B.Tech Ist year

Mahaveer
Date
Page

Unit I Semiconductor

1. valence electrons:

→ Most of the atoms of diff. elements do not have their outermost shells completely filled i.e. they do not have eight e⁻ in outermost shell.

→ The e⁻ occupying the outermost shell of an atom are called valance e⁻.

→ Those elements which have one or two valance e⁻, are good conductors of electricity.

→ These valence e⁻ are responsible for forming atomic bonds.

→ Si & Ge are tetravalent, they have four valence e⁻.

Date ______
Page ______

2 Energy Level in isolated atom :-

$$E_n = -13.6 \frac{Z^2}{n^2} \, eV$$

for hydrogen $Z = 1$; $E_n = -\frac{13.6}{n^2} \, eV$

~~En~~ for K shell, $n = 1$

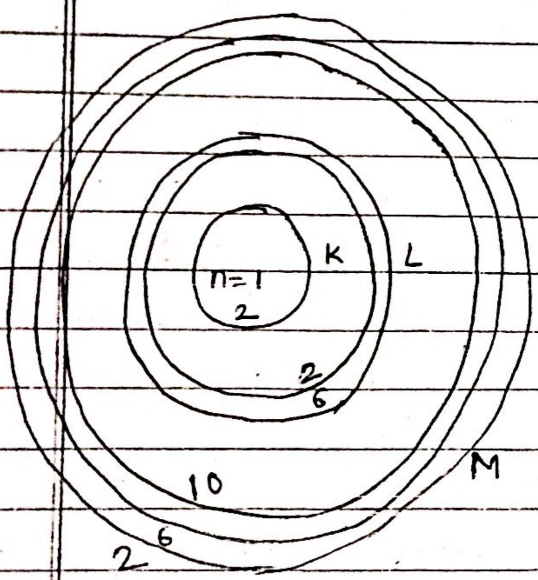
$E_n = -13.6 \, eV$

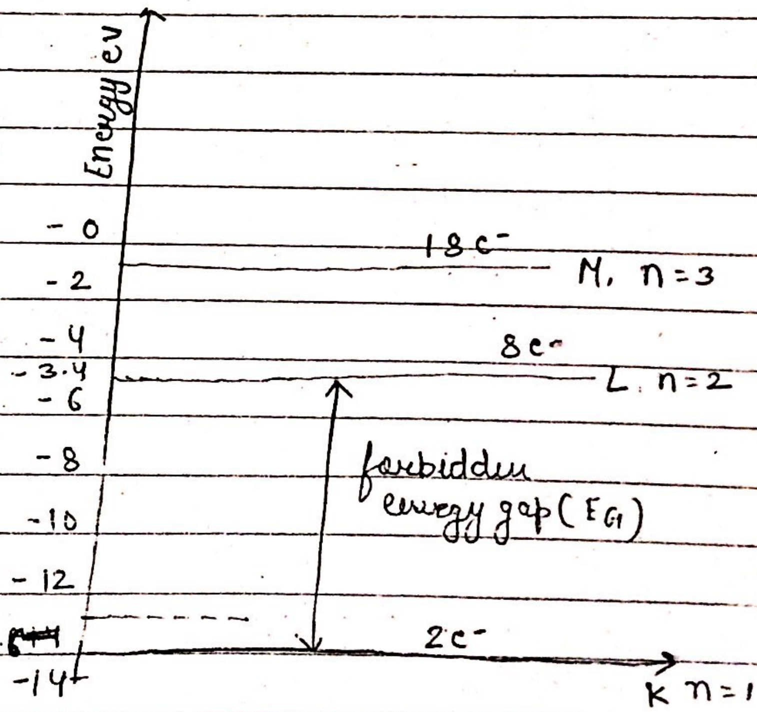
for L , $n = 2$

$E_n = \frac{-13.6}{2^2} = -3.4 \, eV$

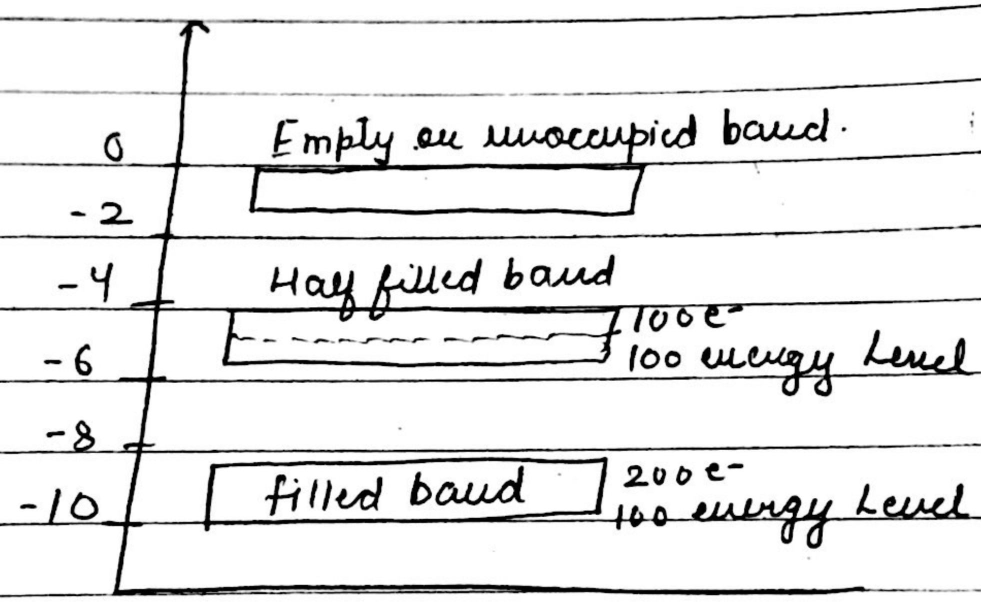
for M , $n = 3$

$E_n = \frac{-13.6}{3^2} = -1.51 \, eV$





Orbit	total no. of e⁻	No. of Suborbit	e⁻ distribu
K (n=1)	2	1	2
L (n=2)	8	2	2, 6
M (n=3)	18	3	2, 6, 10
N (n=4)	32	4	2, 6, 10, 14



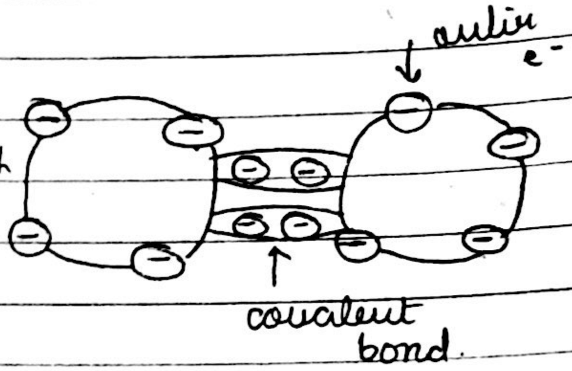
Mahaveer
Date
Page

3. Bonds in solids :-

(i) Ionic Bonds :- These occur between two diff. atoms are due to permanent transfer of valence e- from one atom to another. It is very strong bond.

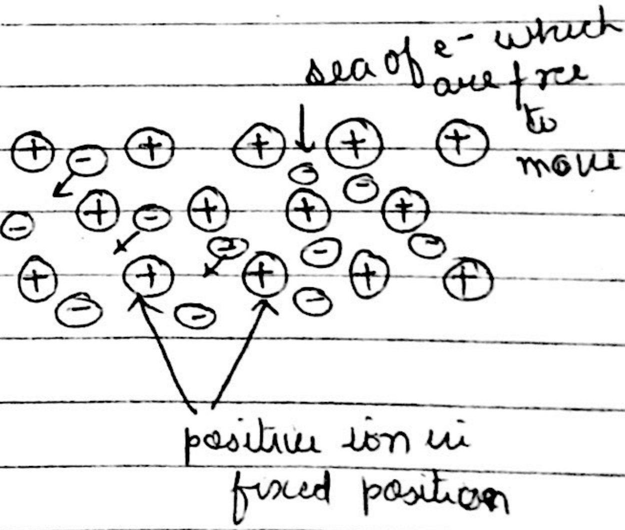
(ii) Covalent bond :- Occur b/w two similar or diff. atoms. There is only sharing of one or more valence e- b/w two atoms each of which tries to fill up its outermost orbit.

It occurs mostly in S.C materials like Si, Ge.
each Si atom shares one e- with surrounding atom, and completing its outermost shell.
Such bound can be broken by supplying efficient energy.

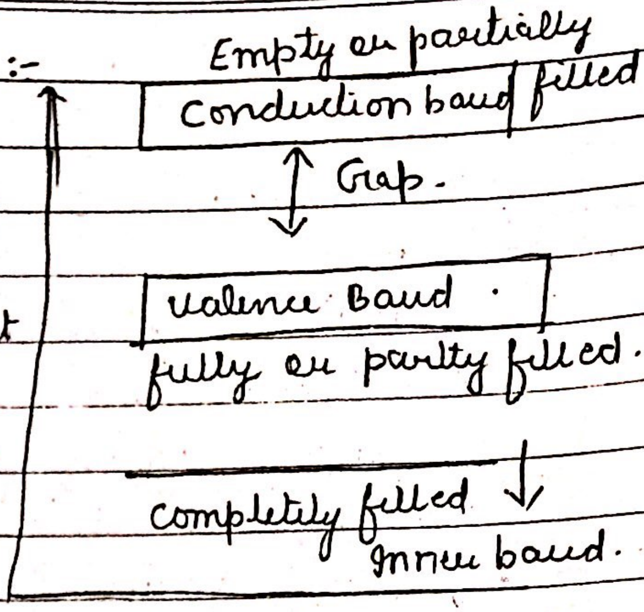


The e- set free by breaking the bond leaves behind a vacancy called positive holes.
Hence each bond breakage results in two charge carriers i.e. e- & holes

(iii) Metallic bond :-
Such bond exist in metals. They arise due to sharing of e- by variable no. of atoms.



4. Valence & conduction Band :-



→ The e- in outermost shell of atom are called valence e-.

→ It is these e- which are most affected when a no. of atoms are brought very close together during the formation of solid.

→ The energy band occupied by valence e- is called valence Bands, and the highest occupied Band.

→ The e- which have left the valence band are called conduction e-.

→ The band occupied by these e- is called conduction band.

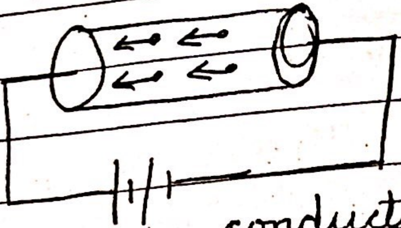
→ In C.B., e- moves freely & conduct e- current through the solid.

→ The V.B & C.B are seperated by the gap, called forbidden band.

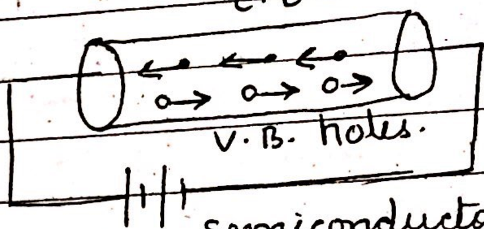
→ Energy is required to lift an e- from V.B. to C.B.

5. Conduction in solids :-

→ Current flow occurs in given material when a vtg. is applied. Which causes charge carrier to move.



→ This is due to e⁻ motion & hole transfer.



→ In e⁻ motion, free e⁻ in C.B. are moved under the influence of electric field set up by the applied voltage.. They travel from -ve terminal to +ve terminal.

→ In good conductors, current flow is due to free e⁻ only.

→ In semicond, current flow partly due to e⁻ & partly due to holes.

→ Conduction e⁻ are found in and freely in C.B.

→ hole exist in & flow in V.B.

→ e⁻ current is in C.B. But hole current is in V.B.

→ conduction e⁻ move almost twice as fast as the holes.

B.Tech Ist year

Unit I

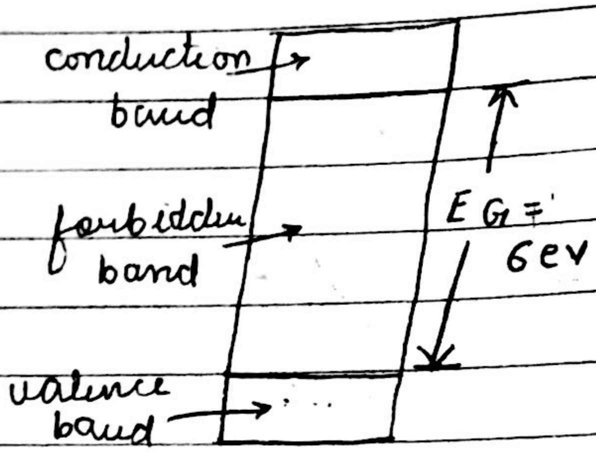
Semiconductor

Insulator :

→ A very poor conductor of electricity is called an insulator.

→ The large F.B. seperates the filled V.B from the vacant C.B.

→ The energy which can be supplied to an e^- from an applied field is too small to carry the particle from V.B to C.B.



→ Since the e^- cannot acquire sufficient applied energy, conduction is impossible, and hence diamond is an insulator.

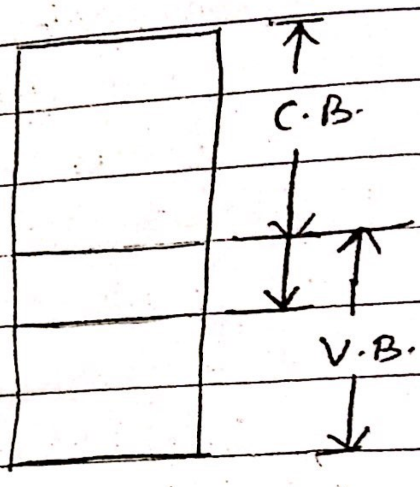
eg: Diamond crystal : Ins.

7.9 Metal

→ An excellent conductor is metal.

→ A solid which contains partly filled band structure is metal.

→ Under the influence of an applied electric field the e^- may acquire additional energy & move into higher states.



8.8. Semiconductor

→ A substance whose conductivity lies b/w these extremes is s.c.

→ for s.c., the width of F.B. is relatively small (~1ev).

→ eg: Germanium (Ge) - EG - 0.785 ev
Silicon (Si) - EG - 1.21 ev

→ These materials are insulators at low temp.

→ However the conductivity ⇑ses with temp., This type of substance known as Intrinsic (pure) s.c.

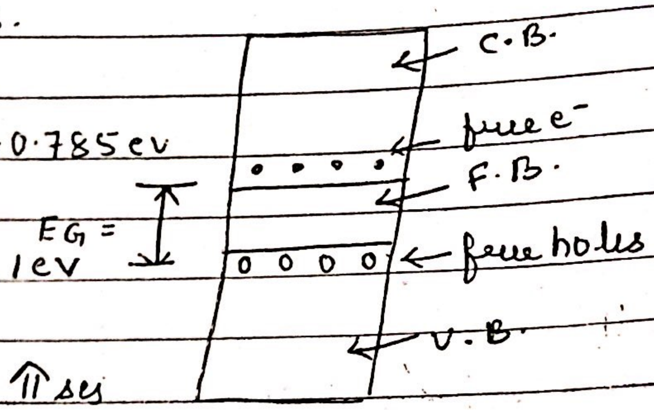


fig: Graphite

→ As the temp. ⇑, some of valence e⁻ acquire thermal energy greater than EG, and have move into the C.B.

→ The absence of e⁻ in V.B. is represented by small circle, and it is called holes.

Type of Semiconductors

- Intrinsic or pure
- extrinsic or impure
  - N type
  - p type

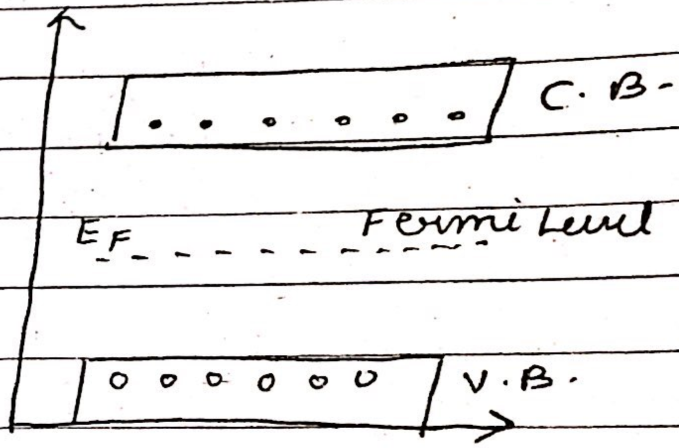
I Intrinsic s.c.

→ It is made of s.c. material in its pure form.

→ eg. pure Ge, pure Si [f.B. - 0.72 eV, 1.1 eV resp.]

→ It may be defined as one in which the no. of e^- = no. of holes.

→ The energy gap is so small that even at ordinary room temp., there are many e^- which posses sufficient energy to jump ~~across~~ from V.B. to C.B.



II extrinsic S.C. :-

→ Those intrinsic S.C. to which some impurity or doping agent has been added are called extrinsic S.C.

→ The doping agents are pentavalent atom having 5 valence e- [bismuth, antimony, arsenic, phosphorus] or trivalent atom having 3 e- [gallium, indium, aluminium, boron].

→ pentavalent doping is known as donor atom, because it donates one e- to the C.B.

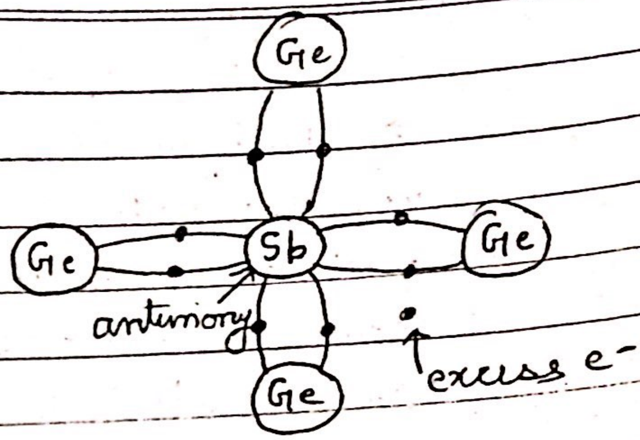
→ Trivalent doping is known as acceptor atom, because it accepts one e-.

→ There are two type of Ex.S.C.

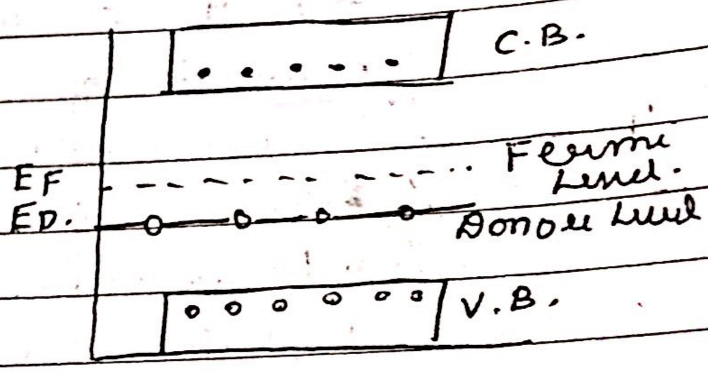
(i) N type Ex.S.C.

(ii) P. type Ex S.C.

(i) N type S.C.

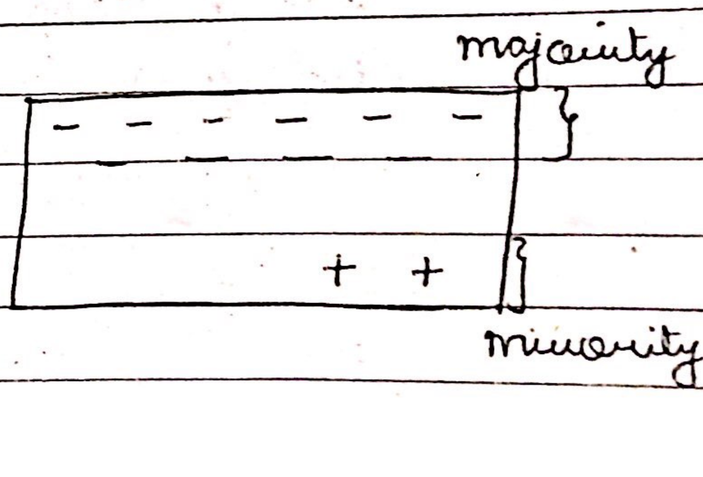


→ In this type of S.C, as shown in fig; each Sb atom form C.B. with surrounding four Ge atom with the help of four of its 5 e^-. The fifth e^- is loosely bound. Hence it can be easily excited from V.B. to C.B. by applied electric field.



→ The addition of antimony greatly ↑ses the no. of conduction e^- in C.B. & no. of holes in V.B

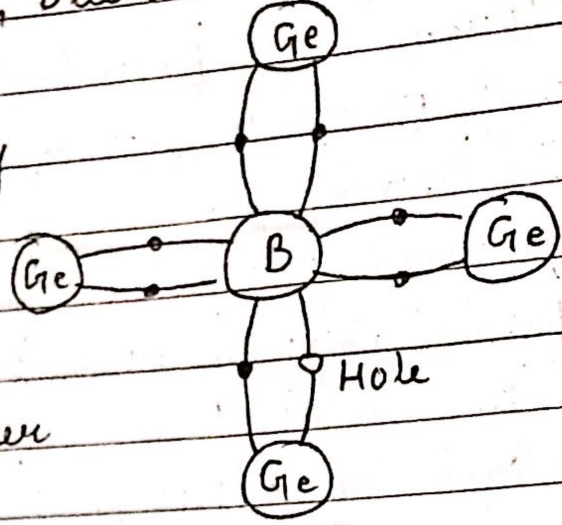
→ Because of this, Fermi level shifts upwards towards the bottom of C.B.



ii) p type S.C :-

→ This type of S.C is obtained when trivalent impurity like Boron (B) are added to a pure Germanium.

→ In this case, the three valence e⁻ of B form covalent Bond with Ge, but one bond is left and give rise to hole.

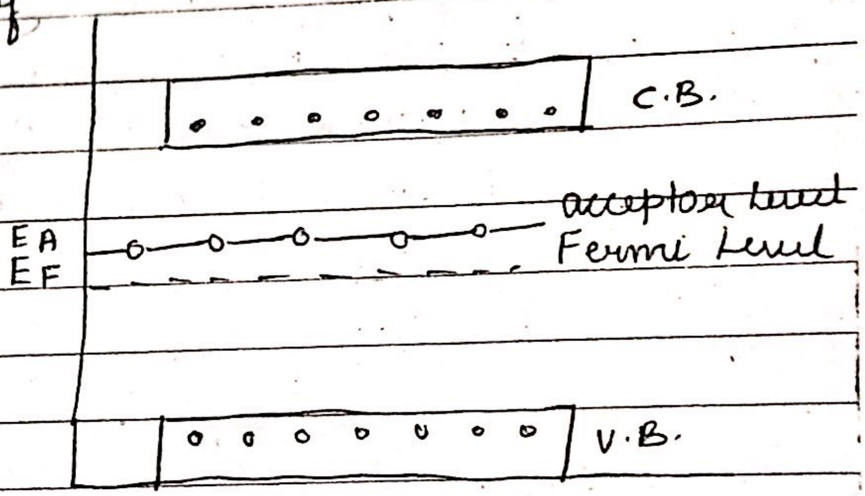


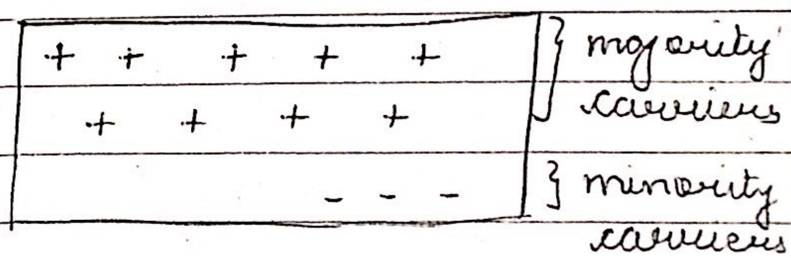
→ In this conduction is by means of holes in V.B.

→ so holes - majority
e⁻ minority

→ Fermi Level shift nearer to V.B.

→ Conduction is by means of hole movement at the top of V.B., the acceptor level readily accepting e⁻ from the V.B.

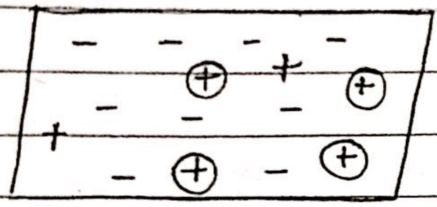




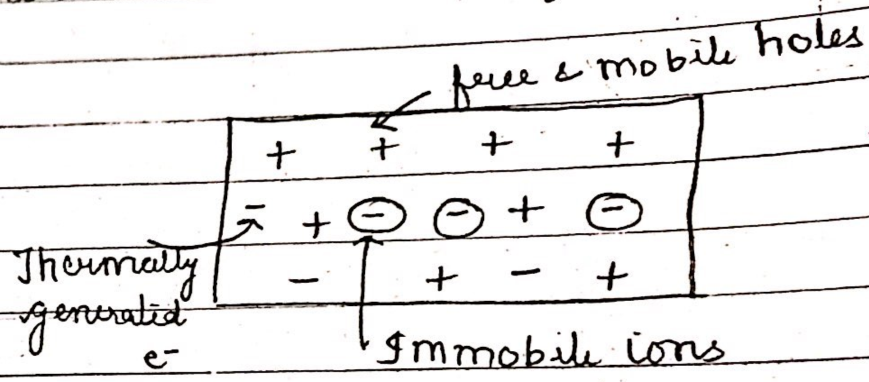
10. Mobile charge carriers & Immobile ions :-

→ When Temp. is raised to room temp., some of covalent bond are broken, as a result e- hole pair are produced. These are called thermally generated charge carriers.

→ In p type, when a hole move away from its parent atom, the remaining atom becomes a -ve ion. Unlike the mobile and free moving hole, this ion cannot take part in conduction because it is fixed in crystal lattice.



eg: N type



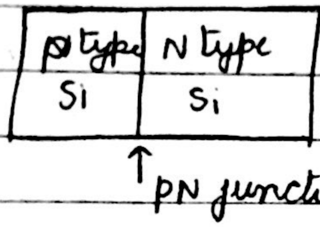
eg: p type

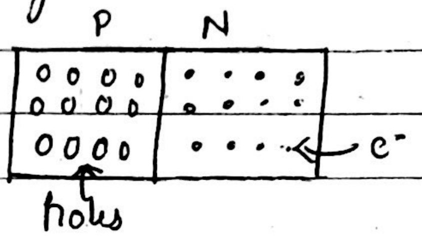
11 The P.N junction -

→ It is possible to manufacture a single piece of S.C. material (either Ge or Si) one half of which is doped by p-type & other half is doped by N type impurity.

→ The plane dividing the two halves or zones is called a P-N junction

→ It is not useful to produce P-N junction by connecting p type to N type by welding etc, because this would rise to discontinuities across the crystal.





→ During the formation of PN junc: ~~falls~~

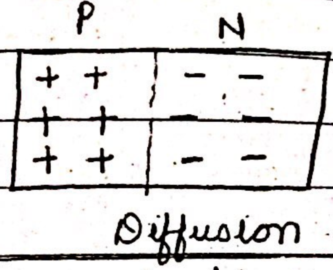
(i) A thin depletion layer is set up on both side of the junc & is so called because it is depleted of free charge carrier. Its width = 1 μm.

(ii) A junc or barrier potential (V_B) is developed across the junc whose value is about 0.3 V for Ge, 0.7 for Si

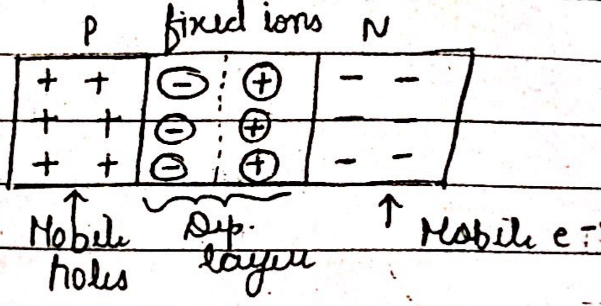
→ When a PN junc is packed as S.C. device, it is called P-N junc diode.

12. Formation of depletion layer :-

→ In P region, no. of holes are greater and in N region, no. of e⁻ are greater.



→ The same charge repel each other so density gradient across the junc resulting in majority carrier diffusion.



→ Holes diffuse from P to N region & e⁻ from N to P region and terminate their existence by recombination.

→ When an e⁻ migrates across the junc from N to P region, it leaves behind an atom i.e. one e⁻ short of its normal quota. This atom is now ionised and has a +ve charge. It is said to be uncovered charges.

→ They form parallel rows or plates of opposite charges facing each other across the depletion layer.

→ As dep. layer contains no free and mobile charge carriers, it behaves like an insulator and due to presence of rows of fixed charges, it posses capacitance.

→ due to the formation of ion on both side of junc, the -ve ion repel the negatively charged e⁻ and after a short time the diffusion process stops i.e. equilibrium condition is achieved.

3 Junction or barrier voltage (V_B) :-

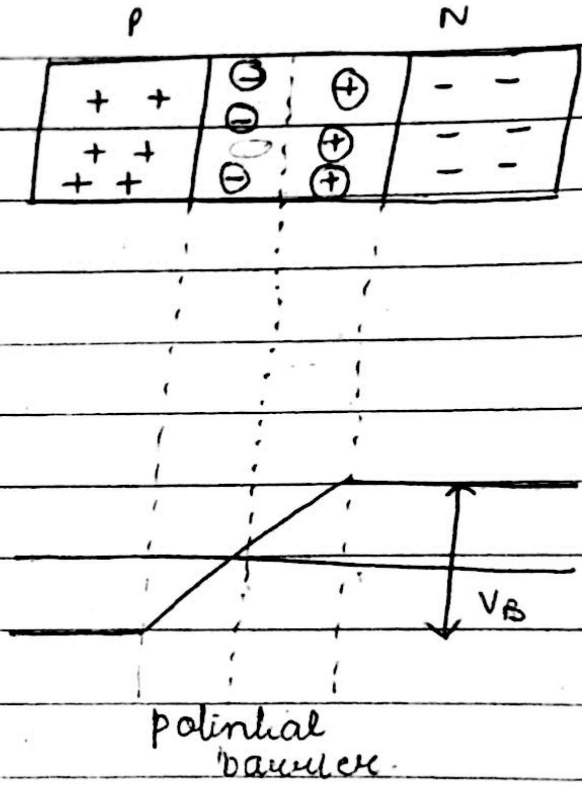
→ Because of the fixed ions of oppositely charged ions on two sides of PN junc, an electric potential V_B is established even when the junc is not connected to any external source of e.m.f. It is known as junc or barrier potential (V_B)

→ It stops further flow of carriers across the junc unless supplied by energy from an external source.

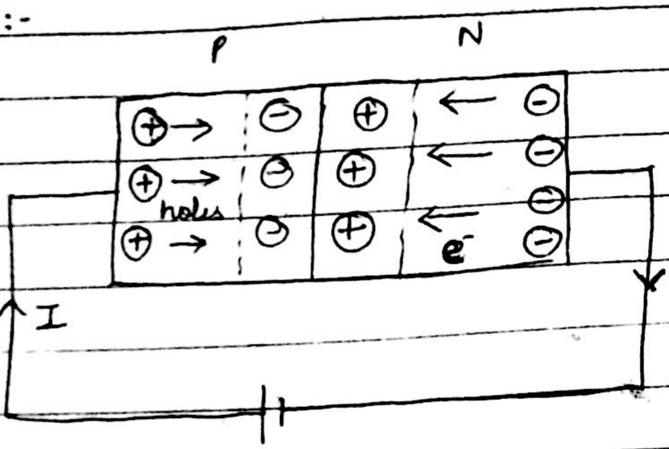
→ The width of dep. layer depends on doping level.

→ for heavy doping, dep layer is physically thin because a diffusion charge carrier has not to travel far across the junc for recombination.

→ for heavy doping, dep. region is thin because PN jun contains large no. of e⁻ & holes i.e. equilibrium is achieved very fast.



14. Forward bias P-N junction :-

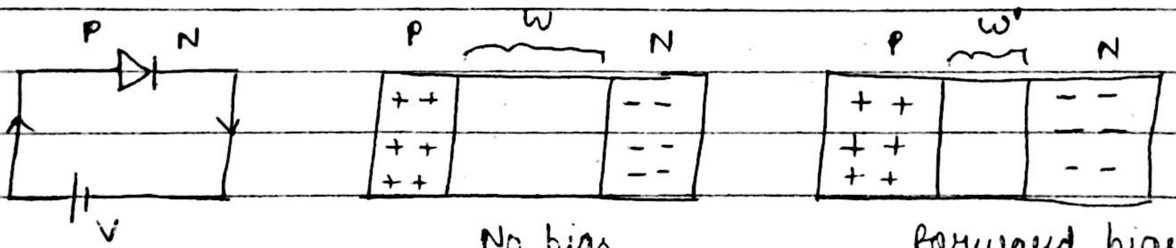


→ In forward bias, P is connected to positive of battery, N is connected to negative of battery.

→ The current flow may be explained as:

(i) As soon as battery connection is made, holes are repelled by +ve of battery & e- are repelled from -ve of battery with the result that both the e- & holes are driven towards the junc where they recombine.
This movement of e^- & holes constitute a large current flow. The crystal offers low resistance in the forward direction.

(ii) Another way to explain is due to applied external vtg, the barrier potential is reduced which now allows more current to flow across the junc.
F.B. reduces the thickness of dep. layer.



No bias   forward bias

W' < W

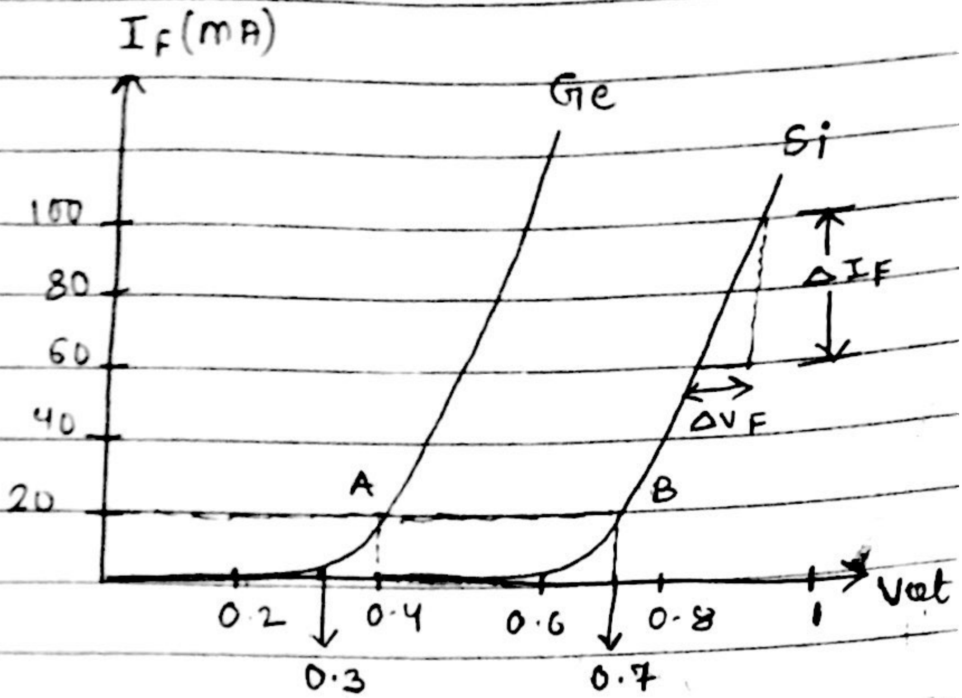
→ Forward current rises exponentially with applied vtg.

→ At ordinary room temp., 0.3V is required before a forward current starts flowing. This is known as threshold vtg (V_{th}), cut in vtg or Knee vtg (V_K). It is equal to V_B.

→ upto to V_{th} current flow is negligible

→ But as vtg ⇑, beyond V_{th}, the I_F ⇑ sharply

→ If V_F is ⇑ beyond a safe value, it will produce an extremely large current which may destroy the junc. due to overheating.



→ for pt B.

$$R_F = \frac{0.8V}{20mA} = 40\Omega$$

for pt A

$$R_F = \frac{0.4V}{20mA} = 20\Omega$$

→ In practice, dynamic resistance / Incremental res. or ac res. of junc is used.

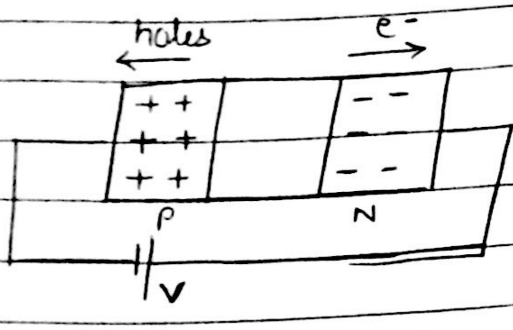
$$r_{ac} = \frac{\Delta V_F}{\Delta I_F}$$

→ Until external d.c. vtg is less than barrier potential there cannot be any conduction. As external vtg ⇑ses than (V_B), the -ve terminal of battery pushes the e^- to cross the junc.

→ Applied vtg overcome the barrier potential across jun, width of dep. layer starts ⇓.

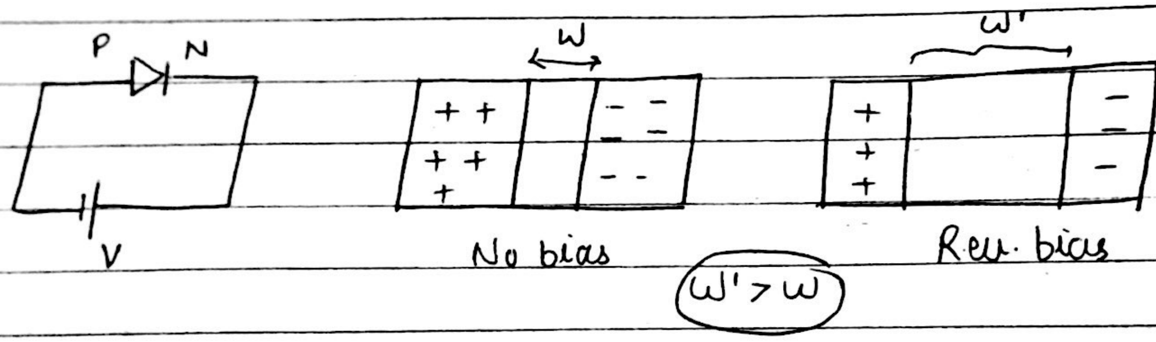
15. Reverse biased P-N junction :-

→ When P type is connected to -ve of battery & N type is connected to +ve of battery, diode is in Rev biased



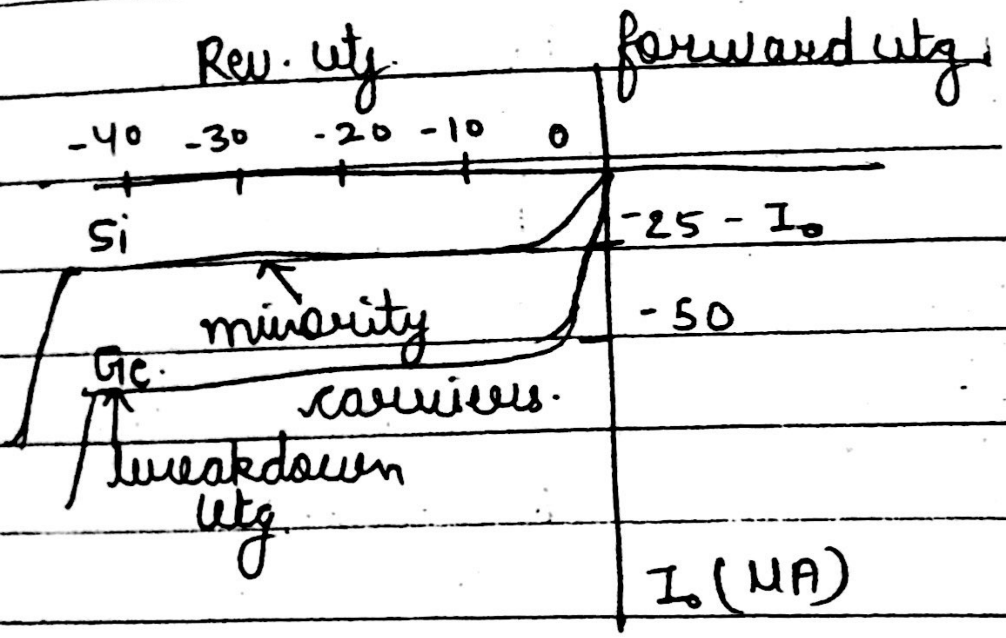
→ holes attracted towards -ve of battery, e^- attracted towards +ve of battery. e^- & holes move away from the junc. Since there is no e^- hole combination, no current flows & the jun offers high resistance.

→ Under R.B condition, width of dep layer ↑ses because majority charge carriers pulled away from the jun. It also ↑ses the potential barrier.



→ In R.B., there is practically no current due to maj carrier, but the small amount of current is flow due to minority carriers across the junc.

→ The applied vtg act as a forward vtg for these minority carriers, so small current called reverse current or reverse saturation current or leakage current.


Rev. vtg.
forward vtg.
-40 -30 -20 -10 0
Si
-25 - I₀
-50
minority
carriers.
Ge.
breakdown
vtg.
I₀ (μA)

Date
Page

16. Junction breakdown :-

→ If the R.B. applied to PN junc is ↑sed, a point is reached When the jun breakdown & reverse current rises sharply. The critical value of vtg is known as (VBR) breakdown vtg.

→ It is found that once breakdown has occured, very little ↑ in vtg is required to ↑ the current to relatively high values.

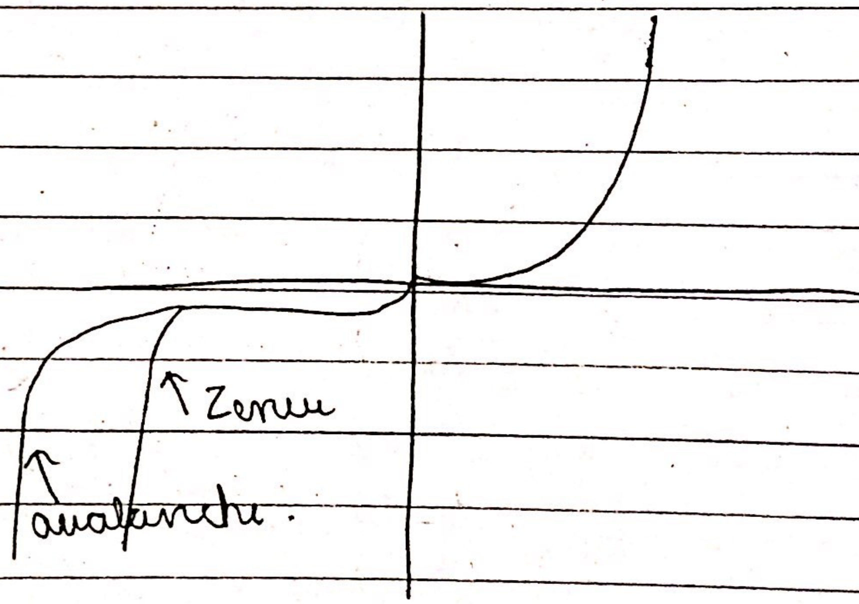
→ Now if reverse vtg is ↑, velocity of minority carriers ↑ses, kinetic energy associated with minority carriers also ↑ses. These carriers collide with the stable atom and impart their energy to valence e⁻. Due to gaining energy these valence e⁻ break covalent bond & jump to conduction band, and available as minority carriers.

→ Now these minority carriers due to high rev. vtg get accelarated & breaks more covalent bonds. & chain reaction starts.

→ The two mechanism are responsible for breakdown

(i) Zener breakdown :- This occurs in jun, being heavily doped, have thin dep. layers. The rev. vtg set up very strong electric field to break covalent bond. Therefor generating e⁻ hole pair.

(ii) Avalanche breakdown :- This occurs in lightly doped junc, have ~~width~~ wide dep. layer where the electric field is not enough strong to produce Zener breakdown. Instead, the minority carriers collide with s.c. atom in dep. region. Upon collision with valence e⁻ covalent bonds are broken & e-hole pairs are generated. These newly generated e-hole pair are also accelerated by electric field resulting in more collision.



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17. Junction capacitances :-

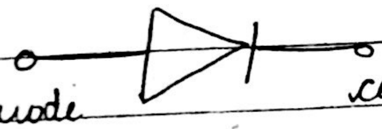
(i) Transition capacitance or space charge capacitance

→ When a PN jun is reverse bias, the dep. reg act like a insulator or as a dielectric material essential for making capacitance.

(ii) diffusion or storage capacitance :
→ The capacitive effect is present in F.B., it is called diffusion capacitance..

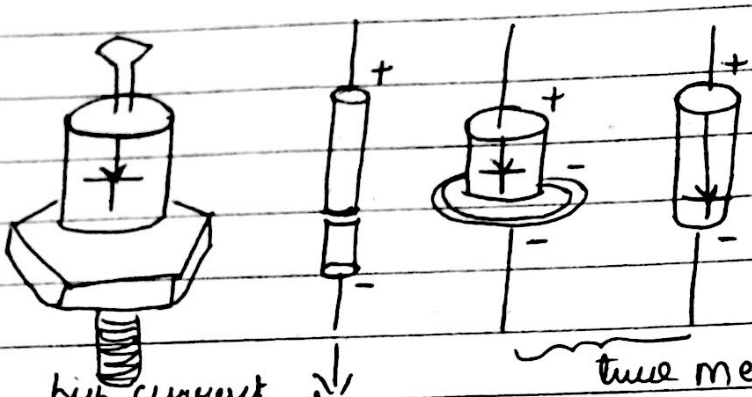
18. PN junc diode - Construction :-

→ It is two terminal device consisting of P N junc. ~~forward~~



→ P side - anode
N side - cathode
arrowhead - dirn of current flow.
(opposite dirn of e- flow)

→ commercially available diodes have standard notation consist of no. preceded by IN 240 & IN 1250.
Here 240, 1250 - colour bands.



→ The end which has black band is the cathode & the other is anode.

→ Low current diode : body 3mm Long
If (forward current) = 100mA
saturation current = 5 μA
Rev. vtg = 75V

→ Two medium current :- If = 500mA
Rev. vtg - 250V

→ high current diode :- If = many A.
Rev. vtg : survive for many hundred

19. Diode Mounting :

→ Low & medium current diode are usually mounted by soldering their leads to the connecting terminals. The heat generated is small enough to be carried away by air convection.

→ High current diode, generate large amount of heat for which air convection is totally inadequate for cooling, they need heat sink made of metals such as copper or Aluminium. which are good conductors of heat. The sink absorbs heat from the device & then transfers it to surrounding air by convection and radiation since it has large surface area. It has finned to ↑se its surface area & hence its cooling efficiency.

20. Diode parameters :-

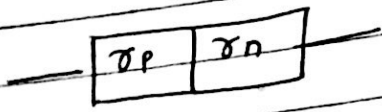
(i) Bulk resistance (r_B) :

$$r_B = r_P + r_N$$

↳ res. value of P & N type S.C. of which diode is made.

$$r_B = \frac{V - V_K}{I_F}$$

it is res. offered by the diode well above the knee vtg. i.e. when current is large. Obviously this res. offered in forward dirn.

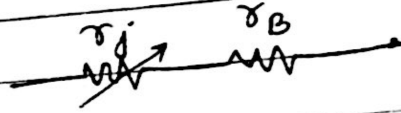


$r_B = r_P + r_n$

(ii) junc resistance (r_j) - its value for F.B. junc depends on the magnitude of forward dc current.

$$r_j = \frac{25mV}{I_F mA} \quad \text{... for Ge}$$

$$= \frac{50mV}{I_F mA} \quad \text{for Si}$$



obviously it is var. resistance

(iii) dynamic or ac res. :

~~rac / (rd)~~ =

$$r_{ac} \text{ or } r_d = r_B + r_j$$

(iv) forward vtg. drop = $\frac{\text{power dissipated}}{\text{forward dc current}}$

(V) Rev. sat. current (I_0)

(VI) Rev. breakdown vtg (VBR)

(VII) Rev. dc Res. $R_R = \frac{\text{Rev. vtg}}{\text{Rev current}}$

(viii) equation of diode current

Date

Page

The analytical eq^n which describes both the forward & Rev. char is called Boltzman diode eq^n

$$I = I_0 (e^{40V} - 1) \quad \text{if } V > 1$$

$$= I_0 (e^{40V})$$

21 Application :-

1. As power or rectifier diode - Convert ac into dc.
2. As signal diode in comm. ckt. for modulation & demod. of small signal
3. As zener diode in vtg stablizing ckt.
4. As varactor diode - for vtg controlled tuning ckt.
5. In logic ckt. used in computers.

Mahaveer
Date
Page

22 diode Ratings or specifications - In order to select a diode for a particular application, one must know the specification as given in data sheet provided by device manufacturer. These specification indicate the absolute rating of diode. It is important that these rating should never be exceeded.

1) peak Inv. vtg (PIV) :- Max. Rev. vtg that can be applied to the diode without distruction.
- peak Rev. vtg (PRV) - rev. breakdown vtg (VR)
- Max Rev. vtg (VRM)

2) Avg. forward current IF(av) :- Continious forward current which the diode can pass at normal temp.
- max. steady state forward current (IFM)
- Repetitive forward current (Irep)

3) forward surge current :- The large current which a diode can safely handle for a very short time. (I_{FS})

4) Maximum forward vtg :- Max. forward vtg that the diode can have without burnout (VFM)

5) forward vtg :- forward vtg of diode at given temp and for a specific value of for. current (VF).

6) Rev. current :- max. Rev. saturation current at the max. rev. vtg at a given temp. (I_R)

7) power dissipation :- given as max. power that the diode can safely dissipate on a continue basis in free air

8) Reverse Recovery time :- Max. time taken by device to switch from ON to OFF state. (t_{rr}). it is usually in nanoseconds.

Q3. Optoelectronic Devices :-

→ product of the technology that combines optics with electronics

→ Two broad categories are :

(i) Device that convert electricity into light → emitters. (LED)

(ii) light into electricity → photoemissive & photodetectors

↓

photodiode

↓ PN

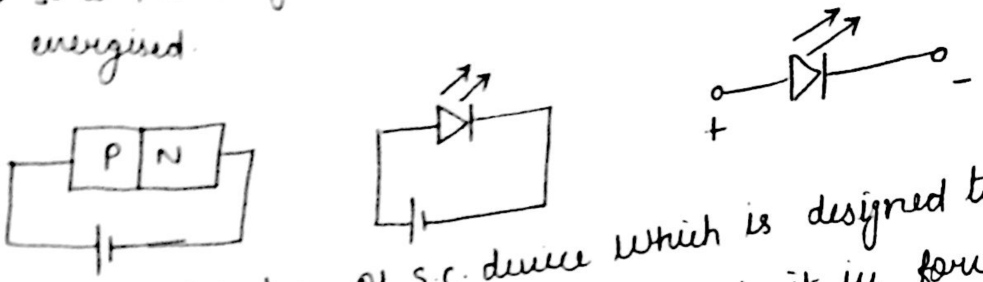
↓ PIN

↓ avalanche

24. LED (light emitting diode) :-

(1) Theory :-

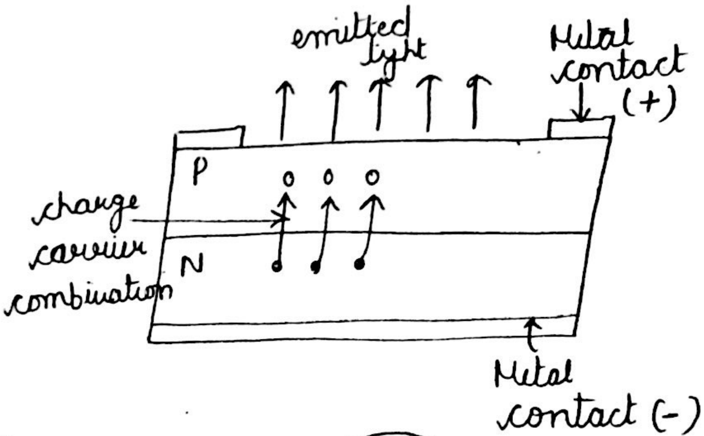
→ It is F.B. PN junction which emits visible light when energised.



→ It is special type of S.C. device which is designed to emit light when current passes through it in forward dirn.

→ It is a useful display device, which emits light in diff. colors like red, green, yellow, orange & white.

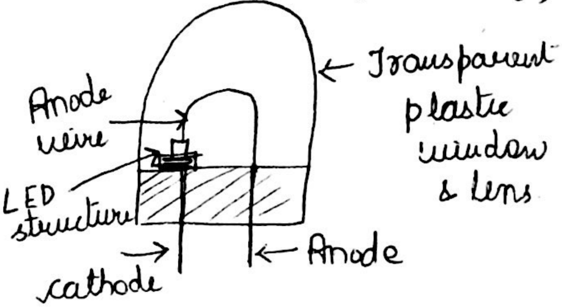
(2) Construction :-



→ An N layer is grown on a substrate & a p layer is deposited on it by diffusion.

→ ~~Since carrier are~~

→ The metal anode connection are made at outer edge of P layer so as to allow more central surface area for the light to escape.



→ A metal film is applied to the bottom of the substrate for reflecting as much as light possible to surface of the device and also provide cathode connection.

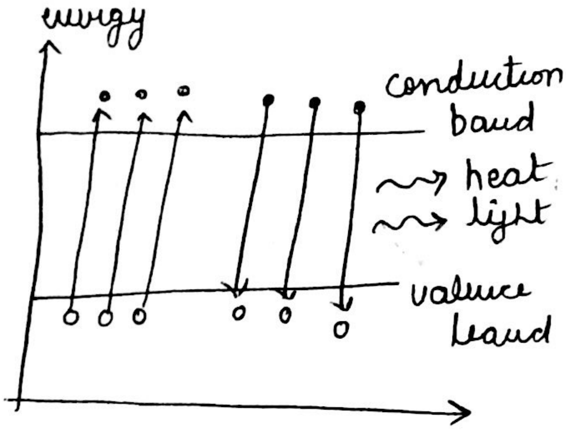
→ LED's are always encased to protect their delicate wires.

→ It is rugged & has a life of more than 10,000 hours

→ The S.C material used are GaAs (Gallium Arsenide), GaP (Gallium phosphide), GaAsP (Gallium Arsenide phosphide).

→ The back radiation are absorbed by lattice. The lens helps to focus light out of LED structure.

(3) Working principle :-



→ When a PN junc is F.B., the forward current flows due to free e⁻ crosses from N side & recombining with holes on P side.

→ When e⁻ is excited from V.B. to C.B., the e⁻ hole pair created.

→ e⁻ stay in CB for a very short period called life time & return back.

→ In transition from higher energy state to lower energy state, these e⁻ release energy.

→ Some of these energy will be given off as heat & some in form of light.

→ In Si & Ge, the greater % is of heat & light is negligible. So it is not useful for LED.

→ Some other material such as GaAs, GaP, GaAsP are used because, the greater % is of light & heat is negligible.

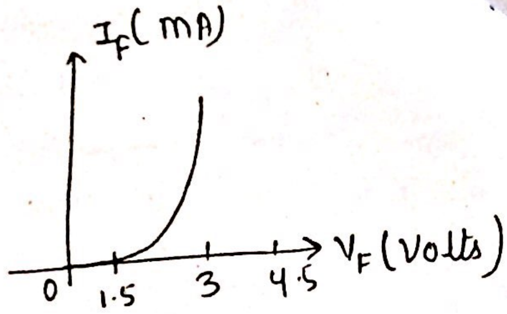
→ The intensity of light depends upon no. of recombination which is propotional to forward current in diode.

→ LED emit no light when Rev. biased. In fact operate it in Reverse bias will destroy them.

(4) V-I charateristics :-

→ cut in vtg of LED is about 1·5V. Which is considerably larger than original diode.

→ When PN junc is F.B with a vtg greater than about 1·5V, e-hole recombination takes place.



(5) Application :-

(i) used in visual display of all type. eg: 7 segment display.
LED are commonly use because they are cheap, reliable, easy to interface. numeric display in hand held or pocket calculator.
display alphanumerics.

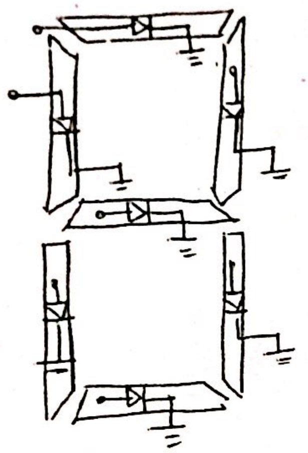
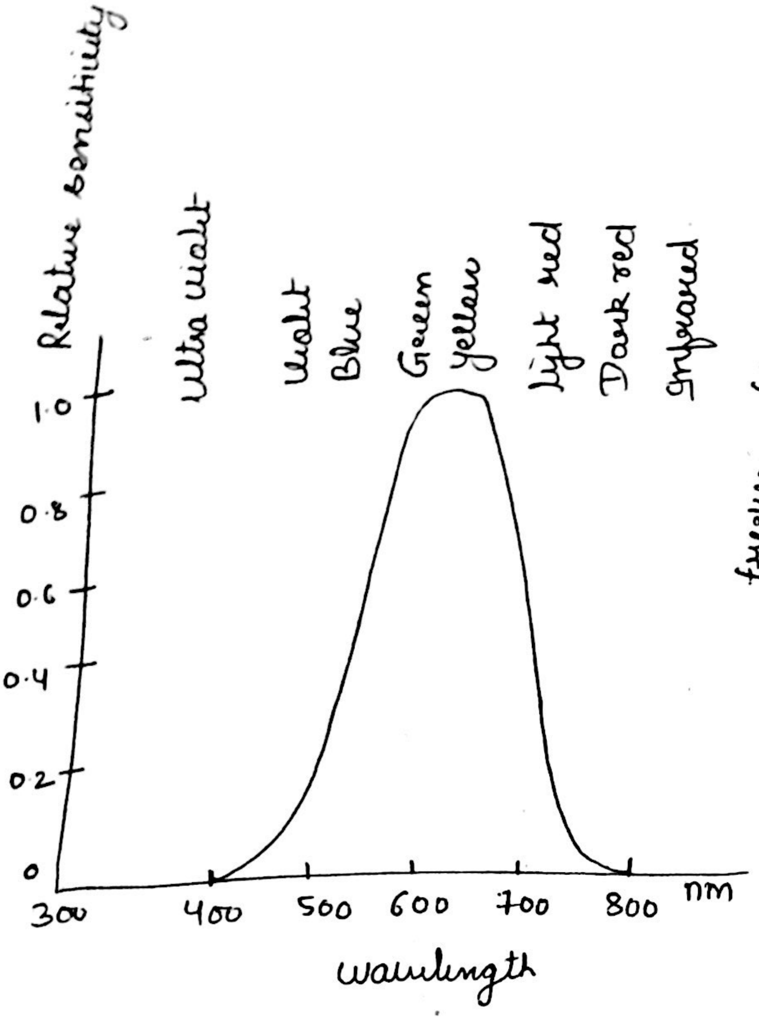
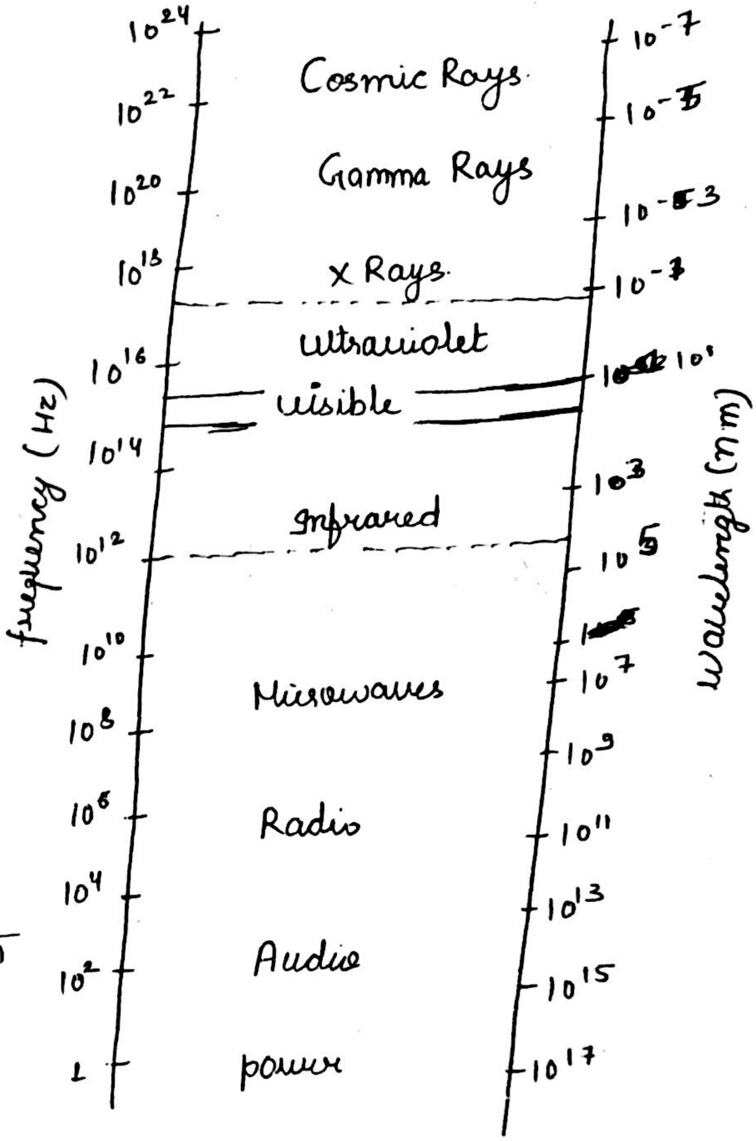


fig: common cathode 7 segment display

(ii) burglar Alarm system
(iii) for solid state video display
(iv) Image sensing circuit
(v) In optical communication

(6) range of wavelength of visible light is 10^1 to 10^3 nanometers.





25. photodiodes :-

→ It is divide into three types

(i) PN diode

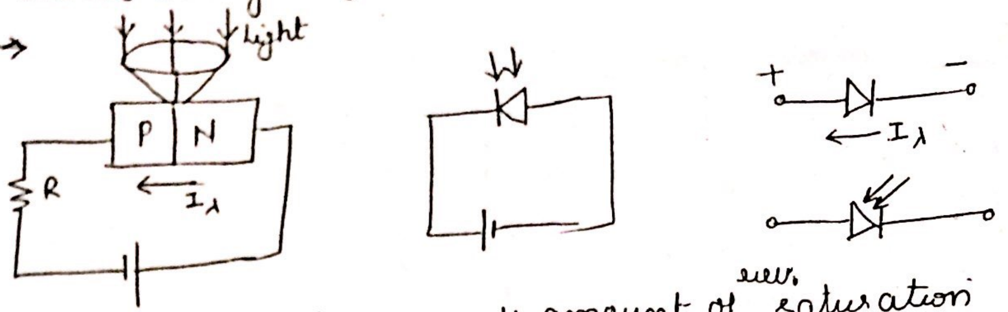
(ii) PIN diode

(iii) avalanche diode

I PN junction photodiode :-

→ It is a two terminal device which is operated by first reverse biasing the junc & then illuminating it.

→



→ A R.B. PN junc has a small amount of rev. saturation current I_s due to thermally generated e- hole pairs.

→ The no. of these minority carriers depends on the intensity of light incident on the junc.

→ When the diode is in glass package, light can reach the junc & thus change the reverse current.

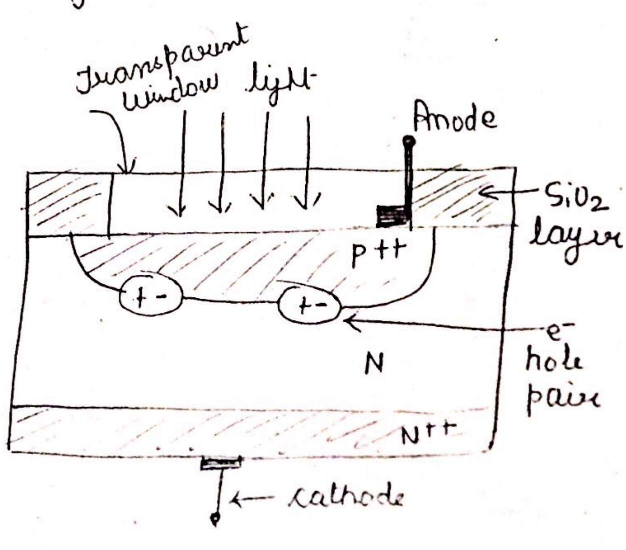
→ The variation in O/P current is linear w.r.t. luminous.

→ The photodiode has small transparent window that allows light to incident on PN junc.

(1) Construction :-

→ A heavily doped and Shallow P region is diffused into a lightly doped N region.

→ An SiO_2 layer is deposited on a very small region on the top of P++ region.



→ An external lead is taken out from P++ region for electrical connection known as anode.

→ The cathode connection is made from N++ region.

→ It may be noted that N++ layer is formed below the lightly doped N region.

→ finally the whole assembly is sealed in a plastic encapsulation which has a transparent window on top of it to permit light into the structure.

(2) <u>Working principle</u> :-

→ The diode has small reverse current (I_λ) when R.B.

→ When the device is exposed to illumination, I_λ the reverse current changes

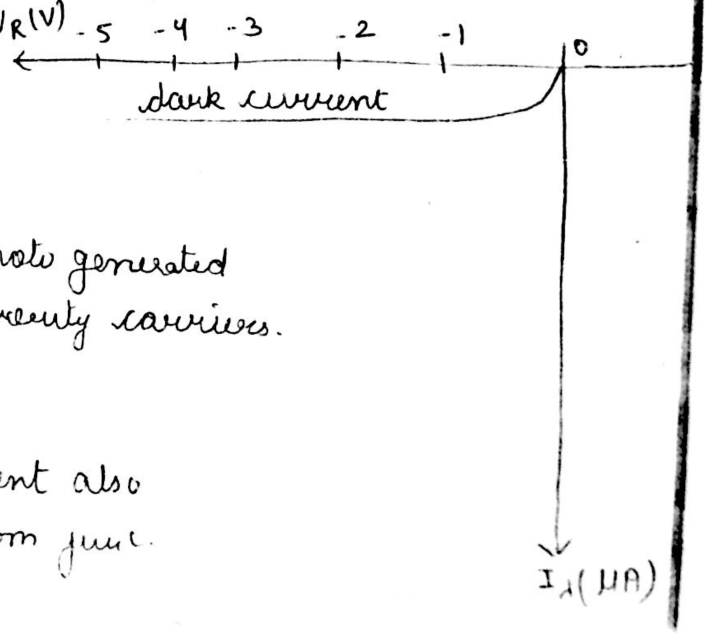
→ The variation in current is linear w.r.t luminous flux.

→ When there is no light, I_λ is almost negligible & called <u>dark current</u>.

→ The application of light to the jun. results in transfer of energy from incident light in the form of photons, result in e-hole pair generation.

→ due to R.B. the current will ↑se due to minority carriers & hence there is an ↑se in Reverse current.

→ concentration of e-hole pair depends on intensity of light.



→ so $I = I_0 + I_L$ → due to photo generated minority carriers.

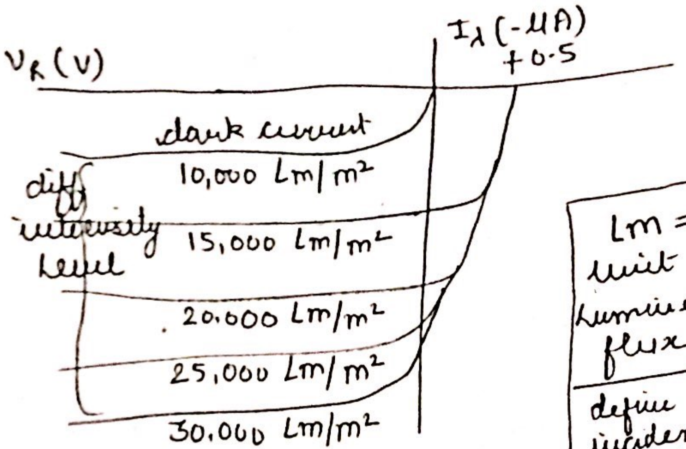
(I_0) due to thermally generated minority carriers

→ Magnitude of Reverse current also depends upon distance from junc.

larger is the distance lesser will be the current.
(Since chances of recombination is higher for pt. away from junc)

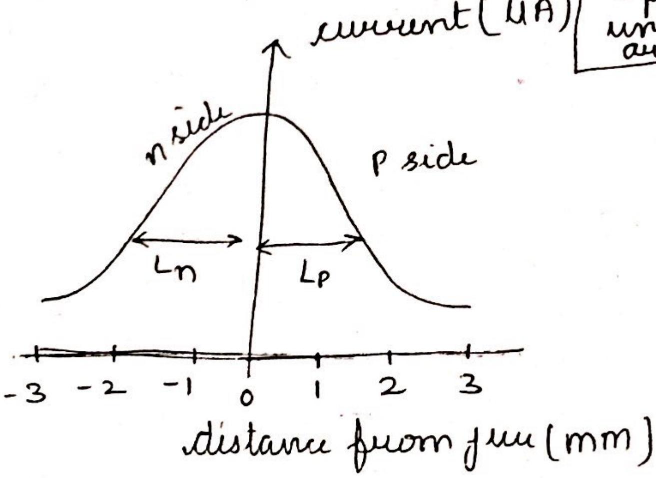
→ A lens has been used focus max. light on R.B. junc.

→ A photodiode can turn its current ON & OFF is ns. Hence it is photodetector. It is used where it is required to switch light ON & OFF at max. rate.



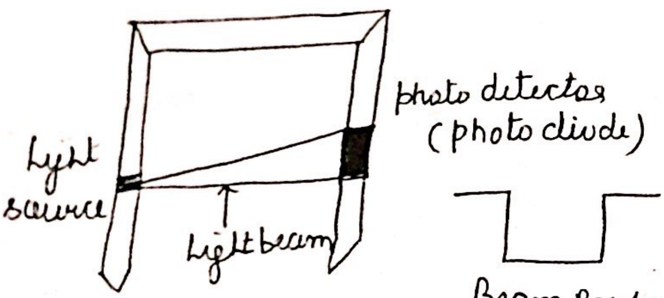
Lm = unit of luminous flux

define incident light per unit area



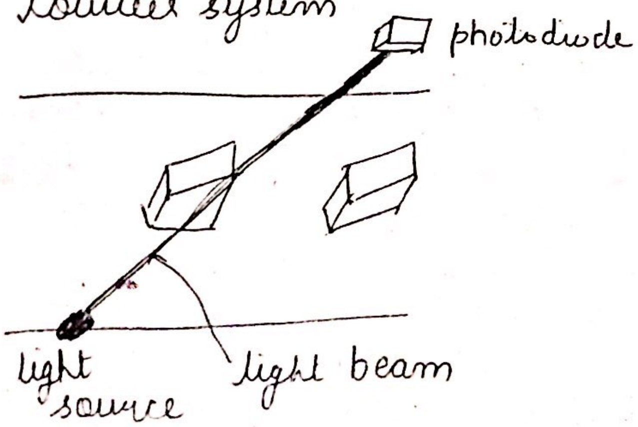
(3) Application:-

(i) Alarm system



Beam Broken when somebody enters the doorway.

(ii) Counter system



it is used to count items on conveyer belt. As each item passes, the light beam is broken. I_λ drops to dark current & the counter is ↑sed by one

(iii) Light detecting system

(iv) reading of film sound track

(v) Light operated switches

(vi) High speed reading of computer punched cards & tapes

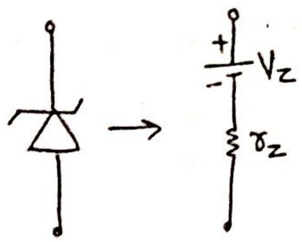
(vii) In optocoupler

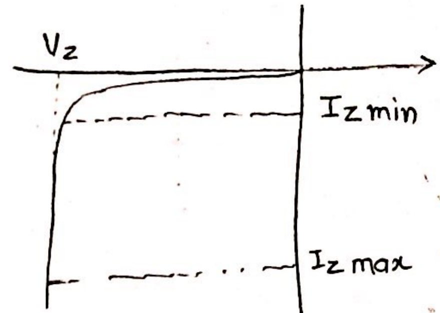
26. Zener diode :-

→ R.B heavily doped PN junc diode which is operated in breakdown region.

→ Si is preferred to Ge because of its higher temperature & current.

→ At Rev. vtg less than 6V, Zener effect predominates. Above 6V, avalanche effect is predominant.





→ The location of Zener region can be controlled by varying doping level.

→ An ⇑ in doping will ⇓ the zener potential

→ range 3V to 200V.

→ ~~Inventor~~ - carl Zener - Inventor

→ After the breakdown, reverse current is indep. of applied voltage., it is limited by external resistance.

→ The vtg at which breakdown occurs remains stable. Hence Zener diode are used in regulator ckt.

→

exact equivalent

ideal equivalent

(a) forward bias
(work as F.B. PN junc)

when reverse vtg $\geq V_z$

when rev. vtg $< V_z$

(b) Reverse bias

→ Zener biasing : for proper working of Zener diode it must .

- be R.B.
- have vtg across it greater than V_Z.
- be in a ckt. where current is less than $I_{Z.max}$.

→ looks like any other diode and is recognised by its IN no. such as IN750 or IN4000.

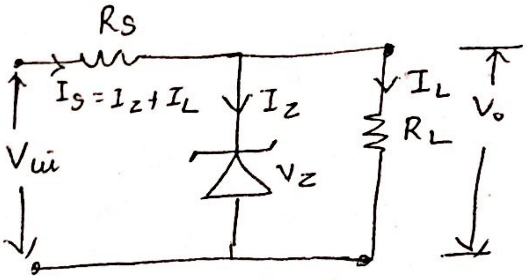
Applications :

(i) voltage Regulator : constant Rev. breakdown vtg makes it useful in vtg regulation ckt.

$I_S = I_Z + I_L$ — (i)

$V_{in} = I_S R_S + V_Z$

$V_{in} = (I_Z + I_L) R_S + V_Z$ — (ii)

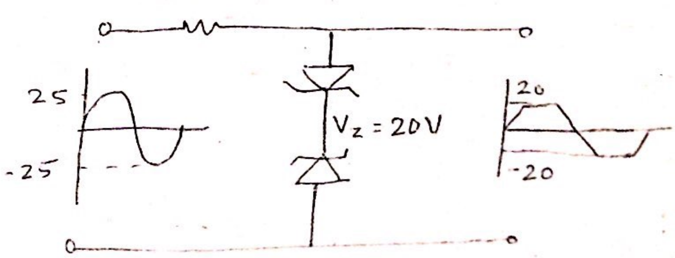


due to supply vtg variation V_{in} ↑↓ses, vtg across Zener diode will remain constant.
the drop across Rs will ↑↓ $(I_Z + I_L) R_S$
But the vtg across R_L connected in parallel to Zener diode will also remain constant and hence I_L will be constant.
Therefore the only quantity that ↑↓ses is I_Z
I_Z ↑↓ to keep load vtg constant.

I_Z can vary b/w $I_{Z min}$ & $I_{Z max}$.

Thus inspites to variation in i/p vtg., the o/p vtg remains constant.

(ii) peak clipper :–



- Zener diode – short – forward dirn
  open – Reverse dirn till it goes into breakdown at V_Z.

- During +ve half cycle

  D_1 – F.B. – short

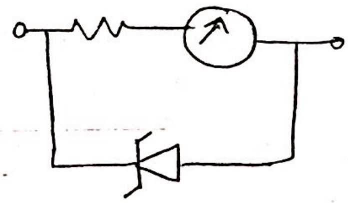
  D_2 – R.B. – open till V_Z (20V)

- Thereafter it goes into breakdown & holds the O/P vtg. constant till I/P vtg falls below 20V.

- During –ve cycle: D_1 & D_2 is reversed.

(iii) Meter protection:

→ used for meter movements against burn out from accidental overload



→ If it is set to 2.5V, and the test lead are connected to 25V, an unprotected meter will be burned out.

→ These is ~~removed~~ avoided by connecting Zener diode in parallel with Meter

Keerti Dagliya   2nd year ECE   elec. devices & circuits
2nd year EE   power electronics I

27. BJT

Unit 3
BJT

Book
U.P. Tiwari
Riya Tiwari
A.P. Godse

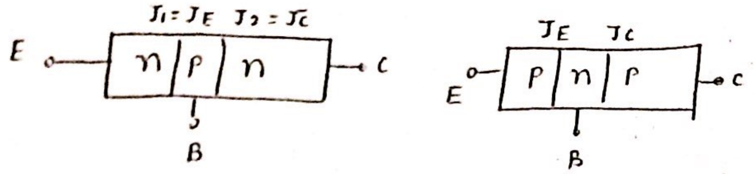
1. BJT (Bipolar junction transistor) :-

⇒ used for amplification of signals.

⇒ current conduction is due to Both type of charge carriers i.e. e^- & holes.

⇒ It is divided into two types : (i) NPN (ii) PNP

⇒ It is 2 jun, 3 terminal, 3 layer device.



⇒ Holes are maj. carrier in PNP, e- are maj. in npn.

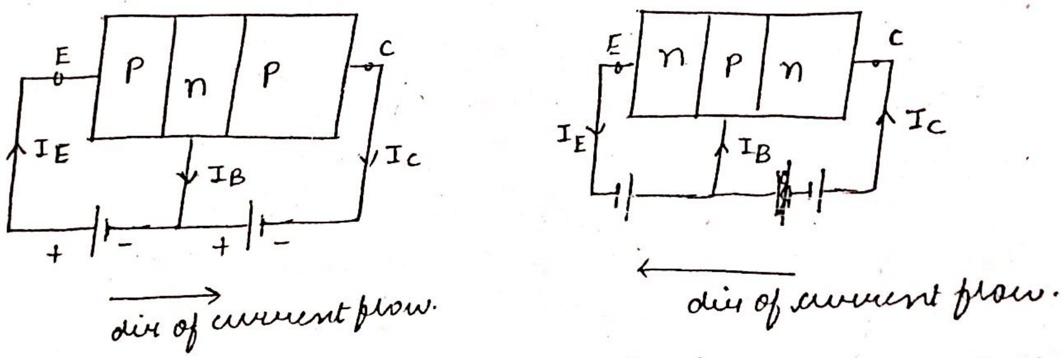
⇒

→ The arrowhead is always at the emitter. arrowhead points from Emitter to Base.

⇒ arrow indicates the dirn of current flow.

⇒ mobility of e^- is greater than holes, so switching speed of npn is more than PNP.

⇒



⇒ collect collects the e^- & holes and size is more than E due to following reasons :

(i) amp factor α, β ↑, if no. of charge carrier ↑.

(ii) more heat is ~~dissipated at collector jun~~, developed at collector jun, so if area is large than more heat is dissipate due to reverse bias.

⇒ If base is thin and lightly doped, then recombination of e⁻ & holes ↓, and max no of e⁻ & holes injected to collector from E, so amp factor ↑.

⇒ depletion layer width $\propto \frac{1}{\text{doping level}}$

⇒ doping level B < C < E — Emitter heavily doped: because its func is to emit e⁻/holes.

⇒ depletion layer width B > C > E

⇒ Due to the different doping level, two depletion layer doesnot have same width.

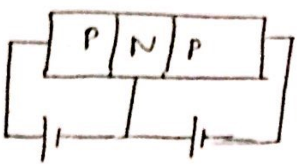
Operating Regions :-

(i) Active region : (a) J_E = forward bias, J_C = reverse bias

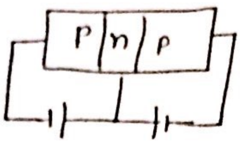
(ii) cut off region : J_E, J_C = reverse

(iii) saturation region : J_E, J_C = forward bias.

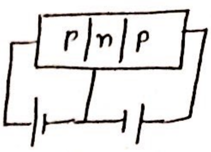
PNP Tx :



(i) Active



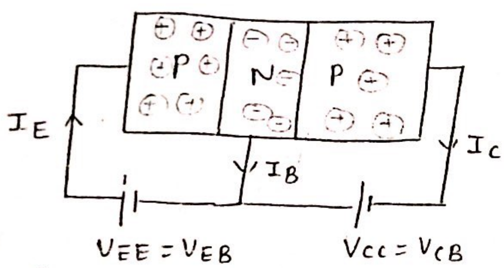
(ii) cut off



(iii) Saturation

⇒ Tx is current controlled device.

2. Working of PNP Tx :-



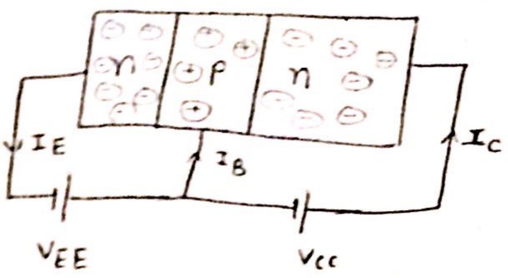
⇒ E is connected to +ve of battery V_{EE}, so holes present in p layer are repelled and injected into base.

⇒ But base is very thin, so only 2% of holes recombine with e⁻ and small amount of I_B is flow.

⇒ 98% of holes are injected into collector and C is connected to the -ve of battery V_{CC}. So holes are attracted and I_C current is flow.

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

. Working of NPN Tx :-



⇒ E is connected to -ve of battery V_{EE}, so e- is present in n layer are repelled and injected into base. e- moves from E to C so current I_E flow in opp dirn. i.e from C to E.

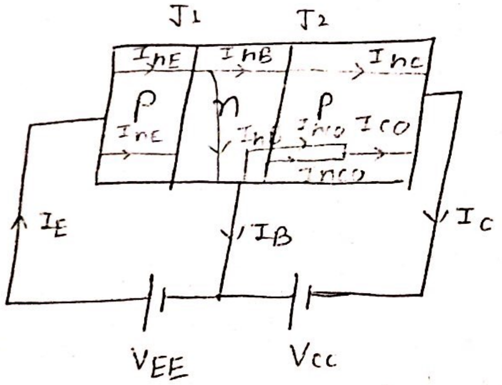
⇒ 2% of e- are recombine with holes in p layer and I_B current is flow.

⇒ 98% of e- are injected into collector from E. C is connected to +ve of battery V_{CC}. So e- are attracted towards +ve of battery and current I_C flows in opposite dirn from e- flow.

3. Current Components :-

I In PNP Tx →

⇒ In BJT, Both e- & holes participate in current cond.
⇒ forward bias : current flow due to maj carriers
⇒ Reverse bias : current flow due to min. carriers.



I current comp at forward bias jun J_1 →

⇒ J_1 is forward bias, so maj carriers contribute the flow of current, ~~Both carriers~~ so two comp. e- current & hole current is present. e- current is due to e- present in n layer and hole current is due to hole ~~current~~ present in p layer.

(a) Hole current :-

⇒ At J_E jun current is known as I_{hE}.

⇒ holes present in p layer diffuse into n type base and I_{hB} generate

⇒ 2% holes combine with e^- in base and 98% holes injected into c, so I_{hC} generated.

$$I_{hE} = I_{hB} + I_{hC}$$

(b) e^- current :-

⇒ e^- present in n layer are attracted towards +ve of battery V_{EE}, so I_{nE} generated and flow in opp. dirn of e^- flow.

$$I_E = I_{hE} + I_{nE}$$

II current comp at reverse bias jun J_2:-

⇒ J_2 is reverse bias, so only min carriers can cross this jun. ~~i.e. holes moves from B to C region~~.

(a) hole current :-

⇒ hole current is due to min carrier present in n layer. ~~and~~ This holes are attracted towards -ve of battery V_{CC}. and I_{hCO} current is flow.

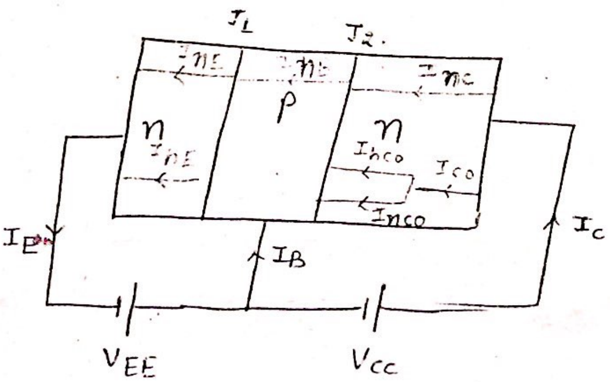
(b) e^- current :-

⇒ e^- current is due to e^- present in p layer. This e^- are repelled due to -ve of battery V_{CC} and I_{nCO} is flow in opposite dirn of e^- flow.

$$I_{CO} = I_{hCO} + I_{nCO}$$

III In addition $$I_C = I_{hC} + I_{CO}$$

II In npn Tx :-



I current comp at forward bias jun J_1 :

⇒ forward bias current cond due to maj carriers

(a) Hole current → holes are present in p layer as a maj carrier which are attracted towards -ve of battery V_{EE} and current I_{hE} is flow

(b) e⁻ current → e⁻ are present in n layer as a maj carrier which are repelled into base region and current I_{nE} is flow in opp dirn of e⁻ flow. This e⁻ are recombine with holes, so I_{nB} current is flow. 98% of e⁻ injected into collector which are attracted towards +ve of battery V_{CC} and I_{nC} current is flow whose dirn is opposite to the e⁻ flow.

$$I_E = I_{nE} + I_{hE}$$

$$I_{nE} = I_{nB} + I_{nC}$$

II current comp. at Reverse bias jun J_2 :

⇒ Reverse bias : current cond due to min. carriers.

(a) Hole current :- holes are min. carrier in n layer which are repelled due to +ve of battery V_{CC} and I_{hCO} current is flow.

(b) e⁻ current :- e⁻ are min. carrier in p type which are attracted towards +ve of battery V_{CC}, so I_{nCO} is flow whose dirn is opp to flow of e⁻.

$$I_{CO} = I_{hCO} + I_{nCO}$$

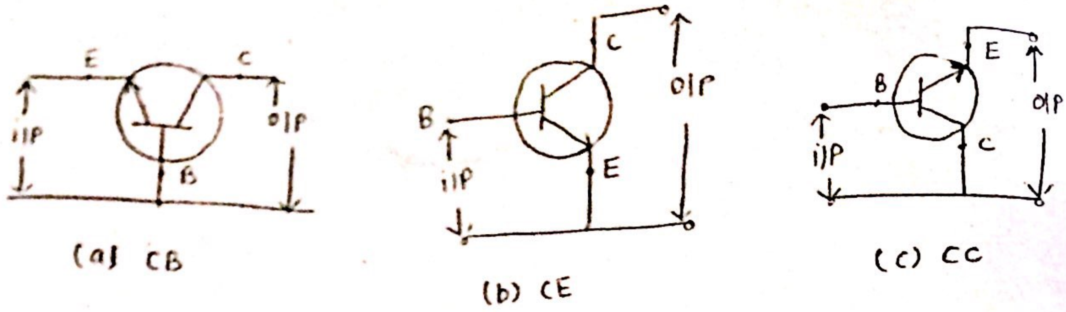
$$I_C = I_{nC} + I_{CO}$$

4. Transistor configuration :- there are 3 type of Tx conf :-

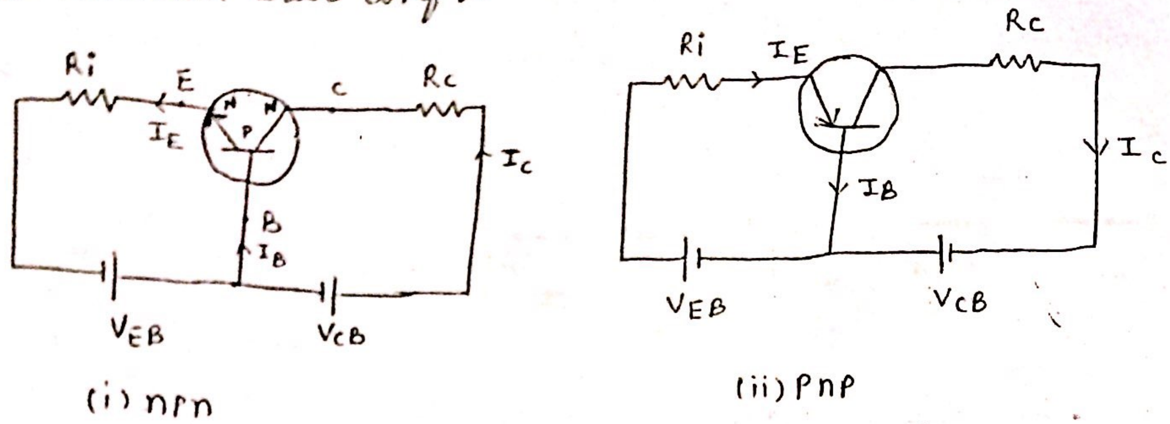
(i) CB (common base)
(ii) CE (common em.)
(iii) CC (common collector)

⇒ The EB jun. is always F.B. while the CB jun is always R.B. to operate Tx in Active region.

⇒ current gain is defined by ratio of O/P to I/P current and it is α, β, γ resp for CB, CE, CC.



I common Base conf :-



⇒ In this base is selected as common terminal
⇒ i/p is applied b/w E, B. o/p is applied b/w C, B.

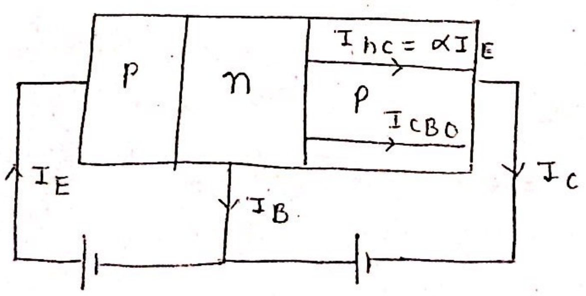
Current relation in CB conf :-

current amp. factor α is given as ratio of o/p to i/p current.

$$\alpha = \frac{I_C}{I_E} \quad -(1)$$

The value of α is less than one, since a small part of I_E is drained off in the base through recombinations. But practically, base width is kept as small as possible, Hence chances of recombination are less and α become nearly equal to 1.

$$\alpha = 0.95 \text{ to } 0.995$$



$$I_E = I_B + I_C$$

$$I_C = \alpha I_E + I_{CBO} \text{ (from fig.)}$$

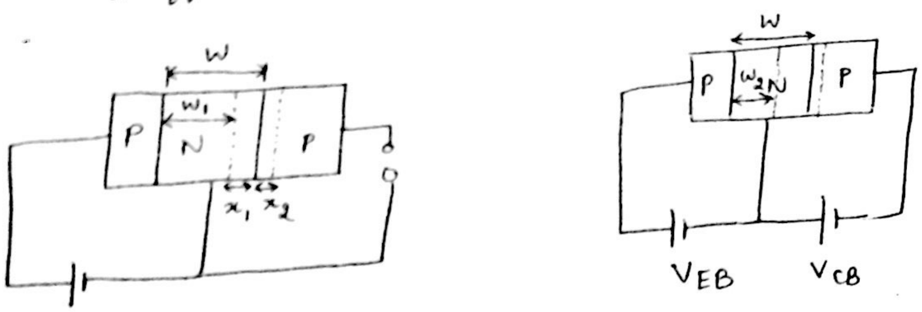
$$I_E = I_B + \alpha I_E + I_{CBO}$$

I_{CBO} is reverse leakage current and its value is very small due to min carriers, hence negligible

$$I_E = I_B + \alpha I_E$$

$$\boxed{I_B = (1-\alpha) I_E}$$

early effect or base width modulation :-



=> An ⇑ in R.B at CB jun reduces effective width of lightly doped base region. This is known as base width modulation or early effect.

=> The width of depletion layer depends on two parameters (i) doping (ii) applied biasing.

=> The less the doping level the more will be depletion width. and effective base width decreases.

=> Similarly if applied R.B ⇑, width of depletion region ⇑. hence effective base width W ⇓.

=> This ⇓ in W has two consequences :

(i) first there is less chance for recombination within the base region. Hence amp. factor ⇑.

(ii) the charge gradient is ⇑ within the base. hence no. of charge carriers ⇑ in collector due to less recombination in base region and hence collector current ⇑.

Input characteristics :- for i/p char, curve is plot b/w i/p current I_E & i/p vtg V_{EB} when o/p vtg V_{CB} is kept constant.

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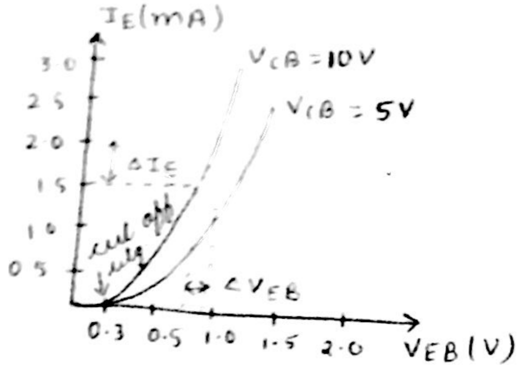


⇒ Here there is threshold vtg (cut off vtg) below which $I_E = 0$

for Si Tr $V_\gamma = 0.7$

Ge Tr $V_\gamma = 0.3$

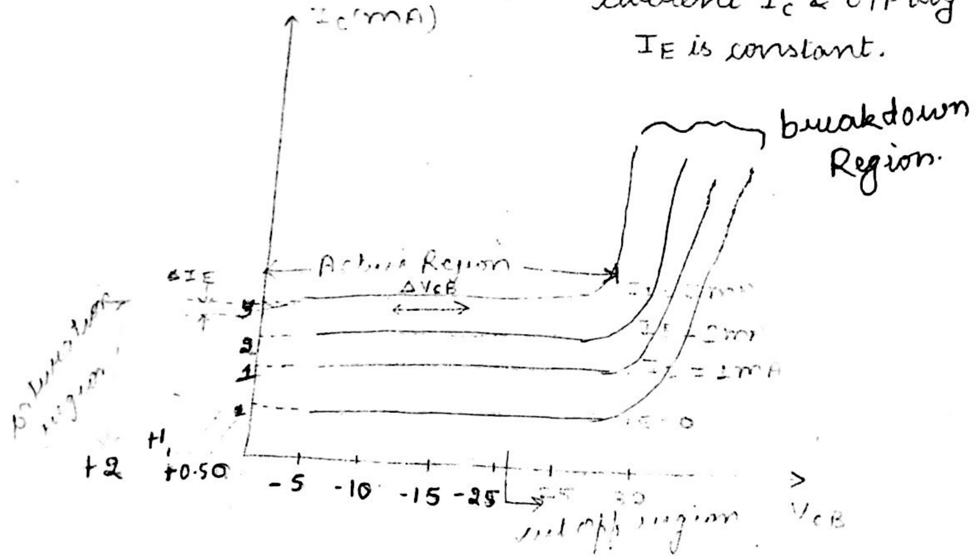
⇒ After cut off vtg, I_E ⇑ rapidly with small ⇑ in V_{EB}. It means that Ri is very small. This Ri is known as dynamic i/p res.

$$r_i = \frac{\Delta V_{EB}}{\Delta I_E}\Big|_{V_{CB} = \text{constant}}$$

⇒ It is observed that there is slight ⇑ in I_E with ⇑ in V_{CB}. This is due to change in the width of dep region in base under RB condition. Early effect can explain above effect.

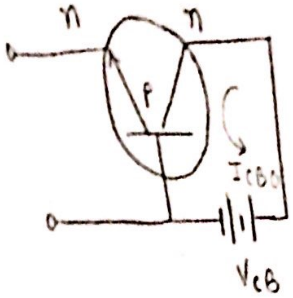
∵ Due to early effect I_C ⇑ with ⇑ in V in V_{CB}. So I_E also increases because $I_C \cong I_E$

Output characteristics :- for o/p char, curve is plot b/w o/p current I_C & o/p vtg V_{CB} when I_E is constant.

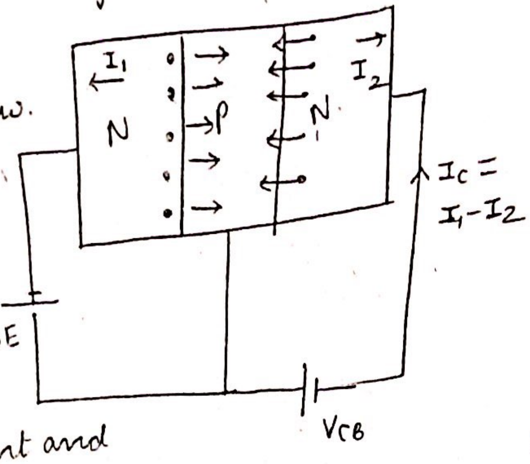


⇒ In Active region $I_C \cong I_E$, ∵ I_E is not completely equal to I_C because I_E is divided into I_B & I_C. The value of I_B is very small so $I_E \cong I_C$. When V_{CB} ⇑, I_C is slightly ⇑ due to min. carriers but after min. carrier crosses junc, current is

⇒ In cut off region, when $I_E = 0$, A small amount of current is flow due to reverse leakage current I_{CBO}. So in this region a small amount of current is flow when V_{CB} ⇑ & $I_E = 0$. I_{CBO} flows due to min carrier at R.B. junc.



⇒ In saturation region, junc. J_1 & J_2 are F.B. e- present in N layer are repells due to -ve of battery. VBE. So I_1 is flow.



and e- present in N layer are also repells due to -ve of battery V_{CB} and I_2 is flow. The dirn of I_1 & I_2 is opposite. So $I_C = I_1 - I_2$

current I_1 depends on VBE & I_2 depends on V_{CE}. If VBE is constant and V_{CB} is ⇑ then I_2 will ⇑.

V_{CB} ⇑, I_2 ⇑, I_C ⇓

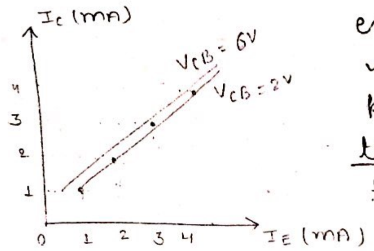
I_1	-	I_2	=	I_C
5	-	1	=	4
5	-	2	=	3
5	-	3	=	2
5	-	4	=	1

so I_2 ⇑, I_C ⇓

⇒ dynamic O/P resistance :

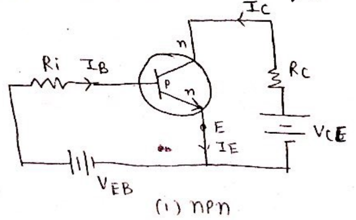
$$r_0 = \left.\frac{\Delta V_{CB}}{\Delta I_C}\right|_{I_E = \text{constant}}$$

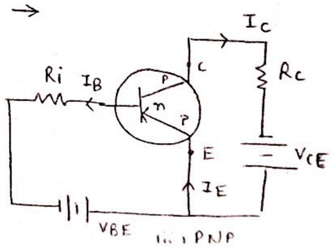
Transfer characteristics :- for this char. curve is plot b/w I/P & O/P current i.e b/w I_E & I_C which is shown in fig. In this V_{CB} is constant.



→ if V_{CB} ⇑ continuously, effective width of base ⇓ due to ⇑ in dep. layer. at some value of V_{CB}, base becomes zero. emitter touches collector. This is known as punch through. under this breakdown achieve. I_C ⇑.

II common emitter configuration →





⇒ In this E is common to both I/P & O/P circuits. I/P is applied b/w B.E. O/P is applied b/w E, C.

⇒ current Relation :-

$$I_E = I_B + I_C \quad -(1)$$

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

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

$$\frac{I_C}{\alpha} - \frac{I_{CBO}}{\alpha} = I_E$$

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

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

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

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

$$\text{Now } \beta = \frac{\alpha}{1-\alpha} = \frac{0.995}{1-0.995} = 199$$

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

$$I_C = \beta I_B + I_{CEO}$$

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

$$\beta >>> 1, \ I_{CEO} > I_{CBO}$$

I_{CEO} in terms of α

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

$$\boxed{I_{CEO} = \frac{I_{CBO}}{1-\alpha}}$$

current amp. factor $\boxed{\beta = \frac{I_C}{I_B}}$

Relation between α & β :-

$$\beta = \frac{I_C}{I_B}, \quad \alpha = \frac{I_C}{I_E}$$

$$I_E = I_C + I_B$$

$$\beta = \frac{I_C}{I_E - I_C}$$

$$\beta = \frac{I_C / I_E}{1 - \frac{I_C}{I_E}}$$

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

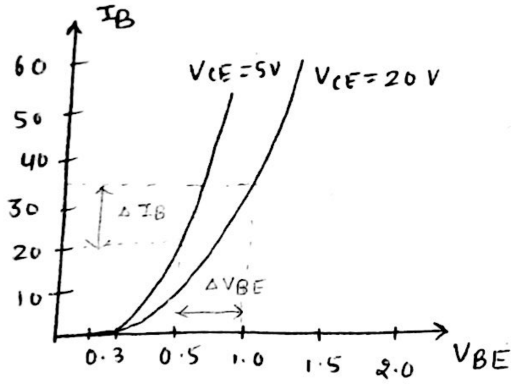
$$\frac{\beta}{1+\beta} = \frac{\frac{\alpha}{1-\alpha}}{1+\beta} \quad \text{(dividing by } (1+\beta) \text{ on both sides)}$$

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

$$\frac{\beta}{1+\beta} = \frac{\alpha}{1}$$

$$\boxed{\alpha = \frac{\beta}{1+\beta}}$$

input characteristics :– curve is plot between I_B & V_{BE}.



⇒ After the cut off vtg. I_B ⇑, with ⇑ in V_{BE}. It means dynamic i/p Res. is very small which is given by

$$\boxed{r_i = \frac{\Delta V_{BE}}{\Delta I_B}}\Bigg|_{V_{CE}} \quad V_{CE} = \text{constant}$$

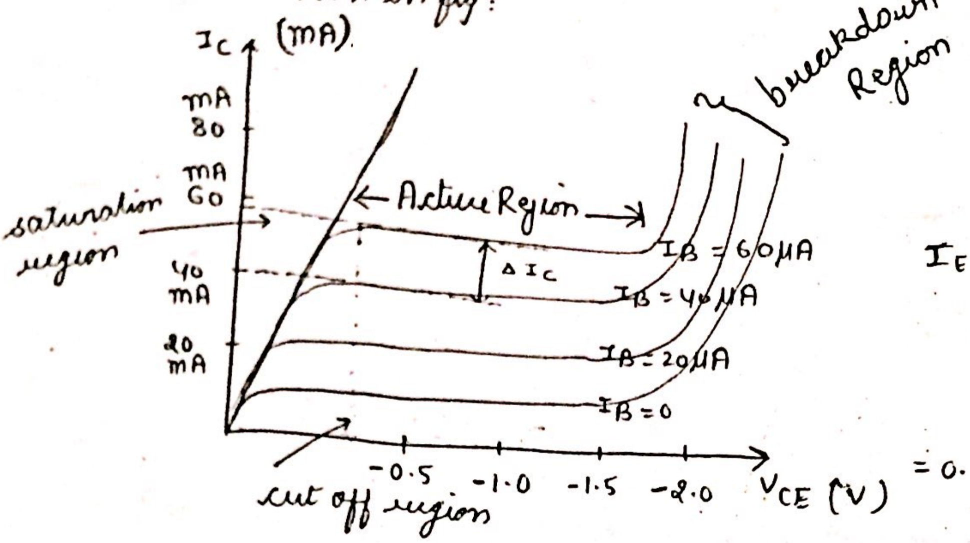
⇒ for a fixed value of V_{BE}, I_B ⇑ as V_{CE} ⇓, because if we ⇑ V_{CE}, the depletion region ⇑ and base width⇓, so recombination is less, and amount of I_B ⇓. It is explain by early effect.

output characteristics :- curve is plot between I_C & V_{CE}. for fixed value of I_B.

⇒ In active region $I_C \cong I_E$. some current of I_E is diverted in I_B which is very small so I_E is not completely equal to I_C but nearly equal to I_E.

⇒ In cut off region. when $I_B = 0$, then a small current is flow due to reverse leakage current I_{CEO} which is present due to min. carriers.

⇒ In saturation region, I_C no longer depends on the I_B for a given V_{CE}. The saturation value of $V_{CE}(sat)$ usually b/w 0.1 to 0.3V. which is shown in fig:



$I_E = I_B + I_C$

$= 20\times10^{-6} + 20\times10^{-3}$

$= 20\times10^{-3}(10^{-3}+1)$

$= \frac{20}{1000}(1.001)$

$= 0.02002$

so $I_E = 0.020$

$I_C = 0.02$

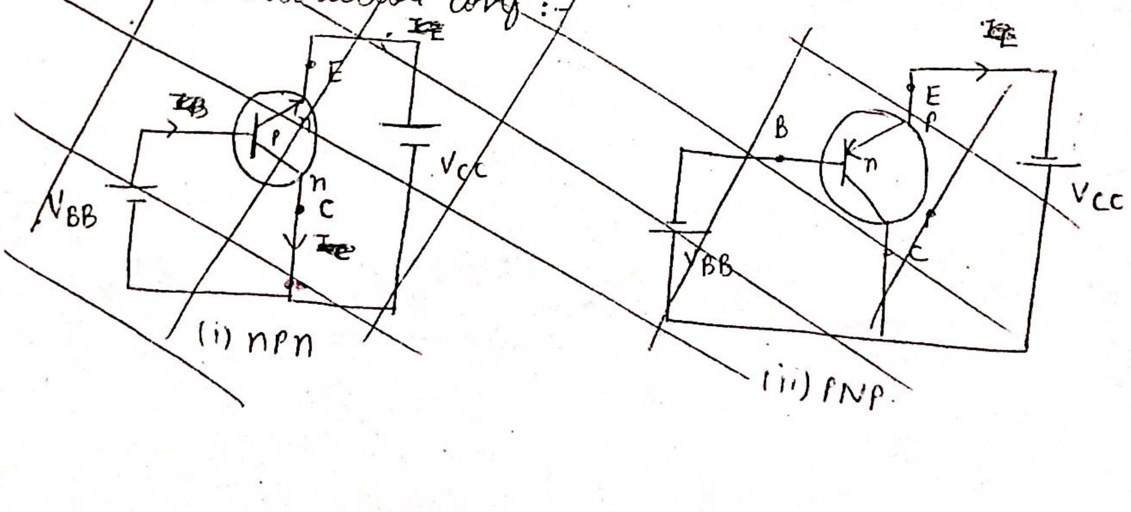
$I_C \cong I_E$

⇒ output dynamic res:

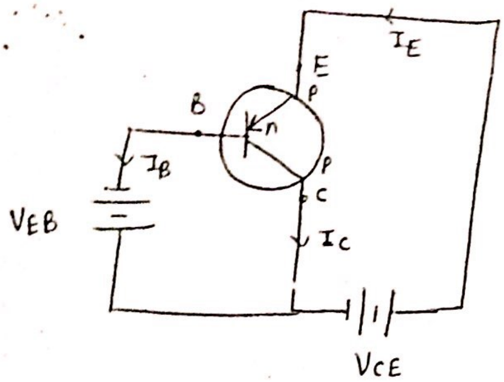
$$r_o = \frac{\Delta V_{CE}}{\Delta I_C}\Big|_{I_B = \text{constant}}$$

⇒ In the active region, J_C jun is reverse bias. for every Tx there is limit on max. value for this R.B. voltage. If these limit is exceeded, the breakdown occurs in the Tx. This effect is commonly known as punch through effect.

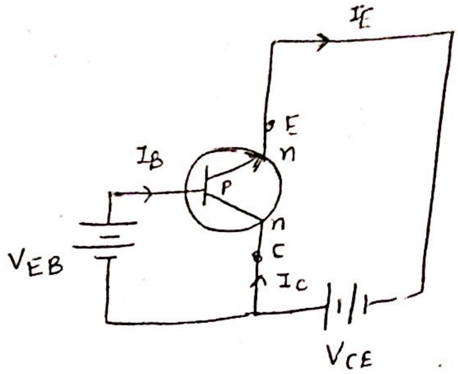
~~III common collector conf:~~



III common collector conf :-



(i) PNP.



(ii) NPN.

current Relation:

$$I_E = I_B + I_C$$

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

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

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

$$\beta = \frac{\alpha}{1-\alpha}, \quad 1+\beta = \frac{1}{1-\alpha}$$

$$\boxed{I_E = (1+\beta) I_B}$$

(I_{CBO} is very ~~negligible~~ small, hence negligible)

$$\boxed{\gamma = \frac{I_E}{I_B}}$$

Relation b/w α, β, γ

$$\gamma = \frac{I_E}{I_E - I_C}$$

$$= \frac{1}{1 - \frac{I_C}{I_E}}$$

$$\boxed{\gamma = \frac{1}{1-\alpha}}$$

$$\because \beta + 1 = \frac{1}{1-\alpha}$$

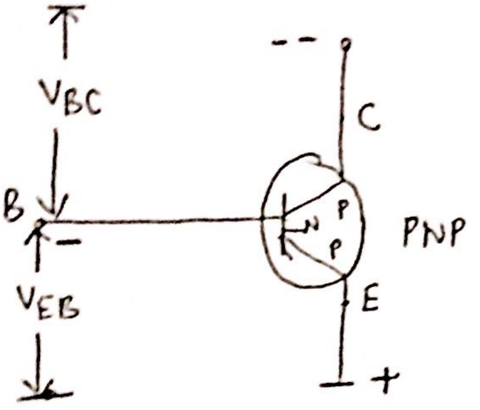
$$\boxed{\gamma = \beta + 1}$$

characteristics

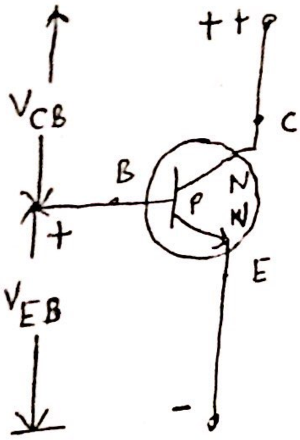
input char are plot b/w I_B & V_{BB}. which is similar to the ~~~~ i/p char of CE conf. because in CE conf. i/p char is plot b/w I_B & V_{BE}.

o/p char are plot b/w I_E & V_{CE} which is similar to o/p CE conf. because in CE conf. o/p char is plot b/w I_C & V_{CE}. ($I_C \simeq I_E$) so curve b/w I_E & V_{CE} is similar to graph b/w I_C & V_{CE}.

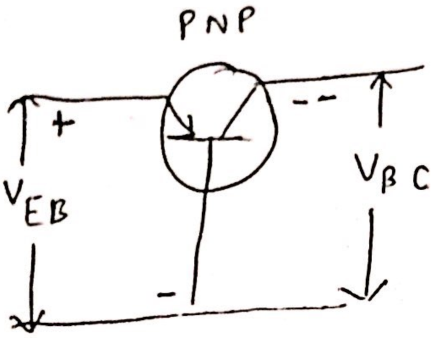
Important biasing rule:

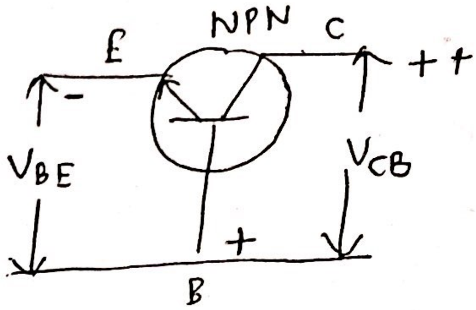


collector is more negative than Base.



collector is more positive than Base.





PNP Tx.

- V_{EB} → Emitter is more positive (or less Neg)
  - → Base is neg.
- V_{BE} (not similar to V_{EB})
- V_{BC} → B less Negative
  - C More neg.

(V_{CB} – diffrent to V_{BC}).

NPN Tx

- V_{BE} → B is +ve
  - E is -ve
- V_{CB} → C more pos.
  - B less pos.

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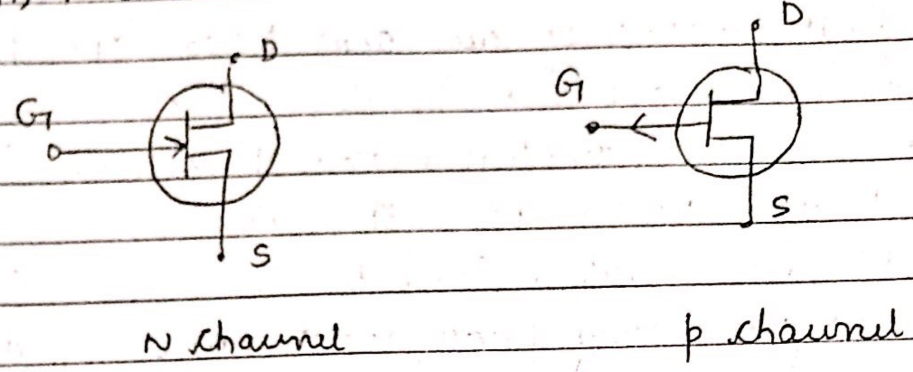
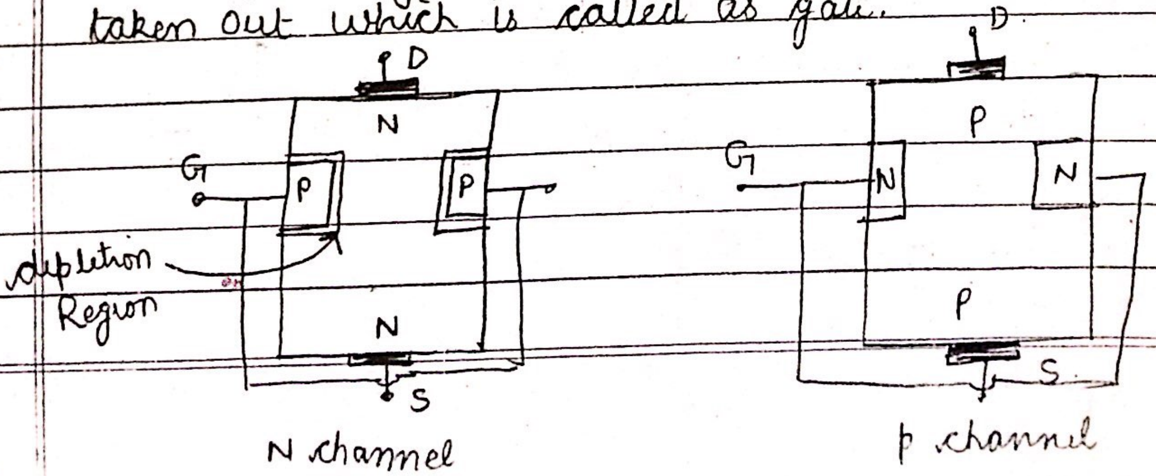
23. JFET (Junction field effect transistor)

→ Three terminal S.C. device [source, drain, gate]
→ current conduction is due to one type of carrier i.e. e^- & holes.
→ current conduction is controlled by electric field b/w the gate & channel.
→ Depending on the type of S.C. bar used FET is divided into two parts:
(i) N channel FET
(ii) P channel FET



→ Source → Through which majority carrier enters the bar.
→ Drain → through which majority carrier leaves the bar.
→ gate → On both side of S.C. bar, impurity region are formed. These impurity region are internally connected & single terminal is taken out which is called as gate.



Construction :-

→ A small bar of extrinsic S.C material, N type is taken & at its two ends, two ohmic contacts are made which are the D & S terminal of FET.

→ Heavily doped electrodes of p type material form p-n junc on each side of the bar.

→ The thin region b/w two p gates is called the channel. Since this channel is in n type bar, FET is known as N channel JFET.

Working of JFET :-

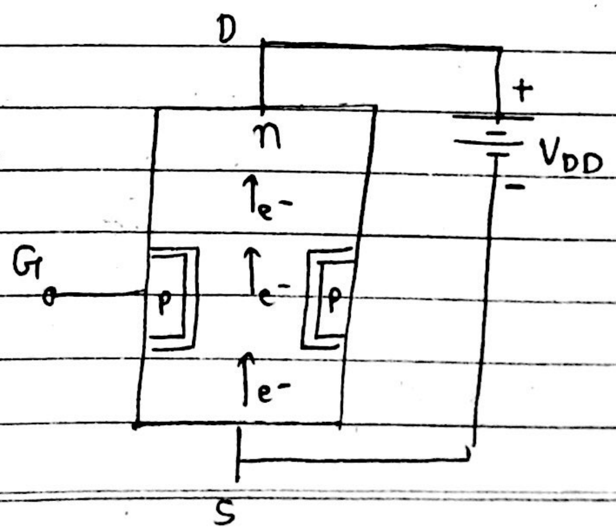
→ In the absence of any applied vtg, JFET has gate channel junction (PN jun) under no bias condition. The result is a depletion region at each junc.

→ In JFET, PN jun b/w gate & source is always kept in RB condition. Since the current in R.B. PN jun is very small, practically zero, the gate current is often neglected & assumed to be zero.

→ charge carriers move from S to D through channel.

→ Width of channel depends on thickness of dep. layer

→ thickness of dep. layer depends upon concentration of doping.



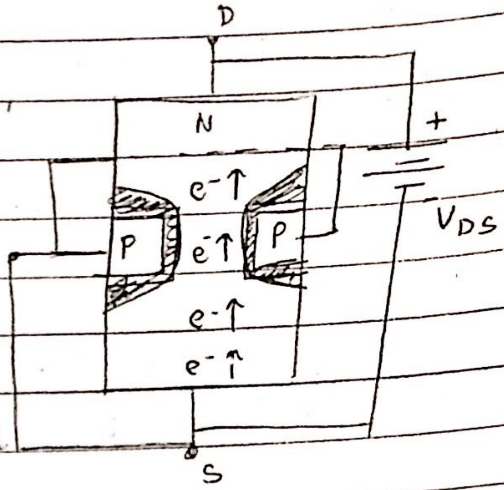
⇒ Gate terminal is kept open

- V_{DD} is applied b/w D & S.
- due to +ve terminal of battery e^- starts flowing from S to D.
- The flow of e^- makes the drain current I_D.

• The width of channel is controlled by gate vtg.

case 1 :- When $V_{GS} = 0$

• When $V_{GS} = 0$, V_{DS} is connected, D is connected to +ve of battery, so e^- attract towards battery & current I_D starts flowing



• since N channel is resistive due to dep layer at PN junc, I_D causes vtg drop across channel. This vtg drop reverse biases PN junc & caused the dep. region penetrate into channel due to lightly doped channel.

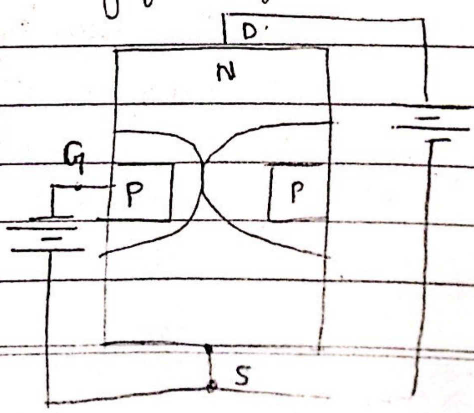
• Dep. layer width is more at D side and less at S side due to concentration of e^- is higher at D side.

• The R.B. is not uniform near the junc, it gradually ↑ses from S to D side.

case 2 :- When $V_{GS} < 0$

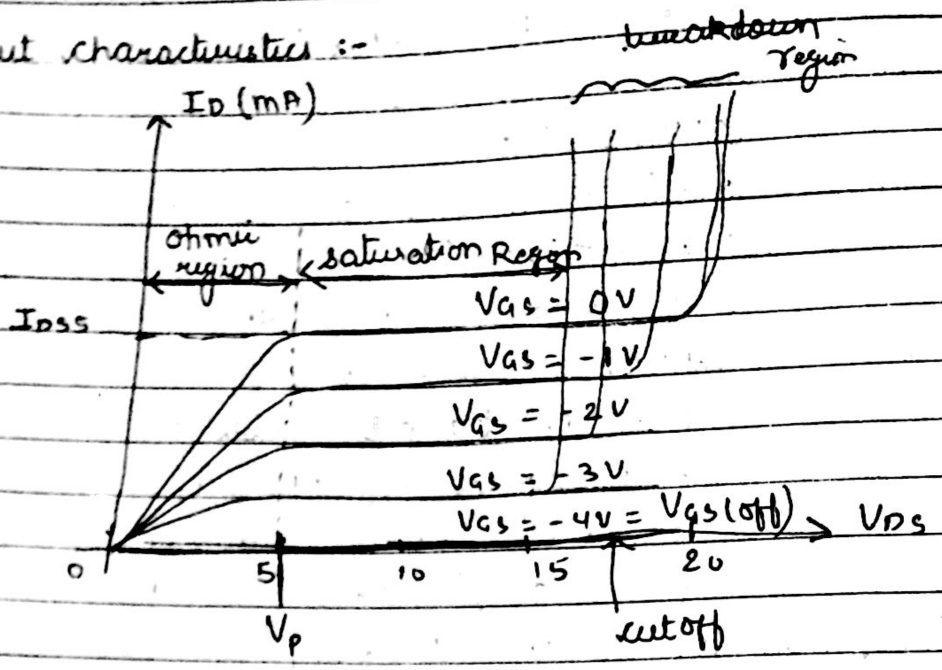
• When V_{DS} constant, V_{GS} ↑, R.B. ↑, dep. layer ↑. channel width ↓, so I_D ↓ due to less no. of e^- can cross the ~~..~~ channel.

• As we continuously ↑ V_{GS}, and stage will come when ~~...~~ the width of depletion Region will be equal to width of channel. This will prevent any flow of current from S to D.



• The V_{GS} that produces cut off is known as cut off vtg $V_{GS(off)}$

drain / output characteristics :-



(i) $V_{GS} = V_{DS} = 0$;

$V_{GS} = 0$, the channel is entirely open

$V_{DS} = 0$ so there is no attractive force for e^-,

hence I_D does not flow.

(ii) self pinch off at $V_{GS} = 0$;

as $V_{GS} = 0$, but V_{DS} ⇑, so I_D ⇑ linearly.

due to resistive nature, I_D is increased upto a particular level.

At some value of V_{DS}, I_D cannot be ⇑sed further due to reduction in channel width. Any further ⇑se in V_{DS}, does not change I_D.

The I_D reaches at saturation level.

This level of V_{DS}, after which I_D is constant is known as pinch off vtg. (V_P).

(iii) $V_{GS} < 0$:

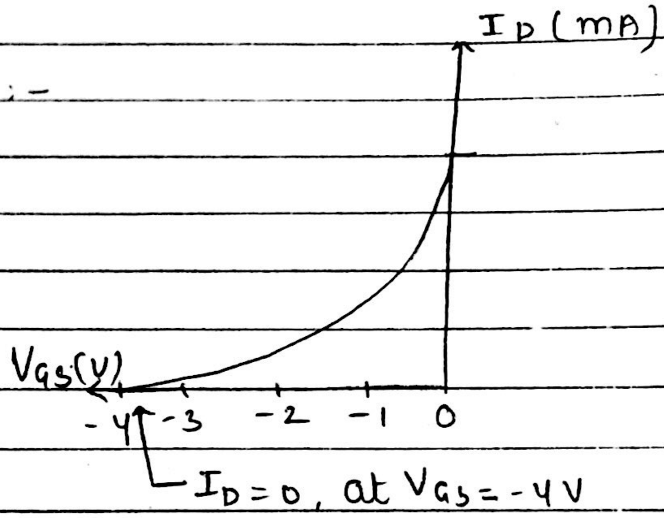
As R.B. ⇑, dep. layer ⇑, channel width ⇓,

at some particular value, channel width becomes zero, $I_D = 0$

(IV) breakdown region :- If V_{DS} ↑ beyond pinch off vtg the I_D remain constant for certain value of V_{DS}.
~~The vtg will be reached~~
If we further ↑ the vtg, the gate channel break down

(V) ohmic region :- In this, I_D varies with V_{DS} and JFET is behave as voltage variable resistor.

~~(vi) satur~~
Transfer characteristics :-



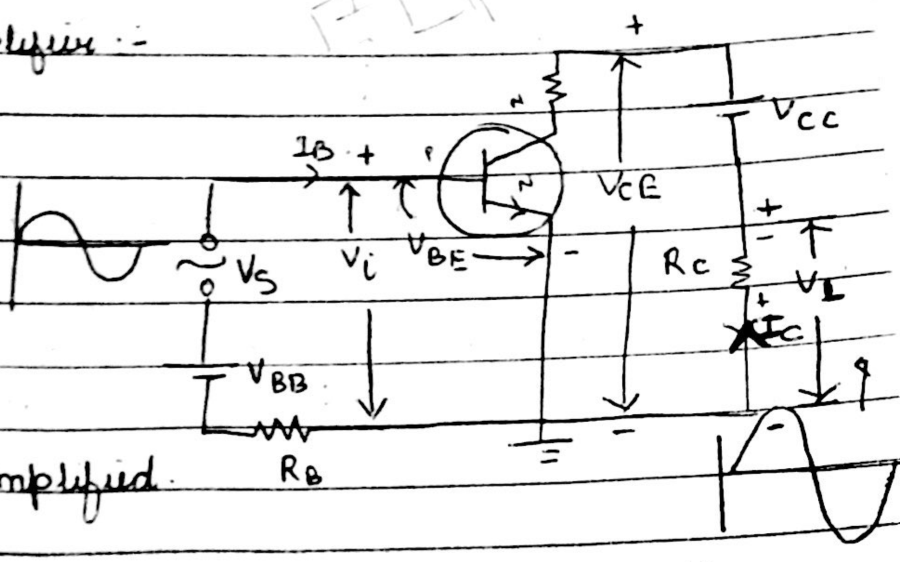
(1) relation b/w I_D & V_{GS} is given by shockley's eqn

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

(2) $I_D = 0$; $V_{GS} = V_{GS(off)}$

$I_D = I_{DSS}$; $V_{GS} = 0$

29 ~~20~~ Transistor as an Amplifier :-



→ A Tx transfers weak signal from low i/p resistance to high output resistance and therefore signal is amplified.

→ A ckt shown in fig. is kept in active Region with the help of VBB & Vcc.

→ The weak AC signal is applied b/w B & E. & o/p is taken across Rc.

→ An i/p has low Resistance, therefore a small change in input signal causes an appreciable change in I_B. This causes larger change in I_C ($I_C = \beta I_B$).

→ The I_C flowing through high Load Resistance R_C produces a large vtg. across it.

→ Thus a weak signal appears in amplified form.

→ The dc eq^n is

$$I_B = \frac{V_{BB}}{R_B} \quad ; \quad I_C = \beta I_B$$

$$V_{CE} = V_{CC} - I_C R_C$$

operation :- When +ve half cycle is applied:

(i) ~~VBE ↑ because~~ F.B. is ↑ of BJT, so I_B ↑ses.

(ii) I_C ↑ by β times of ↑ in I_B

(iii) so $I_C R_C$ is ↑sed, & V_{CE} is ↓ from eq^n.

(iv) vtg across $I_C R_C$ is ↑ i.e. output vtg

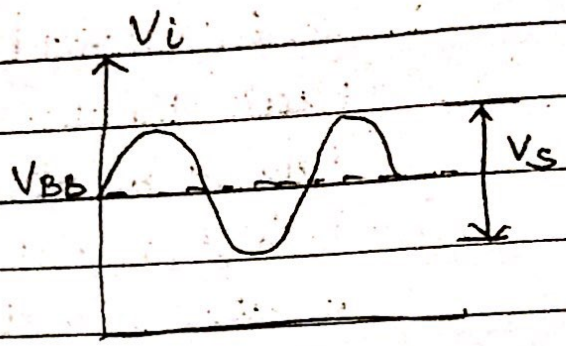
hence we get Amplified O/P signal.

Mathematical Analysis:

→ $V_i = V_s + V_{BB}$

(V_s ↑ AC, V_{BB} ↑ dc)

input vtg swing around V_{BB}.



→ change in i/p vtg $\Delta V_i = V_s$

→ Similarly change in collector current is also due to AC component i_c & due to DC component I_c.

$$\text{so } \Delta I_c = i_c.$$

→ $\Delta V_L = -\Delta I_c R_c = -i_c R_c$

$$\text{vtg gain} = \frac{\text{Change in o/p vtg}}{\text{change in input vtg}}$$

$$A_v = \frac{\Delta V_L}{\Delta V_i} = \frac{-i_c R_c}{V_s} = \frac{-\beta i_b \cdot R_c}{V_s}$$

$$\because r_b = \frac{V_s}{i_b}$$

$$A_v = \frac{-\beta R_c}{r_b}.$$

since $\beta >> 1$, $r_c >> r_b$

so $A_v >> 1$

Therefore we can say that Tx works as an Amplifier.