ELECTRONICS AND COMMUNICATION

PHYSICS - 2 | **UNIT - 10**

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SCHOOL :

EXAM NO :

கேடில் விழுச்செல்வம் கல்வி யொருவற்கு
மாடல்ல மற்றை யவை

கல்வி ஒன்றே அழிவற்ற செல்வமாகும். அதற்கு ஒப்பான சிறந்த
செல்வம் வேறு எதுவும் இல்லை

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2 and 3 Mark Questions & Answers

1. What is called electronics?

- ✶ Electronics is the branch of physics incorporated with technology towards the design of circuits using transistors and microchips.
- ✶ It depicts the behaviour and movement of electrons in a semiconductor, vacuum, or gas.

2. What are passive components and active components?

- ✶ Components that cannot generate power in a circuit are called passive components
  (e.g.) Resistors, inductors, capacitors
- ✶ Components that can generate power in a circuit are called active components.
  (e.g.) transistors

3. What is energy band?

- ✶ When millions of atoms are brought close to each other, the valence orbitals and the unoccupied orbitals are split according to the number of atoms. Their energy levels will be closely spaced and will be difficult to differentiate the orbitals of one atom from the other and they look like a band
- ✶ *This band of very large number of closely spaced energy levels in a very small energy range is known as energy band.*

4. What is valance band, conduction band and forbidden energy gap?

- ✶ The energy band formed due to the valence orbitals is called ***valence band***.
- ✶ The energy band that formed due to the unoccupied orbitals is called the ***conduction band***
- ✶ The energy gap between the valence band and the conduction band is called ***forbidden energy gap***.

5. What is called intrinsic semiconductor?

- ✶ A semiconductor in its pure form without impurity is called an intrinsic semiconductor.
- ✶ Its conduction is low.
  (e.g.) Silicon, Germanium

6. Define dopping.

- ✶ The process of adding impurities to the intrinsic semiconductor is called ***doping***.
- ✶ It increases the concentration of charge carriers (electrons and holes) in the semiconductor and in turn, its electrical conductivity.
- ✶ The impurity atoms are called ***dopants***.

7. What is extrinsic semiconductors?

- ✶ The semiconductor obtained by dopping either pentavalent impurity or trivalent impurity is called extrinsic semiconductor.
  (e.g.) P - type and N-type semicondutor

8. Define hole.

- ✶ When an electron is excited, covalent bond is broken. Now octet rule will not be satisfied.
- ✶ Thus each excited electron leaves a vacancy to complete bonding.
- ✶ This 'deficiency' of electron is termed as a 'hole'

9. What is called P-type semiconductor?

- ✶ A P - type semiconductor is obtained by doping a pure Germanium (or Silicon) crystal with a dopant of trivalent elements (acceptor impurity) like Boron, Aluminium, Gallium and Indium
- ✶ In P-type semicondutors,
  Holes are majority charge carriers
  Electrons are minority charge carriers

10. What is N-type semiconductor?

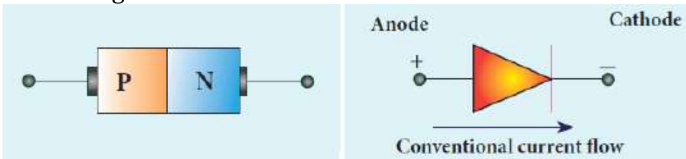
- ✶ A N - type semiconductor is obtained by doping a pure Germanium (or Silicon) crystal with a dopant of pentavalent elements (donor impurity) like Phosphorus, Arsenic and Antimony
- ✶ In N-type semicondutors,
  Electrons are majority charge carriers
  Holes are minority charge carriers

11. Define junction potential or barrier potential.

- ✶ When P - type and N - type semiconductors combine to form PN junction, due to diffusion of majority charge carriers a depletion region is formed near the junction.
- ✶ It prevents the charge carriers to further diffusion across the junction. Because a potential difference is set up by the immobile ions in this depletion region.
- ✶ This difference in potential across the depletion layer is called the barrier potential or junction potential.
- ✶ This barrier potential approximately equals ***0.7 V for Silicon*** and ***0.3 V for Germanium***.

12. What is P-N juction diode? Give its symbol.

- ✶ A P-N junction diode is formed when a P -type semiconductor is fused with a N-type semiconductor.
- ✶ It is a device with single P-N junction
- ✶ The Schematic representation and circuit symbol is given below.



13. What is called biasing? Give its types.

- ✶ Biasing is the process of giving external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.
- ✶ The external voltage applied to the p-n junction is called bias voltage.
- ✶ Depending on the polarity of the external source to the P-N junction we have two types of biasing
  (1) Forward bias
  (2) Reverse bias

14. Differentiate forward bias and reverse bias.

Forward bias :

- ✶ If the positive terminal of the external voltage source is connected to the P-side and the negative terminal to the N-side, it is called forward biased
- ✶ It reduces width of the depletion region.

Reverse bias :

- ✶ If the positive terminal of the battery is connected to the N-side and the negative potential to the P-side, the junction is said to be reverse biased
- ✶ It increases width of the depletion region.

15. What is meant by rectification?

- ✶ The process of converting alternating current into direct current is called rectification.
- ✶ The device used for rectification is called rectifier.
- ✶ A P-N junction diode is used as rectifier.

16. What is mean by break down voltage?

- ✶ The reverse saturation current due to the minority charge carriers is small.
- ✶ If the reverse bias applied to a P-N junction is increased beyond a point, the junction breaks down and the reverse current rises sharply.
- ✶ The voltage at which this breakdown happens is called the breakdown voltage
- ✶ It depends on the width of the depletion region, which in turn depends on the doping level.

17. Write a note on Zener breakdown.

<u>**Zener breakdown**</u> :

- ✶ It wil occur in heavily doped P-N junction which have narrow depletion layers (< 10^{-6} m)
- ✶ When a reverse voltage across this junction is increased to the breakdown limit, a very strong electric field of strength **3×10^{7} V m^{-1}** is set up across the narrow layer.
- ✶ This electric field is strong enough to break or rupture the covalent bonds in the lattice and thereby generating ***electron-hole pairs***. This effect is called Zener effect.
- ✶ Even a small further increase in reverse voltage produces a large number of charge carriers.
- ✶ Hence the junction has very low resistance in the breakdown region.
- ✶ This process of emission of electrons due to the rupture of bands in from the lattice due to strong electric field is known as ***internal field emission*** or ***field ionization***.
- ✶ The electric field required for this is of the order of **10^{6} V m^{-1}**

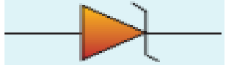
18. Write a note on avalanche break down.

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

- ✶ It will occurs in lightly doped junctions which have wide depletion layers.
- ✶ Here the electric field is not strong enough to produce breakdown.
- ✶ But the minority charge carriers accelerated by the electric field gains sufficient kinetic energy, collide with the semiconductor atoms while passing through the depletion region.
- ✶ Thisleads to the breaking of covalent bonds and in turn generates electron-hole pairs.
- ✶ The newly generated charge carriers are also accelerated by the electric field resulting in more collisions and further production of charge carriers.
- ✶ This cumulative process leads to an avalanche of charge carriers across the junction and consequently reduces the reverse resistance.
- ✶ This is known as avanlanche breakdown.
- ✶ Here the diode current increases sharply.

19. What is called Zener diode? Give its circuit symbol.

- ✶ Zener diode is a reverse biased heavily doped Silicon diode which is specially designed to be operated in the breakdown region.
- ✶ The circuit symbol of Zener diode is given below.

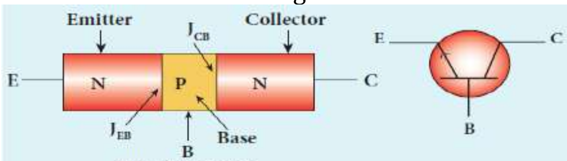


20. Give the applications of Zener diode.

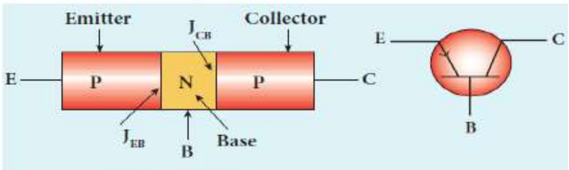
- ✶ Voltage regulators
- ✶ Peak clippers
- ✶ Calibrating voltages
- ✶ Provide fixed reference voltage in a network for biasing
- ✶ Meter protection against damage from accidental application of excessive voltage.

21. Write a note on bipolar junction transistor(BJT).

- ✶ The bipolar junction transistor (BJT) consists of a semiconductor (Silicon or Germanium) crystal in which an N-type material is sandwiched between two P-type materials called ***PNP transistor*** or a P -type material sandwiched between two N-type materials called ***NPN transistor***.
- ✶ The three regions formed are called emitter (E), base (B) and collector (C)
- ✶ The schematic symbol and circuit symbol of PNP and NPN transistors are given below.



NPN Transistor



PNP Transistor

22. Discuss the different modes of transistor biasing.

(1) <u>**Forward Active**</u> :

- ✶ In this bias the emitter-base junction (J_{EB}) is forward biased and the collector-base junction (J_{CB}) is reverse biased.
- ✶ The transistor is in the active mode and in this mode, the transistor functions as an amplifier.

(2) <u>**Saturation**</u> :

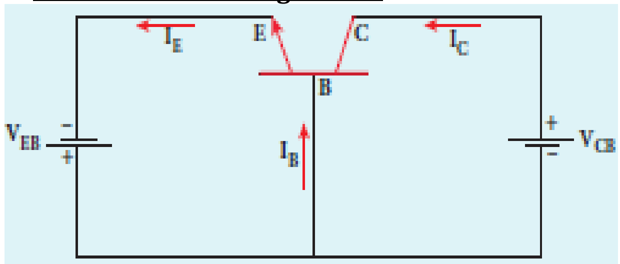
- ✶ Here, both the emitter-base junction (J_{EB}) and collector-base junction (J_{CB}) are forward biased.
- ✶ The transistor has a very large flow of currents across the junctions and in this mode, transistor is used as a closed switch.

(3) <u>**Cut-off**</u> :

- ✶ In this bias, both the emitter-base junction (J_{EB}) and collector-base junction (J_{CB}) are reverse biased.
- ✶ Transistor in this mode is an open switch.

23. Draw the circuit diagram of common base configurations of NPN transistor.

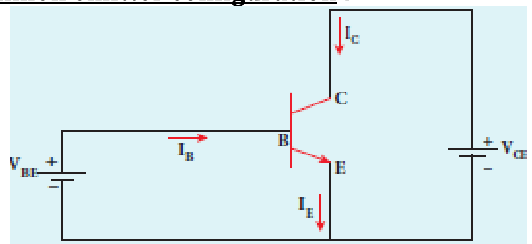
<u>**Common base configuration**</u> :



- ✶ Input termial - Emitter
  Output terminal - Collector
  Common terminal - Base
- ✶ Input current $= I_E$
  Output current $= I_C$
- ✶ The input signal (V_{BE}) is applied across emitter - base junction
- ✶ The output signal (V_{CB}) is measured across collector - base junction.

24. Draw the circuit diagram of common emitter configurations of NPN transistor.

<u>**Common emitter configuration**</u> :

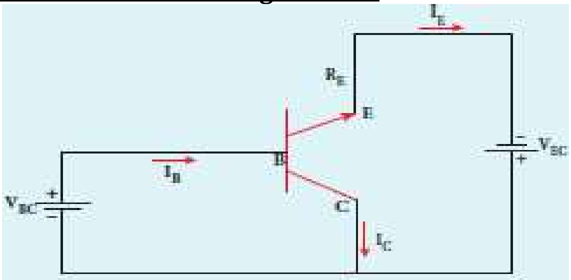


- ✶ Input termial - Base
  Output terminal - Collector
  Common terminal - Emitter

- Input current $= I_B$
  Output current $= I_C$
- The input signal (V_{BE}) is applied across base - emitter junction
- The output signal (V_{CE}) is measured across collector - emitter junction.

25. **Draw the circuit diagram of common emitter configurations of NPN transistor.**

<u>**Common collector configuration :**</u>



- Input termial - Base
  Output terminal - Emitter
  Common terminal - Collector
- Input current $= I_B$
  Output current $= I_E$
- The input signal (V_{BC}) is applied across base - collector junction
- The output signal (V_{EC}) is measured across emitter - collector junction.

26. **Define input resistance of transistor.**
- The ratio of the change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at a constant collector-emitter voltage (V_{CE}) is called the input resistance (r_i).

$$r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B}\right]_{V_{CE}}$$

- The input resistance is high for a transistor in common emitter configuration.

27. **Define output resistance of transistor.**
- The ratio of the change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current (I_B) is called the output resistance (r_o).

$$r_o = \left[\frac{\Delta V_{CE}}{\Delta I_C}\right]_{I_B}$$

- The output resistance is very low for a transistor in common emitter configuration.

28. **Define forward current gain.**
- The ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}) is called forward current gain (β).

$$\beta = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{CE}}$$

- Its value is very high and it generally ranges from 50 to 200.

29. **Give the relation between α and β**
- Forward current gain in common base mode,

$$\alpha = \left[\frac{\Delta I_C}{\Delta I_E}\right]_{V_{CE}}$$

- Forward current gain in common emitter mode,

$$\beta = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{CE}}$$

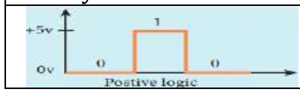
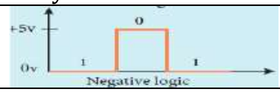
- From the above two equations, we have

$$\alpha = \frac{\beta}{1+\beta} \quad (or) \quad \beta = \frac{\alpha}{1-\alpha}$$

30. **Distinguish between analog and digital signal.**

Analog signal	Digital signal
It is continuously varying voltage or current with respect to time	It contains only two discreate values of voltages (i.e.) low (OFF) and high (ON)
These signals are employed in rectifying circuits and transistor amplifier circuits	These signals are employed in signal processing. communication etc.,

31. **Distinguish between positive and negative logic.**

Positive logic	Negative logic
Binary 1 stands for +5 V Binary 0 stands for 0 V	Binary 1 stands for 0V Binary 0 stands for +5 V
	

32. **Why digital signals are preferred than analog signals?**
- Because of their better performance, accuracy, speed, flexibility and immunity to noice.

33. **State Demorgan's theorems.**

<u>**Theorem - 1**</u> :
- The complement of the sum of two logical inputs is equal to the product of its complements.

$$\overline{A+B} = \bar{A}\,.\,\bar{B}$$

<u>**Theorem - 2**</u> :
- The complement of the product of two logical inputs is equal to the sum of its complements.

$$\overline{A\,.\,B} = \bar{A} + \bar{B}$$

34. **What is an integrated circuit?**
- An integrated circuit (IC) or a chip or a microchip is an electronic circuit, which consists of thousands to millions of transistors, resistors, capacitors, etc. integrated on a small flat piece of Silicon.

35. **What are the application of integrated circuits (ICs)**
- Low cost
- great performance.
- Very small in size
- High reliability
- They can function as an amplifier, oscillator, timer, microprocessor and computer memory.

36. **Distinguish between digital IC and analog IC**

<u>**Digital IC :**</u>
- Digital ICs uses digital signals (logical 0 and 1). They usually find their applications in computers, networking equipment, and most consumer electronics.

<u>**Analog IC**</u> :
- Analog (or) linear ICs work with continuous values. Linear ICs are typically used in audio and radio frequency amplification.

37. **How electron-hole pairs are created in a semiconductor material?**
- A small increase in temperature is sufficient enough to break some of the covalent bonds and release the electrons free from the lattice.
- Hence a vacant site is created in the valanceband and this vacancies are called holes which are treated to possess positive charges.
- Thus electrons and holes are the two charge carriers in semiconductors.

38. **A diode is called as a unidirectional device. Explain**
- An ideal diode behaves as conductor when it is forward biased and behaves as an insulator when it is reverse biased.
- Thus diode coducts current only from P -type to N -type through the junction when it is forward biased.
- Hence Diode is a unidirectional device.

39. What is called modulation? Give its types.

- For long distance transmission, the low frequency base band signal (input signal) is superimposed on to a high frequency carrier signal (radio signal) by a process called modulation.
  (1) Amplitude Modulation (AM)
  (2) Frequency Modulation (FM)
  (3) Phase Modulation (PM)

40. What is the necessity of modulation?

- When the information signal of low frequency is transmitted over a long distances, there will be information loss occurs.
- As the frequency of the carrier signal is very high, it can be transmitted to long distances with less attenuation.
- Thus in the modulation process, carrier signal of very high frequency signal (radio signal) is used to carry the baseband signal(information)

41. Define amplitude modulation (AM)

- If the amplitude of the carrier signal is modified according to the instantaneous amplitude of the baseband signal, then it is called amplitude modulation (AM)

42. Give the advantages and limitations of amplitude modulation (AM)

Advantages of AM :

- Easy transmission and reception
- Lesser bandwidth requirements
- Low cost

Limitations of AM :

- Noise level is high
- Low efficiency
- Small operating range

43. Define frequency modulation (FM)

- If the frequency of the carrier signal is modified according to the instantaneous amplitude of the baseband signal then it is called frequency modulation (FM)

44. Give the advantages and limitations of frequency modulation (FM)

Advantages of FM :

- Large decrease in noise. This leads to an increase in signal-noise ratio.
- The operating range is quite large.
- The transmission efficiency is very high as all the transmitted power is useful.
- FM bandwidth covers the entire frequency range which humans can hear. Due to this, FM radio has better quality compared to AM radio.

Limitations of FM :

- FM requires a much wider channel.
- FM transmitters and receivers are more complex and costly.
- In FM reception, less area is covered compared to AM.

45. Define phase modulation (PM)

- The instantaneous amplitude of the baseband signal modifies the phase of the carrier signal keeping the amplitude and frequency constant is called phase modulation

46. What is called centre frequency (resting frequency)?

- When the frequency of the baseband signal is zero (no input signal), there is no change in the frequency of the carrier wave.
- It is at its normal frequency and is called as centre frequency or resting frequency.
- Practically **75 kHz** is the allotted frequency of the FM transmitter.

47. Compare FM and PM ?

Comparison between FM and PM :

- PM wave is similar to FM wave.
- PM generally uses a smaller bandwidth than FM. In other words, in PM, more information can be sent in a given bandwidth.
- Hence, phase modulation provides high transmission speed on a given bandwidth.

48. Define reverse saturation current.

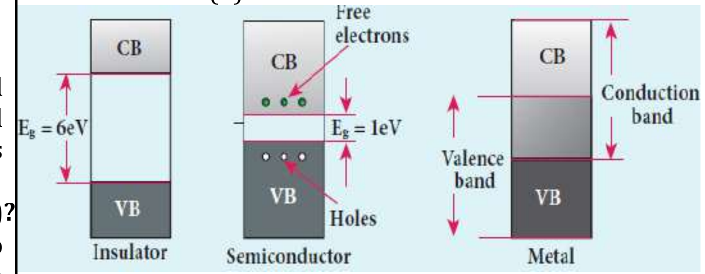
- ✶ Under reverse bias, a small current flows across the junction due to the minority charge carriers in both regions.
- ✶ Because the reverse bias for majority charge carriers serves as the forward bias for minority charge carriers.
- ✶ The current that flows under a reverse bias is called the reverse saturation current or leakage current (Is).
- ✶ It depends on temperature.

5 marks Questions & Answers

1. Explain the classification of solids on the basis of energy band theory.

Classification of solids :

- ✶ Based on the energy band theory, solids are classified in to three types, namely
  (1) Insulators
  (2) Metals (Condutors)
  (3) Semiconductors



Insulators :

- ✶ In insulator the valence band (VB) and the conduction band (CB) are separated by a large energy gap.
- ✶ The forbidden energy gap (E_g) is approximately 6 eV in insulators.
- ✶ The gap is very large that electrons from valence band cannot move into conduction band even on the application of strong external electric field or the increase in temperature.
- ✶ Therefore, the electrical conduction is not possible as the free electrons are almost nil and hence these materials are called insulators.
- ✶ Its resistivity is in the range of $10^{11} - 10^{19}\ \Omega\, m$

Metals (Conductors) :

- ✶ In metals, the valence band and onduction band overlap
- ✶ Hence, electrons can move freely into the conduction band which results in a large number of free electrons in the conduction band.
- ✶ Therefore, conduction becomes possible even at low temperatures.
- ✶ The application of electric field provides sufficient energy to the electrons to drift in a particular direction to constitute a current.
- ✶ For metals, the resistivity value lies between $10^{-2} - 10^{-8}\ \Omega\, m$

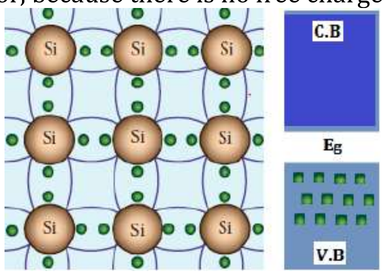
Semiconductors :

- ✶ In semiconductors, there exists a narrow forbidden energy gap ($E_g < 3\ eV$) between the valence band and the conduction band.
- ✶ At a finite temperature, thermal agitations in the solid can break the covalent bond between the atoms.
- ✶ This releases some electrons from valence band to conduction band.
- ✶ Since free electrons are small in number, the conductivity of the semiconductors is not as high as that of the conductors.
- ✶ The resistivity value of semiconductors is from $\mathbf{10^{-5} - 10^{6}\ \Omega\, m}$.
- ✶ When the temperature is increased further, more number of electrons is promoted to the conduction band and increases the conduction.
- ✶ Thus, the electrical conduction increases with the increase in temperature. (i.e.) resistance decreases with increase in temperature.
- ✶ Hence, semiconductors are said to have negative temperature coefficient of resistance.
- ✶ The most important elemental semiconductor materials are ***Silicon (Si)*** and ***Germanium (Ge).***
- ✶ At room temperature,
  forbidden energy gap for Si ; $\boldsymbol{E_g = 1.1\ eV}$ and
  forbidden energy gap for Ge ; $\boldsymbol{E_g = 0.7\ eV}$

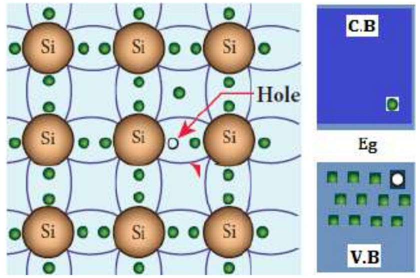
2. Explain in detail the intrinsic semiconductor.

Intrinsic semiconductor :

- ✶ A semiconductor in its pure form without impurity is called an intrinsic semiconductor.
  (e.g) silicon, germanium
- ✶ Consider Silicon lattice. Each Silicon atom is covalently bonded with the neighbouring four atoms to form the lattice.
- ✶ At absolute zero (0 K), this will behaves as insulator, because there is no free charges.



- ✶ But at room temperature, some of the covalent bonds are brakes and releases the electrons free from the lattice.



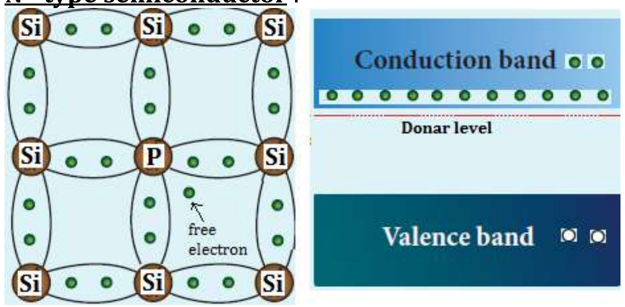
- ✶ As a result, some states in the valence band become empty and the same number of states in the conduction band will be occupied.
- ✶ The vacancies produced in the valence band are called holes which are treates as positive charges.
- ✶ Hence, electrons and holes are the two charge carriers in semiconductors.
- ✶ In intrinsic semiconductors, the number of electrons in the conduction band is equal to the number of holes in the valence band.
- ✶ The conduction is due to the electrons in the conduction band and holes in the valence band
- ✶ The total current (I) is always the sum of the electron current ($\boldsymbol{I_e}$) and the hole current ($\boldsymbol{I_h}$)

$$\boldsymbol{I = I_e + I_h}$$

- ✶ The increase in temperature increases the number of charge carriers (electrons and holes).

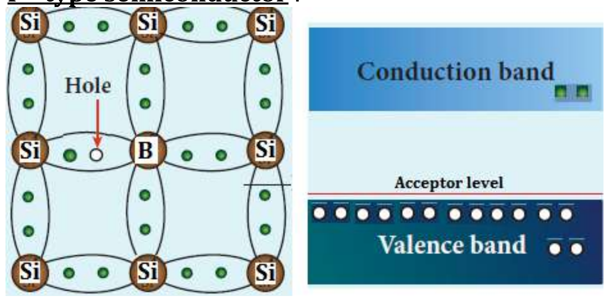
3. Elucidate the formation of a N-type and P-type semiconductors.

N - type semiconductor :



- ✶ A n-type semiconductor is obtained by doping a pure Silicon (or Germanium) crystal with a dopant from pentavalent elements like Phosphorus, Arsenic, and Antimony
- ✶ The dopant has five valence electrons while the Silicon atom has four valence electrons.
- ✶ During the process of doping, four of the five valence electrons of the impurity atom are bound with the 4 valence electrons of the neighbouring replaced Silicon atom.
- ✶ The fifth valence electron of the impurity atom will be loosely attached with the nucleus as it has not formed the covalent bond.
- ✶ The energy level of the loosely attached fifth electron is found just below the conduction band edge and is called the ***donor energy level***
- ✶ The energy required to set free a donor electron is only 0.01 eV for Ge and 0.05 eV for Si.
- ✶ At room temperature, these electrons can easily move to the conduction band with the absorption of thermal energy.
- ✶ The pentavalent impurity atoms donate electrons to the conduction band and are called ***donor impurities***.
- ✶ Therefore,each impurity atom provides one extra
- ✶ electron to the conduction band in addition to the thermally generated electrons
- ✶ Hence, in an N - type semiconductor, the
  majority carriers - Electrons
  minority carriers - Holes

P - type semiconductor :

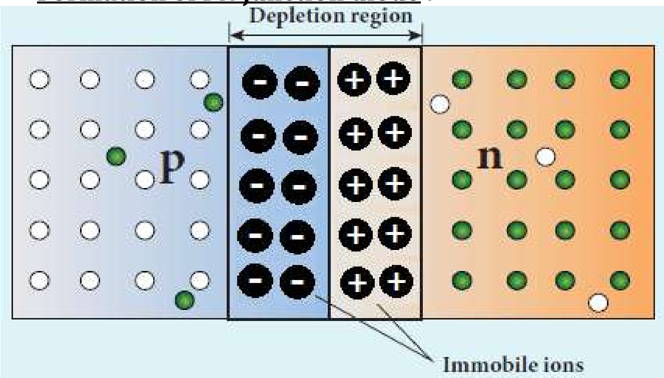


- ✶ A n-type semiconductor is obtained by doping a pure Silicon (or Germanium) crystal with a dopant from trivalent elements like Boron, Aluminium, Gallium and Indium
- ✶ The dopant has three valence electrons while the Silicon atom has four valence electrons.
- ✶ During the process of doping, the dopant with three valence electrons are bound with the neighbouring three Silicon atoms.

- ✶ As Silicon atom has four valence electrons, one electron position of the dopant in the crystal lattice will remain vacant.
- ✶ The missing electron position in the covalent bond is denoted as a hole.
- ✶ To make complete covalent, the dopant is in need of one more electron.
- ✶ These dopants can accept electrons from the neighbouring atoms. Therefore, this impurity is called an ***acceptor impurity***.
- ✶ The energy level of the hole created by each impurity atom is just above the valence band and is called the ***acceptor energy level***.
- ✶ For each acceptor atom, there will be a hole in the valence band in addition to the thermally generated holes.
- ✶ Hence, in an P - type semiconductor, the
  majority carriers - Holes
  minority carriers - Electrons

4. Explain the formation of PN junction diode..

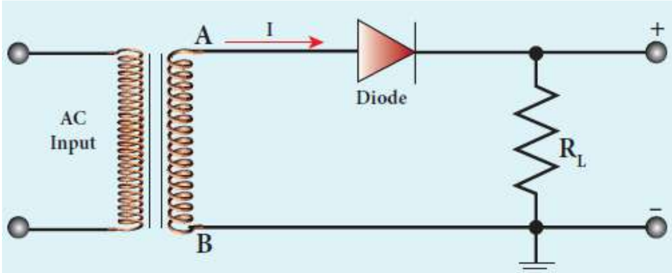
<u>Formation of PN junction diode</u> :



- ✶ A P-N junction is formed by joining N -type and P-type semiconductor materials.
- ✶ Here the N-region has a high electron concentration and the P-region a high hole concentration.
- ✶ So the electrons diffuse from the N-side to the P-side. Simillarly holes also diffuse from P - side to the N- side. This causes ***diffusion current***.
- ✶ In a P-N junction, when the electrons and holes move to the other side of the junction, they leave behind exposed charges on dopant atom sites, which are fixed in the crystal lattice and are unable to move.
- ✶ On the n-side, positive ion cores are exposed and on the p- side, negative ion cores are exposed
- ✶ An electric field E forms between the positive ion cores in the n-type material and negative ion cores in the p-type material.
- ✶ The electric field sweeps free carriers out of this region and hence it is called ***depletion region*** as it is depleted of free carriers.
- ✶ A ***barrier potential*** (V_b) due to the electric field E is formed at the junction.
- ✶ As this diffusion of charge carriers from both sides continues, the negative ions form a layer of negative space charge region along the p-side.
- ✶ Similarly, a positive space charge region is formed by positive ions on the n-side.
- ✶ The positive space charge region attracts electrons from P-side to n-side and the negative space charge region attracts holes from N-side to P -side.
- ✶ This moment of carriers happen in this region due to the formed electric field and it constitutes a current called ***drift current***.
- ✶ The diffusion current and drift current flow in the opposite direction and at one instant they both become equal.
- ✶ Thus, a P-N junction is formed.

5. Draw the circuit diagram of a half wave rectifier and explain its working.

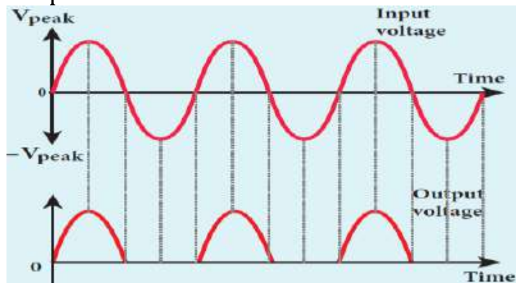
<u>Half wave rectifier</u> :



- ✶ In a half wave rectifier circuit, either a positive half or the negative half of the AC input is passed through while the other half is blocked.
- ✶ Only one half of the input wave reaches the output. Therefore, it is called half wave rectifier.
- ✶ This circuit consists of a transformer, a P-N junction diode and a resistor (R_L)
- ✶ Here, a P-N junction diode acts as a rectifying diode.

During positive half cycle of input AC	During negative half cycle of input AC
Terminal A becomes positive with respect to terminal B.	Terminal B becomes positive with respect to terminal A.
The diode is forward biased and hence it conducts	The diode is reverse biased and hence it does not conducts
The current flows through the load resistor R_L and the AC voltage developed across R_L constitutes the output voltage V_0	No current passes through R_L and there is no voltage drop across R_L (The reverse saturation current in a diode is negligible)

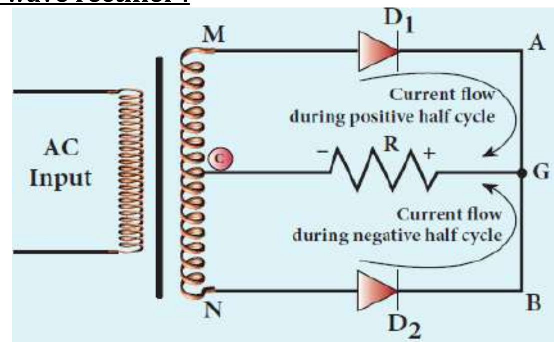
- ✶ The output waveform is shown below.



- ✶ The output of the half wave rectifier is not a steady dc voltage but a pulsating wave.
- ✶ A constant ora steady voltage is required which can be obtained with the help of filter circuits and voltage regulator circuits.
- ✶ Efficiency (η) is the ratio of the output dc power to the ac input power supplied to the circuit. Its value for half wave rectifier is **40.6 %**

6. Explain the construction and working of a full wave rectifier.

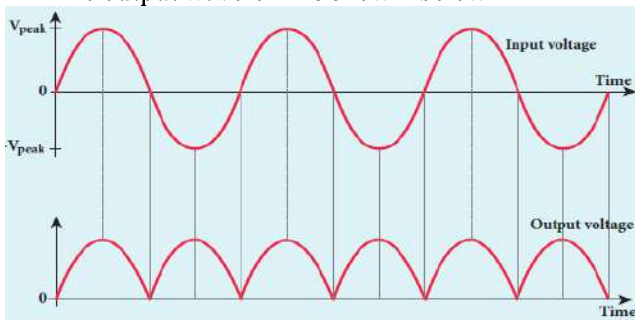
<u>Full wave rectifier :</u>



- ✶ The positive and negative half cycles of the AC input signal pass through this circuit and hence it is called the full wave rectifier.
- ✶ It consists of two P-N junction diodes, a center tapped transformer, and a load resistor (R_L).
- ✶ The centre (C) is usually taken as the groundor zero voltage reference point.
- ✶ Due to the centre tap transformer, the output voltage rectified by each diode is only one half of the total secondary voltage.

During positive half cycle of input AC	During negative half cycle of input AC
Terminal M is positive, G is at zero potential and N is at negative potential	Terminal M is negative, G is at zero potential and N is at positive potential
Diode D_1 is forward biased Diode D_2 is reverse biased	Diode D_1 is reverse biased Diode D_2 is forward biased
D_1 conducts and current flows along the path **MD_1AGC**	D_2 conducts and current flows along the path **ND_2 BGC**
The voltage appears across R_L in the direction G to C	The voltage appears across R_L in the same direction G to C

- ✶ Hence in a full wave rectifier both postive and negative half cycles of the input signal pass through the circuit in the same direction
- ✶ The output waveform is shown below.

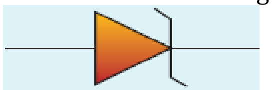


- ✶ Though both positive and negative half cycles of ac input are rectified, the output is still pulsating in nature.
- ✶ The efficiency (η) of full wave rectifier is twice that of a half wave rectifier and is found to be 81.2 %.

7. Write a note on Zener diode. Explain the V - I characteristics of Zener diode.

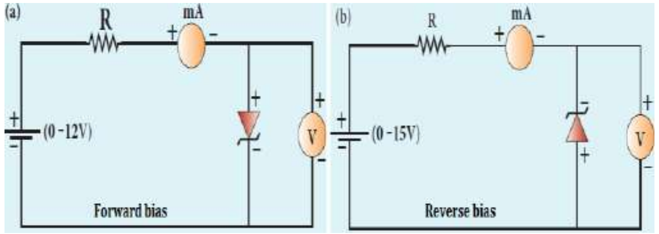
<u>Zener diode</u> :

- ✶ Zener diode is a reverse biased heavily doped Silicon diode, designed to be operated in the breakdown region.
- ✶ Zener breakdown occurs due to the breaking of covalent bonds by the strong electric field set up in the depletion region by the reverse voltage.
- ✶ It produces an extremely large number of electrons and holes which constitute the reverse saturation current.
- ✶ The circuit symbol of Zener diode is given below.

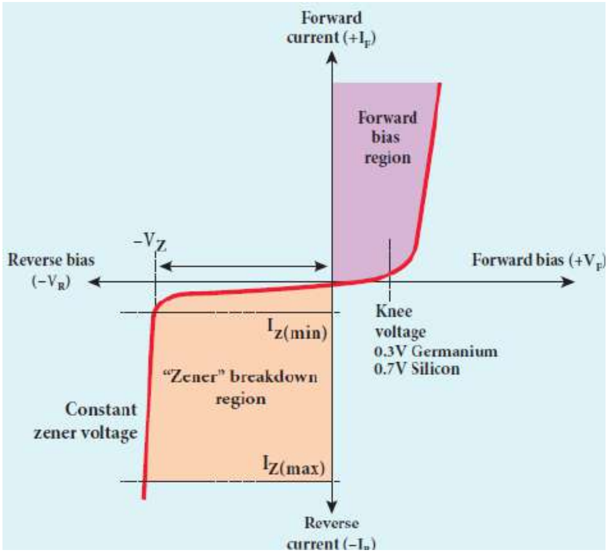


<u>V-I Characteristics of Zener diode</u> :

- ✶ The circuit to study the forward and reverse characteristic s of a Zener diode is shown below.



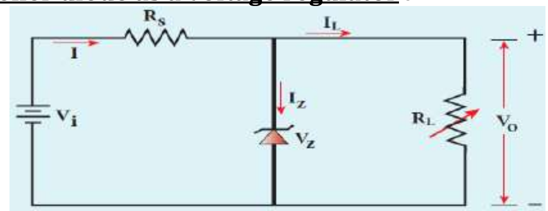
- ✶ The V-I characteristics of a Zener diode is shown below.



- ✶ The forward characteristic of a Zener diode is similar to that of an ordinary P-N junction diode.
- ✶ It starts conducting approximately around 0.7 V.
- ✶ However, the reverse characteristics is highly significant in Zener diode.
- ✶ The increase in reverse voltage normally generates very small reverse current.
- ✶ While in Zener diode, when the reverse voltage is increased to the breakdown voltage (V_Z), the increase in current is very sharp.
- ✶ The voltage remains almost constant throughout the breakdown region.
- ✶ Here, I_Z(max) represents the maximum reverse current.
- ✶ If the reverse current is increased further, the diode will be damaged.
- ✶ The important parameters on the reverse characteristics are
  V_Z→Zener breakdown voltage
  I_Z(min)→minimum current to sustain breakdown
  IZ(max)→maximum current limited by maximum power dissipation.
- ✶ The Zener diode is operated in the reverse bias having the voltage greater than V_Z and current less than I_Z(max).
- ✶ The reverse characteristic is not exactly vertical which means that the diode possesses some small resistance called Zener dynamic impedance.
- ✶ Zener resistance is the inverse of the slope in the breakdown region. It means an increase in the Zener current produces only a very small increase in the reverse voltage which can be neglected.
- ✶ Thus the voltage of an ideal Zener diode does not change once it goes into breakdown.
- ✶ It means that V_Z remains almost constant even when I_Z increases considerably.

8. Explain the working of Zener diode as a voltage regulator.

<u>Zener diode as a voltage regulator</u> :



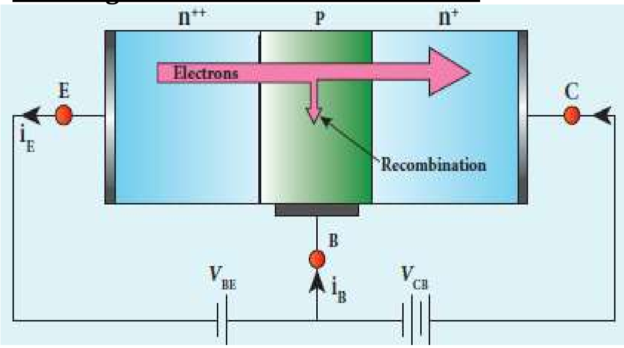
- ✶ A Zener diode working in the breakdown region can serve as a voltage regulator.
- ✶ It maintains a constant output voltage even when input voltage (V_i) or load current (I_L) varies.
- ✶ Here, in this circuit the input voltage V_i is regulated at a constant voltage Vz (Zener voltage) at the output represented as V_0 using a Zener diode.
- ✶ The output voltage is maintained constant as long as the input voltage does not fall below Vz .
- ✶ When the potential developed across the diode is greater than V_Z, the diode moves into the Zener breakdown region.
- ✶ It conducts and draws relatively large current through the series resistance R_S .
- ✶ The total current I passing through R_S equals the sum of diode current I_Z and load current I_L (i.e.)

$$I = I_Z + I_L$$

- ✶ It is to be noted that the total current is always less than the maximum Zener diode current.
- ✶ Under all conditions $V_O = V_Z$
- ✶ Thus, output voltage is regulated.

9. Explain transistor action in common base configuration.

<u>Working of NPN transistor in CB mode</u> :



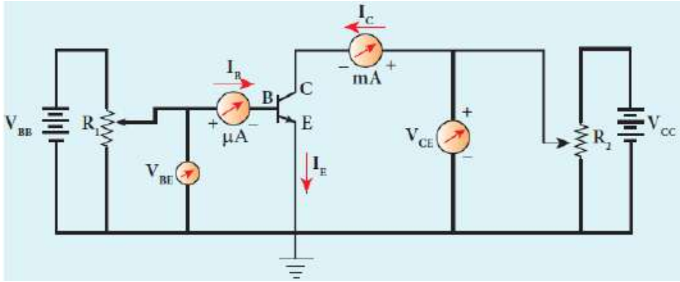
- ✶ Basically, a BJT can be considered as two P-N junction diodes connected back to- back.
- ✶ In the forward active bias of the transistor, the emitter-base junction is forward biased by V_{EB} and the collector-base junction is reverse biased by V_{CB}.
- ✶ The forward bias decreases the depletion region across the emitter-base junction and the reverse bias increases the depletion region across the collector-base junction.
- ✶ Hence, the barrier potential across the emitter-base junction is decreased and the collector-base junction is increased.
- ✶ In an NPN transistor, the majority charge carriers in the emitter are electrons. As it is heavily doped, it has a large number of electrons.
- ✶ The forward bias across the emitter-base junction causes the electrons in the emitter region to flow towards the base region and constitutes the ***emitter current*** **(I_E).**
- ✶ The electrons after reaching the base region recombine with the holes in the base region.
- ✶ Since the base region is very narrow and lightly doped, all the electrons will not have sufficient holes to recombine and hence most of the electrons reach the collector region.
- ✶ Eventually, the electrons that reach the collector region will be attracted by the collector terminal as it has positive potential and flows through the external circuit.
- ✶ This constitutes the ***collector current*** **(I_C).**
- ✶ The holes that are lost due to recombination in the base region are replaced by the positive potential of the bias voltage V_{EB} and constitute the ***base current*** **(I_B).**
- ✶ The magnitude of the base current will be in micoamperes as against milliamperes for emitter and collector currents.
- ✶ It is to be noted that if the emitter current is zero, then the collector current is almost zero.
- ✶ It is therefore imperative that a BJT is called a ***current controlled device***.
- ✶ Applying Kirchoff 's law, we can write the emitter current as the sum of the collector current and the base current. $I_E = I_B + I_C$
- ✶ Since the base current is very small, we can write, $I_E \approx I_C$
- ✶ There is another component of collector current due to the thermally generated electrons called reverse saturation current, denoted as I_{CO}.
- ✶ This factor is temperature sensitive.
- ✶ The ratio of the collector current to the emitter current is called the forward current gain (α_{dc}) of a transistor.

$$\alpha_{dc} = \frac{I_C}{I_E}$$

- ✶ The α of a transistor is a measure of the quality of a transistor. Higher the value of α better is the transistor.
- ✶ The value of α is less than unity and ranges from **0.95** to **0.99**.

10. Sketch the static characteristics of a common emitter transistor and bring out the essence of input and output characteristics.

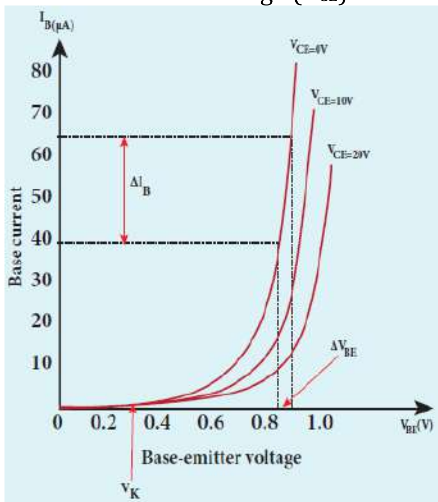
<u>Static characteristics of NPN transistor in CE mode</u> :



V_{BE} – Base - emitter voltage
V_{CE} – Collector - emitter voltage
I_B – Base current
I_C – Collector current
V_{BB} & V_{CC} –Biasing voltages
R_1 & R_2 – Variable resistors

(1) **<u>Input characteristics</u>** :

- ✶ Input Characteristics curves give the relationship between the base current (I_B) and base to emitter voltage (V_{BE}) at constant collector to emitter voltage (V_{CE})



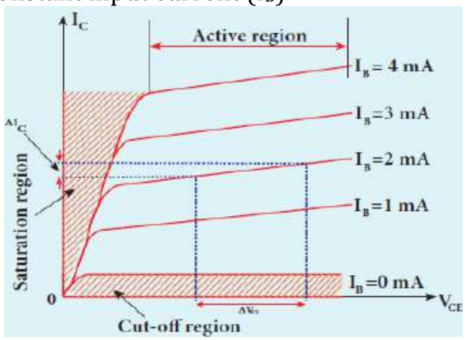
- ✶ The curve looks like the forward characteristics of an ordinary P-N junction diode.
- ✶ There exists a threshold voltage or knee voltage (V_k) below which the base current is very small.
- ✶ Beyond the knee voltage, the base current increases with the increase in base-emitter voltage.
- ✶ It is also noted that the increase in the collector-emitter voltage decreases the base current. This shifts the curve outward.
- ✶ This is because the increase in collector-emitter voltage increases the width of the depletion region in turn, reduces the effective base width and thereby the base current.
- ✶ The ratio of the change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at a constant collector-emitter voltage (V_{CE}) is called the ***input resistance*** (r_i).

$$r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B}\right]_{V_{CE}}$$

- ✶ The input resistance is high for a transistor in common emitter configuration.

(2) **Output characteristics** :

- ✶ The output characteristics give the relationship between the variation in the collector current (ΔI_C) with respect to the variation in collector-emitter voltage (ΔV_{CE}) at constant input current (I_B)



- ✶ There are four important regions in the curve
  - (i) Saturation region
  - (ii) Cut-off region
  - (iii) Active region
  - (iv) Break down region

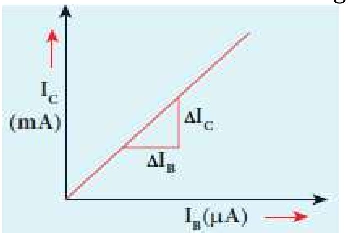
- ✶ The ratio of the change in the collectoremitter voltage (ΔV_{CE}) to the corresponding change in the collector current (ΔI_C) at constant base current (I_B) is called output resistance (r_o).

$$r_o = \left[\frac{\Delta V_{CE}}{\Delta I_C}\right]_{I_B}$$

- ✶ The output resistance for transistor in common emitter configuration is very low.

(3) **Current transfer characteristics** :

- ✶ This gives the variation of collector current (I_C) with changes in base current (I_B) at constant collector-emitter voltage (V_{CE})



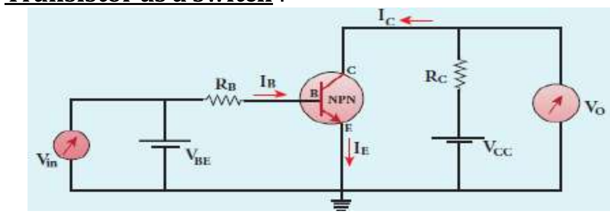
- ✶ It is seen that a small I_C flows even when I_B is zero.
- ✶ This current is called the common emitter leakage current (I_{CEO}), which is due to the flow of minority charge carriers.
- ✶ The ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}) is called forward current gain (β).

$$\beta = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{CE}}$$

- ✶ Its value is very high and it generally ranges from 50 to 200.

11. Transistor functions as a switch. Explain.

Transistor as a switch :



- ✶ The transistor in saturation and cut-off regions functions like an electronic switch that helps to turn ON or OFF a given circuit by a small control signal.

Presence of dc source at the input (saturation region) :

- ✶ When a high input voltage (V_{in} = +5 V) is applied, the base current (I_B) increases and in turn increases the collector current.
- ✶ The transistor will move into the saturation region (turned ON).
- ✶ The increase in collector current (I_C) increases the voltage drop across R_C, thereby lowering the output voltage, close to zero.
- ✶ The transistor acts like a closed switch and is equivalent to ON condition.

Absence of dc source at the input (cutoff region) :

- ✶ A low input voltage (V_{in} = 0 V), decreases the base current (I_B) and in turn decreases the collector current (I_C).
- ✶ The transistor will move into the cut-off region (OFF).
- ✶ The decrease in collector current (I_C) decreases the drop across R_C, thereby increasing the output voltage, close to +5 V.
- ✶ The transistor acts as an open switch which is considered as the OFF condition.
- ✶ It is manifested that, a high input gives a low output and a low input gives a high output.
- ✶ Therefore, a transistor can be used as an inverter in computer logic circuitry.

12. State and prove De Morgan's First and Second theorems.

De Morgan's First Theorem :

- ✶ The complement of the sum of two logical inputs is equal to the product of its complements.

$$\overline{A+B} = \overline{A}\,.\,\overline{B}$$

Proof :

- ✶ The Boolean equation for NOR gate is

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

- ✶ The Boolean equation for a bubbled AND gate is

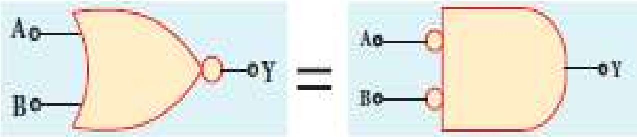
$$Y = \overline{A}\,.\,\overline{B}$$

A	B	A+B	$\overline{A+B}$	$\overline{A}$	$\overline{B}$	$\overline{A}\,.\,\overline{B}$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

- ✶ From the above truth table, we can conclude

$$\overline{A+B} = \overline{A}\,.\,\overline{B}$$

- ✶ Thus De Morgan's First Theorem is proved.
- ✶ It also says that a NOR gate is equal to a bubbled AND gate.
- ✶ The corresponding logic circuit diagram



De Morgan's First Theorem :

- ✶ The complement of the products of two logical inputs is equal to the sum of its complements.

$$\overline{\boldsymbol{A}\,.\,\boldsymbol{B}} = \overline{\boldsymbol{A}} + \overline{\boldsymbol{B}}$$

Proof :

- ✶ The Boolean equation for NAwD gate is

$$\boldsymbol{Y} = \overline{\boldsymbol{A}\,.\,\boldsymbol{B}}$$

- ✶ The Boolean equation for a bubbled OR gate is

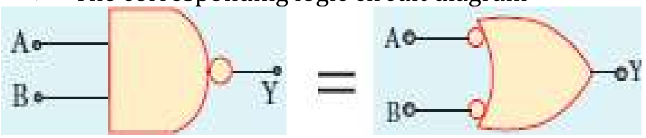
$$\boldsymbol{Y} = \overline{\boldsymbol{A}} + \overline{\boldsymbol{B}}$$

A	B	A .B	$\overline{A.B}$	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

- ✶ From the above truth table, we can conclude

$$\overline{\boldsymbol{A}\,.\,\boldsymbol{B}} = \overline{\boldsymbol{A}} + \overline{\boldsymbol{B}}$$

- ✶ Thus De Morgan's second Theorem is proved.
- ✶ It also says that a NAND gate is equal to a bubbled OR gate.
- ✶ The corresponding logic circuit diagram



13. State Boolean laws. Elucidate how they are used to simplify Boolean expressions with suitable example.

Boolean laws :

(1) Complement law :

(i) $\overline{\overline{A}} = A$

(2) OR –Laws:

(i) $A + 0 = A$
(ii) $A + 1 = 1$
(iii) $A + A = A$
(iv) $A + \overline{A} = 1$

(3) AND –Laws:

(i) $A\,.0 = 0$
(ii) $A\,.1 = A$
(iii) $A\,.\,A = A$
(iv) $A\,.\,\overline{A} = 0$

(4) Commutative Laws :

(i) $A + B = B + A$
(ii) $A\,.\,B = B\,.\,A$

(5) Associative Laws :

(i) $A + (B + C) = (A + B) + C$
(ii) $A\,.\,(B.\,C) = (A\,.\,B).\,C$

(6) Distributive Laws :

(i) $A\,(B + C) = A\,B + A\,C$
(ii) $A + (B\,C) = (A + B)(A + C)$

Example :

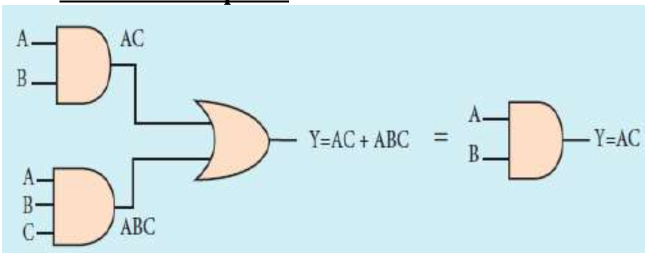
Simplify the following Boolean expression.

$$\boldsymbol{AC + ABC}$$

Solution :

$AC + ABC = AC\,(1 + B)$
$AC + ABC = AC\,.1$ [OR –law (2)]
$\boldsymbol{AC + ABC = AC}$ [AND –law (2)]

Circuit description



14. What is called modulation? Explain the types of modulation with help of necessary diagrams.

Modulation :

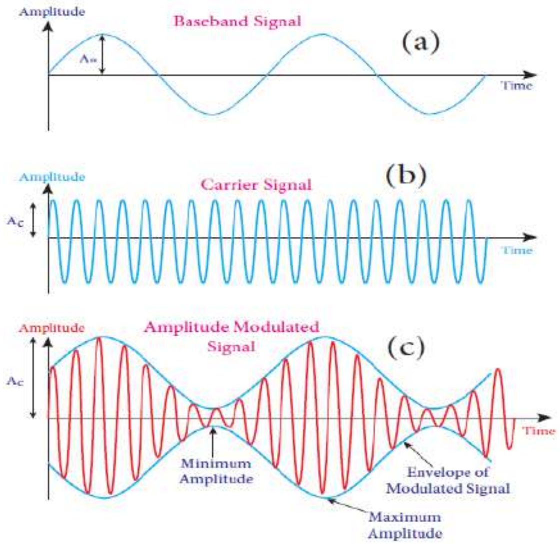
- ♦ For long distance transmission, the low frequency baseband signal (input signal) is superimposed onto a high frequency radio signal by a process called modulation.
- ♦ In the modulation process, a very high frequency signal called carrier signal (radio signal) is used to carry the baseband signal.

Types of modulation :

(1) Amplitude modulation (AM)
(2) Frequency modulation (FM)
(3) Phase modulation (PM)

Amplitude modulation (AM) :

- ♦ If the amplitude of the carrier signal is modified according to the instantaneous amplitude of the baseband signal, then it is called amplitude modulation.
- ♦ Here the frequency and the phase of the carrier signal remain constant.



- ♦ We can see clearly that the carrier wave is modified in proportion to the amplitude of the baseband signal.
- ♦ Amplitude modulation is used in radio and TV broadcasting.

Advantages of AM :

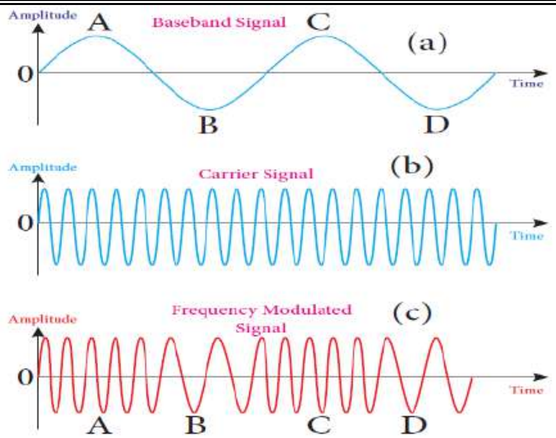
- ♦ Easy transmission and reception
- ♦ Lesser bandwidth requirements
- ♦ Low cost

Limitations of AM :

- ♦ Noise level is high
- ♦ Low efficiency
- ♦ Small operating range

Frequency modulation (FM) :

- ♦ If the frequency of the carrier signal is modified according to the instantaneous amplitude of the baseband signal, then it is called frequency modulation.
- ♦ Here the amplitude and the phase of the carrier signal remain constant.



- When the amplitude of the baseband signal is zero, the frequency of the modulated signal is the same as the carrier signal.
- The frequency of the modulated wave increases when the amplitude of the baseband signal increases in the positive direction (A, C).
- The increase in amplitude in the negative half cycle (B, D) reduces the frequency of the modulated wave
- When the frequency of the baseband signal is zero (no input signal), there is no change in the frequency of the carrier wave.
- It is at its normal frequency and is called as ***centre frequency*** or ***resting frequency***.
- Practically **75 kHz** is the allotted frequency of the FM transmitter.

Advantages of FM :

- Large decrease in noise. This leads to an increase in signal-noise ratio.
- The operating range is quite large.
- The transmission efficiency is very high as all the transmitted power is useful.
- FM bandwidth covers the entire frequency range which humans can hear. Due to this, FM radio has better quality compared to AM radio.

Limitations of FM :

- FM requires a much wider channel.
- FM transmitters and receivers are more complex and costly.
- In FM reception, less area is covered compared to AM.

Phase modulation (PM) :

- The instantaneous amplitude of the baseband signal modifies the phase of the carrier signal keeping the amplitude and frequency constant is called phase modulation
- This modulation is used to generate frequency modulated signals.