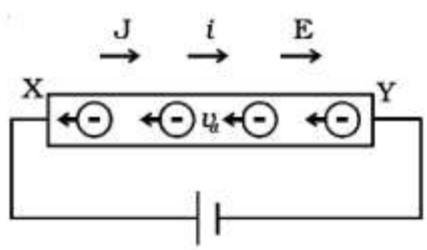
INDIAN SCHOOL MUSCAT

SENIOR SECTION

3 MARK AND FIVE MARK QUESTIONS AND ANSWERS IN

Electrostatics and Current electricity

1. Define drift velocity . Derive Relation between mobility and drift velocity.



Consider a conductor XY connected to a battery as in the figure. A steady electric field **E** is established in the conductor in the direction X to Y.

The free electrons at the end Y experience a force **F =** e**E** in a direction opposite to the electric field. Consider a conductor XY connected to a battery as in the figure. A steady electric field **E** is established in the conductor in the direction X to Y.

Drift velocity is defined as the average velocity with which free electrons get drifted towards the positive terminal, when an electric field is applied.

$v_d = a\tau$

The force experienced by the electron of mass *m* is

$\mathbf{F} = m\mathbf{a}$ Hence $a = e\mathbf{E}/m$

$$\text{Hence} \quad a = \frac{eE}{m}$$

$$\therefore v_d = \frac{eE}{m}\tau = \mu E$$

2. Explain how the Metre bridge is used to determine the specific resistance of a material.

Metre bridge is one form of Wheatstone 's bridge. It is as shown in the figure.

An unknown resistance P is connected in the gap G1 and a standard resistance Q is connected in the gap G2.

Adjust the position of metal jockey on metre bridge wire so that the galvanometer shows zero deflection. Let the point be J. The portions AJ and JC of the wire now replace the resistances R and S of Wheatstone's bridge. Then

$$\frac{P}{Q} = \frac{R}{S} = \frac{r.AJ}{r.JC}$$

where r is the resistance per unit length of the wire.

where $AJ = l_1$ and $JC = l_2$

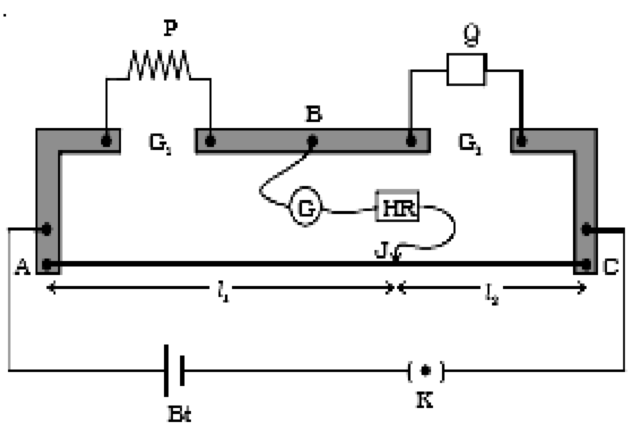
$$\therefore \quad P = Q\frac{l_1}{l_2}$$

The error in the value of unknown resistance can be eliminated, if another set of readings are taken with P and Q interchanged and the average value of P is found, provided the balance point J is near the midpoint of the wire AC.

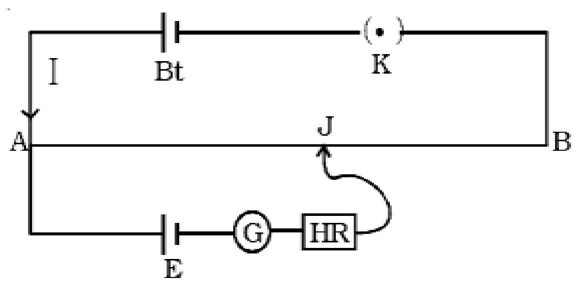
Determination of specific resistance

The specific resistance of the material of a wire is determined by knowing the resistance (P), radius (r) and length (L) of the wire using the expression

$$\rho = \frac{P\pi r^2}{L}$$



3. State and Explain the principle of potentiometer.



If the potential difference between A and J is equal to the emf of the cell, no current flows through the galvanometer. It shows zero deflection. AJ is called the balancing length.

If the balancing length is *l*, **the potential difference across AJ = I r l**

where r is the resistance per unit length of the potentiometer wire.

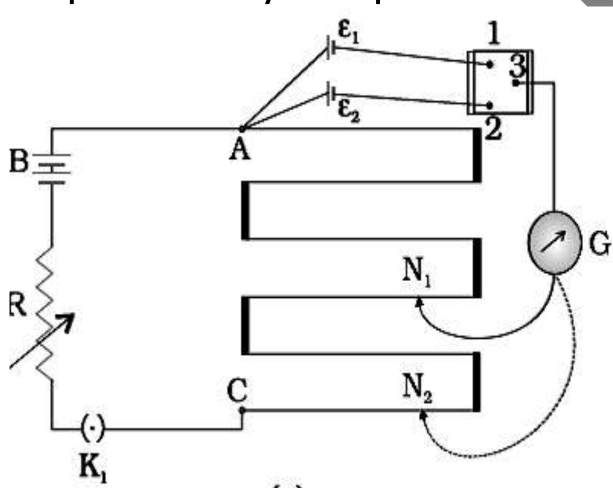
p d across given length of a potentiometer wire is directly proportional to the balancing length when a steady current flows through it.

∴ $\varepsilon = I r l$,

$\varepsilon \propto l$.

Hence emf of the cell is directly proportional to its balancing length. This is the principle of a potentiometer.

4. Explain how will you compare the ems of two cells using potentiometer.



Initially the cell of emfε1 is connected to the galvanometer and jockey is adjusted to get zero deflection

The potential difference across the balancing length l_1 is = I r l_l. Then, by the principle of potentiometer,

$\varepsilon_1 = I r l_l$ ...(1)

then the galvanometer is connected to cell of emf ε_2 , balancing length for null deflection is l_2

.

The potential difference across the balancing length l_2 is

= Irl_2, then

$\varepsilon_2 = I r l_2$ ...(2)

Dividing (1) by (2) we get

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

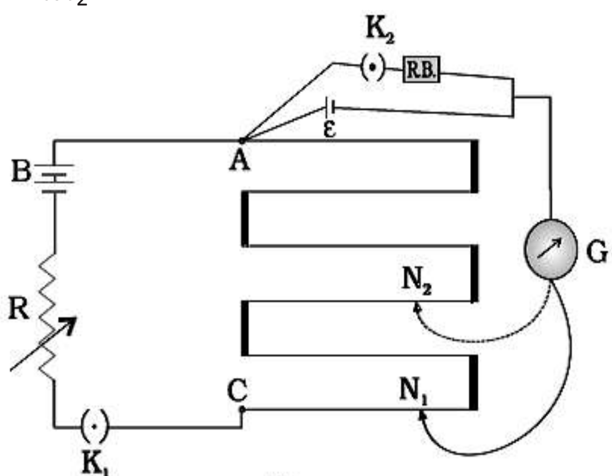
5. Explain how will you determine the internal resistnce of a cell using potentiometer.

With key K_2 open, balance is obtained at length l_1 (AN1). Then,

$\varepsilon = k\, l_1$ **where k =I r is known as potential gradient , Pd per unit length,**

When key K_2 is closed, the cell sends a current I through the resistance box *R*. If *V* is the terminal potential difference of the cell and balance is obtained at length l_2 (AN2),

$V = k\, l_2$



So, we have

$$\varepsilon / V = l_1 / l_2$$

But, $\varepsilon = I\,(r + R)$ and $V = IR$. This gives

$$\varepsilon / V = (r+R)/R$$

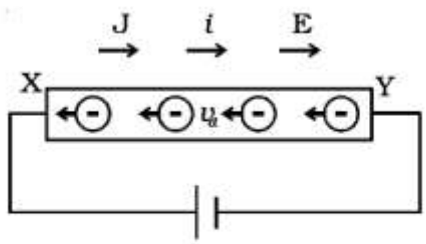
from the above two equations we get

$$(R+r)/R = l_1 / l_2$$

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

Where r is the external resistance.

6. Derive the Relation between drift velocity and current.



Let n be the number of free electrons per unit volume.
The free electrons move towards the left with a constant drift velocity vd.
The number of conduction electrons in the conductor = nAL
The charge of an electron = e
The total charge passing through the conductor q = (nAL) e
The time in which the charges pass through the conductor

$$t = \frac{L}{v_d}$$

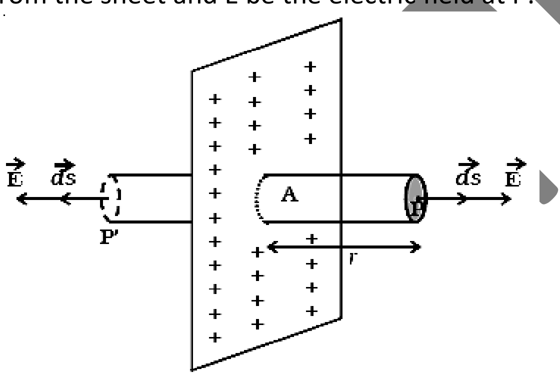
The current flowing through the conductor,

$$I = \frac{q}{t} = \frac{(nAL)e}{(L/v_d)}$$

$$I = nAev_d$$

7. ***Electric field due to an infinite charged plane sheet***

Consider an infinite plane sheet of charge with surface charge density σ. Let P be a point at a distance *r* from the sheet and E be the electric field at P.



By symmetry, the electric field is at right angles to the end caps and away from the plane. Its magnitude is the same at P and at the other cap at P'.

Therefore, the total flux through the closed surface is given by

$$\phi = \left[\oint E.ds\right]_P + \left[\oint E.ds\right]_{P'} \qquad (\because \theta = 0, \cos\theta = 1)$$

$$= EA + EA = 2EA$$

If σ is the charge per unit area in the plane sheet, then the net positive charge q within the Gaussian surface is, $q = \sigma A$

Using Gauss's law,

$$2EA = \frac{\sigma A}{\varepsilon_0}$$

$$\therefore E = \frac{\sigma}{2\varepsilon_0}$$

8. Derive expression for the energy stored in a capacitor.
Let q be the charge and V be the potential difference between the plates of the capacitor. If dq is the additional charge given to the plate,
then work done is, dw = Vdq

$$dw = \frac{q}{C}\,dq \qquad \left(\because V = \frac{q}{C}\right)$$

Total work done to charge a capacitor is

$$w = \int dw = \int_0^q \frac{q}{C}\,dq = \frac{1}{2}\frac{q^2}{C}$$

This work done is stored as electrostatic potential energy (U) in the capacitor.
9. Define energy density and derive an expression for it.

Energy Density of a capacitor

Energy stored in the capacitor U =

$$= \frac{1}{2}\frac{Q^2}{C} = \frac{(A\sigma)^2}{2} \times \frac{d}{\varepsilon_0 A}$$

The surface charge density σ is related to the electric field *E* between the plates,

$$E = \frac{\sigma}{\varepsilon_0}$$

From the above 2 equations , we get
Energy stored in the capacitor

$$U = (1/2)\,\varepsilon_0 E^2 \times Ad$$

Ad is the volume of the region between the plates (where electric field alone exists).
Energy density is defined as energy stored per unit volume of space
u = U/volume =(½) $\boldsymbol{\varepsilon_0 E^2 Ad/Ad}$ gives

$$u = (1/2)\varepsilon_0 E^2$$