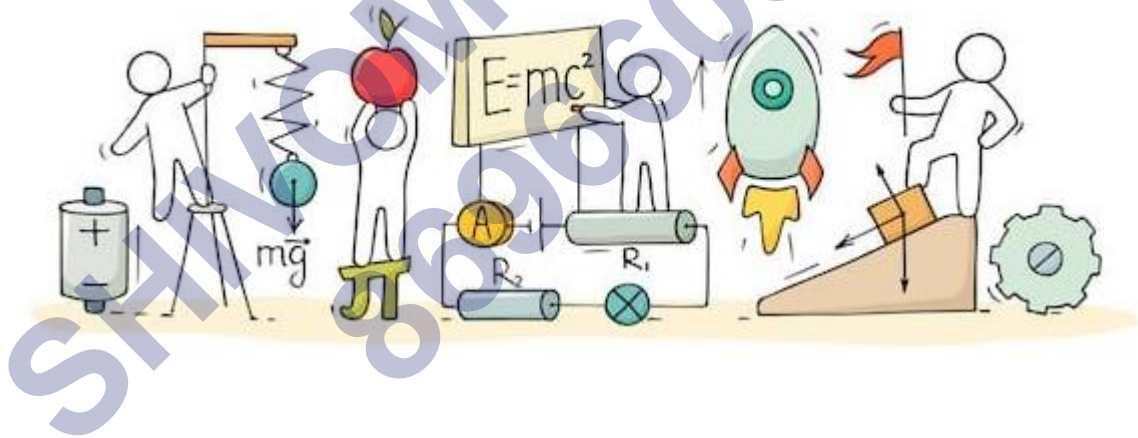


# PHYSICS

## CHAPTER 14: SEMICONDUCTOR ELECTRONICS



## SEMICONDUCTOR ELECTRONICS

### Classification of Metals:

On the basis of the relative values of electrical conductivity ( $\sigma$ ) or resistivity ( $\rho = \frac{1}{\sigma}$ ), the solids are broadly classified as:

#### Metals:

They possess very low resistivity (or high conductivity).

$$\rho \sim 10^{-2} - 10^{-8} \Omega \text{ m}$$

$$\sigma \sim 10^2 - 10^8 \text{ S m}^{-1}$$

#### Semiconductors:

They have resistivity or conductivity intermediate to metals and insulators.

$$\rho \sim 10^{-5} - 10^6 \Omega \text{ m}$$

$$\sigma \sim 10^5 - 10^6 \text{ S m}^{-1}$$

#### Insulators:

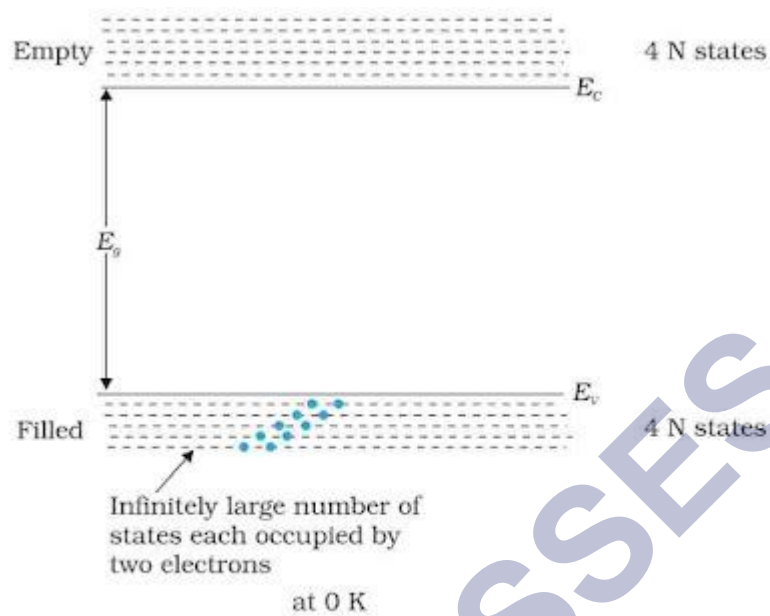
They have high resistivity (or low conductivity).

$$\rho \sim 10^{11} - 10^{19} \Omega \text{ m}$$

$$\sigma \sim 10^{-11} - 10^{-19} \text{ S m}^{-1}$$

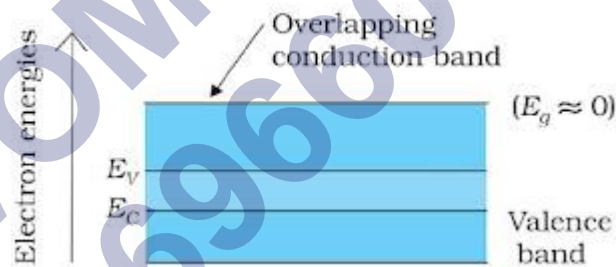
### Classification of Metals on the Basis of Energy Bands:

When the atoms come together to form a solid they are so close to each other that the fields of electrons of outer orbits from neighboring atoms overlap. This makes the nature of electron motion in a solid very different from that in an isolated atom. Inside the solid, each electron has a unique position, and no two electrons have same pattern of surrounding charges.



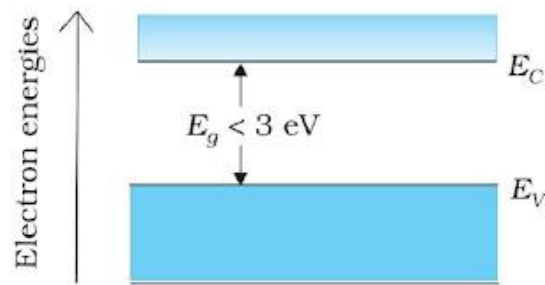
### Metals:

In metals, conduction band and valence band are overlapped to each other. The electrons from the valence band can easily move into the conduction band. Normally, the conduction band is empty but when it overlaps on the valence band, electrons can move freely into it, and it conducts electric current through it.



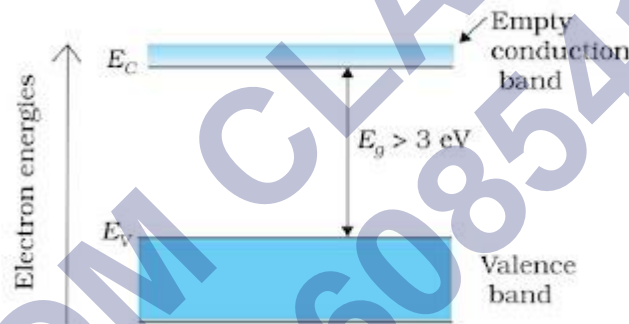
### Semiconductors:

Semiconductors are the core fundamental materials which are used in solid-state electronic devices such as transistors, diodes etc. The material's atomic structure decides whether the material will turn out to be a metal, semiconductor, or insulator. Semiconductors could also be elements such as Ge, Si or compounds such as CdS or GaAs.



### Insulators:

In semiconductors, a small and finite energy band gap exists. Because of the small energy band gap some electrons from valence band, at room temperature, acquire enough energy to cross the energy gap and enter the conduction band. These electrons are very few and can move in the conduction band. Hence, the resistance of semiconductors is not as high as that of the insulators.



### Intrinsic Semiconductor:

The pure semiconductors in which the electrical conductivity is totally governed by the electrons excited from the valence band to the conduction band and in which no impurity atoms are added to increase their conductivity are called intrinsic semiconductors and their conductivity is called intrinsic conductivity. Electrical conduction in pure semiconductors occurs by means of electron-hole pairs. In an intrinsic semiconductor,

$$n_e = n_h = n_i$$

where  $n_e$  = the free electron density in conduction band,  $n_h$  = the hole density in valence band, and  $n_i$  = the intrinsic carrier concentration.

### Extrinsic Semiconductors:

A Semiconductor doped with suitable impurity atoms so as to increase its conductivity is called an extrinsic semiconductor.

### Types of Semiconductor:

**Extrinsic semiconductors are basically of two types:**

**n-type semiconductors:**

The pentavalent impurity atoms are called donors because they donate electrons to the host crystal and the semiconductor doped with donors is called n-type semiconductor. In n-type semiconductors, electrons are the majority charge carriers and holes are the minority charge carriers. Thus,  $n_e \gg n_h$

**p-type semiconductors:**

The trivalent impurity atoms are called acceptors because they create holes which can accept electrons from the nearby bonds. A semiconductor doped with acceptor type impurities is called a p-type semiconductor. In p-type semiconductor, holes are the majority carriers and electrons are the minority charge carriers Thus,

$$n_h \gg n_e$$

**Diode:**

Diodes are being for the purpose of AC voltage rectification which means restricting the voltage to follow one direction only using a capacitor or a filter, a dc voltage can be achieved.

**The types of diodes are:**

**Zener Diode:** This is used in places where voltage regulation is needed.

**P-N junction diode:** It is used in photonic or optoelectronic devices and the entity is the photon. Examples are solar cells, light-emitting diodes etc.

**Holes:**

The vacancy or absence of electron in the bond of a covalently bonded crystal is called a hole. A hole serves as a positive charge carrier.

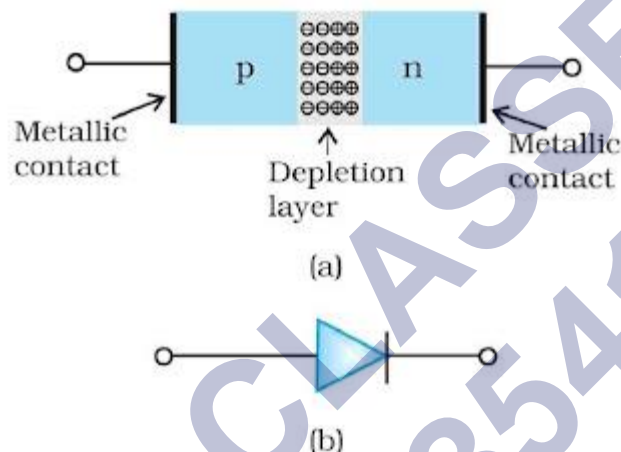
**p-n Junction Formation:**

In the n-region of a p-n junction, the concentration of free electrons is higher than that of holes, whereas in the p-region, the concentration of holes is much higher than that of free electrons. Therefore, when a p-n junction is formed, some electrons from the n-region will diffuse into the p-region. Since the hole is nothing but the vacancy of an electron, an electron diffusing from the n- to the p-region simply fills this vacancy, i.e., it completes the covalent bond. This process is called electron-hole

recombination.

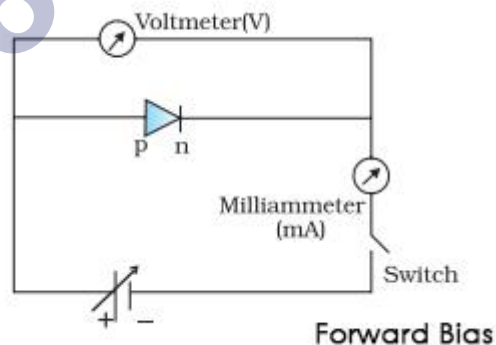
### Semiconductor Diode:

A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. The symbol for the simplest electronic device, namely the p-n junction is shown as. The direction of the thick arrow is from the p to the n-region. The p-side is called the anode and the n-side is known as the cathode.



### Forward Biasing of a pn-junction:

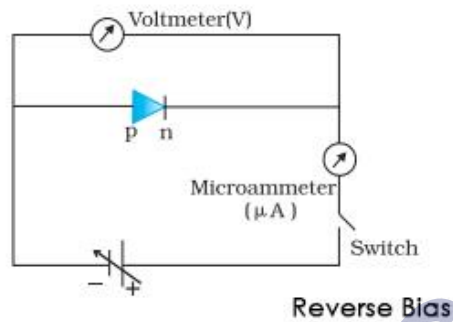
If the positive terminal of a battery is connected to the p-side and the negative terminal to the n-side, then the pn-junction is said to be forward biased. Both electrons and holes move towards the junction. A current, called forward current, flows across the junction. Thus, a pn-junction offers a low resistance when it is forward biased.



### Reverse Biasing of a pn-junction:

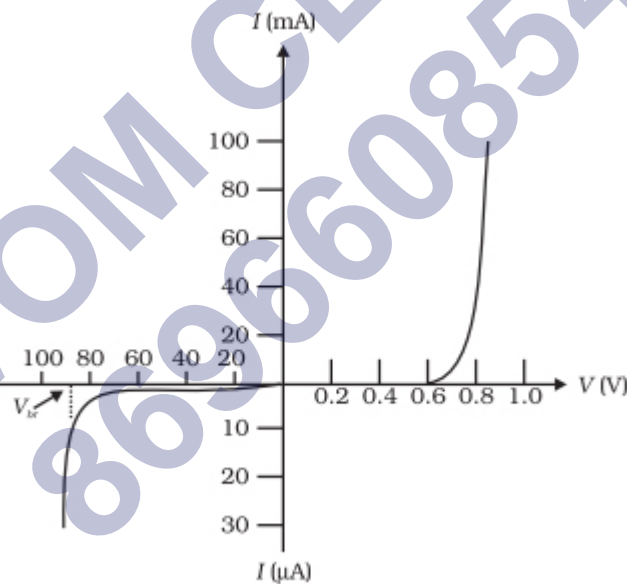
If the positive terminal of a battery is connected to the n-side and negative terminal to the p-side, then pn-junction is said to be reverse biased. The majority charge carriers move away from the junction. The potential barrier offers high resistance during the

reverse bias. However, due to the minority charge carriers a small current, called reverse or leakage current flows in the opposite direction. Thus, junction diode has almost a unidirectional flow of current.



### Characteristics of Junction Diode:

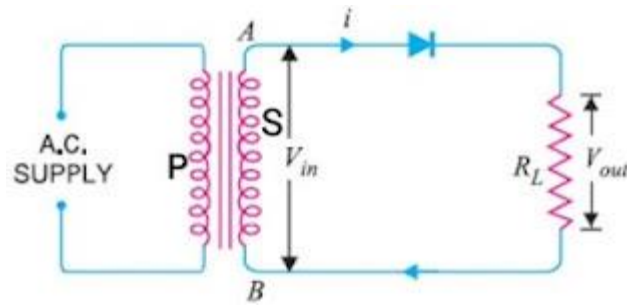
With increasing forward bias, the current first increases non-linearly up to a certain forward-biased voltage called knee voltage or cut-in voltage and beyond which the current varies non-linearly.



### Diode as 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.

There are two ways of using a diode as a rectifier i.e.



### Half-wave Rectifier:

Let during the first half of AC input cycle, the end A of secondary S of transformer be at positive potential and end B at the negative potential. In this situation, the diode is forward biased and a current flow in the circuit. Consequently, an output voltage across load  $R_L$  is obtained.

During the second half of AC input, the end A of secondary S of transformer is at negative potential and diode D is in reverse bias. So, no current flows through load  $R_L$  and there is no output voltage across  $R_L$ .



In the next positive half-cycle of AC input, we again get the output and so on. Thus, we get output voltage as shown in Fig. Here, the output voltage, though still varying in magnitude, is restricted to only one direction, and is said to be rectified. Since, the rectified output of the circuit is obtained only for half of the input AC wave, the device is called half-wave rectifier.

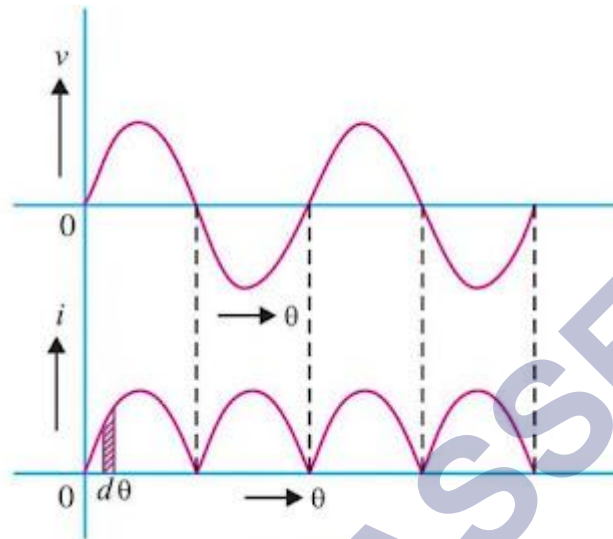
### Full-wave rectifier:

During the first half cycle of the input voltage, the terminal A is positive with respect to O while B is negative with respect to O. Diode first is forward bias and conducts while diode second is reverse bias and does not conduct, the current flow through  $R_L$  from D To O. During the second half cycle, A is negative, and B is positive with respect to O, thus diode first is reverse bias and diode second is forward biased. The current through  $R_L$  is in the same direction as during the first half cycle. The resulting output current is a continuous series.

As we are getting output in positive half as well as negative half of AC input cycle, the



rectifier is called a full wave rectifier. Obviously, this is a more efficient circuit for getting rectified voltage or current than a half wave rectifier.



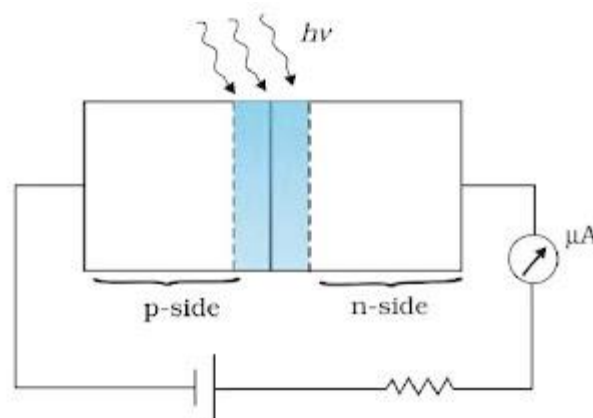
### Zener diode:

The specially designed junction diodes which can operate in the reverse breakdown voltage region continuously without being damaged, are called Zener diodes.



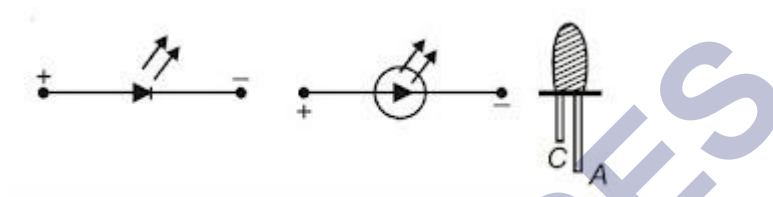
### Photodiode:

A junction diode made from photosensitive semiconductor is called a photodiode. In photodiode one region is made so thin that incident light may reach the depletion region.



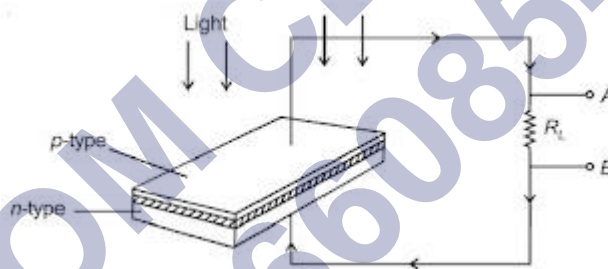
### Light-Emitting Diode (LED):

Light-emitting diode is a heavily doped p-n junction encapsulated with a transparent cover so that emitted light can come out. 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.



### Solar cell:

In a solar cell, one region is made very thin so that most of the light incident on it reaches the depletion region. In this diode when photons of visible light incident to depletion region, electrons jump from valence band to conduction band producing electron-hole pairs.



### Action of a transistor:

When the emitter-base junction of an n-p-n-transistor is forward biased, the electrons are pushed towards the base. As the base region is very thin and lightly doped, most of the electrons cross over to the reverse biased collector. Since few electrons and holes always recombine in the base region, so the collector current  $I_C$  is always slightly less than emitter current  $I_E$ .

$$I_E = I_C + I_B$$

Where  $I_B$  is the base current.

## Digital Electronics and Logic Gates:

There are three basic logic gates:

(i) OR gate (ii) AND gate, and (iii) NOT gate.

**NOT Gate:**

This is the most basic gate, with one input and one output. It produces an inverted version of the input at its output i.e., it produces a '1' output if the input is '0' and vice versa. This is why it is also known as an inverter.

**AND gate:**

An AND gate can have any number of inputs but only one output. It gives a high output (1) if inputs A and B are both high (1), or else the output is low (0). It is described by the Boolean expression.

$$A.B = Y$$

Which is read as 'A and B equals Y.'

**Combination of Gates:****The NAND gate:**

If the output Y' of AND gate is connected to the input of NOT gate, the gate so obtained is called NAND gate. Boolean expression for the NAND gate is  $Y = \overline{A.B}$

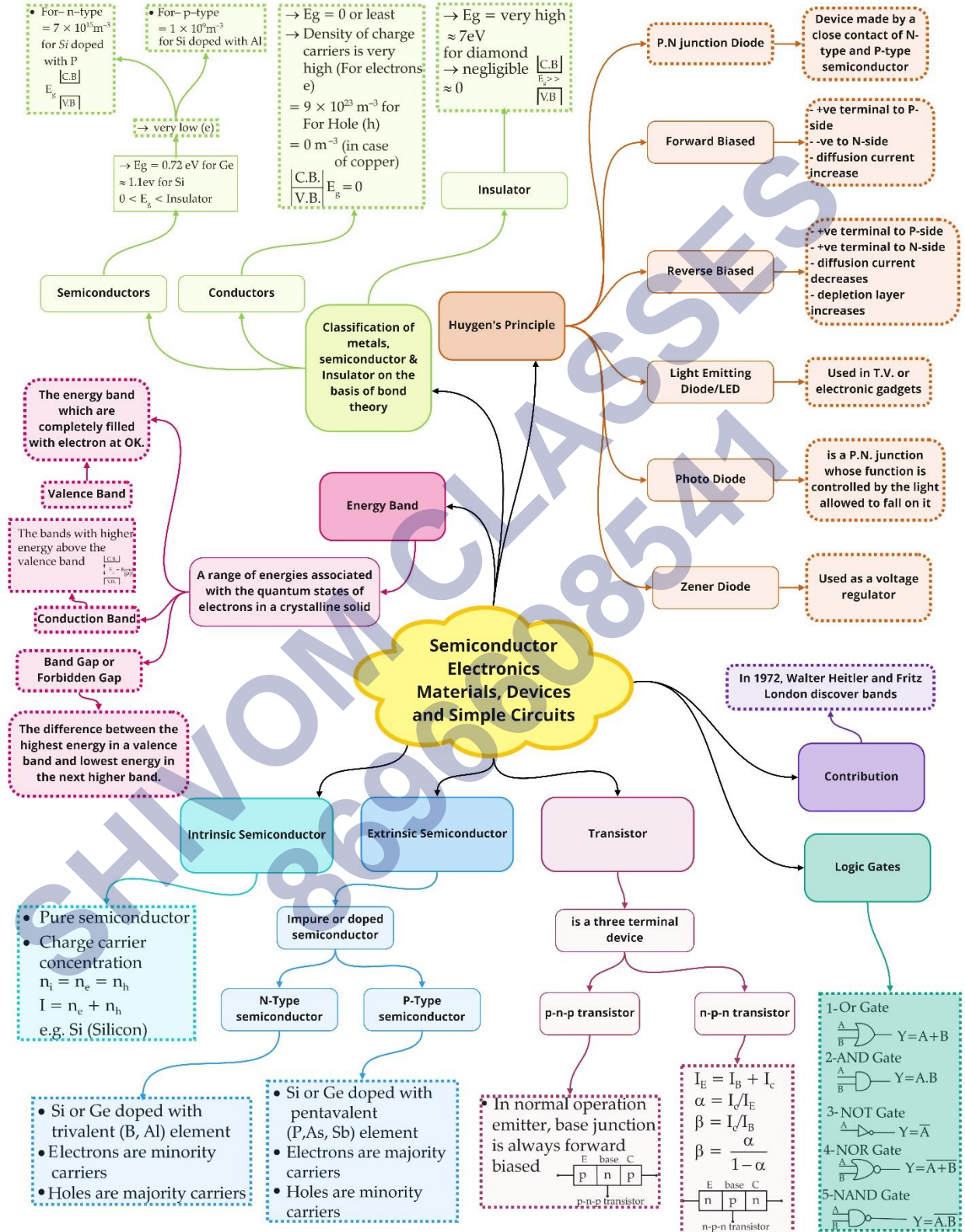
**The NOR gate:**

If the output (Y') of OR gate is connected to the input of a NOT gate, the gate so obtained is called the NOR gate. Boolean expression for the NOR gate is  $Y = \overline{A + B}$ .

**Integrated Circuits:**

The concept of fabricating an entire circuit (consisting of many passive components like R and C and active devices like diode and transistor) on a small single block (or chip) of a semiconductor has revolutionized the electronics technology. Such a circuit is known as Integrated Circuit (IC).

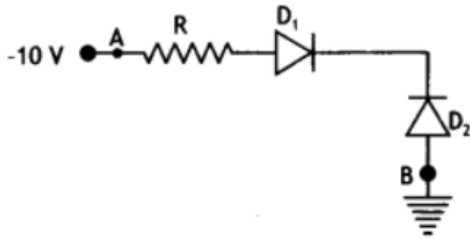
Class : 12th Physics  
Chapter- 14 : Semiconductor Electronics Materials, Devices & Simple Circuits



## Important Questions

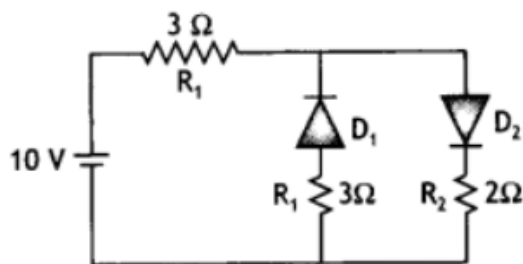
### Multiple Choice questions-

1. In the figure, assuming the diodes to be ideal,



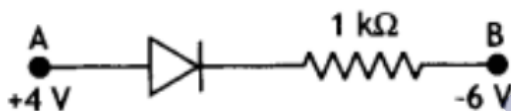
- A.  $D_1$  is forward biased and  $D_2$  is reverse biased and hence current flows from A to B.
- B.  $D_2$  is forward biased and  $D_1$  is reverse biased and hence no current flows from B to A and vice versa.
- C.  $D_1$  and  $D_2$  are both forward biased and hence current flows from A to B.
- D.  $D_1$  and  $D_2$  are both reverse biased and hence no current flows from A to B and vice versa.
2. Hole is:
- A. an anti-particle of electron.
- B. a vacancy created when an electron leaves a covalent bond.
- C. absence of free electrons.
- D. an artificially created particle.
3. For the depletion region of a diode which one is incorrect?
- A. There are no mobile charges.
- B. Equal number of holes and electrons exists, making the region neutral.
- C. Recombination of holes and electrons has taken place.
- D. Immobile charged ions exist.
4. To reduce the ripples in a rectifier circuit with capacitor filter which one is false?
- A.  $R_L$  should be increased.
- B. Input frequency should be decreased.
- C. Input frequency should be increased.
- D. Capacitors with high capacitance should be used.

5. Carbon, silicon and germanium have four valence electrons each. These are characterised by valence and conduction bands separated by energy band gap respectively equal to  $(E_g)_C$ ,  $(E_g)_{Si}$  and  $(E_g)_{Ge}$ . Which of the following statements is true?
- A.  $(E_g)_{Si} < (E_g)_{Ge} < (E_g)_C$
  - B.  $(E_g)_C < (E_g)_{Ge} > (E_g)_{Si}$
  - C.  $(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$
  - D.  $(E_g)_C = (E_g)_{Si} = (E_g)_{Ge}$
6. In an unbiased p-n junction, holes diffuse from the p-region to n-region because:
- A. free electrons in the n-region attract them.
  - B. they move across the junction by the potential difference.
  - C. hole concentration in p-region is more as compared to n-region.
  - D. All the above.
7. In a p-n junction diode, change in temperature due to heating:
- A. affects only reverse resistance
  - B. affects only forward resistance
  - C. Does not affect resistance of p-n junction
  - D. affects the overall V-I characteristics of p-n junction
8. A specimen of silicon is to be made p-type semiconductor for this one atom of indium, on an average, is doped in  $5 \times 10^7$  silicon atoms. If the number density of silicon is  $5 \times 10^{22}$  atoms  $m^{-3}$ , then the number of acceptor atoms per  $cm^3$  will be:
- A.  $2.5 \times 10^{30}$
  - B.  $1.0 \times 10^{13}$
  - C.  $1.0 \times 10^{15}$
  - D.  $2.5 \times 10^{36}$
9. The given circuit has two ideal diodes connected as shown in the figure below. The current flowing through the resistance  $R_1$  will be:



- A. 1.43 A
- B. 3.13 A
- C. 2.5 A
- D. 10.0 A

10. Consider the junction diode as ideal. The value of current flowing through AB is:



- A. 0 A
- B.  $10^{-2}$  A
- C.  $10^{-1}$  A
- D.  $10^{-3}$  A

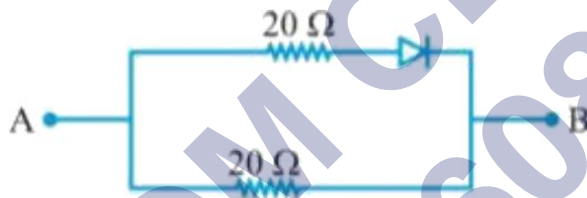
### Very Short Questions:

1. Give the ratio of number of holes and the number of conduction electrons in an intrinsic semiconductor.
2. What type of impurity is added to obtain n-type semiconductor?
3. Doping of silicon with indium leads to which type of semiconductor?
4. Draw an energy level diagram for an intrinsic semiconductor.
5. A semiconductor has equal electron and hole concentration of  $6 \times 10^8 \text{ m}^{-3}$ . On doping with a certain impurity electron concentration increases to  $3 \times 10^{12} \text{ m}^{-3}$ . Identify the type of semiconductor after doping.
6. How does the energy gap of an intrinsic semiconductor vary, when doped with a trivalent impurity?
7. How does the width of the depletion layer of p-n-junction diode change with decrease in reverse bias?
8. Under what condition does a junction diode work as an open switch?

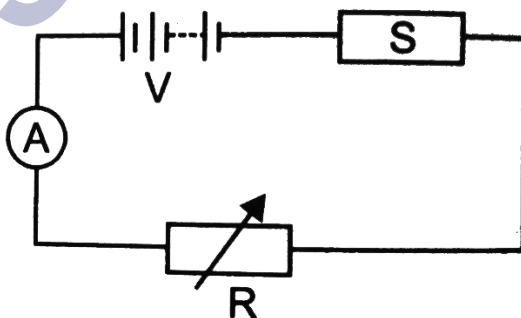
9. Which type of biasing gives a semiconductor diode very high resistance?
10. If the output of a 2-input NAND gate is fed as the input to a NOT gate,
  - a) name the new logic gate obtained and
  - b) write down its truth table

### Short Questions :

1. If the frequency of the input signal is  $f$ . What will be the frequency of the pulsating output signal in case of :
  - (i) half wave rectifier?
  - (ii) full wave rectifier?
2. Find the equivalent resistance of the network shown in figure between point A and B when the p-n junction diode is ideal and :
  - (i) A is at higher potential
  - (ii) B is at higher potential

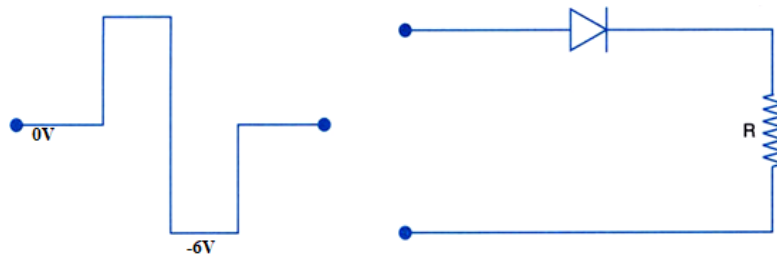


3. Potential barrier of p.n. junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why?
4. The diagram shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter A constant, when semiconductor S is heated? Give reason.

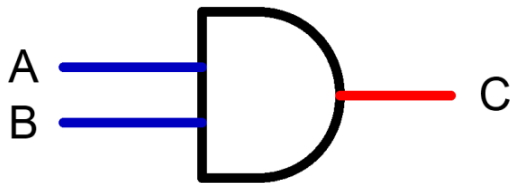


5. Why is a photo diode used in reverse bias?
6. What is an ideal diode? Draw the output wave form across the load resistor R, if the input waveform is as shown in the figure.

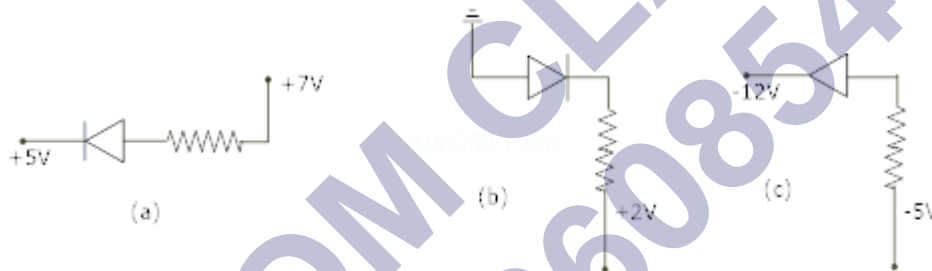




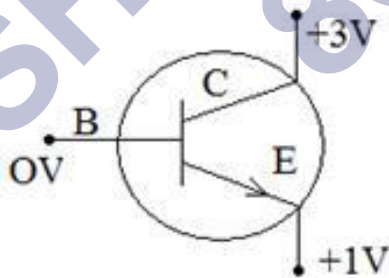
7. With the help of a labeled circuit diagram, explain full wave rectification using junction diode. Draw input and output wave forms?
8. Name the gate shown in the figure and write its truth table?



9. In the following diagrams indicate which of the diodes are forward biased and which are reverse bias?



10. In the given figure, is
  - (i) The emitter base
  - (ii) collector base forward or reverse biased? Justify.



(i)

### Long Answers Q.:

1. Distinguish between conductors, insulators and semiconductors on the basis of energy band diagrams?
2. The following truth table gives the output of a 2-input logic gate.

3.

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

Identify the logic gate used and draw its logic symbol. If the output of this gate is fed as input to a NOT gate, name the new logic gate so formed?

4. With the help of a diagram, show the biasing of a light emitting diode (LED). Give its two advantages over conventional incandescent lamps?
5. The input resistance of a silicon transistor is  $665\Omega$ . Its base current is changed by  $15\mu A$ , which results in the change in collector current by  $2mA$ . This transistor is used as a common emitter amplifier with a load resistance of  $5k\Omega$ . Calculate current gain ( $\beta_{ac}$ ).
6. Draw the symbol for zener diode? Zener diodes have higher dopant densities as compared to ordinary p-n junction diodes. How does it affect the (i) width of the depletion layer (ii) junction field?
7. A P-N-P transistor is used in common – emitter mode in an amplifier circuit. A change of  $40\mu A$  in the base current brings a change of  $2mA$  in collector current and  $0.04V$  in base – emitter voltage. Find (i) input resistance (ii) current amplification factor ( $\beta$ ). If a load resistance of  $6k\Omega$  is used, then find voltage gain?
8. A semiconductor has equal electron and hole concentration of  $6 \times 10^8 / m^3$ . On doping with certain impurity, electron concentration increases to  $8 \times 10^{12} / m^3$ .
  - (i) Identify the new semiconductor
  - (ii) Calculate the new hole concentration.
  - (iii) How does the energy gap vary with doping?
9. Draw a labeled circuit diagram of a common emitter transistor amplifier. Draw the input and the output wave forms and also state the relation between input and output signal?

10. In an intrinsic semiconductor the energy gap  $E_g$  is 1.2 eV. Its hole mobility is much smaller than electron mobility and independent of temperature. What is the ratio between conductivity at 600K and that at 300K? Assume that the temperature dependence of intrinsic carrier concentration  $n_i$  is given by

$$n_i = n_0 \exp\left[-\frac{E_g}{2k_B T}\right]$$

where  $n_0$  is a constant.

11. In a p-n junction diode, the current  $I$  can be expressed as

$$I = I_0 \exp\left(\frac{eV}{2k_B T} - 1\right)$$

where  $I_0$  is called the reverse saturation current,  $V$  is the voltage across the diode and is positive for forward bias and negative for reverse bias, and  $I$  is the current through the diode,  $k$  is the Boltzmann constant ( $8.6 \times 10^{-5}$  eV/K) and  $T$  is the absolute temperature. If for a given diode  $I_0 = 5 \times 10^{-12}$  A and  $T = 300$  K, then

- What will be the forward current at a forward voltage of 0.6 V?
- What will be the increase in the current if the voltage across the diode is increased to 0.7 V?
- What is the dynamic resistance?
- What will be the current if reverse bias voltage changes from 1 V to 2 V?

### Assertion and Reason Questions –

1. Two statements are given—one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

- Both A and R are true and R is the correct explanation of A.
- Both A and R are true but R is not the correct explanation of A.
- A is true but R is false.
- A is false and R is also false.

**Assertion:** The ratio of free electrons to holes in intrinsic semiconductor is greater than one.

**Reason:** The electrons are lighter particles and holes are heavy particles.

2. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes(a), (b), (c) and (d) as given below.

- Both A and R are true and R is the correct explanation of A.
- Both A and R are true but R is not the correct explanation of A.
- A is true but R is false.
- A is false and R is also false.

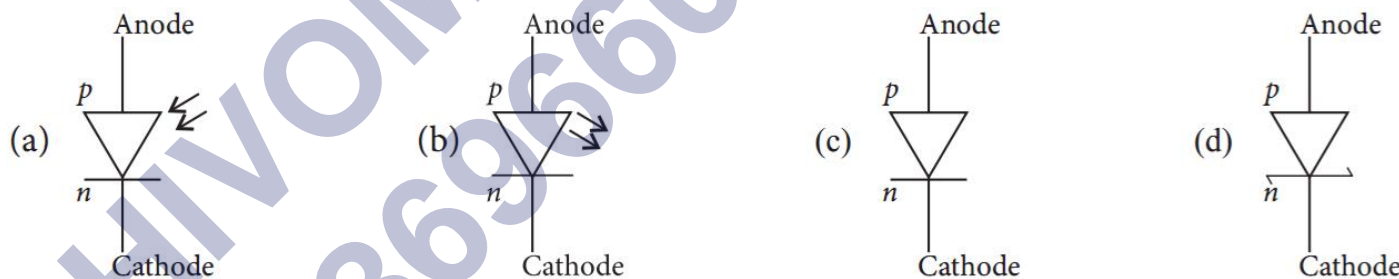
**Assertion:** : The half-wave rectifier work only for positive half cycle of ac.

**Reason:** In half-wave rectifier only one diode is used.

### Case Study Questions –

1. Solar cell is a p-n junction diode which converts solar energy into electric energy. It is basically a solar energy converter. The upper layer of solar cell is of p-type semiconductor and very thin so that the incident light photons may easily reach the p-n junction. On the top face of p-layer, the metal finger electrodes are prepared in order to have enough spacing between the fingers for the lights to reach the p-n junction through p-layer.

(i) The schematic symbol of solar cell is:



(ii) The p-n junction which generates an emf when solar radiations fall on it, with no external bias applied, is a:

- Light emitting diode.
  - Photodiode.
  - Solar cell.
  - None of these.
- (iii) For satellites the source of energy is:
- Solar cell.
  - Fuel cell.
  - Edison cell.
  - None of these.

(iv) Which of the following material is used in solar cell?

- a) Barium.
- b) Silicon.
- c) Silver.
- d) Selenium.

(v) The efficiency of a solar cell may be in the range:

- a) 2 to 5%
- b) 10 to 15%
- c) 30 to 40%
- d) 70 to 80%

2. P-n junction is a single crystal of Ge or Si doped in such a manner that one half portion of it acts as p-type semiconductor and other half functions as n-type semiconductor. As soon as a p-n junction is formed, the holes from the p-region diffuse into n-region, and electron from n region diffuse in p-region. This results in the development of V<sub>b</sub> across the junction which opposes the further diffusion of electrons and holes through the junction.

(i) In an unbiased p-n junction electrons diffuse from n-region to p-region because:

- a) Holes in p-region attract them.
- b) Electrons travel across the junction due to potential difference.
- c) Electron concentration in n-region is more as compared to that in p-region.
- d) Only electrons move from n to p region and not the vice-versa.

(ii) Electron hole recombination in p-n junction may lead to emission of:

- a) Light.
- b) Ultraviolet rays.
- c) Sound.
- d) Radioactive rays.

(iii) In an unbiased p-n junction:

- a) Potential at p is equal to that at n.
- b) Potential at p is + ve and that at n is - ve.
- c) Potential at p is more than that at n.
- d) Potential at p is less than that at n.

(iv) The potential of depletion layer is due to:

- a) Electrons.
- b) Holes.
- c) Ions.

- d) Forbidden band.
- (v) In the depletion layer of unbiased p-n junction,
- It is devoid of charge carriers.
  - Has only electrons.
  - Has only holes.
  - P-n junction has a weak electric field.

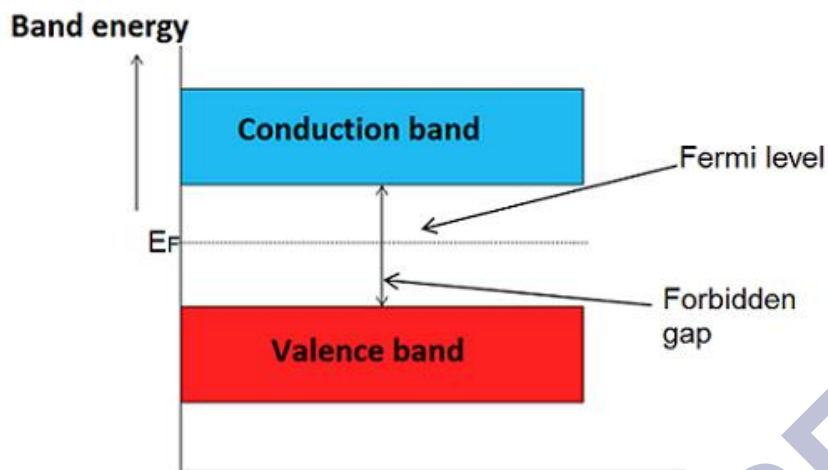
### Multiple Choice question's Answers –

- D2 is forward biased and D1 is reverse biased and hence no current flows from B to A and vice versa.
- a vacancy created when an electron leaves a covalent bond.
- There are no mobile charges.
- Input frequency should be decreased.
- $(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$
- hole concentration in p-region is more as compared to n-region.
- affects the overall V-I characteristics of p-n junction
- $1.0 \times 10^{15}$
- 2.5 A
- 10-2A

### Very Short Answers :

- $\frac{n_h}{n_e} = 1$  (In intrinsic semiconductor,  $n_e = n_h$ ).
- Pentavalent atoms (group -15) like Phosphorus (P), Arsenic (As), etc.
- Doping of Silicon with Indium produces a p-type semiconductor as Indium is a trivalent impurity.
- In intrinsic semiconductor,  $n_e = n_h$

The energy level diagram for an intrinsic semiconductor is shown below:



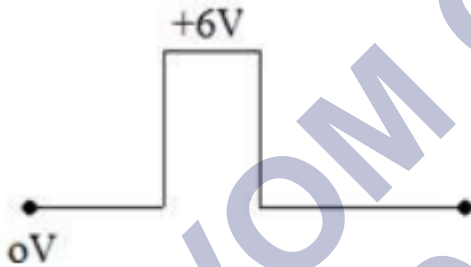
5. According to the question, after doping,  $n_e > n_h$ .  
Clearly, we get an n-type semiconductor after doping.
6. An acceptor energy level is formed in the forbidden energy gap above the valence band when an intrinsic semiconductor is doped with a trivalent impurity.  
Due to this, electrons quickly jump to the acceptor energy level.
7. The width of the depletion layer will decrease with decrease in reverse bias.
8. A junction diode works as an open switch when it is connected under reverse bias conditions.
9. Reverse biasing gives a semiconductor diode very high resistance.
10.
  - a) An AND gate is obtained when the output of a 2-input NAND gate is fed as the input to a NOT gate.
  - b) Truth table for an AND gate is given below.

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

1	1	1
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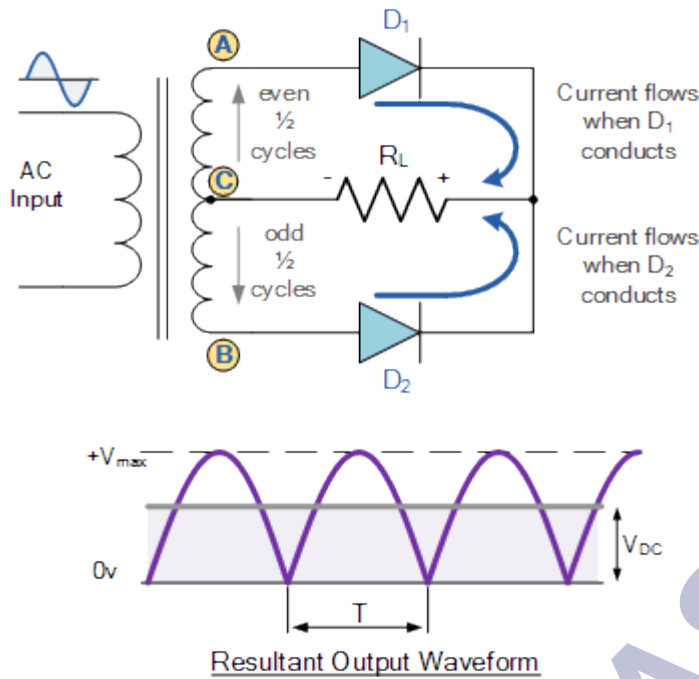
### Short Answers:

1. Frequency of output in half wave Rectifier is  $f$  and in full wave rectifier is  $2f$ .
2. Equivalent resistance is
  - (i)  $10\Omega$
  - (ii)  $20\Omega$
3. Because there is no free charge carrier in depletion region.
4. On heating  $S$ , resistance of semiconductors  $S$  is decreased so to compensate the value of resistance in the circuit  $R$  is increased.
5. In this case diode is sensitive and it gives very large amount of current in this situation.
6. An ideal diode has zero resistance when forward biased and an infinite resistance when it is reverse biased. Output wave from is:



7. Full wave rectifier consists of two diodes and a transformer with central tap. For any half cycle of a.c. input only one diode is forward biased where as the other one is reverse biased.





Suppose for positive half of a.c. input diode  $D_1$  is forward biased and  $D_2$  is reverse biased, then the current will flow across  $D_1$  where as for negative half of a.c. input diode  $D_2$  is forward biased and the current flows across  $D_2$ . Thus for both the halves output is obtained and current flows in the same direction across load resistance  $R_2$  and thus a.c. is converted into d.c.

8. It is AND gate and its truth table is:

Input		Output
A	B	$Y=A.B$
0	0	0
0	1	0
1	0	0
1	1	1

9. (a) Forward Biased  
 (b) Reverse Biased  
 (c) forward Biased

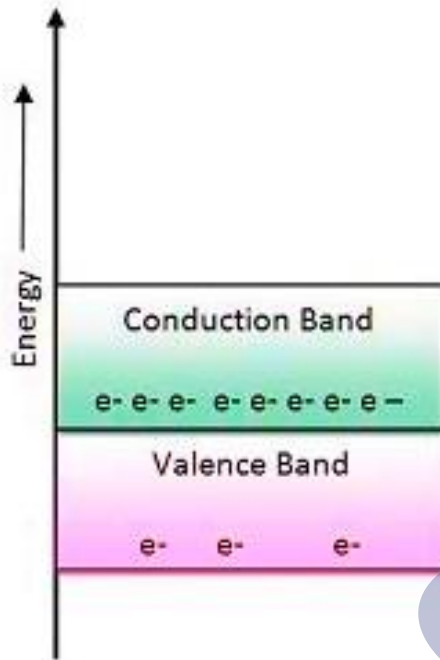
10. Figure shows n-p-n transistor

- (ii) Emitter is reversed biased because n-region is connected to higher potential.  
 (iii) Collector is also reversed biased because n-region of p-n junction is at higher potential than p-region.

**Long Answers:**

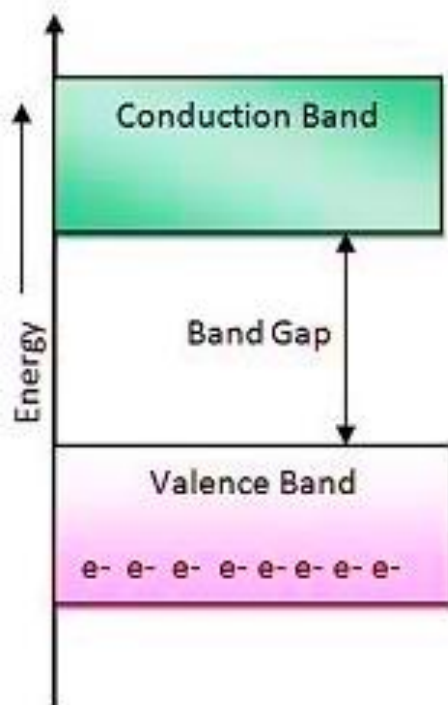
1.

**Conductor** – Conduction band in a conductor is either partially filled or conduction and valence band overlaps each other. There is no energy gap in a conductor.



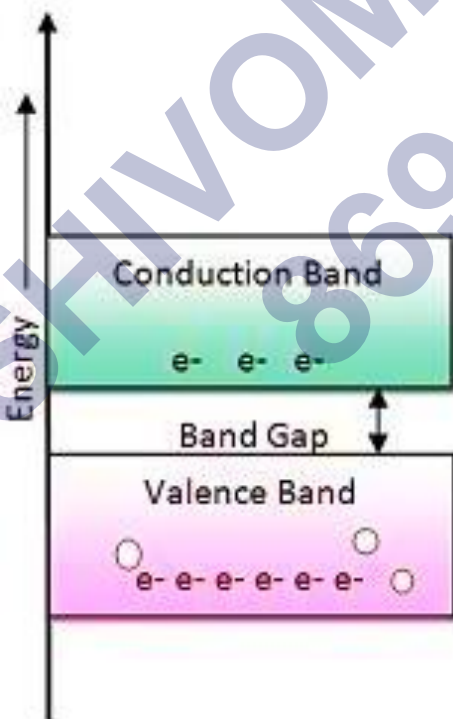
### Conductors

**Insulators** – conduction band and valence band of all insulator are widely separated by an energy gap of the order 6 to 9eV. Also, the conduction band of an insulator is almost empty.



Insulators

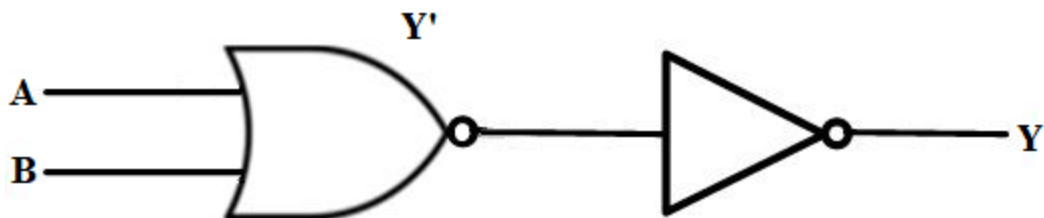
**Semiconductor** – In semiconductors the energy gap is very small i.e. about 1ev only.



Semiconductors

- The gate is NOR gate. If the output of NOR gate is connected to a NOT gate

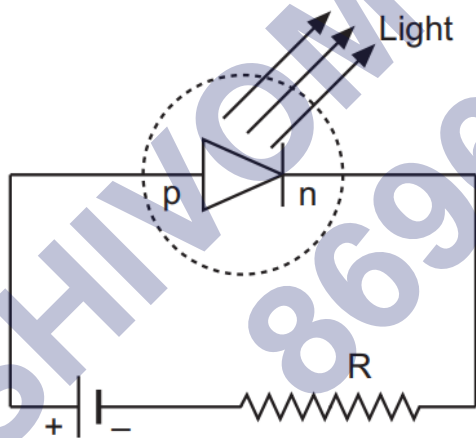
then the figure will be:



New truth table is:

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

3. Light emitting diode is forward biased i.e. energy is released at the junction.



Advantages of LED

- 1) They are used in numerical displays as compact in size.
  - 2) It works at low voltage and has longer life than incandescent bulbs.
- 4.
- (1) Trans conductance (gm) (2) voltage gain (Av) of the amplifier.

$$\text{Here } \Delta I_B = 15 \mu A = 15 \times 10^{-6} A$$

$$\Delta I_C = 2 mA = 2 \times 10^{-3} A$$

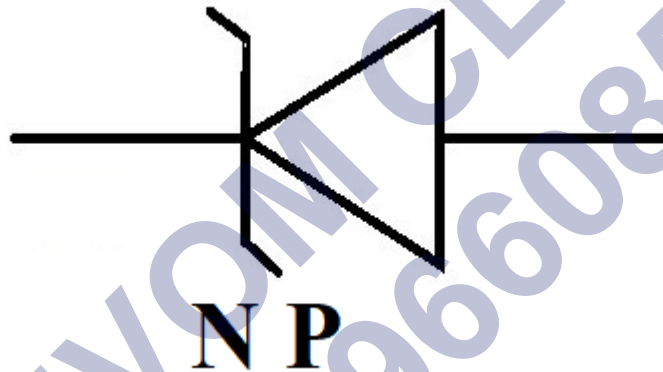
$$R_{in} = 665 \Omega, R_2 = 5 k\Omega = 5 \times 10^3 \Omega$$

$$\beta_{ac} = \frac{\Delta I_C}{\Delta I_B} = \frac{2 \times 10^{-3}}{15 \times 10^{-6}} = 133.3$$

$$(1) \text{ Trans conductance, } g_m = \frac{\beta_{ac}}{R_{in}} = \frac{133.3}{665} = 0.2 \Omega^{-1}$$

$$(2) \text{ Voltage gain (Av)} = g_m R_L = 0.2 \times 5 \times 10^3 = 1000$$

5. Symbol for zener diode



(i) Width of the depletion layer of zener diode becomes very small due to heavy doping of p and n-regions

(ii) Junction field will be high..

6. Ans:

$$\Delta I_B = 40 \mu A = 40 \times 10^{-6} A$$

$$\Delta I_C = 2 mA = 2 \times 10^{-3} A$$

$$\Delta V_{BE} = 0.04 V$$

$$R_L = 6 k\Omega = 6 \times 10^3 \Omega$$

$$R_{in} = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{0.04}{40 \times 10^{-6}} = 1 \times 10^3 \Omega = 1 k\Omega$$

$$\beta = \frac{\Delta v_C}{\Delta I_B} = \frac{2 \times 10^{-3}}{40 \times 10^{-6}} = 50$$

$$\text{Voltage gain} = \beta R_L / R_i = \frac{50 \times 6 \times 10^3}{1 \times 10^3} = 300$$

7.

(i) New semiconductor obtained is N-type because

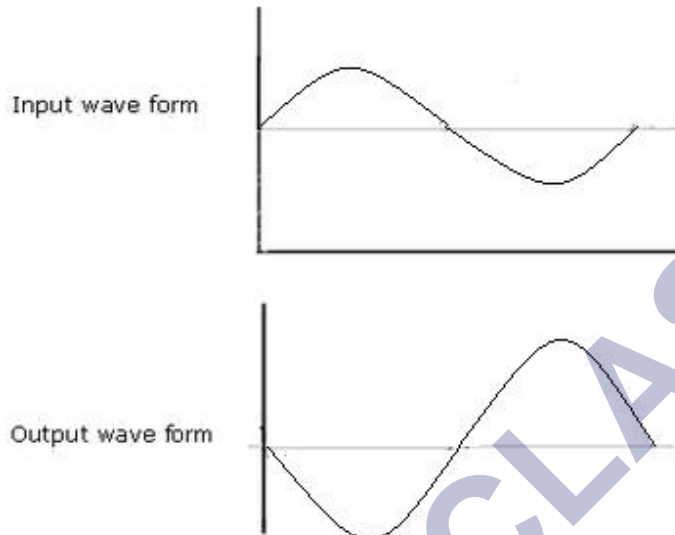
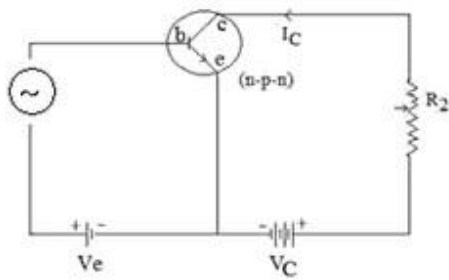
(ii)  $nenh = ne^2$

$$nh = \frac{ni^2}{ne} = \frac{36 \times 10^{15}}{8 \times 10^{12}}$$

$$nh = 4.5 \times 10^4 / m^3$$

(ii) Energy gap decreases due to creation of donor level in between the valence band and the conduction band.

8. Diagram:



Relation – output waveform has  $180^\circ$  phase reversal as compared to input and also the output is being amplified.

9. Energy gap of the given intrinsic semiconductor,  $E_g = 1.2 \text{ eV}$

The temperature dependence of the intrinsic carrier-concentration is written as:

$$n_i = n_0 \exp \left[ -\frac{E_g}{2k_B T} \right]$$

Where  $k_B$  = Boltzmann constant =  $8.62 \times 10^{-5} \text{ eV/K}$

$T$  = Temperature

$n_0$  = Constant

Initial temperature,  $T_1 = 300 \text{ K}$

The intrinsic carrier-concentration at this temperature can be written as:

$$n_{i1} = n_0 \exp \left[ -\frac{E_g}{-2k_B \times 300} \right] \dots (1)$$

Final temperature,  $T_2 = 600 \text{ K}$

The intrinsic carrier-concentration at this temperature can be written as:

$$n_{i2} = n_0 \exp \left[ -\frac{E_g}{-2k_B \times 600} \right] \dots (2)$$

The ratio between the conductivities at 600 K and at 300 K is equal to the ratio between the respective intrinsic carrier-concentrations at these temperatures.

$$\begin{aligned} \frac{n_{i2}}{n_{i1}} &= \frac{n_0 \exp \left[ -\frac{E_g}{2k_B 600} \right]}{n_0 \exp \left[ -\frac{E_g}{2k_B 300} \right]} \\ &= \exp \frac{E_g}{2k_B} \left[ \frac{1}{300} - \frac{1}{600} \right] \\ &= \exp \left[ \frac{1.2}{2 \times 8.62 \times 10^{-5}} \times \frac{2-1}{600} \right] \\ &= \exp [11.6] = 1.09 \times 10^5 \end{aligned}$$

Therefore, the ratio between the conductivities is  $1.09 \times 10^5$ .

10. In a p-n junction diode, the expression for current is given as:

$$I = I_0 \exp \left( \frac{eV}{2k_B T} - 1 \right)$$

Where,

$I_0$  = Reverse saturation current =  $5 \times 10^{-12} \text{ A}$

$T$  = Absolute temperature = 300 K



$K_B =$  Boltzmann constant  $= 8.6 \times 10^{-5} \text{ eV} / \text{K} = 1.376 \times 10^{-23} \text{ JK}^{-1}$

$V =$  Voltage across the diode

(a) Forward voltage,  $V = 0.6 \text{ V}$

$$\therefore \text{Current, } I = 5 \times 10^{-12} \left[ \exp \left( \frac{1.6 \times 10^{-19} \times 0.6}{1.376 \times 10^{-23} \times 300} \right) - 1 \right]$$

$$= 5 \times 10^{-12} \times \exp[22.36] = 0.0256 \text{ A}$$

Therefore, the forward current is about 0.0256 A.

(b) For forward voltage,  $V' = 0.7 \text{ V}$ , we can write:

$$= 5 \times 10^{-12} \left[ \exp \left( \frac{1.6 \times 10^{-19} \times 0.7}{1.376 \times 10^{-23} \times 300} \right) - 1 \right]$$

$$= 5 \times 10^{-12} \times \exp[26.25] = 1.257 \text{ A}$$

Hence, the increase in current,  $\Delta I = I' - I$

$$= 1.257 - 0.0256 = 1.23 \text{ A}$$

(c)

$$\text{Dynamic resistance} = \frac{\text{Change in voltage}}{\text{Change in current}}$$

$$= \frac{0.7 - 0.6}{1.23} = \frac{0.1}{1.23} = 0.081 \Omega$$

(e) If the reverse bias voltage changes from 1 V to 2 V, then the current ( $I$ ) will almost remain equal to  $I_0$  in both cases. Therefore, the dynamic resistance in the reverse bias will be infinite.

### Assertion and Reason Answers –

1. (b) Both A and R are true but R is not the correct explanation of A.

**Explanation:**

In intrinsic semiconductor  $\frac{n_e}{n_h} = 1$  and holes are not particles but vacancies created due to breakage of covalent bond.

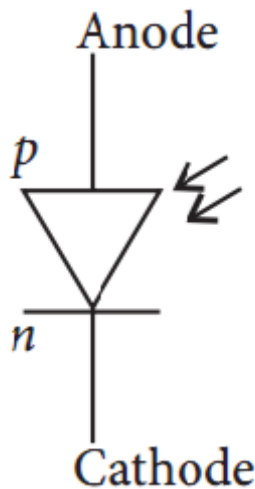
2. (a) Both A and R are true and R is the correct explanation of A.

**Explanation:**

In half wave rectifier, the one diode is biased only when ac is in positive half of its cycle. For negative half of the ac cycle the diode is reversed biased and there is no output corresponding to that. Since for only one-half cycle we get a voltage output, because of which it is called half wave rectifier.

**Case Study Answers –****1. Answer :**

(i) (a)



(ii) (c) Solar cell.

(iii) (a) Solar cell.

**Explanation:**

Solar cells are the source of energy for satellites.

(iv) (b) Silicon.

**Explanation:**

Silicon is used in solar cell.

(v) (b) 10 to 15%

**2. Answer :**

(i) (c) Electron concentration in n-region is more as compared to that in p-region.

**Explanation:**

Electron concentration in n-region is more as compared to that in p-region. So electrons diffuse from n-side to p-side.

(ii) (a) Light.

**Explanation:**

When an electron and a hole recombine, the energy is released in the form of light.

(iii) (a) Potential at p is equal to that at n.

**Explanation:**

In an unbiased p-n junction, potential at p is equal to that at n.

(iv) (c) Ions.

**Explanation:**

The potential of depletion layer is due to ions.

(v) (a) It is devoid of charge carriers.

**Explanation:**

In the depletion layer of unbiased p-n, junction has no charge carriers.

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