Chp-14: Semiconductor

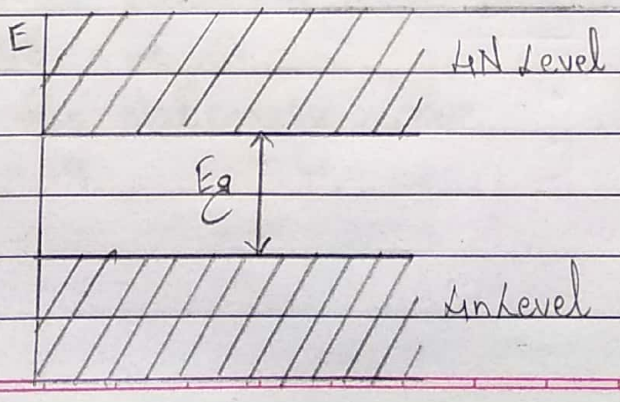
* Semiconductor:

- There are certain materials like silicon and germanium which has a quality is that their Conductivity has a value less than that of metals and its Conductivity has value more than insulator.

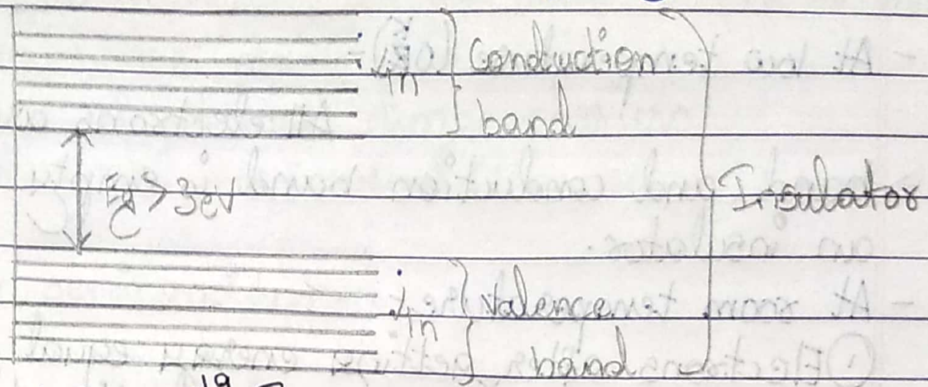
	Material	Resistivity ρ	Conductivity $\left(\frac{1}{\rho}\right)$
1.	Metal	$10^{-2} - 10^{-8}\ \Omega m$	$10^{2} - 10^{8}\ Sm^{-1}$
2.	Semi-conductor	$10^{-5} - 10^{-6}\ \Omega m$	$10^{5} - 10^{-6}\ Sm^{-1}$
3.	Insulator	$10^{11} - 10^{19}\ \Omega m$	$10^{-11} - 10^{-19}\ Sm^{-1}$

- Elemental semiconductor - Si and Ge.
- Compound semiconductor:
  1. Inorganic - CdS, GaAs, CdSe.
  2. Organic - Anthracene doped phthalocyanine.
  3. Organic polymer - Poly pyrrole, Poly aniline, poly theophene.

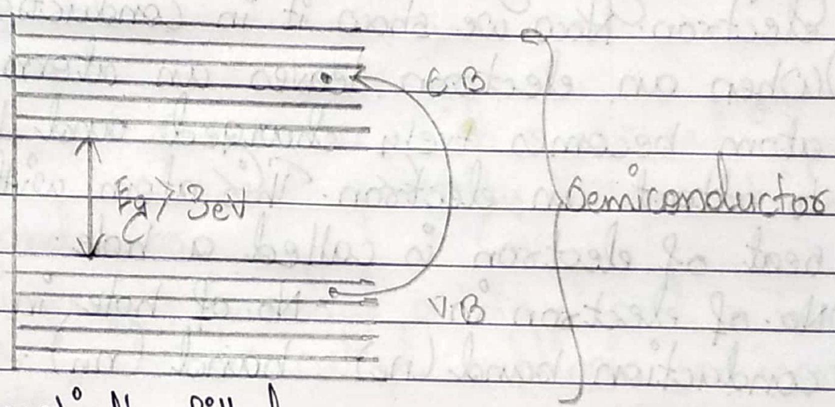
* Energy level of electrons:



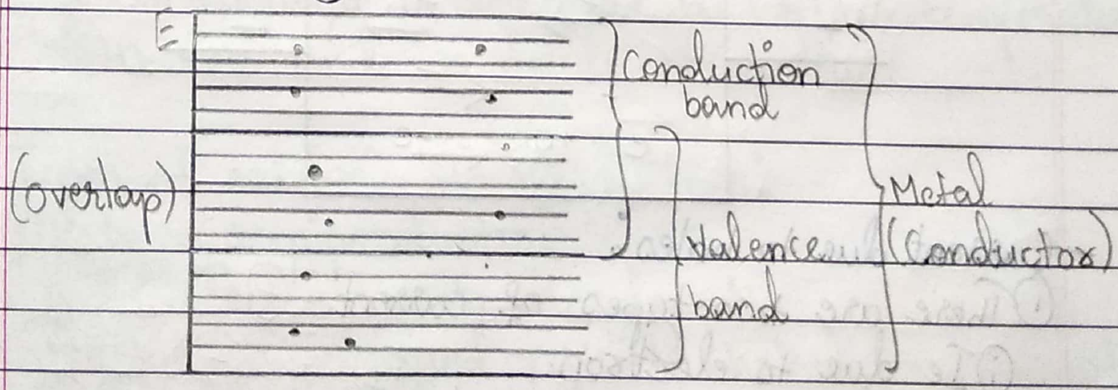
- Conductivity classification of energy graph:



Ps: 1ev = 1.6×10^{-19} J.



VB is partially filled.
CB is partially filled.



* Intrinsic semiconductor:

- At low temperature (0K):
  All electrons are in valence band and conduction band is empty. Behaves like an insulator.
- At room temperature:
  1. Electrons after getting energy equal or more than gap energy (E_g) becomes conduction (free electron) electron. Now we show it in conduction band.
  2. When an electron leaves an atom rest of atom becomes +vely charged and has tendency to attract an electron. This atom with vacant seat of electron is called a hole.
  3. No. of electron in conduction band (n_e) = No. of hole in valence band (n_h).
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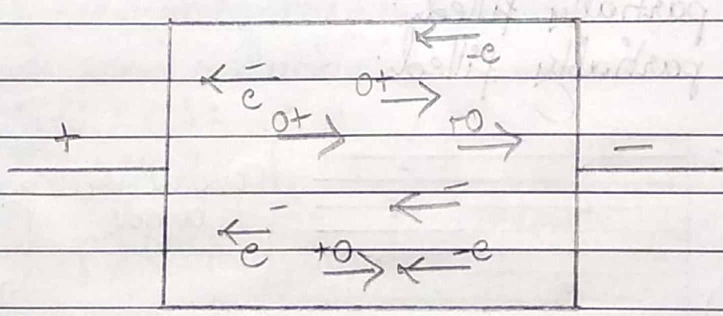
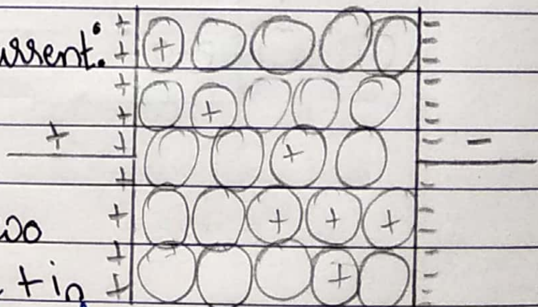


- Current due to holes:
  1. There are two types of current:
     (i) I_e due to electron.
     (ii) I_h due to holes.
  2. So, a semiconductor has two types. Total current $i = i_e + i_h$



- Shortcoming in intrinsic semiconductor:
  1. Conductivity is low.
  2. Current is controlled by temperature which is not

in our control.

③ $n_e = n_h$ in intrinsic, but we need $n_e \neq n_h$ to make devices, hence intrinsic is unfit.
(n_i = no. of intrinsic charge carriers)

$n_e \times n_h = n_i^2 \rightarrow$ Constant

* Extrinsic semiconductor:

- Doping an intrinsic semiconductor makes it extrinsic.
- Doping:

① Doping is a process in which a choosed impurity is mixed in measured quantity to an intrinsic semiconductor.

② This impurity is called a 'dope' and a material prepared is now called extrinsic semiconductor.

③ Benefits:

(i) Conductivity increases.
(ii) Conductivity is controlled by Us (not temperature).
(iii) $n_e \neq n_h$ and we decide $\frac{n_e}{n_h}$ ratio.

- Types of extrinsic semiconductors:

① P-type semiconductor:

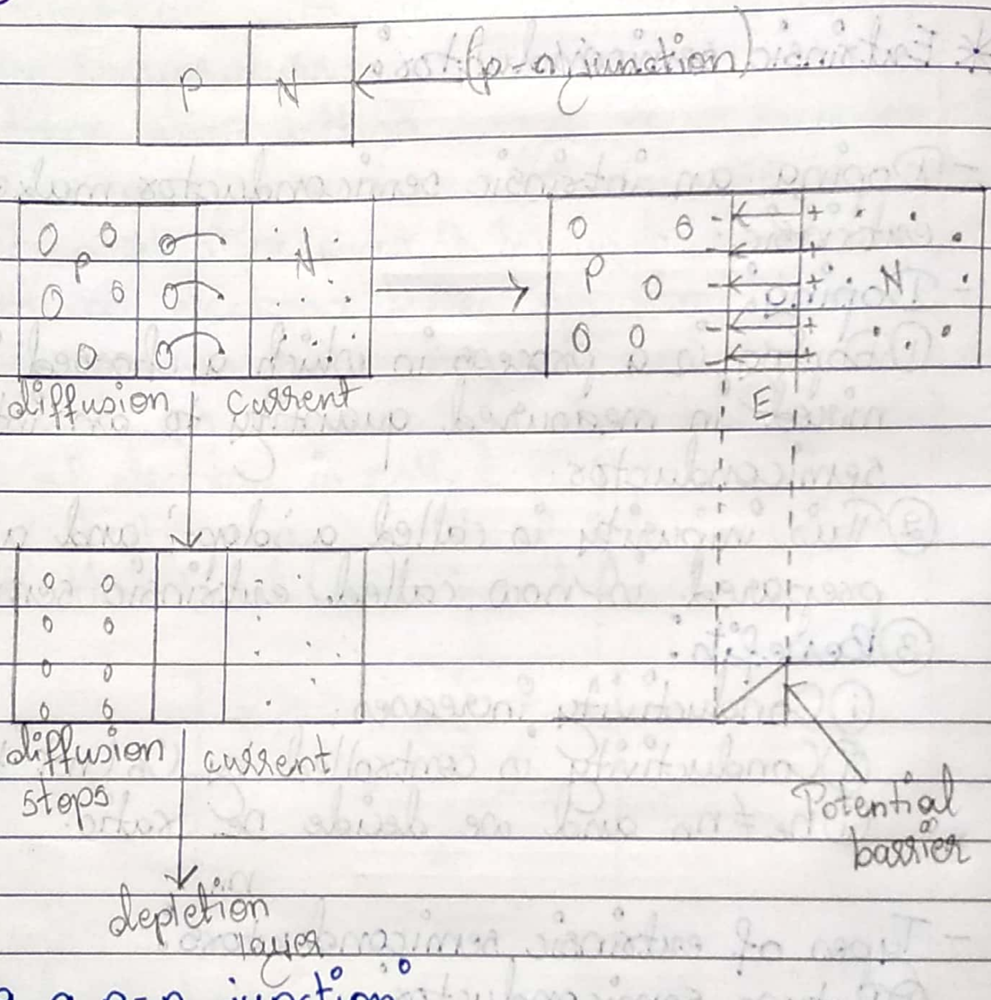
(i) Trivalent elements are doped.
(ii) Positively charged carriers (holes) are generated. Therefore, it is called p-type semiconductor.
(iii) Holes created in valence band. Conduction electron decreases in C.B.

② n-type semiconductor-

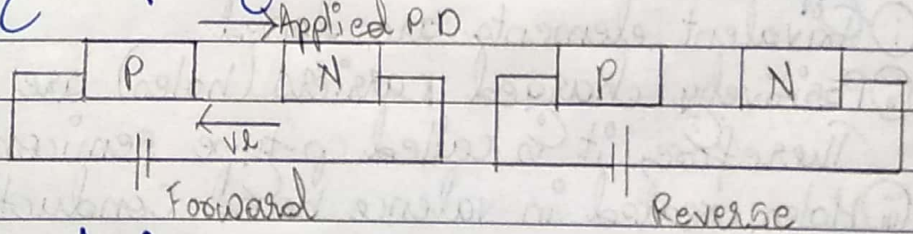
By mixing pentavalent impurity such as arsenic, antimony and phosphorus.

4 electrons are used in pairing and one ~~electron~~ extra, 5th electron becomes free electron which helps in conduction.

* p-n junction (diode):



- **Biasing a p-n junction:**



① Forward bias-

In forward bias junction becomes conductor because width of depletion layer goes on decreasing and finally at appropiate voltage it vanishes.

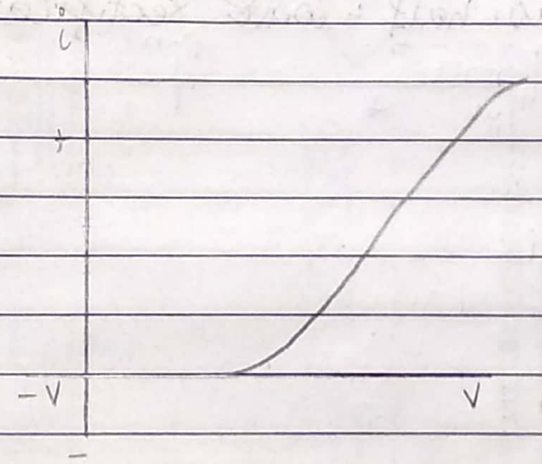
② **Reverse bias:**

(i) Depletion layer width increases.
(ii) Potential barrier gets height and it increases.
(iii) Charges are not allowed to cross layers.
(iv) Current is not allowed to flow
(v) Behaves like an insulator.

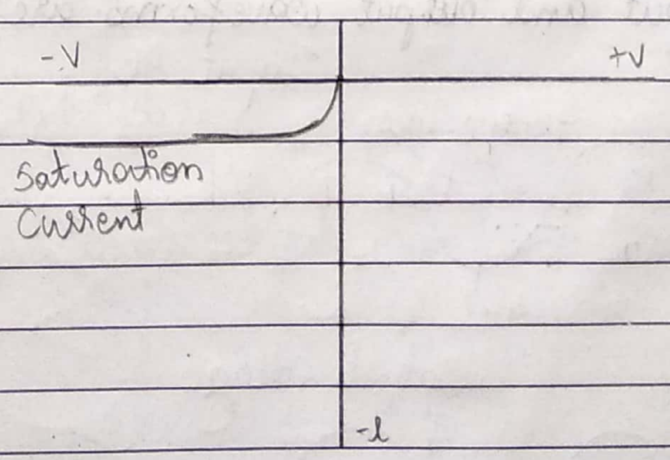
③ **Reverse current -**

In reverse biasing, due to minority charge carriers, a current starts flowing in it.

④ **Forward characteristics:**



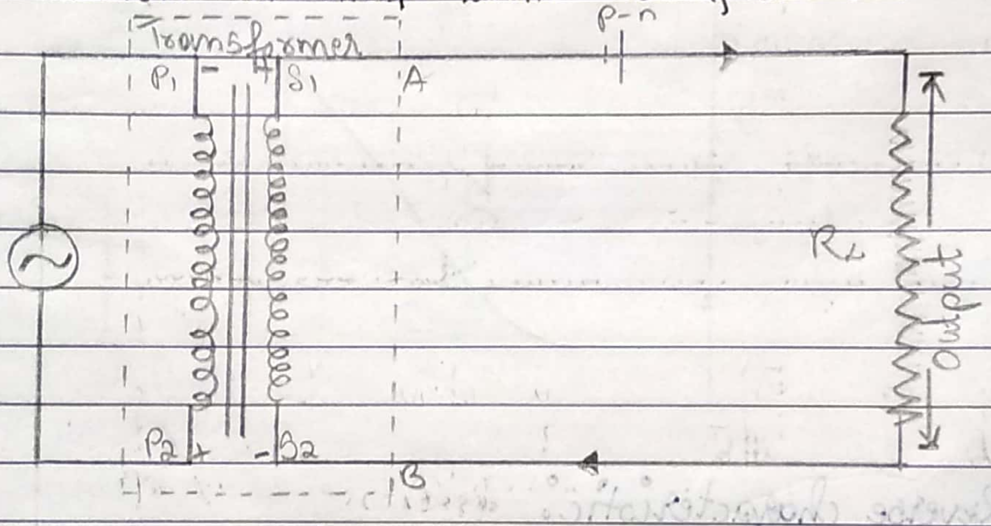
⑤ **Reverse characteristic:**



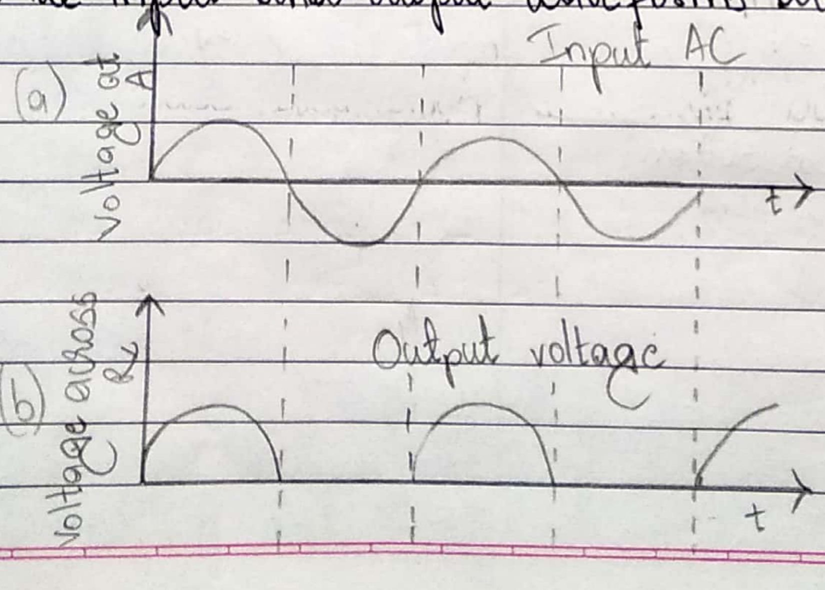
* Diode as a rectifier:

- The process of converting alternating voltage/current into direct voltage/current is called rectification.
- Diode is used as a rectifier for converting alternating current/voltage into direct current/voltage.
- Diode as a half-wave rectifier:

① Diode conducts corresponding to positive half cycle and does not conduct during negative half cycle. Hence, AC is converted by diode into unidirectional pulsating DC. This action is known as half-wave rectification.

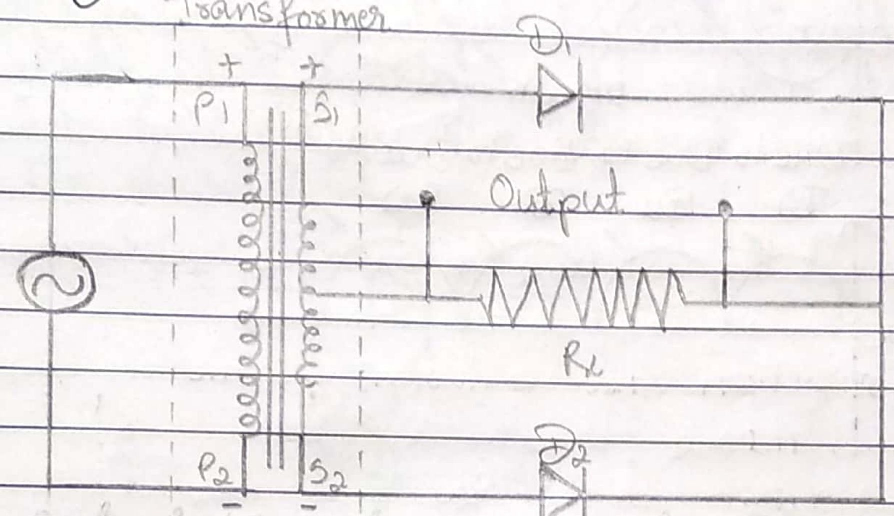


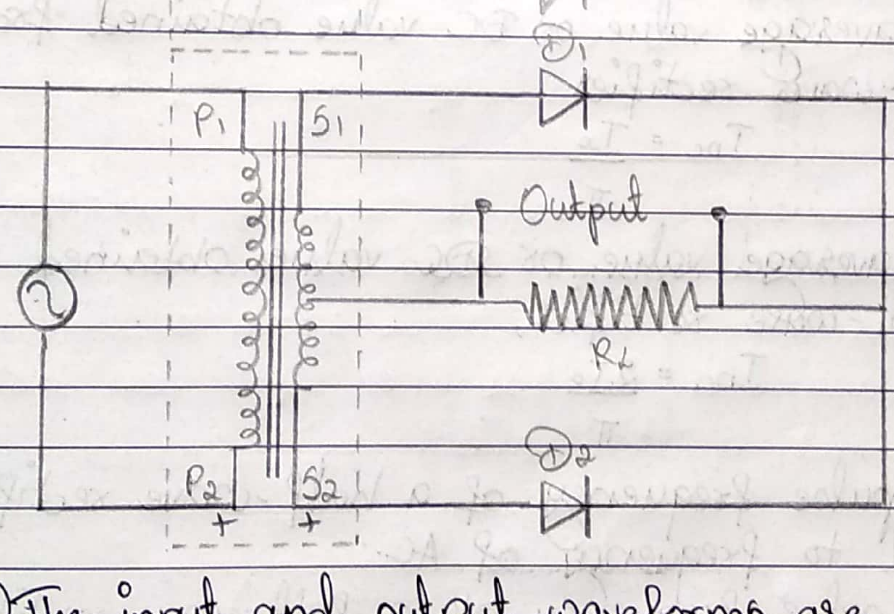
② The input and output waveforms are as follows:



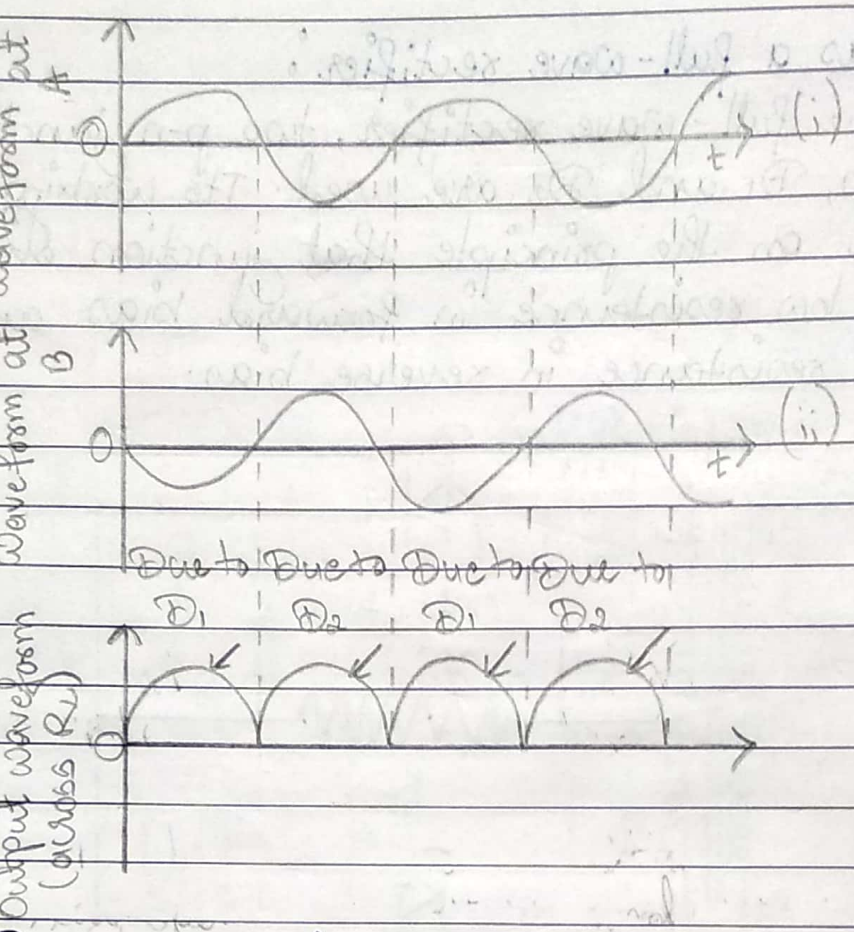
- Diode as a full-wave rectifier:

① In the full-wave rectifier, two p-n junction diodes, D_1 and D_2 are used. Its working is based on the principle that junction diode offer very low resistance in forward bias and very high resistance in reverse bias.





② The input and output waveforms are as follows:



③ The average value or DC value obtained from a half-wave rectifier

$$I_{DC} = \frac{I_0}{\pi}$$

④ The average value or DC value obtained from a full-wave rectifier,

$$I_{DC} = \frac{2I_0}{\pi}$$

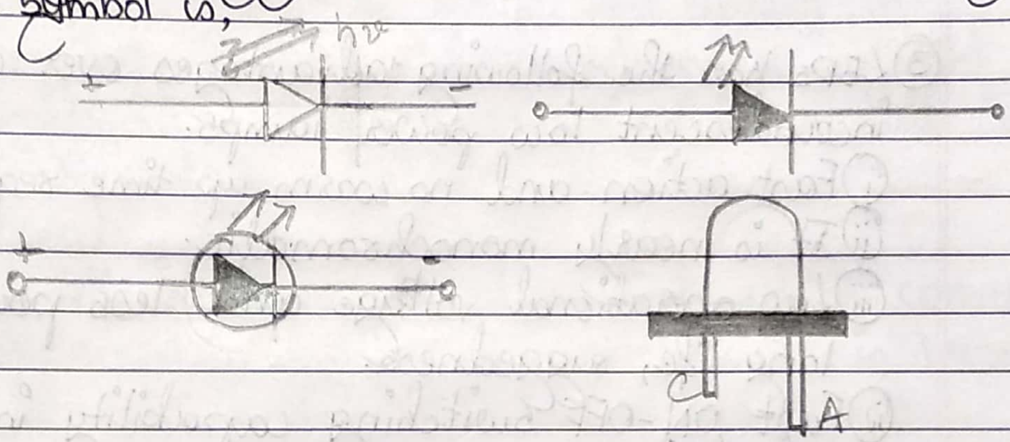
⑤ The pulse frequency of a half-wave rectifier is equal to frequency of AC.

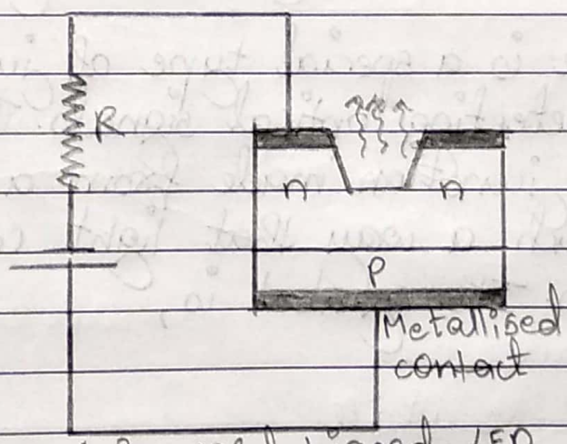
⑥ The pulse frequency of a full-wave rectifier is double to that of AC.

* Optoelectronic junction devices:

- Semiconductor diodes in which carriers are generated by photons i.e. photo-excitation, such devices are known as optoelectronic devices.
- Light Emitting Diode (LED):

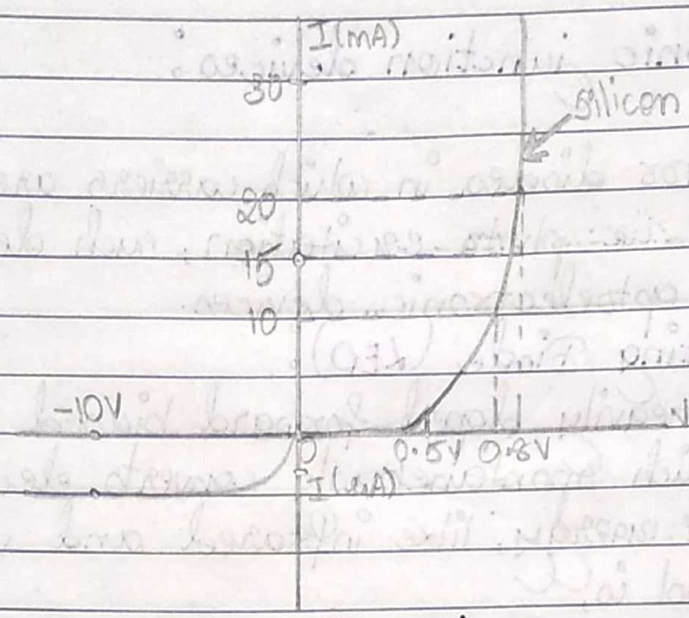
(1) It is a heavily doped forward biased p-n junction diode which spontaneously converts electrical energy into light energy, like infrared and visible light. Its symbol is,





A forward biased LED

(2) V-I characteristics of LED are shown as:

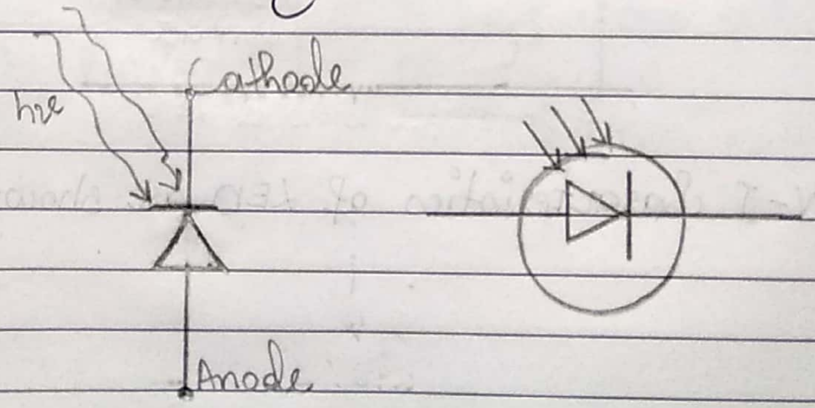


③ LEDs has the following advantages over conventional incandescent low power lamps.

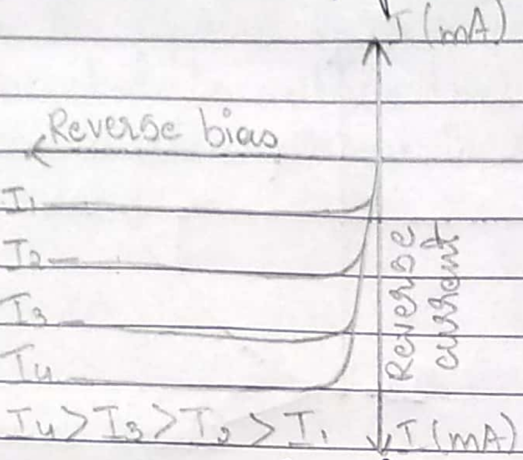
(i) Fast action and no warm up time required.
(ii) It is nearly monochromatic.
(iii) Low operational voltage and less power consumed, long life, ruggedness.
(iv) Fast ON-OFF switching capability in nanoseconds.

- Photodiode:

① A photodiode is a special type of junction diode used for detecting optical signals. It is a reverse biased p-n junction made from a photosensitive material. Such a way that light can fall on its junction. Its symbol is,



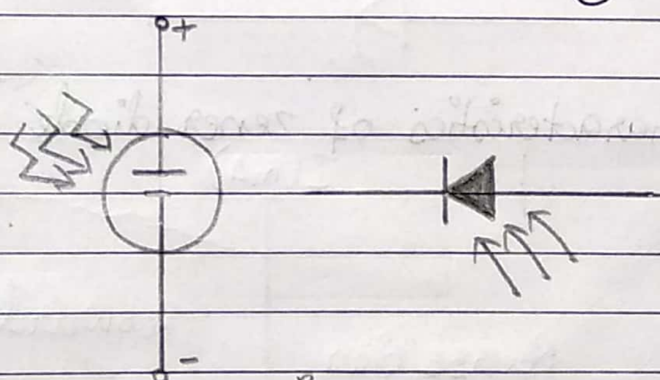
② V-I characteristics of photodiode are shown as :

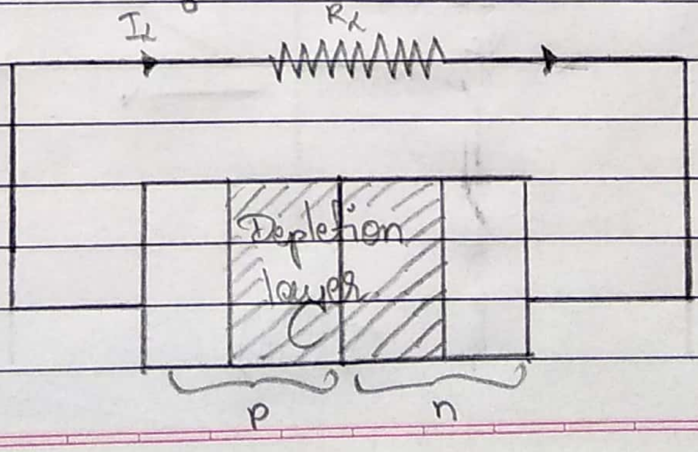


We observe from the figure that current in photodiode changes with the changes in light intensity (I), when reverse bias is applied. In light operated switches.

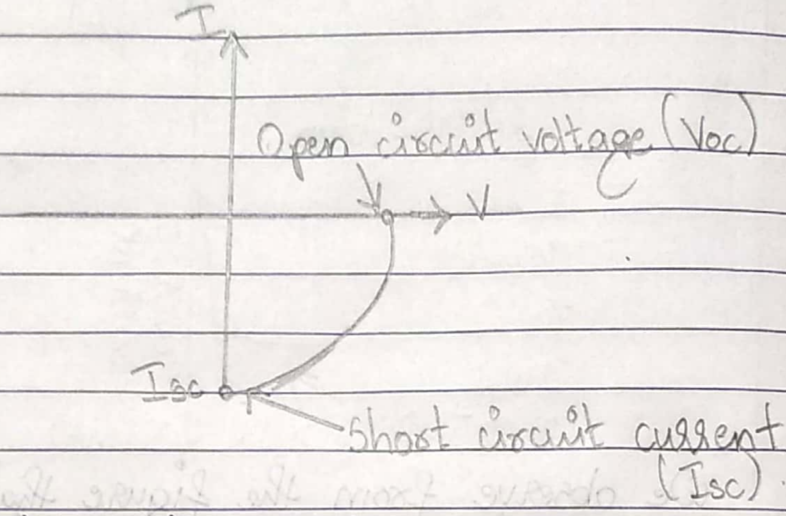
- Solar cell :

① Solar cell is a p-n junction diode which converts solar energy into electrical energy. It is based on the photovoltaic effect. Its symbol is,





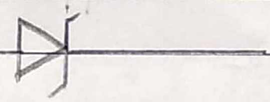
② V-I characteristics of solar cell are shown as:



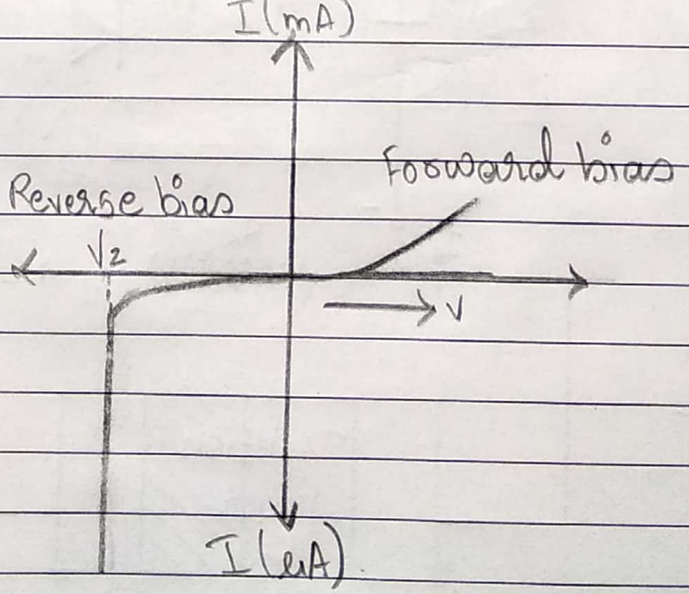
③ The materials used for solar cell are SI and GaAs.

- ~~The~~ Zener diode:

① Zaener diode is a reverse biased heavily doped p-n junction diode. It is operated in breakdown region. Its symbol is,



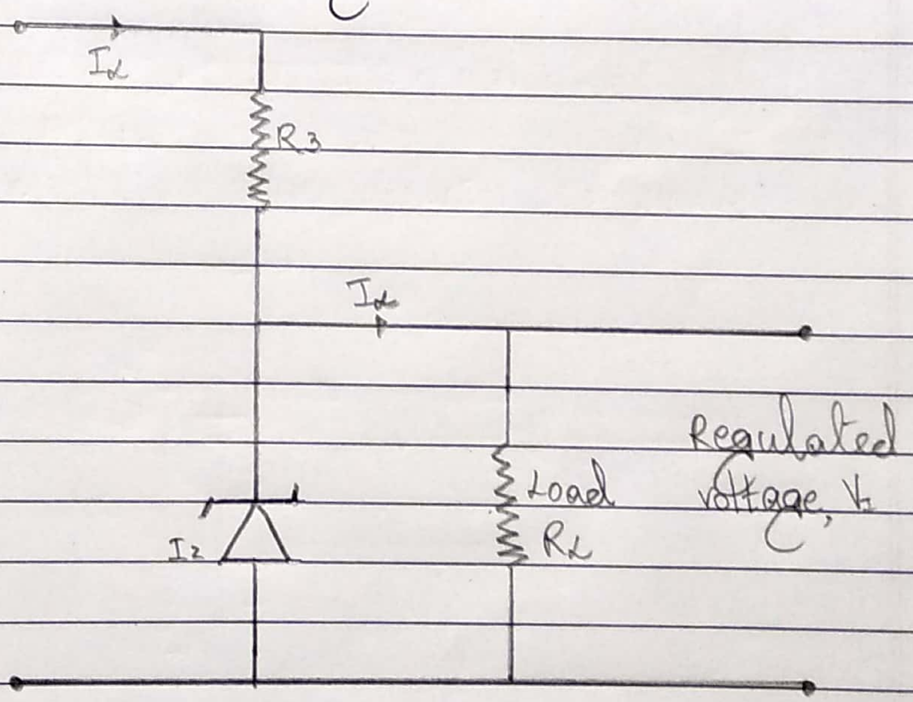
② V-I characteristics of zener diode are shown as:



③ Zener diode as a voltage regulator:

ⓘ When the applied reverse voltage (V) reaches the breakdown voltage (V_z) of the zener diode there is a large change in the current. So, after the breakdown voltage V_z, a large change in the current can be produced by almost insignificant change in the reverse bias voltage i.e zener voltage remains constant even though the current through the current through the zener diode varies over a wide range. The circuital arrangement is shown here.

ⓘⓘ This breakdown in a diode due to the band to band tunneling is called zener breakdown.



Circuit diagram of zener diode as voltage regulator