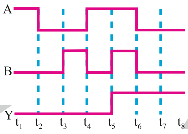


Unit IX

Electronic Devices

Unit IX
ELECTRONIC DEVICES

KEY POINTS

ELECTRONIC DEVICES

1. Solids are classified on the basis of

(i) Electrical conductivity	Resistivity	Conductivity
Metals	ρ(Ωm)	σ(Sm^{-1})
	$10^{-2} - 10^{-8}$	$10^{2} - 10^{8}$
Semi-conductors	$10^{-5} - 10^{6}$	$10^{-6} - 10^{5}$
Insulators	$10^{11} - 10^{19}$	$10^{-19} - 10^{-11}$

(ii) Energy Bands **(a) Metals →**

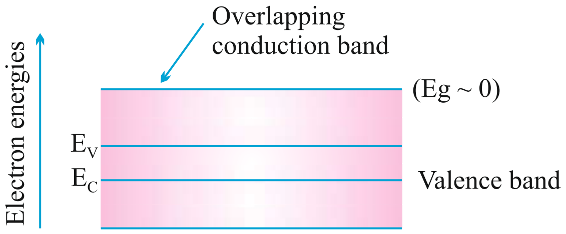


Fig. (*a*)

(b) Insulators →

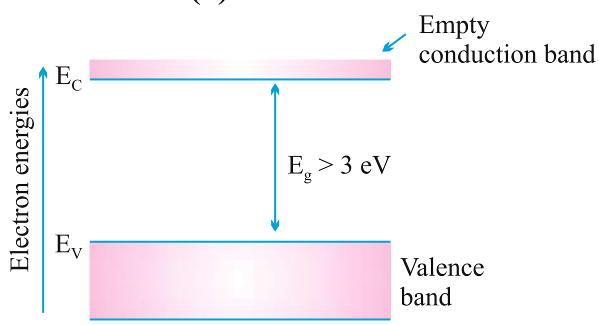


Fig (*b*)

(c) Semiconductors →

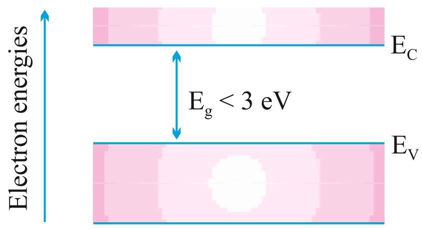


Fig (*c*)

2. Types of Semi-conductors

2 Types of semi-conductors

- Elemental
  Si, Ge
- Compound
  - Inorganic
    CdS, GaAS,
    CdSe, InP etc.
  - Organic, Anthracene
    Doped Pthalocyamines etc.

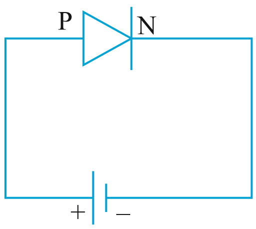
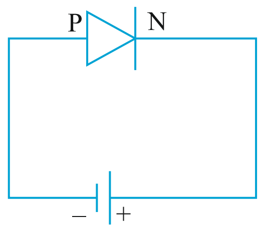
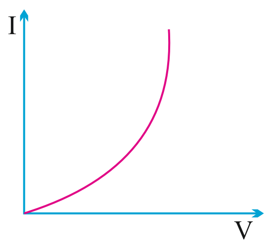
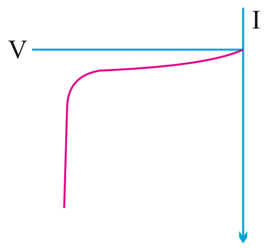
3. In intrinsic semiconductors (Pure Si, Ge) carrier (electrons and holes) are generated by breaking of bonds within the semiconductor itself. In extrinsic semiconductors carriers (*e* and *h*) are increased in numbers by 'doping'.

4. An intrinsic semiconductor at 0 K temperature behaves as an insulator.

5. Pentavalent (donor) atom (As, Sb, P etc) when doped to Si or Ge give *n*-type and trivalent (acceptor) atom (In, Ga, Ag, etc) doped with Si or Ge give *p*-type semiconductor. In *n*-type semiconductor electrons are the majority charge carriers & in *p*-type holes are the majority charge carriers.

6. Net charge in *p*-type or *n*-type semiconductor remains zero.
7. Diffusion and drift are the two processes that occur during formation of *p-n* junction.
8. Diffusion current is due to concentration gradient and drift current is due to electric field.
9. In depletion region movement of electrons and holes depleted it of its free charges.
10. *p-n* Junction is the most important semiconductor device because of its different behaviours in forward biasing (as conductor for $V > V_b$) and reverse biasing (as insulator for $V < V_b$) a *p-n* junction can be used as Rectifier, LED, photodiode, solar cell etc.

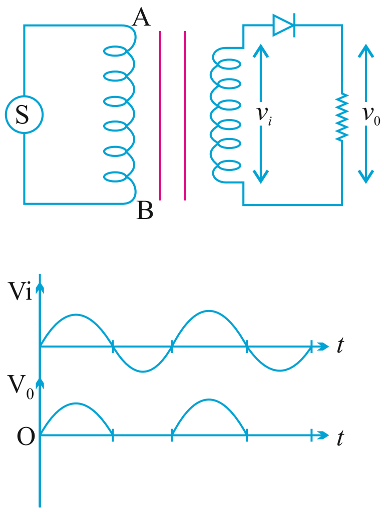
Differences between FB and RB junction diodes :

Forward Bias	Reverse Bias
	
Depletion layer is decreased	Depletion layer is increased
Lower resistance	Higher resistance
$R \rightarrow 0$ ideal diode	$R \rightarrow \infty$ ideal diods
	
Current due to majority charge carrier.	Current due to minority charge carrier.

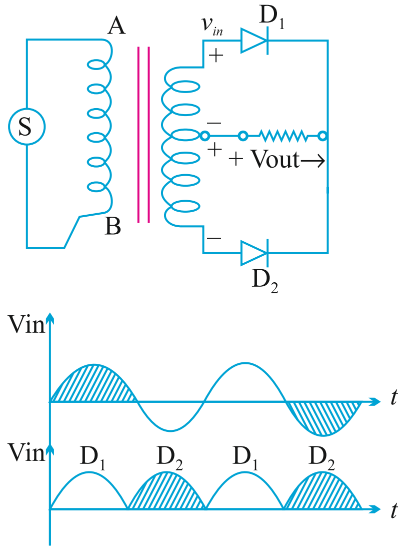
11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

Rectifier p-n junction diode

Half Wave Rectifier



Full Wave Rectifier



12. When a zener diode is reverse biased, voltage across it remains steady for a range of currents above zener breakdown. Because of this property, the diode is used as a voltage regulator.

QUESTIONS

Chapter 14- Semiconductor Electronics : Materials, Devices and Simple Circuits

1. Let n_h and n_e be the number of holes and conduction electrons in an extrinsic semiconductors. Then—

   (a) $n_h > n_h$ (b) $n_h = n_e$

   (c) $n_h < n_e$ (c) $n_h \neq n_e$

2. Electric conduction in a semiconductor takes place due to

   (a) electrons only (b) holes only

   (c) both electrons and holes (d) neither electrons nor holes

3. In a p-type semiconductor, the current conduction is due to—

   (a) holes (b) protons

   (c) electrons (d) neutrons

4. What happens to the resistance of semiconductors on heating?

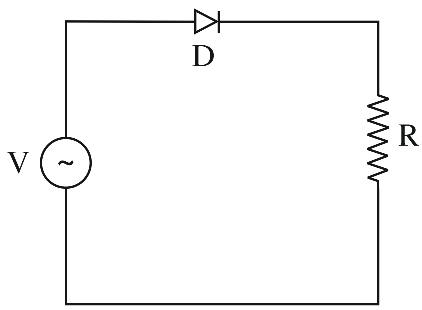
   (a) Increases

   (b) decreases

   (c) Remains same

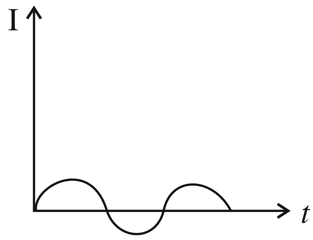
   (d) First decreases than increase

5. A half wave rectifier circuit is constructed using a p-n function diode D, load resistance R and AC source as shown below:

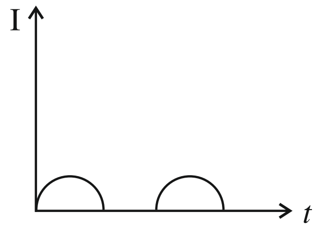


The output current through R varies as—

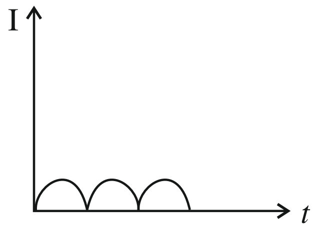
(a)



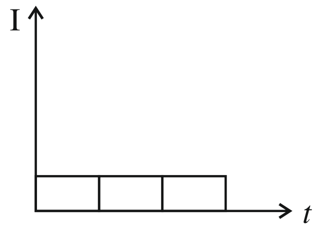
(b)



(c)



(d)



Answers

1. (d) 2. (c) 3. (a) 4.(b) 5. (b)

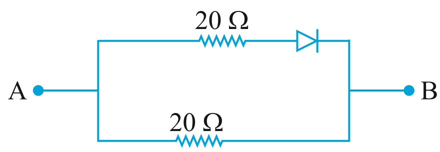
SHORT ANSWER QUESTIONS (2 MARKS)

1. If the frequency of the input signal is f. What will be the frequency of the pulsating output signal in case of :

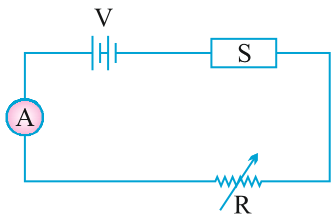
   (i) half wave rectifier ?   (ii) full wave rectifier ?

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



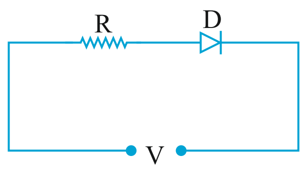
3. Potential barrier of *p-n.* junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why ?
4. Diode is a non linear device. Explain it with the help of a graph.
5. A *n*-type semiconductor has a large number of free electrons but still it is electrically neutral. Explain.
6. 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.



7. In the given circuit, D is an ideal diode. What is the voltage across R ? When the applied voltage V makes the diode.

(a) Forward bias ?

(b) Reverse bias ?



8. What are the characteristics to be taken care of while doping a semiconductor ? Justify your answer.

Ans. (a) The size of the dopant atom should be such that it do not distort the pure semiconductor lattice.

(b) It can easily contribute a charge carrier on forming covalent bond with pure Si or Ge.

9. Give two examples each of
(i) elemental (ii) compound inorganic semiconductors
(iii) compound organic semiconductors

10. Show the donor energy level in energy band diagram of *n*-type semiconductor.

11. Show the acceptor energy level in energy band diagram of *p*-type semiconductor.

12. What is the value of knee voltage in

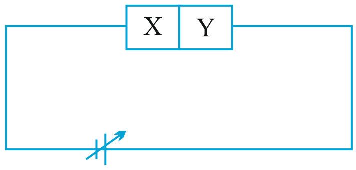
(a) Ge junction diode.

(b) Si junction diode.

13. On the basis of energy band diagrams, distinguish between metals, insulators and semiconductors.

14. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two

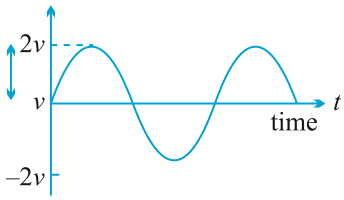
are joined at lattice level and connected to a battery as shown.



(i) Will the junction be forward biased or reversed biased ?

(ii) Sketch a V-I graph for this arrangement.

15. Following voltage waveform is fed into half wave rectifier that uses a silicon diode with a threshold voltage of 0.7 V. Draw the output voltage waveform.



SHORT ANSWER QUESTIONS (3 MARKS)

1. What is depletion region in *p-n* junction diode. Explain its formation with the help of a suitable diagram.

2. What is rectification ? With the help of labelled circuit diagram explain half wave rectification using a junction diode.

3. With the help of a circuit diagram explain the V–I graph of a *p-n* junction in forward and reverse biasing.

4. What is *p-n* junction ? How is *p-n* junction made ? How is potential barrier developed in a *p-n* junction.

5. Give three differences between forward bias and reverse bias.

6. Draw the characteristic (V-I) curve of a junction diode. Write down in your graph the approximate values of voltage and current. On the basis of your graph, explain how a junction diode works in forward biasing and reverse biasing.

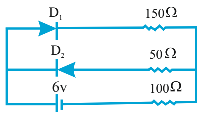
7. Write three differences between *n*-type semiconductor and *p*-type semiconductor.

LONG ANSWER QUESTIONS (5 MARKS)

1. What is *p-n* junction diode ? Define the term dynamic resistance for the junction. With the help of labelled diagram, explain the working of *p-n* junction as a full wave rectifier.

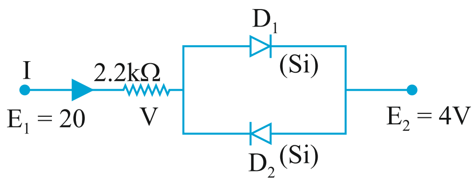
NUMERICALS

1. In a *p-n* junction, width of depletion region is 300 nm and electric field of 7×10^5 V/m exists in it.
   (i) Find the height of potential barrier.
   (ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the *n*-side to the *p*-side ?
2. The circuit shown in the figure contains two diodes each with a forward resistance of 50 ohm and with infinite reverse resistance. If the battery voltage is 6 V, Find the current through the 100 ohm resistance (in ampere).

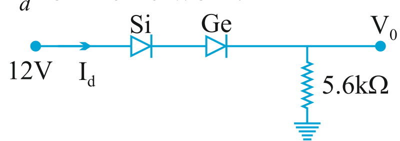


Ans. 0.02A

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



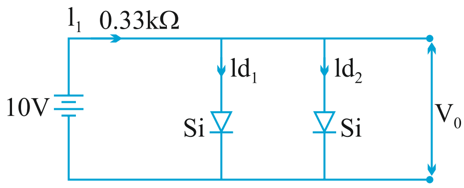
4. Determine V_0 and I_d for the network.



5. A *p-n* junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm ? Justify your answer.

Ans. Eneryg of photon of wavelength 600 *n m* = 2.07 eV .... working condition of photodiode $h\nu$ > Eg but Eg > $h\nu$ so photodiode can not detec the given wavelength

6. Determine V_0, I_{d1} and I_{d2} for the given network. Where D_1 and D_2 are made of silicon. $\left(I_{d_1} = I_{d_2} = \frac{I_1}{2} = 14.09 \text{ mA}\right)$



Ans. $V_0 = V_{si} = 0.7V$

$$I_1 = \frac{10-0.7}{.33\times 10^3}$$

$= 28.18$ mA

$$\therefore \quad I_{d_1} = I_{d_2} = \frac{28.18}{2}$$

$= 14.09\ mA$

7. Pure Si at 300 K has equal electron (n_e) and hole (n_h) concentration of $1.5 \times 10^{16}/m^3$. Doping by indium increases n_h to $4.5 \times 10^{22}/m^3$. Calculate n_e in the doped silicon. [**Ans. :** $5 \times 10^9\ m^{-3}$]

SHORT ANSWER QUESTIONS (2 MARKS)

1. Frequency of output in half wave rectifier is *f* and in full have rectifier is 2*f*.

2. Equivalent resistance is

(i) 10Ω, As diode is forward biased

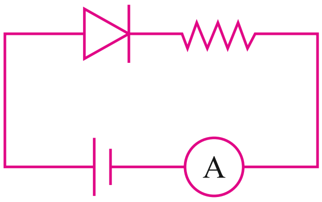
(ii) 20Ω, diode is reverse biased

3. Because there is no free charge carrier in depletion region.

6. On heating S, resistance of semiconductors S is decreased so to compensate the value of resistance in the circuit R is increased.

Assertion - Reason question (Semiconductor)

1. Assertion : A pure semiconductor has negative temperature coefficient.
   Reason : On increasing temperature, charge carriers are generated.
2. Assertion : In the given diagram, the ammeter will NOT show any reading (consider diode to be ideal)

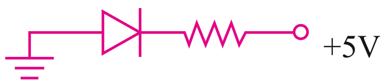


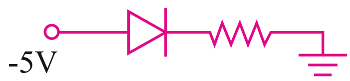
   Reason : An ideal diode offers infinite resistance in forward bias.
3. Assertion: Electron has higher mobility than hole in a semi-conductor
   Reason: The mass of electron is less than hole.
4. Assertion: A p-type semi-conductor is a positive type crystal
   Reason: A p-type semi -conductor is an uncharged crystal
5. Assertion : In a n-type semiconductor holes are majority carriers & electrons are minority carriers.
   Reason : The net charge on a p-type semiconductor is positive.

Case Study Question

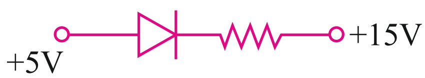
When an intrinsic semiconductor is doped with group-15 and group-13 elements we get a new semiconductor called extrinsic semiconductor. Adding impurities to extrinsic semiconductors is called doping, when the two extrinsic semiconductors are joined the resultant device is called junction diode. Applying suitable voltage across a diode is called biasing . There are two types of biasing- forward biasing and reverse biasing. We have different types of special purpose diodes used in specific biasing mode according to the purpose.

1. When X is added in a pure silicon we get a p-type semiconductor. The X is-
   a) Carbon
   b) Germanium
   c) Indium
   d) Arsenic
2. An intrinsic semiconductor is doped with an impurity, the resultant semiconductor contains electron as mojority carrier- The impurity is-
   a) Aluminum
   b) Indium
   c) Phosphorous
   d) Carbon
3. Ideal diode has resistance of ______ Ω in forward biasing
   a) 10
   b) 0
   c)
   d) 100
4. In which of the following figure, the diode is forward biased -

a) 

b) 

c) 

d) 

5. Which of the following is true for a diode in forward bias-

a) The width of depletion layer is increased

b) The height of potential barrier is decreased

c) The conduction is due to minority charge carriers

d) The junction resistance is increased

Answers Assertion-Reasoning Questions

1. (a) 2. (d) 3. (a) 4. (d) 5. (d)

Case study questions

1. (c) 2. (c) 3. (c) 4. (c) 5. (b)

NUMERICALS

1. (i) $V = Ed = 7 \times 10^5 \times 300 \times 10^{-9} = 0.21$ V

(ii) Kinetic energy = eV = 0.21 eV

3. $$I = \frac{E_1 - E_2 - V_d}{R} = \frac{20 - 4 - 0.7}{2.2 \times 10^3} = 6.95 \text{ mA}$$

4. $V_0 = E - V_{si} - V_{Ge} = 12 - 0.7 - 1.1 = 12 - 1.8 = 10.2$ V

$$I_d = \frac{V_0}{R} = \frac{10.2}{5.6 \times 10^3} = 1.82 \text{ mA.} \quad V_0 = 12 - 0.7 - 0.3 = 11 \text{ V}$$

$$I_d = \frac{11}{5.6 \times 10^3} = 1.96 \text{ mA}$$

❑❑