Semiconductor Electronics - Materials, Devices and Simple Circuits

1. Ge is doped with As. Due to doping, (2024)

(A) the structure of Ge lattice is distorted.

(B) the number of conduction electrons increases.

(C) the number of holes increases.

(D) the number of conduction electrons decreases.

Ans. (B) the number of conduction electrons increases.

2. Plot a graph showing the variation of current with voltage for the material GaAs. On the graph, mark the region where: (2024)

(a) resistance is negative, and

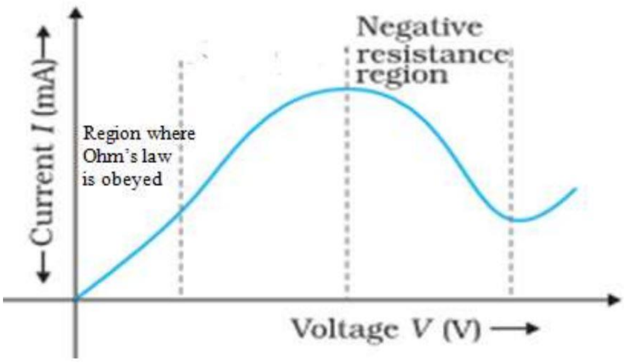
(b) Ohm's law is obeyed.

Ans. Plotting the graph

Marking the region where:

(a) resistance is negative

(b) Ohm's law is obeyed



3. Junction Diode as a Rectifier : (2024)

The process of conversion of an ac voltage into a dc voltage is called rectification and the device which performs this conversion is called a rectifier. The characteristics of a p-n junction diode reveal that when a p-n junction diode is forward biased, it offers a low resistance and when it is reverse biased, it offers a high resistance. Hence, a p-n junction diode conducts only when it is forward biased. This property of a p-n junction diode makes it suitable for its use as a rectifier.

Thus, when an ac voltage is applied across a p-n junction, it conducts only during those alternate half cycles for which it is forward biased. A rectifier which rectifies only half cycle of an ac voltage is called a half-wave rectifier and one that rectifies both the half cycles is known as a full-wave rectifier.

(i) The root mean square value of an alternating voltage applied to a full-wave rectifier is $\frac{V_0}{\sqrt{2}}$. Then the root mean square value of the rectified output voltage is :

(A) $\frac{V_0}{\sqrt{2}}$ (B) $\frac{V_0^2}{\sqrt{2}}$

(C) $\frac{2V_0}{\sqrt{2}}$ (D) $\frac{V_0}{2\sqrt{2}}$

Ans.

(A) $\frac{V_0}{\sqrt{2}}$

(ii) In a full-wave rectifier, the current in each of the diodes flows for :

(A) Complete cycle of the input signal

(B) Half cycle of the input signal

(C) Less than half cycle of the input signal

(D) Only for the positive half cycle of the input signal

Ans. (B) Half cycle of the input signal

(iii) In a full-wave rectifier :

(A) Both diodes are forward biased at the same time.

(B) Both diodes are reverse biased at the same time.

(C) One is forward biased and the other is reverse biased at the same time.

(D) Both are forward biased in the first half of the cycle and reverse biased in the second half of the cycle.

Ans. (C) One is forward biased and the other is reverse biased at the same time.

(iv) An alternating voltage of frequency of 50 Hz is applied to a half-wave rectifier. Then the ripple frequency of the output will be :

(A) 100 Hz

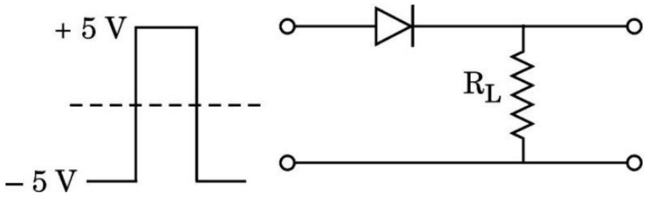
(B) 50 Hz

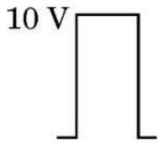
(C) 25 Hz

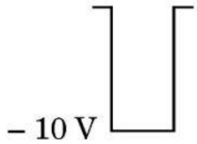
(D) 150 Hz

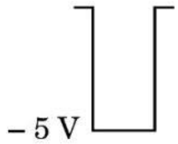
Ans. (B) 50 Hz

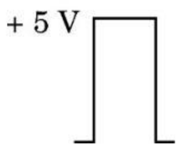
(v) A signal, as shown in the figure, is applied to a p-n junction diode. Identify the output across resistance R_L :



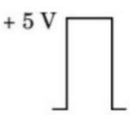
(A) 

(B) 

(C) 

(D) 

Ans.

(D) 

Previous Years' CBSE Board Questions

14.2 Classification of Metals, Conductors and Semiconductors

MCQ

1. 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 *(2023)*

VSA (1 mark)

2. The _____, a property of materials C, Si and Ge depends upon the energy gap between their conduction and valence bands. *(2020)*

SA I (2 marks)

3. What is meant by energy band gap in a solid? Draw the energy band diagrams for a conductor, an insulator and a semiconductor. *(Term II 2021-22)*

4. Distinguish between a metal and an insulator on the basis of energy band diagrams. *(Foreign 2014)* R

SA II (3 marks)

5. Draw a plot showing the variation of resistivity of a (i) conductor and (ii) semiconductor, with the increase in temperature. *(2/3, Delhi 2014C)*

6. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. *(AI 2014)* R

14.3 Intrinsic Semiconductor

MCQ

7. **Assertion (A)** : The resistance of an intrinsic semiconductor decreases with increases in its temperature.
Reason (R) : The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature.
(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A)
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false. *(2023)*

density of holes but the crystal maintains an overall charge neutrality.
Reason (R) : The charge of electrons donated by donor atoms is just equal and opposite to that of the ionised donor.
(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false. *(2023)*

9. 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 valance band.
(d) in the conduction band. *(2020)* R

10. When the temperature of an *n*-type semiconductor is increased, then the
(a) number of free electrons increases while that of the holes decreases.
(b) number of holes increases while that of the free electrons decreases.
(c) number of free electrons and holes remains unchanged.
(d) number of both the free electrons and the holes increase equally. *(2020 C)*

SA I (2 marks)

11. Name the extrinsic semiconductors formed when a pure germanium is doped with (i) a trivalent and (ii) pentavalent impurity. Draw the energy band diagrams of extrinsic semiconductors so formed. *(Term II 2021-22)*

12. What is meant by doping of an instrinsic semiconductor? Name the two types of atoms used for doping of Ge/Si. *(Term II 2021-22)*

13. Distinguish between 'intrinsic' and 'extrinsic' semiconductors. *(Delhi 2015)* R

Assertion (A)

(c) Assertion (A) is true, but Reason (R) is False.

(d) Assertion (A) is false, but Reason (R) is true. *(2023)*

14.4 Extrinsic Semiconductor

MCQ

8. **Assertion (A) :** In '*n*' type semiconductor, number density of electrons is greater than the number

SA II (3 marks)

14. Draw the energy band diagram of (i) *n*-type, and (ii) *p*-type semiconductors at temperatures $T > 0$ K.

In the case of *n*-type Si-semiconductor, the donor energy level is slightly below the bottom of conduction band whereas in *p*-type semiconductor, the acceptor energy level is slightly above the top of valence band. Explain, giving examples, what role do these energy levels play in conduction and valence bands. *(AI 2019, AI 2015 C)* U

15. (i) Distinguish between *n*-type and *p*-type semiconductors on the basis of energy band diagrams.

(ii) Compare their conductivities at absolute zero temperature and at room temperature. *(Delhi 2015C)*

14.5 *p-n* Junction

SA II (3 marks)

16. (a) Explain the formation of a *p-n* junction.

(b) Can we take one slab of *p*-type semiconductor and physically join it to another *n*-type semiconductor to get a p-n junction? Explain *(2022 C)* U

17. Answer the following, giving reason :

(a) The resistance of a *p-n* junction is low when it is forward biased and is high when it is reversed biased.

(b) Doping of intrinsic semiconductors is a necessity for making electronic devices. *(Term II 2021-22)*

18. Write the two processes that take place in the formation of a *p-n* junction. Explain with the help of a diagram, the formation of depletion region and barrier potential in a *p-n* junction. *(Delhi 2017)* U

OR

Explain with the help of the diagram the formation of depletion region and barrier potential in a *p-n* junction. *(2/3, AI 2016)*

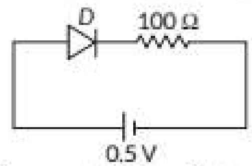
OR

Write briefly the important processes that occur during the formation of *p-n* junction. With the help of necessary diagrams, explain the term barrier potential. *(Foreign 2015)*

14.6 Semiconductor Diode

MCQ

21. 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, 0 A (b) Reverse biasing, 0 A

(c) Forward biasing, 5 mA (d) Reverse biasing, 2 mA *(2023)*

22. 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. *(2020)* R

VSA (1 mark)

23. In an unbiased *p-n* junction diode, the *p*-side of the junction is at ______ potential as compared to that on the *n*-side of the junction. *(2020)*

24. How does an increase in doping concentration affect the width of depletion layer of a *p-n* junction diode? *(2020)* Ap

SA I (2 marks)

25. Explain the formation of the barrier potential in a p-n junction. *(Term II 2021-22)* U

26. With the help of the circuit diagram, explain the working of a silicon *p-n* junction diode in forward biasing and draw its *I-V* characteristics. *(2020 C)*

27. Explain the term 'depletion layer' and 'potential barrier' in a *p-n* junction diode. How are the (a) width of depletion layer, and (b) value of potential barrier affected when the *p-n* junction is forward biased? *(2020)*

28. Draw *V-I* characteristics of a *p-n* junction diode. Explain, why the current under reverse bias is almost

LA (5 marks)

19. (i) A germanium crystal is doped with antimony. With the help of energy-band diagram, explain how the conductivity of the doped crystal is affected.
(ii) Briefly explain the two processes involved in the formation of a *p-n* junction.
(iii) What will the effect of (1) forward biasing, and (2) reverse biasing be on the width of depletion layer in a *p-n* junction diode? *(2023)*

20. State briefly the processes involved in the formation of *p-n* junction explaining clearly how the depletion region is formed. *(2/5, Delhi 2014)*

OR

Explain with the help of diagram, how a depletion layer and barrier potential are formed in a junction diode. *(3/5, Delhi 2014C)*

SA II (3 marks)

30. Draw *V-I* characteristics of a *p-n* junction diode. Answer the following giving reasons :
(a) Why is the reverse bias current almost independent of applied voltage up to breakdown voltage?
(b) Why does the reverse current show a sudden increase at breakdown voltage? *(2022 C)* U

31. (a) Why is an intrinsic semiconductor deliberated converted into an extrinsic semiconductor by adding impurity atoms?
(b) Explain briefly the two processes that occur in *p-n* junction region to create a potential barrier. *(2020)*

32. Explain the formation of potential barrier and depletion region in a *p-n* junction diode. What is effect of applying forward bias on the width of depletion region? *(2020)*

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

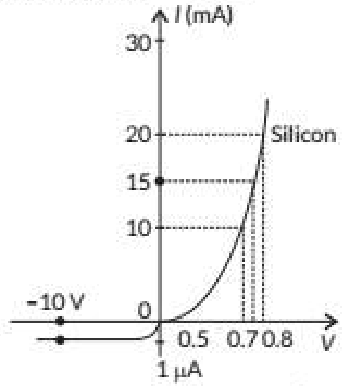
(1/3, AI 2017) R

LA (5 marks)

34. Draw the circuit arrangement for studying *V-I* characteristics of a *p-n* junction diode in (i) forward biasing and (ii) reverse biasing. Draw the typical *V-I* characteristics of a silicon diode. Describe briefly the following terms : (i) minority carrier injection

independent of the applied voltage up to the critical voltage. *(2020)*

29. 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 = −10 V



(Foreign 2015) An

SA I (2 marks)

37. Write the characteristics of a *p-n* junction which make it suitable for rectification. *(Term II 2021-22)* R

38. Give two difference between a half wave rectifier and a full wave rectifier. *(Term II 2021-22)*

SA II (3 marks)

39. With the help of a circuit diagram, explain briefly how a *p-n* junction diode works as a half-wave rectifier. *(Term II 2021-22)*

40. (i) Draw *V-I* characteristics of a *p-n* junction diode.
(ii) Differentiate between the threshold voltage and the breakdown voltage for a diode.
(iii) Write the property of a junction diode which makes it suitable for rectification of ac voltages. *(Term II 2021-22)* Ap

41. Draw the circuit diagram of a full wave rectifier and explain its working. Also, give the input and output waveforms. *(Delhi 2019)* R

OR

A student wants to use two *p-n* junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works. *(2/3, 2018)*

OR

Draw the circuit diagram of a full wave rectifier and state how it works. *(2/3, AI 2017)* in forward biasing and (ii) breakdown voltage in reverse biasing. *(2023)*

35. 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. *(Delhi 2017)*

OR

Using the necessary circuit diagrams, show how the *V-I* characteristics of a *p-n* junction are obtained in
(i) Forward biasing.
(ii) Reverse biasing. *(Delhi 2014)*

OR

Draw the circuit arrangement for studying the *V-I* characteristics of a *p-n* junction diode in (i) forward and (ii) reverse bias. Briefly explain how the typical *V-I* characteristics of a diode are obtained and draw these characteristics. *(AI 2014C)* An

14.7 Application of Junction Diode as a Rectifier

VSA (1 mark)

36. The ability of a junction diode to _____ an alternating voltage, is based on the fact that it allows current to pass only when it is forward biased. *(2020)* R

OR

Explain briefly, with the help of circuit diagram, the working of a full wave rectifier. Draw its input and output waveforms. *(Delhi 2015C)*

LA (5 marks)

42. (i) With the help of a circuit diagram, briefly explain the working of a full-wave rectifier using *p-n* junction diodes.
(ii) Draw *V–I* characteristics of a p-n junction diode. Explain how these characteristics make a diode suitable for rectification.
(iii) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor? *(2023)*

43. Name two important processes involved in the formation of *p-n* junction diode. With the help of a circuit diagram explain the working of junction diode as a full wave rectifier. Draw its input and output waveforms. State the characteristic property of a junction diode that makes it suitable for rectification. *(2023)*

44. Draw the circuit diagram of a half wave rectifier and explain its working. *(AI 2016)* An

CBSE Sample Questions

14.2 Classification of Metals, Conductors and Semiconductors

MCQ

1. **Assertion (A) :** The electrical conductivity of a semiconductor increases on doping.
Reason (R) : Doping always increases the number of electrons in the semiconductor.
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false. *(2022-23)*

14.4 Extrinsic Semiconductor

SA I (2 marks)

2. In a pure semiconductor crystal of Si, if antimony is added then what type of extrinsic semiconductor is obtained. Draw the energy band diagram of this extrinsic semiconductor so formed. *(Term II 2021-22)*

3. 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. *(2020-21)* Ap

14.5 *p-n* Junction

VSA (1 mark)

4. When a voltage drop across a *pn* junction diode is increased from 0.70 V to 0.71 V, the change in the diode current is 10 mA .What is the dynamic resistance of diode? *(2020-21)* Ap

5. How does the width of a depletion region of a *pn* junction vary if doping concentration is increased? *(2020-21)* U

14.7 Application of Junction Diode as a Rectifier

VSA (1 mark)

6. In half wave rectification, what is the output frequency if input frequency is 25 Hz. *(2020-21)*

SA II (3 marks)

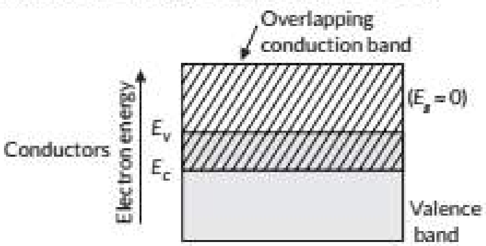
7. Explain with a proper diagram how an *ac* signal can be converted into *dc* (pulsating) signal with output frequency as double than the input frequency using *pn* junction diode. Give its input and output waveforms. *(Term II 2021-22)* Ev

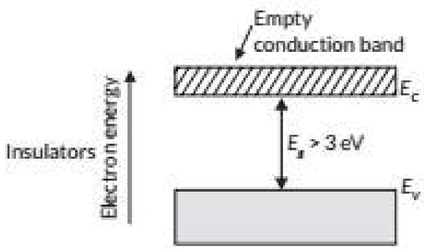
Previous Years' CBSE Board Questions

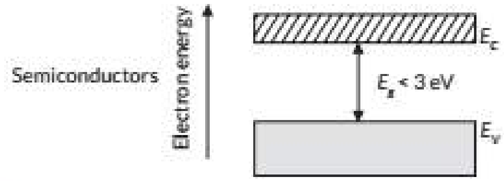
1. (d): For silicon it is 1.1 eV.

2. Conductivity

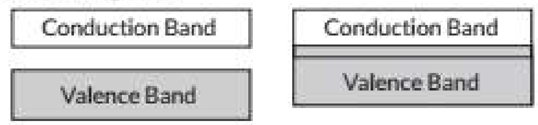
3. The energy gap between valence band and conduction band is known as energy band gap in a solid.







4. Metals : For metals, the valence band is completely filled and the conduction band can have two possibilities- either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with the two bands overlapping each other as shown in the figure.

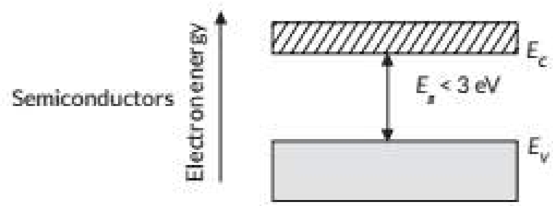


On applying even a small electric field, metals can conduct electricity.

Insulators : For insulators, the energy gap between the conduction and valence bands is very large. Also, the conduction band is completely empty,

as shown in the figure.

When an electric field is applied across such a solid, the electrons find it difficult to acquire such a large amount of energy to reach the conduction band. Thus, the conduction band continues to be empty. That is why no current flows through insulators.



Two Distinguishing features :

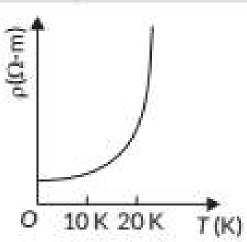
(i) In conductors, the valence band and conduction band tend to overlap (or nearly overlap) while in insulators they are separated by a large energy gap and in semiconductors are separated by a small energy gap.

(ii) The conduction band of a conductor has a large number of electrons available for electrical conduction. However, the conduction band of insulators is almost empty while that of the semiconductor has only a (very) small number of such electrons available for electrical conduction.

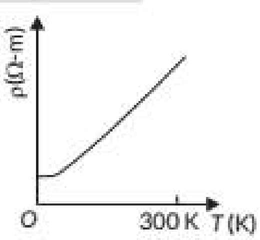
Key Points

- The size of the energy gap between conduction band and valence band for different materials is different.

5. (i) The resistivity of a conductor increases non-linearly with increase in temperature.

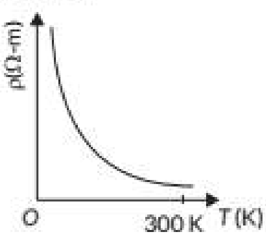


(For low temperature)



(For high temperature)

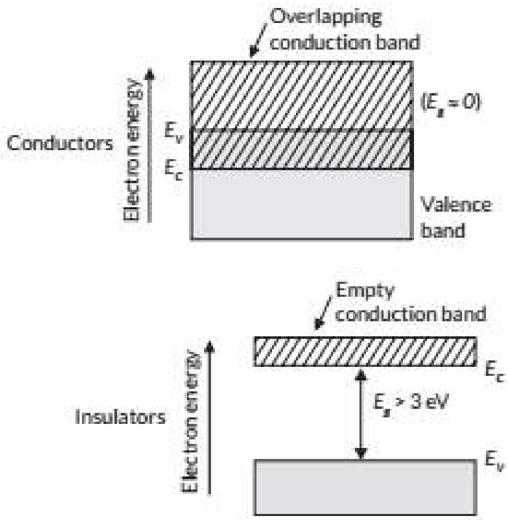
(ii) The resistivity of a semiconductor decreases with increase in temperature.



Concept Applied

- With the rise in temperature the conductivity of a conductor decreases and the conductivity of a semiconductor increases.

6.



7. (a): Assertion : Correct.

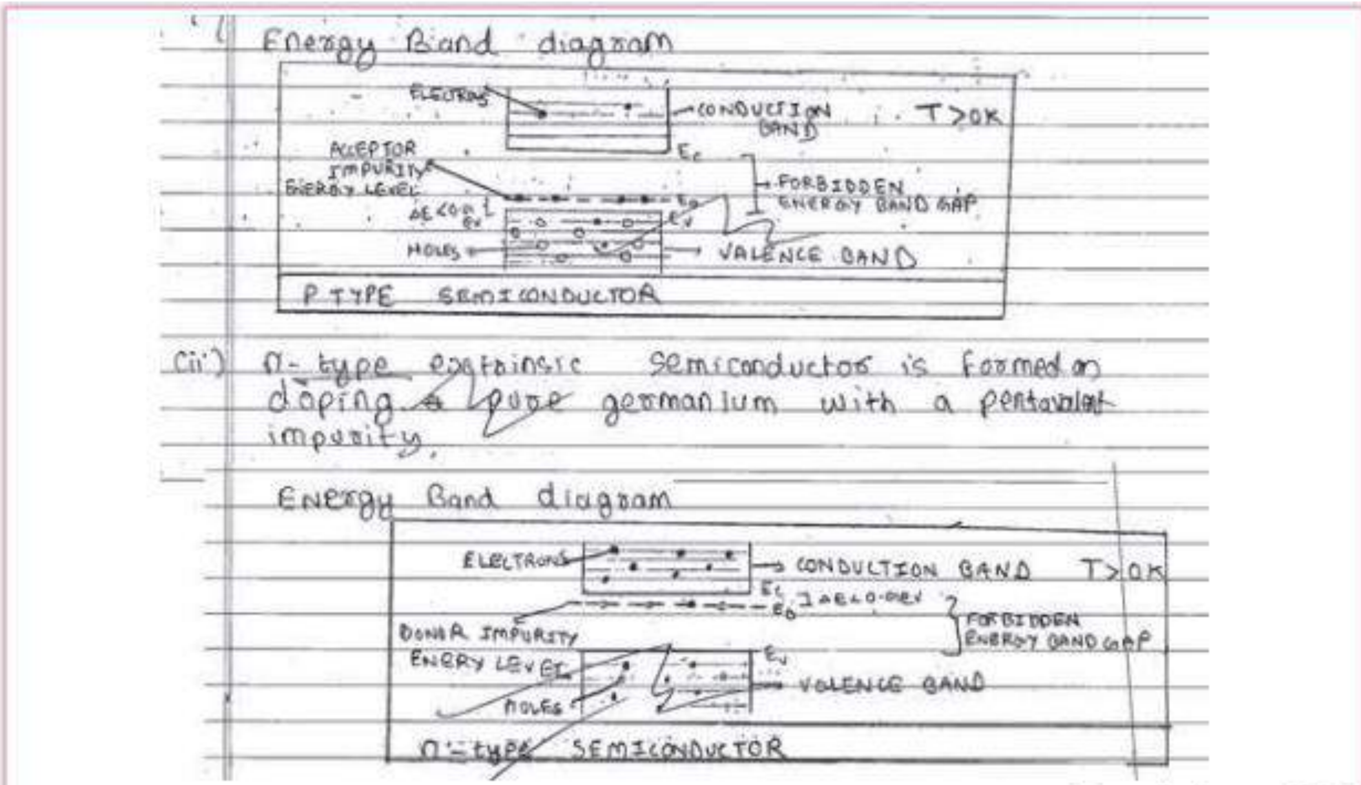
Reason : correct, the number of e^- or hole increase in conduction band. They jump from valence band to conduction band.

8. (a): When a atom is ionised, it creates a free electron and also it creates a positively ionised donor atom. The charge on the free electron and the ionised donor are equal and opposite. So, as long as the electron doesn't go anywhere, the net charge remains zero.

9. (b): In *n*-type semiconductor, the donor energy level lies just below the conduction band.

10. (b): As the temperature increases the carrier concentration increases significantly. This is because extra electrons are excited from the valence band to the conduction band, due to which the number of free electron - hole pairs increases.

11.



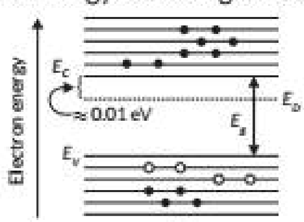
[Topper's Answer, 2022]

12. Intrinsic semiconductors have very small conductivity at room temperature. When certain impurities in small amount ($\simeq$ 1 part per million) are added to an intrinsic semiconductor, electrical conductivity of doped semiconductor increases to a great extent and made it useful in many practical applications. Pentavalent atoms and trivalent atoms are used for doping Ge/Si.
Pentavalent atoms such as – As and Sb etc
Trivalent atoms such as – Al and B etc

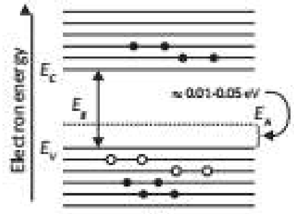
13.

	Intrinsic Semiconductors	Extrinsic Semiconductors
(i)	These are pure semiconducting tetravalent crystals.	These are semiconducting tetravalent crystals doped with impurity atoms of group III or group V.
(ii)	Their electrical conductivity is low.	Their electrical conductivity is high.
(iii)	There is no permitted energy state between valence and conduction bands.	There is permitted energy state of the impurity atom between valence and conduction bands.

14. The required energy band diagrams are given below:



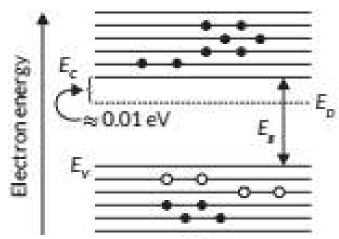
(a)
Energy band diagram of
n-tpe semiconductor
at $T > 0$ K



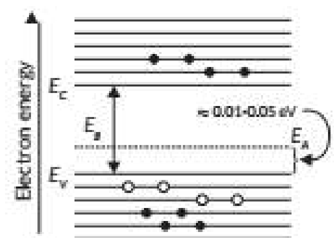
(b)
Energy band diagram of
p-type semiconductor
at $T > 0$ K

In *n*-type extrinsic semiconductors, the number of free electrons in conduction band is much more than the number of holes in valence band. The donor energy level lies just below the conduction band. In *p*-type extrinsic semiconductor, the number of holes in valence band is much more than the number of free electrons in conduction band. The acceptor energy level lies just above the valence band.

15. (i) The required energy band diagrams are given below:

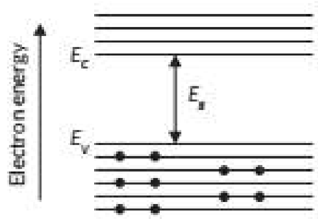


(a)
Energy band diagram of
n-tpe semiconductor
at $T > 0$ K



(b)
Energy band diagram of
p-type semiconductor
at $T > 0$ K

(ii)

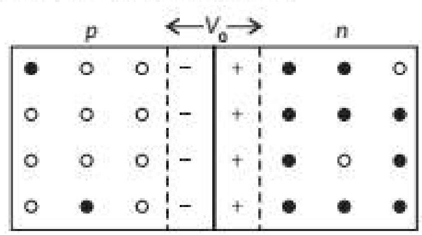


Energy band diagram of
semiconductor
at $T = 0$ K

At absolute zero temperature (0 K) conduction band of semiconductor is completely empty, *i.e.*, $\sigma = 0$. Hence the semiconductor behaves as an insulator. At room temperature, some valence electrons acquire enough thermal energy and jump to the conduction band where they are free to conduct electricity. Thus the flow of current when reverse biased.

(b) Intrinsic semiconductors have very small conductivity at room temperature. When certain impurities in small amount ($\simeq$ 1 part per million) are added to an intrinsic semiconductor, electrical conductivity of doped semiconductor increases to a great extent and made it useful in many practical applications.

18. Two processes that take place in the formation of a *p-n* junction are diffusion and drift.

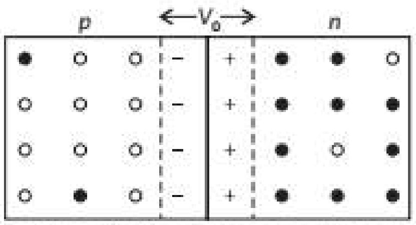


semiconductor acquires a small conductivity at room temperature.

Key Points

- In *n*-type semiconductors, electrons are majority carriers and holes are minority carriers.

16. (a) Two processes that take place in the formation of a *p*-*n* junction are diffusion and drift.



When *p*-*n* junction is formed, then at the junction free electrons from *n*-type diffuse over to *p*-type, thereby filling in the holes in *p*-type. Due to this a layer of positive charge is built on *n*-side and a layer of negative charge is built on *p*-side of the *p*-*n* junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (*i.e.*, electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the *p*-*n* junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

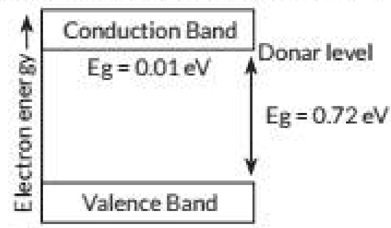
(b) No, because surface of both crystals have some roughness and contact at atomic level is not possible when slabs of *p*-type of *n*-type semiconductor are physically joined.

17. (a) In forward biasing, the forward voltage opposes the potential barrier. As a result, potential barrier height is reduced and the width of depletion region decreases. Small increase in forward voltage shows large increase in forward current. Thus resistance in forward bias is reduced.

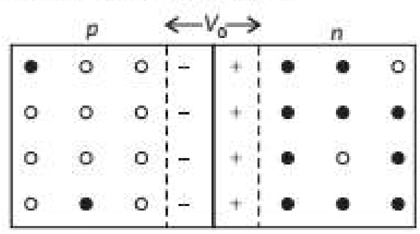
In reverse bias, barrier potential height increases. For large increase in reverse voltage shows small increase in reverse current. Thus, resistance of p-n junction is high to

When *p*-*n* junction is formed, then at the junction free electrons from *n*-type diffuse over to *p*-type, thereby filling in the holes in *p*-type. Due to this a layer of positive charge is built on *n*-side and a layer of negative charge is built on *p*-side of the *p*-*n* junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (*i.e.*, electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the *p*-*n* junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

19. (i) As germanium is an intrinsic semiconductor. The new obtained semiconductor is extrinsic semiconductor *i.e.*, *n*-type and electrons are majority charge carriers.



(ii) Two processes that take place in the formation of a *p*-*n* junction are diffusion and drift.



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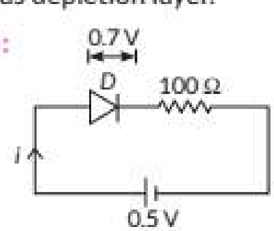
Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the *p*-*n* junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

(iii) (1) Forward biased : As forward voltage opposes the potential barrier and effective barrier potential decreases. It makes the width of the depletion layer smaller.

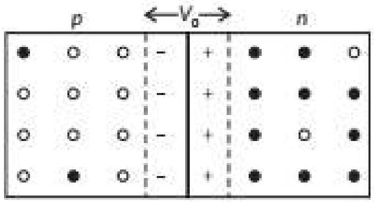
containing immobile positive and negative charges is known as depletion layer.

21. (a):



(2) Reverse biased : As reverse voltage supports the potential barrier and effective barrier potential increases. It makes the width of the depletion layer larger.

20. Two processes that take place in the formation of a *p-n* junction are diffusion and drift.



When *p-n* junction is formed, then at the junction free electrons from *n*-type diffuse over to *p*-type, thereby filling in the holes in *p*-type. Due to this a layer of positive charge is built on *n*-side and a layer of negative charge is built on *p*-side of the *p-n* junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (*i.e.*, electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the *p-n* junction called potential barrier or junction barrier. The thin region around the junction

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.

22. (c) : Zero as diffusion and drift current are equal and opposite.

23. In an unbiased *p-n* junction diode, the *p*-side of the junction is at higher potential as compared to that on the *n*-side of the junction.

24.

Concept Applied

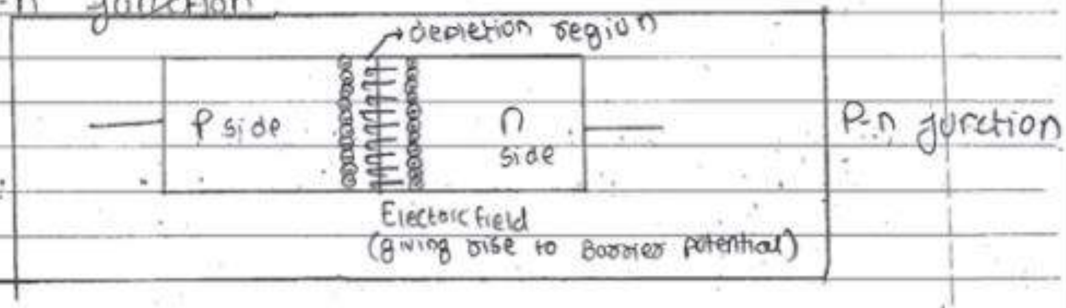
- Increasing doping concentration increases charge carriers.

When there is an increase in doping concentration carrier concentration increases. The associated increase in potential difference causes an electric field which acts opposite to the potential barrier. This results in reducing the potential barrier and hence the width of depletion layer decreases.

25.

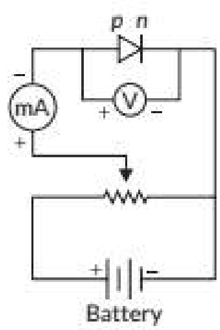
- When a p-n junction diode is formed, two process occur simultaneously : Diffusion and Drift
- Diffusion : The p side has more holes than the n side and the n side has more electrons than the p side. Hence the holes from the p side and the electrons from the n side diffuse out to the n side and p side respectively due to concentration gradient.
- As the electrons from the n side diffuse to the p side, it leaves behind an ionised donor (positively charged). Hence a layer of positive charge starts to develop in the n side near the junction.
- Further, as the holes from p side diffuse to n side, it leaves behind an ionised acceptor atom (negatively charged). Hence a layer of negative charge starts to develop in the p side near the junction.

- The layers of opposite charges developed ~~the~~ create an electric field (from n side to p side) between the junction region called the depletion region.
- Drift: Minority charge carriers of the either sides are swept by this electric field in the depletion region into their respective majority zones
- At equilibrium drift current and diffusion current are equal.
- The potential difference which is now developed due the layer of opposite charges in the depletion region is called the barrier potential.
- This is how the barrier potential is developed in a p-n junction

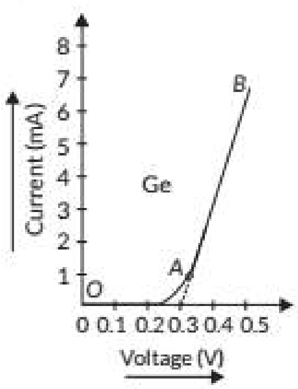


[Topper's Answer, 2022]

26. 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.



(a)



(b)

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 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.

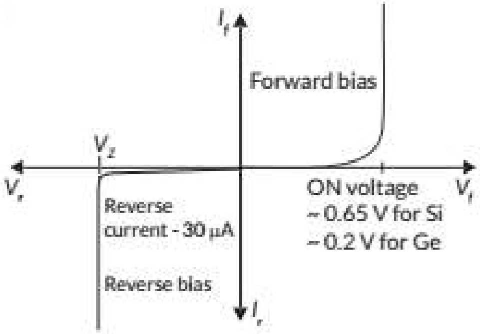
27. Depletion layer : The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called the depletion layer.

Barrier potential : Due to accumulation of negative charges in the *p*-region and positive charges in the *n*-region sets up a potential difference across the junction sets up. This acts as a barrier and is called potential barrier V_B which opposes the further diffusion of electrons and holes across the junction.

(a) In forward biasing the width of depletion layer reduced and the external applied field is able to overcome the strong electric field of depletion layer. In reverse biasing the width of depletion layer increases and the electric field of depletion layer become more stronger.

(b) As forward voltage opposes the potential barrier and effective barrier potential decreases. It makes the width of the depletion layer smaller.

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*

28. 

The reverse current is due to minority charge carriers and even a small voltage is sufficient to sweep the minority carriers from one side of the junction to the other side of the junction. Here the current is not limited by the magnitude of the applied voltage but is limited due to the concentration of the minority carrier on either side of the junction.

29. (i) From the given curve, we have
voltage, $V = 0.8$ volt for current, $I = 20$ mA
voltage, $V = 0.7$ volt for current, $I = 15$ mA

$\Rightarrow \quad \Delta I = (20 - 15)\text{mA} = 5 \times 10^{-3}$ A

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

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

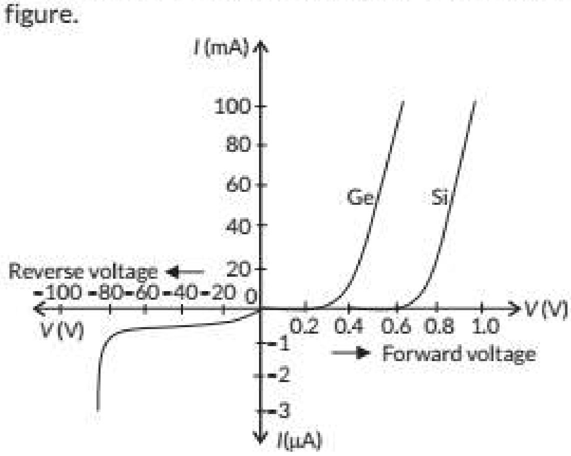
$\Rightarrow \quad R = \dfrac{0.1}{5 \times 10^{-3}}$

$\Rightarrow R = 20\ \Omega$

(ii) For $V = -10$ V, we have
$I = -1\ \mu\text{A} = -1 \times 10^{-6}$ A

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

30. I-V characteristics of a p-n junction : The *I-V* characteristics of a *p-n* junction do not obey Ohm's law. The *I-V* characteristics of a *p-n* junction are as shown in the figure.



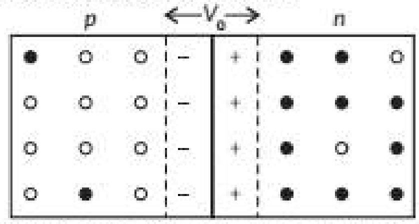
Answer Tips

- The height of potential barrier in *p-n* junction diode is proportional to temperature in kelvin.

(b) During breakdown voltage, enormous covalent bond breaks. As a result large number of charge carriers increases. Therefore current increases at breakdown voltage.

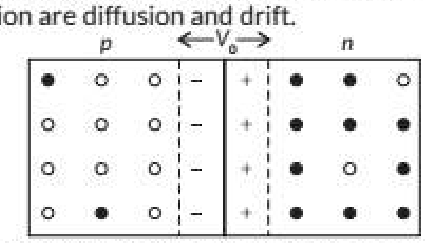
31. (a) Intrinsic semiconductors have very small conductivity at room temperature. When certain impurities in small amount (≃ 1 part per million) are added to an intrinsic semiconductor, electrical conductivity of doped semiconductor increases to a great extent and made it useful in many practical applications.

(b) Two processes that take place in the formation of a *p-n* junction are diffusion and drift.



When *p-n* junction is formed, then at the junction free electrons from *n*-type diffuse over to *p*-type, thereby filling in the holes in *p*-type. Due to this a layer of positive charge is built on *n*-side and a layer of negative charge is built on *p*-side of the *p-n* junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (*i.e.*, electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the *p-n* junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

32. Two processes that take place in the formation of a *p-n* junction are diffusion and drift.



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(a) The current of order in reverse bias is due to the drifting of minority charge carriers from one region to another through the junction. A small amount of applied voltage is sufficient to sweep the minority charge carriers through the junction. So, reverse current is almost independent of critical voltage.

containing immobile positive and negative charges is known as depletion layer.

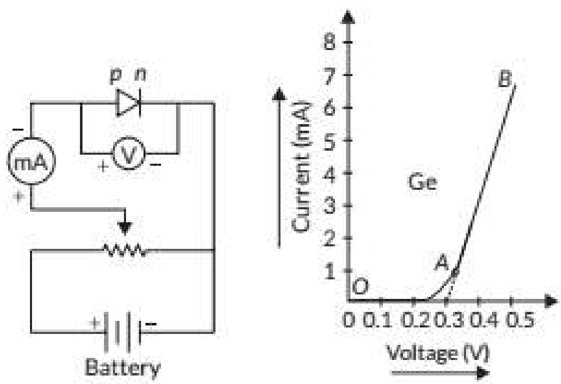
Depletion layer : The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called the depletion layer.

Barrier potential : Due to accumulation of negative charged ion in the *p*-region and positive charged ion in the *n*-region sets up a potential difference across the junction sets up. This acts as a barrier and is called potential barrier V_B which opposes the further diffusion of electrons and holes across the junction.

In forward biasing the width of depletion layer reduced and the external applied field is able to overcome the strong electric field of depletion layer.

33. Voltage at *p* side is less than the voltage at *n* side of the diode so it is in reverse bias.

34. 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.



(a) (b)

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.

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.

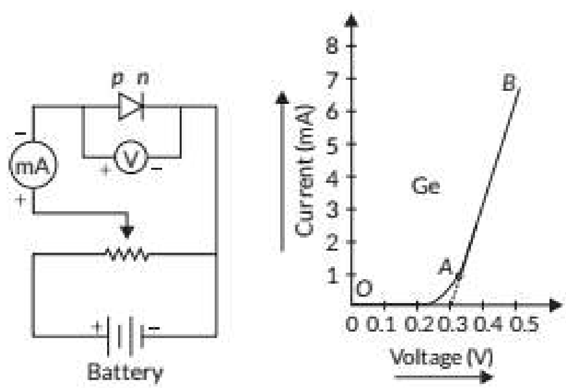
Motion of minority charge carriers is also supported by internal potential barrier, so all the minority carriers cross over the junction.

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.

(i) Minority carrier injection in forward biasing : In *p*- type semiconductors, holes are majority carriers and electrons are minority carriers, if a battery is connected to the semiconductor material, the *p*-type material may acquire additional electrons, injected into the *p*-type from the *n*-type by the flow of electrons from the battery.

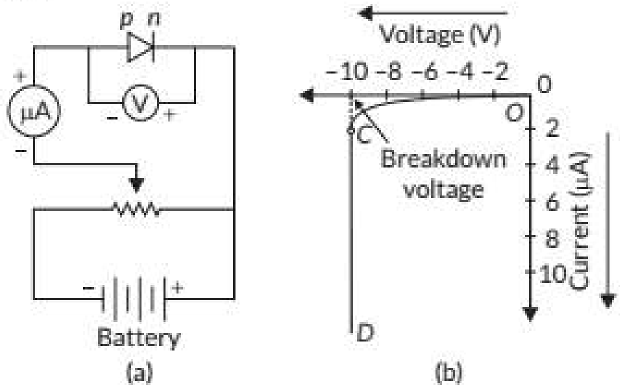
(ii) Breakdown voltage in Reverse Biasing : It is the minimum voltage that must be applied across the diode for the current to start flowing through it.

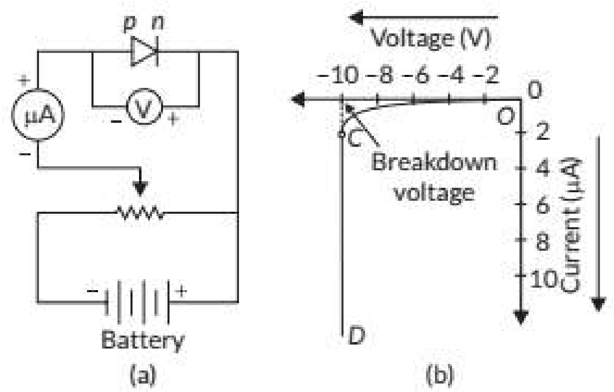
35. Forward biased characteristics : The circuit diagram for studying forward biased characteristics is shown in the figure. Starting from a low value, forward bias voltage is increased step by step (measured by voltmeter) and forward current is noted (by ammeter). A graph is plotted between voltage and current. The curve so obtained is the forward characteristic of the diode.



(a) (b)

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.

36. The ability of a juction diode to rectify an alternating voltage is based on the fact that it conducts only when it is forward biased.

37. Rectifier is based on the fact that, a forward bias *p-n* junction conducts and a reverse bias *p-n* junction does not conduct.

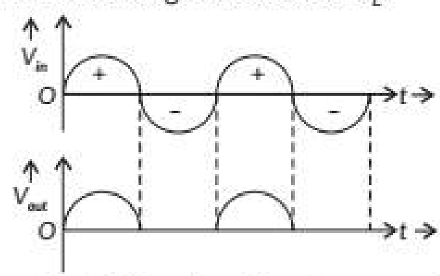
38. Differences between half wave rectifier and full wave rectifier are:

Half wave rectifier		Full wave rectifier	
(i)	A half wave rectifier is an electronic circuit	(i)	Full wave rectifier is an electronic

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.

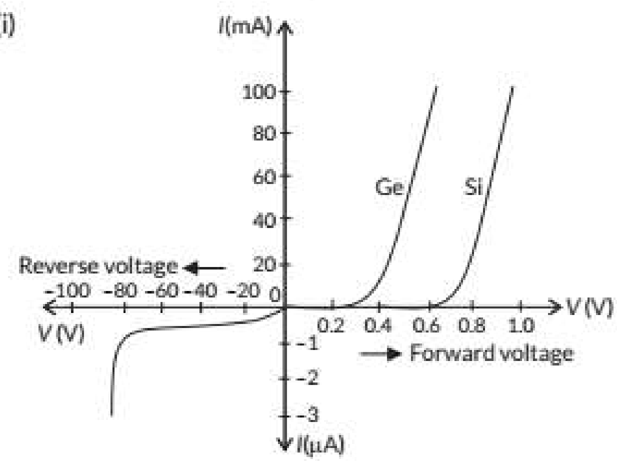
Reverse biased characteristics : The circuit diagram for studying reverse biased characteristics is shown in the figure.

It consists of a diode *D* connected in series with load resistor R_L across the secondary windings of a step-down transformer. Primary of transformer is connected to a.c. supply. During positive half cycle of input a.c., end *A* of the secondary winding becomes positive and end *B* becomes negative. Thus, diode *D* becomes forward biased and conducts the current through it. So, current in the circuit flows from *A* to *B* through load resistor R_L.



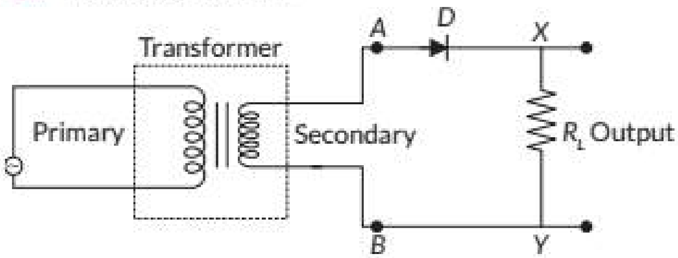
During negative half cycle of input a.c., end *A* of the secondary winding becomes negative and end *B* becomes positive. Thus, diode *D* becomes reverse biased and does not conduct any current. So, no current flows in the circuit. Since electric current flows through load R_L only during positive half cycle, in one direction only *i.e.*, from *A* to *B*, so d.c. is obtained across R_L.

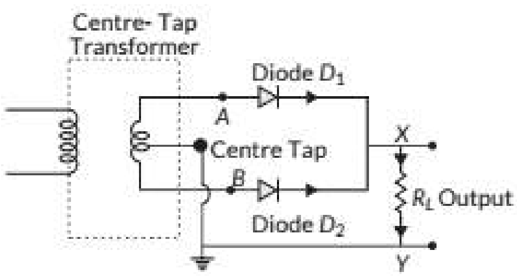
40. (i)



	which converts only one-half of the AC cycle into pulsating DC. It utilizes only half of AC cycle for the conversion process.		circuit which converts entire cycle of AC into pulsating DC.
(ii)	Output frequency of half wave rectifier is equal to the input frequency.	(ii)	Output frequency of full wave rectifier is double the input frequency.

39. Half wave rectifier:





A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a center tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes between A and B as shown in the circuit.

During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y.

(ii) Threshold voltage : In forward bias, current first increases very slowly, till voltage across diode crosses a certain value. After this voltage, diode current increases significantly even for very small increase in diode bias voltage. This voltage is called threshold voltage.

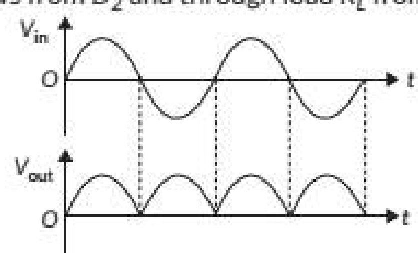
Breakdown voltage : A very small current flow through p-n junction, when it is reverse biased. The flow of the current is due to the movement of minority charge carriers. If the reverse bias voltage is continuously increased, for a certain reverse voltage, the current through the p-n junction will increase abruptly. This reverse bias voltage is thus known as breakdown voltage.

(iii) Since junction diodes conduct in forward bias and does not conduct in reverse bias, it is used in rectification of ac voltages.

41. Two p-n junction diodes can be used to make full wave rectifier which is used to convert alternating current into direct current.

Thus diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

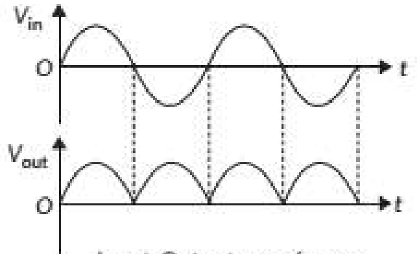
During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y.



Input-Output waveforms

Since in both the half cycles of input a.c., electric current through load R_L flows in the same direction, so d.c. is obtained across R_L. Although direction of electric current through R_L remains same, but its magnitude changes with time, so it is called pulsating d.c.

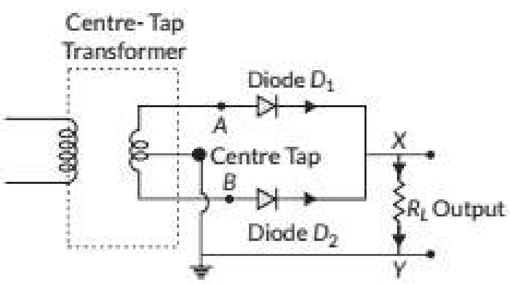
(ii) If an alternating voltage is applied across a junction diode, then the current will only in the part where it is



Input-Output waveforms

Since in both the half cycles of input a.c., electric current through load RL flows in the same direction, so d.c. is obtained across RL. Although direction of electric current through RL remains same, but its magnitude changes with time, so it is called pulsating d.c.

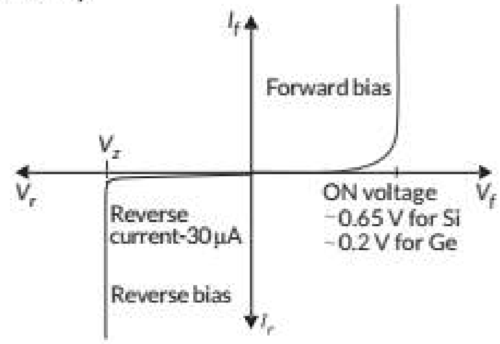
42. (i) Two p–n junction diodes can be used to make full wave rectifier which is used to convert alternating current into direct current.



A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a center tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes between A and B as shown in the circuit.

During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative.

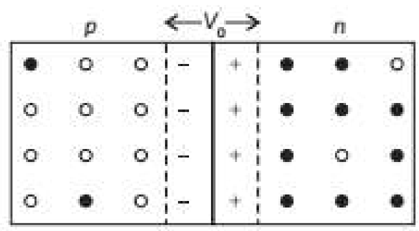
forward biased. This property of junction diode can be used to rectify.



(iii) Carbon and silicon both are the elements of the carbon family and have 4 valence electrons in the valance shell.

The 4 bonding electrons of C and Si are in the second and third orbit. Hence, energy required to take out an electron from these atoms will be least for silicon and highest for carbon due to this, the number of free electrons for conduction will be significant in silicon but will be negligibly small for carbon. That is why carbon is an insulator while silicon is intrinsic semiconductor.

43. Two processes that take place in the formation of a p-n junction are diffusion and drift.

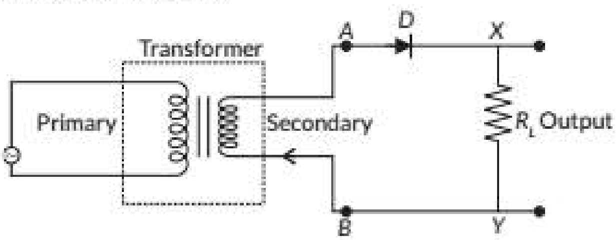


When p-n junction is formed, then at the junction free electrons from n-type diffuse over to p-type, thereby filling in the holes in p-type. Due to this a layer of positive charge is built on n-side and a layer of negative charge is built on p-side of the p-n junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (*i.e.*, electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the p-n junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

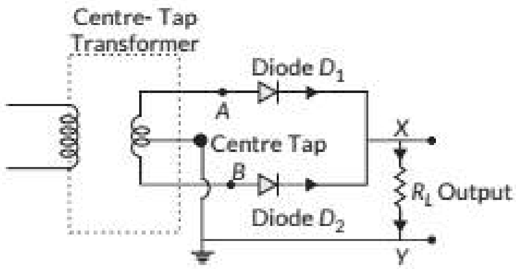
If an alternating voltage is applied across a junction diode, then the current will flow only in the part where it is forward biased. This property is used for rectification.

Two p–n junction diodes can be used to make full wave rectifier which is used to convert alternating current into direct current.

44. Half wave rectifier:



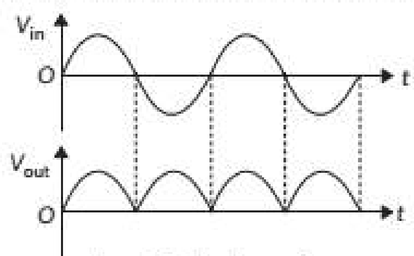
It consists of a diode D connected in series with load resistor R_L across the secondary windings of a step-down transformer. Primary of transformer is connected to a.c. supply. During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus, diode D becomes forward biased and conducts the current through it. So, current in the circuit flows from A to B through load resistor R_L.



A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a center tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes between A and B as shown in the circuit.

During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

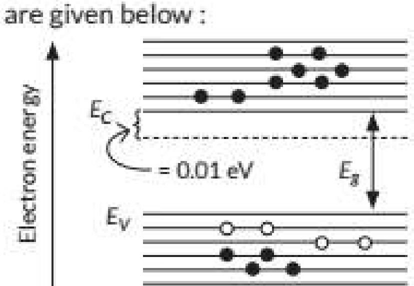
During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y.



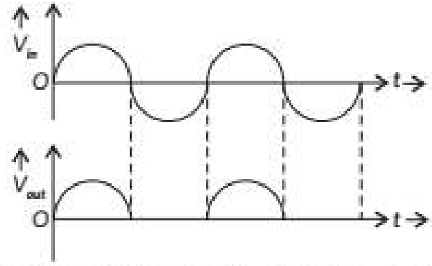
Input-Output waveforms

Since in both the half cycles of input a.c., electric current through load RL flows in the same direction, so d.c. is obtained across RL. Although direction of electric current through RL remains same, but its magnitude changes with time, so it is called pulsating d.c.

3. When antimony is doped with germanium n type semiconductor is formed. The required energy band diagrams are given below :



(a)
Energy band diagram of n-type semiconductor at $T > 0$ K



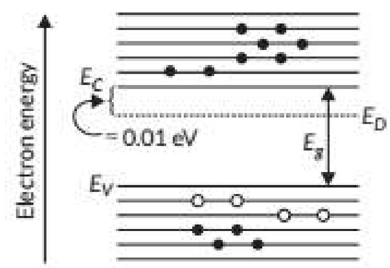
During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive. Thus, diode D becomes reverse biased and does not conduct any current. So, no current flows in the circuit. Since electric current through load R_L flows only during positive half cycle, in one direction only *i.e.*, from A to B, so d.c. is obtained across R_L.

CBSE Sample Questions

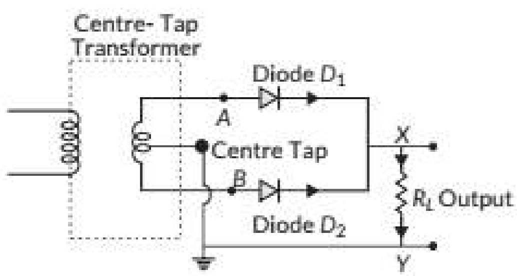
1. (c) : The electrical conductivity of semiconductor increases on adding an appropriate amount of suitable impurity or doping. It can be done with an impurity which is electron rich or electron deficient. **(1)**

2. Antimony (Sb) is a pentavalent impurity. So, when antimony is added to pure Si crystal, a n-type extrinsic semiconductor would be obtained.

Energy level diagram of n-type semiconductor



(a)
Energy band diagram of n-type semiconductor at $T > 0$ K **(2)**



(1)

A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a center tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes

In n-type extrinsic semiconductors, the number of free electrons in conductors band is much more than number of holes in valence band. The donor energy level lies just below the conduction band. Here the majority charge carriers are electrons. **(2)**

4. Given, $\Delta I = 10$ mA, $V_1 = 0.70$ V, $V_2 = 0.71$ V

Dynamic resistance, $r_d = \frac{\text{change in voltage}}{\text{change in current}}$

$$= \frac{\Delta V}{\Delta I} = \frac{(0.71 - 0.70)\,\text{V}}{10 \times 10^{-3}\,\text{A}} = 1\,\Omega$$ **(1)**

5. If the doping level is further increased, then even more number of free electrons and holes are generated. This will create a large electric field at n-side and p-side. This electric field dominates the opposing electric field from the ions. This decreases the width of depletion region. **(1)**

6. Here, input frequency = 25 Hz

For a half-wave rectifier, the output frequency is equal to the input frequency.

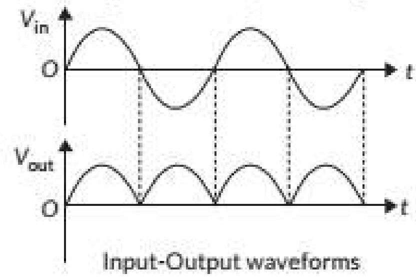
So, output frequency is also 25 Hz. **(1)**

7. Two p–n junction diodes can be used to make full wave rectifier which is used to convert alternating current into direct current.

between A and B as shown in the circuit.

During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y.



Input-Output waveforms

Since in both the half cycles of input a.c., electric current through load R_L flows in the same direction, so d.c. is obtained across R_L. Although direction of electric current through R_L remains same, but its magnitude changes with time, so it is called pulsating d.c. **(2)**