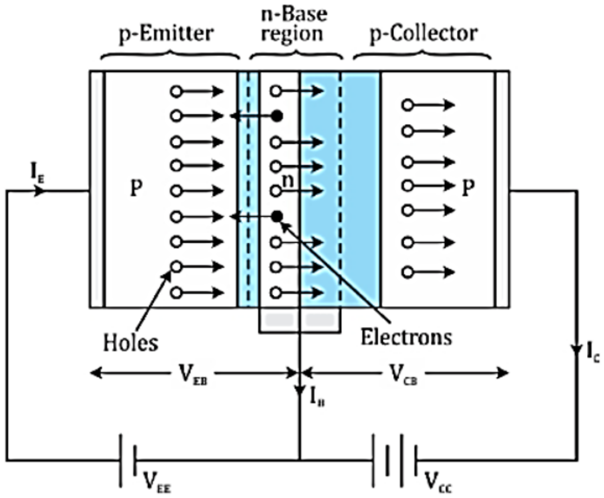
# Solution

## SEMICONDUCTORS

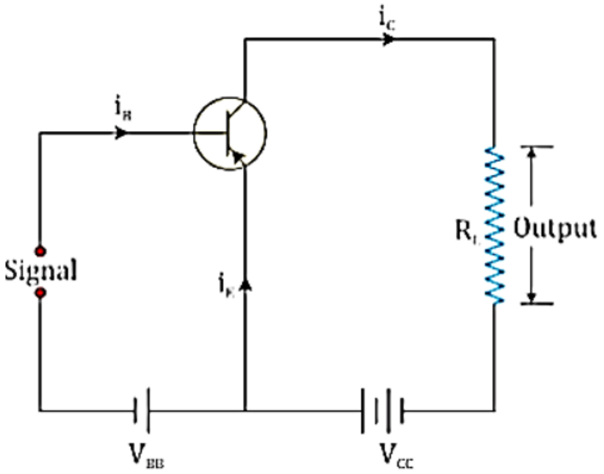
## Class 12 - Physics

1.
   **(b)** raises the potential barrier
   **Explanation:**
   When a diode is connected in a Reverse Bias condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material. The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode.
   The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator. The result is that a high potential barrier is created thus preventing current from flowing through the semiconductor material.

2. **(a)** the number of conduction electrons increases.
   **Explanation:**
   the number of conduction electrons increases.
3. **(a)** 1 mA
   **Explanation:**
   E = 5.5 V
   $V_D = 0.4$ V
   R = 5.1 k$\Omega$
   The current through the circuit is
   $\mathrm{I}=\frac{\mathrm{E}-\mathrm{V}_{\mathrm{D}}}{\mathrm{R}}$
   $\mathrm{I}=\frac{5.5-0.4}{5100}$
   = 0.001 A = 1 mA
4. **(a)** excess of electrons
   **Explanation:**
   When a strong current is passed through a semiconductor, many covalent bonds break up due to heating and thereby liberating a large number of free electrons.
5. **(a)** intrinsic and p-type semiconductors
   **Explanation:**
   intrinsic and p-type semiconductors
6.
   i. Heavy doping makes the depletion region very thin. This makes the electric field of the junction very high, even for a small reverse bias voltage. This in turn helps the Zener diode to act as a voltage regulator.
   ii. When operated under reverse bias, the photodiode can detect changes in current with changes in light intensity more easily because the fractional change in minority charge carriers is more than that in majority charge carriers.
   iii. The photon energy, of visible light photons, varies from about 1.8 eV to 3 eV. Hence for visible LEDs, the semiconductor must have a bandgap of 1.8 eV.
7. If the bias of the emitter-base junction of a transistor is sufficient to send a forward current and the collector-base junction is reversed biased, the transistor is said to be in the active state. The circuit diagram of a p-n-p transistor is as shown below:



A transistor when operated in the active state acts as an amplifier. The working of a common emitter transistor as an amplifier is based on the principle that a weak input signal given to the base region produces an amplified output signal in the collector region. The circuit diagram for a p-n-p common emitter transistor amplifier can be drawn as shown below:

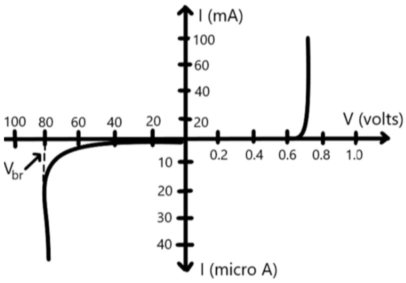


The battery VBB forward biases the emitter-base junction and the battery $V_{CC}$ reverse biases the emitter-collector region. The e.m.f. of the batteries should be greater than the barrier potential across base-emitter and collector-emitter junction. The output current produces a potential difference across the load resistance $R_L$. A weak alternating signal is applied between the base and the emitter. When the signal increases in the positive direction, the base current also increases. The base current is amplified b times and appears at the collector. The collector current flowing through the collector load resistance produces a voltage. This output voltage is equal to the collector current times the load resistance. Thus, an amplified output is obtained. The voltage gain = output voltage/input voltage.

In a transistor, the base is thin and lightly doped so that it contains smaller number of majority carriers. This reduces the recombination rate of free electrons and holes in the base region when the majority carriers go from the emitter to the collector. On the other hand, the emitter region in a transistor is heavily doped because the emitter supplies the majority carriers for the current flow.

8. LED is heavily doped p-n junction diode which emits spontaneous radiation in forward baising. The diode is encapsulated with a transparent cover so that emitted light can come out.
   When LED is forward biased the electrons and holes approaches to the junction boundaries and on each recombination of electron & hole at or near the junction \& hole at or near the junction boundary the LED emits radiation/photon.
   Advantages-
   i. Low operational voltage and less power
   ii. Long life and ruggedness

9. a.

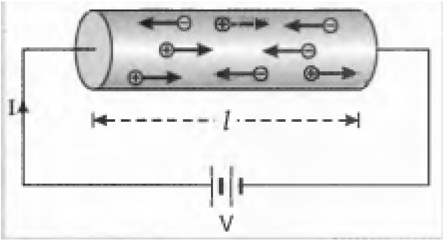


b. **Threshold Voltage:** Forward bias voltage at which the current increases significantly (exponentially) even for a very small increase in voltage.

**Break down voltage:** Reverse bias voltage at which current increases suddenly.

c. **Junction Diode:** conducts when it is forward biased and does not conduct when reverse biased.

10. Consider a block of semiconductor of length l, area of cross-section A and having number density of electrons and holes as $n_e$ and $n_h$ respectively. Suppose that on applying a potential difference, say V, a current I flows through it as shown in Fig.



The total current in the semi-conductor will be the sum of current due to electrons as well as holes, i.e.

$I = I_e + I_h \quad \dots\dots\dots\dots (i)$

If $n_e$ is the number density of conduction band electrons in the semiconductor and $v_e$, the drift velocity of electrons, then electron current is given by

$I_e = n_e e A v_e$

Also, the hole current,

$I_h = n_h e A v_h$

So, $I = n_e e A v_e + n_h e A v_h$

$I = eA[n_e v_e + n_h v_h]$

$\frac{I}{A} = e[n_e v_e + n_h v_h]$ ......(ii)

As we know that E = $\frac{V}{l}$ (in magnitude)

Also, $R = \rho \frac{l}{A}$

Thus, $\rho = \frac{RA}{l}$

where ρ is resistivity and R is resistance.

So,

$\frac{E}{\rho} = \frac{V}{l} \times \frac{l}{RA}$

or $\frac{E}{\rho} = \frac{I}{A}$ ...(iii)

Putting eq(iii) in eq(ii) we get,

$\frac{E}{\rho} = e[n_e v_e + n_h v_h]$

$\Rightarrow \frac{1}{\rho} = \frac{e}{E}[n_e v_e + n_h v_h]$

Also, $\frac{1}{\rho}$ = $\sigma$ is called the conductivity of the material of semiconductor.

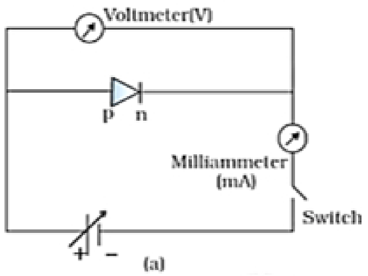
$\Rightarrow \sigma = e[n_e \frac{v_e}{E} + n_h \frac{v_h}{E}]$

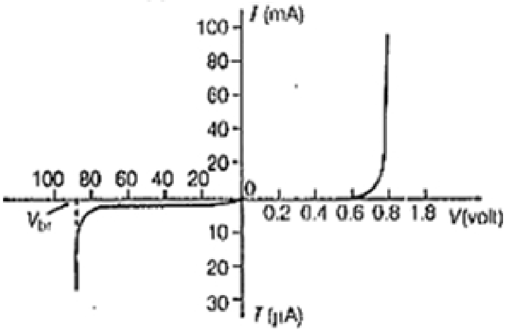
Now, mobility (m) = $\frac{Drift\ velocity}{Electric\ field}$

Thus, $\sigma = e[n_e m_e + n_h m_h]$

This is the expression for the conductivity of a semiconductor.

11. i.





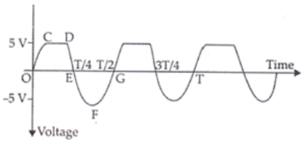
Beyond threshold voltage in forward bias diode current increases significantly even for very small increases in diode bias voltage.

ii. $V_A - 5 \times 10^3 \times 0.2 \times 10^{-3} - 0.3 - 5 \times 10^3 \times 0.2 \times 10^{-3} - V_B = 0$

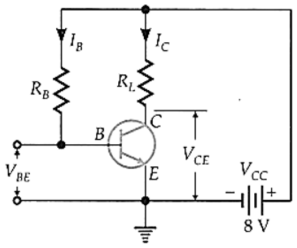
$V_A - V_B = 2.3$ volt

Hence, the voltage difference between A and B is 2.3 volt.

12. When signal 20 sin $\omega$t gives input voltage less than 5 volt (because after 5V diode will get positive voltage at its P-junction) then diode will be in reverse bias so resistance of diode remain infinity so input signal will not pass through diode and battery path so output across A and B will increase from 0-5 V (graph OC).
Now when the input voltage 20 sin ωt increase beyond 5V then path of diode 5 V battery will offer very low resistance, so the current passes through diode and battery and output (across A and B) remain 5V (graph CD).
Now when the voltage decreases the diode will be in reverse bias and output will again fall from 5V to 0V as input changes (graph DE). When input voltage becomes negative (there is opposite of 5V battery in p-n junction input voltage becomes more than 5V now) the diode is in reversed bias it will not conduct current through CD, and in output across AB will get same as input AC i.e. for negative cycle diode offer infinite resistance as compared to R in series graph E, F, G.
Same repetition of input and output continues-graph showing the output waveform.



13. An n-p-n transistor in a common-emitter mode with connections as given is shown in the figure.



Collector emitter voltage,

$V_{CE} = V_{CC} - I_C R_L$

$\therefore R_L = \frac{V_{CC} - V_{CE}}{I_C}$

$= \frac{8\text{ V} - 4\text{ V}}{4 \times 10^{-3}\text{ A}}$

$= 10^3\ \Omega = 1\Omega$

As $\beta_{dc} = \frac{I_C}{I_B}$

$\therefore I_B = \frac{I_C}{\beta_{dc}} = \frac{4 \times 10^{-3}\text{ A}}{100} = 4 \times 10^{-5}$ A

Base-emitter voltage,

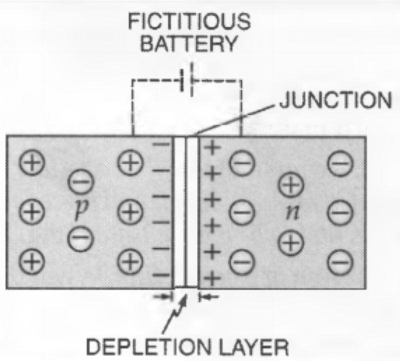
$V_{BE} = V_{CC} - I_B R_B$

$\therefore R_B = \frac{V_{CC}-V_{BE}}{I_B} = \frac{8\text{ V}-0.6\text{ V}}{4\times10^{-5}\text{ A}}$

$= 1.85 \times 10^5\ \Omega = 185\ \text{k}\Omega$

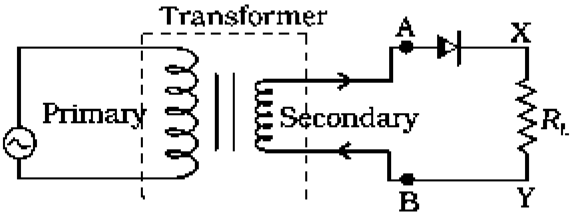
14. i. A p-n juntion is a basic semiconductor device.

In the p-section, holes are the majority carriers; while in n-section, the majority carriers are electrons. Due to the high concentration of different types of charge carriers in the two sections, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, when an electron meets a hole, the two cancel the effect of each other and as a result, a thin layer at the junction becomes devoid of charge carriers. This is called **depletion layer** as shown in Fig.

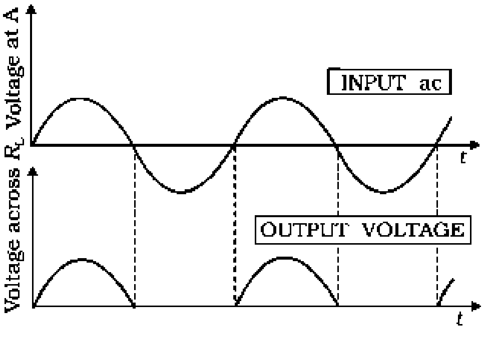


Due to the diffusion of holes and electrons, the two sections of the junction diode no longer remain neutral. The p-section of the junction diode becomes slightly negative, while the n-section is rendered positive. It appears as if some fictitious battery is connected across the junction with its negative pole connected to p-region and positive pole connected to n-region. The potential difference developed across the junction due to migration of majority charge carriers is called **potential barrier**. It opposes the further diffusion of charge carriers.

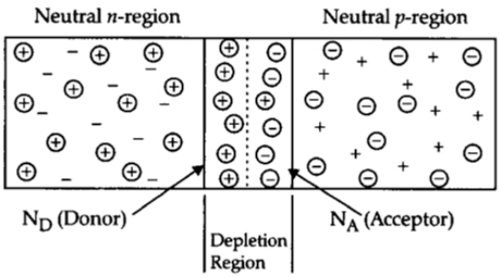
ii. The half-wave rectifier circuit is shown in the figure.



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 the positive half-cycle of a.c. there is a current through the load resistor $R_L$ and we get an output voltage, as shown in Fig., whereas there is no current in the negative halfcycle. In the next positive half-cycle, again we get the output voltage. Thus, the output voltage, though still varying, is restricted to only one direction and is said to be rectified. Since the rectified output of this circuit is only for half of the input ac wave it is called as half-wave rectifier. The input-output waveforms are shown in the Fig. below.



15. **Read the text carefully and answer the questions:**

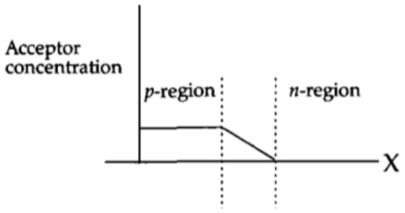


The donor concentration is high at n side and acceptor concentration is high at p-side. There is no acceptor concentration at n-side and no donor concentration at p-side.

For simplicity, let us assume that there is no hole concentration in n-side and no electron concentration in p-side.

After diffusion and drift of electrons and holes, depletion region is formed around the junction where there is no free charge. There are only immobile ions: +ve ions in n-side and -ve ions in p-side.

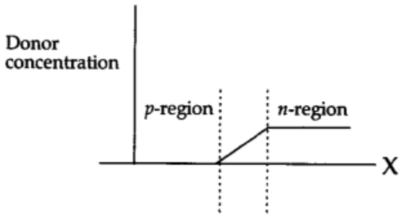
(i) **(c)**



**Explanation:**

The donor concentration is high at n side and acceptor concentration is high at p-side. There is no acceptor concentration at n-side and no donor concentration at p-side.

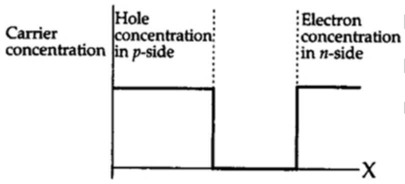
(ii) **(a)**



**Explanation:**

The donor concentration is high at n side and acceptor concentration is high at p-side. There is no acceptor concentration at n-side and no donor concentration at p-side.

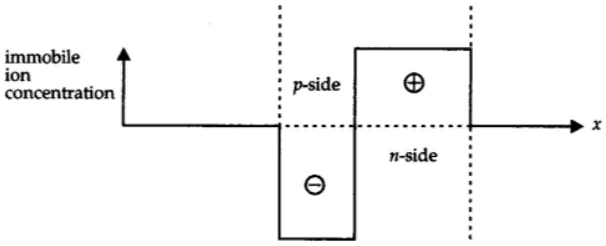
(iii) **(b)**



**Explanation:**

In p-side there are only holes. There is no electron concentration. In n-side there are only electrons. There is no hole concentration. At depletion region, there is no charge carrier.

(iv) **(c)**



**Explanation:**

After recombination of free electrons and holes, around the depletion region, there will be positively charged ions in the n-side and negatively charged ions in p-side.

(v) **(d)** Both Will reduce when the p-n junction is reverse biased and Will increase when the p-n junction is forward biased.

**Explanation:**

In forward bias, applied voltage does not support potential barrier. As a result, the depletion layer width decreases. In reverse bias, applied voltage supports potential barrier. As a result, depletion layer widens.