Date-10/30/2021

Question: what is Electronics.
It is the branch of physics which deals with the study of semi-conductor.

Classification of Solid Materials :

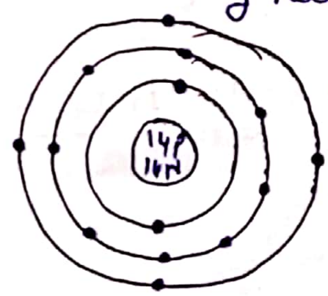
(a) conductor: Good conductor of electricity as they have large no of mobile charge carriers or free electrons
Resistivity : $10^{-8}\Omega m$ and increases with increase in temperature.

(b) Insulator: Bad conductor of electricity, no charge carriers or free electrons.
Resistivity : $10^{12}\Omega m$, constant up to limit after which it suddenly fall.

(c) Semiconductor: conductivity lie between those of conductor and insulator.
Resistivity : 10^{-4} to $0.5\Omega m$, decreases with increase in temperature.

Structure of An atom : Nucleus (proton Neutrons) + electrons. An orbit or shell can contain:

- Maximum $2n^2$ electrons, except last shell which can only hold up to 8 electrons $n \rightarrow$ no. of orbit



Silicon atom($14e^-$)

Each isolated atom can be only a contain no. of orbit, each orbit has fixed amount of energy associated with it and electron moving in particular orbit posses the energy of that orbit.

Energy Bands in Solids :

In isolated atom, electrons revolving in any shell posses a certain amount of Energy, But when atoms from a solid, the orbit of an electron is affected not only by the charges of its own atom but by neucleus and electrons of each atom in solid.

Because of this, electrons in the same orbit have a range of ~~eng~~ energies called energy band.

∴ "Range of energies possessed by electrons of the same orbit in a solid is called energy band"

⇒ Bands of majaor consideration are:

(1.) Valance Band: Energy band which possesses the valence electrons is called valence band.

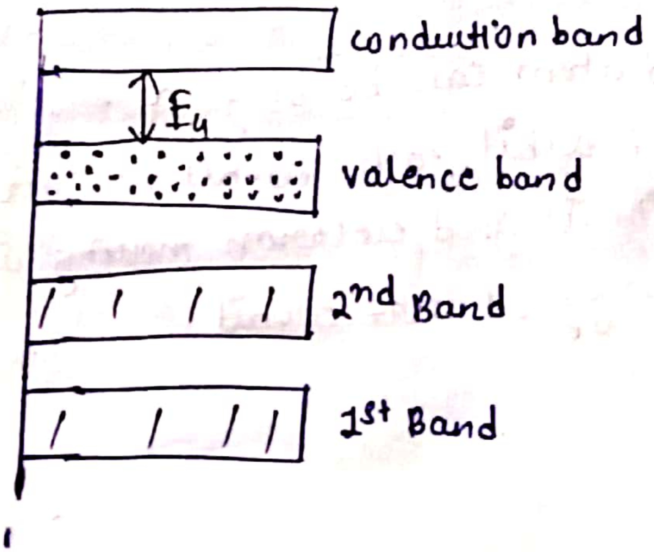
(2.) Conduction Band: Energy band which possesses free electrons is called conduction band.

Forbidden Energy Gap:

Valence band and conduction band are seperated by an Energy gap in no electron can normally exist.

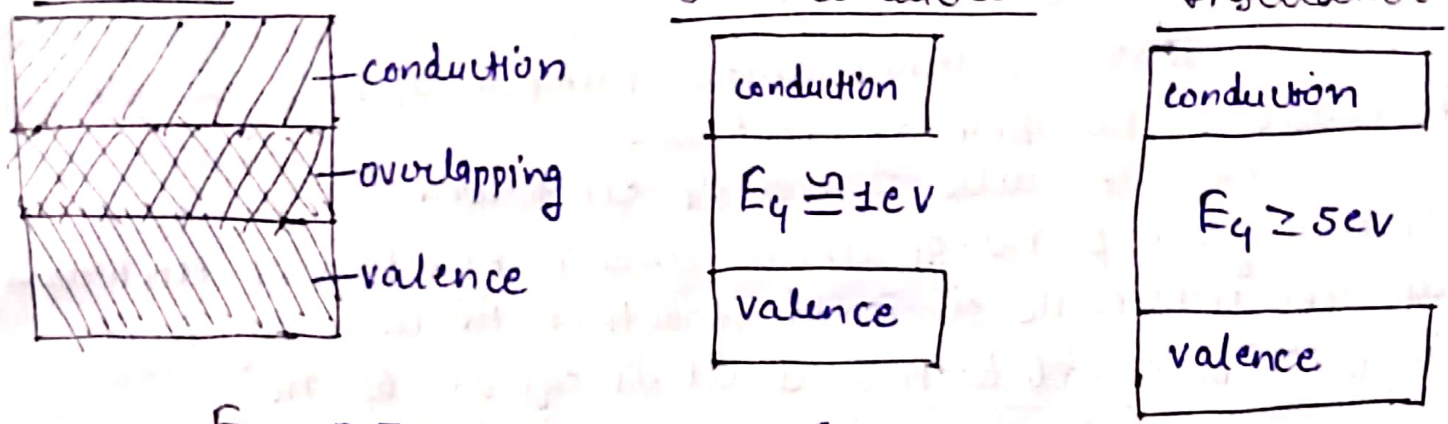
To make valence electron free, some external Energy through heat or light equal to E_g should be supplied.

∴ Energy Band Diagram (silicon)



• Energy Band Diagram :-

Metal | Semi-conductor | Insulator



$E_g = 0.72eV$ for germanium

$E_g = 1.12eV$ For silicon

Question - why silicon is preffer over the Germinium.

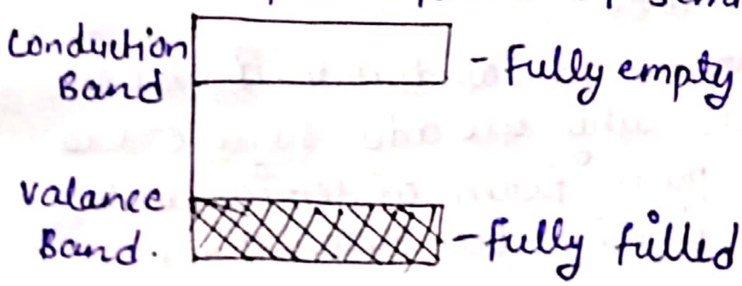
① Silicon is easily available in nature i.e. more economical as compared to germenium

② silicon is more temperature resistive as compared to germenium as the band gap of Germenium is less than the silicon.

Types of semiconductors.

① Intorinsic semi-conductor-

• It is a pure form of semiconductor.



• whenever in intrensic semiconductor whenever an electron moves from valance band to conduction band ~~and hence~~ it will create a hole in the valance band and hence in this manner in a semi-conductor the free electron moving in the conduction and the holes are moving in the valance band i.e. the conductivity of a semiconductor depends upon the movement of electron as well as the movement of holes. Hence there are two types of charge carriers in the semiconductor.

① negatively charged electrons.

② positive charged holes.

- for in Intrinsic semiconductor number of holes is always be equal to number of electrons.

no. of holes = no. of electrons

if, there are 'p' no. of holes and 'n' number of electrons in an intrinsic semiconductor then we will say that 'p' will be equal to 'n' and it is equal to n_i

$$\boxed{p = n = n_i}$$

n_i → Intrinsic concentration of charge carriers.

for silicon,

$$n_i = 1.5 \times 10^{10} / cm^3$$

For Germenium,

$$n_i = 2.5 \times 10^{13} / cm^3$$

(2) Extrinsic Semi-conductor :-

There are two types of Extrinsic semiconductor

→ n type (penta-valent impurities)

→ p type (Trivalent impurities)

- Since, the conductivity of intrinsic semiconductor is not enough to drive a load that's why we add some extra elements or impurities to the pure form of semiconductor and the process is called the doping. Due to Doping the conductivity of the semi-conductor will increase and is said to be extrensic semiconductor.

① n-Type semiconductor :-

whenever be dop elements of 5^{th} Group or pentavalent impurities to the instrensic semi-conductor then it is said to be n-type semi-conductor.

- pentavalent impurity is known as donar impurities.
- The pentavalent impurities are donating an electron as the donar impurities and due to this the no. of free electrons will increase in the semi-conductar and hence we will stay that the conductivity of the semiconductar increasing by increasing the no. of electron.

Suppose, the concentration of the donar ~~it~~ impurities is represented by N_D it means that the number of extra free electrons will be $\boxed{n = N_D}$

let, 'n_0' and 'p_0' are the concentration of electrons and holes at room temperature due to the breaking of the bond then,

The total no. of electrons

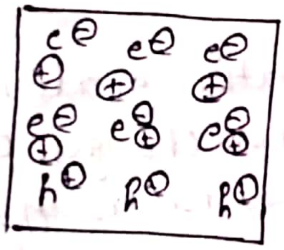
$n_0 + n$

no. of holes

p_0

$e^\ominus$ are majority charge carriers

holes$^\oplus$ are minority charge carriers



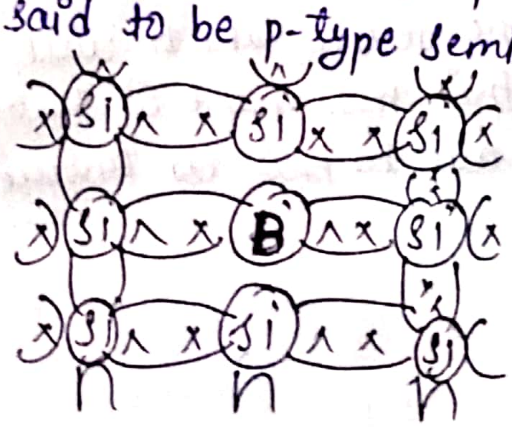
$e^\ominus \rightarrow$ majority charge carrier

$h^\oplus \rightarrow$ minority charge carrier

$\oplus \rightarrow$ donar ions.

② P-Type:-

when ever we dope the trivalent impurities like boron, hellium, Indium to the pure form of semiconductar then it said to be p-type semi-conductar.



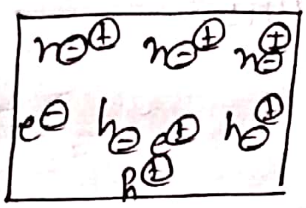
Acceptar impurity

Suppose, we dope the acceptor impurities having the concentra-tion of N_A atoms/cm^3 then the number of extra holes, then the no. of extra holes due to the acceptor impurity will also be equal to N_A.

$$\boxed{p = N_A}$$

The no. of extra electrons

let N_0 and p_0 represents the no. of electrons and wholes respectively in an intrensic semiconductor then after doping with trivalent impurities the number of wholes equal to $\boxed{p + p_0 >> n_0}$ and hence this semiconductor is know as p-type semiconductor.



$h^+ \rightarrow$ majority charge carriers
$e^- \rightarrow$ miniority charge
$\ominus \rightarrow$ Accepter ions
(do not move any where)

Diffusion:-
whenever there is a concentration gradient of charge carriers in a material then the charges flow without any force and this process is known as the diffusion and the current due to this is known as the diffusion.

Drift current:-
whenever we apply an external voltage to a device it will create an electric field in the device which will force the charge carriers to move this movement is known as the drift movement and current due to this is known as the drift velocity.

⇒ Law of Mass Action :-

At thermal equilibrium the product of the ~~constitution~~ concentration of holes and electrons will always remain constant and it is equal to the square of the intrinsic concentration.

If no. of holes = p

and no. of electron n = n

$$\boxed{n \times p = n_i^2}$$

for n-type semiconductor,

$N_D = n$

no. of electron

$$\boxed{n_0 + n \simeq n}$$

$$p = \frac{n_i^2}{n} \quad (\because n = N_D)$$

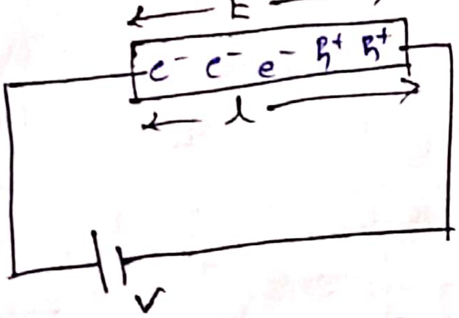
$$\boxed{\frac{n_i^2}{N_D} = p}$$

For p-type semiconductor :

$N_A = p$

$p_0 + p \simeq p$

$$\boxed{n = \frac{n_i^2}{p} = \frac{n_i^2}{N_A}}$$



$$\boxed{E = V/l}$$

- The mobility of electrons is greater than the mobability of holes due to mass

$$\boxed{e \to h}$$

$$\boxed{\mu_n >> \mu_p}$$

- Drift velocity :

$$\boxed{V_d = \mu E}$$

- Conductivity.

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

- Total conductivity of semiconductor:-

$$= \sigma_p + \sigma_n$$

where, $\boxed{\sigma_p = pq\mu_p}$

$$\boxed{\sigma_n = nq\mu_n}$$

for extrinsic:

$$\boxed{\sigma_{(doped)} = q(n\mu_n + p\mu_p)}$$

For intrinsic:

$$\boxed{\sigma_{(intrinsic)} = n_i q(\mu_n + \mu_p)}$$

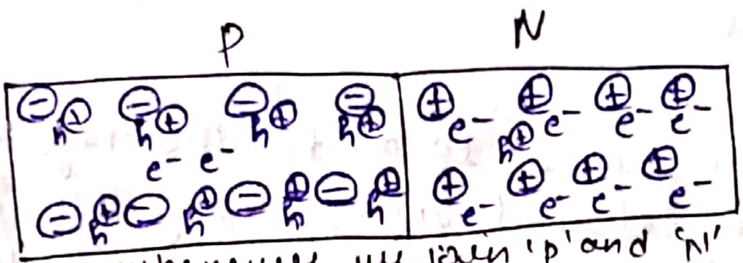
current density:

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

$$\boxed{J = I/A}$$

Scanned with CamScanner

Diode: p-N Junction



(p and N type semiconductor)

whenever we join 'p' and 'N' type conducter:

Step 1: • electrons will differ from N to p
• wholes ($h^{\oplus}$) will differ from p to N

Step 2: As the electrons and wholes interact at the junction they will recombined with each other leaving behind negative ions in the p-side and positive ions in the N-side.

Step 3: Due to this a potential difference will setup at the junction which will induced in electric field. at the junction and due to this the charge carriers will also start drifting

Step 4: The electrons will drift from p to N and the wholes are drift to N to p.

As this process goes on the diffusion and drift will oppose each other and at the equilibrium point the diffusion will become equal to drift and hence no further flow of charges will take place across the junction.

Step 5: At this point a layer is create across the junction which will consist of only the immobile ions which is known as the depletion layer (free of any mobile carriers)

• **potential Barrier:-**

It is the builting potential developed at the junction whenever be joined 'p' and 'N' type semiconductor.

It is denoted as 'V_B'

for silicon, $V_B = 0.7\,V$

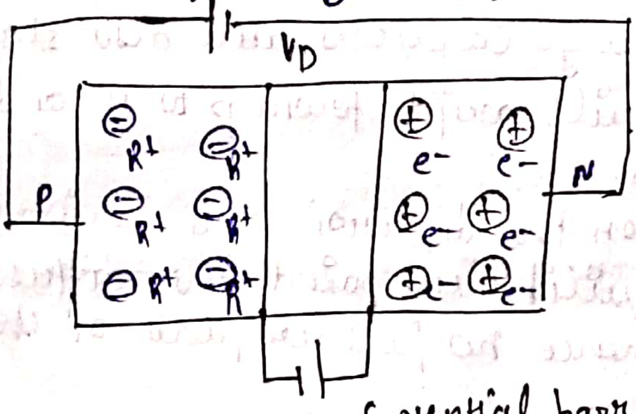
for germanium, $V_B = 0.3\,V$

(2) Forward Bias ($V_D = +ve$)

P-type = +ve terminal

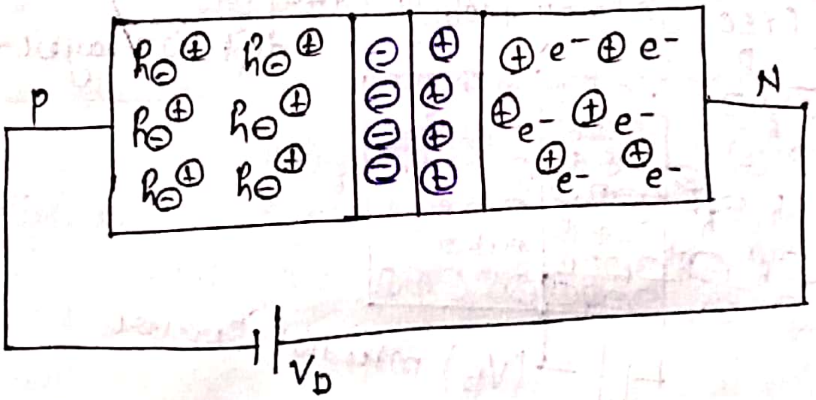
N-type = -ve termine

Whenever we connect positive terminal to p-side and negative terminal to N-side of an external voltage supply then it will force the wholes of p-side and the electrons of N-side to move further and whenever they entered the depletion layer they will recombine with their respective ions and hence the width of the depletion layer will gets reduce. As soon as the voltage becomes greater than the potential barrier the depletion layer is completely reduced and hence the flow of charge particles will take place from one side to another side and in this manner we will say that the current is flowing through the diode in the forward bias condition



V_B (potential barrier)

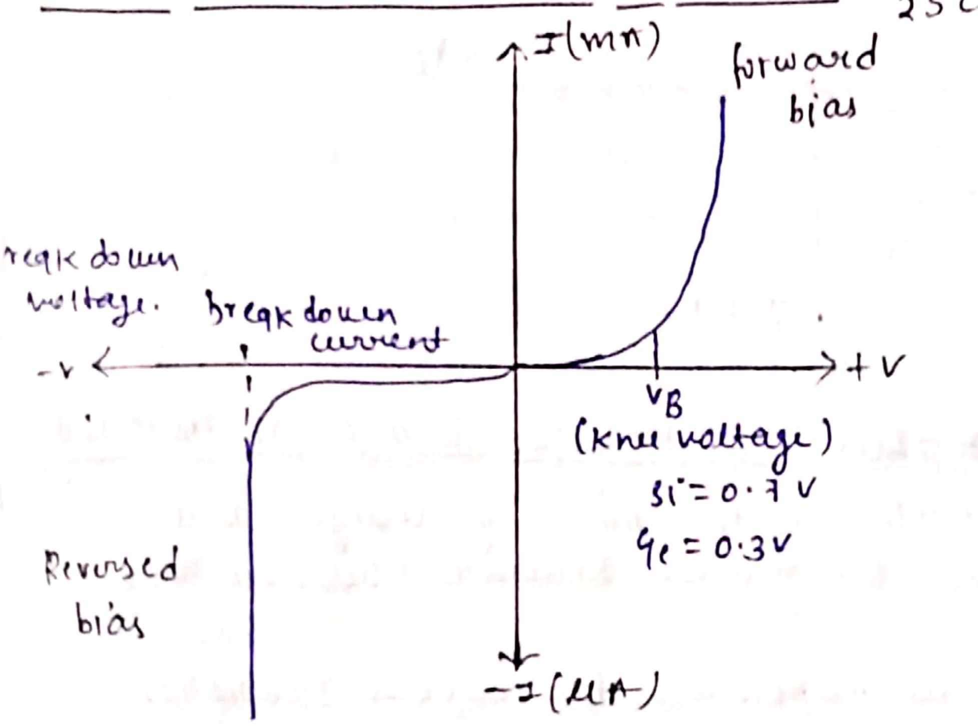
Reversed Bias :-



In the Reversed biased condition the negative terminal of the external battery is connected to the p-side and the positive terminal of the battery is connected to the N-side in this manner the positive and negative terminals of the battery will attract the electrons of N-side and holes of the p-side towards themselves respectively, due to which the width of the depletion layer will get increase and hence no movement of majority large carriers will take place across the junction and ideally the current will be zero.

practically, In the reverse bias condition the movement of minority charge carriers take place across the junction due to the electric field intensity in the depletion layer. and hence a very small current is following in the reversed biased condition due to these minority charge carriers which is known as the reverse saturation current (I_s).

• V-I Characteristics of diode:



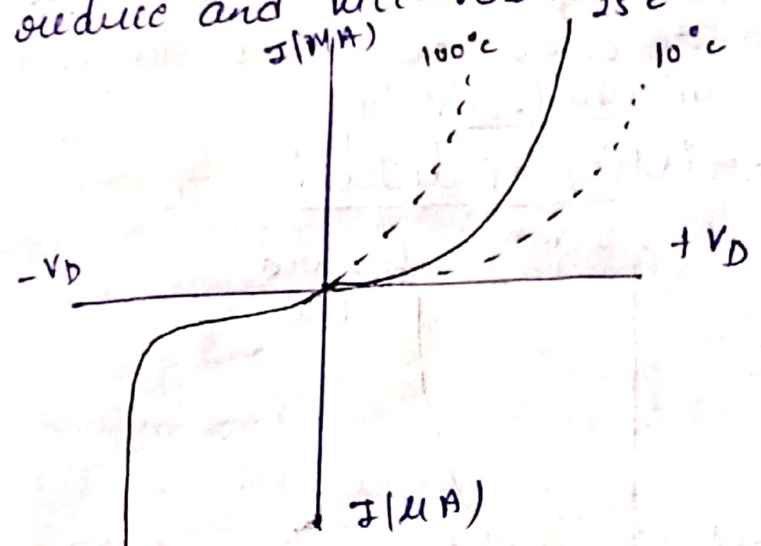
Avalenche breakdown:

In reverse biase condition as be increases the reverse voltage the kinetic Energy of the minority charge carriers increases and when they move with very high energy they will collide with the ions of the depletion layer and break there covalent bond. so, in this manner the no. of charge carriers will increase is known as Avalenche multiplication due to this large no. of charge carriers the reverse current increases randomly and this is known as Avalenche breakdown.

Effect Of Temperature on V-I characteristics of a diode.

① Effect of temperature on Barrier potential (V_B):

when be increase the temperature as the no. of carriers in the semiconductor material increases therefore the barrier potential will reduce and vice-versa.



② Effect of Temperature on Reverse Saturation current:

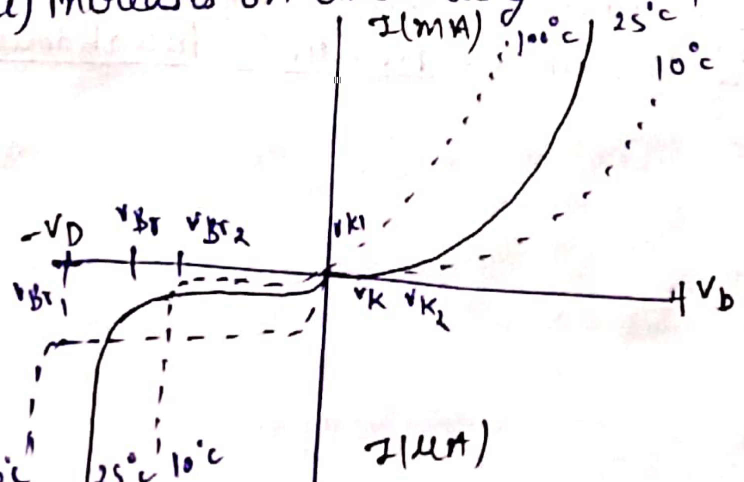
On increasing the temperature as the minority charge carriers is also increasing therefore the reverse saturation current also increases.

- On every 10°c rise in temperature the reverse saturation current gets doubble.

Imp

$$\boxed{I_{s(new)} = I_{s(old)} \times \left(2^{\left(\frac{T_2 - T_1}{10}\right)}\right)}$$

- As on increasing the temperature the ion in the depletion layer starts vibrating therefore, the charge carriers will require more energy to break there covalent bond and hence the breakdown voltage (Avalanche) increases on increasing the temperature and vice-versa.



$\left.\begin{array}{l} V_{K_1} < V_K \\ I_{S_1} > I_S \\ V_{Br} > V_{Br} \end{array}\right\}$ 25°c

$\left.\begin{array}{l} V_{K_2} > V_K \\ I_{S_2} < I_S \\ V_{Br_2} < V_{Br} \end{array}\right\}$ 25°c

Shockley Equation :

$$\boxed{I_D = I_S\left[\left(e^{V_D/nV_T}\right) - 1\right]}$$

where, I_D = Diode current.

I_S = Reverse saturation current.

V_D = Applied voltage.

n = ideality factor. (for silicon = 2 and Ge = 1)

V_T = Temperature equivalent voltage.

$$\therefore \boxed{V_T = \frac{KT}{q}}$$

where, K = Boltzmann constant $= 1.38 \times 10^{-23}$ J/K

$T \rightarrow$ Temperature in kelvin.

$q \rightarrow$ charge $(1.6 \times 10^{-19}C)$

At room temperature, (300°K)

$$\boxed{V_T = 26mV = 0.26V}$$

Question:

The current flowing in diode is 2×10^{-7} Ampere at room temperature when a reverse voltage is applied. calculate current through the diode when a forward bias of 0.1 volt is applied across diode at room temperature.

$$I_D = 2 \times 10^{-7}\left[\left(e^{0.1/2(.026)}\right) - 1\right]$$

$$= 2 \times 10^{-7}(6.84 - 1)$$

$$= 2 \times 10^{-7}(5.84)$$

$$= 11.68 \times 10^{-7}$$

(2) At room temperature current through a germanium diode is 5 milli ampere at 0.35 V find the value of current if applied voltage is .4V.

Given: $V_{D_1} = 0.35V$ $I_{D_1} = 5 \times 10^{-3}$ A

$I_{D_2} = ?$ $V_{D_2} = 0.4V$

Soln:

As, $I_D = I_S\left(e^{(V_D/nV_T)} - 1\right)$

$$= \frac{I_{D_1} = \cancel{I_S}\left(e^{(V_{D1}/nV_T)} - 1\right)}{I_{D_2} = \cancel{I_S}\left(e^{(V_{D2}/nV_T)} - 1\right)} \simeq \frac{e^{V_{D1}/nV_T}}{e^{V_{D2}/nV_T}}$$

$$= \frac{I_{D1}}{I_{D2}} = e^{\frac{V_{D1}-V_{D2}}{nV_T}}$$

$$\frac{I_{D1}}{I_{D2}} = e^{\frac{-0.05}{\cancel{2}(0.026)}}$$

$$I_{D2} = \frac{5\times10^{-3}}{e^{\frac{-0.05}{0.026}}}$$

$$= \frac{5\times10^{-3}}{e^{-1.923}}$$

$$=$$

$\boxed{\text{Ans} - 34.2\ mA}$

Diode Resistance :-

· DC Resistance :-

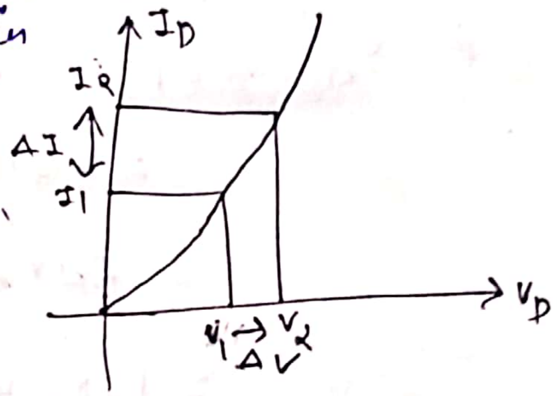
when ever we applied DC voltage to a diode it will offer the resistance which is termed as DC resistance.

$$\boxed{R_D = \frac{V_D}{I_D}} \text{ forward} \qquad \boxed{R_D = \frac{V_D}{I_S}} \text{ reversed}$$

where, R_D = D.C Resistance

· AC Resistance :- (Dynamic Resistance)

whenever we applied A.c voltage to the diode the resistance offered will be termed as the A.c resistance and it is given by the ratio of the change in applied potential to the change in current.



$$\boxed{r_d = \frac{\Delta V}{\Delta I}}$$

$$I_D = I_S\left[e^{V_D/nV_T} - 1\right]$$

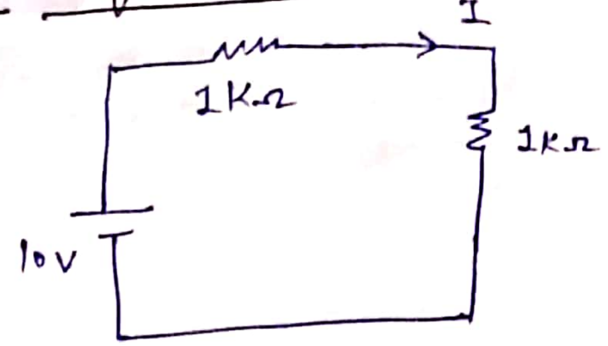
$$\frac{dI_D}{dV_D} = I_S\left[\frac{e^{V_D/nV_T}}{nV_T}\right]$$

$$\left(\therefore\ I_D = I_S e^{V_D/nV_T} - I_S \qquad I_S e^{V_D/nV_T} = I_D + I_S\right)$$

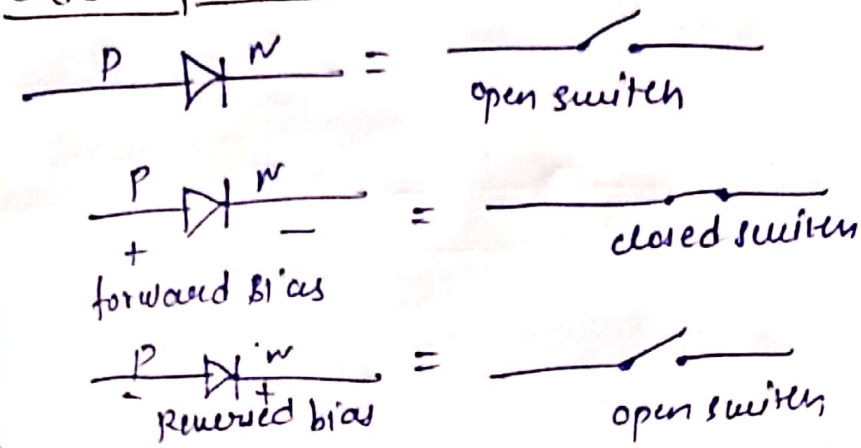
$$\boxed{\frac{dI_D}{dV_D} = \frac{I_D + I_S}{nV_T} \simeq \frac{I_D}{nV_T}}$$

$$\boxed{r_d = \frac{nV_T}{I_D}}$$

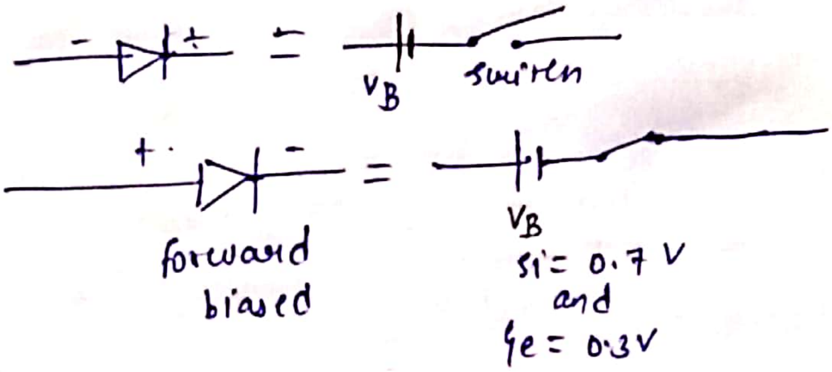
Diode Equivalent circuit



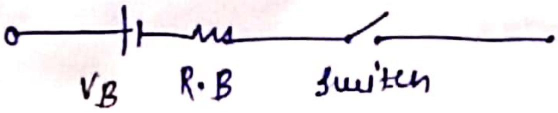
① Ideal proximation:



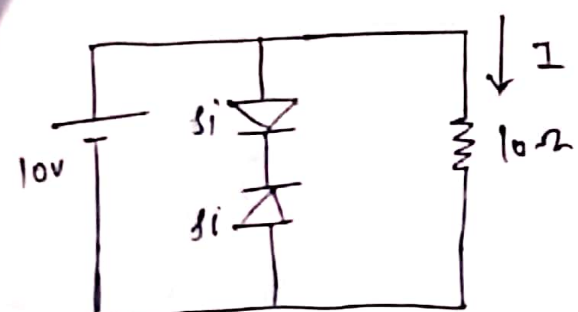
② practical Approximation (Ge and Si):



③ Piece-wise linear model Approximation:

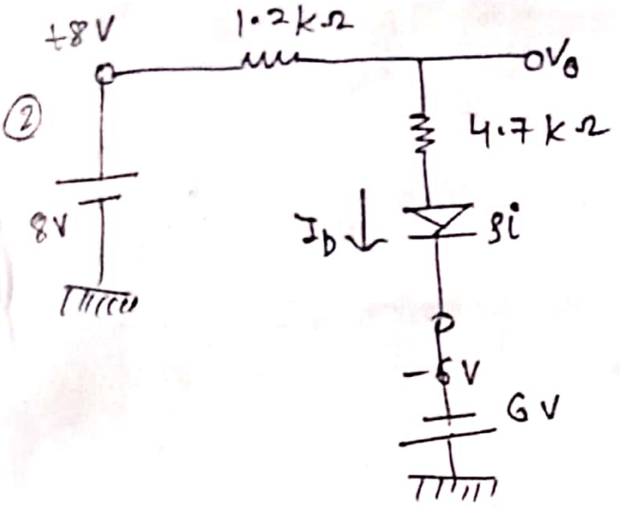


Ex:



$\boxed{\text{Current, } I = 1\text{ A}}$

(2)



$$8-1.2I_D-4.7I_D-0.7+6V=0$$

$$-15.9I_D=+13.3$$

$$I_D=\frac{13.3}{5.9}$$

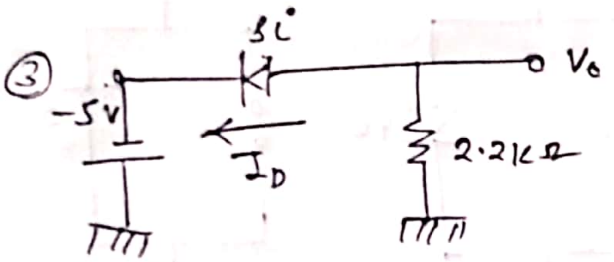
$$\boxed{I_D=2.25A}$$

$$V_0=4.7I_D+0.7-6$$

$$V_0=4.7\times2.25+0.7-6$$

$$\boxed{V_0=5.27V}$$

(3)



$$-5+0.7+(-2.2I_D)=0$$

$$-4.3-2.2I_D=0$$

$$2.2I_D=5.7$$

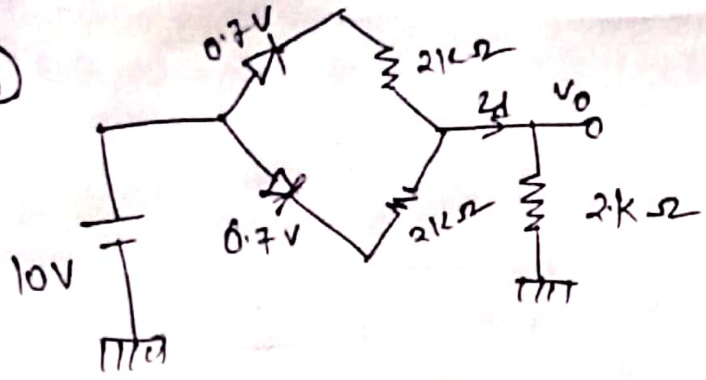
$$I_D=\frac{4.3}{2.2}$$

$$\boxed{I_D=1.95A}$$

$$V_D=+2.2I_D$$

$$\boxed{V_D=4.29V}$$

(4)



$$+10 - 0.7 - 2I_D - 4I_D = 0$$

$$6I_D + (-9.3) = 0$$

$$6I_D = 9.3$$

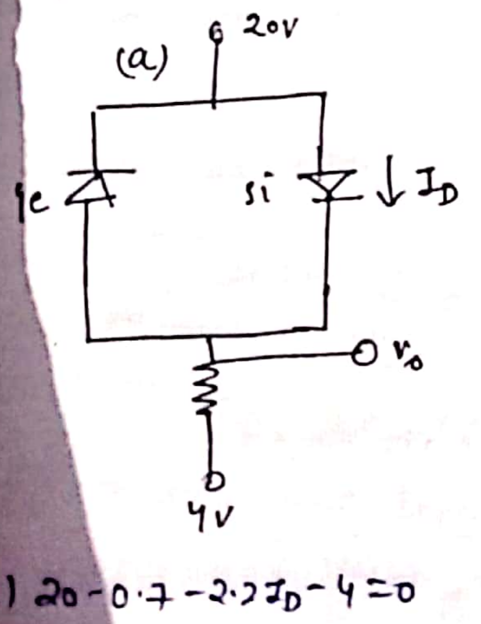
$$I_D = \frac{9.3}{6}$$

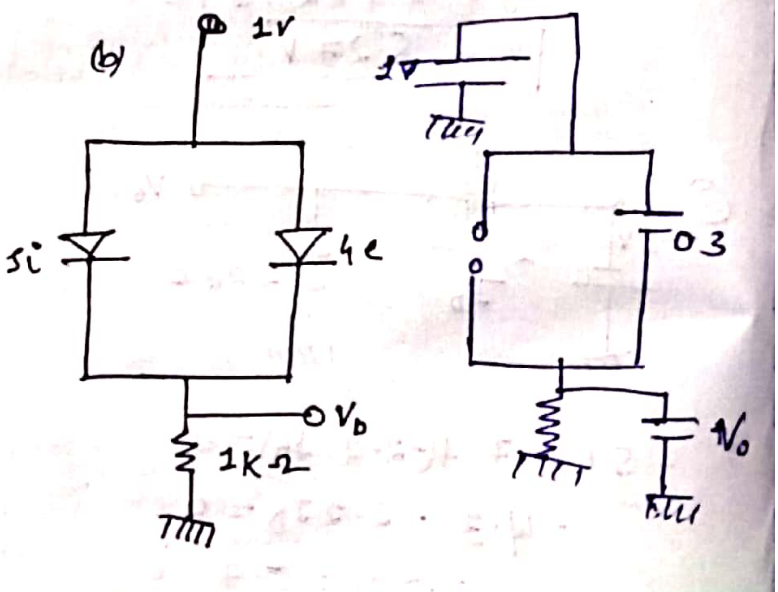
$$\boxed{I_D = 1.55\ A}$$

$$V_0 = 2(2I_D)$$

$$= 2(2 \times 1.55)$$

$$\boxed{V_D = 6.2V}$$





(a) $20 - 0.7 - 2.2I_D - 4 = 0$

$$-2.2I_D + 15.3 = 0$$

$$I_D = \frac{15.3}{2.2}$$

$$\boxed{I_D = 6.95mA}$$

$$V_0 - 2.2I_D - 4 = 0$$

$$V_0 = 2.2I_D + 4$$

$$\boxed{V_0 = 19.29\ V}$$

(b) $1 - 0.3 - 1I_D = 0$

$$\boxed{I_D = 0.7mA}$$

$$V_0 - 1I_D = 0$$

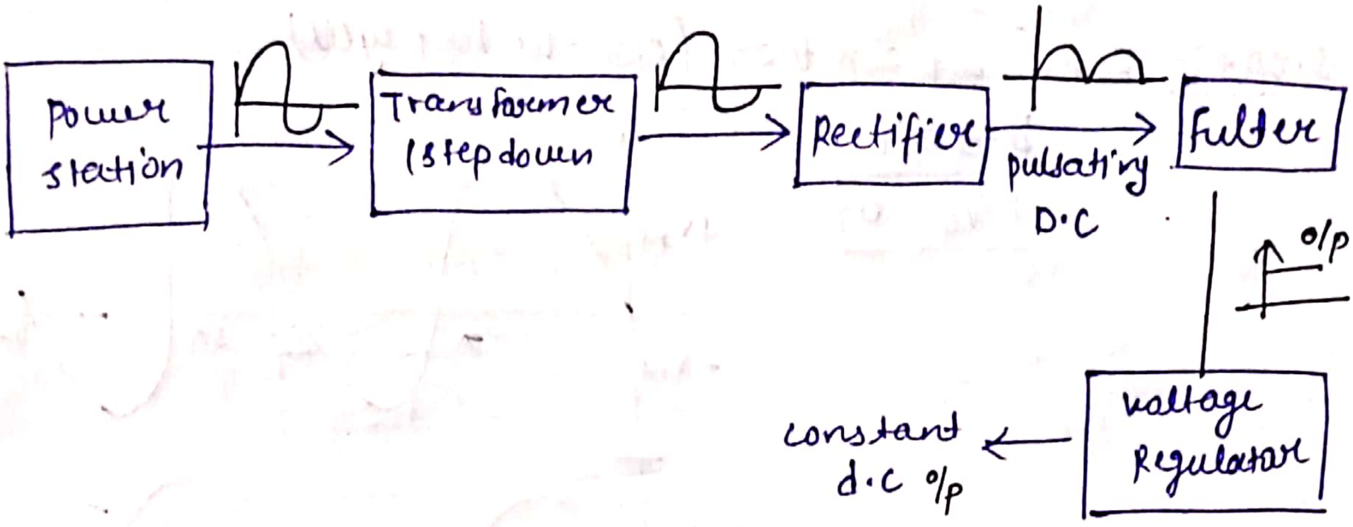
$$V_0 = 1I_D$$

$$\boxed{V_0 = 0.7\ V}$$

Diode Application :-

① Rectifier :-

DC power supply system :-

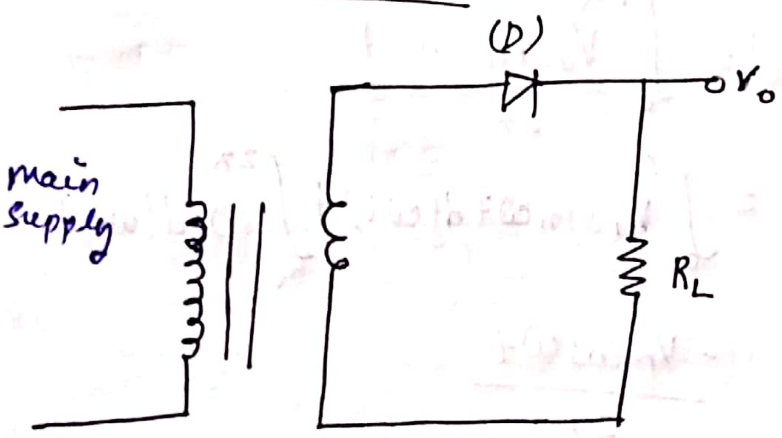


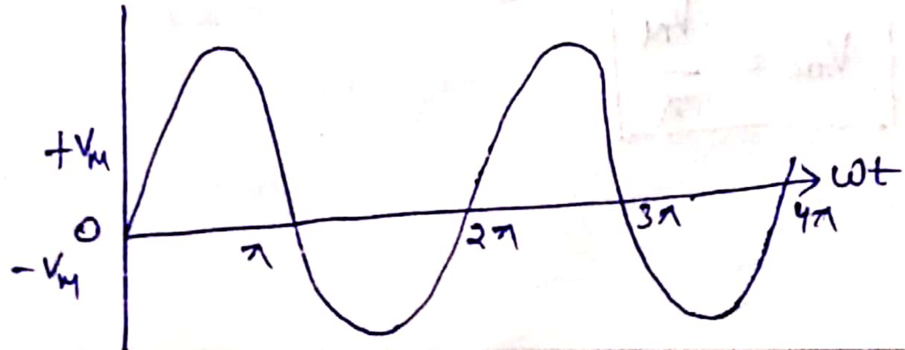
⇒ Rectifier

(It is converted in to D.C to A.C)

- Half wave rectifier
- Full wave rectifier
  - Center tap
  - Bridge

① Half wave rectifier :-





$(V_M = -V_M \sin \omega t)$

Step1:- From $\omega t = 0$ to π (For +ve half cycle)

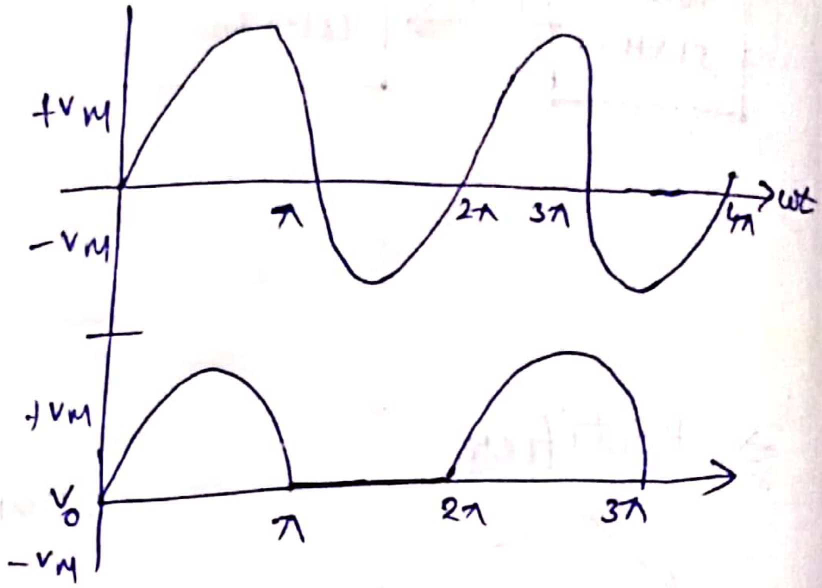
D → ON

$$\boxed{V_o = V_{in}}$$

Step2:- From $\omega t = \pi$ to 2π (For -ve half cycle)

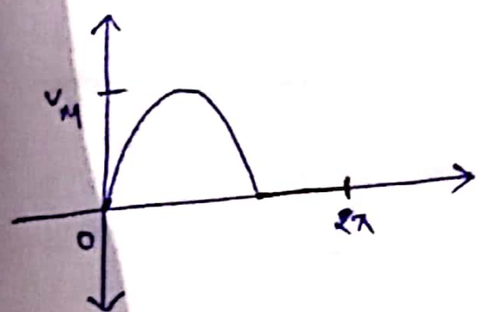
D → off

$$\boxed{V_o = 0}$$



Charateristics of half wave Rectifier:-

$$\boxed{\begin{aligned} V_{out} &= V_m \sin\omega t \quad 0 \le \omega t \le \pi \\ &= 0 \quad \text{to } \pi\, \omega t < 2\pi \end{aligned}}$$



$$DC \text{ value}(V_{dc}) = \int_0^{2\pi} \frac{V_{out} d(\omega t)}{2\pi}$$

$$= \int_0^{\pi} V_M \sin\omega t\, d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)$$

$$= \frac{-V_M \cos\omega t}{2\pi}$$

$$\boxed{V_{dc} = \frac{V_M}{\pi}}$$

② RMS value (Root mean square) :-

$$V_{rms} = \sqrt{\frac{\int_0^{2\pi} V_{out}\, d(\omega t)}{2\pi}}$$

$$\boxed{V_{rms}^2 = V_{ac}^2 + V_{dc}^2}$$

$$= \sqrt{\frac{\int_0^{\pi} V_M^2 \sin^2\omega t\, d(\omega t) + \cancel{\int_0^{2\pi} (0 \cdot d(\omega t))}}{2\pi}}$$

$$= \sqrt{\frac{V_M^2 \int_0^{\pi} \frac{1-\cos\omega t}{2}\, d(\omega t) + \int_0^{2\pi}}{2\pi}}$$

$$= \sqrt{\frac{\frac{V_M^2}{2}\left[\omega t - \frac{\sin\omega t}{\omega}\right]_0^{\pi}}{2\pi}}$$

$$= \sqrt{\frac{\frac{V_M^2}{2}(\cancel{\pi})}{2\cancel{\pi}}}$$

$$\boxed{V_{rms} = \frac{V_M}{2}}$$

③ Ripple factor :-

The ripple factor represents the amount of AC voltage at the output with respect to the dc voltage.

$$\boxed{r = \frac{V_{ac}}{V_{dc}}}$$

It is represented as 'r'

$$r = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} \qquad \left(\because V_{rms}^2 = V_{ac}^2 + V_{dc}^2 \right)$$

$$r = \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{(V_{dc})^2}} \qquad V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

$$r = \sqrt{\frac{V_{rms}^2}{(V_{dc})^2} - 1}$$

$$\boxed{r = \sqrt{\left(\frac{\cancel{V_m}/2}{\cancel{V_m}/\pi}\right)^2 - 1} = \sqrt{\frac{\pi^4}{4} - 1} = 1.21}$$

It represents the A.C voltage.