PRACTICE PAPER 14
CHAPTER 14 ELECTRONIC DEVICES

SUBJECT: PHYSICS **MAX. MARKS : 40**
CLASS : XII **DURATION : 1½ hrs**

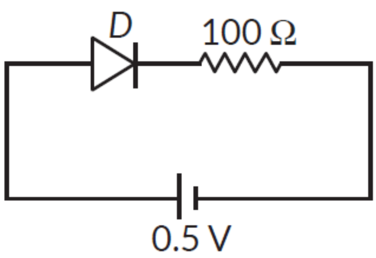
General Instructions:
(i). **All** questions are compulsory.
(ii). This question paper contains 2**0** questions divided into five Sections A, B, C, D and E.
(iii). **Section A** comprises of **10 MCQs** of **1 mark** each. **Section B** comprises of 4 questions of **2 marks** each. **Section C** comprises of 3 questions of **3 marks** each. **Section D** comprises of 1 question of **5 marks** each and **Section E** comprises of 2 Case Study Based Questions of **4 marks** each.
(iv). There is no overall choice.
(v). Use of Calculators is not permitted

SECTION – A
Questions 1 to 10 carry 1 mark each.

1. A pure Si crystal having 5×10^{28} atoms m^{-3} is dopped with 1 ppm concentration of antimony. If the concentration of holes in the doped crystal is found to be 4.5×10^{9} m^{-3}, the concentration (in m^{-3}) of intrinsic charge carriers in Si crystal is about
(a) 1.2×10^{15} (b) 1.5×10^{16} (c) 3.0×10^{15} (d) 2.0×10^{16}

2. The energy required by an electron to jump the forbidden band in silicon at room temperature is about
(a) 0.01 eV (b) 0.05 eV (c) 0.7 eV (d) 1.1 eV

3. The threshold voltage for a p-n junction diode used in the circuit is 0.7 V. The type of biasing and current in the circuit are



(a) Forward biasing, 0A (b) Reverse biasing, 0 A
(c) Forward biasing, 5mA (d) Reverse biasing, 2 mA

4. In an extrinsic semiconductor, the number density of holes is 4 × 1020 m –3. If the number density of intrinsic carriers is 1.2 × 1015 m –3, the number density of electrons in it is:
(a) 1.8×10^{9} m^{-3} (b) 2.4×10^{10} m^{-3} (c) 3.6×10^{9} m^{-3} (d) 3.2×10^{10} m^{-3}

5. The formation of depletion region in a p-n junction diode is due to:
(a) movement of dopant atoms
(b) diffusion of both electrons and holes
(c) drift of electrons only
(d) drift of holes only.

6. Which one of the following elements will require the highest energy to take out an electron from them? Pb, Ge, C and Si
(a) Ge (b) C (c) Si (d) Pb

7. At equilibrium, in a p-n junction diode the net current is:
(a) due to diffusion of majority charge carriers

(b) due to drift of minority charge carriers
(c) zero as diffusion and drift currents are equal and opposite
(d) zero as no charge carriers cross the junction.

8. In an n-type semiconductor, the donor energy level lies:
(a) at the centre of the energy gap
(b) just below the conduction band
(c) just above the valence band
(d) in the conduction band.

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** The temperature coefficient of resistance is positive for metals and negative for p-type semiconductors.
Reason (R): The charge carriers in metals are negatively charged, whereas the majority charge carriers in p-type semiconductors are positively charged.

10. **Assertion (A):** The electrical conductivity of a semiconductor increases on doping.
Reason (R): Doping always increases the number of electrons in the semiconductor.

SECTION – B

Questions 11 to 14 carry 2 marks each.

11. Answer the following giving reasons:
(a) A p-n junction diode is damaged by a strong current.
(b) Impurities are added in intrinsic semiconductors.

OR

Draw V–I characteristics of a p–n junction diode. Explain, why the current under reverse bias is almost independent of the applied voltage up to the critical voltage.

12. Distinguish between an intrinsic semiconductor and p-type semiconductor.
Give reason, why p-type semiconductor crystal is electrically neutral, although $n_h >> n_e$?

OR

(a) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor?
(b) What type of extrinsic semiconductor is formed when
(i) germanium is doped with indium?
(ii) silicon is doped with bismuth?

13. (a) Which charge carriers in intrinsic semiconductor will have conduction?
(b) How does the resistance of a semiconductor change when heated?

OR

Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of Antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it.

14. (a) Why a pure semiconductor behaves like an insulator at 0 K?
(b) Why is the energy gap much more in silicon than in germanium?

OR

Answer the following questions.

(i) Can the potential barrier across a p-n junction be measured by simply connecting a voltmeter across the junction?

(ii) Why are elemental dopants for Silicon or Germanium usually chosen from group 13 or group 15?

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. Explain with the help of a diagram, how depletion region and potential barrier are formed in a junction diode. How does (a) an increase in the doping concentration, and (b) biasing across the junction, affect the width of the depletion layer?

OR

Draw energy band diagrams of n-type and p-type semiconductors at temperature T > 0 K, depicting the donor and acceptor energy levels. Mention the significance of these levels.

16. Explain the following, giving reasons:

(a) A doped semiconductors is electrically neutral.

(b) In a p - n junction under equilibrium, there is no net current.

(c) In a diode, the reverse current is practically not dependent on the applied voltage.

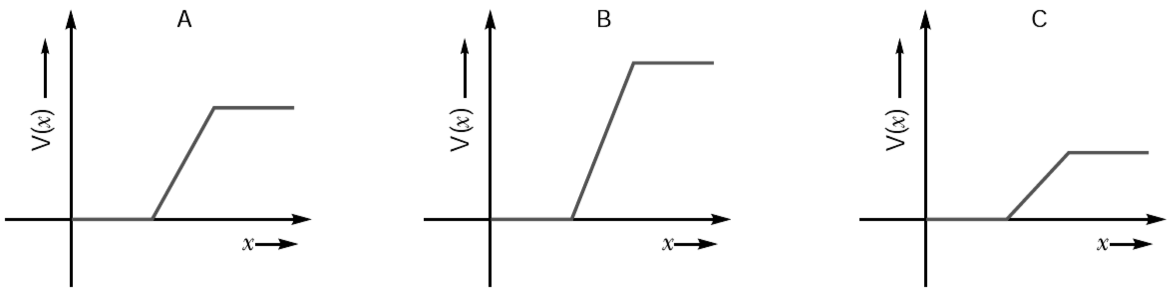
OR

Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases.

17. What will the effect of (i) forward biasing, and (ii) reverse biasing be on the width of depletion layer in p-n junction diode?

OR

The graph of potential barrier versus width of depletion region for an unbiased diode is shown in A. In comparison to A, graphs B and C are obtained after biasing the diode in different ways. Identify the type of biasing in B and C and justify your answer.



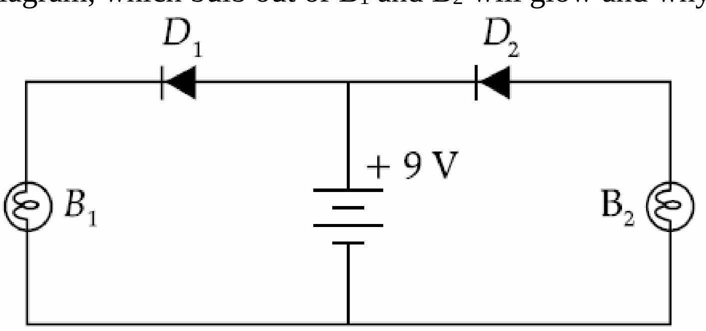
SECTION – D

Questions 18 carry 5 marks.

18. Draw a labelled circuit diagram of a full-wave rectifier and briefly explain its working principle. Give its input and output waveforms.

OR

(a) In the following diagram, which bulb out of B_1 and B_2 will glow and why?

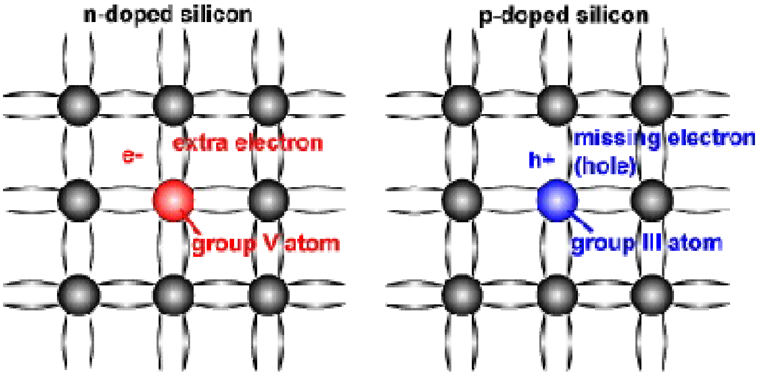


(b) Draw a diagram of an illuminated p-n junction solar cell.
(c) Explain briefly the three processes due to which generation of emf takes place in a solar cell.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. A pure semiconductor like Ge or Si, when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a p-n junction by doping it with suitable impurity. Two processes, diffusion and drift take place during formation of a p-n junction. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. A p-n junction allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration.



(i) When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about:
(a) 0.001 eV (b) 0.01 eV (c) 0.72 eV (d) 1.1 eV

(ii) At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0×10^{10} cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8×10^{3} cm^{-3}. The number of electrons in the semiconductor is:
(a) 2×10^{24} m^{-3} (b) 4×10^{23} m^{-3} (c) 1×10^{22} m^{-3} (d) 5×10^{22} m^{-3}

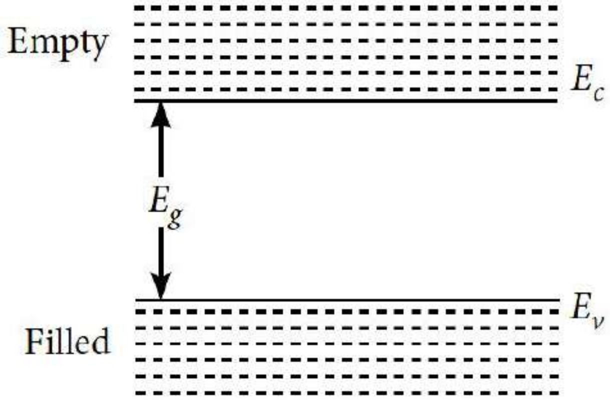
(iii) During the formation of a p-n junction:
(a) electrons diffuse from p-region into n-region and holes diffuse from n-region into p-region.
(b) both electrons and holes diffuse from n-region into p-region.
(c) electrons diffuse from n-region into p-region and holes diffuse from p-region into n-region.
(d) both electrons and holes diffuse from p-region into n-region.

(iv) Initially during the formation of a p-n junction:
(a) diffusion current is large and drift current is small.
(b) diffusion current is small and drift current is large.
(c) both the diffusion and the drift currents are large.
(d) both the diffusion and the drift currents are small.

OR

(v) An AC voltage V = 0.5 sin (100pt) volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be:
(a) 25 Hz, 50 Hz (b) 25 Hz, 100 Hz (c) 50 Hz, 50 Hz (d) 50 Hz, 100 Hz

20. Energy Band Gap: From Bohr’s atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap.



(i) In an insulator energy band gap is

(a) $E_g = 0$ (b) $E_g < 3$ eV (c) $E_g > 3$ eV (d) None of the above

(ii) In a semiconductor, separation between conduction and valence band is of the order of

(a) 0 eV (b) 1 eV (c) 10 eV (d) 50 eV

(iii) Based on the band theory of conductors, insulators and semiconductors, the forbidden gap is smallest in

(a) conductors (b) insulators (c) semiconductors (d) All of these

(iv) 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.

OR

(v) Solids having highest energy level partially filled with electrons are

(a) semiconductor (b) conductor (c) insulator (d) none of these

PRACTICE PAPER 14
CHAPTER 14 ELECTRONIC DEVICES (ANSWERS)

SUBJECT: PHYSICS | **MAX. MARKS : 40**
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(iv). There is no overall choice.
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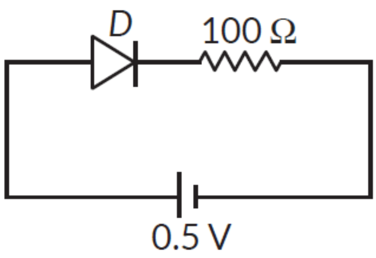
SECTION – A
Questions 1 to 10 carry 1 mark each.

1. A pure Si crystal having 5×10^{28} atoms m^{-3} is dopped with 1 ppm concentration of antimony. If the concentration of holes in the doped crystal is found to be 4.5×10^{9} m^{-3}, the concentration (in m^{-3}) of intrinsic charge carriers in Si crystal is about
(a) 1.2×10^{15} (b) 1.5×10^{16} (c) 3.0×10^{15} (d) 2.0×10^{16}
Ans. (b) 1.5×10^{16}

$$n_e = \frac{5\times10^{28}}{10^6} = 5 \times 10^{22}\ m^{-3}$$
$$n_h = 4.5 \times 10^9\ m^{-3}$$
$$\therefore\quad n_i^2 = n_e \times n_h = 5 \times 10^{22} \times 4.5 \times 10^9$$
$$\therefore\quad n_i = 1.5 \times 10^{16}\ m^{-3}$$

2. The energy required by an electron to jump the forbidden band in silicon at room temperature is about
(a) 0.01 eV (b) 0.05 eV (c) 0.7 eV (d) 1.1 eV
Ans. (d):For silicon it is 1.1 eV.

3. The threshold voltage for a p-n junction diode used in the circuit is 0.7 V. The type of biasing and current in the circuit are



(a) Forward biasing, 0A (b) Reverse biasing, 0 A
(c) Forward biasing, 5mA (d) Reverse biasing, 2 mA
Ans. (a) Forward biasing, 0A
Here, the applied voltage (0.5 V) is less than barrier potential (0.7 V).
Thus, it is an example of forward biasing and there is no flow of current.
So, answer is (a) forward biasing, 0 Amp.

4. In an extrinsic semiconductor, the number density of holes is 4 × 1020 m –3. If the number density of intrinsic carriers is 1.2 × 1015 m –3, the number density of electrons in it is:
(a) $1.8 \times 10^{9}\ m^{-3}$ (b) $2.4 \times 10^{10}\ m^{-3}$ (c) $3.6 \times 10^{9}\ m^{-3}$ (d) $3.2 \times 10^{10}\ m^{-3}$

Ans. (c) 3.6×10^9 m^{-3}
Given that the number density of holes in the extrinsic semiconductor is 4×10^{20} m^{-3}, we can infer that it is a *p*-type semiconductor, where the majority carrier is holes.
The number density of intrinsic carriers, $n_i^2 = n_e n_h$
Where n_e is the number density of electrons, and n_h is the number density of holes.
Substituting the given values, we get:
$(1.2 \times 10^{15})^2 = (4 \times 10^{20})\, n_e$
Solving for *n*, we get: n_e = 3.6 × 109 m–3

5. The formation of depletion region in a p-n junction diode is due to:
(a) movement of dopant atoms
(b) diffusion of both electrons and holes
(c) drift of electrons only
(d) drift of holes only.
Ans. (b) diffusion of both electrons and holes.
The formation of a depletion region in a p-n junction diode is due to the diffusion of both electrons and holes.

6. Which one of the following elements will require the highest energy to take out an electron from them? Pb, Ge, C and Si
(a) Ge (b) C (c) Si (d) Pb
Ans. (b) C
Energy gap of carbon is maximum; hence, it will require maximum energy to remove an electron from it.

7. At equilibrium, in a p-n junction diode the net current is:
(a) due to diffusion of majority charge carriers
(b) due to drift of minority charge carriers
(c) zero as diffusion and drift currents are equal and opposite
(d) zero as no charge carriers cross the junction.
Ans. (c) zero as diffusion and drift currents are equal and opposite.
At equilibrium, the p-n junction has the same number of majority and minority carriers moving in opposite directions. The net current is sum of drift and diffusion current. So, the net current will be zero as diffusion and drift currents are equal and opposite.

8. In an n-type semiconductor, the donor energy level lies:
(a) at the centre of the energy gap
(b) just below the conduction band
(c) just above the valence band
(d) in the conduction band.
Ans. (b) just below the conduction band

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** The temperature coefficient of resistance is positive for metals and negative for p-type semiconductors.
Reason (R): The charge carriers in metals are negatively charged, whereas the majority charge carriers in p-type semiconductors are positively charged.
Ans (b) Both Assertion and Reason are true and Reason is not the correct explanation of Assertion.

Temperature coefficient of metals is positive because higher temprature means more collisions between electrons and hence more resistivity whereas all semiconductors have negative temperature coefficient as number of free charge carriers increase with the temperature which means more conductivity.

10. Assertion (A): The electrical conductivity of a semiconductor increases on doping.
Reason (R): Doping always increases the number of electrons in the semiconductor.
Ans. (c) Assertion is true but Reason is false.
The conductivity of semiconductors is increased by adding an appropriate amount of suitable impurity or doping. Doping can be done with an impurity which is electron rich or electron deficient as compared to the intrinsic semiconductor, silicon or germanium. Such impurities introduce electronic defects in them. When silicon is doped with electron rich impurities the extra electron becomes delocalized.

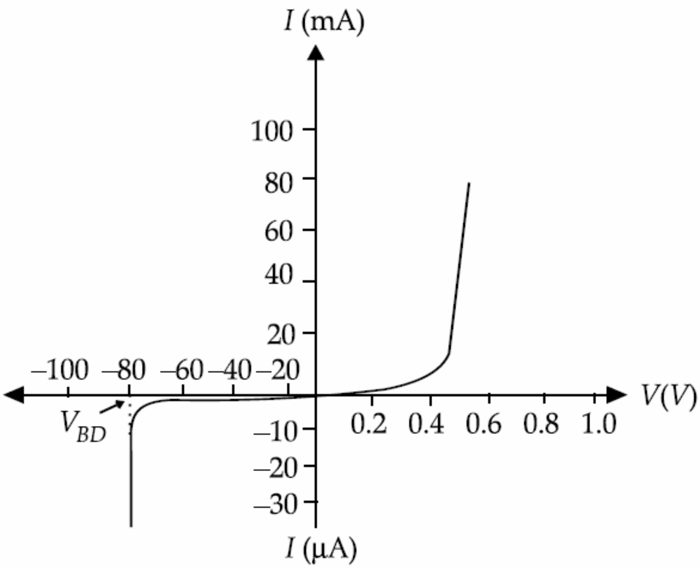
SECTION – B

Questions 11 to 14 carry 2 marks each.

11. Answer the following giving reasons:
(a) A p-n junction diode is damaged by a strong current.
(b) Impurities are added in intrinsic semiconductors.
Ans. (a) A p-n junction diode can be damaged by a strong current due to excessive heating.
(b) Impurities are added to intrinsic semiconductors in a process called doping to increase their electrical conductivity.

OR

Draw V–I characteristics of a p–n junction diode. Explain, why the current under reverse bias is almost independent of the applied voltage up to the critical voltage.
Ans:



Since, reverse current is due to flow of minority charge carriers across the junction, it is limited due to the concentration of minority carriers on either side of the junction. It is therefore independent of the voltage applied.

12. Distinguish between an intrinsic semiconductor and p-type semiconductor.
Give reason, why p-type semiconductor crystal is electrically neutral, although $n_h >> n_e$?
Ans. Intrinsic semiconductor is a pure semiconductor which is free from any impure atoms. p-type semiconductor: When a semiconductor is doped with a trivalent atoms like indium, boron or aluminium (acceptor atom) the resulting material has excess holes and is called p-type semiconductor. In p-type semiconductor $n_h >> n_e$.
A p-type semiconductor is electrically neutral, because the charge of additional charge carries is just equal and opposite to that of the ionized cores in the lattice.

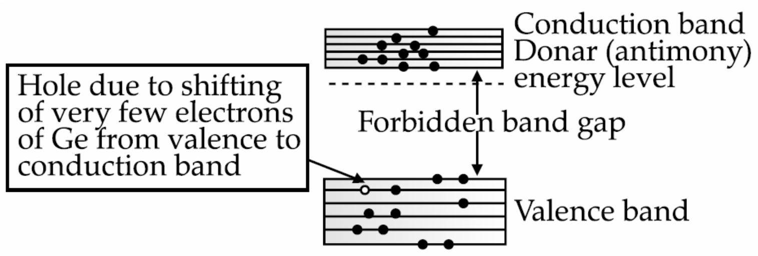
OR

(a) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor?
(b) What type of extrinsic semiconductor is formed when
(i) germanium is doped with indium?
(ii) silicon is doped with bismuth?
Ans. (a) The 4 bonding of electrons of C and Si lie respectively, in the second and third orbit. Hence energy required to take out an electron from their atoms will be much less than for C. Hence number of free e– for conduction in Si significant but negligibly small for C.
(b) (i) Indium is trivalent, so germanium doped indium is a p-type semiconductor.
(ii) Bismuth is pentavalent, so silicon doped bismuth is an n-type semiconductor.

13. (a) Which charge carriers in intrinsic semiconductor will have conduction?
(b) How does the resistance of a semiconductor change when heated?
Ans: (a) Electrons and holes. These are the change carriers which are responsible for conduction. In p type of semiconductor holes are majority charge carriers while in n-type, electrons are majority charge carriers.
(b) Resistance decreases. As with rise in temperature, number of free charge carriers increases due to breaking of more and more covalent bonds and hence its resistivity decreases.

OR

Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of Antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it.
Ans:



This is an n-type extrinsic semiconductor.
Majority carriers are electrons.

14. (a) Why a pure semiconductor behaves like an insulator at 0 K?
(b) Why is the energy gap much more in silicon than in germanium?
Ans: (a) The main cause for the conduction of any semiconductor is the number of free electrons in it. The free electrons has the kinetic energy which depends upon the temperature. As the temperature is 0 K, the kinetic energy will be zero and the free electrons are not available for conduction.
(b) The behaviour of semiconductor depends upon the extent of the energy gap between the valence band and conduction band. Thus, the valence electrons are quite tightly bound to the parent nuclei in case of silicon as compared to germanium.

OR

Answer the following questions.
(i) Can the potential barrier across a p-n junction be measured by simply connecting a voltmeter across the junction?
(ii) Why are elemental dopants for Silicon or Germanium usually chosen from group 13 or group 15?
Ans: (i) No, because the voltmeter must have a resistance very high compared to the junction resistance, then later being nearly infinite.

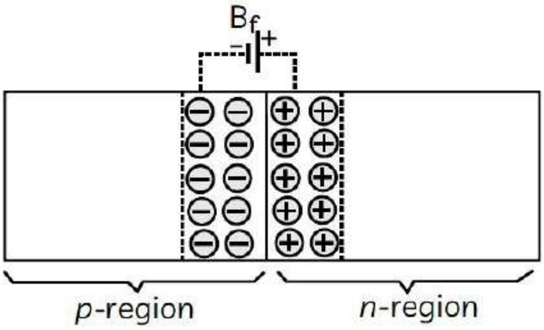
(ii) The size of dopant atoms should be such as not to distort the pure semiconductor lattice structure and yet easily contribute a charge carrier on forming covalent bonds with Si or Ge.

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. Explain with the help of a diagram, how depletion region and potential barrier are formed in a junction diode. How does (a) an increase in the doping concentration, and (b) biasing across the junction, affect the width of the depletion layer?

Ans. **Formation of depletion layer:** When p-n junction is prepared, electrons from n-region diffuse into p-region and holes diffuse from p-region to n-region it leaves behind an ionized donor on n-side. This ionized donor (positive charge) is immobile as it is bonded to the surrounding atoms. Thus, due to diffusion of electrons from n-p, a layer of positive space charge is developed on n-side of the junction. Similarly due to diffusion of holes from p-n, a layer of negative space charge on the p-side of the junction is developed. This space charge region on either side of the junction together is known as the "depletion region" or "depletion layer".



Barrier potential: Due to diffusion of holes from p-region to n-region and diffusion of electrons in the reverse direction, part of depletion layer on n-side of junction becomes positively charged and the part of depletion layer on p-type of junction becomes negatively charged. Thus, a junction potential is developed, which opposes further diffusion of holes/electrons. Hence, this potential acts as a barrier and is known as "barrier potential" V_B.

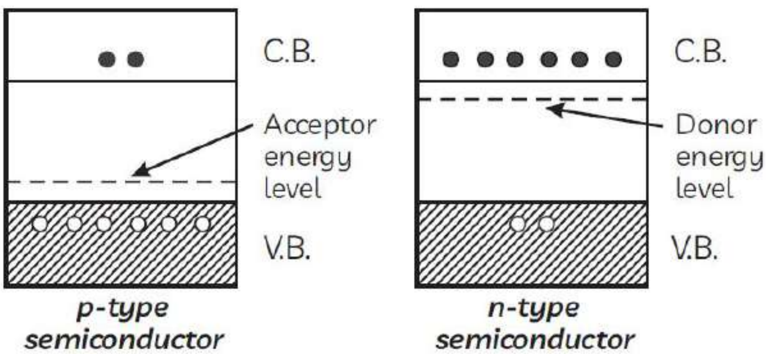
(a) The width of the depletion layer decreases on increasing the doping concentration.

(b) In forward biasing arrangement the width of depletion layer decreases but in reverse biasing the width of depletion layer increases.

OR

Draw energy band diagrams of n-type and p-type semiconductors at temperature T > 0 K, depicting the donor and acceptor energy levels. Mention the significance of these levels.

Ans.



Significance:

n-type semiconductors – small energy gap between donor level and conduction band which can be easily covered by thermally excited electrons.

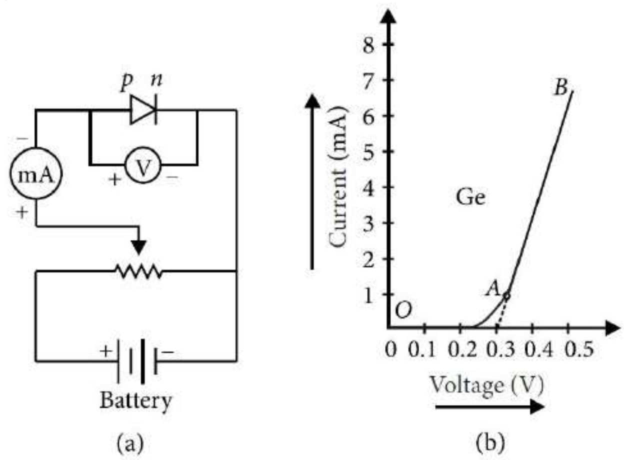
p- type semiconductors – small energy gap between acceptor level and valence band which can be easily covered by thermally excited electrons.

16. Explain the following, giving reasons:

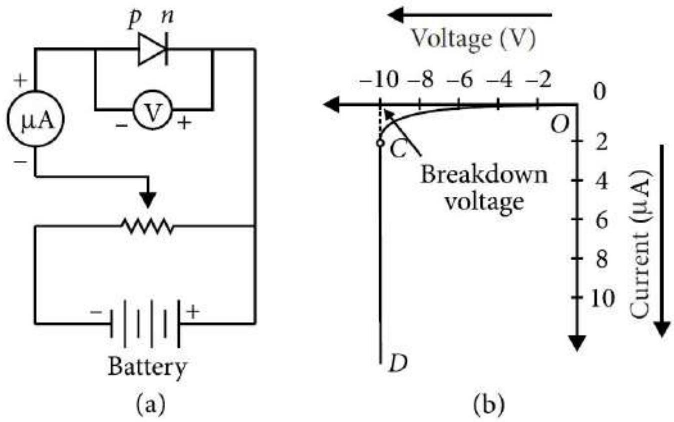
(a) A doped semiconductors is electrically neutral.
(b) In a p - n junction under equilibrium, there is no net current.
(c) In a diode, the reverse current is practically not dependent on the applied voltage.
Ans. (a) A doped semiconductor is electrically neutral because it has equal number of electrons as there are protons. By doping, only the conductivity of semiconductor increases.
(b) In a p-n junction under equilibrium, there is not net current because diffusion current is exactly equal and opposite to the drift current for both carriers.
(c) In a diode, the reverse current is practically not dependent on the applied voltage because the reverse current is due to the drifting of the minority charge carriers from one region to another through the junction. Hence a small amount of voltage is enough to carry on the sweeping of the minority charge carriers.

OR

Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases.
Ans: **Forward biased characteristics:** The circuit diagram for studying forward biased characteristics is shown in the figure. Starting from a low value, forward bias voltage is increased step by step (measured by voltmeter) and forward current is noted (by ammeter). A graph is plotted between voltage and current. The curve so obtained is the forward characteristic of the diode.
At the start when applied voltage is low, the current through the diode is almost zero. It is because of the potential barrier, which opposes the applied voltage. Till the applied voltage exceeds the potential barrier, the current increases very slowly with increase in applied voltage (OA portion of the graph). With further increase in applied voltage, the current increases very rapidly (AB portion of the graph), in this situation, the diode behaves like a conductor. The forward voltage beyond which the current through the junction starts increasing rapidly with voltage is called threshold or cut-in voltage. If line AB is extended back, it cuts the voltage axis at potential barrier voltage.



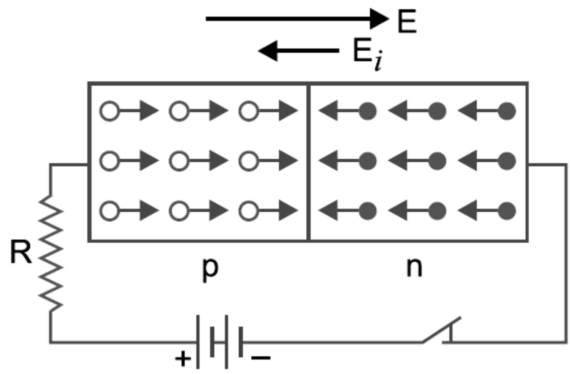
Reverse biased characteristics: The circuit diagram for studying reverse biased characteristics is shown in the figure.



In reverse biased, the applied voltage supports the flow of minority charge carriers across the junction. So, a very small current flows across the junction due to minority charge carriers. Motion of minority charge carriers is also supported by internal potential barrier, so all the minority carriers cross over the junction. Therefore, the small reverse current remains almost constant over a sufficiently long range of reverse bias, increasing very little with increasing voltage (OC portion of the graph). This reverse current is voltage independent upto certain voltage known as breakdown voltage and this voltage independent current is called reverse saturation current.

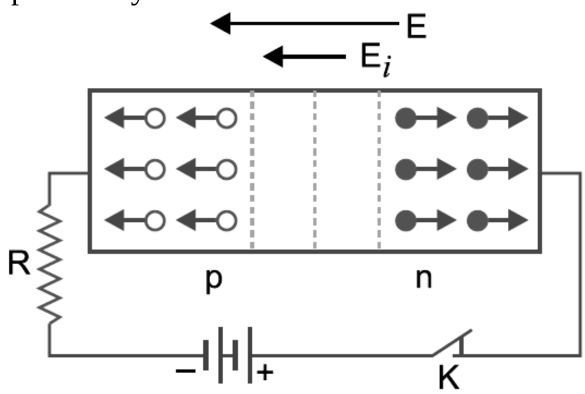
17. What will the effect of (i) forward biasing, and (ii) reverse biasing be on the width of depletion layer in p-n junction diode?

Ans. (*i*) Under forward biasing the applied potential difference causes a field which acts opposite to the potential barrier. This results in reducing the potential barrier, and hence the width of depletion layer decreases.



Forward current

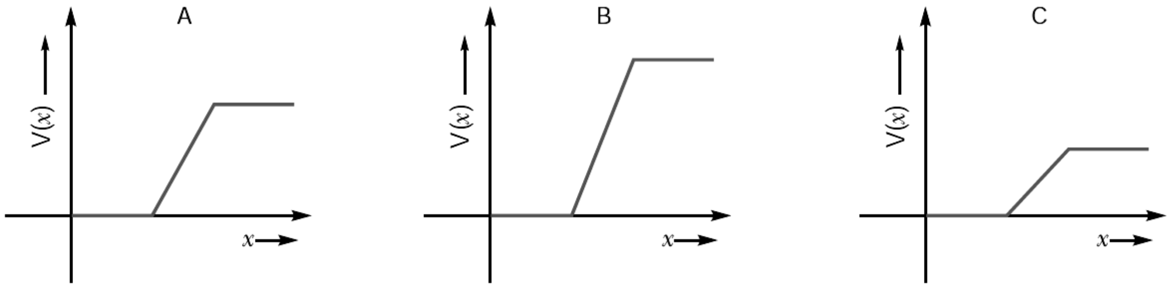
(*ii*) Under reverse biasing the applied potential difference causes a field which is in the same direction as the field due to internal potential barrier. This results in an increase in barrier voltage and hence the width of depletion layer increases.



Reverse current

OR

The graph of potential barrier versus width of depletion region for an unbiased diode is shown in A. In comparison to A, graphs B and C are obtained after biasing the diode in different ways. Identify the type of biasing in B and C and justify your answer.



Ans. **B : Reverse biased**

Justification: When an external voltage *V* is applied across the semiconductor diode such that *n*-side is positive and *p*-side is negative, the direction of applied voltage is same as the direction of barrier potential. As a result, the barrier height increases and the depletion region widens due to the change in the electric field. The effective barrier height under reverse bias is $(V_0 + V)$.

C : Forward biased

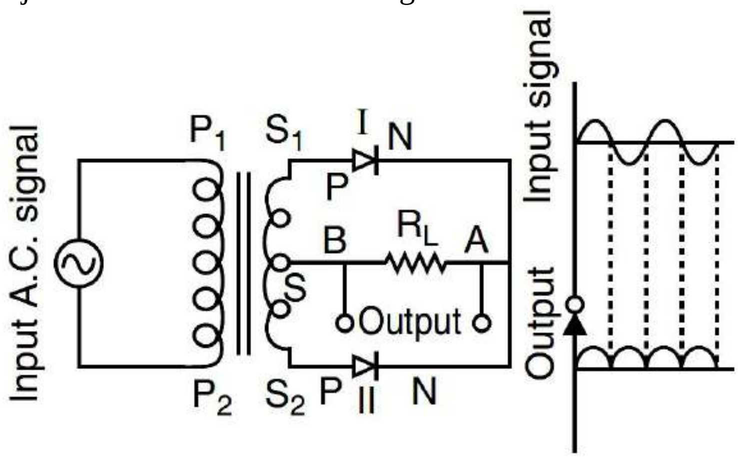
Justification: When an external voltage *V* is applied across a diode such that *p*-side is positive and *n*-side is negative, the direction of applied voltage (*V*) is opposite to the barrier potential (V_0). As a result, the depletion layer width decreases and the barrier height is reduced. The effective barrier height under forward bias is $(V_0 – V)$.

SECTION – D

Questions 18 carry 5 marks.

18. Draw a labelled circuit diagram of a full-wave rectifier and briefly explain its working principle. Give its input and output waveforms.

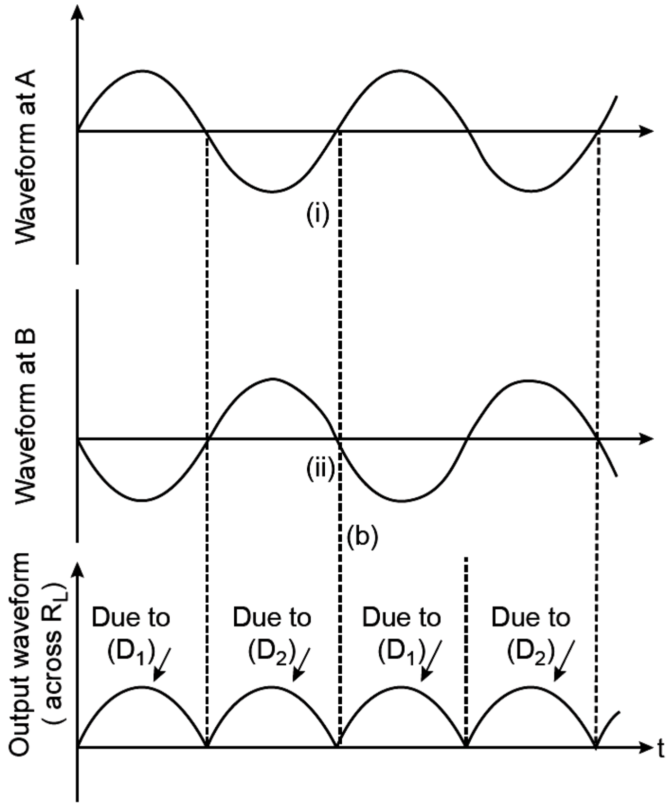
Ans: For full wave rectifier we use two junction diodes. The circuit diagram for full wave rectifier using two junction diodes is shown in figure.



Suppose during first half cycle of input ac signal the terminal S_1 is positive relative to *S* and S_2 is negative relative to *S*, then diode I is forward biased and diode II is reverse biased. Therefore current flows in diode I and not in diode II. The direction of current i_1 due to diode I in load resistance R_L is directed from *A* to *B*. In next half cycle, the terminal S_1 is negative relative to *S* and S_2 is positive relative to *S*. Then diode I is reverse biased and diode I_I is forward biased.

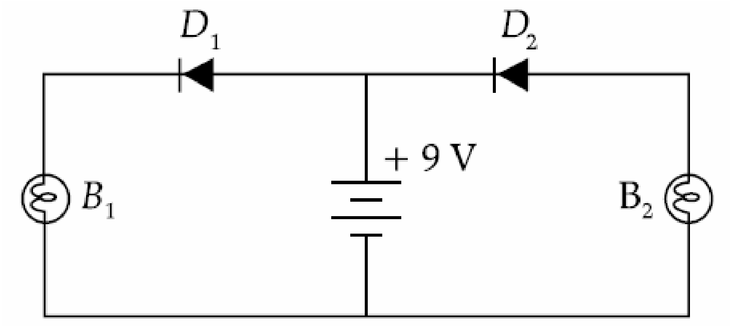
Therefore current flows in diode II and there is no current in diode I. The direction of current i_2 due to diode II in load resistance is again from *A* to *B*. Thus for input a.c. signal the output current is a continuous series of unidirectional pulses. This output current may be converted in fairly steady current by the use of suitable filters.

Input and output waveforms.



OR

(a) In the following diagram, which bulb out of B_1 and B_2 will glow and why?

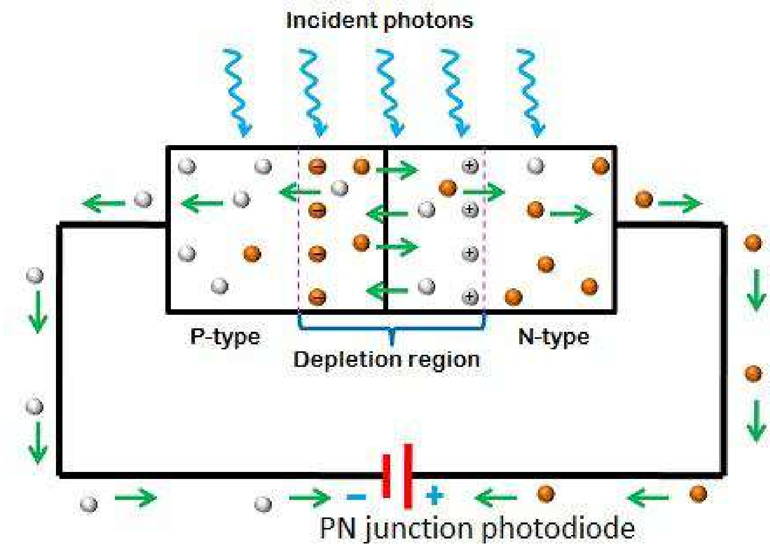


(b) Draw a diagram of an illuminated p-n junction solar cell.

(c) Explain briefly the three processes due to which generation of emf takes place in a solar cell.

Ans: (a) In the diagram, diode D_1 is in forward bias and diode D_2 is in reverse bias, So current will flow through D_1 and D_2 will not allow flowing the current, So bulb B_1 will glow and bulb B_2 will not glow.

(a)

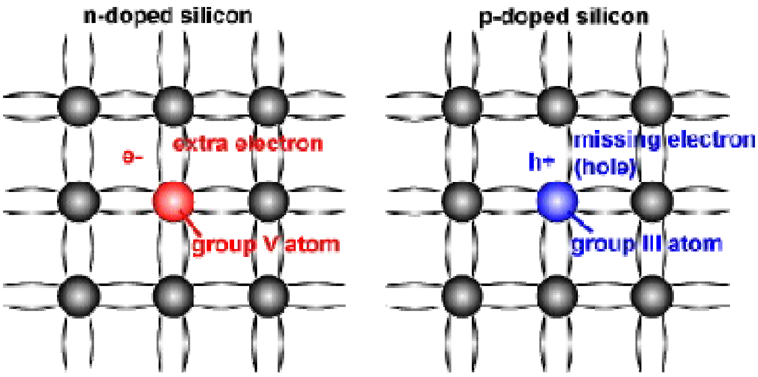


(c) When the photodiode is illuminated with light, with energy greater than the energy gap of the semiconductor, then electron-hole pairs are generated due to the absorption of photons, in or near the depletion region. Due to the electric field of the junction, electrons and holes are separated before the recombine electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When connected to an external load is current flows, whose magnitude depends on the intensity of incident light. The photodiode can be used as a photodetector to detect optical signals.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. A pure semiconductor like Ge or Si, when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a p-n junction by doping it with suitable impurity. Two processes, diffusion and drift take place during formation of a p-n junction. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. A p-n junction allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration.



(i) When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about:
(a) 0.001 eV (b) 0.01 eV (c) 0.72 eV (d) 1.1 eV

(ii) At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0×10^{10} cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8×10^3 cm^{-3}. The number of electrons in the semiconductor is:
(a) 2×10^{24} m^{-3} (b) 4×10^{23} m^{-3} (c) 1×10^{22} m^{-3} (d) 5×10^{22} m^{-3}

(iii) During the formation of a p-n junction:
(a) electrons diffuse from p-region into n-region and holes diffuse from n-region into p-region.
(b) both electrons and holes diffuse from n-region into p-region.
(c) electrons diffuse from n-region into p-region and holes diffuse from p-region into n-region.
(d) both electrons and holes diffuse from p-region into n-region.

(iv) Initially during the formation of a p-n junction:
(a) diffusion current is large and drift current is small.
(b) diffusion current is small and drift current is large.
(c) both the diffusion and the drift currents are large.
(d) both the diffusion and the drift currents are small.

OR

(v) An AC voltage V = 0.5 sin (100pt) volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be:

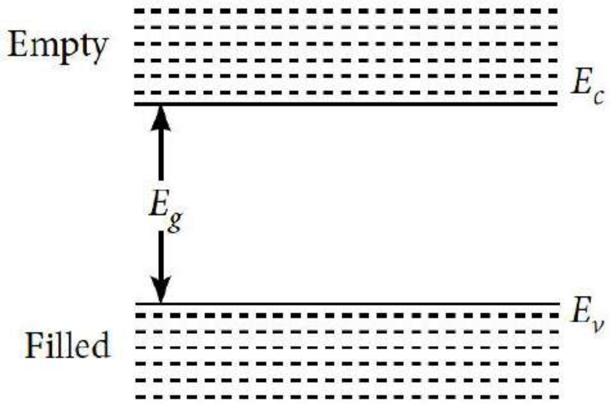
(a) 25 Hz, 50 Hz (b) 25 Hz, 100 Hz (c) 50 Hz, 50 Hz (d) 50 Hz, 100 Hz

Ans. (i) *(b) 0.01 eV*
When Ge is doped with pentavalent impurity, four electrons of impurity bond with four Ge neighbour atoms but the fifth remains weakly bound to its parent atom. So, the energy required is very small and for Ge, it is about 0.01 eV.
(ii) (d) $5 \times 10^{22}\ m^{-3}$
(iii) (c) electron diffuse from n-region to p-region and holes diffuse from p-region into n-region.
The electrons diffuse from higher concentration to lower concentration as well as holes. The ions left behind by the charge carriers form a depletion layer of significant with which stops the diffusion process.
(iv) (a) diffusion current is large and drift current is small.
During formation of depletion layer a large number of electron and holes get diffused to other side which makes the diffusion current significantly larger than the drift current. But after the formation of depletion layer diffusion stops and drift current becomes larger.

OR

(v) (d) 50 Hz, 100 Hz

20. Energy Band Gap: From Bohr's atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap.



(i) In an insulator energy band gap is
(a) $E_g = 0$ (b) $E_g < 3$ eV (c) $E_g > 3$ eV (d) None of the above

(ii) In a semiconductor, separation between conduction and valence band is of the order of
(a) 0 eV (b) 1 eV (c) 10 eV (d) 50 eV

(iii) Based on the band theory of conductors, insulators and semiconductors, the forbidden gap is smallest in
(a) conductors (b) insulators (c) semiconductors (d) All of these

(iv) 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.

OR

(v) Solids having highest energy level partially filled with electrons are
(a) semiconductor (b) conductor (c) insulator (d) none of these

Ans. (i) (c) $E_g > 3$ eV
In insulator, energy band gap is > 3 eV
(ii) (b) 1 eV
In conductor, separation between conduction and valence bands is zero and in insulator, it is greater than 1 eV. Hence in semiconductor the separation between conduction and valence band is 1 eV.
(iii) (a) conductors
According to band theory the forbidden gap in conductors $Eg \approx 0$, in insulators $Eg > 3$ eV and in semiconductors $Eg < 3$ eV.
(iv) (a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
The four valence electrons of C, Si and Ge lie respectively in the second, third and fourth orbit. Hence energy required to take out an electron from these atoms (*i.e.* ionisation energy Eg) will be least for Ge, followed by Si and highest for C. Hence, the number of free electrons for conduction in Ge and Si are significant but negligibly small for C.

OR

(v) (b) conductor