ENERGY BAND DIAGRAMS

• Metals, the conduction band and valence band partly overlap each other and there is no
  forbidden energy gap.

• In insulators, the conduction band is empty and valence band is completely filled and
  forbidden gap is quite large = 6 eV. No electron from valence band can cross over to
  conduction band at room temperature, even if electric field is applied. Hence there is no
  conductivity of the insulators.

• In semiconductors, the conduction band is empty and valence band is totally filled. But
  the forbidden gap between conduction band and valence band is quite small, which is
  about 1 eV. No electron from valence band can cross over to conduction band.
  Therefore, the semiconductor behaves as insulator. At room temperature, some
  electrons in the valence band acquire thermal energy, greater than energy gap of 1 eV
  and jump over to the conduction band where they are free to move under the influence
  of even a small electric field. Due to which, the semiconductor acquires small
  conductivity at room

Differences
Distinction between Intrinsic and Extrinsic Semiconductor

<table>
<thead>
<tr>
<th></th>
<th>Intrinsic</th>
<th>Extrinsic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is pure semiconducting material and no impurity atoms are added to it</td>
<td>It is prepared by doping a small quantity of impurity atoms to the pure semiconducting material.</td>
</tr>
<tr>
<td>2</td>
<td>Examples are crystalline forms of pure silicon and germanium.</td>
<td>Examples are silicon and germanium crystals with impurity atoms of arsenic, antimony, phosphorous etc. or indium, boron, aluminum etc.</td>
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</table>
**P N junction:-** A p-n junction consists of wafers of p-type and n-type semiconductors fused together of grown on each other. At the time of junction formation, the free electrons from n-type semiconductor and holes from p-type semiconductor diffuse into each other and their recombination creates a depletion region (of few μm thickness). It results in development of a potential barrier $V_\text{b}$. Potential barrier depends on the material of semiconductor.

<table>
<thead>
<tr>
<th></th>
<th>The number of free electron in conduction band and the number of holes in valence band is exactly equal and very small indeed.</th>
<th>The number of free electrons and holes is never equal. There is excess of electrons in n-type semiconductors and excess of holes in p-type semiconductors.</th>
</tr>
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<tbody>
<tr>
<td>3</td>
<td>Its electrical conductivity is low</td>
<td>Its electrical conductivity is high.</td>
</tr>
<tr>
<td>4</td>
<td>Its electrical conductivity is a function of temperature alone</td>
<td>Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped in the structure.</td>
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### Distinction between n-type and p-type semiconductors

<table>
<thead>
<tr>
<th></th>
<th>n-type semiconductors</th>
<th>p-type semiconductors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is an extrinsic semiconductors which is obtained by doping the impurity atoms of Vth group of periodic table to the pure germanium or silicon semiconductor.</td>
<td>It is an intrinsic semiconductors which is obtained by doping the impurity atoms of III group of periodic table to the pure germanium or silicon semiconductor.</td>
</tr>
<tr>
<td>2</td>
<td>The impurity atoms added, provide extra electrons in the structure, and are called donor atoms.</td>
<td>The impurity atoms added, create vacancies of electrons (i.e. holes) in the structure and are called acceptor atoms.</td>
</tr>
<tr>
<td>3</td>
<td>The electrons are majority carriers and holes are minority carriers.</td>
<td>The holes are majority carriers and electrons are minority carriers.</td>
</tr>
<tr>
<td>4</td>
<td>The electron density ($n_e$) is much greater than the hole density ($n_h$) i.e. $n_e &gt;&gt; n_h$</td>
<td>The hole density ($n_e$) is much greater than the electron density ($n_h$) i.e. $n_h &gt;&gt; n_e$</td>
</tr>
<tr>
<td>5</td>
<td>The donor energy level is close to the conduction band and far away from valence band.</td>
<td>The acceptor energy level is close to valence band and is far away from the conduction band.</td>
</tr>
<tr>
<td>6</td>
<td>The Fermi energy level lies in between the donor energy level and conduction band.</td>
<td>The Fermi energy level lies in between the acceptor energy level and valence band.</td>
</tr>
</tbody>
</table>
The barrier potential sets up a field across the junction directed from n-type to p-type semiconductor. Under the influence of this field, minority charge carriers drift across the junction in a direction opposite to the direction of diffusion current till the two currents equalize and equilibrium is reached. This whole process is complete as soon as the junction is formed.

Depletion region: It is the region near the p-n junction that is depleted of any mobile charge carrier. It only consists of immobile charge carriers. The width of depletion layer depends on (i) extent of doping – more doping means thinner depletion layer, (ii) type of biasing – forward biasing decreasing the thickness of depletion layer Potential barrier: the potential difference across the p-n junction under equilibrium is called potential barrier. Potential barrier depends on the nature of semiconductor material.

Figure: (a) Diode under equilibrium (b) Barrier potential under no bias (V = 0)

Semiconductor diode: A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. It is a two terminal device.
Biasing of p-n junction diode: The application of external voltage to the junction diode in a certain direction is known as biasing of p-n junction diode. It can be done in two ways – (i) forward biasing and (ii) reverse biasing. (i) Forward biasing of p-n junction: A p-n junction is said to be in forward bias when p region of diode is maintained at a higher potential with respect to the n region. In forward bias, majority charge carriers in both the regions are pushed through the junction. The depletion region’s width decreases and junction offers low resistance.

(ii) Reverse biasing of p-n junction: A p-n junction is said to be in reverse bias when n region of diode is maintained at a higher potential with respect to the p region. In reverse bias, majority charge carriers are pushed away from the junction. The depletion region’s width increases. The minority charge carriers are pushed through the junction thereby causing a little current.

I-V characteristics of a p-n junction diode: The graphs plotted to show the variation of current flowing through the junction Vs the Potential difference applied are known as I-V characteristics of junction diode. (a) Forward characteristics of p-n junction diode:
b) Forward I-V characteristics of Junction diode

In forward bias, the current first increases very slowly, almost negligibly, till the voltage across the diode crosses threshold value. After the threshold voltage, the diode current increases exponentially. The dynamic resistance of diode \( r_d = \frac{AV}{dI} \) is small in forward bias.

(a) Reverse characteristics of p-n junction diode:-

In reverse bias, the diode does not conduct current. The voltage across the diode increases exponentially with a small current flowing through it. The reverse current is negligible compared to the forward current.

(a) Circuit diagram to draw the reverse characteristics

\( V_{be} \) is the voltage across the diode in reverse bias.
(b) Reverse I-V characteristics of Junction diode

In reverse bias, the current is very small (of the order of μA) and almost remains constant with change in bias voltage. It is called reverse saturation current. However at very high reverse bias (breakdown voltage), the current suddenly increases. In reverse bias, for voltage below the breakdown voltage, the dynamic resistance of diode is very high.

Junction diode as a rectifier:- Rectifier is the electronic circuit which convert AC voltage into DC voltage. The working of a rectifier is based on the principle that a junction diode allows current to pass only when it is forward biased.

The rectifier circuit is basically of two different types-

(a) Half wave rectifier  
(b) Full wave rectifier

(a) Half wave rectifier:- If an alternating voltage is applied across a diode in series with a load, a pulsating voltage will appear across the load only during the half cycles of the ac input during which the diode is forward biased. Such rectifier circuit, as shown in figure, is known as half wave rectifier circuit. The secondary of a transformer supplies the desired ac voltage across terminals A and B. When the voltage at A is positive, the diode is forward biased and it conducts. When A is negative, the diode is reverse-biased and it does not conduct. Therefore in positive half cycle of ac there is a current through the load resistor RL and we get an output voltage whereas there is no current in the negative half cycle. Thus, the output voltage is restricted to only one direction is said to be rectified. Since the rectified output of this circuit is only for half of the input ac wave it is called half wave rectifier.

Circuit diagram of Half wave rectifier Input
(b) **Full wave rectifier:** The circuit using two diodes as shown in circuit diagram gives rectified output for both positive as well as negative half of ac cycle. Hence, it is called full wave rectifier. In this type of rectifier, each diode rectifies only one half of the ac cycle turn by turn. In one half cycle, diode D1 conducts whereas in the next half cycle, diode D2 conducts, but through the load resistor current flows for both half of ac cycles in the same direction. Hence, rectified output is obtained for the full cycle of input ac voltage.

**Centre -Tap Transformer**

**Circuit diagram for full wave rectifier**

Input and output waveform for full wave rectifier
Zener diode:- Zener diode is a special purpose junction diode designed to operated under reverse bias in reverse breakdown voltage. It is used as a voltage regulator for the output of rectifiers. It is a heavily doped p-n junction having a very thin depletion layer (\(< 10^4\) V/m). When small reverse bias voltage is applied across zener diode junction fields increases very rapidly causing internal field emission and hence, a reverse breakdown at relatively low voltage. The reverse bias current (known as Zener current) increases abruptly for negligible increase in reverse bias voltage in breakdown region as shown below.
Zener diode as a voltage regulator:- Zener diode is used to stabilise the output voltage of a rectifier by absorbing the fluctuations of rectified output voltage of a rectifier. The unregulated dc voltage (filtered output of a rectifier) is connected to the Zener diode through a series resistance $R_s$ such that the Zener diode is reverse biased. If the input voltage increases, the current through $R_s$ and Zener diode also increases. This increases the voltage drop across $R_s$ without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes. Similarly, if the input voltage decreases, the current through $R_s$ and Zener diode also decreases. The voltage drop across $R_s$ decreases without any change in the voltage across the Zener diode. Thus any increase/decrease in the input voltage results in, increase/decrease of the voltage drop across $R_s$ without any change in voltage across the Zener diode. Thus the Zener diode acts as a voltage regulator.

Optoelectronic junction devices:- The semiconductor diodes in which the charge carriers are generated by photons are known as optoelectronic devices. They are photo diode, LED and Solar cell

(I) Photo diode:- it is used for detecting optical signals. A Photodiode is a p-n junction diode fabricated with a transparent window to allow light to fall on the diode. It is operated under reverse bias. When the photodiode is illuminated with light
(photons) with energy (hν) greater than the energy gap (Eg) of the semiconductor, then electronhole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity of incident light. (Photocurrent is directly proportional to the intensity of incident light.)

(ii) Light Emitting Diode (LED):

(a) Biasing of LED

It is a heavily doped p-n junction which under forward bias emits spontaneous radiation. The diode is encapsulated with a transparent cover so that emitted light can come out. When the diode is forward biased, electrons are sent from n → p (where they are minority carriers) and holes are sent from p → n (where they are minority carriers). At the junction boundary the concentration of minority carriers increases compared to the equilibrium concentration (i.e., when there is no bias). Thus at the junction boundary on either side of the junction, excess minority carriers are there which recombine with majority carriers near the junction. On recombination, the energy is released in the form of photons. Photons with energy equal to or slightly less than the band gap are emitted.
(a) The intensity of emitted light depends on the forward current flowing through LED. When the forward current of the diode is small, the intensity of light emitted is small. As the forward current increases, intensity of light increases and reaches a maximum.

(b) The colour of the light emitted by an LED depends on the composition of material of LED (wavelength of emitted light =  \lambda = \frac{h \nu}{E_g} )

LEDs have the following advantages over conventional incandescent low power lamps:

(i) Low operational voltage and less power.
(ii) Fast action and no warm-up time required.
(iii) The bandwidth of emitted light is 100 Å to 500 Å or in other words it is nearly (but not exactly) monochromatic.
(iv) Long life and ruggedness.
(v) Fast on-off switching capability.

(C) Solar Cell:-
A solar cell is basically a p-n junction which generates emf when solar radiation falls on the p-n junction. It is very lightly doped in which the depletion layer is very wide and n & p regions are very thin. The generation of emf by a solar cell, when light falls on, it is due to the following three basic processes: generation, separation and collection—
(i) generation of e-h pairs due to light (with  \nu > E_g ) close to the junction;
(ii) separation of electrons and holes due to electric field of the depletion region. Electrons are swept to n – side and holes to p – side;
(iii) the electrons reaching the n – side are collected by the front contact and holes reaching p – side are collected by the back contact. Thus p – side becomes positive and n – side becomes negative giving rise to photo-voltage.

When an external load is connected as shown in figure, a photocurrent  I_L  flows through the load. A typical I – V characteristics of a solar cell is drawn in forth quadrant.
Junction Transistor:-

A transistor has three doped regions forming two p-n junctions between them. Obviously, there are two types of transistors. There are two types of transistor-

(i) n-p-n transistor : Here two segments of n-type semiconductor (emitter and collector) are separated by a segment of p-type semiconductor (base).

(ii) p-n-p transistor: Here two segments of p-type semiconductor (termed as emitter and collector) are separated by a segment of n-type semiconductor (termed as base).
- **Emitter**: This is the segment on one side of the transistor. It is of moderate size and heavily doped. It supplies a large number of majority carriers for the current flow through the transistor. 

- **Base**: This is the central segment. It is very thin and lightly doped.

- **Collector**: This segment collects a major portion of the majority carriers supplied by the emitter. The collector side is moderately doped and larger in size as compared to the emitter.

**Transistor Action**: PNP Transistor
- The emitter-base junction of the transistor is forward biased whereas the collector-base junction is reverse bias in its active state. The heavily doped emitter has a high concentration of majority carriers. These majority carriers enter the base region in large numbers. The base is thin and lightly doped. So the majority carriers there would be few. In a p-n-p transistor the majority carriers in the base are electrons since base is of n-type semiconductor. The large number of holes entering the base from the emitter swamps the small number of electrons there. As the base collector-junction is reverse biased, these holes, which appear as minority carriers at the junction, can easily cross the junction and enter the collector. The holes in the base could move either towards the base terminal to combine with the electrons entering from outside or cross the junction to enter into the collector and reach the collector terminal. The base is made thin so that most of the holes find themselves near the reverse-biased base-collector junction and so cross the junction instead of moving to the base terminal. The current entering into the emitter from outside is equal to the emitter current $I_E$. Similarly the current emerging from the base terminal is $I_B$ and that from collector terminal is $I_C$. It is obvious from the above description that the emitter current is the sum of collector current and base current:

$$ I_E = I_C + I_B $$

![Transistor Diagram](image_url)
Common emitter transistor characteristics:
When a transistor is used in CE configuration, the input is between the base and the emitter and the output is between the collector and the emitter.

Input Characteristics:
The variation of the base current $I_B$ with the base-emitter voltage $V_{BE}$ at constant output voltage $V_{CE}$ is called the input characteristic.

Output Characteristics:
The variation of the collector current $I_C$ with the collector-emitter voltage $V_{CE}$ is called the output characteristic.

Circuit diagram to draw the n-p-n transistor characteristics in CE configuration

Input Characteristic

Output characteristics
Input characteristic of transistor is identical for different output voltage. These characteristics are like forward characteristics of a junction diode.

Output characteristics shows that when $I_b$ increases $I_c$ also increases. The plot of $I_c$ versus $V_{ce}$ for different fixed values of $I_b$ gives one output characteristic. So there will be different output characteristics corresponding to different values of $I_b$ as shown.

**Saturation State:**
The output characteristics show that initially for very small values of $V_{ce}$, $I_c$ increases almost linearly. This happens because the base-collector junction is not reverse biased and the transistor is not in active state. In fact, the transistor is in the saturation state and the current is controlled by the supply voltage $V_{cc}(=V_{ce})$ in this part of the characteristic.

**Active State:**
When $V_{ce}$ is more than that required to reverse bias the base-collector junction, $I_c$ increases very little with $V_{ce}$. The reciprocal of the slope of the linear part of the output characteristic gives the values of output resistance $r_o$. The output resistance of the transistor is mainly controlled by the bias of the base-collector junction. The high magnitude of the output resistance (of the order of 100 kΩ) is due to the reverse-biased state of this diode. In this state for a small change in base current, a large change is observed in collector current.

Output resistance $r_o = \left( \frac{\Delta V_{ce}}{\Delta I_c} \right)_{I_b = \text{const}}$ and

Current gain/amplification factor $\beta = \left( \frac{\Delta I_c}{\Delta I_b} \right)_{V_{ce} = \text{const}}$

**Cut-off state:**
when the base-emitter voltage is negligible such that $I_b = 0$, then $I_c$ is almost zero. This state of transistor is said to be cut-off state.
**Transistor as an amplifier in common emitter configuration:** An amplifier is an electronic circuit that increases the amplitude of the ac voltage using dc energy. For using the transistor as an amplifier we will use the active region of the $V_C$ versus $V_i$ curve.

**Phase reversal:**

The slope of the linear part of the curve represents the rate of change of the output with the input. It is negative because the output is $V_{cc} - I_BR$. That is why as input voltage of the CE amplifier increases its output voltage decreases and the output is said to be out of phase with the input.

Voltage amplification by the amplifier is defined as

$$A_v = \frac{\Delta V_o}{\Delta V_i}$$

Where $\Delta V_o$ and $\Delta V_i$ are small changes in the output and input voltages.

If the $V_{be}$ voltage has a fixed value corresponding to the mid-point of the active region, the circuit will behave as a CE amplifier.

If we first assume that $V_i = 0$ then applying Kirchoff’s law to the output and input loop,

$$V_{CC} = V_{CE} + I_C R_C$$

and

$$V_{BB} = V_{BE} + I_B R_B$$

When $V_i$ is not zero we get

$$V_i + V_{an} = V_{BE} + I_a R_a + \Delta V_{BE} + \Delta I_a R_a$$

If the input junction resistance is

$$R_i = \frac{\Delta V_{BE}}{\Delta I_a}$$

The change in $I_a$ causes a change in $I_c$

$$\beta_{ac} = \frac{\Delta I_c}{\Delta I_B} = \frac{I_c}{I_b}$$
Which is also known as the ac current gain

The change in $I_1$ due to a change in $I_2$ causes a change in $V_{ci}$ and the voltage drop across the resistor $R_1$ because $V_{ce}$ fixed.

$$\Delta V_{cc} = \Delta V_{ce} + R_L \Delta I_C = 0$$

or

$$\Delta V_{ce} = -R_L \Delta I_C$$

The change in $V_{ce}$ is the output voltage $V_o$

$$v_o = \Delta V_{ce} = -\beta_{ac} R_L \Delta I_B$$

The voltage gain of the amplifier is

$$A_v = \frac{V_o}{V_i} = \frac{\Delta V_{ce}}{r \Delta I_B}$$

$$= -\frac{\beta_{ac} R_L}{r}$$

**Analog and Digital Signals:**

A signal in the form of continuous, time varying voltage or current is called an analogue signal.

A pulse waveform in which only discrete values of voltage or current is possible is called a digital signal.

**Logic Gates:**

It is a digital circuit that follows certain logical relationship between one or more than one input and the output are voltages which are always in two states only.

Basic Logic gates are

**OR gate:** The output of OR gate is 1 if at least one of the inputs are at 1 state.
AND gate:- The output of AND gate is 1 only when all the inputs are at 1 state.

\[
\begin{array}{c}
A \\
B
\end{array} \quad \begin{array}{c}
Y
\end{array}
\]

NOT gate:- It is one input gate. The output of NOT gate is inverse of input.

\[
\begin{array}{c}
A \\
\end{array} \quad \begin{array}{c}
Y
\end{array}
\]

Apart from the above basic gates, there are two universal gates-

NOR gate:- The output of NOR gate is 0 if at least one of the inputs are at 1 state.

\[
\begin{array}{c}
A \\
B
\end{array} \quad \begin{array}{c}
Y
\end{array}
\]

NAND gate:- The output of NAND gate is 0 only when all the inputs are at 1 state.

\[
\begin{array}{c}
A \\
B
\end{array} \quad \begin{array}{c}
Y
\end{array}
\]
QUESTIONS

SEMICONDUCTORS

1. What is the order of energy gap in an intrinsic semiconductor? (1)

2. How does the energy gap vary in a semiconductor when doped with penta-valent element? (1)

3. How does the conductivity change with temperature in semiconductor? (1)

4. What type of semiconductor we get when: Ge is doped with Indium? Si is doped with Bismuth? (1)

5. In a semiconductor concentration of electron is $8 \times 10^{13} \text{cm}^{-3}$ and holes $5 \times 10^{12} \text{cm}^{-2}$: is it p or n type semiconductor? (1)

6. Draw energy gap diagram of a p Type semiconductor? (1)

7. What is Fermi energy level? (1)

8. Energy gap of a conductor, semiconductor, insulator are $E_1$, $E_2$, $E_3$ respectively. Arrange them in increasing order. (1)

9. Name the factor that determines the element as a conductor or semiconductor? (1)

10. Why semiconductors are opaque to visible light but transparent to infrared radiations? (2)

   Ans: The photons of infrared radiation have smaller energies, so they fall to excite the electrons in the valence band. Hence infrared radiations pass through the semiconductors as such; i.e. a semiconductor is transparent to infrared radiation.

11. The ratio of number of free electrons to holes $\frac{n_e}{n_h} = 1$ for two different materials A and B are 1 and $<1$ respectively. Name the type of semiconductor to which A and B belongs. (2)

   Ans: If $\frac{n_e}{n_h} = 1$. Hence A is intrinsic semiconductor. If $\frac{n_e}{n_h} < 1$, $n_e < n_h$ hence B is P-type.
P-N JUNCTION DIODE

1. How does the width of depletion layer change, in reverse bias of a p-n junction diode? (1)

2. Draw VI characteristic graph for a Zener diode? (1)

3. In a given diagram, is the diode reverse (or) forward biased? (1)

Ans: Reverse biased.

4. Why Photo diode usually operated at reverse bias? (2)

5. State the factor which controls wave length and intensity of light emitted by LED. (2)

Ans: (i) Nature of semi-conductor

(ii) Forward Current

6. With the help of a diagram show the biasing of light emitting diode. Give two advantages over conventional incandescent Lamp. (2)

Ans: Monochromatic, Consume less power.

8. Draw a circuit diagram to show, how is a photo diode biased? (2)

9. Pure SI at 300K has equal electron and holes concentration $1.5 \times 10^{16}$ per $m^3$. Doping by Indium Increases hole concentration to $4.5 \times 10^{22}$ per $m^3$. Calculate new electron concentration. (2)

Ans: $n_e n_h = n_i^2$

10. In the following diagram, identify the diodes which are in forward biased and which are in reversed biased.
11. A semiconductor has equal electron and hole concentrations of $6 \times 10^9 / \text{m}^3$. On doping with a certain impurity, the electron concentration increases to $9 \times 10^{12} / \text{m}^3$. (2)

(i) Identify the new semiconductor obtained after doping.

(ii) Calculate the new hole concentrations.

**Ans:**

(i) n-type semiconductor.

(ii) $n_e n_h = n_i^2 \Rightarrow n_e = \frac{6 \times 10^9 \times 6 \times 10^9}{9 \times 10^{12}} = 4 \times 10^4 / \text{m}^3$

12. Determine the current through resistance “$R$” in each circuit. Diodes $D_1$ and $D_2$ are identical and ideal. (2)

**Ans:** In circuit (i) Both $D_1$ and $D_2$ are forward biased hence both will conduct current and resistance of each diode is “0”. Therefore $I = 3/15 = 0.2 \text{ A}$

(ii) Diode $D_1$ is forward bias and $D_2$ is reverse bias, therefore resistance of diode $D_1$ is “0” and resistance of $D_2$ is infinite. Hence $D_1$ will conduct and $D_2$ do not conduct. No current flows in the circuit.

13. From the given graph identify the knee voltage and breakdown voltage. Explain? (2)
14. Which special type of diode acts as voltage regulator? Give the symbol. Draw its V-I characteristics. (3)

**TRANSISTORS**

1. How does the dc current gain of a transistor change, when the width of the base region is increased? (1)

2. In only one of the circuits given below, the lamp “L” glows. Identify the circuit? Give reason for your answer? (2)

```
(I)  R   CV
    L

(II)  R
  6V
    L

(III)  R
  6V
    L
```

**Ans:** In fig (i) emitter–base junction has no source of emf. Therefore Ic = 0, bulb will not glow. In fig (ii) emitter–base junction is forward biased; therefore lamp “L” will glow.

(iii) Emitter–base junction is reversed biased so the bulb will not glow.

3. Why do we prefer NPN transistor to PNP for faster action? (2)

**Ans:** For faster action NPN Transistor is used. In an NPN transistor, current conduction is mainly by free electron, whereas in PNP type transistor, it is mainly holes. Mobility of electrons is greater than that of holes.

4. In which mode, the cut off, active or saturation, the transistor is used as a switch? Why? (2)

**Ans:** Cut off & saturation

5. In NPN transistor circuit, the collector current is 5mA. If 95% of the electrons emitted reach the collector region, what is the base current? (2)
\begin{align*}
I_b &= 0.25 \text{ mA} \\
I_c &= 95\% \text{ of } I_e = \frac{95}{100} \times I_e \\
I_e &= \frac{100}{95} \times 5 \text{ mA} = 5.26 \text{ mA}, \\
I_e &= I_c + I_b
\end{align*}

6. Which of input and output circuits of a transistor has a higher resistance and why? (3)

Ans: The output circuit of a transistor has a higher resistance. Hint: The ratio of resistance of output circuit \( (r_o) \) is 10 times that of input circuit \( r_i \); i.e., \( r_o = 10 \times r_i \).

7. The base current of a transistor is 105 \( \mu \text{A} \) and collector current is 2.05 mA. (3)

a) Determine the value of \( \beta \), \( I_b \),

b) A change of 27 \( \mu \text{A} \) in the base current produces a change of 0.65 mA in the collector current. Find \( \beta_{ac} \)

\begin{align*}
I_b &= 105 \times 10^{-6} \text{ A} \\
I_c &= 2.05 \times 10^{-3} \text{ A} \\
\beta &= \frac{I_c}{I_b} = 19.5 \text{ Also,} \\
I_e &= I_b + I_c = 2.155 \times 10^{-3} \text{ A} \\
\Delta I_b &= 27 \mu \text{A} = 27 \times 10^{-6} \text{ A} \\
\beta_{ac} &= \frac{\Delta I_c}{\Delta I_b} = 24.1
\end{align*}

8. Explain through a labeled circuit diagram, working of a transistor, as an amplifier in common emitter configuration. Obtain the expression for current gain, voltage gain and power gain.

9. Draw a circuit diagram to study the input and output characteristic of an NPN transistor in common emitter configuration. Draw the graphs for input and output characteristics. (3)

10. Define trans conductance of a transistor. (2)

\textbf{Ans:} \quad g_m = \frac{\Delta I_c}{\Delta V_b}
11. How does the collector current change in junction transistor if the base region has larger width? Ans: Current decreases. (2)

12. The input of common emitter amplifier is 2kΩ. Current gain is 20. If the load resistances is 5kΩ. Calculate voltage gain trans conductance. (3)

Ans: \[ g_m = \frac{\beta}{R_i}, A_v = \beta \frac{R_l}{R_i} \]

13. Define input, output resistance, current amplification factor, voltage amplification factor, for common emitter configuration of transistor. (3)

14. A change 0.2 mA in base current causes a change of 5mA in collector current in a common emitter amplifier.

(i) Find A.C current gain of Transistor.

(ii) If input resistance 2kΩ and voltage gain is 75. Calculate load resistance used in circuit.

\[ \beta_{ac} \text{ current gain} = \frac{\Delta I_c}{\Delta I_b} \] (3)

15. In a transistor the base current is changed by 20μA. This results in a change of 0.02V in base emitter Voltage and a change of 2mA in collector current. (3)

(i) Find input resistance,

(ii) Trans conductance.

16. With the help of circuit diagram explain the action of a transistor. (3)

17. Draw the transfer characteristics of a transistor in common emitter configuration. Explain briefly the meaning of the term active region and cut off region in this characteristic. (3)

18. Explain with the help of a circuit diagram the working of N-P-N transistor as a common emitter amplifier. Draw input and output wave form. (3)

19. Draw a labeled circuit diagram of common emitter amplifier using P-N-P transistor. Define voltage gain and write expression. Explain how the input and output voltage are out of phase 180° for common emitter transistor amplifier. (3)
LOGIC GATES

*1. Modern technology use poly silicon instead of metal to form the gate. Why?

(1) Ans: Poly silicon has high conductivity compared to metal.

2. Identify the logic gate; Give its truth table and output wave form?

Ans: NAND GATE.

*3. Draw the logic circuit and the output wave form for given output Y=0, 0, 1, 1

Ans: The output of the AND gate is Y = A.B consequently the input of the OR gate are A and A.B. Then the final Y' = A + A.B
4. Construct the truth table for the Boolean equation $Y = (A+B) \cdot C$ and represent by logic circuit.

\[ Y = (A+B) \cdot C \]

**Ans:** The output of OR gate is $A+B$. Consequently, the inputs of AND gate are $A+B$ & $C$ Hence the Boolean equation for the given circuit is

\[ Y = (A+B) \cdot C = Y \cdot C \]

\[ Y = (A+B) \]
5. Construct AND gate using NAND GATE and give its truth table? (2)

**Ans:** AND Gate using NAND GATE:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Y = A. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

6. Identify which basic gate OR, AND and NOT is represented by the circuits in the dotted lines boxes 1, 2 and 3. Give the truth table for the entire circuit for all possible values of A and B? (3)

**Ans:** The dotted line box 1 represents a NOT gate. The dotted line box 2 represents an OR gate. Here we use de Morgan’s theorem. The dotted line 3 represents AND gate.
7. Two input waveforms A and B shown in figure (a) and (b) are applied to an AND gate. Write the Output

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input A</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Input B</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Output Y = A. B</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Input waveform.

8. A circuit symbol of a logic gate and two input waveforms A and B are shown.
   a) Name the logic gate
   b) Give the output wave form
a. Name the logic gate
b. Give the output wave form

**Ans:** Current amplifier = $\frac{\Delta I_c}{\Delta I_p} = \frac{(9.5 - 2.5)}{50 \times 10^6}$

1. Identify the Logic gate.

   ![Logic Gate Diagram](image)

   **Ans:** OR gate

2. Identify the Logic gate

   ![Logic Gate Diagram](image)

   **Ans:** $P = \text{OR gate, } Q = \text{AND gate, } R = \text{NAND gate}$

4. Identify the gate:

   ![Logic Gate Diagram](image)

   **Ans:** AND Gate