BEC
Unit 1
Introduction to Semiconductors

Semiconductor : whose conductivity lies b/w a conductor and an insulator.

Conductors
↓
metals
resistance ↓
free flow of e−

Insulator
↓
wood, rubber

SK sendey

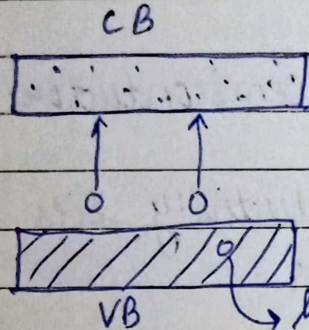
Semiconductor eg − Si, Ge

There are 2 types of semiconductors −

Intrinsic
- sc in its pure form
- Its valence band is completely filled & conduction band is completely empty.
- when some heat energy is supplied to it, some of the valence electrons are shifted to valence band leaving behind holes in the valence band.

Extrinsic

Impurity called dopant is added either as trivalent or penta-valent impurity to ↑ conductivity that's why we add dopant.

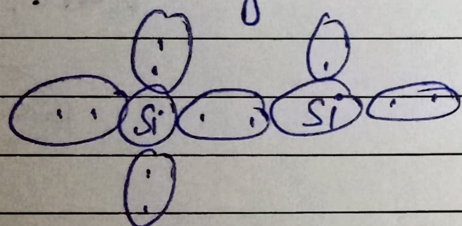


e-s free to move ie electricity is produced.

holes in VB after e-s move to CB.

-ve coefficient of resistivity.

↑ temp ↓ resistivity or become like conductor.



→ Doping: The process by which an impurity is added to a semiconductor is called doping.

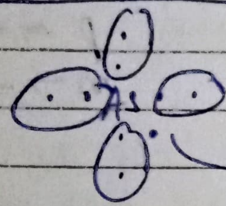
Depending on the type of impurity added, extrinsic semiconductor are classified as-

n-type p-type

- If a pentavalent impurity is added to a pure semiconductor, a large no. of free electrons will exist. This will result in n-type semi--conductor.

If a trivalent impurity is added to a pure semiconductor, large no. of holes will exist in semiconductor, resulting in p-type Sc.

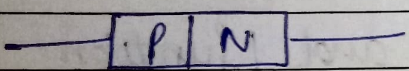
→ <u>Pentavalent impurity</u>: Arsenic (33)
(2, 8, 18, 5)
↓
pentavalent



→ free e^-
(n-type semiconductor)

→ <u>Trivalent impurity</u>: Gallium (31)
(2, 8, 18, 3)

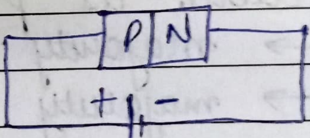
p-type semiconductor.

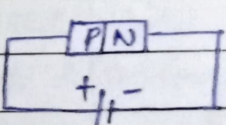


↓
junction
→ doesn't move e⁻s from p to n or n to p. Its because of high resistance and widened distance between them.

(~~n type to -ve end~~
p type to +ve end)

: Biasing → forward
→ reverse
(providing voltage from outside)





→ <u>Diode conduct</u>
Biasing → forward biasing
→ reverse biasing.

It conducts only in forward biasing not as much as in reverse biasing.

forward   reverse
↓   p → −
p type + of battery   n → +
n type with −ve battery

- Diode conduct when forward biased.
  p → n junction diode.

⇒ <u>Semiconductor Diode</u> −

Diode has 2 terminal and 1 junction.

—[P|N]— 2 terminals.

transitor : has 3 terminal, 2 junction
pnp   npn

smartwatches − all made up of diode, transistor

- basic diode is pn junction.
  p → majority e^- minority holes
  n → majority holes minority e^-

—[P|N]

At room temp., holes will try to merge in e^- and e^- to merge in holes and after diffussion they create a potential barrier. But at some time only they can recombine so due to potential barrier now not able to recombine.

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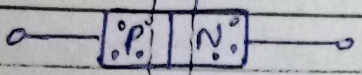


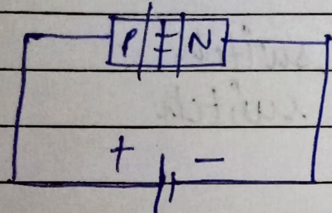
potential barrier

potential barrier : is voltage

So we give extra source of voltage so that they can recombine and extra source of voltage is called biasing.

forward biasing

reverse biasing



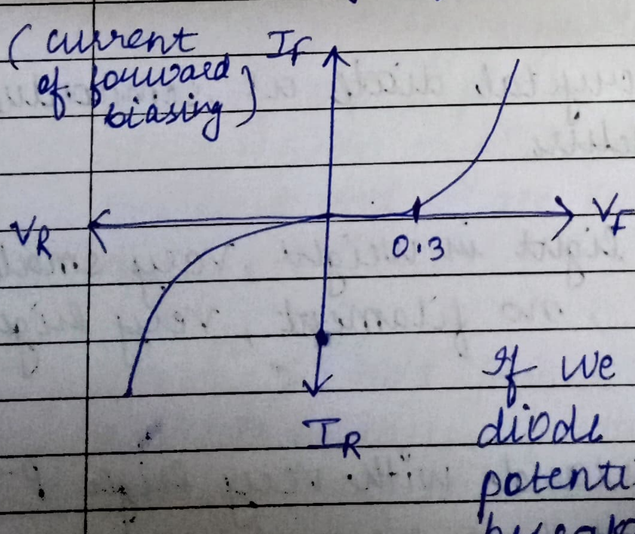
0.3 V → Ge
0.7 V → Si

So due to forward biasing, potential difference will be thier and there will be a change of electrons

P → −
N → +

We need 0.3 or Ge then 0.3 V to cross the voltage is potential barrier.

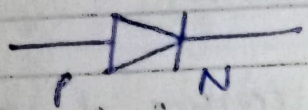
In this potential barrier will be more wide and no current flow.



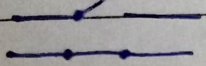
V-I characteristic of forward biasing

If we give max voltage to diode up to its breakdown potential, it will lead to breakdown voltage.

Symbol of diode -

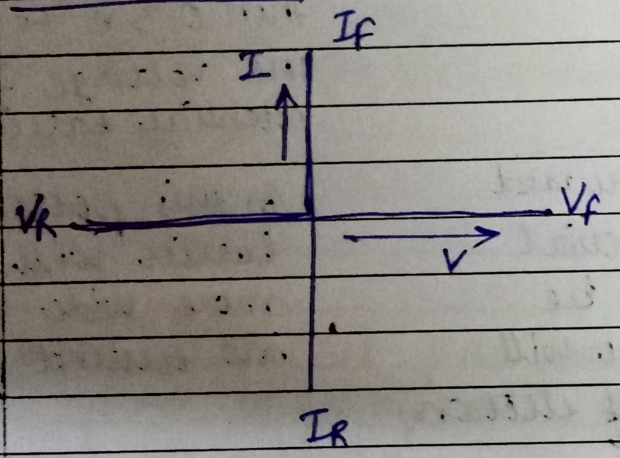


→ Ideal diode : means if forward bias so work as close switch means no current should go in reverse biasing.
Ideal diode to work as close or open switch.



open switch
closed switch

Characteristic



value of current in reverse should be 0 ie. 0 reverse current means with very low voltage current shootup.

→ Diode also called crystal diode as semiconductor have crystal structure.

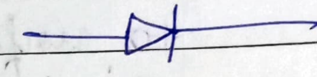
Merits : compact, light in weight, very small, occupy less space, no filament, very high efficiency.

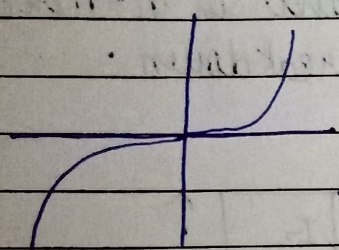
Demerits : can't stand with very high P^{-1} V. cannot be operated at very high temp.

Zener Diode : (special diode).

LED diode, photodiode.

Works in reverse breakdown feature (also in zero, forward bias).
It has sharp breakdown region. construction is such way that sharp breakdown in reverse region.

symbol :- 



Avalanche Breakdown : Thicker junction when voltage is provided, chain process.
• minority add up with more minority carrier and shoot up
For thicker junctions the breakdown mechanism is by the process of avalanche breakdown when the electric field existing in the depletion layer is sufficiently high. The velocity of carrier crossing the depletion layer ↑. These carrier collide with crystal atoms. some collision are so violent that e^- are ~~known~~ knocked off the crystal.

Creating e^- hole pairs. These pair attain high velocities to cause further pair generation through more collisions. This is a cummulative process and as the breakdown voltage approaches the field becomes so large that the chain

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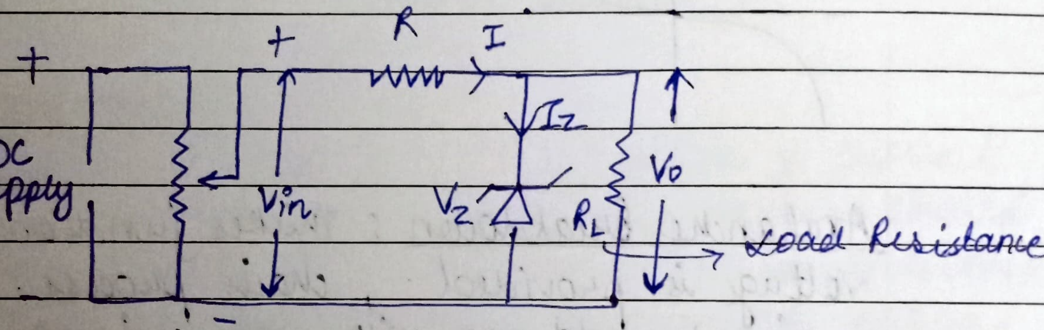
of collisions can give rise to almost ∞ current. This is known as avalanche breakdown.

Zener breakdown: Takes place in a thin junction when the electric field becomes high in the depletion layer with only a small applied reverse biased voltage. Therefore some electrons jump across the barrier from valence band in p-material to unfilled conduction band in n-material. This is known as zener breakdown.

Imp:

Application of zener diode



zener diode as Voltage Regulator

$$\underbrace{V_{in} - V_Z}_{\text{voltage drop accross } R} = R$$

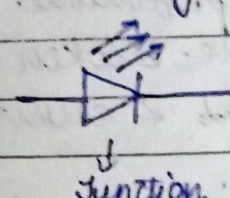
This is also known as <u>voltage stabalisation</u>

Let a variable voltage V_{in} be applied across load R_L ~~when the~~

(i) When $V_{in} < V_Z$, no current flows through it and the same voltage appears across the load.

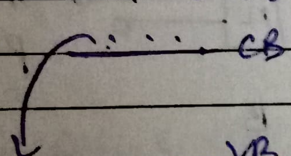
(ii) When $V_{in} > V_Z$, this will cause the zener diode to conduct a large current I_Z consequently more current flows through series resister R which i.e. the voltage drop across it. Thus, Vin excess of V_Z i.e. $V_{in} - V_Z$ is absorbed by the series resister. Hence, a constant voltage V_0 ($= V_Z$) is maintained across load R_L.

⇒ LED (Light Emitting Diode) : Special purpose diode because it emits light as normal p-n junction doesn't emit light. It emits different coloured light.

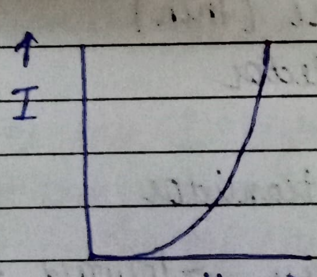


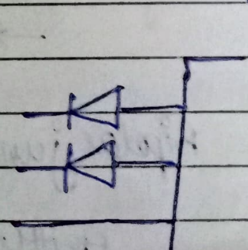
• emit photons because of which we can see light.
↓
lie in visible spectrum of EM waves.

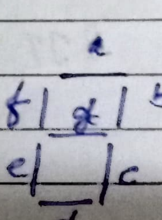
It is made up of compound semiconductor due to which it emits light.



~~lower~~ higher energy to lower energy thats why releases energy and emits light.







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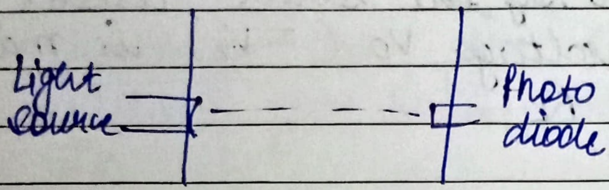
⇒ Photodiode : used for object identification and home security system.



Dark current I_r

By less no. of minority carrier when current is generated it is called as dark current.

In malls when we enter we see footfall & they have count of person. There photodiode is used. We have broken the flow of current & count increases by 1.

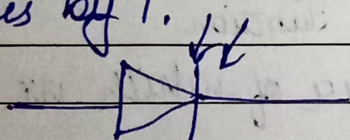
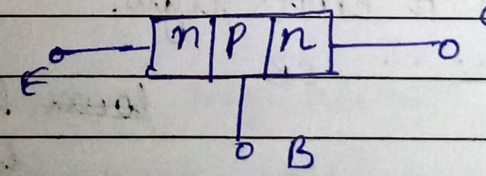


photo diode symbol

It is connected in reversed biased.

The dark current always works on reverse biasing.

⇒ Transistors



npn
pnp

3 terminals → Emitter
→ Base (thin)
→ Collector

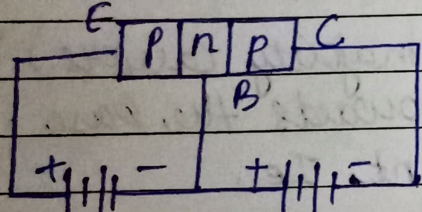
BJT – Bipolar junction transistor

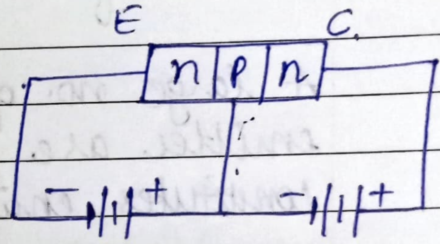
Emitter : Base → forward biased
Base : Collector → reverse biased.

⇒ Emitter : Supplies large no. of majority carriers.
- It is always forward biased w.r.t base so as to supply large no. of majority carrier to its junction with the base.
- It is heavily doped but moderate in size.

⇒ Collector : It collects the major portion of the majority carriers supplied by the emitter.
- collector base junction is reverse biased.
- It is moderately doped but larger in size so that it can collect most of the majority carrier ~~select by~~ supplied by emitter.

⇒ Base : The middle part is base. Base forms two circuits.



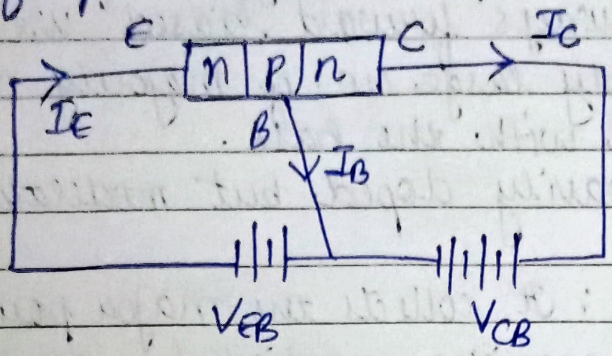


The base emitter junction is forward biased providing low resistance and base collector junction is reversed biased offering high resistance path.

The base is lightly doped and very thin so that it can pass on most of the majority carriers supplied by emitter to the collector.

Configuration –
common base
common emitter
Common collector

Working of npn transistor –



I_E inwards then
I_C and I_B outwards

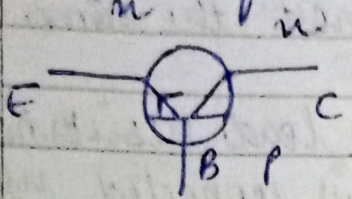
$\boxed{I_E = I_B + I_C}$

The emitter base junction is forward biased. The voltage V_{EB} is quite small and reverse biased voltage V_{CB} is considerably high because of E.B junction is forward biased.

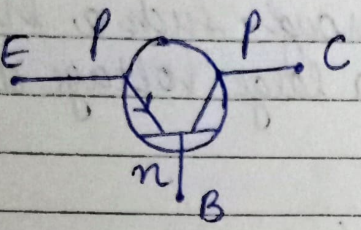
A large no. of e⁻s (majority carriers) in the emitter are pushed towards the base. This constitutes emitter current I_E.

When these e⁻s enter the base region, they combine with the holes. Since the base is lightly doped and is thin. Only a few e⁻s (less than 5%) combine with the holes and constitute base current I_E, the remaining e⁻s diffuse across the thin base region and reach under the collector, comes under the influence of +vely biased n-region. Therefore, they are attracted towards the collector and constitute the collector current I_C.

⇒ Symbols of transistors –

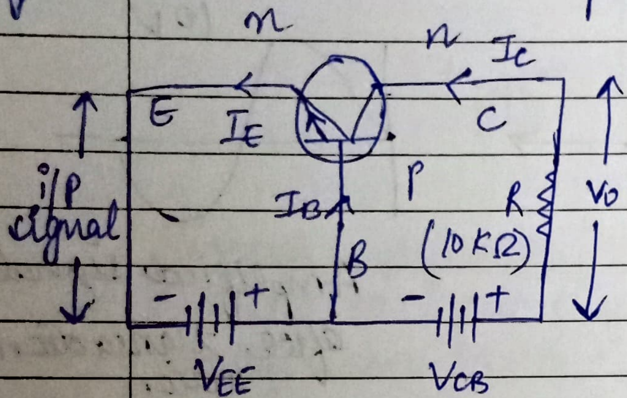


→ npn transistor



→ pnp transistor

⇒ Transistor as an amplifier –

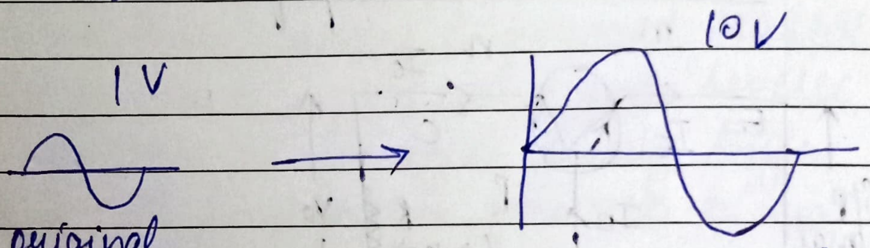


- A transistor is a device which raises the strength of a weak signal and thus acts as an amplifier.
- The input (weak signal) is applied across emitter base and the output (amplified signal) is obtained across load resistance R connected in the collector circuit.
- When a weak signal is applied at the input, a small change in signal voltage causes an appreciable change in emitter current.

Eg – A change of 0.1 V in signal voltage causes a change of 1 mA in ammeter current as the input circuit has very low resistance. This causes almost the same change in collector current.

- In the collector circuit, a load resistance R of high value say 10 KΩ is connected when collector current flows through such a high resistance, it produces a large voltage drop

$$V = IR$$
$$V_0 = 10\,K\Omega \times 1mA$$
$$V_0 = 10\,V$$



original signal.

Amplified signal after transaction action

√. Imp

⇒ Configurations of a transistor –

There are 3 basic configurations in which a transistor can work i.e –

common base (CB)
common emitter (CE)
common collector (CC)

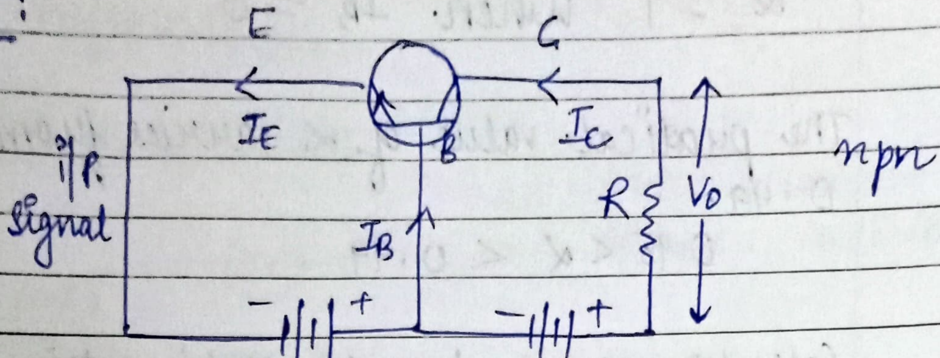
(In actual we have 4 terminals but to make it 3 we take any one as common)

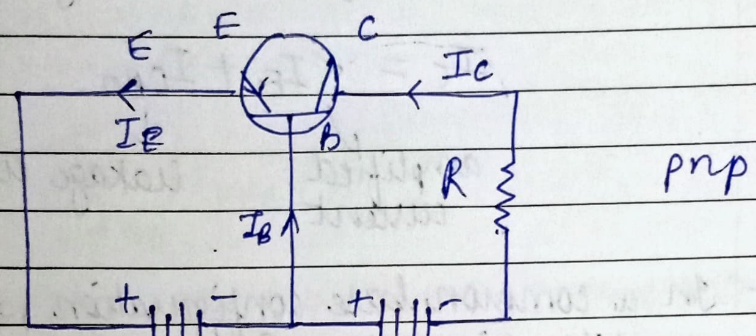
CE is most used for amplification.

~~CB~~

_/_/_

• **CB :**





<u>Current amplification factor (α)</u> : The ratio of output current to input current is known as current amplification factor.

$$\boxed{\alpha = \frac{\Delta I_C}{\Delta I_E}}$$

$$= \frac{\Delta I_C}{\Delta I_B + \Delta I_C} \quad (\because I_E = I_B + I_C)$$

$$I_E = I_B + I_C$$

$$\Delta I_E = \Delta I_B + \Delta I_C$$

$$\frac{\Delta I_E}{\Delta I_E} = \frac{\Delta I_B}{\Delta I_E} + \frac{\Delta I_C}{\Delta I_E}$$

$$1 = \alpha + \frac{\Delta I_B}{\Delta I_E}$$

$$\boxed{\alpha = 1 - \frac{\Delta I_B}{\Delta I_E}} \text{ for C.B}$$

$\Rightarrow \alpha < 1$; The value of α is less than 1.

$\alpha = 1$ when $I_B = 0$

The practical value of α varries from 0.95 to 0.99.

$$0.95 < \alpha < 0.99$$

Collector current for CB configuration -

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

amplified current   leakage current

Q - In a common base configuration, the current amplification factor is 0.97 if the emitter current is 1 mA. Determine the value of base current:

$\alpha = 0.97$

$I_E = 1 mA$

$$\alpha = 1 - \frac{\Delta I_B}{\Delta I_E}$$

$$0.97 = 1 - \Delta I_B$$

$$\Delta I_B = 1 - 0.97$$

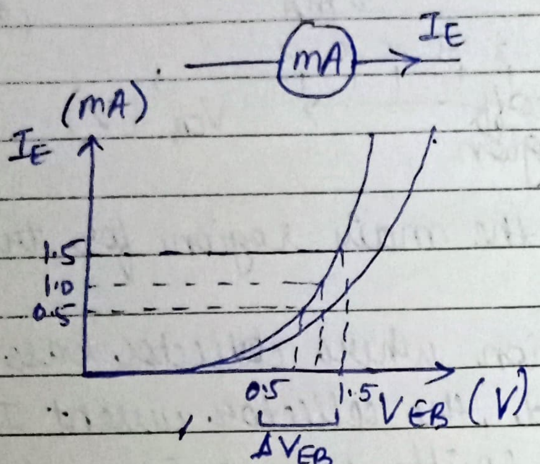
$$\Delta I_B = 0.03 \text{ mA}$$

→ ~~CB configuration -~~

→ CB configuration

input characteristics

Input : Emitter
output : Collector



In CB configuration, the curve plotted between emitter current I_E and Emitter base voltage V_{EB} ~~and~~ at constant collector base voltage V_{CB} is called input characteristics.

- For a particular value of V_{CB}, the curve is just like diode characteristic in the forward region.
- When V_{CB} is increased, the value I_E increases slightley for the given value of V_{EB}. Hence, the junction becomes better diode.

Input resistance $\boxed{r_i = \frac{\Delta V_{EB}}{\Delta I_E}}$ at constant V_{CB}.

output characterictics

In CB configuration, the curve plotted between ~~charact~~ collector current I_C and collector base voltage V_{CB} at constant emitter current I_E is called output characteristics.

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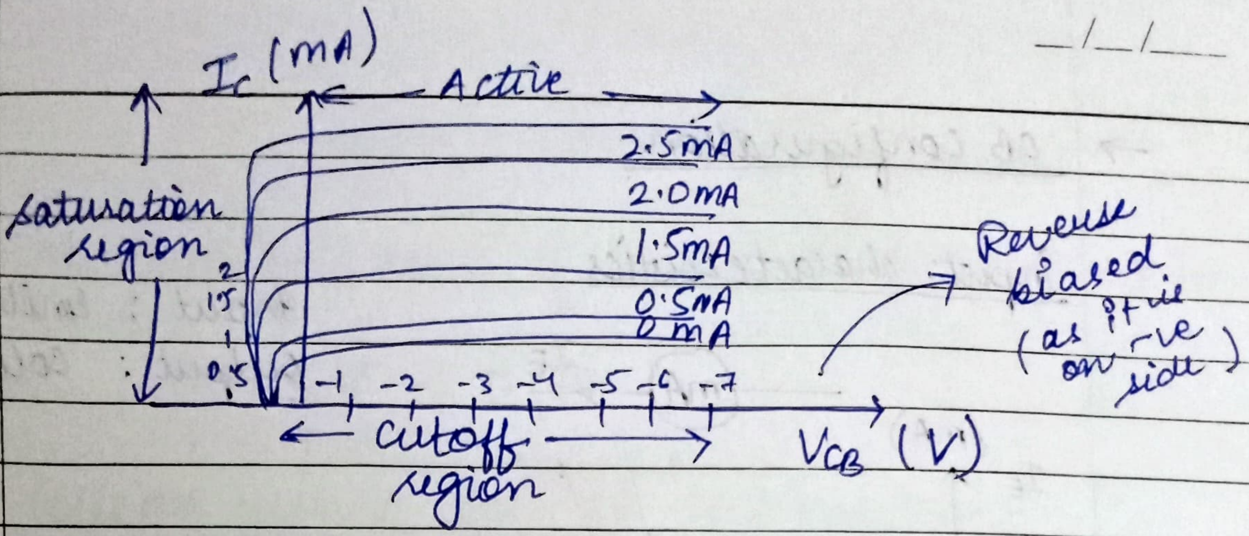


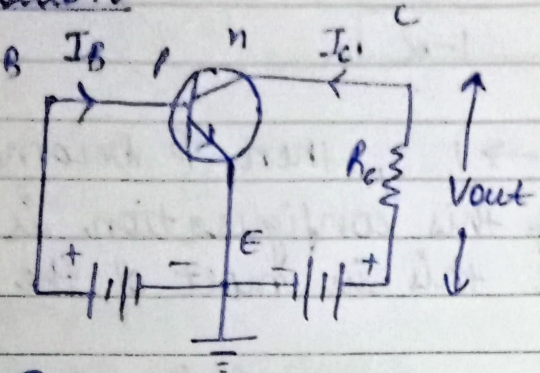
Active region is the main region for transistors.

- In the active region where collector base junc. is reverse biased, the collector current I_C is almost equal to emitter current I_E and the transistor is always operated in this region.
- When V_{CB} becomes positive ie. C B junction is forward biased the collector current I_C decreases abruptly, this region is known as saturation region. Here I_C doesnot depend on I_E.
- When $I_E = 0$, collector current $I_C \neq 0$. Although its value is very small. Infact this is the reverse leakage current (I_{CBO}) that flows in the collector circuit.

Output resistance $\boxed{r_o = \frac{\Delta V_{CB}}{\Delta I_C}}$ at constant I_E

most imp.

→ CE Configuration -



$I_E = I_B + I_C$

Base current amplification factor (β) : The ratio of change in collector current to the change in base current is known as base current amplification factor.

$$\boxed{\beta = \frac{\Delta I_C}{\Delta I_B}}$$

Relation b/w α and β -

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \quad \text{— (ii)} \qquad \beta = \frac{\Delta I_C}{\Delta I_B} \quad \text{— (i)}$$

$$I_E = I_B + I_C$$

$$\Delta I_E = \Delta I_B + \Delta I_C \quad \text{— (iii)}$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$ → Substituting in eq (i)

$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C} \quad \text{— (iv)}$$

Dividing (iv) by ΔI_E

$$\beta = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}}$$ (from eq.-(ii))

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

If $\alpha \to 1$, then, β becomes infinite so, gain of this configuration is high thate why we use this in most of the configurations.

Q- Find the value of β if $\alpha = 0.9$, $\alpha = 0.94$, $\alpha = 0.98$

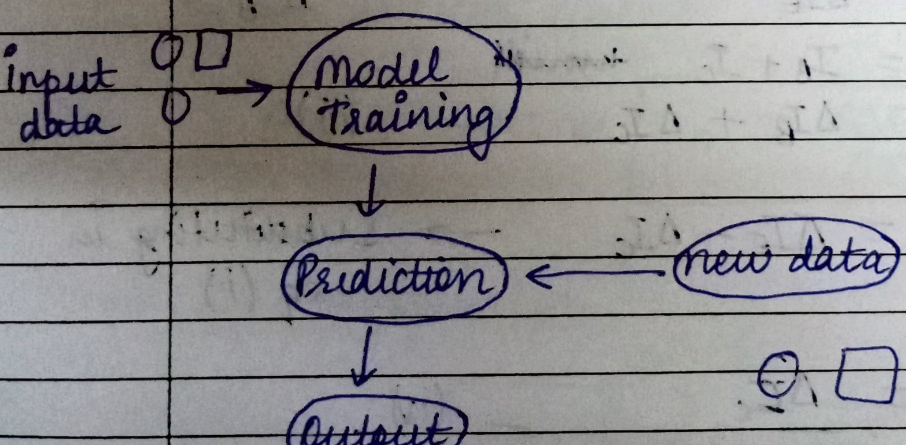
$$\beta = \frac{0.9}{1-0.9} = \frac{0.9}{0.1} = 9$$

$$1.00 - 0.94 = 0.06$$

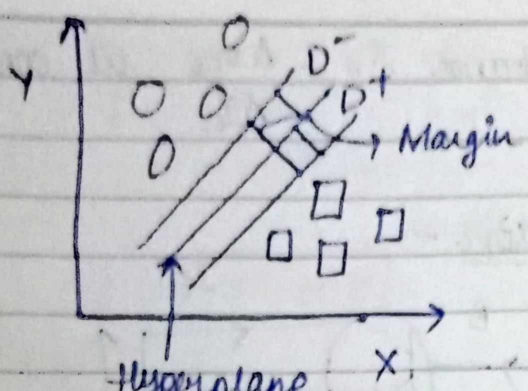
$$\beta = \frac{0.94}{1-0.94} = \frac{0.94}{0.06} = \frac{94}{6} = \frac{47}{3} = 15.66$$

$$\beta = \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = 49$$

→ Support Vector Regression (SVR)



Iron Brownly

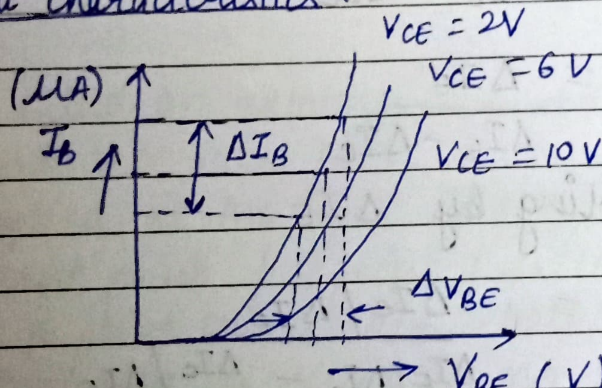


(It acts as 2-D plane)

Distance b/w line touching circle and hyperplane is D^-.
Distance b/w line touching square and hyperplane is D^+.

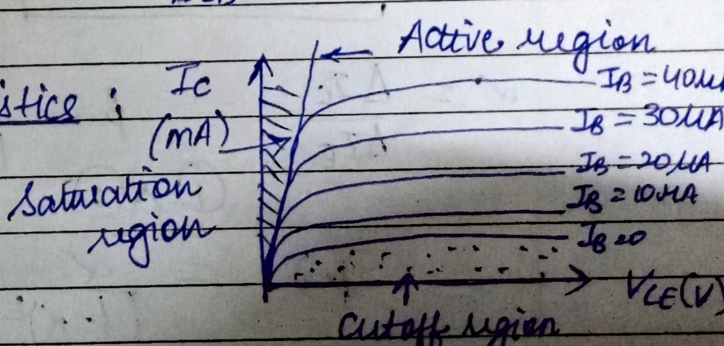
→ CE configuration -

- Input characteristics :

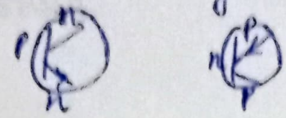


Input resistance $r_i = \frac{\Delta V_{BE}}{\Delta I_B}$ at constant V_{CE}

- Output characteristics :

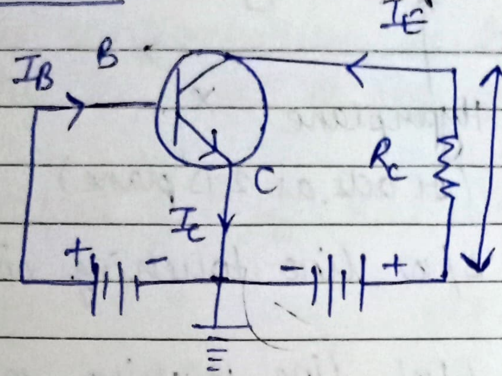


current is always in p to n direction



Output resistance $r_o = \dfrac{\Delta V_{CE}}{\Delta I_C}$ at constant I_B.

CC configuration -



$$\gamma = \frac{\Delta I_E}{\Delta I_B} \quad \text{—(i)} \qquad\qquad \alpha = \frac{\Delta I_C}{\Delta I_E} \quad \text{—(ii)}$$

$$I_E = I_C + I_B$$
$$\Delta I_E = \Delta I_C + \Delta I_B$$
$$\Delta I_B = \Delta I_E - \Delta I_C$$

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

Dividing by ΔI_E

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

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

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \qquad \beta = \frac{\alpha}{1-\alpha} \text{ —(1)} \qquad \gamma = \frac{1}{1-\alpha} \text{ (2)}$$

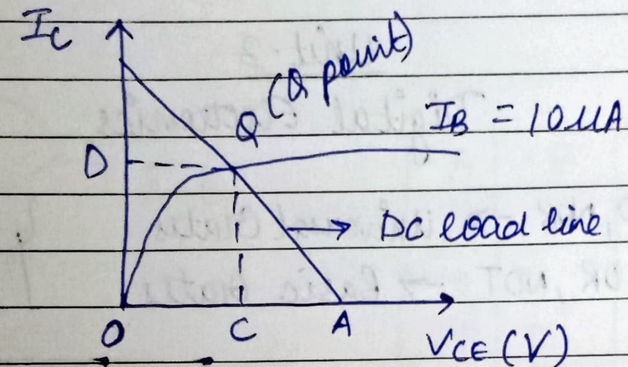
(1) × (2).

$$\beta \cdot \gamma = \frac{\alpha}{(1-\alpha)^2}$$

$$\frac{\beta}{\gamma} = \frac{\frac{\alpha}{\cancel{1-\alpha}}}{\frac{1}{\cancel{1-\alpha}}}$$

$$\boxed{\beta = \alpha\gamma}$$

→ <u>Operating point</u>: The point obtained by the value of I_C and V_{CE} when no signal is applied at the input is known as operating point.



It is called an operating point since variation of I_C and V_{CE} takes place at this point then signal is applied at the input. This point is also called Quiscent point / Q point / silent point because it is a point on I_C - V_{CE} characteristics when the transistor is silent ie no signal is applied at the input. The Q point can be determined by DC load line where

$$OA = V_{CC} = V_{CE}$$

$$OB = I_C = \frac{V_{CC}}{R_E}$$

is drawn on the output characteristics. The point Q where DC load line intersect the output characteristics of $I_B = 10\mu A$ is the operating point.

MST 1 : Ch-1, 2 Part A
Ch-3 Part B

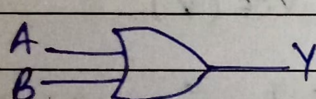
→ Assignment (next friday)

1) How can Zener diode be used for regulation of voltage?
(b) Can photodiode work as photovoltaic and photoconductive device? Write applications.

2) Explain common emitter configuration in detail and highlight the applications of transistors. Also compare the 3 configurations of transistors.

Unit-3
Digital Electronics

NAND, NOR → Universal Gates } Logic Gates
AND, OR, NOT → Basic Gates }

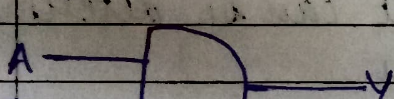


$\boxed{\text{OR Gate}}$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

For n inputs, we have 2^n outputs

$Y = A + B$

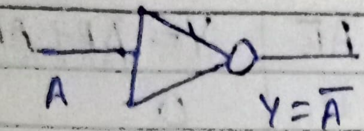


$Y = A \cdot B$

$\boxed{\text{AND Gate}}$

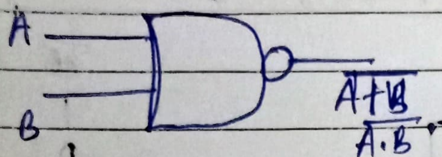
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

$Y = A \cdot B$



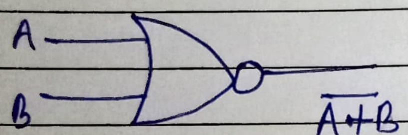
NOT

A	Y = $\overline{A}$
0	1
1	0



NAND

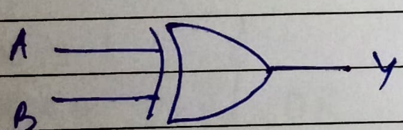
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0



NOR

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

→ Exclusive-OR (EXOR / XOR)



$Y = A\overline{B} + \overline{A}B$