CHAPTER 20

Semiconductor Communication

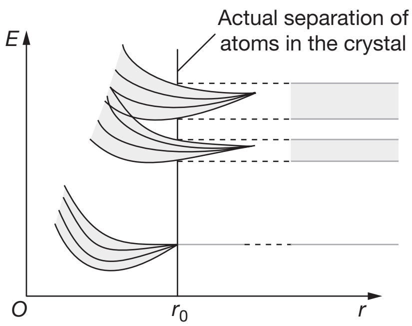
Chapter Highlights

Semiconductors; semiconductor diode: I-V characteristics in forward and reverse bias; diode as a rectifier; I-V characteristics of LED, photodiode, solar cell and Zener diode; Zener diode as a voltage regulator. Junction transistor, transistor action, characteristics of a transistor; transistor as an amplifier (common emitter configuration) and oscillator. Logic gates (OR, AND, NOT, NAND and NOR). Transistor as a switch. Propagation of electromagnetic waves in the atmosphere; Sky and space wave propagation, Need for modulation, Amplitude and Frequency Modulation, Bandwidth of signals, Bandwidth of Transmission medium, Basic Elements of a Communication System (Block Diagram only)

SEMICONDUCTOR DEVICES

Introduction

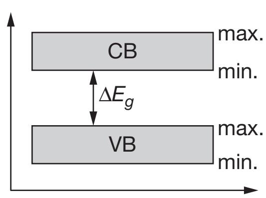
In isolated atom the valence electrons can exist only in one of the allowed orbitals each of a sharply defined energy called energy levels. But when two atoms are brought nearer to each other, there are alterations in energy levels and they spread in the form of bands.



Origin of energy bands in a solid

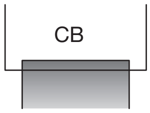
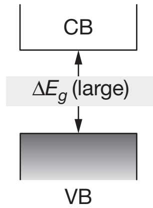
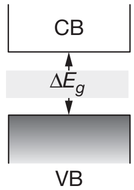
Energy bands are of following types:

1. **Valence band:** The energy band formed by a series of energy levels containing valence electrons is known as valence band. At 0 K, the electrons fill the energy levels in valence band starting from lowest one.
   (i) This band is always filled with electrons.
   (ii) This is the band of maximum energy.
   (iii) Electrons are not capable of gaining energy from external electric field.
   (iv) No flow of current due to electrons present in this band.
   (v) The highest energy level which can be occupied by an electron in valence band at 0 K is called fermi level.
2. **Conduction band:** The higher energy level band is called the conduction band.
   (i) It is also called empty band of minimum energy.
   (ii) This band is partially filled by the electrons.
   (iii) In this band the electrons can gain energy from external electric field.
   (iv) The electrons in the conduction band are called the free electrons. They are able to move anywhere within the volume of the solid.
   (v) Current flows due to such electrons.
3. **Forbidden energy gap (ΔE_g):** Energy gap between conduction band and valence band $\Delta E_g = (CB)_{min} - (VB)_{max}$



   (i) No free electron is present in forbidden energy gap.
   (ii) Width of forbidden energy gap depends upon the nature of substance.
   (iii) As temperature increases (↑), forbidden energy gap decreases (↓) very slightly.

Types of Solid

Properties	Conductors	Insulators	Semiconductors
Electrical conductivity	10^2 to 10^8 ℧/m	10^{-8} ℧/m	10^{-5} to 10^0 ℧/m
Resistivity	10^{-2} to 10^{-8} Ω-m (negligible)	10^8 Ω-m	10^5 to 10^0 Ω-m
Band structure			
Energy gap (E_g)	Zero or very small	Very large; for diamond it is 6 eV	Ge → 0.7 eV Si → 1.1 eV GaAs →1.3 eV GaF_2 → 2.8 eV
Current carriers	Free electrons	—	Free electrons and holes
Condition of VB and CB at ordinary temperature	VB and CB are completely filled or CB is somewhat empty	VB – completely filled CB – completely unfilled	VB – somewhat empty CB – somewhat filled
Temperature co-efficient of resistance	Positive	Zero	Negative
Effect of temperature on conductivity	Decreases	—	Increases
Effect of temperature on resistance	Increases	—	Decreases
s	Cu, Ag, Au, Na, Pt, Hg etc.	Wood, plastic, mica, diamond, glass etc.	Ge, Si, Ga, As etc.
Electron density	$10^{29}/m^3$	—	Ge ~ $10^{19}/m^3$ Si ~ $10^{16}/m^3$

Holes in Semiconductors

1. When an electron is removed from a covalent bond, it leaves a vacancy behind. An electron from a neighbouring atom can move into this vacancy, leaving the neighbour with a vacancy. In this way the vacancy formed is called hole (or cotter), and can travel through the material and serve as additional current carriers.
2. A hole is considered as a seat of positive charge, having magnitude of charge equal to that of an electron.
3. Holes acts as virtual charge, although there is no physical charge on it.
4. Effective mass of hole is more than electron.
5. Mobility of hole is less than electron.

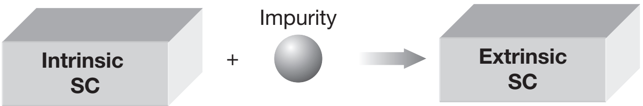
Intrinsic Semiconductors

1. A pure semiconductor is called intrinsic semiconductor. It has thermally generated current carriers.
2. They have four electrons in the outermost orbit of atom and atoms are held together by covalent bond.
3. Free electrons and holes both are charge carriers and n_e (in CB) $= n_h$ (in VB)
4. The drift velocity of electrons (v_e) is greater than that of holes (v_h)
5. For them fermi energy level lies at the centre of the CB and VB
6. In pure semiconductor, impurity must be less than 1 in 10^8 parts of semiconductor.
7. In intrinsic semiconductor $n_e^{(o)} = n_h^{(o)} = n_i$; where $n_e^{(o)} =$ Electron density in conduction band, $n_h^{(o)} =$ Hole density in VB, $n_i =$ Density of intrinsic carriers.
8. The fraction of electrons of valance band present in conduction band is given by $f \propto e^{-E_g/kT}$; where E_g = Fermi energy or k = Boltzmann's constant and T = Absolute temperature

9. Because of less number of charge carriers at room temperature, intrinsic semiconductors have low conductivity so they have no practical use.
10. Number of electrons reaching from valence band to conduction band $n = AT^{3/2}e^{-E_g/2kT}$

Extrinsic Semiconductor

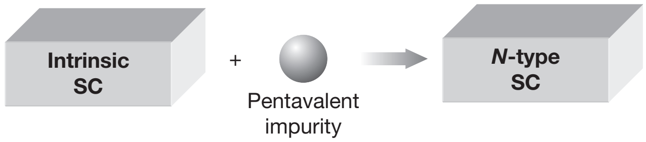
1. An impure semiconductor is called extrinsic semiconductor
2. When pure semiconductor material is mixed with small amounts of certain specific impurities with valency different from that of the parent material, the number of mobile electrons/holes drastically changes. The process of addition of impurity is called doping.

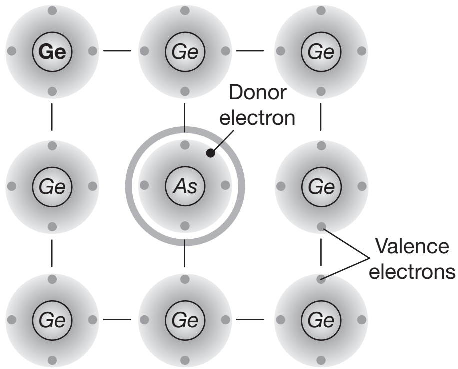


3. **Pentavalent impurities:** The elements whose atom has five valance electrons are called pentavalent impurities e.g. As, P, Sb etc. These impurities are also called donor impurities because they donate extra free electron.
4. **Trivalent impurities:** The elements whose each atom has three valance electrons are called trivalent impurities e.g. In, Ga, Al, B, etc. These impurities are also called acceptor impurities as they accept electron.
5. The compounds of trivalent and pentavalent elements also behave like semiconductors e.g. GaAs, InSb, In P, GaP etc.
6. The number of atoms of impurity element is about 1 in 10^8 atoms of the semiconductor.
7. In extrinsic semiconductors $n_e \neq n_h$
8. In extrinsic semiconductors fermi level shifts towards valence or conduction energy bands.
9. Their conductivity is high and they are used for practical purposes.
10. In a doped extrinsic semiconductor, the number density of e^- of the conduction band (n_e) and the number density of holes in the valence band (n_h) differs from that in a pure semiconductor. If n_i is the number density of electron in conduction band or the number density of holes in valence band in a pure semiconductor then $n_e n_h = n_i^2$ (mass action law).
11. Extrinsic semiconductors are of two types:
    (i) *N*-type semiconductor
    (ii) *P*-type semiconductor

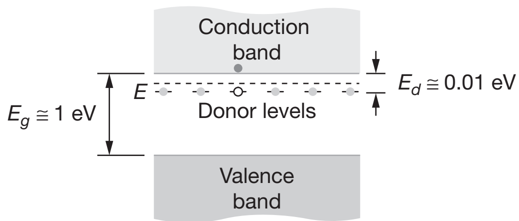
N-Type Semiconductor

These are obtained by adding a small amount of pentavalent impurity to a pure sample of semiconductor (*Ge*).





1. Majority charge carriers – electrons
   Minority charge carriers – holes
2. $n_e >> n_h$; $i_e >> i_h$
3. Conductivity $\sigma \approx n_e \mu_e e$
4. *N*-type semiconductor is electrically neutral (not negatively charged)
5. Impurity is called Donor impurity because one impurity atom generate one electron.
6. Donor energy level lies just below the conduction band.



P-Type Semiconductor

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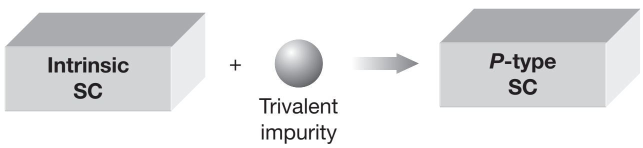
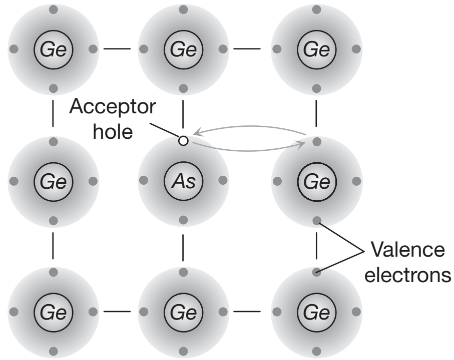
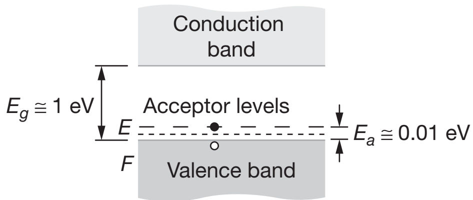




1. Majority charge carriers – holes
   Minority charge carriers – electrons
2. $n_h >> n_e$; $i_h >> i_e$
3. Conductivity $\sigma \approx n_h \mu_h e$
4. *P*-type semiconductor is also electrically neutral (not positively charged)
5. Impurity is called Acceptor impurity.
6. Acceptor energy level lies just above the valence band.



Density of Charge Carriers

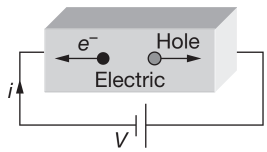
Due to thermal collisions, an electron can take up or release energy. Thus, occasionally a valence electron takes up energy and the bond is broken. The electron goes to the conduction band and a hole is created. And occasionally, an electron from the conduction band loses some energy, comes to the valence band and fills up a hole. Thus, new electron-hole pairs are formed as well as old electron-hole disappear. A steady-state situation is reached and the number of electron-hole pairs takes a nearly constant value. For silicon at room temperature (300 K), the number of these pairs is about 7×10^{15} m^3. For germanium, this number is about 6×10^{19}/m^3.

Densities of charge carriers

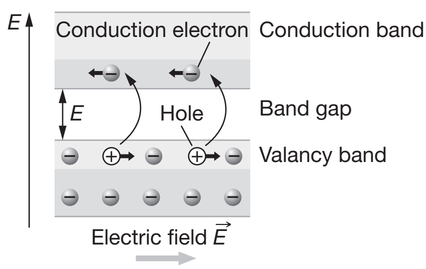
Material	Type	Density of conduction electrons (m^{-3})	Density of holes (m^{-3})
Copper	Conductor	9×10^{28}	0
Silicon	Intrinsic semiconductor	7×10^{15}	7×10^{15}
Silicon doped with phosphorus (1 part in 10^6)	*N*-type semiconductor	5×10^{22}	1×10^9
Silicon doped with aluminium (1 part in 10^6)	*P*-type semiconductor	1×10^9	5×10^{22}

Conductivity of Semiconductor

1. In intrinsic semiconductors $n_e = n_h$. Both electron and holes contributes in current conduction.
2. When some potential difference is applied across a piece of intrinsic semiconductor current flows in it due to both electron and holes
   i.e. $i = i_e + i_h \Rightarrow i = eA[n_e v_e + n_h v_h]$.



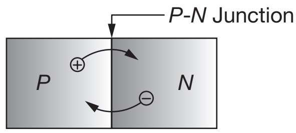
3. As we know $\sigma = \dfrac{J}{E} = \dfrac{i}{AE}$. Hence conductivity of semiconductor $\sigma = e[n_e\mu_e + n_h\mu_h]$; where v_e = drift velocity of electron, v_h = drift velocity of holes, E = Applied electric field $\mu_e = \dfrac{v_e}{E}$ = mobility of electron and $\mu_h = \dfrac{v_h}{E}$ = mobility of holes.
4. Motion of electrons in the conduction band and of holes the valence band under the action of electric field is shown below

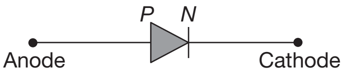


5. At absolute zero temperature (0 K) conduction band of semiconductor is completely empty *i.e.* $\sigma = 0$. Hence the semiconductor behaves as an insulator.

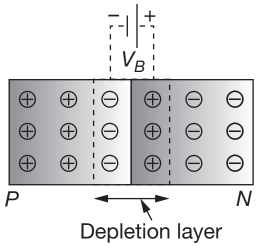
P-N JUNCTION DIODE

When a *P*-type semiconductor is suitably joined to an *N*-type semiconductor, then resulting arrangement is called *P-N* junction or *P-N* junction diode





1. **Depletion region:** On account of difference in concentration of charge carrier in the two sections of *P-N* junction, the electrons from *N*-region diffuse through the junction into *P*-region and the hole from *P* region diffuse into *N*-region.



Due to diffusion, neutrality of both *N* and *P*-type semiconductor is disturbed, a layer of negative charged ions appear near the junction in the *P*-crystal and a layer of positive ions appears near the junction in *N*-crystal. This layer is called depletion layer

(i) The thickness of depletion layer is 1 micron $= 10^{-6}$ m.

(ii) Width of depletion layer $\propto \dfrac{1}{\text{Dopping}}$

(iii) Depletion is directly proportional to temperature.

(iv) The *P-N* junction diode is equivalent to capacitor in which the depletion layer acts as a dielectric.

2. **Potential barrier:** The potential difference created across the *P-N* junction due to the diffusion of electron and holes is called potential barrier.

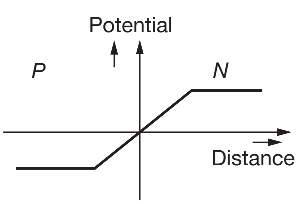
For *Ge* $V_B = 0.3\,\text{V}$ and for silicon $V_B = 0.7\,\text{V}$

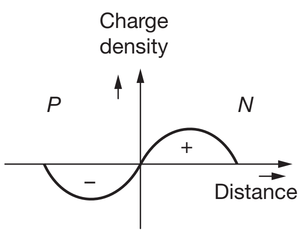
On the average the potential barrier in *P-N* junction is ~ 0.5 V and the width of depletion region ~ 10^{-6} m.

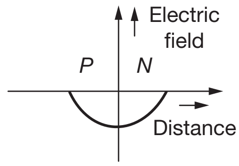
So the barrier electric field

$$E = \frac{V}{d} = \frac{0.5}{10^{-6}} = 5\times10^5 \text{ V/m}$$

3. Some important graphs





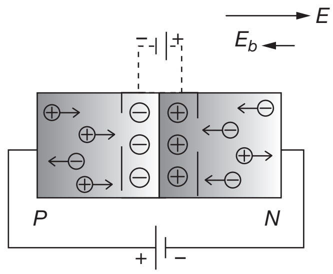


4. **Diffusion and drift current:** Because of concentration difference holes/electron tries to diffuse from their side to other side. Only those holes/electron crosses the junction, which have high kinetic energy. This diffusion results in an electric current from the *P*-side to the *N*-side known as diffusion current (i_{df}).

As electron hole pair (because of thermal collisions) is continuously created in the depletion region. There is a regular flow of electrons towards the *N*-side and of holes towards the *P*-side. This makes a current from the *N*-side to the *P*-side. This current is called the drift current (i_{dr}).

Biasing

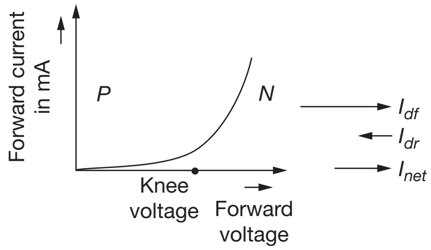
It means the way of connecting emf source to *P-N* junction diode. It is of following two types



Forward Biasing

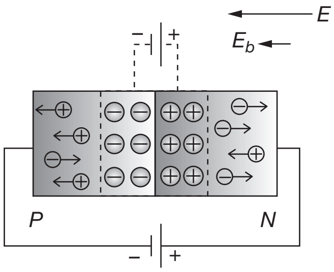
Positive terminal of the battery is connected to the *P*-crystal and negative terminal of the battery is connected to *N*-crystal

1. In forward biasing width of depletion layer decreases
2. In forward biasing resistance offered $R_{\text{Forward}} \approx 10\ \Omega$ – $25\ \Omega$
3. Forward bias opposes the potential barrier and for $V > V_B$ a forward current is set up across the junction.
4. The current is given by $i = i_s(e^{eV/kT} - 1)$; where $i_s =$ Saturation current, In the exponent $e = 1.6 \times 10^{-19}$ C,
   $k =$ Boltzmann's constant
5. Cut-in (Knee) voltage The voltage at which the current starts to increase rapidily. For *Ge* it is 0.3 V and for *Si* it is 0.7 V.
6. *df* – diffusion
   dr – drift

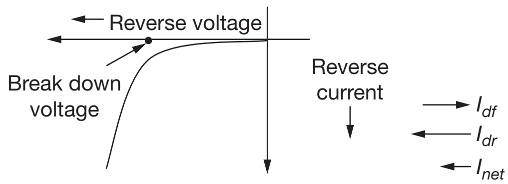


Reverse Biasing

Positive terminal of the battery is connected to the *N*-crystal and negative terminal of the battery is connected to *P*-crystal



1. In reverse biasing width of depletion layer increases
2. In reverse biasing resistance offered $R_{\text{Reverse}} \approx 10^5 \Omega$
3. Reverse bias supports the potential barrier and no current flows across the junction due to the diffusion of the majority carriers.
   (A very small reverse current may exist in the circuit due to the drifting of minority carriers across the junction)
4. Break down voltage Reverse voltage at which break down of semiconductor occurs. For *Ge* it is 25 V and for *Si* it is 35 V.
5.



Reverse Breakdown

If the reverse based voltage is too high, then breakdown of *P-N* junction diode occurs. It is of following two types

Zener Breakdown

When reverse bias is increased the electric field across the junction also increases. At some stage the electric field becomes so high that it breaks the covalent bonds creating electron, hole pairs. Thus a large number of carriers are generated. This causes a large current to flow. This mechanism is known as Zener breakdown.

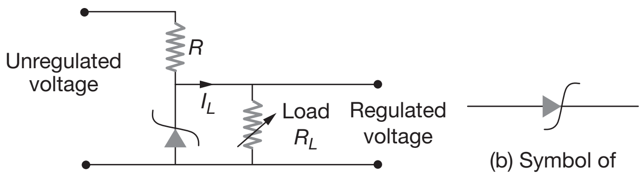
Avalanche Breakdown

At high reverse voltage, due to high electric field, the minority charge carriers, while crossing the junction acquires very high velocities. And these by collision breaks down the covalent bonds, generating more carriers. A chain reaction is established, giving rise to high current. This mechanism is called avalanche breakdown.

Special Purpose Diodes

Zener diode

It is a highly doped *P-N* junction which is not damaged by high reverse current. It can operate continuously, without being damaged in the region of reverse background voltage. In the forward bias, the zener diode acts as ordinary diode. It can be used as voltage regulator



(a) Zener diode as a voltage regulator

(b) Symbol of zener diode

Light Emitting Diode (LED)

Specially designed diodes, which give out light radiations when forward biases. LED'S are made of GaAsp, Gap etc.

These are forward biased *P-N*-junctions which emit spontaneous radiation.

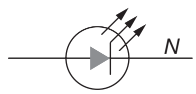
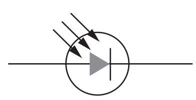


Photo Diode

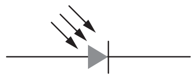
Photo diode is a special type of photo-detector. Suppose an optical photons of frequency ν is incident on a semiconductor, such that its energy is greater than the band gap of the semiconductor (i.e. $h\nu > E_g$) This photon will excite an electron from the valence band to the conduction band leaving a vacancy or hole in the valence band.

Which obviously increase the conductivity of the semiconductor. Therefore, by measuring the change in the conductance (or resistance) of the semiconductor, one can measure the intensity of the optical signal.



Solar cells

It is based on the photovoltaic effect. One of the semiconductor regions is made so thin that the light incident on it reaches the *P-N* junction and gets absorbed. It converts solar energy into electrical energy.



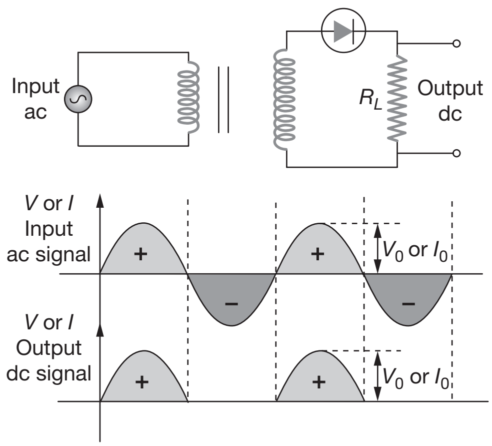
P-N Junction Diode as a Rectifier

Rectifier is a circuit which converts ac to unidirectional pulsating output. In other words it converts ac to dc. It is of following two types

Half Wave Rectifier

When the *P-N* junction diode rectifies half of the ac wave, it is called half wave rectifier.

1. During positive half cycle
   Diode $\longrightarrow$ forward biased
   Output signal $\longrightarrow$ obtained
2. During negative half cycle
   Diode $\longrightarrow$ reverse biased
   Output signal $\longrightarrow$ not obtained



3. Output voltage is obtained across the load resistance R_L. It is not constant but pulsating (mixture of ac and dc) in nature.
4. Average output in one cycle

   $I_{dc} = \dfrac{I_0}{\pi}$ and $V_{dc} = \dfrac{V_0}{\pi}$; $I_0 = \dfrac{V_0}{r_f + R_L}$ (r_f = forward biased resistance)
5. R.M.S. output: $I_{rms} = \dfrac{I_0}{2}, V_{rms} = \dfrac{V_0}{2}$
6. The ratio of the effective alternating component of the output voltage or current to the dc component is known as ripple factor.

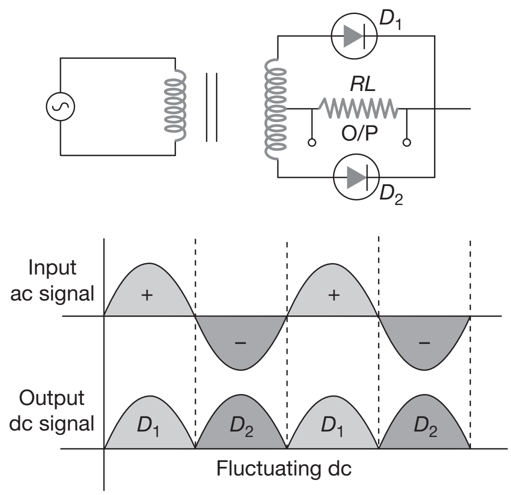
   $$r = \frac{I_{ac}}{I_{dc}} = \left[\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1\right]^{1/2} = 1.21$$
7. Peak Inverse Voltage (PIV) The maximum reverse biased voltage that can be applied before commoncement of Zener region is called the PIV. When diode is not conducting PIV across it = V_0.
8. Efficiency it is given by $\%\eta = \dfrac{P_{out}}{P_{in}} \times 100 = \dfrac{40.6}{1 + \dfrac{r_f}{R_L}}$

   If $R_L >> r_f$ then $\eta = 40.6\%$
   If $R_L = r_f$ then $\eta = 20.3\%$
9. Form factor = $\dfrac{I_{rms}}{I_{dc}} = \dfrac{\pi}{2} = 1.57$
10. The ripple frequency (ω) for half wave rectifier is same as that of ac.

Full Wave Rectifier

It rectifies both halves of ac input signal.

1. During positive half cycle
   Diode : $D_1 \longrightarrow$ forward biased
   $D_2 \longrightarrow$ reverse biased
   Output signal $\longrightarrow$ obtained due to D_1 only
2. During negative half cycle
   Diode : $D_1 \longrightarrow$ reverse biased
   $D_2 \longrightarrow$ forward biased
   Output signal $\longrightarrow$ obtained due to D_2 only



3. Fluctuating dc $\longrightarrow$ Filter $\longrightarrow$ constant dc.
4. Output voltage is obtained across the load resistance R_L. It is not constant but pulsating in nature.
5. Average output: $V_{av} = \dfrac{2V_0}{\pi}, I_{av} = \dfrac{2I_0}{\pi}$.

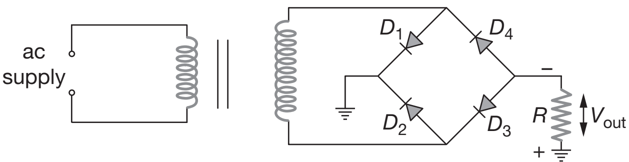
6. r.m.s. output: $V_{rms} = \frac{V_0}{\sqrt{2}}, I_{rms} = \frac{I_0}{\sqrt{2}}$.
7. Ripple factor: $r = 0.48 = 48\%$.
8. Ripple frequency: The ripple frequency of full wave rectifier = 2 × (Frequency of input ac).
9. Peak Inverse Voltage (PIV): It's value is $2V_0$.
10. Efficiency $\eta\% = \frac{81.2}{1+\frac{r_f}{R_L}}$ for $r_f << R_L$, $\eta = 81.2\%$

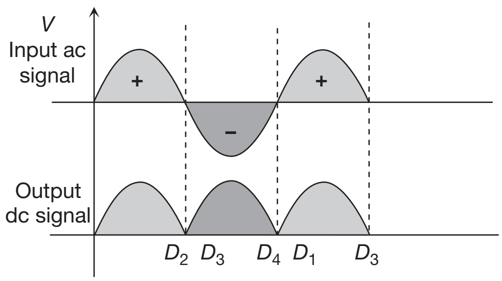
Full Wave Bridge Rectifier

Four diodes D_1, D_2, D_3 and D_4 are used in the circuit.

During positive half cycle D_1 and D_3 are forward biased and D_2 and D_4 are reverse biased.

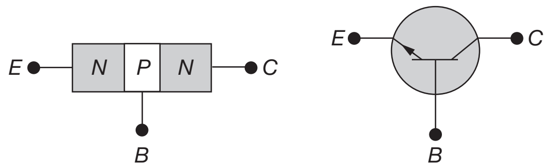
During negative half cycle D_2 and D_4 are forward biased and D_1 and D_3 are reverse biased.





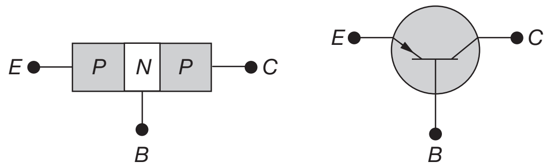
TRANSISTOR

1. The name of this electronic device is derived from its fundamental action transfer resistor.
2. Transistor does not need any heater or hot filament, transistor is small in size and light in weight.
3. Transistor in general is known as bipolar junction transistor.
4. Transistor is a current operated device.
5. It consists of three main regions
   (i) Emitter (E): It provides majority charge carriers by which current flows in the transistor. Therefore the emitter semiconductor is heavily doped.
   (ii) Base (B): The based region is lightly doped and thin.
   (iii) Collector (C): The size of collector region is larger than the two other regions.
6. Junction transistor is of two types:
   (i) *NPN* transistor: It is formed by sandwiching a thin layer of *P*-type semiconductor between two *N*-type semiconductors



In *NPN* transistor electrons are majority charge carriers and flow from emitter to base.

   (ii) *PNP* transistor: It is formed by sandwiching a thin layer of *N*-type semiconductor between two *P*-type semiconductors



In *PNP* transistor holes are majority charge carriers and flow from emitter to base.

In the symbols of both *NPN* and *PNP* transistor, arrow indicates the direction of conventional current.

Working of Transistor

1. There are four possible ways of biasing the two *P-N* junctions (emitter junction and collector junction) of transistor.
   (i) Active mode: Also known as linear mode operation.
   (ii) Saturation mode: Maximum collector current flows and transistor acts as a closed switch from collector to emitter terminals.
   (iii) Cut-off mode: Denotes operation like an open switch where only leakage current flows.
   (iv) Inverse mode: The emitter and collector are inter changed.

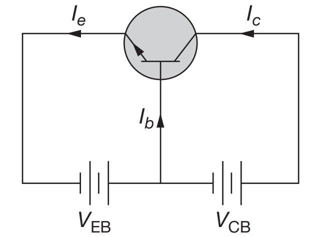
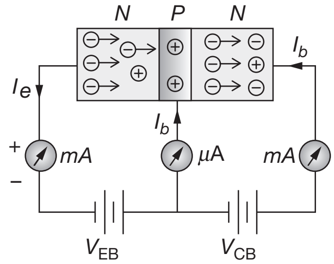
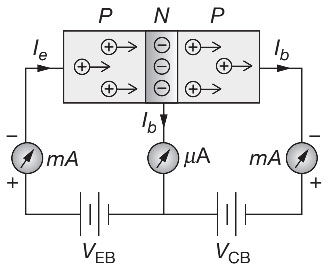
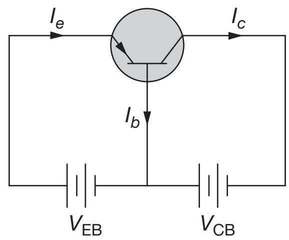
Different modes of operation of a transistor

Operating mode	Emitter base bias	Collector base bias
Active	Forward	Reverse
Saturation	Forward	Forward
Cut off	Reverse	Reverse
Inverse	Reverse	Forward

2. A transistor is mostly used in the active region of operation i.e. emitter base junction is forward biased and collector base junction is reverse biased.

3. From the operation of junction transistor it is found that when the current in emitter circuit changes. There is corresponding change in collector current.
4. In each state of the transistor there is an input port and an output port. In general each electrical quantity (V or I) obtained at the output is controlled by the input.

Circuit diagram of PNP/NPN transistor

NPN – transistor	PNP – transistor
	
	
5% emitter electron combine with the holes in the base region resulting in small base current. Remaining 95% electrons enter the collector region.	5% emitter holes combine with the electrons in the base region resulting in small base current. Remaining 95% holes enter the collector region.
$I_e > I_c$, and $I_e = I_b + I_c$	$I_e > I_c$, and $I_e = I_b + I_c$

Transistor Configurations

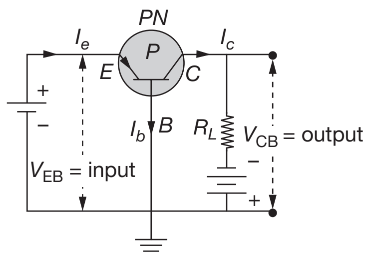
A transistor can be connected in a circuit in the following three different configurations.

Common Base (CB), Common Emitter (CE) and Common Collector (CC) configuration.

CB Configurations

Base is common to both emitter and collector.

1. Input current = I_e
2. Input voltage = V_{EB}
3. Output voltage = V_{CB}
4. Output current = I_C
   With small increase in emitter-base voltage V_{EB}, the emitter current I_e increases rapidly due to small input resistance.



5. Input characteristics: If V_{CB} = constant, curve between I_e and V_{EB} is known as input characteristics. It is also known as emitter characteristics

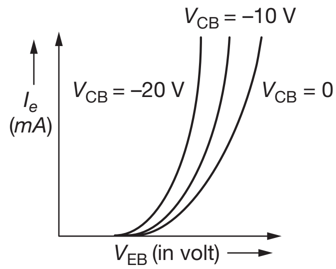


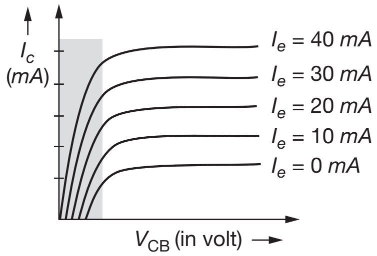
Fig. 20.1

Input characteristics of *NPN* transistor are also similar to the above Fig. 20.1 but I_e and V_{EB} both are negative and V_{CB} is positive.

Dynamic input resistance of a transistor is given by

$$R_i = \left(\frac{\Delta V_{EB}}{\Delta I_e}\right)_{V_{CB}=\text{constant}} \qquad \{R_i \text{ is of the order of } 100\ \Omega\}$$

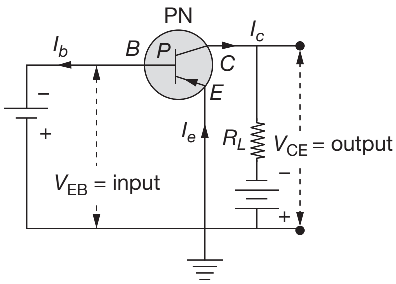
6. Output characteristics: Taking the emitter current i_e constant, the curve drawn between I_C and V_{CB} are known as output characteristics of *CB* configuration.



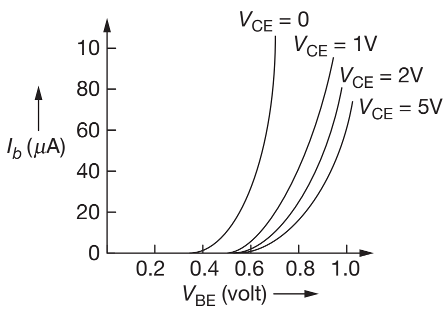
Dynamic output resistance $R_o = \left(\frac{\Delta V_{CB}}{\Delta i_C}\right)_{i_e\ =\ \text{constant}}$

CE Configurations

Emitter is common to both base and collector. The graph between voltages and currents, when the emitter of a transistor is shown common to input and output circuits are known as CE characteristics of a transistor.

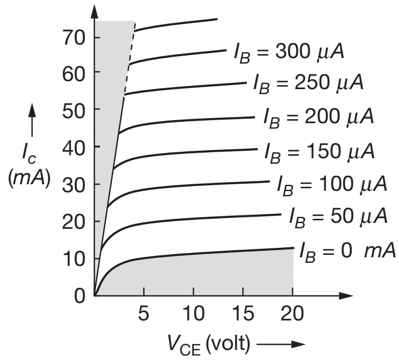


Input characteristics: Input characteristic curve is drawn between base current I_b and emitter base voltage V_{EB}, at constant collector emitter voltage V_{CE}.



Dynamic input resistance $R_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE} \to \text{constant}}$

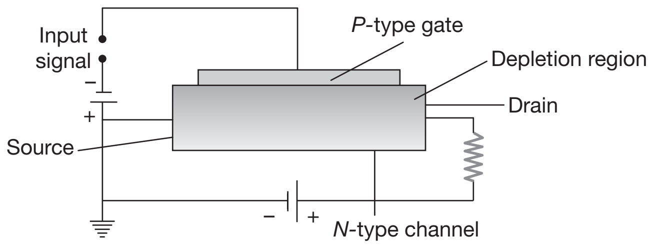
Output characteristics: Variation of collector current I_C with V_{CE} can be noticed for V_{CE} between 0 to 1 V only. The value of V_{CE} up to which the I_C changes with V_{CE} is called knee voltage. The transistor is operated in the region above knee voltage.



Dynamic output resistance $R_0 = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B \to \text{constant}}$

Field-Effect Transistor

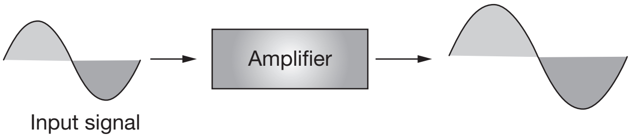
The low input impedance of the junction transistor is a handicap in certain applications. In addition, it is difficult to incorporate large numbers of them in an integrated circuit and they consume relatively large amounts of power. The field-effect transistor (FET) lacks these disadvantages and is widely used today although slower in operation than junction transistors.



An *n*-channel FET consists of a block of *N*-type material with contacts at each end together with a strip of *P*-type material on one side that is called the gate. When connected as shown, electrons move from the source terminal to the drain terminal through the *N*-type channel. the *P*-*N* junction is given a reverse bias, and as a result both the *N* and *P* materials near the junction are depleted on charge carriers. The higher the reverse potential on the gate, the larger the depleted region in the channel and fewer the electrons available to carry the current. Thus the gate voltage controls the channel current. Very little current passes through the gate circuit owing to the reverse bias, and the result is extremely high input impedance. FET is uni-polar.

Transistor as an Amplifier

A device which increases the amplitude of the input signal is called amplifier.

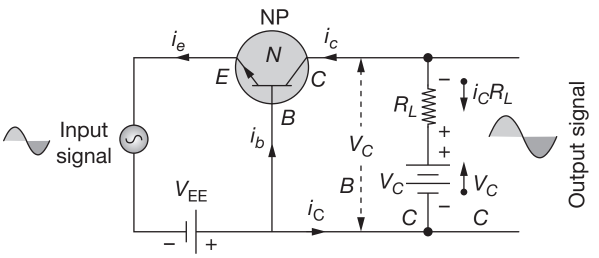


The transistor can be used as an amplifier in the following three configurations

(i) CB amplifier (ii) CE amplifier (iii) CC amplifier

NPN Transistor as CB Amplifier

1. $i_e = i_b + i_C$; $i_b = 5\%$ of i_e and $i_C = 95\%$ of i_e
2. $V_{EE} < V_{CC}$
3. Net collector voltage $V_{CB} = V_{CC} - i_C R_L$

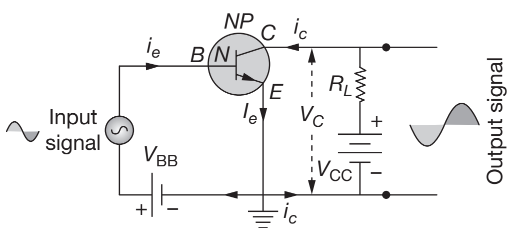


When the input signal (signal to be amplified) is fed to the emitter base circuit, it will change the emitter voltage and hence emitter current. This in turn will change the collector current (i_c). This will vary the collector voltage V_{CB}. This variation of V_{CB} will appear as an amplified output.

4. Input and output signals are in same phase

NPN Transistor as CE Amplifier

1. $i_e = i_b + i_C$; $i_b = 5\%$ of i_e and $i_C = 95\%$ of i_e
2. $V_{CC} > V_{BB}$
3. Net collector voltage $V_{CE} = V_{CC} - i_C R_L$
4. Input and output signals are 180° out of phase.



Different Gains in CE/CB Amplifiers

Transistor as CB Amplifier

1. ac current gain

$$\alpha_{ac} = \frac{\text{Small change in collector current } (\Delta i_c)}{\text{Small change in collector current } (\Delta i_e)}$$

V_B (constant)

2. dc current gain $\alpha_{dc}(\text{or}\,\alpha) = \dfrac{\text{Collector current}(i_c)}{\text{Emitter current } (i_e)}$

   value of α_{dc} lies between 0.95 to 0.99

3. Voltage gain $A_v = \dfrac{\text{Change in output voltage}(\Delta V_o)}{\text{Change in input voltage } (\Delta V_i)}$

   $\Rightarrow A_v = \alpha_{ac} \times$ Resistance gain

4. Power gain $= \dfrac{\text{Change in output power}(\Delta P_o)}{\text{Change in input power}(\Delta P_c)}$

   $\Rightarrow$ Power gain $= \alpha_{ac}^2 \times$ Resistance gain

Transistor as CE Amplifier

1. ac current gain $\beta_{ac} = \left(\dfrac{\Delta i_c}{\Delta i_b}\right)$ V_{CE} = constant
2. dc current gain $\beta_{dc} = \dfrac{i_c}{i_b}$
3. Voltage gain: $A_v = \dfrac{\Delta V_o}{\Delta V_i} = \beta_{ac} \times$ Resistance gain
4. Power gain $= \dfrac{\Delta P_o}{\Delta P_i} = \beta_{ac}^2 \times$ Resistance gain
5. Transconductance (g_m): The ratio of the change in collector current to the change in emitter base voltage is called transconductance. i.e., $g_m = \dfrac{\Delta i_c}{\Delta V_{EB}}$. Also $g_m = \dfrac{A_V}{R_L}$; R_L = Load resistance

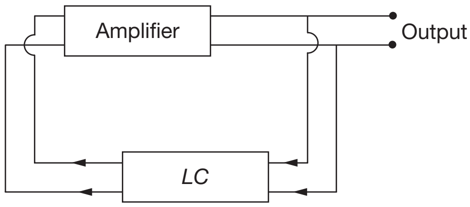
Relation between α and β

$$\beta = \frac{\alpha}{1-\alpha} \quad \text{or} \quad \alpha = \frac{\beta}{1+\beta}$$

Transistor as an Oscillator

1. It is defined as a circuit which generates an ac output signal without any externally applied input signal.
   Audio frequency oscillators generate signals of frequencies ranging from a few Hz to 20 kHz and radio frequency oscillators have a range from few kHz to MHz.
2. In an oscillator the frequency, waveform, and magnitude of ac power generated is controlled by circuit itself.
3. An oscillator may be considered as amplifier which provides its own input signal.
4. The essential of a transistor oscillator are
   (i) Tank circuit: Parallel combination of L and C. This network resonates at a frequency $v_0 = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}}$.
   (ii) Amplifier: It receives dc power from the battery and converts into ac power.
   The amplifier increases the strength of oscillations.

(iii) Feed-back circuit: This circuit supplies a part of the collector energy to the tank circuit.



5. A basic common-emitter *NPN* oscillator is shown in the Fig. 20.2.

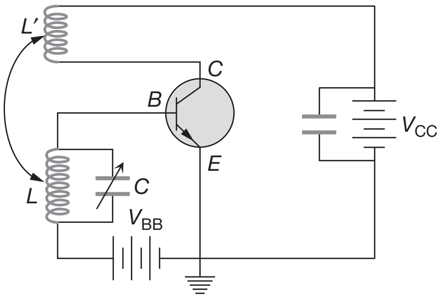


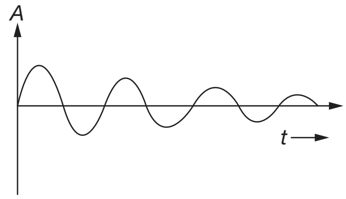
Fig. 20.2

A tank circuit (*L-C* circuit) is connected in the base-emitter circuit, in which the capacitance *C* is kept variable. By changing *C* oscillations of a desired frequency can be obtained. An inductance coil *L′* connected in the collector-emitter circuit is coupled to coil *L*.

On completion of the circuit electrical oscillations are developed in the tank circuit. The circuit amplifies these oscillations. A part of the amplified signal in the collector circuit is fed back in the base circuit by the coupling between *L* and *L′*. Due to this feedback amplitude of oscillation builds up till power dissipation in the oscillatory circuit becomes equal to power feedback. In this state the amplitude of oscillations becomes constant.

The oscillations can be transferred to an external circuit by mutual induction in a coil connected in that circuit.

6. Need for positive feedback: The oscillations are damped due to the presence of some inherent electrical resistance in the circuit. Consequently, the amplitude of oscillations decreases rapidly and the oscillations ultimately stop. Such oscillations are of little practical importance. In order to obtain oscillations of constant amplitude, we make an arrangement for regenerative or positive feedback from the output circuit to the input circuit so that the losses in the circuit can be compensated.



Comparison between CB, CE and CC amplifier

Characteristic	Amplifier		
	CB	CE	CC
Input resistance (R_i)	≈ 50 to 200 Ω low	≈ 1 to 2 kΩ medium	≈ 150 – 800 kΩ high
Output resistance (R_o)	≈ 1 – 2 kΩ high	≈ 50 kΩ medium	≈ kΩ low
Current gain	0.8 – 0.9 low	20 – 200 high	20 – 200 high
Voltage gain	Medium	High	Low
Power gain	Medium	High	Low
Phase difference between input and output voltages	Zero	180°	Zero
Used as amplifier for	Current	Power	Voltage

DECIMAL AND BINARY NUMBER SYSTEM

Decimal Number System

In a decimal number system, we have ten digits i.e. 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

A decimal number system has a base of ten (10)

e.g. 1971 = 1000 + 900 + 70 + 1

$= 1 \times 10^3 + 9 \times 10^2 + 7 \times 10^1 + 1 \times 10^0$

MSD LSD

LSD = Least significant digit
MSD = Most significant digit

Binary Number System

A number system which has only two digits i.e. 0 (Low) and 1 (High) is known as binary system. The base of binary number system is 2.

1. Each digit in binary system is known as a bit and a group of bits is known as a byte.

2. The electrical circuit which operates only in these two state i.e. 1 (On or High) and 0 (i.e. Off or Low) are known as digital circuits.

Different names for the digital signals

State Code	1	0
Name for the State	On	Off
	Up	Down
	Close	Open
	Excited	Unexcited
	True	False
	Pulse	No pulse
	High	Low
	Yes	No

Decimal to Binary Conversion

1. Divide the given decimal number by 2 and the successive quotients by 2 till the quotient becomes zero.
2. The sequence of remainders obtained during divisions gives the binary equivalent of decimal number.
3. The most significant digit (or bit) of the binary number so obtained is the last remainder and the least significant digit (or bit) is the first remainder obtained during the division.

For example: Binary equivalence of 61

2	61	Remainder
2	30	1 LSD
2	15	0
2	7	1
2	3	1
2	1	1
	0	1 MSD

$\Rightarrow (61)_{10} = (111101)_2$

Binary to Decimal Conversion

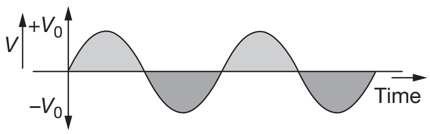
The least significant digit in the binary number is the coefficient of 2 with power zero. As we move towards the left side of LSD, the power of 2 goes on increasing.

For example: $(11111100101)_2 = 1\times2^{10}+1\times2^9+1\times2^8+1\times2^7+1\times2^6+1\times2^5+0\times2^4+0\times2^3+1\times2^2+0\times2^1+1\times2^0 = 2021$

Voltage Signal

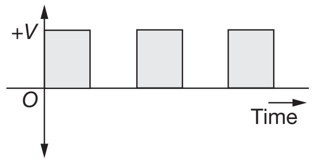
Analogue Voltage Signal

The signal which represents the continuous variation of voltage with time is known as analogue voltage signal



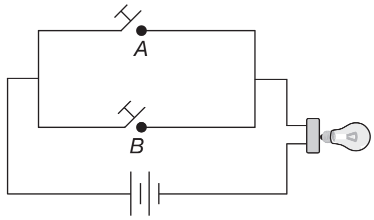
Digital Voltage Signal

The signal which has only two values. i.e. either a constant high value of voltage or zero value is called digital voltage signal



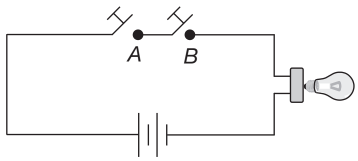
Boolean Algebra

1. In Boolean algebra only two states of variables (0 and 1) are allowed.
2. The variables (A, B, C ….) of Boolean Algebra are subjected to three operations.
   (i) OR Operation : Represented by (+) sign

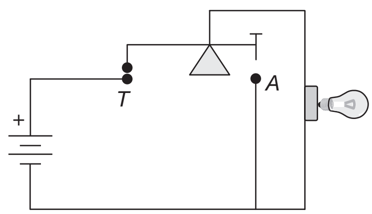


Boolean expression $Y = A + B$
When switch A or B is closed – Bulb glows

(ii) AND Operation: Represented by (·) sign
Boolean expression $Y = A \cdot B$
When switches A and B both are closed – Bulb glows



(iii) NOT Operation: Represented by bar over the variables
Boolean expression $Y = \overline{A}$



A OFF → Lamp ON
A ON → Contact at *T* is broken
→ Lamp OFF

LOGIC GATES AND TRUTH TABLE

Logic Gate

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

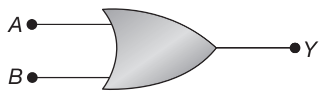
There are primarily three logic gates namely the OR gate, the AND gate and the NOT gate.

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 the truth table. To write the truth table we use binary digits 1 and 0.

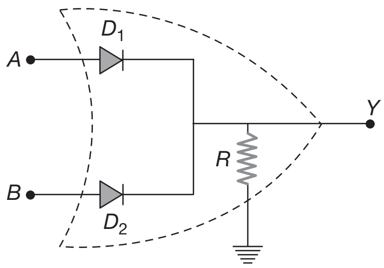
The 'OR' Gate

1. It has two inputs (A and B) and only one output (Y).
2. Boolean expression is $Y = A + B$ and is read as "Y equals A OR B".



Logical symbol of OR gate

3. Realization of OR gate



(i) $A = 0, B = 0$
Both diodes D_1 and D_2 do not conduct and hence $Y = 0$

(ii) $A = 0, B = 1$
D_1 = Does not conducts, D_2 = Conducts, hence $Y = 1$

(iii) $A = 1, B = 0$
D_1 = Conducts, D_2 = Does not conduct, hence $Y = 1$

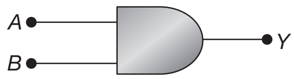
(iv) $A = 1, B = 1$
Both D_1 and D_2 conducts, hence $Y = 1$

4. **Truth table for 'OR' gate**

A	B	Y = A + B
0	0	0
0	1	1
1	0	1
1	1	1

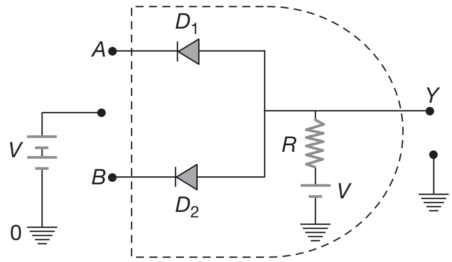
The 'AND' Gate

1. It has two inputs (A and B) and only one output (Y).
2. Boolean expression is $Y = A \cdot B$ is read as "Y equals A AND B".



Logical symbol of AND gate.

3. Realization of AND gate



(i) $A = 0, B = 0$
The voltage supply through R is forward biasing diodes D_1 and D_2 (offers low resistance) the voltage V would drop across R
The output voltage at Y = the voltage across diode = 0

(ii) $A = 0, B = 1$
D_1 = conducts, D_2 = Not Conducts
the out voltage at Y = The voltage across the diode $(D_1) = 0$

(iii) $A = 1, B = 0$
D_1 = Conducts, D_2 = Not conducts
the out voltage at Y = The voltage across the diode $(D_2) = 0$

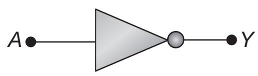
(iv) $A = 1, B = 1$
None of the diode conducts the out voltage at Y = Battery voltage = 1

4. Truth table for 'AND' gate

A	B	Y = A · B
0	0	0
0	1	0
1	0	0
1	1	1

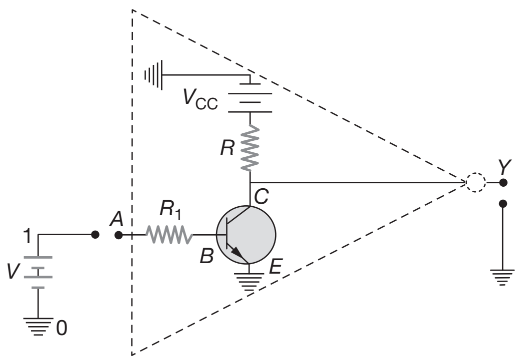
The 'NOT' Gate

1. It has only one input and only one output.
2. Boolean expression is $Y = \overline{A}$ and is read as "y equals not A"



Logical symbol of NOT gate

3. Realization of NOT gate : The transistor is so biased that the collector voltage $V_{CC} = V$ (Voltage corresponding to 1 state)
   The resistors R and R_1 are so chosen that if the input is low i.e. O, the transistor is in the cut off and hence the voltage appearing at the output will be the same as applied V. Hence $Y = V$ (or state 1)



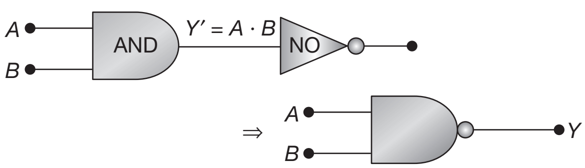
   If the input is high, the transistor current is in saturation and the net voltage at the output Y is 0 (in state 0)
4. Truth table for NOT gate:

A	$Y = \bar{A}$
0	1
1	0

Combination of Logic Gates

The 'NAND' gate

From 'AND' and 'NOT' gate

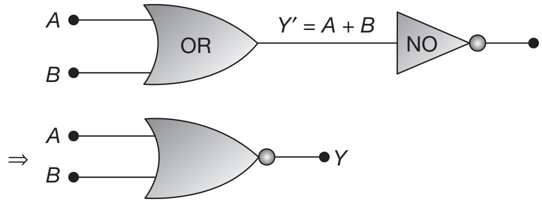


Boolean expression and truth table: $Y = \overline{A \cdot B}$

A	B	$Y' = A \cdot B$	Y
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

The 'NOR' gate

From 'OR' and 'NOT' gate



Boolean expression and truth table: $Y = \overline{A + B}$

A	B	$Y' = A + B$	Y
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

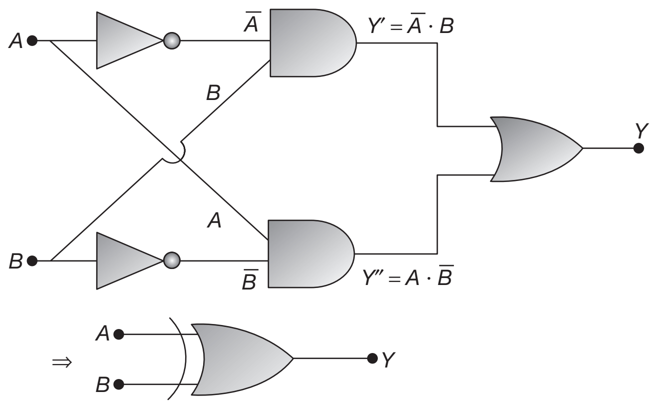
The 'XOR' gate

From 'NOT', 'AND' and 'OR' gate. Known as exclusive OR gate.

or

The logic gate which gives high output (i.e., 1) if either input A or input B but not both are high (i.e. 1) is called exclusive OR gate or the XOR gate.

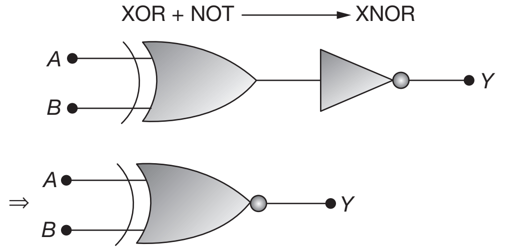
It may be noted that if both the inputs of the XOR gate are high, then the output is low (i.e., 0).



Boolean expression and truth table: $Y = A \oplus B = \bar{A}B + A\bar{B}$

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

The Exclusive Nor (XNOR) gate



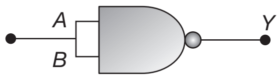
Boolean expression: $Y = A \odot B = \bar{A}\,\bar{B} + AB$

Logic Gates using 'NAND' Gate

The NAND gate is the building block of the digital electronics. All the logic gates like the OR, the AND and the NOT can be constructed from the NAND gates.

Construction of the 'NOT' gate from the 'NAND' gate

1. When both the inputs (A and B) of the NAND gate are joined together then it works as the NOT gate.

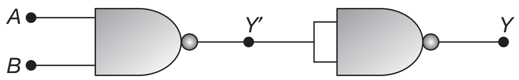


2. Truth table and logic symbol

Input	Output
$A = B$	Y
0	1
1	0

Construction of the 'AND' gate from the 'NAND' gate

1. When the output of the NAND gate is given to the input of the NOT gate (made from the NAND gate), then the resultant logic gate works as the AND gate

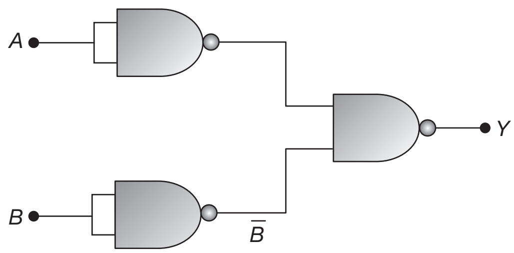


2. Truth table and logic symbol

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

Construction of the 'OR' gate by the 'NAND' gate

1. When the outputs of two NOT gates (obtained from the NAND gate) is given to the inputs of the NAND gate, the resultant logic gate works as the OR gate



2. Truth table and logic symbol

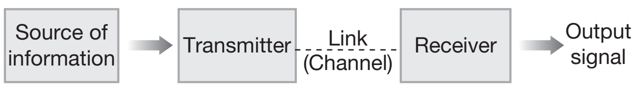
A	B	$\bar{A}$	$\bar{B}$	Y
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1

PRINCIPLES OF COMMUNICATION

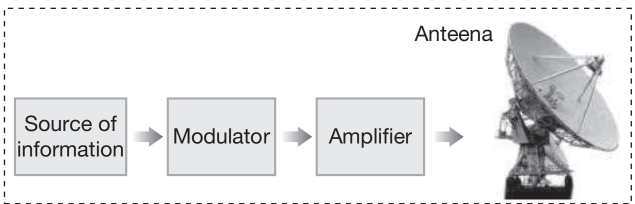
The term communication refers to the transmitting, receiving and processing of information by electronic means.

BASIC COMMUNICATION SYSTEM

A basic communication system consists of an information source, a transmitter, a link and a receiver.



1. Information: The idea/message that is to be conveyed is information. The message may be individual one or a set of messages. The message may be a symbol, code, group of words or any pre decided unit.
2. Transmitter: In radio transmission, the transmitter consists of a transducer, modulator, amplifier and transmitting antenna.
   Transducer: Converts sound signals into electric signal.
   Modulator: Mixing of audio electric signal with high frequency radio wave.
   Amplifier: Boosting the power of modulated signal.
   Antenna: Signal is radiated in the space with the aid of an antenna.



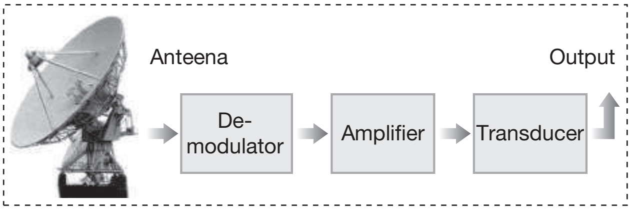
Transmitter

3. Communication channel: The function of communication channel is to carry the modulated signal from transmitter to receiver. The communication channel is also called transmission medium or link.
   The term channel refers to the frequency range allocated to a particular service or transmission.

Different channels

Type of communication	Channels or links
Radio communication	Free space
Telephony and Telegraphy communication	Transmission line
Optical communication	Optical fibre

4. Receiver: The receiver consists of
   Pickup antenna: To pick the signal
   Demodulator: To separate out the audio signal from the modulated signal
   Amplifier: To boost up the weak audio signal
   Transducer: To convert back audio signal in the form of electrical pulses into sound waves.



Receiver

Types of Communication System

Communication systems can be classified according to the nature of information or mode of transmission or types of transmission channel.

According to the nature of information source

1. Speech transmission
2. Picture transmission
3. Facsimile transmission (FAX): This involves exact reproduction of a document or picture which are static.

According to the mode of transmission

1. Analog communication: The communication system, which make use of analog signals are called analog communication system.

Few analog communication systems

System	Specification
Telegraphy	Message in the form of codes are sent.
Television broadcast	Both sound as well as pictures is sent.
Telephony	It sends voice signal from one place to another by means of wire.
Radar	It means radio detection and ranging. It is used for determining the distance and direction of objects using microwave.
Teleprinting	Message can be typed and telegraphed to distant receivers

2. Digital communication: In this system digital signals are used.

Few digital communication system

System	Specification
Facsimile transmission (FAX)	This involves exact reproduction of a document or picture which are static
Mobile phone	Such telephones are also called cellular phones, because they operate within a network of radio cells.
E-mail	the message sent via a computer network are called e-mail
Tele conferencing	It is a system in which persons sitting at coloured television screens. See and talk to each other via a computer communication network.
Communication satellite	Used to relay radio and television programmers.
Global positioning system (GPS)	It is a navigation system based on a network of earth orbiting satellites. The users can find their positions within an accuracy of 100 m by receiving.

According to the transmission channel

1. Line communication
2. Space communication

According to the type of modulation

1. Amplitude modulation (AM)
2. Frequency modulation (FM)
3. Phase modulation (PM)
4. Pulse amplitude modulation (PAM)
5. Pulse time modulation (PTM)
6. Pulse code modulation (PCM)

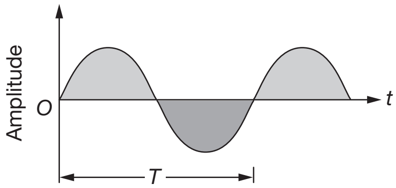
Analog and Digital Signals

In communication system, a signal means a time varying electrical signal containing informations.

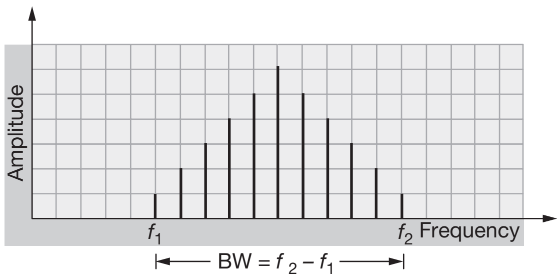
Analog Signals

It is a continuous wave form which changes smoothly over time.

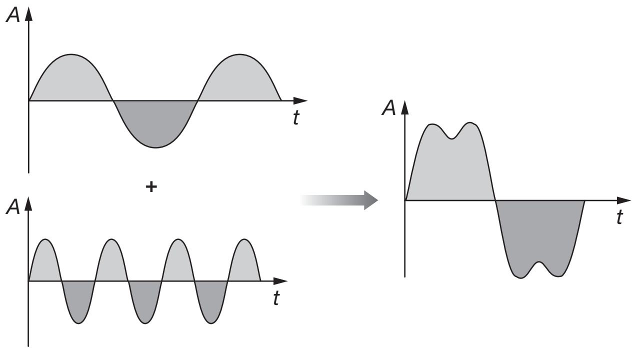
1. Such signals can be easily generated from the source of information by using an appropriate transducer e.g. pressure variations in the sound waves can be converted into corresponding current or voltage pulses with the help of a microphone.
2. A simple analog signal is represented by a sine wave



3. The frequency of analog signals associated with speed or music varies over a range between 20 Hz to 20 KHz.
4. The range over which the frequencies of a signal vary is called band width.



5. The term base band designates the band of frequencies representing the signal supplied by the source of information.
6. A signal consists of two or more waves of different frequencies is known as a complex analog signal.



Digital Signals

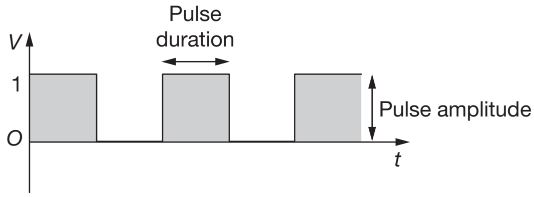
A digital signal is a discontinuous function of time. It has only two voltage levels i.e. either low (0) or high (1).

Either of 0 and 1 is known as bit. A group of bit is called byte.

A byte comprising of 2 bits can give on the four code combination i.e. 00, 01, 10 and 11.

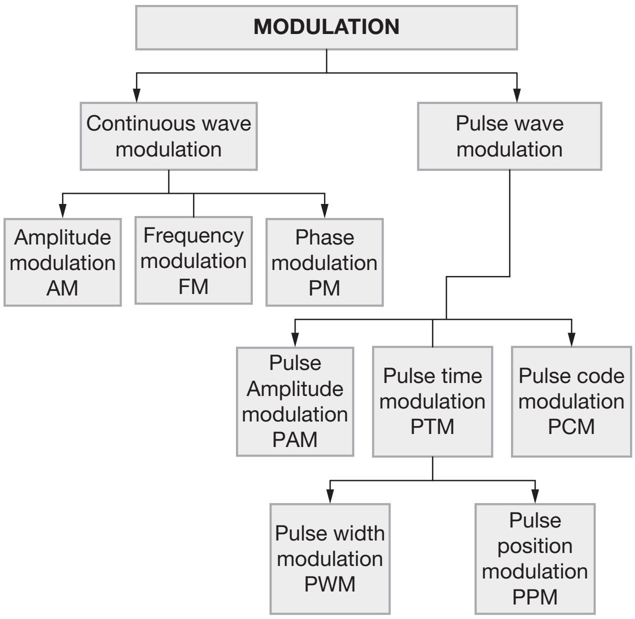
The number of code combination increase with number of bits in a byte is given by $N = 2^x$, where x = number of bits in a byte.

The number of binary digits (bits) per second, which describe a digital signal is called it's bit rate. Bit rate is expressed in bits per second (bps).



MODULATION

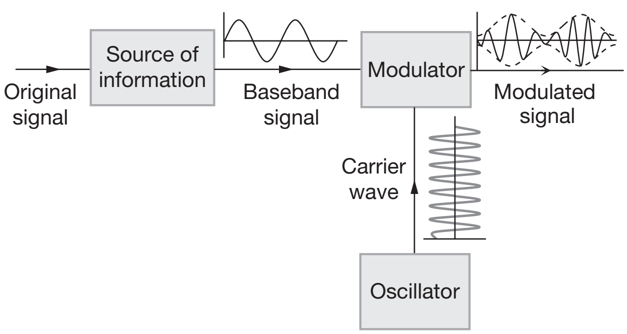
1. Digital and analog signals to be transmitted are usually of low frequency and hence cannot be transmitted as such.
2. These signals require some carrier to be transported. These carriers are known as carrier waves or high frequency signals.
3. The process of placement of a low frequency (LF) signal over the high frequency (HF) signal is known as modulation.



4. **Need for modulation:** The sound wave (20 Hz to 20 KHz) cannot be transmitted directly from one place to another for the following reasons.
   (i) Height of antenna: For efficient radiation and reception, the height of transmitting and receiving antennas should be comparable to a quarter of wavelength of the frequency used. For 15 KHz it is 5000 m (too large) and for 1 MHz it is 75 m.

The energy radiated from an antenna is practically zero, when the frequency of the signal to be transmitted is below 15 Hz.

(ii) Detecting signals: All audible signals are in the range of 20 Hz to 20 KHz so the signals from all sources remains heavily mixed up in air. It will be very difficult to differentiate or detect the broadcast signal at the receiving station.



Thus modulation is necessary for a low frequency signal. When it is to be sent to a distant place so that the information may not die out in the way it self as well as for the proper identification of a signal and to keep the height of antenna small also.

Amplitude Modulation (AM)

The process of changing the amplitude of a carrier wave in accordance with the amplitude of the audio frequency (AF) signal is known as amplitude modulation (AM).

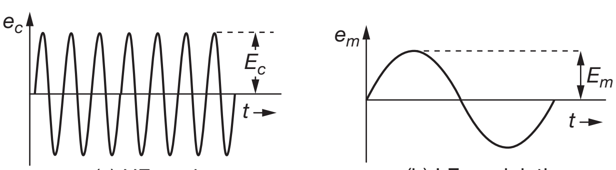
In AM frequency of the carrier wave remains unchanged.

The amplitude of modulated wave is varied in accordance with the amplitude of modulating wave.

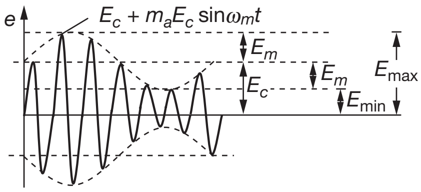
Modulation Index

The ratio of change of amplitude of carrier wave to the amplitude of original carrier wave is called the modulation factor or degree of modulation or modulation index (m_a).

$$m_a = \frac{\text{Change in amplitude of carrier wave}}{\text{Amplitude of original carrier wave}} = \frac{kE_m}{E_c}$$



(a) HF carrier (b) LF modulating



(c) AM wave

where $k = A$ factor which determines the maximum change in the amplitude for a given amplitude E_m of the modulating signal. If $k = 1$ then $m_a = \dfrac{E_m}{E_c} = \dfrac{E_{max} - E_{min}}{E_{max} + E_{min}}$.

If a carrier wave is modulated by several sine waves the total modulated index m_t is given by $m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + \dots\dots}$.

Voltage Equation for AM Wave

Suppose voltage equations for carrier wave and modulating wave are $e_c = E_c \cos\omega_c t$ and $e_m = E_m \sin\omega_m t = mE_c \sin\omega_m t$

where e_c = Instantaneous voltage of carrier wave, E_c = Amplitude of carrier wave, $\omega_c = 2\pi f_c$ = Angular velocity at carrier frequency f_c, e_m = Instantaneous voltage of modulating, E_m = Amplitude of modulating wave, $\omega_m = 2\pi f_m$ = Angular velocity of modulating frequency f_m

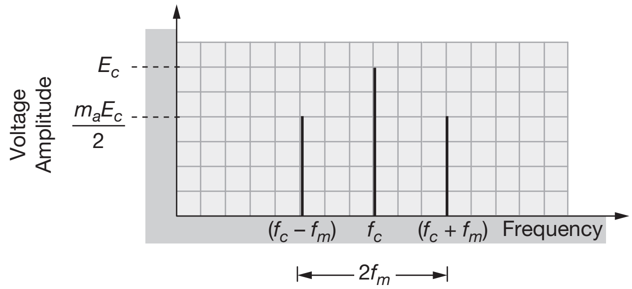
Voltage equation for AM wave is

$$\begin{aligned} e &= E \sin\omega_c t = (E_c + e_m)\sin\omega_c t \\ &= (E_c + e_m \sin\omega_m t)\sin\omega_c t \\ &= E_c \sin\omega_c t + \frac{m_a E_c}{2}\cos(\omega_c - \omega_m)t \\ &\quad - \frac{m_a E_c}{2}\cos(\omega_c + \omega_m)t \end{aligned}$$

The above AM wave indicated that the AM wave is equivalent to summation of three sinusoidal wave, one having amplitude E_c and the other two having amplitude $\dfrac{m_a E_c}{2}$.

Side Band Frequencies and Band width in AM Wave

1. Side band frequencies: The AM wave contains three frequencies $f_c, (f_c + f_m)$ and $(f_c - f_m)$, f_c is called carrier frequency, $(f_c + f_m)$ and $(f_c - f_m)$ are called side band frequencies.
   $(f_c + f_m)$: Upper side band (USB) frequency
   $(f_c - f_m)$: Lower side band (LSB) frequency
   Side band frequencies are generally close to the carrier frequency.
2. Band width: The two side bands lie on either side of the carrier frequency at equal frequency interval f_m.
   So, band width $= (f_c + f_m) - (f_c - f_m) = 2f_m$



Power in AM waves

Power dissipated in any circuit $P = \dfrac{V_{\text{rms}}^2}{R}$.

$$\text{Hence (i) carrier power } P_c = \frac{\left(\dfrac{E_c}{\sqrt{2}}\right)^2}{R} = \frac{E_c^2}{2R}$$

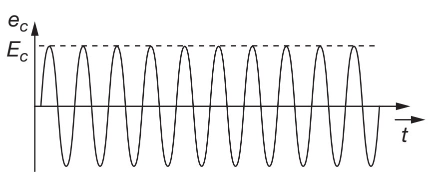
Limitation of Amplitude Modulation

1. Noisy reception
2. Low efficiency
3. Small operating range
4. Poor audio quality

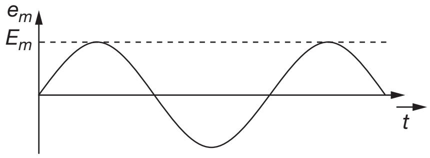
Frequency Modulation (FM)

The process of changing the frequency of a carrier wave in accordance with the audio frequency signal is known as frequency modulation.

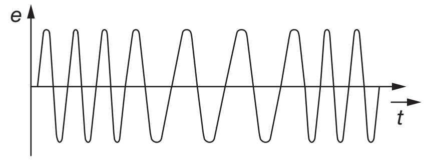
1. Audio quality of AM transmission is poor. There are need to eliminate amplitude sensitive noise. This is possible if we eliminate amplitude variation. (i.e. a need to keep the amplitude of the carrier constant). This is precisely what we do in FM.
2. In FM the overall amplitude of FM wave remains constant at all times.
3. In FM, the total transmitted power remains constant.



(a) HF carrier wave



(b) LF modulating

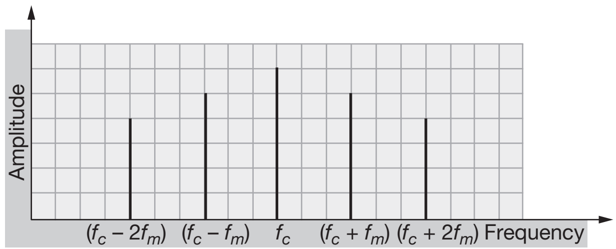


(c) FM wave

4. Frequency deviation: The maximum change in frequency from mean value (ν_c) is known as frequency deviation. This is also the change or shift either above or below the frequency ν_c and is called as frequency deviation.

   $$\therefore \quad \delta = (f_{\max} - f_c) = f_c - f_{\min} = k_f \cdot \frac{E_m}{2\pi}$$

   k_f = Constant of proportionality. It determines the maximum variation in frequency of the modulated wave for a given modulating signal.
5. Carrier swing (CS): The total variation in frequency from the lowest to the highest is called the carrier swing.
   i.e. $CS = 2 \times \Delta f$
6. Frequency modulation index (m_f): The ratio of maximum frequency deviation to the modulating frequency is called modulation index. $m_f = \dfrac{\delta}{f_m} = \dfrac{f_{\max} - f_c}{f_m} = \dfrac{f_c - f_{\min}}{f_m} = \dfrac{k_f E_m}{f_m}$
7. Frequency spectrum: FM side band modulated signal consist of infinite number of side bands whose frequencies are $(f_c \pm f_m), (f_c \pm 2f_m), (f_c \pm 3f_m)$.......
   The number of side bands depends on the modulation index m_f.



In FM signal, the information (audio signal) is contained in the side bands. Since the side bands are separated from each other by the frequency of modulating signal f_m so
Band width $= 2n \times f_m$; where n = number of significant side band pairs

8. Deviation ratio: The ratio of maximum permitted frequency deviation to the maximum permitted audio frequency is known as deviation ratio. Thus, deviation ratio $= \dfrac{(\Delta f)_{\max}}{(f_m)_{\max}}$

9. Percent modulation: The ratio of actual frequency deviation to the maximum allowed frequency deviation is defined as percent modulation. Thus, percent modulation, $m = \frac{(\Delta f)_{\text{actual}}}{(\Delta f)_{\text{max}}}$

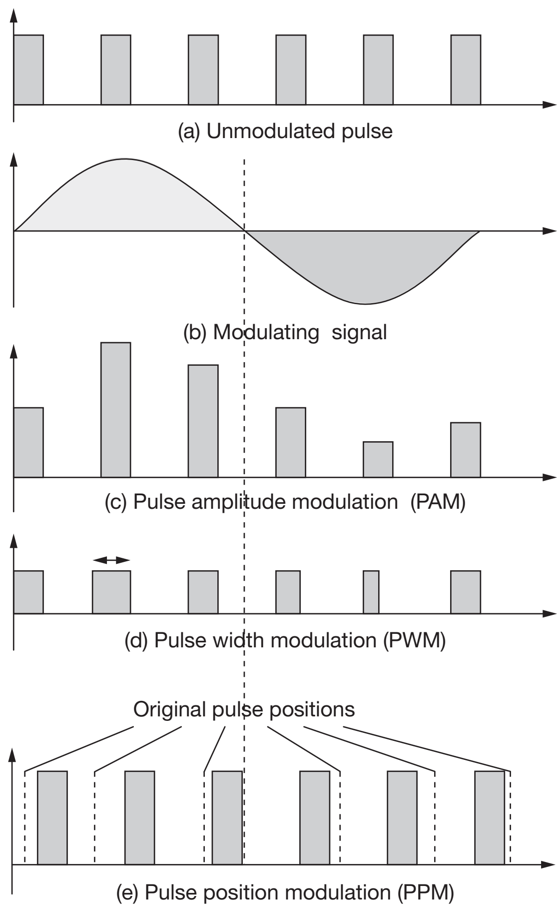
Range of frequency allotted for FM radio/TV broadcast

Type of broadcast	Frequency band
FM radio	88 to 108 MHz
UHF TV	47 to 230 MHz
UHF TV	470 to 960 MHz

Pulse Modulation

Here the carrier wave is in the form of pulses.

1. Pulse amplitude modulation (PAM): The amplitude of the pulse varies in accordance with the modulating signal.
2. Pulse width modulation (PWM): The pulse duration varies in accordance with the modulating signal.



3. Pulse position modulation (PPM): In PPM, the position of the pulses of the carrier wave train is varied in accordance with the instantaneous value of the modulating signal.

Pulse Code Modulation

The pulse amplitude, pulse width and pulse position modulations are not completely digital.

A completely digital modulation is obtained by pulse code modulation (PCM).

An analog signal is pulse code modulated by following three operations.

1. Sampling: It is the process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal.
   The number of samples taken per second is called sampling rate.
2. Quantization: The process of dividing the maximum amplitude of the analog voltage signal into a fixed number of levels is called quantisation.
   e.g. amplitude 5 V of the analog voltage signal divides into six. Quantization level viz 0, 1, 2, 3, 4, 5.
   Pulses having amplitude between – 0.5 V to 0.5 V are approximated (quantised) to a value 0 V, amplitude between 0.5 V to 1.5 V are approximated to a value of 1 V and so on.
3. Coding: The process of digitising the quantized pulses according to some code is called coding.

DEMODULATION

The process of extracting the audio signal from the modulated wave is known as demodulation or detection.

The wireless signals consist of radio frequency (high frequency) carrier wave modulated by audio frequency (low frequency). The diaphragm of a telephone receiver or a loud speaker cannot vibrate with high frequency. So it is necessary to separate the audio frequencies from the radio frequency carrier wave.

SIMPLE DEMODULATOR CIRCUIT

A diode can be used to detect or demodulate an amplitude modulated (AM) wave. A diode basically acts as a rectifier i.e. it reduces the modulated carrier wave into positive envelope only.

The AM wave input is shown in Fig. 20.3. It appears at the output of the diode across *PQ* as a rectified wave (since a diode conducts only in the positive half cycle). This rectified wave after passing through the *RC* network does not contain the radio frequency carrier component. Instead, it has only the envelope of the modulated wave.

In the actual circuit the value of RC is chosen such that $\frac{1}{f_c} << RC$; where f_C = frequency of carrier signal.

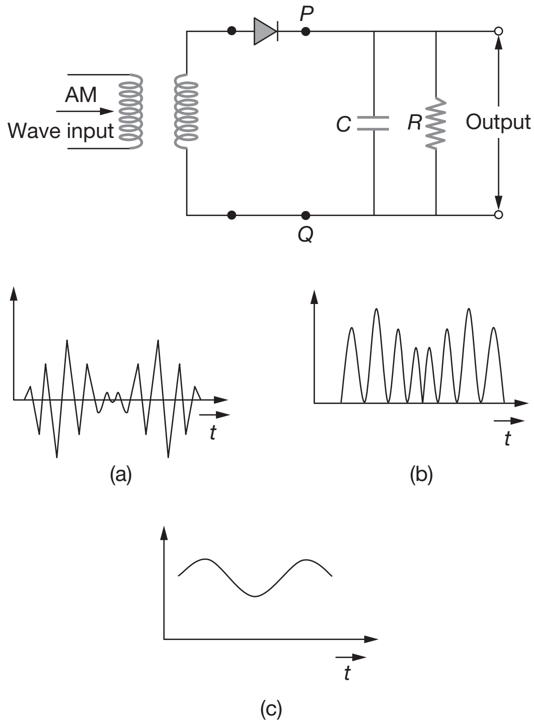


Fig. 20.3

Data Transmission and Retrieval

The term data is applied to a representation of facts, concepts or instructions suitable for communication, interpretation or processing by human beings or by automatic means. Data in most cases consists of pulse type of signals.

The pulse code modulated (PCM) signal is a series of 1's and 0's. The following three modulation techniques are used to transmit a PCM signal.

Amplitude Shift Keying (ASK)

Two different amplitudes of the carrier represent the two binary values of the PCM signal. This method is also known as on-off keying (OOK)

1: Presence of carrier of same constant amplitude.
0: Carrier of zero amplitude.

Frequency Shift Keying (FSK)

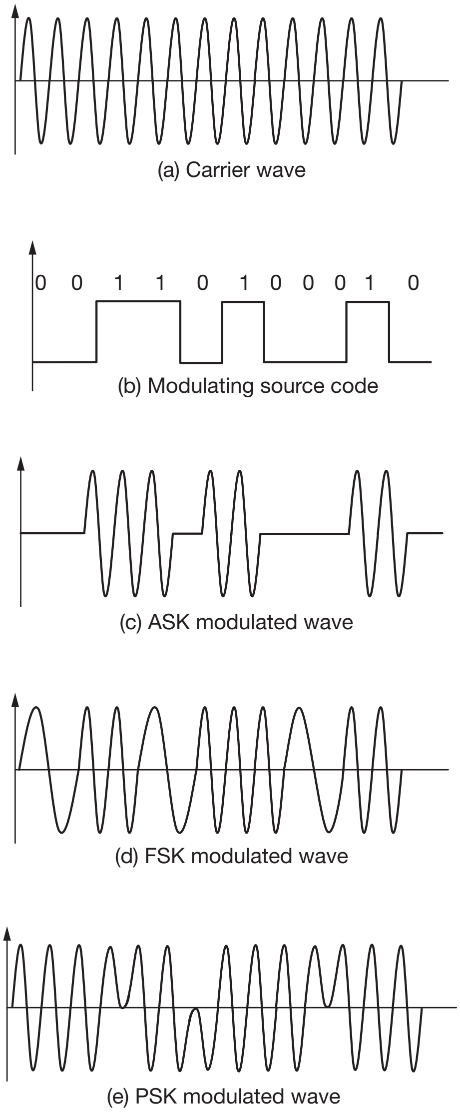
The binary values of the PCM signal are represented by two frequencies.

1: Increase in frequency
0: Frequency unaffected

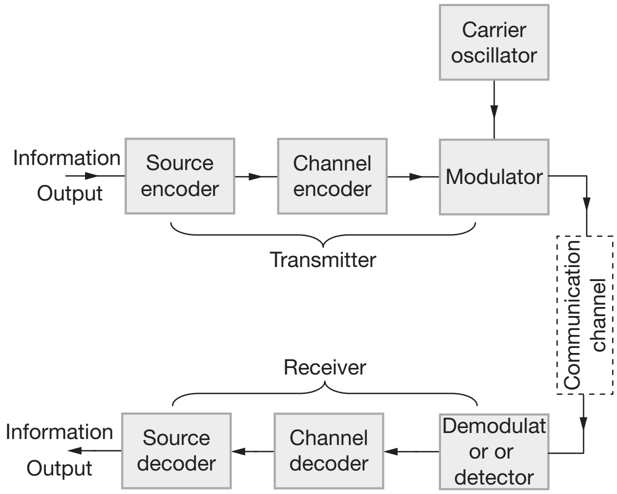
Phase Shift Keying (PSK)

The phase of the carrier wave is changed in accordance with modulating data signal.

1: Phase changed by π
0: Phase remains unchanged



The analog signal is sampled by the sampler. The sampled pulses are then quantised. The encoder codes the quantised pulses according to the binary codes. After modulating the PCM signal (by ASK, FSK or PSK method) the modulated signal is, then transmitted into free space in the form of bits.

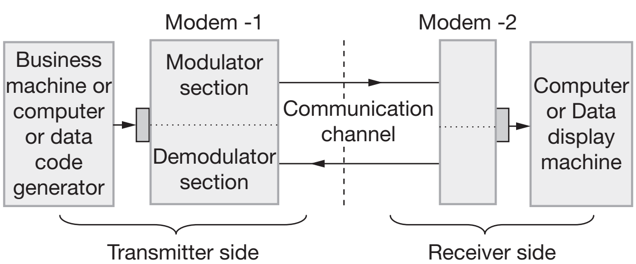


Modem and Fax

Modem

Modems are used to interface two digital sources/receivers.

1. Word modem has been obtained from the words modulator and demodulator. As the name implies both the functions (modulation) and demodulation) are included in a signal unit.
2. Modems are placed at both ends of the communication circuit as shown.



3. The modem at the transmitting station changes the digital output from a computer (or any other business machine) to a (analog signal) which can be easily sent via a communication channel (Telephone line etc.). While the receiving modem reverses the process.
4. There are three modes of operation of a modem.
   (i) Simplex mode: In this mode data is transmitted in only one direction.
   (b) Half duplex: In this mode data is transmitted between the transmitter and the receiver in both direction, but only in one direction at a time.
   (c) Full duplex: In this mode, the data are transmitted between the transmitter and receiver in both directions at the same time.

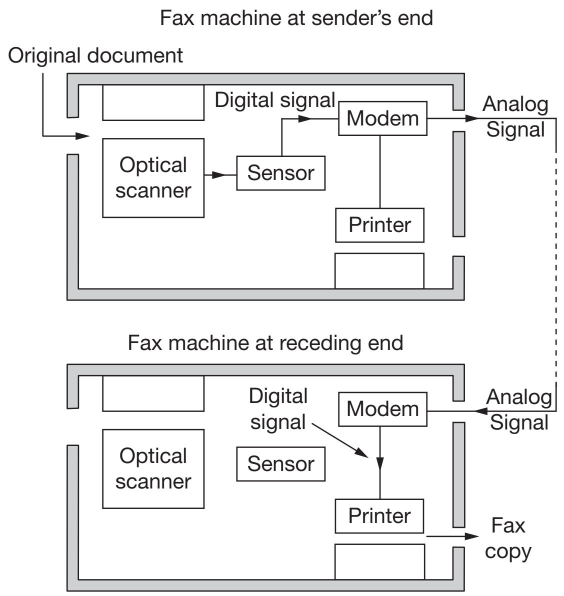
Modem data transmission speed

Types	Speed in bits per sec and (bps)
Low speed modem	600 bps
Medium speed modem	600 to 2400 bps
High speed modem	2400 to 10,800 bps

Fax (Facsimile transmission)

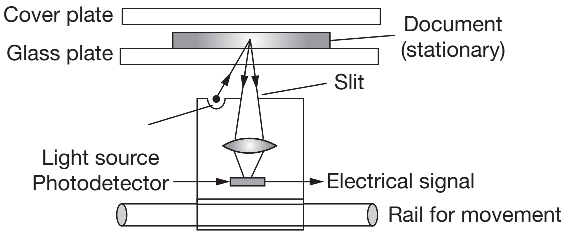
The electronic reproduction of a document at a distance place is known as facsimile transmission (FAX).

The original written document is converted into transmittable codes at the sending end. These codes are converted back into a copy of the original document at the receiving end.



The original written document is put into the machine. A scanner scans the whole document.

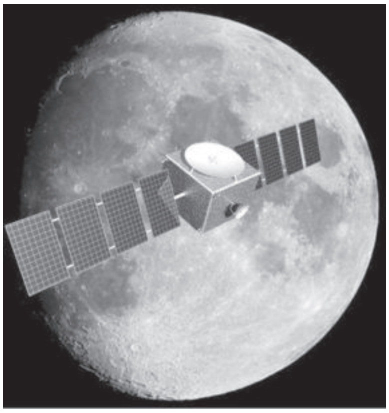
The scanned written document is then moved on a glass plate. A beam of light from a given source is projected through the glass and is reflected from the surface of the document.



The reflected light is focussed on a device known as photo detector which converts the optical signals (carrying the information regarding the patterns/writings/signatures etc.) in to electrical signals.

These electrical signals are then modulated and transmitted on to the telephone lines to the receiving end.

SPACE COMMUNICATION



The communication process utilising the physical space around the earth is termed as space communication.

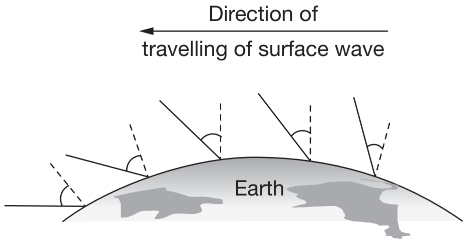
Electromagnetic waves which are used in Radio, Television and other communication system are radio waves and microwaves.

The radio waves emitted from a transmitter antenna can reach the receiver antenna by the following mode of operation.

1. Ground wave propagation
2. Sky wave propagation.
3. Space wave propagation.

Ground Wave Propagation

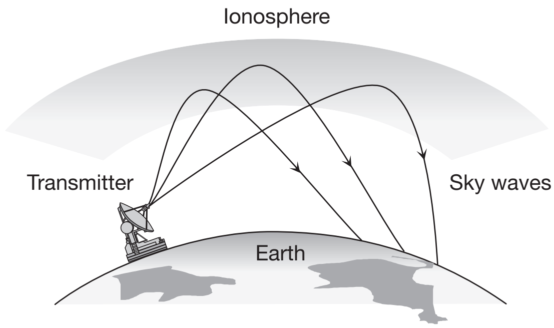
1. In ground wave propagation, radio waves travel along the surface of the earth (following the curvature of earth).
2. These waves induce currents in the ground as they propagate due to which some energy is lost.
3. The decrease in the value of energy (i.e. attenuation) increases with the increase in the frequency of radio wave.
4. As the ground wave propagates over the earth, it tilts over more and more due to diffraction. (This is another cause of attenuation of ground wave). After covering some distance, the wave just lies down which means its death.



5. Ground wave propagation can be sustained only at low frequencies (~ 500 kHz to 1500 kHz) or for radio broadcast at long wavelengths.

Sky Wave Propagation

1. These are the waves which are reflected back to the earth by ionosphere. Ionosphere is a layer of atmosphere having charged particles, ions and electrons and extended above 80 km – 300 km from the earth's surface.



2. These are the radio waves of frequency range 2 MHz to 30 MHz.
3. Sky waves are used for very long distance radio communication at medium and high frequencies (i.e. at medium waves and short waves).
4. The sky waves being electromagnetic in nature, changes the dielectric constant and refractive index of the ionosphere. The effective refractive index of the ionosphere

is $n_{\text{eff}} = n_0\left[1-\dfrac{Ne^2}{\varepsilon_0 m\omega^2}\right]^{1/2} = n_0\left[1-\dfrac{80.5N}{f^2}\right]^{1/2}$

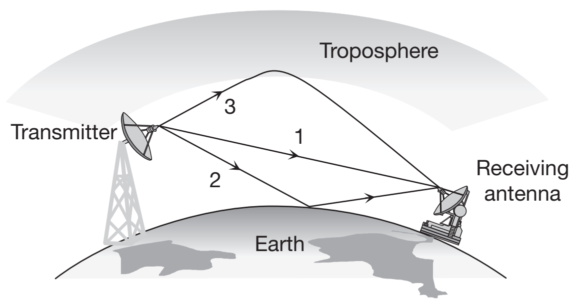
where n_0 = refractive index of free space, N = electron density of ionosphere, ε_0 = dielectric constant of free space, e = charge on electron, m = mass of electron ω = angular frequency of EM wave.

5. As we go deep into the ionosphere, N increases so n_{eff} decreases. The refractions or bending of the beam will continue and finally it reflects back.
6. Critical frequency (f_c): It is defined as the highest frequency of radio wave, which gets reflected to earth by the ionosphere after having been sent straight to it.
   If maximum electron density of the ionosphere is N_{max} per m^3, then $f_c \approx 9(N_{max})^{1/2}$. Above f_c, a wave will penetrate the ionosphere and is not reflected by it.
7. Maximum usable frequency (MUF): It is the highest frequency of radio waves which when sent at some angle of incidence θ, towards the ionosphere, get reflected and return to the earth. $\text{MUF} = \dfrac{f_c}{\cos\theta}$

Space Wave Propagation

The space waves are the radio waves of very high frequency (30 MHz to 300 MHz) ultra-high frequency (300 MHz to 3000 MHz) and microwave (more than 3000 MHz). At such high frequencies, the sky wave as well as ground wave propagation both fails.

These waves can be transmitted from transmitting to receiving antenna either directly or after reflection from the ground or in troposphere, the wave propagation is called space wave propagation.



The space wave propagation is also called as line of sight propagation. The line of sight distance is the distance between transmitting antenna and receiving antenna at which they can see each other.

Space wave propagation can be utilised for transmitting high frequency TV and FM signals.

Television Signal Propagation

Frequency range for propagation is 80 MHz to 200 MHz

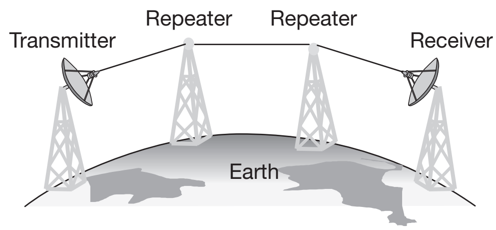
Height of transmitting antenna: $h = \dfrac{d^2}{2R}$ (d = distance covered by the signal, R = Radius of the Earth)

$$\text{Area covered: } A = \pi d^2 = 2\pi Rh$$

Population cover: Population density × Area covered

Microwave Communication

Microwave communication systems are used for long distance communication. Since at microwave frequencies, electromagnetic waves cannot bend across the obstacles, such as the top of the buildings, mountains etc., it is therefore necessary that microwave transmission is in line-of-sight.

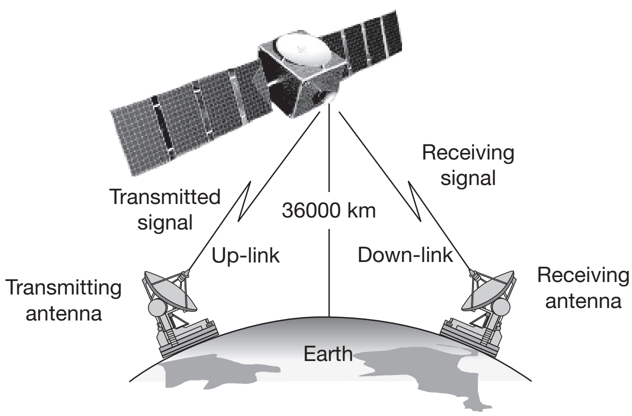


Due to curvature in the surface of earth, the range of microwave transmission is very small (≈ 50 km). The range of microwave transmission is also limited by the fact that signals gets weaker and weaker as it propagates. However, these problems are overcome by using repeaters (A repeater is basically an amplifier, which amplifies the attenuated signal and then retransmits it.) at intervals between the transmitter and the receiver. Due to this, the cost of transmission of signal between the two stations increases.

The problems faced in a microwave communication system are solved to a large extent by using a geostationary satellite as a communication satellite.

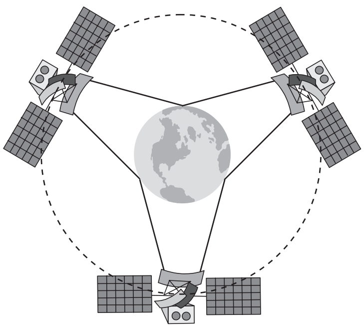
SATELLITE COMMUNICATION

1. Satellite communication is like the line-of-sight microwave transmission. In this case, a beam of modulated microwave is projected towards the satellite.



2. Satellite communication is mainly done through geostationary satellites (for steady reliable transmission and reception).

3. A geostationary satellite has the same time period of revolution of earth (i.e. 24 hrs.). It appears stationary with respect to earth. It locates at the height of 36000 km above the earth's surface (well above the ionosphere).
4. A communication satellite is a spacecraft placed in an orbit around the earth which carriers a transmitting and receiving equipment called radio transponder. It amplifies the microwave signals emitted by the transmitter from the surface of earth and send them to the receiving station on earth.
5. The transmitted signal is UP-LINKED and received by the satellite station which DOWN-LINKS it with the ground station through its transmitter.
   The up-link and down-link frequencies are kept different (both frequencies being in the regions of UHF/microwave).
6. A single satellite cannot cover the entire surface of the earth. At least three geo-stationary satellites are required which are 120° apart from each other to have the communication link over the entire globe of earth.

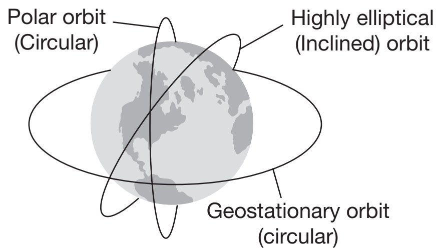


7. Satellite technology is very useful in collecting information about various factors of the atmosphere which governs the weather and climatic conditions.
   The satellite communication can be used for establishing mobile communication with great use the communication satellites are now being used in Global Positioning System (GPS). The ordinary users can find their positions within accuracy of 100 m.
   There are two types of satellites used for long distance transmission.
   (i) Passive satellite: It acts as reflector only for the signals transmitted from earth. Moon the natural satellite of earth is a passive satellite.
   (ii) Active satellite: It carries all the equipment used for receiving signals sent from the earth, processing them and then re-transmitting them to the earth. Nowadays active satellites are in use.
8. The Indian communication satellites INSAT-2B and INSAT-2C are positioned in such away in the outer space that they are accessible from any place in India.

REMOTE SENSING

Remote sensing is the technique to obtain information about an object (in respect of its size, colour nature, location, temperature etc.) by observing it from a distance and without coming to actual contact with it.

1. There are two types of remote sensing instruments: active and passive. Active instruments provide their own energy to illuminate the object of interest, as radar does. They send an energy pulse to the object and then receive and process the pulse reflected from the object. Passive instruments sense only radiations emitted by the object or solar radiation reflected from the object.
2. The remote sensing is done through a satellite. The satellite used in remote sensing should move in an orbit around the earth in such a way that it always passes over the particular area of the earth at the same local time.
   The orbit of such a satellite is known as sun-synchronous orbit. A remote sensing orbit can be circular polar orbit or in highly inclined elliptical orbit.



3. A remote sensing satellite takes, photographs of a particular region which nearly the same illumination every time it passes through that region.
4. The most useful remote sensing technology is that it makes possible the repetitive surveys of vast areas in a very short time, even if the areas are inaccessible.
5. Space based remote sensing is a new technology. It has high potential for applications in nearly all aspects of resource management.
6. The Indian remote sensing satellites are IRS-1A, JRS-1B, and IRS-1C.
7. Some applications of remote sensing includes
   (i) Meteorology: (development of weather systems and weather for casting).
   (ii) Climatology: Monitoring climatic changes.
   (iii) Oceanography: (Sea surface temperatures, mapping of sea-ice and oil pollution monitoring).
   (iv) Archaeology, geological surveys.
   (v) Water resource surveys.
   (vi) Urban land use surveys.
   (vii) Agriculture and forestry and natural disaster.

(viii) In the field of spying to detect movements of enemy army at their positions.

(ix) It is used to locate the place where underground nuclear explosion has carried out.

LINE COMMUNICATION

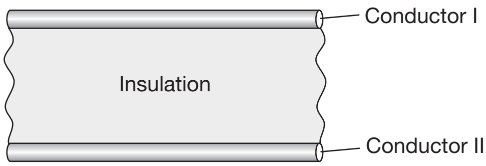
Line communication means interconnection of two points that are at some distance from each other with the help of wires for exchange of information e.g. interconnection between a transmitter and receiver or a transmitter and antenna or an antenna and receiver.

Two Wire Transmission Line

The most commonly used two wire lines are: Parallel wire, twisted pair wires and co-axial cable.

Parallel Wire Line

In a two wire transmission line, two metallic wires are arranged parallel to each other inside a protective insulation coating.

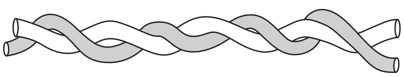


1. The wires may be hard or flexible depending on the power to be handled.
2. It is commonly used to connect an antenna with TV receiver.
3. Such wires can suffer from interferences and losses.

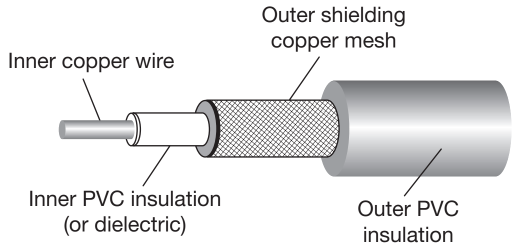
Twisted Pair Wire

It consists of two insulated copper wires twisted around each other at regular intervals to minimize electrical interference.

1. Twisted pair wires are used to connect telephone systems. It works well up to a distance of about 10 *cm*. They cannot transmit signals over very large distances.



2. They can be used for transmitting both, the analog and digital signals.
3. They are easy to install and cost effective.



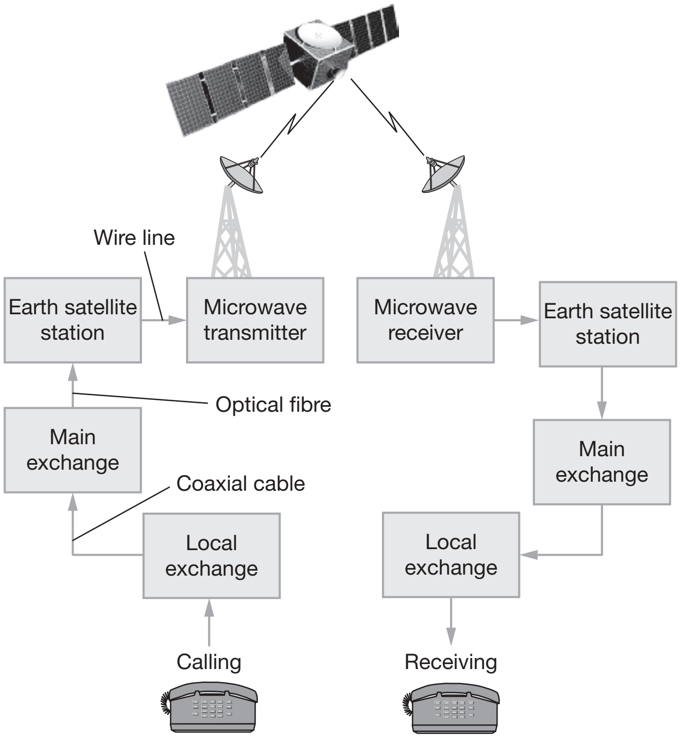
Coaxial Wire Lines

It consist of a central copper wire (which transmits the signals) surrounded by a PVC insulation over which a sleeve of copper mesh (outer conductor) is placed. The outer conductor is normally connected to ground and thus it provides an electrical shield to the signals carried by the central conductor. The outer conductor is externally covered with a polymer jacket for protection.

1. Co-axial line wires can be used for microwaves and ultra-high frequency waves.
2. The communication through co-axial lines is more efficient than through a twisted pair wire lines.
3. Co-axial cables can be gas filled also. To reduce flash over between the conductors handling high power, N_2-gas is used in the cable.

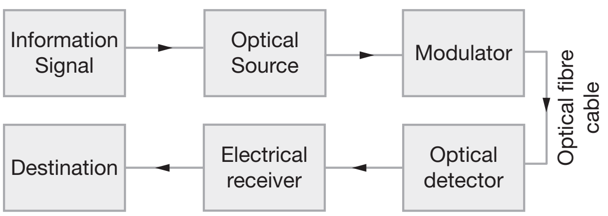
Telephone Links

1. Telephone is the most common means of communication. Nowadays, the telephone system is required to converse from earth to other heavenly bodies like moon etc.
2. A telephone link can be established with the help of co-axial cables, ground waves, sky waves, microwaves or optical fibre cables.
3. Simultaneous transmission of a number of messages over a single channel without their interfering with one another is called multiplexing. Two types of multiplexing techniques are in use:
   (i) Frequency division multiplexing uses analog modulation of message signals.
   (ii) Time division multiplexing makes use of pulse modulation of message signals.
4. Twisted pair wire lines provide a band width of 2 MHz, while co-axial cable provides a band width of 20 MHz. For further increase in band width, we use
   (i) microwave link.
   (ii) communication satellite link.



OPTICAL COMMUNICATION

1. The use of optical carrier waves for transmission of information from one place to another is called optical communication.
2. The useful optical frequency range is 10^{12} Hz to 10^{16} Hz which is very high as compared to radio and microwave frequencies (10^6 Hz – 10^{11} Hz).
3. The information carrying capacity ∝ bandwidth ∝ frequency of carrier wave. So, optical communication is better than others. (because of high frequency).
4. Basic setup of optical communication shown below

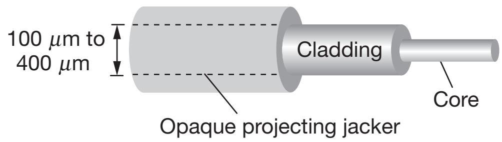


5. Light emitting diodes (LED) and diode lasers are preferred for optical source. LED's are used for small distance transmission while diode laser is used for very large distance transmission.
6. In order to transmit information signal via an optical communication system, it is necessary to modulate light with the information signal.
7. The optical signal reaching the receiving end has to be detected by a detector which converts light into electrical signals, So that the transmitted information may be decoded. Semiconductor based photo-electors are used.

Optical Fibre

The optical fibres are used to transmit light signals from one place to another without any practical loss in the intensity of light signal.

1. Design: Optical fibre is made of a thin glass core (diameter 10 to 100 μm) surrounded by a glass coating called cladding are protected by a jacket of plastic.



2. Principle: It works on the principle of total internal reflection.
3. Action: The refractive index of the glass used for making core ($\mu_1 \approx 1.7$) is a little more than the refractive index of the glass ($\mu_2 \approx 1.5$) used for making the cladding i.e. $\mu_1 > \mu_2$.
   The core dimension is so small ($\approx 10\ \mu$m) that the light entering will almost essentially be having incident angle (θ_i) more than the critical angle (θ_C) and will suffer total internal reflection at the core. Cladding boundary such successive total reflections at opposite boundaries will confine the light to the core as shown in Fig. 20.4.

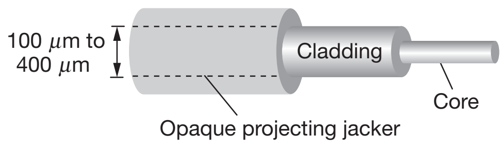


Fig. 20.4.

Advantages of Optical Fibres over Wires

1. Lower cost in the long run.
2. Low loss of signal typically less than 0.3 dB/km), so repeater-less transmission over long distances is possible.
3. Large data-carrying capacity (thousands of times greater, reaching speeds of up to 1.6 Tb/s in field deployed systems and up to 10 Tb/s in lab systems).
4. No electromagnetic radiation; difficult to eavesdrop.
5. High electrical resistance, so safe to use near high-voltage equipment or between areas with different earth potentials.
6. Low weight.

7. Signals contain very little power.
8. No cross talk between cables.
9. No sparks (e.g. in automobile applications)
10. Difficult to place a tap or listening device on the line, providing better physical network security.

LASER

Laser is a process by which we get a beam which is coherent, highly monochromatic and almost perfectly parallel. Such a beam is also called laser.

Coherent

Because all the photons in the light beam, emitted by different atoms, at different instant are in phase.

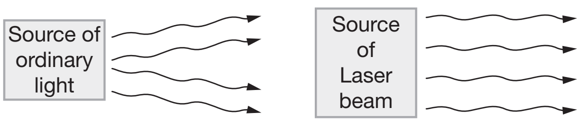
Monochromatic

Because, the spread $\Delta\lambda$ in wavelength is very small, of the order of 10^{-6} nm.

Perfectly parallel

Because, a laser beam can be sent to a far off place and returns back without any practical loss of intensity.

The term LASER stands for Light Amplification by Stimulated Emission Radiation.

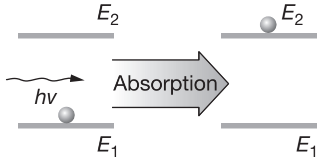


(a) In coherent beam (b) Coherent beam

Concepts Related to Production of Laser

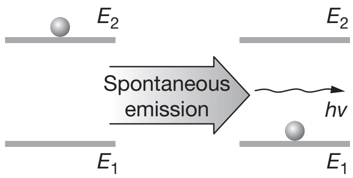
Stimulated Absorption

Consider an atom which has an allowed state at energy E_1 and another allowed state at a higher energy E_2. Suppose the atom is in the lower energy state E_1. If a photon of light having energy $E_2 - E_1$ is incident on this atom, the atom may absorb the photon and jump to the higher energy state E_2. This process is called stimulated absorption of light photon. The incident photon has stimulated the atom to absorb the energy.



Spontaneous Emission

If an atom is present in the higher energy state, it tends to return to the lower energy state within a time of 10^{-8} s by emitting a photon of energy $h\nu = E_2 - E_1$. We call this process spontaneous emission because the event was not triggered by any outside influence.

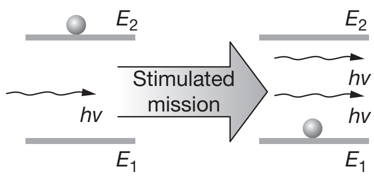


Stimulated Emission

Suppose a photon of energy $h\nu = E_2 - E_1$ interacts with an atom that is already in the excited state E_2.

The incident photon may stimulate the atom to emit a photon, the energy, phase, and direction of travel of this second photon are exactly the same as those of the incident photon. That is the quantum state of the stimulated photon is identical to that of the incident photon. This process is called stimulated emission.

If these two photons then interact with two more excited state atoms, two more photons are produced, and soon. Therefore, the stimulation process leads to photon amplification.



Population Inversion

Usually the number of atoms in the lower energy state is more than the number of atoms in the excited state. To emit photons which are coherent (i.e. in phase), the number of atoms in the higher state must be greater than the number of atoms in the lower energy state. In other words, population of atoms in the higher energy state must be larger than the population of atoms in the lower energy state. The process of making the population of atoms in the higher energy state more than that of lower energy state is known as population inversion.

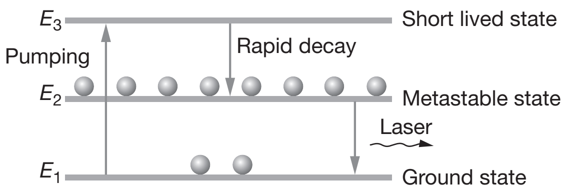
The method used to invert the population of atoms is known as pumping.

Metastable States

A metastable state is one, which has a mean life time of the order of 10^{-3} s or more i.e. much larger than 10^{-8} s, the life time of a higher energy state. Some atomic systems, such as chromium, neon, etc possess metastable states. The atom of such an atomic system, when in higher energy state, does not come down to lower energy state directly. It first returns to metastable state and then after a finite lapse of time of the order of 10^{-3} s, returns to the lower energy state. Since such atom stays in metastable state for a sufficiently long time, the population inversion can sustain in such atomic system.

A system in which population inversion is achieved is called the active system.

Principle of Laser

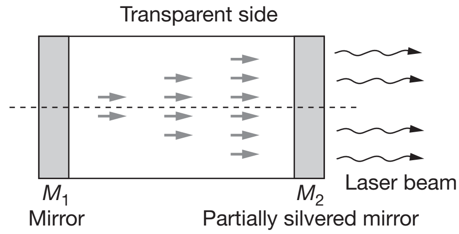


Atoms from the ground state E_1 are 'pumped' up to an excited state E_3. From E_3 the atom decays rapidly to state of energy E_2. For lasing (lasing means laser action) to occur, this state must be metastable. If conditions are right, state E_2 can then become more heavily populated than state E_1, thus providing the needed population inversion.

When photon of energy $h\nu = E_2 - E_1$ is incident on one of the atoms present in the metastable state, the atom will drop to lower energy state E_1, emitting a photon of same energy as that of the incident photon, which is in phase with it and is emitted in the same direction. The two photons then interact with two more atoms present in metastable state and so on. This process is called amplification of light.

For smooth process two conditions are necessary

1. The metastable state should all the time have larger number of atoms than the number of atoms in lower energy state. (It is achieved by pumping)
2. The photons emitted due to stimulated emission should stimulate other atoms to multiply the photons inside the system.
   (It is achieved by two mirrors are fixed at the ends of the system containing lasing material. The mirrors reflect the photons back and forth to keep them inside the region for a long time.)



SOLVED EXAMPLES

1. For a transistor the parameter $\beta = 99$. The value of the parameter α is
   (A) 0.9 (B) 0.99 (C) 1 (D) 9

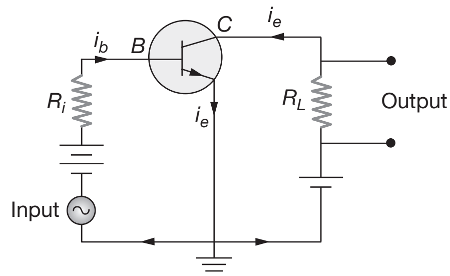
Solution: (B)

$$\alpha = \frac{\beta}{1+\beta} = \frac{99}{1+99} = 0.99 .$$

2. A transistor is used in common emitter mode as an amplifier. Then
   (A) The base-emitter junction is forward biased
   (B) The base-emitter junction is reverse biased
   (C) The input signal is connected in series with the voltage applied to the base-emitter junction
   (D) The input signal is connected in series with the voltage applied to bias the base collector junction

Solution: (A) and (C)

The circuit of a *CE* amplifier is as shown below.



This has been shown a *NPN* transistor. Therefore base emitter is forward, biased and input signal is connected between base and emitter.

3. In a *PNP* transistor the base is the *N*-region. Its width relative to the *P*-region is
   (A) Smaller (B) Larger
   (C) Same (D) Not related

Solution: (A)

The base is always thin

4. A common emitter amplifier is designed with *NPN* transistor ($\alpha = 0.99$). The input impedance is 1 KΩ and load is 10 KΩ. The voltage gain will be

(A) 9.9 (B) 99 (C) 990 (D) 9900

Solution: (C)

Voltage gain = $\beta \times$ Resistance gain

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{(1-0.99)} = 99$$

$$\text{Resistance gain} = \frac{10\times 10^3}{10^3} = 10$$

$\Rightarrow$ Voltage gain = 99 × 10 = 990.

5. The part of a transistor which is heavily doped to produce a large number of majority carriers, is

(A) Base (B) Emitter
(C) Collector (D) None of these

Solution: (B)

Emitter is heavily doped.

6. For a transistor, the current amplification factor is 0.8. The transistor is connected in common emitter configuration. The change in the collector current when the base current changes by 6 mA is

(A) 6 mA (B) 4.8 mA
(C) 24 mA (D) 8 mA

Solution: (C)

$$\alpha = 0.8 \Rightarrow \beta = \frac{0.8}{(1-0.8)} = 4$$

Also

$$\beta = \frac{\Delta i_c}{\Delta i_b} \Rightarrow \Delta i_c = \beta \times \Delta i_b = 4 \times 6 = 24 \text{ mA}.$$

7. In a common base amplifier circuit, calculate the change in base current if that in the emitter current is 2 mA and $\alpha = 0.98$

(A) 0.04 mA (B) 1.96 mA
(C) 0.98 mA (D) 2 mA

Solution: (A)

$$\Delta i_c = \alpha\, \Delta i_e = 0.98 \times 2 = 1.96 \text{ mA}$$

$$\therefore\ \Delta i_b = \Delta i_e - \Delta i_c = 2 - 1.96 = 0.04 \text{ mA}$$

8. In a transistor, a change of 8.0 mA in the emitter current produces a change of 7.8 mA in the collector current. What change in the base current is necessary to produce the same change in the collector current?

(A) 50 μA (B) 100 μA
(C) 150 μA (D) 200 μA

Solution: (D)

$$\Delta i_e = \Delta i_c + \Delta i_b$$

$\Rightarrow$ $8 = 7.8 + \Delta i_b \Rightarrow \Delta i_b = 0.2 \text{ mA} = 200\ \mu\text{A}.$

9. The relation between α and β parameters of current gains for a transistors is given by

(A) $\alpha = \dfrac{\beta}{1-\beta}$ (B) $\alpha = \dfrac{\beta}{1+\beta}$

(C) $\alpha = \dfrac{1-\beta}{\beta}$ (D) $\alpha = \dfrac{1+\beta}{\beta}$

Solution: (B)

$$i_e = i_b + i_c \Rightarrow \frac{i_e}{i_c} = \frac{i_b}{i_c} + 1 \Rightarrow \frac{1}{\alpha} = \frac{1}{\beta} + 1 \Rightarrow \alpha = \frac{\beta}{(1+\beta)}.$$

10. When *NPN* transistor is used as an amplifier

(A) Electrons move from base to emitter
(B) Electrons move from emitter to base
(C) Electrons moves from base to emitter
(D) Holes moves from base to emitter

Solution: (B)

In *NPN* transistor when emitter-base is forward biased, electrons move from emitter to base.

11. In a transistor in *CE* configuration, the ratio of power gain to voltage gain is

(A) α (B) β/α
(C) $\beta\alpha$ (D) β

Solution: (D)

For *CE* configuration voltage gain $= \beta \times R_L / R_i$

$$\text{Power gain} = \beta^2 \times R_L / R_i \Rightarrow \frac{\text{Power gain}}{\text{Voltage gain}} = \beta$$

12. In the study of transistor as an amplifier, if $\alpha = I_c / I_e$ and $\beta = I_c / I_b$, where I_c, I_b and I_e are the collector, base and emitter currents, then

(A) $\beta = \dfrac{1-\alpha}{\alpha}$ (B) $\beta = \dfrac{\alpha}{1-\alpha}$

(C) $\beta = \dfrac{\alpha}{1+\alpha}$ (D) $\beta = \dfrac{1+\alpha}{\alpha}$

Solution: (B)

As we know

$$i_E = i_C + i_B$$

$$\Rightarrow \frac{i_e}{i_c} = 1 + \frac{i_b}{i_c} \Rightarrow \frac{1}{\alpha} = 1 + \frac{1}{\beta} \Rightarrow \beta = \frac{\alpha}{1-\alpha}.$$

13. The following truth table corresponds to the logic gate

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

(A) NAND (B) OR
(C) AND (D) XOR

Solution: (B)

For 'OR' gate $X = A + B$

i.e. $0+0=0$, $0+1=1$, $1+0=1$, $1+1=1$

14. The combination of 'NAND' gates shown here under Fig. 20.6 is equivalent to

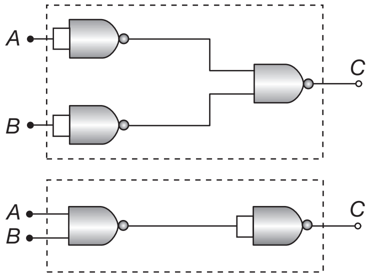
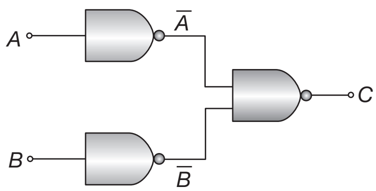


Fig. 20.6

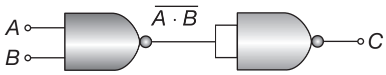
(A) An OR gate and an AND gate respectively
(B) An AND gate and a NOT gate respectively
(C) An AND gate and an OR gate respectively
(D) An OR gate and a NOT gate respectively

Solution: (A)



$C = \overline{\bar{A} \cdot \bar{B}} = \overline{\bar{A}} + \overline{\bar{B}} = A + B$ (De morgan's theorem)

Hence output C is equivalent to OR gate.



$$C = \overline{\overline{AB} \cdot \overline{AB}} = \overline{\overline{AB}} + \overline{\overline{AB}} = AB + AB = AB$$

In this case output C is equivalent to AND gate.

15. A truth table is given below. Which of the following has this type of truth table?

A	0	1	0	1
B	0	0	1	1
y	1	0	0	0

(A) XOR gate (B) NOR gate
(C) AND gate (D) OR gate

Solution: (B)

In 'NOR' gate $Y = \overline{A+B}$

i.e $\overline{0+0} = \bar{0} = 1$, $\overline{1+0} = \bar{1} = 0$

$\overline{0+1} = \bar{1} = 0$, $\overline{1+1} = \bar{1} = 0$

16. The truth table shown in figure is for

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

(A) XOR (B) AND
(C) XNOR (D) OR

Solution: (C)

For 'XNOR' gate $Y = \bar{A}\,\bar{B} + AB$

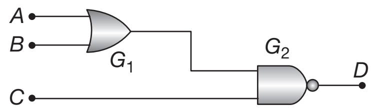
i.e. $\bar{0}.\bar{0} + 0.0 = 1.1 + 0.0 = 1 + 0 = 1$

$\bar{0}.\bar{1} + 0.1 = 1.0 + 0.1 = 0 + 0 = 0$

$\bar{1}.\bar{0} + 1.0 = 0.1 + 1.0 = 0 + 0 = 0$

$\bar{1}.\bar{1} + 1.1 = 0.0 + 1.1 = 0 + 1 = 1$

17. For the given combination of gates, if the logic states of inputs A, B, C are as follows $A = B = C = 0$ and $A = B = 1$, $C = 0$ then the logic states of output D are



(A) 0, 0 (B) 0, 1
(C) 1, 0 (D) 1, 1

Solution: (D)

The output D for the given combination

$D = \overline{(A+B) \cdot C} = \overline{(A+B)} + \bar{C}$

If $A = B = C = 0$ then

$D = \overline{(0+0)} + \bar{0} = \bar{0} + \bar{0} = 1 + 1 = 1$

If $A = B = 1, C = 0$ then

$D = \overline{(1+1)} + \bar{0} = \bar{1} + \bar{0} = 0 + 1 = 1$

18. The logic behind 'NOR' gate is that it gives

(A) High output when both the inputs are low
(B) Low output when both the inputs are low
(C) High output when both the inputs are high
(D) None of these

Solution: (A)

The Boolean expression for 'NOR' gate is $Y = \overline{A+B}$
i.e. if $A = B = 0$ (Low), $Y = \overline{0+0} = \bar{0} = 1$ (High)

19. A gate has the following truth table

P	1	1	0	0
Q	1	0	1	0
R	1	0	0	0

The gate is

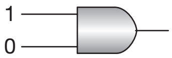
(A) NOR (B) OR
(C) NAND (D) AND

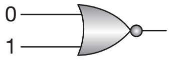
Solution: (D)

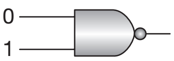
The Boolean expression for 'AND' gate is $R = P \cdot Q$

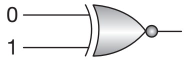
$$\Rightarrow 1.1 = 1,\ 1.0 = 0,\ 0.1 = 0,\ 0.0 = 0$$

20. Which of the following gates will have an output of 1?

(A) 

(B) 

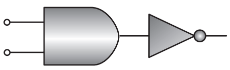
(C) 

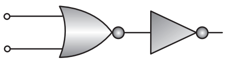
(D) 

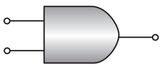
Solution: (C)

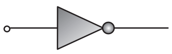
For 'NAND' gate (option c), output $= \overline{0.1} = \overline{0} = 1$

21. Which one represents NAND gate?

(A) 

(B) 

(C) 

(D) 

Solution: (A)

$$\text{AND} + \text{NOT} \rightarrow \text{NAND}$$

22. The given truth table is of

A	X
0	1
1	0

(A) OR gate (B) AND gate
(C) NOT gate (D) None of above

Solution: (C)

For 'NOT' gate $X = \overline{A}$

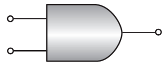
23. If A and B are two inputs in AND gate, then AND gate has an output of 1 when the values of A and B are

(A) $A = 0, B = 0$ (B) $A = 1, B = 1$
(C) $A = 1, B = 0$ (D) $A = 0, B = 1$

Solution: (B)

For 'AND' gate, if output is 1 then both inputs must be 1.

24. Which logic gate is represented by the following diagram?



(A) AND (B) OR
(C) NOR (D) XOR

Solution: (A)

The given symbol is of 'AND' gate.

25. To get an output 1 from the circuit shown in the Fig. 20.7, the input must be

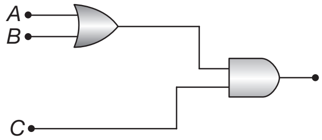


Fig. 20.7

(A) $A = 0,\ B = 1,\ C = 0$
(B) $A = 1,\ B = 0,\ C = 0$
(C) $A = 1,\ B = 0,\ C = 1$
(D) $A = 1,\ B = 1,\ C = 0$

Solution: (C)

The Boolean expression for the given combination is output $Y = (A + B) \cdot C$

The truth table is

A	B	C	Y = (A + B)·C
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
1	1	0	0
0	1	1	1
1	0	1	1
1	1	1	1

Hence, $A = 1,\ B = 0,\ C = 1$

26. The combination of the gates shown in the Fig. 20.8 below produces

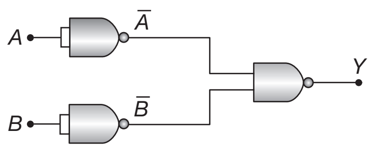
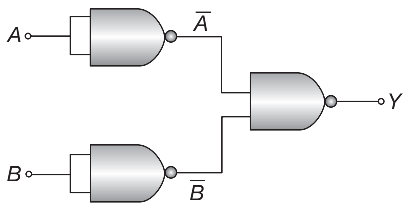


Fig. 20.8

(A) NOR gate (B) OR gate
(C) AND gate (D) XOR gate

Solution: (B)



$$Y = \overline{\overline{A}\cdot\overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$$

This output equation is equivalent to OR gate.

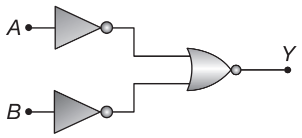
27. The output of a NAND gate is 0
(A) If both inputs are 0
(B) If one input is 0 and the other input is 1
(C) If both inputs are 1
(D) Either if both inputs are 1 or if one of the inputs is 1 and the other 0

Solution: (C)

If inputs are A and B then output for NAND gate is $Y = \overline{AB}$

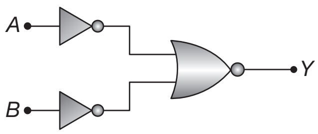
$\Rightarrow$ If $A = B = 1$, $Y = \overline{1.1} = \overline{1} = 0$

28. Which logic gate is represented by the following combination of logic gates?



(A) OR (B) NAND
(C) AND (D) NOR

Solution: **(C)**



$$Y = \overline{\overline{A} + \overline{B}}$$

According to De Morgan's theorem

$$Y = \overline{\overline{A} + \overline{B}} = \overline{\overline{A}}\cdot\overline{\overline{B}} = A\cdot B$$

This is the output equation of 'AND' gate.

29. The output of OR gate is 1
(A) If both inputs are zero
(B) If either or both inputs are 1
(C) Only if both input are 1
(D) If either input is zero

Solution: (B)

The output of OR gate is $Y = A + B$.

30. Which gates is represented by this Fig. 20.9.

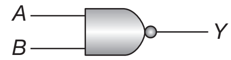


Fig. 20.9

(A) NAND gate (B) AND gate
(C) NOT gate (D) OR gate

Solution: (A)

The given symbol is of NAND gate.

31. A ground receiver station is receiving a signal at (i) 5 MHz and transmitted from a ground transmitter at a height of 300 m, located at a distance of 100 km from the receiver station. The signal is coming via. Radius of earth = 6.4×10^6 m. N_{max} of isosphere = 10^{12} m^3
(A) Space wave
(B) Sky wave propagation
(C) Satellite transponder
(D) All of these

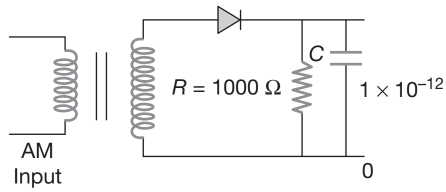
Solution: (B)

Maximum distance covered by space wave communication $\sqrt{2Rh} = 62\,\text{km}$

$$\text{Critical frequency} = f_c = 9(N_{max})^{1/2} \simeq 9\,\text{MHz}$$

5 MHz < f_c, sky wave propagation (ionospheric propagation)

32. In the given detector circuit, the suitable value of carrier frequency is



(A) << 10^9 Hz (B) << 10^5 Hz
(C) >> 10^9 Hz (D) None of these

Solution: (A)

$$\text{Using } \frac{1}{f_{carrier}} << RC$$

$$\text{We get time constant, } RC = 1000 \times 10^{-12} = 10^{-9}\,\text{s}$$

$$\text{Now } \nu = \frac{1}{T} = \frac{1}{10^{-9}} = 10^9\,\text{Hz}$$

Thus the value of carrier frequency should be much less than $10^9\,\text{Hz}$, say 100 kHz.

33. The impedance of coaxial cable, when its inductance is 0.40 μH and capacitance is 1×10^{-11} F, can be

(A) $2\times10^2\ \Omega$ (B) $100\ \Omega$
(C) $3\times10^3\ \Omega$ (D) $3\times10^{-2}\ \Omega$

Solution: (A)

Using $Z=\sqrt{\dfrac{L}{C}}$ we get $Z=\sqrt{\dfrac{0.40\times10^{-6}}{10^{-11}}}=2\times10^2\,\Omega$

34. A wave is represented as $e=10\sin(10^8t+6\sin1250t)$ then the modulating index is

(A) 10 (B) 1250
(C) 10^8 (D) 6

Solution: (D)

Comparing with standard equation.

35. An optical fibre communication system works on a wavelength of 1.3 μm. The number of subscribers it can feed if a channel requires 20 kHz are

(A) 2.3×10^{10} (B) 1.15×10^{10}
(C) 1×10^5 (D) None of these

Solution: (B)

Optical source frequency

$$f=\frac{c}{\lambda}=\frac{3\times10^8}{1.3\times10^{-6}}=2.3\times10^{14}\,\text{Hz}$$

$\therefore$ Number of channels or subscribers $=\dfrac{2.3\times10^{14}}{20\times10^3}$

$=1.15\times10^{10}$

36. In an FM system a 7 kHz signal modulates 108 MHz carrier so that frequency deviation is 50 kHz. The carrier swing is

(A) 7.143 (B) 8
(C) 0.71 (D) 350

Solution: (A)

$$\text{Carrier swing}=\frac{\text{Frequency deviation}}{\text{Modulating frequency}}=\frac{50}{7}=7.143$$

37. In a radio receiver, the short wave and medium wave stations are tuned by using the same capacitor but coils of different inductance L_s and L_m respectively then

(A) $L_s>L_m$ (B) $L_s<L_m$
(C) $L_s=L_m$ (D) None of these

Solution: (B)

$$\text{As } v=\frac{c}{\lambda}\Rightarrow v_m=\frac{c}{\lambda_m}\text{ and } v_s=\frac{c}{\lambda_s}$$

$\because$ $\lambda_m>\lambda_s\Rightarrow v_m<v_s$

Also $v_m=\dfrac{1}{2\pi\sqrt{L_mC}}$ and $v_s=\dfrac{1}{2\pi\sqrt{L_sC}}$

$\Rightarrow$ $\dfrac{v_m}{v_s}=\sqrt{\dfrac{L_s}{L_m}}\Rightarrow L_s<L_m.$

38. The electron density of E, F_1, F_2 layers of ionosphere is 2×10^{11}, 5×10^{11} and 8×10^{11} m^{-3} respectively. What is the ratio of critical frequency for reflection of radio waves

(A) 2 : 4 : 3 (B) 4 : 3 : 2
(C) 2 : 3 : 4 (D) 3 : 2 : 4

Solution: (C)

$$f_c\propto(N)^{1/2}\Rightarrow(f_c)_E:(f_c)_{F_1}:(f_c)_{F_2}$$
$$=(2\times10^{11})^{1/2}:(5\times10^{11})^{1/2}:(8\times10^{11})^{1/2}=2:3:4$$

39. A carrier is simultaneously modulated by two sine waves with modulation indices of 0.4 and 0.3. The resultant modulation index will be

(A) 1.0 (B) 0.7
(C) 0.5 (D) 0.35

Solution: (C)

$$m=\sqrt{m_1^2+m_2^2}=\sqrt{(0.16)+(0.09)}=0.5$$

40. Mean optical power launched into an 8 km fibre is 120 μW and mean output power is 4 μW, then the overall attenuation is (Given log 30 = 1.477)

(A) 14.77 dB (B) 16.77 dB
(C) 3.01 dB (D) None of these

Solution: (A)

$$\text{Attenuation}=10\log\frac{120}{4}=10\log30$$
$$=10\times1.4771=14.77\,\text{dB}.$$

41. A antenna current of an AM broadcast transmitter modulated by 50% is 11 A. The carrier current is

(A) 10.35 A (B) 9.25 A
(C) 10 A (D) 5.5 A

Solution: (A)

$$I_{\text{Carrier}}=\frac{I_{\text{rms}}}{\sqrt{1+\dfrac{m_a^2}{2}}}=\frac{11}{\sqrt{1+\dfrac{(0.5)^2}{2}}}=10.35\,\text{A}$$

42. Because of tilting which waves finally disappear

(A) Microwaves (B) Surface waves
(C) Sky waves (D) Space waves

Solution: (B)

43. A transmitter transmits a power of 10 kW when modulation is 50%. Power of carrier wave is

(A) 5 kW (B) 8.89 kW
(C) 14 kW (D) 5.7 kW

Solution: (B)

$$P_c = \frac{P}{\left(1+\frac{m_a^2}{2}\right)} = \frac{10000}{\left(1+\frac{(0.5)^2}{2}\right)} = \frac{10000}{1.125} = 8.89\,\text{kW}$$

44. A telephone link operating at a central frequency of 10 *G*Hz is established. If 1% of this is available then how many telephone channel can be simultaneously given when each telephone covering a band width of 5 kHz

(A) 2×10^4 (B) 2×10^6
(C) 5×10^4 (D) 5×10^6

Solution: (A)

$$1\% \text{ of } 10 \text{ GHz} = 10\times10^9\times\frac{1}{100} = 10^8\,\text{Hz}$$

$$\text{Number of channels} = \frac{10^8}{5\times10^3} = 2\times10^4$$

EXERCISES

Single Options Correct Type

1. The *P-N* junction diode is used as

(A) An amplifier (B) A rectifier
(C) An oscillator (D) A modulator

2. Two *P-N* junctions can be connected in series by three different methods as shown in the Fig. 20.5. If the potential difference in the junctions is the same, then the correct connections will be

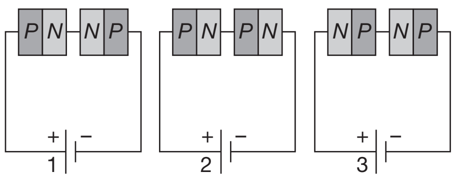


Fig. 20.5

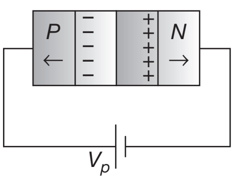
(A) In the circuit (1) and (2)
(B) In the circuit (2) and (3)
(C) In the circuit (1) and (3)
(D) Only in the circuit (1)

3. On increasing the reverse bias to a large value in a *P-N* junction diode, current

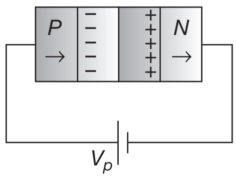
(A) Increases slowly (B) Remains fixed
(C) Suddenly increases (D) Decreases slowly

4. In the case of forward biasing of *P-N* junction, which one of the following figures correctly depicts the direction of flow of carriers?

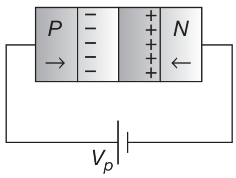
(A)



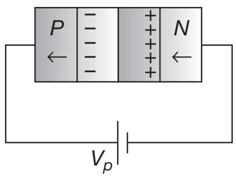
(B)



(C)



(D)



5. In forward bias, the width of potential barrier in a *P-N* junction diode

(A) Increases
(B) Decreases
(C) Remains constant
(D) First increases then decreases

6. In a *P-N* junction diode not connected to any circuit

(A) The potential is the same everywhere
(B) The *P*-type is a higher potential than the *N*-type side
(C) There is an electric field at the junction directed from the *N*- type side to the *P*- type side
(D) There is an electric field at the junction directed from the *P*-type side to the *N*-type side

7. Which of the following statements is not true?

(A) The resistance of intrinsic semiconductors decrease with increase of temperature

(B) Doping pure *Si* with trivalent impurities give *P*-type semiconductors

(C) The majority carriers in *N*-type semiconductors are holes

(D) A *P*-*N* junction can act as a semiconductor diode

8. The dominant mechanisms for motion of charge carriers in forward and reverse biased silicon *P*-*N* junctions are

(A) Drift in forward bias, diffusion in reverse bias

(B) Diffusion in forward bias, drift in reverse bias

(C) Diffusion in both forward and reverse bias

(D) Drift in both forward and reverse bias

9. The depletion layer in the *P*-*N* junction region is caused by

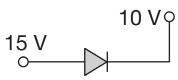
(A) Drift of holes

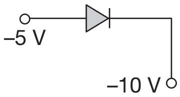
(B) Diffusion of charge carriers

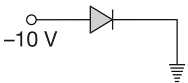
(C) Migration of impurity ions

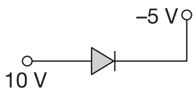
(D) Drift of electrons

10. Which one is reverse-biased?

(A)


(B)


(C)


(D)


11. In a *P*-*N* junction diode if *P* region is heavily doped than *n* region then the depletion layer is

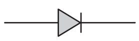
(A) Greater in *P* region

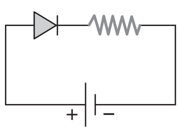
(B) Greater in *N* region

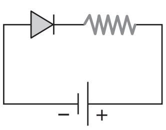
(C) Equal in both region

(D) No depletion layer is formed in this case

12. Which one is in forward bias?

(A)


(B)


(C)


(D) None of these

13. The reason of current flow in *P*-*N* junction in forward bias is

(A) Drifting of charge carriers

(B) Minority charge carriers

(C) Diffusion of charge carriers

(D) All of these

14. Consider the following statements *A* and *B* and identify the correct choice of the given answers

A: The width of the depletion layer in a *P*-*N* junction diode increases in forwards bias

B: In an intrinsic semiconductor the fermi energy level is exactly in the middle of the forbidden gap

(A) *A* is true and *B* is false

(B) Both *A* and *B* is false

(C) *A* is false and *B* is true

(D) Both *A* and *B* is true

15. Avalanche breakdown is due to

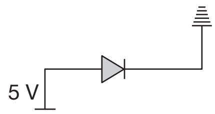
(A) Collision of minority charge carrier

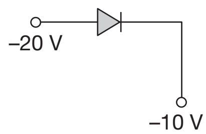
(B) Increase in depletion layer thickness

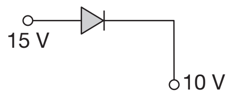
(C) Decrease in depletion layer thickness

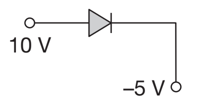
(D) None of these

16. Which is reverse biased diode?

(A)


(B)


(C)


(D)


17. Zener breakdown in a semi-conductor diode occurs when

(A) Forward current exceeds certain value

(B) Reverse bias exceeds certain value

(C) Forward bias exceeds certain value

(D) Potential barrier is reduced to zero

18. When forward bias is applied to a *P*-*N* junction, then what happens to the potential barrier V_B, and the width of charge depleted region x

(A) V_B increases, x decreases

(B) V_B decreases, x increases

(C) V_B increases, x increases

(D) V_B decreases, x decreases

19. Function of rectifier is

(A) To convert ac into dc

(B) To convert dc into ac

(C) Both (A) and (B)

(D) None of these

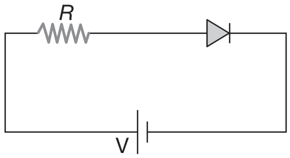
20. When the *P* end of *P*-*N* junction is connected to the negative terminal of the battery and the *N* end to the positive terminal of the battery, then the *P*-*N* junction behaves like

(A) A conductor
(B) An insulator
(C) A super-conductor
(D) A semi-conductor

21. If no external voltage is applied across *P*-*N* junction, there would be

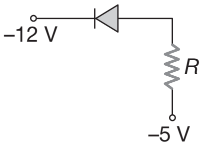
(A) No electric field across the junction.
(B) An electric field pointing from *N*-type to *P*-type side across the junction.
(C) An electric field pointing from *P*-type to *N*-type side across the junction.
(D) A temporary electric field during formation of *P*-*N* junction that would subsequently disappear.

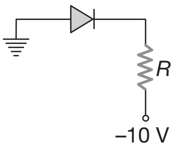
22. For the given circuit of *P*-*N* junction diode, which of the following statement is correct?

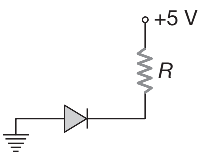


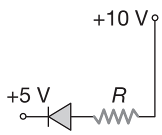
(A) In forward biasing the voltage across *R* is V
(B) In forward biasing the voltage across *R* is 2 V
(C) In reverse biasing the voltage across *R* is V
(D) In reverse biasing the voltage across *R* is 2 V

23. Of the diodes shown in the following diagrams, which one is reverse biased

(A) 

(B) 

(C) 

(D) 

24. The maximum efficiency of full wave rectifier is

(A) 100% (B) 25.20% (C) 40.2% (D) 81.2%

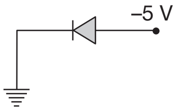
25. In order to forward bias a *P*-*N* junction, the negative terminal of battery is connected to

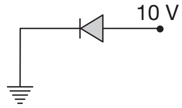
(A) *P*–side
(B) Either *P*-side or *N*-side
(C) *N*–side
(D) None of these

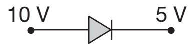
26. Which one of the following statements is not correct?

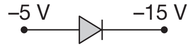
(A) A diode does not obey Ohm's law
(B) A *P*-*N* junction diode symbol shows an arrow identifying the direction of current (forward) flow
(C) An ideal diode is an open switch
(D) An ideal diode is an ideal one way conductor

27. Which of the following semi-conductor diodes is reverse biased

(A) 

(B) 

(C) 

(D) 

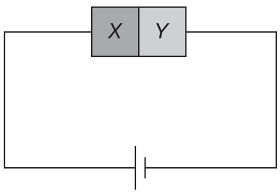
28. No bias is applied to a *P*-*N* junction, then the current

(A) Is zero because the number of charge carriers flowing on both sides is same
(B) Is zero because the charge carriers do not move
(C) Is non-zero
(D) None of these

29. Zener diode is used as

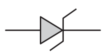
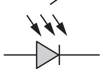
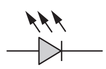
(A) Half wave rectifier
(B) Full wave rectifier
(C) ac voltage stabilizer
(D) dc voltage stabilizer

30. A semiconductor *X* is made by doping a germanium crystal with arsenic ($Z = 33$). A second semiconductor *Y* is made by doping germanium with indium ($Z = 49$). The two are joined end to end and connected to a battery as shown. Which of the following statements is correct?



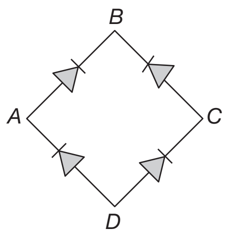
(A) *X* is *P*-type, *Y* is *N*-type and the junction is forward biased
(B) *X* is *N*-type, *Y* is *P*-type and the junction is forward biased
(C) *X* is *P*-type, *Y* is *N*-type and the junction is reverse biased
(D) *X* is *N*-type, *Y* is *P*-type and the junction is reverse biased

31. Symbolic representation of photodiode is

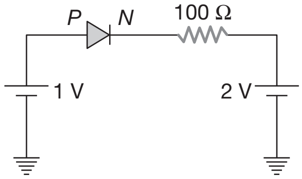
(A) 
(B) 
(C) 
(D) 

32. In the diagram, the input is across the terminals *A* and *C* and the output is across the terminals *B* and *D*, then the output is

(A) Zero
(B) Same as input
(C) Full wave rectifier
(D) Half wave rectifier



33. The current through an ideal *P-N* junction shown in the following circuit diagram will be



(A) Zero (B) 1 mA
(C) 10 mA (D) 30 mA

34. If a full wave rectifier circuit is operating from 50 Hz mains, the fundamental frequency in the ripple will be
(A) 50 Hz (B) 70.7 Hz
(C) 100 Hz (D) 25 Hz

35. A diode having potential difference 0.5 V across its junction which does not depend on current, is connected in series with resistance of 20 Ω across source. If 0.1 A passes through resistance then what is the voltage of the source
(A) 1.5 V (B) 2.0 V
(C) 2.5 V (D) 5 V

36. When *NPN* transistor is used as an amplifier
(A) electrons move from base to collector.
(B) holes move from emitter to base.
(C) electrons move from collector to base.
(D) holes move from base to emitter.

37. The phase difference between input and output voltages of a *CE* circuit is
(A) 0^o (B) 90^o
(C) 180^o (D) 270^o

38. An oscillator is nothing but an amplifier with
(A) Positive feedback
(B) Large gain
(C) No feedback
(D) Negative feedback

39. The emitter-base junction of a transistor is ____ biased while the collector-base junction is ____ biased
(A) Reverse, forward (B) Reverse, reverse
(C) Forward, forward (D) Forward, reverse

40. In an *NPN* transistor the collector current is 24 mA. If 80% of electrons reach collector its base current in mA is
(A) 36 (B) 26 (C) 16 (D) 6

41. A *NPN* transistor conducts when
(A) Both collector and emitter are positive with respect to the base.
(B) Collector is positive and emitter is negative with respect to the base.
(C) Collector is positive and emitter is at same potential as the base.
(D) Both collector and emitter are negative with respect to the base.

42. If $\alpha = 0.98$ and current through emitter $i_e = 20$ mA, the value of β is
(A) 4.9 (B) 49 (C) 96 (D) 9.6

43. For a common base configuration of *PNP* transistor $\frac{l_C}{l_E} = 0.98$ then maximum current gain in common emitter configuration will be
(A) 12 (B) 24 (C) 6 (D) 5

44. In a *PNP* transistor working as a common-base amplifier, current gain is 0.96 and emitter current is 7.2 *mA*. The base current is
(A) 0.4 mA (B) 0.2 mA
(C) 0.29 mA (D) 0.35 mA

45. In a common emitter transistor, the current gain is 80. What is the change in collector current, when the change in base current is 250 μA?
(A) $80 \times 250\ \mu$A (B) $(250 - 80)\ \mu$A
(C) $(250 + 80)\ \mu$A (D) $250/80\ \mu$A

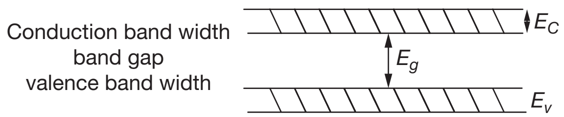
46. Least doped region in a transistor
(A) Either emitter or collector
(B) Base
(C) Emitter
(D) Collector

47. In NPN transistor the collector current is 10 mA. If 90% of electrons emitted reach the collector, then
(A) emitter current will be 9 mA.
(B) emitter current will be 11.1 mA.
(C) base current will be 0.1 mA.
(D) base current will be 0.01 mA.

48. In a pure silicon ($n_i = 10^{16}$ /m^3) crystal at 300 K, 10^{21} atoms of phosphorus are added per cubic meter. The new whole concentration will be

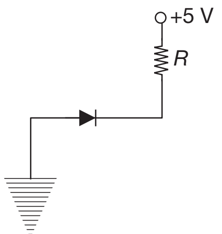
(A) 10^{21} per m^3 (B) 10^{19} per m^3
(C) 10^{11} per m^3 (D) 10^5 per m^3

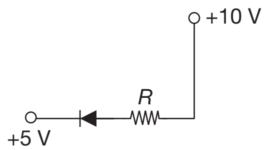
49. If the lattice constant of this semiconductor is decreased, then which of the following is correct?

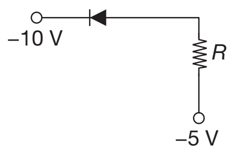


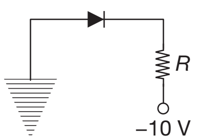
(A) All E_c, E_g, E_v decrease
(B) All E_c, E_g, E_v increase
(C) E_c, and E_v increase but E_g decrease
(D) E_c, and E_v, decrease E_g increase

50. In the following, which one of the diodes is reverse biased?

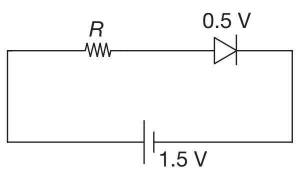
(A)


(B)


(C)


(D)


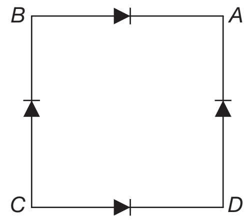
51. A diode used in the circuit shown has constant voltage drop of 0.5 V at all currents and a maximum power rating of 100 milli-watts. What should be the value of the resistor R, connected in series with the diode to obtain maximum current?



(A) 5 Ω (B) 5.6 Ω
(C) 6.76 Ω (D) 20 Ω

52. If the given circuit is to act as a full-wave rectifier, the input and output terminals should be respectively

(A) (B, D) and (A, C) (B) (A, C) and (B, D)
(C) (B, C) and (A, D) (D) None of these



53. The input resistance of a CE amplifier is 333 Ω and the load resistance is 5k Ω. A change of base current by 15μA results in the change of collector current by 1 mA. The voltage gain of the amplifier is

(A) 550 (B) 101 (C) 1001 (D) 501

54. A common emitter amplifier is designed with NPN transistor ($\alpha = 0.99$). The input impedance is 1 kΩ and load is 10 k Ω. The voltage gain will be

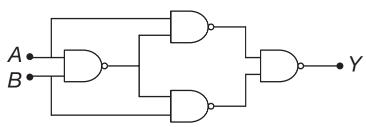
(A) 9.9 (B) 99 (C) 990 (D) 9900

55. In NPN transistor the collector current is 10 mA. If 90% of electrons emitted reach the collector, then

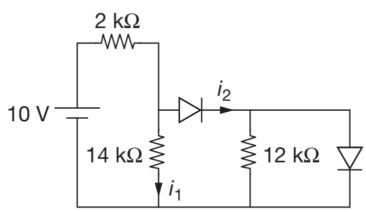
(A) emitter current will be 9 mA.
(B) emitter current will be 11.1 mA.
(C) base current will be 0.1 mA.
(D) base current will be 0.01 mA.

56. Select the outputs Y of the combination of gates shown below for inputs $A = 1$, $B = 0$; $A = 1$, $B = 1$ and $A = 0$, $B = 0$ respectively:

(A) (0 0 1) (B) (1 0 1) (C) (1 1 1) (D) (1 0 0)

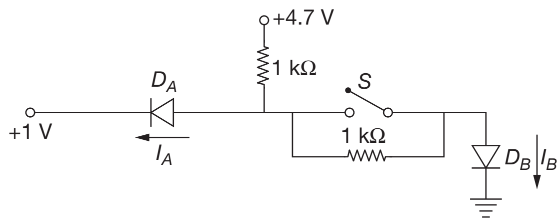


57. In the following circuit i_1 and i_2 are respectively (diodes are ideal)



(A) 0, 0 (B) 0, 5 mA
(C) 5 mA, 0 (D) 5 mA, 5 mA

58. The circuit shown contains two silicon diodes with knee voltage 0.7 V. If the switch S is open, the values of I_A and I_B are given by

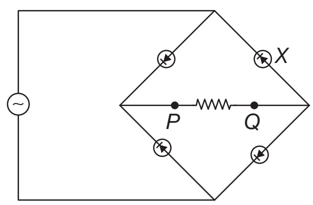


(A) 2 mA; 1 mA (B) 3 mA; 2 mA
(C) 1 mA; 1 mA (D) 4 mA; 2 mA

59. A transistor is used in common-emitter mode as an amplifier. Then
(A) the base-collector junction is forward biased
(B) the base emitter junction is reversed biased
(C) the input signal is connected in series with the voltage applied to the base-emitter junction
(D) the input signal is connected in series with the voltage applied to the base-collector junction.

60. The current gain of a transistor in common emitter circuit is 40. The ratio of emitter current to base current is
(A) 40 (B) 41 (C) 42 (D) 43

61. The figure shows a bridge rectifier with a sinusoidal alternating voltage applied to it, the output terminals P and Q being joined together by a load resistance. If the diode X were removed leaving a break in the circuit, which trace would be seen on a cathode-ray oscilloscope connected across PQ?

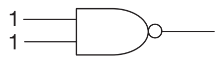


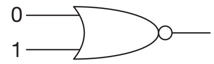
(A)  (B) 
(C)  (D)

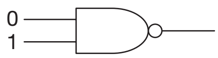
62. In a common base transistor $i_c = 19 i_b$, load and plate resistance are $4\,\text{k}\Omega$ and $1\,\text{k}\Omega$. The voltage gain of amplifier will be
(A) 80 (B) 4.2 (C) 3.8 (D) 76

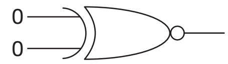
63. In a transistor, the emitter-base junction and the collector-base junction are
(A) forward and forward biased respectively.
(B) reverse and reverse biased respectively.
(C) reverse and forward biased respectively.
(D) forward and reverse biased respectively.

64. Which of the following gates will have an output of 1?

(A) 

(B) 

(C) 

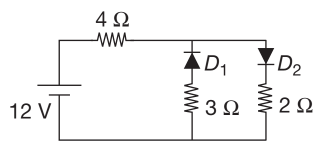
(D) 

65. A p-type semiconductor has acceptor level 57 meV above the valence band. The maximum wavelength of light required to create a hole is
(A) 57 Å (B) 57×10^{-3} Å
(C) 217100 Å (D) 11.61×10^{-33} Å

66. A solid which is transparent to visible light and whose conductivity increases with temperature is formed by
(A) Metallic binding (B) Ionic binding
(C) Covalent binding (D) Vander Waals binding

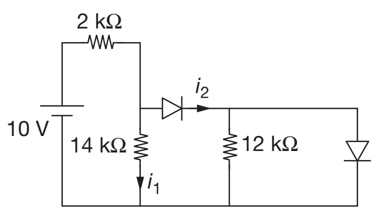
67. If the ratio of the concentration of electrons and that of holes in a semiconductor is $\frac{7}{5}$ and the ratio of currents is $\frac{7}{4}$, then what is the ratio of their drift velocities?
(A) $\frac{7}{4}$ (B) $\frac{5}{8}$ (C) $\frac{4}{5}$ (D) $\frac{5}{4}$

68. The circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit?
(A) 1.33 A (B) 1.71 A (C) 2.00 A (D) 2.31 A



69. If α and β are the current gain in the CB and CE configurations respectively of the transistor circuit, then $\frac{\beta - \alpha}{\alpha\beta}$ is equal to
(A) 1 (B) 2 (C) 3 (D) Zero

70. In the following circuit I_1 and I_2 are respectively (diodes are ideal)

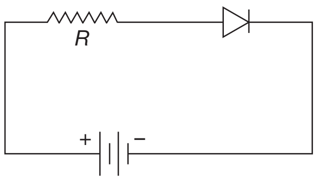


(A) 2 (B) 3 (C) 0 (D) 4

Passage Based Questions

Passage 1

A silicon diode requires a minimum current of 2 mA to be above the knee point (0.7 V) of its V–1 characteristics. Assume that the voltage across the diode is independent of current above the knee point.



71. Find the maximum value of R so that voltage across the diode is above the knee point.

(A) 2.25 Ω (B) 4.65 Ω
(C) 6.25 Ω (D) 2.65 Ω

72. Find the power dissipated in the resistor when current through the circuit is 4 mA.

(A) 37.2 mW (B) 7.2 mW
(C) 3.2 mW (D) 47.2 mW

Passage 2

For a sample of a pure germanium plate, the following date is given at 300 K. Plate area = 1 cm^2. Thickness = 0.3 mm, voltage applied across the faces = 2 V. Concentration of free electrons, $n_1 = 2 \times 10^{19}$m^{-3}. Mobility of electrons $\mu_e = 0.36$ m^2/V-s. Mobility of holes, $\mu_e = 0.17$ m^2/V-s.

73. Find the current produced in the specimen

(A) 0.13 A (B) 0.11 A (C) 1.1 A (D) 1.13 A

If two such plates are joined together to form a p-n junction with donor and acceptor impurities concentration of 10^{23} and 10^{22} m^{-3}, respectively. Assume reverse saturation current as 50 μA.

74. Find the barrier potential difference

(A) 0.28 V (B) 0.38 V
(C) 0.18 V (D) 0.48 V

75. Find the forward and reverse biasing currents at 0.2 V and 2 V, respectively.

(A) 0.11A,50 μA (B) 0.22A, 40 μA
(C) 1.1A,50 μA (D) 2.2A, 40 μA

Passage 3

A transistor is used in common emmiter mode in an amplifier circuit. When a signal of 20 mV is added to the base-emmiter voltage,the base current changes by 20 μA and the collector current changes by 2 mA.The load resistance is 5 kΩ.

76. Then the value of β is

(A) 100 (B) 50 (C) 200 (D) 150

77. The input resistance Ri is.

(A) 0.01 (B) 0.1 (C) 0.001 (D) 1

78. The voltage gain is.

(A) 100 (B) 300 (C) 500 (D) 700

Passage 4

In T.V. transmission tower at a perpendicular station has a height of 160m

79. What is its coverage range?

(A) 45.255 km (B) 65-221 km
(C) 35.321 km (D) 20.225 km

80. What is the population covered by the transmission, if the average population density around the tower is 1200 per square km.

(A) 5.22×10^6 (B) 7.72×10^6
(C) 3.52×10^6 (D) 9.22×10^6

81. By how much height should be increased to double its coverage range?(radius of earth is 6400 km)

(A) 480 m (B) 220 m
(C) 380 m (D) 520 m

Assertion-Reason Type

Direction: Read the following questions and choose

(A) If both **Assertion** and **Reason** are true and **Reason** is the correct explanation of the **Assertion.**
(B) If both **Assertion** and **reason** are true but **Reason** is not correct explanation of the **Assertion**.
(C) If **Assertion** is true but **Reason** is false.
(D) If **Assertion** is false but **Reason** is true.

82. **Assertion:** An ideal junction diode offers zero resistance, when forward biased and infinite resistance, when reverse biased.

Reason: Resistance is low when forward biased and high when reverse biased. Ideal of low is zero and ideal of high is infinity.

(A) A (B) B (C) C (D) D

83. **Assertion:** The conductivity of intrinsic semiconductors at 0 K is zero.

Reason: At 0 K no energy is available. No covalent bond can be broken. No free electron is available for conduction.

(A) A (B) B (C) C (D) D

84. **Assertion:** For forward biasing, positive terminal of external battery is connected to p-type semiconductor and negative terminal of external battery is connected to n-type semiconductor.

Reason: This would support the tendency of majority charge carriers to cross the junction.

(A) A (B) B (C) C (D) D

85. **Assertion:** Conductivity of a semiconductor increases on doping.

Reason: Doping raises the temperature of semiconductor.

(A) A (B) B (C) C (D) D

86. **Assertion:** Thickness of depletion layer is fixed in all semiconductor devices.

Reason: No free charge carriers are available in depetion layer.

(A) A (B) B (C) C (D) D

87. **Assertion:** The temperature coefficient of resistance is positive for metals and negative for p-type semiconductor.

Reason: The effective charge carriers in metals are negatively charged whereas in p-type semiconductors they are positively charged.

(A) A (B) B (C) C (D) D

88. **Assertion:** If the temperature of a semiconductor is increased then its resistance decreases.

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

(A) A (B) B (C) C (D) D

89. **Assertion:** Optical fibres are free from electromagnetic disturbances.

Reason: Optical fibres are electrically insulated.

(A) A (B) B (C) C (D) D

90. **Assertion:** Optical communication system is more economical than other systems of communications.

Reason: The information carrying capacity of a communication system is directly proportional to its band width.

(A) A (B) B (C) C (D) D

91. **Assertion:** The electrical conductivity of earth's atmosphere increase with altitude.

Reason: The high energy particles (i.e., gamma rays and cosmic rays) coming from outer space while entering earth's atmosphere causes ionisation of the atoms of the gases present in atmosphere.

(A) A (B) B (C) C (D) D

92. **Assertion:** The receiver reconstructs the original message or data after its propagation through communication channel.

Reason: The reconstruction is necessary only in some cases.

(A) A (B) B (C) C (D) D

93. **Assertion:** Fax is a modulating and demodulating device.

Reason: It is necessary for exact reproduction of a document.

(A) A (B) B (C) C (D) D

94. **Assertion:** The electromagnetic waves of longer wavelengths can travel longer distances on earth's surface than those of shorter wavelengths.

Reason: Velocity of wave propagation is same of all wavelengths.

(A) A (B) B (C) C (D) D

95. **Assertion:** Modulator or encoder is an essential component of a transmitter.

Reason: The message signal has to be changed into a form suitable for transmission.

(A) A (B) B (C) C (D) D

96. **Assertion:** Ground wave transmission becomes weaker with increase in frequency.

Reason: The ground waves can bend round the corners of the object on the earth.

(A) A (B) B (C) C (D) D

Previous Years' Questions

97. At absolute zero, Si acts as: **[2002]**

(A) Non-metal
(B) Metal
(C) Insulator
(D) None of these

98. By increasing the temperature, the specific resistance of a conductor and a semiconductor: **[2002]**

(A) Increases for both
(B) Decreases for both
(C) Increases, decreases
(D) Decreases, increases

99. The energy band gap is maximum in: **[2002]**

(A) Metals (B) Superconductos
(C) Insulators (D) Semiconductors

100. The part of a transistor which is most heavily doped to produce large number of majority carriers is: **[2002]**

(A) Emitter
(B) Base
(C) Collector
(D) Can be any of the above three.

101. Formation of covalent bonds in compounds exhibits: **[2003]**

(A) Wave nature of electron
(B) Particle nature of electron
(C) Both wave and particle nature of electron
(D) None of these

102. In the middle of the depletion layer of a reverse-biased *P*-*N* junction, the **[2003]**

(A) electric field is zero.
(B) potential is maximum.
(C) electric field is maximum.
(D) potential is zero.

103. The difference in the variation of resistance with temperature in a metal and a semiconductor arises essentially due to the difference in the **[2003]**

(A) crystal structure.
(B) variation of the number of charge carriers with temperature.
(C) type of bonding.
(D) variation of scattering mechanism with temperature.

104. Truth table for system of four NAND gates as shown in Fig. 20.10 is **[2012]**

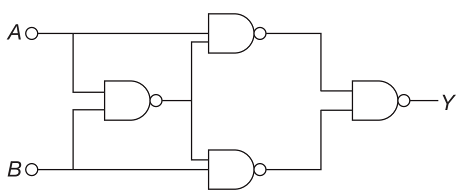


Fig. 20.10

(A)

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

(B)

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

(C)

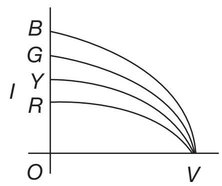
A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(D)

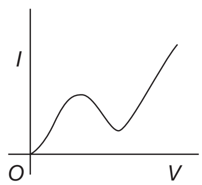
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

105. The I-V characteristic of an LED is **[2013]**

(A)



(B)



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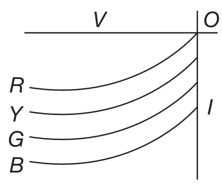
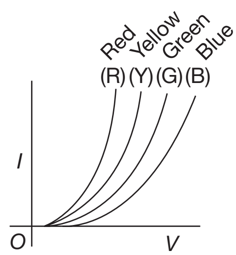


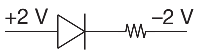
(D)

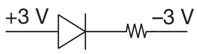


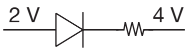
106. A diode detector is used to detect an amplitude modulated wave of 60% modulation by using a condenser of capacity 250 pico farad in parallel with a load resistance 100 kilo ohm. Find the maximum modulated frequency which could be detected by it. **[2013]**

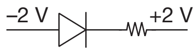
(A) 10.62 kHz (B) 5.31 MHz
(C) 5.31 kHz (D) 10.62 MHz

107. The forward biased diode connection is **[2014]**

(A) 

(B) 

(C) 

(D) 

108. When *n-p-n* transistor is used as an amplifier **[2004]**

(A) electrons move from base to collector.
(B) holes move from collector to base.
(C) electrons move from collector to base.
(D) holes move from base to emitter.

109. The manifestation of band structure in solids is due to **[2004]**

(A) Heisenberg's uncertainty principle.
(B) Pauli's exclusion principle.
(C) Bohr's correspondence principle.
(D) Boltzmann's law.

110. When *p-n* junction diode is forward biased, then **[2004]**

(A) the depletion region is reduced and barrier height is increased.
(B) the depletion region is widened and barrier height is reduced.
(C) both the depletion region and barrier height are reduced.
(D) both the depletion region and barrier height are increased.

111. In a common-base amplifier, the phase difference between the input signal voltage and output voltage is **[2005]**

(A) $\frac{\pi}{4}$ (B) π (C) Zero (D) $\frac{\pi}{2}$

112. A solid which is not transparent to visible light and whose conductivity increases with temperature is formed by: **[2006]**

(A) Ionic binding (B) Covalent binding
(C) Van der Waal's binding (D) Metallic binding

113. For a transistor amplifier in common emitter configuration for load impedance of $1k\Omega (h_{fe} = 50)$ and $(h_{oe} = 25\ \mu A/V)$, the current gain is **[2004]**

(A) –5.2 (B) –15.7
(C) –24.8 (D) –48.78

114. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap for the semiconductor is **[2005]**

(A) 1.1 eV (B) 2.5 eV
(C) 0.5 eV (D) 0.7 ev

115. In a full wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be **[2005]**

(A) 50 Hz (B) 25 Hz
(C) 100 Hz (D) 70.7 Hz

116. If the ratio of the concentration of electrons to that of holes in a semiconductor is $\frac{7}{5}$ and the ratio of currents is $\frac{7}{4}$, then what is the ratio of their drift velocities? **[2006]**

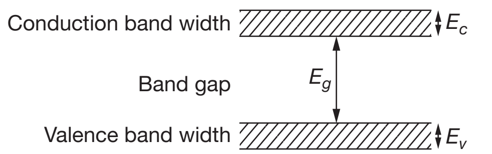
(A) $\frac{5}{8}$ (B) $\frac{4}{5}$ (C) $\frac{5}{4}$ (D) $\frac{4}{7}$

117. In a common-base mode of transistor, the collector current is 5.488 mA for an emitter current of 5.60 mA. The value of the base current amplification factor (β) will be **[2006]**

(A) 49 (B) 50 (C) 51 (D) 48

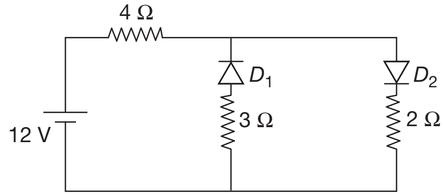
118. If the lattice constant of this semiconductor is decreased, then which of the following is correct? **[2006]**

(A) All E_c, E_g, E_v increase
(B) E_c and E_v increase, but E_g decreases
(C) E_c and E_v decrease, but E_g increases
(D) All E_c, E_g, E_v decrease



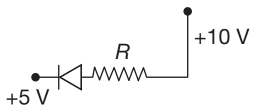
119. The circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit? **[2006]**

(A) 1.71 A (B) 2.00 A
(C) 2.31 A (D) 1.33 A

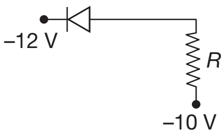


120. In the following, which one of the diodes is reverse biased? **[2006]**

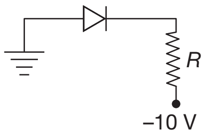
(A)



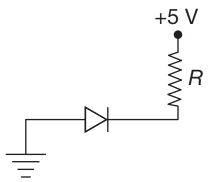
(B)



(C)



(D)



121. Carbon, silicon and germanium have four valence elements each. At room temperature which one of the following statement(s) is most appropriate? **[2007]**

(A) The number of free electrons for conduction is significant in all the three

(B) The number of free electrons for conduction is significant only in Si and Ge but small in *C*

(C) The number of free conduction electrons is significant in *C* but small in Si and Ge

(D) The number of free conduction electrons is negligibly small in all the three

122. A working transistor with its three legs marked *P*, *Q* and *R* is tested using a multimeter. No conduction is found between *P* and *Q*. By connecting the common (negative) terminal of the multimeter to *R* and the other (positive) terminal to *P* or *Q*, some resistance is seen on the multimeter. Which of the following is true for the transistor ? **[2008]**

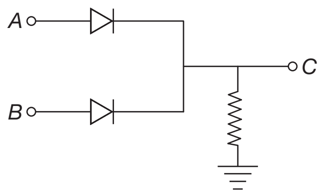
(A) It is a *pnp* transistor with *R* as emitter

(B) It is an *npn* transistor with *R* as collector

(C) It is an *npn* transistor with *R* as base

(D) It is a *pnp* transistor with *R* as collector

123. In the circuit below, *A* and *B* represent two inputs and *C* represents the output. **[2008]**



The circuit represents

(A) NAND gate (B) OR gate

(C) NOR gate (D) AND gate

ANSWER KEYS

Single Options Correct Type

1. (B)	**2.** (B)	**3.** (C)	**4.** (C)	**5.** (B)	**6.** (C)	**7.** (C)	**8.** (B)	**9.** (B)	**10.** (C)
11. (B)	**12.** (B)	**13.** (C)	**14.** (C)	**15.** (A)	**16.** (B)	**17.** (B)	**18.** (D)	**19.** (A)	**20.** (B)
21. (B)	**22.** (A)	**23.** (C)	**24.** (D)	**25.** (C)	**26.** (C)	**27.** (A)	**28.** (B)	**29.** (C)	**30.** (D)
31. (C)	**32.** (C)	**33.** (A)	**34.** (C)	**35.** (C)	**36.** (A)	**37.** (C)	**38.** (A)	**39.** (D)	**40.** (D)
41. (B)	**42.** (B)	**43.** (B)	**44.** (C)	**45.** (A)	**46.** (B)	**47.** (B)	**48.** (C)	**49.** (D)	**50.** (A)
51. (A)	**52.** (A)	**53.** (C)	**54.** (C)	**55.** (B)	**56.** (D)	**57.** (B)	**58.** (A)	**59.** (C)	**60.** (B)
61. (B)	**62.** (C)	**63.** (D)	**64.** (C)	**65.** (C)	**66.** (C)	**67.** (D)	**68.** (C)	**69.** (A)	**70.** (C)

Passage Based Questions

Passage 1

71. (B) **72.** (A)

Passage 2

73. (A) **74.** (B) **75.** (A)

Passage 3

76. (A) **77.** (B) **78.** (C)

Passage 4

79. (A) **80.** (B) **81.** (A)

Assertion-Reason Type

82. (A) **83.** (A) **84.** (A) **85.** (C) **86.** (D) **87.** (B) **88.** (A) **89.** (A) **90.** (A) **91.** (A)
92. (C) **93.** (D) **94.** (D) **95.** (A) **96.** (B)

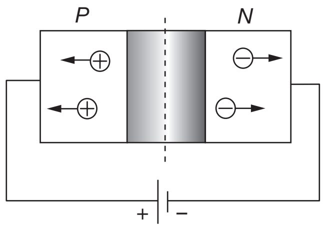
Previous Years' Questions

97. (C) **98.** (C) **99.** (C) **100.** (A) **101.** (A) **102.** (A) **103.** (B) **104.** (A) **105.** (D) **106.** (A)
107. (A) **108.** (D) **109.** (B) **110.** (C) **111.** (C) **112.** (B) **113.** (D) **114.** (C) **115.** (C) **116.** (C)
117. (A) **118.** (C) **119.** (B) **120.** (D) **121.** (D) **122.** (C) **123.** (B)

HINTS AND SOLUTIONS

Single Options Correct Type

1. It is used to convert ac into dc (rectifier)



The correct option is (B)

2. Because in case (1) N is connected with N. This is not a series combination of transistor.

The correct option is (B)

3. After a large reverse voltage is P-N junction diode, huge current flows in the reverse direction suddenly. This is called Breakdown of P-N junction diode.

The correct option is (C)

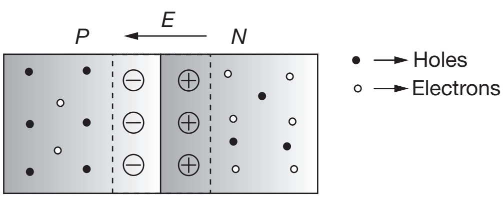
4. In forward biasing, both positive and negative charge carriers move towards the junction.

The correct option is (C)

5. In forward biasing, width of depletion layer decreases.

The correct option is (B)

6. At junction a potential barrier/depletion layer is formed, with N-side at higher potential and P-side at lower potential. Therefore there is an electric field at the junction directed from the N-side to P-side



The correct option is (C)

7. In N-type semiconductor majority charge carriers are electrons

The correct option is (C)

8. In forward biasing the diffusion current increases and drifts current remains constant so not current is due to the diffusion.

In reverse biasing diffusion becomes more difficult so net current (very small) is due to the drift.

The correct option is (B)

9. Due to the large concentration of electrons in N-side and holes in P-side, they diffuse from their own side to other side. Hence depletion region produces.

The correct option is (B)

10. Only in option (C), P-side is more negative as compared to N-side.

The correct option is (C)

11. Depletion layer is more in less doped side.

The correct option is (B)

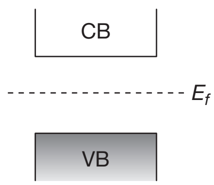
12. In forward biasing P-side is connected with positive terminal and N-side with negative terminal of the battery

The correct option is (B)

13. In forward biasing of P-N junction diode, current mainly flows due to the diffusion of majority charge carriers.

The correct option is (C)

14. In forward biasing of P-N junction diode, width of depletion layer decreases. In intrinsic semiconductor fermi energy level is exactly in the middle of the forbidden gap



The correct option is (C)

15. At high reverse voltage, the minority charge carriers, acquires very high velocities. These by collision break down the covalent bonds, generating more carriers. This mechanism is called Avalanche breakdown.

The correct option is (A)

16. Because P-side is more negative as compared to N-side.

The correct option is (B)

17. When reverse bias is increased, the electric field at the junction also increases. At some stage the electric field breaks the covalent bond, thus the large number of charge carriers are generated. This is called Zener breakdown.

The correct option is (B)

18. In forward biasing, both V_B and x decreases.

The correct option is (D)

19. ac → Rectifier → dc

The correct option is (A)

20. In this condition P-N junction is reverse biased.

The correct option is (B)

21. Across the P-N junction, a barrier potential is developed whose direction is from N region to P region

The correct option is (B)

22. In forward biasing, resistance of P-N junction diode is zero, so whole voltage appears across the resistance.

The correct option is (A)

23. Because N-side is more positive as compared to P-side.

The correct option is (C)

24. For full wave rectifier $\eta = \dfrac{81.2}{1+\dfrac{r_f}{R_L}}$

$\Rightarrow \quad n_{max} = 81.2\% \; (r_f << R_L)$

The correct option is (D)

25. In reverse biasing negative terminal of the battery is connected to N-side.

The correct option is (C)

26. Diode acts as open switch only when it is reverse biased

The correct option is (C)

27. Because P-side is more negative than N-side.

The correct option is (A)

28. In unbiased condition of P-N junction, depletion region is generated which stops the movement of charge carriers.

The correct option is (B)

29. For a wide range of values of load resistance, the current in the zener diode may change but the voltage across it remains unaffected. Thus the output voltage across the zener diode is a regulated voltage.

The correct option is (C)

30. Arsenic has five valence electrons, so it a donor impurity. Hence X becomes N-type semiconductor. Indium has only three outer electrons, so it is an acceptor impurity. Hence Y becomes P-type semiconductor. Also N (i.e. X) is connected to positive terminal of battery and P (i.e. Y) is connected to negative terminal of battery so P-N junction is reverse biased.

The correct option is (D)

31. In photodiode, it is illuminated by light radiations, which in turn produces electric current.

The correct option is (C)

32. The given circuit is full wave rectifier

The correct option is (C)

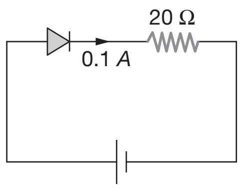
33. The diode is in reverse biasing so current through it is zero

The correct option is (A)

34. In full wave rectifier, the fundamental frequency in ripple is twice that of input frequency.

The correct option is (C)

35.



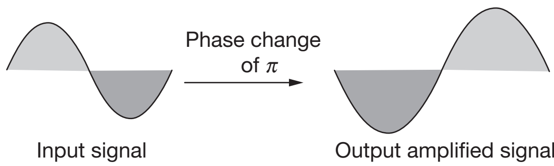
$$V' = V + IR$$
$$= 0.5 + 0.1 \times 20$$
$$= 2.5 \text{ V}$$

The correct option is (C)

36. When NPN transistor is used as an amplifier, majority charge carrier electrons of N-type emitter move from emitter to base and then base to collector

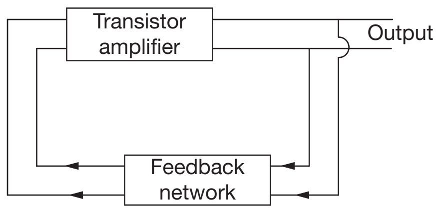
The correct option is (A)

37.



The correct option is (C)

38. In oscillator, a portion of the output power is returned back (feedback) to the input in phase with the starting power. This process is termed as positive feedback.



The correct option is (A)

39. The emitter base junction is forward biased while collector base junction is reversed biased

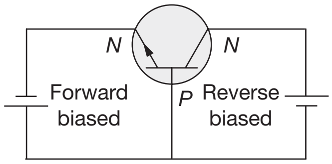
The correct option is (D)

40. Given $i_c = \frac{80}{100} \times i_e \Rightarrow 24 = \frac{80}{100} \times i_e \Rightarrow i_e = 30\,\text{mA}$

By using $i_e = i_b + i_c \Rightarrow i_b = 30 - 24 = 6$ mA.

The correct option is (D)

41.



The correct option is (B)

42. $\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = 49$

The correct option is (B)

43. $\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24.$

The correct option is (B)

44. $\alpha = \frac{i_c}{i_e} = 0.96$ and $i_e = 7.2$ mA

$\Rightarrow i_c = 0.96 \times i_e = 0.96 \times 7.2 = 6.91$ mA

$\therefore i_e = i_c + i_b \quad \Rightarrow \quad 7.2 = 6.91 + i_b$

$\Rightarrow \quad i_b = 0.29$ mA

The correct option is (C)

45. Current gain $\beta = \frac{\Delta i_c}{\Delta i_b} \Rightarrow \Delta i_c = \beta \times \Delta i_b = 80 \times 250\,\mu\text{A}$

The correct option is (A)

46. In transistor, base is least doped.

The correct option is (B)

47. $I_C = 0.9 I_E \Rightarrow I_E = \frac{10}{0.9} = 11.1$ mA

The correct option is (B)

48. By using mass action law $n_1^2 = n_e n_h$

$\Rightarrow \quad n_h = \frac{n_1^2}{n_e} = \frac{(10^{16})^2}{10^{21}} = 10^{11}$ per m^3

The correct option is (C)

49. The correct option is (D)

50. The correct option is (A)

51. Diode current $= \frac{P}{V} = \frac{100 \times 10^{-3}}{0.5} = 0.2\,\text{A}$

Potential difference across $R = 1.5 - 0.5 = 1$ V

$IR = V \Rightarrow R = \frac{1}{0.2} = 5\,\Omega$

The correct option is (A)

52. The correct option is (A)

53. Voltage gain, $A_v = \frac{\Delta I_c \times R_L}{\Delta I_b \times R_i} = \frac{1 \times 10^{-3} \times 5 \times 10^3}{15 \times 10^{-6} \times 333} = 1001$

The correct option is (C)

54. Voltage gain $= \beta \times$ Resistance gain $\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = 99$

Voltage gain = 99 × 10 = 990

The correct option is (C)

55. $I_C = 0.9 I_E \Rightarrow I_E = \frac{10}{0.9} = 11.1$ mA

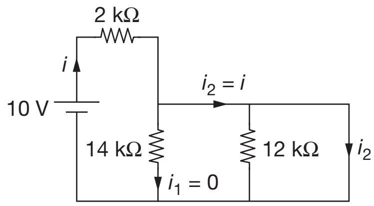
The correct option is (B)

56. By Boolean Algebra, we have

$Y = A\overline{B}$

The correct option is (D)

57.

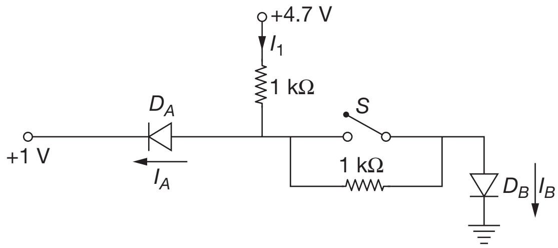


$i = \frac{10}{2} = 5\text{ mA} = i_2$

$i_1 = 0$

The correct option is (B)

58.



When S is open, D_B is forward biased

$\therefore \quad V_P = 1 + 0.7 = 1.7$ V

$\therefore \quad I_1 = \frac{4.7 - 1.7}{1 \times 10^3} = 3\text{ mA}$ and $I_B = \frac{1.7 - 0.7}{1 \times 10^3} = 1\text{ mA}$

$\therefore \quad I_A = 2$ mA

The correct option is (A)

59. The correct option is (C)

60. $\frac{i_c}{i_b} = 40 \Rightarrow i_c = 40 i_b,\ i_e = i_c + i_b = 41 i_b$

The correct option is (B)

61. The correct option is (B)

62. $\alpha = \frac{i_c}{i_e} = \frac{i_c}{i_c + i_b} = \frac{19 i_b}{19 i_b + i_b} = \frac{19}{20}$

voltage gain $= \frac{19}{20} \times \frac{4}{1} = 3.8$

The correct option is (C)

63. The correct option is (D)

64. The correct option is (C)

65. $\lambda = \dfrac{12375}{E(\text{eV})}\text{Å} = \dfrac{12375}{57 \times 10^{-3}} = 217100\ \text{Å}$

The correct option is (C)

66. Covalent binding

The correct option is (C)

67. $\dfrac{n_e}{n_h} = \dfrac{7}{5}\ \ \dfrac{I_e}{I_h} = \dfrac{7}{4}$

$\dfrac{(V_d)_e}{(V_d)_h} = \dfrac{I_e}{I_h} \times \dfrac{n_h}{n_e} = \dfrac{5}{4}$

The correct option is (D)

68. D_1 is reverse biased therefore it will act like an open circuit.

$i = \dfrac{12}{6} = 2.00\ \text{A}$

The correct option is (C)

69. Since, $\beta = \dfrac{\alpha}{1-\alpha} \Rightarrow \alpha\beta = \dfrac{\alpha^2}{1-\alpha}$

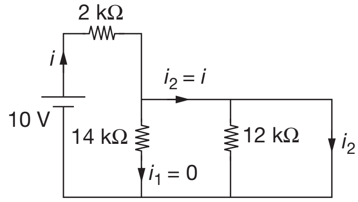
$\beta - \alpha = \dfrac{\alpha}{1-\alpha} - \alpha = \dfrac{\alpha^2}{1-\alpha}$

$\therefore\ \left(\dfrac{\beta-\alpha}{\alpha\beta}\right) = \left(\dfrac{\alpha^2}{1-\alpha}\right)\left(\dfrac{1-\alpha}{\alpha^2}\right) = 1$

The correct option is (A)

70. $i = \dfrac{10}{2} = 5\,\text{mA} = i_2$

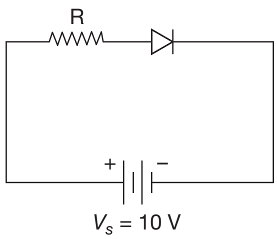
$i_1 = 0$



The correct option is (C)

Passage Based Questions

Passage 1



71. $I_{\min} = 2$ mA

$V_p = V_{\text{knee}} = 0.7$ V

Taking $V_s = 10$ V

Applying KVL,

$10 = I_{\min} \cdot R_{\max} + V_p$

$= 2\ \text{mA} \cdot R_{\max} + V_p$

$2\ \text{mA} \cdot R_{\max} = 10 - V_p$

$= 10 - 0.7 = 9.3$ V

$\therefore\ R_{\max} = \dfrac{9.3\ \text{V}}{2 \times 10^{-3}\ \text{A}}$

$= \dfrac{9.3 \times 10^3}{2}$

$= 4.65 \times 10^3\ \Omega$

$\therefore\ R_{\max} = 4.65\ \text{k}\Omega$

The correct option is (B)

72. Now $I = 4$ mA, then voltage across R should be,

$V_R = V_s - V_p = 10 - 0.7 = 9.3$ V

Then $R = \dfrac{V_R}{I} = \dfrac{9.3}{4\ \text{mA}} = 2325\ \Omega$

Power distribured through R,

$\therefore\ P = I^2 R$

$= (4\ \text{mA})^2 \times 2325\ \Omega$

$= 37200 \times 10^{-6}$

$= 37.2$ mW

$\therefore\ P = 32.7$ mW

The correct option is (A)

Passage 2

73. $I = neA(\mu_p + \mu_n)E$

$n = 2 \times 10^{19}\ \text{m}^{-3}$

$e = 1.6 \times 10^{-19}\text{C}\quad A = 1\ \text{cm}^2 = 10^{-4}\ \text{m}^2$

$E = \dfrac{V}{d} = \dfrac{2V}{0.3\ \text{mm}} = \dfrac{2}{3} \times 10^4\ \text{V/m}$

$\mu_p = 0.17\ \text{m}^2/\text{V-s},\ \mu_n = 0.36\ \text{m}^2/\text{V-s}$

$I = 2 \times 10^{19} \times 1.6 \times 10^{-19} \times 10^{-4}(0.36 + 0.17)\dfrac{2}{3} \times 10^{-4}\ \text{A}$

$I = 1.13$ A

The correct option is (A)

74. $V_0 = V_T \ln\left(\dfrac{N_A \times N_D}{n_i^2}\right)$

$N_A = 10^{22}\ \text{m}^{-3},\ N_D = 10^{23}\ \text{m}^{-3}$

$n_i = 2 \times 10^{19}\ \text{m}^{-3}$

V_T(Thermal voltage at room temperature) = 26 mV

$V_T = \dfrac{kT}{9} = 26$ mV

$V_0 = 26\ \text{mV} \ln\left(\dfrac{10^{22} \times 10^{23}}{(2 \times 10^{19})^2}\right) = 26\ \text{m} \ln \dfrac{10^{45}}{4 \times 10^{38}}$

$= 26\ \text{mV}\ \ \ln 2.5 \times 10^6$

$V_0 = 0.382$ V

The correct option is (B)

75. $I = I_0\left(e^{\frac{V_D}{V_T}} - 1\right)$

$= 50\,\mu A\left(e^{0.2} - 1\right) = 109521.2934 \times 10^{-6}$

$\cong 0.109 = 0.11$ A

Reverse saturation current remains same for any forward biased voltage.

The correct option is (A)

Passage 3

76. Current gain (β) in common emitter amplifier

$= \frac{\Delta I_C}{\Delta I_B} = \frac{\cancel{2}\text{ mA}}{\cancel{2}0\ \mu\text{A}} = \frac{100\cancel{0}}{1\cancel{0}}$

$\beta = 100$

The correct option is (A)

77. Input resistance $= \frac{\Delta V_{ib}}{\Delta i_b} = \frac{20\text{ mV}}{20\ \mu\text{A}}$

$= 10^3\,\Omega = 1\text{ k}\Omega$

The correct option is (B)

78. Voltage gain $= A_v = \frac{\Delta V_0}{\Delta V_i} = \frac{\Delta I_C \cdot R_L}{\Delta I_B \cdot R_L}$

$A_v = \frac{\beta \cdot R_L}{R_i} = \frac{100 \times 5\cancel{000}}{1\cancel{000}}$

$A_v = 500$

The correct option is (C)

Passage 4

79. Range $\sqrt{2Rh} = \sqrt{2 \times 6400 \times 10^3 \times 160}$

Range $= 8 \times 4 \times 10^3 \sqrt{2} = 45.248 \times 10^3$ m

Range $= 45.255$ km

The correct option is (A)

80. Area covered by antenna = π (Range)^2

$= 3.14 \times (45.255)^2$ km^2

Population covered in this area

$= 1200 \times 3.14 \times (45.255)^2$

$= 7.72 \times 10^6$ people

The correct option is (B)

81. Let h be the height

$\therefore$ 2(Range) $= \sqrt{2Rh}$

$4 \times (45.255)^2 = 2Rh$

$h = \frac{4 \times (45.255)^2 \times 10^6}{2 \times 6400 \times 10^3} = \frac{\overset{2}{\cancel{4}} \times (45.255)^2}{2 \times \underset{32}{\cancel{64}}} \times 10$

$h = 320$

Height of Antenna= 320 + 160 = 48 m

The correct option is (A)

Previous Years' Questions

97. Semiconductors, like Si, Ge, act as insulators at low temperature.

The correct option is (C)

98. For conductor, ρ increases as temperature rises. For semiconductor, ρ decreases as temperature rises.

The correct option is (C)

99. The energy band gap is maximum in insulations

The correct option is (C)

100. The emitter is most heavily doped.

The correct option is (A)

101. Wave nature of electron and covalent bonds are corrected.

The correct option is (A)

102. Electric field is zero in the middle of the depletion layer of a reverse biased *P-N* junction.

The correct option is (A)

103. Variation of number of charge carriers with temperature is responsible for variation of resistance in a metal and a semiconductor.

The correct option is (B)

104. $Y = \overline{\{\bar{A}.(A+B)\} + \{\bar{B}.(A+B)\}} = A.B + \bar{A}.\bar{B}$

A	B	$\bar{A}$	B	Y
0	0	1	1	1
0	1	0	1	0
1	0	0	1	0
1	1	0	0	1

The correct option is (A)

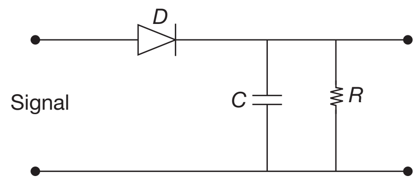
105. It is diode characteristics

The correct option is (D)

106. $\tau = RC = 100 \times 10^3 \times 250 \times 10^{-12}$ s

$= 2.5 \times 10^7 \times 10^{-12}$ s

$= 2.5 \times 10^{-5}$ s



The higher frequency which can be detected with tolerable distortion is

$$f = \frac{1}{2\pi m_a RC} = \frac{1}{2\pi \times 0.6 \times 2.5 \times 10^{-5}} \text{ Hz} = \frac{100 \times 10^4}{25 \times 1.2\pi}$$

$$= \frac{4}{1.2\pi} \times 10^4 \text{ Hz} = 10.61 \text{ kHz}$$

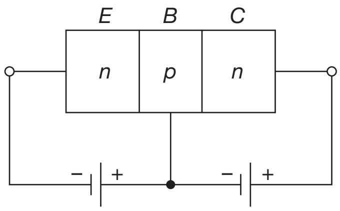
This condition is obtained by applying the condition that rate of decay of capacitor voltage must be equal or less than the rate of decay modulated signal voltage for proper detection of modulated signal.

The correct option is (A)

107. For diode to be forward biased, potential of *p* side should be higher in comparison to that of *n*-side.

The correct option is (A)

108.



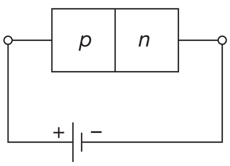
n-p-n transistor works as an amplifier when is forward biased. In forward biasing of *n-p-n* transistor, electrons move from emitter to base and holes move from base to emitter.

The correct option is (D)

109. According to Pauli Exclusion Principle no two fermions can exist in identical energy quantum states and it is applied to solids as "No two electrons in a solid can have identical energy states". This leads to the manifestation of bond structure in solids.

The correct option is (B)

110. When *p*-terminal of *p-n* junction diode is connected to positive terminal of battery and *n*-terminal is connected to negative terminal of battery, then *p-n* junction is said to be forward biased. In forward bias electrons in n-region move towards *p*-region.



Region and holes from *p*-region move towards n-region. Therefore, majority current due to majority carriers takes place through the junction causing more recombination of electron-hole pairs thus causing reduction in height of depletion region and barrier potential.

111. In common base amplifier, the input signal is amplified but remains in phase with output signal

The correct option is (C)

112. Covalent bonding

The correct option is (B)

113. For common emitter amplifier current gain

$$\beta = \frac{-h_{ef}}{1 + h_{ee} R_L}$$

$$\Rightarrow \beta = \frac{-50}{1 + 20 \times 10^{-6} \times 1 \times 10^{-3}}$$

$$\Rightarrow \beta = \frac{-50}{1 + 25 \times 10^{-3}}$$

$$= -48.78$$

The correct option is (D)

114. $E_g = \dfrac{hc}{\lambda}$

$$\Rightarrow E_g = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{2480 \times 10^{-9}}$$

$$= 8.01 \times 10^{-20} \text{ J}$$

$$\Rightarrow E_g = \frac{8.01 \times 10^{-20}}{1.6 \times 10^{-19}} = 0.5 \text{ eV}$$

The correct option is (C)

115. Given $f = 50$ Hz

$\therefore \quad T = \dfrac{1}{50}.$

For fuel wave rectifies, $T_1 = \dfrac{f}{2} = \dfrac{1}{100}$

$\therefore \quad f_1 = 100 \text{ Hz}$

The correct option is (C)

116. Given $\dfrac{n_e}{n_h} = \dfrac{7}{5}.$

and $\dfrac{I_e}{I_h} = \dfrac{7}{4}.$

$I = nev_d A$

$I_e = n_e e v_{de} A$

$I_h = n_h e v_{dh} A$

$$\therefore \quad \frac{(v_d)_e}{(v_d)_h} = \left(\frac{I_e}{I_h}\right) \times \left(\frac{n_h}{n_e}\right)$$

$$= \frac{7}{4} \times \frac{5}{7} = \frac{35}{28}$$

$$\frac{(v_d)_e}{(v_d)_h} = \frac{5}{4}.$$

The correct option is (C)

117. Given $I_C = 5.488$ mA

$I_E = 5.60$ mA

$I_B = I_E - I_C$

and $\beta = \dfrac{I_C}{I_B} = \dfrac{5.488 \text{ mA}}{0.112 \text{ mA}} = 49.$

The correct option is (A)

118. Since $E_g \propto \left(\dfrac{1}{a_0^2}\right)$

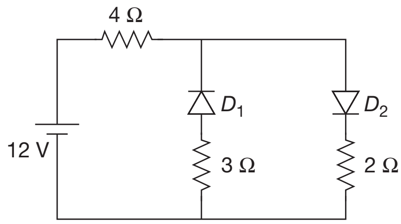
Where E_g = Energy gap

a_0 = lattice constant

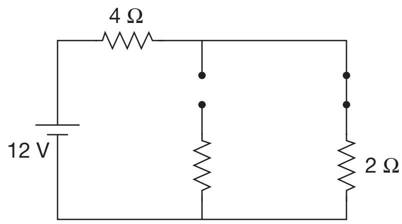
So, as lattice constant decreases, E_g increases and E_c and E_r decreases.

The correct option is (C)

119.



As D_1 is reversed biases so, it will behave as open circuit. As D_2 is forward biased it behaves as short circuit hence the circuit becomes



$\therefore \quad I = \dfrac{V}{R_{eq}}$

$I = \dfrac{12 \text{ V}}{(4+2)\Omega}$

$\therefore \quad I = \dfrac{12}{6} = 2 \text{ A}.$

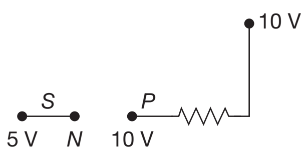
The correct option is (B)

120. For forward bias $V_P > V_N$

For reverse bias $V_N > V_P$

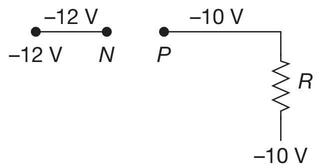
To check open the diode and find V_P and V_N and compare them.

(A)



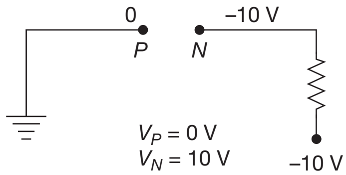
$V_P = 10$ $\quad V_N = 5$ $\quad V_P > V_N$ forward bias

(B)



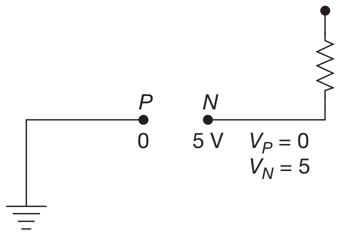
$V_P > V_N$ forward bias

(C)



$V_P > V_N$ forward bias

(D)



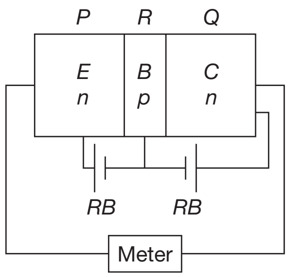
$V_P < V_N$ Reverse bias

The correct option is (D)

121. At room temperature no free charge carriers in silicon and germanium. Carbon doesn't loose or provide electron for conduction at sufficiently large temperature.

The correct option is (D)

122.



No any direct current between P and Q mean P and Q isolated to each other. When negative terminal of multimeter is connected to R and positive to P or Q both record some resistance, so P and Q are of same kind and in reverse bias therefore no current flows.

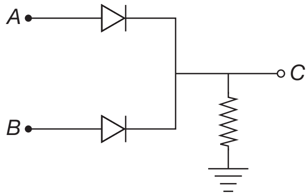
So, P and Q are of n-type

R – of p-type

Transistor n-p-n(PQR).

The correct option is (C)

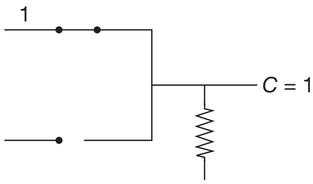
123.



Case I:

$A = 1$

$B = 0$

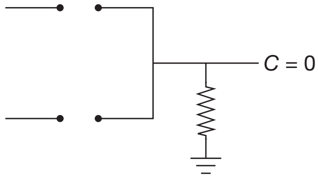


Case II:

$A = 0, B = 1$

then $C = 1$

$A = 0, B = 0$



OR gate

The correct option is (B)