SOLID AND SEMICONDUCTOR DEVICES

*Crystal structure=lattice + basis

- Lattice=It is a regular arrangement of points in space in which atoms, molecules, ion is located.
- Basis=It is an assembly of atoms, ions or molecules identical in composition, arrangement and orientation located at each lattice point.

*Types of solids

Crystalline solids	Amorphous solids
1.They have regular and periodic arrangement of atoms or ions or molecules.	1. They have not regular and periodic arrangement of atoms or ions or molecules.
2. They have sharp melting point.	2.They have not sharp melting point.
3. They are anisotropic i.e. Their physical properties are different along different directions.	3. They are isotropic i.e. Their physical properties are same in all directions.
Eg: copper sulphate, diamond ,graphite, sugar ,NaCl etc	Eg. glass , chalk , plastic etc

Energy bands in solids:

In solids, there are large no. of atoms closely packed together so that their outer electrons interact with each other but the inner electrons are least affected. Due to interaction, if there are n atoms surrounding an atom, an energy level of the atom is splitted up into n energy levels. *The range of energy possessed by an electron in a solid is called energy band.*

Valence band	Conduction band	Forbidden band
It is the energy band formed by valence electrons of an atom.	It is the energy band formed by conduction or free electrons.	It is the separation between valence band and conduction band.
It is partially or completely filled but never empty	It can be empty or partially filled	There is no energy state in it. it indicates the external energy required to move an electron from valence band to conduction band.

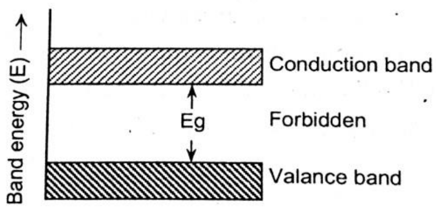
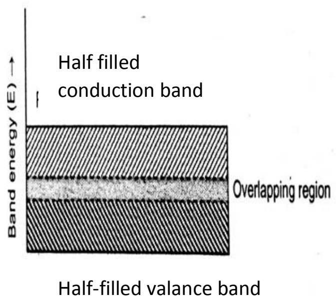
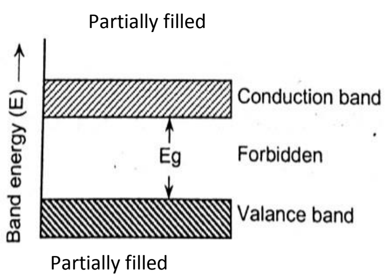
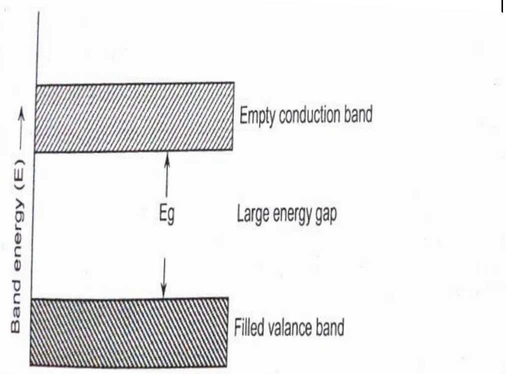


Fig: ;.18.2: Energy band diagram

***Differentiate between conductor, semiconductor and insulator on the basis of band theory:**

CONDUCTOR	SEMICONDUCTOR	INSULATOR
1. There is no forbidden energy gap i.e. the valence band and conduction band are overlapping.	There is small forbidden energy gap(~1ev)	There is large forbidden energy gap (>3eV)
2. At room temperature, conduction band is half filled.	At room temperature, conduction band is partially filled.	At room temperature, the conduction band is empty.
3. At absolute zero, valence band and conduction band is half filled	At absolute zero, valence band is completely filled and conduction band is empty	At absolute zero, valence band is completely filled and conduction band is empty
4. Temperature coefficient of resistance is positive.	Temperature coefficient of resistance is negative.	Temperature coefficient of resistance is negative.
5. The electrical conductivity is large. eg. copper ,silver ,gold	The electrical conductivity is intermediate between conductor and insulator. e.g. silicon, germanium,graphite	The electrical conductivity is very small e.g. diamond, paper, rubber
 Fig: Energy Band diagram of conductor	 Fig:energy band diagram of semiconductor	 Fig Energy band diagram of insulator

Charge carriers in a semiconductor:

Free electron	hole
1. **It is an electron in conduction band**	**It is a vacancy created in a valance band due to the transfer of electron to the conduction band.**
2. **Electron current is due to the movement of free electrons in conduction band.**	**Hole current is due to the movement of holes in valance band.**
3. **It moves towards the anode of the battery in conduction band.**	**It moves opposite to the electrons in valance band.**
4. **It is a negative charge**	**It acts as positive charge carrier**

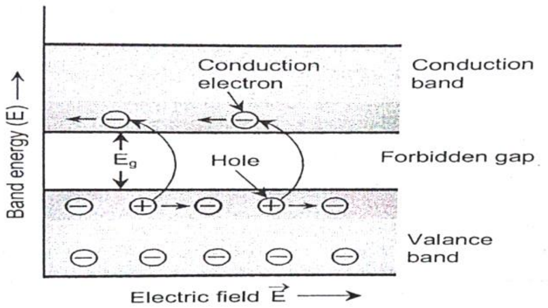
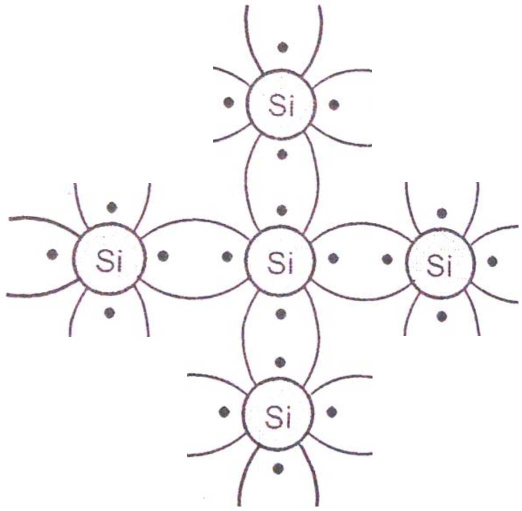
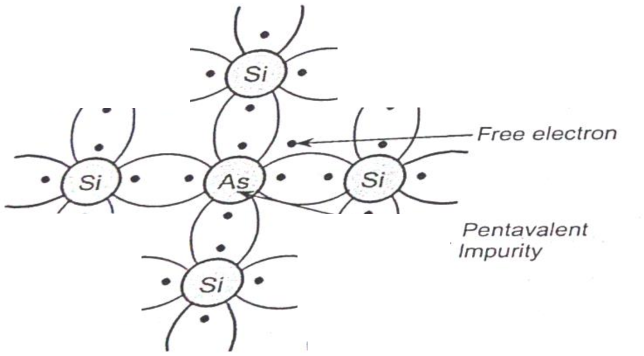


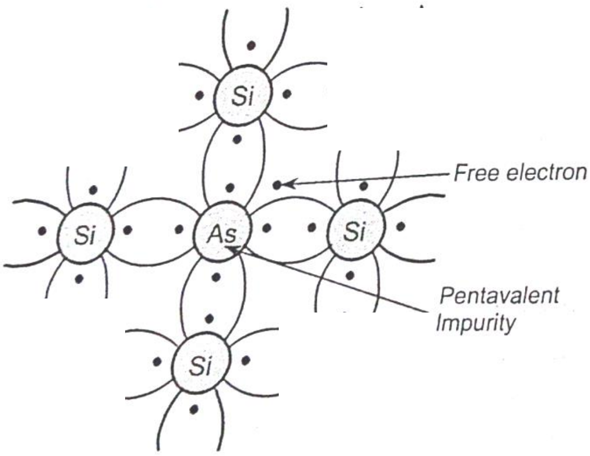
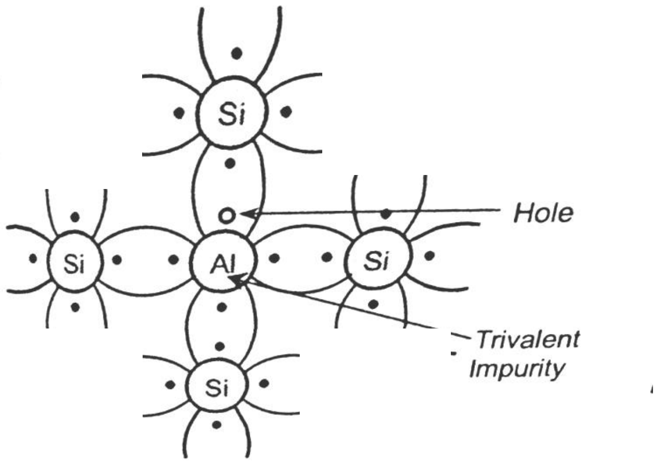
Fig. : Motion of electrons in the C.B. and of holes in the V.B. of a semiconductor under the action of $\vec{E}$.

***Types of semiconductor:**

Intrinsic semiconductor	Extrinsic semiconductor
1. It is a pure semiconductor.	It is an impure or doped semiconductor.
2. In this semiconductor, the no. of free electrons in conductor in conduction band is equal to the no. of holes in valence band.	In this semiconductor, the no. of free electrons in conduction band is not equal to the no. of holes in valence band.
3. Its electrical conductivity is low.	Its electrical conductivity is high
4. Its electrical conductivity depends only on temperature.	Its electrical conductivity depends only on temperature and quantity of doping impurity.
For example: pure Ge and pure Si	For example: Si doping with As, Si doping with Al

 **Fig: pure silicon semiconductor**	 *Fig. Bonding diagram of n-type semiconductor* Fig: Extrinsic Semiconductor

Types of extrinsic semiconductor:

N-type semiconductor	P-type semiconductor
1. It is formed by doping pentavalent impurity to a pure semiconductor.	It is formed by doping trivalent impurity to a pure semiconductor.
2. The impurities are donors.	The impurities are acceptors.
3. The electrons are majority charge carriers and holes are minority charge carriers.	The holes are majority charge carriers and electrons are minority charge carriers.
4. The electron density is much greater than hole density.	The hole density is much greater than electron density
 *Fig. Bonding diagram of n-type semiconductor*	 *Fig. Bonding diagram of p-type semiconductor*

PN Junction diode

When a P-type semiconductor is placed in contact with a N-type semiconductor so as to form one piece, the device obtained is called PN junction diode. The surface of contact of P and N type of semiconductor is called PN junction.

Figure (a) P-N junction diode. (b) Symbolic representation of P-N junction diode.

Depletion layer and potential barrier:

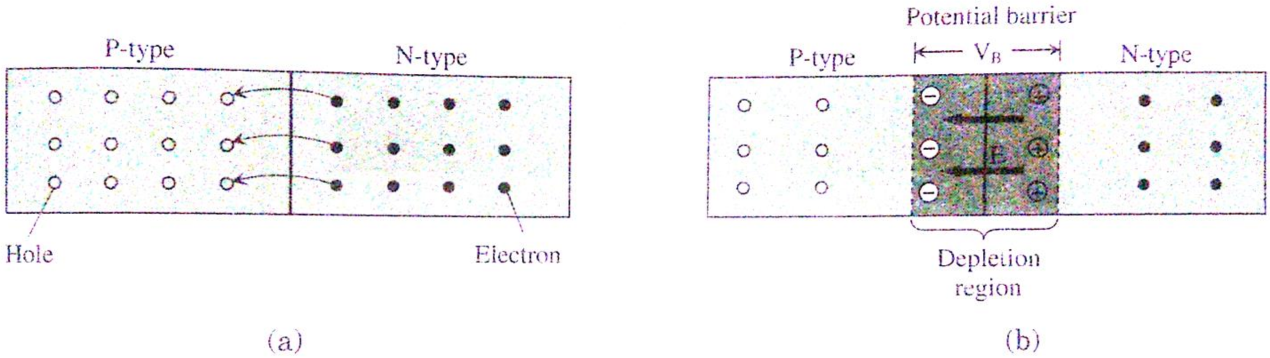


Figure (a) P-N Junction. (b) Depletion region and potential barrier in a P-N junction

In the P-type region, holes are majority charge carriers and in the N-type region, electrons are majority charge carriers. When a P-N junction is formed, some of the electrons diffuse from N-region to P-region and some of the holes diffuse from P-region into N-region .When an electron migrates from N to P region, it fills a hole and makes a negative ion on P -side and leave behind positive ion on the N –sidewhich are immobile .As a result, *a narrow region formed in the junction which is devoid of mobile charge carriers but contain immobile positive and negative ions is called depletion layer*. *The potential difference developed across the junction due to the migration of charge carriers is calledpotential barrier.* It opposes the further migration to charge carriers.The value of potential barrier for germanium is about 0.3 V and about 0.7 V for silicon.

Biasing of PN junction diode:

The process of connecting a battery across the terminals of the diode is called biasing.

There are two types of biasing:

1. **Forward bias:**

   A diode is said to be forward biased if P side is connected to the positive terminal of the battery and N side is connected to the negative terminal of the battery.

   If the forward bias is greater than the potential barrier, the majority charge carriers (holes of P –section and electrons of N-section) move towards the junction and cross it. The current which flows due to majority charge carriers is called forward current and it increases with forward bias.

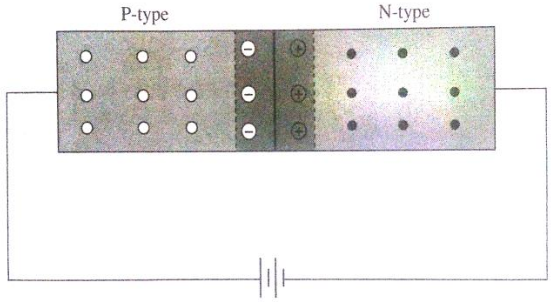


Figure Forward biased P-N junction diode.

When diode is forward biased:

- The width of depletion layer decreases
- The potential barrier decreases
- The flow of current inside the diode is due to the majority charge carriers
- The diode offers very low resistance called forward resistance and it acts as an closed switch

2. Reverse bias

A diode is said to be reverse biased if P side is connected to the negative terminal of the battery and N side is connected to the positive terminal of the battery.

When reverse bias is applied, the majority charge carriers are pulled away from the junction and minority charge carriers move towards the junction and cross it. The current which flows due to the minority charge carriers is called reverse current.

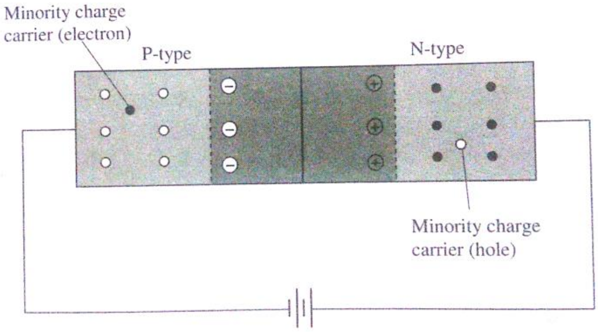


Figure Reverse biased diode.

When diode is reverse biased:

- The width of depletion layer increases
- The potential barrier increases
- The flow of current inside the diode is due to the minority charge carriers
- The diode offers very high resistance called reverse resistance and it acts as a open switch

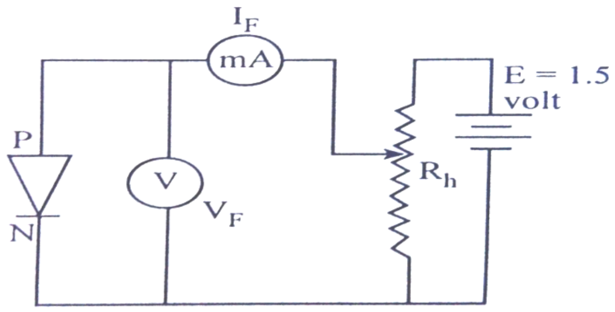
Characteristic of junction diode:

The graph between the potential difference across the junction diode and the current through it,is called the characteristic of junction diode.

These are of two types:

Forward characteristics:

A circuit diagram to study forward characteristics of a diode is as shown in fig. . The milliammeter(mA) measures the forward current through the diode and voltmeter V measures the forward voltage drop across the diode. With the help of rheostat R_h , value of forward voltage V_F is varied and the corresponding forward current I_F is noted. A graph between V_F and I_F is as shown in fig.



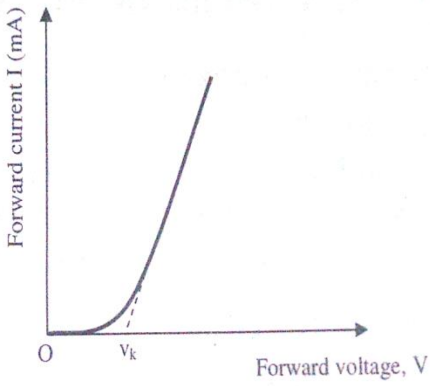


Fig: circuit diagram to study forward characteristics

Fig: forward characteristics

When the junction diode is given increasing forward bias, almost no current flows until the potential barrier is over come. As the forward bias is further increased, the current increases sharply. *The value of forward bias at which current starts rising sharply is called Knee voltage (V_K) which is equal to the potential barrier of the diode.* Its value is 0.7 volt for a silicon diode and 0.3 volt for the germanium diode.

REVERSE CHARACTERISTICS:

A circuit diagram to study reverse characteristics of a diode is as shown in fig. The microammeter (µA) measures the reverse current through the diode and voltmeter V measures the reverse voltage drop across the diode. With the help of rheostat R_h , value of reverse voltage V_R is varied and the corresponding reverse current I_R is noted. A graph between V_R and I_R is as shown in fig.

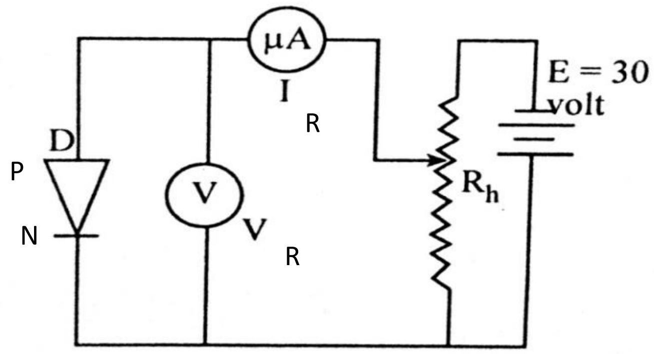


Fig: circuit diagram to study reverse characteristics

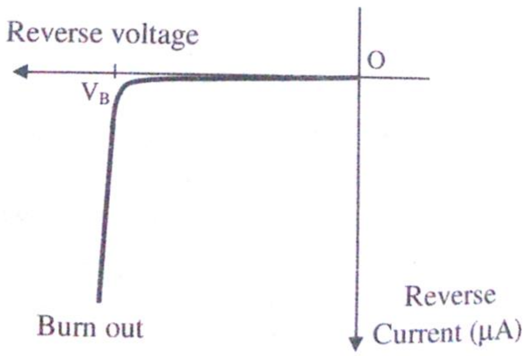


Fig : reverse characteristics

When the junction diode is given increasing reverse bias, the reverse current remains very small over a long range and on further increasing the voltage,at one point the current suddenly rises. *The value of reverse bias at which current starts rising sharply is called breakdown voltage (V_B).*

RECTIFIER:

An electronic device which converts ac into dc is called rectifier and the process involved is called rectification.

The diode conducts in forward bias due to low resistance and does not conduct in reverse bias due to high resistance. This unidirectional property of diode enables it to be used as a rectifier.

HALF WAVE RECTIFIER:

A rectifier which converts only half cycle of ac into dc is called half wave rectifier.

The circuit diagram of half wave rectifier is as shown in fig. The input ac V_{in} is applied across the primary coil P of the transformer. A diode D and resistor R_L is connected to the secondary coil S of the transformer in series. When an ac input is connected to primary coil of the transformer, the diode receives alternating positive and negative cycle of the ac input.

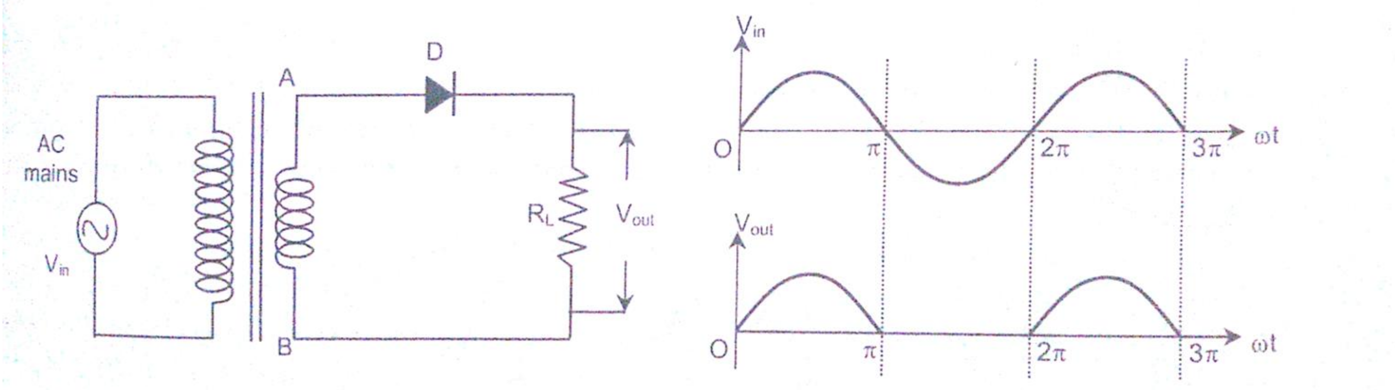


Fig. (a) Circuit diagram of half wave rectifier (b) Input and output voltage in half wave rectifier

During the positive half cycle, the point A with respect to B will be at positive potential and the diode D is forward biased and conducts the current. Hence,the positive half cycle appears as output of the circuit in resistor R_L. During the negative half cycle, the point A with respect to B will be at negative potential and the diode D is reverse biased and does not conduct the current. The negative half cycle does not appear as output of the circuit in resistor R_L. The same process will be repeated for other cycles too. As the diode conducts only the positive cycle of ac input, output is pulsating dc and the circuit is known as half wave rectifier.

FULL WAVE RECTIFIER:

A rectifier which converts full *cycle of ac into dc is called full wave rectifier.*

- Centre tapped full wave rectifier:

  The circuit diagram of centre tapped full wave rectifier is as shown in fig.The input ac V_{in} is applied across the primary coil P of the transformer. The P-section of the diodes D_1 and D_2 are connected to the ends of the secondary coil S of the transformer. The centre tapping is connected to the N-section of the diodes through resistor R_L.

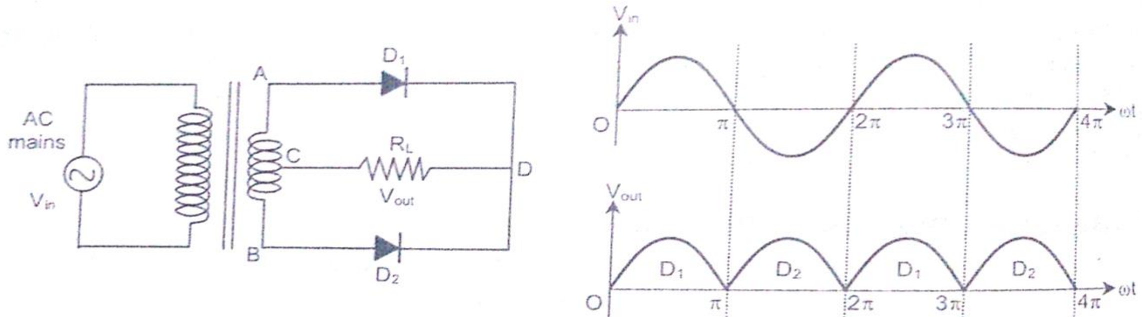


Fig. (a) Circuit diagram of full wave rectifier (b) Input and output voltage in full wave rectifier

During the positive half cycle, the point A with respect to B will be at positive potential and the diode D_1 is forward biased and conducts the current whereas the diode D_2 is reverse biased and does not conduct the current. Hence the positive half cycle appears as output of the circuit in resistor R_L due to diode D_1. During the negative half cycle, the point A with respect to B will be at negative potential and the diode D_1 is reverse biased and does not conduct the current whereas the diode D_2 is forward biased and conduct the current. Hence the negative half cycle appears as output of the circuit in resistor R_L due to diode D_2. In both half cycles, unidirectional current flows through R_L from D to C. As the diodes conduct full cycle of ac input, the circuit is known as full wave rectifier.

FILTER CIRCUIT:

The circuit which is connected between rectifier and load to convert pulsating dc output of a rectifier into smooth dc is called filter circuit.

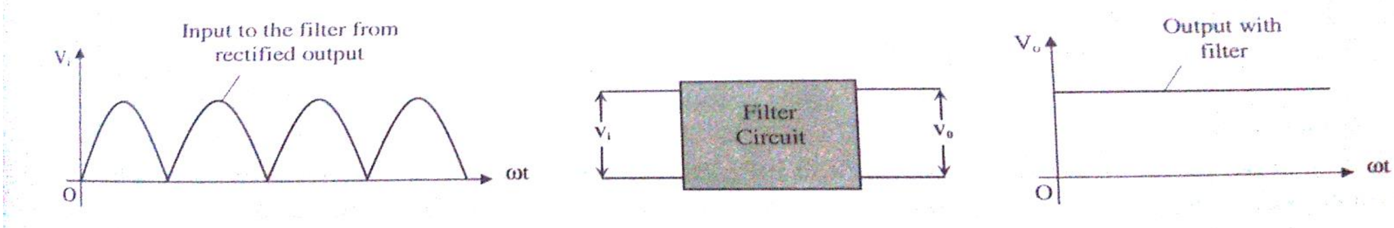


Figure 2 Rectified voltage is filtered out through a filter circuit.

The filter circuit consists of passive elements like inductor, capacitor, resistor or their combination.
For capacitor:

Capacitive reactance (X_c) = $\frac{1}{2\pi fC}$

For inductor:

Inductive reactance (X_L) =$2\pi fL$

For dc, f = 0, then $X_c = \infty$ and X_L=0 i.e. capacitor blocks dc and inductor allows dc.

For ac, f= finite, then X_C =low and X_L=high i.e. capacitor allows ac and inductor block ac.

1. Capacitor filter
   In this filter a capacitor is connected across the rectifier output and the load. The capacitor offers high resistance for dc component and low resistance for ac component. Therefore, capacitor bypass the appreciable amount of ac component to the ground while passes the dc component towards the load.
2. Inductor filter
   In this filter an inductor is connected across the rectifier output and the load. The inductor offers high resistance for ac component and low resistance for dc component. Therefore, inductor blocks the appreciable amount of ac component while passes the dc component towards the load.
3. LC filter:
4. Π filter:

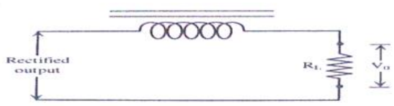


Figure Inductor filter.

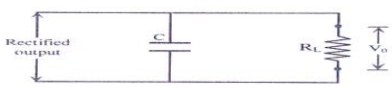


Figure Capacitor filter.

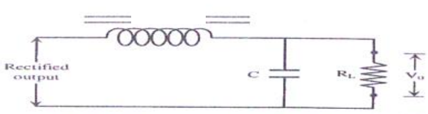


Figure L.C. filter.

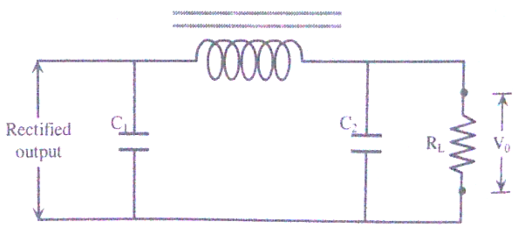


Figure 2 π-filter.

REVERSE BREAKDOWN:

1. Zener breakdown (Zener effect)

   If the diode is heavily doped and has narrow depletion layer, even a relatively smaller reverse voltage can set up very high electric field across the junction. If the electric field becomes of the order 10^8 V/m, even a slight increase in reverse voltage breaks the covalent bonds, thus creating a large number of electron-hole pairs. Hence, the current rises sharply. This effect is called Zener breakdown. The reverse voltage at which the zener breakdown occurs is called zener voltage. Zener effect is prominent at breakdown voltage less than 4V.

2. Avalanche breakdown(Avalanche effect)

   If the diode is lightly doped and the depletion layer is wide, the electric field due to the reverse voltage across the junction does not become enough to cause zener breakdown. However, there are minority charge carrier in the diode which are accelerated by the electric field, collide with the semiconductor atoms in the depletion layer, break the covalent bond and create electron-hole pair. These newly generated electrons are accelerated in the field and collide with more atoms breaking more covalent bonds, thus creating more charge carriers and so on. This leads to an avalanche of charge carriers resulting a large current in the diode. This effect is called avalanche effect or avalanche breakdown. Avalanche effect is prominent at breakdown voltage above 6V.

ZENER DIODE:

A zener diode is a properly heavily doped diode operates in reverse breakdown region without damage. It has sharp breakdown voltage ranging from 2V to 800V.

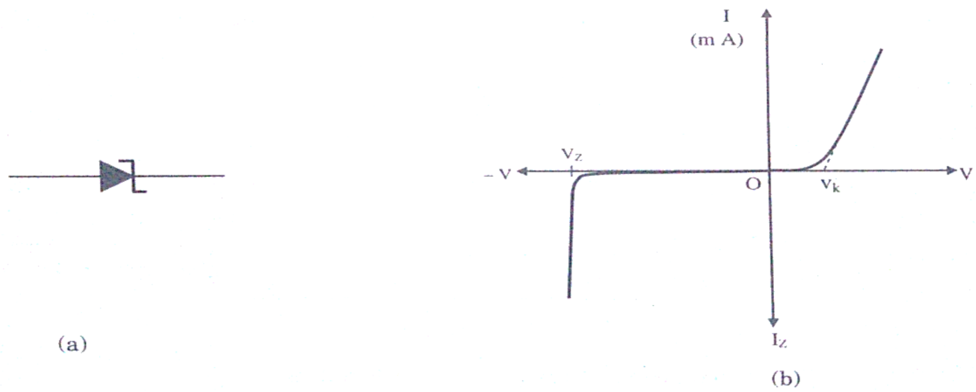


Figure : (a) Symbol of zener diode. (b) I-V characteristics of zener diode.

Zener diode as a voltage regulator:

Voltage regulation is the ability of the circuit to maintain constant output voltage irrespective of the variation of input voltage and load resistance.

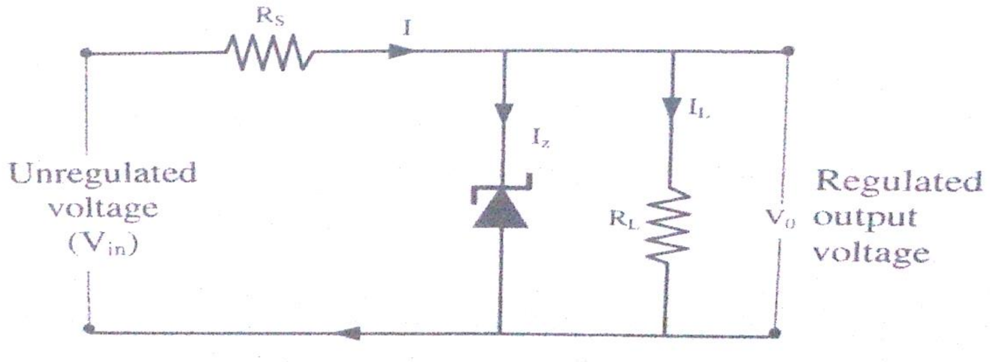


Figure Circuit diagram of zener diode as a voltage regulator.

The circuit diagram of zener diode as voltage regulator is as shown in fig.A series current limiting resistor R_s limits the current through the circuit. A zener diode is connected parallel to the load resistor R_L. For the proper operation, the input voltage (V_{in}) must be greater than the zener voltage(V_Z) which ensures that the zener diode operates in reverse breakdown region.

Now, total current (I) = I_L+I_Z where I_L = load current and I_Z = zener current

and input votlage(V_{in}) = IR_s+V_Z whereVz = V_L or V_0

Working:

1. Regulation with varying input voltage

   When input voltage V_{in} increases the input current also increases. This increases the current through zener diode I_Z without affecting the load current I_L. The increase in input current will also increase the voltage drop across the series resistance R_S, thereby keeping the load voltage V_L constant. On the other hand, when input voltage V_{in} decreases the input current also decreases. This decreases the current through zener diode I_Z without affecting the load current I_L. The decrease in input current will also decrease the voltage drop across the series resistance R_S, thereby keeping the load voltage V_L constant.
2. Regulation with varying load resistance

   When the load resistance R_L decreases, the load current I_L increases. This decreases the zener current I_Z .As a result of this, the input current I and the voltage drop across the series resistance R_S remains constant, thereby keeping load voltage V_L constant. On the other hand, when the load resistance R_L increases, the load current I_L decreases. This increases the zener current I_Z .As a result of this, the input current I and the voltage drop across the series resistance R_S remains constant, thereby keeping load voltage V_L constant.

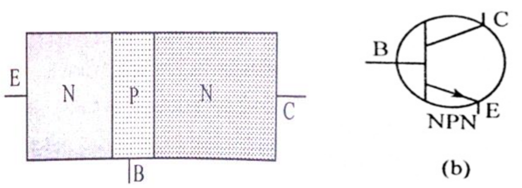
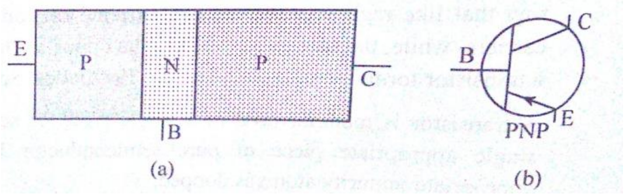
TRANSISTOR:

A transistor is a three terminal electronic device in such a way that its extreme sections are made by same type of semiconductor and middle region are made by opposite type of semiconductor. It can be use as an amplifier and as a switch.

Three regions of transistor:

Emitter	**Base**	**collector**
1. It is heavily doped region.	It is lightly doped region	It is moderately doped region
2. It is thinner than collector but much thicker than base.	It is thinnest region	It is thickest region
3. Its main function is to supply the majority charge carriers to other regions.	Its main function is to pass the majority charge carriers from the emitter to the collector.	Its main function is to collect the majority charge carrier supplied by emitter and passed by the base.

Types of transistor:

NPN TRANSISTOR	PNP TRANSISTOR
1. Emitter and collector are N-type and base is P-type semiconductor.	Emitter and collector are P-type and base is N-type semiconductor.
	

TRANSISTOR CONFIGURATION:

When a transistor is connected in a circuit, one of the three terminal is made common terminal so that there will be two terminal for input and two terminal for output. For the proper operation of a transistor, base emitter junction is forward biased and collector base junction is reverse biased.

Types of transistor configuration:

1. Common emitter configuration
2. Common base configuration
3. Common collector configuration

For any transistor, $I_E=I_B+I_C$ Where I_E = emitter current
I_B = base current
I_C = collector current

COMMON EMITTER CHARACTERISTICS:

The graphical representation between input and output currents and voltages of a transistor are called the characteristics of a transistor. The circuit diagram for common emitter characteristics of NPN transistor is as shown in fig. The microammeter (mA) measures the base current (I_B), the milliammeter (mA) measures the collector current(I_C), the voltmeter V_1 measures V_{BE} and voltmeter V_2 measures V_{CE}. The rheostats Rh_1 and Rh_2 are used to vary V_{BE} and V_{CE} respectively.

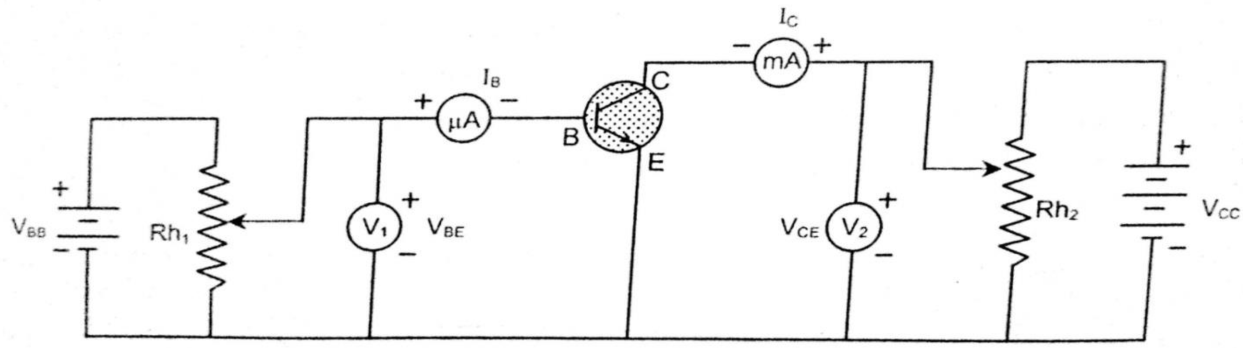


Fig. : Circuit diagram for drawing characteristics of npn common transistor

Input characteristics:

These are the curves showing the variation of base current I_B and base–emitter voltage V_{BE} at constant collecter-emiiter voltage V_{CE} .

To draw input characteristics,

1. V_{CE} is maintained at a constant value.
2. The value of V_{BE} is varied with the help of Rh_1 and corresponding value of I_B is noted.
3. A graph is plotted between V_{BE} taken along X –axis and I_B taken along Y-axis.
4. The experiment is repeated for different values of V_{CE}.
5. The reciprocal of the slope of the graph gives input resistance of the transistor.

   i.e. input resistance(r_i)=$\left(\frac{\Delta V_{BE}}{\Delta I_B}\right)$ V_{CE}=constant

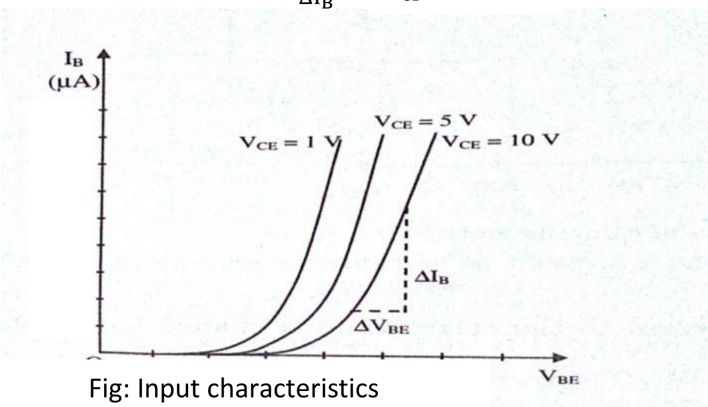


Fig: Input characteristics

Output characteristics:
These are the curves showing the variation of collector current I_c and collector–emitter voltage V_{CE} at constant base current I_B .

To draw output characteristics,

1. I_B is maintained at a constant value.
2. The value of V_{CE} is varied with the help of Rh_2 and corresponding value of I_C is noted.
3. A graph is plotted between V_{CE} taken along X –axis and I_C taken along Y-axis.
4. The experiment is repeated for different values of I_B .
5. The reciprocal of the slope of the graph gives output resistance of the transistor.

   i.e. output resistance(r_o)=($\frac{\Delta V_{CE}}{\Delta I_C}$) I_B =constant

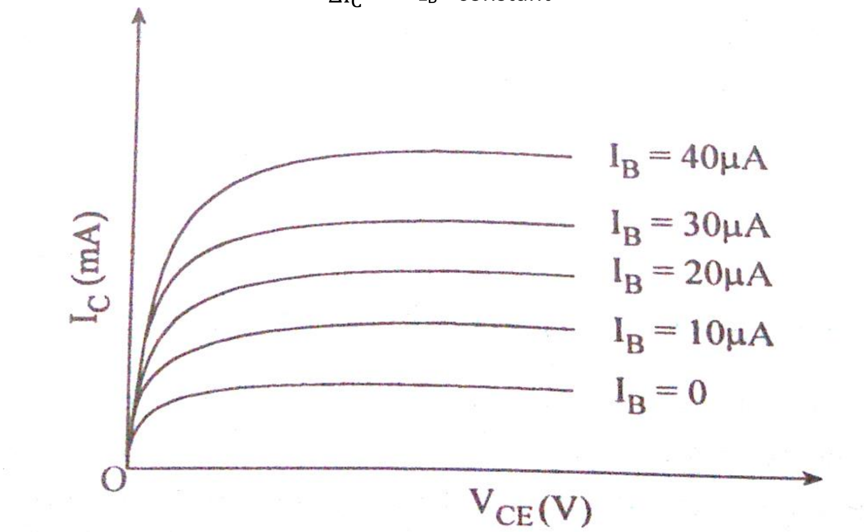


Fig: output characteristics

Current transfer characteristics:
These are the curves showing the variation of collector current I_c and base current I_B at constant Collector –emitter voltage V_{CE} .

To draw input characteristics,

1. V_{CE} is maintained at a constant value.
2. The value of I_B is varied with the help of Rh_1 and corresponding value of I_C is noted.
3. A graph is plotted between I_B taken along X –axis and I_C taken along Y-axis.
4. The experiment is repeated for different values of V_{CE} .
5. The slope of the graph gives current gain of the transistor.

   i.e. current gain(β)=($\frac{\Delta I_C}{\Delta I_B}$) V_{CE}=constant

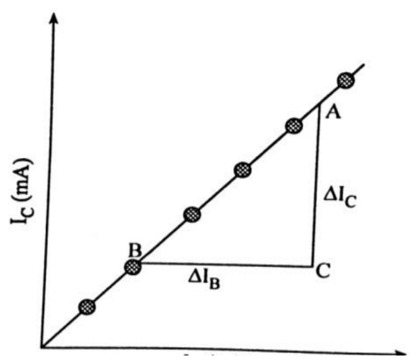


Fig: current transfer characteristic

Transistor as an Amplifier

A device which increases the amplitude of input signal is called amplifier. Figure shows the circuit diagram of NPN common emitter amplifier.

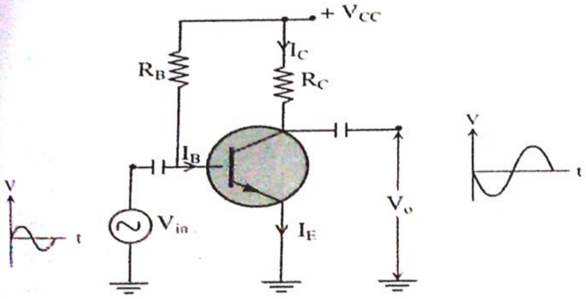


Figure ircuit diagram of NPN common emitter amplifier

The biasing voltage V_{CC} forward biases the emitter and reverse biases the collector. The emitter is common to both input and output circuits. Input signal to be amplified is applied across the input circuit (base emitter circuit) when base voltage increases. The base current also increases and this increases the collector current by β times as $I_C = \beta I_B$. The amplified output is taken from collector emitter circuit.

From the figure $V_{CC} = I_C R_C + V_{CE}$

$$\therefore \quad V_{CE} = V_{CC} - I_C R_C$$

During positive half cycle of the input signal, the forward bias voltage of emitter base junction increases. This increases the base current and hence the collector current $I_C = \beta I_B$ which increases the voltage drops across R_C. According to the above equation the output voltage $V_O = V_{CE}$ decreases i.e. the amplified negative signal is obtained across the output.

Similarly, during the negative half cycle of input signal, forward bias voltage of emitter base junction decreases. This decrease the base current and hence the collector current which decrease the voltage drop across R_C. According to above equation output voltage $V_O = V_{CE}$ increases i.e. the amplified positive signal is obtained. In this way the circuit acts as amplifier with phase difference 180° between the input and output signal as shown in **Fig.**

Transistor as a switch

A device which turns ON or OFF electric current in an electric circuit is called a switch. A common emitter transistor acts as a switch when it is driven back and forth between saturation and cut off region. Figure shows circuit diagram of NPN common emitter transistor as a switch.

When input voltage V_{in} is very low so that the transistor is not forward biased, no current flows through the base ($I_B = 0$). Then no current flows through R_C i.e., I_C is 0 and hence output voltage $V_O = V_{CE} = V_{CC} - I_C R_C = V_{CC}$. The transistor is in cut off mode, and it is not conducting. Under this condition the transistor acts as the open switch and open condition or OFF state.

When the input voltage V_{in} is sufficiently high, the transistor is forward biased and a large current I_C flows through R_C. In this situation voltage drop across $R_C = I_C R_C = V_{CC}$ and $V_{CE} = 0$. The transistor comes in saturation state and acts as a closed switch i.e., ON state. In this way a transistor acts as a switch.

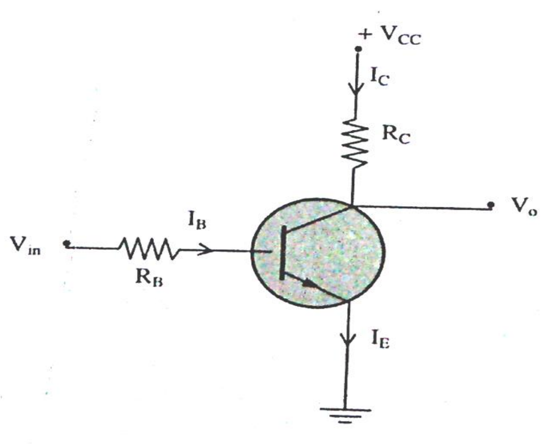


Figure Circuit diagram of NPN common emitter transistor as a switch

Transistor parameters:

α-parameter:

It is the ratio between collector current I_C and emitter I_E of the transistor at constant collector-base (V_{BE}) voltage.

i.e. $\alpha = \frac{I_c}{I_E}$

Since $I_C < I_E$, so α is less than 1. It is the current gain of common base amplifier. Since there is no current gain, a common base amplifier is not used as a current amplifier.

β-parameter:

It is the ratio between collector current I_C and base current I_B at constant collector-emitter voltage (V_{CE})

i.e.$\beta=\frac{I_c}{I_B}$

Since $I_C>>I_B$, so β is much greater than 1.It is the current gain of common emitter amplifier.

Relation between α and β:

For any configuration,

$I_E = I_B + I_C$

Dividing both sides by I_C

$\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C}$

or, $\frac{1}{\alpha} = 1 + \frac{1}{\beta}$

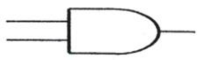
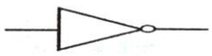
or, $\frac{1}{\alpha} = \frac{\beta+1}{\beta}$

or, $\alpha = \frac{\beta}{1+\beta}$

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

Logic gates: logic gates are electronic circuits which make logic decision. These are building block of digital system. Functions of logic gates are based on Boolean algebra. It accepts two state input-output are0 and 1 or low and high or on and off etc. It has only one output terminal and can have one or more than one input terminals.

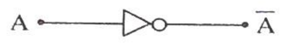
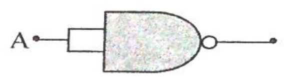
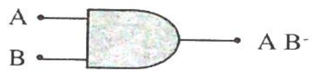
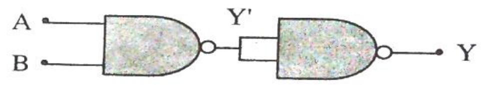
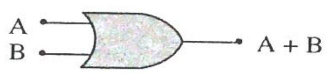
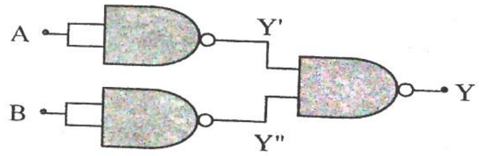
The different logic gates with their symbols, Boolean algebra and truth tables are given below:

Type	Symbols	Boolean algebra between A and B	Truth table
AND		$A . B$	INPUT: A, B / OUTPUT: A AND B 0 0 0 0 1 0 1 0 0 1 1 1
OR		$A + B$	INPUT: A, B / OUTPUT: A OR B 0 0 0 0 1 1 1 0 1 1 1 1
NOT		$\overline{A}$	INPUT: A / OUTPUT: NOT A 0 1 1 0
NAND		$\overline{A . B}$	INPUT: A, B / OUTPUT: A NAND B 0 0 1 0 1 1 1 0 1 1 1 0
NOR		$\overline{A + B}$	INPUT: A, B / OUTPUT: A NOR B 0 0 1 0 1 0 1 0 0 1 1 0

NAND Gate as a Universal Gate

The NAND gate is a universal gate because its repeated use can produce other logic gates. The **Table** shows how NAND gates can be connected to produce NOT gate, AND gate and OR gate.

Table Logic gates for NAND gates

Logic Function	Symbol	Circuit using NAND gates only
NOT		
AND		
OR		

0=low or off
1=high or on

LONG QUESTIONS:

1. What is an extrinsic semiconductor? Explain the formation of potential barrier and depletion region in a P-N junction.
2. What is P-N junction? Describe forward biased and reverse biased condition of P-N junction.
3. What is P-N junction diode? Explain the characteristics of it in the forward and reversed biased condition.
4. What is rectification? Explain the working of half wave rectifier.
5. What is rectifier? Explain the working of full wave rectifier with filter circuit.
6. What is a Zener diode and Zener breakdown? Describe how a zener diode can be used as a voltage regulator.
7. How is an NPN transistor formed? Discuss the input and output characteristics of the transistor in CE configuration.
8. What are logic gates? Describe with truth tables, three basic gates: OR, AND and NOT.

SHORT QUESTIONS ANSWERS:

1. **2052 Q.No. 12 f**

What do you mean by hole in the semi-conductor? [2]

At absolute zero temperature, in a pure semiconductor, all the electrons lie en a valance band. As a result, the valance band is completely filled by electrons and conduction band is empty. When temperature of semiconductor increases, the valance electrons get thermal energy and jump to the conduction band creating a vacant space in valance band. This vacant space in valence band is called hole in semiconductor. This hole acts as positive charge.
When a trivalent impurity atom is added to a pure semiconductor, the three valance electrons of trivalent atom form three covalent bonds with sharing three electrons of semiconductor atom and, the fourth covalent bond has a deficiency of electron. This vacant space is also called hole in semiconductor.

2. **2054 Q.No. 12 e**

Why may the addition of small quantities of suitable impurities to an intrinsic semiconductor result in a considerable decrease in its resistivity? [2]

In a pure semiconductor crystal, there are equal number of free electrons in conduction band and holes in valance band. When small quantities of impurity atoms (either pentavalent atoms or trivalent atoms) are added to the pure semiconductor crystal, there is excess of electrons in conduction band by addition of pentavalent atoms and holes in valance band by addition of trivalent atoms. It means the number of charge carriers increases and hence conductivity increases. The resistivity is the reciprocal of conductivity ($\rho = 1/\sigma$). Thus, on increasing impurity, the resistivity decreases.

3. **2055 Q.No. 12 a**

How is it possible to rectify an AC? [2]

Rectification is the process of conversion of AC into DC by using a device which is called rectifier. There are two types of rectifier: Half wave and full wave rectifier. In half wave rectifier, only half cycle of AC is rectified because there is only one diode and it rectifies only in forward bias. In full wave rectifier, there are two diodes which rectifies both (positive and negative) half cycle at once because these diodes are so adjusted that one diode become forward biased during positive half cycle and another during negative half cycle.

4. **2055 Q.No. 12 d**

When examining a circuit diagram, how is it possible to tell whether a transistor is a n-p-n or p-n-p? [2]

The arrow in the circuit symbol of the transistor can be used to differentiate an N-P-N transistor from P-N-P transistor. If the arrow in the emitter terminal pointed in (Pointed In means P-N-P) as shown in the figure (a), the transistor must be a P-N-P transistor. If the arrow in the emitter terminal points out (Not pointed in means ~N-P-N) as shown in the figure (b), the transistor must be an N-P-N transistor.

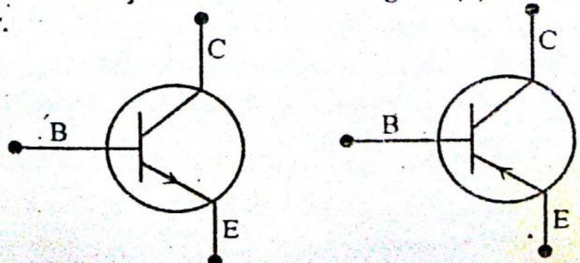


Fig. (a) Fig. (b)

5. 2056 Q.No. 12 b

How the conductivity of a semiconductor changes with the presence of impurities? [2]

In a pure semiconductor, there are no more free electrons in the conduction band and holes in valance band and hence there is low conductivity of semiconductor. When pentavalent impurity atoms are added to the pure semiconductor crystal, the number of free electrons in the conduction band increases. Similarly the number of free holes increases on adding the trivalent impurity atoms to the pure semiconductor crystal. This increase in holes in valance band and free electrons in conduction band increases the conductivity of semiconductor.

6. 2057 Q.No. 2 f

The base region of a transistor is made very thin as compared with emitter and collector regions, why? [2]

A transistor is taken as good amplifier as it can deliver large collector current for very small base current. The base and collector currents are related with emitter current as $I_E = I_C + I_B$. So, at constant emitter current (I_E), the base current (I_B) should be very small for large collector current (I_C). This condition is satisfied only when very small number of majority charges carriers from emitter combines with the opposite charge carriers at the base. The chances of combination in the base will be less if the number of opposite charge carriers is very low there. This number is reduced by making the base thin and doping it lightly. Thus, the base region of a transistor is made very thin as compared with emitter and collector regions.

7. 2058 Q.No. 1 f

A p-n diode conducts electricity when forward biased and does not conduct when reserve biased. Explain. [2]

When a positive terminal of the source is connected with P-type and negative terminal to N-type of P-N junction diode, then it is said to be forward biased. In such biasing, electrons are repelled by negative terminal of battery in the N-region and holes are repelled by positive terminal of battery in the P-region. So, the width of barrier potential decreases and charges cross the junction and conducts the flow of current (switch ON).

When a positive terminal of the source is connected with N-type and negative terminal to P-type of material, then it is said to be reverse biasing. In this biasing, holes are attracted by negative terminal and electrons are attracted by positive terminal. Consequently, the barrier potential of the P-N junction diode increases and the flow of charges through the junction become impossible. As no charge flows in reverse biasing, conduction of electricity also does not take place (switch OFF).

8. 2059 Q.No. 1 f

What factors determine whether a material is a semiconductor or an insulator? [2]

The solid substance which has small energy gap between the valence band and conduction band is known as semiconductor. The energy gap in insulator is large. At lower temperature (0°K), the semiconductor also acts like insulator because both have the empty conduction band and filled valence band. But at room temperature, conduction band is partially filled for semiconductors but still empty for insulator. Thus, the factors like energy gap, temperature and conductivity of the material determine whether the material is a semiconductor or an insulator.

9. 2062 Q.No. 1 f

What do you mean by biasing a transistor? [2]

The proper application of dc voltage across the three terminals of transistor is called biasing of the transistor. The voltage is applied either in emitter-base junction or in collector-base junction in such a manner that the emitter-base junction is always forward-biased and the collector-base junction is always reverse-biased. So the resistance of the emitter-base junction is low while the resistance of the collector-base junction is high. This is why; the forward bias voltage applied to the emitter-diode is very small whereas reverse bias voltage applied to the collector-diode is larger.

10. 2062 Q.No. 2 g

When P and N type materials are interfaced, there exists a depletion layer at the interface. Explain [2]

When a P-type of semiconductor is joined with a N-type of semiconductor, the free electron from the N-type is diffused into the P-type. This is because the concentration of free electrons in the N-side of material is greater than that in the P-side of material. Thus, there will be a layer of positive and negative ions at the junction - called depletion layer. In the depletion layer, there is net positive charge on the N-side and negative charge on the P-side. These collections of positive and negative charges at the junction produces an electric field which opposes further diffusion. This region is called barrier region and corresponding potential produced is called barrier potential.

11. 2063 Q.No. 1 f

Give the circuit symbol and truth table of NAND gate. [2]

NAND gate is the combination of AND and NOT gate in such a way that the output of AND gate is connected to the input of a NOT gate. The symbolic representation of the NAND gate is shown in fig. This gate produces high output if any one of the input is low.

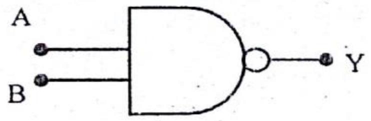


Fig. Symbol of NAND gate

If A and B represent the input and Y represents the output of NAND gate then $Y = \bar{A}\,.\,\bar{B}$. Thus truth table for NAND gate is given by:

Inputs		A·B	Outputs
A	B		$Y = \overline{A.B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

12. 2065 Q.No. 1 f

How is p-type semiconductor formed? Explain. [2]

When a trivalent impurity atom (like boron, gallium etc) is added to pure semiconductor crystal of Silicon or Germanium, P-type semiconductor is formed. The three valance electrons of trivalent impurity atoms form covalent bond by sharing with three valence electrons of pure semiconductor atoms and the forth covalent bond of semiconductor atom has a deficiency of electron.

This deficiency of one electron in valance band creates a hole. Due to this reason, there are large number of holes and small number of free electron in conduction band in P-type of semiconductor.

13. 2067 Q.No. 2b

A student asserts that Si and Ge became good conductors at very high temperatures and good insulators at very low temperature. Do you agree? Explain your reasoning. [2]

I agree with the statement that Si and Ge became good conductors at very high temperatures and good insulators at very low temperature. At very low temperature, all the electrons lie in the valance band and there are no free electrons in the conduction band and holes in valance band. Due to this reason the semiconductors become insulators. When temperature increases and reaches to room temperature, some of the valance electrons jump to the conduction band by gaining thermal energy which creates holes in the valance band and these electrons become free in the conduction band. Hence the number of holes in the valance band and the electrons in the conduction band increase on increasing temperature. Hence, the conductivity of semiconductor increases on increasing temperature and become conductor at high temperature.

14. 2067 Sup Q.No. 2b

An n- type semiconductor has a large number of electrons. It is electrically neutral? Explain. [2]

An intrinsic semiconductor is made up of neutral atoms and hence it is electrically neutral. In N-type semiconductor, neutral pentavalent atoms are added to pure semiconductor crystal. Due to this reason, the number of electrons and protons are not changed in n-type of semiconductor and hence it is electrically neutral particle even it has large number of free electron.

15. 2067 Sup Q.No. 2c

What are logic gates? Give truth table for a two-input AND gate. [2]

The logic gates are the electronic circuits which give the logic decisions. AND gate is an electronic circuit which gives high output when all of the inputs are high. The symbol of two input AND gate is given below which consists of two inputs named A and B and one output say y.

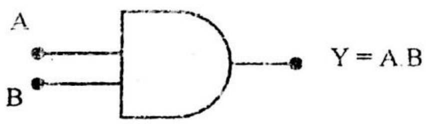


Fig. Symbol of AND gate

The truth table and for two-input AND gate is given below;

Inputs		Output A·B
A	B	
0	0	0
0	1	0
1	0	0
1	1	1

16. 2068 Can. Q.No. 2c

How does the suitable impurity increase the conductivity of a semiconductor? [2]

Please refer to 2056 Q. No 12 b

17. 2068 Q.No. 2b

Would there be any advantage to adding n-type or p-type impurities to copper. Why or why not? [2]

No, there will no advantage to adding n-type or p-type impurities to copper because copper has already large number of free electrons in its conduction band and there is no meaning of adding the impurity atoms.

18. 2068 Old . Q.No. 1f

Why is the emitter of a transistor doped heavily? **[2]**

A transistor consists of three terminals called emitter, base and collector. The function of emitter is to emit the charges, base is to supply charge and collector is to collect the charge. For emission of charge, doping is needed high and so the emitter of transistor is doped heavily.

19. 2069 (Set B) Q.No. 2d

What is a logic gate? Draw the truth table for an AND gate. **[2]**

Please refer to 2067 Q. No. 2 c

20. 2069 (Set A) Q.No. 2b

A p-type semiconductor has a large number of holes but still it is electrically neutral. Explain. **[2]**

An intrinsic semiconductor is made up of neutral atoms and hence it is electrically neutral. A p-type semiconductor is made by doping the neutral trivalent impurity atoms in neutral intrinsic semiconductor. Hence p-type semiconductor is also electrically neutral even it has large number of holes.

21. 2069 Supp Set B Q.No. 2 d

What is doping? Discuss its significance in semiconductor studies. **[2]**

Doping is the process of adding impurity atoms to pure semiconductor crystal of silicon or germanium. The impurity atoms either are pentavalent atoms or trivalent atoms. When pentavalent atoms are added to pure semiconductor crystal, the no. of free electrons increase in conduction band while the addition of trivalent impurity atoms increases the holes in valance band. Hence the addition of impurity atoms to the pure semiconductor crystal increases the conductivity of semiconductor.

22. 2070 Set D Q.No. 2 c

What is a logic gate? Give logic symbol and truth table for a two- input AND gate. **[2]**

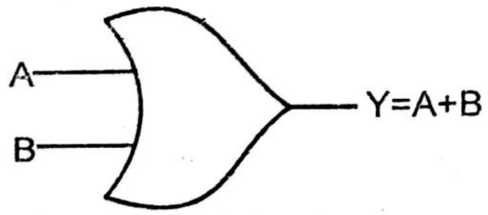
Please refer to 2067 Supp Q. No. 2 c

23. 2070 Set C Q.No. 2 c

What is logic gate? Give logic symbol and truth table for an OR gate. **[2]**

The logic gate is the electronic circuit which gives the logic decisions.

OR gate is an electronic circuit which gives high (1) output when any or all inputs are high (1). One of input is high. It has two or more inputs and single output. Logic symbol, Boolean expression and truth table of two inputs OR gate are as follows:

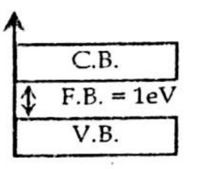


Symbol of OR gate

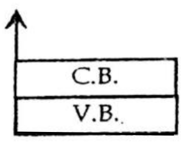
Inputs		Output
A	B	Y = A + B
1	1	1
1	0	1
0	1	1
0	0	0

24. 2070 Sup (Set A) Q.No. 2 e

Based on the band theory of solids, how would you distinguish between conductors and semi conductors? **[4]**



Semiconductor



Conductor

According to band theory of solids, there are three types of bands. They are: Valance band, conduction band and forbidden band. The valance band is energy related to valance electrons, conduction band is energy related to conduction electrons or free electrons and forbidden band is energy gap between valance band and conduction band. For semiconductor, the energy gap between conduction band and valance band is small nearly 1 eV while for conductor the gap is zero i.e. two bands are overlapped to each other as shown is figure.

25. 2070 Supp. (Set B) Q.No. 2 d

An n-type semiconductor has a large number of free electrons at room temperature, yet it is said to be electrical neutral. Why? [2]

✍ Please refer to 2067 Sup. Q. No. 2 b

26. 2071 Set C Q.No. 2 b

Draw a circuit diagram for a p-n junction diode in forward bias. Sketch the voltage-current graph for the same. [2]

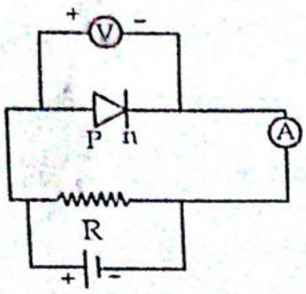


Fig: Forward biasing of P-n junction

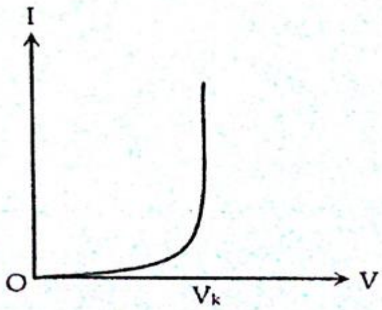


Fig: IV curve in forward biasing

27. 2071 Set C Q.No. 2 d

What is truth table? Write down the truth table for a two-input NAND gate. [2]

✍ Please refer to 2063 Q. No. 1 f

28. 2071 Set D Q.No. 2 d

What is nanotechnology? Explain.

✍ **Nanotechnology:** Nanotechnology is the study of control of matter in atomic and molecular size i.e. in nanometer scale. So, nanotechnology is the study of structure of materials of small size in the range of nanometer. This helps to develop the device of very small in size. It has the potential to create many new and small devices which are used in nano-medicine diagnosis, drug delivery, tissue engineering, nano-batteries, opto-electronics, semiconductor devices, quantum computer, etc.

29. 2071 Supp Q.No. 2b

When examining a circuit diagram, how is it possible to tell whether a transistor is PNP or NPN? [2]

✍ Please refer to 2055 Q.No. 12d.

30. 2072 Set C Q.No. 2b

What are logic gates? Give a truth table for a two input NOR gate. [2]

✍ The logic gates are electron circuits which gives logic decisions. The output of such circuits is either high or low but not intermediate value.

NOR gate: NOR gate is the electronic output which gives the high output when all of inputs are zero. It is combination of OR and NOT gate. The output of OR gate is connected to input of NOT gate. The truth table and symbol of NOR gate is given below.

Inputs		Output of OR gate Y= A+B	Output of NOR gate $Y = \overline{A + B}$
A	B		
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

31. 2072 Set D Q.No. 2a

The output of two-input AND gate is fed to a NOT gate. Draw the logic circuit of the combination of gates. Write down its truth table. [2]

✍ Please refer to 2063 Q.No. 1f

32. 2072 Set E Q.No. 2b

What is meant by a charge carrier hole in a semi conductor? Can it be created in a conductor? [2]

✍ **First Part:** Please refer to 2052 Q.No. 12f

Second Part: No hole can't be created in a metal because the conduction band and valance band overlap with each other.

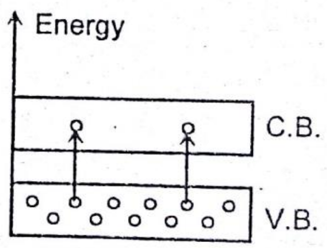
33. 2072 Supp Q.No. 2c

Explain the essential characteristics for an element to serve as (i) a donor impurity (ii) an acceptor impurity in a semiconductor. [2]

✍ The essential characteristics for an element to serve as a donor impurity is pentavalent or has five valence electrons which provides one free electrons while dropping to a semiconductor crystal and an acceptor impurity is trivalent or having three valance electrons which provides one free hole which accept an electrons.

34. 2073 Set C Q.No. 2b

How does the conductivity of semiconductor vary with temperature? Explain. [2]



✍ AT absolute zero temperature, all the valance bands completely field and conductions bands are empty and semiconductor acts as insulator. When temperature of semiconductor increase, some of covalent bonds of valance bands break down and the electrons jump to the conduction band where the electrons become free to conduct electricity. For higher temperature more covalent bonds break down & more electrons are knocked to conductor band. Hence electrical conductivity increases on increasing temperature.

35. 2073 Set D Q.No. 2a

Explain how the conductivity of a semiconductor varies with temperature? [2]

✍ Please refer 2073 Set C O.No. 2b

36. Why is silicon preferred than germanium in manufacturing the semiconductor devices?

Silicon devices are preferred than germanium devices while manufacturing the semi-conductor devices because

a) Current sensitivity of silicon with temperature is less than that in germanium.
b) The leakage current due to minority charge carrier is less in silicon than that in germanium.
c) Silicon can be operated upto about 200°C and germanium can be operated up to about 100°C. i.e. Silicon has higher tolerance to temperature than germanium.

- Bridge full wave rectifier:

The circuit diagram for bridge full wave rectifier is as shown in fig. It consists of four diodes D_1,D_2,D_3 and D_4 arranged in the form of Wheatstone bridge network. The input ac is applied across the primary of a transformer. The ends of the terminals of the secondary are connected to two opposite ends A and C of the network. The remaining ends B and D of the network are connected to the load resistor R_L.

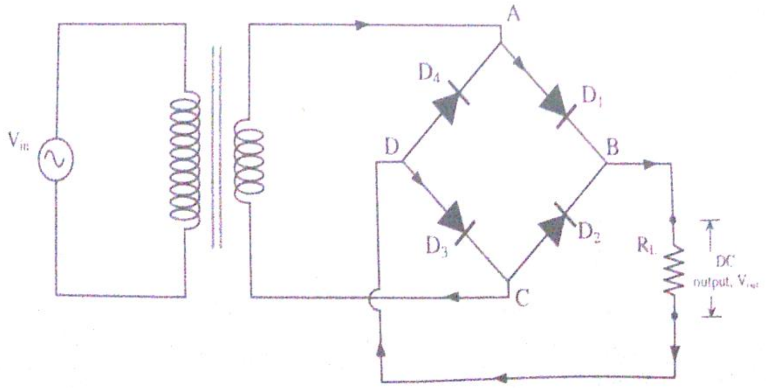


Figure 2 Circuit diagram of bridge rectifier.

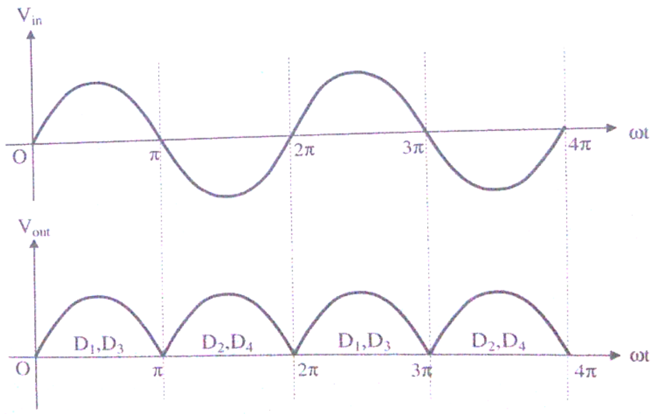


Figure 3 Input and output voltage in bridge rectifier.

During the positive half cycle, the point A with respect to C will be at positive potential and the diode $D_1$and $D_3$are forward biased and conduct the current whereas the diode D_2 and D_4 are reverse biased and do not conduct the current in the direction $AD_1BR_LDD_3CA$. Hence the positive half cycle appears as output of the circuit in resistor $R_L$due to diodes $D_1$and D_3. During the negative half cycle, the point A with respect to C will be at negative potential and the diodes $D_1$and D3 are reverse biased and does not conduct the current whereas the diodes $D_2$and D4 are forward biased and conduct the current in the direction of $CD_2BR_LDD_4AC$. Hence the negative half cycle appears as output of the circuit in resistor $R_L$due to diodes $D_2$and D_4.In both half cycles, unidirectional current flows through R_L from BR_LD.As the diodes conduct full cycle of ac input, the circuit is known as full wave rectifier.