ELECTRONIC DEVICES

Quick Review

1. Semiconductors have four valence electrons. With increase in temperature, more free electrons are made available and make semiconductors a better conductor. Resistivity of semiconductors reduce with increase in temperature.

2. Based on energy bands, materials are classified as

Conductor – If band gap is absent or over lapping conduction and valence band.

Semiconductor – Gap of 1 eV between the conduction and valence band.

Insulator – Gap of the order of 6 eV or 3 eV.

3. In the band gap between the conduction and the valence band, electrons are absent. Identified by the non-availability of a real wave function for these energies.

4. Intrinsic semiconductors are pure form of semiconductors. The intrinsic carrier concentration n_i is given by $n_e n_h = n_i^2$ where n_n and n_h refer to the number of electrons and holes per unit volume respectively. In this form $n_e = n_h = n_i$.

5. Extrinsic semiconductors are impurity added form of semiconductors. The imparity added can be a pentavalent e.g., As, Sb etc., producing a n-type semiconductor ($n_e >> n_h$) or a Even here $n_e n_h = n_i^2$ holds good. Both are neutral and not changed.

6.

n-type semiconductor	p-type semiconductor
(i) Doping with pentavalent element	(i) Doping with trivalent element
(ii) $n_e >> n_h$	(ii) $n_h >> n_e$
(iii) Electrons are majority carriers	(iii) Holes are the majority carriers
(iv) Donor energy level is just below the conduction band (≃ 0.01 eV).	(iv) Acceptor energy level is just above the velence band (≃ 0.05 eV)

7. Conduction in semiconductors is due to both electrons and holes. So the net current $I = I_e + I_h$.

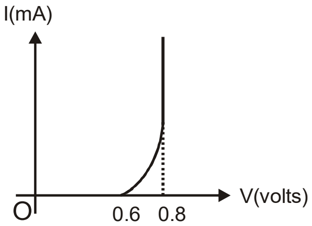
8. Electrical conductivity of semiconductors is given by $\sigma = e(n_e\mu_e + n_h\mu_h)$ where μ_e and μ_h are the mobilities of electron and hole.

9. Mobility is the velocity possessed by the charged particle per unit electric field. It's S.I. unit is C m/N s or $m^2V^{-1}\,s^{-1}$.

10. A single brick of a p and n type material with a space-charge region in between is called a pn-junction. On the p-side, there will be electrons and on the n-side there will be holes in the space-charge region.

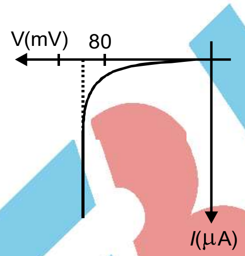
11. The space-charge region depletes the movement of majority carries across the junction. So it is called depletion region. Since there exists a uniform electric field there is a potential gradient which acts as a barrier. It is called Potential barrier.

12. When the p-side is connected to positive and n-side is connected to the negative terminal it is called forward biasing. The barrier reduces causing movement of majority carriers. With increased forward bias, the current grows as shown in the figure given (Silicon diode).



13. When the p-side is connected to negative and n-side is connected to the positive terminal, it is called reverse biasing. The barrier grows in size and the potential difference increases causing a block to the majority carriers.

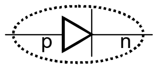
With increased reverse bias, the barrier further grows, but there will be a slight current due to the majority carriers flowing across the junction as shown for silicon diode in the given figure.

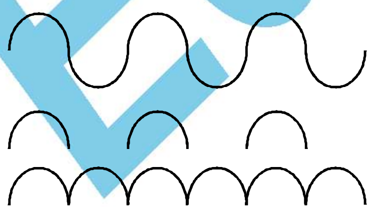


14. **Knee voltage :** The forward voltage at which the current through the junction increases rapidly is called Knee voltage.

15. **Breakdown voltage :** The reverse voltage at which the current due to minority conduction increases rapidly is called Breakdown voltage.

16. **Dynamic resistance :** The ratio between the small change in voltage ΔV to a small change in current Δ I is the pn-junction in called dynamic resistance. $r_d = \dfrac{\Delta V}{\Delta I}$.

17. A pn-junction diode [represented in circuits as ] is used to rectify ac. For a given ac, the half-wave (one cycle rectified) and a full-wave (both cycle rectified) are shown below.

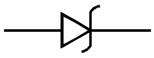


a.c. input

Half-wve rectified output

Full-wave rectified output

The device which does this is called a rectifier. If the frequency of a.c. is f, the frequency of the half-wave and full-wave rectified output are f and 2f respectively.

18. **Zener diode :** A special purpose diode, operated under reverse bias close to breakdown is called zener diode. It is a heavily doped diode used for regulating voltage. It is represented as "" in circuits. Over a wide range of current variation it maintains a constant voltage called Zener voltage is reverse bias.

19. **Photodiode** is a special purpose diode operated in reverse bias and allows current flow when the junction made with transparent window receives light of suitable energy. The intensity of the light decides the current.

20. Lightemitting diode is a heavily doped pn-junction operated in forward bias to emit light when proper bias conditions exits. LED's are biased to have higher light emitting efficiency. They have higher Knee voltage depending on the wavelength of light and a lower reverse breakdown voltage.

21. LED's are having the advantage over incandescent low power lamps by
(i) having lower operating potential and less power
(ii) faster and instantaneous action
(iii) almost monochromatic or lower band width
(iv) having longer life and durability.

22. Solar cells are pn-junctions generating emf when sun light falls on it. To get more power output, the junction are is kept more.

23. Transistor is a three terminal, two pn-junctioned semiconductor device. It can be pnp or npn with three terminals named as emitter, base and collector.

24. **For basic functioning of a transistor,**
(i) The emitter should be densely doped
(ii) The base should be thin and very lightly doped
(iii) The collector should be moderately doped
(iv) The emitter should be forward biased
(v) The collector should be reverse biased.

25. From the conservation of charge, $i_e = i_b + i_c$ holds good as a transistor in conduction

26. Transistors are used as amplifiers in three configuration common-base, common emitter and Common-collector, **as an Oscillator** and as a **Switch.**

27. In CE-common emitter configuration

The current gain is $\beta = \frac{\Delta i_c}{\Delta i_b}$ or $\frac{i_c}{i_b}$

The voltage gain is $A_v = \frac{\Delta V_a}{\Delta V_i} = \frac{i_c R_l}{i_b R_t}$

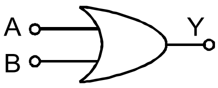
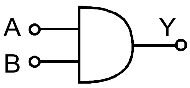
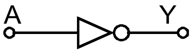
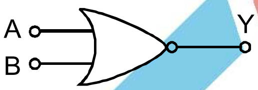
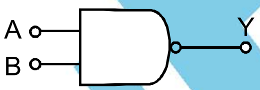
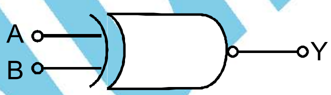
The power gain is $= \beta A_v = \beta^2 \frac{R_l}{R_t}$

28. Oscillator produces Oscillations using d.c. energy. It is a positive feedback amplifier. The frequency of the oscillation produced is $f = \frac{1}{2\pi\sqrt{LC}}$ where L and C are the inductance and capacitance in the tank circuit, where energy varies sinusoidally between the electrical and magnetic from.

29. Transistor in CE configuration has 180 º phase difference between the output and the input.

30. when transistor is in forward bias in CE format, there will be saturation conduction making the output zero.
When there is not bias in emitter, the transistor remains cut-off and so there will be an output which is non-zero.
Thus a transistor can behave as a switch in two states.

31.

Logic Function	**Symbol**	**Logic Equation**	**Truth table**
(i) OR		$Y = A + B$	**A B Y** 0 0 0 0 1 1 1 0 1 1 1 1
(ii) AND		$Y = A.B$	**A B Y** 0 0 0 0 1 0 1 0 0 1 1 1
(iii) NOT		$Y = \overline{A}$	**A B** 0 1 1 0
(iv) NOR		$Y = \overline{A + B}$	**A B Y** 0 0 1 0 1 0 1 0 0 1 1 0
(v) NAND		$Y = \overline{A.B}$	**A B Y** 0 0 1 0 0 1 1 0 1 1 1 0
(vi) XOR		$Y = A\overline{B} + B\overline{A}$	**A B Y** 0 0 0 0 1 1 1 0 1 1 1 0

SOLVED PROBLEMS

1. Why is the base region of a transistor made very thin and lightly doped ?

Sol. Base contains a smaller number of majority charge carriers which reduces the recombination rate of electrons and holes at the base - emitter junction. It reduces base current and increases both collector current and current gain of the transistor.

2. If the base region of a transistor is made large, as compared to a usual transistor, how does it affect
(i) the collector current and
(ii) current gain to this transistor ?

3. If the emitter and the base of a transistor have same doping concentration, how will the base current and collector current be affected ?

Sol. The rate of recombination of electrons and holes increases as the majority charge carriers follow across the emitter-base junction. So, the base current increases and collector current decreases.

4. Can we interchange emitter and collector of a transistor ?

Sol. No, because (i) the doping level of emitter is higher than that of collector. (ii) The contact area of emitter-collector junction is larger than that of emitter - base junction.

5. In the working of a transistor, the emitter-base junction is forward biased while collector-base junction is reverse biased. Why ?

Sol. If the emitter is reverse biased, no charge carriers will flow towrds the collector and hence no current will flow thorugh the transistor.

6. In a transistor, the forward bias is always smaller than the reverse bias. Why ?

Sol. If we apply a large forward biasing across the emitter, the majority charge carriers whould move from emitter to collector thorugh the base with a high velocity. This would produce excessive heating which would damage the transistor.

7. How would you test in a simple way whether the transistor is spoiled or in working order ?

Sol. For a transistor in working order, the forward biased emitter-base junction has a low resistance while the reverse biased base - collector junction has a high resistance. In a spoiled transistor, the resistance is low (or the path is conducting) in both situations.

8. Which one of the transistors p-n-p and n-p-n is more useful and why ?

Sol. n-p-n transistor is more useful than p-n-p transitor, as electrons are the main charge carriers in n-p-n and electrons have higher mobility than holes.

9. Give Conversion of decimal number to binary number :

Examples :

1. Binary equivalence of 2

2	2	
2	1	0
	0	1

$\therefore\ (2)_{10} = (10)_2$

2. Binary equivalence of 3

$$\begin{array}{r|c|l} 2 & 3 & \\ \hline 2 & 1 & 1 \\ \hline & 0 & 1 \end{array}$$

$\therefore\ (3)_{10} = (11)_2$

3. Binary equivalence of 12

$$\begin{array}{r|c|l} 2 & 12 & \\ \hline 2 & 6 & 0 \\ \hline 2 & 3 & 0 \\ \hline 2 & 1 & 1 \\ \hline & 0 & 1 \end{array}$$

$\therefore\ (12)_{10} = (1100)_2$

4. Binary equivalence of 13

$$\begin{array}{r|c|l} 2 & 13 & \\ \hline 2 & 6 & 1 \\ \hline 2 & 3 & 0 \\ \hline 2 & 1 & 1 \\ \hline & 0 & 1 \end{array}$$

$\therefore\ (13)_{10} = (1101)_2$

Conversion of Binary number to decimal number :

Examples :

$110 = 1\times 2^2 + 1\times 2^1 + 0\times 2^0 = 4+2+0 = 6$

$111 = 1\times 2^2 + 1\times 2^1 + 0\times 2^0 = 4+2+1 = 7$

$1101 = 1\times 2^3 + 1\times 2^2 + 0\times 2^1 + 1\times 2^0 = 8+4+0+1 = 13$

$1011 = 1\times 2^3 + 0\times 2^2 + 1\times 2^1 + 1\times 2^0 = 8+0+2+1 = 11$

$111101 = 1\times 2^5 + 1\times 2^4 + 1\times 2^3 + 1\times 2^2 + 0\times 2^1 = 32+16+8+4+0+1 = 61$

Ex. Convert 37 into binary number.

$$\begin{array}{r|cl} & & \text{Remainder} \\ 2 & 37 & \\ \hline 2 & 18 & 1 \\ \hline 2 & 9 & 0 \\ \hline 2 & 4 & 1 \\ \hline 2 & 2 & 0 \\ \hline 2 & 1 & 0 \\ \hline & 0 & 1 \end{array}$$

Therefore$(37)_{10} = (100101)_2$

10 Is a n-type or a p-type semiconductor charged ? Give reason.

Sol. No since they are made by doping element of different valency but neutral net charge is zero.

11. Can an amplifier be used for all frequencies ?

Sol. No, energy amplifier has a range of frequency in which it has better performance.

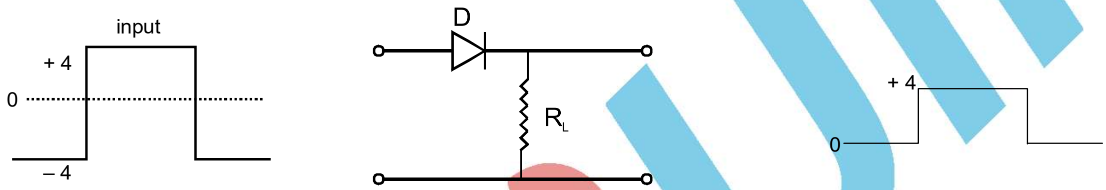
12 What is the property of a pn-junction that makes it to be used in a rectifier?

Sol. Uni-directional property -conducting under forward bias only is used to make a rectifier.

13 Name three factors on which the resistivity of a semiconductor depend upon.

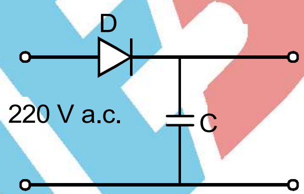
Sol. Temperature, number density of electrons and holes and their mobilities affect the resistivity of semiconductors.

14 A square input signal is given to a pn-junction diode as shown. Draw the output waveform.



Sol. The output waveform is shown.

15. A diode is connected to 220 V a.c. in series with a capacitor as shown. What is the voltage V across the capacitor ?



Sol. Diode conducts only for half of the cycle. During half of the cycle capacitor is charged to the peak value of supply voltage. Thus

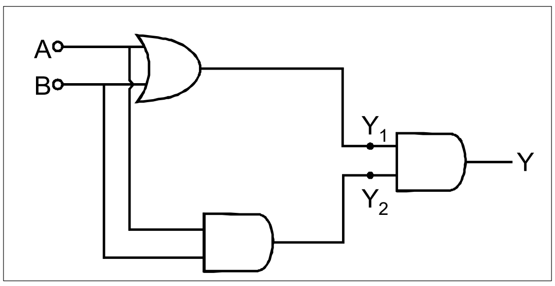
$$V = E_{rms} \times \sqrt{2}$$

$$= 220 \times \sqrt{2} = 311.1 \text{ volt}$$

16 Can the potential barrier of a p-n junction be measured by connecting a sensitive voltmeter across the junctions?

Sol. There are no free charges in the depletion region, so in the absence of forward biasing it offers infinite resistance. Thus, voltmeter cannot measure the potential barrier.

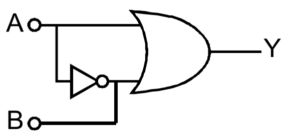
17 Write the truth table for the combination of gates shown.



Sol.

A	B	$Y_1 = A + B$	$Y_2 = \overline{A.B}$	$Y = Y_1.Y_2$
0	0	0	1	0
0	1	1	1	1
1	0	1	1	1
1	1	1	0	0

18 ***The logic circuit shown in the figure yields the given truth table. Identify the gate marked X in the circuit.***



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Sol. From the truth table, we get

$A + B = Y$

$Y = A + X$

$A + X = A + B$

$= A + B\,.\,(A + \bar{A})$ $\qquad [\therefore A + \bar{A} = 1]$

$= A + B\,.\,A + B\,.\,\bar{A}$

$= A\,.(1 + B) + \bar{A}\,.\,B$ $\qquad [\because A + \bar{A} = 1]$

$= A + \bar{A}\,.\,B$

Thus , $\bar{A}\,.\,B = X$, which is AND gate with inputs $\bar{A}$ and B.

19. Why in a transistor, the forward bias voltage is always smaller than the reverse bias voltage?

Sol. On increasing forward bias voltage, the majority charge will move form the emitter to the collector thorough the base with higher velocities. This would produce excessive heat and transistor might get damaged.

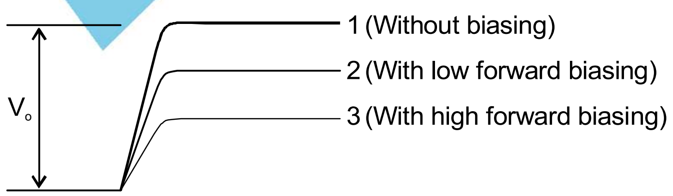
20. Depict height of the barrier potential

(i) Without biasing

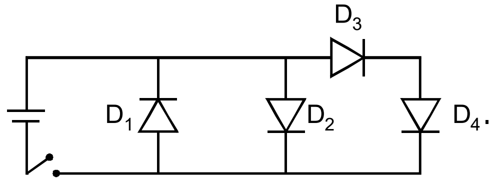
(ii) With low forward biasing

(iii) With high forward biasing.

Sol.



21. ***Analyse the following circuit diagram and write answers to the questions***



(i) Choose from the option below the diodes which are in forward bias when the switch is ON.

(a) D_2, D_4 (b) D_1 D_3 (c) D_1, D_3, (d) D_2, D_3, D_4

Sol. (i) (d) D_2, D_3, D_4

(ii) When the p-end of a diode is connected to the positive pole and the π-end to the negative pole of a cell, the diode is said to be forward biased.

(iii) diode is used as rectifier and detractor.

22. **Explain Biasing of p-n Junction in two ways**

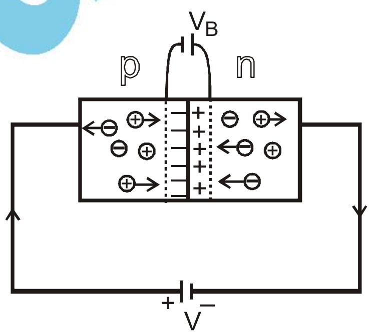
(i) Forward biasing (ii) Reverse biasing

Sol. (i) **Forward Biasing** : A p-n junction is said to be forward biased if the +ve teminal of extenal battery is connected to p-side & –ve terminal to the n-side of p-n junction diode. As a result of forward biasing :

1. The applied forward bias voltage V opposes the potential barrier V_B. Due to it. potential barrier is reduced & the depletion layer becomes thin.

2. The majority carriers, electrons in the n-region are repelled by –ve terminal of the battery & move towards the p-n junction. Similarly, the majority carriers, holes in the p-region are repelled by the +ve terminal & move towards the junction. On crossing the junction, the number of electrons & holes will combine each other. For each electron - hole combination, a covalent band near the +ve termianl the the battery is broken & the liberated electron enters the +ve terminal of the battery. At the same time, an electron from the –ve terminal of the battery enter the n-region to replace the lost electron due to the combination with the hole at the junction. Thus an electric current will flow due to the migration of majority carriers across the p-n junction, which is called forward current.

3. Since the small increase in forward voltage shows large increase in forward current, hence the resistance of p - n junction is low to the flow of forward current.

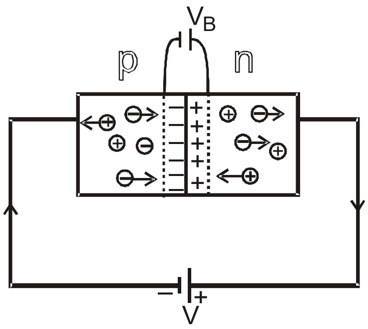


(ii) Reverse biasing : A p -n junction is said to be reverse biased if the +ve terminal of the external battery is connected to n - side & –ve terminal to the p-side of the p-n jucntion diode. As a result of reverse biasing.

1. The reversebias voltage (i.e. potential of external battery) supports the potential barrier V_B. The majority carrier are repelled away from the junction & the depletion layer becomes thick. There is no conduction across the juction due to majority carriers.

2. However, a few minority carriers (hole in n-section & electrons in p-section) of p-n junction does cross the junction after being accelerated by high reverse bias voltage. They constitute a current that flows in the opposite direction. This is called reverse current.

3. Since the large increase in reverse voltage shows small increase in reverse current, hence the resistance of p-n junction is high to the flow of revese current. If the reverse bias is increased to a high value, the covalent bonds near the junction break down and a large number of electron hole pairs are liberated. Thus, the reverse current increase abruptly to a very high value. This phenomenon is called break down and this value of revese voltage is called **zener voltage.**



Note : Potential barrier opposes the forward current, while it aids the reverse current.

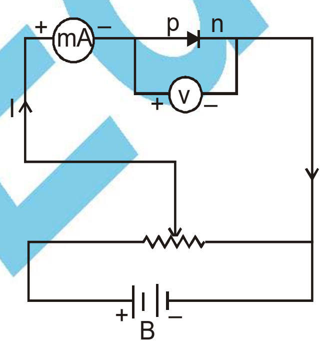
23. Explain Characteristic of p-n junction diode in
(i) Forward bias (ii) Reverse bias

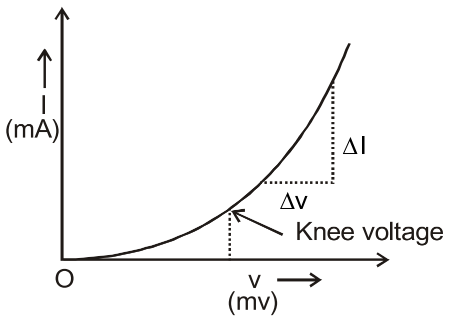
Sol. The variation of current with the applied voltage across the junction diode is known as the characteristic of p-n junction dipole. Two types of characteristic curve of diode are :

(i) Forward characteristics (ii) Reverse characteristics

(i) **Forward Characteristics** : The +ve pole of the battery is connected to the p-section & the –ve pole to the n-section of the diode. When the battery voltage is zero, diode does not conduct and the diode current is zero. As the battery voltage increases, the barrier potential starts decreasing and a small current begins to flow. The forward current increases slowly at first but as soon as the batery voltage beocmes geater than the barier potential V_B, the forward currrent inceases rapidly. The battery voltage at which the forward curent starts increasing repidly is known as knee voltage. After the knee voltage, the variation of current with the applied voltage across the junction is almost linear.

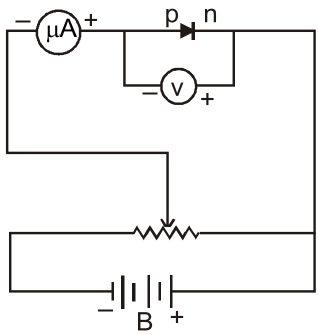
Knee Voltage : It is the forward voltage beyound which the current through the junction starts increasing rapidly with voltage, showing the linear variation. Below the knee voltage, the variation is non-linear.

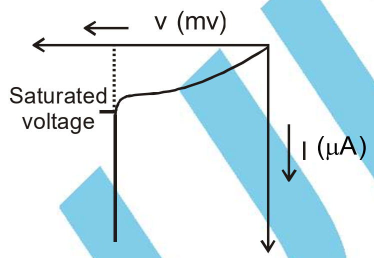




Dynamic resistance or AC resistance of junction diode : It is defined as the ratio of small change in applied voltage ΔV to the corresponding small change in junction current ΔI i.e. $R_d = \frac{\Delta V}{\Delta I}$

Reverse Characteristics : If p-section is connected to –ve terminal & n-section to the +ve terminal of the battery, the junction diode is said to be reverse biased. For a given reverse bias voltage a reverse current flows through micro ammeter due to the migration of minority carriers across the p-n junction. Plotting a graph between reverse bias volage & reverse current we get the reverse characteristics. Initially, the reverse current is small but attains its maximum or saturation value immediately and becomes independent of reverse voltage. It depends on the temperature of the junction diode. The reverse bias voltage at which the current through p-n junction increases abruptly is known as break down voltage or Zener voltage.





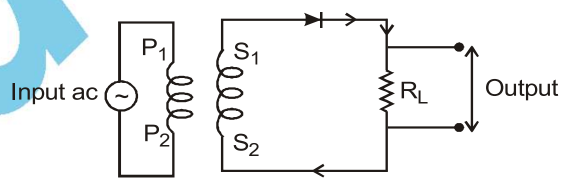
24. **What is a Rectifier. Explain Principle, working of :**
(a) Half wave rectifier **(b) Full wave rectifier**

Sol. **Junction Diode as a rectifier :** Rectifier is a device used for converting alternating current/ voltage into direct current/voltage. It can be used in two ways : (a) Half wave rectifier (b) Full wave rectifier

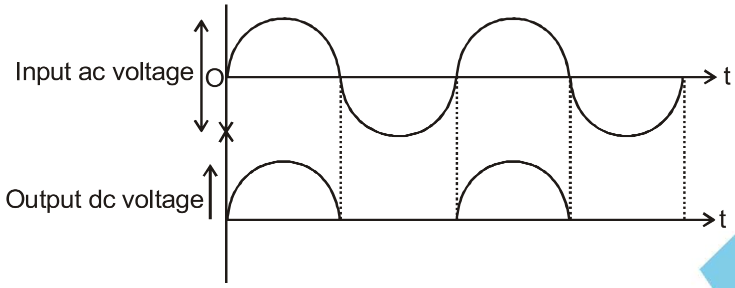
(a) Junction diode as a half wave rectifier : The rectifier which converts only one half of ac into dc is called half wave rectifier.

Principle : It is based on the fact that resistance of p-n junction becomes low when forward biased & becomes high when reverse biased.

Circuit : AC to be rectified is connected to primary P_1P_2 of a step down transformer. S_1S_2 is the secondary coil of the same transformer. S_1 is connected to p-section & S_2 to n-section of junction diode. Output is taken across the load resistance R_L.

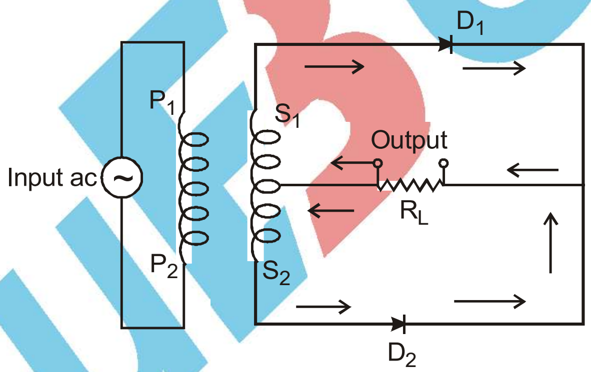


Working : During the +ve half cycle of the input ac thorugh the primary coil, an induced emf is set up in the secondary coil due to mutual induction. The direction of induced emf is such that the upper end of the secondary coil becomes positive and lower end becomes negative. So the p-n junction diode is forward biased during the positive half of input ac. The resistance of p-n junction becomes low. The forward current flows in the direction shown by arrow head. Thus we get output across load. During the negative half cycle of theinput ac thorugh the primary coil, again induced emf is set up across the secondary coil due to mutual induction such that the p-n junction becomes reverse biased. It offers high resistance & hence there is no flow of current & thus no output across the load. The process is repeated. In the output we have current obtained. It is not of much use.

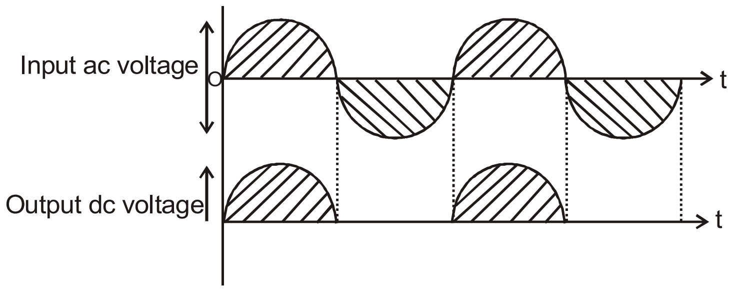


Junction diode as full wave rectifier : Full wave rectifier rectifies both halves of ac input signal.

Circuit : For full wave rectification, two p-n junction diodes are used. It works on the principle that a junction diode offers low resistance during forward bias & high resistnace when reverse biased. The ac input signal is fed to the primary coil of the transformer. The p-regions of both the diodes D_1 and D_2 are connected to the two ends of the secondary coil. The load resistance R_L across which output is obtained is connected between common point of n regions and central tapping of the secondary coil.

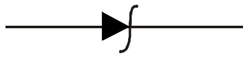


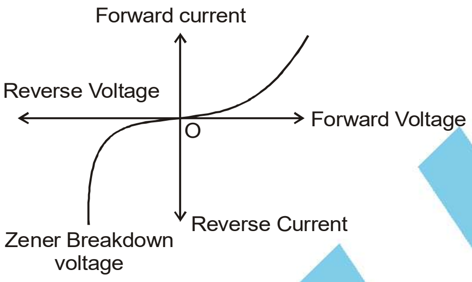
Working : During the +ve half of the input ac thorugh the primary coil, induced emf is set up in the secondary coil due to mutual induction. The direction of induced emf is such that the upper end of the secondary coil becomes positive while the lower end becomes negative. Thus, the upper diode D_1 is forward biased & the lower diode D_2 is reverse biased. The forward current flows due to majority carriers of D_2 across R_L. During both halves current through R_L. flows in the same direction. The ouput has dc & ac components of voltage . It can be converted into purely dc voltage by filtering through filter circuit using large capacitors, before it can be put to any use.



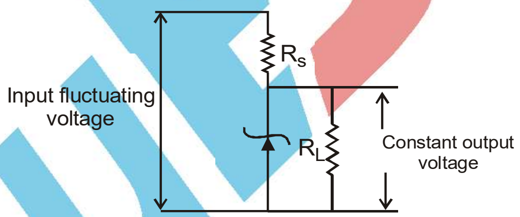
25. Give different Types of Junction Diodes :

Sol.

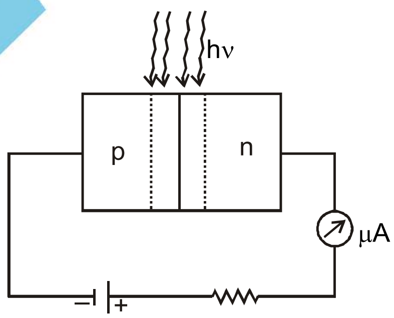
1. Zener Diode : Specially designed p-n junction diode which can operate in the reverse break down voltage region continuously without being damaged is called Zener diode. In Zener diode both p and n sections are heavily doped due to which depletion layer formed in very thin (10^{-6}m), so electric field is very high. Its symbols is  In the reverse break down region, the voltage across the Zener diode remains constant even if the current through Zener diode increases considerably. V - I characteristics of Zener diode is as shown :

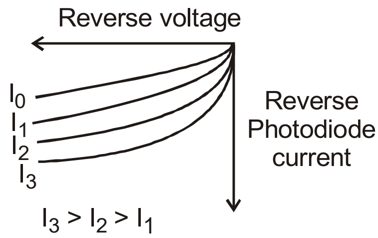


Zener Diode as Voltage Regulator : Important use of Zener diode is in making constant voltage power supply. Zener diode is connected in reverse bias to the fluctuating dc voltage through a resistance R_s. Thus the voltage gets divided between R_s and Zener diode. If the input voltage increases, the current thorugh R_s and Zener diode increases to high value. This increases the voltage across R_s without any change in voltage across Zener diode. This is because in breakdonw region, Zener voltage remains constant. Similarly, if input voltage decreases, the current through R_s decreases without any change in the voltage across Zener diode. Hence, the voltage across Zener diode is constant. As load resistance R_L is connected to Zener diode, so voltage across R_L remains constant.



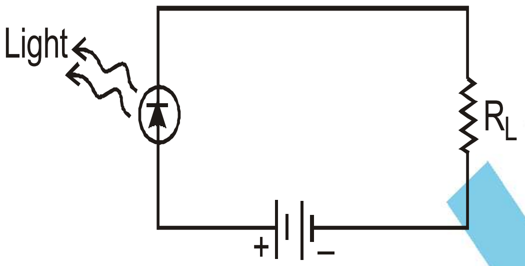
2. Photo Diode : A photo diode is a reverse biased p-n junction semiconductor diode made of photo sensitive semiconductor material. When this diode is illuminated with light of energy greater than energy gap which is allowed to fall from a transparent window, the e-hole pairs are generated in the depletion layer or near the junction due to absorption of photons. These charge carriers are separated by the junction lied and made to flow across the junction. The value of reverse saturation current increases with the increase in intensity of incident light. When no light is incident i.e. at I_0, some current flows through the photodiode called as dark current. The V-I characteristics of a photodiode are shown in the figure.





Uses : (i) In photo detecton for optical signals. (ii) In electronic counters.
(iii) They are used as light operated switches (iv) In optical communication equipments.

3. **Light Emitting diode (LED) :** A p-n junction diode which emits light energy when forward biased is called as light emitting diode. When p-n junction is forward biased, electrons move from n to p and holes from p to n. Due to the recombination of electrons & holes, energy is liberated in the form of heat & light. In Ge & Si p-n junction, a larger % of the energy is given in the form of het i.e. emits infrared radiations. But in some semicondcutors like gallium phosphide (GaP), gallium arsenide phosphide (GaAsP) a greater % of energy is released in the form of visible light (red, green, organe etc.) LEDs emit no light when reverse biased, they will be destroyed.



Uses : (i) In Burglar alarm systems & remote control shcemes

(ii) In calculators & digital watches.

(iii) In the field of optical communication.

Advantages of LED over other power lamps :

(i) They work at low operational voltage and low power.

(ii) Fast action and no warm up time required.

(iii) Fast on - off switching capability.

(iv) LEDs are easily manufactured

(v) They have a longer life.

4. **Solar Cell :** It is p-n junction device which converts solar energy into electrical energy. It works on the same principle as the photodiode, but here no external bias is applied and the junction area is kept much larger for solar radiation to be incident. A p-type Si wafer of nearly 300 μm thickness is taken over which a thin n-layer of thickness nearly 0.3 μm is grown by diffusion process. The other side of p-type is coated with a metal called as back constact. On the top of n-type layer, metal finger electrode is deposited. This acts as front contact. This metal grid occupies a small fraction of cell area so that the light can be incident on the a larger part of the cell. The generation of emf by a solar cell, when light falls on it is due to the following three preocesses: generation, separation and collection.

(i) Generation: generation of electron-hole pairs takes place close to the juction due to the light incident of energy greater than energy gap.

(ii) Separation : separation of electron and holes due to electric field of the depletion region. Here electrons move towards n-side and holes to p-side.

(iii) Collection : electrons reaching n-side are collected by front contact and holes reaching p-side are collected by back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photovoltage.

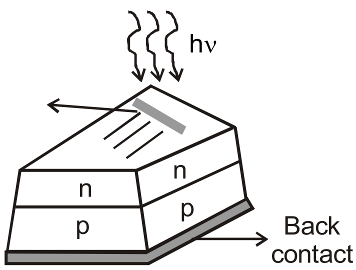
When an external load is connected a photo current 'I^L' flows thorugh the load. The output power depends on the intensity of incident light.

Uses :

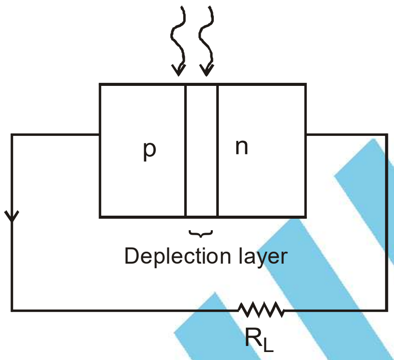
1. For charging storage batteries in day time which can supply power during night.

2. Used to power electronic devices in satallites and space vehicles.

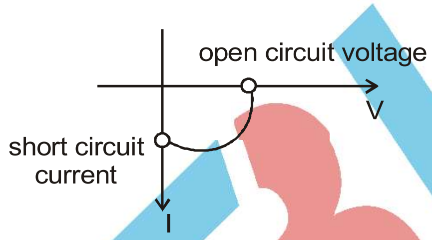
3. Used in calculators, wrist watches.



Metallised finger electrode



V-I characteristic curve for a solar cell is as shown :



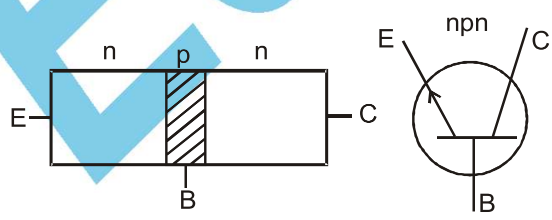
26. Draw block diagram and logic symbol of p-n-p & n-p-n Transistors and give its working

Sol. A transistor is a three terminal semiconductor device. A junction transistor is obtained by growing a thin layer of one type of semiconductor in between two thick layers of othe similar type semiconductors. Two types of transistors are n-p-n junction transistor & p-n-p junction transistor. In n-p-n transistor, the p-section is sandwiched between two n-section. In p-n-p transistor, the n-section is sand wiched between two psections. The three sections of the transistor are called emitter (E), base (B), & collector (C)

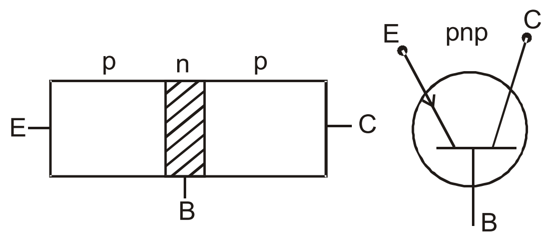
Emitter : The left region of transistor is known as emitter. It suplies majority charge carriers to the base region. Emitter region is heavily doped.

Collector : The right region of transistor is known as collector. It is also heavily doped. The collector collects the majority charge carriers.

Base : The middle region of the transistor is known as base. The base is very thin as compared to the emitter and collector regions and it is lightly doped.



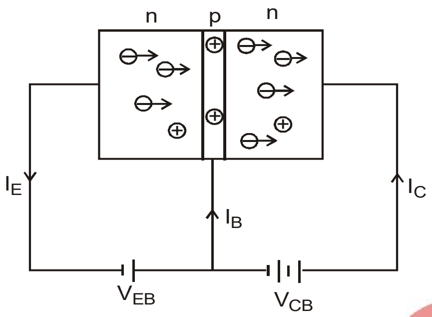
n-p-n transistor

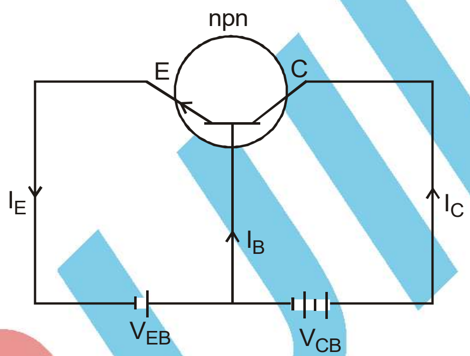


p-n-p transistor

Here arrowhead points hole current i.e. conventional current. In n-p-n transistor the arrowhead on the emitter points away from the base, while in p-n-p transistor arrowhead points towards the base.

Action of n-p-n transistor : The emitter - base junction is forward biased i.e. +ve role of emitter base battery V_{EB} is connected to base & –ve pole to emitter. The resistance of emitter base junction is very low. The collector - base junction is reverse biased i.e. +ve pole of collector base battery V_{CB} is connected to collector & –ve pole to base. The resistance of this junction is very high, electrons which are majority carries in emitter are repelled towards base by –ve potential of V_{EB} resulting emitter current I_E. The base being thin & lightly doped has low number density of holes. When electrons enter in the base region, then only a few electrons (say 5%) get neutralized by the electron-hole combination, resulting base current I_B. The remaining 95% electrons pass over to the collector, due to +ve potential of V_{CB}, resulting collector current I_C.



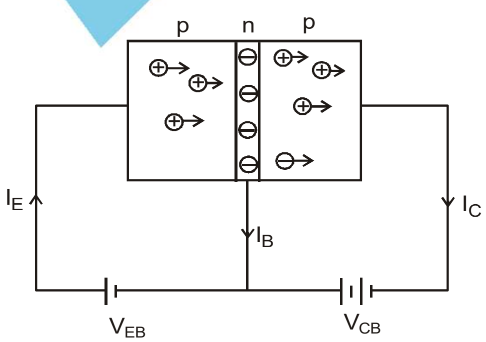


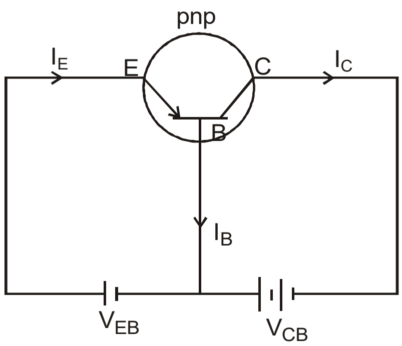
As one electron reaches the collector, it flows to the +ve terminal of V_{CB}, At the same time one electron flows from negative terminal of V_{CB} to +ve terminal of V_{EB} & one electron flows from –ve terminal of V_{EB} to emitter. Thus, in n-p-n transistor, the current is carried inside the transistor as well as in external circuit by electron. So the direction of conventional current is opposite to direction of flow of electrons.

Thus, $I_E = I_B + I_C$

Action of p-n-p transistor : The emitter-base junction is forward b ased i.e. +ve pole of emitter base battery V_{EB} is connected to emitter & –ve pole to base. Colector-base junction is reverse biased i.e. –ve pole of collector base battery V_{CB} is connected to collector & its +ve pole to the base. The resistance of emitter base junction is very low & the resistance of collector base junction is very high.

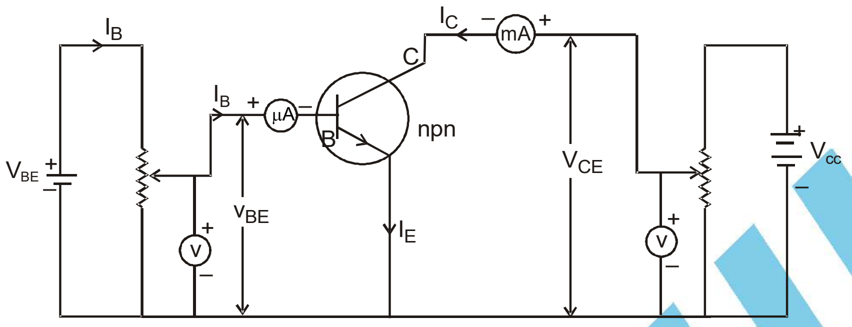
Holes which are majority carries in emitter are repelled by +ve potential of V_{EB} and move towards base resulting emitter current I_1. The base being thin & lightly doped has low number density of electrons. When holes from emitter enter the base, only a few holes (say 5%) get neutralized by the electron - hole combination, resulting base current I_B. The remaining 95% holes pass to collector due to +ve potential of V_{CB}, resulting collector current I_e. As one hole reaches the collector, one electron from ve terminal of V_{CB} flows to the collector. At the same time a covalent bond in emitter is broken, electron released goes to +ve terminal of V_{EB} & hole moves towards the base. Thus the current in p-n-p transistor is carried by holes & at the same time concentration is maintained. Thus, $I_E = I_B + I_C$





27. Give Transistor characteristies in common emitter configuration

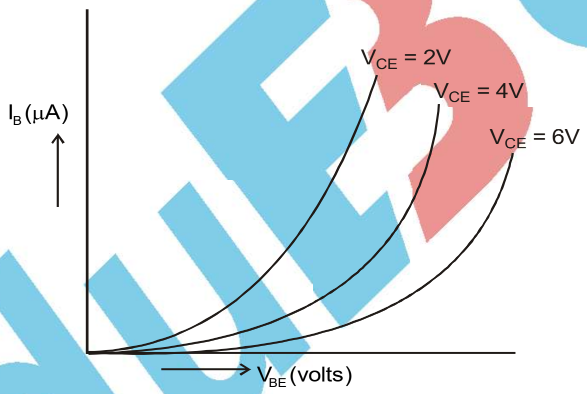
Sol. In common emitter configuration, emitter teminal of transistor is common between input and output circuits.



Input characteristics : These characteristics represent the variation of base current I_B with base - emitter voltage V_{BE}, keeping collector-emitter voltage V_{CE} constant.

Input Resistance : It is defined as the ratio of small charge in base - emitter voltage to the small change produced in base current at constant collector - emitter voltage

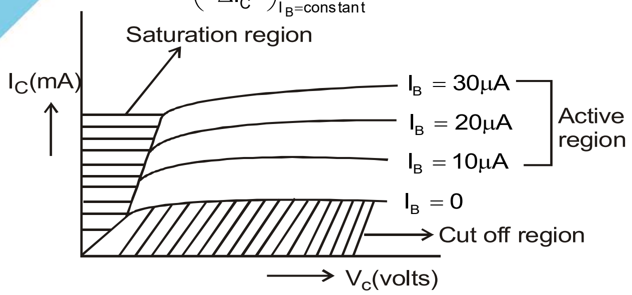
$$R_{input} = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}=constant}$$



Output characteristics : These characteristics represent the variation of collector current I_C with collector mitter voltage V_{CE}, keeping base current I_B constant.

Output resistance : It is defined as the ratio of small change in collector-emitter voltage to small change produced in collector current at constant base current.

$$R_{output} = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B=constant}$$



Output characteristics of a transistor in common - emitter configuration are divided into three regions :

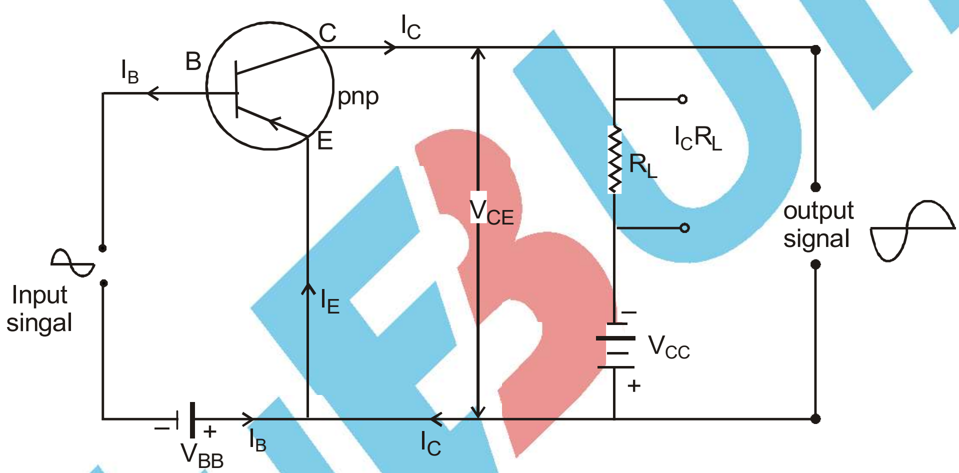
(i) Active-region : Active region lies above $I_B = 0$. In this region, collector junction is reverse biased and emitter junction is forward biased. For a given value of I_B, collector current increases as V_{CE} increases. A transistor is operated in active region if it is used as an amplifier.

(ii) Cut off region : Cut off region lies below $I_B = 0$. The collector current has finite value. In order to cut off the transistor, the emitter junctions has to be made slightly reverse biased in addition to $I_B = 0$

(iii) Saturation region : Saturation lies close to zero voltage axis where all the curves coincide. In this region, collector current is independent of the base current.

28. Explain p-n-p transistor as common emitter amplifier

Sol. Emitter is common to both input & output circuit. The input (emitter-base) circuit is forward biased with battery V_{BB} & the output (collector-emitter) circuit is reverse biased. Due to which the resistance of input circuit is low & that of output circuit is high. A load resistance R_L is connected in series in the collector circuit.



When no ac signal is applied to the input circuit, then according to Kirchhoff's 1st law

$I_E = I_B + I_C$ ....(1)

If we assume that 5% of emitter current appears as base current due to electron-hole combination in base, then 95% of the emitter current flows as collector current.

I_B = 5% of $I_E = 0.05\ I_E$

I_C = 95% of $I_E = 0.95\ I_E$

I_C flows through the load resistance R_L which produces a potential drop I_CR_L which is in opposition to V_{CC} net collector voltage $V_{CE} = V_{CC} - I_CR_L$ ...(2)

where V_{CE} is the potential difference between collector & emitter. When the input signal is fed to the emitter base circuit, it will change the emitter voltage & hence the emitter current which in turn will change the collector current [from equation (1)]. Due to which the net collector voltage V_{CE} varies in accordance with equation (2). These variations in collector voltage appear as amplified output.

Phase relationship between input & output signals :

Amplification of positive half of input signal. The +ve half cycle of the input signal opposes the forward biasing of base-emitter circuit. Due to the decreases in forward bias, the emitter current & hence the collector current decreases. This decreases the potential drop I_CR_L. From equation (2) V_{CE} increases. In other words input signal, the negative half cycle of output signal is obtained.

Amplification of negative half of input signal :

The –ve half cycle of input signal supports the forward biasing of base-emitter circuit. Due to increase in forward bias, the emitter current & hence the collector current inccreases. This increases the potential drop I_CR_L. From equation (2) V_{CE} decreases. In other words collector becomes les negative. So positive output signal is obtained. Thus, for negative half cycle of input signal, the +ve half cycle of output signal is obtained. When p-n-p transistor is used as common emitter amplifier, the output & input signals are 180° out of phase.

Various gains in Common Emitter Amplifier :

1. Current gain : It is of two types :

(i) d.c. current gain : It is defined as the ratio of collector current (I_C) to the base current (I_B). It is denoted by β.

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

(ii) a.c. circuit gain : It is defined as the ratio of change in collector current (ΔI_C) to the change in base current (ΔI_B) at constant collector-emitter voltage. It is denoted $\beta_{ac.}$

$$\boxed{\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}}$$

Its value lies between 15 to 50, for a transistor.

2. **Trans-conductance(g_m) :** It defined as the ratio of change in collector current (ΔI_C) to the change is abse emitter voltage i.e. input voltage (ΔV_i)

$$g_m = \frac{\Delta I_C}{\Delta V_i} = \frac{\Delta I_C}{\Delta I_B} \times \frac{\Delta I_B}{\Delta V_i}$$

$$\boxed{g_m = \frac{\beta_{ac}}{R_i}} \qquad \left(\because R_i = \frac{\Delta V_i}{\Delta I_B}\right)$$

3. **a.c. voltage gain (A_v) :** It is defined as the ratio of change in output voltage (ΔV_C) to the change in input voltage (ΔV_i)

$$A_v = \frac{\Delta V_C}{\Delta V_i} = \frac{\Delta I_C \times R_0}{\Delta I_B \times R_i} = \beta_{ac} \times \frac{R_0}{R_i}$$

$$\boxed{A_v = \beta_{ac} \times \text{Resistance gain}}$$

$$A_v = \frac{\beta_{ac}}{R_i} \times R_0$$

$$\boxed{A_v = g_m \times R_0}$$

4. **a.c. power gain :** It is defined as the ratio of change in output power to change in input power.

$$\text{Power gain} = \frac{\Delta P_0}{\Delta P_i} = \frac{\Delta I_C^2}{\Delta I_B^2} \times \frac{R_0}{R_i}$$

$$\boxed{\text{Power gain} = \beta_{ac}^2 \times \text{resistance gain}}$$

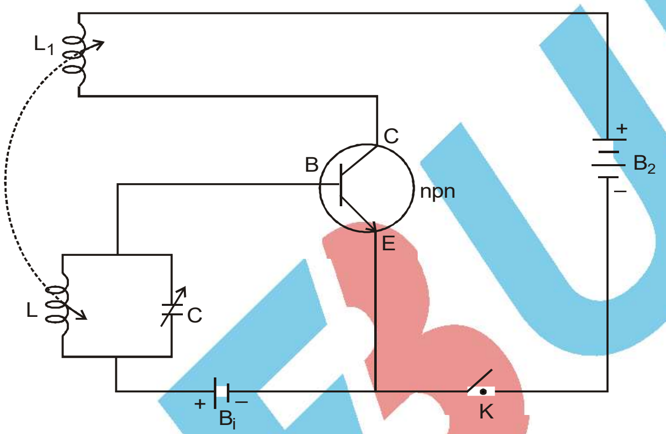
$$\boxed{\text{Power gain} = \beta_{ac} \times A_v}$$

29. Explain working of transistor as Oscillator

Sol. Tank circuit consisting of an inductance L & a capacitor C, connected in parallel is the simplest type electrical oscillating system. In this circuit electrical energy once given to the circuit, oscillates as magnetic energy in the inductance & electrostatic energy in the capacitance. frequency of oscillations is given by

$$v = \frac{1}{2\pi\sqrt{LC}}$$

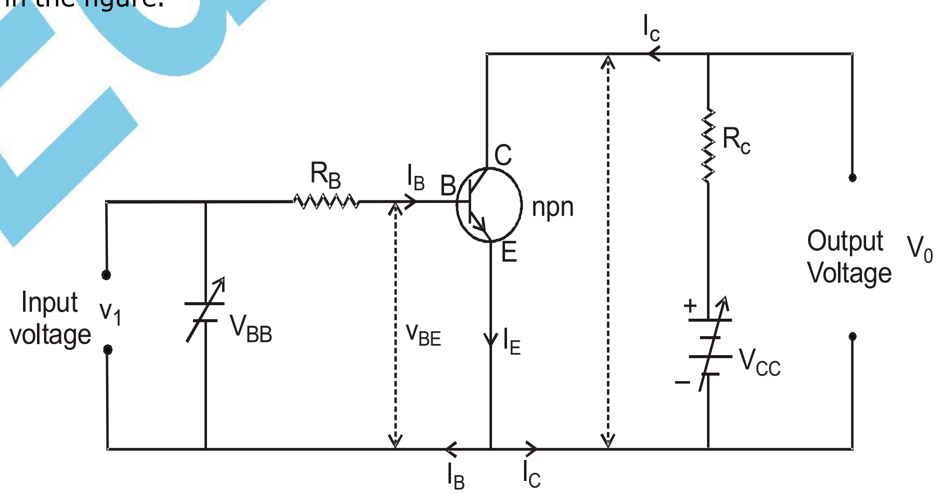
Here LC circuit is inserted in emitter-base circuit of transistor which is forward biased with battery B_1. The collector-emitter circuit is reverse biased with battery B_2. A coil L_1 is inserted in collector emiter circuit. I is coupled with L in such a way that if increasing magnetic flux is linked with L it will support the forward bias of emitter-base circuit & decreasing magnetic fiux will oppose the forward bias.



Working : When K is closed, the current starts rising due to L_1. As a result magnetic flux linked with L_1 increases & hence increases with L. Due to mutual induction; an emf is induced in L which will charge the upper plate of the capacitor with positive charge which supports the forward biasing of base-emitter circuit. This results in an increase in the emitter current & hence an increase in collector current. In this way the collector current through L_1 goes on increasing, till the induced emf across L attains a saturation value.

30. Discribe Transistor as a switch

Sol. To understand the operation of the transistor as a switch (i.e. a device for the on and off the current in the circuit), we use n-p-n transistor with common emitter transistor circuit as shown in the figure.



Using Kirchoof's voltage law ; for the input circuit we have

$$-V_{BB} + I_B R_B + V_{BE} = 0 \text{ or } V_{BB} = I_B R_B + V_{BE} \quad ....(1)$$

For the output circuit, we have

$$-V_{CC} + I_C R_C + V_{CE} = 0 \quad \text{or} \quad V_{CE} = V_{CC} - I_C R_C \quad ....(2)$$

We shall assume V_{BB} as the d.c. input voltage V_i and V_{CE} as the output voltage V_o. Then

From (1), $V_i = I_B R_B + V_{BE}$ .... (3)

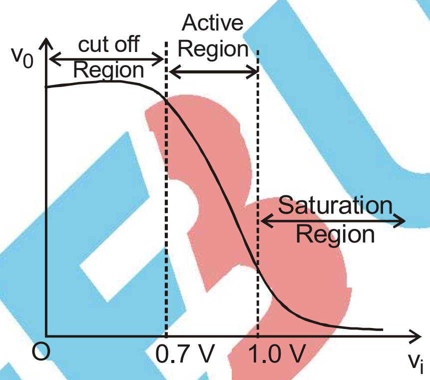
From (2), $V_0 = V_{CC} - I_C R_C$ ....(4)

Now we shall try to understand how V_0 changes as V_i increases from zero onwards.

In case of Si - transistor as long as V_i < 0. 7V, thr transistor will be in cut off state and current I_C will be zero.

The from (4), $V_0 = V_{CC}$

When V_i > 0.7 V, the transistor is in active state. There will be some current I_C in the collector-emitter circuit. From (3) we note that the value of output voltage V_0 decreases as the term $I_C R_C$ increases. With the increase of $V_b I_C$ increases of V_0 with V_i becomes non-linear and transistor goes to saturation state. With further increase in V_i, V_0 is found to decrease further towards zero but never becomes zero.



From above, we note that a long as V_i is low (i.e. V_i < 0.7 V), V_0 is high (=V_{cc}). The transistor is in cut off state. It means the transistor is said to be in switched on state. If V_i is high (i.e., V_i > 1.0 V), the transistor is in saturation state, the V_0 is low and is very near to zero. It means the transistor is not conducting. In this situation the transistor is said to be in the switched off state.

If we define low and high states as below and above certain voltage levels corresponding to cut off and saturation states of transistor, then we can say that a low input state switches the transistor on and a high input state switches it off. It means the low input to transistor gives a high output and a high input gies a low output. It shows that a transistor acts as a switch.

31. Explain OR AND and NOT gate used in digital circuit

Sol. Boolean algebra and logic operations :

George Boole developed algebra to solve the logical problems. This algebra is known as **BOOLEAN ALGEBRA.** This logic is a binary or two valued logic. So this algebra allows only two values or states for a variable. These two values or states represent either 'true' or 'false' ; 'ON' or 'OFF' ; 'closed' or 'open'; 'high' or 'low' etc. by 1 and 0 respectively.

Logic Gates :

The digital circuit that can be analysed with the help of Boolean algebra is called logic gate or logic circuit. A logic gate has one or two input but only one output.

There are primarily three logic gates namely the **OR** gate, the **AND** gate and the **NOT** gate.

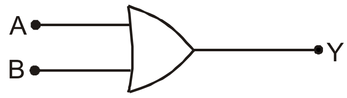
Truth table : The operation of a logic gate or circuit can be represented in a table which contains all possible inputs and their corresponding output is called truth table.

The OR gate:

OR gate has two inputs (A and B) and only one ouput (Y). The relation between the output (Y) and the inputs (A and B) is given by the Boolean expression.

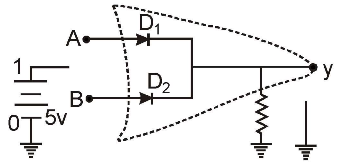
$Y = A + B$ and is read as "Y equal A OR B"

Logic symbol of OR gate is shown as



OR gate used in digital circuit

OR gate consists of two diodes connected in such a way that their n-regions are connected at a common point. The input applied to A or B is either 0 or 1. These diodes are assumed to be ideal (zero resistance).



Following cases may heppen :

1. When A = 0 and B = 0, both the diodes are revese biased. In this case, non of the diodes conducts and hence there is no output i.e. Y = 0

2. When A = 0 and B = 1. In this case, D_2 is forward biased and D_1 is reverse biased. So diode D_2 conducts. The whole input voltage (i.e. 5V) appers at the output as diode D_2 is ideal one. The high voltage (5V) is represented by 1, so the output Y = 1.

3. When A = 1 and B = 0. In this case, diode D_1 is forward biased and diode D_2 is reverse biased. So diode D_1 conducts. The whole input voltage (5V) appears at the output as diode D_1 is ideal. The high voltage (i.e. 5V) is represented by 1. So output Y = 1

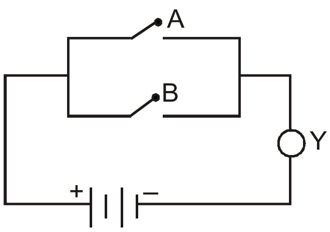
4. When A = 1 and B = 1. In this case, both the diodes are forward biased and hence both conduct. The output voltages of two diodes obtained across R are in parallel, so the net ouput Y = 1 (i.e. 5V)

The **truth table of OR gate** is given below :

Inputs		Output
A	**B**	**Y**
0	0	0
0	1	1
1	0	1
1	1	1

The operation OR can be understood with the help of the following example.

Consider a circuit having two parallel switches A and B and an electric bulb in the circuit will glow only if either switch A or switch B or both are closed. If both the switches are open, the bulb will not low at all.

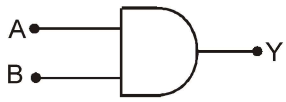


The AND Gate :

AND gate has two inputs and only one output. The relation between inputs (A and B) and the output (Y) is Given by the Boolean expression.

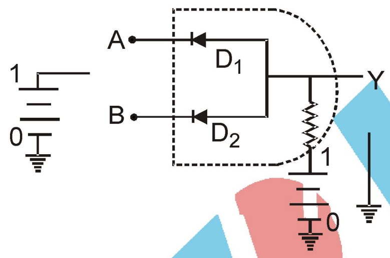
Y = A. B and is read as "Y equal A AND B"

Logic symbol of the AND gate is shown as



The AND gate used in digital circuit

The AND gate consists of two diodes connected in such a way that their p-regions are connected at common point. The diodes are assumed to be ideal.



Following cases may happen :

1. When A = 0 and B = 0. In this case both the diodes are forward biased and hence they conduct. In this case, terminals A and B both are actually grounded because they are connected to grounded terminal of battery B_1. The diodes being ideal, no voltage drop takes place across either diode and as such the output is zero. i.e. output Y = 0

2. When A = 0 and B =1. In this case diode D_1 is forward biased and diode D_2 is reverse biased. So diode D_1 conducts. As the diodes are ideal, so ouput voltage is again zero i.e output Y = 0

3. When A = 1 and B = 0. In this case, diode D_1 is reverse biased and diode D_2 is forward biased. So diode D_2 conducts. As such output voltage is again zero i.e. output Y = 0

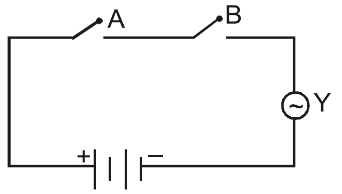
4. When A = 1 and B = 1. In this case both the diodes are reverse biased and hence do not conduct. So the output voltage (Y) is equla to the battery voltage connected to the resistance R. Hence Y = 1.

The truth table of AND gate is given below :

Inputs		Output
A	**B**	**Y**
0	0	0
0	1	0
1	0	0
1	1	1

The operation ANDcan be understood with the help of the following example.

Consider a circuit having switches A and B in series with a bulb. The bulb will glow only if both the switches are closed. If any one of the switches is open, the bulb will not glow.



The NOT Gate :

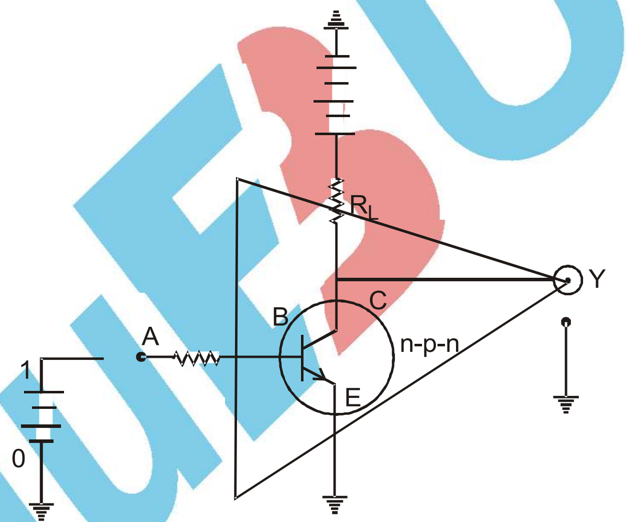
The NOT has only one input and only one output.

The relation between input(A) and output (Y) is given by Boolean expression as Y = A and is read as Y NOT equal to A.

This shows that if A = 0, Y = 1 and if A = 1, Y = 0. It means NOT gate inverts the input. Due to this reason, NOT gate is also known as inverter.

NOT gate used in digital circuit :

Since input signal is to be inverted so a transistor amplifier in common-emitter configuration is used instead of a diode. This type of transistor configuration changes the phase of the signal or introduces a phase inversion. The NOT gate used in a digital circuit is shown in figure.



Following cases may happen :

1. When A = 0, the emitter - base junction is reverse biased and hence ther eis no collector current. The transistor is cut - off. So there is no potential drop across R_L. Thus, the output voltage (Y) is equal to voltage of the battery connected to the collector. Since high voltage is represented by 1, so Y = 1.
2. When A = 1, the emitter - base junction is forward biased and hence large collector current flows through R_L. The transistor is saturated. The voltage drop across R_L is equal to the voltage of the battery connected to the collector. Hence Y = 0

The truth table of Not gate is given below :

Input (A)	Output (Y) $Y = \overline{A}$
0	1
1	0

32. What is Integrated circuts (IC) give advantage, limitation and its uses

Sol. **Integrated circuit is an assembly of large number of transistors, capacitors and** resistors joined on a single piece (square or rectangel) of silicon, which may be very small in size. In other words, integrated circuit is a collection of interconnected transistors, diodes, resistors and capacitors fabricated onto a single piece of silicon, known as chip.

Advantages of IC's

1. The have low cost.
2. They are the more reliable because there is no solder joint inside IC's
3. IC's are smaller and hence the device formed by IC's is very compact.
4. A complex circuit of reasonable size can be designed by using IC's
5. They require low powe to operate.
6. Greater ability of operate at extreme values of temperature.

Limitations :

1. If any one component goes out of order, the whole IC has to be replaced.
2. It is not possible to produce high power (> 10 W) by 1 C's
3. It is not possible to fabricate inductors and transformers on the surface of the chip.

Uses :

IC technology is widely used in televisions, computers, amplifiers, radios, video recorders, telecommunication equipments etc.

EXERCISE - I UNSOLVED PROBLEMS

1. What is the ratio of number of holes to number of conduction electrons in (i) n-type (ii) p-type extrinstic semiconductor ? It is more, less or equal to one.

2. What is the ratio number of holes to number of conduction electrons in an intrinsic semiconductor ?

3. Why is the conductivity of n-type semiconductor greater than that of the p-type semiconductor even when both of these have same level of doping ?

4. How does the energy gap vary with doping in a pure semiconductor ?

5. Why Germanium is preferred over Silicon for making semiconductor devices.

6. Why does the conductivity of a semiconductor increase with rise of temperature ?

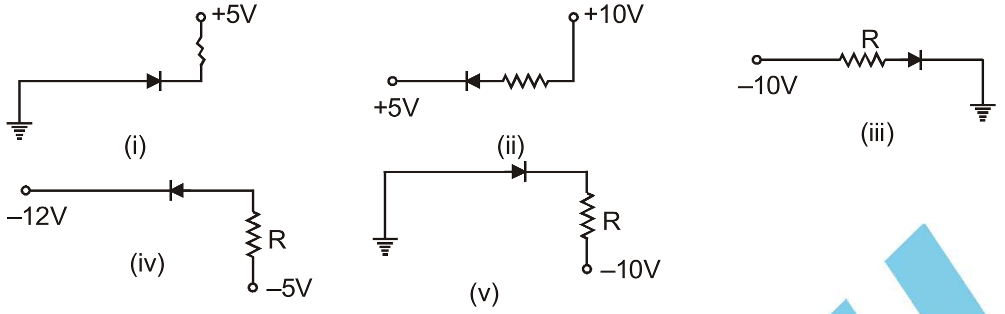
7. In a semiconductor the concentration of electrons is 8×10^{13} cm^{-3} and that of holes is 5×10^{12} cm^{-3}. Is it p-type or n-type semiconductor?

8. Carbon and Silicon are known to have similar lattice structures. However, the four bonding electrons of C are present in second orbit while those of Si are present in its third orbit. How does this difference result in a difference in their electical conductivities ?

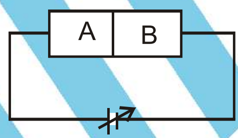
9. A semiconductor has equal electron and hole concentration of 6×10^{8} m^{-3}. On doping with a certain impurity, electron concentation increases to 8×10^{12} m^{-3}. (i) Identify the new semiconductor obtained after doping. (ii) Calculate the new hole concentration (iii) How does the energy gap vary with doping ?

10. What is the net charge on (i) p-type (ii) n-type semiconductor ?

11. Which of the diodes are forward biased and which are revese biased ? Give reason.



12. Two semiconductor mateials A and B made by doping Ge crystal with As and In respectively. The two are joined end to end and connected to a battery as shown :
(i) Will the junction be forward biased or reverse biased ?
(ii) Sketch V - I graph for this arrangement.



13. When a forward bias is applied to a p - n junction, it
(i) raises the potential barrier
(ii) reduces the majority carrier current to zero
(iii) lowers the potential barrier
(iv) none of the above

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

15. What is the phase relationship between collector and base voltage in common emitter configuration.

16. Which type of biasing gives a semiconductor diode a very high resistance ?

17. In a CE transistor amplifier, the current gain is 100, input resistance is 1kΩ, output resistance is 10kΩ. Find the voltage gain of the circuit.

18. A transistor has a current gain of 50. If the collector resistance is 5kΩ and the input resistance is 1kΩ. Calculate the output voltage if the input voltage is 0.01 V.

19. In a CE circuit, if V_{CE} is changed by 0.2 V, collector current changes by 0.004mA. Calcualte the output resistance.

20. The current gain for CE amplifier is 59. If the emitter current is 6mA, find the base curent and collector current.

EXERCISE - II BOARD PROBLEMS

1. Give the logic symbol of NOR gate.

2. (i) With the help of circuit diagrams, distinguish between forward biasing and reverse biasing of a p-n junction diode.

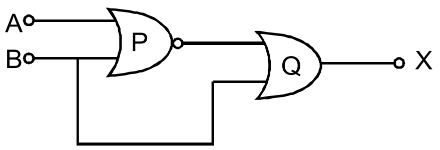
(ii) Draw V – I characteristics of a p-n junction diode in (a) forward bias, (b) reverse bias.

3. With the help of a suitable diagram, explain the formation of depletion region in a p-n junction. How does its width change when the junction is (i) forward biased, and (ii) reverse biased?

4. Give a circuit diagram of a common emitter amplifier using an n-p-n transistor. Draw the input and output waveforms of the signal. Write the expression for its voltage gain.

5. Explain with the help of a circuit diagram how a never diode works as a dC voltage regulator. Draw its I – V characteristics.

6. (i) Identify the logic gates marked P and Q in the given logic circuit.



(ii) Write down the output at X for the inputs A = 0, B = 0 and A = 1, B = 1.

7. Draw a schematic diagram of a step-up transformer. Explain its working principle. deduce the expression for the secondary to primary voltage in terms of the number of turns in the coils. In an ideal transformer, how is this ratio related to the currents in the two coils?

How is the transformer used in large scale transmission and distribution of electrical energy over long distances?

8. (a) Draw the circuit diagrams of a n-n junction diode in (i) forward bias, (ii) reverse bias. How are these circuits used to study the V–I characteristics of a silicon diode? Draw the typical V – I characteristics.

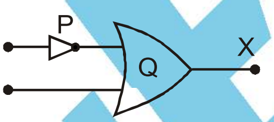
(b) What is a light emitting diode (LED) ? Mention two important advantages of LEDs over conventional lampls.

9. (a) Draw the circuit arrangement for studying the input and output characteristics of an n-p-n transistor in CE configuration.

(ii) Current amplification factor.

(b) Describe briefly with the help of a circuit diagram how an n-p-n transistor is used to produce self-sustained oscillations.

10. (i) Identify the logic gates makred P & Q in the given logic circuit

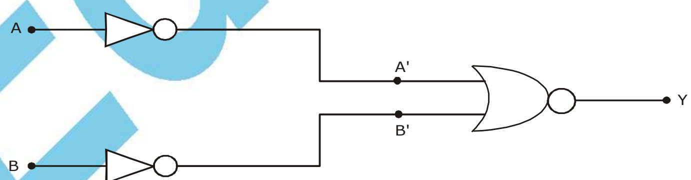


(ii) Write down the output of x for inputs A = 0, B = 0 and A = 1, B = 1

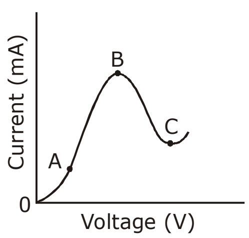
11. Describe briefly with the help of a circuit diagram, how the flow of current carriers in a p-n-p transistor is regulated with emitter-base junction forward biased and base-collector junction reverse biased.

12. (a) Explain briefly the principle on which a transistor amplifier works as an oscillator. Draw the necessary circuit diagram and explain its working.

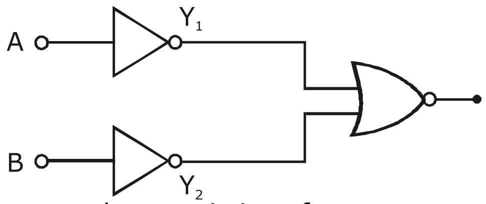
(b) Identify the equivalent gate for the following circuit and write its truth table.



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



14. In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table.



15. Draw typical output characteristics of an n-p-n transistor in CE configuration. Show how these characteristics can be used to determine output resistance.

16. 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 cirtical voltage ?
Name any semiconductor device which operates under the reverse bias in the breakdown region.

ANSWER KEY

EXERCISE - I — UNSOLVED PROBLEMS

1. (i) Less than one (ii) More than one
2. 1 : 1
3. Under a given electric field, free electrons have higher mobility than holes.
4. Decreases
5. Because the energy gap for Ge is 0.72 eV where as for Si, it is 1.1 eV
6. When a semiconductor is heated, more and more electrons jump across the forbidden gap from VB to CB where there are free to conduct electricity.
7. n-type
8. It is easier to eject electrons from third orbit than from second orbit, so conductivity of Si is higher than that of C.
9. (i) n-type (ii) $n_e n_i = n_i^2 \Rightarrow n_h = 4.5 \times 10^4\ m^{-3}$ (iii) reduces the forbidden energy gap.
10. Zero, zero
11. (i) Reverse (ii) Forward (iii) Reverse (iv) Forward (v) Forward 12. Reverse biased
13. (iii) 14. No.
15. 180° out of phase **16.** Reverse biasing **17.** 1000 **18.** 2.5V **19.** 50kΩ
20. 0.1mA, 5.9mA

EXERCISE - II — BOARD PROBLEMS

6. (i) P - Nand Gate
Q - Or gate

(ii)

A	B	X	B	X'
1	1	0	1	1
1	0	1	0	1
0	1	1	1	1
0	0	1	0	1

10. (i) P = NOT Gate Q = OR Gate

(ii)

A	B	X
1	0	1
0	1	1