Quadrant -II- Transcript and Related Materials

Programme :- T.Y. B.Sc.

Subject : Physics

Semester : VI

Paper Code : PYC109

Paper Title : Solid State Devices and Instrumentation

Section II : Instrumentation

Module Name : LVDT, HALL Effect Transducer

Module Number : 06

Name of the presenter Shakeel alias AGA D. A.

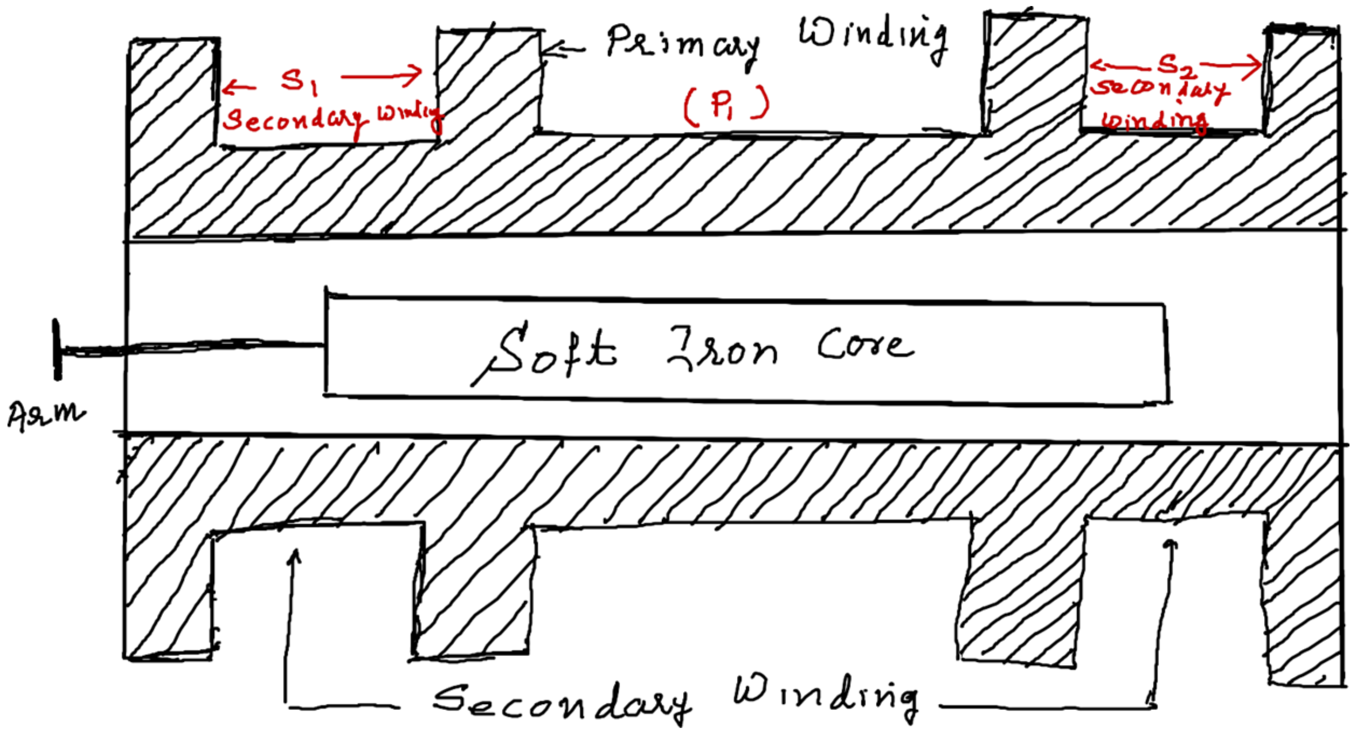
Associate Professor

Notes:- LINEAR VARIABLE DIFFERENTIAL TRANSDUCER (LVDT)

The Differential transformer is a passive inductive transformer.

The basic construction of LVDT is as shown

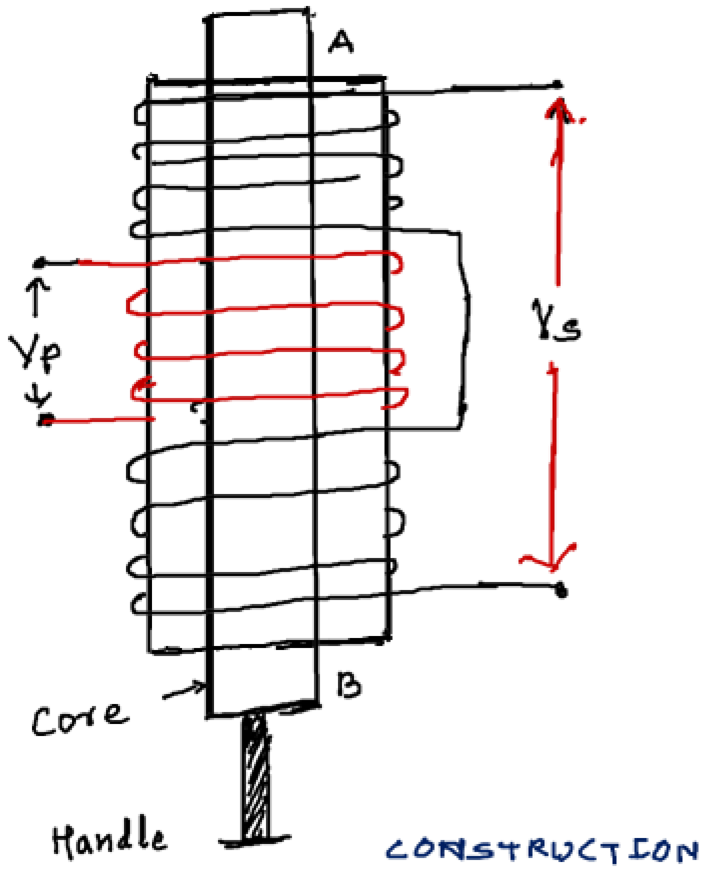
Construction of LVDT



The transformer consist of a single primary winding P1 and Two Secondary windings S1 and S2, which is wound on a hollow cylindrical former.

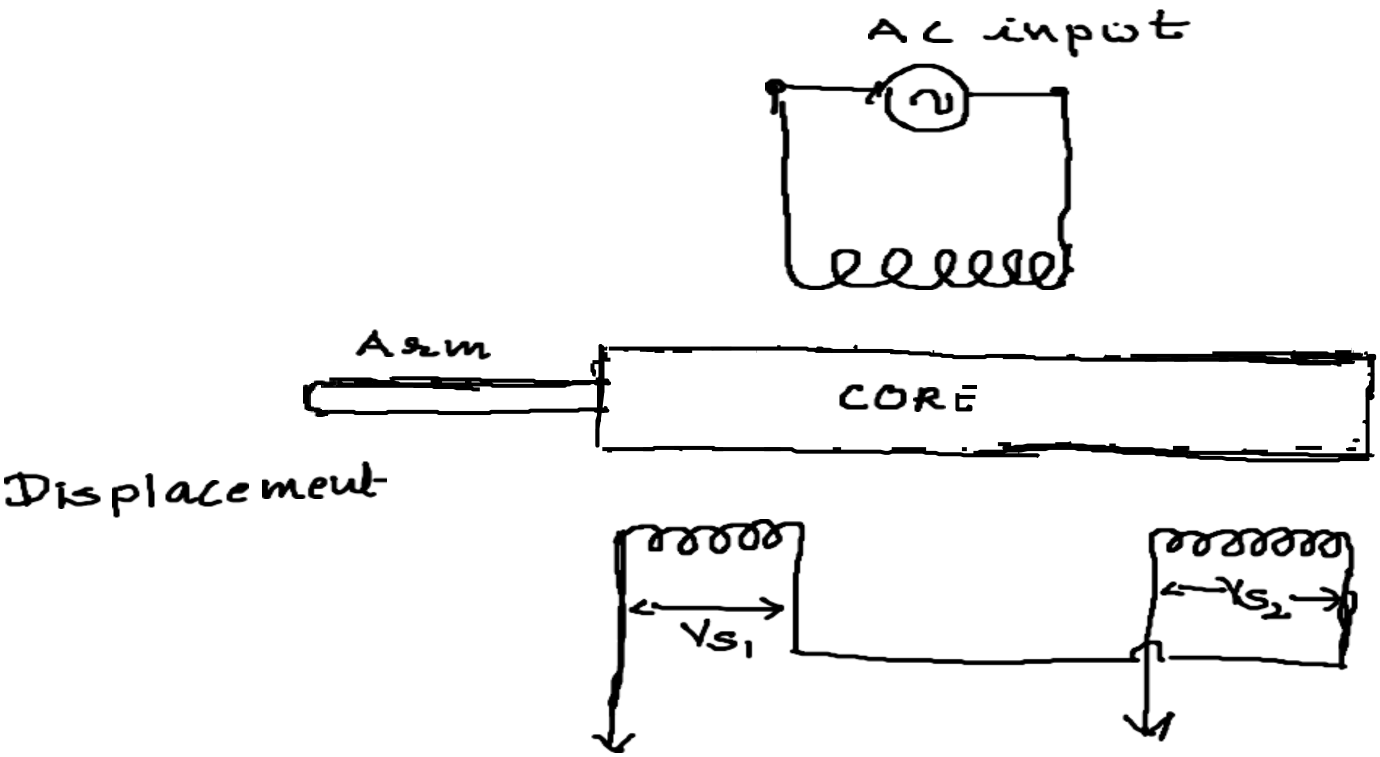
The secondary of the transformer have equal number of turns and identically placed on either side of the primary windings. The primary winding is connected to an ac source i.e. as shown.

DIAGRAM



[redacted]

=



The movable soft iron core slides within the hollow former and therefore it affects the magnetic coupling between the primary and the two secondaries. The displacement to be measured is applied to an arm attached to the soft iron core. Actually the core is made up of a nickel-iron alloy which is slotted longitudinally to reduce eddy current losses.

When the core is at normal position I .e at null position then EQUAL voltages are indu·ced in the two secondary windings.

The frequency of the ac input voltage applied to the primary winding ranges from 50 Hertz to 20 Kilo-Hertz .

The output voltage of the secondary winding S_1 is V_{S1} and that of the secondary winding S_2 is V_{S2}.

In order to convert the output from S_1 to S_2 into a single voltage, the two secondaries S_1 and S_2 are connected in series i. e as shown, then the output voltage of the Transducer is the difference of the two Voltages. Therefore the differential output voltage is =Vo

i.e $$Vo = Vs_1 \sim Vs_2$$

.

When the is at its normal position, the flux linking with both secondary is equal. Therefore the voltage induced in both the windings is same. Hence at null position Vs1=Vs2. Since the output voltage of the transducer is the difference of the Two voltages, The output voltage is Zero at null position.

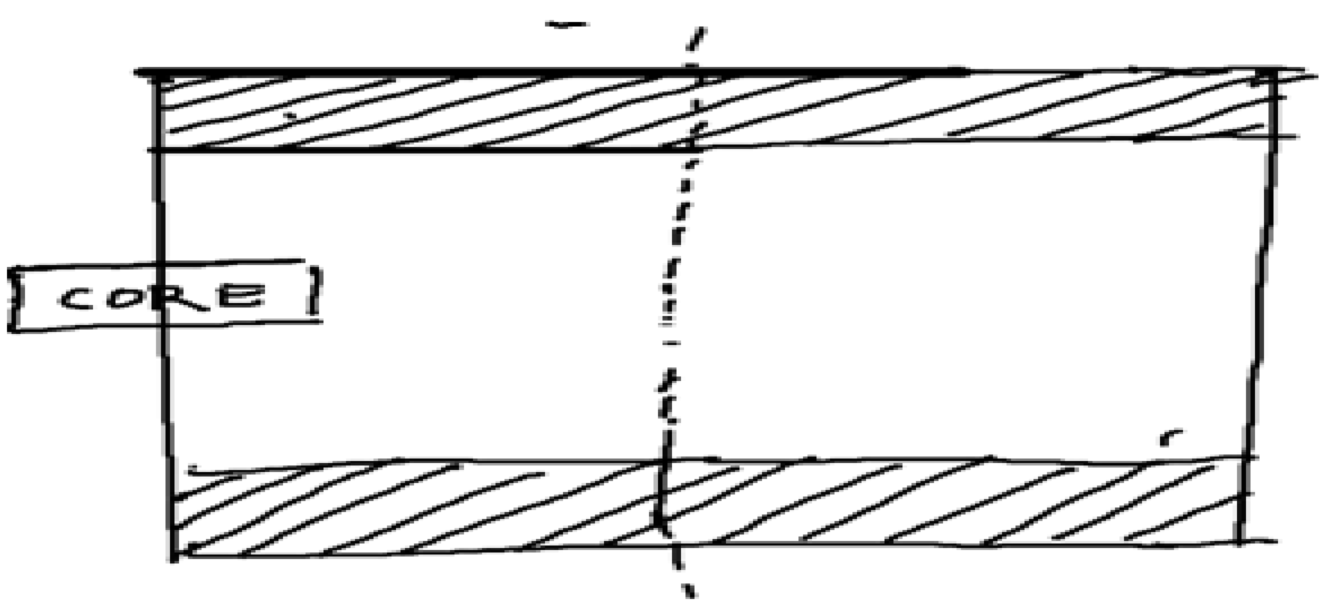
Now if the core is moved to the left of the null position, more flux links with winding S1 and less with winding S2. Hence output voltage Vs1 of the secondary winding S1 is greater than Vs2. The magnitude of the output voltage of the secondary is Vs1 – Vs2, in phase with Vs_1.(Output voltage of the secondary winding)

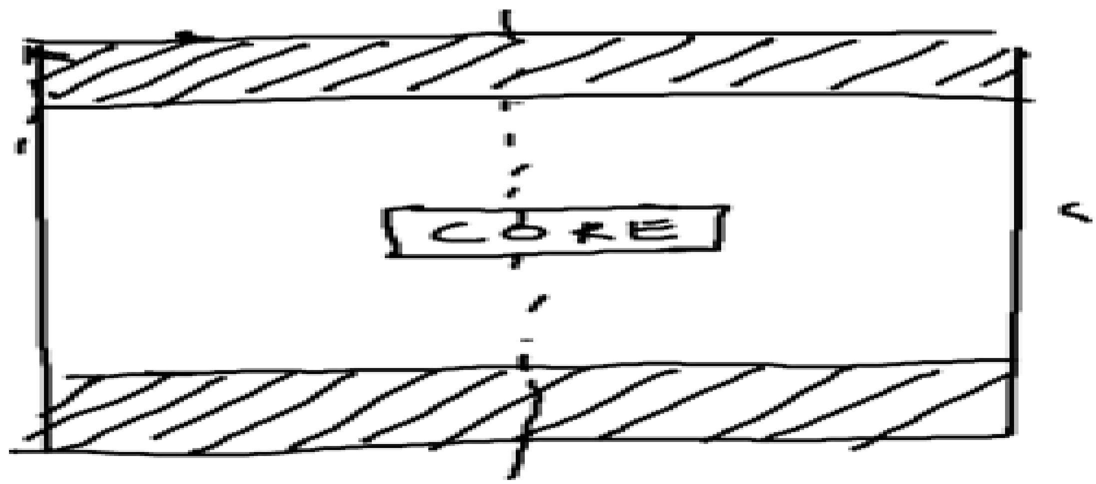
Similarly, If the core is moved to the right of the null position, the flux linking with winding S_2 becomes greater than the linked with winding S_1. Hence Vs_2 becomes greater than Vs_1. The output voltage in this is $Vo=Vs_2-Vs_1$. It is in phase with Vs_2.

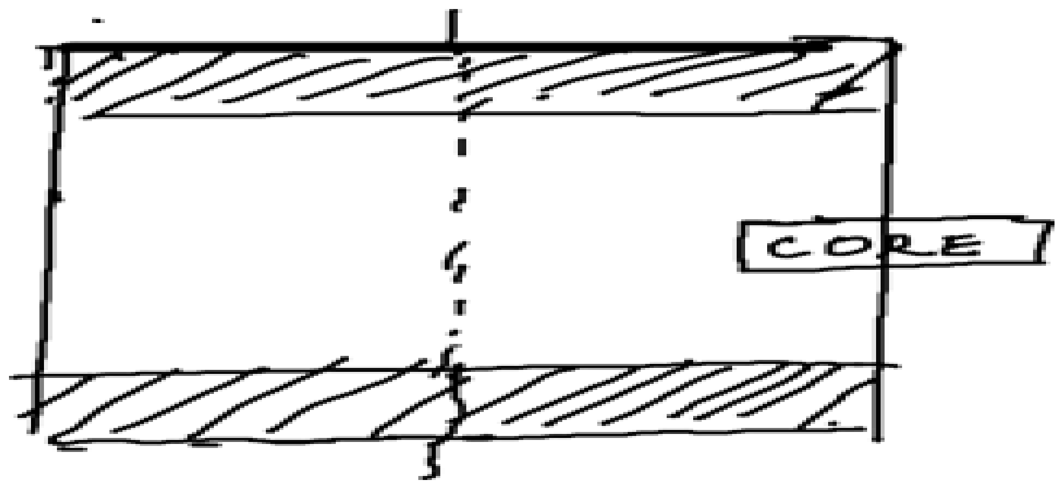
Here the amount of voltage change in the secondary windings is proportional to the movement of the core.

The output voltage of LVDT is a linear function of the core displacements for various position of the core.

Diagram shows the three different positions of the core.




CORE


CORE

In figure (b), the core is at 0, which is central zero or null position. Therefore Vs_1=Vs_2 and Vo/p=0

When the core is at left i.e as shown in figure (a). Here Vs_1 is more than Vs_2 . i.e $Vs_1 – Vs_2$ is positive.

When the core is at right i.e. as shown in figure (c). Vere Vs_1 is less than Vs_2 i.e $Vs_1 – Vs_2$ is negative.

Advantages of LVDT

1) Linearity :- The output voltage of this transducer is practically linear for displacement.

2) Infinite resolution 3) High Output 4) High sensitivity

Disadvantages of LVDT

1) Large displacements are required for appreciable differential output.

2) LVDTs are sensitive to stray magnetic fields.

3) Temperature affects the transducer.

Example :- An AC LVDT has input voltage Vp= 6.3 volts. Output voltage is= 5.2 volts for the range of ±1.6 cm.

1) Calculate the output voltage for core position going from
+ 0.50 cm to – 0.35cm.

2) The output voltage when the core is -0.30 cm.

Solution:- 1) 1.6 cm displacement produces output voltage of 5.2 volts then +0.50cm and - 0.35 cm produces how much voltage?

i) +0.50 cm X 5.2/1.6 cm =+1.625 V

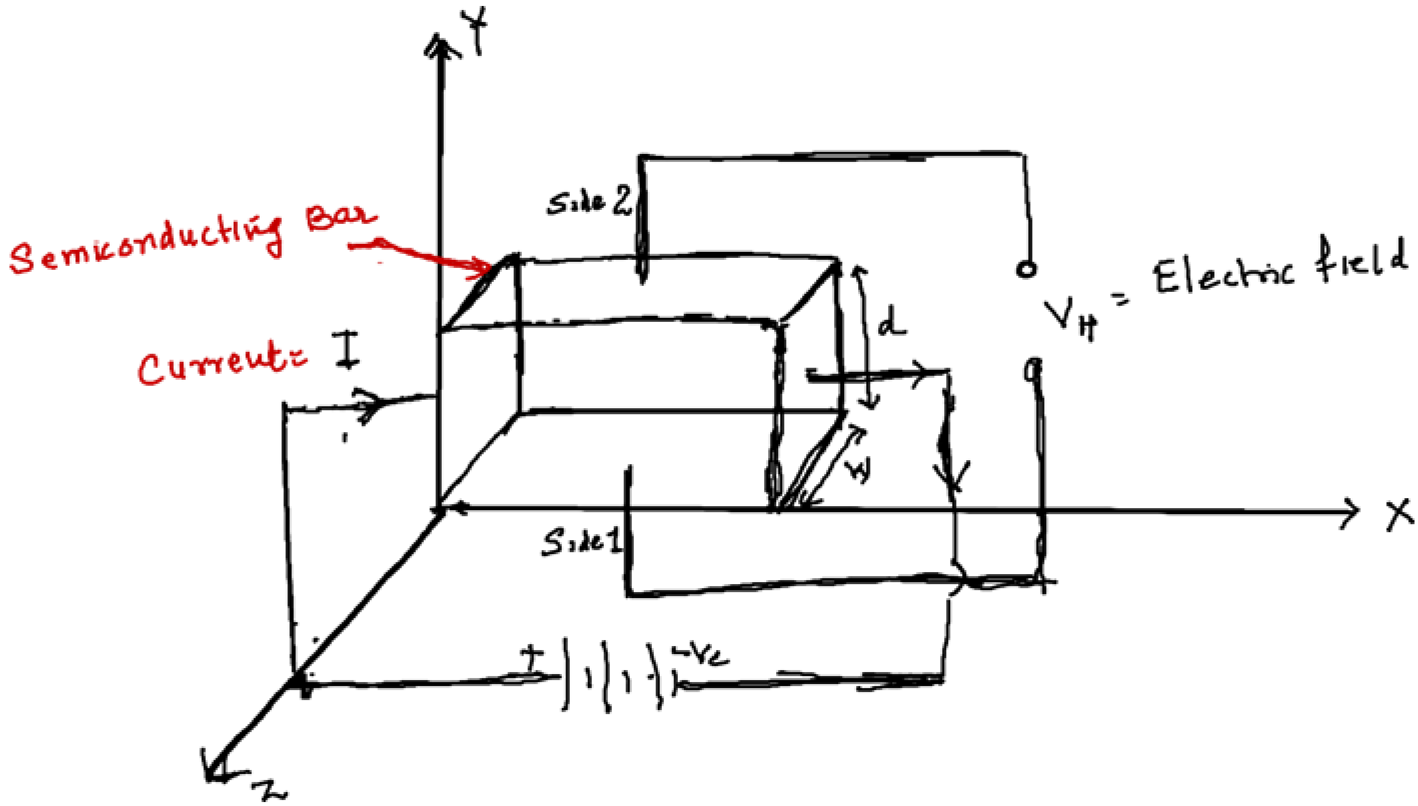
ii) -0.35 cm X 5.2/1.6cm = - 1.137V

2) Output Voltage = -0.30cm X 5.2/1.6cm= - 0.976V

HALL EFFECT :- When a magnetic field is applied to a current carrying conductor in a direction perpendicular to that of the flow of the flow of current, a potential difference or transverse electric field is created across the conductor. This phenomenon is known as Hall Effect.

If a metal or semiconductor carrying a current "I" is placed in a uniform transverse magnetic field "B", an electric field "E" is induced perpendicular both "I" and "B" then this phenomenon is known as HALL EFFECT.

HALL EFFECT DIAGRAM



Consider the figure shown above. Here Current I is in the positive X-direction. Magnetic field B is in positive Z-direction then induced electric field will be in the Negative y-direction.

Here the current I may be due to holes moving from left to right or electrons moving from right to left in the semiconductor specimen. The carriers either electrons or holes. It depends on the semiconductor is n-type or p-type.
If the semiconductor is of n-type then the current is carried out by electrons. These electrons will accumulate on side-1 and this surface will become negatively charged with respect to side-2. The Voltage appears between Side-1and Side-2 is called as Hall Voltage. (VH)

Mathematical Expression of hall Effect :- Measurement of Hall Voltage (VH), Hall coefficient (RH), Mobility (µ) and the Hall angle (ϕ).

Under steady state condition the force exerted on the charge carriers due to the electric field generated due to Hall effect will balance the magnetic force exerted on charge carriers due to magnetic field.

i. e. $e E_H = B e v$-----------(1)

Where e is the magnitude of the charge on electron or hole and v is the drift velocity.

But the electric field $E_H = V_H/d$ -------(2)

Here d is the distance between surface-1 and surface-2

from equation-2 VH = EH .d -----------(3)

From equation -1 EH = B.v ----------(4)

If ρ is the charge density and w is the width of the specimen then,

V= I/ ρ.w.d -----------------(5)

Substitute equation (4) &(5) in equation (3) we get,

V_H = B.v.d= B .I/ ρ.w.d Xd

VH = B. I/ ρ.w -----------(6)

Therefore ρ = B.I/VH .w --------(7)

From equation (7), the value of charge density can be determined, if we know the values of B, I,VH and w .

Here the current density is J= I/A = I/wd =ρ .v

HALL Co-efficient:- The Hall Coefficient can be defined as the Hall's field per unit current density per unit magnetic field.

Mathematically it can be written as :-

Mathematically it can be written as :-

R_H = (Electric field due to hall effect/current density X magnetic field)

$= E_H/JXB = ((V_H/d)/J\ XB)$

In extrinsic semiconductor the current carrying charge carriers are of one type either electrons or hole, like in

N-type semiconductor the charge carriers are electrons and in P-type semiconductor the charge carriers are holes.

The conductivity σ is given as

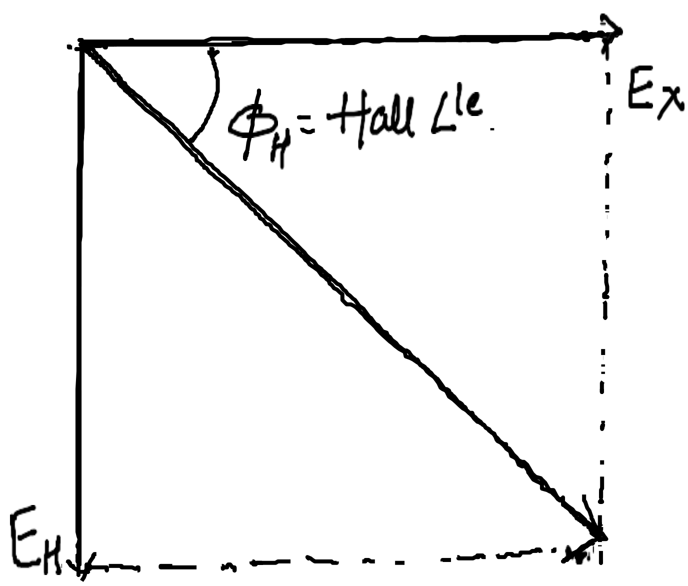
$\sigma = \rho.\mu$

Therefore $\mu = \sigma/\rho$ But $1/\rho = R_H$

Therefore $\mu = \sigma R_H$

Here μ is the mobility, σ is the conductivity and R_H is the Hall Coefficient.

Hall Angle :- The resultant electric field (E) (due to electric field in X-direction (Ex) and Hall's field acting in Y-direction (EH)) makes some angle with the electric field in x-direction Ex. This is called as Hall angle ϕH.



Here Hall angle, $\phi_H = \tan^{-1} E_H/\mathrm{Ex}$

Here $E_H = V_H/d$

and Electric field component in X-direction can be written as,

Ex= $Voltage\ drop\ along\ the\ length$/Length of the specimen

Ex = I/A X resistivity

EX = J X I/σ

Substituting the values of EX and EH in the expression of Hall's Angle we get,

$$\phi_H = \tan^{-1} E_H/Ex$$

i. e $\phi_H = \tan^{-1}(V_H/d)/J/\sigma)$

Where ρ =charge density, σ=conductivity and J=current density.

Applications of HALL EFFECT :-

1) To determine polarity:- It is used to determine the type of semiconductor that is either N-type or P-type.

2) To determine carrier concentration :- It is used to determine the electrons and holes concentration.

3) To determine Conductivity :- Hall effect is used to find conductivity of a material and mobility.

4) To measure displacement and current :- It is used for the measurement of displacement and current in mechanical sensors.

5) To measure Power :- Power measurement in an electromagnetic wave can be done with the help of HALL EFFECT.