CBSE Class-12 Physics Quick Revision Notes
Chapter-14: Semiconductor Electronics

- **Intrinsic Semiconductor:**
  The pure semiconductors in which the electrical conductivity is totally governed by the electrons excited from the valence band to the conduction band and in which no impurity atoms are added to increase their conductivity are called intrinsic semiconductors and their conductivity is called intrinsic conductivity. Electrical conduction in pure semiconductors occurs by means of electron-hole pairs. In an intrinsic semiconductor,

  $$n_e = n_h = n_i$$

  where n_e = the free electron density in conduction band, n_h = the hole density in valence band, and n_i = the intrinsic carrier concentration.

- **Extrinsic Semiconductors:**
  A Semiconductor doped with suitable impurity atoms so as to increase its conductivity is called an extrinsic semiconductor.

- **Types of Extrinsic Semiconductors:**
  Extrinsic semiconductors are of two types
  i)   n-type semiconductors
  ii) p-type semiconductors
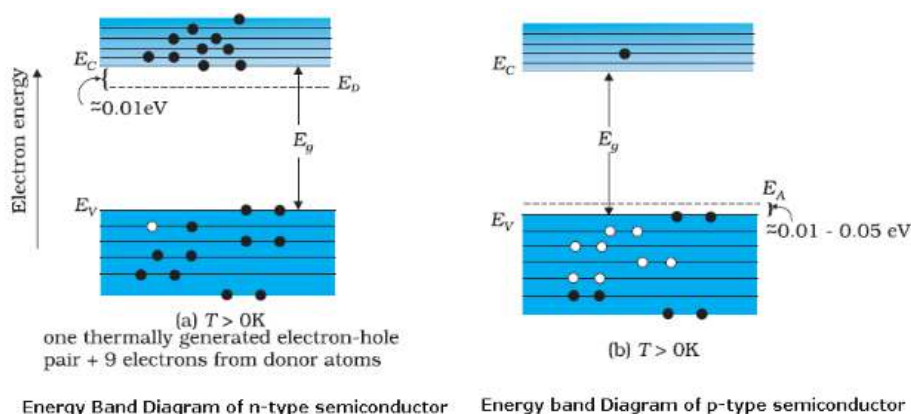
- **n-type semiconductors:**
  The pentavalent impurity atoms are called donors because they donate electrons to the host crystal and the semiconductor doped with donors is called n-type semiconductor. In n-type semiconductors, electrons are the majority charge carriers and holes are the minority charge carriers. Thus,

  $$n_e \gg n_h$$

- **p-type semiconductors:**
  The trivalent impurity atoms are called acceptors because they create holes which can accept electrons from the nearby bonds. A semiconductor doped with acceptor type impurities is called a p-type semiconductor. In p-type semiconductor, holes are the majority carriers and electrons are the minority charge carriers Thus,

  $$n_h \gg n_e$$

(a) $T > 0K$
one thermally generated electron-hole
pair + 9 electrons from donor atoms

(b) $T > 0K$

Energy Band Diagram of n-type semiconductor   Energy band Diagram of p-type semiconductor

- **Holes:**

  The vacancy or absence of electron in the bond of a covalently bonded crystal is called a hole. A hole serves as a positive charge carrier.

- **Mobility:**

  a) The drift velocity acquired by a charge carrier in a unit electric field is called its electrical mobility and is denoted by μ.

  $$\mu = \frac{V_d}{E}$$

  b) The mobility of an electron in the conduction band is greater than that of the hole (or electron) in the valence band.

- **Electrical conductivity of a Semiconductor:**

  a) If a potential difference V is applied across a conductor of length L and area of cross-section A, then the total current I through it is given by,

  $$I = eA(n_e v_e + n_h v_h)$$

  where n_e and n_h are the electron and hole densities, and v_e and v_h are their drift velocities, respectively.

  b) If μ_h are the electron and hole mobilities, then the conductivity of the semiconductor will be,

  $$\rho = e(n_e \mu_e + n_h \mu_h)$$

  and the resistivity will be,

  $$\rho = \frac{1}{e(n_e \mu_e + n_h \mu_h)}$$

  c) The conductivity of an intrinsic semiconductor increases exponentially with temperature as,

 $$\sigma = \sigma_0 \exp\left(-\frac{E_g}{2k_B T}\right)$$

- **Forward Biasing of a pn-junction:**

  If the positive terminal of a battery is connected to the p-side and the negative terminal to the n-side, then the pn-junction is said to be forward biased. Both electrons and holes

move towards the junction. A current, called forward current, flows across the junction. Thus a pn-junction offers a low resistance when it is forward biased.

- **Reverse Biasing of a pn-junction:**

  If the positive terminal of a battery is connected to the n-side and negative terminal to the p-side, then pn-junction is said to be reverse biased. The majority charge carriers move away from the junction. The potential barrier offers high resistance during the reverse bias. However, due to the minority charge carriers a small current, called reverse or leakage current flows in the opposite direction. Thus junction diode has almost a unidirectional flow of current.

(a) Forward Bias: pn Junction   (b) Reverse Bias: pn Junction
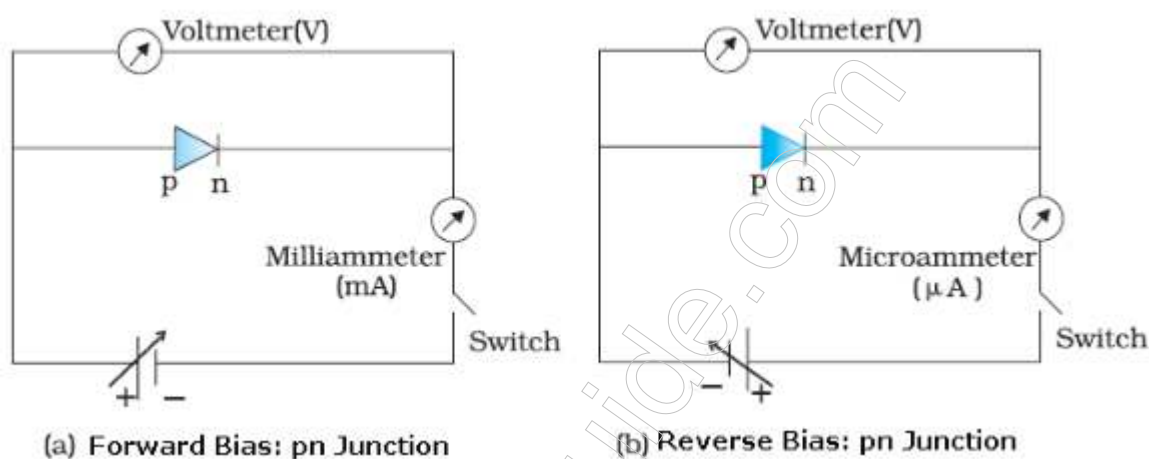
- **Action of a transistor:**

  When the emitter-base junction of an npn-transistor is forward biased, the electrons are pushed towards the base. As the base region is very thin and lightly doped, most of the electrons cross over to the reverse biased collector. Since few electrons and holes always recombine in the base region, so the collector current I_c is always slightly less then emitter current I_E.

  $$I_E = I_C + I_B$$

  Where I_B is the base current.

- **Three Configurations of a Transistor:**

  A transistor can be used in one of the following three configurations:

  a) Common-base (CB) circuit.
  b) Common-emitter (CE) circuit.
  c) Common-collector (CC) circuit.

- **Current Gains of a Transistor:**

  Usually low current gains are defined:

  a) **Common base current amplification factor or ac current gain α:**

     It is the ratio of the small change in the collector current to the small change in the emitter current when the collector-base voltage is kept constant.

     $$\alpha = \left[\frac{\delta I_C}{\delta I_E} \right]_{V_{CB}=\text{constant}}$$

b) **Common emitter current amplification factor or ac current gain β:**

It is the ratio of the small change in the collector current to the small change in the base current when the collector emitter voltage is kept constant.

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

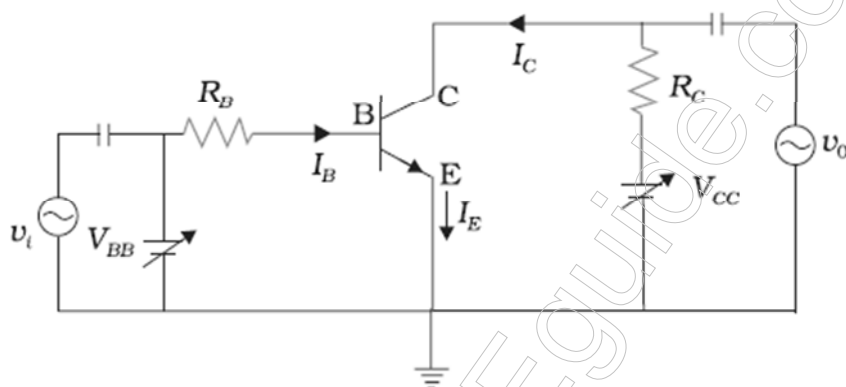- **Relations between α and β:**

The current gains α and β are related as,

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

- **Transistor as an amplifier:**

An amplifier is a circuit which is used for increasing the voltage, current or power of alternating form. A transistor can be used as an amplifier.

- **AC Current Gain:**

AC current gain is defined as,

$$\beta_{ac} \ \text{or} \ A_i = \left[\frac{\delta I_C}{\delta I_B} \right]_{V_{CE= constant}}$$

- **DC Current Gain:**

DC current gain is defined as,

$$\beta_{dc} = \left[\frac{I_C}{I_B} \right]_{V_{CE= constant}}$$

- **Voltage Gain of an Amplifier:**

It is defined as,

$$A_v = \frac{V_0}{V_i} = \frac{\text{A small change in output voltage}}{\text{A small change in input voltage}}$$

$$A_V = \frac{\delta V_{CE}}{\delta V_{BE}}$$

$$A_V = \beta_{ac} . \frac{R_{out}}{R_{in}} = A_i . A_r$$

i.e., Voltage gain = Current gain X Resistance gain

- **Power Gain of an Amplifier:**

  It is defined as,

  $$A_p = \frac{\text{Output power}}{\text{Input power}} = \text{current x voltage gain}$$

  or

  $$A_p = A_i.A_v = \beta_{ac}^2.\frac{R_{out}}{R_{in}}$$

- **Logic Gate:**

  A logic gate is a digital circuit that has one or more inputs but only one output. It follows a logical relationship between input and output voltage.

- **Truth Table:**

  This table shows all possible input combination and the corresponding output for a logic gate.

- **Boolean Expression:**

  It is a shorthand method of describing the function of a logic gate in the form of an equation or an expression. It also relates all possible combination of the inputs of a logic gate to the corresponding outputs.

- **Positive and Negative Logic:**

  If in a system, the higher voltage level represents 1 and the lower voltage level represent 0, the system is called a positive logic. If the higher voltage represents 0 and the lower voltage level represents 1, then the system is called a negative logic.

- **OR Gate:**

  An OR gate can have any number of inputs but only one output. It gives higher output (1) if either input A or B or both are high (1), otherwise the output is low (0).

  $$A + B = Y$$

  Which is read as 'A or B equals Y'.

- **AND gate:**

  An AND gate can have any number of inputs but only one output. It gives a high output (1) if inputs A and B are both high (1), or else the output is low (0). It is described by the Boolean expression.

  $$A . B = Y$$

  Which is read as 'A and B equals Y'.

- **NOT Gate:**

  A NOT gate is the simplest gate, with one input and one output. It gives as high output (1) if the input A is low (0), and vice versa.

  Whatever the input is, the NOT gate inverts it. It is described by the Boolean expression:

  $$\bar{A} = Y$$

  Which is read as 'not A equal Y'.

- **NAND (NOT+AND) gate:**
  It is obtained by connecting the output of an AND gate to the input of a NOT gate. Its output is high if both inputs A and B are not high. If is described by the Boolean expression.

  $$\overline{A.B} = Y \text{ or } \overline{AB} = Y$$

  Which is read as 'A and B negated equals Y'.

- **NOR (NOT+OR) Gate:**
  It is obtained by connecting the output of an OR gate to the input of a NOT gate. Its output is high if neither input A nor input B is high. It is described by the Boolean expression.

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

  Which is read as 'A and B negated equals Y'.

- **XOR or Exclusive OR gate.** The XOR gate gives a high output if either input A or B is high but not when both A and B are high or low. It can be obtained by using a combination of two NOT gates, two AND gates and one OR gate. It is described by Boolean expression:

  $$Y = \overline{AB} + \overline{AB}$$

  The XOR gate is also known as difference gate because its output is high when the inputs are different.

- **Integrated Circuits:**
  The concept of fabricating an entire circuit (consisting of many passive components like R and C and active devices like diode and transistor) on a small single block (or chip) of a semiconductor has revolutionized the electronics technology. Such a circuit is known as Integrated Circuit (IC).