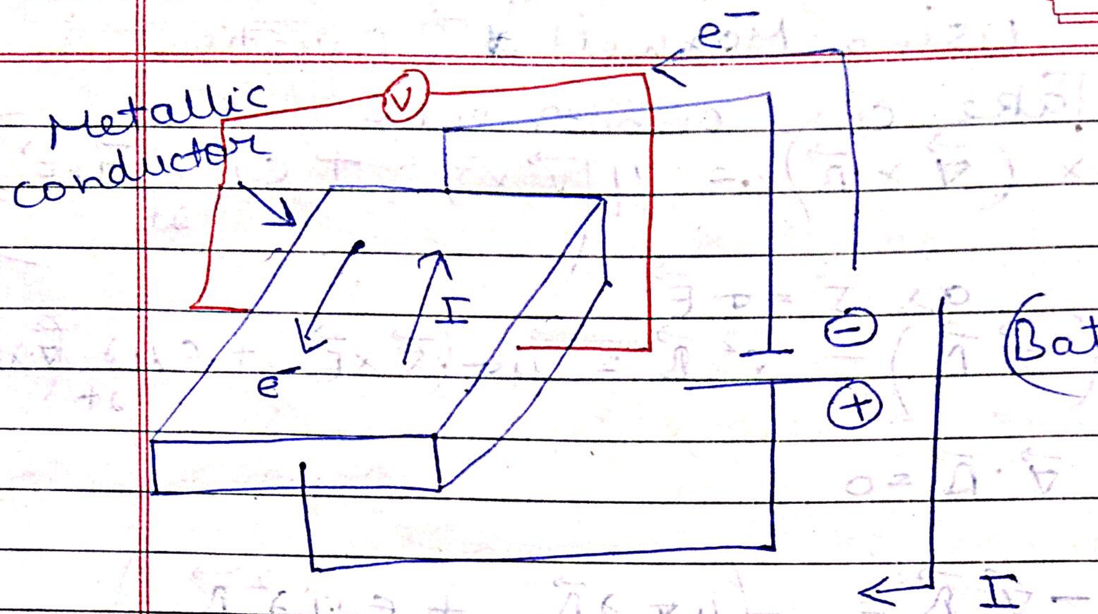
This effect was discovered by Edwin Hall 1879

⇒ It is related to the behavior of Moving Charges in Magnetic field

Hall effect

Let us consider a Metallic conductor

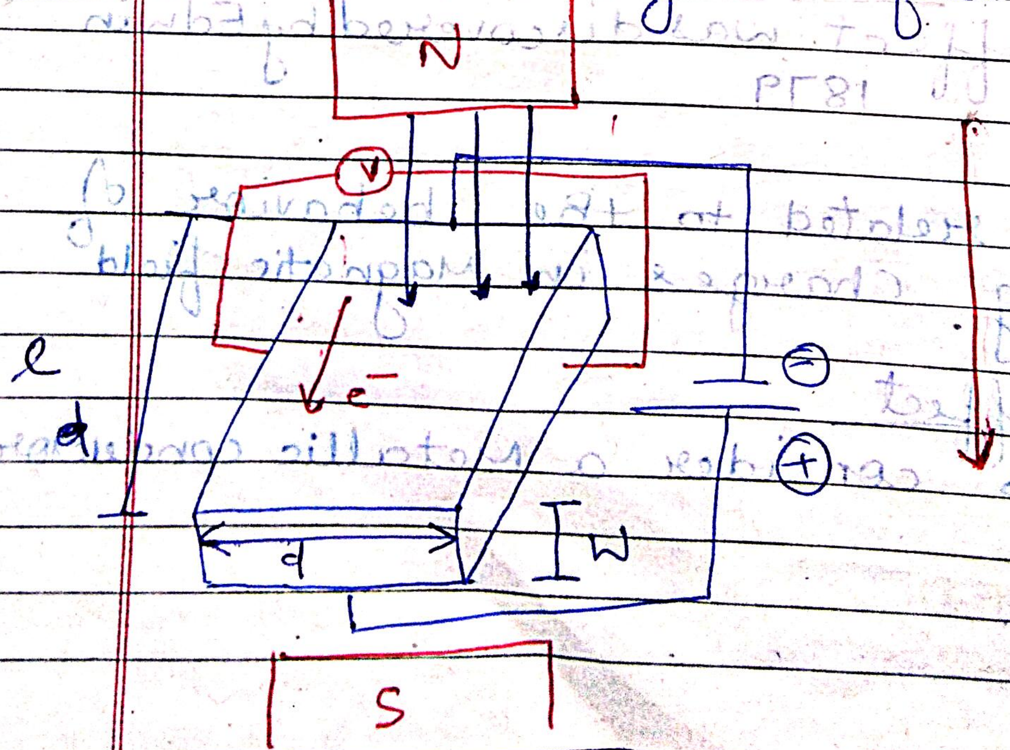
Now the Metallic conductor is connected to battery



⇒ when battery is connected to current starts flowing in the direction opposite to the flow of electrons

⇒ and when voltmeter is connected across the two ends of the conductor the Potential difference comes out to be zero

⇒ But when Magnetic field is applied



=) As we know that Magnetic field lines goes from North Pole to South Pole

=) In that case we find a certain Potential difference

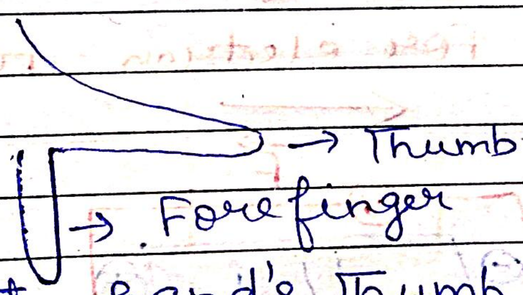
=) This voltage is called Hall Voltage
This is Hall effect

Reason

=) When Charge Particle Moves in a Magnetic field a force will act on it
This force is called Lorentz Force

Direction of Lorentz Force

=) The direction of Lorentz Force is given by flemings Left hand Rule



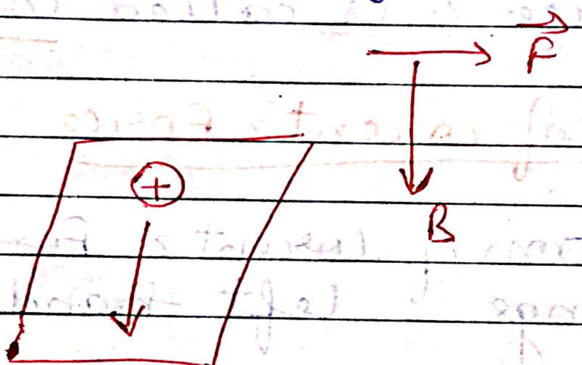
=) If your left hand's Thumb, Forefinger and Middle finger all are ⊥ to each other

=) If Fore finger represent Magnetic field

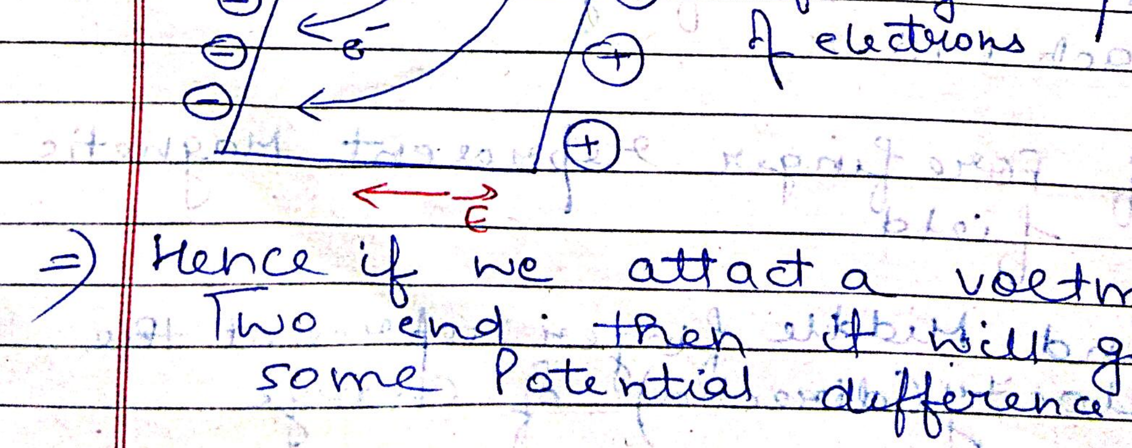
=) and Middle finger represent the velocity (direction) of charge

Point to be Remember

But here is one imp thing to Notice that Flemings left hand rule the Middle finger gives the direction of velocity of +ve Charge So here in the Hall effect we are dealing with the Movement of electron There fore the direction given by the Middle finger will be for +ve Charge So we will consider the opposite direction automatically in order to find the direction of −ve Charge.



But For electron For will act towards left



$$\boxed{E = \frac{V}{d}}$$

⇒ Hence if we attact a voltmeter across Two end then it will given some Potential difference.

Hall Effect

The Production of Potential difference across the electrical conductor, transverse to electric current in the conductor and to the applied Magnetic field

Force acting on electron

$$\vec{F} = q(\vec{v} \times \vec{B})$$

$$\vec{F} = -e(\vec{v} \times \vec{B}) \quad -(1)$$

$$\boxed{\vec{E} = \frac{\vec{F}}{q}}$$ → We know that

$\Rightarrow \vec{F} = q\vec{E}$

Put in eq^n (1)

$$q\vec{E}_H = -e(\vec{v} \times \vec{B})$$

$$\cancel{-e}\vec{E}_H = \cancel{-e}(\vec{v} \times \vec{B})$$

$$\vec{E}_H = \vec{v} \times \vec{B} \quad -(2)$$

$$\left[\begin{array}{l} \vec{A} \times \vec{B} = AB\sin\theta \\ \vec{v} \times \vec{B} = vB\sin\theta \end{array}\right.$$

θ is angle b/w $\vec{v}$ and $\vec{B}$

Here $\theta = 90^\circ$

$\Rightarrow \sin 90^\circ = 1$

Eq^n (2) will Become

$$\boxed{E_H = vB = \frac{V_H}{d}} \quad -(3)$$

DATE
PAGE No.

$$E_H = vB = \frac{V_H}{d}$$

$\boxed{V_H = vBd}$ → Hall effect — (4)

We know that $I = \frac{q}{t}$ — (5)

Now $q = Ne$

$N =$ No. of electrons in a conductor

$e =$ charge of each electron

Now we know that $n = \frac{N}{V}$

where $n =$ no. density of e^- (No. of e^-s per unit volume)

$\Rightarrow N = nV = \underline{nA\,dl}$

Put all the values in eq^n (5)

$$I = \frac{nA\,dl\,e}{t} \quad — (6)$$

Now $\frac{dl}{t}$ is velocity

so eq^n (6) will become

$I = nAve$

$I = nWdve$

$$\boxed{v_d = \frac{I}{nWe}} \quad — (7)$$

DATE
PAGE No.

By Putting eq^n 7 in eq^n 4

we get

$$V_H = \frac{IB}{nWe}$$

$$V_H = \frac{IB}{W}\left(\frac{1}{ne}\right)$$

where $\frac{1}{ne} = R_H$ = Hall coefficient

$$\boxed{V_H = \frac{IBR_H}{W}} \quad - (8)$$

Mobility of Moving e^- inside conductor

⇒ As e^- is Moving inside the conductor so Mobility define how easily it can Move

$$\mu = ne\mu\frac{1}{ne}$$

$$\mu = ne\mu R_H$$

$$\boxed{\mu = \sigma R_H}$$

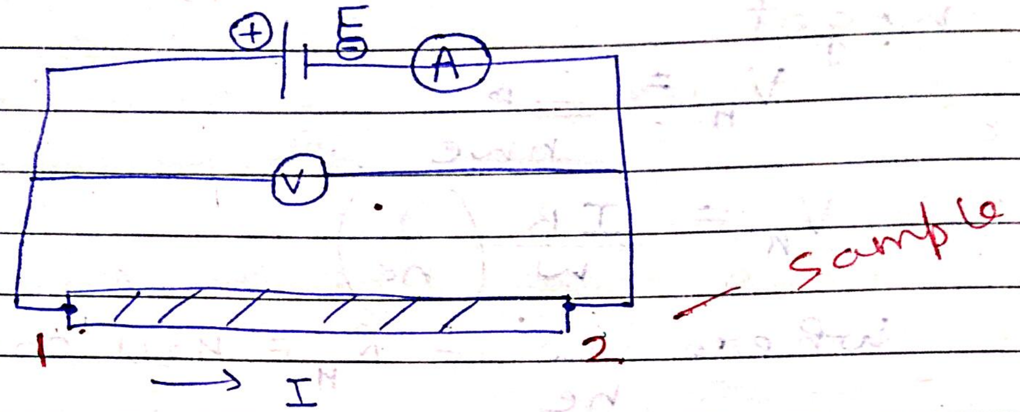
Resistivity $\rho = \frac{1}{\sigma}$

Four Probe Method

DATE
PAGE No.

Two Probe Method

Probe → A Point Metal tip for Making electrical contact with circuit



A be the cross sectional area
l be the length of wire

$\boxed{V = IR}$ → ohm's Law

$$R = \rho \frac{l}{A}$$

$$\boxed{\rho = \frac{RA}{l}}$$

⇒ Two Probe Method is used to find the restivity of the Material
⇒ Here we have a long thin wire of uniform cross sectional area connected to a battery E such that I be the current flowing through the wire

Drawbacks of two Probe Methods

1) Major Problem in this Method is error due to contact Resistance of Measuring wire
2) This Method cannot be used for

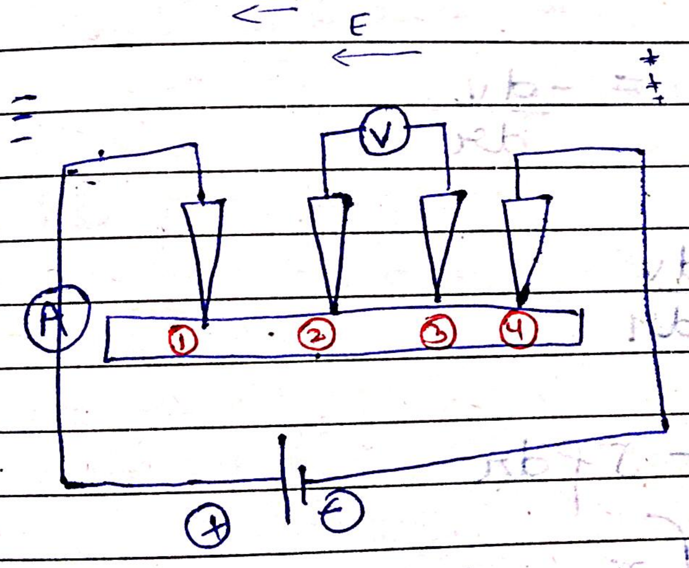
DATE
PAGE No.

Material having random shapes.

(3) The heating of sample due to soldering results in injection of impurities into the Material thereby affecting its resistivity.

Four Probe Method

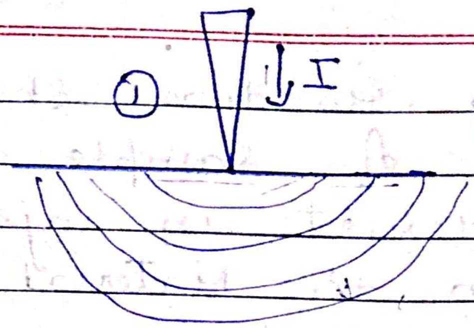
Here we consider four equally space tungsten Metal Tip. Each tip is supported by Spring at the back to Minimized the sample damage



⇒ Current enters through Probe 1 and leaves through Probe 4

⇒ Pointed Tip of Metal is used in order to avoid contact Resistance

S_1 → Distance b/w Probe 1 and 2
S_2 → Distance b/w Probe 2 and 3
S_3 → Distance b/w Probe 3 and 4



⇒ current starting spreading Radially

$$J = \frac{I}{\text{Area}} = \frac{I}{2\pi r^2}$$ (Area of half sphere with radius r)

$$\boxed{J = \sigma E = \frac{E}{\rho}}$$

$$E = J\rho = -\frac{dV}{dr}$$

$$J\rho = -\frac{dV}{dr}$$

$$dV = -J\rho\, dr$$

$$\int_0^V dV = -\int \frac{I}{2\pi r^2}\rho\, dr$$

$$\int_0^V dV = -\frac{I}{2\pi}\rho \int_0^r \frac{dr}{r^2}$$

$$V - 0 = -\frac{I\rho}{2\pi}\left(-\frac{1}{r}\right)$$

$$\boxed{V = \frac{I\rho}{2\pi r}}$$

DATE
PAGE No.

Voltage across Probe 2

$$V_2 = \frac{I\rho}{2\pi}\left[\frac{1}{S_1} - \frac{1}{S_1+S_2}\right]$$

voltage across Probe 3

$$V_3 = \frac{I\rho}{2\pi}\left[\frac{1}{S_1+S_2} - \frac{1}{S_3}\right]$$

Voltage drop across Probe 2 and 3

$$V = V_2 - V_3 = \frac{I\rho}{2\pi}\left[\frac{1}{S_1} - \frac{1}{S_1+S_2} - \frac{1}{S_1+S_2} + \frac{1}{S_3}\right]$$

Since Probes are at Equal distance

$$S_1 = S_2 = S_3 = S_4 = S$$

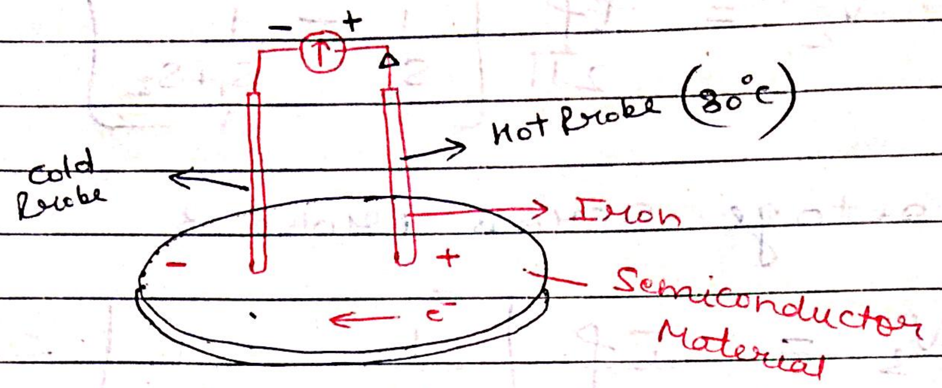
$$V = \frac{I\rho}{2\pi}\left[\frac{1}{S} - \frac{1}{2S} - \frac{1}{2S} + \frac{1}{S}\right]$$

$$V = \frac{I\rho}{2\pi}\left[\frac{2}{S} - \frac{1}{S}\right]$$

$$V = \frac{I\rho}{2\pi S}$$

$$\boxed{\rho = \frac{V \times 2\pi S}{I}}$$

Hot Point Probe Method



N-type

1. This is simple Method used to determine the Type of semiconductor (weather n-type or p-type)
2. Two fine Metal (Iron) Probes are Placed on the semiconductor and a galvanometer of Multimeter is placed between them.
3. One probe is kept at room Temperature that is cold end and the other is heated to about 80°C (hot end)
4. The Probe heats the semiconductor thus the K.E of the carriers increases and the charge carrier will started diffusing.
5. All the produces deflection in galvanometer or give +ve reading / -ve reading on the Multimeter depending on the Type of Semiconductor
6. The voltage produced is called Thermo voltage and the current flows is called thermo-current.
7. If the semiconductor is n-type, electrons will Move away from the hot probe towards the cold probe so that the hot probe aquires Positive charge w.r.t the cold probe and the current flows in the

DATE
PAGE No.

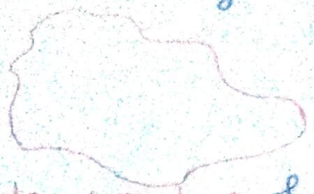
counter clockwise direction i.e galvanometer deflects towards left. In a p-type semiconductor the holes moves away from the hot probe towards the cold probe so that the hot probe aquires negative charge w.r.t the cold probe aquires Negative charge w.r.t the cold probe and the current flows in the circuit in the clock wise direction in the direction of current flow.

VAN DER PAW METHOD

This Method is used to find ρ (resistivity) of a semiconductor of any arbitrary shape

Resistivity → Inherent capability of the specimen/Material to resist the flow of current

$$\rho = \frac{RA}{L}$$



Formula used → $\rho = R_s t \left[\frac{R_s L t}{L}\right]$

Conditions → ① Thickness → uniform
→ Should be less than length and width of the specimen

② Material should be flat.

③ Probe should be connected on the circumference of the Material

Formula → $$e^{\frac{-\pi R_{vertical}}{R_s}} + e^{\frac{-\pi R_{horizontal}}{R_s}} = 1$$

$$R_{vertical} \cong R_{Horizontal} = R$$

$$e^{-\pi \frac{R}{R_s}} + e^{-\pi \frac{R}{R_s}} = 1$$

$$2 e^{-\pi \frac{R}{R_s}} = 1$$

$$e^{-\pi \frac{R}{R_s}} = \frac{1}{2}$$

$$e^{\pi \frac{R}{R_s}} = 2$$

$$\frac{\pi R}{R_s} = \ln(2)$$

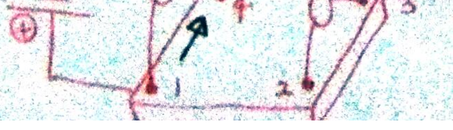
$$R_s = \frac{\pi R}{\ln(2)}$$

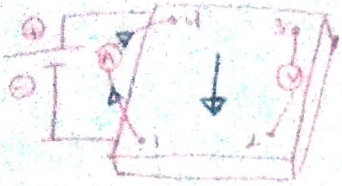
$$R_s = \frac{3.14 R}{2.303 \log_{10}(2)} = \frac{3.14 R}{2.303 \times 0.3010} = \frac{3.14R}{0.6932} = 4.53R$$

$$\boxed{R_s = 4.53 R}$$

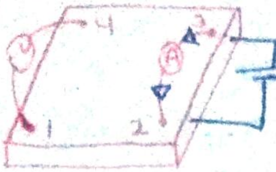
Vertical arrangement ($R_{vertical}$)

$$R(14, 23) = \cancel{\frac{I_{14}}{V_{23}}} \quad \frac{V_{23}}{I_{14}}$$





$$R_{(41,32)} = \cancel{\frac{I_{41}}{V_{32}}} \quad \frac{V_{32}}{I_{41}}$$

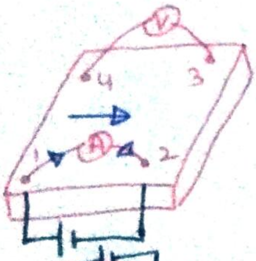


$$R_{(32,41)} = \frac{V_{41}}{I_{32}}$$

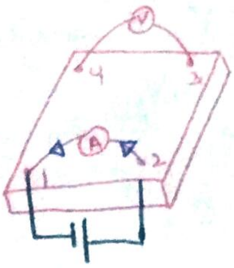
$$R_{vertical} = \frac{R_{(41,32)} + R_{(32,41)} + R_{(23,14)} + R_{(14,23)}}{4}$$

$$R_{(23,14)} = \frac{V_{14}}{I_{23}}$$

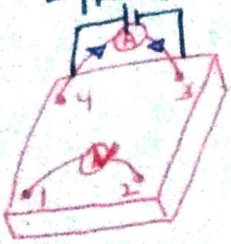
Horizontal arrangement



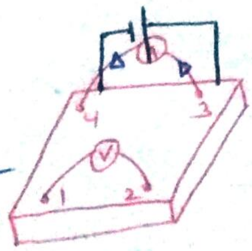
$$R_{(12,43)} = \cancel{\frac{I_{12}}{V_{43}}} \quad \frac{V_{43}}{I_{12}}$$



$$R_{(21,34)} = \cancel{\frac{I_{21}}{V}} \quad \frac{V_{34}}{I_{21}}$$



$$R_{(43,12)} = \cancel{\frac{I_{43}}{V_{12}}} \quad \frac{V_{12}}{I_{43}}$$



$$R_{(34,21)} = \frac{V_{21}}{I_{34}}$$

$$R_{Horizontal} = \frac{R_{(12,43)} + R_{(43,12)} + R_{(21,34)} + R_{(34,21)}}{4}$$

$$R_{vertical} = \frac{R_{(41,32)} + R_{(32,41)} + R_{(23,14)} + R_{(14,23)}}{4}$$

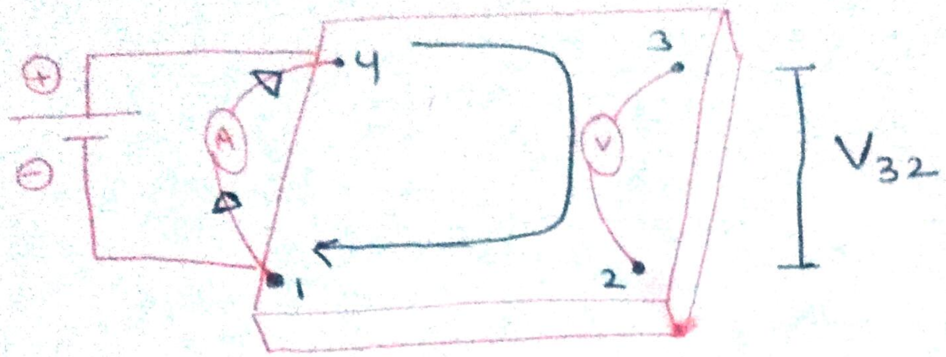
$$R_s = 4.53 \times R$$

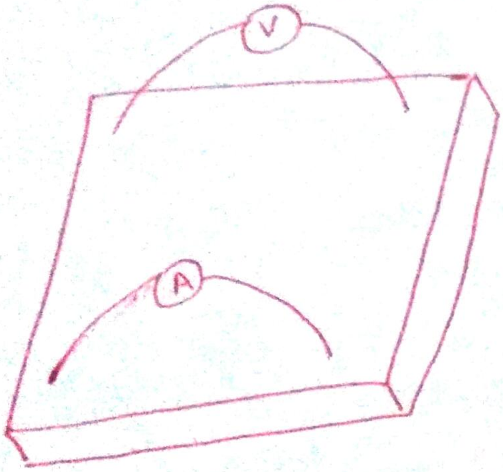
$$\rho = R_s t$$

$t \rightarrow$ Thickness of the specimen

$R_s \rightarrow$ Sheet Resistance

Vertical Arrangement





horizontal arrangement