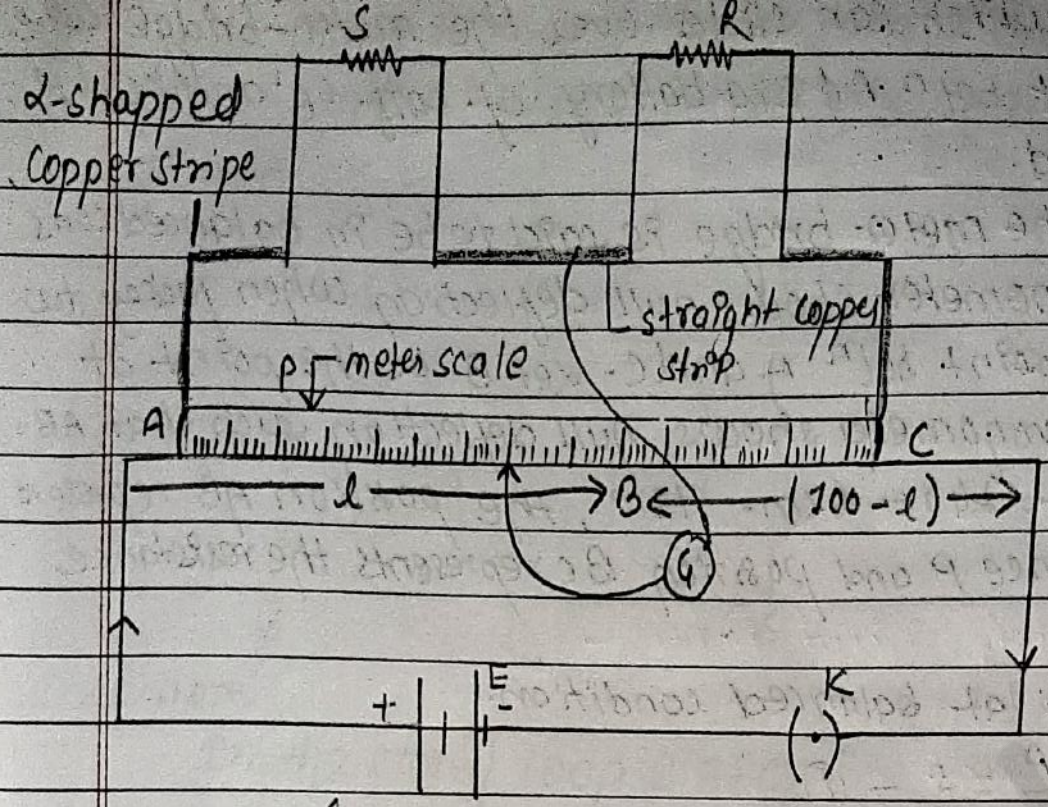


fig ⓐ Meter Bridge.

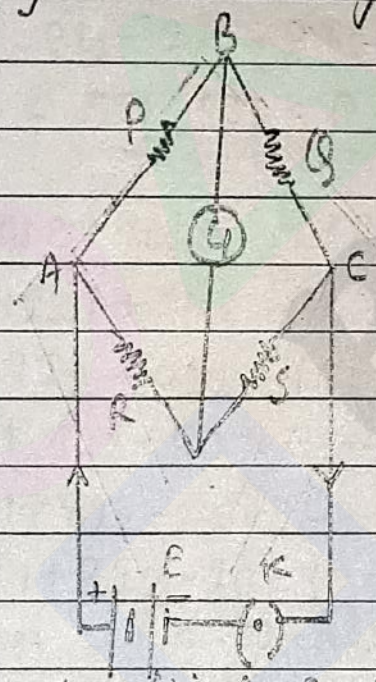


fig (b) equivalent circuit of fig (a)

— Of them a straight copper strip is connected. In gaped betn α-shaped copper strip & straight copper straight, a variable resistance 'R' and unknown resistance 'S' is connected. At the middle of straight copper strip, a highly ~~sent~~ sensitive galvanometer along with jockey is

connected which can slide over the meter-bridge wire. In the point betn A & C, a battery of emf 'ε' and key 'K' is connected.

The meter bridge is said to be in balanced cons if a galvanometer shows null deflection when jockey touches any point betn A and C. Let B be the point at which galvanometer shows null deflection such that AB = l cm & BC = 100 − l cm. Here, the position AB represents the resistance P and position BC represents the resistance Q.

we know at balanced condition.

$$\frac{P}{Q} = \frac{S}{R} \quad \text{--- (i)}$$

Also,

$P \propto l$

$Q \propto 100 - l$

$$\therefore \frac{P}{Q} = \frac{l}{100 - l} \quad \text{--- (ii)}$$

From eqn (i) & (ii)

$$\frac{S}{R} = \frac{l}{100 - l}$$

$$\boxed{S = R \times \left(\frac{l}{100 - l}\right)}$$

knowing the value of R and l the value of unknown resistance S can be determined.

Aaun? = (+)
Jan? = (−)

mayo = (−)
malena = (+)

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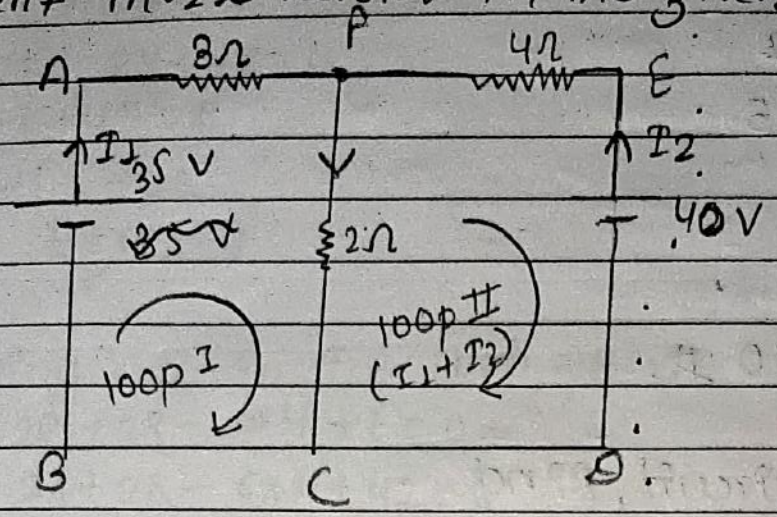
(*) Using Kirchoff's law of current and voltage, find the current in 2Ω resistor in the given current.



Here,

In the closed loop BAFCB

$+35+(-3\times I_1)+(-2\times(I_1+I_2)=0$

or, $35-3I_1-2I_1-2I_2=0$

or, $35-5I_1-2I_2=0$ —— (i)

In closed loop CFEDC

$2(I_1+I_2)+4I_2-40=0$

$2I_1+2I_2+4I_2-40=0$

$2I_1+6I_2-40=0$ —— (ii)

or, $2(I_1+3I_2-20)=0$

$I_1+3I_2-20=0$ —— (iii)

From (i) $I_1=20-3I_2$ —— (iii)

or, $35-5I_1-2I_2=0$

or, $35-5(20-3I_2)-2I_2=0$

or, $35-100+15I_2-2I_2=0$

or, $-65+13I_2=0$

or, $13I_2=65$

$I_2=65/13$

$\therefore I_2=5.$

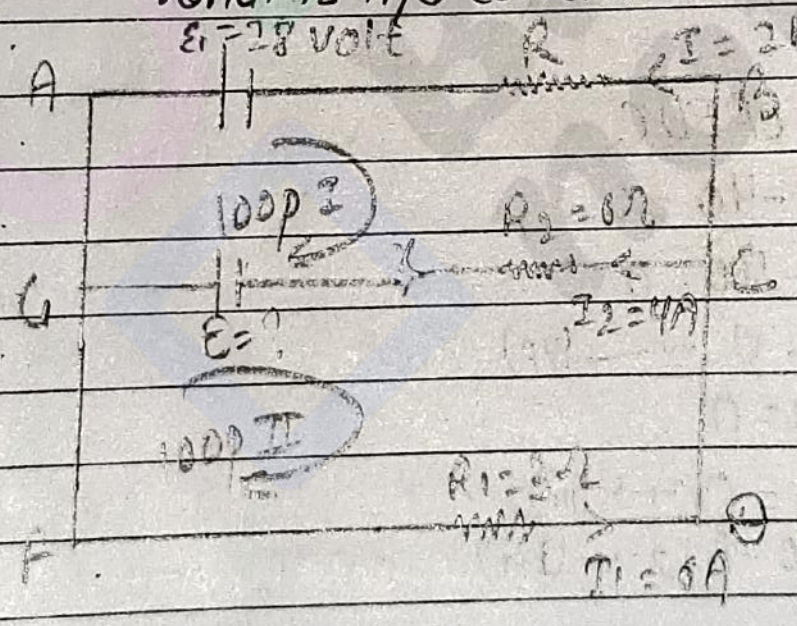
Putting value of I_2 in eqn (iii)

$$I_1 = 20 - 3I_2$$
$$= 20 - 3 \times 5$$
$$= 20 - 15$$
$$= 5$$

Now

$$I_1 + I_2 = 5 + 5 = 10\ A$$

(2) In the given circuit, find
(a) the current in resistor R.
(b) Unknown emf (ε).
(c) Resistance (R)
(d) If the current is broken at point n. what is the current in the resistor R?



Here,

(i) Applying KCL at point C.

$$6 - 4 - I = 0.$$
$$2 - I = 0$$
$$I = 2A.$$

(iii) Applying KCL in the loop. GCDFG.

$-E+6\times4+3\times6=0$

$-E+24+18=0$

$-E+42=0$

$+E=+42$

$E=42\ V$.

(iii) Applying KCL in the loop ABCGA.

$-28+2R-6\times4+E=0$

$-28+2R-6\times4+42=0$

$-28+2R-24+42=0$

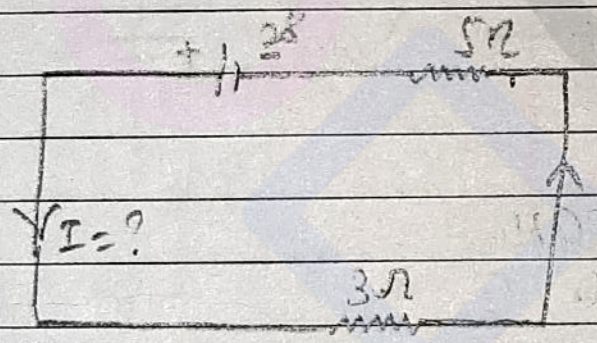
$-10+2R=0$

$2R=10$

$R=10/2$

$R=5\Omega$

(iv) If circuit is broken at point 7 then circuit becomes



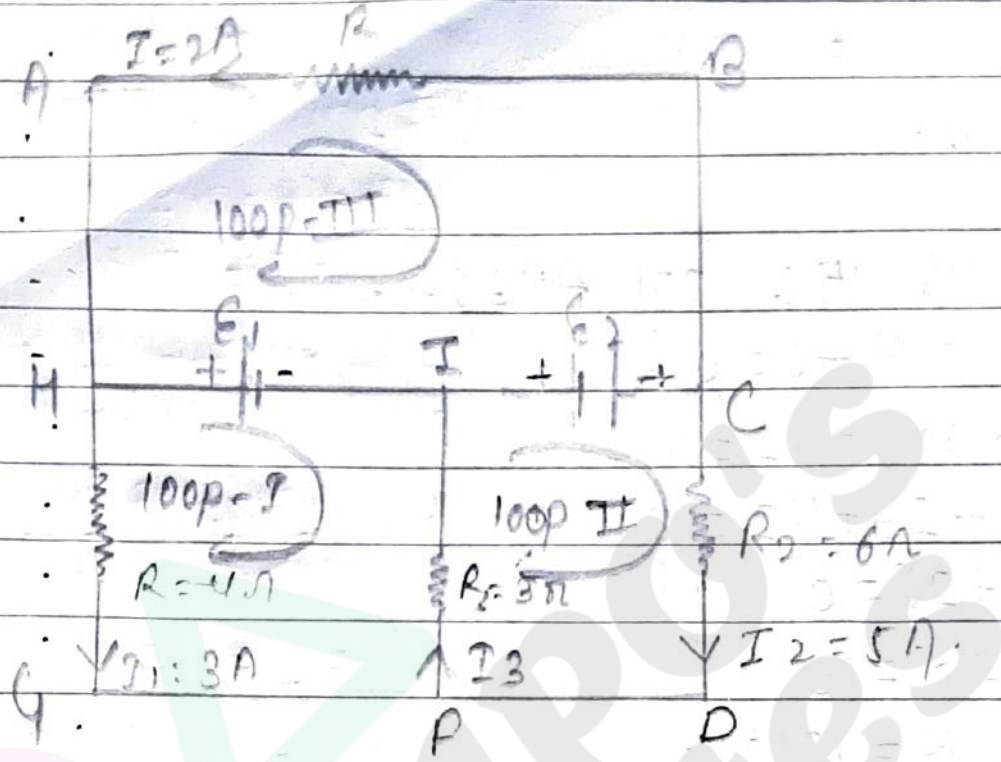
Here,

$I=\frac{\varepsilon}{R}\left(\frac{emf}{TR}\right)$

$=\frac{28}{8}$

$=3.5\ A$.

(3) In the circuit find.
(a) the current in 3 Ω resistor.
(b) the unknown emf ε_1 and ε_2.
(c) the resistor R.



(i) Applying KCL at point F

$3A + 5A - I3 = 0$

$8A - I3 = 0$

$+I3 = +8A$

$I3 = 8A$

(ii) In the closed loop HIFGH.

$-\varepsilon_1 + 3\times8 + 4\times3 = 0$

$-\varepsilon_1 + 24 + 12 = 0$

$-\varepsilon_1 + 36 = 0$

$+\varepsilon_1 = +36$

$\varepsilon_1 = 36$

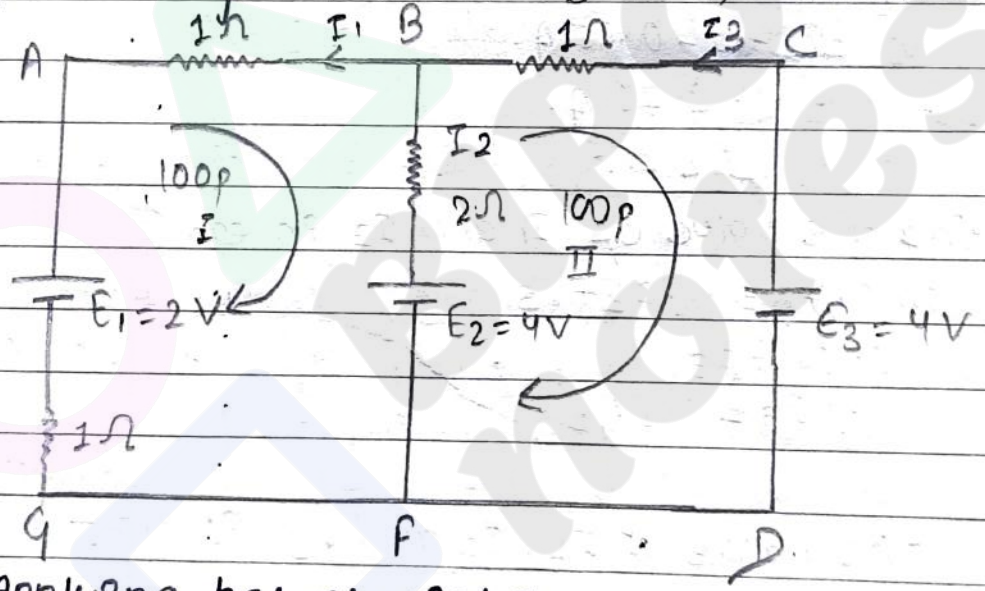
(iii) In the closed loop ICDFI.

$$\mathcal{E}_2 - 6\times5 - 8\times3 = 0$$
$$\mathcal{E}_2 - 30 - 24 = 0$$
$$\mathcal{E}_2 - 54 = 0$$
$$\mathcal{E}_2 = 54.$$

(iii) In the closed loop ABCHA.

$$2R - 54 + 36 = 0.$$
$$2R - 18 = 0.$$
$$2R = 18.$$
$$R = 18/2.$$
$$R = 9\Omega \text{ Ans.}$$

4. Find the value of I_1, I_2 and I_3 in the circuits.



Applying KCL at point B,

$$-I_1 + I_2 + I_3 = 0$$
$$\therefore I_1 = I_2 + I_3 \quad \text{— (i)}$$

Applying KVL in the closed ~~loop~~ loop ABFGA.

$$\text{or, } 1\times I_1 + I_2\times 2 - 4 + I\times I_1 + 2 = 0.$$
$$\text{or, } I_1 + 2I_2 - 4 + I_1 + I_2 = 0$$
$$\text{or, } 2I_1 + 2I_2 = 2$$
$$\text{or, } 2(I_1 + I_2) = 2$$
$$\therefore I_1 + I_2 = 1 \quad \text{— (ii)}$$

Applying KVL in the closed loop BCDEFB.

$$1 \times I_3 - \cancel{4} + \cancel{4} - 2 \times I_2 = 0$$

$$I_3 = 2I_2 \quad \text{--- (iii)}$$

From eqn (i) and (iii)

$$I_1 = I_2 + 2I_2$$

$$\therefore I_1 = 3I_2 \quad \text{-- (iv)}$$

From (ii) and (iv) we get

or, $3I_2 + I_2 = 1$.

$$\therefore I_2 = \frac{1}{4} = 0.25\ A.$$

Putting value of I_2 in eqn (ii)

$$I_1 = 1 - 0.25\ A.$$

$$= 0.75\ A.$$

putting the value of I_1 and I_2 in eqn (i)

or, $0.75 = 0.25 + I_3$

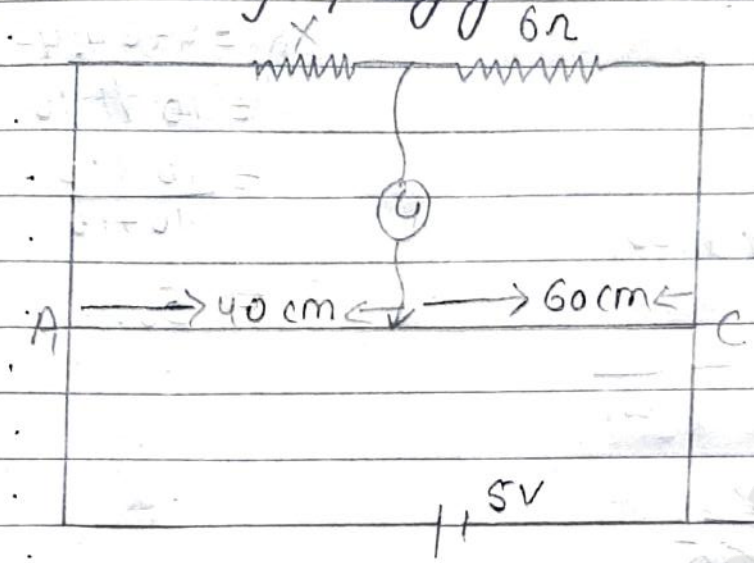
or, $0.5A = I_3$

$$\therefore I_3 = 0.5A.$$

$\therefore$ The value of I_1, I_2 and I_3 is 0.75 A and 0.5A respectively.

DATE

(5) In the circuit as shown in fig meter Bridge is in its balance state. Find the value of unknown resistant X, and current drawn from battery of negligible resistance.



= Here,

for 1 cm length of wire resistance = 0.1 Ω

for 40 cm length of wire resistance = 0.1 × 40 = 4 Ω

for 60 cm length of wire resistance = 0.1 × 60 = 6Ω

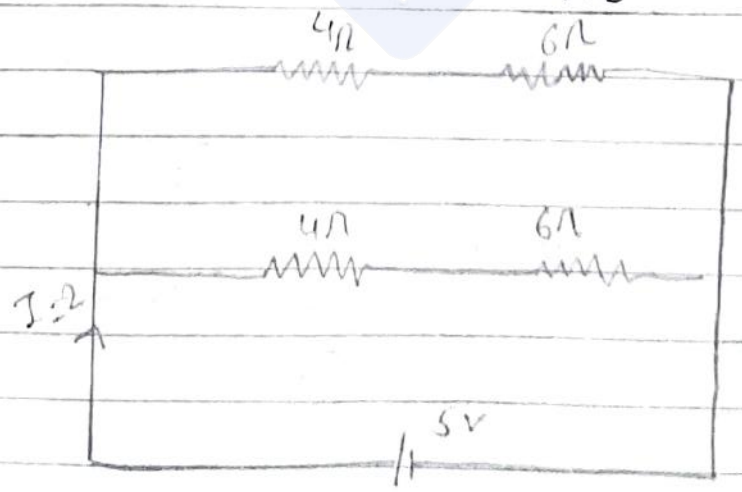
Now,

At balanced condition = $\frac{l}{\phi} = \frac{h}{R}$

or $h = \frac{l}{\phi} \times R$

$= \frac{4}{\cancel{6}} \times \cancel{6}$

$= 4\Omega$



Here,

In series

$R_1 = 4\Omega + 6\Omega$

$= 10\Omega$

$R_2 = 4\Omega + 6\Omega$

$= 10\Omega$

Now, in parallel,

$$\frac{1}{R} = \frac{1}{10\Omega} + \frac{1}{10\Omega}$$

Or, $\frac{1}{R} = \frac{2}{10}$

$\therefore \boxed{R = 5\Omega}$

In short,

$R = 4+6 \,//\, 4+6$

$= 10 \,//\, 10$

$= \frac{10 \times 10}{10+10}$

$\Rightarrow 5\Omega.$

Now,

$E = IR$

Or, $5 = I \times 5$

$\therefore \boxed{I = 1A}$

(6) When a cell of emf 1.5 V is connected to a potentiometer wire balancing length is found to be 650 cm. When a cell of unknown emf is connected to a potentiometer, the balancing length is found to be 450 cm. What is the value of unknown emf.

⇒ Given,

E.M.F of known cell $(E_1) = 1.5V$

length $(l_1) = 650$ cm

EMF of unknown cell $(E_2) = ?$

length $(l_2) = 450$ cm.

we know,

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

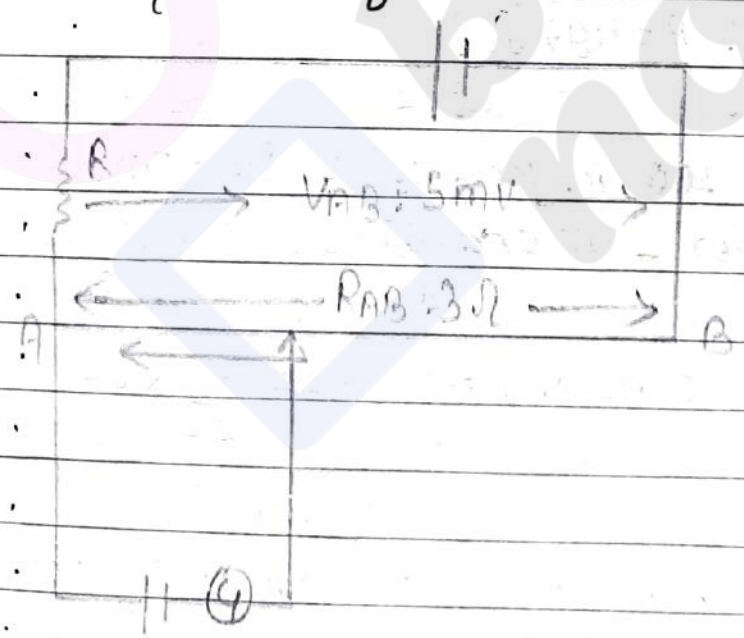
or, $\frac{1.5}{\varepsilon_2} = \frac{650}{490}$

or, $\frac{735}{650} = \varepsilon_2$

$\therefore \boxed{\varepsilon_2 = 1.13\ V}$

(Standard)

7) The driver cell of a potentiometer has an emf of 2V and negligible resistance. The potentiometer wire has a resistance of 3Ω. Calculate the resistance needed in series with the wire. If a p.d of 5 mV is required across the whole wire. The wire is 100 cm long and balanced length of 60 cm is obtained for a thermocouple of EMF 'ε'. What is the value of 'ε'?



Here

→ Let 'R' be the resistance connected in series with potentio meter wire to produce pd 5 mV $(5\times10^{-3}\ V)$

$\Rightarrow 0.05\ V.$

Now

$$I = \frac{2}{R + R_{AB}} \quad \text{--- (i)} \quad \left(\frac{\text{Total emf}}{\text{Total resistance}}\right)$$

Also,

$$V_{AB} = IR_{AB} \quad \text{--- (ii)}$$

Putting (i) and (ii), we get.

$$V_{AB} = IR_{AB}$$

$$\text{or, } 0.05 = \left(\frac{2}{R + R_{AB}}\right) \times 3$$

$$\text{or, } 0.05R + 0.05R_{AB} = 6.$$

$$\text{or, } 0.05R + 0.05 \times 3 = 6.$$

$$\text{or, } 0.05R + 0.015 = 6.$$

$$R = \frac{6 - 0.015}{0.05}$$

$$R = \frac{5.985}{0.005}$$

$$\boxed{\therefore R = 1197\ \Omega}$$

Again

For 100 cm long wire, P.d = 5mv.

$\therefore$ for 1 cm long wire, P.d = $\frac{5}{100}$ mv

$\therefore$ For 60 cm long wire, $E = \frac{5}{100} \times 60$

$$= \boxed{3mv}$$

Hence, the required resistance is $1197\ \Omega$ and the value of E is 3mv.

Galvonometer.

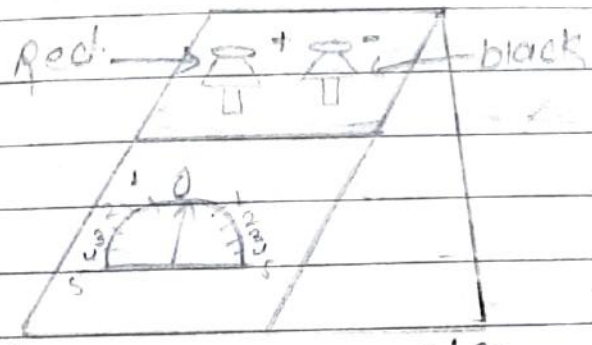


fig:- galvonometer.

It is a highly sensitive device which is used to detect small amount of current. It consists of two terminals. One is (+ve) terminal indicated by red colour & another (-ve) terminal indicated by black colour. The ~~fle~~ deflection of galvonometer depends upon direction of current. It is found that deflection in the galvonometer is directly proportional to the amount of current passing through it.

Ammeter:-

If high amount of current is flowing in the circuit, the galvonometer cannot detect the current because it shows large deflection when small amount of current is following. To measure large amount of current we use ammeter. Hence, ammeter is a very low resistance device which is used to measure very large amount of current. It is always connected in series with conductor whose current is to be measured. It consist of two terminals. One is (+ve) terminal or indicated by red colour and connected to (+ve) terminal of the battery. Similarly, another is (-ve) terminal indicated by black colour connected to the (-ve) terminal of the battery.

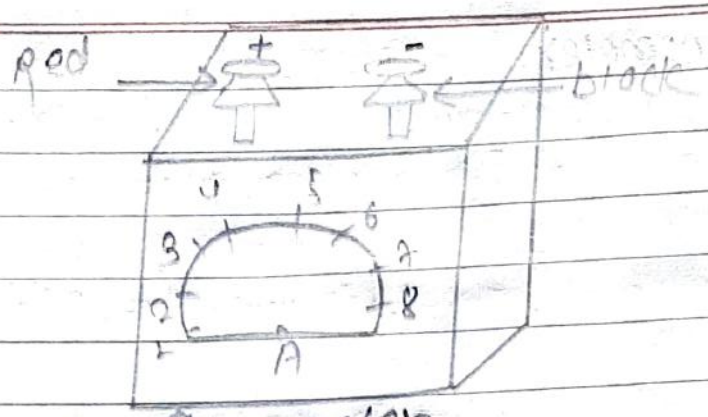


fig (a) Ammeter

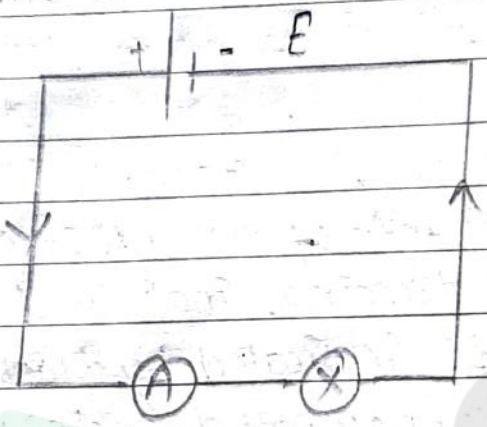


fig (b)

Voltameter:-

voltmeter is a device used to measure p.d. It has very high resistance. It is always connected in parallel with load whose p.d is to be measured as shown in fig (b). It consists of two terminals one is '+ve' terminal (red colour) & another is '-ve' terminal (black colour)

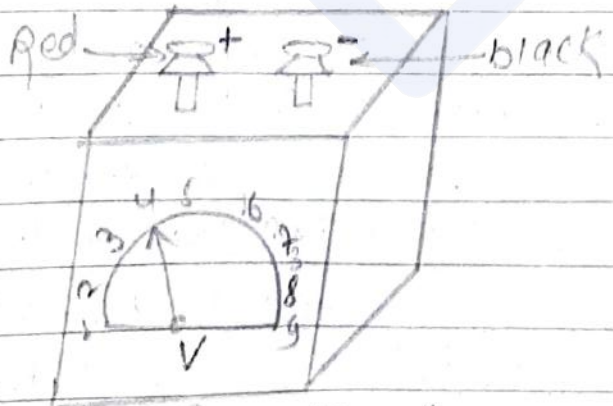


fig (a) voltmeter

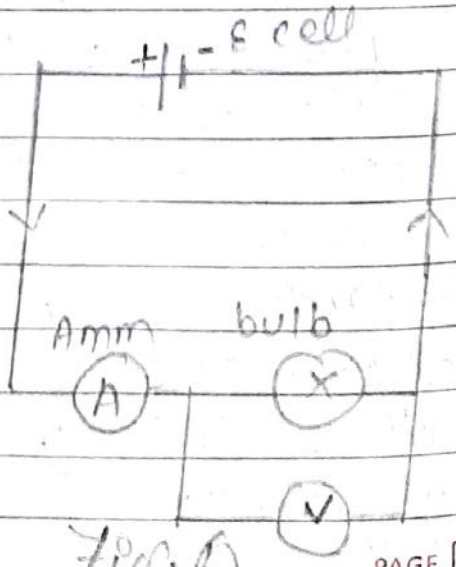


fig: (b)

How to convert ammeter & voltmeter in the circuit?

1. Why ammeter is always connected in series with load
2. Why voltmeter is always connected in parallel with load?

S.Q

→ An ammeter is a very low resistance device. It is always connected in series with load. If it is connected in parallel with load in the circuit, the equivalent resistance of the load changes drastically. This changes the current & voltage of the other components in the circuit and the ammeter cannot give an accurate reading. If it is connected in series with load, the equivalent resistance almost remains same & hence current and voltage in the circuit donot change drastically ~~& almost remain same~~ and hence the current measured by ammeter becomes correct. Due to which, it is always connected in series with load.

→ A voltameter is a very high resistance device. The resistance of an ideal voltmeter should be infinite. When such a device is connected in series with a load whose pd is to be measured, the net resistance of the circuit becomes very high. As a result the currents & voltage in the circuit changes drastically. If the voltmeter is connected in parallel with load, the equivalent resistance of the load almost remain same and hence current and voltage in the circuit is also almost remain same & the voltameter gives accurate reading. So voltmeter ~~gives accurate reading~~ is always connected in parallel with load whose pd is to be measured.

Shunt.

S.Q

It is a very low resistance device which is connected in parallel with galvanometer & which provide extra path for the extra current in the circuit.

Uses of shunt.

- If a heavy current flows in the circuit, shunt provides alternative path to the extra current so that galvanometer is saved being damaged.
- It can be used to increase the range of measurement of the instruments.
- shunts is used to convert galvanometer into ammeter of suitable range.

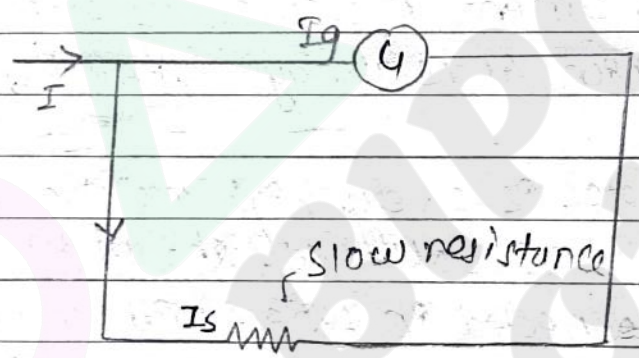


fig :- shunt.

Imp

Conversion of galvanometer into ammeter.

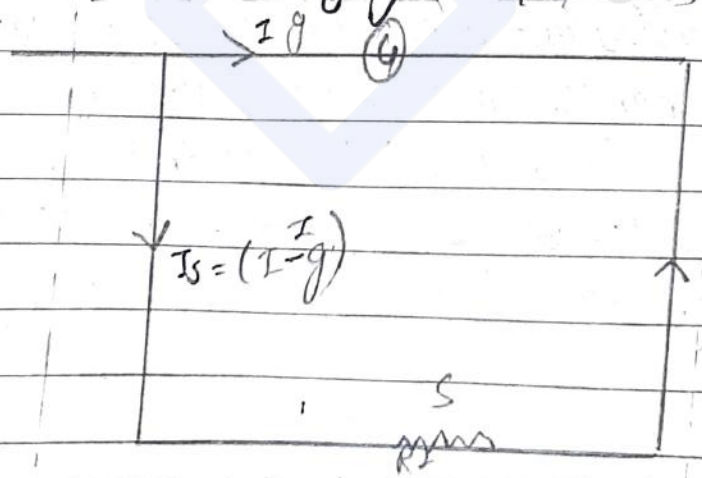


fig :- Conversion of galvanometer into ammeter.

classmate PAGE

To convert galvanometer into ammeter of suitable range, a very low resistance device called shunt is connected in parallel with galvanometer. In doing so, when a current (I) to be measured is connected only the to amount of current passes through galvanometer and rest of current passes through the shunt.

Let, I = current to be measured.

I_g = max. amount of current having through galvanometer for full deflection.

$I_s = (I - I_g)$ = current passing through shunt.

R_g = resistance of galvanometer coil.

R_s = resistance of the shunt.

Since, galvanometer of shunt are connects in parallel. so, pd across galvanometer = Pd across shunt.

i.e. $V_g = V_s$

$\Rightarrow I_g R_s = I_s R_s$ but $I_s = I - I_g$

$\Rightarrow I_g R_g = (I - I_g) R_s$

$\Rightarrow R_s = \frac{I_g R_g}{I - I_g}$ ---- (i).

If we connect these value of resistance in parallel with galvanometer, galvanometer is connected into ammeter of suitable range.

Conversion of galvanometer into voltameter.

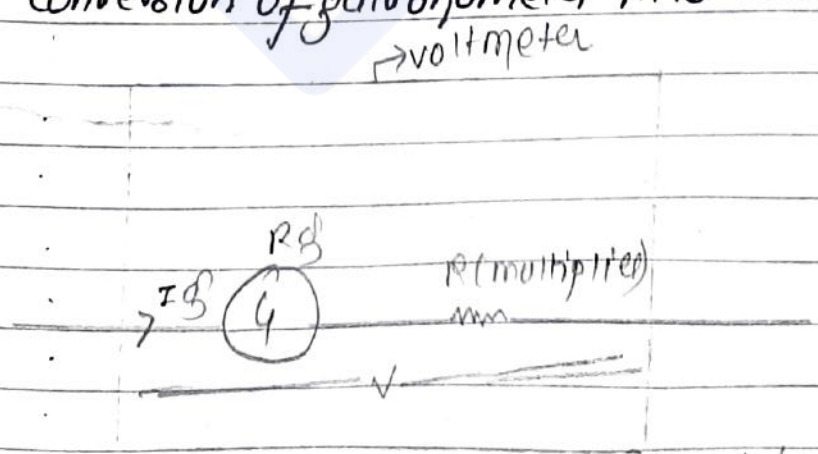


fig :- conversion of (G) into (V)

To convert galvonometer into voltmeter, a high resistance device called the multiplier (R) is connected in series with coil of galvonometer. In doing so, when it is connected across the pd to be measured, the current through galvonometer dosenot exceed the full deflection value.

Let I_g = current through galvonometer for full deflection.

R_g = resistance of galvonometer.

R = value of high resistance (multiplier)

V = potential to be measured.

Here, galvonometer & multiplier are connected in series so, the total pd is to measured is,

$$V = V_g + V_R$$

$$\Rightarrow V = I_g R_g + I_g R.$$

$$\Rightarrow V = I_g (R_g + R).$$

$$\Rightarrow \frac{V}{I_g} = R_g + R.$$

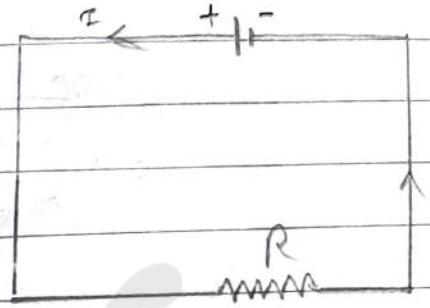
$$R = \frac{V}{I_g} - R_g \quad \text{--- (2)}.$$

If we connect this value of resistance in series with coil of galvonometer, a galvonometer is converted into voltmeter of range (0 - V) volt.

Heating effect of current.

The potential of heat from electricity is called heating effect of current. eg:- boiling the water in electric kettle.

Cause of heating effect.



when the resistance (R) is connects to a cell as shown in fig, current flows in the circuit & resistance offers an opposing force to the current. For the current to flow through the resistance, work is done by cell which appear in the resistance in the form of current which is called heating effect of current.

Joule's law of heating

In 1841, Joule found that amount of heat produced in the conductor when an electric current is passed through it is;

i) directly proportional to the square of current passing through it i.e $H \propto I^2$.

ii) directly proportional to the resistance of the conductor i.e $H \propto R$

iii) directly proportional to the time for which electric current is passed through the conductor i.e $H \propto t$

Combining we get

$$H \propto I^2 R T$$

$$\Rightarrow H = \frac{I^2 R T}{J}$$

where (J) is called Joule's mechanical equivalent of heat. It's value is $J = 4.2$ joule/calorie. Here I^2RT is expressed in Joule and when it divided by Joule I^2RT is connected into calories.

Imp Experimental verification of Joule's law of heating

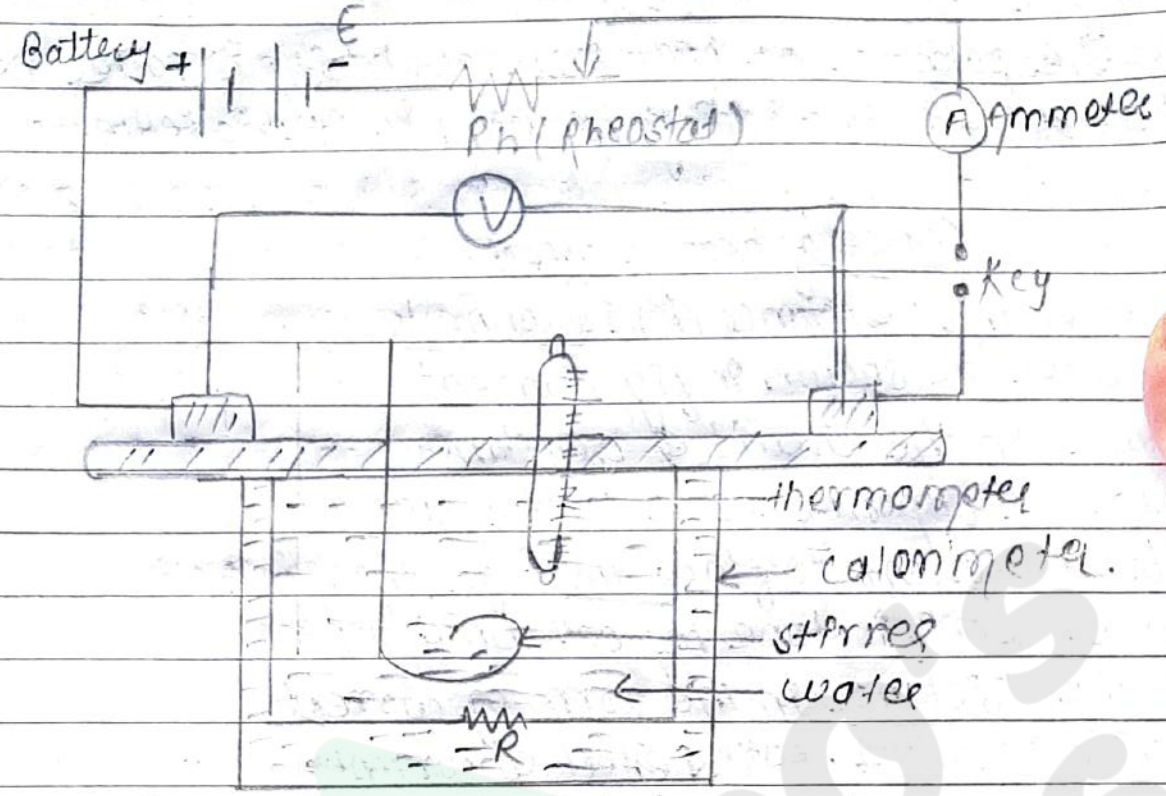


Fig:- Experimental verification of Joule's law of heating

The experimental arrangement to verify Joule's law of heating is shown above in which a heating coil of resistance 'R' is immersed in a copper calorimeter containing water, stirrer & thermometer. The coil is connected to the battery through Rheostat, ammeter and key. A voltmeter is connected across the coil to measure p.d. Here, rheostat is used to change the current ammeter is used to measure the current 'I' thermometer is used to measure the temp^n and stirrer is used to maintain the uniform temp^n.

To verify Joule's law of heating, following procedure are adopted.

First law ($H \propto I^2$)

i) A initial temp^n of water is noted. Let it be θ_0°c.

(i) Certain amount of current say (I) is passed through coil for fixed time (10–15 min). After this time, final tempn of water is to be noted. Let it be θ_1 °C.

(ii) Let 'w' be the weight water equivalent of calorimeter including water & stirrer. Then, heat develops in the coil for the current (I), is given by

$$H_1 = w(\theta_1 - \theta_0) \quad \ldots (i)$$

(iii) Again water is cooled to its initial tempn θ_0 °C & another current I_2 is passed through the coil for the same time and through the same coil. Let θ_2 be final tempn of the water. Then, heat develop in the coil is given by,

$$H_2 = w(\theta_2 - \theta_0) \quad - (ii)$$

(iv) The same experiment is repeated for the different currents $I_3, I_4, I_5 \ldots$ so on and corresponding heat developed $H_3, H_4, H_5 \ldots$ so on is measured for the same time and same coil. Then experimentally it is found that,

$$\frac{H_1}{I_1^2} = \frac{H_2}{I_2^2} = \frac{H_3}{I_3^2} \ldots \text{ so on.}$$

i.e. $\frac{H}{I^2}$ = constant

$\therefore H \propto I^2$.

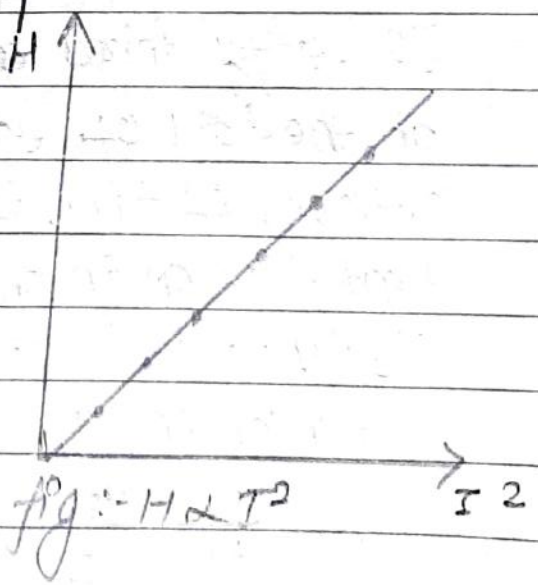


fig :- $H \propto I^2$

Second law ($H \propto R$) [I & $t \Rightarrow$ fixed]

To verify second law, the same current I is passed through the different coils of resistances R_1, R_2, R_3, R_4 - so on for the same time 't' & corresponding heat develop in the respective coils H_1, H_2, H_3, H_4 .... so on is to be noted. Then experimentally it is found that

$$\frac{H_1}{R_1} = \frac{H_2}{R_2} = \frac{H_3}{R_3} = \frac{H_4}{R_4} = \ldots \text{ so on}$$

i.e $\frac{H}{R}$ = constant

$\therefore H \propto R$

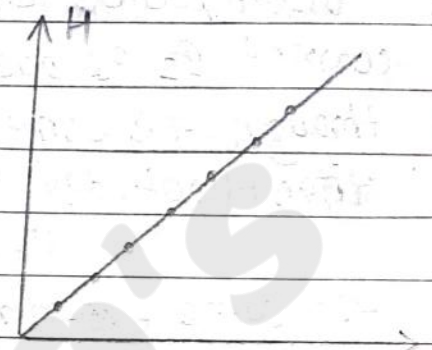


fig:- $H \propto R$

Third law ($H \propto t$) [$I, R \Rightarrow$ fixed]

To verify third law, same current 'I' is passed through the coil of same resistance 'R' but for different interval of time t_1, t_2, t_3, t_4 .... so on & corresponding heat develop in the coil for diff. time interval H_1, H_2, H_3, H_4 .... so on is to be measured.

Experimentally it is found that;

$$\frac{H_1}{t_1} = \frac{H_2}{t_2} = \frac{H_3}{t_3} = \frac{H_4}{t_4} = \ldots \text{ so on}$$

i.e $\frac{H}{t}$ = constant

$\therefore H \propto t$.

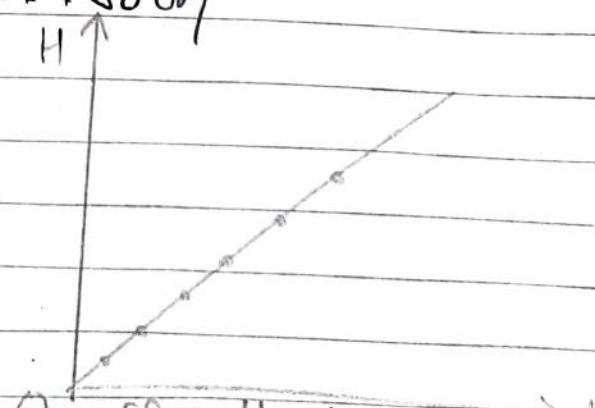


fig:- $H \propto t$

→ Electrical energy and power consumed by circuit.

When a battery is connected to the circuit and, it drives current through components in the circuit and has to do the work against the resistances of the components. The work done by the battery appears in the components as heat. The energy this lost as heat in the circuit also called energy consumed by the circuit.
If 'V' is the p.d & 'I' is the current flowing through the components. Then energy consumed by the circuit after time 't' is given by,

$$V = \frac{W}{q}$$

$$W = V \times q \quad \text{but } q = It$$

$$\boxed{W = VIt}$$

→ One joule of energy

We know,

$$W = VIT$$

If $V = 1$ volt, $I = 1A$, $t = 1$ sec

$$W = 1 \text{ Joule}$$

Hence, an electrical circuit is said to have consumed 1 joule of energy if the current of 1 amper flowing through it for 1sec when the pd across is 1 volt.

→ Power(P)

The power of an electrical circuit is defined as the rate at which energy is consumed by the circuit which is given by

$$P = \frac{W}{t}$$

or, $P = \frac{VIt}{t}$

In series $\Rightarrow P \propto R$
In parallel $\Rightarrow P \propto \frac{1}{R}$

$$\boxed{P = VI = \frac{V^2}{R} = I^2R}$$

DATE

$\therefore$ $\boxed{\text{Power} = VI}$ It's unit is watt.

→ Commercial unit of electrical energy (

the commercial unit of electrical unit is kwh and it is defined as the electrical energy consumed by the electrical appliances having power rating of 1 kw for an hour.

Note:

Total cost (C) = No of unit × Rate

$$\boxed{C = N \times R}$$

$$\boxed{1\,kwh = 3.6 \times 10^6\ J}$$

→ Source of emf

A device which connected to the resistor ~~price~~ produces p.d is called source of emf, Eg:- battery Solarcell etc

→ Emf of a cell (E)

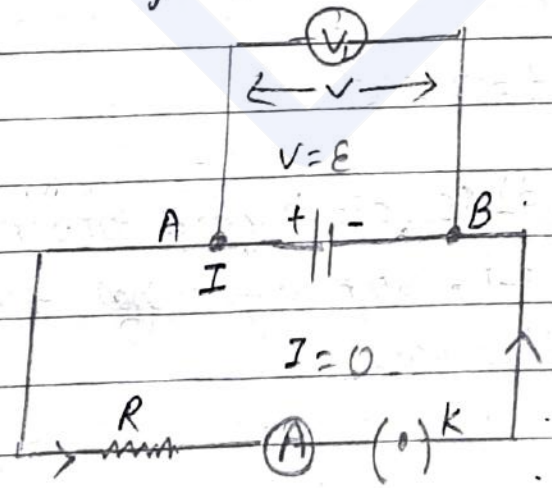


fig:- Emf of a cell.

The emf of cell or battery is defined as amount of workdone by the cell in order to drive 1 ~~con~~ coulomb of charge from anode to its cathode through external circuit.

- It is also defined as pd between anode and cathode when cell is in <u>open circuit</u>.

* Terminal Potential difference

$$V = E + Ir$$
$$V = E - Ir$$

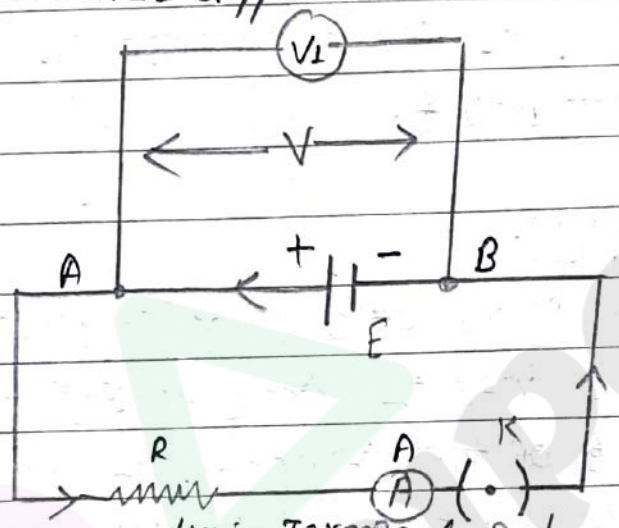


fig :- Terminal p.d

The terminal pd is defined as pd between anode and cathode of the cell when it is in a <u>closed circuit</u>.

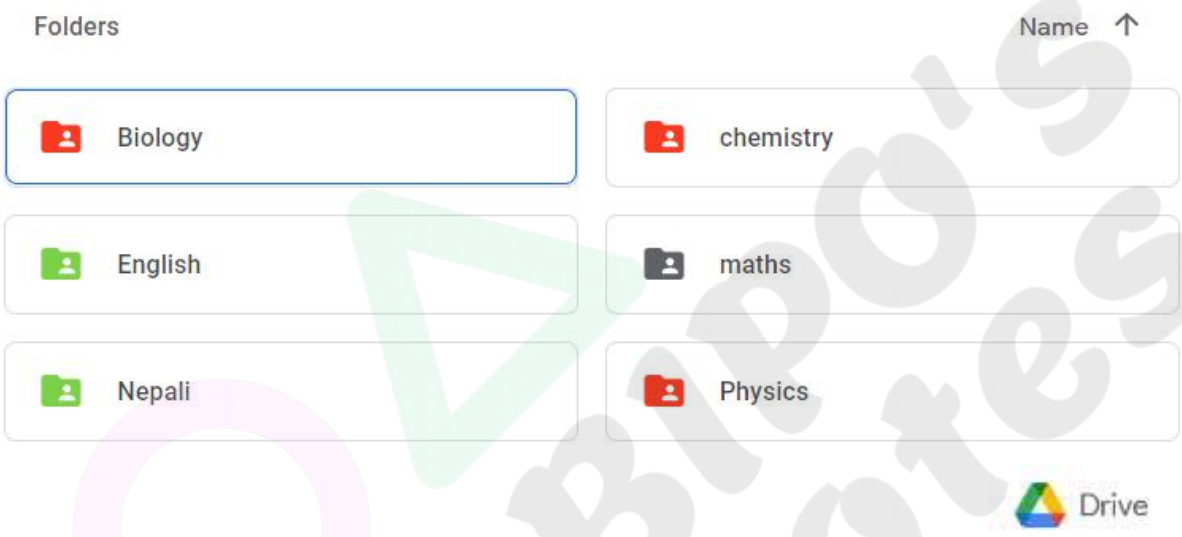
Imp * Difference between EMF and terminal Pd.

EMF	Terminal Pd
(1) The pd between anode and cathode of cell when it is open circuit.	(1) The pd between anode and cathode of cell when it is in closed circuit.
(2) It is a <u>cause</u>.	(2) It is an <u>effect</u>.
(3) EMF of cell is independent of internal resistance of cell.	(3) It depends upon internal resistance of the cell.

Bipin Khatri

(Bipo)

Class 12 complete notes and paper collection.



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