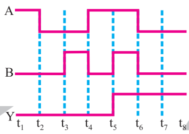


Unit IX

ELECTRONIC DEVICES

KEY POINTS

ELECTRONIC DEVICES

1. Solids are classified on the basis of

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

(ii) Energy Bands **(a) Metals →**

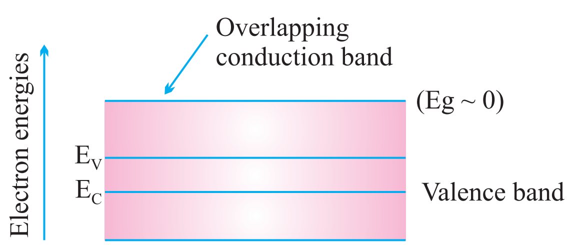


Fig. (*a*)

(b) Insulators →

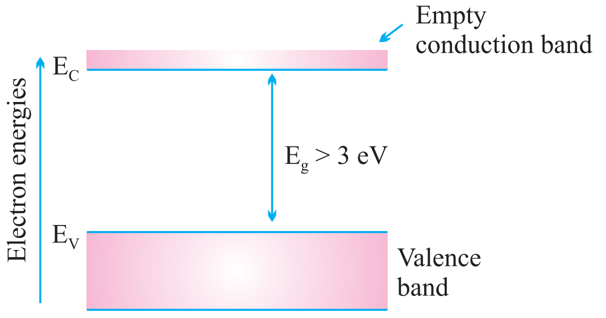


Fig (*b*)

(c) Semiconductors →

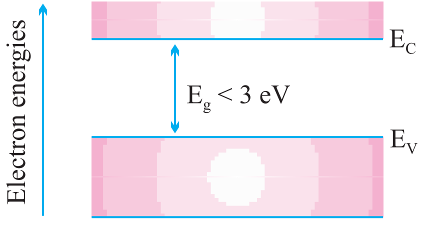


Fig (*c*)

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.

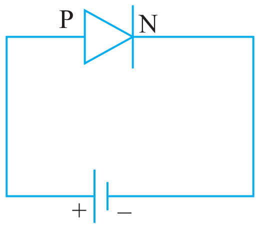
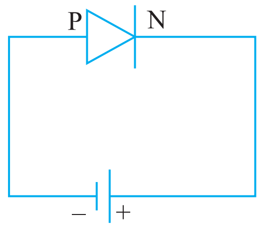
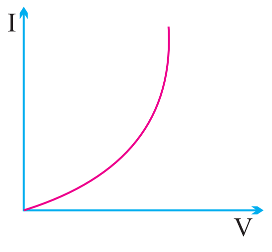
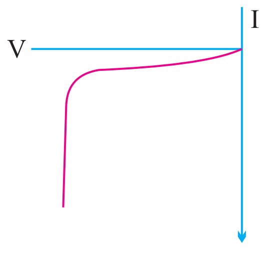
3. In intrinsic semiconductors (Pure Si, Ge) carrier (electrons and holes) are generated by breaking of bonds within the semiconductor itself. In extrinsic semiconductors carriers (*e* and *h*) are increased in numbers by 'doping'.

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 (accestor) 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.

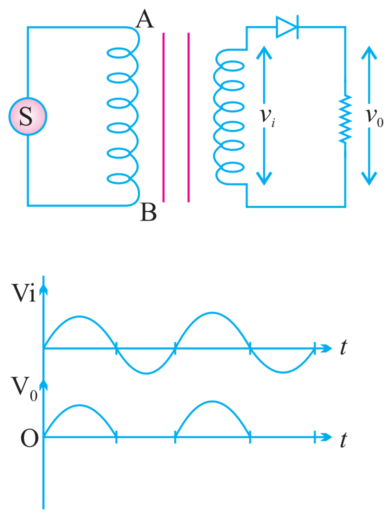
    Differences between FB and RB junction diodes :

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.

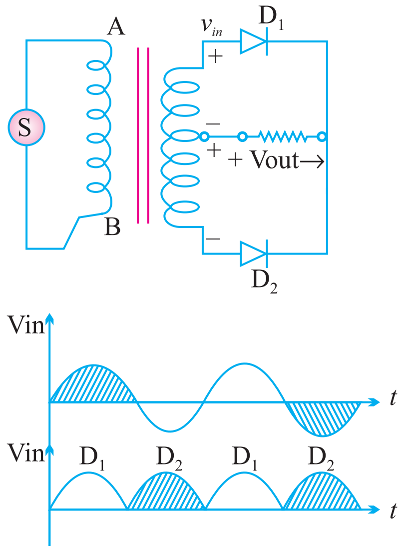
11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

    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

VERY SHORT ANSWER QUESTIONS

1. Name the process involved in the formation of *p-n* junction diode. [Drift and Diffusion]
2. Name three processes involved in the formation of solar cell. [generation, separation and collection]
3. Distinguish between intrisic and extrinsic semiconductors on the basis of energy band diagrams.
4. How does energy gap in intrinsic semiconductor vary when it is doped with a(i) pentavalent impurity (ii) trivalent impurity?
5. Which type of extrinsic semiconductor has more mobility and why?

6. Name the factors which determines (i) frequency and (ii) intensity of light emitted by LED. [(i) Bandgap (ii) doping]

7. How does the width of depletion region of a *p-n* junction diode change with decrease in reverse bias?

8. What is the direction of diffusion current in a function diode? [*p-n*]

9. Zener diode has higher dopant density as compared to ordinary *p-n* function diode. How does it effect (i) width of deflection layer and (ii) function field.

[(i) ↓ (ii) ↑ as $E_{\beta} = \frac{V_B}{d}$]

10. How does the height of potential barrier vary with increase in temp. [↑]

11. Write the relation between number density of holes and number density of free electrons in an intrinsic semiconductor.

Ans. $n_e = n_h$

12. Write the value of resistance offered by an ideal diode when (i) forward based (ii) reverse biased.

Ans. (i) Zero (ii) infinite

13. Write any one use of (i) photodiode (ii) LED.

Ans. (i) Use of Photodiode
(a) In detection of optical signal
(b) In demodulation of optical signal
(c) In light operated switches
(d) In electronic counters

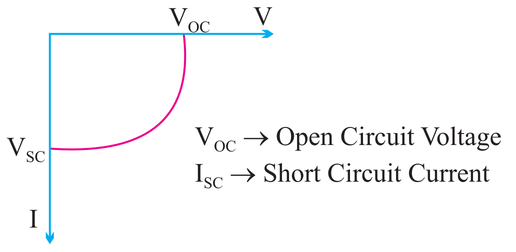
(ii) Use of LED
(a) Infrared LEDs are used in burglar alarm
(b) In optical communication
(c) LED's are used as indicator lamps in radio receivers
(d) In remote controls

14. A semiconductor is damaged when strong current passes through it. Why ?

Ans. Because bonds break up, crystal lattice breakdown takes place and crystal lattice becomes useless.

15. Draw I–V characteristic of a solar cell.

Ans.



16. What is the direction of diffusion current in a junction diode ?

Ans. The direction of diffusion current is from P to N in a semiconductor junction diode.

17. Draw a circuit diagram showing the biasing of a photodiode.

18. Name the semiconductor device that can be used to regulate an unregulated dc power supply.

Ans. Zener diode

19. Name the *p-n* junction diode which emits spontaneous radiation when forward biased.

Ans. Light emitting diode (LED)

20. Name the material used to make a light emitting diode.

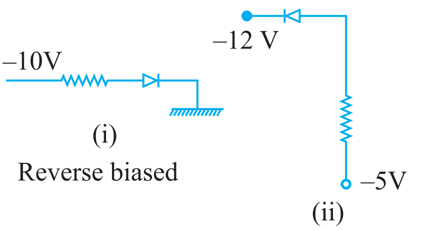
Ans. GaAs and GaP

21. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. When polarity of the battery is reversed, the current drops to almost zero. Name the semiconductor device.

Ans. P–N junction

(Junction Diode)

22. In the following diagram write which of the diode is forward biased and which is reverse biased ?



(i) Reverse biased

(ii) Forward biased

23. How does the energy gap in semiconductor vary, when doped, with a pentavalent impurity ?

Ans. The energy gap decreases.

19. What is the order of energy gap in a conductor, semiconductor and insulator.

Ans. Conductor–no energy gap

Semiconductor < 3 eV

Insulator > 3 eV

20. The ratio of the number of free electrons to holes n_e/n_h for two different materials A and B are 1 and < 1 respectively. Name the type of semiconductor to which A and B belong.

Ans. $\frac{n_e}{n_h} = 1 \Rightarrow n_e = n_h$ $\therefore$ Intrinsic semiconductor

$\frac{n_e}{n_h} < 1 \Rightarrow n_e < n_h$ $\therefore$ *p* type extrinsic semiconductor

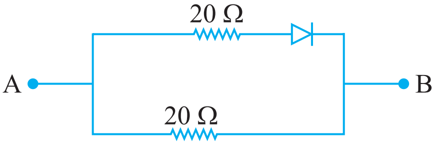
SHORT ANSWER QUESTIONS (2 MARKS)

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

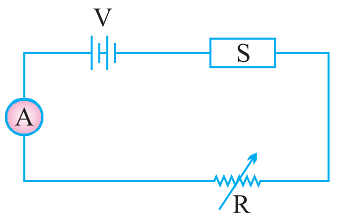


3. Potential barrier of *p-n*. junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why ?

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.

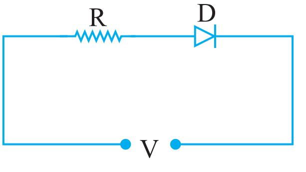
6. The diagram shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter A constant, when semiconductor S is heated ? Give reason.



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 dopent atom should be such that it do not distort the pure semiconductor labtice.

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

9. Which special type of diode can act as a voltage regulator ? Give the symbol of this diode and draw the general shape of its V-I characteristics.

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.

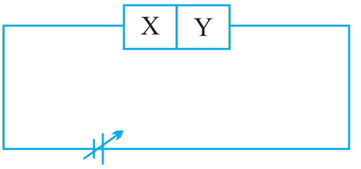
12. What is the value of knee voltage in

(a) Ge junction diode.

(b) Si junction diode.

13. Describe the working principle of a solar cell. Mention three basic processes involved in the generation of emf.

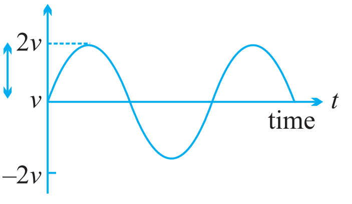
14. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two are joined at lattice level and connected to a battery as shown.



(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. Show the biasing of a photodiode with the help of a circuit diagram. Draw graphs to show variations in reverse bias currents for different illumination intensities.

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

LONG ANSWER QUESTIONS (5 MARKS)

3. 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

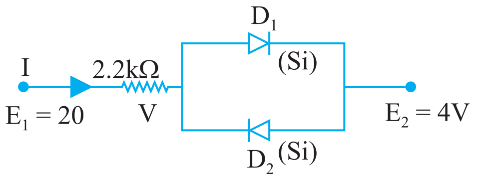
1. In a *p-n* junction, width of depletion region is 300 nm and electric field of 7×10^5 V/m exists in it.

(i) Find the height of potential barrier.

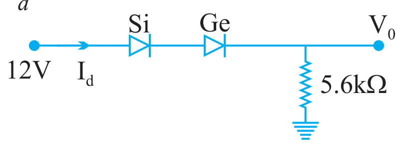
(ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the *n*-side to the *p*-side ?

2. An LED is constructed from a *p-n* junction of a certain semiconducting material whose energy gap is 1.9eV. What is the wavelength of light emitted by this LED ? [**Ans.** $\lambda = 6.54 \times 10^{-7}$ m]

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.

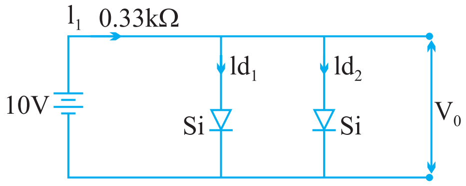


5. A *p-n* junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm ? Justify your answer.

Ans. Eneryg of photon of wavelength 600 *n m* = 2.07 eV .... working condition of photodiode *hv* £ Eg but Eg > *hv* so photodio can not detecthe 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. $V_0 = V_{si} = 0.7V$

$$I_1 = \frac{10-0.7}{.33\times10^3}$$

$= 28.18$ 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. :** 5×10^9 m^{-3}]

8. The solar radiation spectrum shows that maximum solar intensity is near to energy $h\nu$ = 1.5 eV. Answer the following :

(i) Why are Si and GaAs are preferred materials for solar cells.

(ii) Why Cd S or CdSe (Eg ~ 2.4 eV) are not preferred.

(iii) Why we do not use materials like PbS (Eg ~ 0.4 eV).

Ans. (i) For photo-excitation, $h\nu$ > Eg. Si has Eg. ~ 1.1 eV and for GaAs, Eg. ~ 1.53 eV.

GaAs is better than Si because of its relatively higher absorption coefficient.

(ii) If we choose CdS or CdSe, we can use only the high energy component of the solar energy for photo-conversion and a significant part of energy will be of no use.

(iii) The condition $h\nu$ > Eg. is satisfied, but if we use Pbs, most of solar radiation will be absorbed on the top-layer of solar cell and will not reach in or near depletion region.

SHORT ANSWER QUESTIONS (2 MARKS)

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

2. Equivalent resistance is

(i) 10Ω, As diode is forward biased

(ii) 20Ω, diode is reverse biased

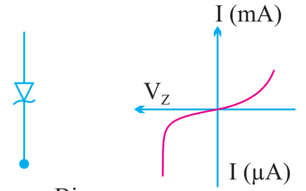
3. Because there is no free charge carrier in depletion region.

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

9. In this case diode is sensitive and it is easier to observe fractional change in current with change in intensity.

16. (a) V (b) Zero

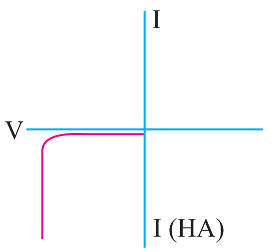
21. Zener diode



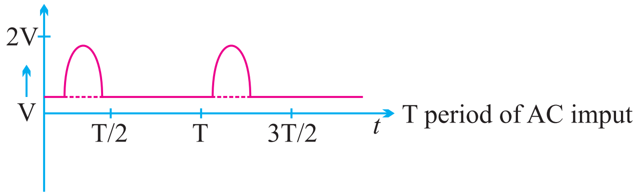
(i) Reverse Bias (ii) V-I characterstic

26. Ge ~ 0.3 V
Si ~ 0.7 V

29. (i) Reverse bias
(ii)



31. Output waveform is :



NUMERICALS

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

(ii) Kinetic energy = eV = 0.21 eV

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

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

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

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

❑❑