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SFI GEC PALAKKAD

Section B

(Subject Code: EST 130) _(KTU 2019_ Regulation)

BASIC ELECTRONICS ENGINEERING

Syllabus

MODULE 4

Introduction to Semiconductor devices: Evolution of electronics – Vacuum tubes to nano electronics. Resistors, Capacitors and Inductors (constructional features not required): types, specifications. Standard values, colour coding. PN Junction diode: Principle of operation, V-I characteristics, Zener Diode, principle of avalanche breakdown and Zener breakdown. Bipolar Junction Transistors: PNP and NPN structures, Principle of operation, relation between current gains in CE, CB and CC, input and output characteristics of common emitter configuration.

MODULE 5

Basic electronic circuits and instrumentation: Rectifiers and power supplies: Block diagram description of a dc power supply, working of a full wave bridge rectifier, capacitor filter (no analysis), working of simple zener voltage regulator. Amplifiers: Block diagram of Public Address system, Circuit diagram and working of common emitter (RC coupled) amplifier with its frequency response, Concept of voltage divider biasing. Electronic Instrumentation: Block diagram of an electronic instrumentation system.

MODULE 6

Introduction to Communication Systems: Evolution of communication systems – Telegraphy to 5G. Radio communication: principle of AM & FM, frequency bands used for various communication systems, block diagram of super heterodyne receiver, Principle of antenna – radiation from accelerated charge. Mobile communication: basic principles of cellular communications, principle and block diagram of GSM.

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MODULE 4

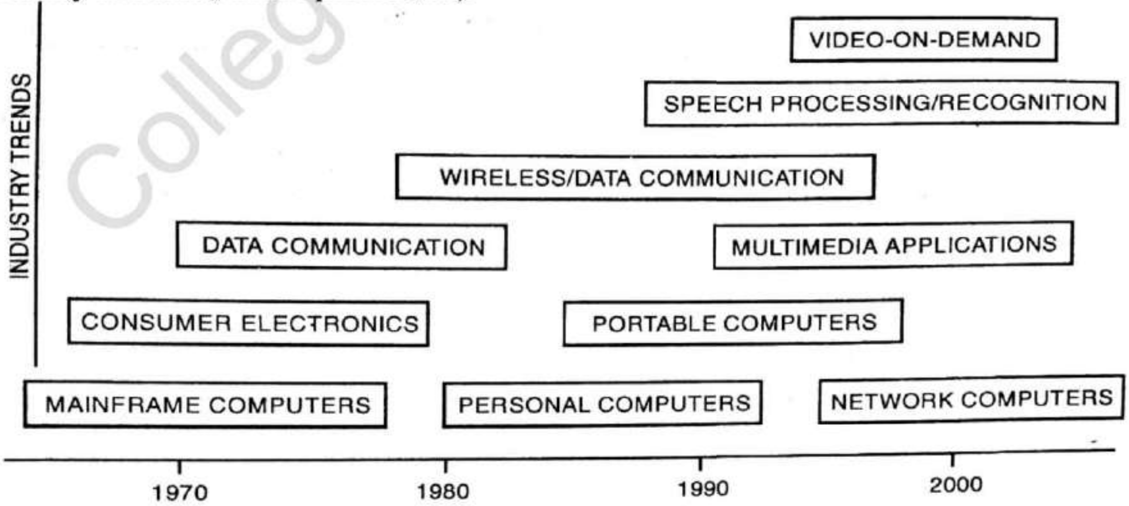
- Electronics is a branch of science which deals with the flow of electrons and their effects in materials like vacuum, gas and semiconductors.
- Electronic engineering is concerned with the design, fabrication and working of electronic circuits devices and systems.
- Electronics deals with low range of voltages current and power but it has capability to control high voltage current and power devices
- The word '**electronics**' is derived from electron mechanics, which means **the study of the behaviour of an electron under different conditions of externally applied fields.**

Evolution of Electronics

Evolution of Electronics is mainly through three components **vacuum tubes, transistors and integrated chip.**

1900's	**The Vacuum Tube. (1st Generation)**
1904	**First electronic diode vacuum tube** is built by **John A Fleming**, allowing the change of current into a direct one-way path
1906	**First electronic triode vacuum tube** is built by **Lee DeForest**, allowing signals to be controlled and amplified. Technology of electronics is born.
Late 1940	**The Transistor (2nd Generation)**
1947	**First transistor** made by **John Bardeen, Walter Brattain, and William Shockley** at the **Bell Laboratories**
Late 1950s	**Integrated Circuits (IC) (3rd Generation)**
1958	**First silicon IC built by Jack Kilby.**
	SSI
	MSI
	LSI
1970s	**VLSI (4th Generation)**
Late 1990 onward (upto present)	**ULSI (5th Generation)**

In SSI (Small Scale Integration) — 10–100 transistors/chip
In MSI (Medium Scale Integration) — 100–1000 transistors/chip
In LSI (Large Scale Integration) — 1000–10,000 transistors/chip
In VLSI (Very Large Scale Integration) —10,000–1 million transistors/chip
In ULSI (Ultra Large Scale Integration) —above 1 million transistors /chip (Eg; smart watches, VR reality modules, smart phones,etc).



Vacuum Tube

The vacuum tube is a glass tube that has its gas removed, creating a vacuum. Vacuum tubes contain electrodes for controlling electron flow and were used in early computers as a switch or an amplifier.

Vacuum tubes were also used in radios, televisions, radar equipment, and telephone systems during the first half of the 1900s.
In the 1950s, the transistor started to replace the vacuum tube. As computing devices started to become smaller in size, transistors were more ideal to use due to their smaller size as well. Vacuum tubes were larger in size and did not fit well for smaller computing devices, thus leading to their reduced usage. Today, vacuum tubes are no longer used in electronic equipment.

Applications of electronics

Electronics play a major role in almost every sphere of our life. The main applications of electronics are as follows.

1) **Communication**
    - Radio communication
    - mobile communication,
    - cable TV
    - internet
    - fax
    - telephoning, etc
2) **Entertainment**
    - Music player
    - video player
    - social media applications
    - video games, TV programs, etc
3) **Defense Applications**
    - RADAR (radio detection and ranging): To detect and find the exact location of the enemy aircraft.
    - SONAR (sound navigation ranging) is used for underwater applications.
4) **Industrial Applications**
    - Used in **automatic control systems**, **quality control system and measuring of various parameters.**
    - Electronics is widely used in **lighting systems, Security System**, **operating machines**.
    - Electronic computers are used to store and analyse industrial data and they are also used for arithmetic operations and problem solving.
    - **CCTV, fingerprint detection** are used in security systems
5) **Medical Field**
    Biomedical instrumentation is a branch of Electronics which deals with various electronic equipments. They include
    - ECG (to measures the electrical activity of heart),
    - EEG (to measures the electrical activity of brain),
    - laser based surgical equipments, etc.
    - Electronic scanning Equippments like MRI (Magnetic resonance imaging), CT (Computed tomography), ultrasound, X-ray
6) **Instrumentation**: CRO, signal generator, stress gauge, sensor, etc

Electronic Components

Electronic components are mainly classified into two types. They are:

1) **Passive components:**
    - These components are **themselves not capable of amplifying or processing an electrical signal. i.e., they can't generate power**
    - They **store/dissipate energy only.**

    Based on this, passive components are categorized into

    a) Energy dissipating device: Eg: **Resistor**

    b) Energy absorbing device: Eg : **Capacitor, Inductor** and transformer.

2) **Active components**

    They are capable of amplifying or processing an electrical signal. i.e., they can generate voltage or current. Eg: Transistors, MOSFET, Diode, vacuum tube, etc

Resistors

A resistor is a passive electronic component that offers a specific amount of electrical resistance to the flow of current when connected in a circuit.

Unit of resistance: ohm (Symbol: Ω).

Important Specifications of Resistors

1) **Resistance: The resistance value is either written on its body or indicated by colour coding.**
2) **Tolerance: It is the % deviation (variation) from the rated value.**
3) **Wattage rating: Maximum power that the given resistor can handle w/o getting damaged.**

    Unit: Watt

Other specifications are temperature coefficient, voltage rating, maximum operating temperature, etc.

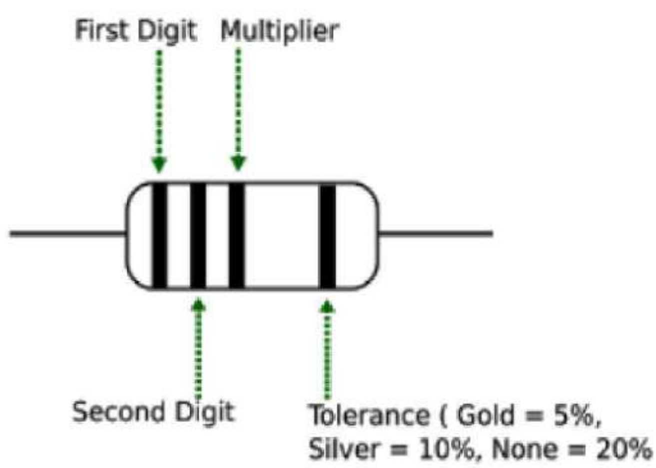
*Colour Coding of Resistors:

The colour bands are read from left to right.

The first and second bands represent significant digits respectively of the resistance value.

The third band shows the multiplier value. The fourth band gives the tolerance value.

Colour	Significant figure	Multiplier	Tolerance
Black	0	10^0	-
Brown	1	10^1	± 1%
Red	2	10^2	± 2%
Orange	3	10^3	-
Yellow	4	10^4	-
Green	5	10^5	-
Blue	6	10^6	-
Violet	7	10^7	-
Gray	8	10^8	-
White	9	10^9	-
Gold	-	0.1	± 5%
Silver	-	0.01	± 10%
No colour	-	-	± 20%



Remember tips: BBROY of **G**reat **B**ritain has a **V**ery **G**ood **W**ife.

0 1 2 3 4 5 6 7 8 9

Q1) A resistor has a colour band sequence: yellow, violet, orange and gold. Find the range in which its value must lie so as to satisfy the manufacturer's tolerance.
Solution: With the help of the colour coding table, we find

1st band	*2nd band*	*3rd band*	*4th band*
Yellow	Violet	Orange	Gold
4	7	10^3	$\pm 5\ \% = 47\ k\Omega \pm 5\ \%$

$$\text{Now, } 5\ \% \text{ of } 47\ k\Omega = \frac{47 \times 10^3 \times 5}{100}\ \Omega = 2.35\ k\Omega$$

Therefore, the resistance should be within the range 47 k$\Omega \pm$ 2.35 kΩ,
or between 44.65 kΩ and 49.35 kΩ.

Q2) A resistor has a colour band sequence: gray, blue, gold and gold. What is the range in which its value must lie so as to satisfy the manufacturer's tolerance?
Solution:

1st band	*2nd band*	*3rd band*	*4th band*
Gray	Blue	Gold	Gold
8	6	10^{-1}	$\pm 5\ \% = 86 \times 0.1\ \Omega \pm 5\ \%$
			$= 8.6\ \Omega \pm 5\ \%$

$$5\ \% \text{ of } 8.6\ \Omega = \frac{8.6 \times 5}{100} = 0.43\ \Omega$$

The resistance should lie somewhere between the values (8.6 - 0.43) Ω and (8.6 + 0.43) Ω
or 8.17 Ω and 9.03 Ω.

Q3) Yellow, Violet, Gold, Brown Ans:4.7 $\Omega \pm$ 1%

<u>Types of Resistors</u>

1) **Fixed Resistors** (=> Resistance value is constant.)
   i. **Carbon-composition Resistor (or carbon resistor)**
   ii. **Film Resistor (or Precision Type Resistor)**
      a) Carbon Film Resistor
      b) Metal Film Resistor
   iii. **Wire-Wound Resistor**

2) **Variable Resistors** (=> the resistance value can be varied over a specified resistance range.)
   i. **Rheostats** (: High power Variable Resistors)
   ii. **Potentiometer (or Pots)** (: Smaller variable resistors commonly used in electronic circuits)

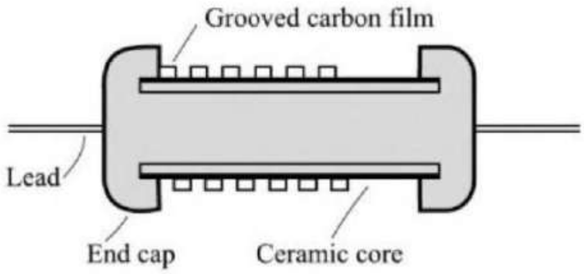
Carbon composition resistor (or carbon resistor)

- Made from a solid cylindrical resistive element with embedded wire leads or metal end caps
- The resistive material is of carbon-clay composition.
- Handle very low voltage and current
- Range: 1 Ω – 22 MΩ
- They are quite inexpensive.
- Tolerance range of $\pm$5 to $\pm$20 %.
- The relative sizes of all fixed (and also variable) resistors change with the power rating.

i.e size increases for increased wattage rating in order to withstand higher currents and dissipation losses.

Film Resistor (or Precision Type Resistor)

- Made by depositing a homogeneous film of pure-carbon (or some metal) over a glass, ceramic or other insulating core.
- Only approximate values of resistance can be obtained by this method.



- Desired values are obtained by either
  - ✓ trimming the layer thickness or
  - ✓ by cutting helical grooves of suitable pitch along its length.

  During this process, the value of resistance is monitored constantly. The cutting of grooves is stopped as soon as the desired value of resistance is obtained. Contact (metal) caps are fitted on both ends. The lead wires, made of tinned copper, are then welded to these end caps.
- **High Accuracy resistance** value Obtained with **tolerance of** $\pm$**1 %**
  So it is known as **Precision Type Resistor**

Wire-wound resistor

- Uses a length of resistance wire, such as nichrome.
- This wire is wound onto a round, hollow core made of an insulating material (Eg: porcelain).
- The ends of the winding are attached to metal pieces inserted in the core.
- Tinned copper wire leads are attached to these metal pieces. This assembly is coated with an enamel containing powdered glass.
- It is then heated to develop a coating known as vitreous enamel. This coating is very smooth and gives mechanical protection to the winding. It also helps in conducting heat away from the unit quickly.
- Resistance values ranging from 1 **Ω** to 100 k**Ω**.
- Power ratings up to about 200 W.

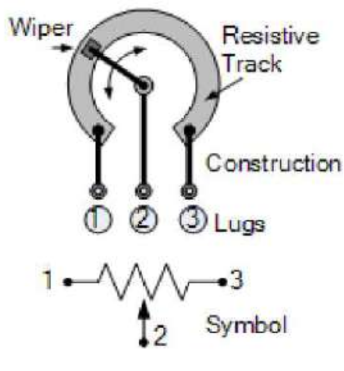
Variable resistors: In electronic circuits, sometimes it becomes necessary to adjust the values of currents and voltages. For example, it is often desired to change the volume (or loudness) of sound, the brightness of a television picture, etc. Such adjustments can be done by using variable resistors.

Rheostats

- High power Variable Resistors
- Have sliding contact through which resistance value can be changed in a linear manner.

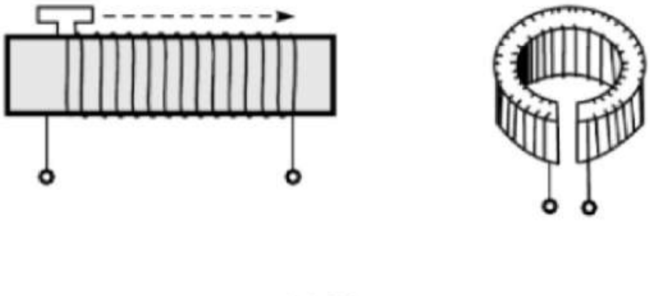
Potentiometer (or Pots)

- Smaller variable resistors commonly used in electronic circuits**.**
- Some have a **wire-wound resistance** as their primary element,
  While others have a **carbon-film element**.
- There are three terminals coming out of a potentiometer.

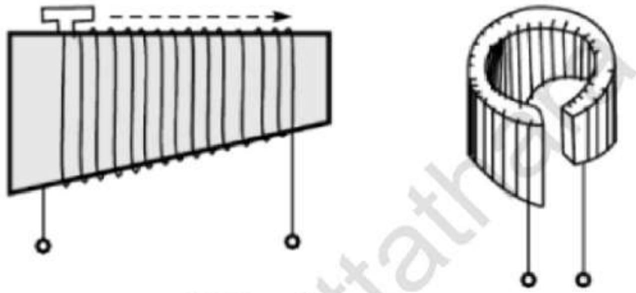


- The outer two terminal are connected to the end points of the resistance element and the middle leads to the rotating contact.
- There is a rotating shaft at the centre of the core. The shaft moves the contact point from end to end of the resistance element.
- By rotating the shaft, resistance value is varied from minimum (0 ohm) or maximum rated value

A potentiometer can be either linear or non-linear.



(a) Linear type



(b) Non-linear type

Wire wound over an **uniform core**	Wire wound over a **non-uniform core**
Resistances varies uniformly with Linear variation of contact point	**Resistances varies non-uniformly** with Linear variation of contact point

Capacitors

- A capacitor is a device that stores energy in the form of Electric Field.
- Capacitance is a measure of a capacitor's ability to store charge.
- Amount of charge stored in a capacitor is proportional to applied voltage. And the proportionality constant is capacitance

$$Q = CV$$

where Q – charge stored (in coulombs)
V- voltage across the capacitor

- The unit of capacitance is the Farad (F) and capacitors are commonly found ranging from a few picofarads (pF) to hundreds of microfarads (μF).
- Impendence of capacitance: $X_c = \frac{1}{jwC}$; $w = 2\pi f$

$$X_c = \frac{1}{j2\pi f C}$$

Info:

Impedance = Resistance + Reactance

Electrical **impedance** is the measure of the opposition that a circuit presents to a current when a voltage is applied. **Impedance** extends the concept of resistance to AC circuits, and possesses both magnitude and phase, unlike resistance, which has only magnitude.

- A capacitor offers **low impedance to AC**, but very **high impedance to DC**.
  i.e, it allows AC to pass through it and block DC.
- Applications:
  - ✓ Used in filtering circuits
  - ✓ Used as coupling capacitor so as to couple different AC circuits.
  - ✓ Used in Amplifier circuits
  - ✓ Used as a bypass capacitor, where it bypasses the ac through it without letting the ac to go through the circuit across which it is connected.

- The most common form of capacitors is made of two parallel plates separated by a dielectric material.

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

A : Area of the plate

ε: *permeability of dielectric material*; $\varepsilon = \varepsilon_0 \varepsilon_r$

d : distance b/w two plates

Extra info:

A dielectric (or dielectric material) is an electrical insulator that can be polarized by an applied electric field. The dielectric constant - also called the relative permittivity, ε_r indicates how easily a material can become polarized by imposition of an electric field on an insulator.

ε_0 : permittivity of space or vacuum".

Types of Capacitors

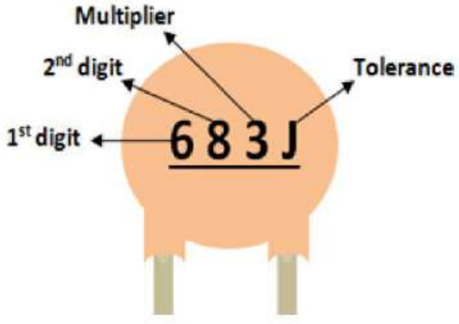
1. Fixed capacitor are classified based on dielectric used
    a) Mica capacitor
    b) Paper capacitor
    c) Electrolytic capacitor
    d) Ceramic capacitor
2. Variable capacitor are mostly air-gang capacitor

Mica capacitors

- ✓ Mica is used as dielectric
- ✓ Constructed from plates of aluminium foil separated by sheets of mica
  The plates are connected to two electrodes.
- ✓ The mica capacitors have excellent characteristics in high temperature and high voltage condition.
- ✓ Available capacitances range from 5 to 10,000 pF.
- ✓ Mica capacitors are usually rated at 500 V.
- ✓ Its leakage current is very small ($R_{leakage}$=1000M**Ω**)

Ceramic capacitors

- ✓ Ceramic is used as dielectric.
- ✓ Available in different shapes and sizes.
- ✓ A ceramic disc is coated on two sides with a metal, such as copper or silver. These coatings act as the two plates and leads are also attached to each plate. Then the entire unit is coated with plastic and marked with its capacitance value—either using numerals or a colour code.
- ✓ Besides the value of the resistor (or capacitor), it also indicates the tolerance and temperature coefficients.
- ✓ Voltage ranges from 3 V (for use in transistors) up to 6000 V.
- ✓ Capacitance ranges from 3 pF to about 2 μF. Ceramic capacitors have a very low leakage currents.
- ✓ Its leakage current is very low. ($R_{leakage}$ = 1000M**Ω**)
  Hence, they are used in AC and DC circuits.



Identifying Ceramic Capacitors: The value of a ceramic capacitance will not be directly mentioned on the capacitor. There will always be a three digit number followed by a variable.

In this case 68 is the digit and 3 is the multiplier. So 68 should be multiplied with 10^3. Simple put it is 68 followed by 3 zeros. Hence the value of this capacitor will be 68000 pF.

Code	Tolerance	Colour
F	**±1%**	**Brown**
G	**±2%**	**Red**
J	**±5%**	**Green***
K	**±10%**	**White***
M	**±20%**	**Black***

Notice the unit should always be pF.

Some times, Tolerance value may not be written in the code

Code	**Picofarad (pF)**	Nanofarad (nF)
100	**10pF**	0.01nF
470	**47pF**	0.047nF
104	**10000pF**	100nF

Note: UNITS

1000 nanofarad(nF) = 1 microfarad(μF)

1 picofarad = 10^{-12}farads.

Nano= 10^{-9}

Micro= 10^{-6}

1 Nano Farad= 10^{-9} Farad

1 Microfarad (μF)= 10^{-6} Farad

1 nF = 1000 pF

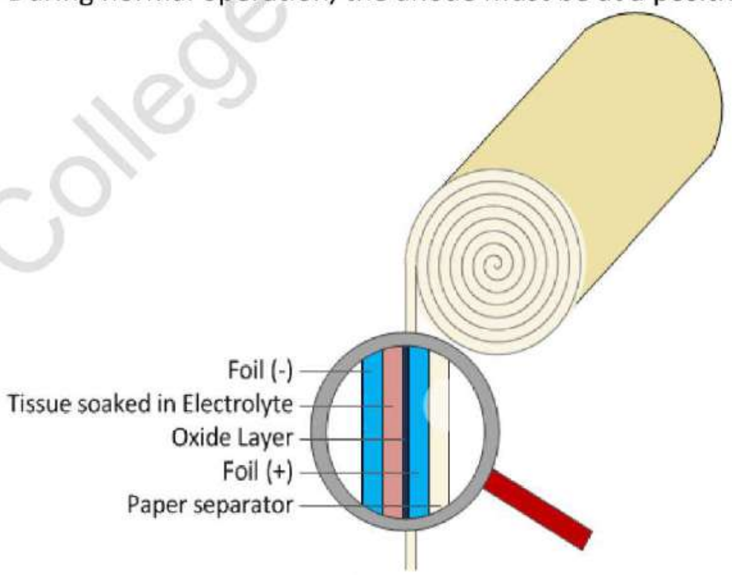
1 pF = 0.001 nF

Paper capacitors

- ✓ Paper is used as dielectric.
- ✓ The capacitor consists of two metal foils separated by strips of paper.
- ✓ This paper is soaked with a dielectric material such as wax, plastic or oil.
- ✓ capacitances ranging from 0.0005 μF to several μF
- ✓ Voltage rated from about 100 V to several thousand volts.
- ✓ They can be used for both DC and AC circuits. Its leakage resistance is of the order of 100 M**Ω**

Electrolytic capacitor

- ✓ Electrolyte is used as dielectric.
- ✓ Made of two Aluminium foils and a paper spacer soaked in electrolyte.
  Aluminium foils covered with an oxide layer acts as the anode,
  while the uncoated Aluminium foils acts as a cathode.
  During normal operation, the anode must be at a positive voltage in relation to the cathode



- Ordinary Electrolytic capacitor uses Al metal foil. They are also known as Aluminium Electrolytic capacitor
- Tantalum Electrolytic capacitor uses tantalum metal foil. They are small in size and have precise value compared to Aluminium Electrolytic capacitor

- ✓ Uses an electrolyte to achieve a larger capacitance than other capacitor types.

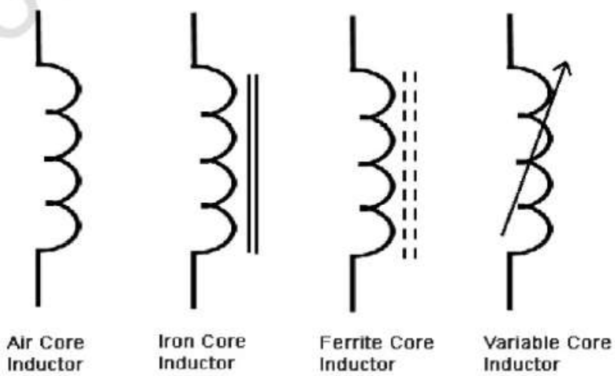
- ✓ Almost all electrolytic capacitors are polarized, which means that the voltage on the positive terminal must always be greater than the voltage on the negative terminal.
- ✓ Since they are polarized, they may be used **only in DC circuits.**
- ✓ A capacitor that has "4.7µF 25V" printed on it has a nominal capacitance value of 4.7µF and a maximum voltage rating of 25 volts, which is never to be exceeded.
- ✓ Drawback: large leakage currents and high tolerances
- ✓ There are many applications which do not need tight tolerances and AC polarization, but **require large capacitance values.**
  - Used as filtering devices in various power supplies to reduce the voltage ripple.
  - Used filters in audio amplifiers
  - Used as a bypass capacitor
  - Remove noise from a circuit
- ✓ High capacitance to size ratio. => A larger capacitance in a small volume
- ✓ Capacitance value may range from 1 µF to several thousand µF.
- ✓ Voltage ratings may range from 1 V to 500 V, or more.

Air-gang capacitor

- Air is used as dielectric
- It has two plates: One fixed and other is movable.
- By rotating the shaft at one end, we can change the common area between the movable and fixed set of plates. The greater the common area, the larger the capacitance.
- Used in tuning circuits

Inductors

- An inductor is a passive electronic component that stores energy in the form of a magnetic field.
- When current flows through a wire that has been coiled, it generates a magnetic field. This magnetic field reacts so as to oppose any change in the current. This reaction of the magnetic field, trying to keep the current flowing at a steady rate, is known as inductance; and the force it develops is called an **induced emf.** The electronic component producing inductance is called an inductor.
- The unit of inductance is a Henry (H) and common inductors range from nanohenries (nH) to microhenries (µH).

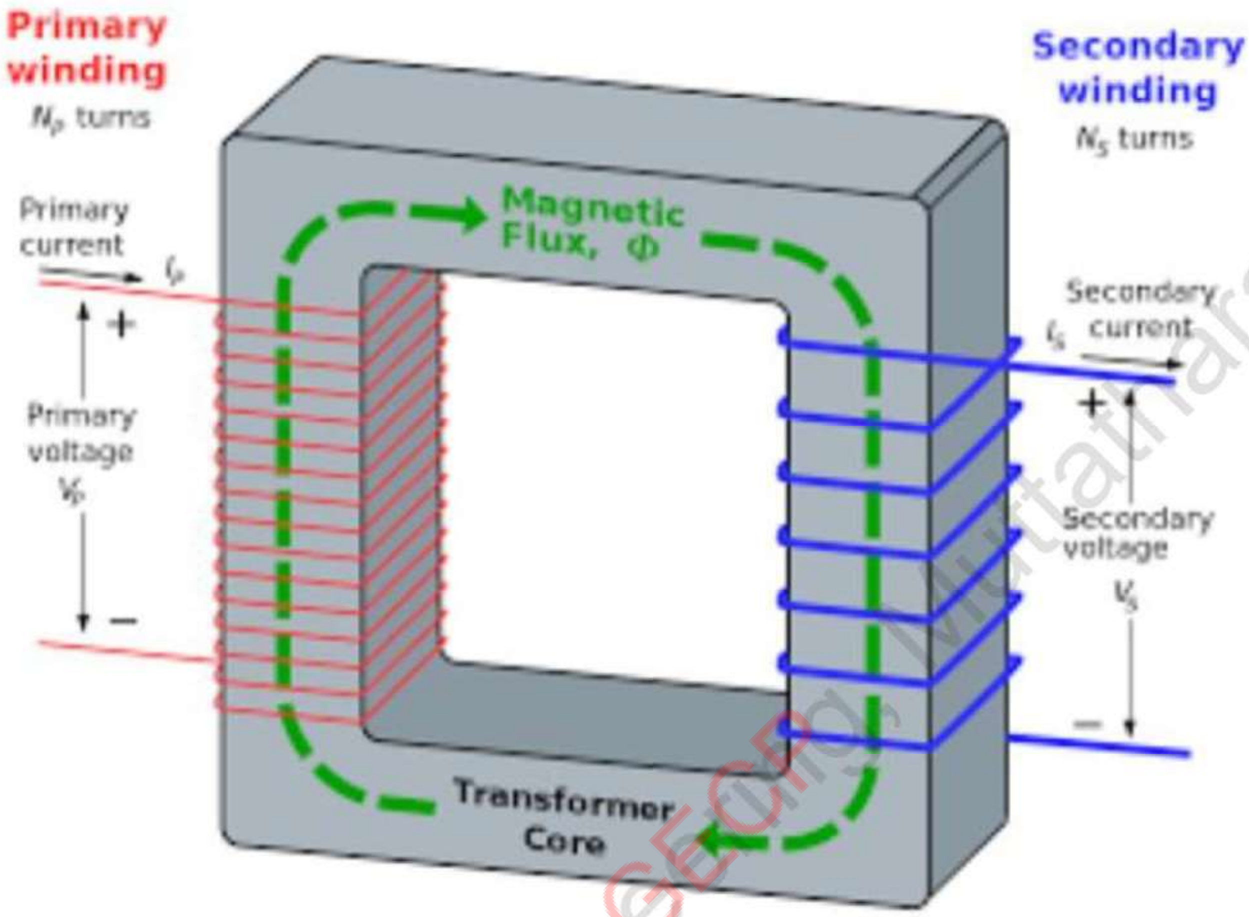


- All inductors can be listed under two general categories: fixed and variable. Different types of inductors are available for different applications.
- Impendence of Inductance: $X_L = jwL \qquad ; w = 2\pi f$

$$X_L = j2\pi f L$$

- No resistance to DC.
- Used in chokes, filter circuits, transformer;
- Variable inductors are used in auto-transformer, oscillators, etc

Transformer



- Transformer is a device which transforms electrical energy from one circuit to another without any direct electrical connection.
- **It transforms the electrical energy with the help of mutual induction between two windings**.
- It **transforms power** from one circuit to another **without change in frequency**, but the voltage may be in different levels.

✓ The two windings are electrically separated from each other but they are magnetically coupled.
✓ The two windings are wound on same core.
✓ The coil to which source is given is called **primary winding** and
✓ the coil to which load is applied is called **secondary winding**.
✓ When A.C supply is given to the primary winding, an induced voltage appears in the secondary winding.
✓ When number of turns in secondary is more than that in primary, it is called a step-up transformer.

Np<Ns
=>Vp<Vs

✓ When number of turns in secondary is less than that in primary, it is called step-down transformer.

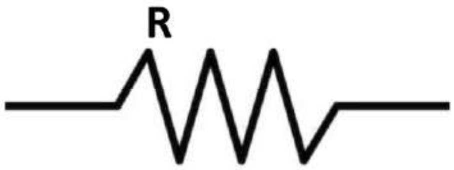
Np>Ns
=>Vp>Vs

✓ In a step-up transformer, output voltage is more than its input voltage and in a step-down transformer output voltage is less than its input voltage.

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

Symbols

Fixed Resistor



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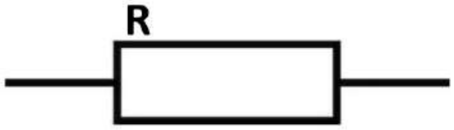
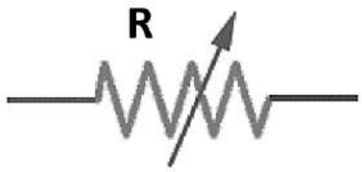


Variable Resistor

1. **Rheostat**



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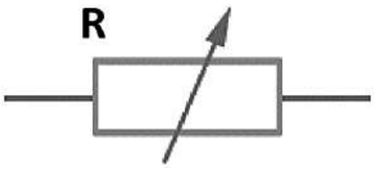

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2. **Potentiometer**

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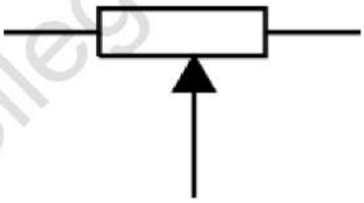
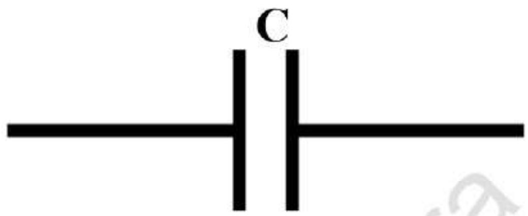


Fixed Capacitor

1) **Non-Polarized**



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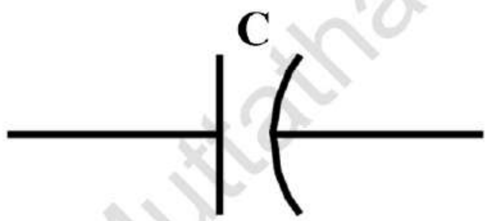

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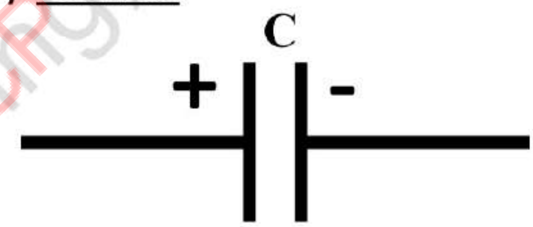
2) **Polarized**



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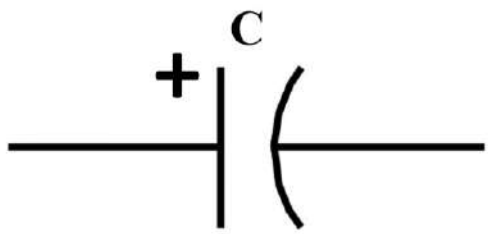
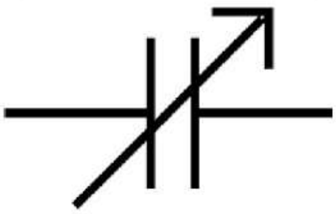
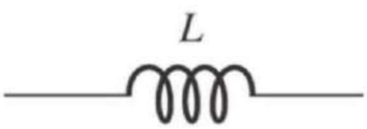


Variable Capacitor



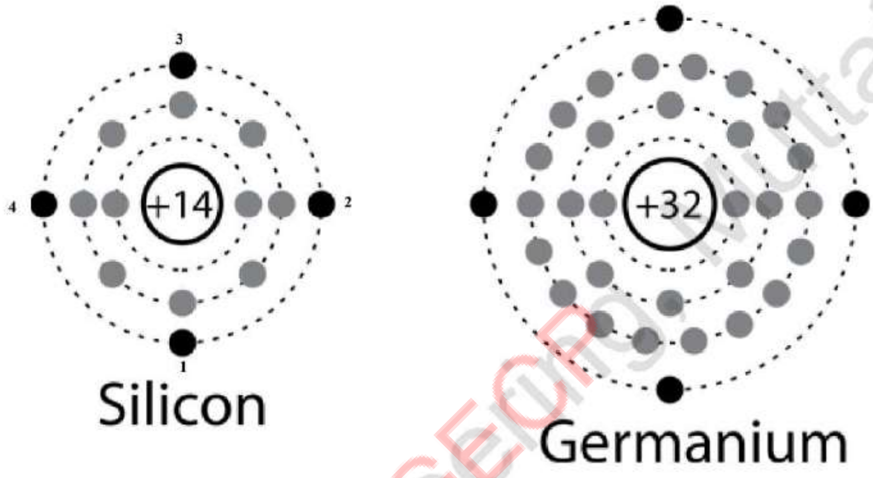
Fixed Inductor



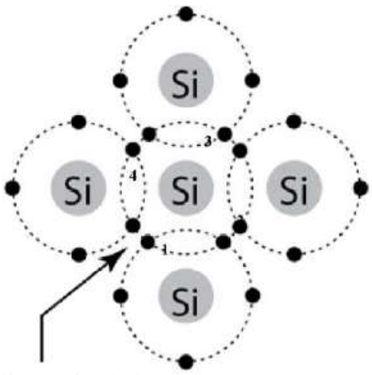
or

Energy Band Diagram

- ✓ In a single isolated atom, the electrons in each orbit have definite energy associated with it.
- ✓ In an atom, the nucleus is surrounded by electrons. Each electron has a quantized energy level.
- ✓ An electron orbiting close to the nucleus is very much firmly bound to the nucleus and keeps only a small amount of energy.
- ✓ Therefore, initial orbit has lowermost energy levels.
- ✓ Electrons farther away from the nucleus have higher energy levels than those closer to the nucleus.
- ✓ So, the energy level of the outmost orbit is maximum. Due to such high energy, valence electrons in the outmost shell can be effortlessly extracted out and therefore such electrons take part in chemical reactions and in bonding with the atoms together. Now this discussion is linked to the electron and shell of one isolated atom.



- ✓ But **in case of solids**, all the atoms are close to each other, so the **energy levels of outermost orbit electrons** are **affected by the neighbouring atoms.**
- ✓ When isolated atoms are brought close to each other, then the **outermost orbit electrons of atoms interact with each other.** i.e, the electrons in the outermost orbit of one atom experience an attractive force from the nearest or neighbouring atomic nucleus. Due to this the energies of the electrons will not be in same level; the energy levels of electrons are changed to a value which is higher or lower than that of the original energy level of the electron.
- ✓ The electrons in same orbit exhibits different energy levels. **The grouping of this different energy levels** is called **energy band.**



Shared electrons
of a covalent
bond. (In case of Semiconductors)

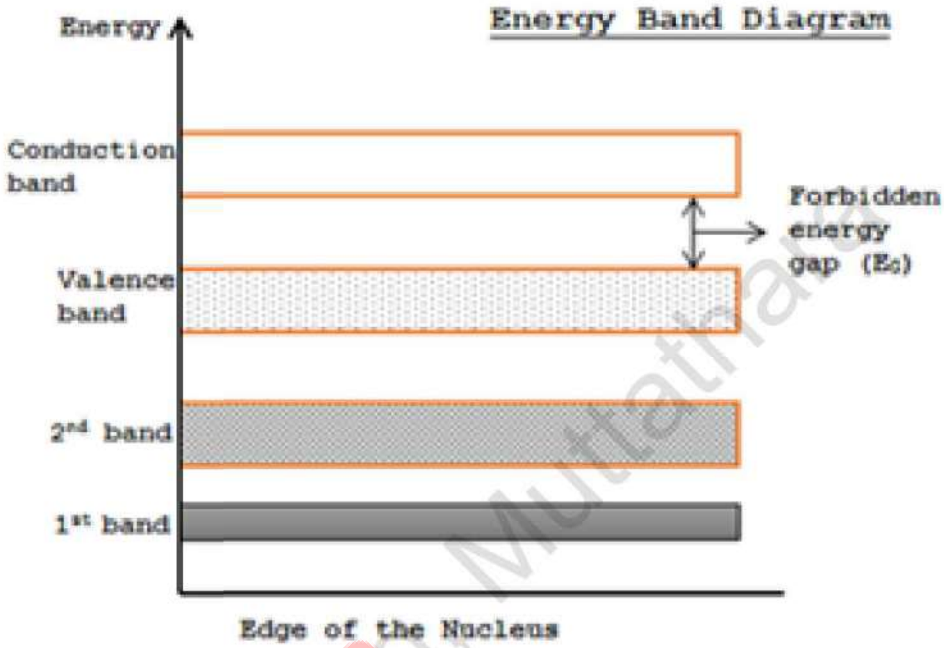
- ✓ However, the energy levels of inner orbit electrons are least affected by the presence of neighbouring atoms.

Important energy bands in solids

There are number of energy bands in solids, but three of them are very important. These three energy bands are important to understand the behaviour of solids.

These energy bands are

1. Valence band
2. Conduction band
3. Forbidden energy gap



<u>**Valence band**</u>

- ✓ The energy band which is formed by grouping the range of energy levels of the valence electrons (or outermost orbit electrons) is called as valence band.
- ✓ Electrons in the valence band have lower energy than the electrons in conduction band.

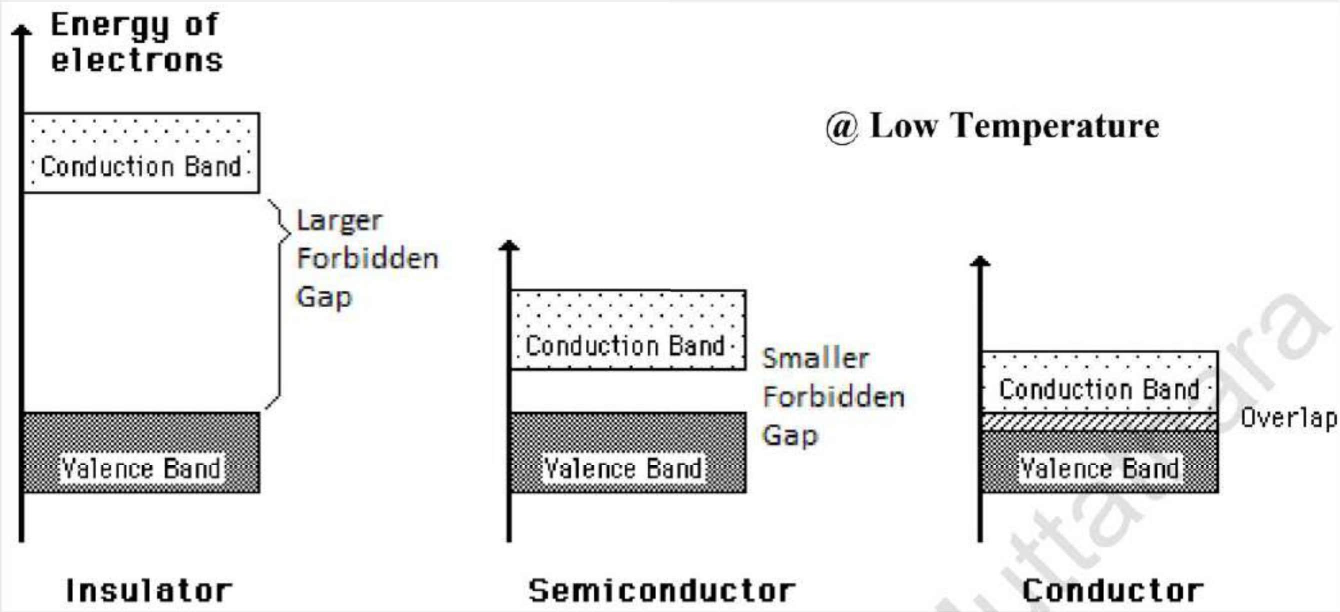
<u>**Conduction band**</u>

- ✓ The energy band which is formed by grouping the range of energy levels of the free electrons is called as conduction band.
- ✓ Generally, Valence band is present below the conduction band.
- ✓ Generally, the conduction band is empty. **But when external energy is applied, the electrons in the valence band jumps in to the conduction band and becomes free electrons**.
  i.e., when an electron leaves its orbit, it becomes a free electron.
  At that same time, it leaves a vacant space in the Valance band & that **vacancy of electron is called a Hole.**
  i.e, for every free electron, there will be a corresponding hole produced, which is known as an **Electron-Hole pair.**
- ✓ Therefore, **Free Electrons in the conduction band**
  a) **have higher energy** than the electrons in valence band.
  b) **are not bound to the nucleus of atom**.

<u>**Forbidden energy gap (E_G)**</u>

- ✓ The **separation between conduction band and valence band** on the energy level diagram is known as forbidden energy gap.
- ✓ measured in the unit of **electron-volt (eV).**
- ✓ In order to push an electron from valence band to the conduction band, **External energy provided must be equal to the forbidden energy gap.**

Classification of Materials based on Energy Band Diagram



(a) **Insulators**

- Insulators are those substances which **do not allow the passage of electric current through them**.
- The Insulator has:
  - ✓ Filled valence band
  - ✓ Empty conduction band
  - ✓ Larger forbidden energy gap **(E_G> 5eV).**
- Therefore, a very high external energy is required to push the valence electrons to the conduction band. For this reason, the electrical conductivity of such materials is extremely small.
- At room temperature, the valence electrons of the insulators do not have enough energy to cross over to the conduction band.
- However, when the temperature is raised, some of the valence electrons may acquire enough energy to cross over to the conduction band. Hence, **the resistance of an insulator decreases with the increase in temperature i.e. an insulator has negative temperature coefficient of resistance.**
- E.g.: wood, glass, plastics, rubber, etc.

(b) **Conductors**

- Conductors are those substances which **easily allow the passage of electric current through them**.
- It is because there are a large number of free electrons available in a conductor.
- In terms of energy band as in Figure, the valence and conduction **bands overlap each other**.
- Due to this overlapping; a slight potential difference across a conductor causes the free electrons to constitute electric current.
- e.g. copper, aluminium, etc

(c) **Semiconductors**

- Semiconductors are those substances whose electrical conductivity lies in between conductors and insulators.
- The semiconductor (@ lower temperature) has:
  - ✓ Filled valence band
  - ✓ Empty conduction band
  - ✓ Small forbidden energy gap (around **1 eV**)
- Semiconductor virtually **behaves as an insulator at low temperatures**.

- However, at higher temperature, some electrons cross over to the conduction band, resulting in little conductivity (i.e., **it behaves like conductor at higher temperature**).
- e.g. germanium, silicon, etc.

Semiconductors are classified into two types

1) Intrinsic Semiconductor

A **semiconductor in an extremely pure form** is known as an intrinsic semiconductor.

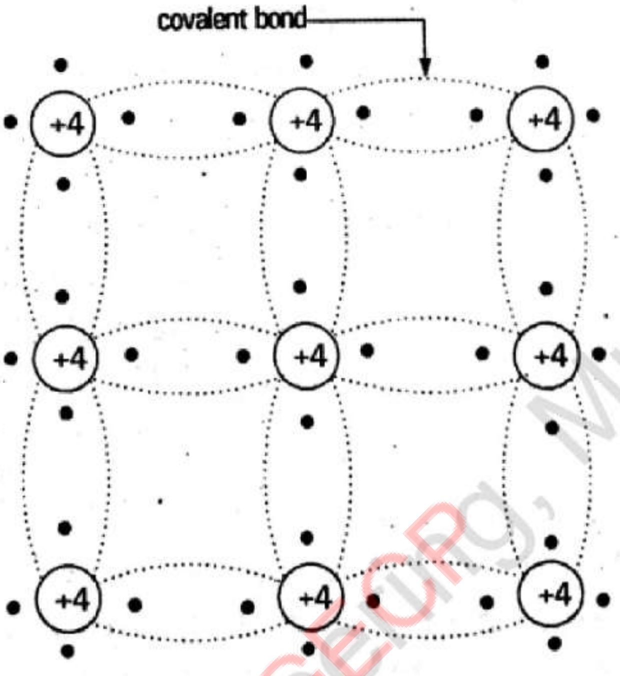
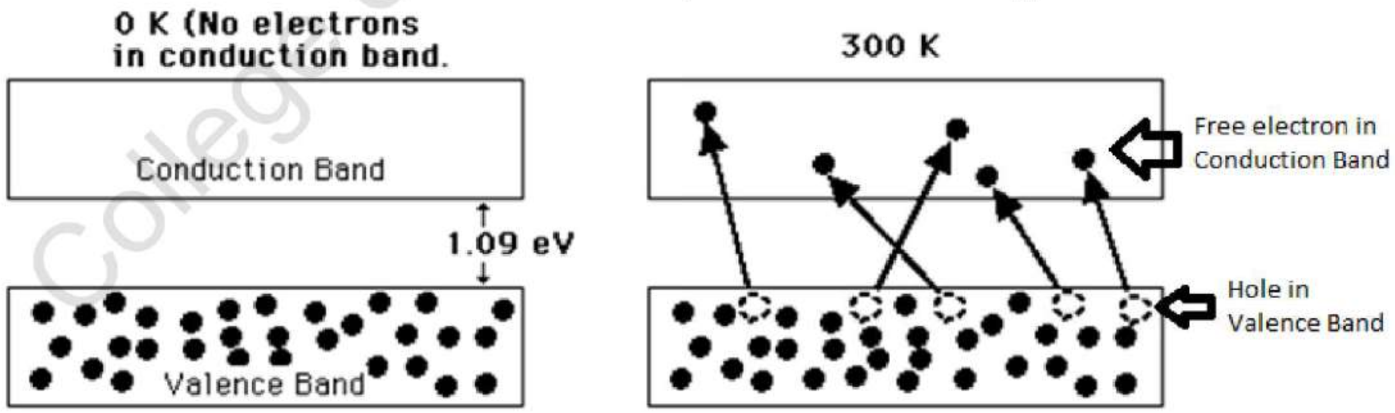


Fig: Valence bond Diagram of an Intrinsic Semiconductor

- The free electrons are produced due to the **breaking up of some covalent bonds by thermal energy.**
- At the same time, holes are created in the covalent bonds.
- Under the influence of electric field, **conduction through the semiconductor is by both free electrons and holes**.
- Therefore, the total current inside the semiconductor is the **sum of currents due to free electrons and holes**.
- An intrinsic semiconductor is also called an **undoped semiconductor** or **i-type semiconductor.**



- **As temperature increases, => more electron-hole pairs are generated**
  => greater the concentration of charge carries
  => increase in conductivity
  => decrease in resistivity

Therefore, Semiconductor has negative temperature coefficient of resistance

2) Extrinsic Semiconductors

- The conductivity of the Semiconductor can be increased by adding a small amount of suitable impurity (having 3 or 5 valence electron) to that semiconductor (having 4 valence electron).
- This process of adding impurity to the semiconductor is known as **Doping.**
- **The material formed by doping is called as Extrinsic Semiconductor**

Extrinsic semiconductors are basically of two types:

(a) **n-type semiconductors**

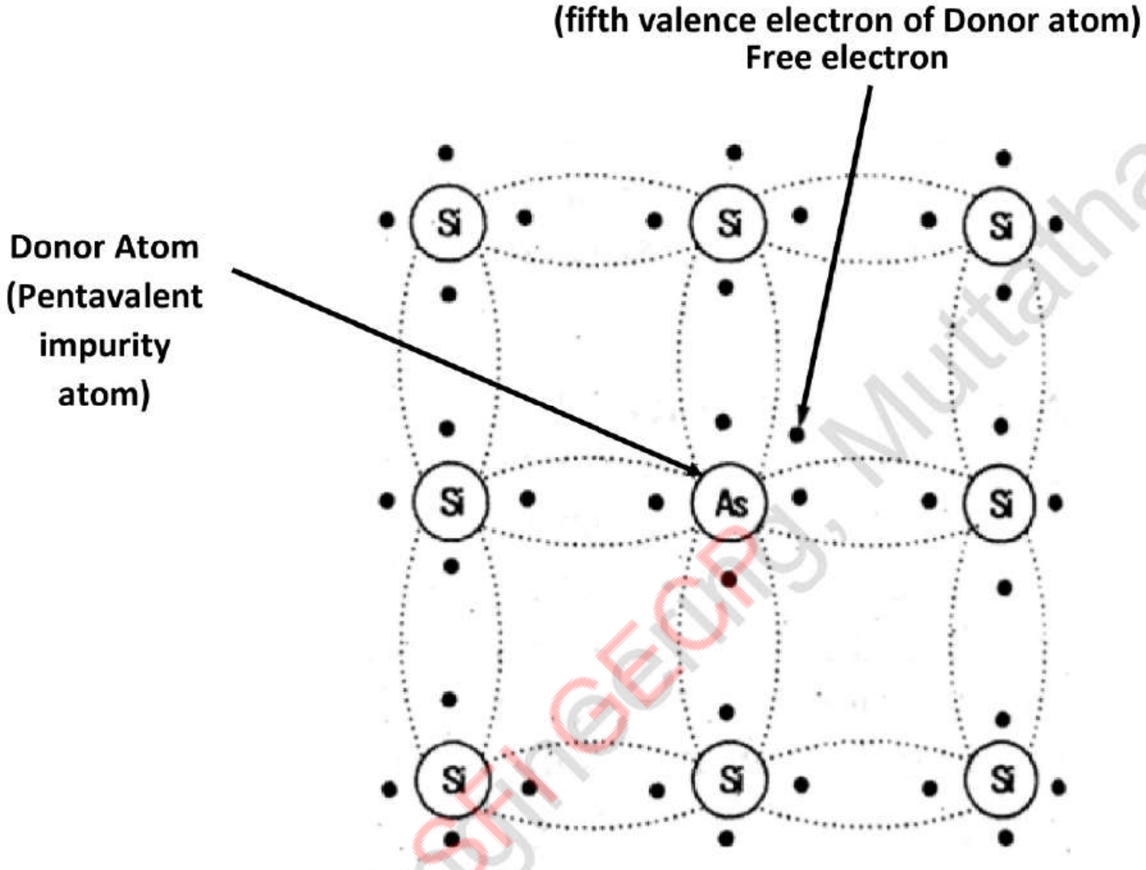
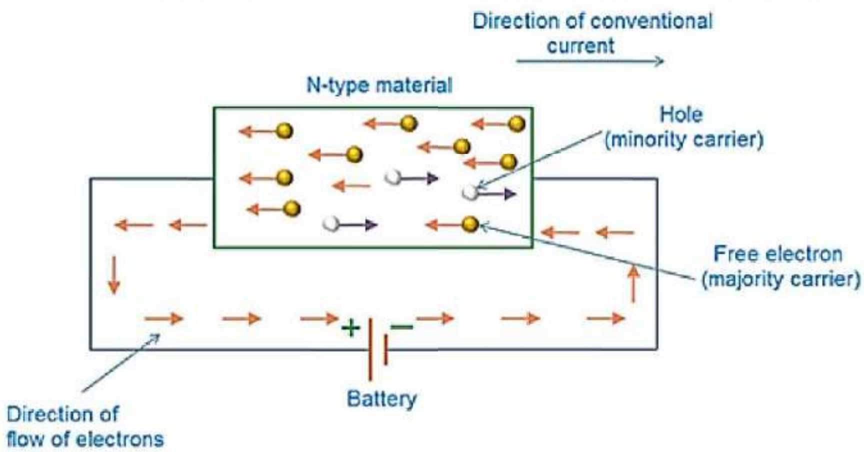


Fig: Valence bond Diagram of an n-type Semiconductor

- Obtained by **doping the Intrinsic semiconductor with a Pentavalent impurity material.**
- E.g. of Pentavalent material**: Arsenic (As), Antimony (Sb), Bismuth (Bi), Phosphorous (P), etc**
- The addition of pentavalent impurity provides a **large number of free electrons** in the semiconductor crystal.
- Such impurities which produce n-type semiconductor are known as **donor impurities** because **they donate or provide free electrons to the semiconductor crystal.**
- **Electrons** are the **majority carriers** whereas **holes are the minority carriers.**



(b) **p-type semiconductors**

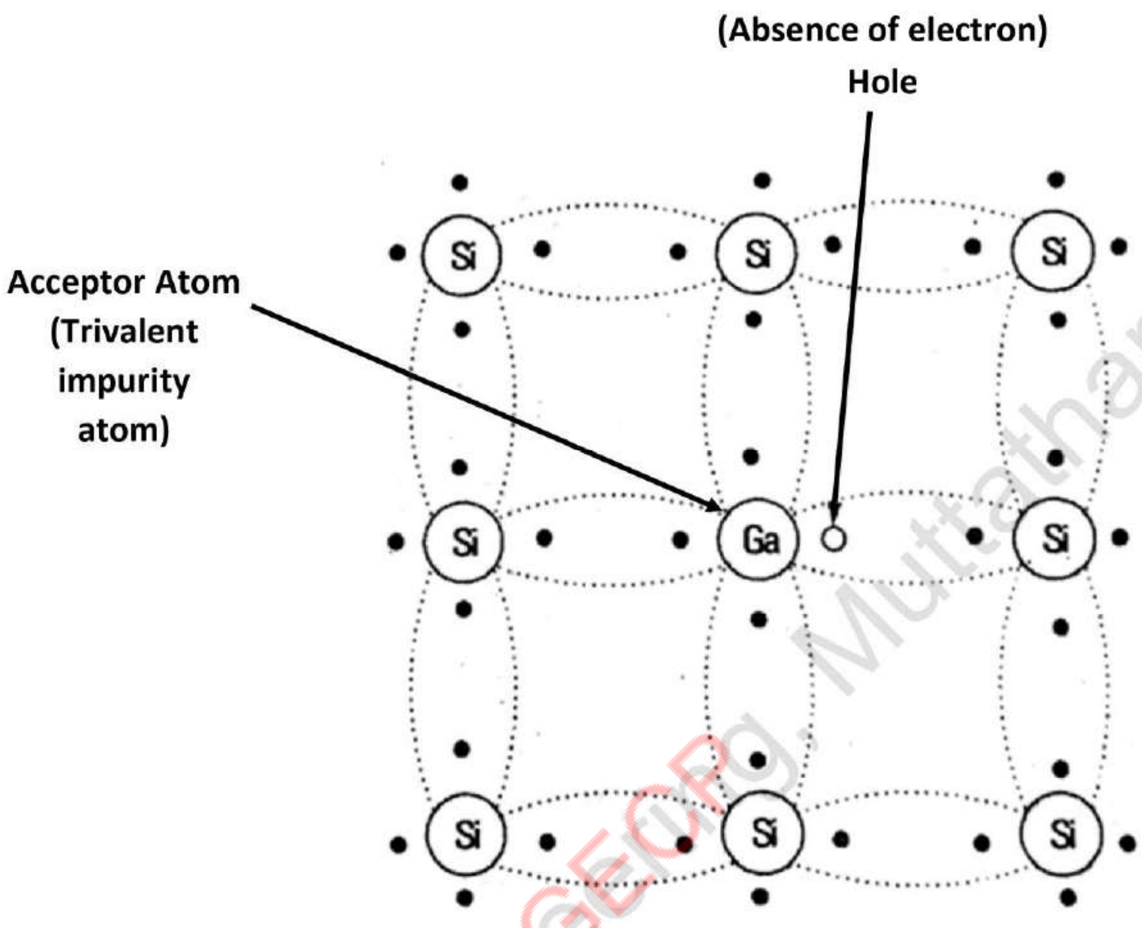
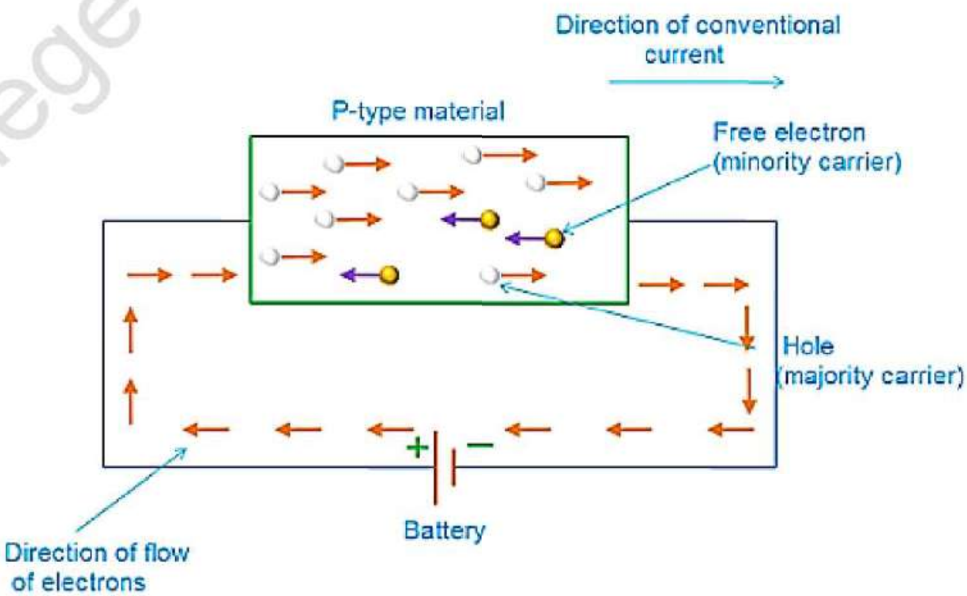


Fig: Valence bond Diagram of an p-type Semiconductor

- Obtained by **doping the Intrinsic semiconductor with a Trivalent impurity material.**
- E.g. of Pentavalent material: **Boron(B), Indium(In), Gallium(Ga),** etc
- The addition of pentavalent impurity provides **a large number of holes in the semiconductor crystal.**
- Such impurities which produce p-type semiconductor are known as **Acceptor impurities** because **the holes are ready to accept the electrons.**
- **Holes** are the **majority carriers** whereas **Electrons are the minority carriers**



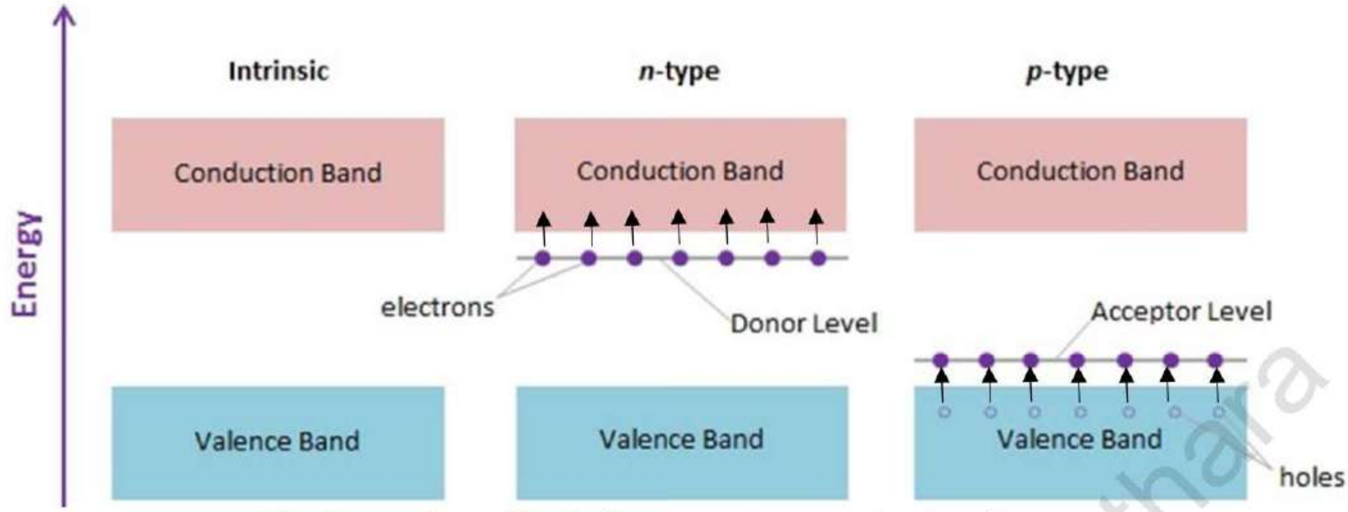
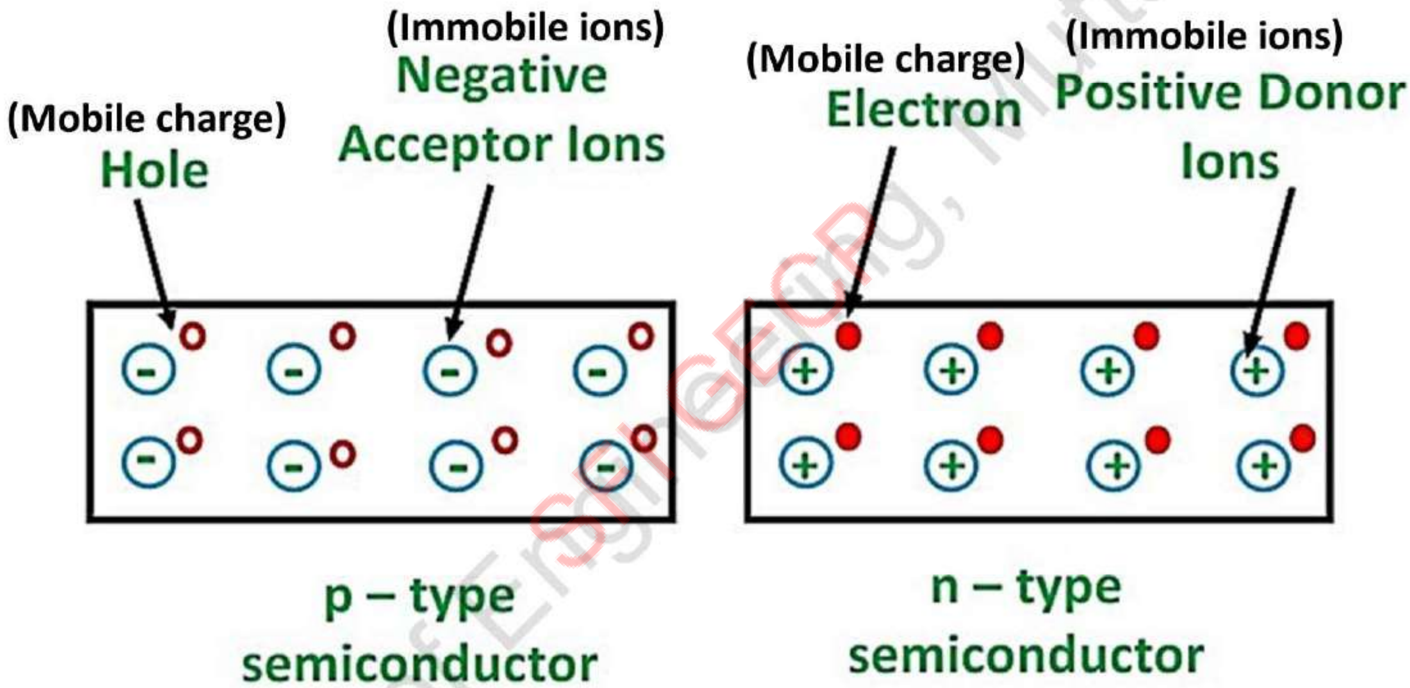
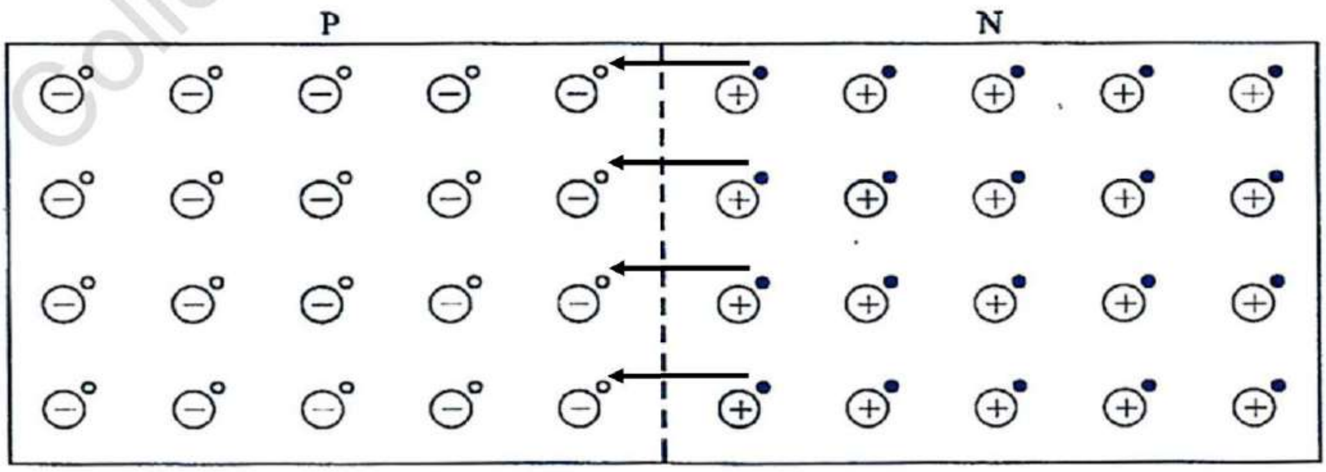


Fig: Comparison of intrinsic, p- type & n-type Semiconductor



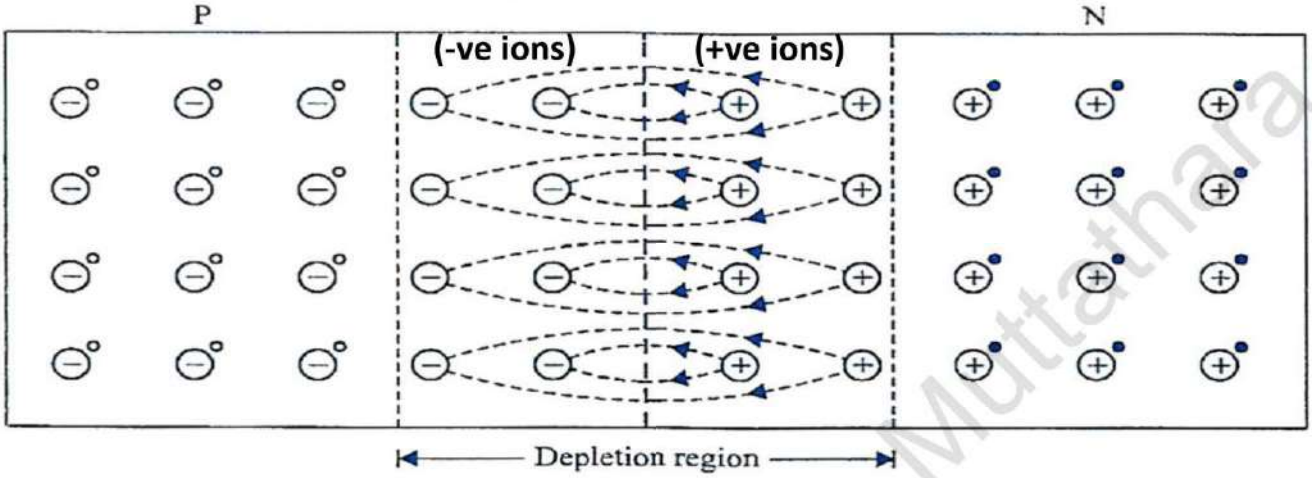
PN Junction diode

- A PN junction diode is formed by **joining a p-type semiconductor with an n-type semiconductor.**



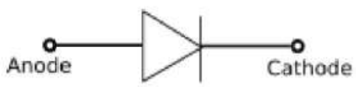
- Just after joining p-type and n-type semiconductors, initial **diffusion of charge carrier occurs** from high concentration region to low concentration region.
  i.e., **free electrons (from the n region near the junction)** begin to **diffuse across the junction into the p-region**. As the **free electrons** from n-side **recombine** with **holes** in p side, the region near the junction lose their neutrality and become charged, forming the **space charge region or depletion layer.**

At Equilibrium Condition



(Depleted of charge carries)
i.e., Region of Immobile ions only which stops any further diffusion of majority charge carriers through the junction)

- **Negative ions created on p-side** close to the junction will **acquire a negative voltage**.
- **Positive ions created on n-side** close to the junction will **acquire a positive voltage**.
- **Negative voltage on p-side** will **repel** diffusion of **electrons from the n-side.**
- **Positive voltage on n-side** will **repel** diffusion of **holes from the p-side.**
- The **dipole effect of oppositely charged immobile ions** in depletion region results in a **potential difference** (i.e., voltage) b/w the two ends of the depletion region.
- At equilibrium, **this potential acts as a barrier to the flow of majority carriers**. So, this potential is called **barrier potential** or **built-in potential** or **contact potential.**
- Barrier potential depends on the type of semiconductor material.
- Its value is **0.7 V for Silicon**
  0.3 V for Germanium **@ room temperature (25° C)**



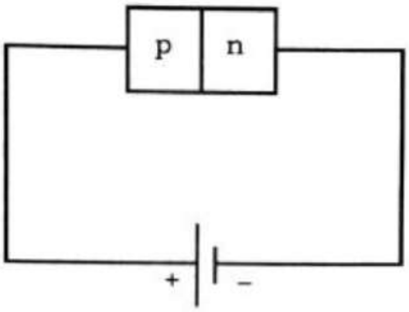
- **Symbol for PN junction diode=>**
- Function: Diodes allow electricity to flow in only one direction.
- The arrow of the circuit symbol shows the direction in which the current can flow.

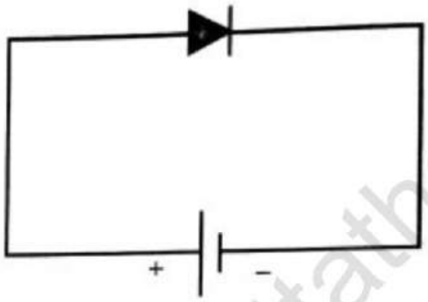
Principle of operation of a PN junction Diode

To bias a diode, you apply a d.c. voltage across it.

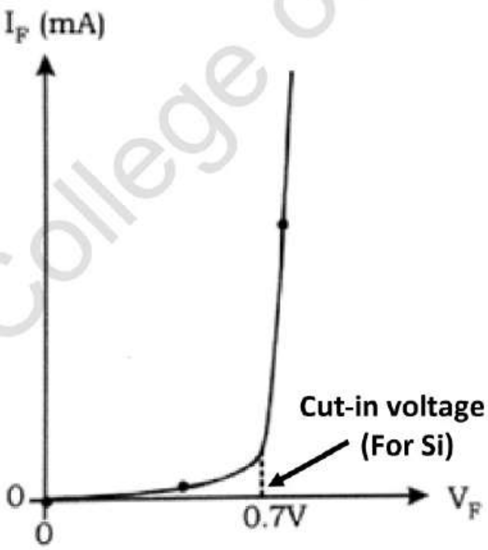
1) **Forward -biased condition**

- A p-n junction diode is said to be forward biased if
  - ✓ **p-side** is connected to **positive terminal** of the **battery** and
  - ✓ **n-side** is connected to **negative terminal** of the **battery**





- When a p-n junction is forward biased, the **positive terminal of the battery repels the holes** in the p-region **towards the junction.**
- Similarly, the **negative terminal of the battery repels the electrons** in the n-region **towards the junction**.
- Since the **holes and electrons have acquired energy from the voltage source**, some of these enter into depletion layer and they recombine at the junction. This **reduces the width of the potential barrier.**
- **If the applied voltage is gradually increased from zero, the barrier potential also gets gradually reduced, until it disappears**.
- This results in the **diffusion of more majority carriers across the junction**.
- A large current known as **forward current flows through the p-n junction**.
- The **forward current I_F** is due to the **movement of holes in the p-region** and **electrons in the n-region.**
- **The current due to holes and electrons flow inside the p-n junction diode.** But in the current in the external circuit is only due to the motion of electrons.
- **Forward Biased V-I characteristics**



✓ The applied voltage V_F increases beyond the certain value, the forward current I_F increases sharply.

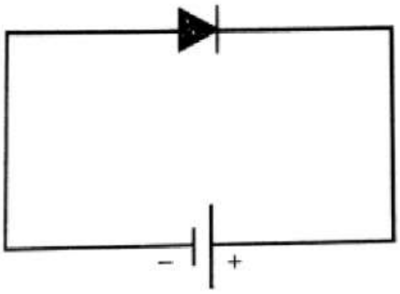
✓ The diode permits the current to flow only if external applied voltage overcomes the barrier potential.

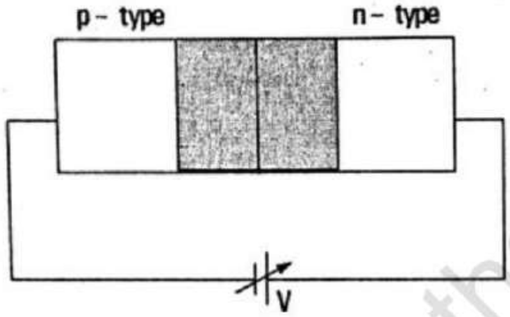
✓ Minimum voltage required for the diode to conduct is called **Cut-in voltage**

✓ If **forward voltage is increased beyond a certain safe value,** it will produce an extremely **large current** which may **destroy the junction due to overheating.**

2) **Reverse Biased condition**

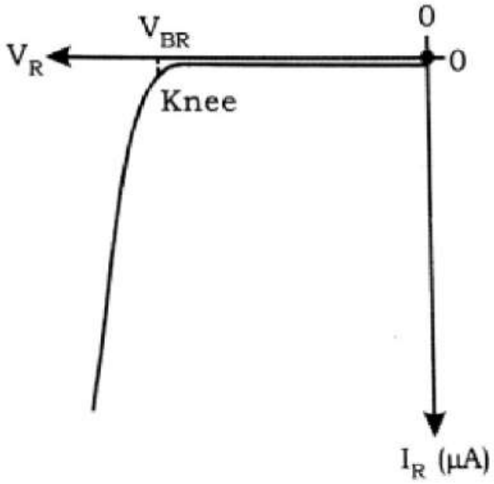
- Reverse bias is the condition that essentially prevents current through the diode.
- A p-n junction diode is said to be reverse biased if
  - ✓ **p-side** is connected to **negative terminal** of the **battery** and
  - ✓ **n-side** is connected to **positive terminal** of the **battery**

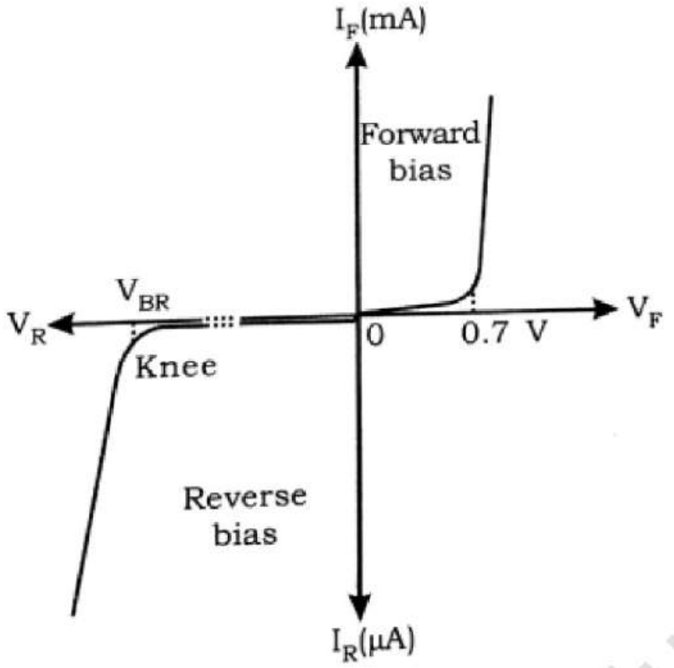




- When a p-n junction is reverse biased
  - ✓ the **holes in the p-region** are **attracted by the negative terminal** of the battery and
  - ✓ the **electrons in n-region** are **attracted by the positive terminal** of the battery.
  - ✓ Because of this, **majority charge carriers repelled away from the junction**.
  - ✓ As a result, **width of the depletion region increases** as **reversed biased voltage increases.**
  - ✓ Due to **increase in barrier potential**, **the majority carrier current cannot flow across the junction**. The **reverse biased p-n junction** thus offers **very high resistance.**
- However, the barrier potential helps the minority carriers in crossing the junction. Because of thermal energy, a **small current** of **the order of** few micro amperes **flows** in the external circuit.
- **The reverse current caused by thermally produced minority carriers is called the reverse saturation current or leakage current.**
- If **reverse voltage is increased continuously beyond a knee value**,
  => **kinetic energy of the electrons (minority carriers)**
  =>These electrons available as minority carriers **get accelerated due to high reverse voltage.**
  =>They **again collide with other atoms** to **generate more minority carriers.**
  =>Finally, **large number of minority carriers** move across the junction,
  => **sudden increase in reverse current**
  =>Thus, **breakdown of the junction occurs**

This effect is known as **avalanche effect** and the mechanism of destroying the junction is called **reverse breakdown of p-n junction**. The reverse voltage at which the breakdown of a p-n junction occurs is called **reverse breakdown voltage V_{RB}.**





Graph: complete V-I characteristics curve of a diode

DC Resistance or Static Resistance:

- ✓ The resistance of a diode at a particular operating point is called the **DC Resistance or Static Resistance of the diode.**
- ✓ It is defined as the ratio of the dc voltage across the diode to the resulting dc current flowing through it.
- ✓ **Static Resistance in the forward biased region is given by**

$$R_{dc} = \frac{V_F}{I_F}$$

AC Resistance or Dynamic Resistance:

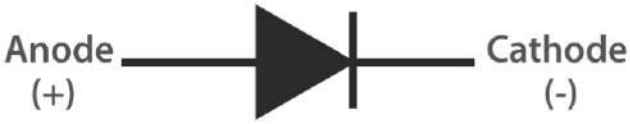
- ✓ It is defined as the ratio of small change in forward voltage to the corresponding change in the diode current.
- ✓ **Dynamic Resistance** of a diode at a particular dc voltage is equal to the reciprocal of the slope of the characteristics at that point
- ✓ **Dynamic Resistance is given by**

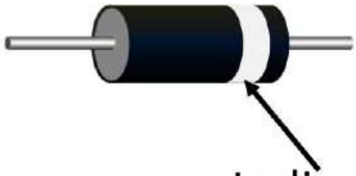
$$R_{ac} = \frac{\Delta V}{\Delta I} = \frac{1}{\Delta I/_{\Delta V}} = \frac{1}{slope}$$

<u>**Avalanche breakdown**</u>

In **reverse-bias condition**, a **thermally generated carrier** comes to the junction barrier and **gains energy from the applied voltage**. This carrier **collides with a crystal ion** and **imports enough energy to break the covalent bond**. Thus, a **new electron-hole pair Is generated**. These **new carriers** may **also gain sufficient energy from the applied field** and produce still **another pair of electron-hole** when they collide with another crystal ion.
In this chain process, **each new carrier may, in turn, produce an additional pair of electron-hole**. This chain process **results in large reverse currents**.
The diode is, then, said to be in the region of avalanche breakdown

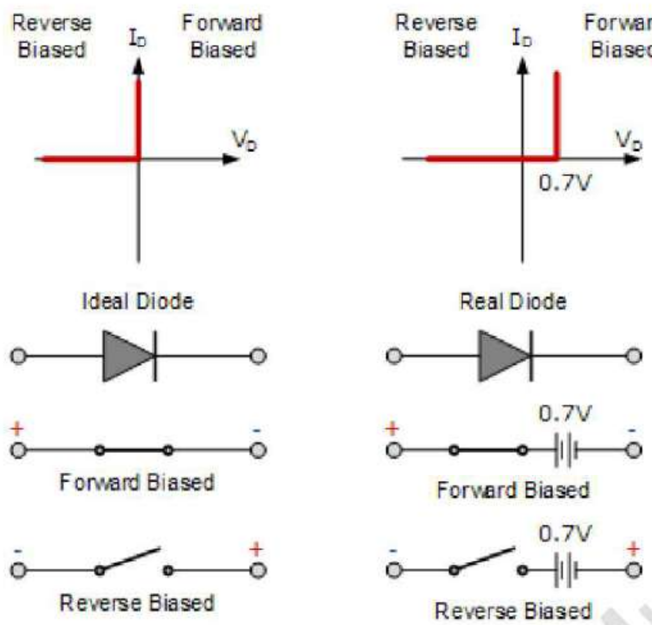
Diode Parameters





1) **Forward voltage drop, V_f**
   - ✓ **It is the voltage drop across the diode when it is forward conduction.**
   - ✓ **For silicon diodes, $V_f = 0.7$ V.**
   - ✓ **For Germanium diodes, $V_f = 0.3$ V.**
   - ✓ Diode Conduct only when the forward bias exceeds the forward voltage drop of the diode.
   - ✓ They do not conduct when reverse biased.
   - ✓ **diode ON: Voltage across the diode = V_f (forward conduction)**
   - ✓ **diode OFF: Voltage across the diode < V_f (I = 0)**
2) **Reverse Breakdown Voltage, V_{RB}**
   - ✓ It is the Minimum reverse voltage at which the breakdown of a p-n junction occurs
3) **Reverse saturation current, I_0**
   - ✓ **Ideally, diode is OFF in RB condition => Current through diode = 0 A**
   - ✓ **Practically, Current through diode $\neq$0 A**
   - ✓ **It is Leakage current due to minority charge carriers in reverse biased condition before Breakdown occurs.**
   - ✓ **Depends on the type of semiconductor used.**
   - ✓ **For Si, it in the order of nA (nano = n = 10^{-9})**
   - ✓ **For Ge, it in the order of μA (micro = μ = 10^{-6})**
   - ✓ So, Silicon diodes are preferred because Leakage current is minimum.
4) **Dynamic Resistance**
5) **Maximum Forward Current:**
   - ✓ This is the **maximum current the diode is rated to conduct**. Higher currents may destroy it.
6) **Peak Inverse Voltage (PIV):**
   - ✓ It is the maximum voltage a diode can withstand in the reverse direction without damage to PN junction.
   - ✓ This is the **maximum reverse operating voltage**. Higher voltages may cause the diode to breakdown.
7) **Maximum power ratting**:
   - ✓ It is the maximum power that can be dissipated without damage the PN junction.

Generalized Operation of Ideal Diode vs Real Diode (Silicon)



Zener Diode

- Conduct in two different bias regions.

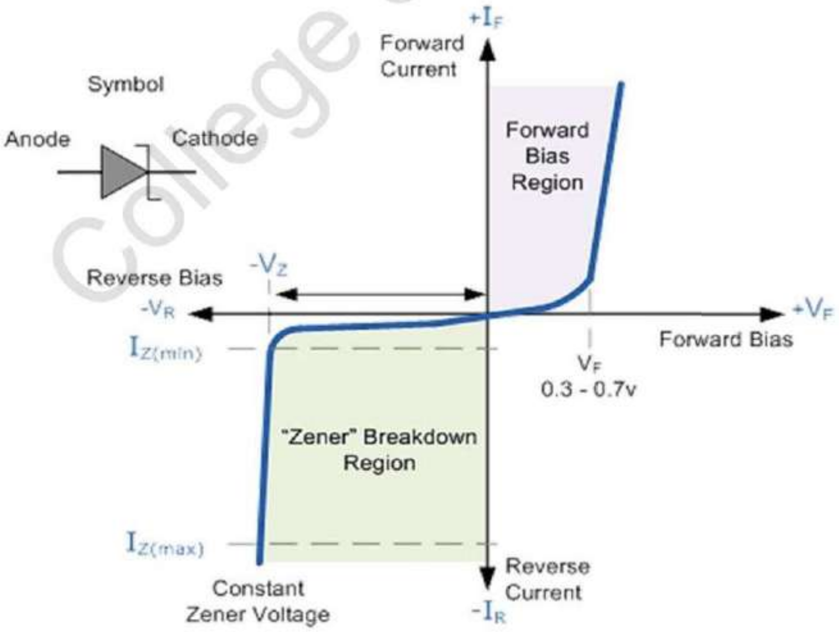
1) **In Forward biased condition, Zener diodes exhibit normal diode behaviour**
   i.e., they conduct when the forward bias exceeds the forward voltage drop of the diode.
2) They conduct in the reverse direction when the reverse bias **exceeds the Zener breakdown voltage.**

zener diode ON: **Voltage across the diode** = V_f (forward conduction)
Voltage across the diode = $-V_Z$ (**reverse** conduction)

zener diode OFF: $-V_r < V_{ac} < V_f$ ($I = 0$)

where, V_f : reverse voltage drop
V_Z : reverse breakdown voltage or **Zener breakdown Voltage** or **Zener Voltage**

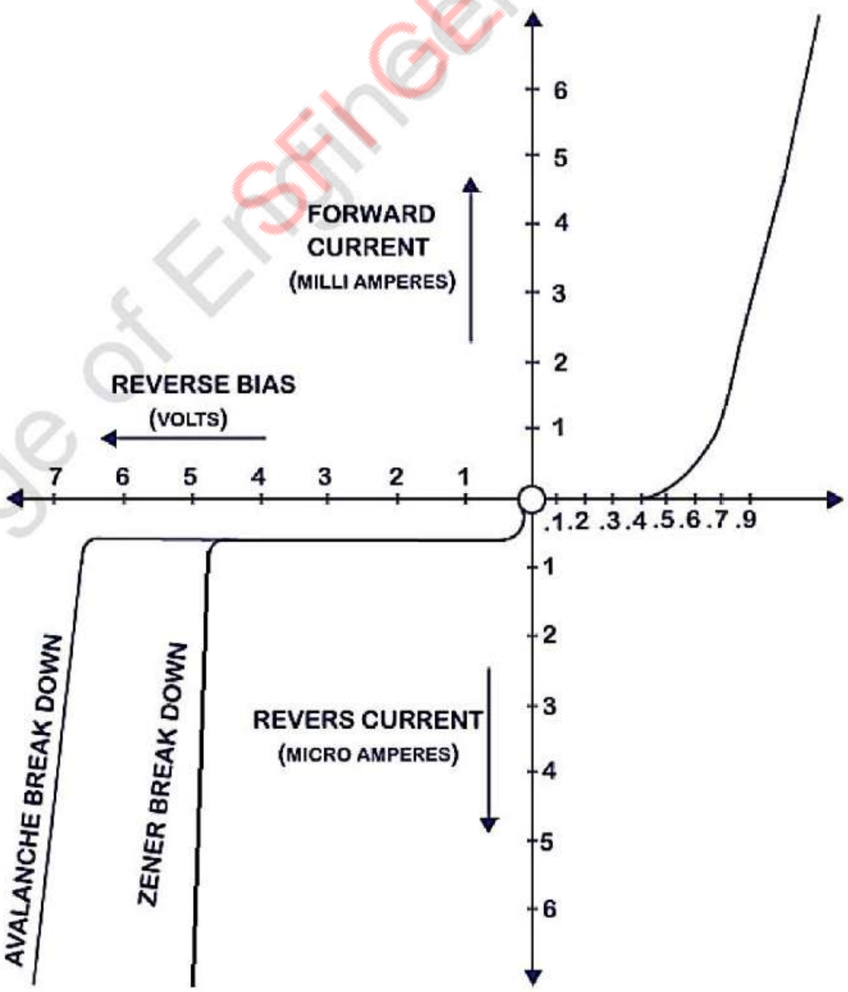
- After Zener Breakdown, Voltage across Zener diode remains constant
- Zener diodes have all the **same characteristics of normal diodes**.
- **Zener diodes are not damaged in the Zener breakdown region.**
- **The difference is that they are designed to operate in the reverse (Zener) breakdown region.**
- **Zener V-I Characteristics**



- There are two different breakdown mechanisms that can occur:
  1) **Zener Breakdown**: This effect predominates at low reverse voltages
  2) **Avalanche breakdown (**due **to Impact ionisation)**: This effect predominates high reverse voltages.
- A Zener is **highly doped to reduce the breakdown voltage**. This **causes** a **thin depletion region**.
- As a result, an **intense Electric Field exist within the depletion layer.**
  - Near the **Zener breakdown voltage (V_z),** the **field is intense enough to pull the electrons from their valance bands and create current.**

Ordinary Diode Vs Zener Diode

- **Ordinary diodes are lightly doped** as compare to the Zener diode.
- **Avalanche break down occurs due to thermal collision** caused by the increased reverse bias voltage, while the **Zener breakdown occurs due to the strong electric field caused by the high doping** (narrow depletion region).
- Therefore, **an ordinary diode can withstand large reverse bias voltage before the avalanche breakdown** happens. **If the diode is highly doped Zener breakdown will occur at low reverse bias voltage (less than 6V).**
- **In Avalanche breakdown, the diode is completely burnt off.**
  In Zener breakdown, the diode is not damaged.
- **After Avalanche Breakdown, Voltage vary. (as shown in V-I chara)**
  After Zener Breakdown, Voltage remains constant.
  i.e., Zener diode act as a constant voltage source after Zener Breakdown.
  For this reason, a zener diode is also called voltage reference diode.

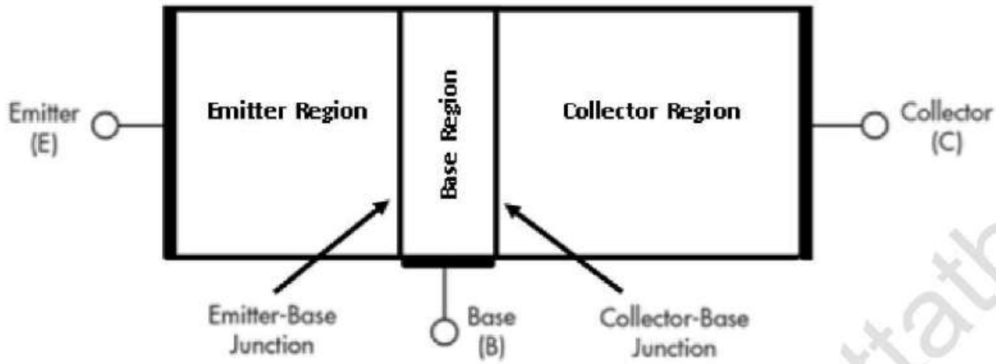


Transistor

Definition: A semiconductor device which transfers a signal from a low resistance to high resistance.

Bipolar Junction Transistor (BJT)

"Bipolar" means the presence of both majority and minority carriers.



BJT has three regions:

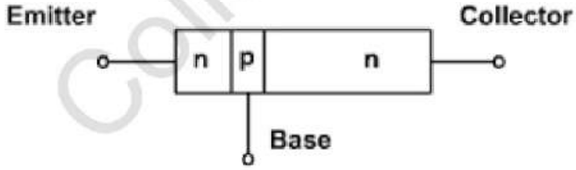
1. **Emitter, E**
    - The section on one side **that supplies carriers (Electrons/Holes).**
    - **Heavily doped** compared to other two region.
    - **Emitter region and Collector region are of same type (N or P type).**
    - **Medium in size.**
2. **Base, B**
    - **The middle section** which forms two pn junctions between emitter & collector **.**
    - **Lightly doped** compared to other two region.
    - **Smallest region.**
    - **This region controls the flow of current**
3. **Collector, C**
    - The section on one side that **collects carriers (Electrons/Holes).**
    - **Moderately doped.**
    - **Largest of all regions because it must dissipate more heat than the emitter or base regions.**

✓ **Based on Doping level: B < C < E**

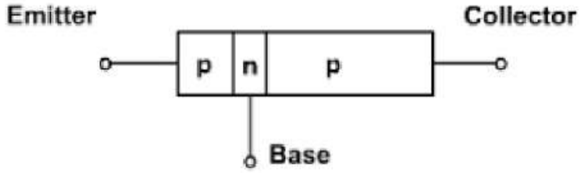
✓ **Based on Physical size: B < E < C**

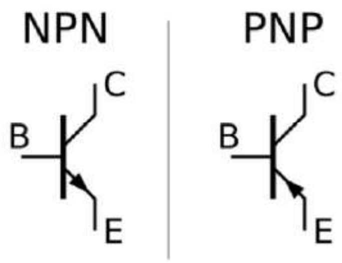
There are two types of transistors namely

i) **n-p-n transistor**



ii) **p-n-p transistor**





Hint: In Symbol representation,

The arrow point outward => npn

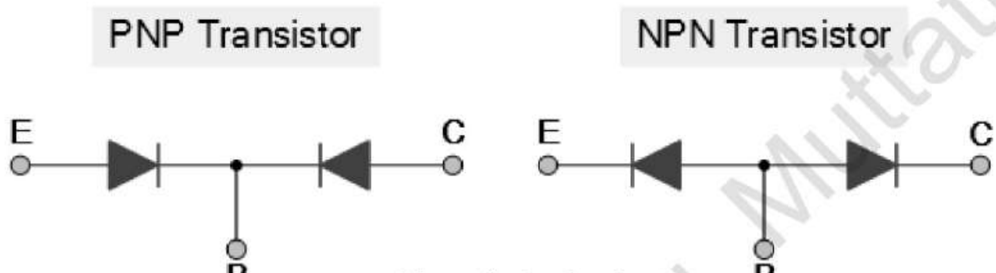
The arrow point inward => pnp

✓ **A PNP transistor is the complement of an NPN transistor.**

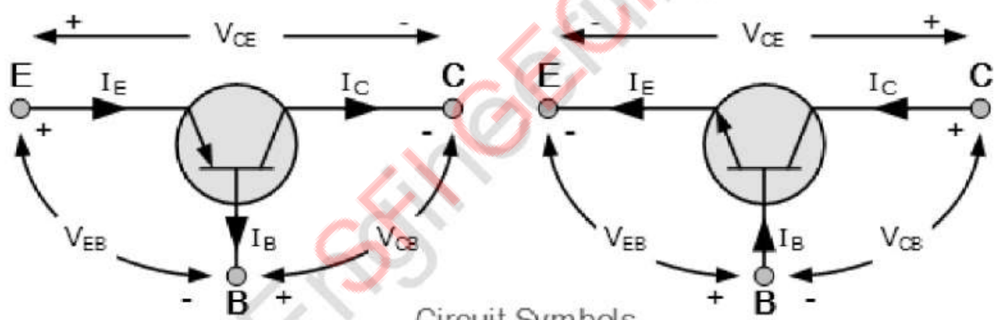
BJT has two PN junctions.

1. **Emitter Base (E-B) junction** (also known as **Emitter junction)**
2. **Collector Base (C-B) junction** (also known as **Collector junction)**

Thus, it is like two PN junction diode connected back to back. => practically, diode connected back to back can't create a transistor.



Two-diode Analogy



Circuit Symbols

Modes of Operation of BJT

E-B Junction	C-B Junction	Region of Operation	Application
Forward Biased	Forward Biased	**Saturation region**	ON Switch
Forward Biased	***Reverse Biased***	***Forward Active region (or simply "Active region")***	***Amplifiers***
Reverse Biased	Forward Biased	Reverse Active region (also known as Inverted region)	None (Inefficient)
Reverse Biased	Reverse Biased	**Cut-off region**	OFF Switch

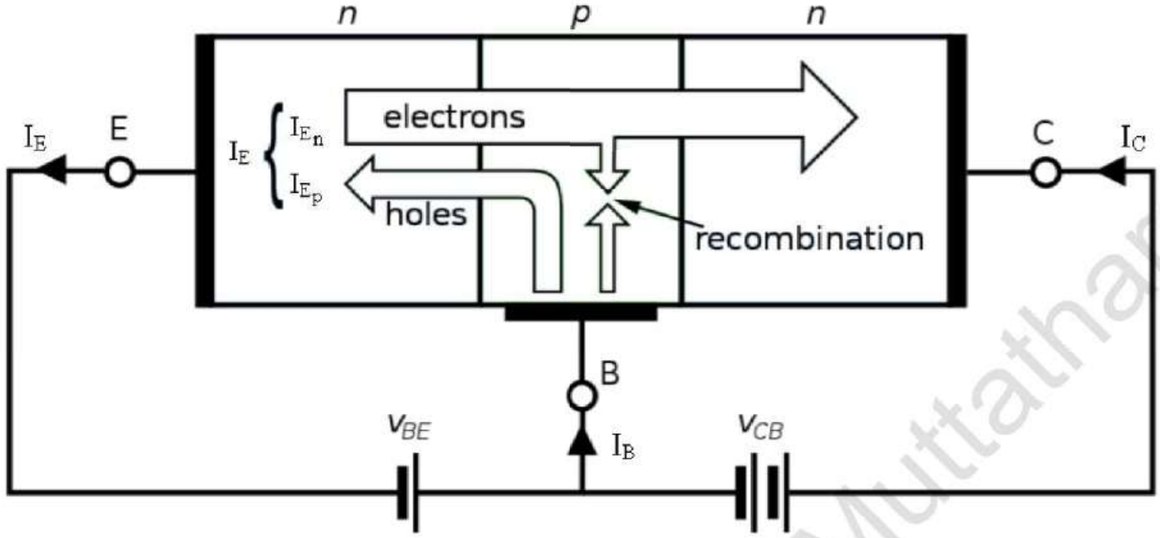
Principle of operation

- Consider an **NPN transistor** biased for **Active operation.**
  - ⇨ E-B Junction is Forward Biased and C-B Junction is RB Biased.
  - ⇨ Depletion layer @ E-B Junction is narrow & Depletion layer @ C-B Junction is wide
- Note: **the direction of current flow is taken opposite to the direction of electron movement.**
- **Majority carrier will diffuse across** E-B Junction.
- **Hence, Emitter current = Electron Diffusion Current + Hole diffusion Current**

$$I_E = I_{E_n} + I_{E_p}$$

- Since base is thin and lightly doped, very less number of holes diffuse into emitter. So,

$$I_{E_n} \gg I_{E_p}$$



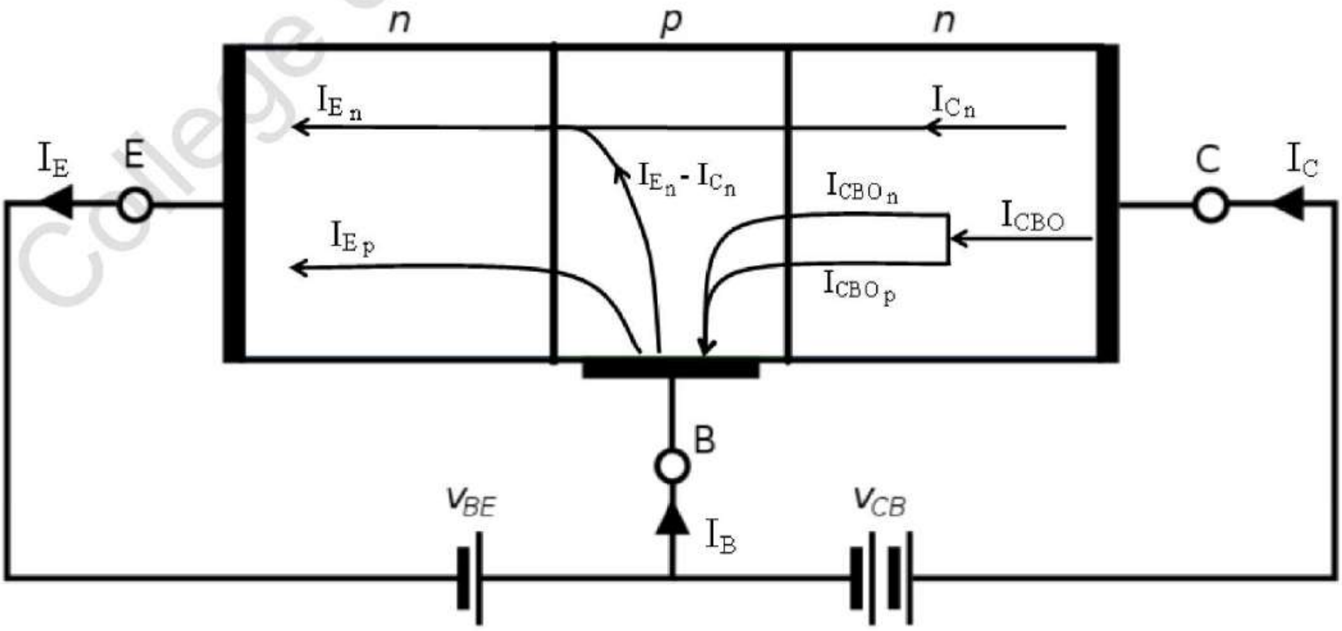
- As the base is thin and lightly doped, **only a few electrons recombine with holes as it crosses the base region to reach the collector.**
- At collector,
  a) Current due to the remaining electrons cross over the into the collector region => I_{C_n}
  b) Since C-B Junction is RB Biased, current due to minority carriers, I_{CBO} (called **Reverse Saturation Current** or **Leakage current** or **Current through C**ollector **B**ase **when E**mitter **is Open**) is also present.

So, Collector current, $I_C = I_{C_n} + I_{CBO}$

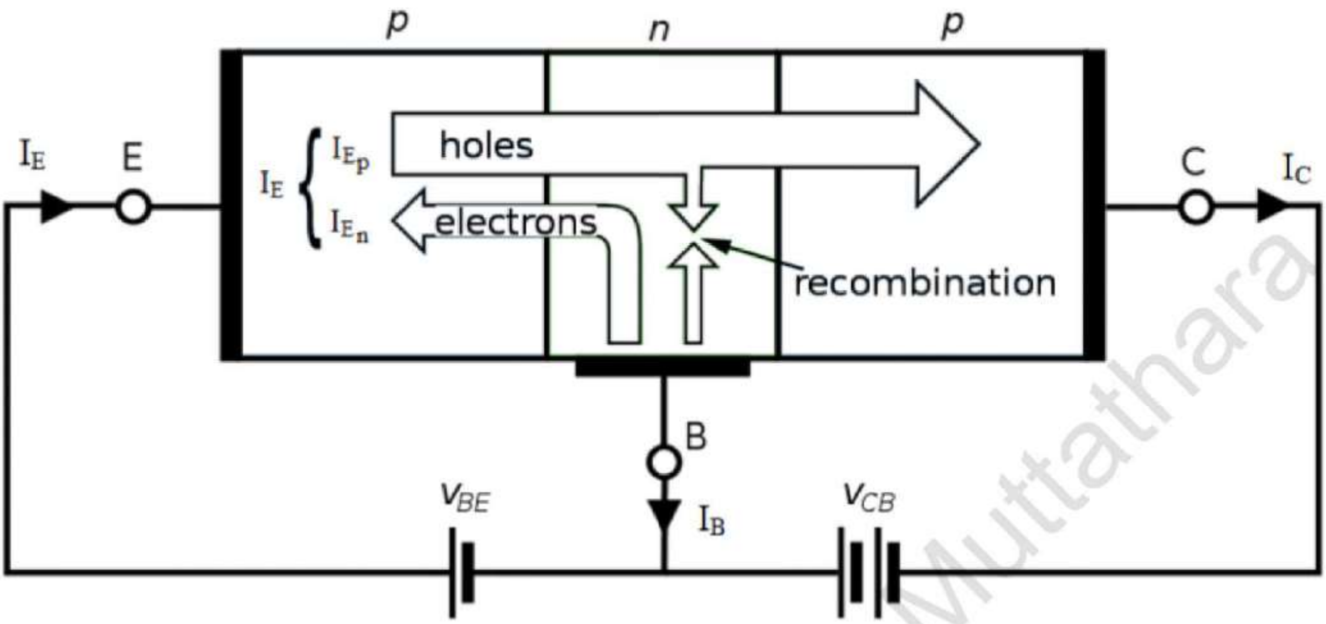
- Using Kirchhoff's Current Law:

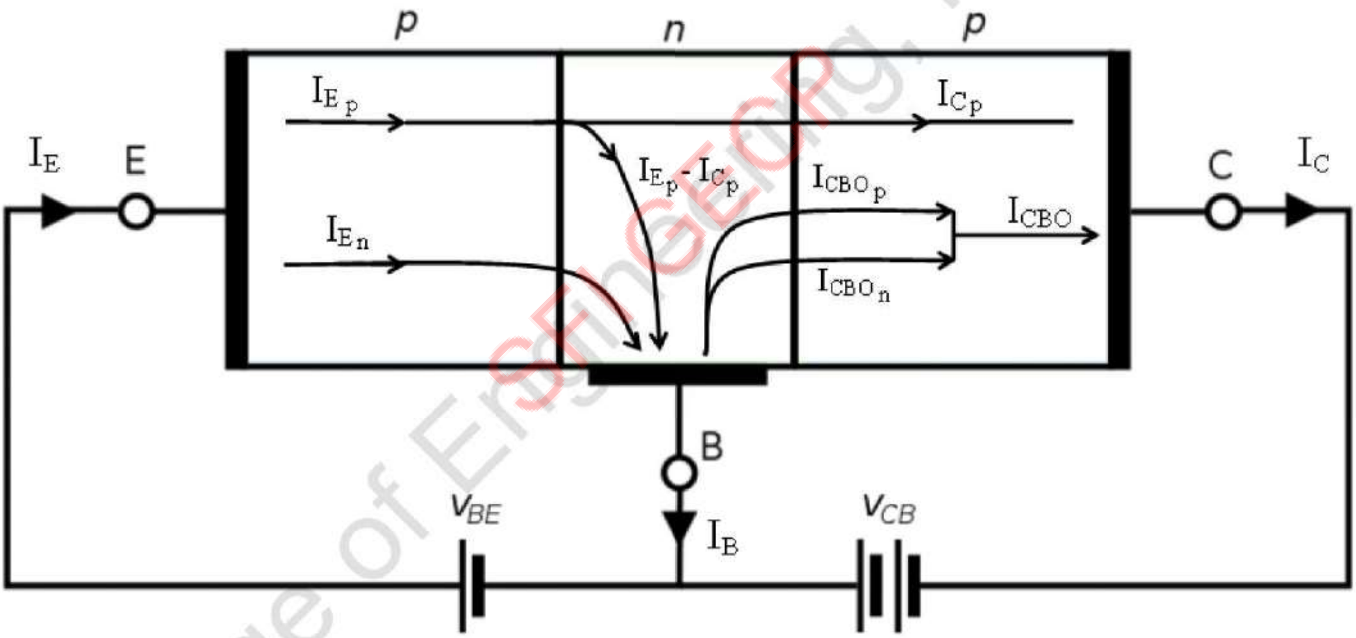
Emitter Current = Base Current + Collector Current

$$I_E = I_B + I_C$$



✓ *Note:* ***A PNP transistor is the complement of an NPN transistor.***





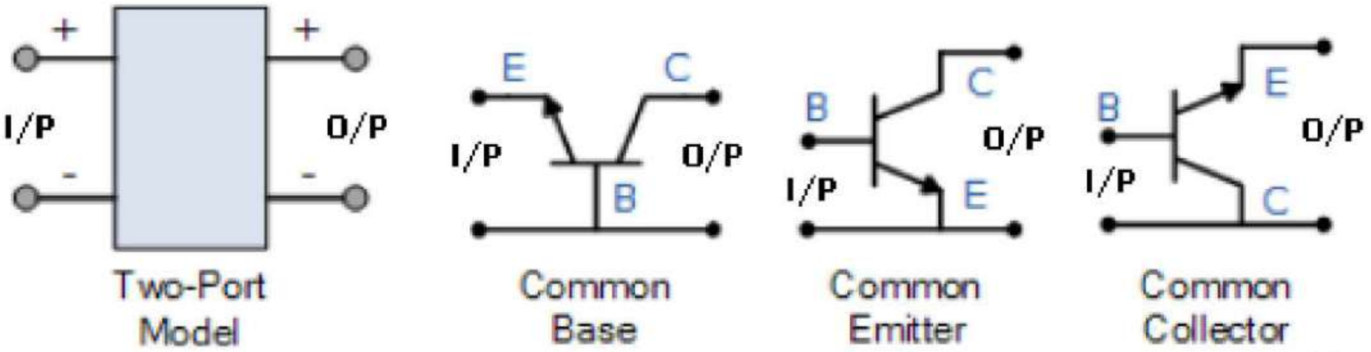
Transistor Configuration

3 Terminal Device (Eg: Transistor) $\xrightarrow[\text{for Input \& Output circuit}]{\text{Making a common terminal}}$ **4 Terminal Device or 2 port (Eg: Amplifier)**

So, there are three different configurations.

They are

1. **Common Base (CB) configuration**
2. **Common Emitter (CE) configuration**
3. **Common Collector (CC) configuration**



Relation between current gains in CE, CB and CC

(Assume only DC voltage and DC current present in the circuit.)

$$Current\ Gain = \frac{Output\ Current}{Input\ Current}$$

Current gain for CB configuration is given by

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

Current gain for CE configuration is given by

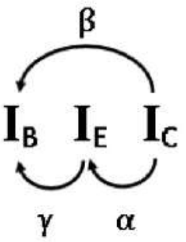
$$\beta = \frac{I_C}{I_B}$$

Current gain for CC configuration is given by

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

Remember Hint: B E Cause

$\alpha\ \beta\ \gamma$



We have the current equation,

$$I_E = I_B + I_C$$

So,

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

Taking inverse

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

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

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

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

Taking inverse

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

$$\Rightarrow \quad I_C = I_E - I_B$$

So,

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

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

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

Rewriting this equation, we get

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

$$\gamma = \beta + 1$$

Comparison between Transistor Configurations (CB, CE & CC)

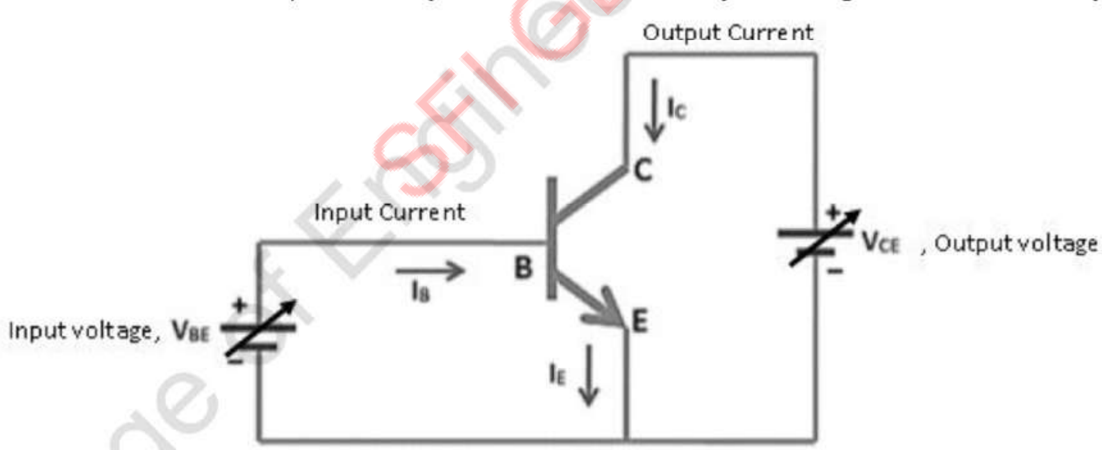
Input Resistance: It is the ratio of change input voltage to the change in input current.
Output Resistance: It is the ratio of change output voltage to the change in output current.

Characteristic	CB	CE	CC
Input Resistance	Very Low (Ω)	Low (Ω)	**Very High (kΩ)**
Output Resistance	**Very High (kΩ)**	**High High (kΩ)**	Low (Ω)
Current Gain	**Less than unity**	High	High
Voltage gain	High	High	**Less than unity**
Phase shift between I/P and O/P	In phase (0°)	**Out of phase(180°)**	In phase (0°)
Application	For High frequency applications	For Audio frequency Applications	For impedance Matching Applications

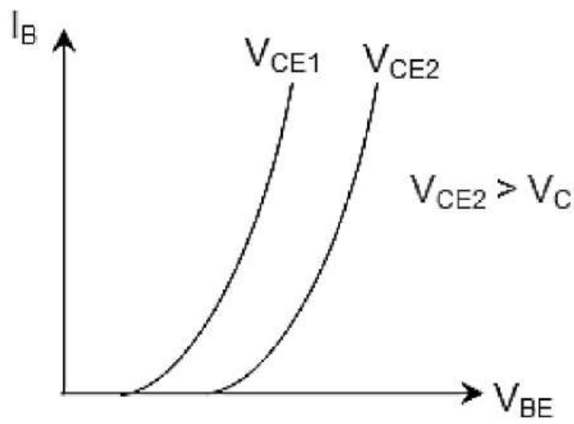
Input and Output characteristics of common emitter configuration

Input Characteristics: These describe the **changes in input current** with **the variation in the values of input voltage** keeping the **output voltage constant**.

Output Characteristics: This is a plot of **output current** versus **output voltage** with **constant input current**.



Input Characteristics



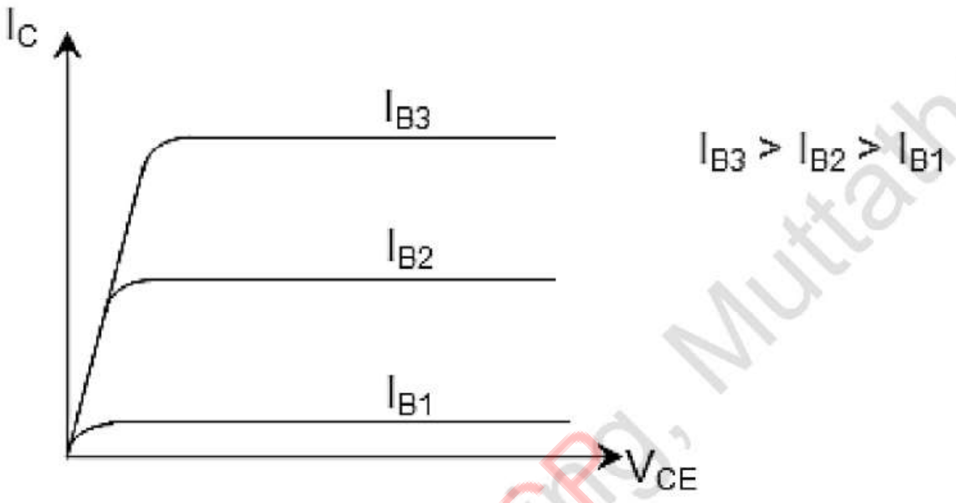
Input Characteristics for CE Configuration

Figure shows the input characteristics for the CE configuration of transistor which illustrates the variation in I_B in accordance with V_{BE} when V_{CE} is kept constant.

The input resistance of the transistor can be obtained as

$$R_{in} = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE}=constant}$$

Output Characteristics



Output Characteristics for CE Configuration

This plot shows the variation in I_C with the changes in V_{CE} when I_B is held constant. From the graph shown, the output resistance can be obtained as:

$$R_{out} = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B=constant}$$

Additional Coding used for indicating value of a capacitor

1. If there are **three digits in the number followed by a letter**, that **letter indicates Tolerance.**
2. If there are only three digits in the number, the third number indicates the number of zeros to be put after two digits and the value will be in pF.
   Eg: **104 means 10,0000pF** or 0.1µF.
3. If the letter **'k'** follows the two digits, the value will be in **k**pF.
   Eg: **10k means 10kpF or 0.01 µF**.
4. If the letter is '**n**' or '**M**' the value will be that much **nano** farads or **micro** farad respectively.
   Eg: **47n means 47nF**
   47M means 47µF.
5. If the letter n, M or k is between two numerals, the value of the capacitor can be obtained by putting a decimal in place of the letter and multiplying by the factor nF, µF, or kpF respectively.
   Eg: **4k7 means 4.7 kpF**
   2M2 means 2.2µF

Questions (Module 4)

PART A

Each question carries 4 marks.

1. **Derive the relationship between α and β of a transistor.**
2. Derive the relationship between β and γ of a transistor.
3. Draw and explain the forward characteristics of a PN junction diode
4. Draw and explain the reverse characteristics of a PN junction diode
5. **Write any four applications of electronics in Medical field.**
6. **Write any four applications of electronics in Industry.**
7. **Write any four applications of electronics in the field of communication.**
8. **Explain the formation of a potential barrier in a P-N junction diode.**
9. **Write down the capacitance values given in coded form as follows: (a) 104 (b) 2M2**
10. **a) For a capacitor with code 104, what is its capacitance value?**
    b) Write down the colour band for a given resistor 390Ω with 10% tolerance
11. **A resistor has a colour band sequence: yellow, violet, orange and gold. Find the range of resistance value.**
12. **Draw the symbol and write the general specifications of the Diode and PNP transistor**
13. **Draw the symbol and write the general specifications of the Zener diode and NPN transistor**
14. Draw the symbol and write the general specifications of the Resister and Capacitor
15. **What is the current gain of Common base, common collector and common emitter configuration?**
16. **For an NPN transistor, α=0.995 and I_E = 10mA, find I_B and I_C?**
17. **For an NPN transistor, β =100 and I_B = 10μA, find I_E and I_C?**
18. **Give the specifications of a resistor. The colour bands marked on a resistor are Blue, Grey, Yellow and Gold. What are the minimum and maximum resistance values expected from that resistance?**
19. **What is meant by avalanche breakdown?**
20. What is the difference between active and passive components? Name atleast two in each category.
21. Draw and explain the electrolytic capacitor
22. What is the property of an inductor?
23. Write the comparison between Transistor Configurations (CB, CE & CC).

PART B

Each question carries 10 marks.

24. a) **Explain with diagram the principle of operation of an NPN transistor**
    b) **Sketch and explain the typical input-output characteristics of a BJT when connected in common emitter configuration**
25. Explain Input and Output characteristics of common emitter configuration with neat diagrams.
26. a) Explain the formation of a potential barrier in a P-N junction diode.
    b) **What do you understand by Avalanche breakdown? Draw and explain the V-I characteristics of a P-N junction and Zener diode**
27. **Draw and explain the forward and reverse characteristics of a PN junction diode**
28. **a) Write down the application of Electronics.**
    b) Briefly describe the evolution of Electronics.
29. a) Write four important milestone developments in the evolution of electronics and also give typical applications of electronics in different fields.
    b) Compare the three transistor configurations and write the applications of each.
30. Explain the classification of Fixed Capacitors
31. **With neat diagrams, explain the classification of fixed resistors.**