Unit IX: Electronic Devices

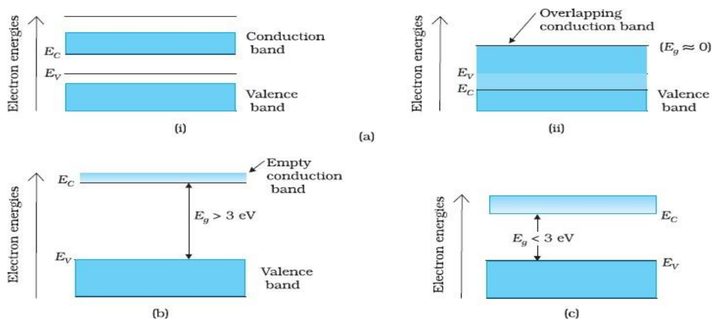
Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits

GIST OF THE CHAPTER:

Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction Semiconductor diode - I-V characteristics inforward and reverse bias, application of junction diode -diode as a rectifier.

Energy bands in solids:

- Due to influence of high electric field between the core of the atoms and the sharedelectrons, energy levels are split-up or spread-out forming energy bands.
- The energy band formed by a series of levels containing valance electrons is called valanceband and the lowest unfilled energy level just above the valance band is called conduction band.
- Filled energy levels are separated from the band of unfilled energy levels by an energy gapcalled **forbidden gap** or energy gap or band gap.



Energy band diagram for, Conductors Semiconductors and Insulators

Conductors (Metals): The conduction band and valance band partly overlap each other and there isno forbidden energy gap in between.Large number of electrons are available for electrical conduction , hence the resistance is low of such materials.Even if a small electric field is applied across the metal, these free electrons start moving.Hence metals behave as a conductor.

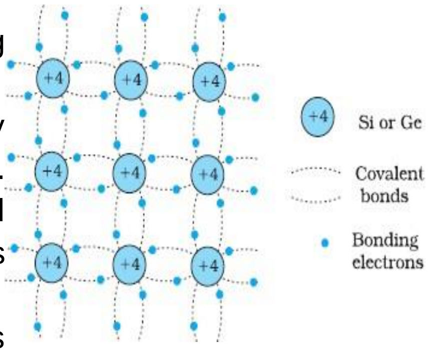
Semiconductors: The conduction and valance bands are separated by the small energy gap (1 eV) called forbidden energy gap. The valence band is completely filled, while the conduction bandis empty at zero kelvin. The electrons cross from valence band to conduction band even when a small amount of energy is supplied. The semiconductor acquires a small conductivity at room temperature.

Insulators: Electrons, however heated, cannot practically jump to conduction band from valenceband due to a large energy gap (>3 eV). Therefore, conduction is not possible in insulators.

INTRINSIC SEMICONDUCTORS:

Intrinsic Semiconductor is a pure semiconductor.

The energy gap in Si is 1.1 eV and in Ge is 0.74 eV.
Si: $1s^2, 2s^2, 2p^6, 3s^2, 3p^2$. (Atomic No. is 14)
Ge: $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^2$. (Atomic No. is 32)
Both Si and Ge have four valance electrons. The four valance electrons form four covalentbonds by sharing the electrons with neighbouring four atoms.
In intrinsic semiconductor, the number of thermally generated electrons always equals thenumber of holes. So, if n_i and p_i are the concentration of electrons and holes respectively, then $n_i = p_i$. The quantity n_i or p_i is referred to as the „intrinsic carrier concentration".
At 0 K, a semiconductor is an insulator i.e., it possesses zero conductivity. When temperature is increased, a few covalent bonds break up and release the electrons. These electrons move to conduction band leaving behind equal number of holes in valence band.The conductivity of an intrinsic semiconductor is due to both electrons and holes.



DOPING:
Doping a Semiconductor: Doping is the process of deliberate addition of a very small amount of impurity (1% of crystal atoms) into an intrinsic semiconductor.
The impurity atoms are called dopants.
The semiconductor containing impurity is known as „**Extrinsic semiconductor'**.
Doping of a semiconductor increases its electrical conductivity to a great extent.
The pentavalent impurity atoms are called donor atoms, while the trivalent impurity atomsare called acceptor atoms
Extrinsic semiconductor**.**
A semiconductor doped with a suitable impurity (pentavalent or trivalent), so as to possessconductivity much higher than the semiconductor in pure form is called an extrinsic semiconductor.
Extrinsic semiconductors are of two types:
1) **n-type semiconductor**
2) **p-type semiconductor**

1.n-type semiconductor:
When a pentavalent impurity, such as arsenic or antimony or phosphorus is added to a pure semiconductor, the four of the five valance electrons of the impurity atoms form covalent bonds by sharing the electrons with the adjoining four silicon atoms, while the fifth electronis very loosely bound with the parent impurity atom and is comparatively free to move.
The number of free electrons become more than the holes in the semiconductor and such anextrinsic semiconductor is called n-type semiconductor. In other words, in a n-type semiconductor, electrons are majority carriers and holes are minority carriers.

2)p-type semiconductor:
When a trivalent impurity, such as indium or gallium or boron is added to a pure semiconductor, three valance electrons of the impurity atoms form covalent bonds by sharing the electrons with theadjoining three silicon atoms.

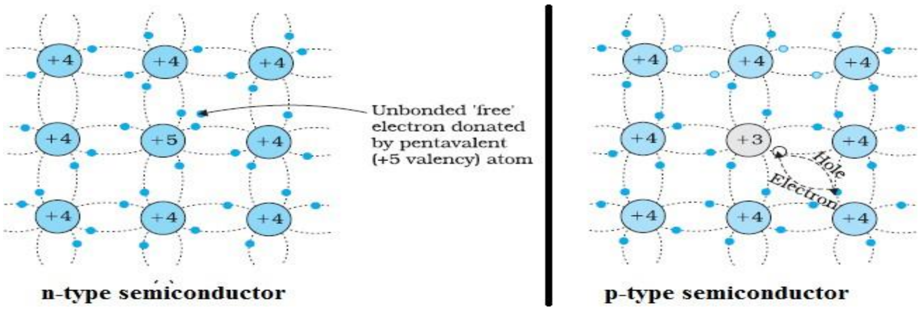
Due to the deficiency of an electron, there is one incomplete covalent bond. The vacancy that existswith the fourth covalent bond with fourth Si atom constitutes a hole.

The semiconductor becomes deficient in electrons i.e. number of holes become more than the number of electrons. Such a semiconductor is called p-type semiconductor. It has holes as majoritycarriers and electrons as minority carriers.

Electrical conductivity of a semiconductor:

The conductivity of a semiconductor is determined by the mobility (μ) of both electrons and holesand their concentration. Mathematically- $\sigma = e\,(n_e \mu_e + n_h \mu_h)$

P-N JUNCTION.



The device obtained by bringing a p-type semiconductor crystal into close contact with n-type semiconductor crystal is called a p-n junction. It conducts in one direction only. It is also called ajunction diode

Depletion layer.

It is a thin layer formed between the p and n-sections and devoid of holes and electrons. Its width is about 10^{-8} m. A potential difference of about 0.7 V is produced across the junction, which gives rise to a very high electric field (= 10^{6} V/ m).

Potential Barrier:

The difference in potential between p and n regions across the junction makesit difficult for the holes and electrons to move across the junction. This acts as a barrier and hencecalled „potential barrier" .**Potential barrier for Si is nearly 0.7 V and for Ge is 0.3 V. The potential barrier opposes the motion of the majority carriers.**

Forward biasing:

The p-n junction is said to be forward biased, when the positive terminal of the external battery isconnected to p-section and the negative terminal to n-section of the junction diode.

P-N JUNCTION.

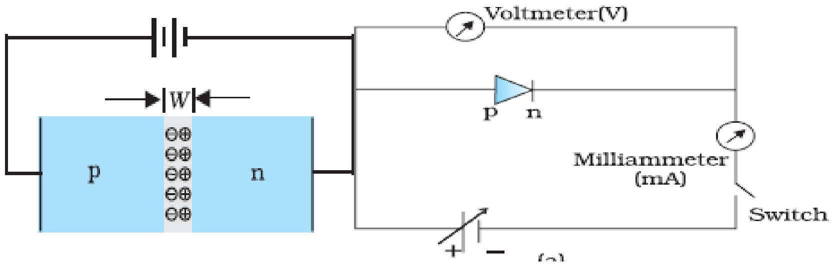
The device obtained by bringing a p-type semiconductor crystal into close contact with n-type semiconductor crystal is called a p-n junction. It conducts in one direction only. It is also called a junction diode

Depletion layer. It is a thin layer formed between the p and n-sections and devoid of holes and electrons. Its width is about 10-8 m. A potential difference of about 0.7 V is produced across the junction, which gives rise to a very high electric field (= 106 V/ m).

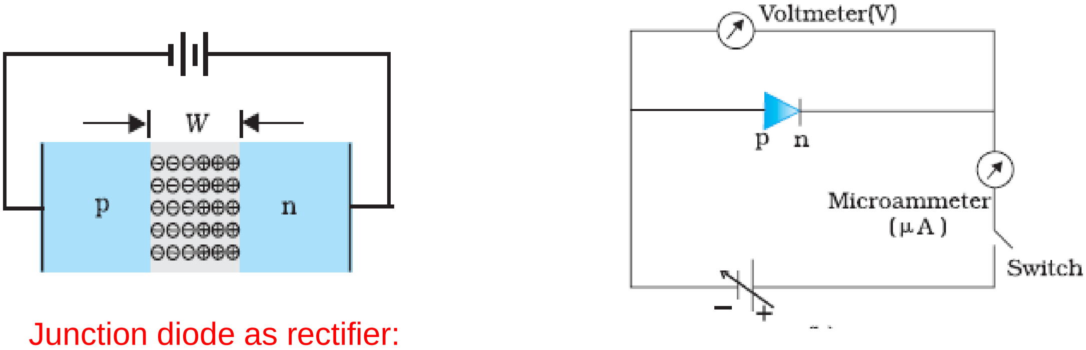
Potential Barrier: The difference in potential between p and n regions across the junction makes it difficult for the holes and electrons to move across the junction. This acts as a barrier and hence called „potential barrier‟.Potential barrier for Si is nearly 0.7 V and for Ge is 0.3 V.The potential barrier opposes the motion of the majority carriers.

Forward biasing:

The p-n junction is said to be forward biased, when the positive terminal of the external battery is connected to p-section and the negative terminal to n-section of the junction diode.



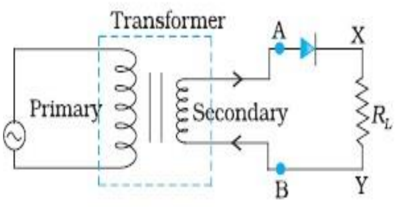
Reverse biasing: The p-n junction is said to be reverse biased, when the positive terminal of the battery is connected to n-section and the negative terminal to p-section of the junction diode.



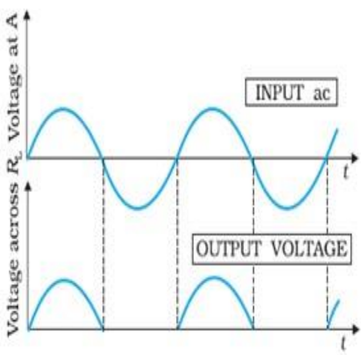
Junction diode as rectifier:

Because of its unidirectional conduction property, the p-n junction is said to convert an a,c.voltage into d. c, voltage, It is, then, said to be acting as a rectifier.

1. **Half wave rectifier:** A rectifier, which rectifies only one half of each a.c. input supply cycle, is called a half wave rectifier. A half wave rectifier gives discontinuous and pulsating d.c. output. As alternative half cycles of the a.c. input supply go waste, its efficiency is very low.

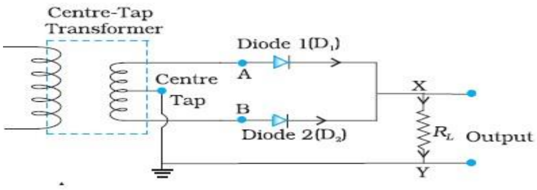


Circuit Diagram

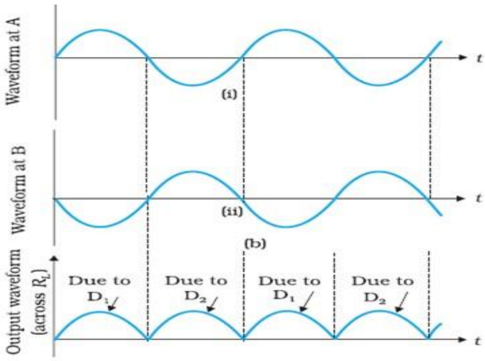


Input- Output Waveform

2. Full wave rectifier: A rectifier which rectifies both halves of each a.c. input cycle is called a full wave rectifier. The output of a full wave rectifier is continuous but pulsating in nature. However, it can be made smooth by using a filter circuit.



Circuit Diagram



Input- Output Waveform

TABLES

1) DIFFERENCE BETWEEN INTRINSIC AND EXTRINSIC SEMICONDUCTORS

S.NO	INRINSIC SEMICONDUCTOR	EXTRINSIC SEMICONDUCTOR
1	Pure form of semiconductor.	Impure form of semiconductor.
2	Conductivity is low	Conductivity is higher than intrinsicsemiconductor.
3	The no of holes is equal to no offree electrons	In n-type, the no. of electrons is greater than that of the holes and inp-type, the no. holes is greater than that of the electrons.
4	The conduction depends on temperature.	The conduction depends on the concentration of doped impurity andtemperature.

DIFFERENCE BETWEEN HALF WAVE AND FULL WAVE RECTIFIER

S.NO	HALF WAVE RECTIFIER	FULL WAVE RECTIFIER
1	Only half cycle of AC is rectified.	Both cycles of AC are rectified.
2	Requires only one diode	Requires two diodes.
3	The output frequency is equal toinput supply frequency. (F)	The output frequency is double of theinput supply frequency. (2F)
4	The electric current through theload is not continuous	A continuous electric current flowthrough the load.

SEMICONDCTOR ELECTRONICS: MATERIALS DEVICES AND SIMPLE CIRCUITS

SOLIDS

CONDUCTORS
$E_g=0$
Charge carrier density: very high (for electrons)

INSULATORS
$E_g > 3$ eV

SEMICONDUCTORS
Eg < 3 eV   Eg=0.72 eV for Ge & Eg=1.1 eV for Si

CONDUCTION BAND: HIGHER ENERGY BAND ABOVE VALANCE BAND

VALANCE BAND COMPLETELY

FORBIDDEN BAND
ENERGY GAP BETWENN V.B.

PURE/INTRINSIC
ni=ne=nh
ex. Si, Ge

IMPURE/EXTRINSIC

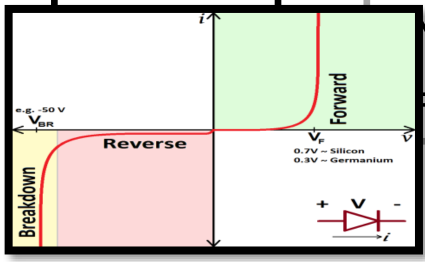
P-TYPE SEMICONDUCTOR:
OBTAINED BY ADDING IMPURITY FROM III-A GROUP in Si or Ge ex. Al,B
- Electrons are majority carriers

N-TYPE SEMICONDUCTOR:
OBTAINED BY ADDING IMPURITY FROM III-A GROUP in Si or Ge ex. P,As,Sb

SEMICONDUCTOR DIODE:

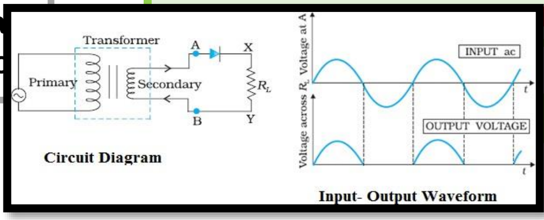
FORWARD

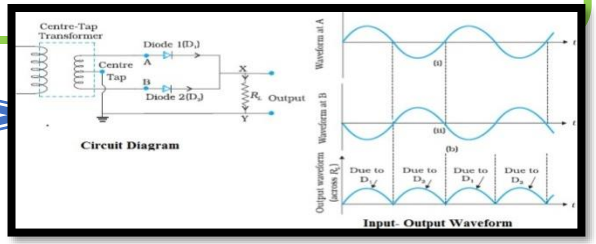
REVERSE BIASED: N side to terminal P-side to



SEMICONDUCTOR DIODE AS RECTIFIER:

AC TO DC





MCQ LEVEL 1

1 The energy band gap is maximum in

(a) Metals (b) superconductors (c) insulators (d) semiconductors

2 At absolute zero, silicon (Si) acts as

(a) Non-metal (b) metal (c) insulator (d) none of these

3 When impurities are added to a pure semiconductor, the procedure is known as

(a) Mixing (b)Doping (c)Diffusing (d)None of the above

4 Silicon is doped with which of the following to obtain P type semiconductor

(a) Phosphorus (b) Gallium (c) Germanium (d) Bismuth

5 When an intrinsic semiconductor is doped with an impurity, the semiconductor's conductivity

(a) Increases (b) decreases (c) remains the same (d) becomes zero

6 6. Correct order of relative values of electrical conductivity σ for different types of solid is…….

(a) σ metal >σ semiconductor > σ insulator

(b) σ semiconductor >σ insulator >σ metal

(c) σ semiconductor >σ metal >σ insulator

(d) σ insulator>σ semiconductor>σ metal

7 To create a p-type semiconductor, an pure semiconductor is doped with the following material:

a) aluminum b) Phosphorous c) Arsenic d) Sodium

8 The following parameters determines a p-n junction's barrier potential:

i) type of semiconductor or material (ii) amount of doping (iii) Temperature

Which one of the following is correct?

(a)Both (i)and(ii) (b)Only(ii) (c)Both (ii)and(iii) (d)(i),(ii)and(iii)

Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

A: If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

B: If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

C:If the Assertion is correct but Reason is incorrect.

D: If both the Assertion and Reason are incorrect

9 Assertion (A): The depletion layer in the p-n junction is free from mobile charge carriers.

Reason (R) : There is no electric field across the junction barrier.

10 Assertion: The energy gap between the valence band and conduction band is greater in silicon than in germanium.

Reason: Thermal energy produces fewer minority carriers in silicon than in germanium

11 Assertion: The total current I in a semiconductor is the sum of electron current and hole current.

Reason: In a semiconductor, motion of holes towards positive potential and free electrons towards negative potential.

12 Assertion: A hole on p-side of a p n- junction moves to n-side just an instant after drifting of charge carriers occurs across junction.

Reason: Drifting of charge carriers reduces the concentration gradient across junction.

13 Assertion (A): When a p-n junction diode is reverse biased, a feeble reverse-current flows known as reverse saturation current.

Reason (R): In reverse bias condition, the minority carries can cross the junction.

14 Assertion : The resistivity of a semi-conductor increases with temperature.

Reason : The atoms of semi-conductor vibrate with larger amplitude as higher temperatures thereby increasing its resistivity.

15 Assertion: If the temperature of a semiconductor is increased then it's resistance decreases.

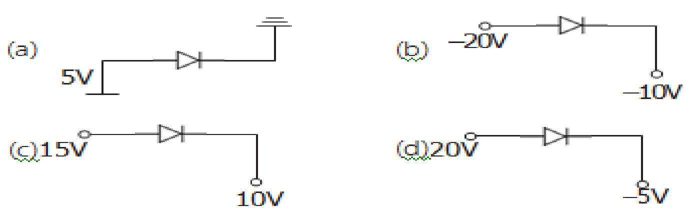
Reason: The energy gap between conduction band and valence band is very small.

16 Assertion: The number of electrons in a p-type silicon semiconductor is less than the number of electrons in a pure silicon semiconductor at room temperature.

Reason: It is due to law of mass action.

MCQ LEVEL 2

1 Which diagram below best illustrates a reverse biased diode?



2 Free electrons have more mobility than free holes due to the following reasons:
(a) they are light (b) they carry negative charge
(c) They mutually collide less d) they require low energy to continue their motion

3 The energy needed for an electron to move from the valance band to the conduction band in Germanium is
(a) 0.12 eV (b)0.72 eV (c)7.2 eV (d)None of these

4. For semiconductors, which of the ones that follow is the most suitable?
(a) large evacuated space (b)external heating arrangement
(c) low operating voltages (d)high power

5 When a forward bias is applied to a p-n junction, it
(a) raises the potential barrier. (b) reduces the majority carrier current to zero. (c) lowers the potential barrier (d)None of the above.

6. In a full wave rectifier, input AC has a frequency ‘v’. The output frequency of current is
(a) v /2 (b) v (c) 2 v (d) None of these

7 When an electric field is applied across a semiconductor,
(a) Electrons move from lower energy level to higher energy level in the conduction band
(b) Electrons move from higher energy level to lower energy level in the conduction band
(c) Holes in the valence band move from lower energy level to higher energy level
(d) None of the above

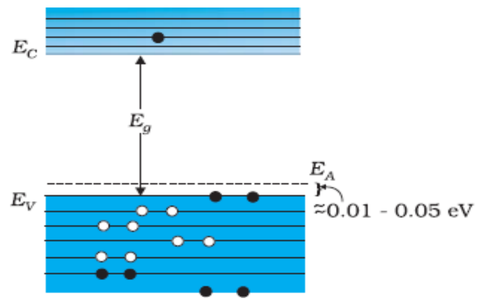
Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.
A: If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
B: If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion. C:If the Assertion is correct but Reason is incorrect.
D: If both the Assertion and Reason are incorrect

8 Assertion (A): For the same doping concentrations, n-type Si material has a higher conductivity than p-type Si material.
Reason (R): In a semiconductor the electrons are less tightly bounded than holes.

9 Assertion (A): n-type semiconductors of silicon are electrically charged.
Reason(R): In n-type semiconductors, the doped atom has no more valence Electron than silicon.

MCQ LEVEL 3

The filled and unfilled circles in the energy band diagram of the material below represent electrons and holes, respectively. The content is



(a) insulator (b)metal (c)n-type semiconductor (d)p-type semiconductor

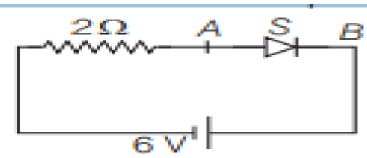
2 As temperature rises, semiconductors' electrical resistance decreases because... (a) temperature provides energy to electrons in valance Band to cross the forbidden band (b) temperature absorbs from electrons
(c) semiconductor converts into perfect conductor due to increase in temperature
(d) temperature provides energy to electrons in conduction Band to cross the forbidden band

3 If the forward voltage in a semiconductor diode is doubled, the width of the depletion layer will…..
(a) Become half (b) Become one-fourth (c) Remain unchanged (d) Become double

4. In order to convert sinusoidal signal into unidirectional signal which of the following device is used?
(a) An amplifier (b) A rectifier (c) An oscillator (d) A modulator

5 Which of these graphs illustrates the potential difference between the equilibrium p-side and n-side of a p-n junction?

6 A silicon diode is the diode that is displayed in the circuit. The potential difference between points A and B will come to be



(a) 6 V (b) 0.6 V (c) 0.7 V (d) 0 V

Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

A: If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

B: If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

C:If the Assertion is correct but Reason is incorrect.

D: If both the Assertion and Reason are incorrect

8 Assertion (A): Electron has higher mobility than hole in a semiconductor.
Reason(R): The mass of electron is less than the mass of the hole.

9 Assertion (A): When two semiconductor of p-type and n- type are brought in contact, they form p-n junction which act like a rectifier.
Reason(R): A rectifier is used to convert alternating current into direct current.

10 Assertion (A): A p-n junction with reverse bias can be used as a photo-diode to measure light intensity.
Reason(R): In a reverse bias condition the current is small but it is more sensitive to changes in incident light intensity.

2 MARK QUESTIONS
LEVEL-1

1 Given that silicon and carbon have four valence electrons each, how may they be distinguished?

2 Draw the n- and p-type semiconductors' energy band diagrams at a temperature T >0K. With their energies, show the energy levels of the donor and acceptor.

3 Using a circuit diagram, describe how a p-n junction diode functions as a half-wave rectifier.

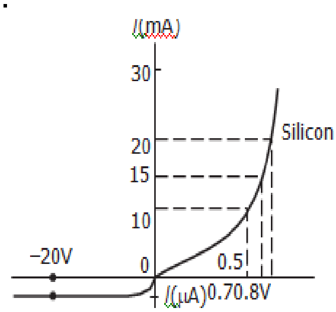
4 Distinguish between intrinsic and extrinsic semiconductors.

5 As far as we are aware, despite having a lot of holes, p-type semiconductors are electrically neutral. Why?

2 MARK QUESTIONS
LEVEL-2

1 Write differences between forward bias and reverse bias.

2 The *V*-***I*** characteristic of a silicon diode is as shown in the figure. Calculate the resistance of the diode at (i) ***I*** = 5 mA and (ii) *V* = –20V



3 How does a doping agent modify a semiconductor's conductivity?

4 How does temperature cause semiconductors' resistivity to decrease?

2 MARK QUESTIONS
LEVEL-3

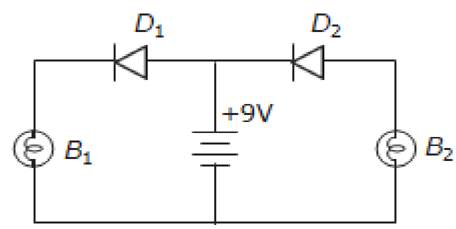
1 What do energy bands mean? Based on energy band diagrams, list any two characteristics that separate conductors, semiconductors, and insulators.
2 What happens when germanium metal is slightly doped with indium?
3 Who are the major charge carriers in n-type and p-type semiconductors?
4 Describe the formation of the depletion area and potential barrier in a junction diode using a diagram.
5 Is using a full wave rectifier preferable to a half wave rectifier? Why?

3 MARK QUESTIONS
LEVEL-1

1 Draw a diode's voltage-current characteristic curve and highlight its key features.
2 Using a diagram, explain how the barrier potential and depletion region develop at a p-n junction.

3 MARK QUESTIONS
LEVEL-2

1 In the following diagram, which bulb out of B1 and B2 will glow and why?



2. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams.
3. Name two important processes that occur during the formation of a p-n junction.
4 The maximum wavelength at which solid begin to absorb energy is 10000 Å. Calculate the energy gap of a solid (in eV).

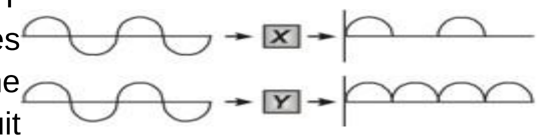
3 MARK QUESTIONS
LEVEL-3

1 (a) Distinguish between n-type and p-type semiconductors on the basis of energy band diagrams.

(b) Compare their conductivities at absolute zero temperature and at room temperature

2. Draw the input and output waveforms of half-wave rectifier and full wave rectifier.

3. An a.c. signal is fed into two circuits X and Y and the corresponding output in the two cases have the wavefront shown in figure. Name the circuit X and Y. Also draw their detailed circuit diagram.



CASE STUDY/SOURCE BASED QUESTIONS
LEVEL-1

1.

On the basis of energy bands materials are also defined as metals, semiconductors and insulators. These semiconductors are classified as intrinsic semiconductors and extrinsic semiconductors also. Intrinsic semiconductors are those semiconductors which exist in pure form. And intrinsic semiconductors have number of free electrons is equal to number of holes. The semiconductors doped with some impurity in order to increase its conductivity are called as extrinsic semiconductors. Two types of dopants are used they are trivalent impurity and pentavalent impurity also. The extrinsic semiconductors doped with pentavalent impurity like Arsenic, Antimony, Phosphorus etc are called as n – type semiconductors. In n type semiconductors electrons are the majority charge carriers and holes are the minority charge carriers. When trivalent impurity is like Indium, Boron, Aluminium etc are added to extrinsic semiconductors then p type semiconductors will be formed. In p type semiconductors holes are majority charge carriers and electrons are the minority charge carriers.

I) What is extrinsic semiconductor?

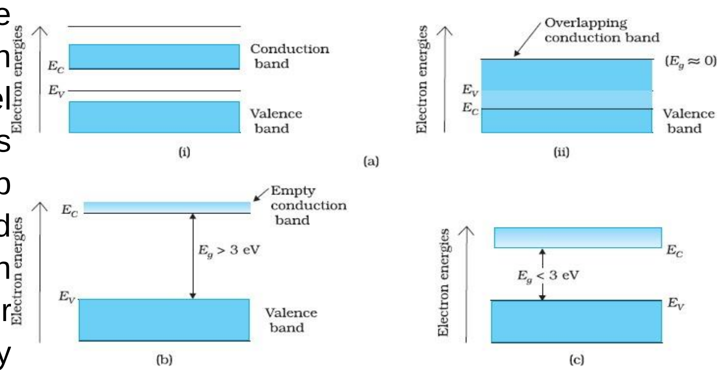
II) What is ratio of number of holes and number of electrons in an intrinsic semiconductor?

III) Why doping is necessary?

IV) Majority charge carriers in p-type semiconductor are

2.

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. Following are the energy band diagrams for conductor fig (ii), for insulators fig (b) and for semiconductors fig (c).

i) In an insulator energy band gap is
a)Eg= 0eV (b) Eg> 3eV (c) Eg< 3eV (d) None of this

ii) In a semiconductor, separation between conduction and valence band is of the order of
(a) Eg= 0eV (b) Eg> 3eV (c) Eg< 3eV (d) None of these

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

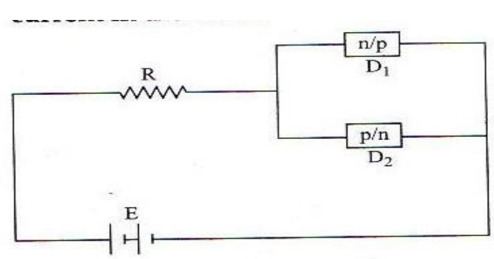
iv) (IV) Solids having highest energy level partially filled with electrons are
(a)semiconductor (b) conductor (c) insulator (d) none of these

5 MARK QUESTIONS
LEVEL-1

1 Draw V-I characteristics of a p-n junction diode. Answer the following questions giving reasons.
(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?
(ii) Why does the reverse current show a sudden increase at the critical voltage?

5 MARK QUESTIONS
LEVEL-2

1 i) How are p- type semiconductors produced?
ii) The forbidden band energy of silicon is 1.1eV. What does it mean?
iii) What is an ideal diode?
iv) Figure shows two p-n junction diode along with a resistance and a d.c battery E. Indicate the path and the direction of appreciable current in the circuit.



5 MARK QUESTIONS
LEVEL-3

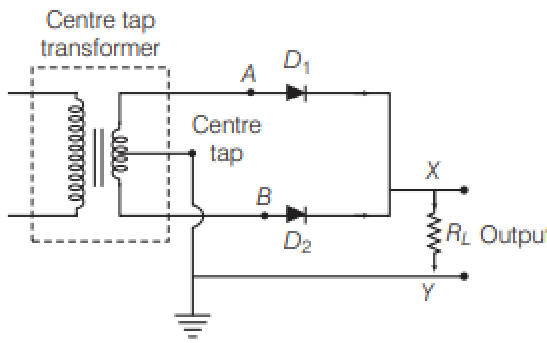
1 i)What is doping? Write the name of the impurities used to fabricate p type & n type Semiconductor.

ii) Draw the energy band diagram of conductor , insulator and semiconductor.

CASE STUDY/SOURCE BASED QUESTIONS
LEVEL-2

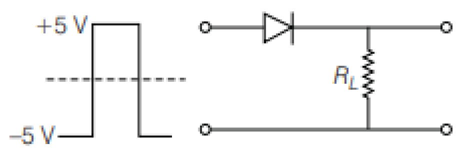
1.

Full Wave Rectifier The process of converting alternating voltage/current into direct voltage/current is called rectification. Diode is used as a rectifier for converting alternating current/voltage into direct current/voltage. Diode allows current to pass only, when it is forward biased. So, if an alternating voltage is applied across a diode, the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify the current/voltage.

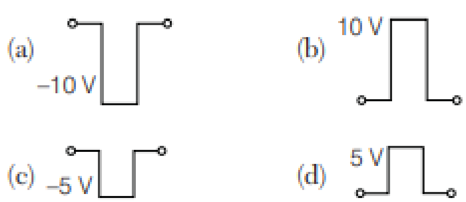


Circuit diagram of full wave rectifier

i) If in a p-n junction, a square input signal of 10V is applied as shown

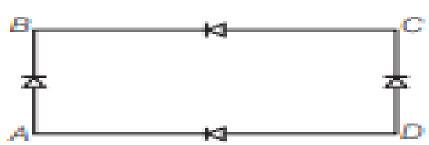


Then, the output across R_L will be



ii) In figure, the input is across the terminals A and C and the output is across B and D. Then, the output is

15



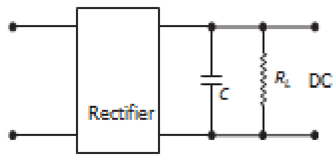
(a) zero
(b) same as the input
(c) half wave rectified
(d) full wave rectified

iii) Which of the following is not true about a rectifier circuit?

(a) It can convert DC to AC. (b) It can convert AC to DC.

(c)It can shift voltage level .(d)None of these

iv) In the given circuit,



Capacitor c is used

(a) for storing potential energy

(b) as a bypass to DC component to get AC in RL

(c) to remove sparking

(d) as a bypass to AC component to get DC in RL

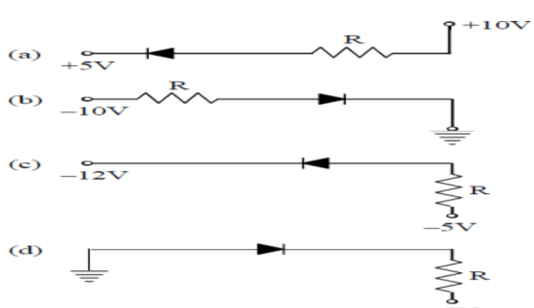
v) The ratio of output frequencies of half-wave rectifier and a full wave rectifier, when an input of frequency 200 Hz is fed at input, is

(a) 1:2 (b)2: 1 (c) 4 :1 (d) 1 : 4

CASE STUDY/SOURCE BASED QUESTIONS
LEVEL-3

1.When the diode is forward biased, it is found that beyond forward voltage V = Vk, called knee voltage, the conductivity is very high. At this value of battery biasing for p-n junction, the potential barrier is overcome and the current increases rapidly with an increase in forwarding voltage. When the diode is reverse biased, the reverse bias voltage produces a very small current about a few microamperes which almost remains constant with bias. This small current is reverse saturation current

i) i) In which of the following figures, the p-n diode is forward biased



(a) a,b and d (b) c only (c) c and a (d) b and d

ii) Based on the V-I characteristics of the diode, we can classify diode as

(a) bi-directional device (b) ohmic device

(c) non-ohmic device (d) passive element

iii) In the case of forwarding biasing of a p-n junction diode, which one of the following statement is correct?

(a) effective barrier potential decreases

(b) majority charge carriers begins to flow away from junction

(c) width of depletion layer increases

(d) effective resistance across the junction increases

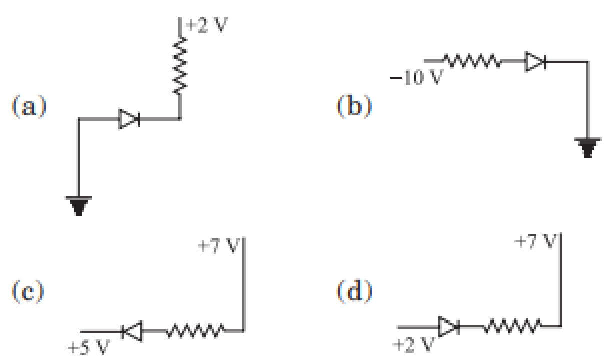
iv) If an ideal junction diode is connected as shown, then the value of the current I is.

(a) 0.005 (b) 0.02 A (c) 0.01 A (d) 0.1A

2.

When the diode is forward biased, it is found that beyond forward voltage V = Vk, called knee voltage, the conductivity is very high. At this value of battery biasing for p-n junction, the potential barrier is overcome and the current increases rapidly with increase in forward voltage. When the diode is reverse biased, the reverse bias voltage produces a very small current about a few microamperes which almost remains constant with bias. This small current is reverse saturation current. 36. In which of the following figures, the p-n diode is forward biased.

i) In which of the following figures, the p-n diode is forward biased

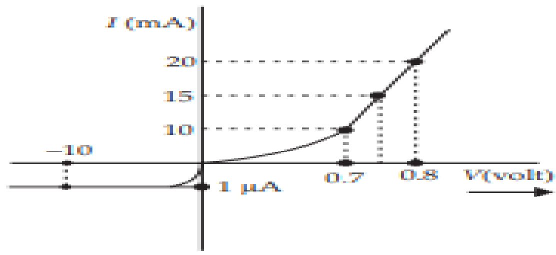


ii) Based on the V-I characteristics of the diode, we can classify diode as

(a) bi-directional device (b) ohmic device

(c) non-ohmic device (d) passive element

iii) The V-I characteristic of a diode is shown in the figure. The ratio of forward to reverse bias resistance is



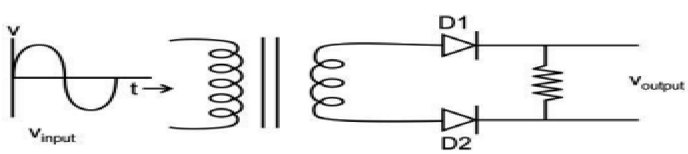
(a) 100 (b) 10^6 (c) 10 (d) 10^{-6}

iv) If an ideal junction diode is connected as shown, then the value of the current I is

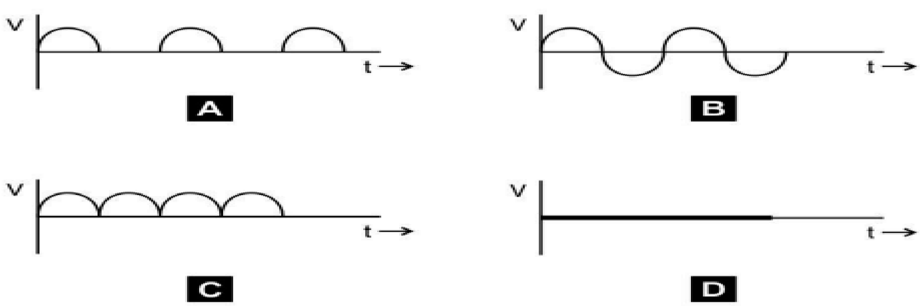
(a) 0.013 A (b) 0.02 A
(c) 0.01 A (d) 0.1 A

COMPETENCY BASED QUESTIONS
MCQ

1 The diagram below shows a transformer whose output terminals are connected to two diodes D1 and D2 01

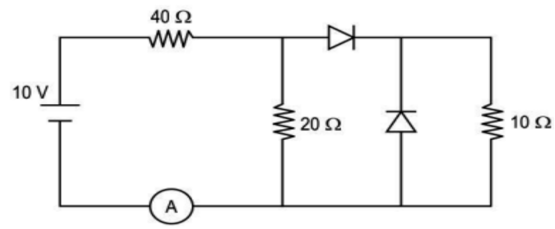


Which of the following represents the waveform obtained at the outpu terminals of the transformer correctly?



A. A
B. B
C. C
D. D D

2 A 10V battery is attached to 3 resistors and two ideal diodes as shown below. What will be the reading of the ammeter? 01



a)1/6 A b)1/5 A c) 1/4 A d)3/14 A

3 What is energy required for an electron to jump to forbidden band in Silicon at room temperature? 01

a) 0.01 eV b)0.05 eV c)0.7 eV d)1.1 Ev

4 A battery, resistance, and semiconductor device are connected in a series circuit. The circuit is determined to be carrying a current. The current almost completely disappears if the battery's polarity is switched. The apparatus could be 01

a) Si Semiconductor b) Si with III-A impurity c) Si With V-A impurity d) diode

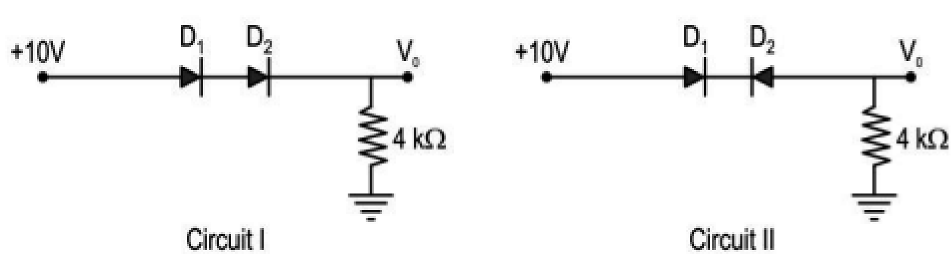
COMPETENCY BASED QUESTIONS

2 MARK QUESTIONS

1 A sample of germanium doped with pentavalent impurity is heated to 300 K. Determine the electron and hole counts if the pentavalent impurity concentration is 12 x 10^{17} cm^{-3}. Assume that the impurity atom has fully ionized. Given: 2.4 x 10^{13} cm^{-3} is the inherent carrier concentration. 02

2 When a forward-biased p-n junction experiences a voltage supply that exceeds the potential barrier, the diffusion current increases exponentially in proportion to the number of holes that diffuse into the n-region. Will the diffusion current eventually reach zero and the hole concentration in the p- and n-regions become equal? Give reasons for your response. 02

3 The threshold voltage for diodes D1 and D2 are 0.3 V and 0.7 V respectively. In circuit I, both the diodes D1 and D2 are forward biased. In circuit II, D1 is forward biased whereas D2 is reverse biased. Determine current through the diodes in series, ID and voltage Vo in each of the two given circuits. 02



4 A p-n junction diode has a depletion layer of thickness 500 nm and an electric field 16 x 105 V/m. 02

a. Find the barrier potential created.

b. Determine the minimum kinetic energy (in eV) that the conduction electrons must have so that they can diffuse from n-side onto p-side, in case of:

i. the junction is unbiased

ii. the junction is forward biased at 0.5 V

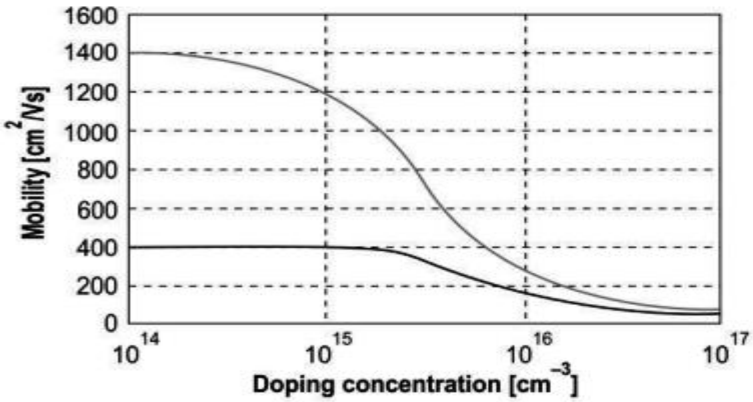
iii. the junction is reverse biased at 0.5 V

5 Almost a constant electric current of 20 μA flows through a given pn junction diode in reverse bias. The current becomes 4 times in case the pn junction diode is forward biased. Determine the diffusion current that flows through the given diode in case it is: 02

a. unbiased b. reverse biased c. forward biased

COMPETENCY BASED QUESTIONS
3 MARK QUESTIONS

1 The graph below shows the variation in the mobility of electrons and holes for a Si semiconductor with doping concentration at 300 K. 03



The pentavalent doping concentration is 10^{15} cm^{-3} and the concentration of intrinsic charge carriers at 300 K is about 10^{10} cm^{-3}

(a) Find the concentration of majority and minority charge carriers.

(b) What is the conductivity of silicon at 300 K? (Calculate conductivity assuming majority charge carriers only.)

The magnitude charge on an electron/hole is 1.6×10^{-19} C. Assume complete dopant ionization.

2 A certain biasing voltage is applied across the pn junction with an initial 03

potential barrier of Vo. The holes approach the pn junction with a non-zero initial kinetic energy from either p or the n- side depending upon the nature of biasing applied.

a. If the holes approach the pn junction from p-side,

i. What type of biasing must have been applied across the pn junction?

ii. Will the kinetic energy of the holes increase or decrease while crossing the junction? Give reason for your answer.

b. If the holes approach the pn junction from n-side,

i. What type of biasing must have been applied across the pn junction?

ii. Will the kinetic energy of the holes increase or decrease while crossing the junction? Give reason for your answer.

3 A diode is connected in series with a 3 V battery and a 30 Ω resistor. A drift current of 10 μA flows through the diode. 03

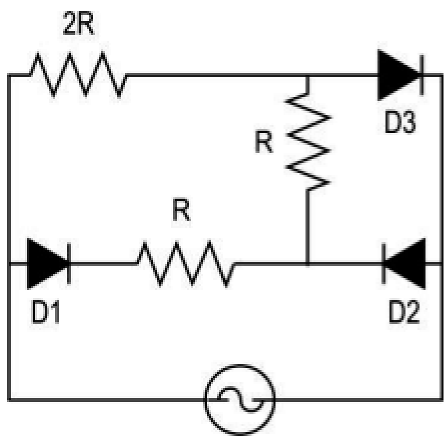
(a) What is the potential drop across the diode?

(b) Is the diode forward-biased or reverse-biased? Draw a circuit diagram to represent the above connections.

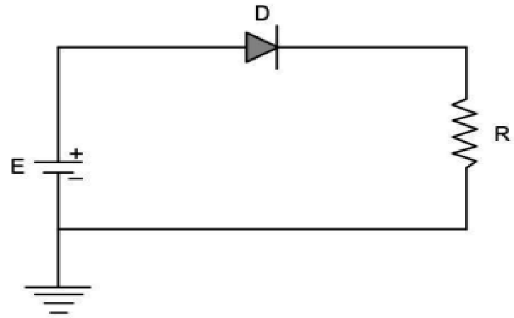
COMPETENCY BASED QUESTIONS
5 MARK QUESTIONS

1 The image below shows a circuit with three diodes and three resistors connected to an AC source with an rms voltage V. 05

What is the average power delivered over one full cycle of AC in the above circuit? Show your calculations and arrive at the final answer in terms of V and R. (Assume the diode is ideal.)



2 In a forward biased, ideal pn diode, the applied forward potential is opposite to the potential barrier of the depletion region. A small forward voltage is sufficient to overcome the potential barrier. Once eliminated, the junction resistance is reduced to zero and an ideal pn junction has zero ohmic potential drop across itself. The voltage at which the current starts to increase rapidly is called threshold voltage or cut in voltage or knee voltage of the pn diode. If the diode voltage is more than knee voltage, it conducts easily otherwise it conducts poorly. For a silicon diode, V(threshold) = 0.7 V 05



a. In the circuit given here, determine the voltage across an ideal silicon diode D and resistor R and the current through the diode and resistor, if E = 3 V and R = 2 k-ohm.

b. How will the values in part (a) change in case E is made 0.3 V?

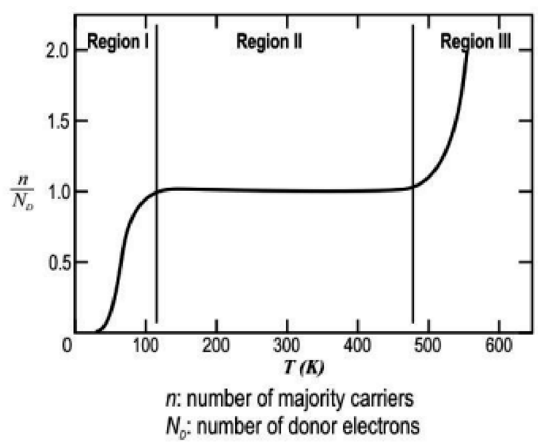
OR

How will the values in part (a) change in case the terminals of E are reversed?

CCT/SOURCE BASED QUESTIONS

1 The graph below represents the variation of n/ND with temperature for an extrinsic n-type semiconductor. The temperature range indicated on the X-axis is divided into three regions, Regions I, II and III.

Study the graph and answer the following questions.



I) Which region(s) has the maximum number of unionized donor atoms? 1

ii) Which of the following relation is definitely TRUE for the semiconductor in region II? (n_e - concentration of free electrons; n_h – concentration of holes) 1

iii) In which region(s) are thermally generated electrons comparable to donor electrons? 1

IV) In region III the semiconductor behaves like? 1

SELF ASSESSMENT PAPER

TOTAL MARKS 25

SECTION A

Q		MARKS
01	Which of the following statements is correct? (a) Hole is an antiparticle of electron. (b) Hole is a vacancy created when an electron leaves a covalent bond. (c) Hole is the absence of free electrons. (d) Hole is an artificially created particle.	01
02	A potential barrier of 0.3 V exists across a p-n junction. If the depletion region is 1 μm wide, what is the intensity of electric field in this region? (a) 2×10^5 V m^{-1} (b) 3×10^5 V m^{-1} (c) 4×10^5 V m^{-1} (d) 5×10^5 V m^{-1}	01
03	The breakdown in a reverse biased p-n junction diode is more likely to occur due to (a) large velocity of the minority charge carriers if the doping concentration is small (b) large velocity of the minority charge carriers if the doping concentration is large (c) strong electric field in a depletion region if the doping concentration is small (d) none of these	01
04	In a full wave junction diode rectifier the input ac has rms value of 20 V. The transformer used is a step up transformer having primary and secondary turn ratio 1 : 2. The dc voltage in the rectified output is (a) 12 V (b) 24 V (c) 36 V (d) 42 V	01
Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as. A: If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion. B: If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion. C:If the Assertion is correct but Reason is incorrect. D: If both the Assertion and Reason are incorrect		
05	Assertion (A) : The half-wave rectifier work only for positive half cycle of ac.	01

	Reason (R) : In half-wave rectifier only one diode is used.	
06	Assertion (A) : In a semiconductor diode, the reverse biased current is due to drift of free electrons and holes. Reason (R) : The drift of electrons and holes is due to thermal excitations	01

SECTION B

07	Explain with the help of a diagram the formation of depletion region and barrier potential in a p-n junction.	02
08	Why are elemental dopants for silicon or germanium usually chosen from group XIII or group XV ?	02

SECTION C

08	In half-wave rectification, what is the output frequency? If the input frequency is 50 Hz, what is the output frequency of a full wave rectifier for the same input frequency?	03
09	i) Differentiate between P-type and N-type semiconductors ii) Draw their energy level diagrams.	03

SECTION D
CASE BASED STUDY

10

Semiconductors consist of Valence band and conduction band. On the basis of energy bands materials are also defined as metals, semiconductors and insulators. In case of metals, conduction band and Valence band overlaps with each other due to which electrons are easily available for conduction. In case of insulators, there is some energy gap between conduction band and Valence band due to which no free electrons are easily available for conduction. And in semiconductors, there is a small energy gap between conduction band and Valence band and if we give some external energy then electron from Valence band goes to conduction band due to which conduction will be possible. These semiconductors are classified as intrinsic semiconductors and extrinsic semiconductors also. Intrinsic semiconductors are those semiconductors which exist in pure form. And intrinsic semiconductors has number of free electron is equal to number of holes. The semiconductors doped with some impurity in order to increase its conductivity are called as extrinsic semiconductors. Two types of dopants are used they are trivalent impurity and pentavalent impurity also. The extrinsic semiconductors doped with pentavalent impurity like Arsenic, Antimony, Phosphorus etc are called as n – type semiconductors. In n type semiconductors electrons are the majority

	charge carriers and holes are the minority charge carriers. When trivalent impurity is like Indium, Boron, Aluminium etc are added to extrinsic semiconductors then p type semiconductors will be formed. In p type semiconductors holes are majority charge carriers and electrons are the minority charge carriers.
i)	In case of p-type semiconductors__ a) $n_h << n_e$ b) $n_h = n_e$ c) $n_h >> n_e$ d) $n_h = n_e = 0$
ii)	An intrinsic semiconductor behaves like _____ at T = 0K. a) conductors b) semiconductors c) insulators d) superconductors
iii)	If the energy band gap Eg> 3 eV then such materials are called as a) conductors b) semiconductors c) insulators d) superconductors
iv)	P- type semiconductor is obtained by adding ……… in pure semiconductor a) zinc b) Magnesium c) Phosphorous d) Aluminum

SECTION E

11	(i) Can a slab of p-type semiconductor be physically joined to another n-type semiconductor slab to form p-n junction? Justify your answer. (ii) In a p-n junction diode, the forward bias resistance is low as compared to the reverse bias resistance. Give reason.	05

****