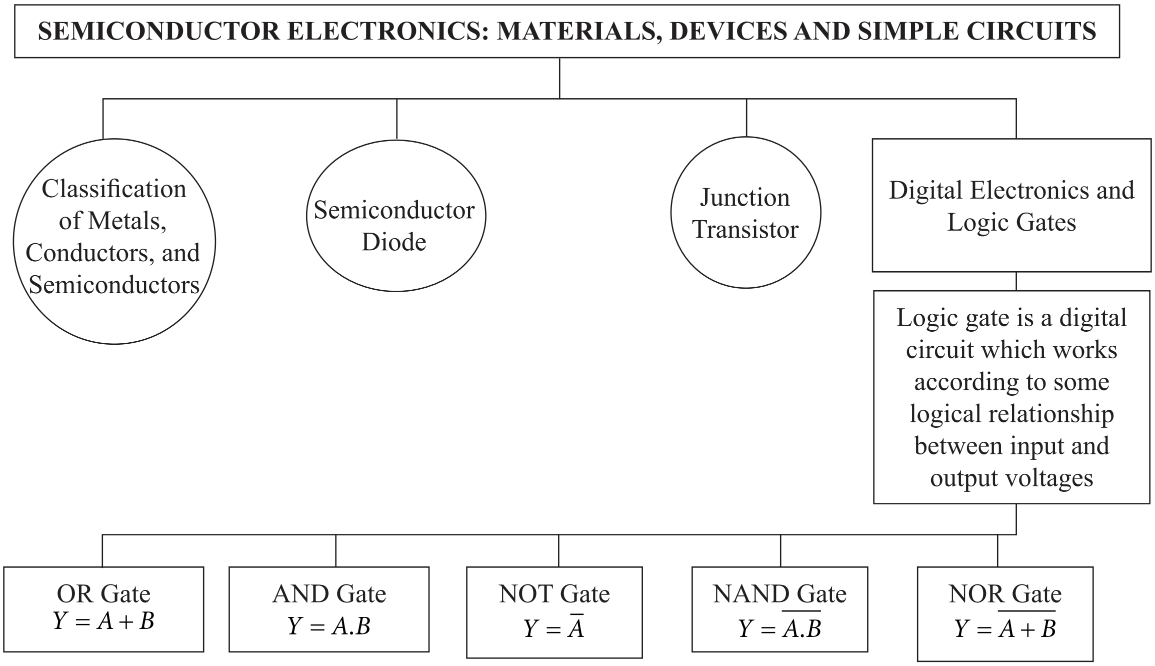
CHAPTER | 14 |

Semiconductor Electronics: Materials, Devices and Simple Circuits

Syllabus

- **Classification of metals, conductors, semiconductors and Insulators :** Energy bands of solids or band theory of solid; conductors; Insulators; and Semiconductors; Intrinsic semiconductor; Doping; Extrinsic semiconductor.
- **Semiconductor diode:** Biasing of the p-n junction diode; Characteristics of a p-n junction diode; Application of junction diode as a rectifier; Zener diode; LED; Photodiode; Solar cell.
- **Junction transistor**: Transistor structure and action; Circuit Connections of Transistor; Basic Transistor Circuit Configurations; Transistor as a switch; Transistor as an Amplifier (CE-Configuration); Transistor as an oscillator.
- **Digital electronics and logic gates**: Logic gates.

MIND MAP



Mind Map 1: Semiconductor Electronics: Materials, Devices and Simple Circuits

CLASSIFICATION OF METALS, CONDUCTORS AND SEMICONDUCTORS

- Energy Bands of Solids or Band Theory of solids
  - Valence Band
    Range of energies associated with valence electrons is called valence band. Valence band is always filled with electrons
  - Conduction Band
    The range of energies associated with conduction electrons is called as conduction band. At 0 K, conduction band is empty
  - Forbidden Energy Gap or Forbidden Band: $E_g = E_c - E_v$
- Conductor
  Solids which have (very) high conductivity
- Insulators
  Solids which have very low (≈ 0) conductivity
- Semiconductors
  Solids whose conductivity lies between that of conductors and insulators
- Intrinsic Semiconductors
  It is a pure semiconductor
- Doping
  Process of adding impurity to a pure semiconductor crystal
- Extrinsic Semiconductors
  Semiconductor doped with suitable impurity atoms
  n-Type Semiconductor
  p-Type Semiconductor

Mind Map 2: Classification of Metals, Conductors, and Semiconductors

SEMICONDUCTOR DIODE

Device which freely allows electric current in one direction but does not allow it in the opposite direction

- Biasing of the p-n Junction Diode
  Applying an external battery across the two ends of the diode
  Forward Biasing of a p-n Junction
  Reverse Biasing of a p-n Junction
- Characteristics of a p-n Junction Diode
  - Reverse Breakdown
    If the reverse biased voltage is too high, then breakdown of p-n junction diode occurs
    Zener Breakdown
    Avalanche Breakdown
  - Dynamic Resistance, $r_d = \frac{\Delta V}{\Delta I}$
- Application of Junction Diode as a Rectifier
  Electronic device which converts A.C. power into D.C. power
  - Half Wave Rectifier
    $I_{dc} = \frac{I_0}{\pi}$ and $V_{dc} = \frac{V_0}{\pi}$, $I_{rms} = \frac{I_0}{2}$, $V_{rms} = \frac{V_0}{2}$
    $I_0 = \frac{V_0}{r_d + R_L}$
  - Full Wave Rectifier
    $V_{dc} = \frac{2V_0}{\pi}$ and $I_{dc} = \frac{2I_0}{\pi}$, $V_{rms} = \frac{V_0}{\sqrt{2}}$, $I_{rms} = \frac{I_0}{\sqrt{2}}$
- Zener Diode
  Specially designed junction diode which can operate in the reverse breakdown voltage region continuously without being damaged
- Zener Diode as Voltage Regulator
  $V_z = V_{in} - I_s R_s$
  $I_z = I_s - I_L$
  $P_z = I_z V_z$
- Zener Diode
  Specially designed junction diode which can operate in the reverse breakdown voltage region continuously without being damaged
- Light Emitting Diode (LED)
  It is specially designed diode which emits light energy forward biased
- Photodiode
  Photodiode is a junction diode made from the photosensitive semiconductor
- Solar Cell
  Semiconductor device that converts solar energy into electrical energy

Mind Map 3: Semiconductor Diode

JUNCTION TRANSISTOR

- Transistor: Structure and Action
  Transistor, in general is known as bipolar junction transistor as it contains two junctions back to back, (either p-n and n-p or n-p and p-n)
  - npn Transistor
    It is formed by sandwiching a thin layer of p-type semiconductor between two n-type semiconductors
  - pnp Transistor
    It is formed by sandwiching a thin layer of n-type semiconductor between two p-type semiconductor
- Circuit Connections of Transistor
  Circuit of a transistor is always joined such as the emitter base circuit is forward biased and collector-base circuit is reversed bias
- Basic Transistor Circuit Configurations
  In a transistor, only three terminals are available, viz. Emitter (E), Base (B), and collector (C)
- Transistor as a Switch
  $V_i = V_{BB} = I_B R_B + V_{BE}$
  $V_0 = V_{CE} = V_{CC} - I_C R_C$
- Transistor as an amplifier (CE configuration)
  When the transistor is used as an amplifier (CE configuration), the emitter terminal is common to both input and output circuits
- Transistor as an Oscillator
  $$\nu = \frac{1}{2\pi\sqrt{LC}}$$

Mind Map 4: Junction Transistor

RECAP

Classification of Metals, Conductors, and Semiconductors

Energy Bands of Solids or Band Theory of solids

- The group of discrete but closely spaced energy levels for the electrons in a particular orbit is called energy band
- The following are the energy bands in solids
  - **Valence Band:** Range of energies associated with valence electrons. Valence band is always filled with electrons
  - **Conduction Band:** Range of energies associated with conduction electrons. At 0 K, conduction band is empty.
  - **Forbidden Energy Gap or Forbidden Band:** The separation between highest energy level of valence band and lowest energy level of conduction band is called as forbidden energy gap.
  - The difference between energies of conduction band and valence band is band gap energy (E_g) and is given by: $E_g = E_c - E_v$
  - No electrons in the atom can occupy energy levels of the forbidden energy gap.
  - Conductivity (σ) of the materials depend upon the value of forbidden energy gap (E_g) as follows:

$$\sigma \propto \frac{1}{E_g}$$

- On the basis of the relative values of electrical conductivity (σ) or $(\rho = 1/\sigma)$, the solids are broadly classified as:
  - Metals: They possess very low resistivity (or high conductivity); Semiconductors; Insulators

Conductors

- Solids with (very) high conductivity. e.g. Fe, Cu, Ag etc. In conductors, there is no forbidden energy gap while valence band and conduction band are either overlapped or separated with extremely small energy gap between them.

Insulators

- Solids which have very low (≈ 0) conductivity are called insulators. E.g. Rubber, wood, stone, etc.
- In insulators, there is large forbidden energy gap between valence band and conduction band.
- The electrons in insulators cannot jump from valence band to occupy the energy levels in conduction band.

Semiconductors

- Solids whose conductivity lies between that of conductors and insulators. E.g. Germanium, Silicon, etc. Gap is very small.
- The electrons in semiconductors can jump from valence band to occupy energy levels in conduction band when sufficient external energy is provided. Number of valence electrons in semiconductors is exactly 4.

Intrinsic Semiconductors

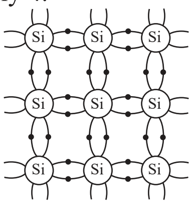


Figure: Silicon (Si) semiconductor

- A pure semiconductor. E.g. Germanium (Ge), Silicon (Si). In this, atoms are held together by covalent bond. At 0 K, intrinsic semiconductors behave like insulators as there are no free electrons in conduction band.
- At room temperature, due to thermal collision few electrons (and holes) are free to move within the semiconductor.
- As temperature increases above room temperature, equal number of holes and electrons are free for conduction due to breaking of large number of covalent bonds and semiconductor behaves like conductor.
- Conductivity is due to both electrons and holes (intrinsic charge carriers). In intrinsic semiconductor,

  $n_e = n_h = n_i =$ electron density in conduction band

  $n_h =$ holes density in valence band

  $n_i =$ density of intrinsic charge carriers

Doping

- Process of adding impurity to a pure semiconductor crystal (Si or Ge crystal) to improve its conductivity.
- The impurity atoms added are called dopants. Dopants are of two types
  - **Pentavalent dopants:** Elements with five valence electrons (donor impurities). E.g. As, P, Sb, etc.
  - **Triyalent dopants:** Elements with three valence electrons (acceptor impurities). E.g. In, Ga, Al, B, etc.

Extrinsic Semiconductors

- Pure semiconductor doped with suitable impurity atoms.
- Depending on nature of dopants, extrinsic semiconductors are of two types:
  - **n-Type Semiconductor:** Pure semiconductor doped with donor impurity
  - The conductivity of n-type semiconductor (σ_n) is, $\sigma_n = n_e \mu_e e$

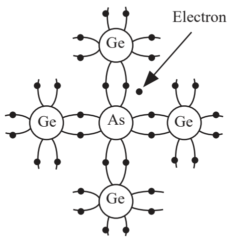


Figure: n-type semiconductor

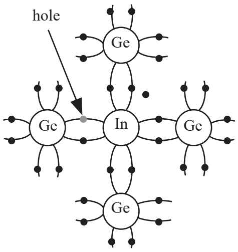


Figure: p-type semiconductor

  - **p-Type Semiconductor:** Pure semiconductor doped with an acceptor impurity.
  - Addition of a trivalent acceptor impurity increases hole density in a pure semiconductor which in turn increases its conductivity.
  - The conductivity of p-type semiconductors (σ_p) is, $\sigma_p = n_h \mu_h e$

Semiconductor Diode

- A device which freely allows electric current in one direction but does not allow in opposite direction is a diode.
- Development of p-type and n-type semiconductors in the two halves of a single semiconducting crystal gives rise to semiconductor diode (p-n junction diode).
- p-side of the diode is called anode and n-side of the diode is called cathode.
- Free charge carriers on p-side are holes and on n side are electrons.
- As soon as junction is formed, free electrons and holes migrate across the junction by diffusion. So, negative and positive ions form at junction.

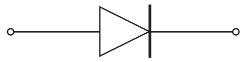


Figure: Symbolic representation of p-n junction diode.

- Region which has only immobile ions and is free from holes and electrons is **depletion layer or depletion region**.
- The width of depletion layer is about 10^{-6} cm.(1 micron).

Biasing of the p-n Junction Diode

- Applying external battery across two ends of diode. A junction diode can be biased in the following two ways:
  - **Forward Biasing of a p-n Junction**
  - In this positive terminal of battery is connected to p-type end and negative terminal of battery is connected to n-type end of the diode. Holes are forwarded towards n-region and electrons are forwarded towards p-region.
  - For external voltage, $V > V_b$ (internal voltage of junction), width of depletion layer decreases and current starts to flow through the diode. Majority charge carriers are responsible for conduction.
  - **Reverse biasing of a p-n Junction**
  - Negative terminal of battery is connected to p-type end and positive terminal of battery is connected to n-type end of diode. Holes and electrons are attracted (or reversed) due to negative and positive terminals of battery.
  - At junction, depletion layer or potential barrier increases. With increase in external voltage V, the width of depletion layer increases and no current flows (due to majority charge carriers) through the diode.
  - Reverse saturation or leakage current is due to minority charge carriers.

Characteristics of a p-n Junction Diode

- Graph showing the variation of current flowing through a p-n junction diode with the voltage applied across it is called the voltage-current or I-V characteristics of a p-n junction diode. The I-V characteristics of a p-n junction do not obey Ohm's law (as shown in figure).

- **Reverse Breakdown**
- If the reverse biased voltage is too high, then breakdown of p-n junction diode occurs known as reverse breakdown.
  - **Zener Breakdown:** When reverse bias voltage for p - n junction diode is increased, the electric field developed across depletion layer increases. As the field goes on increasing with reverse voltage, the covalent bond are broken creating large number of charge carriers. Thus, high current flows through the diode.
  - **Avalanche breakdown:** This occurs due to minority charge carriers. As reverse voltage increases, velocity of minority charge carriers, crossing the junction, also increases. Due to collision, covalent bonds are broken and large current flows through the diode.
- **Dynamic Resistance (A.C. resistance):** Ratio of small change in applied voltage to corresponding current change.

$$r_d = \frac{\Delta V}{\Delta I}$$

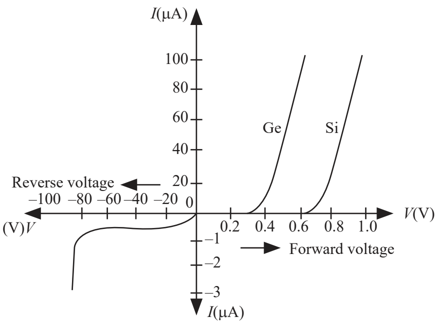


Figure: Characteristics of a p-n Junction Diode

Application of Junction Diode as a Rectifier

- **p-n junction Diode as rectifier**
- An electronic device which converts A.C. power into D.C. power is called a rectifier.
- In junction diode the current flow is unidirectional from p-region to n region.
  - **Half Wave Rectifier**
  - A rectifier which rectifies only the half of each A.C. input supply cycle.
  - Average output in one cycle,

$$I_{dc} = \frac{I_0}{\pi} \text{ and } V_{dc} = \frac{V_0}{\pi}; I_0 = \frac{V_0}{r_d + R_L}$$

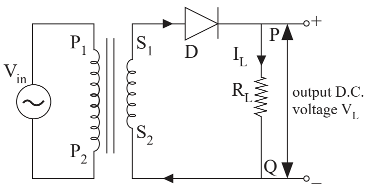


Figure: Half wave rectifier circuit

  - **R. M. S. output**

$$I_{\text{rms}} = \frac{I_0}{2}; V_{\text{rms}} = \frac{V_0}{2}$$

  - **Full Wave Rectifier**
  - A rectifier which rectifies both the halves of each A.C. input cycle
  - Average output,

$$V_{dc} = \frac{2V_0}{\pi} \text{ and } I_{dc} = \frac{2I_0}{\pi}$$

  - **R.M.S output**

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}; I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

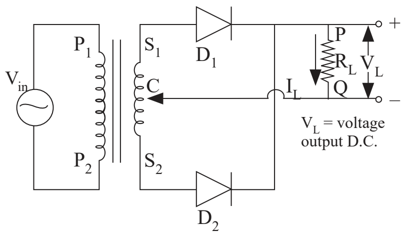


Figure: Full wave rectifier circuit

  - **Ripple factor**

$$r = \frac{I_{ac}}{I_{dc}} = \sqrt{\left(\frac{I_{\text{rms}}}{I_{dc}}\right)^2 - 1}$$

  - **Rectification efficiency**
  - It tells what percentage of total input A.C. power is converted into useful D.C. output power, defined as,

$$\eta = \frac{\text{D.C. power delivered to load}}{\text{A.C. input power from transformer sccondary}}$$

Zener Diode

- Specially designed junction diode which can operate in reverse breakdown voltage region continuously without being damaged.

Zener Diode as Voltage Regulator

- It is used for voltage regulation. So. it is called voltage regulator diode.
- In electronic applications, output voltage should remain constant regardless of variations in input voltage/load. So, zener diode is used.
- It operates in reverse bias condition and develops a constant voltage (V_z) which is the output voltage.
- When A.C. voltage is supplied across it, V_z remains constant. Thus, output D.C. voltage remains constant.

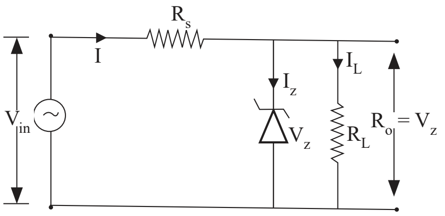


Figure: Zener diode circuit

- Resistance and zener diode are connected in parallel. When current through load resistance increases, it decreases through zener diode. Constant voltage is obtained at output.

  $V_z = V_{in} - I_s R_s ; I_z = I_s - I_L$

- The product of voltage and current is called power dissipation.

  $P_z = I_z V_z$

Light Emitting Diode (LED)

- LED is a specially designed diode which emits light energy when it is forward biased.
- These diodes emit spontaneous radiations. Symbolically it is represented as given in figure:

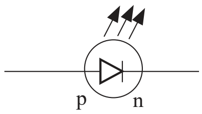


Figure: Light emitting diode

- Working Principle: An electron jumps from the higher energy level to lower energy level and emits photon of energy $h\nu$ equal to the difference between energy levels.
- n-type semiconductor is used as cathode (K) and p-type as anode (A).
- I-V characteristics of LED is similar to Si junction diode. But threshold voltages are much higher and different for each colour. Reverse breakdown voltages of LEDs are very low, around 5 V.
- LEDs are used
  - As pilot lights in electronic appliances to indicate whether the circuit is closed or not.
  - To illuminate a traffic light. In numeric displays (in watches and calculators).
  - In picture phones (to sense images) and video displays.

Photodiode

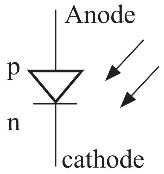


Figure: Photodiode

- The Photodiode is a junction diode made from the photosensitive semiconductor. Symbolically represented as shown in figure. It is operated in the reverse bias only.
- A photodiode is a special purpose p-n junction diode fabricated with a transparent window for incidence of light near depletion region.
  - Used to detect optical signals, in object counters, optocouplers as sensor in remote controlled receivers etc.

Solar Cell

- Semiconductor device that converts solar to electrical energy is solar cell (photo voltaic cell).
- Solar cell is a silicon p-n junction photodiode with large light sensitive area.
- It uses n-type semiconductor substrate made of thin (180 - 350 pm) silicon slices or wafers.
- Solar cells are used,
  - To produce electrical power in remote areas where power from power stations is unavailable.
  - To supply power to the earth's satellites.
  - To supply power to traffic signals.
  - In hand-hold calculators, watches, portable TV sets etc.

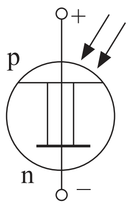


Figure: Solar cell

Junction Transistor

Transistor: Structure and Action

- Known as bipolar junction transistor, contains two junctions back to back (either p-n and n-p or n-p and p-n)
- Transistor is a current-operated device. It consists of three main regions
  - **Emitter (E):** Provides majority charge carriers by which current flows in transistor, so it is heavily doped.
  - **Base (B):** The base region is lightly doped and made thin.
  - **Collector (C):** The size of collector region is larger than the two other regions and it is moderately doped.

- Junction transistors are of two type
  - **n-p-n Transistor**
  - It is formed by sandwiching thin layer of p-type semiconductor between two n-type semiconductors.
  - Electrons are majority charge carriers and flow from emitter to base.

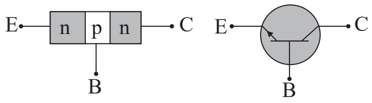


Figure: npn transistor

  - **Action of n-p-n Transistor**
  - n-type emitter is forward biased by connecting it to negative terminal of battery V_{EE} (emitter base battery) and n-type collector is reverse biased by connecting it to positive terminal of the battery V_{CC} (collector-base battery).
  - The majority carriers (electrons) in the emitter are repelled towards the base due to the forward bias.

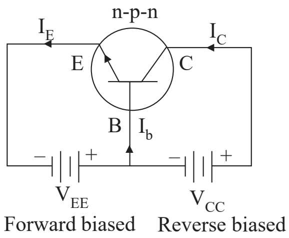


Figure: Circuit diagram of npn transistor

  - **p-n-p Transistor**
  - It is formed by sandwiching a thin layer of n-type semiconductor between two p-type semiconductor.
  - In pnp transistor, holes are majority charge carriers and flow from emitter to base.

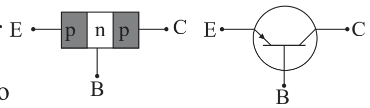


Figure: pnp transistor

  - **Action of p-n-p Transistor**
  - The p-type emitter of a pnp transistor is forward biased by connecting it to positive terminal of battery V_{EE} and the p-type collector is reverse biased by connecting it to the negative terminal of the battery V_{CC}.
  - Majority carriers in the emitter are holes and they are repelled towards the base due to the forward bias. Thus, current in p-n-p transistor is carried by holes and at the same time, their concentration is maintained.
  - **Current in Transistor:** Current through both p-n-p and npn transistors is given by, $I_E = I_B + I_C$

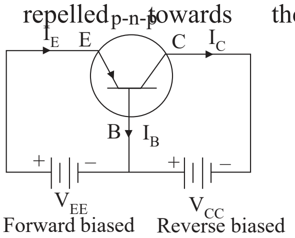


Figure: Circuit diagram of pnp transistor

Circuit Connections of Transistor

- The circuit of a transistor is always joined such as the emitter base circuit is forward biased and collector-base circuit is reversed bias.

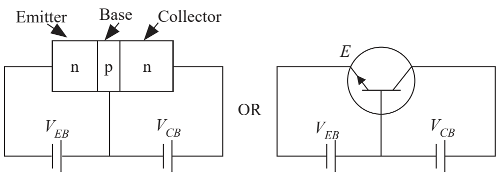


Figure: Circuit connection for npn transistor

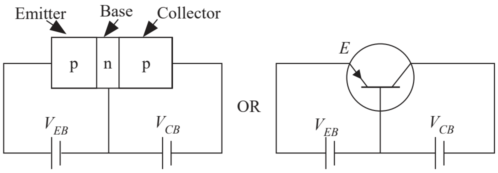


Figure: Circuit connection for pnp transistor

Basic Transistor Circuit Configurations

- In a transistor, only three terminals are available, viz. Emitter (E), Base (B) and collector (C). Therefore in a circuit, the input/output connections have to be such that one of these (E, B or C) is common to both the input and the output. Accordingly, the transistor can be connected in either of the following three configurations:
- Common Emitter (CE), Common Base (CB), Common Collector (CC).
- **Common base current amplification** α

$$\alpha_{dc} = \left[\frac{I_C}{I_E}\right]_{V_{CB\ \text{constant}}} \approx \left[\frac{0.95 I_E}{I_E}\right] \approx 0.95$$

$$\alpha_{ac} = \left[\frac{\Delta I_C}{\Delta I_E}\right]_{V_{CB\ \text{constant}}}$$

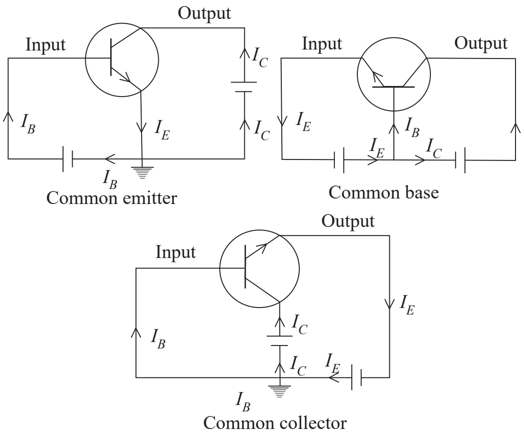


Figure: Transistor Circuit Configurations

- **Common emitter current amplification** β

$$\beta_{dc} = \left[\frac{I_C}{I_B}\right]_{V_{CE\ constant}} \approx \left[\frac{0.95I_E}{0.05I_E}\right] \approx 19; \ \beta_{ac} = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{CE\ constant}}$$

- **Relation between α and β**
- We know,

$$I_E = I_B + I_C; \frac{I_E}{I_C} = \frac{I_B}{I_C} + 1; \frac{1}{\alpha} = \frac{1}{\beta} + 1; \text{So, } \alpha = \frac{\beta}{1+\beta}; \quad \beta = \frac{\alpha}{1-\alpha}$$

- Characteristics of a transistor
  - **Input Characteristics of a Transistor**
  - If V_{CE} = constant, the curve between I_B and V_{BE} is known as input characteristics of a transistor.
  - **Output Characteristics of a Transistor**
  - If I_B= constant, curve between I_C and V_{CE} is known as output characteristics of transistor.

Transistor as a Switch

- When a transistor works only in non conducting (OFF) and conducting (ON) modes, it is known as switch.
- The cut-off state of transistor indicates OFF state of switch and saturation state of transistor indicates ON state.
- The D.C. input voltage V_i and D.C. output voltage V_0 are,

$$V_i = V_{BB} = I_B R_B + V_{BE}; V_o = V_{CE} = V_{CC} - I_C R_C$$

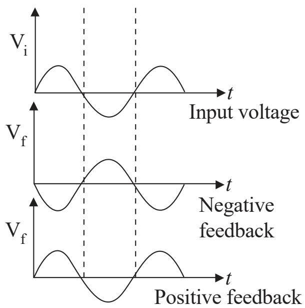
Transistor as an amplifier (CE configuration)

- When transistor is used as amplifier, emitter terminal is common to both input and output circuits. If input circuit (Base emitter circuit) is forward biased, then output circuit is reverse biased (collector-emitter circuit)
- It includes two types of transistors
  - **npn transistor**
  - The base is connected to the positive terminal of a battery of low voltage V_{BB}. So, the input circuit is forward biased. Hence, the resistance of the input circuit is small.
    $I_E = I_B + I_C$
  - The collector current I_C flowing through the load resistance R_L produces a potential drop equal to $I_C R_L$ across R_l. In this stage, net collector voltage,
    $V_{CE} = V_{CC} - I_C R_L$
  - **p-n-p transistor**
  - The base is connected to the negative terminal of a battery of low voltage V_{BB}. So, the input circuit is forward biased. Hence, the resistance of the input circuit is small. The collector is connected to the negative terminal of a battery. So, the output circuit is reverse biased. It causes large resistance of the output circuit.
  - The collector current produces a potential drop $I_C R_L$ in opposition to the applied voltage V_{CC}.
  - Net collector voltage,
    $V_{CE} = V_{CE} - I_C R_L$

Transistor as an Oscillator

- Oscillator is electronic circuit which produces continuous A.C. output voltage without any external input voltage. In electrical oscillating system, (inductor) L and (Capacitor) C are connected parallel to each other (known as tank circuit).
- In tank circuit, given electrical energy oscillates between C (electrostatic energy) and L (magnetic energy). Frequency of oscillations is given by,

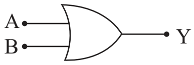
$$\nu = \frac{1}{2\pi\sqrt{LC}}$$



Voltage wave

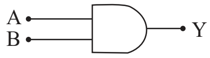
Digital Electronics and Logic Gates

- In electronic circuits, there are two types of signals
  - **Analog signals:** Voltage or current have continuous values.
  - **Digital signals:** Voltage or current have discrete values like 0 (low) or 1 (high)



A	B	Y
0	0	0
1	0	1
0	1	1
1	1	1

Figure: Symbol and truth table for OR gate

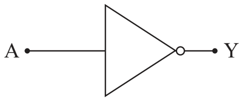


A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

Figure: Symbol and truth table for AND gate

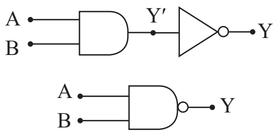
Logic Gates

- It is digital circuit which works according to logical relationship between input and output voltages.
- It may have one or more inputs but only one output. The logical statements that logic gates follow are called **Boolean** expressions.
- The basic Gates are of three types
  - **OR Gate**
  - OR gate is two-input and one output logic gate.
  - Boolean expression for OR gate is,
    $Y = A + B$
  - **AND Gate**
  - Two-input and one output logic gate.
  - Boolean expression is,
    $Y = A.B$
  - **NOT gate or INVERTER circuit**
  - It is one input and one output logic gate.
  - Boolean expression for NOT gate is,
    $Y = \overline{A}$
  - **NAND Gate**
  - Logic circuit where output of AND gate is connected to input of NOT gate. Boolean expression is,
    $Y = \overline{A.B}$
  - **NOR Gate**
  - Logic circuit where output of OR gate is connected to input of NOT gate. Boolean expression is,
    $Y = \overline{A+B}$



A	Y
0	1
1	0

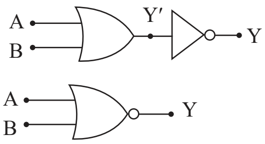
Figure: Symbol and truth table for NOT gate



A	B	Y′	Y
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0

A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

Figure: Symbol and truth table for NAND gate



A	B	Y′	Y
0	0	0	1
1	0	1	0
0	1	1	0
1	1	1	0

A	B	Y
0	0	1
1	0	0
0	1	0
1	1	0

Figure: Symbol and truth table for NOR gate

PRACTICE TIME

Classification of Metals, Conductors, and Semiconductors

1. In a semiconductor:
(a) there are no free electrons at 0 K
(b) there are no free electrons at any temperature
(c) the number of free electrons increases with pressure
(d) the number of free electrons is more than that in a conductor

2. The resistivity of a semiconductor at room temperature is in between:
(a) 10^{-2} to $10^{-5}\ \Omega$cm (b) 10^{-3} to $10^{6}\ \Omega$cm
(c) 10^{6} to $10^{8}\ \Omega$cm (d) 10^{10} to $10^{12}\ \Omega$cm

3. Electric conduction in a semiconductor takes place due to
(a) electrons only
(b) holes only
(c) both electrons and holes
(d) neither electrons nor holes

4. At absolute zero, Si acts as a:
(a) metal (b) semiconductor
(c) insulator (d) none of these

5. A p-type semiconductor is:

(a) positively charged
(b) negatively charged
(c) uncharged
(d) uncharged at 0 K but charged at higher temperatures

6. Let n_h and n_e be the number of holes and conduction electrons in an extrinsic semiconductor. Then:
(a) $n_h > n_e$ (b) $n_h = n_e$
(c) $n_h < n_e$ (d) $n_h \neq n_e$

7. A strip of copper and another of germanium are cooled from room temperature to 80 K. The resistance of:
(a) each of these decreases
(b) copper strip increases and that of germanium decreases
(c) copper strip decreases and that of germanium increases
(d) each of these increases

8. If a small amount of antimony is added to germanium crystal:
(a) it becomes a p-type semiconductor
(b) the antimony becomes an acceptor atom
(c) there will be more free electrons than holes in the semiconductor
(d) its resistance is increased

9. If the energy of a photon of sodium light ($\lambda = 589$ nm) equals the band gap of semiconductor, the minimum energy required to create hole electron pair:
(a) 1.2 eV (b) 1.3 eV
(c) 2.1 eV (d) 3.1 eV

10. In a crystal, the permitted energy states of electrons are present:
(a) in the conduction band and the forbidden gap.
(b) only in the forbidden gap.
(c) in the valence band and conduction band.
(d) in the forbidden gap and the valence band.

11. The forbidden energy band gap in conductors, semiconductors and insulators are E_{g1}, E_{g2}, and E_{g3} respectively. The relation among them is:
(a) $E_{g1} = E_{g2} = E_{g3}$ (b) $E_{g1} < E_{g2} < E_{g3}$
(c) $E_{g1} > E_{g2} > E_{g3}$ (d) $E_{g1} < E_{g2} > E_{g3}$

12. The forbidden energy gap is maximum for:
(a) mercury (b) silicon
(c) diamond (d) silver

13. Forbidden energy gap for diamond is about:
(a) 1 eV (b) 1.5 eV
(c) 6 eV (d) 0.6 eV

14. In n-type semiconductor when all donor states are filled, then the net charge density in the donor states becomes:
(a) 1 (b) < 1, but not zero
(c) > 1 (d) zero

15. The dominant mechanism for motion of charge carriers in forward and reverse biased silicon p-n junction are:
(a) drift in forward bias, diffusion in reverse bias
(b) diffusion in forward bias, drift in reverse bias
(c) diffusion in both forward and reverse bias
(d) drift in both forward and reverse bias

16. In an unbiased p-n junction, holes diffuse from the p-region to n region because:
(a) free electrons in the n region attract them
(b) hole concentration in p-region is more as compared to n region
(c) they move across the junction with same potential
(d) all of these

17. A pure semiconductor:
(a) has low resistance.
(b) is an intrinsic semiconductor.
(c) allows inadequate current to pass through it.
(d) is an extrinsic semiconductor.

18. The intrinsic semiconductor becomes an insulator at:
(a) 0 C (b) −100 C
(c) 300 K (d) 0 K

19. In a pure semiconductor crystal if current flows due to breakage of crystal bonds, then semiconductor is called as:
(a) Acceptor
(b) Donor
(c) Intrinsic semiconductor
(d) Extrinsic semiconductor

20. Doping materials are called impurities because they
(a) change the number of chaise carriers.
(b) alter the crystal structure.
(c) change chemical properties.
(d) make semiconductor less pure.

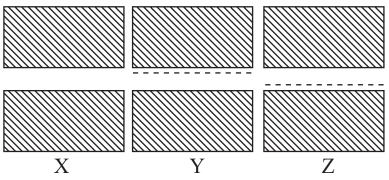
21. A semiconductor has equal electron and hole concentration of $6\times10^{8}\ m^{-3}$. On doping with certain impurity, electron concentration increases to $9\times10^{12}\ m^{-3}$. The new hole concentration is :
(a) $4 \times 10^5\ m^{-5}$ (b) $4 \times 10^4\ m^{-5}$
(c) $4 \times 10^5\ m^{-5}$ (d) $4 \times 10^6\ m^{-5}$

22. When arsenic is added as an impurity to silicon, the resulting material is:
(a) n-type conductor
(b) n-type semiconductor
(c) p-type conductor
(d) p-type semiconductor

23. On doping an intrinsic semiconductor with a group V element, free electrons in the conduction band are the majority charge carriers and the resulting semiconductor has a net:

(a) negative charge
(b) positive charge
(c) charge zero
(d) negative, zero or positive charge

24. The energy band diagram for three semiconductor samples of silicon are as shown. We can then assert that:

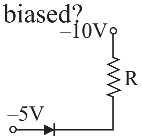


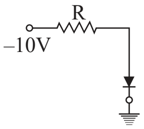
(a) sample X is undoped while Y and Z have been doped with a 'third group' and 'fifth group' impurity respectively.
(b) sample X is undoped while both samples Y and Z have been with a 'fifth group' impurity.
(c) sample X has been doped with equal amounts of 'third and fifth group' impurity while samples Y and Z are undoped.
(d) sample X is undoped while samples Y and Z have been doped with a 'fifth group' and 'third group' impurity respectively.

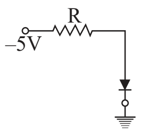
25. A p-type semiconductor is,
(i) a silicon crystal doped with arsenic impurity.
(ii) a silicon crystal doped with aluminium impurity.
(iii) a germanium crystal doped with boron impurity.
(iv) a germanium crystal doped with phosphorus impurity.
(a) (i) and (ii) are correct
(b) (ii) and (iii) are correct
(c) (i) and (iv) are correct
(d) only (i) is correct

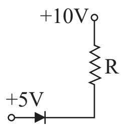
Semiconductor Diode

26. Which of the junction diodes shown below are forward biased?

(a) 

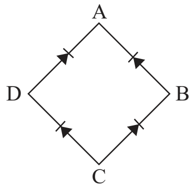
(b) 

(c) 

(d) 

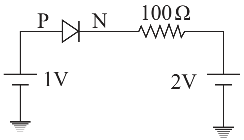
27. The average value of output direct current in a full wave rectifier is:
(a) I_0/π (b) $I_0/2$
(c) $\pi I_0/2$ (d) $2\,I_0/\pi$

28. In bridge rectifier circuit, (see fig.), the input signal should be connected between:



(a) A and D (b) B and C
(c) A and C (d) B and D

29. The current through an ideal p-n junction shown in the following circuit diagram will be:

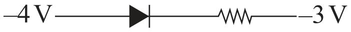


(a) zero (b) 1 mA
(c) 10 mA (d) 30 mA

30. In a p-n junction having depletion layer of thickness 10^{-6} m the potential across it is 0.1 V. The electric field is
(a) 10^7 V/m (b) 10^{-6} V/m
(c) 10^5 V/m (d) 10^{-5} V/m

31. A forward biased diode is:

(a) 

(b) 

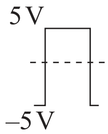
(c) 

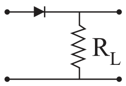
(d) 

32. When the voltage drop across a p-n junction diode is increased from 0.8 V to 0.70 V, the change in the diode current is 5 mA. The dynamic resistance of the diode is:
(a) 20 Ω (b) 10 Ω
(c) 5 Ω (d) 100 Ω

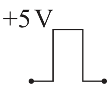
33. In a reverse biased diode when the applied voltage changes by 1 V, the current is found to change by 0.5 μA. The reverse bias resistance of the diode is:
(a) 2×10^5 Ω (b) 2×10^6 Ω
(c) 200 Ω (d) 2 Ω

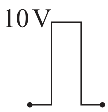
34. If in a p-n junction diode, a square input signal of 10 V is applied as shown.

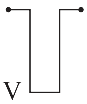


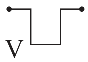


Then the output signal across R_L will be:

(a) 

(b) 

(c) 

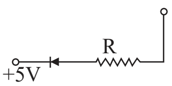
(d) 

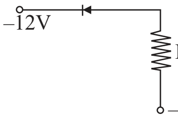
35. When the forward bias voltage of a diode is changed from 0.6 V to 0.7 V, the current changes from 5 mA to 15 mA. Then its forward bias resistance is:
(a) 10 Ω (b) 0.1 Ω
(c) 0.01 Ω (d) 100 Ω

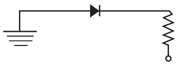
36. The peak voltage in the output of a half wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The D.C. component of the output voltage is:
(a) $\frac{20}{\pi}$ V (b) $\frac{10}{\pi}$ V
(c) $\frac{10}{2\pi}$ V (d) 10 V

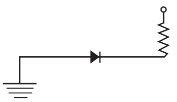
37. The breakdown in a reverse biased p-n junction diode is more likely to occur due to:
(a) large velocity of the minority charge carriers if the doping concentration is small
(b) large velocity of the minority charge carriers if the doping concentration is large
(c) strong electric field in a depletion region if the doping concentration is small
(d) none of these

38. In the half wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be:
(a) 25 Hz (b) 50 Hz
(c) 70.7 Hz (d) 100 Hz

39. Of the diodes shown in the following diagrams, which one is reverse biased?
(a) 

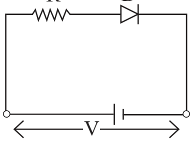
(b) 

(c) 

(d) 

40. If the forward bias on p-n junction is increased from zero to 0.045 V, then no current flows in the circuit. The contact potential of junction i.e. V_B is:
(a) zero (b) 0.045 V
(c) more than 0.045 V (d) less than 0.045 V

41. A D.C. battery of V volt is connected to a series combination of a resistor R and an ideal diode D as shown in the figure below. The potential difference across R will be:



(a) 2V when diode is forward biased
(b) zero when diode is forward biased
(c) V when diode is reverse biased
(d) V when diode is forward biased

42. What happens during regulation action of a Zener diode?
(a) The current through the series resistance (RS) changes
(b) The resistance offered by the zener changes
(c) The zener resistance is constant
(d) Both (a) and (b)

43. A Zener diode is specified as having a breakdown voltage of 8.2 V, with a maximum power dissipation of 410 mW. What is the maximum current the diode can handle?
(a) 20 mA
(b) 30 mA
(c) 40 mA
(d) 50 mA

44. A zener diode of voltage V_Z (= 6 V) is used to maintain a constant voltage across a load resistance R_L (= 1000 Ω) by using a series resistance R_S(= 100 Ω). If the e.m.f. of source is E (= 9 V), what is the power being dissipated in zener diode?
(a) 0.144 watt (b) 0.324 watt
(c) 0.244 watt (d) 0.544 watt

45. In genial maximum rectification efficiency for a half wave rectifier is:
(a) 40.6% (b) 59.8%
(c) 73.1% (d) 85.2%

$$\left[Hind: Use \eta = \frac{0.406}{1-\frac{R_f}{R_L}} \right]$$

46. In the middle of the depletion layer of a reverse biased p-n junction, the:
(a) potential is zero.
(b) electric field is zero.
(c) potential is maximum.
(d) electric field is maximum.

47. LED is the abbreviation of:
(a) Light Editing Diode
(b) Light Editing Display
(c) Light Emitting Display
(d) Light Emitting Diode

48. A light emitting diode is:
(a) always used in forward biased condition.
(b) always used in reverse biased condition.
(c) never used in forward biased condition.
(d) used in both forward and reverse biased position depending upon its application.

49. Colour of light emitted by LED depends on _____:
(a) its reverse bias voltage
(b) its forward bias voltage
(c) type of semiconductor diode
(d) rectifier

50. Electromagnetic energy is converted into electric potential energy using _____.
(a) photodetector (b) photon
(c) photodiode (d) photoelectron

51. Basically, a photodiode is:
(a) a forward biased p-n junction diode
(b) a reverse biased p-n junction diode
(c) a rectifier
(d) an oscillator

52. Gallium Arsenide phosphide LED emits light radiation of wavelength about:
(Given : E_g or GaAsP LED = 1.9 eV)
(a) 3533 Å (b) 4533 Å
(c) 5533 Å (d) 6533 Å

53. In photodiode, the condition for emission of diet electrons is:
(a) $h\nu = E_g$ (b) $h\nu > E_g$
(c) $h\nu < E_g$ (d) $h\nu \le E_g$

54. A solar cell
(a) converts the radiant energy of sun into electrical power.
(b) converts the radiant energy of sun into heat.
(c) reflects all the light from sun.
(d) absorbs energy and converts into sound energy.

55. Solar cell is based on the principle of:
(a) formation of electron-hole pairs with incident light
(b) formation of electron-hole pairs with heating
(c) formation of electron-hole pairs with potential
(d) all of these

56. The most common semiconducting material used to prepare a solar cell is:
(a) Gallium arsenide (b) Indium arsenide
(c) Cadmium arsenide (d) Silicon

57. A solar cell is a p-n junction operating in:
(a) reverse bias condition
(b) unbiased condition
(c) forward bias condition
(d) in both forward and reverse bias condition

58. Match Column I with Column II with appropriate matching.

	Column I		Column II
A	p-n junction operating in unbiased condition	(i)	Photodiodes
B	used as ac voltage stabilizer	(ii)	Solar cell
C	In remote controlled receivers, the sensor are	(iii)	LED
D	electric potential energy is converted into electromagnetic energy	(iv)	Zener diode

(a) A→(iv), B→(i), C→(ii), D→(iii)
(b) A→(ii), B→(iv), C→(i), D→(iii)
(c) A→(ii), B→(iii), C→(iv), D→(i)
(d) A→(iv), B→(iii), C→(i), D→(ii)

59. A p-n photodiode is made of a material with a band gap of 2 eV. The minimum frequency of the radiation that can be absorbed by the material is nearly: (hc = 1240 eVnm)
(a) 0.5×10^{14} Hz (b) 5×10^{14} Hz
(c) 50×10^{14} Hz (d) 20×10^{15} Hz

60. A p-n photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. The signal wavelength is:
(a) 496 Å (b) 5000 Å
(c) 5000 nm (d) 500 Å

Junction Transistor

61. The transistor are usually made of:
(a) metal oxides with high temperature coefficient of resistivity
(b) metals with high temperature coefficient of resistivity
(c) metals with low temperature coefficient of resistivity
(d) semiconducting materials having low temperature coefficient of resistivity

62. To use a transistor as an amplifier, emitter base junction is kept in ..*X*... and base collector junction is kept in... *Y*. Here, *X* and *Y* refer to:

(a) forward bias, forward bias
(b) reverse bias, reverse bias
(c) reverse bias, forward bias
(d) forward bias, reverse bias

63. When npn transistor is used as an amplifier:
(a) electrons move from collector to base
(b) holes move from emitter to base
(c) electrons move from base to collector
(d) holes move from base to emitter

64. Current gain in common emitter configuration is more than one because:
(a) $I_c < I_b$ (b) $I_c < I_e$
(c) $I_c > I_e$ (d) $I_c > I_b$

65. The heavily and lightly doped regions of a bipolar junction transistor are respectively:
(a) base and emitter
(b) base and collector
(c) emitter and base
(d) collector and emitter

66. In a common base amplifier, the phase difference between the input signal voltage and output voltage is:
(a) π (b) 2π
(c) zero (d) $1.5\,\pi$

67. For a transistor amplifier in common emitter configuration for-load impedance of $1\,\text{k}\Omega$ ($h_{fe} = 50$ and $h_{oe} = 25\ \mu s$) the current gain is:
(a) 48.87 (b) 4.87
(c) −48.87 (d) zero

$$\left[Hind: use\ Ai = \frac{-h_{fe}}{1+h_{oe}R_L}\right]$$

68. In a common base mode of a transistor, the collector current is 5.488 mA for an emitter current of 5.60 mA. The value of the base current amplification factor (β) will be:
(a) 49 (b) 50
(c) 51 (d) 48

69. A transistor has a base current of 1 mA and emitter current 90 mA. The collector current will be:
(a) 90 mA (b) 1 mA
(c) 89 mA (d) 91 mA

70. If α and β are the current gain in the CB and CE configurations respectively of the transistor circuit, then $\dfrac{\beta-\alpha}{\alpha\beta} = ?$
(a) 0.01 (b) 0.1
(c) 1 (d) 10

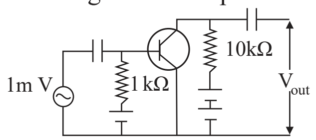
$$\left[Hind: Use\ \beta = \frac{\alpha}{1-\alpha}\right]$$

71. In a npn transistor 10^{10} electrons enter the emitter in 10^{-6} s. 4% of the electrons are lost in the base. The current transfer ratio will be:
(a) 0.98 (b) 0.97
(c) 0.96 (d) 0.94

72. A common emitter amplifier has a voltage gain of 50, an input impedance of $100\,\Omega$ and an output impedance of $200\,\Omega$. The power gain of the amplifier is:
(a) 500 (b) 1000
(c) 1250 (d) 50

73. A transistor is operated in common emitter configuration at $V_C = 2$ V such that a change in the base current from 100 μA to 300 μA produces a change in the collector current from 10 mA to 20 mA. The current gain is:
(a) 50 (b) 75
(c) 100 (d) 25

74. In the following common emitter configuration an n-p-n transistor with current gain $B = 100$ is used. The output voltage of the amplifier will be:



(a) 10 mV (b) 0.1 V
(c) 1.0 V (d) 10 V

75. A npn transistor is connected in common emitter configuration in a given amplifier. A load resistance of $800\,\Omega$ is connected in the collector circuit and the voltage drop across it is 0.8 V. If the current amplification factor is 0.96 and the input resistance of the circuit is $192\,\Omega$, the voltage gain and the power gain of the amplifier will respectively be:
(a) 4, 3.84 (b) 3.69, 3.84
(c) 4, 4 (d) 4, 3.69

76. What is the voltage gain in a common emitter amplifier, where input resistance is $3\,\Omega$ and load resistance $24\,\Omega$ and $\beta = 61$?
(a) 8.84 (b) 48.8
(c) 488 (d) 4.88

77. An n-p-n transistor conducts when:
(a) both collector and emitter are negative with respect to the base.
(b) both collector and emitter are positive with respect to the base.
(c) collector is positive and emitter is negative with respect to the base.
(d) collector is positive and emitter is at same potential as the base.

78. In a pnp transistor, the base is the n region. Its width relative to the p-region is:
(a) Smaller (b) Larger
(c) Same (d) Not related

79. In the working of an n-p-n transistor, the number of free electrons which recombine with holes in the base layer is about:
(a) 97% of the number injected into the base.
(b) 50% of the number injected into the base.
(c) 25% of the number injected into the base.
(d) 3% of the number injected into the base.

80. Match Column I with Column II with appropriate matching.

	Column I		Column II
A	In pnp transistor, the p-type semi-conductor acts as	(i)	emitter
B	Least doped region	(ii)	either an emitter or a collector
C	heavily doped region	(iii)	$I_E = I_C + I_B$
D	In npn transistor	(iv)	Base

(a) A→(iv), B→(i), C→(ii), D→(iii)
(b) A→(ii), B→(iv), C→(i), D→(iii)
(c) A→(ii), B→(iii), C→(iv), D→(i)
(d) A→(iv), B→(iii), C→(i), D→(ii)

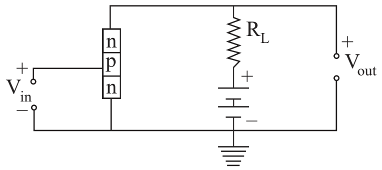
81. In n-p-n transistor, the collector current is 10 mA. If 90% of electrons emitted reach the collector, then:
(a) emitter current will be 9 mA.
(b) emitter current will be 11.1 mA.
(c) base current will be 0.1 mA.
(d) base current will be 0.01 mA.

82. In an n-p-n transistor circuit, the collector current is 10 mA. If 90% of the electrons emitted reach the collector, the emitter current (I_E) and base current (I_B) are given by:
(a) $I_E = -1$ mA, $I_B = 9$ mA
(b) $I_E = 9$ mA, $I_B = -1$ mA
(c) $I_E = 1$ mA, $I_B = 11$ mA
(d) $I_E = 11$ mA, $I_B = 1$ mA

83. In an npn transistor, the base current is 100 μA and the collector current is 10 mA. The emitter current is:
(a) 1.01 mA (b) 10.1 mA
(c) 0.101 mA (d) 0.0101 mA

84. When npn transistor is used as an amplifier:
(a) electrons move from base to collector.
(b) holes move from emitter to base.
(c) electrons move from collector to base.
(d) holes move from base to emitter.

85. An npn transistor circuit is arranged as shown in figure. It is:



(a) a common base amplifier circuit.
(b) a common emitter amplifier circuit.
(c) a common collector amplifier circuit
(d) rectifier circuit.

86. A transistor-oscillator using a resonant circuit with an inductor L (of negligible resistance) and a capacitor C in series produce oscillations of frequency v. If L is doubled and C is changed to $4C$, the frequency will be:
(a) $\frac{1}{2}v$ (b) $\frac{1}{2\sqrt{2}}v$
(c) $\frac{1}{\sqrt{2}}v$ (d) $\frac{3}{2\sqrt{2}}v$

87. Electronic oscillator is better than mechanical one because:
(a) It has better frequency stability.
(b) It has higher efficiency.
(c) It has low frequency stability.
(d) It can produce frequency of 1 GHz.

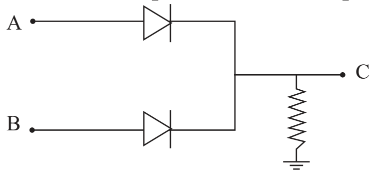
Digital Electronics and Logic Gates

88. Boolean algebra is essentially based on_____.
(a) number (b) truth
(c) logic (d) symbol

89. Logic gates are the building blocks of a_____.
(a) Digital system (b) Analog system
(c) Abacus system (d) House

90. An OR gate gives a logic one output:
(a) Only when all inputs are logical 1.
(b) Only when any two inputs are logical 1.
(c) When all inputs are logical 0.
(d) When anyone of the inputs is logical 1.

91. In the circuit below, A and B represent two inputs and C represents the output. The circuit represents:



(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

92. Which one of the following truth table represents an AND gate:

(a)

A	B	Y
0	0	1
1	0	0
0	1	0
1	1	0

(b)

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

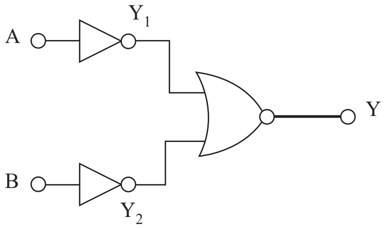
(c)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(d)

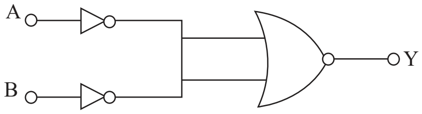
A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

93. Which logic gate is represented by the following combination of logic gales?



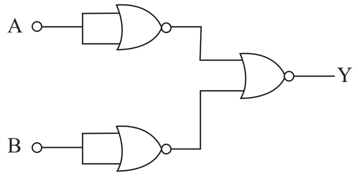
(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

94. The circuit given in figure, is equivalent to:



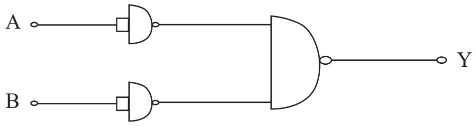
(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

95. For the given digital circuit, write the truth table and identify the logic gate it represents:



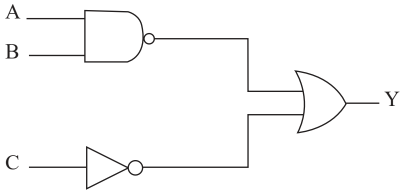
(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

96. The combination of NAND gates is shown in figure. The equivalent circuit is:



(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

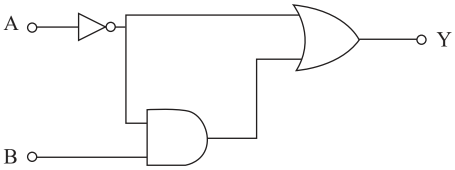
97. The inputs to the digital circuit are shown below. The output *Y* is:



(a) $A+B+\bar{C}$ (b) $(A+B)+\bar{C}$

(c) $\bar{A}+\bar{B}+\bar{C}$ (d) $\bar{A}+\bar{B}+C$

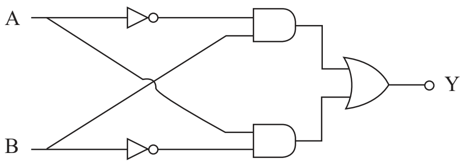
98. The output Y of the logic circuit given below is:



(a) $\bar{A}+B$ (b) $\bar{A}$

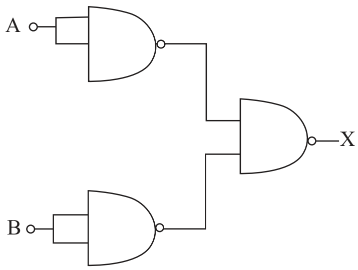
(c) $\overline{\left(\bar{A}+B\right)}.\bar{A}$ (d) $\overline{\left(\bar{A}+B\right)}.A$

99. The following circuit represents:



(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

100. The combination of gates sown below yields:



(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

101. A NAND gate is called "Universal logic element" because
(a) it is used by everybody.
(b) any logic function can be realized by NAND gates alone.
(c) many digital computers use NAND gates.
(d) all minimization techniques are applicable for optimum NAND gate realization.

HIGH-ORDER THINKING SKILL

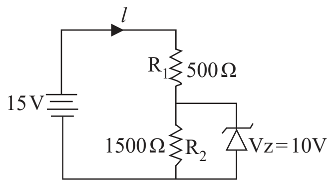
Classification of Metals, Conductors and Semiconductors

1. What is the conductivity of a semiconductor sample having electron concentration of $5\times10^{18}\ m^{-3}$, hole concentration of $5\times10^{19}\ m^{-3}$, electron mobility of $2.0\ m^2V^{-1}s^{-1}$ and hole mobility of $0.01\ m^2V^{-1}s^{-1}$? (Take charge of electron as 1.6×10^{-19} C)
(a) $1.68\ (\Omega\text{-m})^{-1}$ (b) $1.83\ (\Omega\text{-m})^{-1}$
(c) $0.59\ (\Omega\text{-m})^{-1}$ (d) $1.20\ (\Omega\text{-m})^{-1}$

2. The concentration of hole – electron pairs in pure silicon at $T=300$ K is $7\times10^{15}\ m^{-3}$. Antimony is doped into silicon in a proportion of one atom in 10^7 Si atoms. Assuming that half of the impurity atoms contribute electron in the conduction band, calculate the factor by which the number of charge carriers increases due to doping. The number of silicon atoms per cubic meter is 5×10^{28}:
(a) 2.8×10^5 (b) 3.1×10^2
(c) 4.2×10^5 (d) 1.8×10^5

Semiconductor Diode

3. In the circuit given, the current through the zener diode is:



(a) 10 mA (b) 3.33 mA
(c) 33.3 mA (d) 3.33 A

4. A counter made from photodiode is having energy band gap of 1.8 eV. A blinking red LED is kept with the counter in the dark. After five blinks of LED, what will be the count?

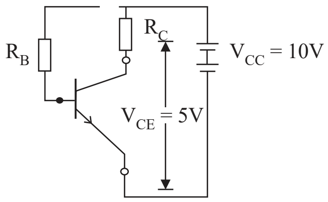
(Given: $h=6.65\times10^{-34}$ Js, $\lambda_4=700$ nm)

(a) 5 (b) 10
(c) Zero (d) Data is insufficient

Junction Transistor

5. A npn transistor is connected in common emitter configuration in a given amplifier. A load resistance of 700 Ω is connected in the collector circuit and the voltage drop across it is 0.8 V. If the current amplification factor is 0.95 and the input resistance of the circuit is 175 Ω, the voltage gain and the power gain of the amplifier will respectively be:
(a) 4, 3.84
(b) 3.8, 3.61
(c) 4, 4
(d) 3.61, 3.8

6. A transistor connected in common emitter configuration has input resistance $R_B=2000\ \Omega$ and load resistance of 5000 Ω. If $\beta=60$ and an input signal 12 mV is applied, calculate the voltage gain, the power gain and the value of output voltage:



(a) $A_v=150,\ V_{out}=1.8$ V and power gain $=9000$

(b) $A_v=20,\ V_{out}=1$ V and power gain $=2000$

(c) $A_v=20,\ V_{out}=1.5$ V and power gain $=2000$

(d) $A_v=150,\ V_{out}=1.5$ V and power gain $=8500$

Digital Electronics and Logic Gates

7. The output (Y) of the combination of gates is:

(a) $Y = A.B$ (b) $Y = A + B$

(c) $Y = \overline{A.B}$ (d) $Y = \overline{A} + \overline{B}$

NCERT EXEMPLAR PROBLEMS

Classification of Metals, Conductors and Semiconductors

1. The conductivity of a semiconductor increases with increase in temperature because

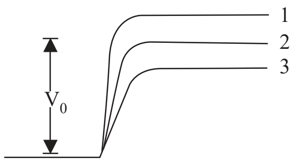
(a) number density of free current carriers increases.
(b) relaxation time increases.
(c) both number density of carriers and relaxation time increase.
(d) number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

2. Hole is:

(a) an anti-particle of electron.
(b) a vacancy created when an electron leaves a covalent bond.
(c) absence of free electrons.
(d) an artificially created particle.

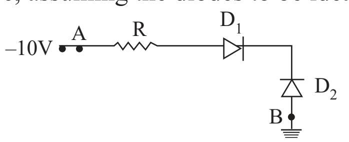
Semiconductor Diode

3. In figure, V_0 is the potential barrier across a p-n junction, when no battery is connected across the junction.



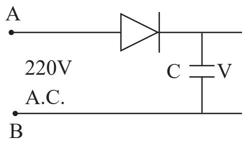
(a) 1 and 3 both correspond to forward bias of junction.
(b) 3 corresponds to forward bias of junction and one corresponds to reverse bias of junction.
(c) 1 corresponds to forward bias and three corresponds to reverse bias of junction.
(d) 3 and 1 both correspond to reverse bias of junction.

4. In figure, assuming the diodes to be ideal,



(a) D_1, is forward biased and D_2 is reverse biased and hence current flows from A to B.
(b) D_2 is forward biased and D_1, is reverse biased and hence no current flows from B to A and vice versa.
(c) D_1 and D_2 are both forward biased and hence current flows from A to B.
(d) D_1 and D_2 are both reverse biased and hence no current flows from A to B and vice versa.

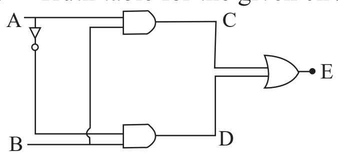
5. A 220 V ac supply is connected between points A and B as shown in figure. What will be the potential difference V across the capacitor?



(a) 220 V (b) 110 V
(c) 0 V (d) $220\sqrt{2}$ V

Digital Electronics and Logic Gates

6. Truth table for the given circuit in figure is:



(a)

A	B	E
0	0	1
0	1	0
1	0	1
1	1	0

(b)

A	B	E
0	0	1
0	1	0
1	0	0
1	1	1

(c)

A	B	E
0	0	0
0	1	1
1	0	0
1	1	1

(d)

A	B	E
0	0	0
0	1	1
1	0	1
1	1	0

ASSERTION AND REASONS

Directions: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as:
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false..

Classification of Metals, Conductors and Semiconductors

1. **Assertion:** If there is some gap between the conduction band and the valence band, electrons in the valence band all remain bound and no free electrons are available in the conduction band. Then the material is an insulator.

   Reason: Resistance of insulators is very low.

2. **Assertion:** Diode lasers are used as optical sources in optical communication.

   Reason: Diode lasers consume less energy.

3. **Assertion:** A pure semiconductor has negative temperature coefficient of resistance.

   Reason: In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

4. **Assertion:** If the temperature of a semiconductor is increased then it's resistance decreases.

   Reason: The energy gap between conduction band and valence band is very small.

5. **Assertion:** At a fixed temperature, silicon will have a minimum conductivity when it has a smaller acceptor doping.

   Reason: The conductivity of an intrinsic semiconductor is slightly higher than that of a lightly doped p-type semiconductor.

6. **Assertion:** An N-type semiconductor has a large number of electrons but still it is electrically neutral.

   Reason: An N-type semiconductor is obtained by doping an intrinsic semiconductor with a pentavalent impurity.

7. **Assertion:** Semiconductors do not Obey's Ohm's law.

   Reason: Current can not be determined by the rate of flow of charge carriers.

8. **Assertion:** The energy gap between the valence band and conduction band is greater in silicon than in germanium.

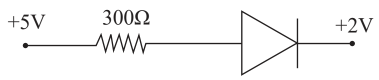
   Reason: Thermal energy produces fewer minority carriers in silicon than in germanium.

Semiconductor Diode

9. **Assertion:** Zener diode works on principle of breakdown voltage.

   Reason: Current increases suddenly after breakdown voltage.

10. **Assertion:** The value of current through p-n junction in the given figure will be 10 mA.



   Reason: In the above figure, p-side is at higher potential than n side.

11. **Assertion:** Two p-n junction diodes placed back to back, will work as a npn transistor.

   Reason: The p-region of two p-n junction diodes back to back will form the base of npn transistor.

Junction Transistor

12. **Assertion:** A transistor amplifier in common emitter configuration has a low input impedance.

   Reason: The base to emitter region is forward biased.

13. **Assertion:** In a transistor, the base is made thin.

   Reason: A thin base makes the transistor stable.

14. **Assertion:** In an oscillator, the feedback is not in the same phase which is called as positive feedback.

   Reason: If the feedback voltage is in opposite phase, the gain is greater than one.

Digital Electronics and Logic Gates

15. **Assertion:** In an OR gate if any of the input is high, the output is high.

   Reason: OR gate is the most basic gate, with one input and one output.

ANSWER KEYS

Practice Time

1	(a)	2	(b)	3	(c)	4	(c)	5	(c)	6	(d)	7	(c)	8	(c)	9	(c)	10	(c)
11	(b)	12	(c)	13	(c)	14	(c)	15	(b)	16	(b)	17	(b)	18	(d)	19	(c)	20	(b)
21	(b)	22	(b)	23	(c)	24	(c)	25	(b)	26	(a)	27	(d)	28	(d)	29	(a)	30	(c)
31	(a)	32	(a)	33	(b)	34	(a)	35	(a)	36	(b)	37	(b)	38	(b)	39	(d)	40	(c)
41	(d)	42	(d)	43	(d)	44	(a)	45	(a)	46	(d)	47	(d)	48	(a)	49	(c)	50	(c)
51	(b)	52	(d)	53	(b)	54	(a)	55	(a)	56	(d)	57	(b)	58	(b)	59	(b)	60	(b)
61	(a)	62	(d)	63	(d)	64	(d)	65	(c)	66	(c)	67	(c)	68	(a)	69	(c)	70	(c)
71	(c)	72	(c)	73	(a)	74	(c)	75	(a)	76	(c)	77	(c)	78	(a)	79	(d)	80	(b)
81	(b)	82	(d)	83	(b)	84	(a)	85	(b)	86	(b)	87	(a)	88	(c)	89	(a)	90	(d)
91	(a)	92	(b)	93	(c)	94	(c)	95	(c)	96	(a)	97	(c)	98	(b)	99	(b)	100	(a)
101	(b)																		

High-Order Thinking Skell

1	(a)	2	(d)	3	(b)	4	(c)	5	(b)	6	(a)	7	(a)

NCERT Exemplar Problems

1	(d)	2	(b)	3	(b)	4	(b)	5	(d)	6	(c)

Assertion and Reasons

1	(c)	2	(c)	3	(a)	4	(a)	5	(c)	6	(b)	7	(d)	8	(b)	9	(b)	10	(b)
11	(d)	12	(a)	13	(c)	14	(d)	15	(c)										

HINTS AND EXPLANATIONS

Practice Time

1 (a) At absolute zero kelvin temperature, covalent bonds are very strong and there are no free electrons and hence semiconductor behaves as perfect insulator.

2 (b) Resistivity of a semiconductor at room temp, is in between 10^{-3} to 10^{6} Ωcm.

3 (c) Electric conduction in a semiconductors occurs due to both electrons and holes.

4 (c) At absolute zero, Si acts as an insulator due to the absence of free electrons in the conduction band.

5 (c) Any type of semiconduction either p or n type both are neutal *i.e.* uncharged.

6 (d) In extrinsic semi conductor the number of holes are not equal to number of electrons i.e.,

$n_h \neq n_e$

$n_h > n_e$ (In $p-$ type)

$n_e > n_h$ (In $n-$ type)

7 (c) Copper is a conductor so its resistance decreases on decreasing temperature as thermal agitation decreases whereas germanium is semiconductor therefore on decreasing temperature resistance increases.

8 (c) When small amount of antimony (pentavalent) is added to germanium crystal then crystal becomes n-type semiconductor. Therefore, there will be more free electrons than holes in the semiconductor.

9 (c) As we know that,

$$E = E_g = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{589\times10^{-9}}\text{ J} = \frac{6.6\times10^{-34}\times3\times10^{8}}{589\times10^{-9}\times1.6\times10^{-19}}\text{ eV} = 2.1\text{ eV}$$

10 (c) Electrons cannot be occupied in forbidden gap.

11 (b) As we know that,

$$E_{g\text{ conductor}} < E_{g\text{ semiconductor}} < E_{g\text{ insulator}}$$

12 (c) Diamond is an insulator.

13 (c) 6 eV.

14 (c) If all the donor states in n-type semiconductor are filled, the number of electrons in donor states will increase. Due to it, the charge density in donor states will become more than one.

15 (b) In p-n junction, the diffusion of majority carriers takes place when junction is forward biased and drifting of minority carriers takes place across the junction, when it is reverse biased.

16 (b) In an unbiased p-n junction the diffusion of charge carriers across the junction takes place from higher concentration to lower concentration.

17 (b) A pure semiconductor is an intrinsic semiconductor.

18 (d) At very low temperature, electrons cannot jump from the valence band to conduction band.

19 (c) Semiconductors have covalent bonding. The current flows due to breaking of bond means a few electrons move from valence band to conduction band. It happens in a pure (intrinsic) semiconductor.

20 (b) Doping alter the crystal structure.

21 (b) As we know that,

$$n_e n_h = n_i^2$$

Given that,

$$n_i = 6\times10^{8}\text{ m}^{-3}\text{ and } n_e = 9\times10^{12}\text{ m}^{-3}$$

$$\therefore\ n_h = \frac{n_i^2}{n_e} = \frac{\left(6\times10^{8}\right)^2}{9\times10^{12}} = 4\times10^{4}\text{ m}^{-3}$$

22 (b) Arsenic is pentavalent impurity. So, each impurity atom will add one free electron in the material.

23 (c) An n-type semiconductor is electrically neutral after doping.

24 (c) In figure Y, donor levels are shown. This is for n-type semiconductor. In figure Z, acceptor levels are shown. This is for p-type semiconductor.

25 (b) Both are trivalent impurities.

26 (a) The p-n junction diode is forward biased when p is at high potential with respect to n. Hence option (a) is correct.

27 (d) The average value of output direct current in a full wave rectifier = average value of current over a cycle = $2I_0/\pi$.

28 (d) The input signal should be connected between two points of bridge rectifier such that in positive half wave of input signal, one p-n junction should be forward biased and other should be reverse biased and in negative half wave of input signal, the reverse should take place. It will be so when input is connected between B and D.

29 (a) In the circuit the diode is in reverse bias and so no current will flow in the circuit.

30 (c) As we know that,

$$E = \frac{V}{d} = \frac{0.1}{10^{-6}} = 10^{5}\text{ V/m}$$

31 (a) A diode is said to be forward biased if p-type semiconductor of p-n junction is at high potential with respect to n-type semiconductor of p-n junction. It is so for circuit (a).

32 (a) As we know that, dynamic resistance is

$$r_d = \frac{\Delta V}{\Delta I}$$

Given that,

$$\Delta V = 0.8 - 0.70 = 0.1\text{ V}$$

$$\Delta I = 5\text{ mA} = 5\times10^{-3}\text{ A}$$

$$\therefore\ r_d = \frac{0.1}{5\times10^{-3}} = 20\ \Omega$$

33 (b) As we know that,

Reverse resistance is,

$$= \frac{\Delta V}{\Delta I} = \frac{1}{0.5\times10^{-6}} = 2\times10^{6}\ \Omega$$

34 (a) The current will flow through R_L when the diode is forward biased.

35 (a) As we know that,

Forward biased resistance,

$$= \frac{\Delta V}{\Delta I}$$
$$= \frac{(0.7-0.6)\ \text{V}}{(15-5)\ \text{mA}}$$
$$= \frac{0.1}{10 \times 10^{-3}}$$
$$= 10\ \Omega$$

36 (b) As we know that,

$$V = \frac{V_0}{\pi}$$
$$= \frac{10}{\pi}\ \text{V}$$

37 (b) In reverse biasing, the minority charge carriers will be accelerated due to reverse biasing, which on striking with atoms cause ionisation resulting in secondary electrons and thus produce more number of charge carriers. When doping concentration is large, there will be large number of ions in the depletion region, which will give rise to a strong electric field.

38 (b) In half wave rectifier, we get the output only in one half cycle of input A.C. Therefore, the frequency of the ripple of the output is same as that of input A.C. i.e. 50 Hz.

39 (d) Positive terminal is at lower potential (0 V) and negative terminal is at higher potential 5 V.

40 (c) When no current flows at the junction plane, then contact potential of junction plane is equal to the forward voltage applied = 0.045 V.

41 (d) In forward biasing, the diode conducts. For ideal junction diode, the forward resistance is zero; therefore, entire applied voltage occurs across external resistance R i.e., there occur no potential drop, but potential across R is V in forward biased.

42 (d) During regulation action of a zener diode, the current through the series resistance changes and resistance offered by the zener changes. The current through the zener changes but the voltage across the zener remains constant.

43 (d) The maximum permissible current is,

$$I_{Z_{\max}} = \frac{P}{V_m}$$
$$= \frac{410 \times 10^{-3}}{8.2}$$
$$= 50\ \text{mA}$$

44 (a) Given that,

$E = 9\ \text{V},\ V_z = 6\ \text{V},\ R_L = 1000\ \Omega$ and $R_S = 100\ \Omega$

Potential drop across series resistor,

$$V = E - V_Z$$
$$= 9 - 6$$
$$= 3\ \text{V}$$

Current through series resistance R_S is,

$$I = \frac{V}{R}$$
$$= \frac{3}{100}$$
$$= 0.03\ \text{A}$$

Current through load resistance R_L is,

$$I_L = \frac{V_Z}{R_L}$$
$$= \frac{6}{1000}$$
$$= 0.006\ \text{A}$$

Current through Zener diode is,

$$I_Z = I - I_L$$
$$= 0.03 - 0.006$$
$$= 0.024\ \text{A}$$

Power dissipated in Zener diode is,

$$P_2 = V_2 I_2$$
$$= 6 \times 0.024$$
$$= 0.144\ \text{watt}$$

45 (a) As we know that,

$$\eta = \frac{0.406}{1 - \frac{R_f}{R_L}}$$

$$\%\eta_{\max} = 40.6\% \quad \ldots\left(\text{if } \frac{R_f}{R_L} << 1\right)$$

46 (d) In the middle of the depletion layer of a reverse biased p-n junction, electric field is maximum.

47 (d) Light Emitting Diode.

48 (a) LED is always used in forward biased condition.

49 (c) Colour of light emitted by LED depends on type of semiconductor diode.

50 (c) photodiode converts Electromagnetic energy into electric potential energy.

51 (b) Photodiode is reverse biased p-n junction diode.

52 (d) As we know that,

$$\lambda = \frac{hc}{E_g}$$

$$\because\ E_g = 1.9\ \text{eV}$$
$$= 1.90 \times 1.6 \times 10^{-19}\ \text{J}$$

$$\therefore\ \lambda = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{1.90 \times 1.6 \times 10^{-19}}$$
$$= 6533\ \text{Å}$$

53 (b) To release the electron from valence band to conduction band, E_g must be overcome.

54 (a) Solar cell converts the radiant energy of sun into electrical power.

55 (a) Formation of electron-hole pairs with incident light taken place in case of solar cell.

56 (d) Silicon.

57 (b) Solar cell is a p-n junction in unbiased condition.

58 (b) p-n junction operating in unbiased condition in case of solar cell.

Zener diode is used as ac voltage stabilizer.

59 (b) As we know that,

Here, $E_g = 2$ eV

$$\therefore \quad \lambda = \frac{hc}{E_g} = \frac{1240}{2} = 620 \text{ nm}$$

$$\therefore \quad \nu = \frac{c}{\lambda} = \frac{3\times10^8}{620\times10^{-9}} = 5\times10^{14}\ \text{Hz}$$

60 (b) The detection occurs only when the energy of incident photon greater than or equal to the energy band gap,

$$\frac{hc}{\lambda} = 2.5 \text{ eV}$$

$$\lambda = \frac{hc}{2.5 \text{ eV}} = \frac{1240}{2.5} = 496 \text{ nm} = 4960 \text{ Å} \cong 5000 \text{ Å}$$

61 (a) transistor is usually made of metal oxides with high temperature coefficient of resistivity.

62 (d) The biasing of the transistor is done differently for different uses. The transistor works as an amplifier with its emitter base junction forward biased and the base collector junction reverse biased.

63 (d) Holes move from base to emitter.

64 (d) As we know that,

$$\beta = \frac{I_c}{I_b} > 1$$

or $I_c > I_b$

65 (c) In a bipolar junction transistor, emitter is heavily doped, base is lightly doped and collector is moderately doped.

66 (c) Zero; In common base amplifier circuit, input and output voltage are in the same phase.

67 (c) In common emitter configuration current gain,

$$A_i = \frac{-h_{fe}}{1+h_{oe}R_L} = \frac{-50}{1+25\times10^{-6}\times1\times10^3} = -48.78$$

Where, h_{fe} = forward current ratio

h_{oe} = output admittance

68 (a) As we know that,

$I_C = 5.488$ mA

$I_e = 5.6$ mA

$$\alpha = \frac{5.488}{5.6} = 0.98$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{0.02} = 49$$

69 (c) As we know that,

$$I_C = I_E - I_B = 90 - 1 = 89 \text{ mA}$$

70 (c) As we know that,

$$\because \quad \beta = \frac{\alpha}{1-\alpha}$$

$$\therefore \quad \alpha\beta = \frac{\alpha^2}{1-\alpha}$$

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

$$\text{or } \beta - \alpha = \frac{\alpha^2}{1-\alpha}$$

$$\therefore \quad \frac{\beta-\alpha}{\alpha\beta} = \left(\frac{\alpha^2}{1-\alpha}\right)\left(\frac{1-\alpha}{\alpha^2}\right) = 1$$

71 (c) No. of electrons reaching the collector,

$$n_C = \frac{96}{100}\times10^{10} = 0.96\times10^{10}, \ n_E = 10^{10}$$

$$I_E = \frac{n_E \times e}{t}$$

$$I_C = \frac{n_C \times e}{t}$$

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

$$= \frac{0.96 \times 10^{10}}{10^{10}}$$
$$= 0.96$$

72 (c) As we know that,

Power gain = voltage gain × current gain

$$= V_G \cdot I_G$$
$$= \frac{V_0}{V_i} \cdot \frac{I_0}{I_i}$$
$$= \frac{V_0^2}{V_i^2} \cdot \frac{R_i}{R_0}$$
$$= 50 \times 50 \times \frac{100}{200}$$
$$= 1250$$

73 (a) The current gain,

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$
$$= \frac{10 \text{ mA}}{200 \text{ }\mu\text{A}}$$
$$= \frac{10 \times 10^3}{200} = 50$$

74 (c) Voltage gain,

$$\frac{V_0}{V_i} = \beta \frac{R_2}{R_1}$$
$$\text{or } V_0 = \left(\beta \frac{R_2}{R_1}\right) \times V_i$$
$$= \left(100 \times \frac{10}{1}\right) \times 1 \times 10^{-3}$$
$$= 1 \text{ V}$$

75 (a) Given that,

$\alpha = 0.96$, $R_L = 800\ \Omega$, $R_i = 192\ \Omega$

So,

$$\beta = \frac{\alpha}{1-\alpha}$$
$$= \frac{0.96}{0.04} = 24$$

Voltage gain for common emitter configuration,

$$A_v = \beta \frac{R_L}{R_i}$$
$$= 24 \times \frac{800}{192} = 100$$

Power gain for common emitter configuration,

$$P_v = \beta A_v$$
$$= 24 \times 100$$
$$= 2400$$

Voltage gain for common base configuration,

$$A_v = \alpha \frac{R_L}{R_P}$$
$$= 0.96 \times \frac{800}{192}$$
$$= 4$$

Power gain for common base configuration,

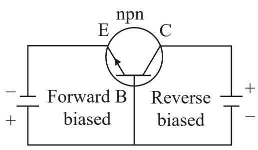
$$P_v = A_v \alpha$$
$$= 4 \times 0.96$$
$$= 3.84$$

76 (c) As we know that,

Voltage gain,

$$A_v = \beta \frac{R_0}{R_i}$$
$$= \frac{61 \times 24}{3} = 488$$

77 (c) By using this figure,



78 (a) The base is always thin.

79 (d) Base is lightly doped hence possess least number of holes.

80 (b) In most transistors, emitter is heavily doped. Its job is to emit or inject electrons into the base. These bases are lightly doped and very thin, it passes most of the emitter injected.

In pnp transistor, the p-type semiconductor acts either as an emitter or as a collector.

81 (b) As we know that,

$$I_C = \frac{90}{100} \times I_E$$
$$\therefore\ I_E = \frac{10 I_C}{9}$$
$$\therefore\ I_E = 11.1 \text{ mA}$$

82 (d) As we know that,

$$I_C = \frac{90}{100} \times I_E$$
$$\therefore\ 10 = 0.9 \times I_E$$
$$\therefore\ I_E = \frac{10}{0.9}$$
$$= 11 \text{ mA}$$
$$\because\ I_E = I_B + I_C$$
$$\therefore\ I_B = 11 - 10$$
$$= 1 \text{ mA}$$

83 (b) As we know that,

$\because\ I_B = 100\ \mu\text{A} = 0.1\text{ mA and } I_C = 10\text{ mA}$

$\therefore\ I_E = I_B + I_C = 10.1\text{ mA}$

84 (a) When npn transistor is used as an amplifier, majority charge carriers (electrons) of n-type emitter move from emitter to base and then from base to collector.

85 (b) In transistor amplifier, collector is always reverse biased and emitter is forward biased.

86 (b) As we know that,

$$v = \frac{1}{2\pi\sqrt{LC}}$$

$$\therefore\ v' = \frac{1}{2\pi\sqrt{L'C'}}$$

$$= \frac{1}{2\pi\sqrt{2L\times 4C}}$$

$$= \frac{1}{2\sqrt{2}} \times \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\sqrt{2}}v \qquad \ldots\left(\because v = \frac{1}{2\pi\sqrt{LC}}\right)$$

87 (a) Electronic oscillator is better than mechanical oscillator due to better frequency stability.

88 (c) The Boolean algebra is based on logic.

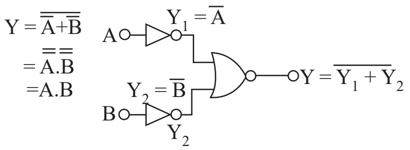
89 (a) Logic gates are the building blocks of a digital system.

90 (d) For OR gate, $Y = A + B$. Any one of the input is high we get high output.

91 (a) When either of them conducts, the gate conducts.

92 (b) As we know that for AND gate, $Y = A.B$

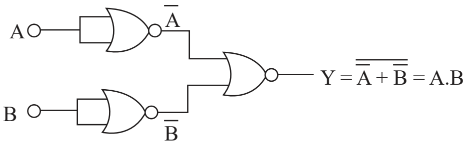
93 (c) As we know that,



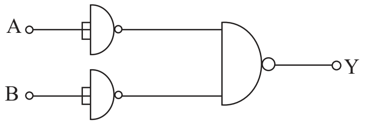
94 (c) The output of circuit, $Y = \overline{\left(\overline{A}+\overline{B}\right)} = \overline{\overline{A}}\cdot\overline{\overline{B}} = A.B.$

Therefore, output is equivalent to AND gate.

95 (c) As we know that,



96 (a) Boolean expression from figure,



$$Y = \overline{\left(\overline{A}\cdot\overline{B}\right)} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$$

This combination of gates represent OR gate.

97 (c) As we know that,

$\overline{(A.B)} + \overline{C} = (\overline{A} + \overline{B} + \overline{C})$

98 (b) As we know that,

$(\overline{A}.B) + \overline{A} = \overline{A}\cdot(B+1)$

But for any value x, $x+1 = 1$

$\therefore\ \overline{A}\cdot(B+1) = \overline{A}.1 = \overline{A}$

99 (b) Output of upper AND gate = $\overline{A}B$

Output of lower AND gate = $A\overline{B}$

Output of OR gate, $Y = A\overline{B} + B\overline{A}$

This is boolean expression for NOR gate.

100 (a) The final boolean expression is,

$X = \overline{(\overline{A}.\overline{B})}$

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

$= A + B$

$\Rightarrow$ OR gate

101 (b) Any logic function can be realized by NAND gates alone.

High-Order Thinking Skill

1 (a) As we know that conductivity of semiconductor,

$\sigma = e\left(\eta_e\mu_e + \eta_\lambda\mu_h\right)$

$= 1.6\times10^{-19}\left(5\times10^{18}\times2 + 5\times10^{19}\times0.01\right)$

$= 1.6\times1.05$

$= 1.68$

2 (d) In pure semiconductor electron-hole pair $= 7\times10^{15}\ \text{m}^{-3}$

$n_{\text{initial}} = n_h + n_e = 14\times10^{15}$ after doping donor impurity

$$N_D = \frac{5\times10^{28}}{10^7} = 5\times10^{21}$$

and, $n_e = \frac{N_D}{2} = 2.5\times10^{21}$

So,

$$n_{final} = n_h + n_e$$

$$\Rightarrow n_{final} \approx n_e \approx 2.5\times10^{21} \quad ...(\because n_e >> n_h)$$

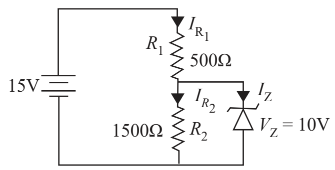
$$\text{Factor} = \frac{n_{final} - n_{initial}}{n_{initial}}$$

$$= \frac{2.5\times10^{21} - 14\times10^{15}}{14\times10^{15}}$$

$$\approx \frac{2.5\times10^{21}}{14\times10^{15}}$$

$$= 1.8\times10^5$$

3 (b) By using this figure,



The voltage drop across R_2 is,

$$V_{R_2} = V_Z = 10 \text{ V}$$

The current through R_2 is,

$$I_{R_2} = \frac{V_{R_2}}{R_2}$$

$$= \frac{10}{1500}$$

$$= 0.667\times10^{-2} \text{ A}$$

$$= 6.67\times10^{-3} \text{ A}$$

$$= 6.67 \text{ mA}$$

The voltage drop across R_1 is,

$$V_{R_1} = 15 - V_{R_2}$$

$$= 15 - 10$$

$$= 5 \text{ V}$$

The current through R_1 is,

$$I_{R_1} = \frac{V_{R_1}}{R_1}$$

$$= \frac{5}{500} = 10^{-2} \text{ A}$$

$$= 10\times10^{-3} \text{ A} = 10 \text{ mA}$$

The current through the zener diode is,

$$I_Z = I_{R_1} - I_{R_2}$$

$$= 10 - 6.67 = 3.33 \text{ mA}$$

4 (c) In photodiode, electron is released from valence band to conduction band and current.
Is established only when energy of incident photon is greater than energy band gap.

i.e., $\frac{hc}{\lambda} > E_g$

Here,

$$E_g = 1.8 \text{ eV}$$

$$= 1.8\times1.6\times10^{-19} \text{ J} = 2.88\times10^{-19} \text{ J}$$

$$\therefore E_r = \frac{hc}{\lambda_r}$$

$$\lambda_r = 700 \text{ nm}$$

$$\therefore E_r = \frac{6.65\times10^{-34}\times3\times10^8}{700\times10^{-9}}$$

$$= 28.5\times10^{-37}\times10^{17} = 2.85\times10^{-19} \text{ J}$$

$$\therefore E_r < E_g$$

Therefore, electron is not released hence counter does not show any count

5 (b) Given that,

$\alpha = 0.95,\ R_L = 700\ \Omega,\ R_i = 175\ \Omega$

So,

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.95}{0.05} = 19$$

Voltage gain for common emitter configuration,

$$A_v = \beta\frac{R_L}{R_i} = 19\times\frac{700}{175} = 76$$

Power gain for common emitter configuration,

$$P_v = \beta A_v = 19\times76 = 1444$$

Voltage gain for common base configuration,

$$A_v = \alpha\frac{R_L}{R_p} = 0.95\times\frac{700}{175} = 3.8$$

Power gain for common base configuration,

$$P_v = A_v\alpha$$

$$= 3.8\times0.95$$

$$= 3.61$$

6 (a) As we know that,
Voltage gain,

$$A_v = \beta\frac{R_C}{R_B}$$

$$= 60\times\frac{5\times10^3}{2\times10^3}$$

$$= 150$$

Power gain,

$$= \beta^2 \frac{R_C}{R_B}$$

$$= 60 \times 60 \times 2.5 = 9000$$

Base current,

$$I_B = \frac{12 \times 10^{-3}}{2 \times 10^3}$$

$$= 6 \times 10^{-6} \text{ A}$$

And, $I_C = \beta I_B$

$$= 60 \times 6 \times 10^{-6}$$

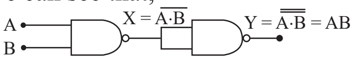
$$= 3.6 \times 10^{-4} \text{ A}$$

Output $= I_C R_L$

$$= 3.6 \times 10^{-4} \times 5 \times 10^3$$

$$= 1.8 \text{ V}$$

7 (a) As we can see that,



A	B	X	Y
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

$$\therefore Y = \overline{\overline{A \cdot B}} = A \cdot B$$

NCERT Exemplar Problems

1 (d) Conductivity of a semiconductor increases with increase in temperature because number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

2 (b) When an electron leaves a covalent bond a vacancy is created. This vacancy is called hole.

3 (b) Height of potential barrier decreases when p-n junction is forward biased and it increases when junction is reverse biased.

4 (b) Diode D_1 is reverse biased as p-side is connected to negative potential and n-side to ground. Diode D_2 is forward biased as p-side is grounded and n-side is at negative potential.

5 (d) Potential difference across capacitor,

$V =$ peak voltage

$$= V_{\text{rms}} \sqrt{2} = 220\sqrt{2} \text{ V}$$

6 (c) Truth table for the given circuit is,

A	B	$C = A \cdot B$	$D = \bar{A} \cdot B$	$E = C + D$
0	0	0	0	0
0	1	0	1	1
1	0	0	0	0
1	1	1	0	1

Assertion and Reasons

1 (c) If there is some gap between the conduction band and the valance band electrons in the valance band all remain bound and no free electrons in conduction band then it makes the material an insulator. Resistance of insulators is very high.

2 (c) High-power laser diodes are used in industrial applications such as heat treating, cladding, seam welding and for pumping other lasers, such as diode-pumped solid-state lasers.
Diode lasers consume high energy.

3 (a) In semiconductors, by increasing temperature covalent bond breaks and conduction hole and electrons increase.

4 (a) In semiconductors the energy gap between conduction band and valence band is small (≈ 1 eV). Due to temperature rise, electron in the valence band gain thermal energy and may jump across the small energy gap, (to the conduction band). Thus conductivity increases and hence resistance decreases.

5 (c) Conductivity of an intrinsic semiconductor is less than that of a lightly doped p-type semiconductor.

6 (b) As we know that,

$$\text{Intrinsic (Semiconductor)} + \text{Pentalvalent(Impurity)} \Rightarrow N\text{-type}$$

7 (d) The assertion is not true. In fact, semiconductor Obeys Ohm's law for low values of electric field (~ 106 V/m). Above this, the current becomes almost independent of electric field.

8 (b) The energy gap is greater in silicon than in germanium because the minimum energy required to break a covalent bond is higher in Si (1.1 eV). than Ge (0.72 eV).

9 (b) Zener diodes are specially designed junction diodes, which can operate in the reverse breakdown voltage region continuously without being damaged. This breakdown voltage occur when reverse bias is increased beyond a particular value, the reverse current increases suddenly on increasing the reverse bias even slightly. In normal diode after this breakdown voltage, low power rating will get destroyed but zener diode is specially designed to work in this region of biasing.

10 (b) As we know that,

$$V = 5 - 2 = 3 \text{ V}$$

$$I = \frac{V}{R}$$

$$= \frac{3}{300} = \frac{1}{100} \text{ A}$$

$$= 10 \text{ mA}$$

11 (d) Two p-n junctions placed back to back cannot work as npn transistor because in transistor the concentration of doping of p-type semiconductor is less as compared to doping of n-type semiconductor.

12 (a) Input impedance of common emitter configuration.

$$= \left|\frac{\Delta V_{BE}}{\Delta i_B}\right|_{V_{CE} = \text{constant}}$$

Where, ΔV_{BE} = voltage across base and emitter (base emitter region is forward biased)

Δi_B = base current which is order of few micro-ampere

13 (c) The base is made thin to offer better conduction of majority carriers from emitter to collector. Due to this, base current is negligible and collector current is nearly equal to emitter current.

14 (d) In an oscillator, the feedback is in the same phase i.e. positive feedback. If the feedback voltage is in opposite phase i.e. negative feedback, the gain is less than one and it can never work as oscillator. It will be an amplifier with reduced gain.

15 (c) An OR gate has two or more inputs with one output. NOT gate is the most basic gate with one input and one output. In an OR gate if any of the input is high, the output will also be high.