**SEMICONDUCTOR:**

**ENERGY BAND THEORY** : Based on Pauli's exclusion principle

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* In an isolated atom, electrons are present in sharply defined energy levels. But in solids atoms are very close to each other.
* So because of their interactions, each electron doesn't have fixed energy.
* It has different energy levels in a certain (small) range called energy band.
* The number of energy levels in a band depends upon the number of interacting atoms.
* The energy band including **valence electrons** is called valence band **(VB**) and the energy band including **conducting** (free) **electrons** is called conduction band (CB).
* Band gap or Forbidden Energy gap (FEG) (ΔEg)

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| **ΔEg = (C B)min – (V B)max**  **(i)** It is the energy gap between CB and VB.  **(ii)** It is also called forbidden energy gap because free electrons can not exist in this gap. |

**(iii)** Width of forbidden energy gap depends upon the nature of substance.   
**(iv)** Width is more, then valence electrons are strongly attached with nucleus.

**(v)** Width of forbidden energy gap is represented in eV.

**(vi)** As temperature increases forbidden energy gap decreases (very slightly

**CLASSIFICATION OF SOLIDS ACCORDING TO ENERGY BAND THEORY**

According to energy band theory, solids are conductor, semiconductor and insulator :

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* **Conductor:**
* In some solids conduction band and valence band are overlapped so there is no band gap between them, it means ΔEg = 0.
* Due to this a large number of electrons are available for electrical conduction and therefore its resistivity is low (ρ = 10–2 – 10–8 Ω-m) and conductivity is high [σ =102 – 108 (Ω-m)–1]
* Such materials are called conductors. For example gold, silver, copper etc.
* **Insulator:**
* In some solids energy gap is large (Eg > 3 eV).
* So in conduction band there are no electrons and so no electrical conduction is possible.
* Here energy gap is so large that electrons cannot be **easily excited** from the valence band to conduction band by any external energy (electrical, thermal or optical).
* Such materials are called as "insulator". Their ρ > 1011 Ω-m and σ < 10–11 (Ω-m) –1
* **Semiconductor**:
* In some solids a finite but small band gap exists (Eg < 3eV). Due to this small band gap some electrons can be thermally excited to "**conduction band"**.
* These thermally excited electrons can move in conduction band and can conduct current.
* Their resistivity and conductivity both are in medium range, ρ= 10–5 – 106 Ω-m and σ=10–6 – 105 Ω-m–1
* **Example of semiconducting materials**
* Elemental semiconductor :Si and Ge
* Compound semiconductor •
  + - * + **Inorganic** : CdS, GaAs, CdSe, InP etc.
        + **Organic :** Anthracene, Doped pthalocyanines etc.
        + **Organic polymers :** Poly pyrrole, Poly aniline, polythiophene

**2. PROPERTIES OF SEMICONDUCTOR :**

* Negative temperature coefficient (α), with increase in temperature resistance decreases.
* Crystalline structure with covalent bonding [Face centred cubic (FCC)].
* Conduction properties may change by adding small impurities.
* Position in periodic table ® IV group (Generally) l Forbidden energy gap (0.1 eV to 3 eV)
* Charge carriers : electron and hole.
* There are many semiconductors but few of them have practical application in electronics like

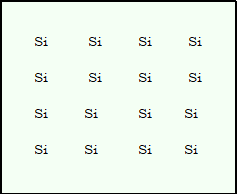
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| **Si14 :** 2, 8, 4  **Ge32 :** 2, 8, 18, 4 |

* There are many semiconductors but few of them have practical application in electronics like
* **Effect of temperature**

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| **At absolute zero kelvin temperature** | * **Above absolute temperature** |
| At this temperature covalent bonds are very  strong and there are no free electrons and semiconductor behaves as perfect insulator. | * With increase in temperature some covalent, bonds are broken and few valence electrons jump to conduction band and hence it behaves as poor conductor. |

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| **at 0 K**  valence band fully filled conduction band fully empty | **at higher temperature**  valence band partially empty conduction band partially filled |

* **CONCEPT OF "HOLES" IN SEMICONDUCTORS**
* Due to external energy (temperature or radiation) when electron goes from valence band to conduction band (i.e. bonded electrons becomes free),vacancy of free e‑creates in valence band.
* The electron vacancy called as **"hole"** which has same charge as electron but **positive.**
* This positively charged vacancy move randomly in semiconductor solid.

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* **Properties of holes :**

•It is missing electron in valence band.

• It acts as positive charge carrier.

• It's effective mass is more than electron.

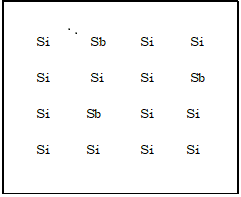
• It's mobility is less than electron.

• Hole acts as virtual charge, although there is no physical charge on it.

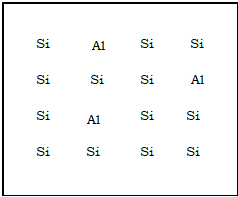
* **EFFECT OF IMPURITY IN SEMICONDUCTOR**
* Doping is a method of addition of "desirable" impurity atoms to pure semiconductor to increase their conductivity.

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| Intrinsic semiconductor  pure form of (Ge, Si)  ne = nh = ni | Extrinsic semiconductor (Doped semicondutor) | |
| **N-type** | **P-type** |
| pentavalent impurity:  (P, As, Sb)  donor impurity (ND) ne >> nh | trivalent impurity  (B, In, Al) acceptor impurity (NA )  nh >> ne |

* **N-type semiconductor**
* When a pure semiconductor (Si or Ge) is doped by pentavalent impurity (P, As, Sb) then four electrons out of the five valence electrons of impurity take part in covalent bonding, with four silicon atoms surrounding it and the fifth electron is set free.
* These impurity atoms which donate free e– for conduction are called as Donor impurity (ND ).
* Here free e– increases very much so it is called as "N" type semiconductor.
* Here impurity ions known as "Immobile Donor positive Ion". "Free e– "called as "majority" charge carriers and "holes" called as "minority" charge carriers.



* **P-type semiconductor**
* When a pure semiconductor (Si or Ge) is doped by trivalent impurity (B, Al, In) then the outermost three electrons of the valence band of impurity, take part in covalent bonding with four silicon atoms surrounded by it.
* This shows that there remains a vacancy in the band. To fill this vacancy, an electron is accepted from the neighbouring atom leaving a hole from its own site.
* Thus an extra hole is formed. These impurity atoms accepting bonded e– from valence band are called as Acceptor impurity (NA ).
* Here holes increases very much so it is called as "P" type semiconductor.
* Here impurity ions known as "Immobile Acceptor negative Ion".
* Free e– are called as minority charge carries and holes are called as majority charge carriers.



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| Intrinsic Semiconductor | N-type (Pentavalent impurity) | P-type(Trivalent impurity) |
| (1) |  |  |
| (2) |  |  |
| (3) Current is due to both electrons and holes | Mainly due to electrons | Mainly due to holes |
| (4) |  |  |
| (5)  (6) Entirely neutral  (7) Quantity of electrons  and holes are equal | Entirely neutral  Majority – Electrons  Minority - Holes | Entirely neutral  Majority – Holes  Minority - Electrons |

**MASS ACTION LAW**

* At room temperature, most of the acceptor atoms get ionised leaving holes in the valence band. Thus at room temperature the density of holes in the valence band is predominantly due to impurity in the extrinsic semiconductor.
* The electron and hole concentration in a semiconductor in thermal equilibrium is given by :

ne nh = ni2

* Though the above description is grossly approximate and hypothetical, it helps in understanding the difference between metals, insulators and semiconductors (extrinsic and intrinsic) in a simple manner.
* **RESISTIVITY AND CONDUCTIVITY OF SEMICONDUCTOR**
* Conduction in conductor As we know that the relation between current (I) and drift velocity (vd ) is
* I = neAvd where n = number of electron in per unit volume
* current density J= =nevd = (because drift velocity of electron vd = μE)
* So, J = neμE = σE
* So Conductivity σ= neμ = 1/ρ
* and Resistivity ρ =

**Conduction in Semiconductor:**

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| Intrinsic semiconductor | P - type | N - type |
| ne = nh | nh >> ne | ne >> nh |
| J = ne [ ve + vh ] | J e nh vh | J e ne ve |
| en [µe + µh ] | enhμh | eneμe |

**Note:**

Number of electrons reaching from valence band to conduction band at temperature T is given by where

k = Boltzmann constant = 1.38 × 10-23 J/K ,

T = absolute temperature, A = constant

ΔEg = energy gap between conduction band and valence band

**P-N JUNCTION** Given diagram shows a P–N junction immediately after it is formed. P region has mobile majority holes and immobile negatively charged impurity ions.

N region has **mobile majority free** electrons and immobile positively charged impurity ions. Due to concentration difference diffusion of holes starts from P to N side and diffusion of e–s starts from N to P side.

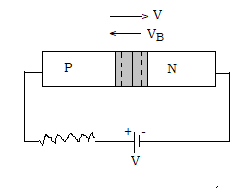
Due to this a layer of only positive ions (in N side) and

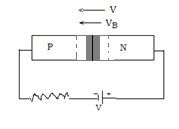
negative

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| ions (in P–side) started to form which generate an electric field (N to P side) which oppose diffusion process, during diffusion magnitude of electric field increases due to this diffusion it gradually decreased. The layer of immobile positive and negative ions, which have no free electrons and holes called as depletion layer as shown in diagram. |

* Due to internal electrical field, an electron on p-side of the junction moves to n-side and a hole on n-side of the junction moves to p-side. The motion of charge carriers due to the electric field is called drift. Thus a drift current flows, which is opposite in direction to the diffusion current. Initially, diffusion current is large and drift current is small. As the diffusion process continues, the space-charge regions on either side of the junction extend, thus increasing the electric field strength and hence drift current. This process continues until the diffusion current equals the drift current.
* At equilibrium condition Direction of diffusion current : P to N side and drift current : N to P side
* If there is no biasing then |diffusion current| = |drift current|
* So total current is zero. In junction N side is at high potential relative to the P side. This potential difference tends to prevent the movement of electron from the N region into the P region. This potential difference is called Barrier potential.

**BEHAVIOUR OF P–N JUNCTION WITH AN EXTERNAL VOLTAGE APPLIED OR BIAS**

* **Forward Bias**
* In this type of biasing we apply a potential difference such that P–side is at high potential and N–side is at low potential as shown in the diagram. The applied voltage is opposite to the junction barrier potential.

****Due to this effective potential barrier decreases, junction width also decreases, so more majority carriers will be allowed to flow across junction. It means the current flow in principally due to majority charge carries called as forward current (in mA)

**Reverse Bias**

In this type of biasing we apply a potential difference such that

**P–side** is at **low potential** and

**N–side** is at **high potential** as shown in the diagram.

* The applied voltage is **same side** of to the junction barrier potential.
* Due to this **effective potential** barrier **increased**, junction width also increased, so no majority carriers will be allowed to flow across junction. Only minority carriers are **drifted.**
* It means the current flow in principally due to minority charge carries and is very small (**µA)** called as **reverse current**.
* The current under reverse bias is essentially voltage independent upto a critical reverse bias voltage, known as breakdown voltage (Vbr).
* When V = Vbr, the **diode reverse current** increases sharply.
* Even a slight increase in the bias voltage causes large change in the current. This phenomena is known as **Breakdown**
* **Breakdown are of two types :-**

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| * **Zener Breakdown** | **Avalanche Breakdown** |
| * Where covalent bonds of depletion layer, itself break, due to high electric field of very high Reverse bias voltage. * This phenomena takes place in   **(i)**  P – N junction having "High doping"  **(ii)** P – N junction having thin depletion layer   * Here **P – N junction** does not damage permanently "In D.C voltage stablizer zener phenomena is used". | * Here covalent bonds of depletion layer are broken by collision of **"Minorities"** * Which aquire high kinetic energy from high electric field of very-very high reverse bias voltage. • This phenomena takes place in   **(i)** P – N junction having "Low doping"   * **(ii)** P – N junction having thick depletion layer * Here P–N junction damages permanently due to abruptly increment of minorities during repeatative collisions. |

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| **Forward Bias** | **Reverse Bias** |
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| 1. Potential Barrier reduces. | 1. Potential Barrier increases. |
| 2. Width of depletion layer decreases. | 2. Width of depletion layer increases |
| 3. P-N Junction provides very small resistance. | 3. P-N Junction provides high resistance. |
| 4 Forward current flow in circuit. | 4. Reverse current flow in circuit |
| 5. Order of forward current is milli ampere. | 5. Order of current is micro ampere (Ge) or Nano ampere (Si). |
| 6. Mainly majority current flows | 6. Mainly minority current flows. |
| 7. Forward characteristic curv | 7. Reverse characteristic curve |
| 8. Forward resistance | 9. Breakdown voltage |
| 9. Knee or cut in voltage  Ge → 0.3 V , Si → 0.7 | 9. Breakdown voltage  Ge →25 V, Si →35 V |
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**Characteristic Curve of P-N Junction Diode:•**



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* In forward bias when voltage is increased from 0V in steps and corresponding value of current is measured, the curve comes as OB of figure.
* We may note that current increases very sharply after a certain voltage knee voltage.
* At this voltage, barrier potential is completely eliminated and diode offers a low resistance.
* In reverse bias a microammeter has been used as current is very very small.
* When reverse voltage is increased from 0V and corresponding values of current measured the plot comes as OCD.
* We may note that reverse current is almost constant hence called reverse saturation current.
* It implies that diode resistance is very high. As reverse voltage reaches value VB , called breakdown voltage, current increases very sharply.

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**4. APPLICATION OF JUNCTION DIODE :**

**4.1 Rectifier**

* It is device which is used for converting alternating current into direct current.
* Half wave rectifier It rectifies only half of the ac input wave
* During the first half (positive) of the input signal, S1 is at positive and S2 is at negative potential. So, the PN junction diode D is forward biased.
* The current flows through the load resistance RL and output voltage is obtained across the RL . During the second half (negative) of the input signal, S1 is at negative potential and S2 is at positive potential.
* The PN junction diode will be reversed biased.
* In this case, practically no current would flow through the load resistance. So, there will be no output across the RL .
* Thus, corresponding to an alternating input signal, we get a unidirectional pulsating output called rectified output.
* **2.** Full wave rectifier
* It rectifies both the cycles of input ac wave.
* It is of two types (fundamentally).
* **(i)** Centre tap rectifier Figure shows the experiemental arrangement for using diode as full wave rectifier.
* When the alternating signal is fed to the transformer, the output signal appears across the load resistance RL .
* During the positive half of the input signal : S1 positive and S2 negative.
* In this case diode D1 is forward biased and D2 is reverse biased.
* So only D1 conducts and hence the flow of current in the load resistance RL is from A to B.
* During the negative half of the input signal : S1 is negative and S2 is positive.
* So D1 is reverse-biased and D2 is forward biased. So only D2 conducts and hence the current flows through the load resistance RL again from A to B.
* It is clear that whether the input signal is positive or negative, the current always flows through the load resistance in the same direction and thus output is called full wave rectified.
* **(ii) Bridge Rectifie**

During positive half cycle During negative half cycle

D1 and D4 are foward biased ‘On’ switch D2 and D3 are foward biased → ‘On’ switch

D2 and D3 are reverse biased → ‘Off’ switch D1 and D4 are reverse biased → ‘Off’ switch

**Rectifier efficiency (η)**

For half wave rectifier :

For full wave rectifier or bridge wave rectifier:

Ripple Frequency

(i) For half wave rectifie

(ii) for full wave rectifier

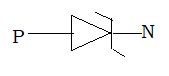
* **Filter Circuit** :
* The rectified output is in the form of pulses or in shape of **half sinusoids.**
* Though it is unidirectional, it does not have a steady value. To get steady dc output from the pulsating voltage, normally a capacitor is connected across the output terminals (parallel to the load RL ) called **filter circuit**.

**(l) Capacitor Filter**

* When the voltage across the capacitor is rising, it gets charge. If there is no external load, it remains charged to the peak voltage of the rectified output.
* When there is a load, it gets discharged through the load and the voltage across it begins to fall. In the next half-cycle of rectified output it again gets charged to the peak value but due to large value of time constant of capacitor, voltage across the capacitor approximate remains constant.

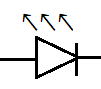
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* **4.2 ZENER DIODE**
* It is a special purpose diode, designed to operate under the reverse bias in the breakdown region and used in voltage regulation.



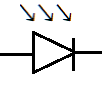
* Symbol of Zener diode is
* In reverse bias of zener diode after the breakdown voltage VZ , a large change in VZ Zener voltage Reverse current Reverse bias the current can be produced by almost insignificant change in the reverse bias voltage.
* In other words zener voltage remains constant, even through current through the zener diode varies over a wide range. This property of the zener diode is used for regulating voltage.
* **Zener diode as a voltage regulator**
* The unregulated dc voltage (filtered output of a rectifier) is connected to the zener diode through a series resistance RS such that the zener diode is reverse biased.
* If the input voltage increases, the current through RS and zener diode also increases.
* This increases the voltage drop across RS without any change in the voltage across the zener diode.
* This is because in the breakdown region, zener voltage remains constant even though the current through the zener diode changes.
* Similarly, if the input voltage decreases, the current through RS and zener diode also decreases.
* The voltage drop across RS decreases without any change in the voltage across the zener diode. Thus any increase/decrease in the input voltage results in, increase/ decrease of the voltage drop across RS without any change in voltage across the zener diode. Thus the zener diode acts as a voltage regulator.
* **4.3 OPTOELECTRONIC JUNCTION DEVICES**

**1. Light emitting diode** (L.E.D)

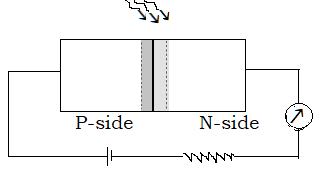
* It is a heavily doped P-N junction which under forward bias emits spontaneous radiation.
* Its symbol is
* When LED is forward biased then electrons move from N → P and holes move from P → N.
* At the junction boundary these are recombined. On recombination, energy is released in the form of photons of energy equal to or slightly less than the band gap.
* When the forward current of the diode is small, the intensity of light emitted is small.
* As the forward current increases, intensity of light increases and reaches a maximum. Further increase in the forward current results in decrease of light intensity.
* LEDs are biased in such a way that the light emitting efficiency should be maximum. In case of Si or Ge diodes, the energy released in recombination lies in **infra-red region.** Therefore to form LED, such semiconductors are to be used which have band gap from 1.8 eV to 3 eV.

**2. Photodiode**

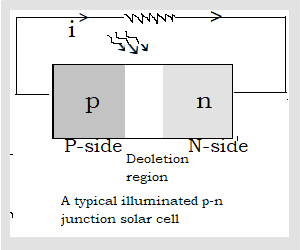
* It is a special purpose junction diode used to sense and measure incident light.



* its symbol is It is operated under reverse bias
* When light of energy "hν'' falls on the photodiode (Here hν > energy gap) more electrons move from valence band to conduction band, due to this current in circuit of photodiode in "Reverse bias", increases.
* As light intensity is increased, the photo current goes on increasing. So photo diode is used "to detect light intensity". Example used in "Video camera".



* **Solar cell**
* A p-n junction which generates emf when solar radiation falls on it, called solar cell. It works on the same principle (photovoltaic effect) as the photodiode, except that no external bias is applied and the junction area is kept much larger for solar radiation to be incident because we are interested in more power.



* When light falls on, emf generates due to the following three basic processes: generation, separation and collection-

**(i)** generation of e-h pairs due to light (with hv > Eg) in junction region;

**(ii)** separation of electrons and holes due to electric field of the depletion region. Electrons are swept to n-side and holes to p-side by the junction field;

**(iii)** On reaching electrons at n-side and holes on at p-side. Thus n-side becomes negative and p-side becomes positive potential and giving rise to photovoltage.

**5. TRANSISTOR**

* Transistor is a three terminal device which transfers a singal from low resistance circuit to high resistance circuit. It is formed when a thin layer of one type of extrinsic semiconductor (P or N type) is sandwitched between two thick layers of other type of extrinsic semiconductor.
* **Transistors are of two types**
* **N-P-N Transistor**
* If a thin layer of P-type semiconductor is sandwitched between two thick layers of N-type semiconductor, then it is known as NPN transistor.
* **P-N-P Transistor**
* If a thin layer of N-type of semiconductor is sandwitched between two thick layer of P-type semiconductor, then it is known as PNP transistor.
* Each transistor has three terminals and these are :-
* **(i) Emitter**
* It is the left most part of the transistor which emits the majority carriers towards base. It is highly doped and medium in size.
* **(ii) Base**
* It is the middle part of transistor which is sandwitched by emitter (E) and collector (C). It is lightly doped and very thin in size.
* **(iii) Collector**
* It is right part of the transistor which collects the majority carriers which is emitted by emitter. It has large size and moderate doping.
* **Every transistor has following two junctions**

(i) The junction between emitter and base is known as emitter-base junction (JEB).

* (ii) The junction between base and collecter is known as base-collector junction (JBC).
* **WORKING OF TRANSISTOR**
* **1. Working of NPN Transistor**
* The emitter base junction is forward biased and base collector junction is reversed biased to study the behaviour of transistor. It is called active state of transistor. N-P-N transistor in circuit and symbolic representation is shown in figure.
* In active state of n-p-n transistor majority electrons in emitter are sent towards base.
* The barrier of emitter base junction is reduced because of forward bias therefore electrons enter into the base.
* About 5% of these electrons recombine with holes in base region results very small current (IB ) in base. The remaining electron ( ≈ 95%) enters into the collector region because these are attracted towards the positive terminal of battery results collecter current (IC )
* The base current is the difference between IE and IC and proportional to the number of electron hole recombination in the base.
* I E = IB +IC , We also see IE ≈ IC because IB is very small.
* **2. Working of PNP Transistor**
* When emitter-base junction is forward biased, holes (majority carriers) in the emitter are repelled towards the base and diffuse through the emitter base junction.
* The barrier potential of emitter-base junction decreases and hole enters into the n-region (i.e. base).
* A small number of holes ( ≈ 5%) combine with electrons of base-region resulting small current (IB ).
* The remaining holes ( ≈ 95%) enter into the collector region because these are attracted towards negative terminal of the battery connected with the collector-base junction.
* These hole constitute the collector current (IC )
* As one hole reaches the collector, it is neutralized by the battery. As soon as one electron and a hole is neutralized in collector, a covalent bond is broken in emitter region and an electron hole pair is produced.
* The released electron enters the positive terminal of battery and holes moves towards the collector. So IE = IB + IC

**CONFIGURATIONS OF A TRANSISTOR AND ITS CHARACTERISTICS**

The transistor is connected in either of the three ways in circuit.

(i) Common base configuration

(ii) Common emitter configuration

(iii) Common collector configuration In these three, common emitter is widely used and common collector is rarely used.

* **Common emitter transistor characteristics**

* **Input characterstics**
* The variation of base current (IB ) (input) with base emitter voltage (VEB) at constant collector emitter voltage (VCE) is called input characteristic.
* (i) Keep the collector-emitter voltage (VCE) constant (say VCE = 10 V)
* (ii) Now change emitter base voltage VBE in steps of 0.1 volt and note the corresponding values of base current (IB ).
* (iii) Plot the graph between VBE and IB .
* **Output characteristics**
* The variation of collector current IC (output) with collector-emitter
* voltage (VCE) at constant base current (IB ) is called output characteristic.
* (i) Keep the base current (IB ) constant (say IB = 10 mA)
* (ii) Now change the collector-emitter voltage (VCE) and note the corresponding values of collector current (IC ).
* (iii) Plot the graph between VCE and IC .
* (iv) A set of such curves can also be plotted at different fixed values of base current (say 20 mA, 30 mA etc.)
* **6. APPLICATIONS OF TRANSISTOR**
* **6.1 Transistor as a switch**
* When a transistor is used in the cut off (off state) or saturation state (on state) only, it acts as a switch. To study this behaviour, we understand base biased CE transistor circuit.
* Applying Kirchhoff's voltage rule to the input and output sides of this circuit we get
* Vi = IB RB + VBE (Vi = dc input voltage)
* and VO = VCC – IC RC (VO = dc output voltage**)**
* Now we can analyse how VO changes as Vi increase from zero onwards.
* In case of Silicon transistor, if Vi is less than 0.6 V, IB will be zero, hence IC will zero and transistor will be said to be in cut-off state, and VO = VCC.
* When Vi become greater than 0.6 V, some IB flows, so some IC flows (transistor is in active state now) and output VO decreases as the term IC RC increase. With increase in Vi the IC increase almost linearly and so VO decreases linearly till its value becomes less than about 1.0 volt.
* **6.2 Transistor as an amplifier**
* The process of increasing the amplitude of input signal without distorting its wave shape and without changing its frequency is known as amplification. A device which increases the amplitude of the input signal is called amplifier.
* To operate the transistor as an amplifier it is necessary to fix its operating point somewhere in the middle of its active region.
* If we fix the value of VBB corresponding to a point in the middle of the linear part of the transfer curve then the dc base current IB would be constant and corresponding collector current IC will also be constant. The dc voltage VCE = VCC – IC RC would also remain constant.
* The operating values of VCE and IB determine the operating point, of the amplifier.
* If a small sinusoidal voltage with amplitude ui is superposed in series with the VBB supply, then the base current will have sinusoidal variations superimposed on the value of IB .
* As a consequence the collector current also will have sinusoidal variations superimposed on the value of IC producing in turn corresponding change in the value of Vo .
* Mathematical Analysis : From KVL equation of base biased CE transistor circuit
* Vi = IBRB + VBE

ΔVi = (ΔI B )RB + ΔVBE  ΔVBE = 0 ⇒ ΔVi = (ΔI B) RB

* Similarily Vo = VCC – ICRC

⇒ΔVo = ΔVCC – (ΔI C )RC ΔVCC = 0 ⇒ ΔVo = –(ΔIC )RC

* So voltage gain of CE amplifier
* AV = = =
* The negative sign represents that output voltage is opposite in phase with the input voltage. Power gain (Ap) = current gain × voltage gain = βac × AV  ⇒ AP > 1
* However it should be realised that transistor is not a power generating device. The energy for the higher ac power at the output is supplied by the battery V .
* Comparative study of transistor configuration
* **1.** Common Base (CB) **2.** Common Emitter (CE) **3.** Common Collector (CC)

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