SEMICONDUCTOR

(CHAPTER-14)

CONDUCTOR	SEMI-CONDUCTOR	INSULATOR
① It conducts easily	It conducts moderately	It doesn't conduct easily
② It has positive temp. coefficient of resistivity	It has negative temp. coefficient of resistivity.	It has negative temp. coefficient of resistivity

CLASSIFICATION OF SEMICONDUCTORS ON THE BASIS OF THEIR CHEMICAL COMPOSITION:-

Ⓐ ELEMENTAL SEMICONDUCTORS:- Si and Ge

Ⓑ COMPOUND SEMICONDUCTORS:-

(i) INORGANIC - CdS, GaAs, InP etc.

(ii) ORGANIC - Polypyrrole, polyaniline, polythiophene etc.

VALENCE BAND:- It is the energy band, which include the energy levels of valence electrons.

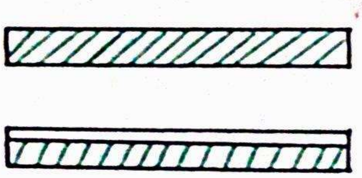
CONDUCTION BAND:- It contains free e^- of solid. It is the energy band above valence band.

ENERGY GAP (E_g):- The difference in energy gap between the upper level of valence band and lower level of conduction band.

Classification of conductors, semi-conductors and Insulators on the basis of energy gap:-

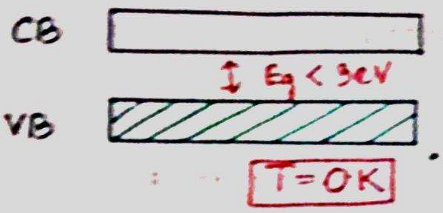
① CONDUCTORS

C·B — Completely filled conduction band.



V·B — partially filled valence band.

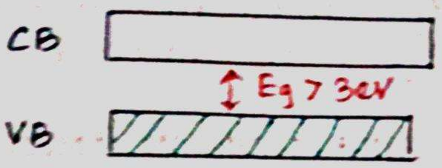
② SEMICONDUCTORS



completely empty CB

completely filled VB

③ INSULATORS:-



completely empty CB

completely filled VB

On the basis of purity, semiconductors are of two types:-

① Intrinsic semiconductors

② Extrinsic semiconductors

It is basically two types:-

(a) n-type semiconductors (b) p-type semiconductors.

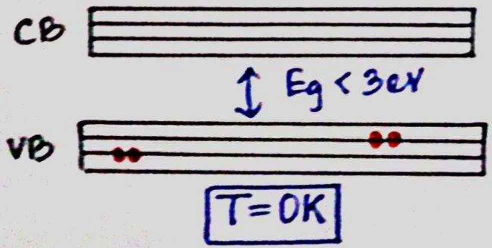
① INTRINSIC/ PURE SEMICONDUCTORS:-

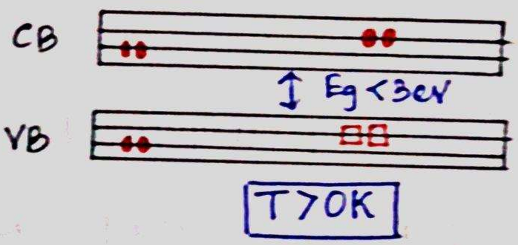
* In this type, $n_e = n_h$ (no. of e^- = no. of holes)
* So, intrinsic carrier concentration:-

$$n_i = n_e = n_h$$

* At equilibrium in any semiconductor:-

$$n_i^2 = n_e \cdot n_h$$



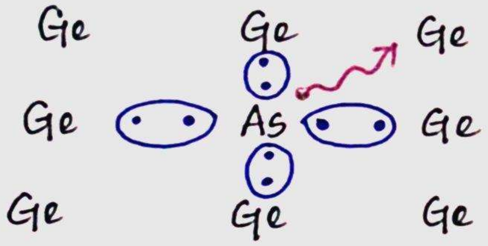


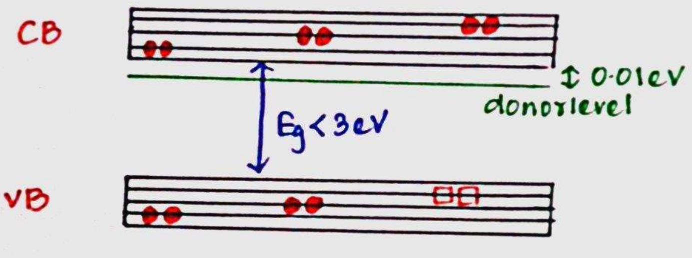
DOPING:- The process of deliberate addition of a desirable impurity to a pure semiconductor so as to increase its conductivity is called doping. The impurity atoms are called dopants.

EXTRINSIC OR DOPED SEMICONDUCTORS:- The semiconductors doped with impurity atoms are called extrinsic semiconductors.

(a) n-type:- This semiconductor is obtained by doping the tetravalent semiconductor Si or Ge with pentavalent impurities such as As, P or Sb of group V of the periodic table. When pentavalent impurity atom (As) is added to pure semiconductor, then $4e^-$s of As participate in band formation. $1e^-$ remains extra on it. Addition of large no. of As atom large no. of such e^- are obtained and they lie in a level called as Donor level which is very close to conduction band.

So, majority charge carriers are free electrons and minority charge carriers are holes.





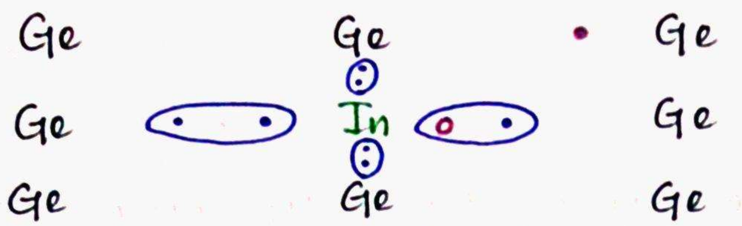
($n_e >>> n_h$)

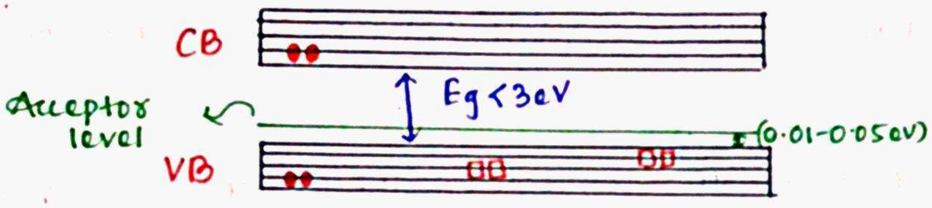
(b) p-type:- This semiconductor is obtained by doping the tetravalent semiconductor Si or Ge with trivalent impurities such as In, B, Al or Ga. When trivalent impurity atom (In) is added to pure semiconductor (Ge), $3e^-$s of In participate in band formation. The lack of $1e^-$ on it is called hole.

→ Addition of large no. of In atom produces large no. of holes in V.B.

→ One level is created just above the V.B called as acceptor level

→ So, majority charge carriers are holes and minority charge carriers are electrons.





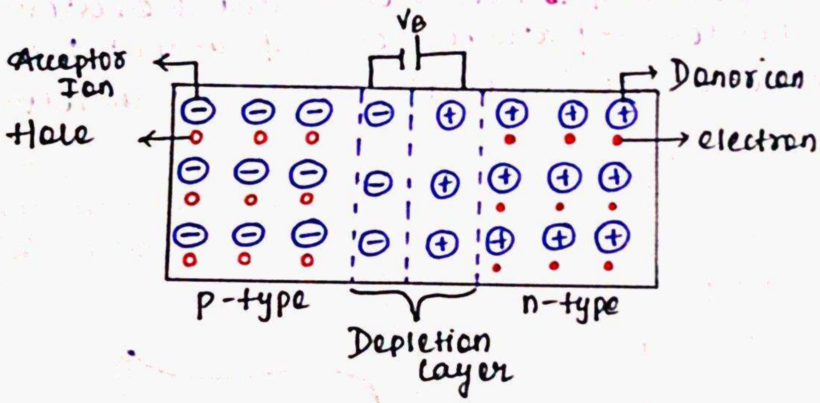
P-N JUNCTION DIODE :-

When p-type semiconductor comes in n-type semiconductor, two processes happen :-

① DIFFUSION :- Due to concentration difference, holes from p-side and e⁻ from n-side move towards each other. The current constituted is called as diffusion current. A potential difference is built at the junction.

② DRIFTING :- Due to a potential difference, minor charge carriers move and the current constituted is called drift current. Diffusing current and drift current are in opposite direction. Equilibrium is reached when diffusion current is equal to drift current. The layer formed at the junction is called depletion layer and the potential difference is called as barrier potential

* The device formed is called as p-n junction diode.



WORKING OF A p-n JUNCTION :-

① FORWARD BIASING :-

P side is connected to +ve and n side is connected to −ve. Applied potential difference is in opposite direction to barrier potential. So effective barrier potential (V_f). $V_f = V_b - V$. By increasing applied potential, V_f gradually decreases, majority charge carrier moves and diode conducts. So diode behaves like a low resistive device.

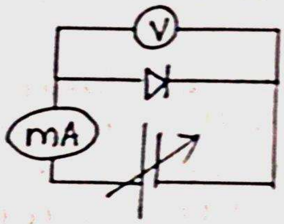
② REVERSE BIASING :-

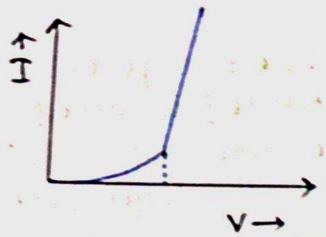
P side is connected to −ve and n side is connected to +ve. Applied potential difference is in same direction to barrier potential. So effective barrier potential (V_f). $V_f = V_b + V$. By increasing applied potential, V_f gradually increases. So diode behaves like a high resistive device.

CHARACTERSTICS CURVE :- It is of 2 types :-

(1) Forward characterstic :-

The graphical representation of variation of forward current and forward voltage is called forward characterstics.

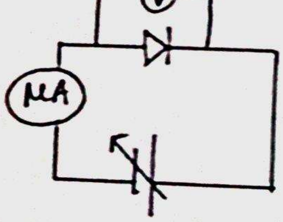


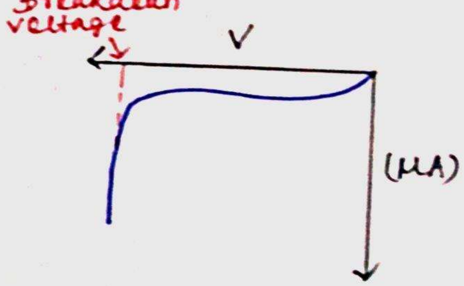


When forward voltage ↑ses, forward I ↑ses slowly due to existence of barrier potential. After a particular forward voltage, forward current ↑ses rapidly, that voltage is known as knee voltage / threshold voltage / cut-in voltage

(2) Reverse characterstic :-

The graphical representation of variation of reverse current and reverse voltage is called reverse characterstic





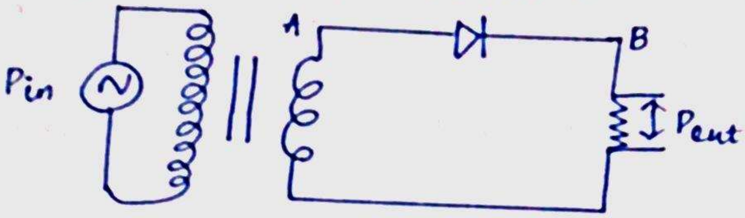
When reverse voltage ↑ses, there is almost no change in reverse current because it is due to minority charge carrier. At a particular reverse voltage, reverse current ↑ses suddenly, that voltage is called as breakdown voltage.

RECTIFIER:- It is an electronic device which converts AC to DC.

PRINCIPLE:- When diode is forward bias it conducts, when diode is reverse bias, it doesnot conduct.

It is of two types:-

① **HALF-WAVE RECTIFIER:-** It consist of single diode connected to step down transformer and a load resistance. Input is given to 1° transformer and DC is taken from the load resistance.



WORKING:-

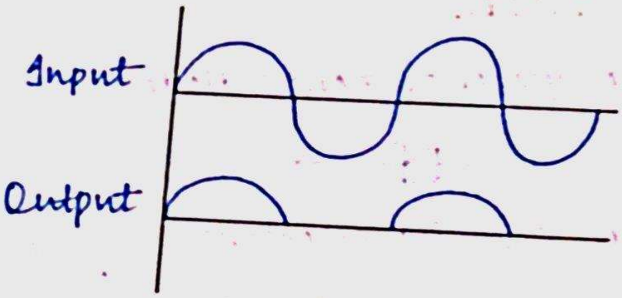
For +ve half cycle of input AC, A is +ve, D is −ve, diode is forward biased and it conducts. This half cycle appears in the output.

For −ve half cycle of input AC, A is −ve, D is +ve, diode is reverse biased and it doesn't conducts. So, this half cycle doesn't appear in the output.

In this way, half of AC converts to DC. So this is called half wave rectifier.

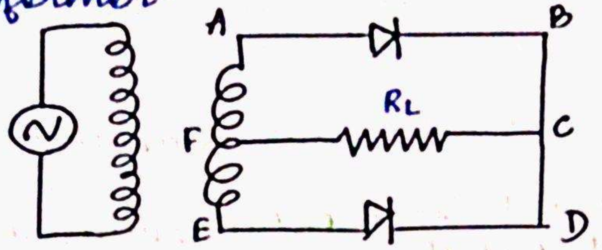
Efficiency:- It is the ratio of output DC power to input AC power.

$$\eta = \frac{P_{out}}{P_{in}} = 40.6\%$$



② **FULL-WAVE RECTIFIER:-** It consist of 2 diodes, D_1 and D_2 connected to a centre taped step down transformer and load resistance.

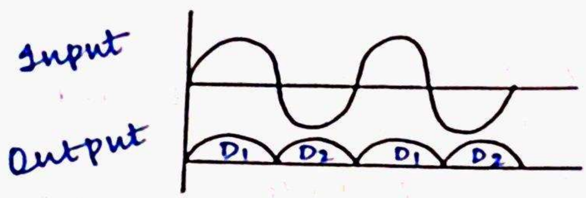
Load resistance is connected to the middle of the 2° coil of the transformer.



WORKING:- For the +ve half cycle of input AC, A is +ve, E is −ve. D_1 is forward biased and D_2 is reverse biased. D_1 conducts and current passes in the cycle ABCFA.

For −ve half cycle of input AC, A is −ve, E is +ve. D_2 is forward biased and D_1 is reverse biased. D_2 conducts and current passes in the cycle EDCFE.

In this way, full cycle of AC converts to DC. So it is called full wave rectifier.



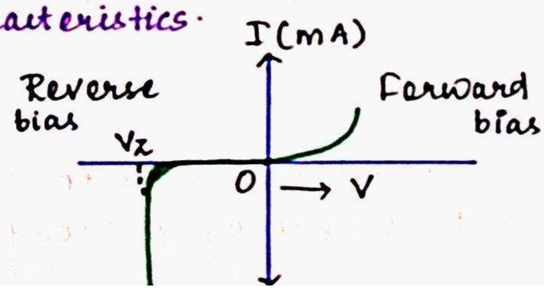
Efficiency:- It is the ratio of output DC power to input AC power.

$$\eta = \frac{P_{out}}{P_{in}} = 81.2\%$$

ZENER DIODE:-

Draw the symbol of zener diode.

Draw the V-I characteristics.



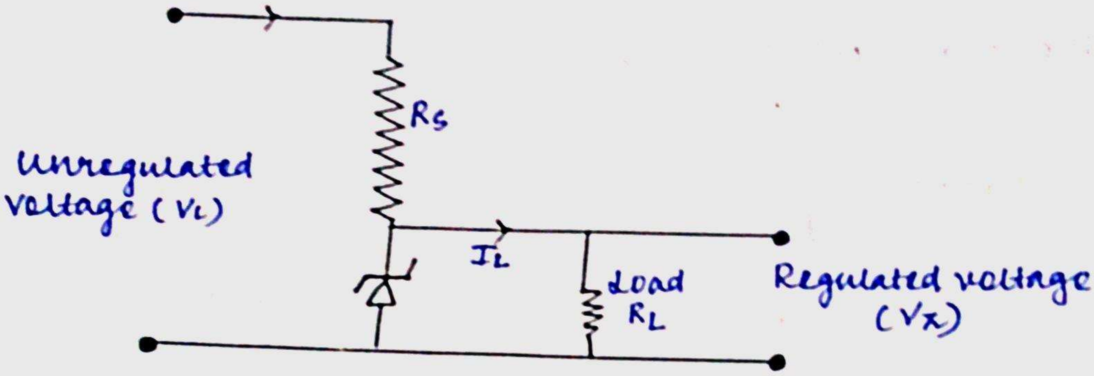
How zener diode is fabricated?

Zener diode is fabricated by heavily doping p and n sides of the junction.

What is the advantage of heavily doping?

Due to heavily doping, depletion region formed is very thin and the electric field to the junction is extremely high even for a small reverse bias voltage.

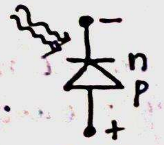
How zener diode is used as voltage regulator?



The unregulated dc voltage is connected to a zener diode through a series resistance Rs such that zener diode is reverse biased. If the input voltage increases, the current through Rs and zener diode also increases. This increases the voltage drop across Rs 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 Rs and zener diode also decreases. The voltage drop across Rs decreases without any change in the voltage across the zener diode. Thus, any increase or decrease in the input voltage results in increase/decrease of the voltage drop across Rs without any change in voltage across the zener diode. Thus, the zener diode act as a voltage regulator.

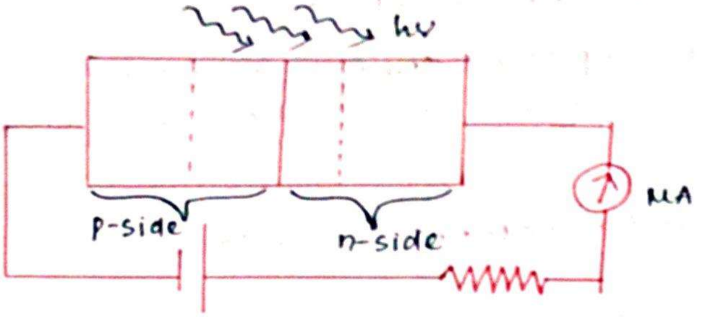
PHOTODIODE :-

(Q):- Draw its symbol.



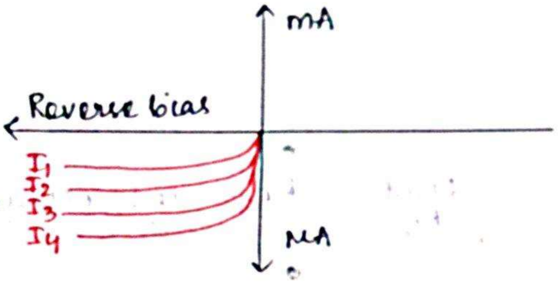
(Q):- How is photodiode fabricated?

It is fabricated with a tranparent window to allow light to fall on the diode.



(Please refer NCERT Pg no 487)

(Q):- Draw the characteristics curve.



The magnitude of the photocurrent depends on the intensity of the incident light

WORKING:-

When the photodiode is illuminated with light (photons), with energy greater than the energy gap of the semiconductor, the electron-hole pairs are generated due to absorption of photons. These charge carriers contribute to the reverse current.

(Q) Why photodiode is always reverse biased?

In case of, an n-type semiconductor, the majority carrier density(n) is considerably larger than the minority hole density.

$n \rightarrow$ majority carrier density
$\Delta n \rightarrow$ excess e^- generated
$p \rightarrow$ minority hole density
$\Delta p \rightarrow$ excess holes generated

$n' = n + \Delta n$
$p' = p + \Delta p$, where $\Delta n = \Delta p$, $n \gg p$

$$\Rightarrow \frac{\Delta n}{n} < \frac{\Delta p}{p}$$

The fractional charge due to the photo effects on the minority carrier dominated reverse bias current is more easily measureable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

LIGHT EMITTING DIODE :-

(Q) :- Draw the circuit symbol of LED.

(Q) :- How LED is fabricated?

The diode is fabricated with a transparent cover so that the emitted light can come out.

(Q) :- Write the advantages of LED.

1. Low operational voltage and less power.
2. Fast action and no warm-up time required.
3. The bandwidth of emitted light is 100 A° to 500 A°
4. Long life and ruggedness.
5. Fast on-off switching capability.

(Q) :- For visible LED band gap should be minimum 1.8 eV. Why?

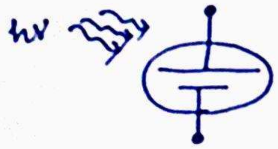
Because the minimum energy of photon of the visible range is 1.8 eV

(Q) :- Why elemental semiconductors is not used in LED?

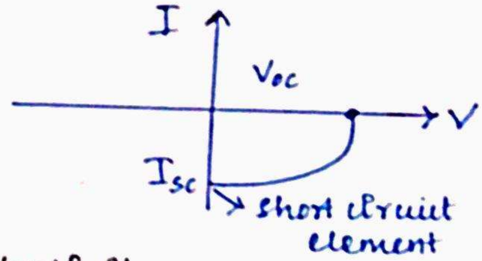
Because number of charge carriers is very less.

SOLAR CELL :-

(Q) :- Draw the circuit symbol of solar cell.



(Q) :- Draw the characterstic curve of solar cell.



(Q) :- Write the criteria to choose a material for solar cell.

1. band gap (~1 to 1.8 eV)
2. cost
3. electrical conductivity
4. availability of raw material
5. high optical absorption.

(Q) :- Write the 3 processes of solar cell.

1. Generation of e-h pairs due to light ($h\nu > E_g$) close to the junction.
2. Separation of electrons and holes due to electric field of the depletion region.
3. The electrons reaching the n-side are collected by the front contact & holes reaching the p-side are collected by back contact. Thus, p side becomes +ve & n side becomes -ve giving rise to photovoltage.