Evolution Of Electronics

1700	Study on static electricity & source of electricity
1800	Ampere, ohm, Faraday – Relationship b/w electricity & magnetism. (electromagnetism)
1883	e^- flow from one metal to other through vaccum – Edison effect.
1904	Flemming applied Edison effect in 2 ~~elct~~ electrode vaccum tube – Diode
1904	3 electrode vaccum tube – Triode (Vaccum tube)
1947	Transistor (Engineers in Bell Lab, John Bardeen, Walter, William shockely) Nobel Prize

Ge → 85°C [Germanium]

Si → 200°C [Silicon]
(commonly used in semiconductor.)

1958 IC [Killby → Texas Instrument]
(Si)

SSI → (10–100) [Small scale Integratn]

MSI → (100–1000) [Medium "]

LSI → (1000–10000) [Large "]

VLSI → (10000 – 10^6) [Very large "]

ULSI → (> 10^6) [Ultra large "]

→ Digital Electronics (0's & 1's)

→ Microprocessor.

→ Optoelectronics.

→ Mechatronics

→ Nanoelectronics (1990)

Electronic Components

Active components	Passive components
1. Non linear circuit elements	1. Linear circuit elements
2. Equivalent circuit contain energy source.	2. Does not contain energy source.
3. Capable of processing signal	3. Not capable of processing the signal.
eg: FET, Diode, Transistor.	eg: R, C, L

Resistor

Specifications → resistance value
→ waltage rating
→ temperature coefficient of resistance
→ Voltage rating

→ tolerance

→ Name suggest oppose the flow of current through it.

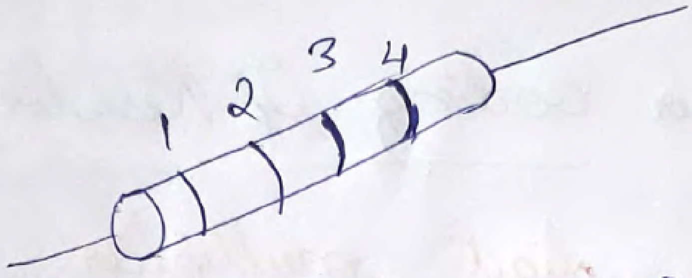
$$R = \frac{\rho l}{A}$$

Colour Coding Of Resistor

Colour	digit	multiplier	Tolerance
Black	0	10^0	–
Brown	1	10^1	$\pm 1\%$
Red	2	10^2	$\pm 2\%$
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Grey	8	10^8	
White	9	10^9	

B B Roy ~~of~~ Of Great Britain had a Very Good Wife.

(BBROYGBVGW)



1 — I^{st} digit

2 — II^{nd} digit

3 → Multiplier

4 → Tolerance.

Gold

~~both~~ digit → –

multiplier → 10^{-1}

Tolerance → $\pm 5\%$

Silver

digit → –

multiplier → 10^{-2}

Tolerance → $\pm 10\%$

No colour

digit → –

Tolerance → ~~10~~ $\pm 20\%$

1) Find the value of the resister with colour coding yellow, violet, silver, red.

Ans: $47 \times 10^{-2} \pm 2\%$ Red Red.

2) Give the colour band of ~~std.~~ $5\,\Omega \pm 1\%$ resistor.

Green, black, Gold, Brown. ~~22000~~

~~5×0~~ $50 \times 10^{-1} \pm 1\%$

3) A resistor has a value of $2.2\,K\Omega \pm 10\%$. Write the colour bands.

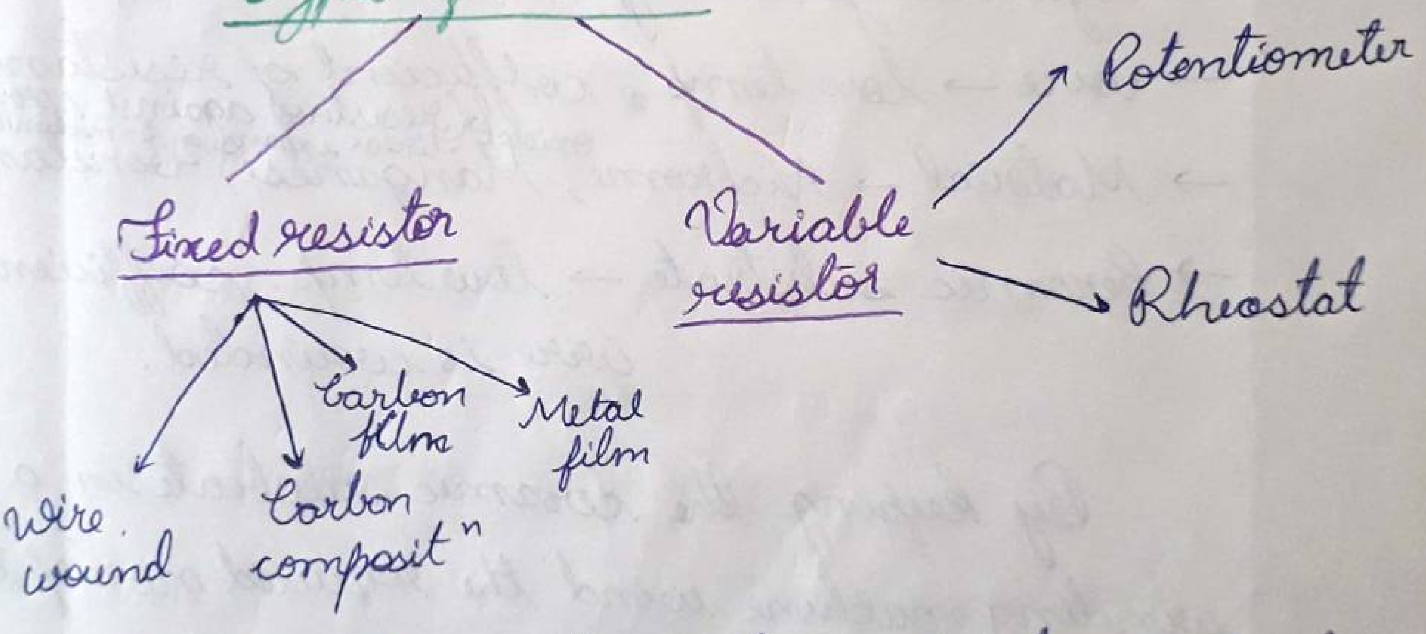
$2.2 \times 10^{3} = 22 \times 10^{-1} \times 10^{3}$

$= \underline{\underline{22 \times 10^{2}}}$.

$22 \times 10^{2} \pm 10\%$

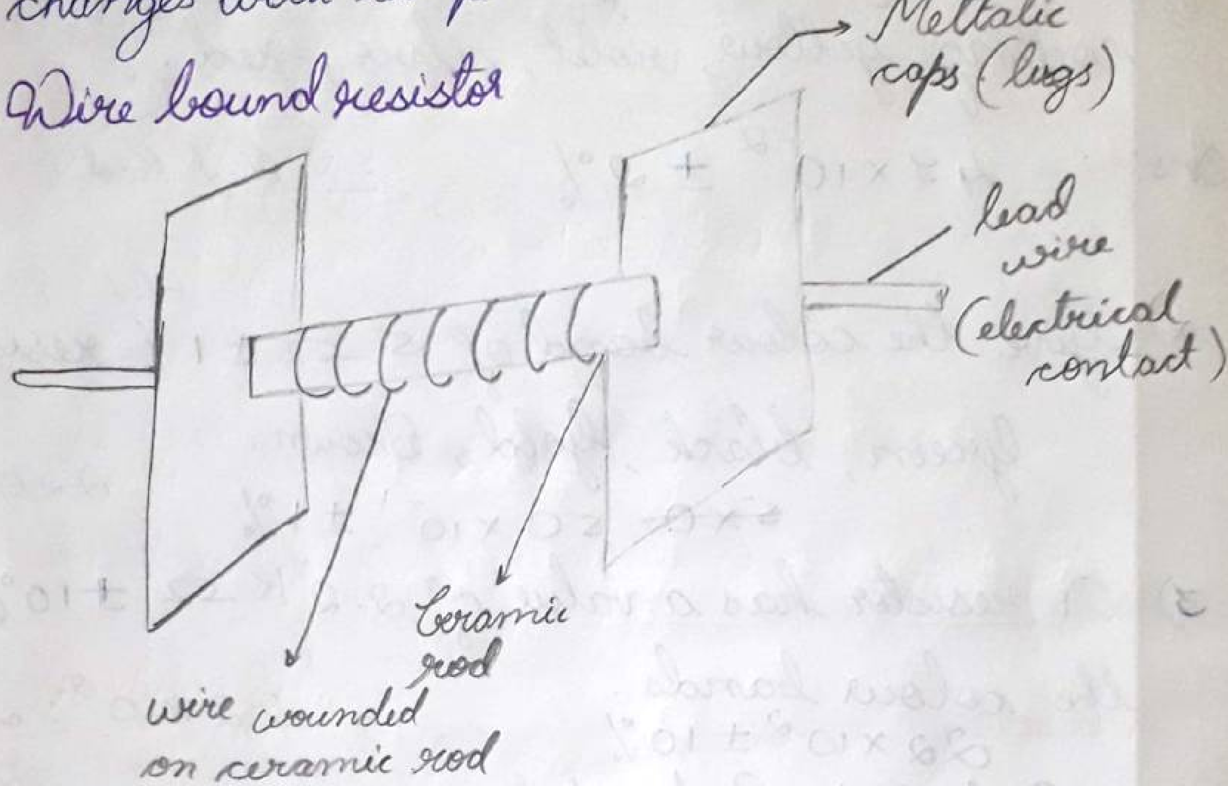
Red, Red, Red, Silver.

Types of resistor



Fixed resistor: A fixed resistor has a specific value which cannot be adjusted. They are made of metals or highly conducting ~~as~~ oxides. Semiconductors are not suitable for fixed resistors because the ~~s~~ resistivity of a semiconductor changes with temp.

(i) Wire bound resistor



→ low ohmic range
→ High voltage rating
→ wire → low temp. coefficient of resistance (resistive against corrosion, oxidat, linear expansion & mechanically strong)
→ Material → Nichrome, Manganese, Constantan
→ Ceramic substrate → low temp. coefficient wire is wounded.

By keeping the ceramic substrate in a winding machine wind the required no: of turns of selected wire on it. The end of the wire are then secured with metallic cap called ~~call~~ lugs. The proper electrical contact are taken from both ends, after the water bath drying & hot treatment it is then cooled into room temp. to

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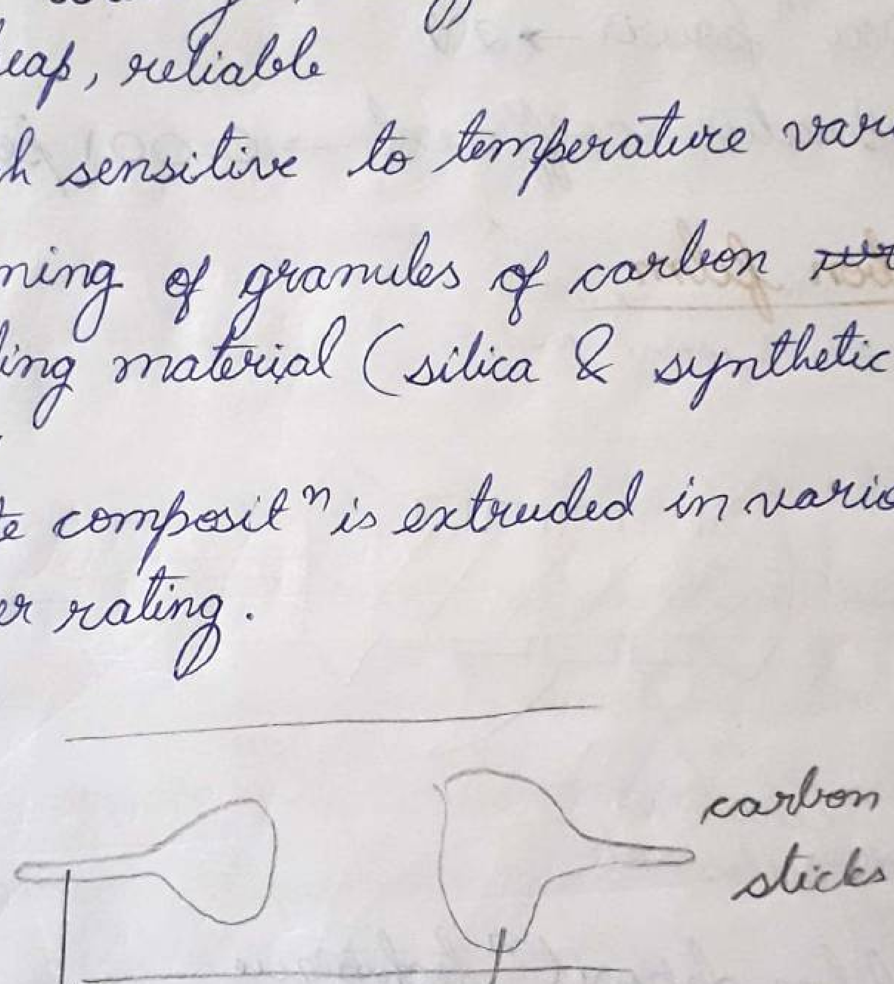
get shiny insulated cover. All these ohmic value, wattage, & tolerance are labelled.

(ii) <u>Carbon Composit^n Resistor.</u>

→ Common type
→ low wattage rating
→ Cheap, reliable
→ High sensitive to temperature variations.
→ Mining of granules of carbon ~~str~~ with a binding material (silica & synthetic resin) to a paste.
→ Paste composit^n is extruded in various thickness as per rating.

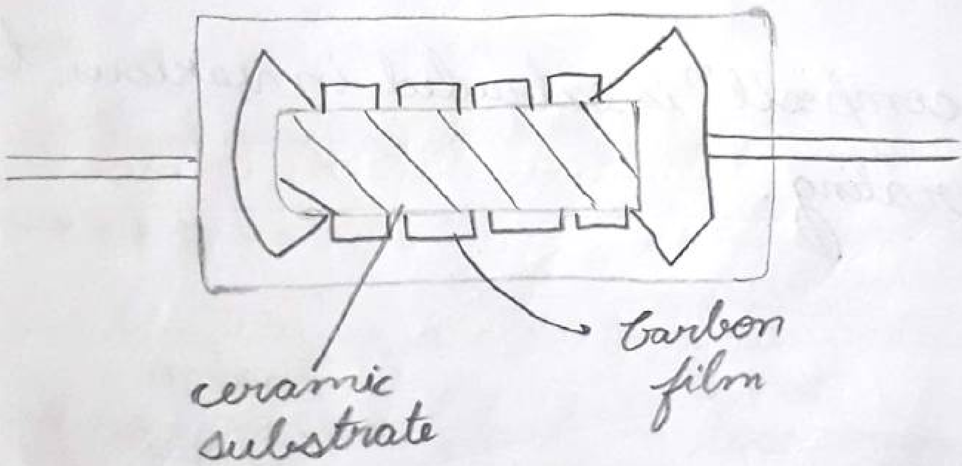


The extruded output is then cut ~~into~~ to the required length to make ~~sbr~~ sticks. Grooves are cut into both ends of each sticks. The sticks are now dried hard and backed at 100°C in oven filled with nitrogen. It is then cooled and given a ~~protected~~ protective synthetic coat finally the sticks are painted and labelled or colour coded.

Characteristics:

- Available range → 1 Ω - 22 M Ω
- Tolerance → 5-20%
- Maxi^m power → 2V
- Temperature coefficient → 0.001 per °C

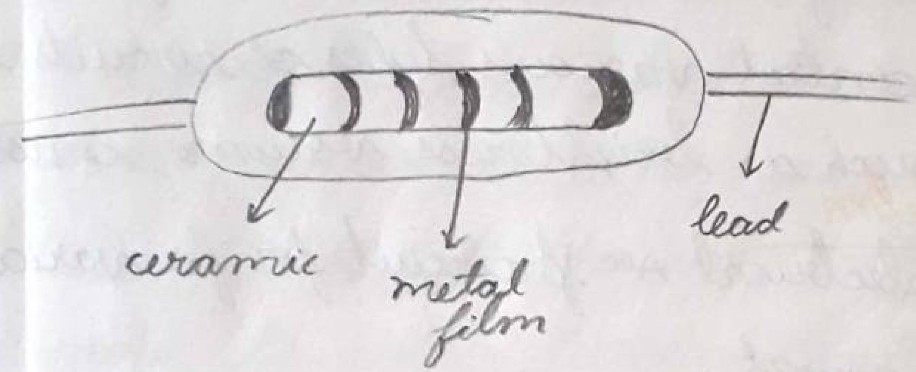
Carbon film



- film deposit^n technique
- low temp. coefficient of resistance on a insulating substrate (glass, ceramic).

~~Metal~~ It is constructed by using film deposit^n technique of depositing a thick film of resistive material having low temp. coefficient of resistivity on an insulating substrate. Metallic caps are attached to the end of the resistor and leads are taken from both sides. They r highly stable. Voltage ~~rat~~ rating is upto 1000V. Available range 100 Ω - 100 MΩ. Tolerance → 0.5%. Maximum power → 2 Watt.

Metal film



They can range in value upto 10,000 MΩ & are much smaller in size. High accuracy, low temperature coefficient, used in low level amplifiers and computers have excellent tolerance. Maximum power 1 watt.

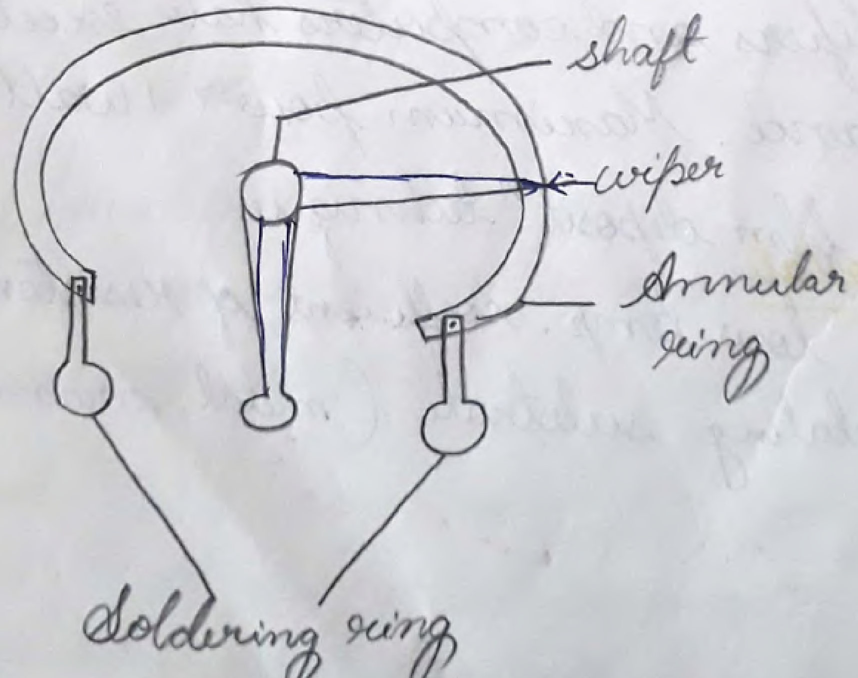
- film depositⁿ technique
- low temp. coefficient of resistance on a insulating substrate (metal, ceramic).

Variable Resistor

Carbon potentiomentic | Rheostat

→ Value changed b/w 0 – Max. range
→ Used to control various types of circuits in receives such as brightness, volume, constrast etc.
→ Used in electrical ~~ac~~ f circuit for for variat^n of voltage current.

Carbon ~~Po~~ Potentiometer :-



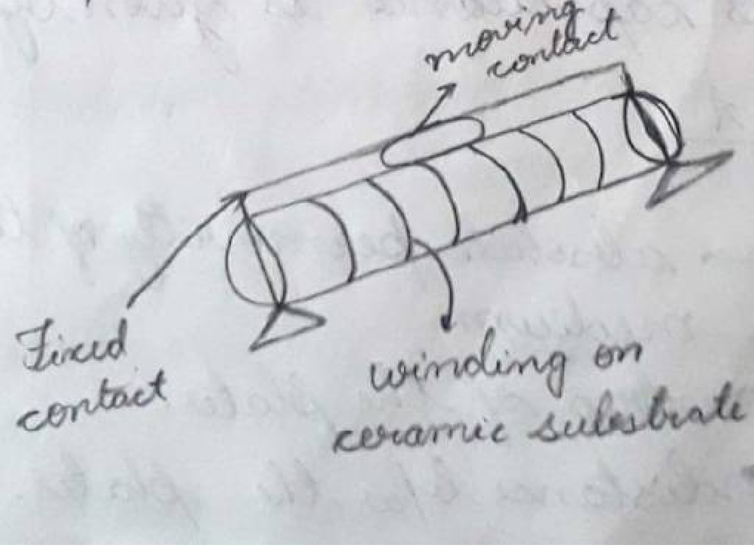
→ Mixture of carbon, resin & clay are made on a plastic base & deposited on ~~bact~~ bakalite substrate ~~a~~ Annular ring to form a circle.

→ Power rating 2W.

The 2 ends are soldered and form the end terminals, the middle leg is connected to the variable arm which is connected to metal spring wiper; the wiper has ~~t~~ a sliding contact. When we rotate the shaft the variable arm moves the wiper to make contact at different points on the annular ring. Hence the resistance b/w shaft & other terminals varies.

Power rating - 2W
Voltage " - 300 - 500V
Tolerance - 10 - 20%

Rheostat



→ High power

High power variable resistor are called rheostat they are formed by winding nichrome wire over a ceramic substrate, it has a movable sliding contact which can move along a line gives linear variations in ~~ressi~~ resistance. The ends of the resistance wire and the movable contact are connected to soldering leads ~~f~~ to form 3 terminals of rheostat.

Capacitors :-

→ ~ passive component commonly used in electronic ~~s~~ circuits.

→ It has the ability to store charge.

→ A capacitor consists of 2 conducting plates seperated by an insulating material known as dielectric. Its capacitance is given by

$$C = \frac{\varepsilon A}{d}$$

where ε → absolute permivitty of the dielectric medium

A → Area of the plates.

d → distance b/w the plates.

Capacitance is measured in Farad (F).

Functions of a capacitor & Its applications

→ Used in circuits for blocking DC voltage.

→ Used for coupling various stages of ~~a~~ a cascaded amplifier.

→ Used as filter in power supply

→ The amount of charge stored in a capacitor

$$q = CV$$

q → charge stored in a capacitor

V → voltage across the capacitor

C → capacitance.

※ Specifications of a capacitor

Imp. ~~sp~~ ~ are

(i) value of capacitance

(ii) voltage rating – max. voltage applied across the capacitor.

(iii) Frequency range – range of frequency over which the capacitor can be used.

(iv) Tolerance – deviation from the rated value of capacitance.

(v) Temp. range –

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Colour coding of capacitor :

Colour	Digit	Multiplier	Tolerance
Black	0	10^{0}	$\pm 20\%$
Brown	1	10^{-1}	$\pm 1\%$
Red	2	10^{-2}	$\pm 2\%$
Orange	3	10^{-3}	$\pm 3\%$
Yellow	4	10^{-4}	$\pm 4\%$
green	5	10^{-5}	$\pm 5\%$
Blue	6	10^{-6}	
Violet	7	10^{-7}	
Grey	8	10^{-8}	
White	9	10^{-9}	$\pm 10\%$

1) A capacitor has colour band sequence as yellow, white, grey and white interpret it.

$49 \times 10^{-8} \pm 10\%$,

~~0.49 μF~~ $0.49 \pm 10\% \, \mu F$

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$\rightarrow 10 \times 10^{2} \times 10^{-6}$

$= 10^{3} \times 10^{-6}$

$= 10^{-3}$

$= 0.001 \mu F$

Types of Capacitor

(a) ~~1)~~ **Fixed**

(1) Mica Capacitor ~~Capaulope~~

(2) ~~Pop~~ Paper "

(3) Ceramic "

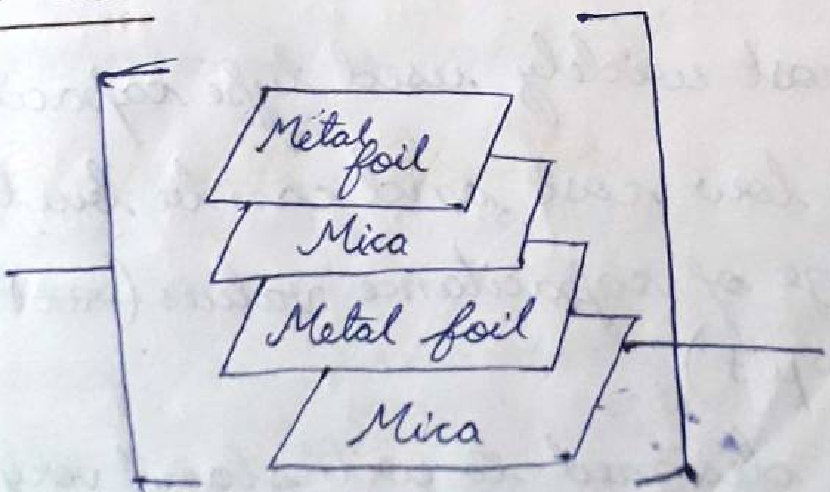
(4) Electrolytic "

(b) Variable

(1) Gang capacitor

(2) Trimer

(a) **Mica**



Important features:

(a) small capacitance value suitable for

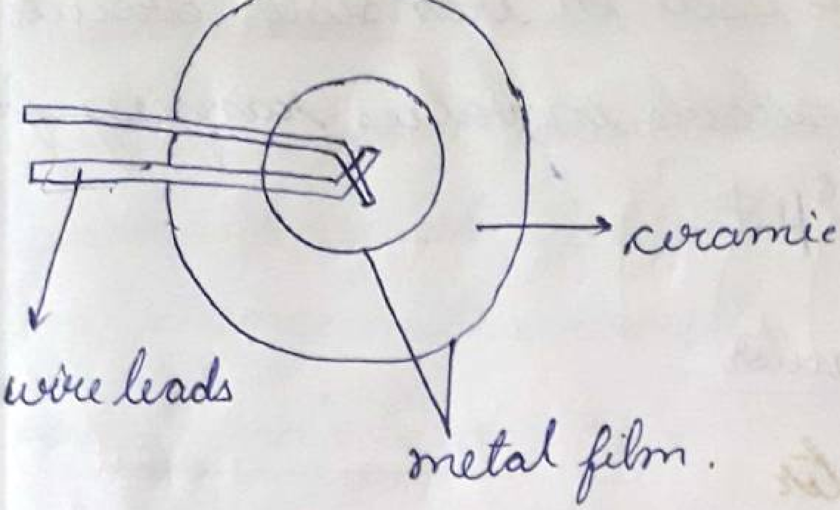
(b) high frequency operation such as.

oscillator, tuning.
(b) high voltage rating
(c) high stability.

(b) Paper Capacitors

→ They are most widely used type capacitor.
→ They are of low cost and can be built in a broad range of capacitance values ~~(500pF~~ (500pF - 50μF).
→ They can be designed to withstand very high voltages.
→ ~~P.~~ ~ can be used for both DC & AC circuits.

(c) Ceramic Capacitors



→ ~ are suitable for generat^n of large power at radiofrequencies.

→ 2 types :- Low dielectric constant capacitor (LDCC)
High dielectric " (HDCC)

→ LDCC have very high leakage resistance & it can be used ~~l~~ in high frequency ~~op~~ amplifications

→ HDCC provide large capacitance value in small ~~volume~~ ~~value~~ volume.

(d) Electrolytic Capacitors

→ ~ ~~us~~ are usually made of Al or tantalum becoz they form~~s~~ oxides with very high dielectric strength.

→ Al electrolyte capacitor consists of 2 ~~Al~~ Al foil one of which is coated by ~~thick ox~~ thin oxide b/w the foil ~~piece~~ is an electrolyte sol^n. The diff.

electrolytes used are borax, carbonate.

→ They can be used in transistor circuits.

→ They are available in values ranging from $1\mu F - 5\times10^{6}\mu F$.

Variable Capacitor :-

(a) Gang capacitor

→ Capacitance variation by changing the area of the plate.

→ Air acts as the ~~direct~~ dielectric medium.

(b) Trimmer Capacitor

→ Capacitance variatⁿ by chaging ~~d~~ the distance b/w the plates.

→ Mica acts as the dielectric medium.

Inductors :-

→ Inductor is a coil wound on a core of suitable material.

→ Oppose sudden change in flow of current.

→ Current flow → Magnetic field generate.

Inductance, $L = \dfrac{\mu N^2 A}{l}$

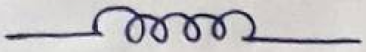
A → Area of cross section.

N → No. of turns

l → length of coil

μ → permicibility

unit → Henry.



When current flows through the circuit it generates magnetic field, this magnetic field oppose any change in the circuit.

⇒ <u>Self Inductance</u>

According to Faraday's law there is a rate of change of flux across a coil. Then an Emf induced in the coil. This principle is called → self induction.

$$\frac{d\phi}{dt} \propto v$$

$$\boxed{L = N\frac{d\phi}{dt}}$$

<u>Specification of Inductors</u>

→ The value of inductance

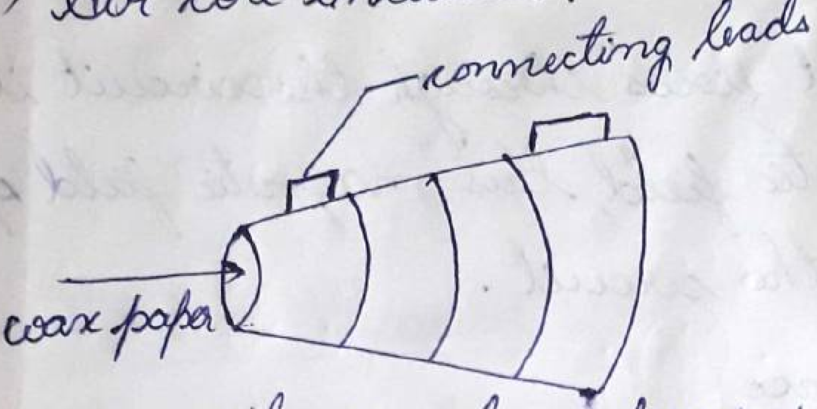
→ Current rating – Max. current it can carry.

→ Frequency range – range of frequencies over which the inductor can be used.

ttd

Classification of inductors

1) Air core inductor.



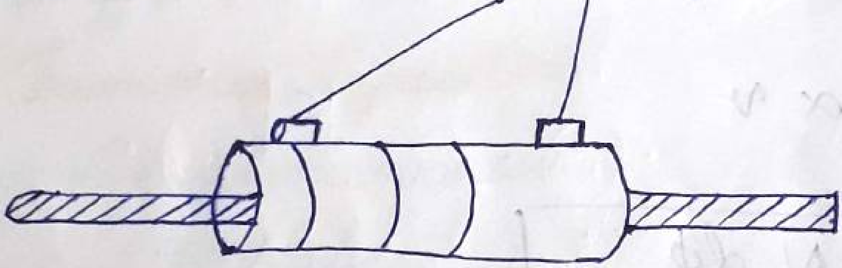
→ coil wound on ferrous ~~mat~~ material

→ Available range 0.1 μH

→ used in HF applicat^n.

→

2) Iron core



→ Coil wound on ferrite core

→ range of ~~50~~ 50 H

→ used in LF applicat^n.

→

Semi-Conductors

Materials are classified into conductors, insulators and semi-conductors. According to the band theory of solids. Conducting materials are good conductors of electricity whereas.

insulating materials are bad conductors.

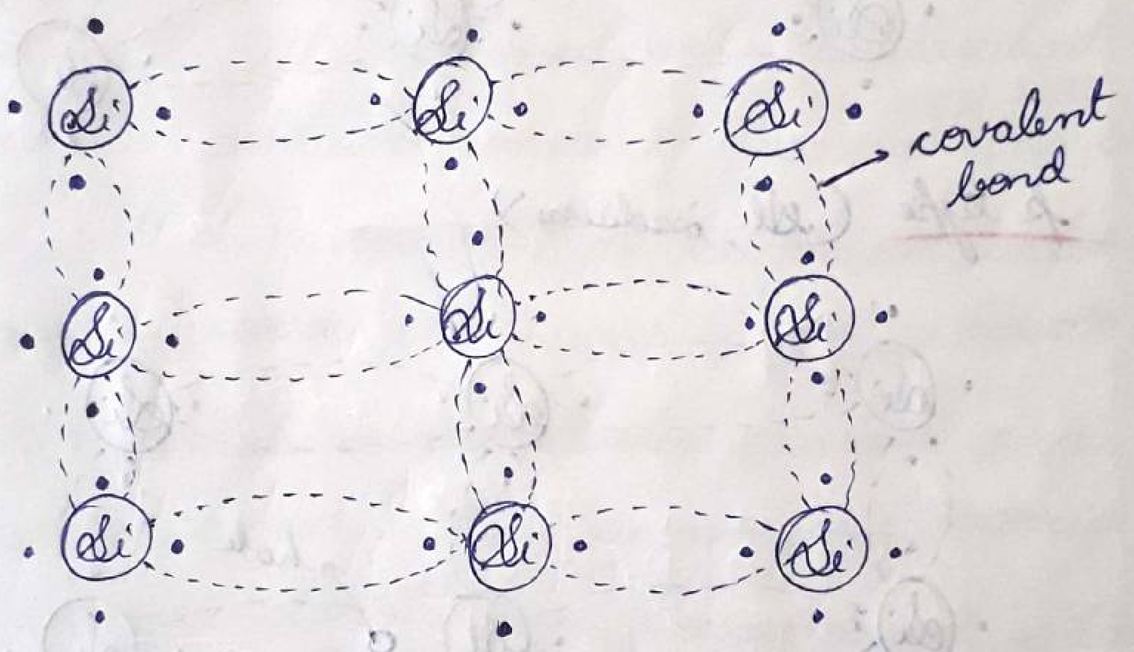
eg:- Conductors → Metals (Al, Cu)

Insulators → Rubber, ~~clot~~ glass etc

Semiconductor is a material whose electrical property lies b/w those of conductor & insulator.

eg:- Si, Ge

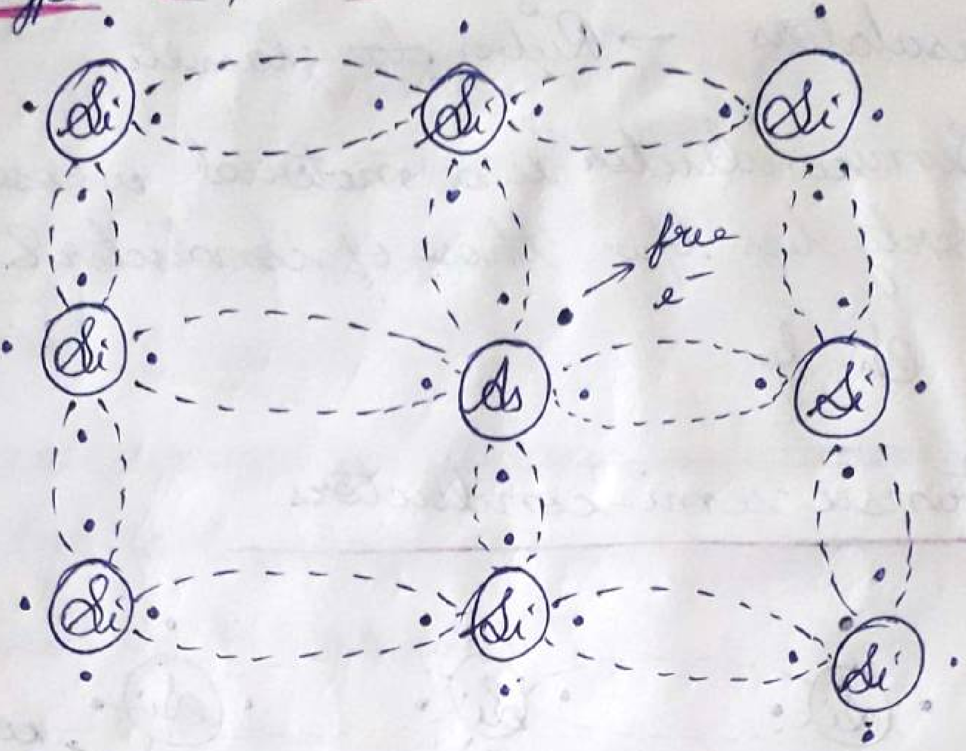
Intrinsic semi-conductors



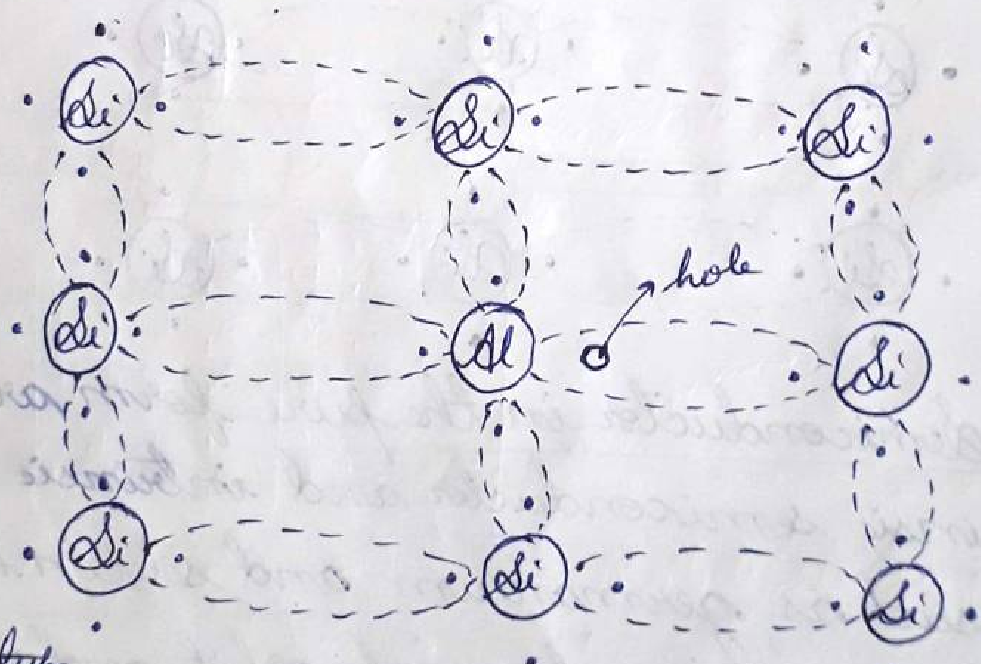
Semiconductor in the pure form are called intrinsic semiconductor and intrinsic semiconductor such as germanium and silicon has only 4 electrons in its outermost orbit and require 4 more electrons to fill the ~~se~~ shell. This is done by sharing one electron from each of the 4 neighbouring atoms to form covalent bond & the resulting pattern is called crystal.

Extrinsic Semiconductor

n type (As, P, Sb)



p type (Al, indium)



n type.

The process of adding impurities to a semiconductor is called doping. The resulting semiconductor is called an extrinsic semiconductor. Doping can be done using pentavalent or trivalent impurities.

Consider the case of a pure silicon doped with a pentavalent impurity ~~(ph P, As, Sb)~~ (P, As, Sb, Bi). Pentavalent atom has 5 electrons in their outermost orbit, of which 4 e^-s ~~from~~ form covalent bond with 4 adjacent silicon atoms. The fifth e^- is free & requires only very little energy to free itself from the attractive force of the nucleus. The silicon doped with pentavalent impurities contains excess of free electrons and hence called an ~~ex~~ n-type semiconductor.

(majority carrier e^-s, minority carriers holes → n type)

An n-type semiconductors contain e^-s as majority carrier & holes as minority carrier. Since electrons are donated by the impurity atoms so n-type semiconductor is called donor type.

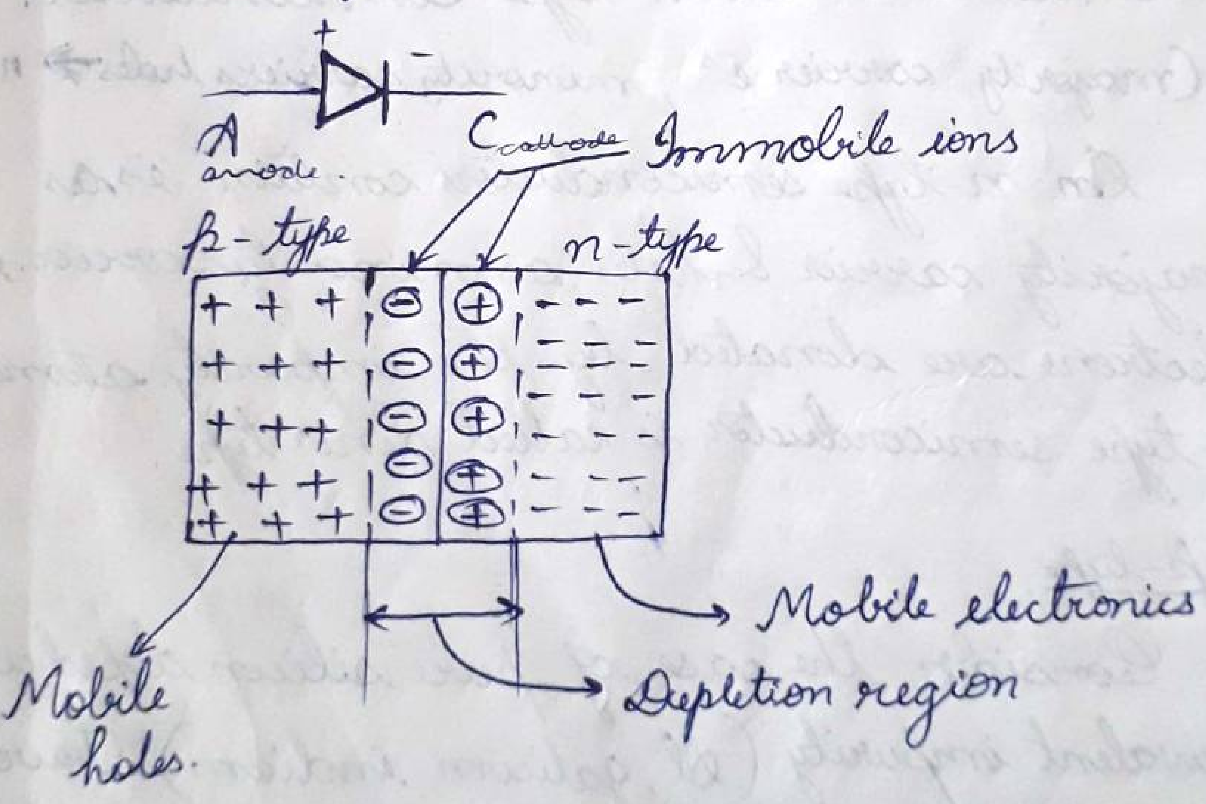
p-type.

Consider the case of pure silicon doped with trivalent impurity (Al, galium, indium). Trivalent impurity has 3 e^-s in the ~~ol~~ outermost orbit. These 3 e^-s share covalent bond with neighbouring silicon atom. The 4 neighbouring silicon atom is unable to form a covalent bond with the impurity ~~a~~

atom ie, one e^- is lacking or there exists a vacancy in the crystal structure. This vacancy is refered to ~~as~~ as a hole. The semiconductor thus formed has excess of holes & are called p-type semiconductors.

The impurity level act as an accepter of e^-s & $\therefore$ p-type semiconductor is called accepter type. p-type semiconductors contain holes as majority carrier & ~~h~~ e^-s as minority carriers.

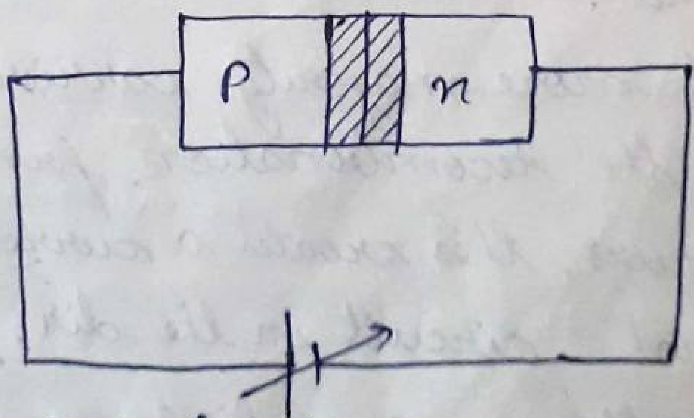
P-N Junction Diode



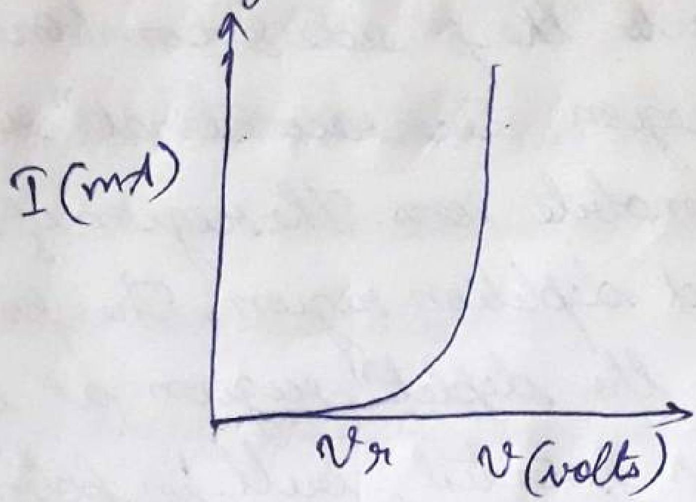
The above figure shows a p-n junction with no external biase is applied. At the instant of formation of the p-n junction ~~I~~ the holes from the p side diffuse in n side & combine with free ~~e~~ e's in the n region |||^ly the e's from the n side diffuse to the p side & combine with the holes in the p-region. The recombinatⁿ results the formatⁿ of immobile ions. The region of immobile carrier is called depletion region. The potential existing across the depletⁿ region at equilibrium is called barrier potential, built-in potential, contact potential.

As the diffusion process continues the current due to the movement of majority carriers called diffusion current also increase the ~~wild~~ width of the depletⁿ layer also ↑ses. When the width of the depletⁿ layer ↑ses the majority carries will not be ~~ap~~ able to cross the 'junctⁿ' & thus the diffusion current gradually ↓ses.

Forward Bias Condition for P-N Junction Diode



e⁻ repelled by the -ve terminal holes repelled by +ve terminal so e⁻ hole diffuse in the depletion region.



$V_r \rightarrow$ cut in voltage

$V_r = 0.7\,V$ for Si

$V_r = 0.3\,V$ for Ge

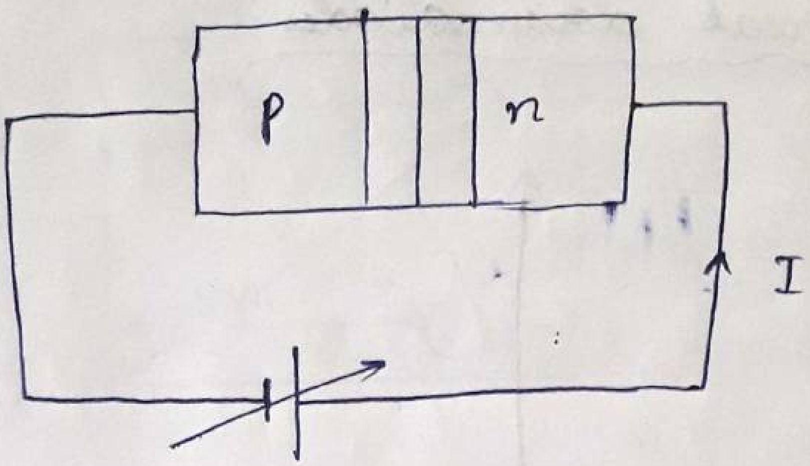
A p-n junction is said to be forward biased if p side is connected to +ve terminal of the battery & n side is connected to -ve terminal of the battery.

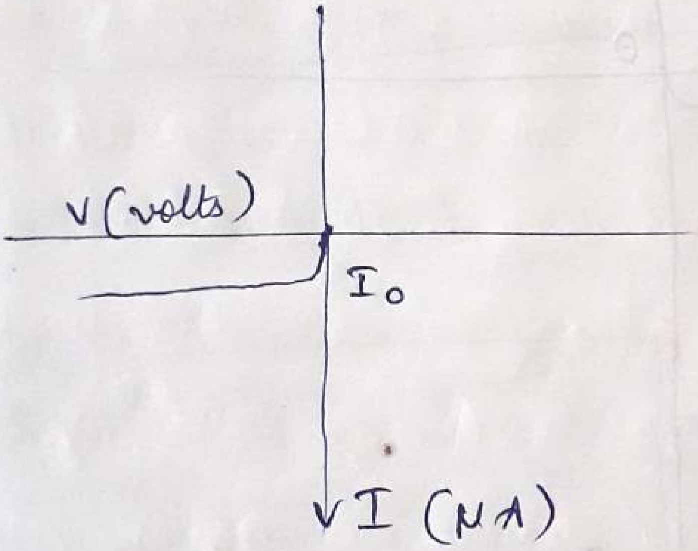
Under this condition free e's are repelled by the -ve terminal of the battery & holes r repelled by +ve terminal.

As a result more majority carriers diffuse across the junctⁿ the recombination process near the junctⁿ occurs, this creates a current flow in the external... circuit in the dir. from proton.

The min voltage required for a pn junctⁿ diode to conduct is called its cut in voltage.

Reverse Bias Condition for p-n junction Diode





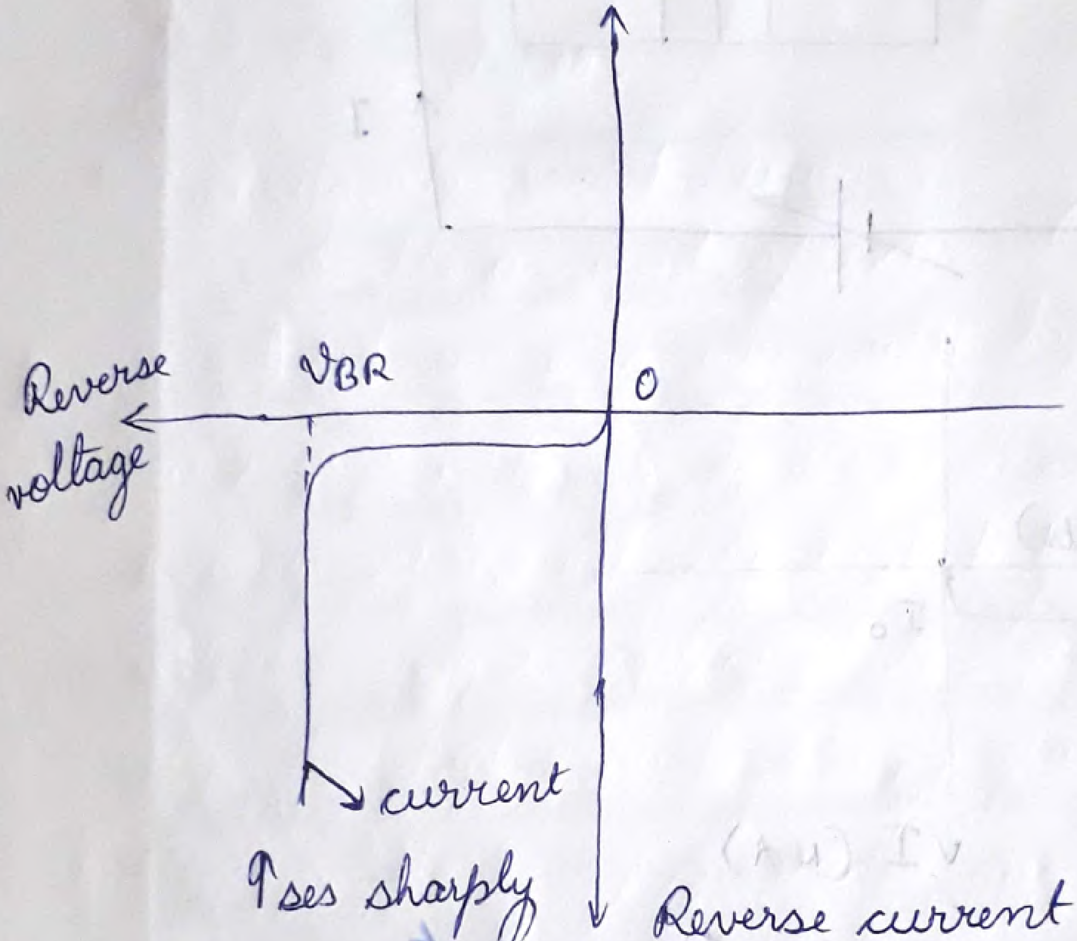
I_0 = reverse saturation current

In reverse biase condition, p side of the diode is connected to -ve terminal of the battery & n side is connected to +ve terminal of the battery.

Now charge carriers are repelled away from the junction & width of the depletion ↑ses, no holes or e^-s can cross the junction and the current flow stops complectely.

The minute current of the order of micro ampere flow through the diode as a result of thermally generated minority carriers. This current is called reverse saturation current I_0.

Break down diodes



* Break down depend on width of depletion region.

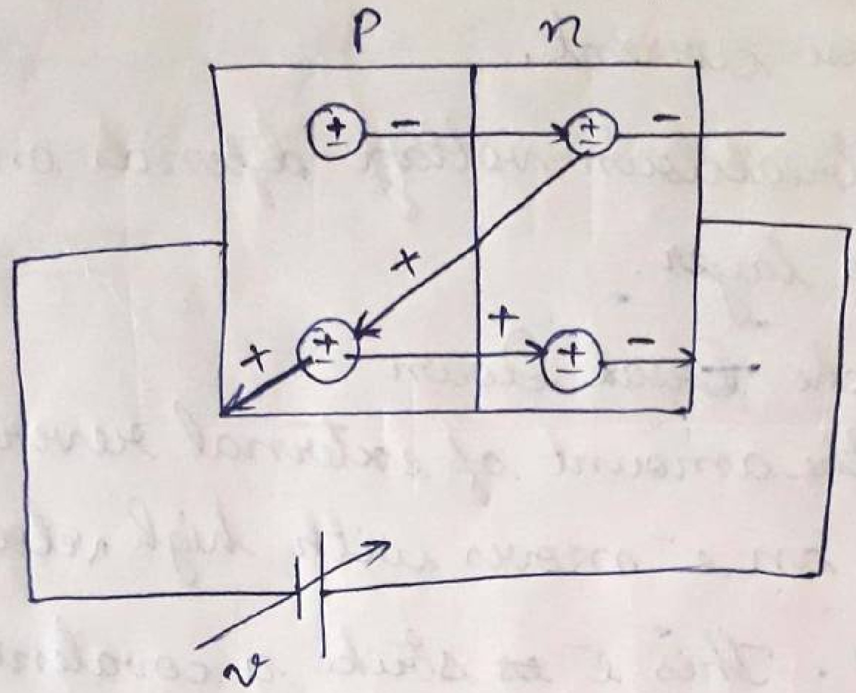
Zener breakdown

Avalanche Breakdown

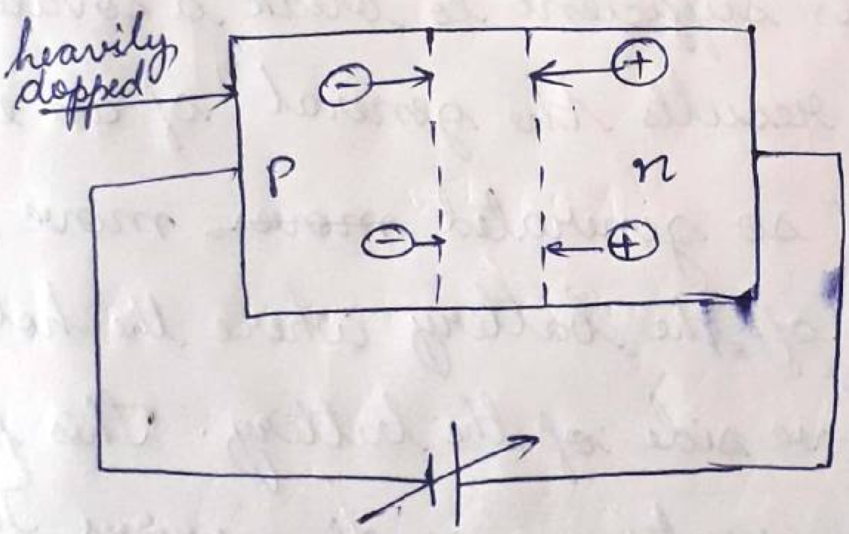
Avalanche Breakdown

→ e⁻ strike covalent bond in the n-side with very high kinetic energy.

→ ē hole pair bond break, ē liberate ~~p side~~ → Psi P side known as impact ionisation.



Zener Breakdown



⇒ Break Down Voltage

If the reverse voltage applied to a p-n junction is ↑sed a pt will reach when the jn breakdown & reverse current ↑ses sharply to a value limited only by the external resistance. This specific value of reverse biase voltage at which break down occurs is called break down voltage.

After break down a very small ↑se in reverse biase voltage causes a very large ↑se in reverse current.

The breakdown voltage depends on width of depletion layer.

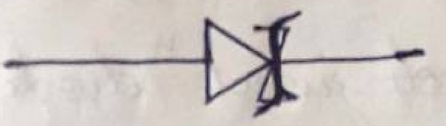
⇒ Avalanche Break Down

As the amount of external reverse biased is ↑sed an e^- moves with high velocity towards n region. This e^- ~~es~~ strike a covalent bond in the n-side with very high KE.
This energy is sufficient to break a covalent bond which results the generat^n of an e^- hole pair. The e^- so generated ~~moves~~ move towards the +ve side of the battery where the hole moves towards the −ve side of the battery. This process continues & creates a no: of carriers. This process is called impact ionisat^n or avalanche breakdown.

⇒ Zener Break Down.

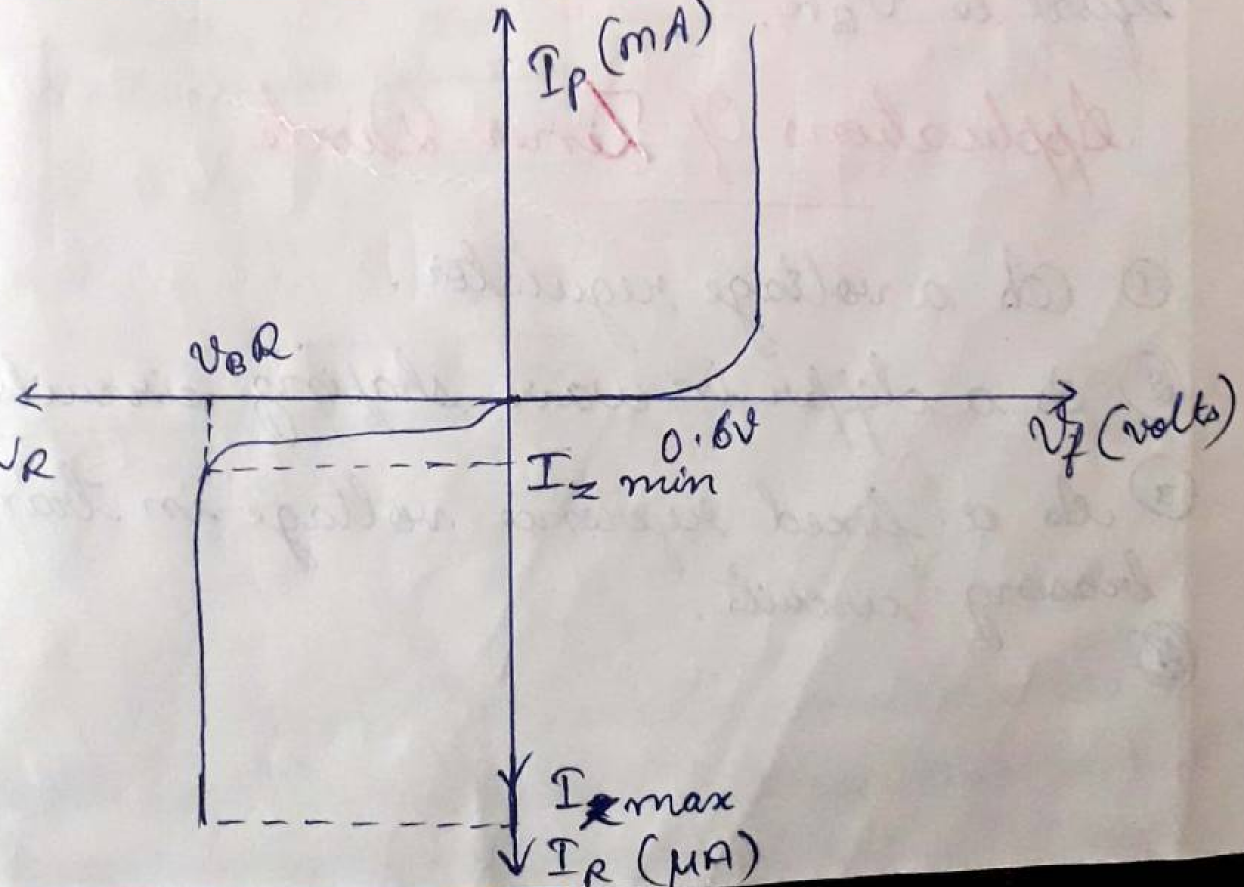
This break down occurs in junctions which are heavily dopped. The applied voltage set up a very strong electric field across narrow depletion region. This field is ~~not~~ strong enough to break the covalent bond generating a large no. of e⁻ hole pair. This phenomenonon is called field ionisation which causes zener breakdown.

Zener diode



It is a ~~ref~~ reverse biased heavily doped p-n junction diode which operates in the breakdown region. Reverse breakdown of a p-n junction may occur either due to zener effect or ~~avan~~ avalanche effect. Zener effect dominates at reverse voltage less than 0.6 volt, the breakdown voltage of a zener diode can be set by controlling the doping level.

V-I characteristics of zenerdiode



Forward characteristics:

Forward biased zener diode behave like a forward biased p-n ~~de~~ junctⁿ diode.

Reverse characteristics:

A we ↑se the reverse biase, initially a small ~~riverse~~ reverse saturation current flows, this current is due to minority carriers. At a certain value of reverse voltage, the reverse current will ↑se suddenly & sharply due to breakdown. The breakdown voltage is called zener breakdown voltage denoted by V_BR. After breakdown the voltage across zener diode remains constant equal to V_BR.

Applications Of Zener Diode

1. ~~As~~ As a voltage regulator.
2. As a clipper in wave shaping circuits.
3. As a fixed reference voltage in transister biasing circuits.
4.

Transistors :-

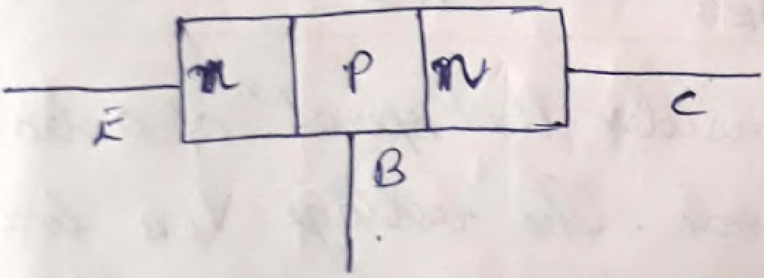
BJT is a 3 terminal semiconductor device, there are 2 types of BJT; (1) NPN transistor
(2) PNP transistor

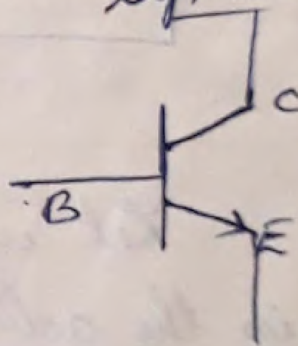
BJT consists of 3 semiconductor regions, emitter, base, collector. $\bar{e}$s, & holes participate in the current conduction process in a BJT hence the name bipolar. The direction of allow in the symbol represents direction of emitter current.

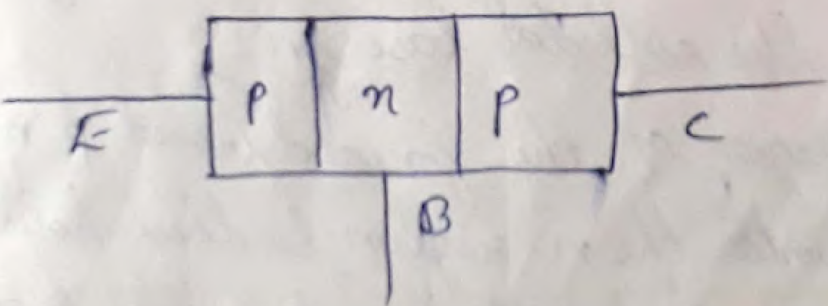
Structure & symbol of NPN & PNP

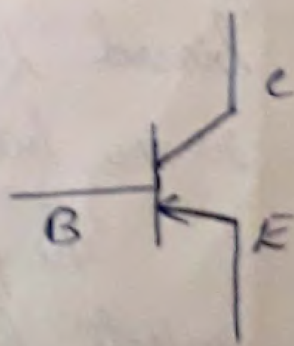
structure:

symbol









A transistor can be considered as a combinat^n of forward biase p-n junct^n & reverse biased p-n junct^n.

Modes of operation of BJT

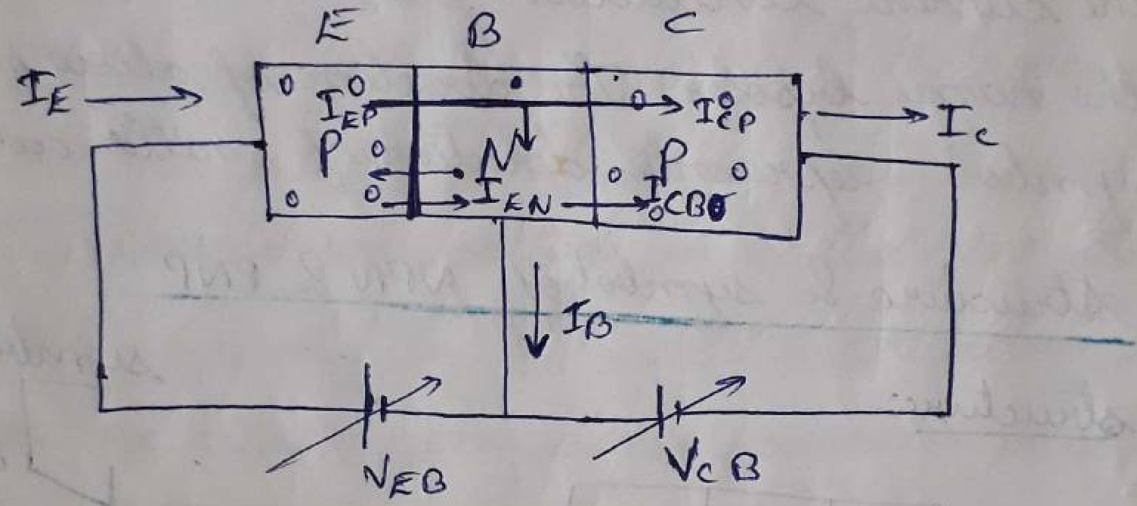
EB → FB   CB → RB → Active mode → Amplifier

EB → FB   CB → FB → saturation

EB → RB   CB → RB → cut off

(saturation and cut off) → switch.

Biasing of a PNP Transistor and its working



Let us consider the operatⁿ of a transistor in the active mode. The voltage V_{EB} forward biased the emitter base jun & the voltage V_{CB} reverse bias the collector base jn.

The p region of the forward biased p-n jn injects holes into the n-region & these holes act as the charge carrier for the second reverse biased p-n jun. Therefore, the p region of the forward biased p-n jn is called as emitter.

The holes injected are collected by the p-region of the reverse biased p-n jn & hence it is refered to as collector.

The middle region is named as base ∴ emitter region is supplying the majority carriers req. for a transistor to conduct. It is made with highest doping conc. Majority of these carriers should take part in the conduct^n of a transistor & hence the recombinat^n within the base region should be min. ∴ base is made with smallest area.

The collector is suppose to collect the carriers injected from the emitter & hence it ~~shd~~ should have sufficient power handling capacity. This emphasis the need for largest area for the collector.

This emphasize the need for largest area for the collector.

Emitter - ~~Modrate~~ moderate area, heavily dopped.

Base :- ~~Small~~ small area, lightly dopped.

Collector : Largest area, ~~moderately dopped.~~ moderately doped

The emitter current consists of 2 components
① holes ~~ing~~ injected from Emitter to base (I_{EP}

② e's injected from base to emitter (~~I_E~~ I_{EN})

ie, $\boxed{I_E = I_{EP} + I_{EN}}$

Some of these holes that are diffusing through the base region will combine with the e's in the base. Since the base is very thin this recombinatⁿ process is very small. Most of the diffusing holes will reach the collector & constitute the collector current I_C.

The ratio of emitter current due to holes to the total emitter current is called emission of injection efficiency (γ)

$$\boxed{\gamma = \frac{I_{EP}}{I_{EP} + I_{EN}}}$$

The majority of holes injected by emitter into the base will reach the collector. I_{CP} denotes the portⁿ of current I_{EP} that reaches the collector this ratio is called base transportatⁿ factor α_T, Then

$$\alpha_t = \frac{I_{CP}}{I_{EP}}$$

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The major contribut^n of I_C is due to I_E.

ie, $\boxed{I_C = \alpha\, I_E}$

where $\alpha \rightarrow$ current gain of common base configurations.

Where we have a collector base reverse biased jun with a ~~lakage~~ leakage current I_{CBO} flowing from base to collector, thus total collector current I_C

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

For a transistor emitter current is the sum of base current & the collected current. ~~That~~

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

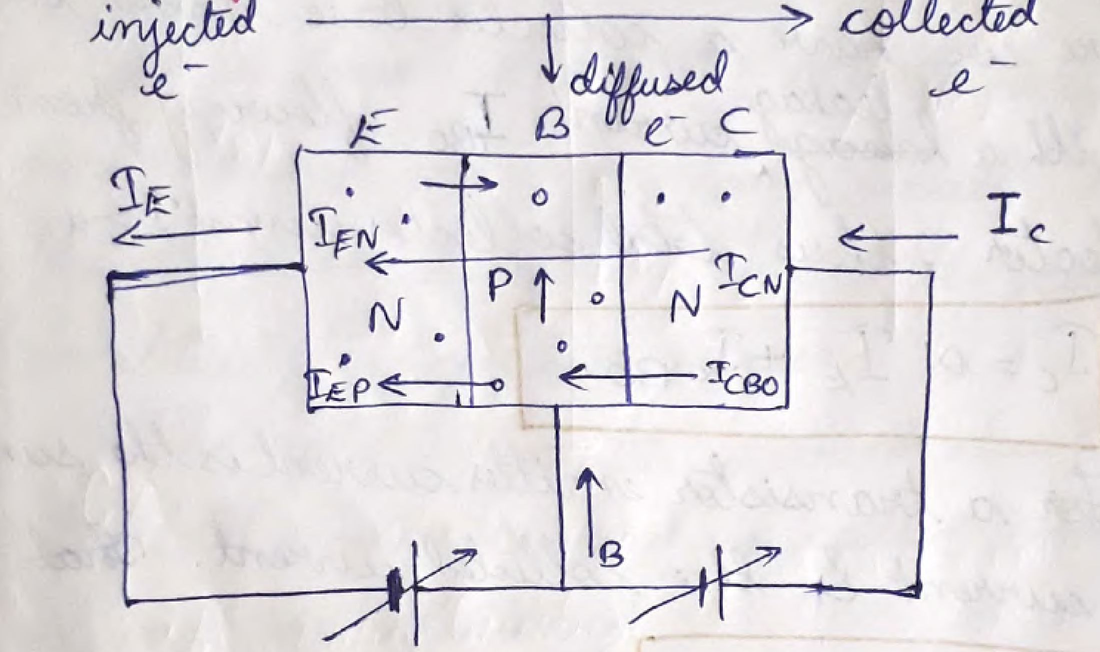
Early Effect OR Base Width Modulation

For a transistor working in active mode when we ↑se collector base reverse voltage, the deplet^n region width b/w collector & base ↑ses since the base of transistor is lightly dopped the deplet^n region will grow more towards the base. Therefore the effective width of the base ↓ses. This effect is called early effect.

Consequences of early effect :

Base current ↓ses emitter & collector current ↑ses .

Working Of N-P-N Transistor (same as for PNP)



$$I_E = I_{EN} + I_{EP}$$

$$\gamma = \frac{I_{EN}}{I_{EP} + I_{EN}}$$

$$\alpha_T = \frac{I_{CN}}{I_{EN}}$$

$$I_c = \alpha I_E$$

$$I_c = \alpha . I_E + I_{CBO}$$

$$I_E = I_B + I_c$$

Transistor is in active mode of operation. V_{EB} forward biased Emitter-base jn. V_{CB} reverse biased Collector – Base jn. N region of forward biased P-N jn injectⁿ e⁻ into the p-region (emitter). The e's are collected by the n-region of reverse biased P-N jn (collector), then middle region base.

(Explanatⁿ ||ᵉˡ to PNP).

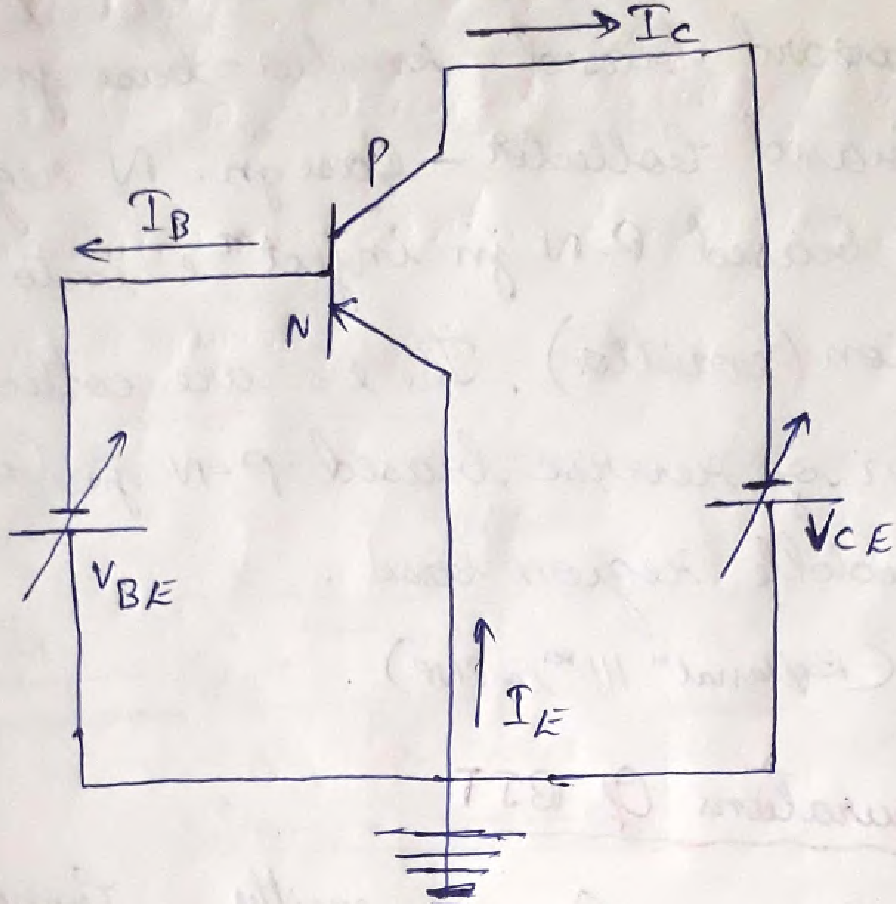
Configurations Of BJT

Common Base	Common emitter	Common collector
$\alpha = \left.\dfrac{\Delta I_C}{\Delta I_E}\right\|_{V_{CB}\ \text{constant}}$	$\beta = \left.\dfrac{\Delta I_C}{\Delta I_B}\right\|_{V_{CE}\ \text{constant}}$	$\gamma = \left.\dfrac{\Delta I_E}{\Delta I_B}\right\|_{V_{EC}\ \text{constant}}$

Current Gain or Current Amplication Factor is defined as the ratio of output current to input current when o/p voltage is kept constant.

Common Emitter Configuratⁿ

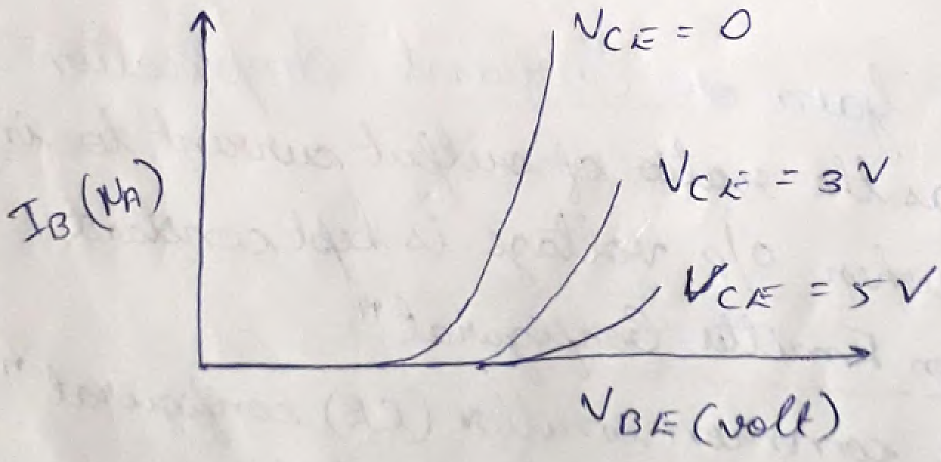
In common emitter (CE) configuratⁿ the emitter is made common to both base and collector



CE.

For NPN & PNP characteristics are same

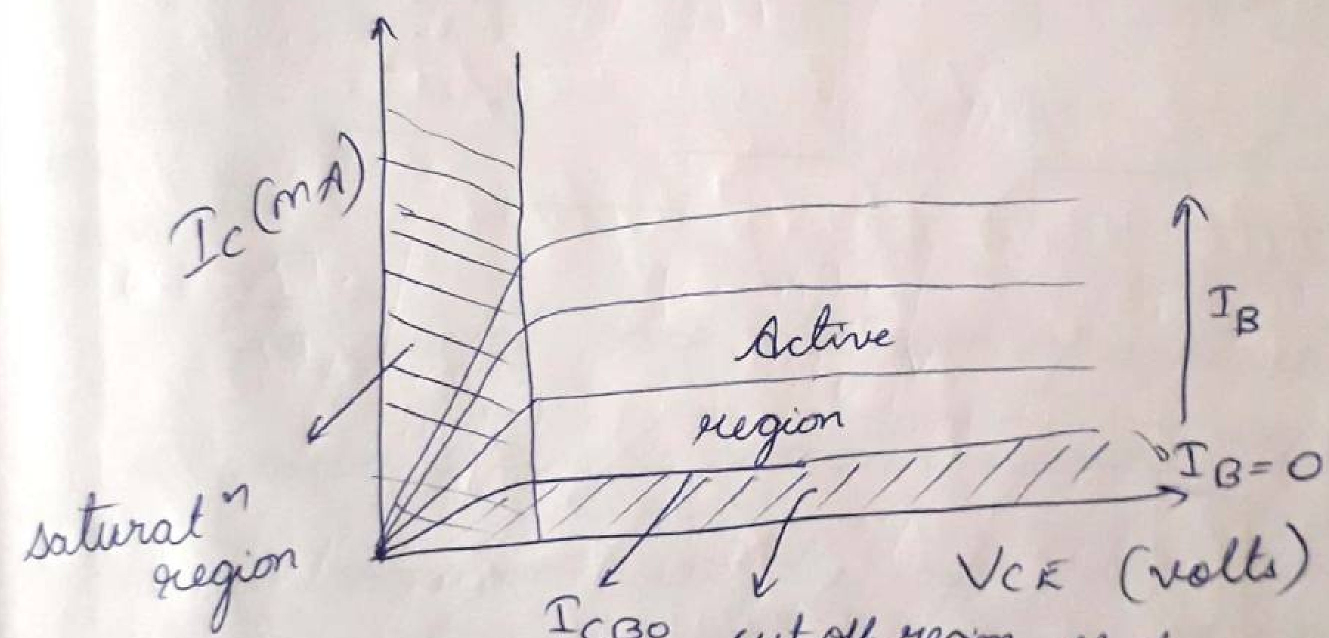
i/p characteristics



V_{CE}

When $V_{CE} = 0V$ we have a forward biased base emitter jn which makes the characteristics identical to a forward biased P-N junction with $V_{CE} = 3V$ base current slightly reduces due to early effect and the characteristics shift outwards

O/P characteristics



Here the variations of collector current is plotted against & variations in V_{CE} for a finite value of I_B.

When $I_B = 0$, transistor behave as a reverse biased P-N jn ($I_B = 0$, ie, $I_C = 0$, cut off region) when input jn is biased in the forward direct^n base current flows so collector current

↑ses linearly. This region is known as saturatn region. For a particular value of V_{CE} I_B ↑ses I_C remains constant. This region is known as active region.