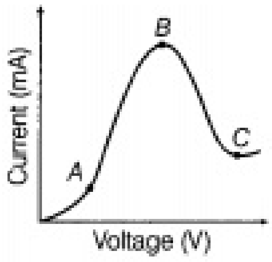
CBSE Test Paper-04

Class - 12 Physics (Electronic Devices)

1. Hole is a vacancy or lack of an electron and can travel through the semiconductor material. It can
   a. None of these
   b. responsible for current carrier in semicondustor
   c. move only if an electron stops
   d. only serves as a vacant spot and cannot conduct current
2. In a middle of the depletion layer of a reverse biased p-n junction, the
   a. electric field is maximum
   b. potential is zero
   c. potential is maximum
   d. electric field is zero
3. A CE amplifier has a voltage gain 50, an input impedance of 100 ohm, and an output impedance of 200 ohm. The power gain of the amplifier will be:
   a. 250
   b. 1100
   c. 1200
   d. 1250
4. The depletion layer in the p-n junction is caused
   a. drift of electrons
   b. migration of impurity ions
   c. diffusion of carrier ions
   d. drift of holes
5. Which of the statements is true for p-type semiconductors.
   a. Electrons are minority carriers and pentavalent atoms are the dopants.
   b. Electrons are majority carriers and trivalent atoms are the dopants.
   c. Holes are majority carriers and trivalent atoms are the dopants.
   d. Holes are minority carriers and pentavalent atoms are the dopants.
6. Name one impurity each, which when added to pure Si, produces
   i. ntype and

ii. ptype semiconductor.

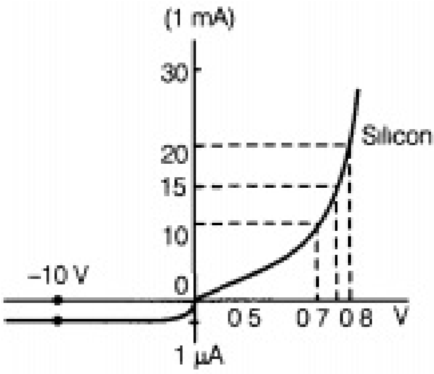
7. The graph shown in the figure represents a plot of current versus voltage for a given semiconductor. Identify the region, if any over which the semiconductor has a negative resistance.



8. Draw the energy band diagrams of p-type and n-type semiconductors. A semiconductor has equal electron and hole concentration $6 \times 10^8 m^{-3}$. On doping with a certain impurity, electron concentration increases to $8 \times 10^{12} m^{-3}$. Identify the type of semiconductor after doping

9. The V-I characteristic of a silicon diode is as shown in the figure. Calculate the resistance of the diode at

i. I = 15 mA and
ii. V = -10V



10. The number of silicon atoms per m^3 is 5×10^{28}. This is doped simultaneously with 5×10^{22} atoms per m^3 of Arsenic and 5×10^{20} per m^3 atoms of Indium. Calculate the number of electrons and holes. Given that, ni = $1.5 \times 10^{16} m^{-3}$. Is the material n-type or p-type?

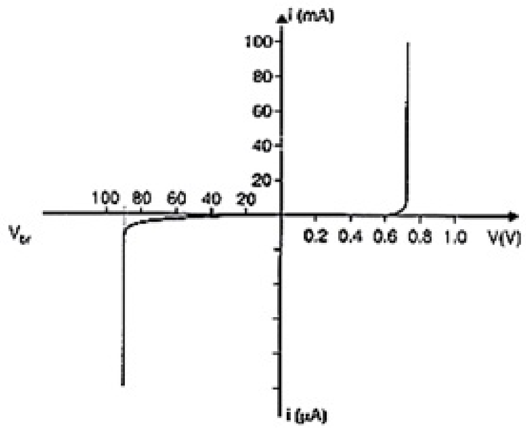
11. A p-n photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Can it detect a wavelength of 600 nm?

12. A Zener diode is fabricated by heavily doping both p-and n-sides of the junction. Explain.
    Briefly explain the use of Zener diode as a DC voltage regulator with the help of a circuit diagram.

13. Name the important processes that occurs during the formation of a p-n junction. Explain briefly, with the help of a suitable diagram, how a p-n junction is formed. Define the term 'barrier potential'?

14. The following figure shows the V-I characteristics of a semiconductor diode

    i. Identify the semiconductor diode used.
    ii. Draw the circuit diagram to obtain the given characteristics of this device.
    iii. Briefly explain how this diode can be used as a voltage regulator



15. a. Distinguish between metals, insulators and semiconductors on the basis of their energy bands.
    b. Why are photodiodes used preferably in reverse bias condition? A photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Can it detect a wavelength of 6000 nm? Justify.

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Answers

1. a. responsible for current carrier in semicondustor

   Explanation: Holes and electrons are the two types of charge carriers responsible for current in semiconductor materials.

   Holes in a metal or semiconductor crystal lattice can move through the lattice as electrons can, and act similarly to positively-charged particles. They play an important role in the operation of semiconductor devices such as transistors, diodes and integrated circuits. However they are not actually particles, but rather quasiparticles; they are different from the positron, which is the antiparticle of the electron.

2. d. electric field is zero

   Explanation: Due to reverse biasing the width of the depletion region increases and current flowing through the diode is almost zero. In this case electric field is almost zero at the middle of the depletion region.

3. d. 1250

   Explanation: Voltage gain, A_V=50

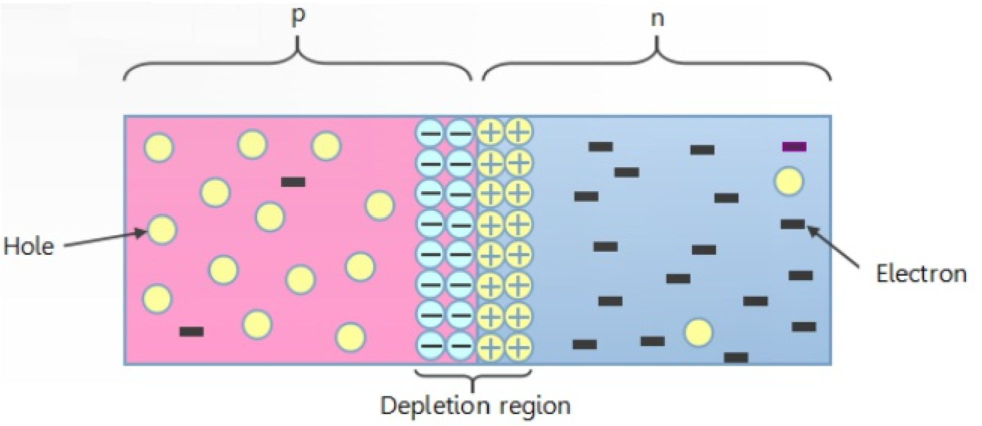
   input impedance, R_i = 100Ω

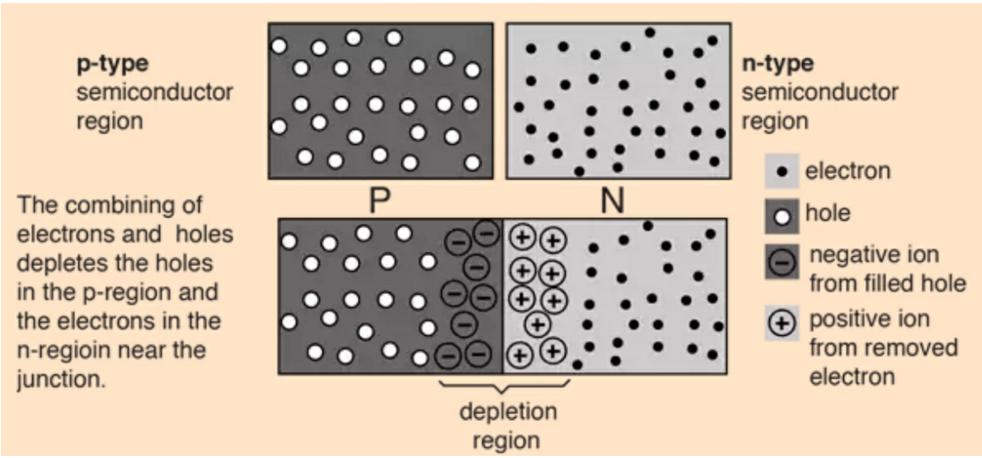
   output impedance R_o=200Ω

   the power gain of the CE Amplifier = $A_v^2 \times \frac{R_i}{R_o}$=$2500 \times \frac{100}{200} = 1250$

4. c. diffusion of carrier ions

   Explanation: When a p-n junction is formed, some of the free electrons in the n-region diffuse across the junction and combine with holes to form negative ions. In so doing they leave behind positive ions at the donor impurity sites. The combining of electrons and holes in the p - region and the electrons in the n - region near the junction.





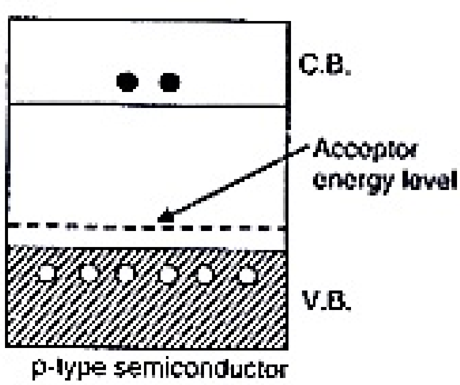
5. c. Holes are majority carriers and trivalent atoms are the dopants.

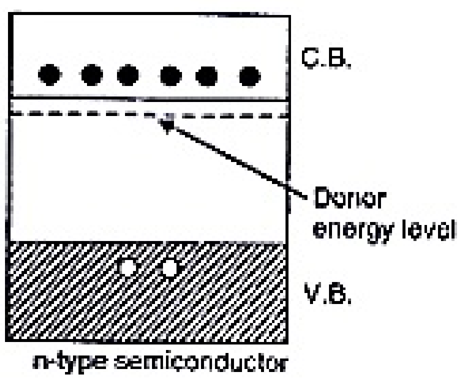
Explanation: p-type semiconductor is obtained by doping Ge or Si with trivalent atoms. In p-type semiconductor holes are majority carriers and electrons are minority carriers.

6. i. As (Arsenic)

ii. In (Indium)

7. The slope of the V I graph gives the resistance. Negative slope of curve means negative resistance, in the given graph part BC of the curve shows the negative resistance as in this region slope is negative and current decreases by increasing the voltage.

8. 



As the electron concentration increases on doping, so the resulting semiconductor is of n-type.

9. i. From the given curve,, V = 0.8 volt for current 20 mA,

   V = 0.7 volt for current 10 mA,

   $\Rightarrow \quad \Delta I = (20 - 10)\mathrm{mA}$

   $\Rightarrow \quad \Delta I = 10mA = 10 \times 10^{-3}\mathrm{A}$

   $\Rightarrow \quad \Delta I = 10^{-2}\mathrm{A}$

   $\Rightarrow \quad \Delta V = (0.8 - 0.7) = 0.1\mathrm{V}$

   $\therefore$ Resistance, $R = \frac{\Delta V}{\Delta I}$

   $\Rightarrow \quad R = \frac{0.1}{10^{-2}}$

   $\Rightarrow \quad R = 10\Omega$

   ii. For V = -10V, we have

   $I = -1\mu A = -1 \times 10^{-6}A$

   R=V/I

   $\Rightarrow \quad R = \frac{10}{1\times10^{-6}} = 1.0 \times 10^{7}\Omega$

10. $n_e = 5 \times 10^{22} - 5 \times 10^{20} = (5 - 0.05) \times 10^{22}$

    $n_h = \frac{n_i^2}{n_e} = \frac{(1.5\times10^{16})^2}{4.95\times10^{22}} = 4.54 \times 10^9\ \mathrm{m}^{-3}$

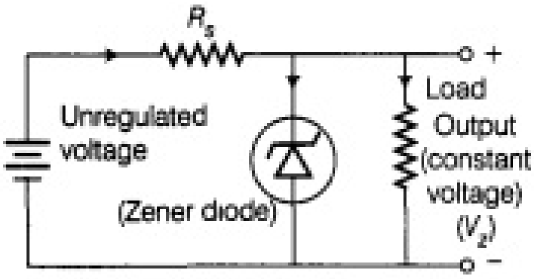
    As $n_e > n_h$, so the material is n-type semiconductor.

11. Energy, $E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{600\times10^{-9}\times1.6\times10^{-19}}eV$

    = 2.06 eV < 2.8 eV

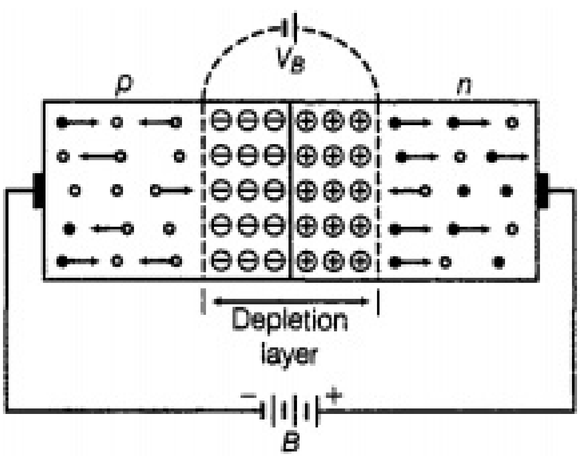
    As $E < E_g$, so p-n junction cannot detect the radiation of given wavelength.

12. Zener diode is fabricated by heavily doping of p-n side of junction so as to operate continously without getting damaged in the region of reverse breakdown voltage. The circuit diagram of a voltage regulator using a Zener diode is shown in figure.



Excess current bypass when $V_{ext} \geq V_z$

Zener diode as voltage regulator: Zener diode is used in regulating fluctuating voltage as shown. It is connected in circuit through resistance R depending on voltage or power rating R_1 is connected in parallel and output is received. On an abrupt increase of voltage across diode becomes constant, equal to breakdown voltage but current rises sharply. Hence, there is an increase in voltage drop R. As R_L is in parallel so voltage across R_L is same.

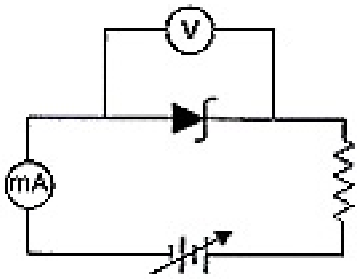
13. 

During the formation of p-n junction, diffusion of charge takes place. when p-type semiconductor is joined with n-type semiconductor, diffusion of free charges across the junction starts. The holes from p-region diffuse into the n-region and electrons from n-region diffuse into p-region and electron-hole pair combine and get annihilated.

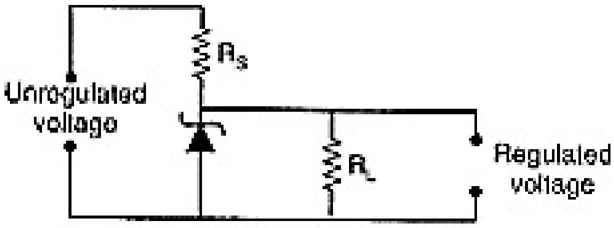
This in turn, produces potential barrier, V_B across the junction which opposes the further diffusion through the junction. Thus, small region forms in the vicinity of the junction which is depleted of free charge carrier and has only immobile ions is called the depletion region. This potential difference then forces the minority charges to move from P side to N and from N side to P. This process is called drift. After some time an equilibrium is achieved between diffusion and drift.

Potential barrier The accumulation of '-ve' charges in the p-region and +ve charges in the n-region sets up a potential difference across the junction (p-n) is called potential barrier (V_g) which opposes the further diffusion of electrons and holes.

14. i. The semiconductor diode whose V-I characteristic is shown in figure is Zener diode.
    ii. Circuit diagram to obtain the given characteristic is shown in figure.



iii. The circuit of Zener diode used as voltage regulator is shown in figure.



The voltage to be regulated is applied across Zener diode as shown in circuit. When input voltage increases the current in Zener diode circuit increases and voltage drop across series resistance R_S increases and across R_L remain same i.e. the voltage drop across Zener diode. Similarly when voltage decreases, the current in the Zener diode circuit decreases and voltage drop across series R_S resistance decreases but across the load resistance remains same, hence the voltage is regulated.

15. a. **Metals:** The energy band diagram for a metal is such that either the conduction band is partially filled with electrons, [see figure (i)] or the conduction and valence band partly overlap each other and there is no forbidden energy band gap in between.

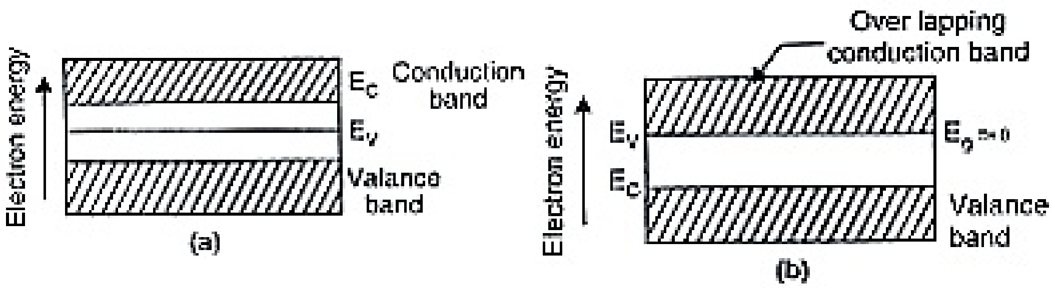
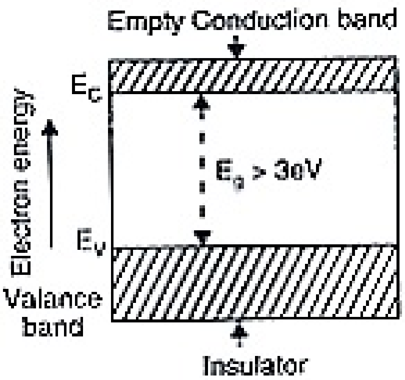


figure (i) b). In both the situations, it can be considered that the metal has a single energy band which is partly filled and partly empty.

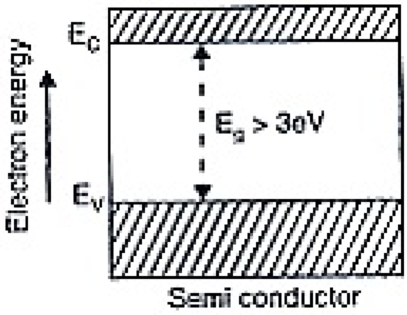
Many electrons from below the Fermi level, by acquiring a little more energy from any source, can shift to the higher energy levels above the Fermi level in the conduction band and behave as free electrons. In this situation, large number of electrons are available for electrical conduction, hence the resistance of such a material is low or the conductivity is high. Even if a small electric field is applied across the metal, these free electrons start moving in a direction opposite to the direction of electric field. Due to it, a current begins to flow through it and hence metal behaves as a conductor.

Insulators: The energy band diagram of insulator is shown in figure (ii). Here, the valence band is completely filled, the conduction band is empty and energy gap is quite large (E_g > 3eV).



For example, in case of diamond, the energy gap is of 6 eV, Since, the valence band is completely filled as per Pauli's exclusion principle, therefore the electrons are not free. Again due to large energy gap, no electron is able to go from the valence band to the conduction band even if electric field is applied. Hence, electrical conduction in these materials is impossible and they behave as insulators.

Semiconductors: The energy band diagram of a semiconductor is shown in figure (iii). Here also, the valence band is totally filled and the conduction band is empty but the energy gap between conduction band and valence band is quite small. It is less than 3 eV. For example, the energy gap for germanium is of 0.72 eV and for silicon it is of 1.1 eV. At zero kelvin temperature, electrons are: not able to cross even this small energy gap and hence the conduction band remains totally empty. Therefore, the semiconductor at zero Kelvin behaves as insulator. However, at room temperature, some electrons in the valence band acquire thermal energy greater than energy band gap less than 3eV and jump over to the conduction band where they are free to move under the influence of even a small electric field. As a result of it, the semiconductor acquires small conductivity at room temperature. The resistance of semiconductor would not be as high as that of insulator.



b. The fractional change due to the photo effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

Numerical:

$\lambda = 6000nm = 6 \times 10^{-6}m$

Since, $E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{6\times10^{-6}} = 3.3 \times 10^{-20}J$

or, $E = \frac{3.3\times10^{-20}}{1.6\times10^{-19}} = 0.206eV$

As the energy of the photon is less than E_g = 2.8eV of the semiconductor so a wavelength of 6000 A cannot be detected.