Semiconductor:

Intro:
Semiconductors are those substances whose electrical resistivity is intermediate between those of good conductors and good insulators.
For eg. Silicon, Germanium, etc.

Types of semiconductor

Intrinsic Semiconductor	Extrinsic Semiconductor
• (Pure form of semiconductor)	• (Impurity added semiconductor)
• Its electrical conductivity is low.	• Its electrical conductivity is high.
• The number of free electrons in conduction band and the no. of holes in valence band is exactly equal and they are small in number.	• The number of free electrons and holes is never equal. There is excess of e^- in n-type semiconductor and excess of holes in p-type semiconductor.
• Examples are crystalline forms of pure silicon and germanium.	• Examples are silicon and germanium crystals with impurity atoms of arsenic or antimony indium

Types of Extrinsic Semiconductor

• P-type semiconductor	N-type semiconductor
• In p-type semiconductor, trivalent impurity like Al, Ga, In etc. are added.	• In n-type semiconductor, pentavalent impurity like P, As, Sb, Bi, etc are added.
• Holes are majority charge carriers and electrons are minority carriers.	• Electrons are majority charge carriers and holes are minority carriers.
• The hole density is much greater than the electron density.	• The electron density is much greater than the hole density.
• The fermi energy level lies in between the acceptor energy level and valence band.	• The fermi energy level lies in between the donor energy level and conduction band.

P-N Junction Diode:

fig: PN junction diode

fig: Symbolic representation of P-N junction diode

Defn: When a pure form of a semiconductor is doped with p-type material at one end and n-type of material at another extreme end, the resulting semiconductor material is called PN junction diode.

A junction diode is called so, because it consists of two electrode P-side of the semiconductor acts as anode and n-side acts as cathode.

- It can be compared with capacitor in which the depletion region acts as dielectric between two capacitor plates.
- Two important process occur during formation of p-n junction: diffusion and drifting.
- Electric field is set up across the depletion layer due to accumulation of charge forming two different polarities.
- The value of barrier potential is about 0.7 V in silicon and 0.3 V in germanium

Biasing of P-N junction Diode:

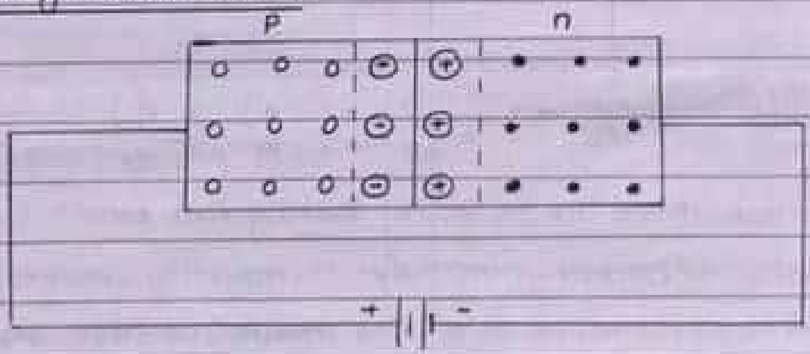


fig: Forward biasing in semiconductor diode.

When diode is forward biased:

a. The width of the depletion layer decreases.

b. The barrier potential decreased ($V - V_B$).

c. The flow of current inside the diode is due to majority charge carriers.

d. The diode offers very low resistance called forward resistance.

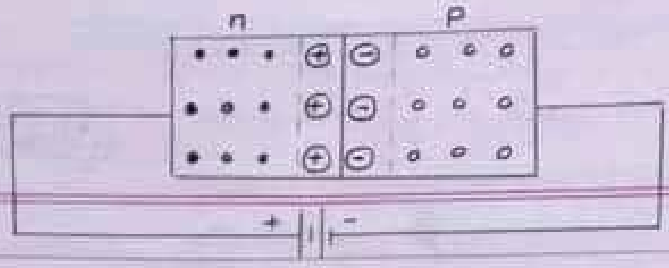


fig: Reverse biasing in semiconductor diode

When the diode is reverse biased:

a. The width of depleting layer increases.

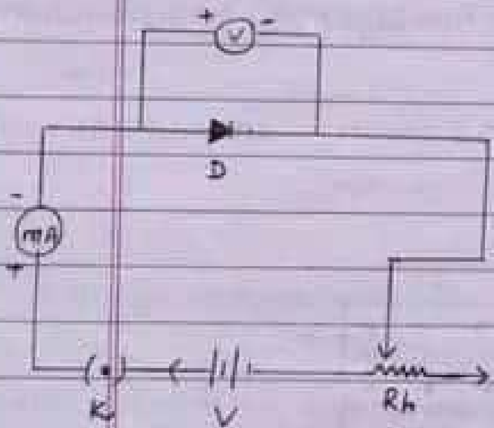
b. The barrier potential increases ($V+V_B$)

c. The flow of negligible current inside the diode is due to minority charge carriers.

d. The diode offers very high resistance called reverse resistance.

Characteristics of a Junction Diode:

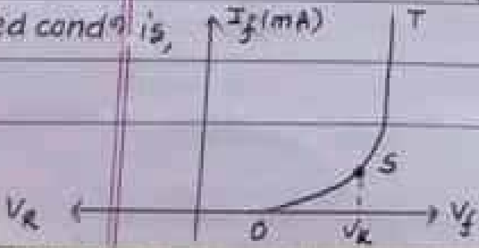
• Forward bias characteristics:



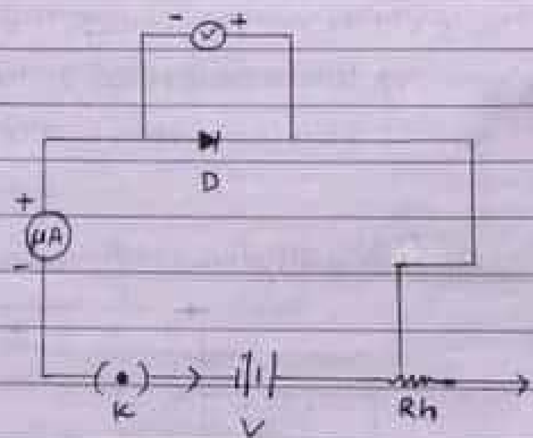
• During this condition, when the applied voltage is gradually increased from zero, current in the ckt. also increases from zero. This current can be recorded by a mA.

• After the applied voltage reaches 0.7V for silicon and 0.3V for Ge. diode, there is abrupt rise in current (called knee voltage).

• The I-V characteristics for forward biased cond^n is,



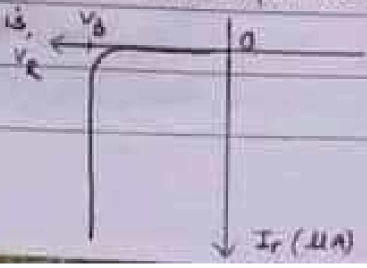
• Reversed bias characteristics:



• During this cond^n, the reverse current due to majority is zero for zero of the applied voltage. When the applied voltage is increased, there is small current in the ckt (called saturation current)

• However, when the reverse voltage is applied beyond a particular value, the current rises sharply due to break down of diode.

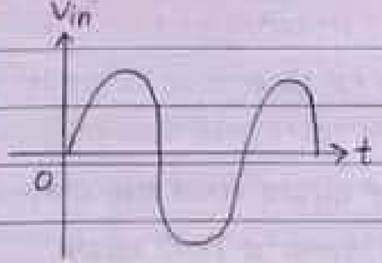
• The I-V characteristics for reverse biased cond^n is,



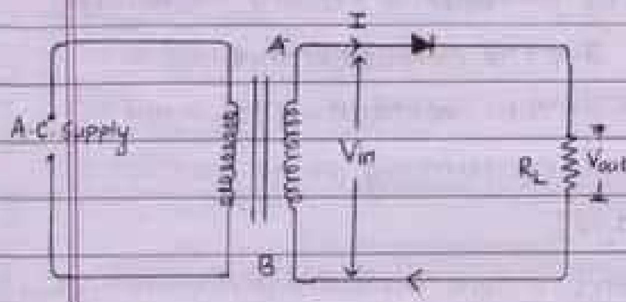
Semiconductor Diode as Rectifier:

Defⁿ: A rectifier is an electric circuit that converts alternating signals to unidirectional signals.

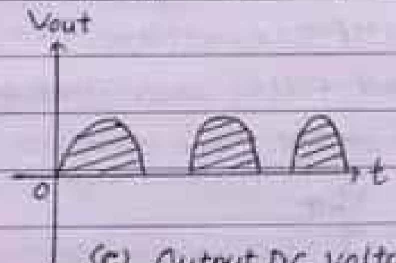
Half-Wave Rectifier



(a) Input AC voltage



(b) Half-wave rectifier



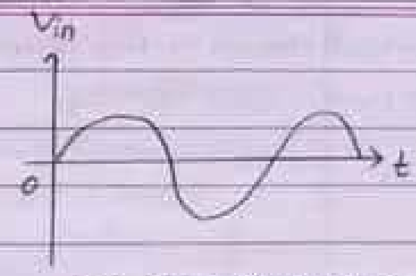
(c) Output DC voltage

A half wave rectifier contains a transformer, a diode and a load resistor. The diode is connected at the secondary coil through a load resistor R. An alternating voltage is supplied to the transformer through the primary coil.

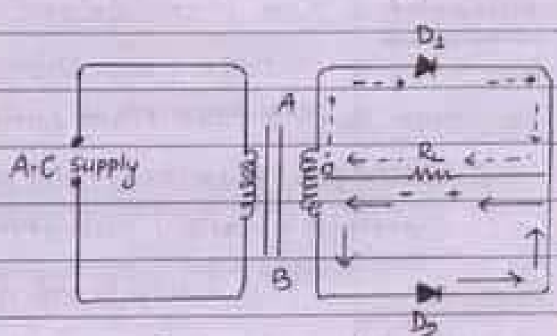
During the (+)ve half cycle of secondary voltage, the diode is forward-biased. Therefore, the current passes through the load resistor.

During the (−)ve half cycle of secondary voltage, the diode is reverse-biased. Therefore, no current passes through the load resistor (R_L).

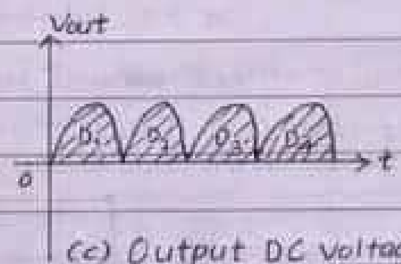
Full-Wave Rectifier



(a) Input AC voltage



(b) Full wave rectifier



(c) Output DC voltage

A full wave rectifier consists of a transformer, with centre tapped secondary coil. Two diodes D_1 and D_2 are connected at the upper and lower ends of the secondary coil of the transformer resp.

During the (+)ve half cycle of secondary voltage, the upper diode (D_1) is forward-biased and the lower diode (D_2) is reversed-biased. Thus, the current flows through the diode (D_1) and load resistor.

During the (−)ve half cycle of secondary voltage, the upper diode (D_1) is reverse-biased and the lower diode (D_2) is forward-biased. Thus, current flows thru' D_2 and the load resistor.

Half-wave rectifier	Full-wave rectifier
Thus, only during the (+)ve half cycle of a.c., the diode conducted and voltage is developed in the load resistor. This clearly shows why the circuit shown in the figure is called half-wave rectifier.	The current flows through R_L for both half cycles of the input voltages. The voltage through the resistor R_L is in the same dir^n. We can consider that a full-wave rectifier is like two back half-wave rectifiers with one working in the first half cycle and the other working in the alternate half cycle.

Filter ckt: The rectifier ckt. is used to provide a steady d.c. voltage, similar to a voltage from the battery. But the output voltage of a rectifier is not free from some portion of a.c. voltage. This kind of d.c. voltages results from a rectifier containing some portion of a.c. voltage (called pulsating voltage).

The portion of a.c. present in the pulsating d.c. voltage results from a rectifier called the ripple.

The a.c. variation from the rectifiers voltage can be filtered or smoothed out using a ckt called filter ckt. Thus, by using filter ckt, a constant d.c. voltage can be obtained.

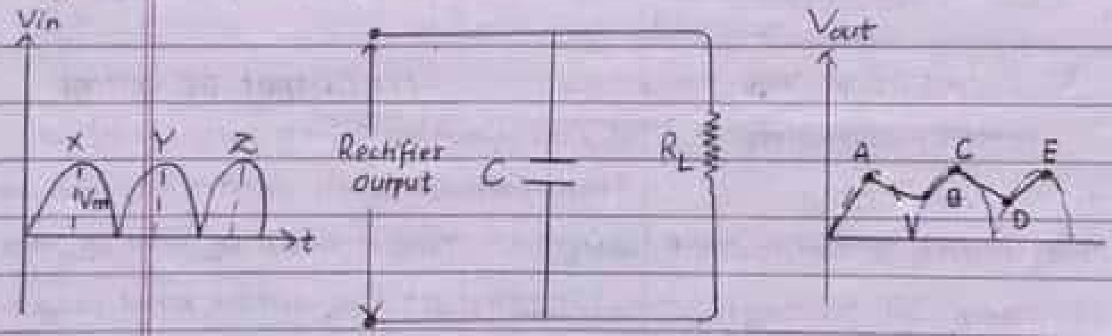


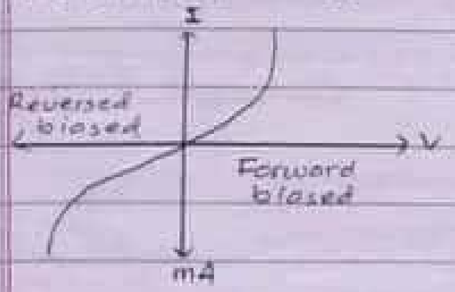
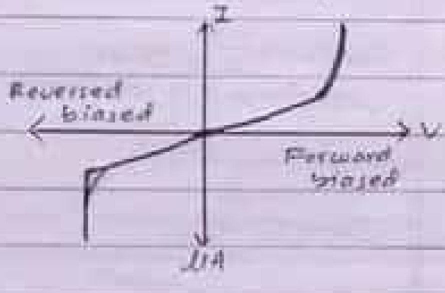
fig: Input voltage   fig: Shunt capacitor filter ckt.   fig: Output voltage

Working:

When the rectifier voltage increases, it charges the capacitor as soon as the quarter cycle is completed, the capacitor is charged to peak value of V_m of the rectifier voltage.

Now as the peak point (x) crosses over, the rectifier voltage starts to decrease. During this time, the capacitor discharges through R_L and voltage across the it decreases slightly as shown by the line AB in fig.

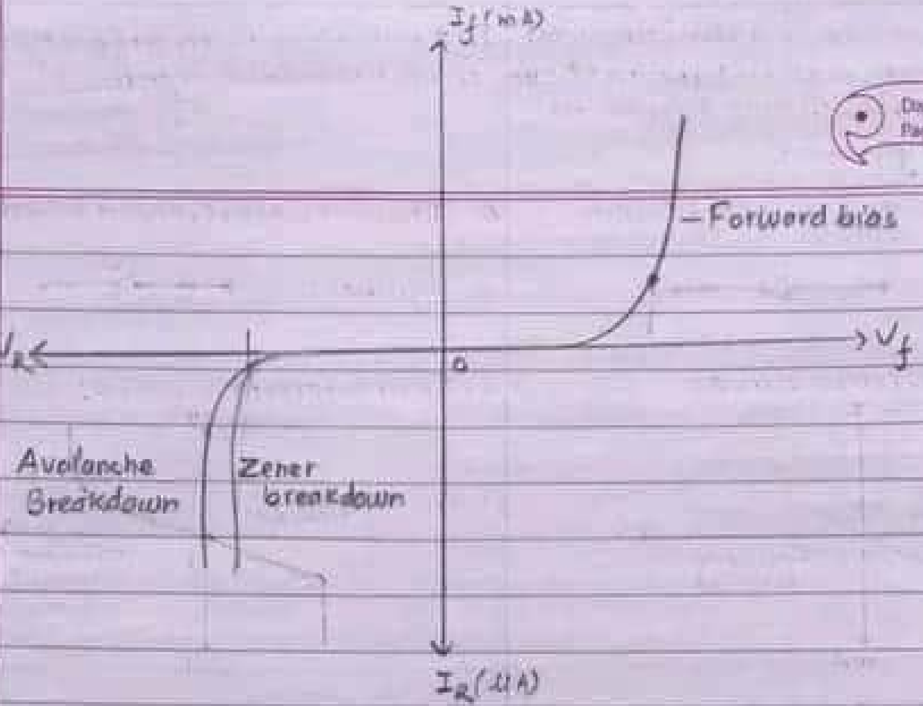
Immediately after it, another peak voltage Y comes and recharges the capacitor. This process is repeated again and again resulting in wave form of the output voltage.

Ordinary diode	Zener diode
1. Ordinary diode is a semiconductor device made up of N-type and P-type semiconductor with two terminals and commonly doped.	1. It is diode with property of diode having sharp breakdown region.
2. It works on forward biased.	2. It works on reversed biased.
3. symbol: 	3. Symbol: 
4. Characteristics curve: 	4. Characteristics curve: 

What are avalanche effect and zener effect? How can a zener diode be used as a voltage regulator?

Zener diode: A zener diode is a properly doped crystal diode having sharp breakdown voltage. It is designated to operate in reverse breakdown region without damage. It works on reverse biased condition.

Zener effect	Avalanche effect
If the diode is heavily doped and has narrow depletion layer, a small reverse voltage can set up very high electric field across the junction. If the electric field becomes very high (10^8 V/m), it breaks down the covalent bonds producing large number of electron-hole pairs. Hence, current rises very sharply. This effect is called zener effect or zener breakdown.	If the diode is lightly doped and the depletion layer is wide, the reverse electric field is unable to create zener effect. However, the minority charge carrier in the diode are accelerated due to electric field. These highly energetic accelerated charges collide with the semiconductor atoms and breakdown the covalent bonds creating large no. of electron-hole pairs. This leads to an avalanche of charge carriers called avalanche effect or an avalanche breakdown.



Zener diode as a voltage regulator:

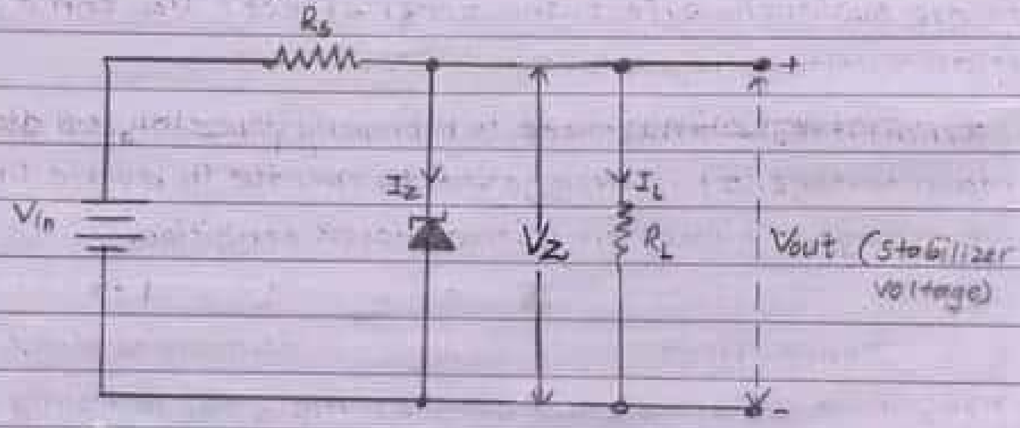


fig: zener voltage as a regulator

The process of maintaining a constant output voltage across the load is known as voltage regulation or voltage stabilization.

A zener diode can be used as a voltage regulator because it maintains a constant output voltage despite the change of current through it.

Inorder to produce breakdown, the source voltage V_i must be greater than the zener breakdown voltage V_z. A series resistor R_s is used to limit the zener current to a fixed value, above which the zener diode will burnout.

If V_i is increased and when it becomes equal to V_z, the breakdown point is reached. The voltage across the zener diode then becomes constant. If V_i is increased further, the output voltage across the load doesnot increase but the voltage drop across R_s

increase. If the current I_s is flowing through R_s then,

$$V_i = I_s R_s + V_z$$

or, $$\boxed{I_s = \frac{V_i - V_z}{R_s}}$$

Thus current I_s flows through the zener diode and current I_L thru' the load. Thus,

$$I_s = I_z + I_L$$

$$\therefore \boxed{I_z = I_s - I_L}$$

This gives that the load current is always less than the main current.

Transistor:

- Invented by J. Bardeen and W. H. Brattain
- The name transistor is for its transfer resistor action.

Types

n-p-n transistor

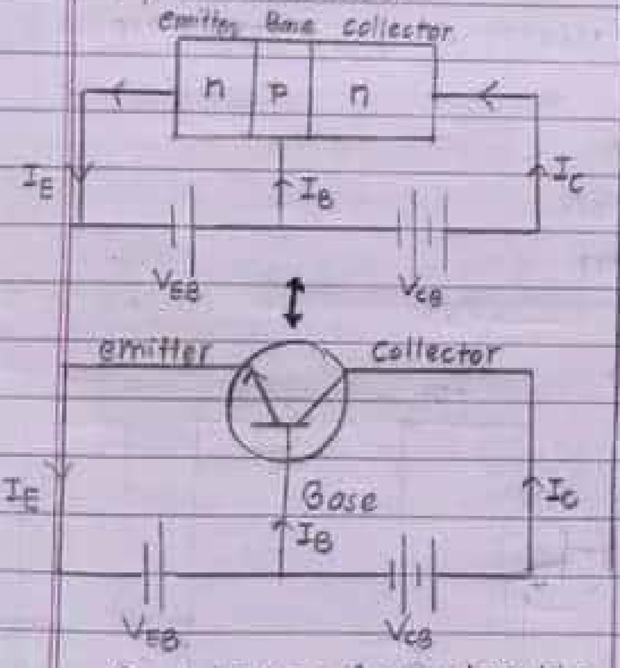


fig: Working of n-p-n transistor

p-n-p transistor

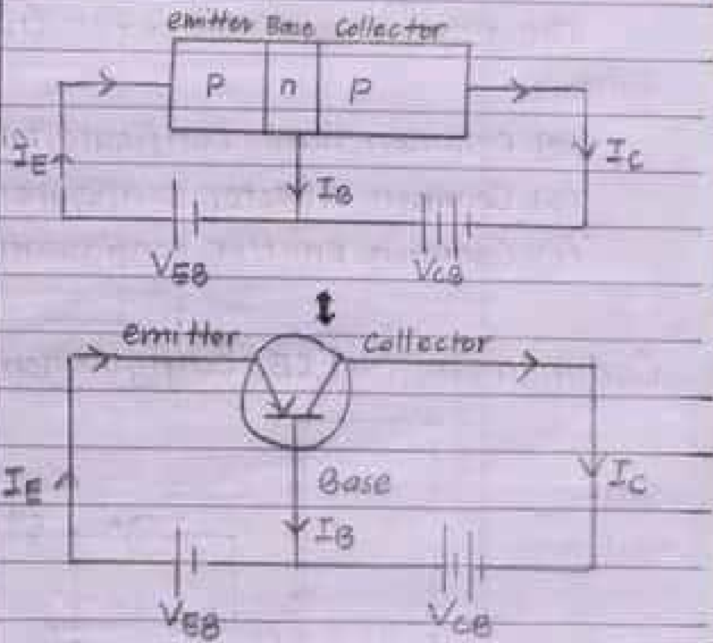


fig: Working of p-n-p transistor

n-p-n transistor:

- In this type of transistor, a p-type material sandwiched between two n-type materials serves as the base, whereas the n-type materials acts as emitter and collector.
- For its proper functioning n-p junction is forward biased and p-n junction is reversed biased.

p-n-p transistor:

- In this type of transistor, a n-type material sandwiched between two p-type materials serves as the base, whereas the p-type materials acts as emitter and collector.
- For its proper functioning p-n junction is forward biased and n-p junction is reversed biased.

- N-region usually abundant with free electrons pushes the e⁻ towards base due to the forward biasing field which constitutes emitter current I_E.	- P-region usually abundant with holes pushes the holes towards base due to the external bias voltage which constitutes emitter current (I_E).
- Since the base is lightly doped, only few electrons (nearly 5%) recombine with hole and constitute base current (I_B).	- since the base is lightly doped, only few holes recombine with e⁻ and constitute base current (I_B).
- The remaining electrons (nearly 95%) cross into collector and constitute collector current (I_C).	- The majority holes then cross into collector region and constitute collector current (I_C)
- In this way, $I_E = I_B + I_C$	- In this way, $I_E = I_B + I_C$

Transistor configuration:

The method of arrangement of transistor in a electric ckt. is k/a transistor configuration.

The three possible ways for transistor configuration are as follows:

(a) Common base configuration
(b) Common collector configuration
(c) Common emitter configuration

Common emitter (CE) configuration:

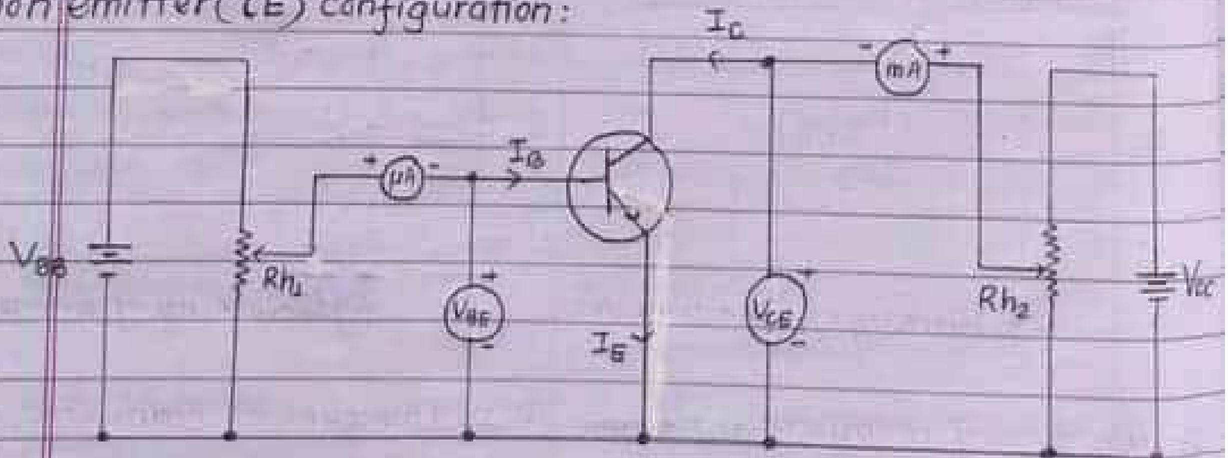


fig: ckt diagram for transistor characteristics

Characteristics refer to different set of curves plotted between the different set of voltages and their corresponding values of current in a transistor.

Basically, there are three types of characteristics curves which are discussed below.

1. Input characteristics:

It is the curve obtained between base current (I_B) and base emitter voltage (V_{BE}) when emitter-collector voltage (V_{CE}) is kept constant.

Informations:

a. As long as V_{BE}, is less than the Knee voltage, the current (I_B) is small. But, when V_{BE} is increased to a value greater than Knee voltage, the current (I_B) increases sharply.

b. The slope of the characteristics curve at a given fixed point gives the value of the input resistance (R_{in}).

ie. $R_{in} = \frac{\Delta V_{BE}}{\Delta I_B}$ (at const. V_{CE})

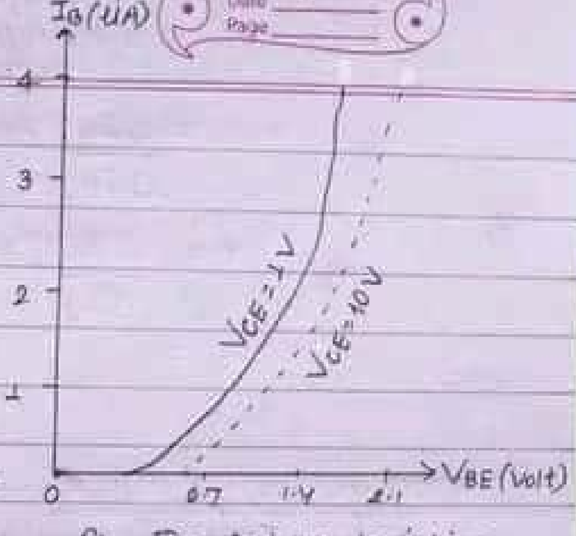


fig: Input characteristics

ii Output characteristics:

It is the curve obtained between collector current (I_C) and collector emitter voltage (V_{CE}) when the base current (I_B) is constant.

Informations:

a. The collector current (I_C) increases rapidly when V_{CE} increased from zero. After a certain value of V_{CE}, I_C remains almost const.

b. When $I_B = 0$, a small collector current (I_C) still flows in the ckt. (called leakage current).

c. The slope of this characteristics curve at a given fixed point gives the value of output resistance (R_{out}).

ie. $R_{out} = \frac{\Delta V_{CE}}{\Delta I_C}$ (at const. I_B)

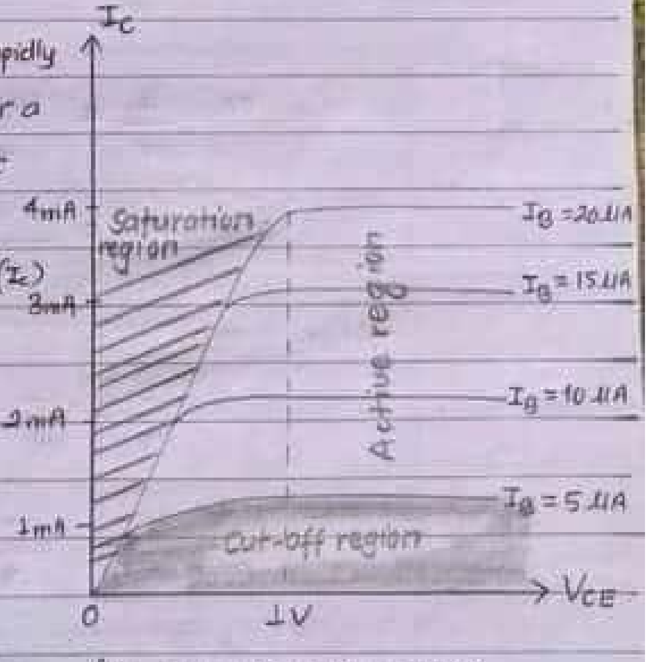


fig: Output characteristics

d. It shows that there exists three operating regions as cut-off, saturation and active region.

iii. Transfer characteristics:

It is the curve obtained between collector current (I_C) and base current (I_B) when the collector-emitter voltage (V_{CE}) is constant.

The slope of this line = $\frac{\Delta I_C}{\Delta I_B}$ (gives current gain)

= transfer ratio

= current amplification factor (β)

i.e. $\beta = \frac{\Delta I_C}{\Delta I_B}$ (for C-E configuration)

lly,

$\alpha = \frac{\Delta I_C}{\Delta I_E}$ (for C-B configuration)

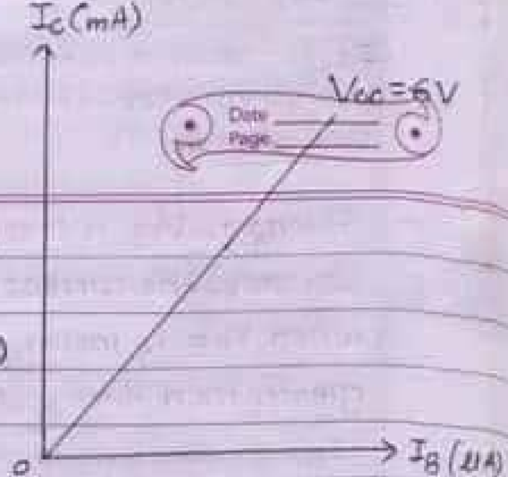


fig: Transfer characteristics

Relation between α and β:

For any transistor, we have,

$$I_E = I_C + I_B$$

Dividing b.s. by I_C, we get

$$\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C}$$

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

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

$$\therefore \boxed{\alpha = \frac{\beta}{1+\beta}} \longrightarrow (1)$$

Also,

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

or, $$\frac{1}{\beta} = \frac{1-\alpha}{\alpha}$$

$$\therefore \boxed{\beta = \frac{\alpha}{1-\alpha}} \longrightarrow (2)$$

Equations (1) and (2) are the relations between α and β.