SOLID AND SEMICONDUCTOR DEVICES (EASY AND SCORING TOPIC)

1. Distinction of metals, semiconductor and insulator on the basis of Energy band of Solids.
2. Types of Semiconductor.
3. PN Junction formation
4. Diode characteristics.
5. Diode as a rectifier
6. Symbol and sections of transistor.
7. Transistor as an Amplifier.
8. Basic logic gates.

Energy Bands of Solids

1**. Energy Band** In a crystal due to interatomic interaction valence electrons of one atom are shared by more than one atom in the crystal. Now splitting of energy levels takes place. The collection of these closely spaced energy levels is called an energy band.

2**. Valence Band** This energy band contains valence electrons. This band may be Partially or completely filled with electrons but never be empty. The electrons in this band are not capable of gaining energy from external electric field to take part in conduction of current.

3. **Conduction Band** This band contains conduction electrons. This band is either empty or Partially filled with electrons. Electrons present in this band take part in the conduction of current.

4**. Forbidden Band** This band is completely empty. The minimum energy required to shift an electron from valence band to conduction band is called band gap (E_g).

Types of Semiconductor

(i) **Intrinsic Semiconductor**: A semiconductor in its pure state is called intrinsic semiconductor.

(ii) **Extrinsic Semiconductor**: A semiconductor doped with suitable impurity to increase its conductivity, is called extrinsic semiconductor.

On the basis of doped impurity extrinsic semiconductors are of two types:

(i) **n-type Semiconductor**: Extrinsic semiconductor doped with pentavalent impurity like As, Sb, Bi, etc in which negatively charged electrons works as charge carrier, is called n-type semiconductor. Every pentavalent impurity atom donate one electron in the crystal, therefore it is called a donor atom
(ii) **p -type Semiconductor:** Extrinsic semiconductor doped with trivalent impurity like Al, B, etc, in which positively charged holes works as charge carriers, is called p-type semiconductor. Every trivalent impurity atom have a tendency to accept one electron, therefore it is called an acceptor atom.

In a doped semiconductor $\mathbf{n_e n_h = n^2}$ where n_e and n_h are the number density of electrons and holes and n_i is number density of intrinsic carriers, i.e., electrons or holes.

In n-type semiconductor, $n_e >> n_h$

In p -type semiconductor, $n_h >> n_e$

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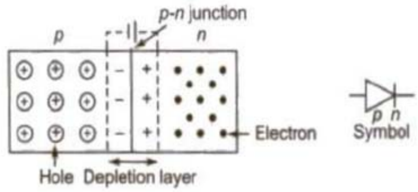
PN Junction:

An arrangement consisting a p -type semiconductor brought into a close contact with n-type Semiconductor is called a p-n junction.



Terms Related to p-n junction:

(i) **Depletion Layer:** At p-n. junction a region is created, where there is no charge carriers. This region is called depletion layer. The width of this region is of the order of $\mathbf{10^{-6}}$ m.

(ii) **Potential Barrier:** The potential difference across the depletion layer is called potential barrier. Barrier potential for Ge is 0.3 V and for Si is 0.7 V.

(iii) **Forward biasing:** In this biasing, the p -side is connected to positive terminal and n-side to negative terminal of a battery.

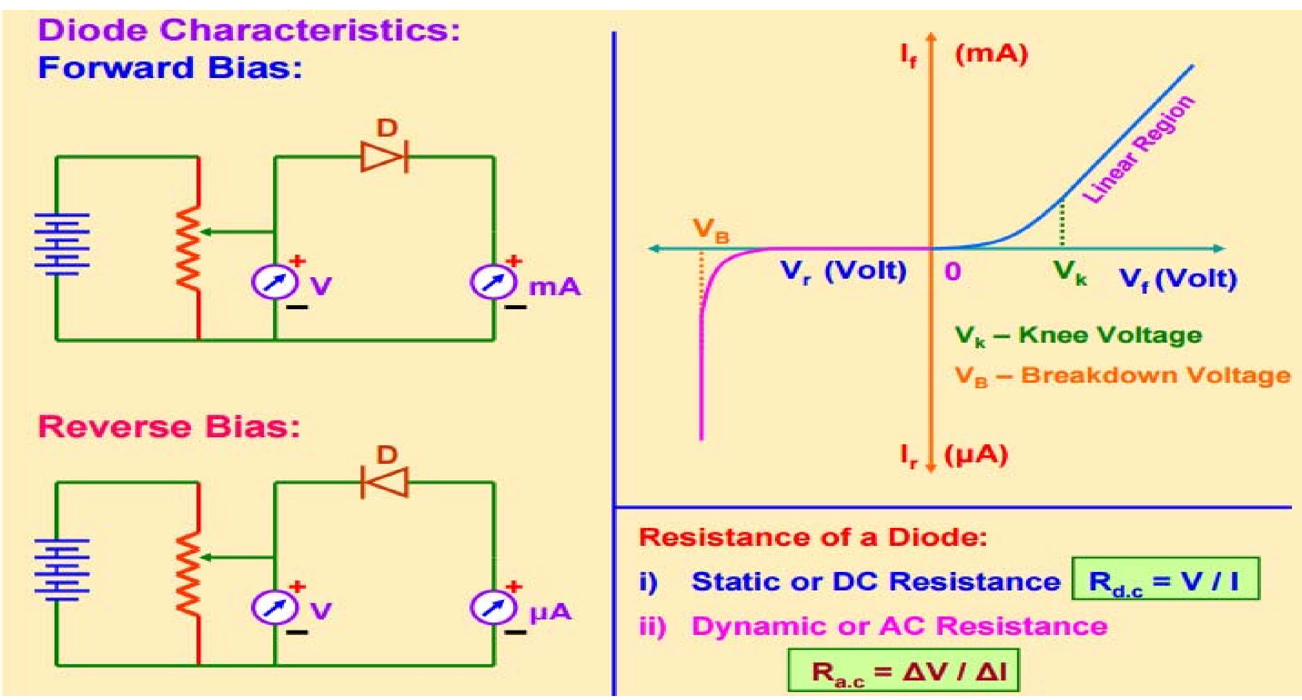
In this biasing, forward current flows due to majority charge carriers.

The width of depletion layer decreases.

(iv) **Reverse biasing:** In this biasing, the p-side is connected to negative terminal and n-side to positive terminal of a battery.

In this biasing, reverse current flow due to minority charge carriers.

The width of depletion layer increases.



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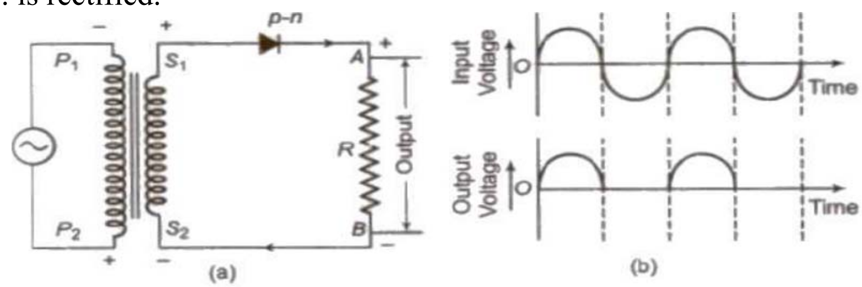
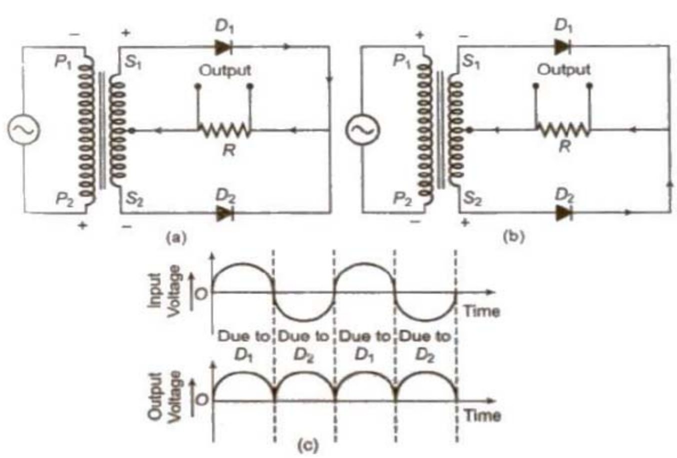
Rectifier: A device which converts alternating current or voltage into direct current or voltage is known as rectifier.
The process of converting AC into DC is rectification.
Half-Wave Rectifier: A half-wave rectifier converts the half cycle of applied AC signal into DC signal.

During the positive half the S_2 end of secondary is negative and S_1 positive. Now the diode is in forward bias and the current flows through resistance R shown in upper figure.
During the negative half the S_1 end of secondary is negative and S_2 positive. Now the junction Diode is in reverse bias and so there is negligible (No current) through resistance R. Hence we get the output as D.C. but half of the input A.C. is rectified.



Full-Wave Rectifier: A full-wave rectifier converts the whole cycle of applied AC signal into DC signal. Centre tap, transformer is used here.

For full wave rectification, we have to use two P-N junctions. During the positive half of the input A.C. the upper P-N junction diode is forward biased and the lower P-N junction diode is reverse biased. The forward current flows on account of majority carriers of upper P-N junction diode.
During the negative half cycle of input of A.C. the upper P-N junction diode is reverse biased, and the lower P-N junction diode is forward biased. The forward current flows on account of majority carriers of lower p-n junction diode. We observe that during both the halves, current through R flows in the same direction. The input and output waveforms are shown in fig. The output signal voltage is unidirectional having ripple contents, i.e D.C components and A.C components both.



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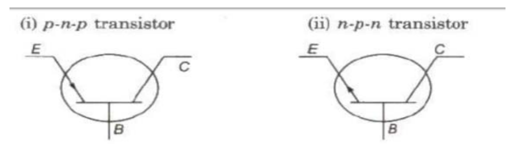
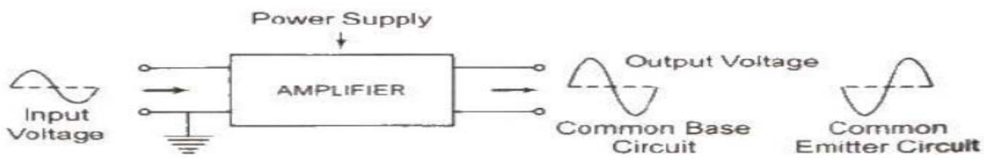
Transistor: A transistor is an arrangement obtained by growing a thin layer of one type of semiconductor between two thick layers of other similar type semiconductor.

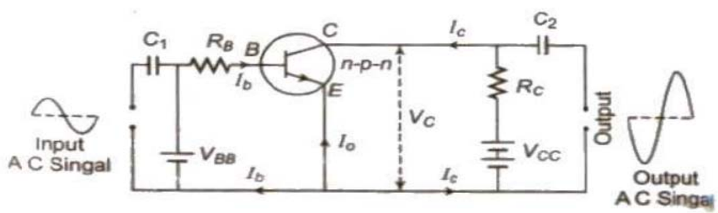
Types of Transistors:



Transistor as an Amplifier: An amplifier is a device which is used for increasing the amplitude of variation of alternating voltage, current or power.
The amplifier thus produces an enlarged version of the input signal.
The general concept of amplification is represented in figure. There are two input terminals for the signal to be amplified and two output terminals for connecting the load; and a means of supplying power to the amplifier.



Common Emitter Amplifier:



It is N-P-N transistor in common emitter configuration.
When no input A.C. signal is applied to the Base-Emitter circuit then the output voltage across the collector circuit can be written as
$V_c = V_{CE} - I_c R_L$
V_c is the potential difference across C and E
During +ve half of the input A.C. signal, the forward bias increases. It increases input current and so output current also increases. $I_c R_L$ also increases. Therefore V_C increases and it makes collector more negative i.e input signal is amplified but in the opposite phase.
During -ve half of the input A.C. signal, the forward bias decreases. It decreases input current and so output current also decreases. $I_c R_L$ also decreases. Therefore V_C decreases and it makes collector more positive i.e input signal is amplified but in the opposite phase.

Light Emitting Diodes (LED): It is forward biased p-n junction diode which emits light when recombination of electrons and holes takes place at the junction. If the semiconducting material of p-n junction is transparent to light, the light is emitting and the junction becomes a light source, i.e., Light Emitting Diode (LED). The colour of the light depends upon the types of material used in making the semiconductor diode.

(i) Gallium – Arsenide (Ga-As) – Infrared radiation

(ii) Gallium – phosphide (GaP) – Red or green light

(iii) Gallium – Arsenide – phosphide (GaAsP) – Red or yellow light

Logic Gate: A digital circuit which allows a signal to pass through it, only when few logical relations are satisfied, is called a logic gate.

Truth Table: A table which shows all possible input and output combinations is called a truth table.

Basic Logic Gates:

(i) OR Gate: It is a two input and one output logic gate.

Symbol

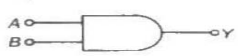
Truth table

A	B	Y = A + B
0	0	0
0	1	1
1	0	1
1	1	1

Boolean expression $Y = A + B$ (Y equals A OR B)

(ii) AND Gate: It is a two input and one output logic gate

Symbol



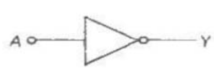
Truth table

A	B	Y = A·B
0	0	0
0	1	0
1	0	0
1	1	1

Boolean expression $Y = A \cdot B$ (Y equals A AND B)

(iii) NOT Gate: It is a one input and one output logic gate.

Symbol



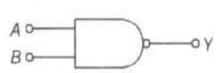
Truth table

A	$Y = \bar{A}$
0	1
1	0

Boolean expression $Y = \bar{A}$ (Y equals NOT A)

(iv) NAND Gate: When output of AND gate is applied as input to a NOT gate, then it is called a NAND gate. Boolean expression Y = A * B (Y equals negated of A AND B)

Symbol

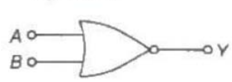


Truth table

A	B	$Y = \overline{A \cdot B}$
0	0	1
0	1	1
1	0	1
1	1	0

(v) NOR Gate: When output of OR gate is applied as input to a NOT gate, then it is called a NOR gate.

Symbol



Truth table

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

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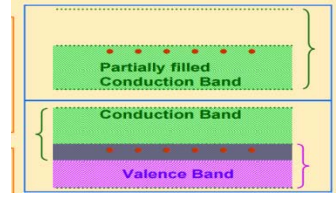
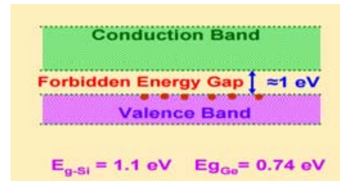
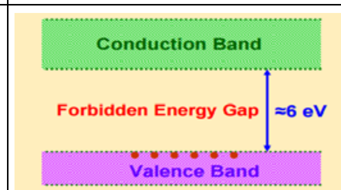
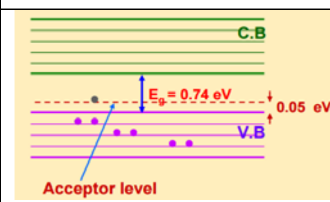
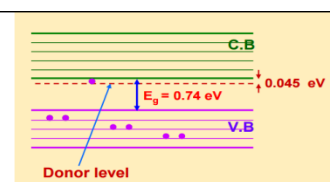
IMPORTANT QUESTIONS

1.Important Energy level Diagrams:

METAL	The electrons in valence band overflow into conduction band and are free to move about in the crystal for conduction.	
SEMICONDUCTOR(INTRINSIC)	At absolute zero temperature, no electron has energy to jump from valence band to conduction band and hence the crystal is an insulator. At room temperature, some valence electrons gain energy more than the energy gap and move to conduction band to conduct even under the influence of a weak electric field. $\frac{ne}{nh}=1$	
INSULATOR	Electrons cannot practically jump to conduction band from valence band due to a large energy gap. Therefore, conduction is not possible in insulators.	
P-TYPE SEMICONDUCTOR	The energy difference between the acceptor energy level and the top of the valence band is much smaller than the band gap. Electrons from the valence band can, therefore, easily move into the acceptor level by being thermally agitated. $\frac{nh}{ne}>1$	
N-TYPE SEMICONDUCTOR	The energy state corresponding to the fifth electron is in the forbidden gap and slightly below the lower level of the conduction band. This energy level is called 'donor level'. $\frac{ne}{nh}>1$	

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2.Why is silicon preferred to germanium in manufacturing semiconductors?

Ans: Silicon is preferred to germanium in manufacturing semiconductors because of the following reasons:

- Silicon has high temperature coefficient than germanium.
- Silicon can operate at high temperature than germanium.
- Silicon is comparatively cheaper.

3. Distinction between Intrinsic and Extrinsic Semiconductor

Intrinsic Semiconductor	Extrinsic Semiconductor
Pure Group IV elements.	Group III or Group V elements are introduced in Group IV elements.
Conductivity is only slight	Conductivity is greatly increased.
Conductivity increases with rise in temperature	Conductivity depends on the amount of impurity added.
The number of holes is always equal to the number of free electrons.	In N-type, the no. of electrons is greater than that of the holes and in P-type, the no. holes is greater than that of the electrons

4. You are given three semiconductors A, B, C with respective band gaps of 3eV, 2eV and 1eV for use in a photo detector to detect λ = 1400nm. Select the suitable semiconductor. Give reasons.

Energy corresponding to $\lambda = 1400\text{nm} = 1400 \times 10^{-9}$ m is

$$E = hc / \lambda = 1.42 * 10^{-19} / 1.6 * 10^{-19} \text{ eV}$$

For detection E must be equal to greater than Eg. Hence only suitable semiconductor is C

5. The ratio of number of free electrons to holes ne/nh for two different materials A and B are 1 and <1 respectively. Name the type of semi conductor to which A and B belongs.

Ans.: If $n_e/n_h = 1$. Hence A is intrinsic semi conductor.
If $n_e/n_h < 1$, $n_e < n_h$ hence B is P-type.

6.In half wave rectification , what is the output frequency if the input frequency is 50 hz. What is the output frequency of a full wave rectification for the same input frequency.

Ans.: For half wave rectification 50 Hz., For Full wave rectification 100Hz.

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

Ans.: Reverse biased.

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