Electronics

- It is based on the movement of electrons.
- Means control of the motion of electrons.
- Application in —

Communication
- Telephony
- Telex
- Fax
- Radio & TV
- Satellite
- Audio systems

Defence
- Radar
- Guided missiles

Industry - Automatic Machine Control

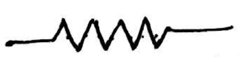
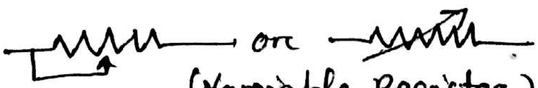
Medical Science
- X-Ray
- ECG (Electro Cardio Gram)

Instrumentation
- CRO
- Multimeter

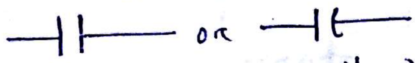
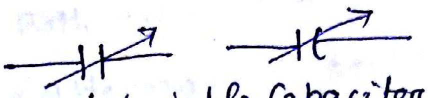
Components

- Passive (Does not do any processing)
  - Resistor
  - Capacitor
  - Inductor
- Active (Do amplification & Processing)
  - Tube Device
  - Semiconductor Device
    - Diode
    - BJT
    - FET
    - UJT
    - SCR
    - Zener Diode
    - LED

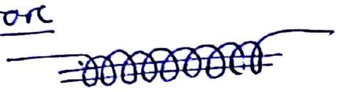
Resistor

- It opposes the flow of charge carriers
- Opposing force is known as Resistance.
- Unit — Ω (ohm), $K\Omega$ (kiloohm), $M\Omega$ (Mega ohm)
- 
  (fixed Resistor)
  
  (Variable Resistor)
- Generally made ~~of~~ by carbon composition.

Capacitor

- It store the charge carriers & release whenever desired.
- The ability to store the charge is known as capacitance.
- Unit = F (Farad), μF (Micro Farad), PF (Pico Farad)
- Made by mica, ceramic, paper, electrolytic, air etc.
-  (Fixed Capacitor)  (Variable Capacitor)
- Capacitor gives low impedance to AC (or bypasses or act as a short ckt)
- Capacitor gives high impedance to DC (or blocks or act as an open ckt.)

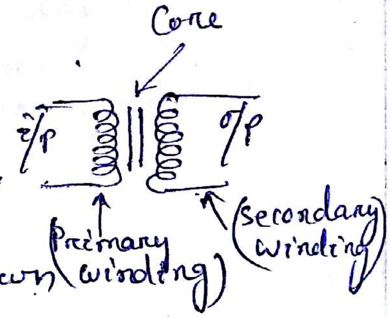
Inductor



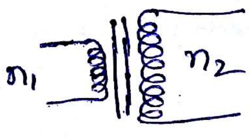
when current → passes throug a coiled wire → generates magnetic field → The magnetic field trey to keep the current flow at a steady rate → known as Inductance

& The magnetic force is developed known as Induced emf

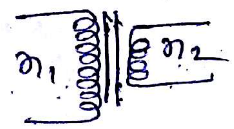
- Measured in H (Henery)
- Basic used is Transformer



Step up



Step Down



If $n_1 : n_2 = 12 : 1$

& Primary Connected to 220 V, 50 Hz

then $V_p = \sqrt{2}\, V_{rms} = \sqrt{2} * 220 = 311 V$

Max Secondary Voltage

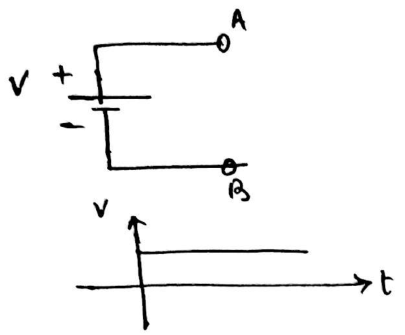
$V_m = \frac{n_2}{n_1} V_p = \frac{1}{12} 311 = \underline{\underline{25.9 V}}$

Voltage Source

- Source is to supply power to load.

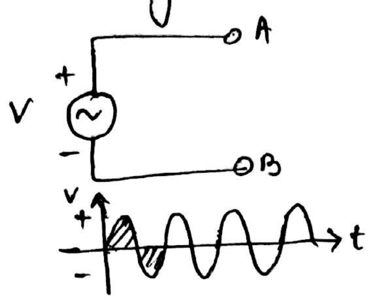
dc (Direct Current)

- It is steady, unchanging, unidirectional.
- Battery, DC Generator, O/P of Rectifier.



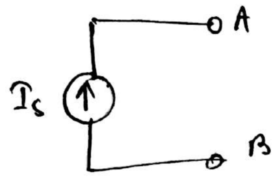
ac (Alternating Current)

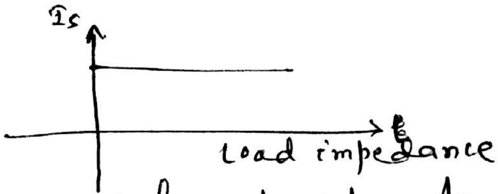
- It is alternating, magnitude is changing.
- Both +ve & -ve w.r.t. time.
- Alternator, Oscillator or Signal Generator.



Current Source

Supply constant current to the load known as current source.





(characteristics of Ideal current source)

Semiconductor

Semi-Conductor ← Neither a good conductor. Nor a Insulator

✓ b/c at room temp. the conductivity is less than that of conductor.

Imp It is Negative temperature coefficient of resistance

b/c Raise in Temperature → Decreases the Resistance of semiconductor.

Free Electron

Those electrons can able to move from one atom to another (Generally in Random manner) known as free electron.

Hole

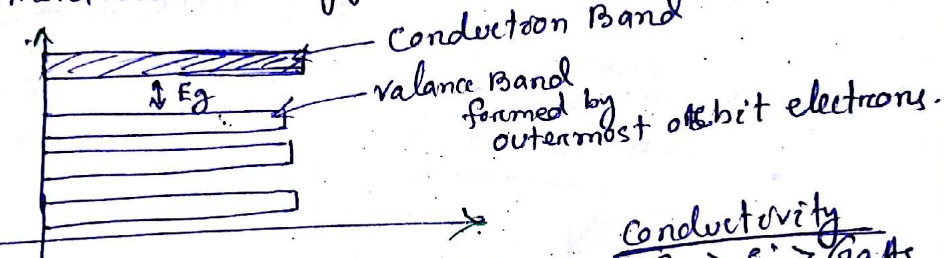
If an electron breaks a covalant bond and move generating a vacancy called "hole".

Absence of electron.

Energy Band

It is the energy level diagram of a solid, form a cluster or band.

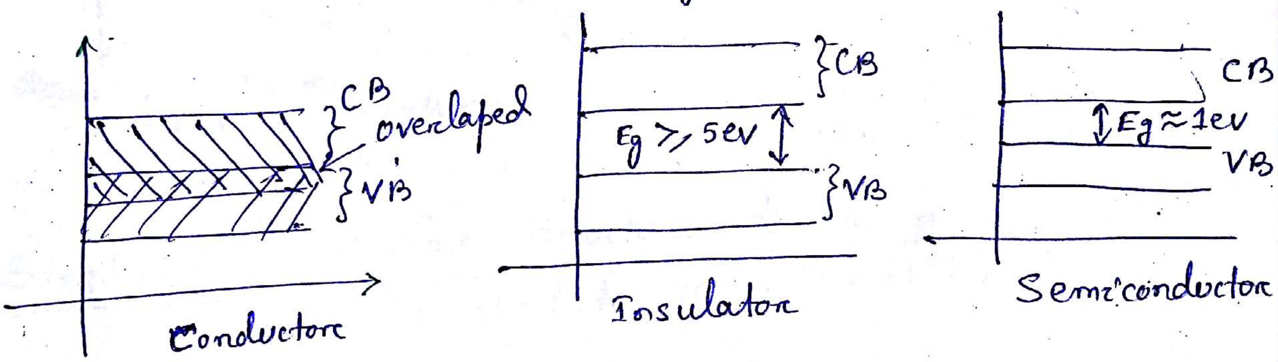
The two dimentional energy level representation is energy band.



Eg = Forbiden gap

for Si → Eg = 1.12 eV
Ge → Eg = 0.72 eV
GaAs → Eg = 1.43 eV

Conductivity
Ge > Si > GaAs



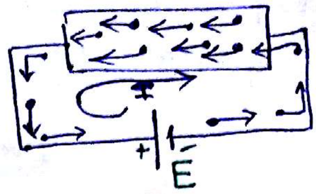
Intrinsic Crystal of Semiconductor

Pure form of semiconductor ~~do covalant~~ whose atoms are bonded with an uniform three dimenssional pattern as covalant bond known as crystal.

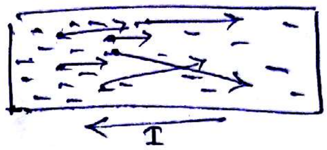
Semiconductor acts as an insulator at absolute zero, because all the half field outermost electrons shared themselves to form covalant bond with the neighbouring atom. No free electrons available for conduction.

Drift & Diffusion Current

- The flow of charge carrier is due to the applied external voltage, then the current known as drift current



- Flow of charge carriers occurs due to difference in charge carrier concentration, then the current known as diffusion current.



(Q)

Semiconductors → Negative Temperature-coefficient of Resistors

Increase of Temperature → More electron, hole pair generated in Intrinsic Semiconductor ⇒ Concentration of charge carrier increased

⇓

Conductivity Increased or Resistivity Decreases

So

⇓

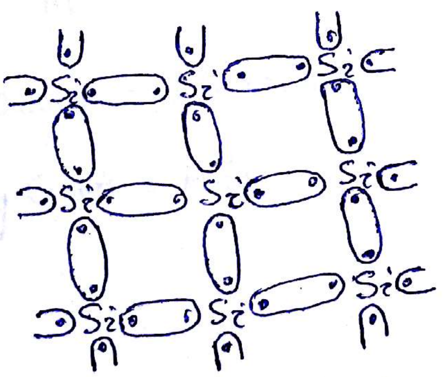
Semiconductors are Negative temp-coefficient of Resistance.

Simplified Crystalline Structure of Silicon

"At absolute zero (−273°K)"

⇓

Act as an Insulator



(Two Dimensional Representation)

The Three Dimensional Structure = Crystal

Doping

A controlled addition of impurities in a pure (intrinsic) semiconductor is known as doping.

The process ← Intrinsic + Dopant

↓ known as Doping

Doping Agent

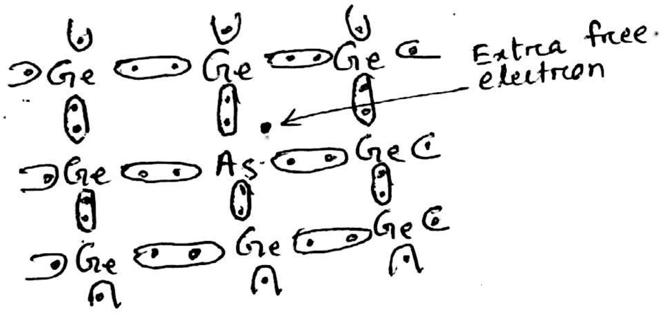
Pentavalent
(Bi, Sb, As, P)

DONOR
→ N-Type Semiconductor
→ Negative charge carrier (electron)

Trivalent
(Ga, In, Al, B)

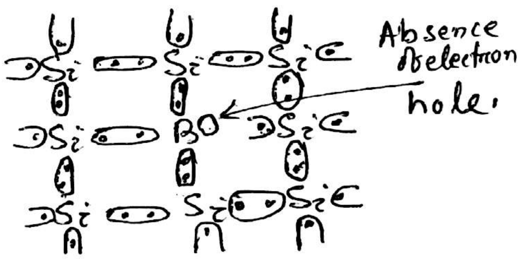
ACCEPTOR
→ P-Type Semiconductor
→ Positive charge carrier (hole)

Doped Semiconductor ⟹ Extrinsic Semiconductor



Majority Carrier = Electron

Minority Carrier = Hole



Majority Carrier = Hole

Minority Carrier = Electron

Intrinsic Concentration

At room temp. & at any instant, the free electrons & holes, the two charge carriers present in equal no.

$$n = p = n_i$$

where,
n = No. of free electrons per unit volume
p = No. of holes per unit volume.
n_i = Intrinsic Concentration.

~~Fermi Label~~

Fermi Level

E_f = Probability of occupancy of an energy level by an electron.

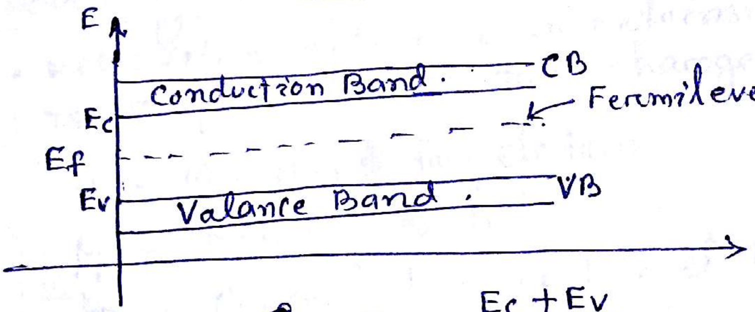
At Absolute Zero

- Probability of finding electrons in conduction band is zero
- Probability of finding holes in valance band is zero

At Increased Temp

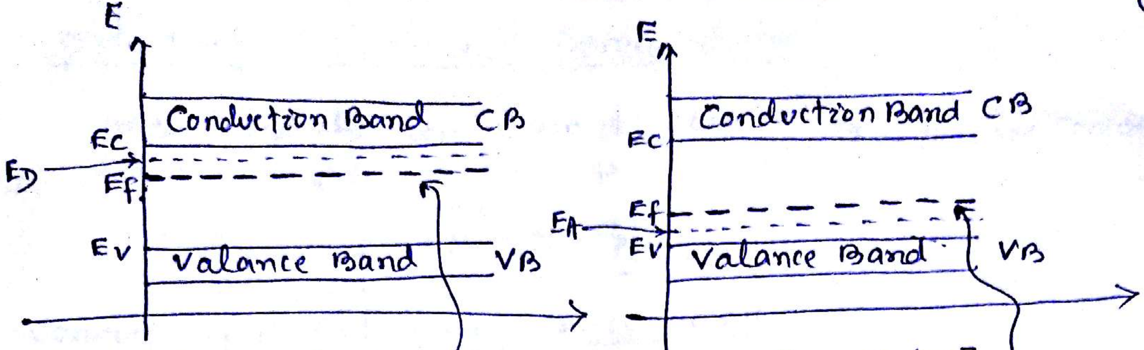
- Equal no. of holes & electrons generated.

So (Probability of electrons at conduction band) = (Probability of holes at valance band)



So $E_f = \frac{E_c + E_v}{2}$

where E_c = lowest energy level of CB
E_v = highest energy level of VB



[N- Type] [P- Type]

Fermi level shifts towards Conduction Band

Fermilevel shifts towards Valance Band

E_D = Donor Energy Level

E_A = Acceptor Energy level

Mobility of Charge Carriers

- When a material is applied external electric field "E" the drift velocity of charge carrier is proportional to E.

$$V \propto E$$

$$\Rightarrow V = \mu E$$

Proportionality constant called Mobility of charged particle.

$$\Rightarrow \boxed{\mu = \frac{V}{E}} \quad \frac{m^2}{V.sec}.$$

Conductivity of Semiconductor

- ~~Well~~ Whether intrinsic or extrinsic the conduction is responsible for two charged particles.

μ_n = Mobility of free electron

μ_p = Mobility of hole

n = Concentration of free electron

p = Concentration of hole

E = Applied field Potential

q = charge of one electron

σ = Conductivity $= \frac{1}{\rho}$ $(\Omega m)^{-1}$

ρ (resistivity)

So
$$\left.\begin{aligned} J_p &= p q \mu_p E \\ J_n &= n q \mu_n E \end{aligned}\right] \text{Current Density due to hole \& electron.}$$

So Total
$$J = J_n + J_p$$
$$= n q \mu_n E + p q \mu_p E$$
$$\Rightarrow \boxed{J = (n\mu_n + p\mu_p) q E}$$

$$J = \sigma E$$

So $\boxed{\sigma = (n\mu_n + p\mu_p) q}$

Conductivity of Semiconductor

Conductivity of Intrinsic Semiconductor

Here no. of electron = no. of hole

$n = p = n_i$ (intrinsic concentration)

So $\boxed{\sigma_i = n_i(\mu_n + \mu_p)q}$

Conductivity of Extrinsic Semiconductor

N-type

N_D = Concentration of Donor

n_n = Concentration of electron

P_n = Concentration of hole

So, conductivity

$\sigma_n = (n_n \mu_n + P_n \mu_p) q$

Here $P_n \ll n_n$

So $\boxed{\sigma_n = n_n \mu_n q}$

or $\boxed{\sigma_n = N_D \mu_n q}$

P-type

N_A = Concentration of Acceptor

P_p = Concentration of hole

n_p = Concentration of electron

So, conductivity

$\sigma_p = (n_p \mu_n + P_p \mu_p) q$

Here $n_n \ll P_n$

So, $\boxed{\sigma_p = P_p \mu_p q}$

or $\boxed{\sigma_p = N_A \mu_p q}$

(Q) Find resistivity of intrinsic Silicon at the temp 27°c. Find resistivity of intrinsic silicon at 300°k as Assume intrinsic concentration of silicon at 300°k as $1.5 * 10^{10}$ per cm³. The mobility of free electron as 1300 cm²/V-sec and holes as 500 cm²/V-sec.

Ans

$n_i = 1.5 * 10^{10}$ per cm³ $= \frac{1.5 * 10^{10}}{10^{-6}}$ per m³

$\mu_n = 1300 \frac{cm^2}{V\text{-}sec} = 1300 * 10^{-4} \frac{m^3}{V\text{-}sec}$

$\mu_p = 500 \frac{cm^2}{V\text{-}sec} = 500 * 10^{-4} \frac{m^2}{V\text{-}sec}$

$q = 1.602 *^{-19}$ coloum.

So, conductivity $\sigma = (n\mu_n + p\mu_p)q$ $\quad (\because n = p = n_i)$

$= n_i(\mu_n + \mu_p)q$

$= \frac{1.5 * 10^{10}}{10^{-6}} * (1300 + 500) * 10^{-4} * 1.602 * 10^{-19}$

$= 4.3254 * 10^{-4} (\Omega\text{-}m)^{-1}$

Resistivity $\rho = \frac{1}{\sigma} = \frac{1}{4.3254 * 10^{-4}}$

$= 2311.92\ \Omega\text{-}m$

(Q) A donor impurity is added to intrinsic Silicon and the resistivity at room temperature is observed to be 9.6 Ω-cm. Calculate the ratio of donor atoms to Silicon atoms per unit volume. Assume μ_n as 1300 cm²/v-sec.

Ans In case of donor impurity, the majority carriers electrons, so $n_n \cong N_D$

$$\therefore \sigma_n = N_D \mu_n q$$

Given $\rho = 9.6\ \Omega\text{-cm} = 9.6 * 10^{-2}\ \Omega\text{-m}$

$$\therefore \sigma_n = \frac{1}{\rho} = \frac{1}{9.6 * 10^{-2}} = 10.416\ (\Omega\text{-m})^{-1}$$

$$\therefore 10.416 = N_D * (1300 * 10^{-4}) * 1.602 * 10^{-19}$$

$$\Rightarrow N_D = 5 \times 10^{20}\ \text{atoms/m}^3.$$

According to table properties silicon atom density is $5 * 10^{22}$ atoms/cm³ $= 5 * 10^{28}$ atoms/m³.

So the ratio of donor atoms to silicon atoms per unit volume $= \frac{5 * 10^{20}}{5 * 10^{28}} = \frac{1}{1 * 10^{8}}$

$$= 1 * 10^{-8}.$$

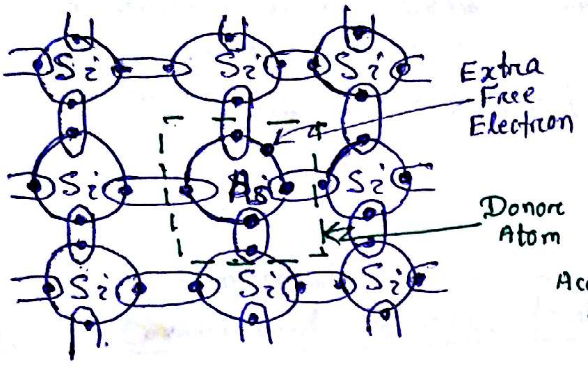
So one donor impurity is added per 10^8 silicon atom.

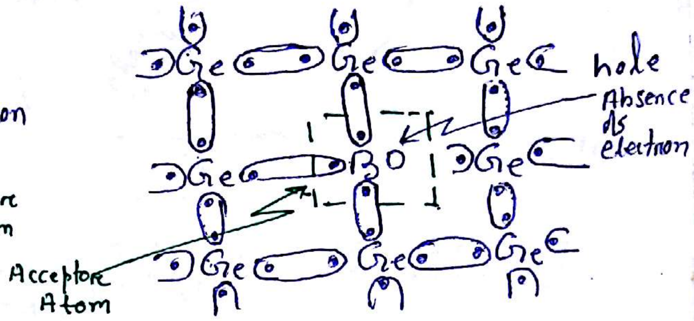
Extrinsic Semiconductore

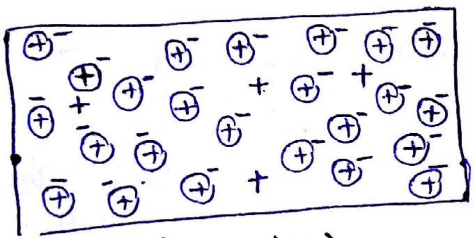
- when doping agent is added in small amount (about 1 part in 10^8) in a pure semiconductore will be called as extrinsic semiconductore.

Pentavalent
⇓
N- Type
majority carriers = electron
minority carriers = hole

Trivalent
⇓
P- Type
majority carriers = hole
minority carriers = electrons

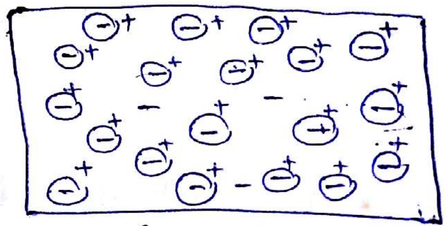






(N-Type)

$\oplus^-$ = Donor Atom
$-$ = Extra Free Electron
$+$ = Holes



(P-Type)

$\ominus^+$ = Acceptor Atom
$+$ = Holes
$-$ = Electrons

* when Donor Atom donates electron became positive charged imobile ion, represented as "$\oplus$"

* when Acceptor Atom accepts electron became negative charged imobile ion, represented as "$\ominus$"

(Q) How is an N-Type Semiconductor is formed?

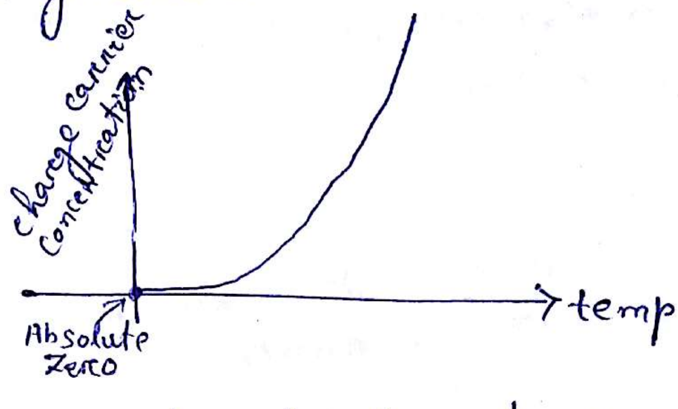
- When pentavalent impurity is added to a pure semiconductor, then the extrinsic semiconductor formed is known as N-Type.

(Add Figure)

(Q) What is the difference betn Intrinsic & Extrinsic Semiconductor?

(Q) What is the effect of heat on a semiconductor?

- At ~~room~~ increased temperature the covalant bond of semiconductor breaks, which generate more electron & hole pair.
- Semiconductor behaves like a good conductore. (In decresed Resitance).



- So semiconductor is called "Negative temperature coefficient of resistance".