



Semiconductor Electronics: Materials, Devices and Simple Circuits



1 ENERGY BANDS

Insulators, conductors and semiconductors are differentiated based on their energy bands.

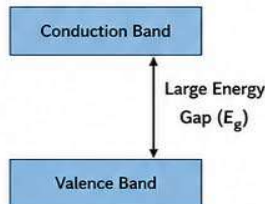
a) Metals (Conductors)

Valence band and conduction band lie very close to each other or overlap.



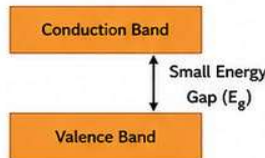
b) Insulators

Conduction band and valence band are separated by a large gap.



c) Semiconductors

Energy band gap is smaller in semiconductors which encourages some electrons to enter the conduction band.



$$E_g (\text{Si}) = 1.1 \text{ eV}$$

$$E_g (\text{Ge}) = 0.74 \text{ eV}$$

2 TYPES OF SEMICONDUCTORS

Semiconductors are classified into two types based on the number of electrons and holes.

- Intrinsic (Pure)
- Extrinsic (Impure)

A. Intrinsic (Pure) Semiconductor

- Free from impurities. Examples: Germanium (Ge) and Silicon (Si)
- For pure Si ($Z=14$) and pure Ge ($Z=32$). Both have 4 valence electrons.
- All 4 valence electrons are involved in covalent bond formation in Si or Ge crystal.
- It has an equal number of holes and free electrons.

$$\text{Thus, } n_e = n_h = n_i$$

Where, n_i = intrinsic carrier concentration

n_e = number of electrons
 n_h = number of holes

B. Extrinsic (Impure) Semiconductor

- The electrical conductivity of intrinsic semiconductor is very poor at room temperature.
- Addition of certain impurities (very small amount—in ppm) increases conductivity.
- The process of addition of impurity is called doping and the impurity atoms are called dopants.
- The impure semiconductor thus formed is called a "doped" semiconductor or Extrinsic Semiconductor.

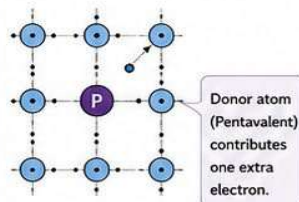
3 EXTRINSIC SEMICONDUCTORS

An extrinsic semiconductor can be of two types based on the type of doping.

(i) n-type Semiconductor

Doped with Pentavalent impurity atoms.

Examples: Phosphorus (P), Arsenic (As), Antimony (Sb)



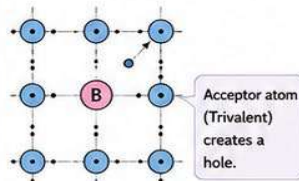
Here, $n_e \gg n_h$

(Number of electrons greater than number of holes)

(ii) p-type Semiconductor

Doped with Trivalent impurity atoms.

Examples: Boron (B), Aluminium (Al), Indium (In)



Here, $n_h \gg n_e$

(Number of holes greater than number of electrons)

In thermal equilibrium:

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

4 P-N JUNCTION

A p-n junction is formed by joining p-type and n-type semiconductor in a single crystal.

p-type	+	+	n-type
+	+	+	-
+	+	+	-
+	+	+	-
+	+	+	-

Formation: Two Important Processes

1. Diffusion

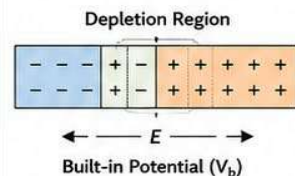
- Majority carriers diffuse from higher concentration to lower concentration across the junction.
- Electrons diffuse from n-side to p-side and holes from p-side to n-side and recombine.

2. Drift

- Due to diffusion, fixed ions are left near the junction creating a space-charge (depletion) region.
- This sets up an electric field that opposes further diffusion.
- Minority carriers drift under the influence of this electric field.

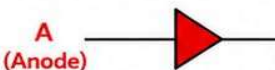
At Equilibrium

Diffusion current equals drift current. A depletion region and a potential barrier are established across the junction which prevents further majority carrier flow.



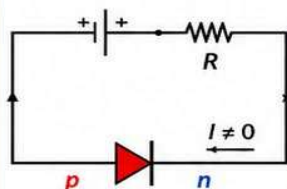
5 SEMICONDUCTOR DIODE (p-n Junction Diode)

- A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage.
- It is a two-terminal device.

Symbol: 

Forward Bias

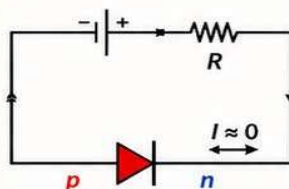
p-side connected to +ve terminal and n-side to -ve terminal.



- Barrier potential decreases.
- Offers very low resistance.
- Large current flows.

Reverse Bias

n-side connected to +ve terminal and p-side to -ve terminal.



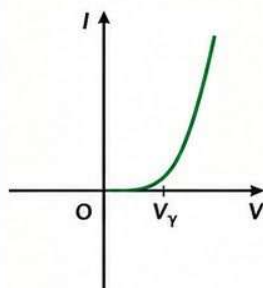
- Barrier potential increases.
- Offers very high resistance.
- Only a small leakage current flows.



The ratio of forward biased to reverse biased resistance for p-n junction diode is $10^{-4} : 1$

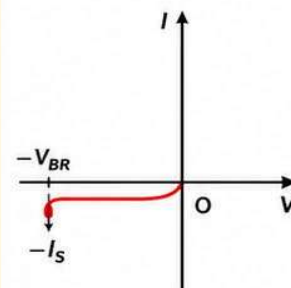
6 V-I CHARACTERISTICS OF DIODE

Forward Bias (Quadrant I)



- Current is almost zero until cut-in voltage (V_Y).
- After V_Y , current rises rapidly.
- $V_Y = 0.7 \text{ V (Si)}$
 $V_Y = 0.3 \text{ V (Ge)}$

Reverse Bias (Quadrant III)



- Small reverse saturation current ($-I_S$) flows.
- At breakdown voltage (V_{BR}), current increases sharply in reverse direction.

Information obtained from V-I characteristics

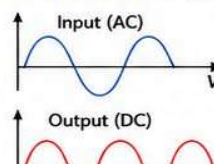
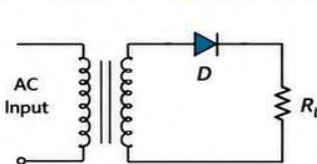
- Cut-in (knee) voltage (V_Y)
- Reverse saturation current (I_S) and breakdown voltage (V_{BR})

7 APPLICATION: DIODE AS RECTIFIER

A rectifier converts alternating current (AC) into direct current (DC) using diodes.

1. Half-Wave Rectifier

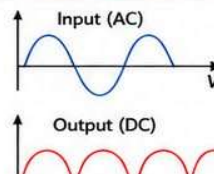
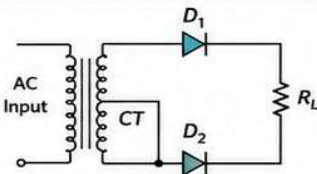
- One diode allows only one-half cycle of AC.
- Output is pulsating DC.



Average value of output direct current: $I_{DC} = \frac{I_o}{\pi}$

2. Full-Wave Rectifier

- Two diodes conduct in alternate half cycles.
- Output is full pulsating DC.
- Use of capacitor or inductor can filter pulsating DC into almost constant DC.



Average value of output direct current: $I_{DC} = \frac{2I_o}{\pi}$

Applications of Rectifiers



Powering DC motors



LED lighting systems



DC power supplies



Battery chargers



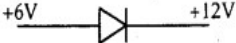
Radio and communication devices

Key Takeaways

- ✓ Semiconductors have a small energy band gap (Si: 1.1 eV, Ge: 0.74 eV).
- ✓ Doping creates n-type (extra electrons) and p-type (extra holes) materials.
- ✓ A p-n junction forms a depletion region and built-in potential.
- ✓ Diodes conduct in forward bias and block in reverse bias.
- ✓ Diodes are widely used as rectifiers to convert AC to DC.

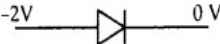
MULTIPLE CHOICE QUESTIONS

- 1 Carbon, silicon and Germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate ?
 - (a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
 - (b) The number of free conduction electrons is significant in C but small in Si and Ge.
 - (c) The number of free conduction electrons is negligibly small in all the three.
 - (d) The number of free electrons for conduction is significant in all the three.
- 2 In the energy band diagram of a semiconductor, if more charge carriers are seen near valence band. It would be
 - (a) an intrinsic semiconductor
 - (b) a metal may be n-type or p-type semiconductor
 - (c) an n-type semiconductor
 - (d) a p-type semiconductor
- 3 The peak voltage in the output of a half wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The d.c. component of the output voltage is
 - (a) $10/\sqrt{2}$ V
 - (b) $10/\pi$ V
 - (c) 10 V
 - (d) $20/\pi$ V
- 4 In which case is the junction diode forward biased.

(a) 

(c) 

(b) 

(d) 
- 5 Assuming that the junction diode is ideal, and resistor has resistance of $200\ \Omega$. The current in the arrangement shown here will be:



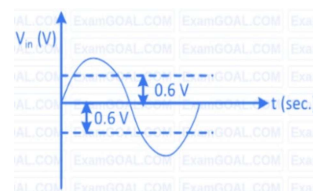
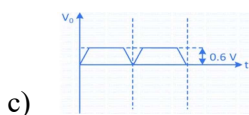
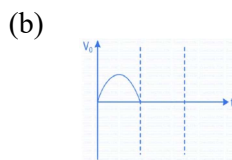
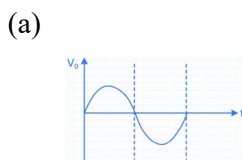
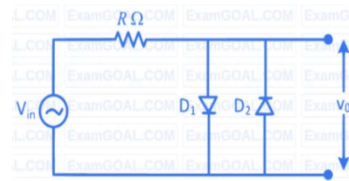
 - (a) 2 mA
 - (b) 30 mA
 - (c) 20 mA
 - (d) 10 mA
- 6 Which of following statements is not true?
 - (a) Resistance of an intrinsic semiconductor decreases with increase in temperature.
 - (b) Doping pure Si with trivalent impurities gives p-type semiconductor.
 - (c) The majority carriers in n-type semiconductor are holes.
 - (d) A p-n junction can act as semiconductor diode.
- 7 A student wants to identify diode from a mixed collection of diodes, resistors, inductors, switch, thyristors, bulb etc using a multimeter. choose the correct statement out of the following about the diode :
 - (a) It is two terminal device which conducts current in both directions.
 - (b) It is two terminal device which conducts current in one direction only.
 - (c) It does not conduct current gives an initial deflection which decays to zero.
 - (d) It is three terminal device which conducts current in the direction only between central terminal and either of the remaining two terminals.
- 8 If the two ends of a p-n junction are joined by a wire
 - (a) there will not be a steady current in the circuit
 - (b) there will be a steady current from the n-side to the p side
 - (c) there will be a steady current from the p-side to the n side
 - (d) there may or may not be a current depending upon the resistance of the connecting wire



Suppose all holes disappeared from a p-type semiconductor.

Would current stop completely? Could the material still conduct? Discuss scientifically.

- 9 The diffusion current in a p-n junction is from the
- n-side to the p-side
 - p-side to the n-side
 - n-side to the p-side if the junction is forward-biased and in the opposite direction it is reverse-biased
 - p-side to the n-side if the junction is forward-biased and in the opposite direction if it is reverse-biased
- 10 In the given circuit the input voltage V_{in} is shown in figure. The cut-in voltage of p-n junction diode (D_1 or D_2) is 0.6 V. Which of the following output voltage (V_0) waveform across the diode is correct?



ANSWERS

1. a, 2. d, 3. d, 4. b, 5. d, 6. c, 7. b, 8. a, 9. b, 10. d

ASSERTION- REASON BASED QUESTIONS

For these Questions two statements are given one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below

- If both Assertion and Reason are true and Reason is correct explanation of Assertion.
- If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
- If Assertion is true but Reason is false.
- If both Assertion and Reason are false.

- Assertion (A):** As the temperature of a semiconductor increases, its resistance decreases.
Reason (R): The energy gap between conduction band and valence band is $> 3\text{eV}$ in semiconductor.
- Assertion (A):** The resistivity of a semiconductor increases with temperature.
Reason (R): The atoms of a semiconductor vibrate with larger amplitude at higher temperature there by increasing its resistivity.
- Assertion(A):** Semiconductors are used to build digital logic circuits.
Reason(R): They cannot easily switch between high and low voltage states.



THINK LIKE AN ENGINEER: Why are impurities added in quantities as small as: # “1 atom per million atoms”

Why not add more impurities?

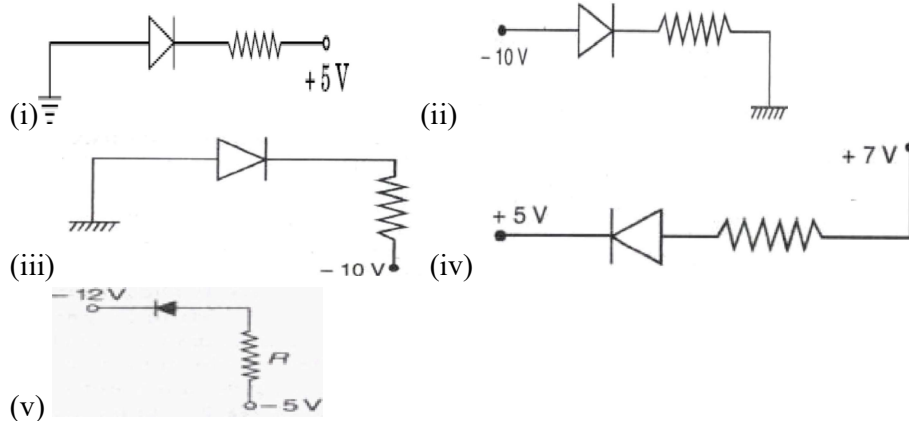
- 4 **Assertion(A):** In digital electronics, we prefer Integrated circuits or diodes etc made up of Silicon over Germanium.
Reason(R): Silicon has better thermal stability.
- 5 **Assertion(A):** In an intrinsic semiconductor, the Fermi level lies midway between conduction and valence bands.
Reason(R): There are more electrons than holes in an intrinsic semiconductor.
- 6 **Assertion(A):** The band gap of Germanium is higher than that of silicon.
Reason(R): Germanium has higher resistivity than silicon.
- 7 **Assertion (A):** The reverse current in a p-n junction diode increases rapidly at high reverse voltages.
Reason (R): High reverse bias causes a reduction in the barrier potential and enhances carrier injection.
- 8 **Assertion (A):** Ideal diode shows zero resistance in forward bias and infinite resistance in reverse bias.
Reason (R): Depletion region of a p-n junction diode extends in reverse bias and contracts in forward bias.
- 9 **Assertion (A):** A pure semiconductor has negative temperature coefficient of resistance.
Reason (R): In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.
- 10 **Assertion (A):** When diode is used as a rectifier, applied voltage should not be exceeded beyond specified reverse breakdown voltage.
Reason (R): When p-n junction diode crosses the reverse break down voltage, it get destroyed.

ANSWERS

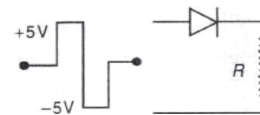
1. c, 2. d, 3. c, 4. a, 5. c, 6. d, 7. c, 8. a, 9. a, 10. a

VERY-SHORT ANSWER QUESTIONS

1. In the following circuit diagram, is the junction diode forward biased or reverse biased?



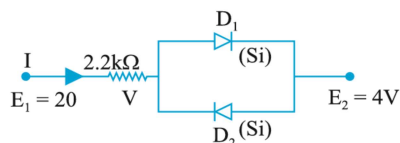
2. Draw and explain the output wave forms across the load resistor R, if the input waveform is as shown in the figure.



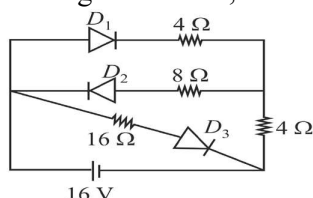
THINK LIKE A RESEARCHER : Suppose scientists create a diode with:

- zero cut-in voltage, zero power loss, no heating. How would technology change?

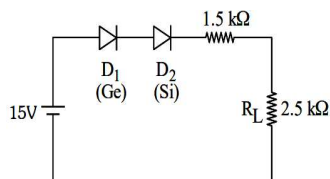
3. Determine the current for the network. (Barrier voltage for the Si diode is 0.7V)



4. A p-n diode is fabricated with a semiconductor with a band-gap of 2.8 eV. Can it detect a wavelength of 6000 nm?
5. In the given circuit, Find the current through the battery?



6. In the given circuit, Find the voltage across load resistance (R_L)

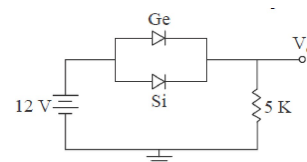


7. How are charge carriers created in an intrinsic semiconductor ? Explain.

8. Write two points of difference between intrinsic and extrinsic semiconductors.

9. Differentiate between n-type and p-type semiconductors.

10. Ge and Si diodes start conducting at 0.3 V and 0.7 V respectively. In the following figure if Ge diode connection are reversed, the value of V_o changes by ?



SHORT-ANSWER QUESTIONS

- (a) Draw the energy – band diagrams for conductors, semiconductors and insulators at $T = 0$ K. How is an electron-hole pair formed in a semiconductor at room temperature?
(b) Carbon and silicon both, are members of IV group of periodic table and have the same lattice structure. Carbon is an insulator whereas silicon is a semiconductor. Explain.
- Differentiate between half-wave and full-wave rectification. With the help of a circuit diagram, explain the working of a full-wave rectifier.
- In an intrinsic semiconductor, carrier's concentration is $5 \times 10^8 \text{ m}^{-3}$. On doping with impurity atoms, the hole concentration becomes $8 \times 10^{12} \text{ m}^{-3}$.
(a) Identify (i) the type of dopant and (ii) the extrinsic semiconductor so formed.
(b) Calculate the electron concentration in the extrinsic semiconductor.

4. Draw energy band diagrams of n-type and p-type semiconductors at temperature $T > 0$ K. Show the donor/acceptor energy levels with the order of difference of their energies from the bands.

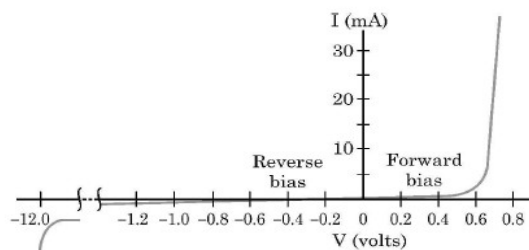


Imagine Earth suddenly loses all semiconductor technology for 24 hours.

Describe the impact? Would modern civilization survive normally? Explain scientifically.

5. A p-type Si semiconductor is made by doping an average of one dopant atom per 5×10^7 silicon atoms. If the number density of silicon atoms in the specimen is 5×10^{28} atoms m^{-3} , find the number of holes created per cubic centimetre in the specimen due to doping. Also give one of such dopants.
6. In an n-type semiconductor electron-hole combination is a continuous process at room temperature. Yet the electron concentration is always greater than the hole concentration in it. Explain.
7. (a) Draw circuit arrangement for studying V-I characteristic of a p-n junction diode.
(b) Show the shape of the characteristics of a diode.
(c) Mention two information that you can get from these characteristics.
8. (a) What are majority and minority charge carriers in an extrinsic semiconductor?
(b) A p-n junction is forward biased. Describe the movement of the charge carriers which produce current in it.
(c) The graph shows the variation of current with voltage for a p-n junction diode.
9. (a) What are majority and minority charge carriers of p-type and n-type semiconductors?
(b) Explain briefly the formation of diffusion current and drift current in a p-n junction diode.

Estimate the dynamic resistance of diode at $V = -0.6$ volt.



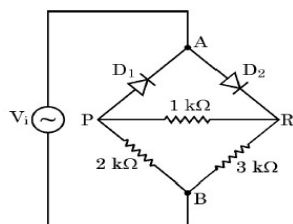
10. Explain the process of formation of 'depletion layer' and 'potential barrier' in a p-n junction region of a diode, with the help of a suitable diagram. Which feature of junction diode makes it suitable for its use as a rectifier?
11. A semiconductor has equal electron and hole concentration of $3 \times 10^8 \text{ m}^{-3}$. On doping with a certain impurity, the hole concentration increases to $6 \times 10^{10} \text{ m}^{-3}$.
(a) What type of semiconductor is obtained on doping?
(b) Calculate the new electron concentration of the semiconductor.
(c) How does the energy gap of semiconductor change with doping?
Draw the energy band diagram for it.
12. (a) Explain the working of a junction diode as a half-wave rectifier.
(b) The efficiency of a half-wave rectifier is 40%. What happens to the remaining 60% power?
13. Suppose a pure Si crystal has 5×10^{28} atoms per m^3 . It is doped with 5×10^{22} atoms per m^3 of Arsenic. Calculate the majority and minority carrier concentration in the doped silicon. (Given : $n_i = 1.5 \times 10^{16} \text{ m}^{-3}$)
14. Draw a circuit diagram of a full-wave rectifier using p-n junction diodes. Explain its working and show the input-output waveforms.



- **Integrated Circuits (ICs) combine thousands to billions of semiconductor components on a tiny chip.**

- Gallium Arsenide (GaAs) semiconductors are faster than silicon and are used in high-frequency applications.

15.



AN ac voltage $V_i = 12 \sin(100\pi t)V$ is applied between points A and B in a network of two ideal diodes and three resistors as shown in figure. During the positive half cycle of the input voltage V_i supplied to the network.

- Identify which of the two diodes will conduct and why ?
 - Redraw an equivalent circuit diagram to show the flow of current.
 - Calculate the output voltage drops V_O across the three resistors when the input voltage attains its peak value.
- Briefly explain the two important processes that occur during the formation of a p-n junction.
 - With the help of circuit diagrams, briefly explain the forward biasing and the reverse biasing of a p-n junction diode.
 - With the help of a circuit diagram, explain the working of a full wave rectifier. Depict the input and output waveforms.
 - The hole concentration in an intrinsic semiconductor is $5 \times 10^8 \text{ m}^{-3}$. When it is doped with certain impurity, the electron concentration becomes $4 \times 10^{12} \text{ m}^{-3}$. Find the new value of the hole concentration. Also identify the type of new semiconductor formed after doping.
 - A sample of Si doped with trivalent impurity and another Si sample which is doped with pentavalent impurity (each with impurity concentration 1 in million).

ANSWERS

- (a) In conductors valence and conduction bands overlap; in semiconductors they are separated by a small gap; in insulators by a large gap. At room temperature, thermal energy breaks some covalent bonds producing electron-hole pairs.
 - (b) Carbon has a larger band gap ($\sim 5.5 \text{ eV}$) so it behaves as an insulator, whereas silicon has a smaller band gap ($\sim 1.1 \text{ eV}$) and acts as a semiconductor.
- Half-wave rectifier uses one half cycle of AC while full-wave rectifier uses both half cycles, giving higher efficiency. In a full-wave rectifier, two diodes conduct alternately during positive and negative half cycles to produce pulsating DC.
- (a) (i) Dopant is trivalent impurity. (ii) Extrinsic semiconductor formed is p-type.
 - (b) Electron concentration = $3.125 \times 10^4 \text{ m}^{-3}$.
- In n-type semiconductor, donor level lies just below the conduction band; in p-type semiconductor, acceptor level lies just above the valence band. The energy difference is very small ($\sim 0.01 \text{ eV}$).
- Number of holes created = 10^{15} cm^{-3} . One suitable dopant is Boron (B).
- In n-type semiconductor, pentavalent impurities provide a large number of free electrons. Though electron-hole recombination occurs continuously, electrons remain much more than holes because electrons are majority carriers.



Pure silicon is like a quiet city. Doping adds “special citizens” that completely transform the city’s behaviour. Pentavalent atoms donate extra electrons. Trivalent atoms create electron vacancies called holes. This tiny modification powers the entire digital world.

7. (a) A battery, resistor, milli ammeter and p-n diode are connected in series with a voltmeter across the diode.
(b) Forward bias gives exponential rise in current; reverse bias gives very small reverse saturation current.
(c) Cut-in voltage and dynamic resistance can be obtained.
8. (a) Majority carriers are electrons in n-type and holes in p-type; minority carriers are holes in n-type and electrons in p-type.
(b) In forward bias, electrons from n-side and holes from p-side cross the junction and constitute current flow.
(c) Current increases rapidly after cut-in voltage in forward bias.
9. (a) In p-type: holes are majority and electrons are minority carriers. In n-type: electrons are majority and holes are minority carriers.
(b) Diffusion current is due to movement of majority carriers across the junction; drift current is due to movement of minority carriers under electric field.
Dynamic resistance: $r_d = \Delta V / \Delta I$.
10. Diffusion of electrons and holes across the junction leaves immobile ions near junction forming depletion layer. This creates an electric field called potential barrier. Unidirectional conductivity makes the diode useful as a rectifier.
11. (a) p-type semiconductor is formed.
(b) Electron concentration = $1.5 \times 10^6 \text{ m}^{-3}$.
(c) Energy gap remains almost unchanged on doping. Acceptor level appears just above valence band.
12. (a) In half-wave rectifier, diode conducts during one half cycle and blocks the other, producing pulsating DC.
(b) Remaining 60% power is lost as heat in the circuit components and unused AC output.
13. Majority carrier concentration = $5 \times 10^{22} \text{ m}^{-3}$.
Minority carrier concentration = $4.5 \times 10^9 \text{ m}^{-3}$.
14. A full-wave rectifier uses two diodes and a centre-tapped transformer. Each diode conducts during alternate half cycles, giving output current in the same direction for both halves.
15. (a) During positive half cycle, the forward biased diode conducts while reverse biased diode does not.
(b) Equivalent circuit contains conducting diode as short circuit and non-conducting diode as open circuit.
(c) At peak: $V_i = 12 \text{ V}$; voltage drops are found using voltage division rule.
16. The two important processes are diffusion of majority carriers across junction and formation of depletion region with potential barrier due to uncovered ions.

17. In forward bias, p-side is connected to positive terminal and n-side to negative terminal reducing barrier potential and increasing current. In reverse bias, barrier potential increases and only small reverse current flows.
18. In a full-wave rectifier, alternate diodes conduct in alternate half cycles so current through load remains in same direction. Output waveform contains both half cycles as pulsating DC.
19. New hole concentration = $6.25 \times 10^4 \text{ m}^{-3}$. Since electron concentration increases, semiconductor formed is n-type.
20. Si doped with trivalent impurity forms p-type semiconductor where holes are majority carriers. Si doped with pentavalent impurity forms n-type semiconductor where electrons are majority carriers.

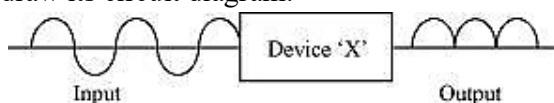


Build Your Own Analogy

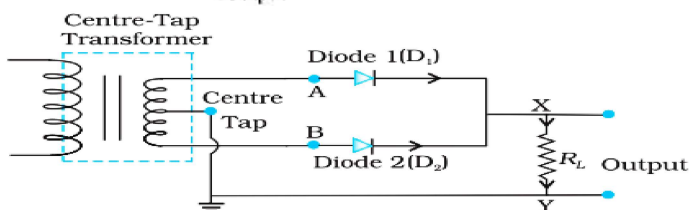
Explain semiconductor behaviour using: traffic system, water flow, school corridors, shopping mall, airport security

LONG ANSWER QUESTIONS

1. (a) Explain the formation of depletion layer and potential barrier in a p-n junction.
(b) In the figure given below the input waveform is converted into the output waveform by a device 'X'. Name the device and draw its circuit diagram.



2. (a) A student connects p-side of a **p-n junction** diode with positive terminal of battery and n-side is connected with negative terminal of battery. Another student connects the diode in opposite way with battery. Identify the biasing in both the cases. Draw the circuit diagram of these biasing of a p-n junction.



- (b) If the ratio of the concentration of electrons to that of holes in a semiconductor is $5/7$ and the ratio of currents is $4/7$. Find the ratio of their drift velocities.

ANSWERS

1. (a) When p-type and n-type semiconductors are joined, electrons and holes diffuse across the junction and recombine, leaving immobile ions near the junction. This region without free charge carriers is called the depletion layer, and the electric field developed across it forms the potential barrier.
(b) The device 'X' is a rectifier diode (p-n junction diode) used as a rectifier. A diode connected in series with a load resistor across an AC source gives pulsating DC output.
2. (a) When p-side is connected to positive terminal and n-side to negative terminal, the diode is forward biased. When connections are reversed, the diode is reverse biased. In forward bias, current flows easily; in reverse bias, only a small leakage current flows.
(b) Given $n/p = 5/7$ and $I_n/I_p = 4/7$. Using $I_n/I_p = (n v_n)/(p v_p)$, we get $v_n/v_p = 4/5$.
Hence, the ratio of drift velocities is $4 : 5$.

CASE STUDY-BASED QUESTIONS

1. Extrinsic semiconductors are made by doping pure or intrinsic semiconductors with suitable impurity.

There are two type of dopants used in doping, Si or Ge, and using them p-type and n-type semiconductors can be obtained. A p-n junction is the basic building block of many semiconductor devices. Two important processes occur during the formation of a p-n junction: diffusion and drift. When such a junction is formed, a depletion layer is created consisting of immobile ion-cores.

This is responsible for a junction potential barrier. The width of a depletion layer and the height of potential barrier changes when a junction is forward-biased or reverse biased. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for application of an external voltage. Using diodes, alternating voltages can be rectified.

(i) Which of the following is a donor impurity atom for Ge ?

- (a) Boron (b) Antimony (c) Aluminium (d) Indium

(ii) When a pentavalent atom occupies the position of an atom in the crystal lattice of Si, four of its electrons form covalent bonds with four silicon neighbours, while the fifth remains bound to the parent atom. The energy required to set this electron free is about :

- (a) 0.5 eV (b) 0.1 eV (c) 0.05 eV (d) 0.01 eV

(iii) During formation of a p-n junction :

- (a) a layer of negative charge on n-side and a layer of positive charge on p-side appear.
 (b) a layer of positive charge on n-side and a layer of negative charge on p-side appear.
 (c) the electrons on p-side of the junction move to n-side initially.
 (d) initially diffusion current is small, and drift current is large.

(iv) (a) In reverse-biased p-n junction :

- (a) the drift current is of the order of few mA.
 (b) the applied voltage mostly drops across the depletion region.
 (c) the depletion region width decreases.
 (d) the current increases with increase in applied voltage.

OR

(v) The output frequency of a full-wave rectifier with 50 Hz as input frequency is :

- (a) 25 Hz (b) 50 Hz (c) 100 Hz (d) 200 Hz

2. A p-n junction diode allows current to pass only when it is forward biased. So, if an alternating voltage is applied across a diode the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify alternating voltages and the circuit used for this purpose is called a rectifier.

If an alternating voltage is applied across a diode in series with a load, a pulsating voltage will appear across the load only during the half cycles of the ac input during which the diode is forward biased. Such rectifier circuit is called a half-wave rectifier.

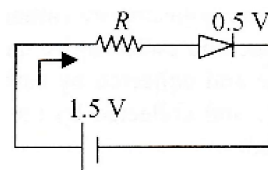
When two diodes are used to give output rectified voltage corresponding to both the positive as well as negative half of the ac cycle, it is known as *full-wave rectifier*.

The rectified voltage is in the form of pulses of the shape of half sinusoids. Though it is unidirectional it does not have a steady value. To get steady dc output from the pulsating voltage normally a capacitor is connected across the output terminals (parallel to the load R_L). One can also use an inductor in series with RL for the same purpose. Since these additional circuits appear to *filter* out the *ac ripple* and give a *pure dc* voltage, so they are called filters.

(i) In an unbiased p-n junction,

- (a) high potential at n-side and low potential at p-side
- (b) high potential at p-side and low potential at n-side
- (c) p and n both are at same potential
- (d) undetermined

- (ii) The diode used in the circuit shown in the figure has a constant voltage drop at 0.5 V at all currents and a maximum power rating of 100 milliwatts. What should be the value of the resistor R, connected in series with diode for obtaining maximum current?



- (a) 6.76Ω (b) 20Ω (c) 5Ω (d) 5.6Ω

- (iii) The average value of full wave rectified voltage with a peak voltage of 66 V is

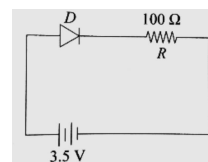
- (a) 66 V (b) 32 V (c) 42 V (d) 88 V

- (iv) The power delivered, and efficiency (for half wave rectifier and full wave rectifier) is

- (a) low for half wave rectifier
- (b) low for full wave rectifier
- (c) same for both half wave rectifier and full wave rectifier
- (d) can not say

OR

- (v) In the given figure, a diode D is connected to an external resistance $R = 100 \Omega$ and an emf of 3.5 V. If the barrier potential developed across the diode is 0.5 V. the current in the circuit will be:



- (a) 40 mA (c) 35 mA (b) 20 mA (d) 30 mA

ANSWERS

- | | | | | | |
|----|--------|---------|---------|-------------------|--------|
| 1. | i).b | (ii). c | (iii).b | (iv). b OR | (v). c |
| 2. | (i). a | (ii). c | (iii).d | (iv). a OR | (v).d |