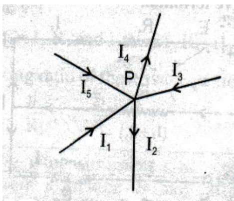
2016- 2017

CURRENT ELECTRICITY

Navlakhi®

KIRCHHOFF's LAWS

Kirchhoff's first law (Current Law or Junction Law):
The algebraic sum of electric current at any junction is always equal to zero. ΣI = 0
The current flowing towards the junction is positive and current flowing away from the junction is negative



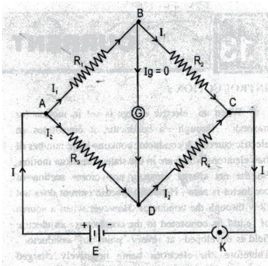
$I_1 + I_3 + I_5 - I_2 - I_4 = 0$ OR $I_1 + I_3 + I_5 = I_2 + I_4$
NOTE: This law is in accordance with law of conservation of charge

Kirchhoff's second Law (Voltage law or loop theorem): *In a closed loop of electrical network, the algebraic sum of potential differences for all components plus the algebraic sum of all E.M.F. is equal to zero.*

$$\Sigma IR + \Sigma E = 0$$

In the direction of conventional current flow the potential difference across the resistances is negative otherwise positive. For EMF if we travel from negative to positive terminal then we take it positive otherwise negative.

WHEATSTONE'S NETWORK



For accurate measurement of unknown resistance
[Construction refer GTB]
Network is said to be balanced if $V_B=V_D$, hence $I_g=0$ (current through galvanometer is zero, called NULL POINT)
Proof: Applying KVL to ABGDA
$-I_1R_1 + I_2R_3 = 0$, thus, $I_1R_1 = I_2R_3$
Applying KVL to BCDGB
$-I_1R_2 + I_2R_4 = 0$, thus, $I_1R_2 = I_2R_4$
Dividing we get $R_1/R_2 = R_3/R_4$, alternately, $R_1R_4=R_2R_3$
This is the balancing condition.
NOTE: If the bridge is balanced Ig = 0 , Thus R_1 and R_2 and in series and so is R_3 and R_4. Thus, total resistance of circuit is $(R_1+R_2)//(R_3+R_4)$

DETERMINATION OF UNKNOWN RESISTANCE BY METER BRIDGE

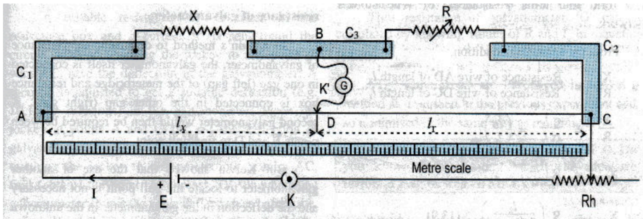


Fig. 13.4 : Wheatstone's meterbridge

AC	- 1 m long uniform wire	C_1,C_2,C_3	- Metal strips, E - Cell
X	- Unknown resistance	D	- Null point
R	- Resistance box	K'	- Sliding key (jockey)
G	- Galvanometer	R_h	- Rheostat

[Construction refer GTB]
A suitable resistance is selected for R such that a point D is obtained on the wire showing zero (null) deflection in the galvanometer. If I is the steady current flowing in the circuit and σ is the resistance per unit length of the wire AC. Then, by Wheatstone balanced bridge condition
X.(σlr) = R.(σlx) that is X.lr = R.lx that is X = R (lx/lr) or

$$X = R\left(\frac{lx}{100 - lx}\right)$$

NOTE: The resistance calculated is not a function of applied voltage or current.

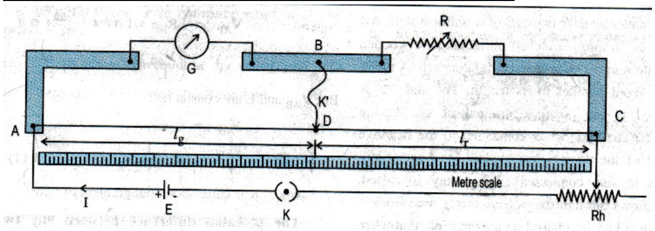
Error while using Meter Bridge:

1. If the wire is not uniform the its resistance will not be proportional to length (σl).
2. At the ends (A and C) contact resistances will be developed
3. The ends of the wire may not coincide with the 0 and 100 mark on the scale

Precautions or How to minimize the errors:

1. Use a wire of uniform cross section
2. The R value should be chosen in such a way that the null point (D) should be close to the centre of the wire
3. Repeat the experiment by interchanging X and R in order to minimize the effect of contact resistance

KELVIN's Method to determine Galvanometer Resistance:



G	- Galvanometer
R	- Resistance from resistance box
AC	- Metal wire one metre long
R_h	- Rheostat
E	- Cell
K	- Plug key
K'	- Jockey

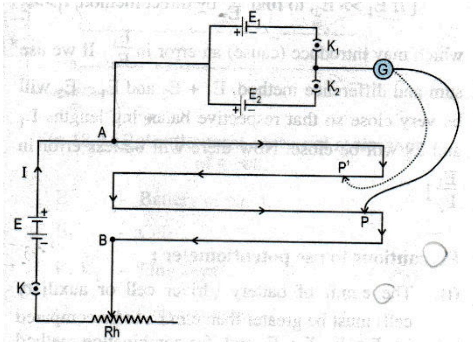
[Construction and setup refer GTB]
With some suitable resistance R you should be able to get opposite side deflections in G when jockey is touched at A and C (indicating there is a null point somewhere in between A and C).
Now without the jockey attached to the wire measure the current in G.
Now touch the jockey on wire to find a point D such that the galvanometer shows the same current as when the jockey was not attached. This point D is the null point and the bridge is balanced.
Thus, G.(σlr)=R.(σlg), which gives G.lr = R.lg which implies G=R(lg/lr)

$$G = R\left(\frac{lg}{100 - lg}\right)$$

POTENTIOMETER:

Principle: The fall in potential per unit length (called potential gradient) of the wire is constant.

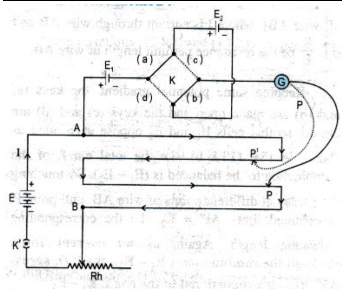
COMPARE TWO EMF using POTENTIOMETER:



Construction refer GTB

With key K1 closed and K2 open find the NULL point P. Thus, VAP = E1 and potential gradient will be E1/AP
Now with K1 open and K2 closed find NULL point P'. Thus, VAP' = E2 and potential gradient will be E2/AP'
But potential gradient in a potentiometer is constant.
Thus, $\frac{E1}{AP} = \frac{E2}{AP'}$
Precautions:
(i) E>E1 , E>E2
(ii) E1 and/or E2 positive end should be connected to the potentiometer where the positive end of E is connected
(iii) The potentiometer wire must be uniform
(iv) The resistance of the potentiometer wire must be high

E1/E2 BY SUM AND DIFFERENCE METHOD (COMBINATION METHOD)



[Construction and setup refer GTB]

With switches aligned along a and b we get E1+E2 and when aligned along c and d we get E1-E2

For E1+E2 configuration we find the balancing length AP

Thus potential gradient = (E1+E2)/AP

For E1 – E2 we find balancing length as AP'

Thus potential gradient = (E1 – E2)/AP'

For a potentiometer the potential gradient will be same

(E1+E2)/(E1 – E2) = AP/AP'

Thus, $\frac{E1}{E2} = \frac{AP+AP'}{AP-AP'}$

Precautions:

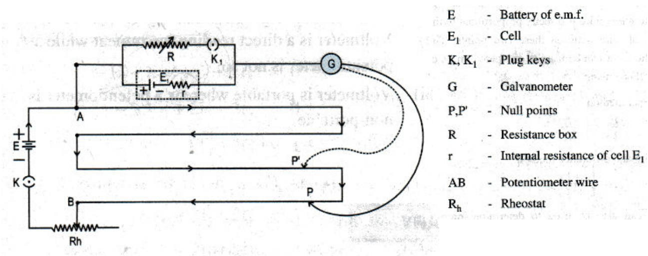
(i) E > (E1+E2), E>E1 , E>E2, E1>E2

(ii) E1 and/or E2 positive end should be connected to the potentiometer where the positive end of E is connected

(iii) The potentiometer wire must be uniform

(iv) The resistance of the potentiometer wire must be high

DETERMINATION OF INTERNAL RESISTANCE OF A CELL



[Refer GTB for construction]

With K1 open find NULL point at P. Thus balancing length for E1 is AP

Thus, potential gradient = E1 / AP

with key K1 plugged in the new balancing length is AP'

Now the potential gradient is (E1-Ir)/AP' or IR/AP'

Potential gradient remains the same, thus,

$$\frac{E1}{AP} = \frac{E1 - Ir}{AP'} \; but \; I = \frac{E1}{R + r}$$

$$\frac{E1}{AP} = \frac{E1 - \frac{E1}{R+r}r}{AP'}$$

$$E1\left(\frac{AP'}{AP}\right) = E1\left(1 - \frac{r}{R + r}\right)$$

$\frac{AP'}{AP} = \frac{R}{R+r}$, reciprocating we get

$$\frac{AP}{AP'} = 1 + \frac{r}{R}$$

$$r = R\left(\frac{AP}{AP'} - 1\right)$$

ADVANTAGE OF POTENTIOMETER OVER VOLTMETER:

(i) Voltmeter can only measure terminal PD of the cell while a potentiometer can measure small PD as well as EMF of cell

(ii) Accuracy of a potentiometer can be increased by increasing the length of the wire

(iii) Potentiometer can measure small PD also accurately unlike a voltmeter as its resistance is high but not infinite

(iv)Internal resistance of a cell can be measured by a potentiometer and not by a voltmeter

DISADVANTAGE OF POTENTIOMETER

(i) Voltmeter is a direct reading instrument while a potentiometer is not

(ii) Voltmeter is easily potable as compared to a potentiometer which is not that portable.

Extra:

1) I = Q/t   and   Q=ne

2) V= IR

3) P = VI = I^2R= V^2/R

4) H = Pt = VIt = I^2Rt= (V^2/R).t

5)If n is the number of electrons per unit volume the Q = (nAL).e

and I = nAL.e/t   BUT t = L/V_d where L is the length and V_d the drift velocity

Thus, I = n.e.A.V_d

Current density = J = I/A = n.e.V_d

NOTE: current density is a vector directed in same direction as E

6) R = ρL/A

7) R = Ro(1+αθ) if PTC   and R = Ro(1-αθ) if NTC

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