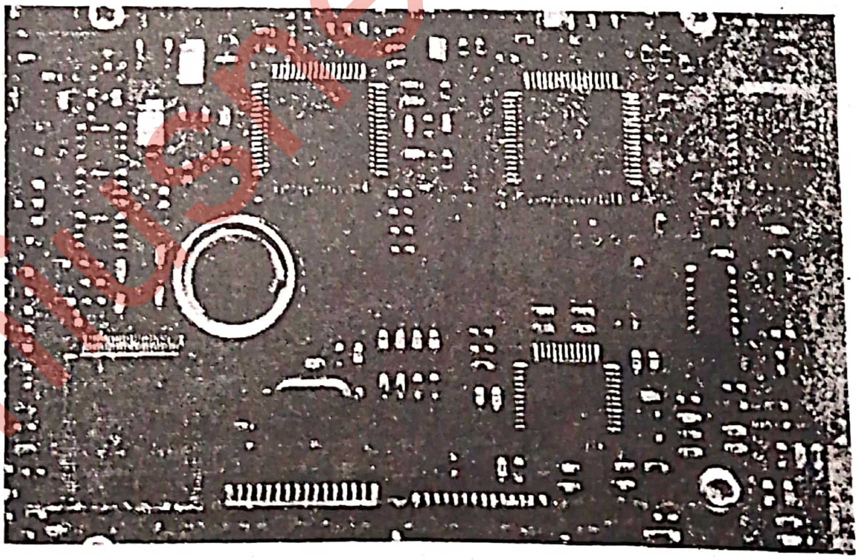
Unit - 17

ELECTRONICS

Learning Objectives

After studying this chapter the students will be able to:

- Distinguish between intrinsic and extrinsic semiconductors.
- Distinguish between P & N type substances.
- Explain the concept of holes and electronics in semiconductors.
- Explain how electrons and holes flow across a junction.
- Describe a PN junction and discuss its forward and reverse biasing.
- Define rectification and describe the use of diodes for half and full wave rectifications.
- Distinguish PNP & NPN transistors.
- Describe the operations of transistors.
- Deduce current equation and apply it to solve problems on transistors.
- Explain the use of transistors as a switch and an amplifier.



Semiconductors are materials having an intermediate electric conductivity between conductors and insulators. Semiconductors are essential to the good functioning of many modern appliances and are key products in the electronic systems.

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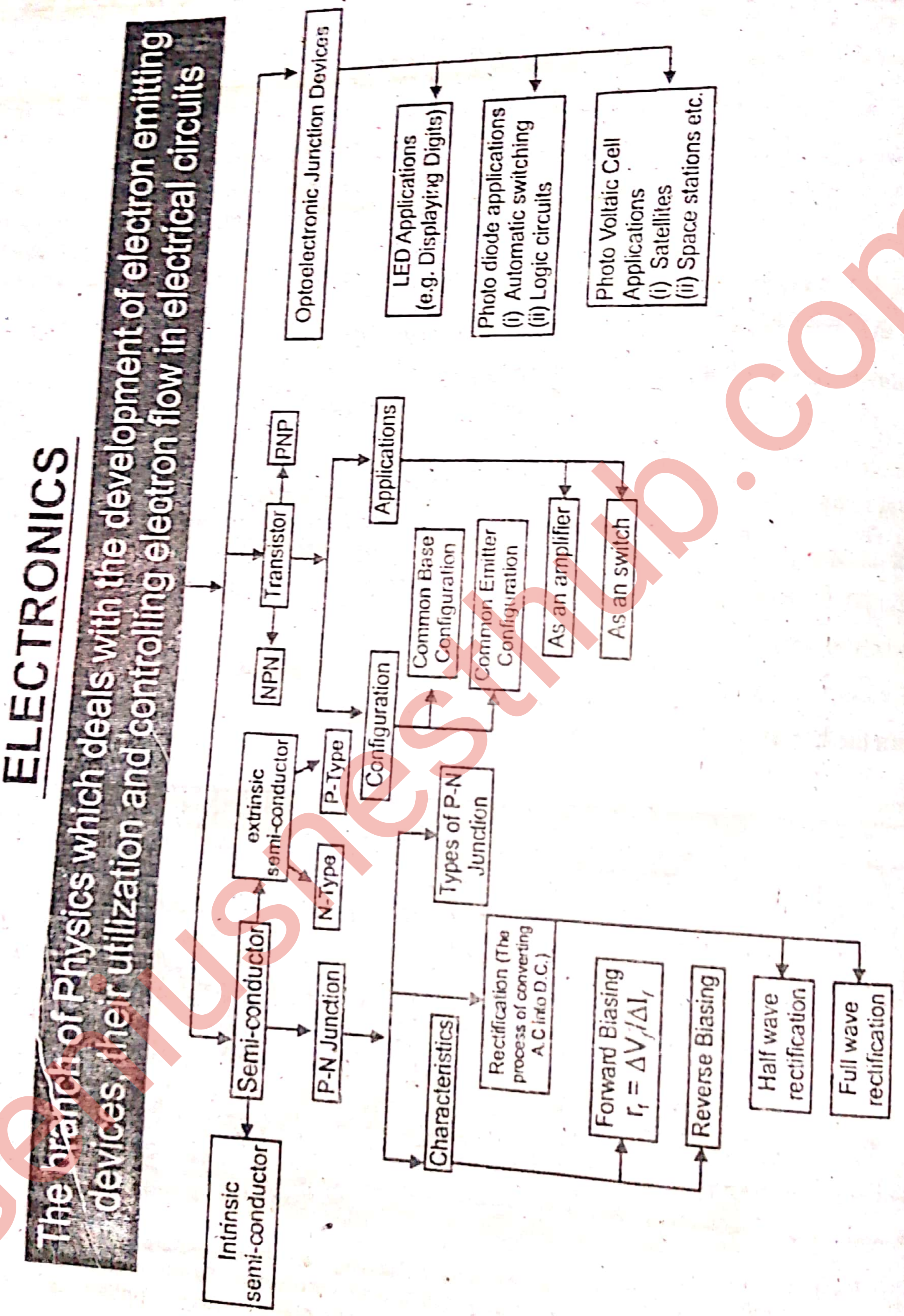
CONCEPT MAP


ELECTRONICS
The branch of Physics which deals with the development of electron emitting devices, their utilization and controlling electron flow in electrical circuits
Intrinsic semi-conductor
Semi-conductor
extrinsic semi-conductor
N-Type
P-Type
P-N Junction
NPN
Transistor
PNP
Optoelectronic Junction Devices
LED Applications (e.g. Displaying Digits)
Photo diode applications (i) Automatic switching (ii) Logic circuits
Photo Voltaic Cell Applications (i) Satellites (ii) Space stations etc.
Applications
Configuration
Common Base Configuration
Common Emitter Configuration
As an amplifier
As an switch
Types of P-N Junction
Characteristics
Rectification (The process of converting A.C into D.C.)
Forward Biasing $r_f = \Delta V_f/\Delta I_f$
Reverse Biasing
Half wave rectification
Full wave rectification

Transistor is the basis of the integrated circuits that run our computers and many modern technologies, including programmable controllers. Many modern technologies use electro-mechanical principles to interface real world sensors and outputs to microprocessors, temperature controllers.

This unit increases students' understanding of the applications and uses of physics.

Semi conductor:

Solids whose conductivity is intermediate between conductors and insulators either due to temperature effect or due to addition of impurity are called semi -conductors.

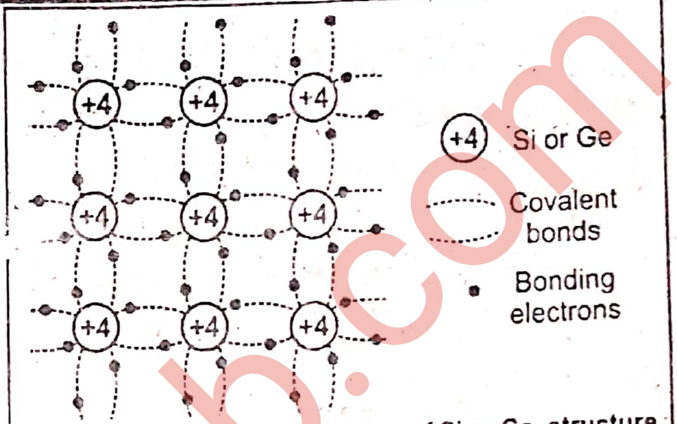
Q.1 Differentiate between intrinsic and extrinsic semiconductor.

Intrinsic Semiconductor

A semiconductor in its extremely pure form is called an intrinsic semiconductor.

A semiconductor is considered to be pure when there is less than one impurity atom in a billion host atoms.

- In a silicon crystal at absolute zero temperature the bonding arrangements may be represented by a two dimensional model as shown.
- In reality the semi- conductor is a three dimensional solid and the sharing of valance electrons occurs between nearest neighbor atoms in three dimensions.
- At zero Kelvin all valance electrons are strongly bound to their atoms and they spend most of the times between neighboring atoms.

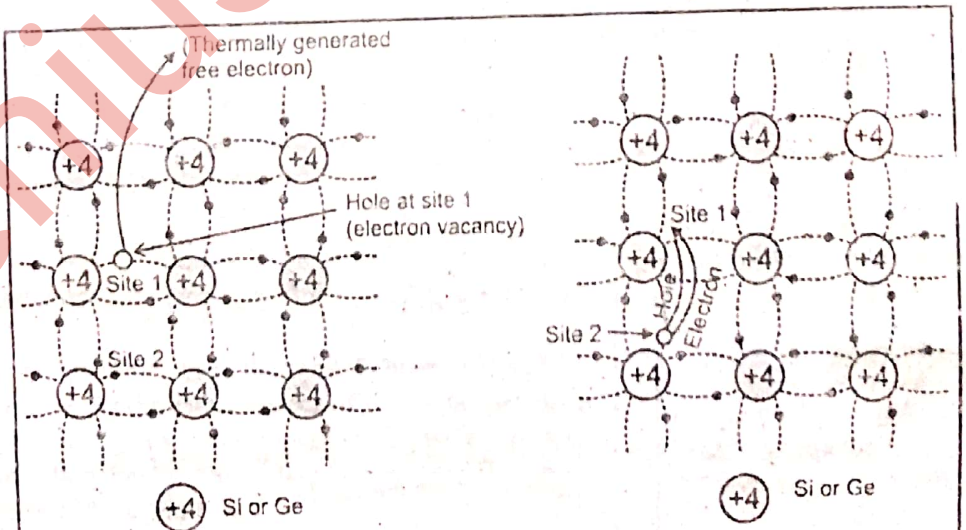


Two dimensional representation of Si or Ge structure. +4 symbols indicate inner cores of Si or Ge.

- Since all the valance electrons are engaged in covalent bonds, the bonds are complete.
- There will be no free electrons in such solids
- So semi-conductor at zero Kelvin does not conduct and behave as perfect insulator.

Intrinsic semiconductors at room temperature:

- At higher temperature, the thermal energy causes each atom in the crystal to vibrate about its mean position. When the vibration become violent, some of the electrons acquire sufficient energy and break away covalent bond. The **electrons liberated from bonds** become free electrons which vibrate more randomly in the empty spaces that exist in the atoms at fixed positions.
- It means some of the electrons convert part of their thermal energy into potential energy. If this potential energy is equal to or more than the band gap energy, electron will be excited from **valance band to conduction band**
- The number of electrons excited to the conduction band depends on the amount of thermal energy received by the crystal.



Model of generation of hole at site 1 and conduction electron due to thermal energy. (b) movement of hole from site 1 to 2.

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- When a covalent bond breaks in **valance band and electron jumps to conduction** band then a vacancy is created in the valance band. The electron in the valance band and electron in the conduction band can be excited to upper vacant level with in respective bands. If an electric field is applied current flows in the crystal at ordinary temperature.

Energy band gap:

It is the minimum amount of energy required to excite an electron from valance band to conduction band. It is characteristic of a particular material.

Note:

The motion of valance electron in the valance band is customarily described in term of fictitious particle called hole which has positive charge +e and its mass is equal to the mass of electron.

Intrinsic carriers:

Inpure semiconductors, a single event of bond breaking leads to two carriers, namely an electron and a hole. The electron and hole are created as a pair and the phenomenon is called electron-hole pair generation. The thermal generation is one possible mechanism for pair generation.

- At any temperature T, the number of electrons generated will be therefore equal to the number of holes generated. If N denotes the number density of electrons in the conduction band and P the number density of holes in the valence band, then,

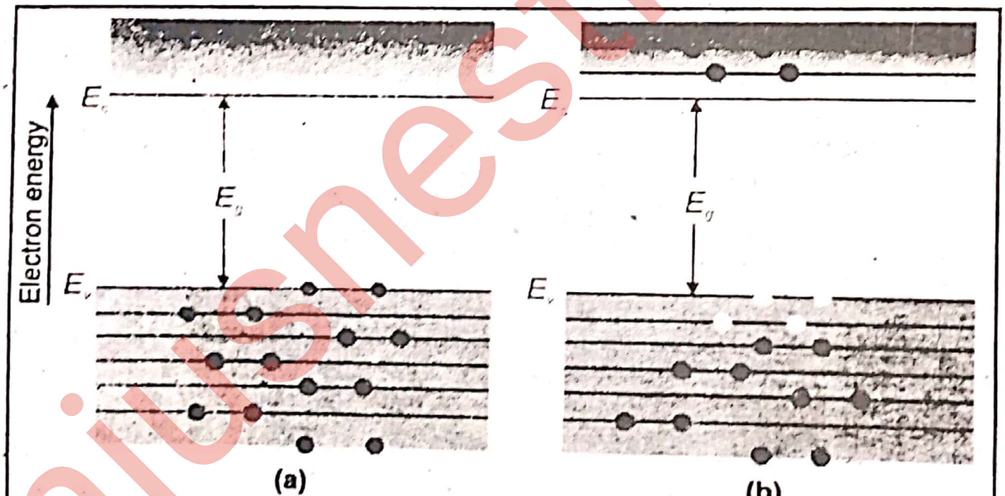
$N = P = N_i$

Where, N_i is called the intrinsic density of intrinsic concentration.

After the generation, the carriers move independently,. The electron moves in the conduction band and the holes moves in the valence bond.

We can also define a semiconductor as intrinsic semiconductor in which free electrons and holes are created only by excitation of electrons from the valence band to the conduction band.

The energy band structure of a semiconductor is characterized by a valence band and a conduction band separated by the band gap E_g as shown in the fig 17.3:



Bandgap energy Eg (b) electron jumping from valence band to conduction band.

The electrons completely occupy the valence band leaving the conduction band vacant. As all the states in the valence band. Electrons in the valence band do not possess enough energy to jump into the conduction band. Therefore, an externally applied electric field cannot cause a flow of current and the semiconductor nearly at 0K behaves as an insulator.

Doping of Impurities

Doping of Impurities:

The intrinsic semiconductors have low conductivity which is of little interest. But, when a small amount of impurity is added to semiconductor crystal then it greatly increases the conductivity of the intrinsic semiconductor.

Doping:

An addition of impurity into an intrinsic semiconductor is called **doping**. The impurity added is called a **dopant**. Pentavalent elements from Group V or trivalent elements from group III are used as dopants. The atoms belonging to

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these two groups are nearly of the same size as silicon or germanium atoms and easily substitute themselves in place of some of the host atoms in the semiconductor crystal. Thus, they are substitution impurities and do not cause any distortion in the original crystal structure.

Extrinsic semiconductor:

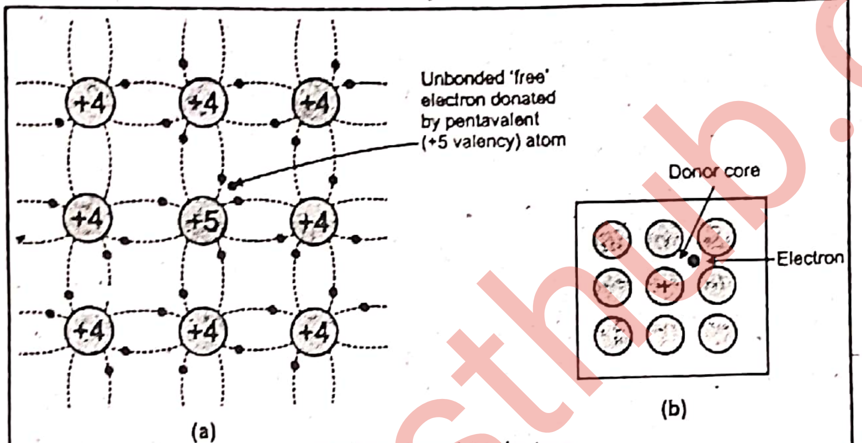
A semiconductor doped with a impurity atoms is called an extrinsic semiconductor.

Two types of extrinsic semiconductors, namely N- type and P-type semiconductors are produced depending upon the group of impurity atom.

Q.2 Differentiate between N-type and P-type extrinsic semiconductor.

N-Type Semiconductor

- An N-type semiconductor is produces when a pure semiconductor is **doped** with a **pentavalent** impurity.
- **Phosphorous** ,**antimony** and **arsenic** are the dopants normally used.
- Suppose a phosphorous atom is doped with a silicon atom in the crystal. Phosphorous atom has five valence electrons. Out of the five electrons, only four can participate in the bonding, since these are only four bonds are shown in the fig the fifth electron does not form a bond and remain loosely bound to the atom.

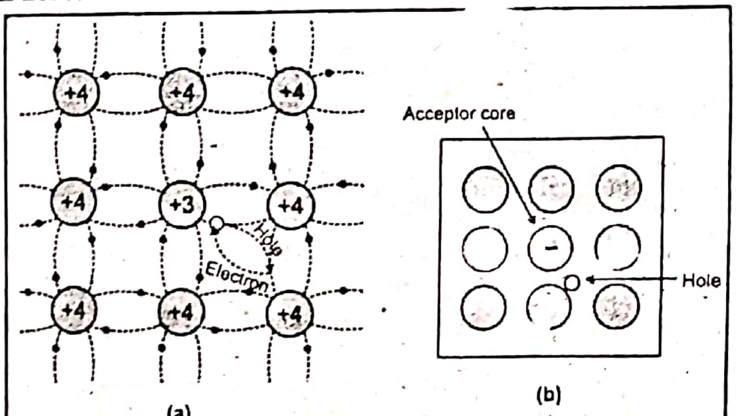


Doping of semiconductors

- The impurity atoms which contribute electrons to the conduction band are called **donor** atoms.
  They produce electrons without producing holes in the valence band.
  At very low temperature, the donor atoms are not ionized and the conduction band is empty.
  At slightly increased temperatures, the donor electrons populate the conduction band.
  At ordinary temperatures, some electrons from the valence band are also excited into the conduction band through the intrinsic process.
  The holes in the valence band are smaller at ordinary temperatures.
- The electrons which are in majority are called **majority carriers** whereas the **holes are called minority carriers**, since they are very small in number.
- As the current is mainly carried by electrons which are negative charge carriers, the semiconductor is called an **N-type extrinsic semiconductor**, where N indicates the **negative sign** of the majority carrier.
- The **net charge** of N-type extrinsic semiconductor **is zero**.

P-Type Semiconductor

- ***The semiconductor which is formed by adding trivalent impurity to a pure semiconductor is called P-type semiconductor.***
- An atom belonging to third group *(Trivalent)*such as aluminium (Al) , boron (B), gallium (Ga) or Indium has three valance electrons.
- When a trivalent impurity atom is added with a silicon atom, it falls short of one electron for completing the four covalent bonds with its neighbors as shown.



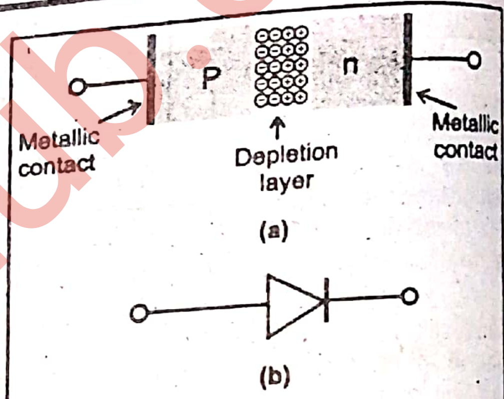
Semiconductors doping

- The substitution of a host silicon atom with, say, a boron atom does not disturb the neutral environment around the boron atom. However, when an electron from a neighboring atom acquires energy and jumps to form a bond, it leaves behind a hole.
  - The boron atom having acquired an additional electron becomes a negative ion.
  - The hole can move freely in the valence band whereas the impurity ion is immobile.
  - The impurity atoms which **accept electrons from the valence band are known as acceptor atoms.**
  - The acceptor impurity atoms produce holes without the simultaneous generation of the electrons, in the conduction band.
  - At ordinary temperatures, holes are produced due to intrinsic process also, by promoting electrons from valence band to conduction band.
  - The result is that no of holes becomes greater than no of electrons in the semiconductor.
  - Therefore, **holes are the majority carriers and electrons are minority carriers** in this type of semiconductor.
  - As positively charged carriers are mainly contributing to the conduction process, this type of semiconductor is known as a P-type extrinsic semiconductor where P signifies positive sign of the majority carriers
  - The net charge of P-type extrinsic semiconductor is zero.

Q.3 What is P-n Junction? Discuss Forward bias and reverse bias PN-Junction their Characteristics in Detail?

PN Junction

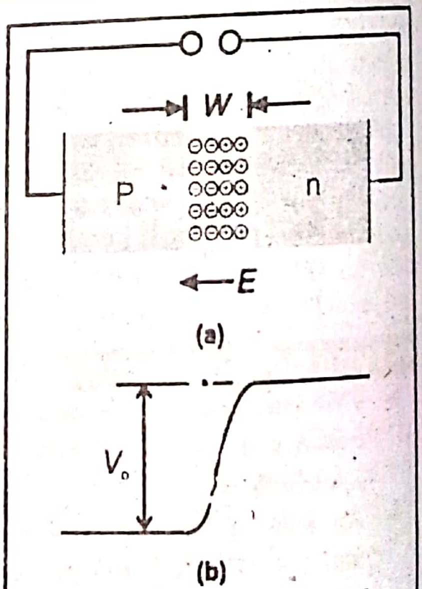
If the crystal of germanium or silicon is grown in such a way that it's one half is doped with trivalent imparity and the other half is doped with pentavalent impurity, p-n junction is formed.



PN Junction

Explanation:

- At the junction, electrons from N-type fill the vacancies in P-region; thus negative and positive ions are formed.
- These ions create an electric field directed from N- to P- type region.
- It stops further diffusion of electrons and holes and maintains the separation of charge carriers.
- The junction region is now free of mobile charges and it is called depletion region or layer.
- The width of depletion layer depends upon carrier concentration. Thus a potential wall or barrier is formed at the junction.
- The symbol of PN junction (diode) is shown in fig.



PN Junction potential barrier

Forward biased PN junction:

When P-type region is connected with positive potential with respect to N-type region and the potential drop is increased slowly, the junction barrier height decreases.

At one point, called as knee voltage, majority charge carriers cross the junction and the current flows, as shown in fig. this is called forward bias and the current is called forward current.

Reverse biased PN junction:

If P-type region is made negative with respect to N-type, no majority charge carries cross the junction and hence there is no current

A small amount of current flows due to minority charge carriers, this biasing is called the reverse bias and the current is called as reverse current.

The reverse current is generally of the order of few microamperes.

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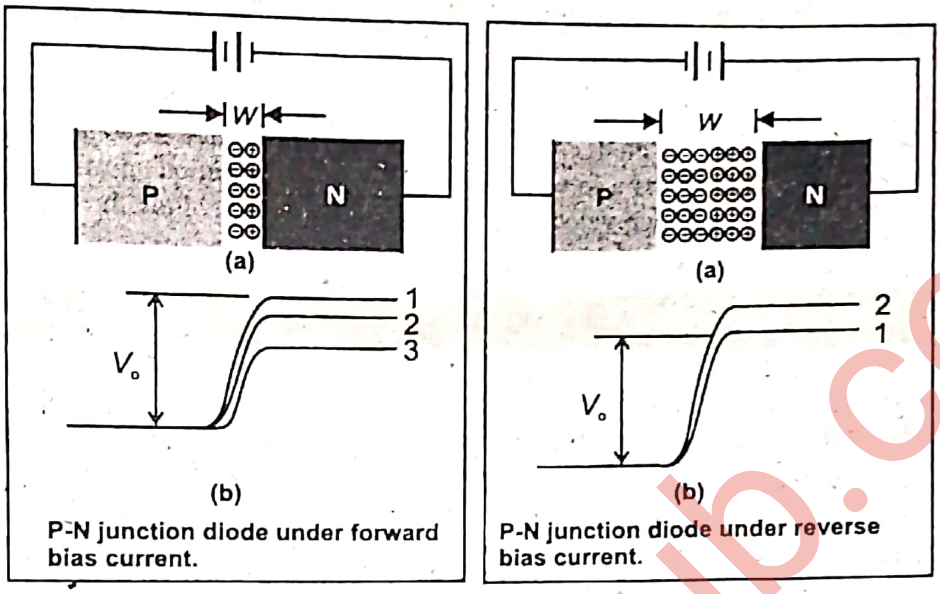
VI Characteristics of PN Junction

Knee voltage:

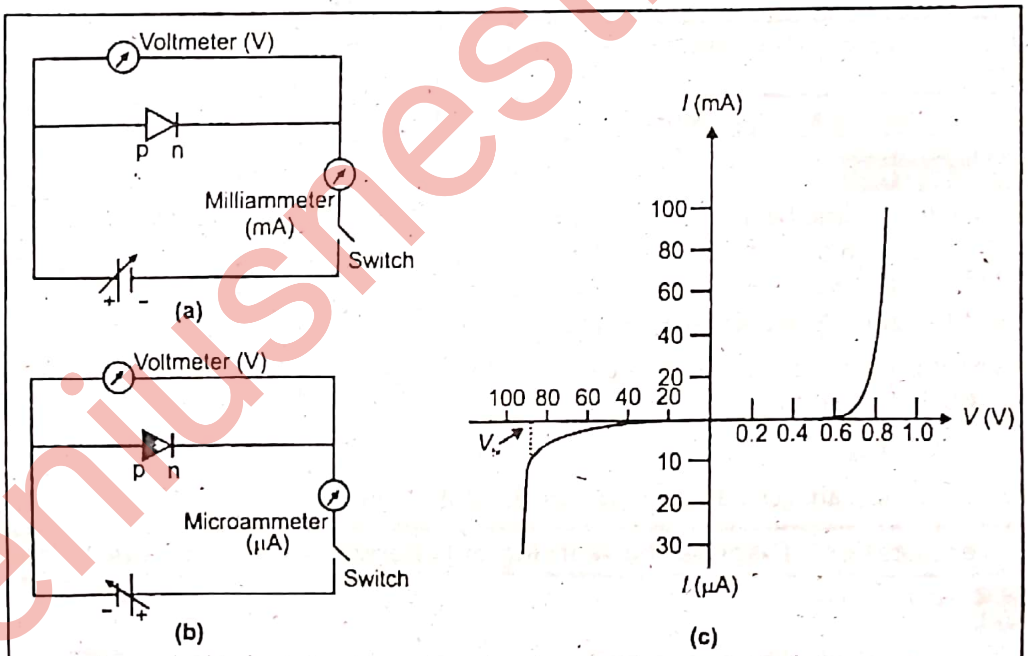
The forward **voltage** at which the current through the PN junction starts increasing rapidly is known as **knee voltage**. It is also called as **cut-in –voltage** or **threshold voltage.**



(b)
P-N junction diode under forward bias current.

(b)
P-N junction diode under reverse bias current.

The VI characteristics of PN junction are shown in fig. The knee voltage is 0.3V for germanium and 0.7V for silicon. From the VI characteristics, we see that the forward current increases rapidly beyond the knee voltage. There exists a maximum current limit for junction, which is decided by the power ratio of the junction. Beyond that, the junction is destroyed.



Experimental circuit arrangement for studying V-I characteristics of a p-n junction diode (a) in forward bias, (b) in reverse bias.(c) Typical V-I characteristics of a silicon diode.

Reverse saturation current:

For a diode in revere bias diode the current is very small (μA) and is called reverse saturation current. It flows due to minority carriers. It increases with a increase in temperature.

Zener effect:

In reverse bias, if voltage is increased, due to available energy, covalent bonds break and large number of electrons are released. This cause a sudden increase in current. This is called as zener effect.

Avalanche effect:

If reverse bias is increased further, minority charge carriers attain high velocity and knock down the bound electrons from covalent bonds and the current increases. This is called as avalanche effect. Using these effects, zener diodes are formed.

Q.4 Differentiate between Zener Breakdown and Avalanche Breakdown:

Ans. When the diode is reverse biased, the kinetic energy of the electrons increases and they move at a high velocity. The high-velocity electrons collide with other atoms and give rise to free electrons. These free electrons, in turn, give rise to a high value of reverse saturation current. This is known as zener breakdown. The avalanche breakdown occurs when a high reverse voltage is applied across the diode. As we increase the applied reverse voltage, the electric field across the junction increases. This electric field exerts a force on the electrons at the junction and frees them from covalent bonds. These free electrons start moving with high velocity across the junction and collide the other atoms creating more free electrons. This results in the rapid increase of net current. Both these breakdowns occur in Zener diodes.

Zener Breakdown	Avalanche Breakdown
• The process in which the electrons move across the barrier from the valence band of p-type material to the conduction band of n-type material is known as zener breakdown.	• The process of applying high voltage and increasing the free electrons or electric current in semiconductors and insulating materials is called an avalanche breakdown.
• This is observed in zener diodes having a zener breakdown voltage Vz of 5 to 8 volts.	• This is observed in zener diode having a zener breakdown voltage Vz greater than 8 volts.
• The valence [illegible]ons are pulled into conduction due to the high [illegible]tric field in the narrow depletion region.	• The valence electrons are pushed to conduction due to the energy imparted by accelerated electrons, which gains its velocity due to its collision with other atoms.
• The increase in temperature decreases the breakdown voltage.	• The increase in temperature increases the breakdown voltage.
• The VI characteristics of a zener breakdown has a sharp curve.	• The VI characteristic curve of the avalanche breakdown is not as sharp as the zener breakdown.
• It occurs in diodes that are highly doped.	• It occurs in diodes that are lightly doped.

Drift of Minority Carrier

It is seen that the electric field across the junction prevents the diffusion of majority carriers. However, the electric field has the right direction to promote the flow of minority carriers across the junction. Electrons arriving at the junction from the bulk of P-region are assisted by the electric field to move into N-region. Similarly, holes in the N-region are helped to move into P-region. As a consequence, an electric current flows across the junction.

As the current is caused by an electric field it is a drift current. The net drift current through the junction is due to electron and hole which is given by.

$$I_{(drift)} = I_e + I_h$$

The minority carriers are generated through breaking of covalent bonds.

Q.5 What is rectification? Discuss the Working of Different types of Rectifier Circuits?

Rectification

Some electronic devices like electronically tune radio and TV receivers require DC for their operation. The DC supplies like cells, batteries etc. are expensive, low power, and short-lived. Therefore generally a DC supply is generated using an A.C. supply.

The conversion of AC into DC is called the rectification and a device used for rectification is called the rectifier.

Diodes provide compact, inexpensive means of rectification therefore it can be used as a rectifier. As we have seen, when diode is forward biased it allows the current to pass and in reverse bas it (almost) stops the current. Thus it can be used as unidirectional device (or rectifier). For most power applications, half-wave rectification is insufficient for task.

If we need to rectify AC power to obtain full use of both half-cycles of sine wave, different rectifier circuit configuration must be used. Such circuit is called full-wave rectifier.

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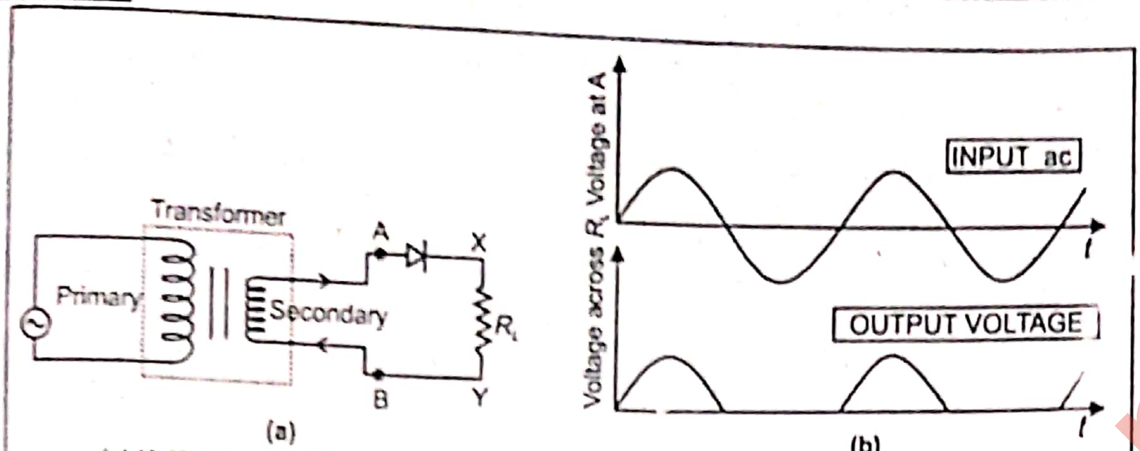
Half wave rectifier



(a) Half-wave rectifier circuit.
(b) input ac voltage and output voltage waveforms from the rectifier circuit.

- The circuit which converts half of the alternating current cycle into direct current is called as half wave rectifier circuit.

A half wave rectifier circuit is shown in figure. This circuit uses a transformer to couple the A.C input voltage from the source to the rectifier because it can step up or step down the source voltage when needed and also because A.C source is electrically isolated from the rectifier thus preventing a shock hazard in the secondary circuit. The voltage across the secondary of transformer is represented as

$$V = V_m \sin \omega t$$

Where V_m is the peak value of alternating voltage.

<u>During the positive half cycle</u> ($0 \longrightarrow T/2$), of the input A.C signal, the diode is forward biased. So it offers low resistance and current flows through it

<u>During the negative half cycle</u>($T/2 \longrightarrow T$), of the input A.C signal, the diode is reverse biased. So it offers very high resistance and no current flow through R.

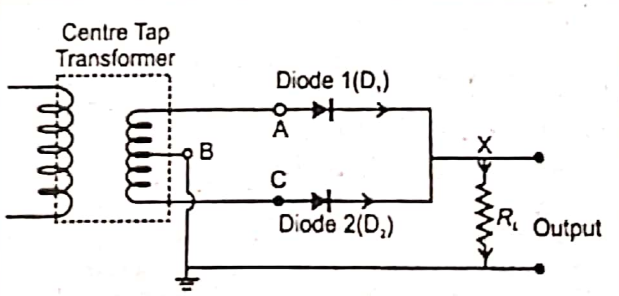
The same process continues for next half cycles and so on for an a. c input. However the current flows in one direction, so it is direct current, which has pulses. The final output is called pulsating D.C.

During negative half of input A.C cycle peak inverse voltage (PIV) is the maximum voltage V_m that the rectifying diodes have to withstand. Thus the maximum voltage that appears across the diode is equal to the peak voltage V_{max}. Hence for half wave rectifier,

$$PIV = V_{max}$$

Full-wave rectifier

The circuit which converts both the half cycles of input A.C signal in to the D.C signal is called full-wave rectifier circuit.



(a) A full-wave rectifier circuit.

Explanation:

A full wave rectifier circuit having a transformer with center-tapped secondary winding and two diodes in alternate switching mode is shown in fig.

A full wave rectifier allows unidirectional (one way) current through the load during the entire cycle of the input cycle, whereas a half wave rectifier allows current through the load during one half of the cycle. The diodes D_1 and D_2 operate in alternate switching mode.

<u>For the first half of input A.C cycle:</u>

For the first half cycle point, A becomes positive with respect to B and B becomes positive with respect to C. thus, D_1 is forward and D_2 is reverse biased. The current through load is only due to D_1 while current due to D_2 is zero.

<u>For the second half of input A.C cycle:</u>

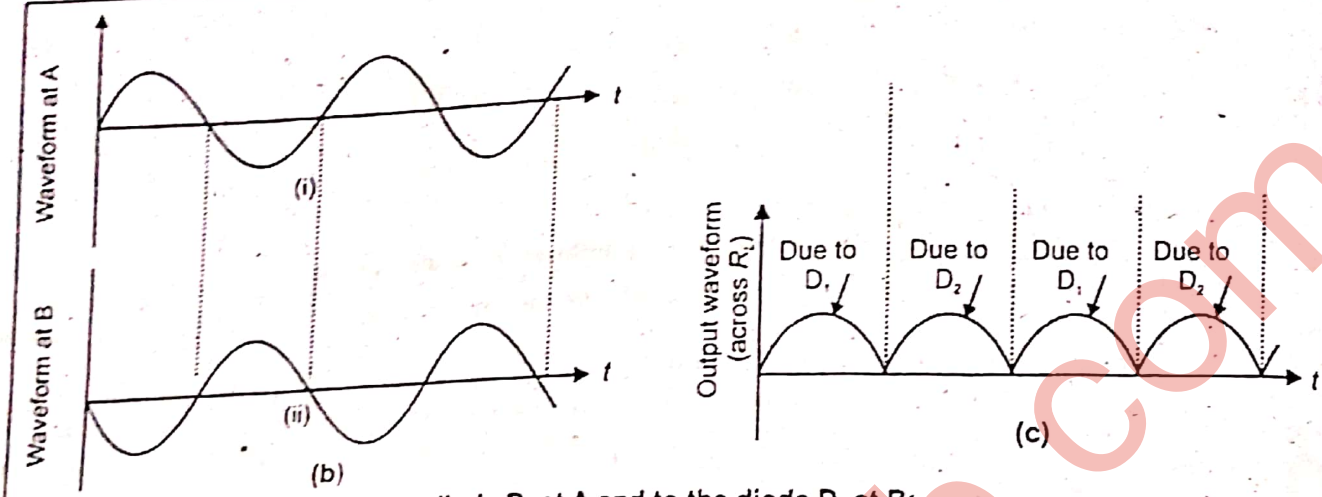
For the second half cycle, point C becomes positive with respects to B and B becomes positive with respect to A.

▶ Now D_2 is forward biased ON and D_1 is reverse biased OFF. The current flows due to D_2.

For the first half of the cycle, the current is due to D_1 and for the second half cycle, the current is due to D_2. Thus full wave is rectified.

Disadvantage:

One disadvantage of this full-wave rectifier design is necessity of transformer with center-tapped secondary winding



(b) input wave forms given to the diode D_1 at A and to the diode D_2 at B;
(c) Output waveform across the load *RL* connected in the full-wave rectifier circuit.

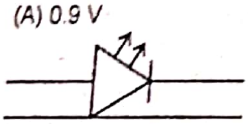
MCQ's From Past Board Papers

1. At 0K semi conductors are
   (A) Conductors (B) Insulators (C) Perfect conductors (D) Perfect insulators
2. In forward biasing, the value of resistance is
   (A) Large (B) Very large (C) Small (D) Very small
3. For rectification we use
   (A) Transformer (B) Diode (C) Choke (D) Generator

Reverse current flows due to
(A) Majority charge carriers (B) Minority charge carriers (C) Electrons (D) Holes

The photodiodes are used for:
(A) Security system (B) Counting system (C) Automatic door system (D) All of above

The potential barrier of Ge is
(A) 0.9 V (B) 0.7 V (C) 0.5V (D) 0.3V


is the electrical symbols for:
(A) Diode (B) Photodiode (C) photocell (D) LED

Conversion of A.C. into D.C. is called:
(A) Modulation (B) Amplification (C) Oscillation (D) Rectification

A potential barrier of 0.7 volt exist across p–n junction made from:
(A) Silicon (B) Germanium (C) Indium (D) Gallium

When a P–N junction is reverse biased, the depletion region is:
(A) Wider (B) Narrow (C) Normal (D) No change

Universal gate is the gate which can perform the function of:
(A) buffer gate (B) any logic gate (C) any basic gate (D) any exclusive gate

The number of terminal in a semiconductor diode are:
(A)2 (B)3 (C)4 (D) 5

A light emitting diode (LED) emits light only when:
(A) Reverse biased (B) Forward biased (C) Unbiased (D) None of these

Which factor does not affect the conductivity of PN–junction diode:
(A) Doping (B) Temperature (C) Voltage (D) Pressure

Light emitting diodes (LED) are made from semi-conductors:
(A) Silicon (B) Germanium (C) Carbon (D) Gallium arsenide

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16. Pulsating out put of full wave rectifier can be made smooth by using circuit called:
(A) Filter (B) Amplifier (C) Resistor (D) Transistor
17. Specially designed p.n. junction used as indicator in electronic circuits is:
(A) LED (B) Solar cell (C) Photo voltaic cell (D) Photodiode
18. When a silicon crystal is doped with a pentavalent element, it becomes
(A) p-type semiconductor (B) n-type semiconductor (C) intrinsic semiconductor (D) only semiconductor
19. A PN-junction can not be used as:
(A) Rectifier (B) Amplifier (C) Detector (D) LED
20. A diode characteristic curve is plotted between
(A) Current and time (B) Voltage and time
(C) Voltage and current (D) Forward voltage and reverse voltage
21. The ratio of potential barriers of Ge to Si at room temperature is :
(A) 7 : 3 (B) 1 : 3 (C) 2 : 5 (D) 3 : 7
22. In full wave bridge rectifier the number of diodes required are equal to
(A) 3 (B) 4 (C) 5 (D) 1
23. The colour of light emitted by a LED depends on
(A) its forward biasing (B) the type of semi conductor material used
(C) the amount of forward current (D) its reverse biasing
24. Depletion region carries
(A) –Ve charge (B) +Ve charge (C) Ions (D) No charge
25. Light emitting diodes (LED) are made from semi-conductors:
(A) Silicon (B) Germanium (C) Carbon (D) Gallium arsenide
26. In photovoltaic cell, current is directly proportional to:
(A) wavelength of light (B) intensity of light (C) frequency of light (D) energy
27. In p-type substances, the minority carries are:
(A) Electrons (B) Protons (C) Holes (D) Neutrons
28. Greater concentration of impurity is added in:
(A) Base (B) Emitter (C) Collector (D) LED
29. Which one can be used as temperature sensor in electric circuit?
(A) Capacitor (B) Diode (C) LDR (D) Thermistor
30. The barrier potential of Silicon Diode at room temperature is:
(A) 0.3 V (B) 0.7 V (C) 3 V (D) 7 V
31. Reverse current flows due to
(A) Majority charge carries (B) Minority charge carriers (C) electrons (D) holes
32. During negative half cycle of A.C then p – n Junction offers.
(A) High resistance (B) Low resistance (C) No resistance (D) All of these
33. The pulsating output voltage of a rectifier can be made smooth by using a circuit known as:
(A) Capacitor and inductor (B) Inductor (C) Filter (D) Resistor
34. A photodiode can turn its current ON and OFF in:
(A) Micro seconds (B) Mega second (C) Nano seconds (D) Milli seconds
35. A.C is converted into D.C by
(A)capacitor (B)inductor (C)transistor (D) diode
36. Which diode works at reverse biasing?
(A) LED (B) Photovoltaic cell (C) Photodiode (D) Silicon diode
37. Photodiode detects
(A) Visible light (B) infra-red light (C) ultraviolet light (D) all of them
38. Photodiode is used for detection of
(A) Heat (B) Magnet (C) Current (D) Light

Answers Key

1. B	2. D	3. B	4. B	5. D	6. D	7. D	8. D	9. A	10. A	11. C	12. A
13. B	14. D	15. D	16. A	17. A	18. B	19. B	20. C	21. D	22. B	23. B	24. C
25. D	26. B	27. A	28. B	29. D	30. B	31. B	32. A	33. C	34. C	35. D	36. C
37. D	38. D										

Q.6 What is a Transistor? Discuss its Construction and Different Types?

Transistor

A transistor consists of two back to back pn-junctions made in a signal piece of semi- conductor crystal. The word transistor is short form of transference of signal across a resistor.

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Types of modern transistor:

Modern transistor are of two types.

1. **Bipolar:** whose function depends upon both (majority and minority) charge carriers. (BJT)
2. **Unipolar:** whose function depends upon majority charge carrier's i.e. field effect transistor. (FET)

Bipolar junction Transistor. (BJTs)

There are two BJTs transistors:

(1) p-n-p transistor (2) n-p-n transistor

(1) p-n-p transistor:

When n-type substance (Si or Ge) is sandwiched between two p-type substances, then device formed is called p-n-p transistor, Its electronic symbolic shown in figure with symbolic representation.

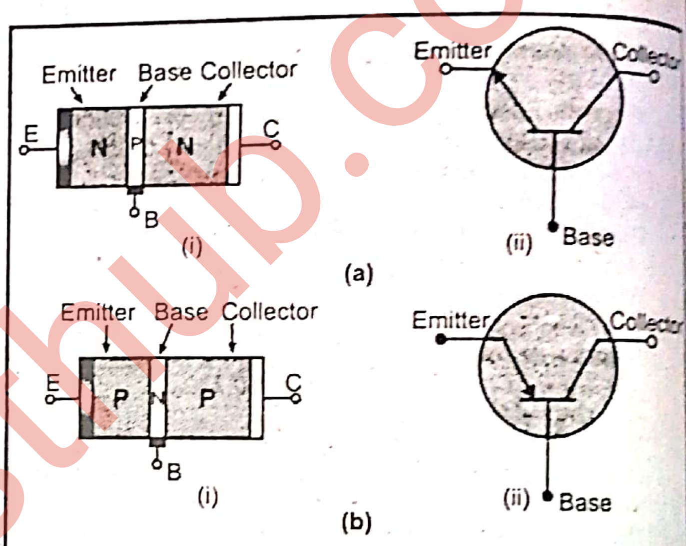
(2) n-p-n transistor:

When a p-type substance is sandwiched between two n-type substances, then device formed is called n-p-n transistor. Its electronic symbol is shown in figure

Parts (or-regions) of Transistor:

The main parts of transistor are:

(i) Emitter (ii) Base (iii) Collector



(a) N-P-N transistor and P-N-P transistor, and
(b) Symbols for N-P-N and P-N-P transistors.

(i) Emitter:

- The emitter has greater concentration of impurity atoms as compared to collector, so it has more charge carriers than collector.
- The arrow on emitter terminal shows the direction of conventional current. (Outward for NPN and inward for PNP)
- Emitter is smaller in size as compared to collector.

(ii) Base:

- The central region is known as base. Usually, the base is very thin of the order of 10^{-6}m.
- It has least concentration of impurity as compared to emitter and collector.
- It controls the flow of electron from emitter to collector.

(iii) Collector:

- The collector collects majority charge carriers through base.
- The collector has less concentration of impurity as compared to emitter.
- The collector is comparatively larger in size than the emitter because it has to dissipate much heat energy.

Working of a Transistor:

- Emitter-base junction is forward biased by V_{IE}
- While base-collector junction is reversed biased by V_{cc}.
- For normal operation V_{cc} is greater than V_{IE}
- After the application of the biasing voltage, emitter base junction is forward biased .
- So emitter injects the large number of electrons in the base region.
- The electrons in the base can follow two paths
- They can either flow out of base to positive terminal of V_{IE} or they can be attracted towards the collector due to V_{cc}.
- Since the base is extremely thin, very few electrons manage to recombine with holes and escape out of the base
- The most all of free electrons injected from emitter into base are attracted into collector by large positive V_{cc}.
- So an electronic current I_E flow from emitter to base, a very small current of it I_B flows out of the base and current

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I_c flows out of the collector.

- The direction of conventional current is opposite to the flow of electron.
- Therefore current equation is

$$\boxed{I_E = I_C + I_B}$$

- In most cases NPN transistors are preferred because mobility of electrons is three times more than that of holes and therefore the operation is faster.

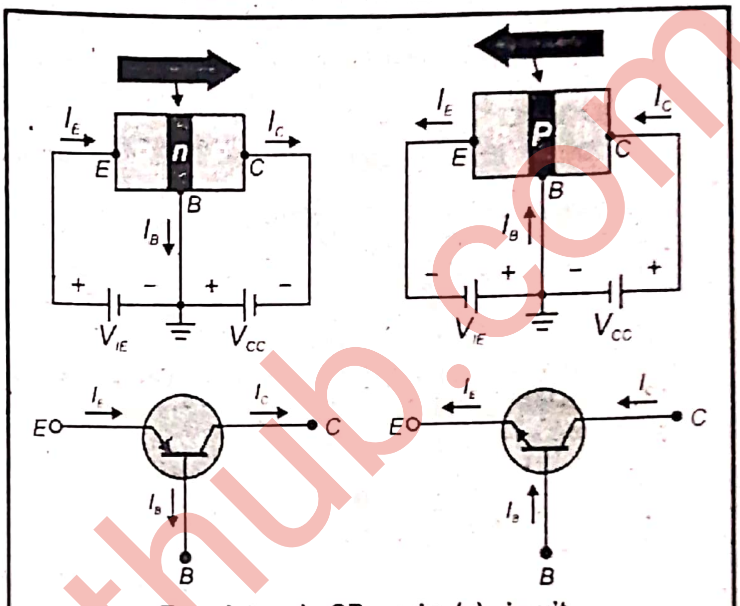
Q.7 Discuss the different types of the Configurations of transistor.

Types of configurations

One electrode is always common to both input and output in transistor circuits so there are three types of configuration of a transistor circuit.

Common base configuration:

When a base is common to both input and output circuits, it is a common base configuration. Figure shows the circuit diagram and input and output characteristics of CB configuration.



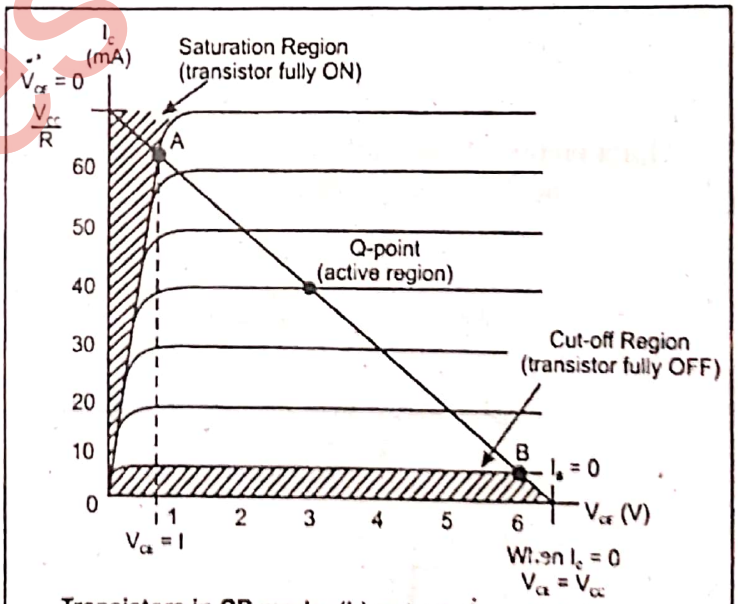
Transistors in CB mode: (a) circuit

Input characteristics:

The variation in the emitter current (I_E) with respect to change in the base- to-emitter voltage (V_{BE}) at the constant collector-to-base voltage (V_{CB}) is input characteristics.

Output characteristics:

The variation in the collector current (I_C) with change in the collector-to-base voltage (V_{CB}) at the constant emitter current (I_E) is output characteristics. The output characteristics have three regions of operation, namely, active, cut-off and saturation.



Transistors in CB mode: (b) output characteristics.

Active region:

When the base-emitter junction is forward biased and the collector-base junction is reversing biased, it is active region.

Cutoff region:

When both, collector-base and base emitter junctions are reverse biased it is cutoff region. The output current is zero in this case.

Saturation region:

When both the junctions are forward biased, it is saturation region. Figure shows these regions.

Alpha factor:

The ratio of I_C and I_E is called as alpha factor. It is an amplification factor.

since $I_C = I_E$, $\alpha = 1$. Therefore,

$$\alpha_{static} = \frac{I_C}{I_E}$$

And

$$\alpha_{dynamic} = \frac{\Delta I_C}{\Delta I_E}$$

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Common emitter configuration:

In common emitter configuration the base emitter junction is forward based while base-collector junction is reverse biased.

Fig shows circuit diagram, input and output characteristics, respectively.

Input characteristics:

The variation in base current (I_B) with change in base-to-emitter voltage (V_{BE}) at constant collector-to-emitter voltage (V_{CE}) are input characteristics.

Output characteristics:

Variation in collector current (I_C) with change in collector-to-emitter voltage (V_{CE}) at constant base current (I are output characteristics.

Fig shows active, cut-off and saturation region of output characteristics.

Beta Factor:

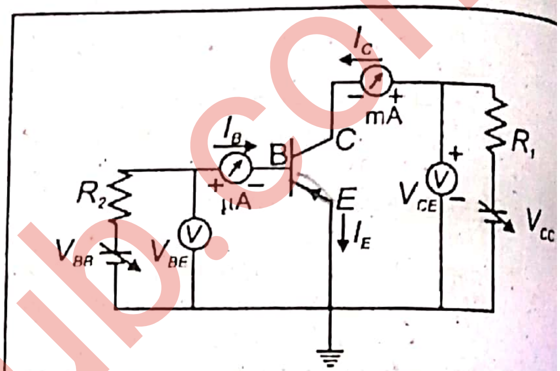
The ratio of collector current I_C and base current I_B is called as beta factor.

That is,

$$\beta_{static} = \frac{I_C}{I_B}$$

And

$$\beta_{dynamic} = \frac{\Delta I_C}{\Delta I_B}$$



(i) Circuit arrangement for CE configuratio

The beta factor is called as **current gain** or **current amplification** factor. Generally it ranges from 50 to 400.

We can write,

$$\beta = \frac{I_C}{I_B}$$

$$\beta = \frac{I_C}{I_E - I_C}$$

$$\beta = \frac{I_C/I_E}{1 - I_C/I_E}$$

$$\beta = \frac{\alpha}{1 - \alpha}$$

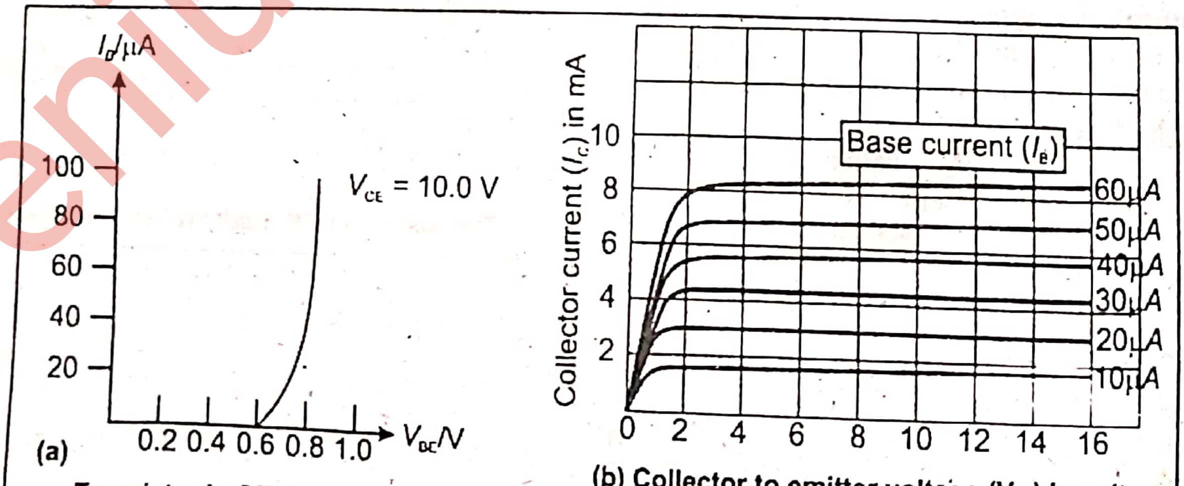
Alpha factor: The ratio of I_C and I_E is called as alpha factor. It is an amplification factor.

Since $I_C \approx I_E$, $\alpha \approx 1$. Therefore,

$$\alpha_{static} = \frac{I_C}{I_E} \quad \dots (17.3)$$

and

$$\alpha_{dynamic} = \frac{\Delta I_C}{\Delta I_E}$$



Transistor in CE mode: (i) circuit (a) input characteristics (b) output characteristics.

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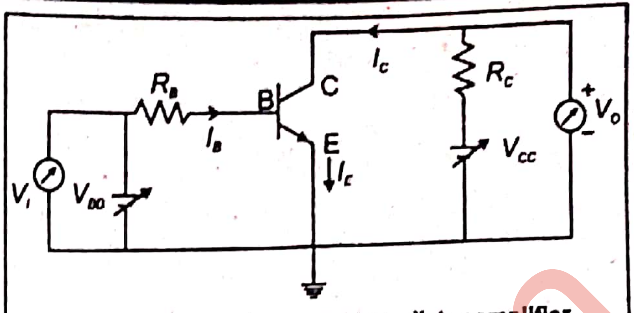
Q.8 How can we Use a Transistor as an Amplifier?

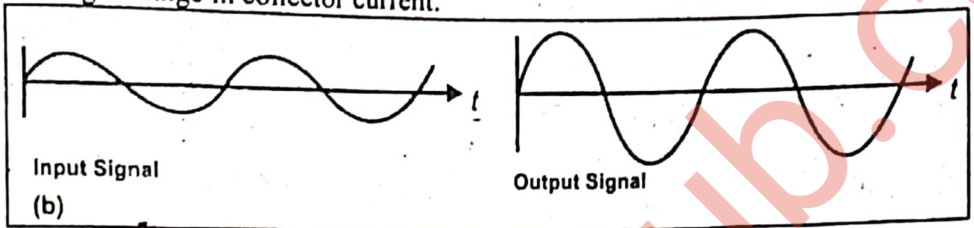
Transistor as an amplifier

Transistor as an amplifier:



(a) A simple circuit of a CE-transistor amplifier.

- A transistor can be characterized as a **current amplifier**.
- It has many applications for **amplification** and **switching**.
- The arrangement of common emitter amplifier is shown in fig.
- In above figure the input voltage appears across base and emitter, and the output voltage appears across the collector and emitter. I.e. the emitter terminal is shared by the input and output.
- An increase in voltage or current level is called as **amplifications**. The transistor can be used as amplifier.
- A small change in input (voltage or current) produces large change in output (voltage or current).
- If β is 100 then the change in collector current is 100 times the change in base current. The small change in base current produces large change in collector current.



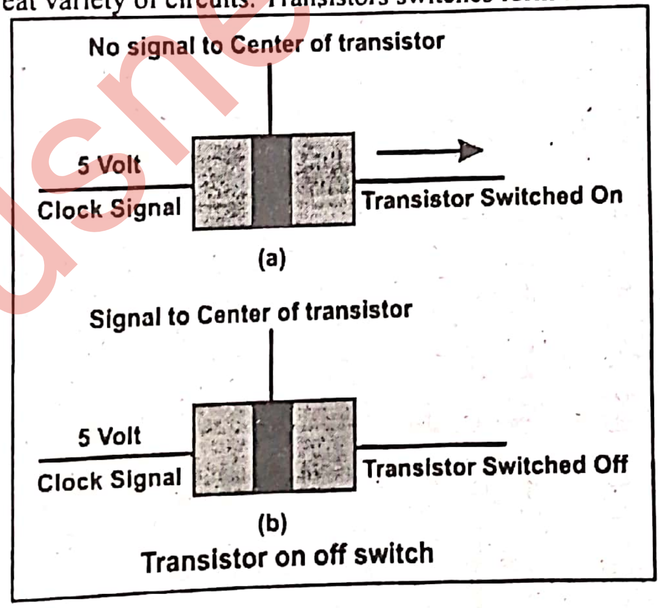
(b)

- Thus transistor acts as an amplifier. The energy required for amplification is taken from the power supply. In most of the cases, CE mode is preferred because its current and voltage gains are high and power gain is the highest.
- At the input, the emitter junction is forward biased therefore input resistance is small and the output, the collector junction is reverse biased therefore output resistance is high. The current is transferred from low-to-high resistance circuit.

Q.9 How can we Use a Transistor as a Switch?

Transistor as a switch

Transistor is used in a great variety of circuits. Transistors switches form the basis of all electronic computers.



Transistor on off switch

As $$\beta = \frac{I_C}{I_B}$$

With the switch closed, base current flow causing collector to flow. The output voltage is $V_{CE} = 0$ V fig. 17.18(a) the battery voltage is dropped across the load causing the collector voltage to fall to a very low value. The transistor is said to be saturated. With a switch open no base current flow, therefore no collector current can flow. The transistor is said to be cutoff. $V_{CE} \approx +V$ (fig 17.18 (b)) these two states are described as 0 and 1, or low and high.

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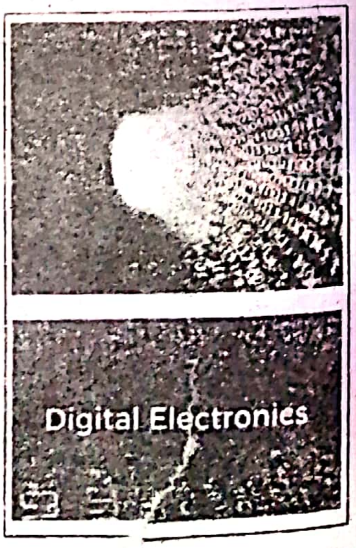
MCQ's From Past Board Papers

1. The use of LDR is in the circuit of:
(A) night switch (B) logic gate (C) rectifier (D) oscillator
2. The size of base in a transistor is:
(A) 10 m (B) 10^{-7}m (C) 10^{-8}m (D) 10^{-6}m
3. The ratio β in transistor is called:
(A) Current gain (B) Voltage gain (C) Nuclear gain (D) Emitter gain
4. For non-inverting amplifier if $R_1 = \infty$ ohm and $R_2' = 0$ ohm, then gain of amplifier is:
(A) –1 (B) Zero (C) +1 (D) Infinite
5. Transistors are made from:
(A) Plastics (B) Metals (C) Conductors (D) Dopped semiconductors
6. The term transistor stands for:
(A) Transfer of current (B) Transfer of voltage (C) Transfer of resistance (D) Transfer of charge
7. An expression for current gain of the transistor is given by:
(A) $\beta = \frac{I_B}{I_C}$ (B) $\beta = I_B + I_C$ (C) $\beta = I_C - I_B$ (D) $\beta = \frac{I_C}{I_B}$
8. The central region of a transistor is called:
(A) Base (B) Emitter (C) Collector (D) Neutral
9. Which one has greater concentration of impurity:
(A) Emitter (B) Base (C) Collector (D) Whole transistor
10. In a common emitter amplifier, the phase difference between the input signal voltage and output signal voltage is: (Federal 2011)
(A) $\frac{\pi}{4}$ (B) π (C) 0 (D) $\frac{\pi}{2}$
11. The common emitter current amplification factor β is given by: (Federal 2011)
(A) $\frac{I_B}{I_E}$ (B) $\frac{I_E}{I_B}$ (C) $\frac{I_C}{I_E}$ (D) $\frac{I_C}{I_B}$
12. The ratio β transistor is called:
(A) Current gain (B) Voltage gain (C) Nuclear gain (D) Emitter gain
13. The gain of non inverting op .Amp of external resistances $k_1 = 10k\Omega$, $R_2 = 100k\Omega$ is
(A) 0.1 (B) 10 (C) 11 (D) –10
14. The gain of Amplifier is given as:
(A) $-\beta R_C / r_{ie}$ (B) $\beta r_{ie} / R_C$ (C) $\frac{-R_2}{R_1}$ (D) $1 + \frac{R_2}{R_1}$
15. The width of central region of a transistor is:
(A) 10^{-4} m (B) 10^{-6} m (C) 10^{-3} m (D) 10^{-9} m
16. SI unit of current gain is:
(A) ampere (B) volt (C) coulomb (D) no unit
17. The gain of transistor amplifier depends upon
(A) Resistance connected with collector (B) Resistance connected at base
(C) Input voltage (D) Output voltage
18. For normal operation of a transistor, the E–B junction is always;
(A) Forward biased (B) Reverse biased (C) Not biased (D) No effect of biasing

Answers Key

1. A	2. D	3. A	4. C	5. D	6. C	7. D	8. A	9. A	10. B	11. D	12. A
13. D	14. A	15. B	16. D	17. A	18. A						
25. D	26. B	27. A	28. B	29. D	30. B						

Q.10 What is digital electronic?



Digital Electronics

- Digital calculators, watches, modern communication systems and computers are widely used in everyday life.
- All persons working in various fields related to electronics must understand the performance of Digital Electronics Circuits.
- All sizes of computers, as we know, perform complicated task with fantastic speed and accuracy.
- At stores, the cash register read out digital display.
- Digital clock and watches flash the time in all city shops and restaurants.
- Most automobiles use microprocessors to control engine functions.
- Aircraft's defense sectors, factory machines and modern diagnostic in medical science are controlled by digital circuits.

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Role of integrated circuits in digital electronics:

The inexpensive fabrication of integrated circuits (ICs) has made the subject digital electronics easy to study. One small IC can perform the task of thousands of Transistors Diodes and Resistors. Many ICs are used to construct Digital Circuits. This is an exciting and rapidly growing field, which uses several principles for the working of computers, communication systems, digital machinery's etc.

Digital Systems and Digital Circuits:

Any device working under Digital Techniques are called Digital Systems and the Electronic Network used to make them operational is called Digital Circuits. The subject as a whole is often referred as Modern Digital Electronics.

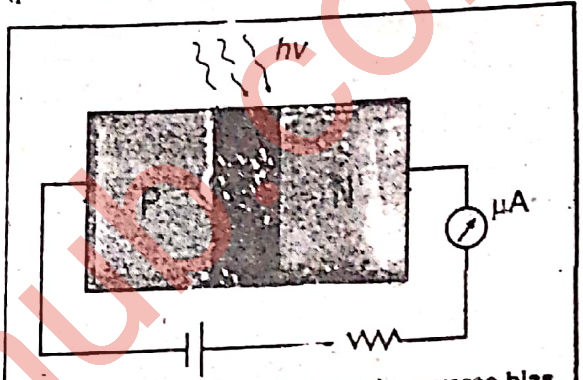
Q.11 What are optoelectronic junction devices. Discuss the Different Types of Especially Designed p-n Junction Diodes?

Optoelectronic junction devices

In semiconductor diodes carriers are generated by photons (photo-excitation). All such devices are called optoelectronic devices. Three commonly used such diodes are

(i) Photodiodes
(ii) Light emitting diodes (LED)
(iii) Photovoltaic

(i) Photo Diode



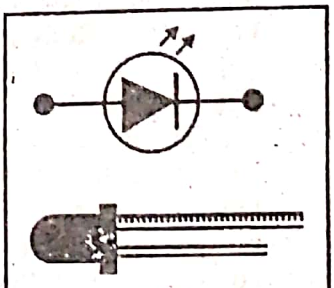
An illuminated photodiode under reverse bias.

A photodiode is a P-N junction diode, operated under reverse bias. When the photodiode is illuminated with light energy (hυ) greater than the energy gap (Eg) of the semiconductor, then electron hole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of electrons holes pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. Electrons are collected on N-side and holes are collected on P-side giving rise to an e.m.f. when an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity of incident light (photo current is proportional to incident light intensity). Hence photodiode can be used for the detection of optical signals.

Uses:

- Detection-both visible and invisible lights.
- Logic circuits.
- Optical communication equipment.
- Security systems.
- Used in T-V to receive the signal of remote control.

(ii) Light emitting diode



It is a heavily doped P-N junction which under forward bias emits spontaneous radiation. When the diode is forward biased, electrons are sent from N→ P (where they are minority carriers) and holes are sent from p → N (where they are minority carriers). At the junction boundary the concentration of the minority carriers increases compared to the equilibrium concentration (i.e., when there is no biasing). On either side of the junction, excess minority carriers are there which recombine with majority carriers near the junction. As a result energy is released in the form of photons. The diode is encapsulated with a transparent cover so that the emitted light can come out (diode converts electrical energy into light). LED's have fast action, long life and endurance and fast on-off switching capability.Special type of semi-conductors such as gallium arsenide and gallium arsenide phosphide are used in LEDs. The color of light depends upon the nature of the semiconductor.

Uses:

- Remote controls,
- Burglar alarm systems,
- Optical communication
- Display system
- Used in traffic signal.

(iii) Solar cell

A solar cell is also a P-N junction which generates e.m.f. when solar radiation falls on the P-N junction. It works on the same principle (photovoltaic effect) as the photodiode, except that no external bias is applied and the junction area is kept much larger. A simple P-N junction solar cell is shown in fig. The generation of emf by a solar cell, When light falls on it, is due to the,

(i) Generation of e-h pairs,

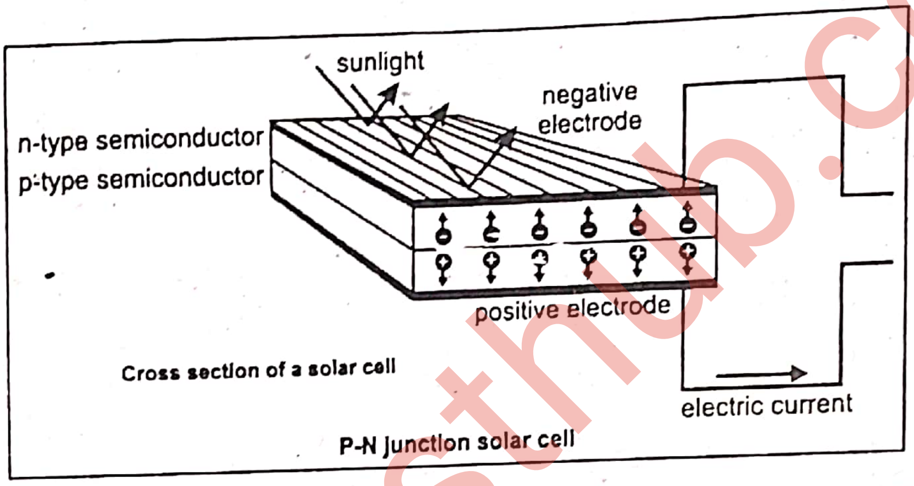
(ii) Separation of electrons and holes. (Electrons are swept to the N-side and holes to P-side)

(iii) The electrons reaching the N-side are collected by the front contact and holes reaching P-side are collected by the back contact.

Thus P side becomes positive and N-side becomes negative giving rise to photo voltage. When an external load is connected as shown in fig. a photocurrent I_L flows through the load.

Uses:

1) To power electronic devices in satellites and space vehicle
2) Solar calculators.
3) Solar watches



P-N Junction solar cell

IMPORTANT SHORT QUESTIONS FOR BOARD EXAMS

1. Write any two characteristics of operational amplifier. **(Fsd 2016)**

Ans. **High Input Resistance:**

It is the resistance between (+) and (–) inputs of amplifier whose value is of the order of several mega ohms (2MΩ or more). So due to large value of R_{in} practically no current flows between the two input terminals.

Note: In ideal case R_{in} is infinite.

Low Output Resistance:

It is the resistance between output terminal and the ground. It value is only a few ohms.

It is low about 100Ω. So, op-amp can deliver practically all its output voltage to a load of 2kΩ or more connected to amplifier, which is an advantage.

Note: Ideal op-amp has zero output resistance.

Open Loop Gain:

It is the ratio of output voltage V_o to voltage difference between inverting and non-inverting inputs, when there is no external connection between the input and output.

So $$A_{OL} = \frac{V_o}{V_+ - V_-} = \frac{V_o}{V_i}$$

The open loop gain of an amplifier is very high of the order of 10^5.

2. What is the principle of virtual ground of operational amplifier?

(D.G.Khan 2015 Group I) (Sgd 2016 Group I)

Ans. **Virtual ground:**

When an op-amp is used as an inverting amplifier, input voltage is applied at inverting terminal while the non-inverting terminal is grounded as shown is fig.

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As open loop gain of op-amp is very high of the order of 10^5. So $V_+ \sim V_-$ hence the input voltage (V_i) is reduced to such a small value that it may be assumed to be at ground. This is called virtual ground. (Clearly, *it is not the real ground*)

3. What is an ideal diode?

Ans. Ideal diode

Ideal diode is that which offers zero resistance when it is forward biased And offers infinite resistance when it is reverse biased.

4. What is reverse or leakage current in p–n junction diode?

Ans. Leakage current

In reverse biased p-n junction, the negative terminal of the battery pulls the holes away from the junction and positive terminal attracts electrons. However, a very small current of the order of few micro amperes flows across the junction due to flow of minority charge carrier. This current is known as reverse current or leakage current in p-n junction diode.

5. What is meant by transistor? Name its three regions.

Ans. Transistor and its different regions

It is an electronic instrument which is formed by the combined effect of p-type and n-type substances, in such a way that the central substance is sandwiched its opposite substances at the other ends. It is used to amplify both current as well as voltage.

Three regions of the transistor are

(i) Emitter
(ii) Base
(iii) Collector

FORMULAE

1	Forward resistance of pn-junction	$r_f = \dfrac{\Delta V_f}{\Delta I_f}$	
2	Transistor current equation	$I_E = I_C + I_B$	
3	Current gain CE-transistor	$\beta = \dfrac{I_C}{I_B}$	
4	Gain of CE-amplifier	$A = \dfrac{\Delta V_o}{\Delta V_{in}}$	$A = -\beta \dfrac{R_C}{r_{ie}}$
5	Voltage equation for output loop	$V_{CC} = I_C R_C + V_{CE}$	
6	Voltage equation for input loop	$V_{CC} = I_B R_B + V_{BE}$	
7	Open loop gain of an operational amplifier	$A_{OL} = \dfrac{V_o}{V_+ - V_-}$	$A_{OL} = \dfrac{V_o}{V_{in}}$

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6	Gain of an inverting amplifier	$G = -\frac{R_2}{R_1}$	
7	Gain of an non-inverting amplifier	$G = 1 + \frac{R_2}{R_1}$	
8	OR Gate	X = A + B	
10	AND Gate	X = A . B	
11	NOT Gate	$X = \overline{A}$	
12	NOR Gate	$X = \overline{A + B}$	
13	NAND Gate	$X = \overline{A . B}$	
14	XOR Gate	$X = A\overline{B} + \overline{A}B$	
15	XNOR Gate	$X = \overline{A\overline{B} + \overline{A}B}$	

UNITS

1	Forward or reversed resistance	ohm	Pa
2	Voltage gain	No unit	
3	Current gain	No unit	

CONSTANTS

1	Current gain (β)	30 – 500	Pa
2	Open loop gain of an operational amplifier	$\sim 10^5$	

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Key Points

- Semiconductors are materials having an intermediate electric conductivity between conductors and insulators.
- Chemically pure semiconductors are known as intrinsic semiconductors.
- In pure semiconductors, a single event of bond breaking leads to two carriers. Namely an electron and hole.
- The minority carriers are generated through breaking of covalent bonds.
- The intrinsic semiconductors have low conductivity which is of little interest. But, when a small amount of impurity is added to semiconductor crystal then it greatly increases the conductivity of the intrinsic semiconductor.
- An N-type semiconductor is obtained by doping an intrinsic semiconductor with trivalent elements such as boron and aluminum.
- PN junction has special properties such as rectification.
- The net drift current through the junction is due to electron a... hole.
- *The conversion of AC into DC is called the rectification and a device used for rectification is called the rotifer.*
- In transistor, there are two PN junctions, which form either PNP or NPN transistor.
- An increase in voltage or current level is called amplification. The transistor can be used as an amplifier.

Solved Examples

Example 17.1:

A transistor is connected in a CE configuration. The collector supply voltage is 10V and the voltage drop across 500Ω connected in the collector circuit is 0.6V. If α = 0.96, find the (a) collector-voltage (b) base current, and (c) the emitter current.

Solution:

To collector current, $I_C = \frac{V_C}{R_C} = \frac{0.6}{500}$

$= 1.2\,mA$

(1) Collector-emitter voltage $V_{CE} = V_{CC} - V_C = 10 - 0.6 = 9.4V$

(2) $\alpha = \frac{I_C}{I_E}$ or $I_E = \frac{I_C}{\alpha} = \frac{1.2}{0.96} = 1.25\,mA$

(3) $I_E = I_B + I_C$ or

$I_B = I_E - I_C = 1.25 - 1.2 = .05\,mA$

Example 17.2:

The constant α of a transistor is 0.95. What is would be the change in the collector current corresponding to a change of 0.4mA in the base current in a common-emitter arrangement?

Solution:

The current gain of transistor in common-emitter arrangement is β, which is related to its current-gain α in common-base arrangement $\beta = \frac{\alpha}{1-\alpha}$ by putting values $\beta = \frac{0.95}{1-0.95} = 19$

But, β is the ratio of change in collector current to the change in base current.

$$\beta = \frac{\Delta I_C}{\Delta I_b}$$

or $\Delta I_c = \beta \times \Delta I_b = 19 \times 0.4 \times 10 - 3A = 7.6\,mA$

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Text Book Exercises

Q.1 Select the correct answer of the following questions.

(i) In an N-type silicon, which of the following statement is true:
(a) Electrons are majority carriers and trivalent atoms are the dopants.
(b) Electrons are minority carriers and pentavalent atoms are the dopants
(c) Holes are minority carriers and pentavalent atoms are the dopants.
(d) Holes are majority carriers and trivalent atoms are the dopants.

(ii) The reverse saturation current in a PN junction diode is only due to:
(a) Majority carriers (b) minority carriers (c) acceptor ions (d) donor ions

(iii) Improper biasing of a transistor circuit produces:
(a) heavy loading of emitter current (b) distortion in the output signal
(c) excessive heat at collector terminal (d) faulty location of load line

(iv) When transistors are used in digital circuit they usually operate in the:
(a) active region (b) breakdown region
(c) saturation and cutoff regions (d) linear region

(v) Most of the electrons in the base of an NPN transistor flow:
(a) out of the base lead (b) into the collector (c) into the emit (d) into the base supply

(vi) In a transistor, collector current is controlled by:
(a) Collector voltage (b) base current (c) collector resistance (d) all of the above

No.	Option	ANSWER	EXPLANATION
(i)	(c)	Holes are minority carriers and pentavalent atoms are the dopants.	Because by doping of pentavalent impurity, each impurity atom donates an electron. So electrons are majority charge carriers and holes are minority charge carriers in N-type methods.
(ii)	(b)	minority carriers	Because for minority charge carrier, the battery in reverse baised state serve like a forward baised.
(iii)	(b)	distortion in the output signal	Because the path of current will not be same as we required.
(iv)	(c)	Saturation and cutoff regions	Because in digital circuit we use only two logics; logic 1 mean saturation and logic 0 means cut off.
(v)	(b)	into the collector	Because base region is thin and lightly dopped and also $V_{CC} >> V_{BB}$
(vi)	(b)	all of the above	As $I_C = \beta I_B$ So for a given transistor collector current is controlled by mean be base current for its normal operation.

Comprehensive Questions

Q.2 Write short answers of the following questions.

1. Describe the energy band structure of insulator, semiconductor and conductor.

Ans: See Theory Question No. 1

2. Explain the significance of depletion layer in an equilibrium state in a PN-junction. Give energy band diagram.

Ans: See Theory Question No. 3

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3. **Explain how PN-junction acts as a half-wave rectifier.**

Ans: See Theory Question No. 5

4. **Explain the working of transistor as an amplifier?**

Ans: See Theory Question No. 8

5. **Draw the circuit for a half wave rectifier and full wave rectifier.**

Ans: See Theory Question No. 5

6. **Compare the advantages and disadvantages of full wave rectifier and half wave rectifier.**

Ans: See Theory Question No. 5

7. **Deduce the relation between α and β of a transistor.**

Ans: See Theory Question No. 7

8. **Explain what is meant by the following terms.**

(a) P-type and N-type materials
(b) Doping of semiconductors
(c) P-N junction
(d) Forward biasing
(e) Reverse biasing
(f) Minority carriers
(g) Majority carriers

Ans: See Theory Question No. 1, 2, 3, 4

9. **Discuss the conductive of extrinsic semiconductors and its band gap energy.**

Ans: See Theory Question No. 1

10. **Explain the formation of depletion region in a PN-junction.**

Ans: See Theory Question No. 11

11. **What causes majority carriers to flow at the moment when P-region and N-region are brought together? Why does this flow not continue until and the carriers have recombined?**

Ans: See Theory Question No. 3, 4

12. **Discuss the carrier's movement across the emitter base and collector base junctions.**

Ans: See Theory Question No. 6

13. **What is the effect of increasing the junction temperature of a diode on reverse saturation?**

Ans: See Theory Question No. 3

14. **In a transistor the emitter and collector are of the same type of semiconducting material. Yet they cannot be interchanging in a circuit connection. Explain.**

Ans: See Theory Question No. 6

15. **Is the frequency content of the output of a half wave rectifier and full wave rectifier the same? Explain.**

Ans: See Theory Question No. 5

16. **Describe the advantages of digital electronics.**

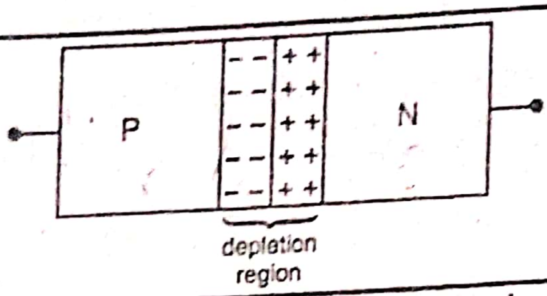
Ans: See Theory Question No. 10

Conceptual Questions

1. **Explain the formation of depletion region in a PN-junction.**

Ans. If one half of the semiconductor material dopped with trivalent impurity while the other half is dopped with pentavalent impurity. So by diffusion of electrons from N-type to P-type region, an ionic region formed. The ionic region contains positive and negative ions which are immobile charges for solids. This ionic region is called depletion region whose width depends upon impurity concentration.

Depletion region have deficiency of majority charge carriers.



2. Explain why in a transistor (a) the base is thin lightly doped and (b) the collector is larger in size.

Ans: (a) The central region of a transistor is called base which is the controlling element of a transistor. It controls the flow of charge carriers from Emitter towards the Collector. Its width is of the order of micron and it is lightly doped.

It is lightly doped so that the depletion region is thin and resistance is small. As the charge carriers will flow from emitter to the base region. So due to its small doping, very few of them will manage to recombine with charge carriers of the base region and over 99 percent charge carrier will flow towards collector to contribute into collector current.

(b) The main function of the collector is to collect the charge carriers in the collector region. Due to interaction of charge carriers, the collector region heats up and all the heat is dissipated through this region, eventually leading transistor to burn out.

So, in order to save the transistor from over heating and burning, the width of the collector region is always greater than emitter and base regions.

3. Explain why the base current is weak as compared to collector current?

Ans. As base is the controlling element of a transistor, which is of small width and lightly doped. Due to these characteristics, the charge carrier move from Emitter to base region, only few of them recombine with hide.

As collector-Base junction is reversed baised by battery voltage V_{CC}, which is very much greater than Emitter-Base junction battery V_{BB} (i.e., $V_{CC} > V_{BB}$) So the voltage V_{CC} swept layer number of charge caries from base to the collector region. Hence the collector current will increase and base current will decrease considerably.

As $I_E = I_B + I_C$

Since I_c is very layer, so I_B will be very small.

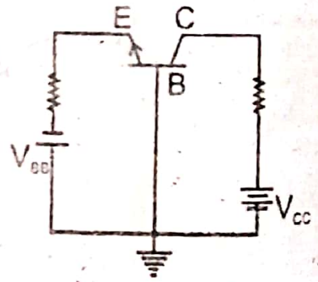
4. Why the emitter base junction is forward based and collector base junction is reverse biased?

Ans: As transistor is the combination of two side by side PN-Junctions, one is emitter-base junction and the other is collector-base junction.

The emitter-base junction is forward baised, so the width of depletion region decreases, which will decrease the forward resistance. Hence a layer number of charge carrier will move from emitter region to the base region.

The collector-base junction is reversed baised, so that this reverse voltage will be able to move the charge carriers from base region along with the charge carriers of collector regions.

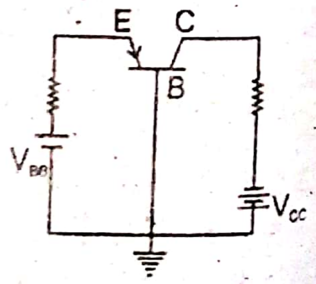
5. Draw the diagram of NPN and PNP transistors and explain how it works.



Ans. **NPN Transistor**

In NPN transistor, a p-type region is sandwiched between two N-type regions. Forward baised voltage at emitter-base junction V_{BB} will move the free electrons from emitter to base region which are swept toward collector region due to layer reverse baised voltage V_{CC} connected at collector-base junction.

PNP Transistor

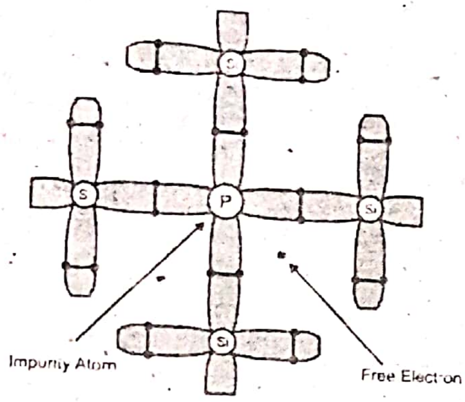
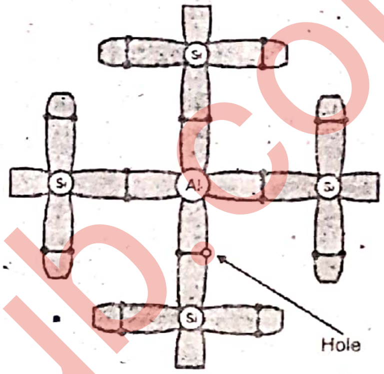


In PNP transistor, a N-type region is sandwiched between two P-type regions.

Forward baised voltage at emitter-base junction V_{BB} will shift the holes from emitter to base region which are swept towards collector region due to layer reverse baised voltage V_{CC} connected at collector-base junction.

6. Distinguish between N-type semiconductors and P-type semiconductors.

Ans.

N-type Materials	P-type Materials
1. They are formed by doping of pentavalent impurity.	1. They are formed by doping of trivalent impurity.
2. Pentavalent impurity such as arsenic, antimony or bismuth belongs to 5th group.	2. Trivalent impurity such as boron, indium or gallium belongs to 3th group.
3. In these materials, majority charge carriers are free electrons.	3. In these materials, majority change carriers are holes.
4. In these materials minority charge carriers are holes. 	4. In these materials minority charge carriers are free electrons. 
5. Impurity atom is donor atom.	5. Impurity atom is acceptor atom.

7. A P-type semiconductor has a large number of holes but still it is electrically neutral. Why?

Ans: First of all we know that atoms are electrically neutral because it contains equal number of electrons and the protons.

As the P-type materials are the result of doping from trivalent impurity in pure semiconductors. This will produce the ability to accept an electron which is called hole and is taken as positive. As the charge on acceptor ion is equal and opposite to the charge on hole, so the crystal will remain to neutral.

8. Explain why CE configuration is widely used in amplifier circuits?

Ans: The common emitter configuration (CE) provides the maximum voltage gain as well as maximum current gain. The other configuration provide either high current gain or voltage gain but not the both. So choice of CE configuration become obvious. For this purpose emitter-base junction is forward baised so input resistance is low whereas collector-base is reversed baised so output resistance is high so the current flows from low resistance to high resistance.

9. Why transistor is called current amplification device?

Ans: Transistor is basically a current amplifying device. Commonly we use common-emitter (CE) configuration for amplification.

As some external signal which is to be amplified is provided between base and emitter, it will cause to change the input voltage. So input current I_B will also change. Since the current gain can be expressed as

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

or $$\Delta I_C = \beta \, \Delta I_B$$

So it will leads the large change in collector current. It expresses that output current. Hence transistor is basically a current operating device.

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10. A doped semiconductor has 10^{10} silicon atoms and 10 trivalent atoms. If the temperature is 25C°, how many free electrons and holes are there inside the semiconductor?

Given data:

$T = 25°C = 298K$

Total no. of atoms $= 10^{10} + 10^{1} = 1 \times 10^{10}$

Solution:

As $K.E = \frac{3}{2}NkT$

$= \frac{3}{2} \times 1 \times 10^{10} \times 1.38 \times 10^{-23} \times 298$

$= 6.17 \times 10^{-11}$ J

$= \frac{6.17 \times 10^{-11}}{1.6 \times 10^{-19}}$ eV

$= 3.86 \times 10^{8}$ eV

As the breakage each covelent bond results in electron-hole pair, so and energy required to break it in Si is 1.09 eV. So

No. of free electrons = no of holes $= \frac{3.86 \times 10^{8}}{1.09}$

$= 3.54 \times 10^{8}$

Where as energy required to break the covelent bond in Ge is 0.72 eV. So

No. of free electrons = no of holes $= \frac{3.86 \times 10^{8}}{0.72}$

$= 5.36 \times 10^{8}$

Numerical Problems

1. In a certain circuit, the transistor has a collector current of 10 mA and a base current of 40 μA. What is the current gain of the transistor?

Given: Collector current $I_C = 10mA = 10 \times 10^{-3}$ A

Base current $I_B = 40\mu A = 40 \times 10^{-6}$ A

To Find:

Current gain $\beta = ?$

Solution:

The current gain 'β' of transistor is

$$\beta = \frac{I_C}{I_B}$$

Putting values

$$\beta = \frac{10 \times 10^{-3} A}{40 \times 10^{-6} A}$$

$\boxed{\beta = 0.250 \times 10^{3} = 250}$

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2. The current flowing into the base of a transistor is 100 μA. Find its collector current I_C, its emitter current I_E, and the ratio I_C/I_E if the value of current gain β is 100.

Given:

Base current $I_B = 100\mu A = 100 \times 10^{-6} A$

Current gain $\beta = 100$

To Find:

Collector current I_C = ?

Emitter current I_E = ?,

$\frac{I_C}{I_E} = ?$

Solution:

The current gain 'β' of transistor is

$$\beta = \frac{I_C}{I_B}$$

$$I_C = \beta I_B$$

Putting values:

$$I_C = 100 \times 10^{-6} A$$

$$\boxed{I_C = 10 \times 10^{-3} A = 10mA}$$

The emitter current I_E is the sum of base current I_B and the collector current I_C.

Therefore $I_E = I_B + I_C$

Putting values $I_E = 100 \times 10^{-6} A + 10 \times 10^{-3} A$

$$\boxed{I_E = 10.1 \times 10^{-3} A = 10.1 mA}$$

The ratio $\frac{I_C}{I_E}$ is

$$\frac{I_C}{I_E} = \frac{10 \times 10\text{-}3 A}{10.1 \times 10\text{-}3 A}$$

$$\boxed{\frac{I_C}{I_E} = 0.99}$$

3. A transistor is connected in CE configuration. The voltage drop across the load resistance (R_C) 3 k Ω is 6 V. Find the base current. The current gain β of the transistor is 0.97.

Given: Load resistance $R_C = 3k\Omega = 3 \times 10^3 \Omega$

Voltage drop at load $V_C = 6V$

Current gain $\beta = 0.97$

To Find: Base current I_B = ?

Solution:

The current gain β of transistor is $\beta \frac{I_c}{I_B}$ or $I_B = \frac{I_c}{\beta} \rightarrow$ (i)

The collector current I_C can be calculated by using Ohm's law $I_c = \frac{V_c}{R_c}$

Putting values: $I_c = \frac{6V}{3 \times 10^3 \Omega}$

$$I_c = 2 \times 10^{-3} A$$

Putting values in equation (i)

$$I_B = \frac{2 \times 10^{-3} A}{0.97}$$

$$\boxed{I_B = 2.06 \times 10^{-3} A}$$

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Additional Conceptual Short Questions With Answers

1. What is difference between an elemental semiconductor and compound semiconductor?

Ans. An elemental semiconductor consist of single species of atoms like Ge, Si. But in compound semiconductor, there are more than one element e.g. Ga As P.

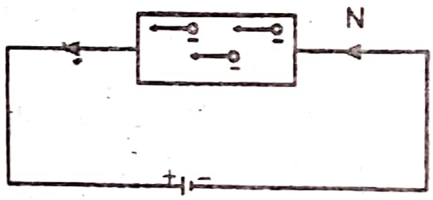
2. How will you distinguish between pure semiconductor and semiconductor made from metals?

Ans. The resistance of semiconductor made of Ge and Si decrease with rise in temperature. But resistance of a semiconductor made from metals increases with rise in temperature.

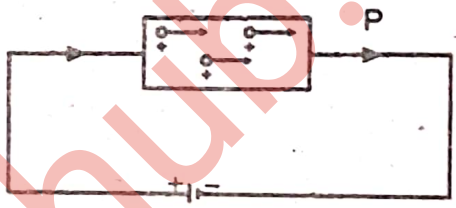
3. How does the motion of an electron in a n-type substance differ from the motion of holes in a p-type substance?

Ans. In n-type substance, electrons are the majority charge carrier. Electron moves from lower potential (negative terminal) to a higher potential (positive terminal). The movement of these electrons is named as electronic current.

In p-type substance, holes are in majority charge carrier. Holes move from higher potential (positive potential) to a lower potential (negative potential). The movement of these holes is named as conventional current.



Electronic current



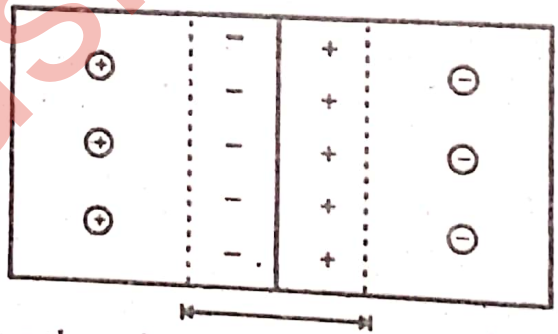
Conventional current

4. What is the net charge on a n-type or a p-type substance?

Ans. There is no net charge on n-type or a p-type substance. There are electrically neutral, because these substances contains same number of positive and negative charges.

5. Why charge carriers are not present in the depletion region?

Ans. An n-region contains free electrons as majority charge carriers and p-region contains holes as majority charge carriers. Just after the formation of the junction, the diffusion of electrons and hole takes place across the junction.



As a result of their diffusion, a charge less region is formed around the junction, in which charge carriers are not present.

6. Which gates are knows as universal gate?

Ans. NOR gate, NAND are called universal gate. Because by a suitable combination of NOR and NAND gates we can produce the basic gates OR, AND and NOT gates.

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Self-Assessment Paper 1

Q.No.1 Encircle the correct option.

1. **In p-n-p transistor, the collector current is _______**
   (A) equal to the emitter current (B) slightly less than emitter current
   (C) greater than emitter current (D) equal to base current
2. **The semiconductor diode can be used as a rectifier because _______**
   (A) it has low resistance to the current flow when forward biased & high resistance when reverse biased
   (B) it has low resistance to the current flow when forward biased
   (C) it has high resistance to the current flow when reverse biased
   (D) none of these
3. **The specially designed semi conductor diodes used as fast counters in electronic circuits are ____**
   (A) the light emitting diodes (B) photo diodes
   (C) photo voltaic cell (D) solar cells
4. **To obtain an n – type semiconductor germanium crysta it must be doped with foreign atoms whose valency is _______**
   (A) 2 (B) 3 (C) 4 (D) 5
5. **In forward bias the width of potential barrier _______**
   (A) increases (B) decreases (C) remains same (D) no effect
6. **In a transistor, collector current is controlled by:**
   (A) Emitter (B) base (C) collector (D) none of these
7. **The thickness of base is a transistor is of the order of.**
   (A) $10^{-3}\,m$ (B) $10^{-9}\,m$ (C) $10^{-6}\,m$ (D) $10^{-6}\,mm$
8. **Light emitting diodes (LED) are made from semiconductors.**
   (A) Silicon (B) Germanium (C) Carbon (D) Gallium arsenide
9. **The reverse saturation current in Pn junction is the result of flow of:**
   (A) majority carriers (B) minority carriers (C) acceptor ions (D) donor ions
10. **The current gain β of a transistor is:**
    (A) $\frac{I_C}{I_B}$ (B) $\frac{I_E}{I_B}$ (C) $\frac{I_C}{I_E}$ (D) $\frac{I_B}{I_C}$

Q.No.2 Write Short Answers any SIX of the following questions.

- What is the principle of virtual ground?
- Explain the formation of depletion region in PN junction.
- What are the applications of photo-diode?
- What is the net charge on n and p-type substance?
- The inputs of a gate are 1 and 0, identify the gate if its output is (a) 0 (b) 1.
- Why the base current in a transistor is very small?
- What are biasing and switching terminal of a common emitter transistor for working its a switch?

Q.No.3 Extensive Question.

(a) What is amplification? Derive the expression for the gain of common emitter amplifier.
(b) In a certain circuit, the transistor has a collector current of 10 mA and a base current of 40 micro ampere. What is the current gain of the transistor?

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Self-Assessment Paper 2

Q.No.1 Encircle the correct option.

1. **The colour of light emitted by LED depends on**
   (A) its forward biasing (B) the type of semi conductor material used
   (C) the amount of forward current (D) its reverse biasing
2. **The energy gap for Germanium at 0K is.**
   (A) 1.12 eV (B) 0.02 eV (C) 6.72 eV (D) 7.2 eV
3. **In reverse bias the width of potential barrier __________**
   (A) increases (B) decreases (C) remains same (D) no effect
4. **To obtain an n – type semiconductor germanium crystal, it must be doped with foreign atoms whose valency is ________**
   (A) 2 (B) 3 (C) 4 (D) 5
5. **Light emitting diodes (LED) are made from semiconductors.**
   (A) Silicon (B) Germanium (C) Carbon (D) Gallium arsenide
6. **A pn junction cannot be used as:**
   (A) A detector (B) A rectifier (C) An amplifier (D) A counter
7. **The minimum number of semi conductor diodes required for full wave rectification are.**
   (A) 1 (B) 2 (C) 3 (D) 4
8. **The gain of non inverting OP – Amp of external resistances $R_1 = 10\,\Omega$; $R_2 = 100\,\Omega$**
   (A) 0.1 (B) 10 (C) 11 (D) – 10
9. **A sensor of light is**
   (A) transistor (B) LED
   (C) light dependent resistance (D) semi conductor diode

Q.No.2 Write Short Answers any SIX of the following questions.

1. What is a logic gate? Explain. Why ordinary silicon light does not emit light?
2. Why base current in transistor is very small?
3. Why transistor is called current amplification device?
4. Why photodiode is operated in reverse biased state?
5. What are forward and reverse biasing of PN junction diode?
6. What are the biasing requirements of the junctions of a transistor for its normal operation? Explain how these requirements are met in a common emitter amplifier?
7. Why NAND and NOR gates are called universal gates?

Q.No.3 Extensive Questions.

Q. (a) Define rectification. Explain half-wave rectifier.

(b) A transistor is connected in CE configuration, The voltage drop across load resistance is 3 kilo ohm is 6V. Find the base curren. The current gain of the transistor is 0.97.

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