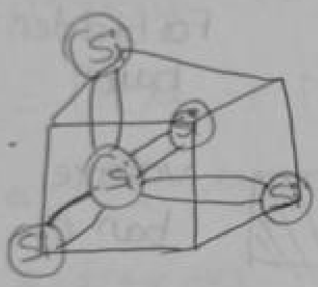
Semiconductors

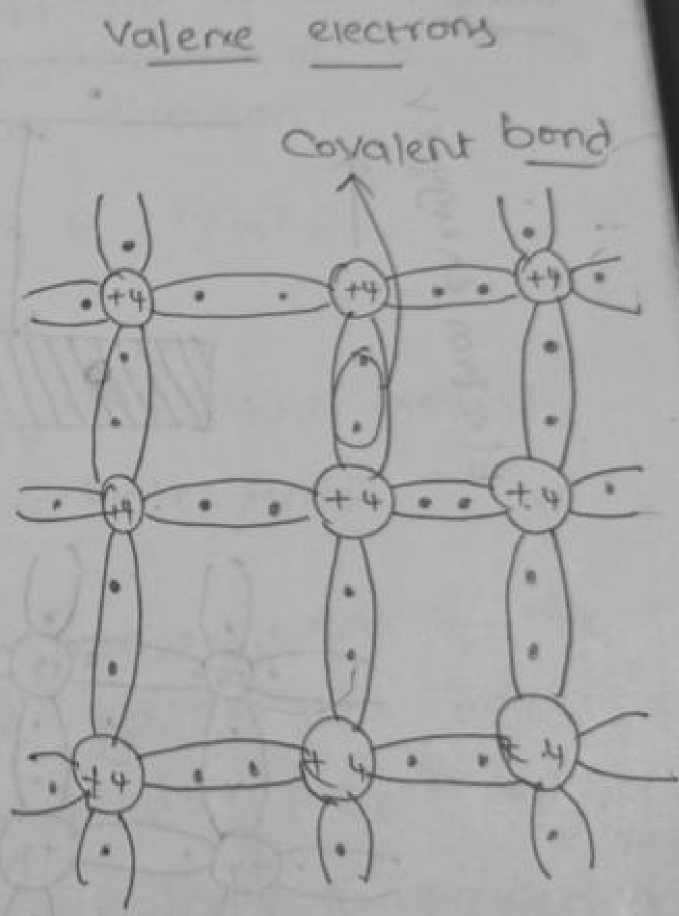
→ What way semi conductors are differ from conductors

In conductors; only electrons are charge carriers

In Semi conductors; Both electrons and holes are charge carriers.

→ By means of conductivity; It may act as conductor (or) insulator depending on baising.



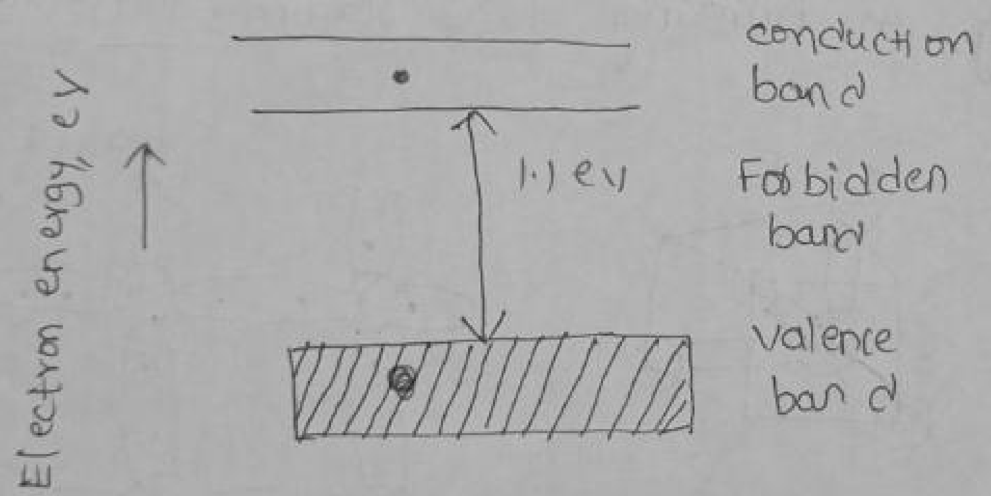


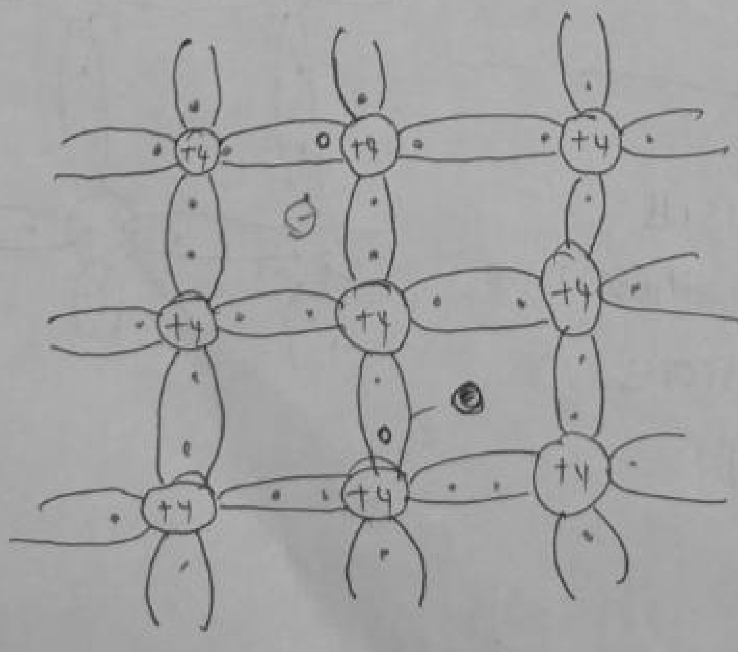
Si, Ge are fourth Group elements (It means that these have four Valence electrons in the outer orbit).

→ These electrons tightly bonded with ... electrons. At this condition, It will act as insulator. [at room Temperature]

→ The energy required to break a covalent bond is about 14.1 eV for Silicon and about 0.7 eV (Check it) for Germanium at room Temperature (about 300K)

Figure above is the energy band diagram of silicon from which it is seen that a valence electron must acqure quantam energy jump of well above 14.1 eV to cross over the conduction band.





Available free electrons at room temperature due to covalent bonds.

An electron released from a covalent bond leave behind a hole and it may fill the hole vacancy in a neighbouring bond which is equivalent to the movement of hole from one position to another. In other words, the hole has moved to the position vacated by the electron from that of earlier vacant bond, which is now occupied by the electron. Thus, both electrons and holes act as charge carriers in semiconductors, different from conduction in metals. (only free electrons as charge carriers).

When an electric field is applied to semiconductor material, electron drift in opposite direction to while holes drift in the direction to ε both adding current to positive direction.

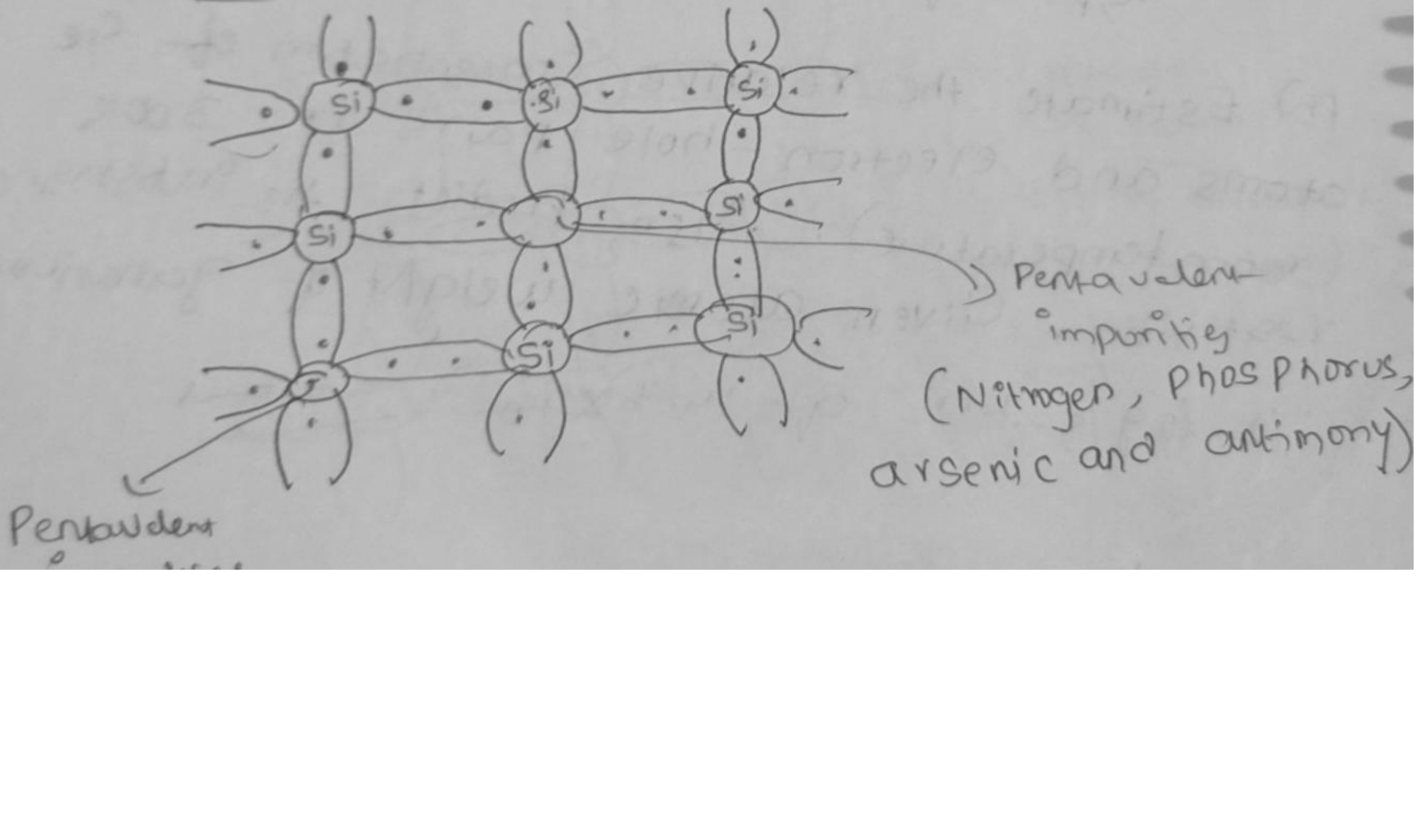
$$J = (n\mu_n + p\mu_p) q \varepsilon \quad A/m^2$$

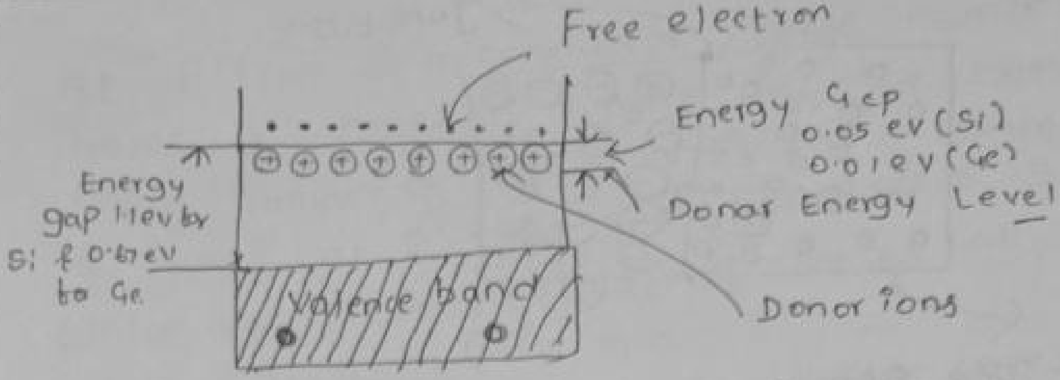
$$\sigma = (n\mu_n + p\mu_p)$$

μ_n = electron mobility μ_p = Hole mobility

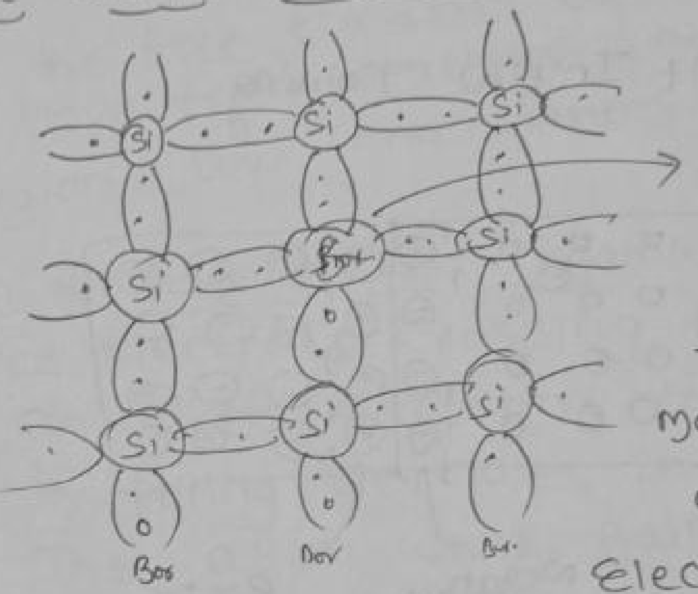
n, p = no of electrons or holes / unit

DOPED SEMI CONDUCTORS (N-TYPE)





P-Type Semi conductors



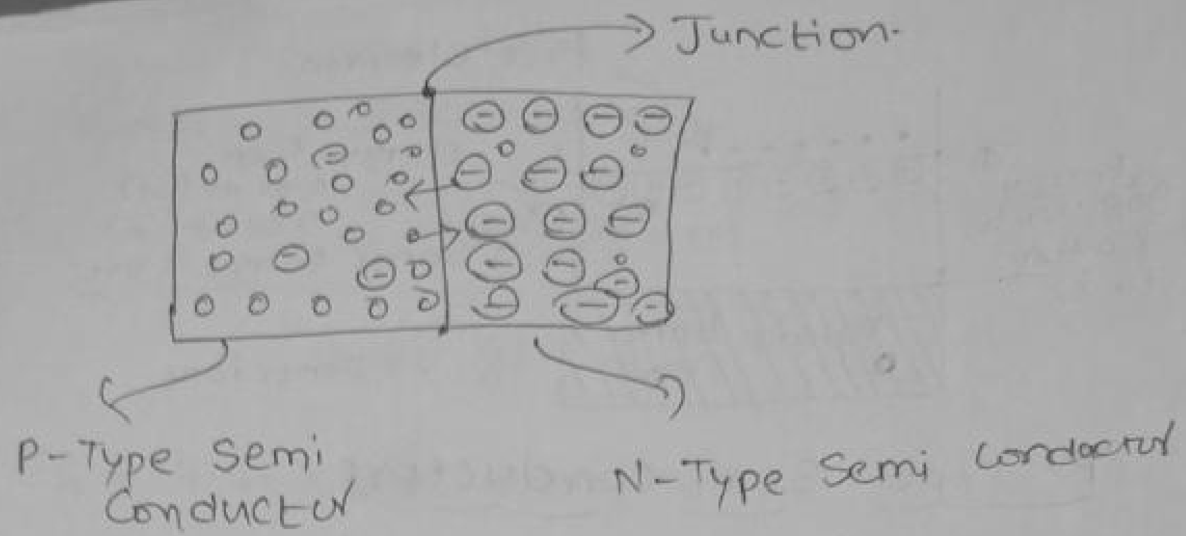
Holes are the major charge carriers

Electrons are minority charge carriers

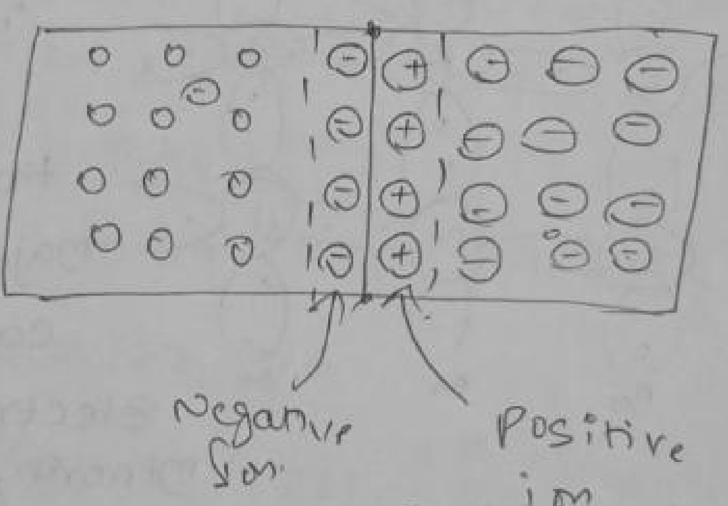
P-N Junction Diode

→ In N-Type Semi Conductor Materials, Pentavalent impurities are added while in P-type Semiconductor material trivalent impurities are added.

→ If the impurities added to P-type and n-type semi conductor materials are not uniform then at one region large number of charge carriers are present while at another region small number of charge carriers are present.



a) At Initial Joining



→ Due to this non uniform doping charge carriers at high concentration region repel from each other and move towards the low concentration region to achieve uniform concentration all over the matrix

At 'P' type Semiconductor large number of holes is present while 'n' type semiconductor Small number of holes is present. concentration of holes at 'P' type semi conductor is high while the concentration of holes at n-type semi conductor is low.

Hence, the holes from the p-side are attracted towards the free electrons at n-side. Thus, the holes move from p-region (high concentration region). to n-region (low concentration region).

Formation of positive and negative ion

The free electrons crossing the junction provide an extra electrons to the p-side atoms by filling the holes in the p-side atoms. The atom which gains extra electron has more number of electrons that protons. we know that, when the atom gains an extra electron from the outside atom it will become a negative ion. Negative ions are also called as acceptors because they accept extra electrons from outside atoms.

** Thus, each free electron that crosses the junction to fill the holes in the P-side. creates negative ions on the P-side.

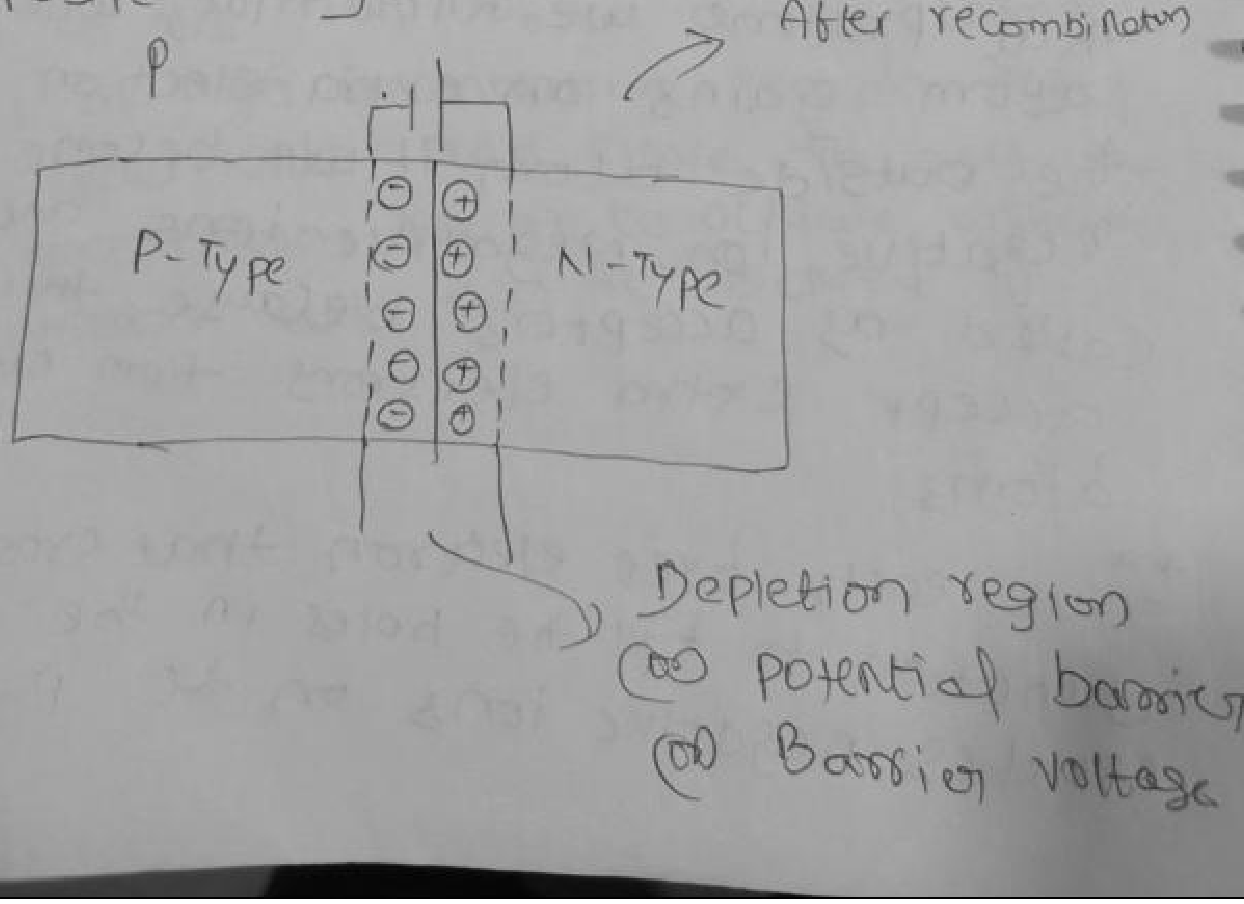
Similarly each free electron that left the n-side atom to fill the holes in the P-side atom creates a hole at n-side atom. The atom which loses an electron has more number of protons than electrons.

we know that, when an ~~electron~~ atom losses an electron it will becomes a positive ions. positive ions are also called as donors because they donate extra electrons to the outside atoms.

Thus, each free electron that left the n-side parent atom and crosses the junction to fill the holes in the P-side atom creates positive ion at n-side.

**

According to coloumb's law there exist an electrostatic force of attractiction between the opposite charges



What is Potential Barrier?

→ The n-Type and p-type semiconductor materials are electrically neutral before the free electrons and holes had crossed the junction.

→ Once crossed the junction, the n-type & p-type semi conductors becomes charged.

charged atom

of the atom has unequal number of electrons and protons, the atom is said to be charged. This charged atom may be positive or negative.

Negatively charged

of atom has more number of electrons than protos

Positively charged

of atom has more number of protons than electrons is said to be positively charged.

positive and negative barrier voltage at p-n junction

~~in positive ion,~~ the

Thus, a net positive charge is built at n-side of the p-n junction due to the positive ions at the n-side; similarly a net negative charge is built at p-side of the p-n junction due to negative ions at p-side

→ This net negative charge at p-side of the p-n junction diode prevents the further flow of electrons crossing from n-side to p-side because the negative charge present at p-side of p-n junction repels free electrons

→ Similarly, the net positive charge at n-side of p-n junction prevents the further flow of holes crossing from p-side to n-side. Hence, positive charge present at n-side and negative charge present at p-side of p-n junction as barrier between p-type and n-type semi conductr.

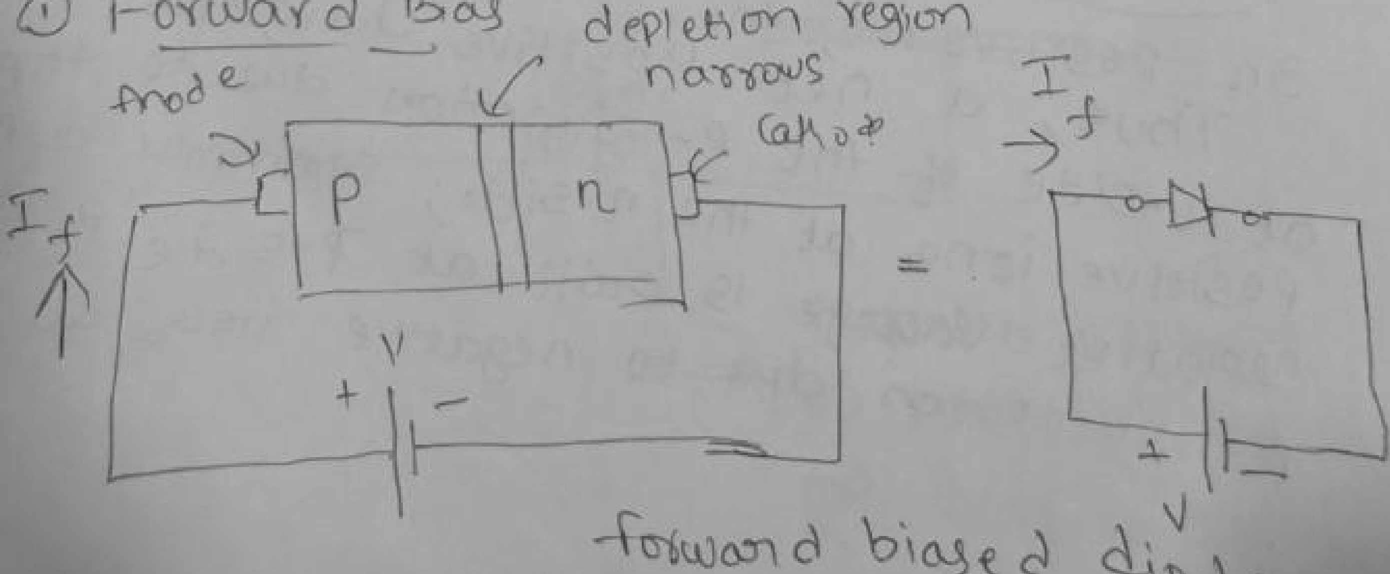
Bias

Adding an external voltage to P-N junction diode is known as biasing.

based on connection; either it is

1. Forward Bias
2. Reverse Bias.

① Forward Bias



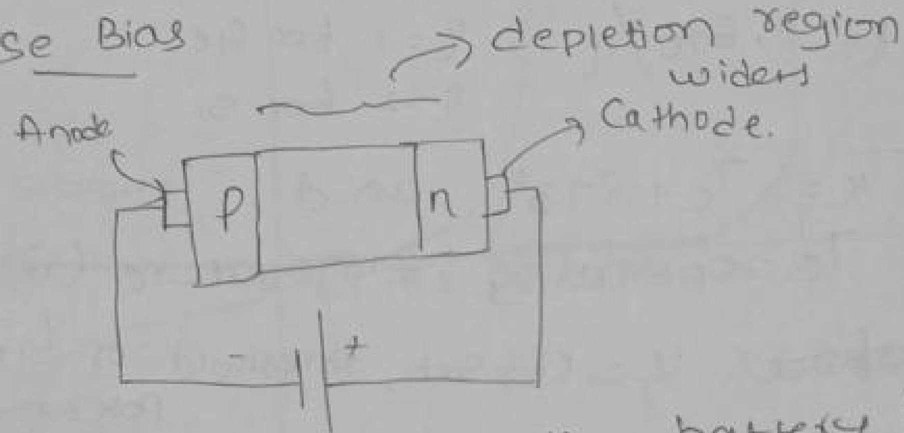
forward biased diode

→ The positive terminal of battery is connected to the anode (P-side) and negative terminal to cathode (N - side).

→ The holes from P-side and electrons from N-side get pushed towards the junction, thereby narrowing the depletion region.

→ As a result, holes easily cross to N-side and electrons to P-side consituting the injunction current (I_i).

Reverse Bias



→ positive terminal of the battery is connected to N-side (cathode) and negative terminal of battery is connected to P-side (anode) as shown in fig.

→ As a result of reverse biasing, the majority of electrons and holes are pulled away from the junction. This causes the width of depletion region to increase. The majority carrier current cannot flow.

→ However, the minority carrier drift current flows but stays at the saturation level I_S & the minority carrier concentration are very low which is almost of negligible order (nA for Si and μA for Ge).

Diode current relationship

$$I_D = I_S\left(e^{kV_T/T_K} - 1\right)$$

I_S = Reverse saturation current.

$k = 11,600/\eta$; $\eta = 1$ for Ge
$\eta = 2$ for Si

$T_K = T_C + 273°$ and
T_C = Operating temperature (25°C)

~~V_T = offset~~ V_T = Offset, threshold or firing potential

$V_T = 0.7V$ for Si diode
$V_T = 0.3V$ for Ge diode,

Pb) An Si diode has $I_S = 10\ nA$ operating at 25°C. Calculate I_D for a forward bias of 0.6V?

Sol:-

$$I_S = 10 \times 10^{-9}\ A$$

$$T_K = 25° + 273° = 298°$$

$$K = \frac{11,600}{2} = 5,800$$

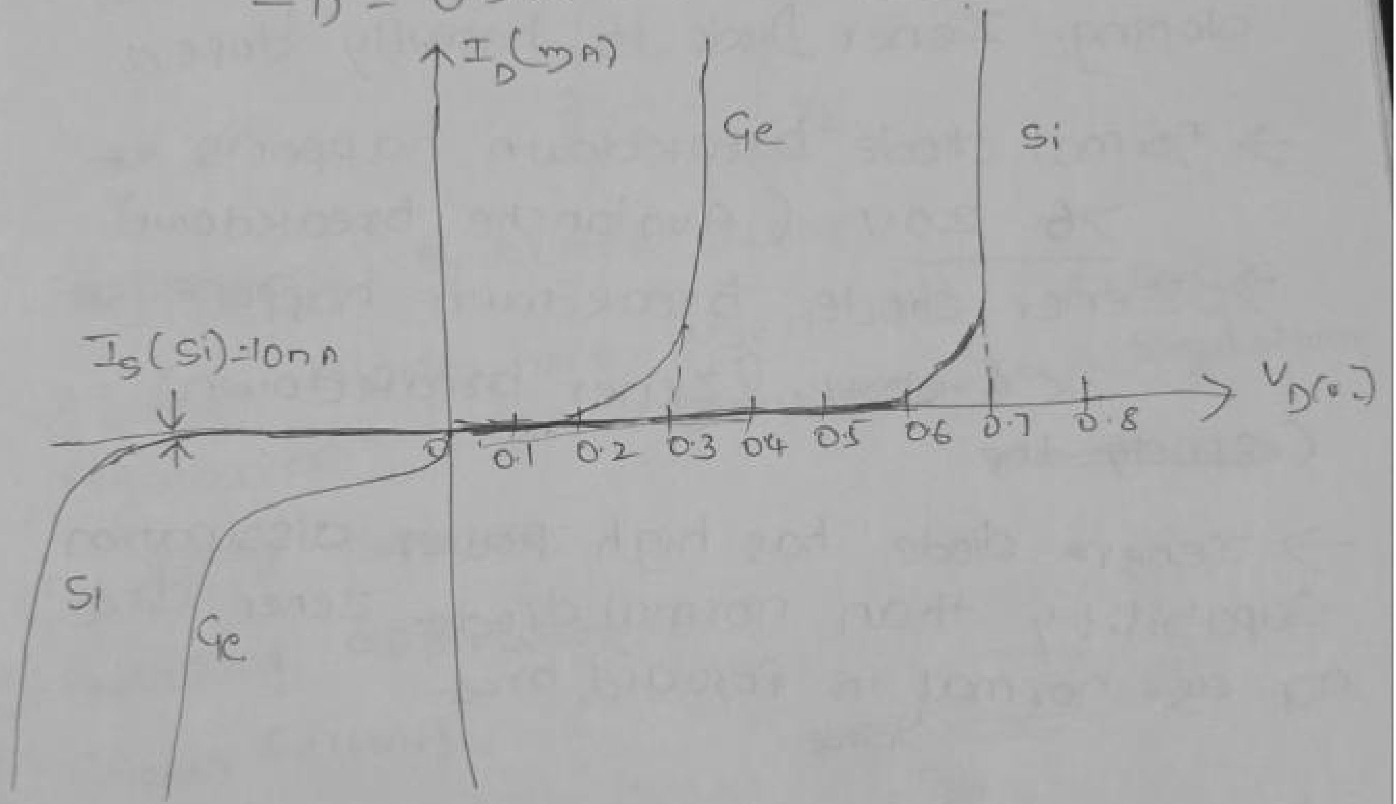
$$\frac{KV_D}{T_K} = \frac{5800 \times 0.6}{298} = 11.68$$

$$e^{11.68} = 117930$$

$$I_D = I_s\left(e^{KV_D/T_K} - 1\right)$$

$$I_D = 10 \times 10^{-9} \times (117930 - 1)$$

$I_D = 0.586$ mA, negligible



Diode V-I Characteristics

ZENER DIODE

→ Zener diode is a special diode widely used in voltage regulation. (Both line regulation and Load regulation)

→ It operates in reverse bias only. the difference between normal diode reverse bias and zener diode is level of doping. Zener Diode is heavily doped.

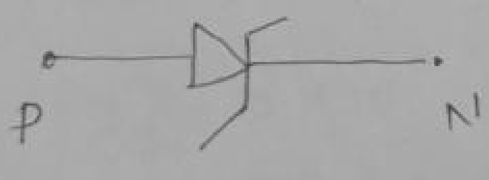
→ Normal diode breakdown happens at
>6-20V (Avalanche breakdown)

→ Zener diode breakdown happens at
<6-V (Zener breakdown)

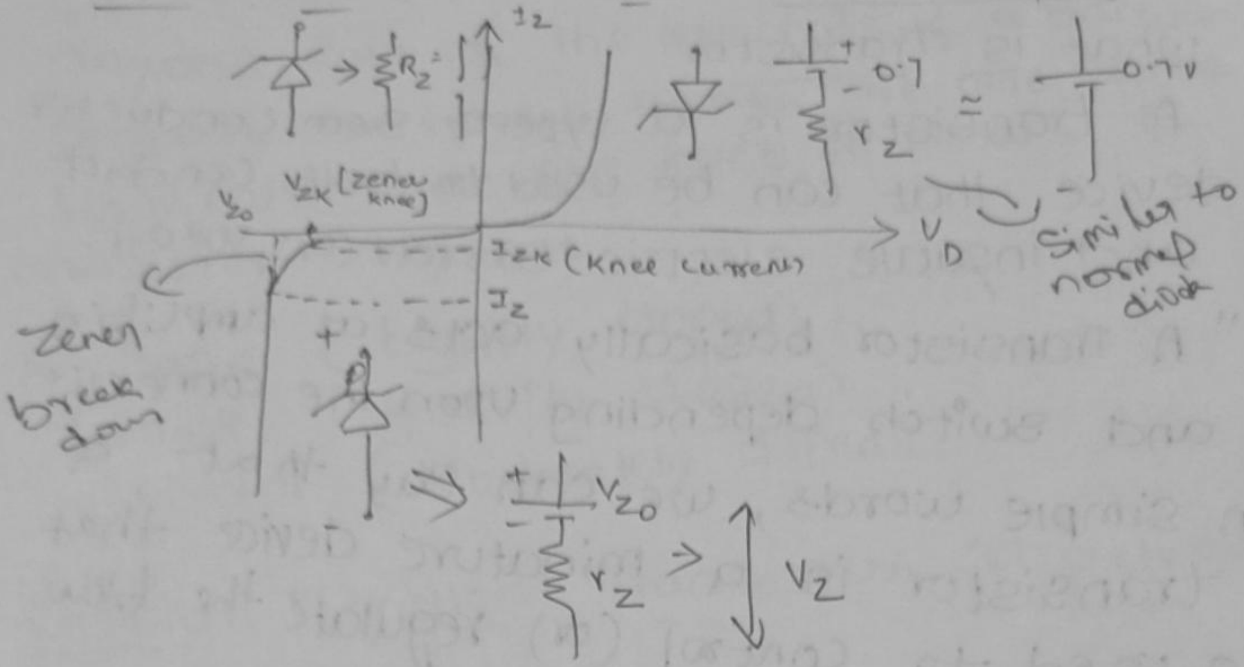
(~~study~~ the

→ Zener diode has high power dissipation capability than normal diode. Zener diode act as normal diode in forward bias.

Symbols



V-I characteristics of ZENER Diode



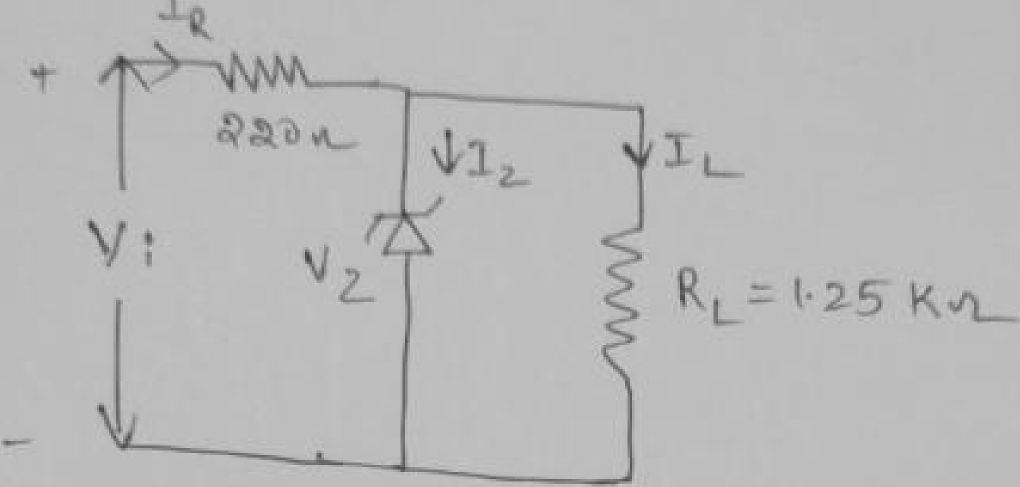
Applications of ZENER DIODE

1. Zener diodes are used for voltage regulation (Line regulation & Load regulation)
2. Surge suppressors
3. Switching applications
4. Clipper circuits.

61 - 75% 61%

ZENER DIODE classical example; how it will act as line regulator

Pb) Determine the range of 'V_i' in which Zener diode of fig 14.19 conducts.



The zenere diode rating was $20\,V = V_Z$

Power rating $P_{Z(max)} = 35$[illegible]w

1200 mw

$V_Z = 20V, \ I_Z = 0$

$I_R = I_L = \frac{20}{1.25 \times 10^3} = 16$ mA

$V_i = 20 + (220) * (16 \times 10^{-3}) = 23.52$ V

$I_Z = I_{Z(max)} = \frac{1200}{20} = 60$ mA

$I_L = 16$ mA

$I_R = 16 + 60 = 76$ mA

$V_i = 20 + 220 \times 76 \times 10^{-3} = 36.72$ V

TRANSISTOR

What is Transistor

A transistor is a type of semiconductor device that can be used to both conduct and insulate electric current (or) voltage.

"A Transistor basically acts as amplifier and switch depending upon the connection. In simple words, we can say that a transistor is a minature device that is used to control (or) regulate the flow of elections".

Transistor = Transfer of resistance from one path to another path.

High resistor to low resistor – Amplifier
low resistor to high resistor – Switch

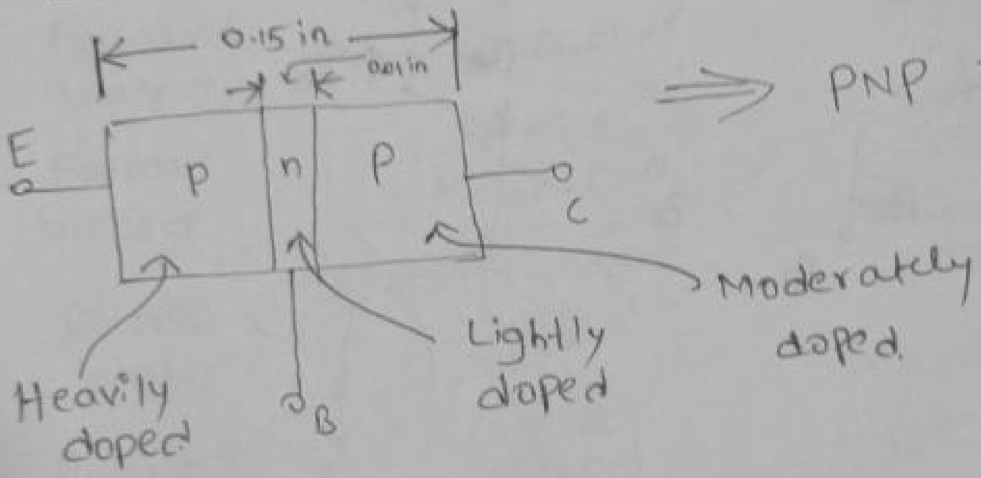
Parts of Transistors

A typical transistor is composed of three layers of semi conductor materials or more specifically terminals which helps make a connection to an external circuit and carry the current.

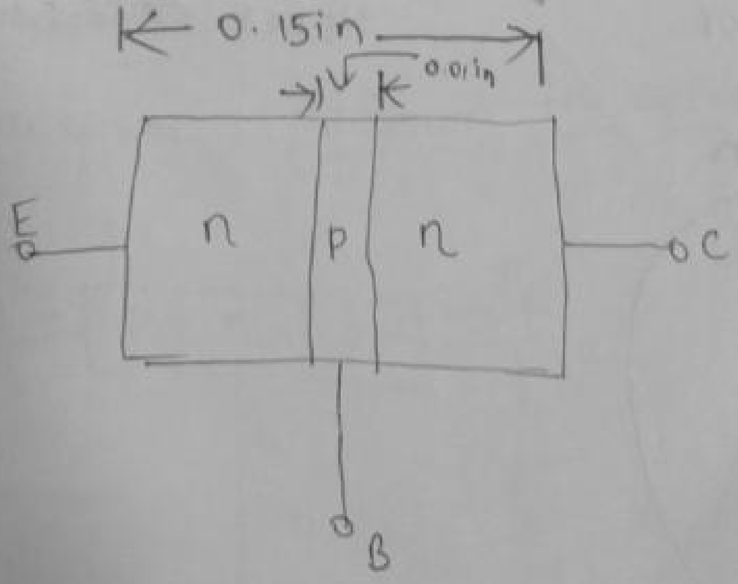
- A Voltage (or) current that is applied to anyone pair of the terminals of a transistor controls the current through the other pair of terminals. There are three terminals of transistor. They are

- Base (Lightly doped)
- Emitter (Heavily doped)
- Collector (Moderately doped)

Bipolar Junction Transistor construction



⇒ PNP Transistor.



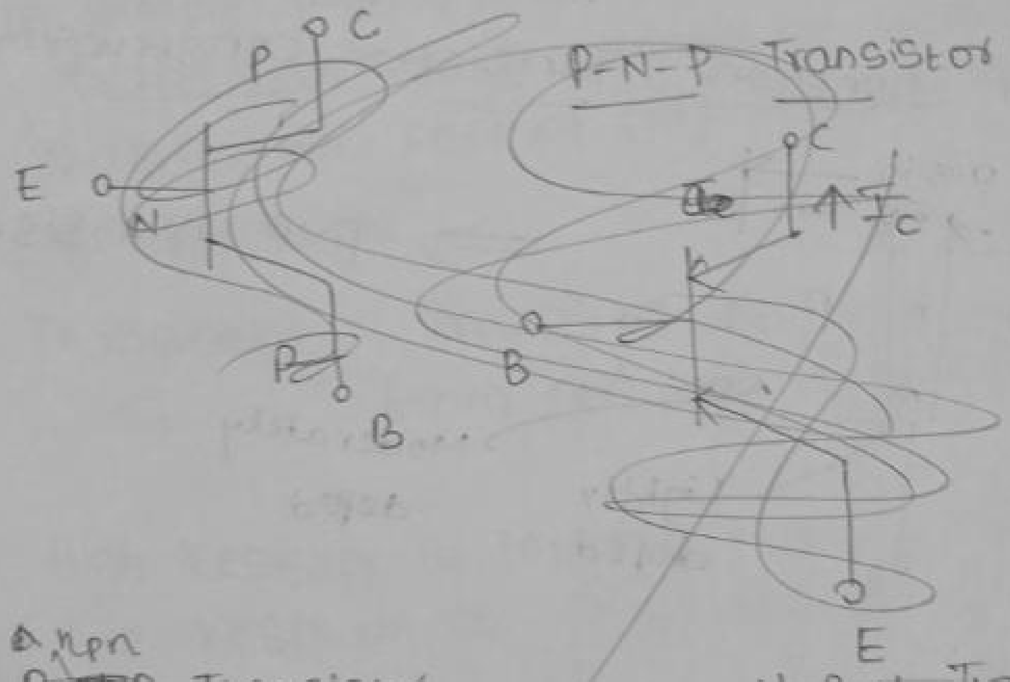
⇒ NPN Transistor.

Table

The constructional details and order of dimension for two types of BJT are shown in fig. 1 & 2.

→ In pnp transistor, a thin N-type layer is sandwiched between P-type layers, where in an npn transistor, a thin layer of p-type is sandwiched between two N-type layers

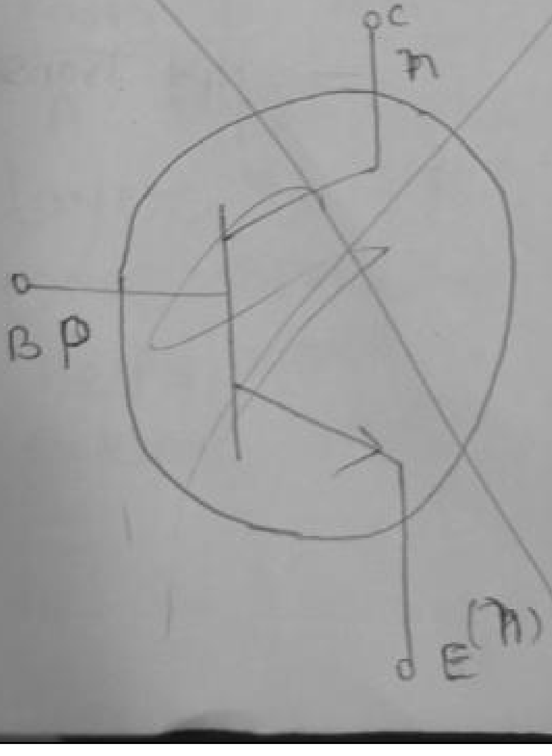
Transistor Symbol



npn Transistor

~~N-P-N Transistor~~

p-n



Biasing

There are two junctions in the transistor

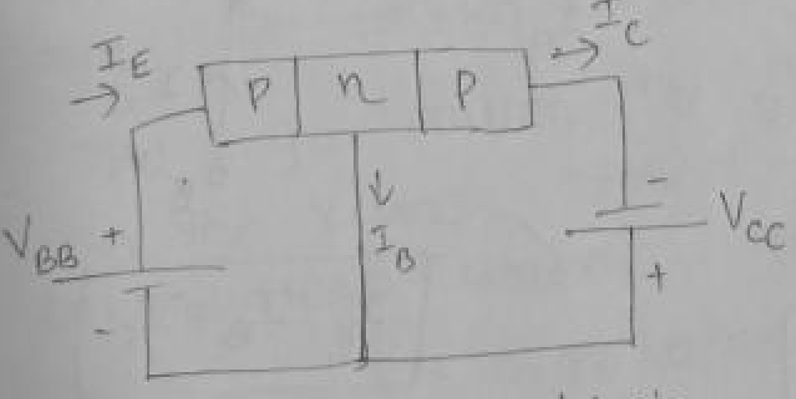
i) Emitter Base Junction

ii) collector Base Junction.

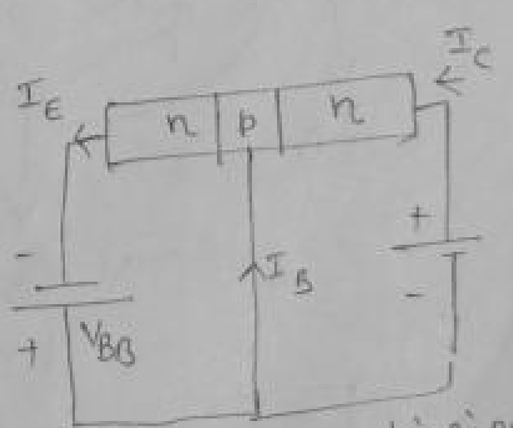
→ Basically biasing combination, the transistor can be operate in four modes

Emitter-Base Junction	Collector - Base Junction	Region of operation
Forward biased	Forward biased	Saturation region
Forward biased	Reverse biased	Active region (Act as amplifier)
Reverse biased	forward biased	Inverse active region
Reverse biased	Reverse biased	cutoff region (Act as switch)

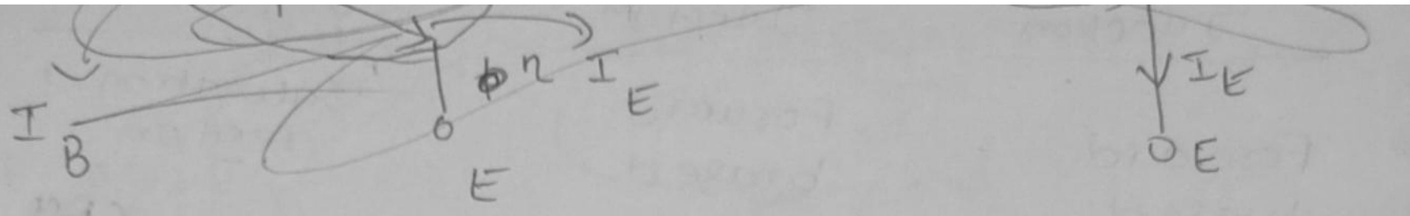
Transistor connection in active region



pnp Transistor biasing

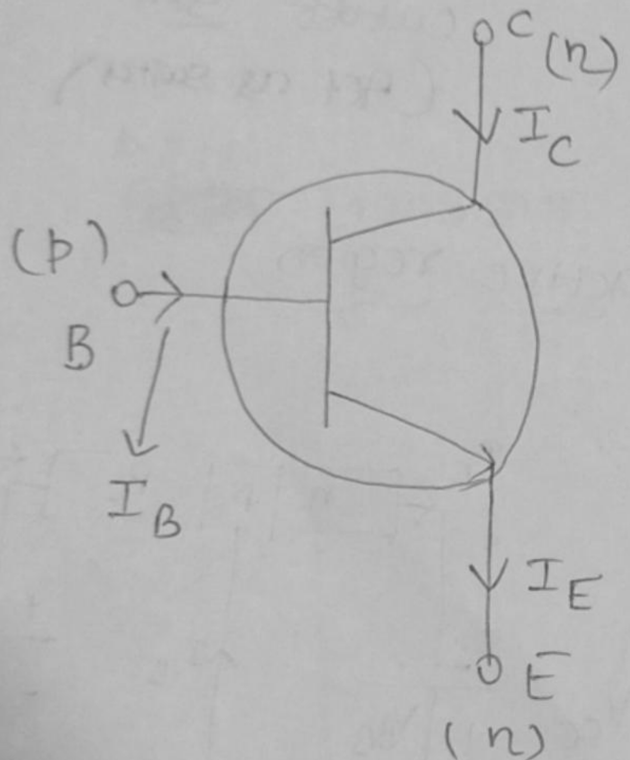


npn Transistor biasing



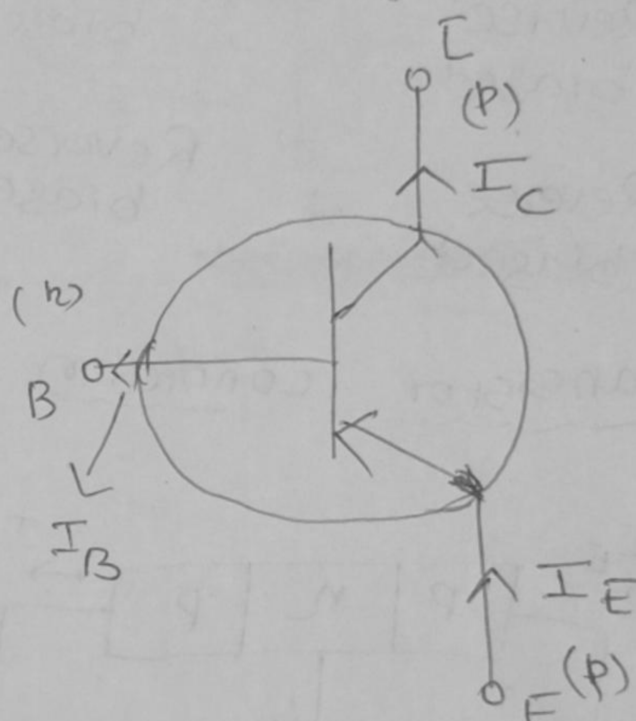
Transistor symbol

n-p-n Transistor



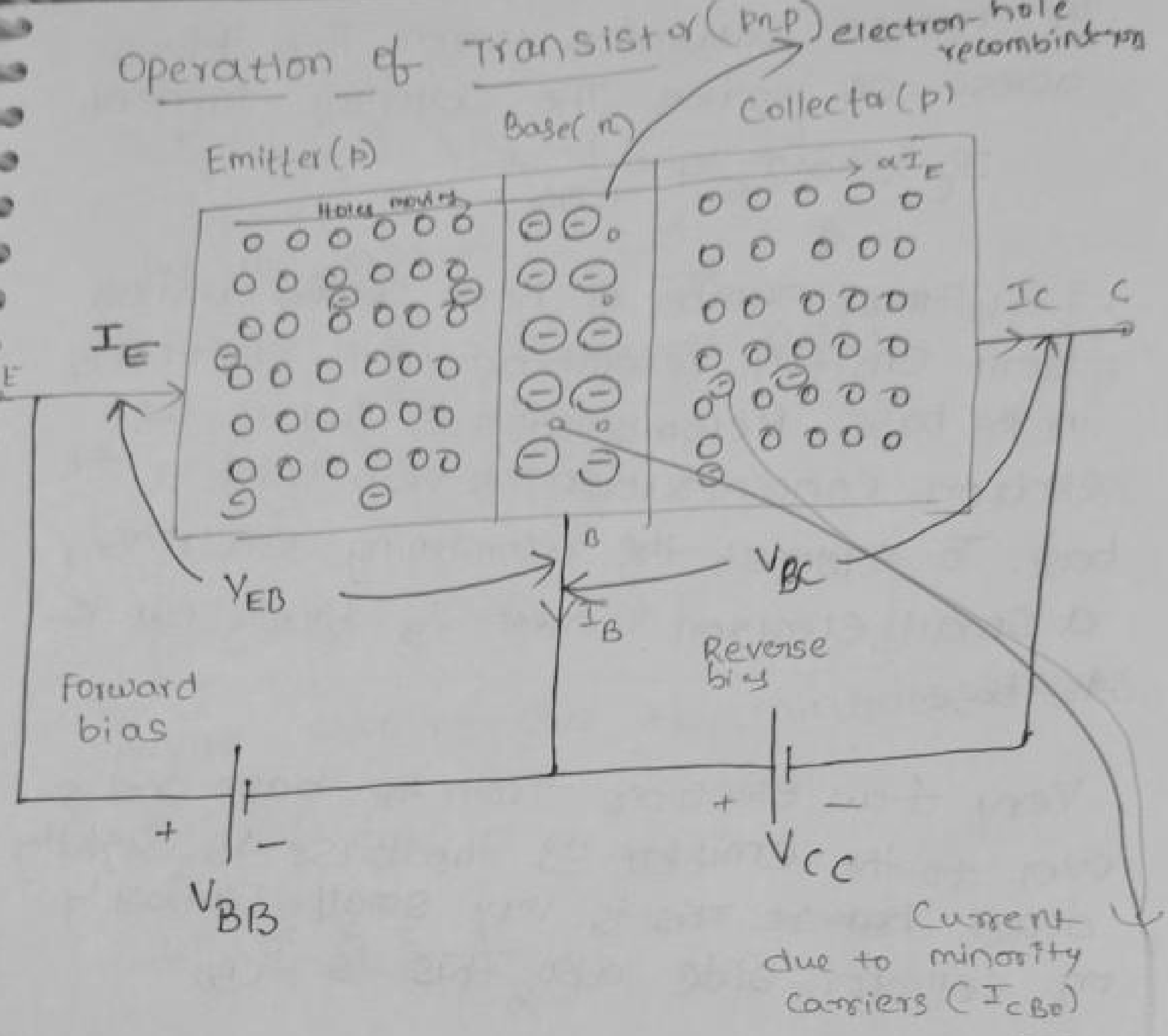
$$\boxed{I_E = I_B + I_C}$$

p-n-p Transistor



$$\boxed{I_E = I_B + I_C}$$

Operation of Transistor (pnp)



- Emitter holes (majority carries) cross the forward-biased EB junction into base. These constitute emitter current I_E.
- The major portion of these holes cross over the reverse-biased CB junction constituting current 'αI_E'

$$\alpha = 0.98 \text{ to } 0.99.$$

This is why base width kept ~~constant~~ small

· The reverse saturation current I_{CBO} flows across CB junction. The collector current

$$I_C = \alpha I_E + I_{CBO}$$

. A small number of holes ~~comes~~ coming from emitter recombine with electrons in the base. Recombination is small as the electron concentration is very light in the base. To replenish the recombining electrons, a small electron current I_B flows out of the base.

. Very few electrons from the base cross over to the emitter as the base is lightly doped. ~~but re~~ This is very small. Similarly on collector side also this is I_{CBO}.

from figure, ~~by applying KCL~~

$$I_C = \alpha I_E + I_{CBO} \rightarrow ①$$

by applying KCL

$$I_E = I_C + I_B \rightarrow ②$$

Sub ② in ①

$$I_C = \alpha(I_C + I_B) + I_{CBO}$$

$$I_C = \alpha I_C + \alpha I_B + I_{CBO}$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

let us assume $\frac{\alpha}{1-\alpha} = \beta$ $\qquad \alpha = \frac{\beta}{1+\beta}$

$\cancel{\frac{1}{1-\alpha} = \frac{\beta}{\alpha}}$ ~~(as $\alpha = 0.98$)~~

~~so~~ $\cancel{\frac{1}{1-\alpha}}$

$$\boxed{I_C = \beta I_B + (1+\beta) I_{CBO}}$$

Ignore current due to minority carriers

$$I_C = \beta I_B$$

where $\beta = \frac{\alpha}{1-\alpha}$

If $\alpha = 0.988$

$$\beta = \frac{0.9888}{1-0.988} = 82.3$$

$$I_C = (82.3) I_B$$

→ In this way in active region transistor act as "amplifier".

→ In cutoff region and saturation region it will act as switch.

Rectifier.

→ A rectifier is an electrical device that converts alternating current (AC), which ~~Peri~~ Periodically reverse direction, to direct current (DC) which flows in only one direction.

Rectifier.

- Low voltage Rectier.
  - Formed by using diode
    - Halfwave rectifier
    - Full wave rectifier
      - centre tapped fullwave rectifier
      - Bridge rectifier.
- High voltage rectifier
  - Formed by using SCRs.

Half-wave Rectifier

→ It converts an AC voltage into a Pulsating dc voltage using only one half of the applied AC voltage.

→ The rectifying diode conducts during one half of the ac cycle only.

fig (a) & fig (b) shows the basic circuit and wave-forms of a half wave rectifier.

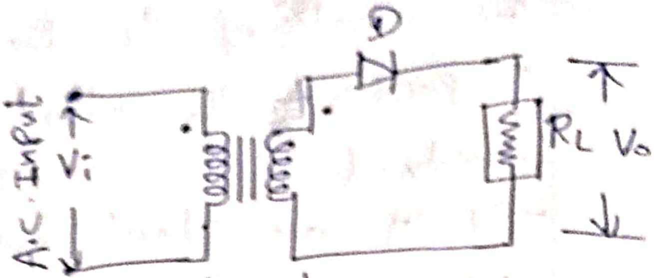


fig (a)

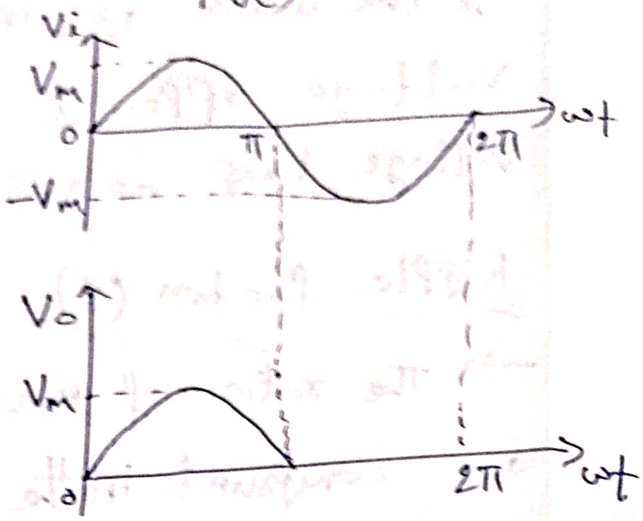


fig (b)

fig (a): Basic structure of a Half-wave Rectifier

fig (b): Input and output wavefor of Half-wave rectifier

→ Let V_i be the Voltage to the primary of the transformer. and given by the equation

$$V_i = V_m \sin\omega t \longrightarrow ①$$

→ During the positive half-cycle of the input sign the anode of the diode become more positive wit respect to the cathode and hence, diode "D" cond

→ During negative half-cycle of the input signa the anode of the diode becomes negative with respect to the cathod and hence, diode 'D' doesn't conduct

→ For an ideal diode, the impedance offered by the diode is inifinity. so the whole input voltage appears across diode D. Hence, the voltage drop across RL is zero.

Ripple factor (r)

→ The ratio of rms value of Ac component to the Dc compount in the output is known as ripple factor (r)

$$r = \frac{\text{rms value of Ac component}}{\text{dc value of component}} = \frac{V_{rms}}{V_{dc}}$$

where $V_{r,rms} = \sqrt{V_{rms}^2 - V_{dc}^2}$

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

→ The dc value (or) Average value of the voltage across the Load and is given by

~~Dc~~ → from output wave form

$$V_{av} = V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_i \, d(\omega t)$$

$$V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)\right]$$

$$V_{av} = V_{dc} = \frac{V_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{V_m}{2\pi}\left[-(\cos\pi) - (-\cos 0)\right]$$

$$= \frac{V_m}{2\pi}\left[-(-1) \mp (-1)\right]$$

$$= \frac{V_m}{2\pi}(1+1)$$

$$= \frac{2V_m}{2\pi}$$

$$\boxed{V_{av} = \frac{V_m}{\pi}} \rightarrow ③$$

→ RMS voltage at the load resistance can be calculte as

$$V_{rms} = \sqrt{\left[\frac{1}{2\pi}\int_0^{2\pi} V_i^2\, d(\omega t)\right]}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} V_m^2 \sin^2\omega t\, d\omega t + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)\right]}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\left[\frac{1-\cos 2\omega t}{2}\right] d(\omega t)}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi}\left[\left[\int_0^{\pi} \frac{1 \cdot d\omega t}{2}\right] - \left[\int_0^{\pi} \frac{\cos 2\omega t\, d(\omega t)}{2}\right]\right]}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[\left[\omega t\right]_0^{\pi} - \left[\frac{\sin 2\omega t}{2\omega t}\right]_0^{\pi}\right]}$$

$$V_{rms} = \frac{V_m^2}{2\pi}\left[\left[\pi - 0\right] - 0\right]$$

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi} \times \pi}$$

$$\boxed{V_{rms} = \frac{V_m}{2}} \rightarrow (4)$$

Substituting eq 3 & 4 in eq (1)

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

$$= \sqrt{\left(\frac{V_m/\pi}{V_m/2}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{\pi}{2}\right)^2 - 1}$$

$$\boxed{r = 1.21}$$

∵ From this expression it is clear that the amount of AC present in the output is 121% of the dc voltage so the half wave rectifier is not practically useful in converting AC to DC.

Average Value of Load current

$$\boxed{I_{dc} = \frac{V_{dc}}{R_L}}$$

where $\boxed{I_{dc} = \frac{I_m}{\pi}}$

RMS Value of current

$$\boxed{I_{rms} = \frac{I_m}{2}}$$

Form factor for Halfwave Rectifier:

$$\text{Form factor} = \frac{\text{rms Value}}{\text{average Value}}$$

$$= \frac{V_m/2}{V_m/\pi} = \frac{\pi}{2} = 1.57$$

$$\boxed{F.F. = 1.57}$$

Peak Factor

$$\text{Peak factor} = \frac{\text{Peak Value}}{\text{rms Value}}$$

$$= \frac{V_m}{V_m/2} = 2.$$

$$\boxed{P.F = 2}$$

Efficiency (η) :-

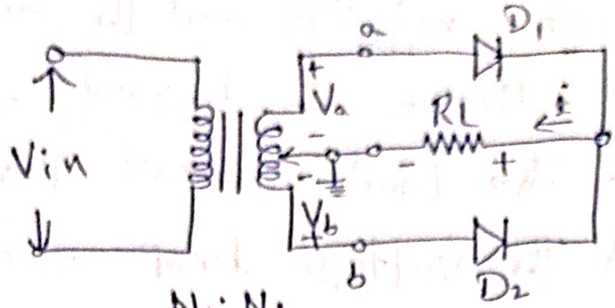
→ The ratio of Dc output Power to Ac input Power is known as rectifier efficiency(η)

$$\eta = \frac{\text{Dc output Power}}{\text{Ac input Power}} = \frac{P_{dc}}{P_{ac}}$$

$$\eta = \frac{(V_{dc})^2/\cancel{R_L}}{(V_{rms})^2/\cancel{R_L}} = \frac{(V_m/\pi)^2}{\left(\frac{V_m}{2}\right)^2} = \frac{4}{\pi^2} = 0.4$$

Full wave rectifier — Centre-Tapped Rectifier / Bridge Rectifier.

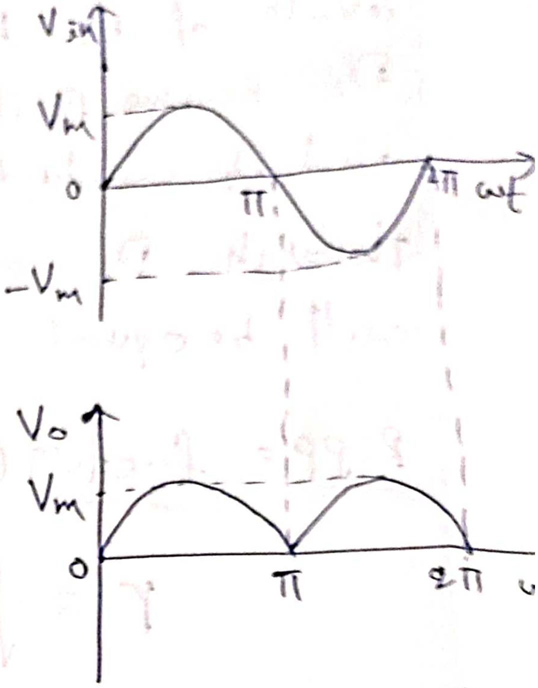
Centre-Tapped Full wave Rectifier



$N_1 : N_2$

$N_1 > N_2$

fig(a) centre tapped Full wave Rectifier.



fig(b):- Input-output Voltage waveform

→ It converts an ac Voltage into a Pulsating dc Voltage using both half cycle of the applied ac Voltage.

→ It uses two diodes of which one conducts during one half-cycle while the other diode conducts du the other half-cycle of the applied ac voltage.

→ fig(a) & fig(b) shows the basic circuit and waveform of full wave rectifier.

→ During Positive half of the input signal, ano of diode D_1 become Positive and at the same the anode of diode D_2 become negative. I D_1 conducts and D_2 does not conduct

→ The Load current flows through D_1 and the voltage drop across R_L will be equal to the input Voltage.

→ During the negative halfcycle of the input, the anode of D_1 become negative and the anode of D_2 become Positive. Hence D_1 does not conduct and D_2 conducts. The Load current flows through D_2 and the voltage drop across R_L will be equal to the i/p voltage.

Ripple factor (r) –

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

→ The average Voltage (or) Dc voltage available across the Load resistance is

$$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m \sin \omega t \, d(\omega t)$$

$$= \frac{V_m}{\pi}\left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{V_m}{\pi}\left[-(\cos\pi) - (-\cos 0)\right]$$

$$= \frac{V_m}{\pi}\left[1+1\right]$$

$$\boxed{V_{dc} = \frac{2V_m}{\pi}} \longrightarrow ②$$

→ RMS value of the voltage at the load

$$V_{rms} = \sqrt{\left[\frac{1}{\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \, d(\omega t)\right]}$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}} \rightarrow (3)$$

substituting eq (2) & (3) in eq (1)

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

$$r = \sqrt{\frac{\pi^2}{8} - 1} = 0.482$$

$$\boxed{r = 0.482}$$

Form factor:

$$\text{Form factor} = \frac{\text{rms value of the out put voltage}}{\text{average value of the output voltage}}$$

$$= \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

$$\boxed{F.F = 1.11}$$

Peak factor (P.F): –

$$\text{Peak factor} = \frac{\text{Peak value of the output v}}{\text{rms value of the output v}}$$

$$\boxed{P.F = \frac{V_m}{V_m/\sqrt{2}} = \sqrt{2}}$$

$$V_{rms} = \sqrt{\left[\frac{1}{\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \, d(\omega t)\right]}$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}} \rightarrow (3)$$

substituting eq (2) & (3) in eq (1)

$$\gamma = \sqrt{\left(\frac{V_m/\sqrt{2}}{2V_m/\pi}\right)^2 - 1}$$

$$\gamma = \sqrt{\frac{\pi^2}{8} - 1} = 0.482$$

$$\boxed{\gamma = 0.482}$$

Form factor

$$\text{Form factor} = \frac{\text{rms value of the output voltage}}{\text{average value of the output voltage}}$$

$$= \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

$$\boxed{F.F = 1.11}$$

Peak factor (P.F):

$$\text{Peak factor} = \frac{\text{Peak value of the output}}{\text{rms value of the output}}$$

$$\boxed{P.F = \frac{V_m}{V_m/\sqrt{2}} = \sqrt{2}}$$

→ Peak inverse voltage for full-wave rect-
ifier is $2V_m$ because the entire secondary
voltage appears across the non-conducting
diode."

Efficiency(η) :- The ratio of dc output power to AC input power is known as rectifier efficiency (η)

$$\eta = \frac{\text{dc output power}}{\text{ac input power}} = \frac{P_{dc}}{P_{ac}}$$

$$\eta = \frac{(V_{dc})^2/R_L}{(V_{rms})^2/R_L} = \frac{\left(\frac{2V_m}{\pi}\right)^2}{\left(\frac{V_m}{\sqrt{2}}\right)^2} = \frac{8}{\pi^2}$$

$$\eta = 0.812 = 81.2\%$$

→ The maximum efficiency of a full-wave rectifier is 81.2%.