2009

Question: 1 – 30 ii-xxviii

Question 1
Why is it necessary that the field lines from a point charge placed in the vicinity of a conductor must be normal to the surface of the conductor at every point? [1]

Answer:
Surface of a conductor is an equipotential surface and field lines are always directed from higher to lower potential, so field lines in the vicinity of a conductor must be normal to the surface of conductor.

Question 2
A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor:
Current, current density, drift speed, electric field? [1]

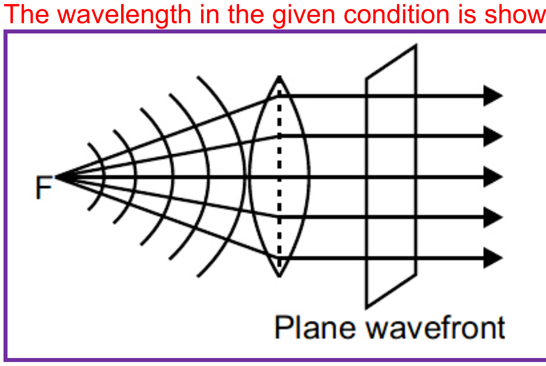
Answer:
Only current is constant along the length as other quantities are inversely proportional to the cross-sectional area which is variable.

Question 3
Name the electromagnetic radiations which are produced when high energy electrons are bombarded on a metal target. [1]

Answer:
X-rays.

Question 4
Draw the wave front coming out of a convex lens when a point source of light is placed at its focus. [1]

Answer:
The wavelength in the given condition is shown in figure below:



Question 5
Unpolarised light of intensity I is passed through a polaroid. What is the intensity of the light transmitted by the Polaroid? [1]

Answer:
Intensity of light transmitted through the polaroid = $\frac{1}{2}$

Question 6
Why are coherent sources required to create interference of light? [1]

Answer:
Coherent sources are required for sustained interference. If sources are incoherent, the intensity at a point will go on changing with time.

Question 7
In the Rutherford scattering experiment the distance of closest approach for an a.-particle is d_0.If a.-particle is replaced by a proton, how much kinetic energy in comparison to a.-particle will it require to have the same distance of closest approach d_0? [1]

Answer:

$$E_k = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{d_0}(\text{for } \alpha\text{ - particle, } q = 2e)$$

$$E'_k = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{d_0}(\text{for proton, } q = e)$$

$$\frac{E'_k}{E_k} = \frac{1}{2} \quad \Rightarrow E'_k = \frac{E_k}{2}$$

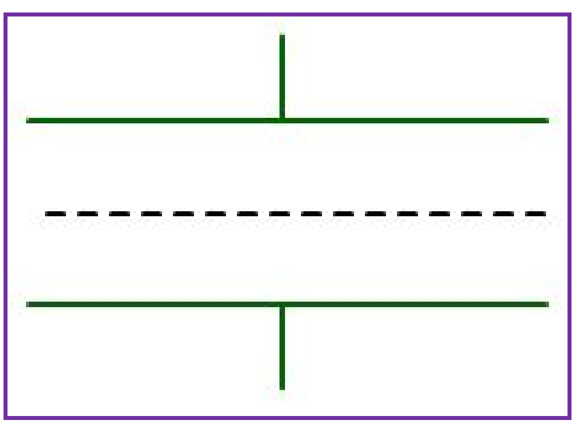
That is KE of proton must be half on comparison with KE of a-particle.

Question 8
State the Faraday's law of electromagnetic induction. [1]

Answer:
The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.
Mathematically, the induced emf is given by

$$e = -\frac{\Delta\phi}{\Delta t}$$

Question 9
Figure shows a sheet of aluminium foil of negligible thickness placed between the plates of a capacitor. How will its capacitance be affected if [2]



i. The foil is electrically insulated?

Answer:

No effect on capacitance if foil is electrically neutral.

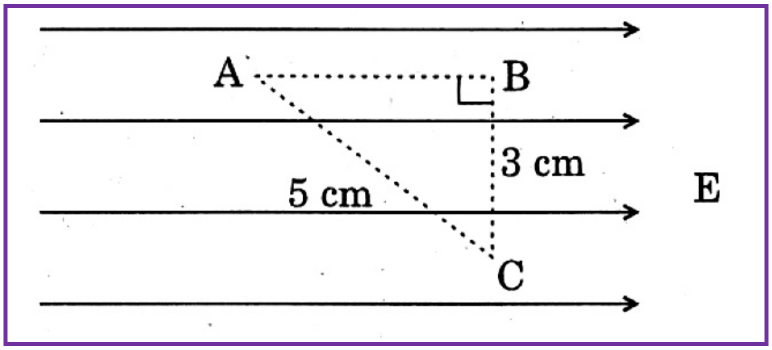
ii. The foil is connected to the upper plate with a conducting wire?

Answer:

If foil is connected to upper plate with a conducting wire, the effective separation between plates become half, so capacitance is doubled.

Question 10

Three points A, Band C lle in a uniform electric field (E) of $5x10^3$ Nc-1 as shown in the figure. Find the potential difference between A and C. [2]



Answer:

The line joining *B* to *C* is perpendicular to electric field, so potential of *B* = potential of *C i.e.,*

$V_B = V_C$

Distance AB = 4 cm

Potential difference between A and C = $E \times (AB)$

$= 5 \times 10^3 \times (4 \times 10^{-2})$

= 200 volt

OR

The sum of two point charges is $7 \mu C$. They repel each other with a force of 1 N when kept 30 cm apart in free space. Calculate the value of each charge. [2]

Answer:

$q_1 + q_2 = 7 \times 10^{-6}$ C ....(1)

$\frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{(0.30)^2} = 1 \qquad \Rightarrow q_1 q_2 = (4\pi\varepsilon_0)(0.30)^2$

Or,

$q1q2 = \frac{1}{9 \times 10^9} \times 9 \times 10^{-2} = 10^{-11}$ ....(2)

$(q_1 - q_2) = (q_1 + q_2) - 4q_1q_2$

$= (7 \times 10^{-6})^2 - 4 \times 10^{-11}$

$$= 49 \times 10^{-12} - 40 \times 10^{-12} = 9 \times 10^{-12}$$

$$q_1 - q_2 = 3 \times 10^{-6}\ C \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Solving (1) and (3), we get

$$q_1 = 5 \times 10^{-6}\ C,\ q_2 = 2 \times 10^{-6}\ C$$

$$\Rightarrow q_1 = 5\mu C, q_2 = 2\mu C$$

Question 11

Name the electromagnetic radiations having the wavelength range from 1 mm to 700 nm. Give its two important applications. [2]

Answer:

Infrared radiations

Applications:

i. Taking photograph during fog and smoke etc.

ii. For therapeutic purposes

Question 12

A wire of length L is bent round in the form of a coil having N turns of same radius. If a steady current I flows through it in a clockwise direction, find the magnitude and direction of the magnetic field produced at its center. [2]

Answer:

$$L = N \times 2\pi r \Rightarrow \quad r = \frac{l}{2\pi N}$$

$$B = \frac{\mu_0 N1}{2r} = \frac{\mu_0 N1}{1\left(\frac{L}{2\pi N}\right)} \qquad \Rightarrow B = \frac{\mu 0 \pi N^2}{L} I$$

The direction of magnetic field is normal to plane of coil in downward direction.

Question 13

Derive an expression for the de-Broglie ·wavelength associated with an electron accelerated through a potential V. Draw a schematic diagram of a localized-wave describing · the wave nature of the moving electron. [2]

Answer:

Expression for de Broglie Wavelength associated with Accelerated Electrons

The de Broglie wavelength associated with electrons of momentum *p* is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv} \ldots\ldots\ldots\ldots\ldots(i)$$

where *m* is mass and *v* is velocity of electron. If *Ek* is the kinetic energy of electron, then

$$Ek = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{p}{m}\right)^2 = \frac{p^2}{2m} \quad (\text{since } p = mv \Rightarrow v = \frac{p}{m})$$

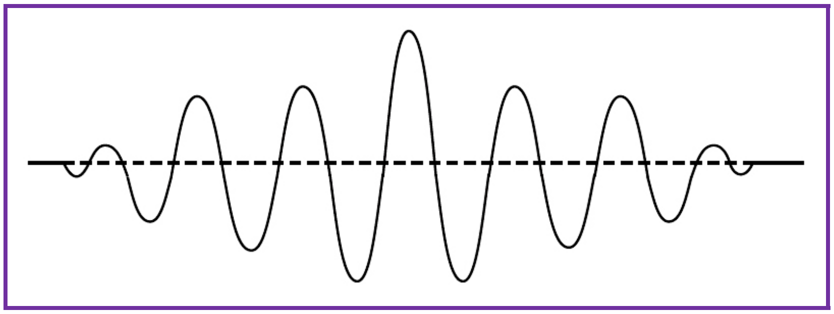
$$\Rightarrow \qquad p = \sqrt{2mE_k}$$

$$\therefore \text{ Equation (i) gives } \lambda = \frac{h}{\sqrt{2mE_k}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(ii)$$

If V volt is accelerating potential of electron, then Kinetic energy,
EK = eV
∴ Equation (*ii*) gives

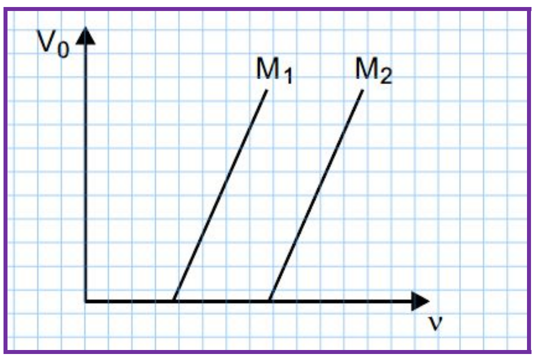
$$\lambda = \frac{h}{\sqrt{2meV}} \quad \text{.......................(iii)}$$

This is the required expression for de Broglie wavelength associated with electron accelerated to potential of *V* volt. The diagram of wave packet describing the motion of a moving electron is shown.



Question 14

Figure shows variation of stopping potential (V_0) with the frequency (v) for two photosensitive materials M_1 and M_2. [2]



i. Why is the slope same for both lines?

Answer:

The slope of stopping potential (v_0) versus frequency (n) is equal to $\left(\frac{h}{e}\right)$ which is universal constant, so slope is same for both lines.

ii. For which material will the emitted electrons have greater kinetic energy for the incident radiations of the same frequency? Justify your answer.

Answer:

K.E. = hv - hv_0

As threshold frequency v_0 is lesser for M_1, so K.E. will be greater for M_1 for same frequency v.

Question 15

The energy of the electron in the ground state of hydrogen atom is -13.6 eV.

i. What does the negative sign signify?

Answer:

Negative sign shows that electron in ground state is bound in H-atom due to attractive force between electron and nucleus.

ii. How much energy is required to take an electron in this atom from the ground state to the first excited state? [2]

Answer:

Energy of electron in H-atom in *n*th orbit is

$$E_n = -\frac{Rhc}{n^2} = -\frac{13.6}{n^2}$$

For first excited state $n = 2$

$$E_2 = -\frac{13.6}{4} eV = -3.4 eV$$

Energy required to take electron from ground state to first excited state

$\Delta E = E_2 - E_1$

$= -13.6\ eV - (-3.4\ eV)$

$= 10.2\ eV$

Question 16

Draw the logic symbol of the gate whose truth table is given below: [2]

Input		**Output**
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

If this logic gate is connected to NOT gate, what will be the output when

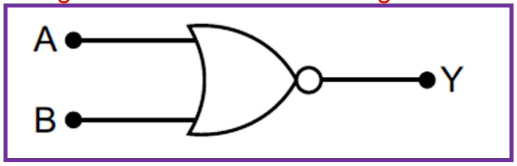
i. A = 0, B = 0

ii. A = 1, B = 1

Draw the logic symbol of the combination.

Answer:

The given truth table is of **NOR** gate. The logic symbol is shown in fig.

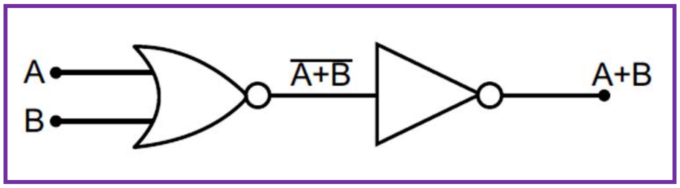


When it is connected to a NOT gate, the gate becomes OR gate.

(i) A = 0, B = 0 gives output **0.**

(ii) A = 1, B = 1 gives output **1.**

The combination is shown in fig.



Question 17

a. What is line of sight communication?

Answer:

LOS Communication: The propagation of a radio wave in a straight line from transmitting to receiving antenna on the ground is called line of sight communication.

b. Why is it pot possible to use sky wave propagation for transmission of TV signals? [2]

Answer:

TV signals have high frequency range 100 to 200 MHz. Ionospheric layers do not reflect back such high frequency signals. Hence, sky waves cannot be used for transmission of TV signals.

Question 18

a. How are eddy currents reduced in a metallic core?

Answer:

A metallic core cuts the path of eddy currents, this reducing the strength of eddy currents.

b. Give two uses of eddy currents. [2]

Answer:

Eddy currents are used in

- i. induction furnace
- ii. induction motor.

Question 19

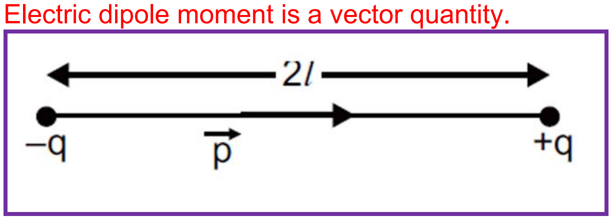
Define the term 'electric dipole moment'. Is it scalar or vector?
Deduce an expression for the electric field at a point on the equatorial plane of an electric dipole of length 2a. [3]

Answer:

The electric dipole moment is a vector quantity whose magnitude is equal to the product of charge on one dipole and distance between them. Its direction is from - *q* to + *q*.

i.e., $\vec{p} = q\,2\vec{l}$

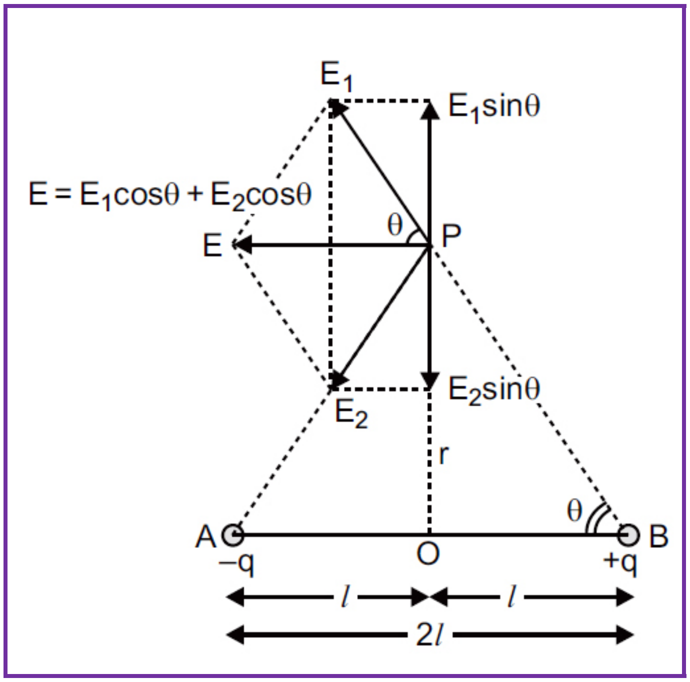
Electric dipole moment is a vector quantity.



Derivation of electric field at a point of equatorial plane:

Consider a point *P* on broad side on the position of dipole formed of charges + *q* and - *q* at separation 2*l*.

From figure,



AP = BP = $\sqrt{r^2 + l^2}$

∴ $\vec{E_1} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2 + l^2}$ along *B* to *P*

$\vec{E_2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2 + l^2}$ along *P* to *A*

∴ Resultant electric field at *P* is $E = E_1\cos\theta + E2\cos\theta$

But $E_1 = E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + l^2)}$

And $\cos\theta = \frac{OB}{PB} = \frac{1}{\sqrt{r^2 + l^2}} = \frac{l}{(r2 + l2)^{\frac{1}{2}}}$

∴ $E = 2E_1\cos\theta = 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + l^2)} \cdot \frac{1}{(r2 + l2)^{\frac{1}{2}}}$

$= \frac{1}{4\pi\varepsilon_0}\frac{2ql}{(r^2 + l^2)^{\frac{3}{2}}}$

But *q*.2*l* = *p* = electric dipole moment

∴ $E = \frac{1}{4\pi\varepsilon_0}\frac{P}{(r^2 + l^2)^{\frac{3}{2}}}$ ....(iii)

If dipole is infinitesimal and point *P* is far away, we have $l << r$, so $l\,2$ may be neglected as compared to $r\,2$ and so equation (3) gives

$$E = \frac{1}{4\pi\varepsilon_0} \frac{P}{(r^2)^{\frac{3}{2}}}$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{P}{r^3}$$

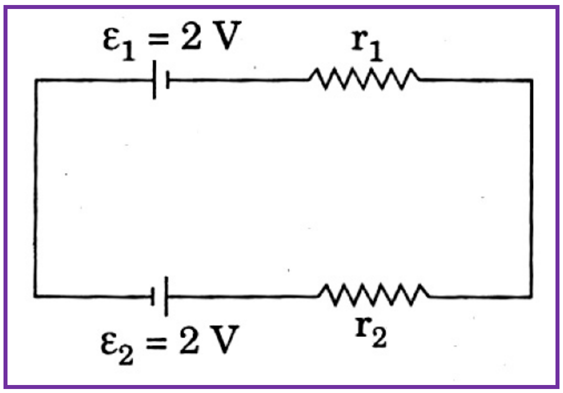
i.e. electric field strength due to a short dipole at broadside on position

$$E = \frac{1}{4\pi\varepsilon_0} \frac{P}{r^3} \text{ parallel to } \overrightarrow{BA} \text{ ....(iv)}$$

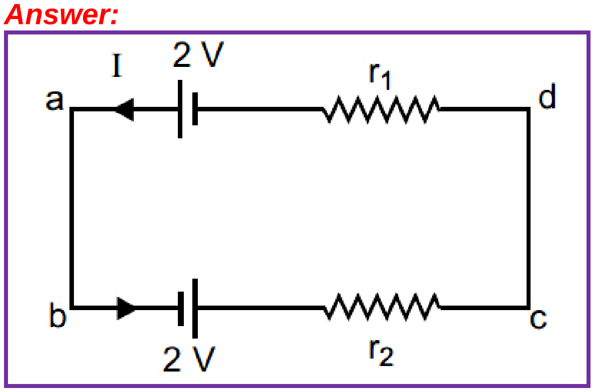
Its direction is parallel to the axis of dipole from positive to negative charge.

Question 20

State Kirchhoff's rules. Use Kirchhoff's rules to show that no current flows in the given circuit. [3]



Answer:



Kirchhoff's Rules:

(i) First law (or junction law): The algebraic sum of currents meeting at any junction is zero,

i.e., $\sum I = 0$

This law is based on conservation of charge.

(ii) Second law (or loop law): The algebraic sum of potential differences of different circuit elements of a closed circuit (or mesh) is zero, *i.e.,*

$$\sum V = 0$$

This law is based on conservation of energy.

Numerical: Applying Kirchhoff's second law $\sum V = 0$ to given closed circuit along the path *abcda*.

$$+2 - Ir_2 - Ir_1 + 2 = 0$$

$\Rightarrow \quad I(r_1 + r_2) = 4$

$I = \frac{4}{r_1 + r_2}$

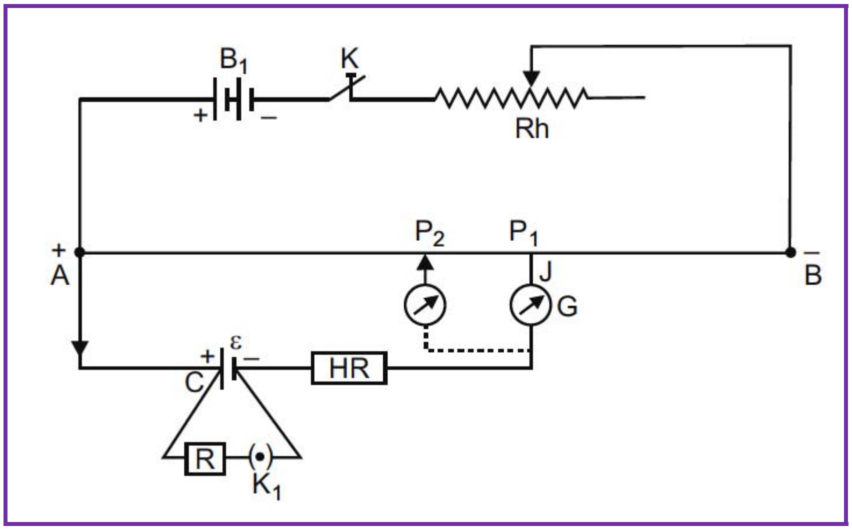
Question 21

a. State the principle of working of a potentiometer.

Answer:

Principle of Potentiometer:

Potentiometer works on the fact that the fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire is of uniform area of cross-section and a constant current is flowing through it.



Suppose *A* and r are respectively the area of cross-section and specific resistance of the material of the wire. Let *V* be the potential difference across the portion of the wire of length *l* whose resistance is *R*. If *I* is the current flowing through the wire, then from Ohm's law;

V = I R

As $R = \frac{\rho l}{A}$

$\therefore \quad V = IP\frac{l}{A}$ (where $K = \frac{I\rho}{A}$)

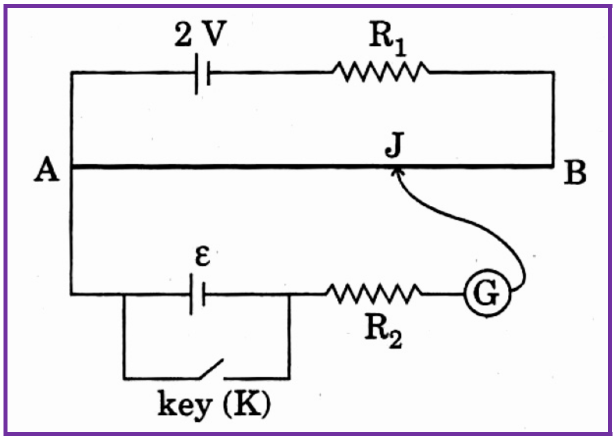
Or $V \propto l$

i.e., potential difference across any portion of potentiometer wire is directly proportional to length of the wire of that portion.

Here, $\frac{V}{l}$ = k= is called potential gradient,

i.e., the fall of potential per unit length of wire.

b. Figure shows ·the circuit diagram of a potentiometer for determining the emf 'ε' of a cell of negligible internal resistance. [3]



i. What is the purpose of using high resistance R_2?

Answer:
The purpose of high resistance R_2 is to reduce the current through the galvanometer. When jockey is far from balance point, this saves the galvanometer and the cell (of emf e) from being damaged.

ii. How does the position of balance point (J) change when the resistance R_1 is ·decreased?

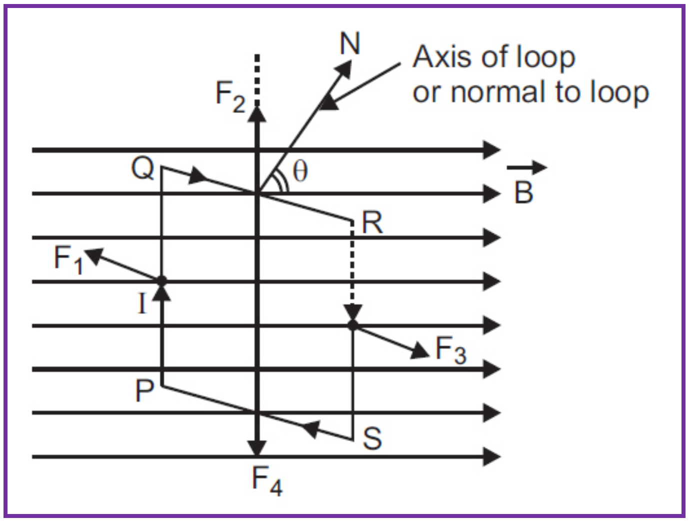
Answer:
When resistance R_1 is decreased, the potential gradient of potentiometer wire increases, so balance point (*J*) shifts to longer length of wire.

iii. Why cannot the balance point be obtained (1) when the emf ε is greater than 2V, and (2) when the key (K) is closed?

Answer:
(1) The balance point is not obtained because maximum emf across potentiometer wire is 2 V.
(2) When key (*K*) is closed, the terminal potential difference of cell is zero; so balance point cannot be between *A* and *B*. (Since $V = kl \Rightarrow l = 0$ for $V = 0$)

Question 22
Deduce the expression for the torque experienced by a rectangular loop carrying a steady current 'I' and placed in a uniform magnetic field $\vec{B}$. Indicate the direction of the torque acting on the loop.
[3]

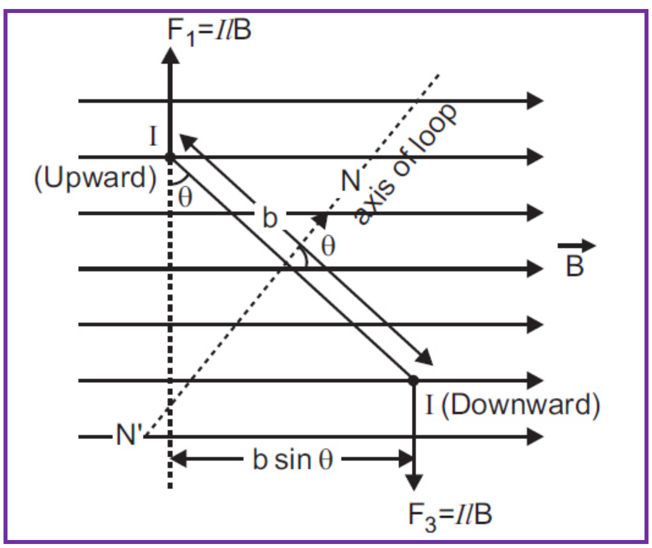
Answer:



Torque on a current carrying loop: Consider a rectangular loop PQRS of length l, breadth b suspended in a uniform magnetic field $\vec{B}$. The length of loop = PQ = RS = l and breadth = QR = SP = b. Let at any instant the normal to the plane of loop make an angle q with the direction of magnetic field $\vec{B}$ and I be the current in the loop. We know that a force acts on a current carrying wire placed in a magnetic field.

Therefore, each side of the loop will experience a force. The net
force and torque acting on the loop will be determined by the forces acting on all sides of the loop. Suppose that the forces on sides PQ, QR, RS and SP are $\vec{F_1}$, $\vec{F_2}$, $\vec{F_3}$ and $\vec{F_4}$ respectively. The sides QR and SP make angle (90° - q) with the direction of magnetic field. Therefore, each of the forces $\vec{F_2}$ and $\vec{F_4}$ acting on these sides has same magnitude F' = BIb sin (90° - q) = BIb cos θ.

According to Fleming's left hand rule the forces $\vec{F_2}$ and $\vec{F_4}$ are equal and opposite but their line of action is same. Therefore, these forces cancel each other i.e. the resultant of $\vec{F_2}$ and $\vec{F_4}$ is zero.



The sides PQ and RS of current loop are perpendicular to the magnetic field, therefore the magnitude of each of forces $\vec{F_1}$ and $\vec{F_3}$ is

F = IlB sin 90° = IlB.

According to Fleming's left hand rule the forces $\vec{F_1}$ and $\vec{F_3}$ acting on sides PQ and RS are equal and opposite, but their lines of action are different; therefore, the resultant force of $\vec{F_1}$ and $\vec{F_3}$ is zero, but they form a couple called the **deflecting couple.** When the normal to plane of loop makes an angle θ with the direction of magnetic field B, the perpendicular distance between F_1 and F_3 is b sin θ.

∴ Moment of couple or Torque,

π = (Magnitude of one force F) ´ perpendicular distance = (BIl) × (b sin θ) = I (lb) B sin θ

But lb = area of loop = A(say)

∴ Torque, π= IAB sin θ

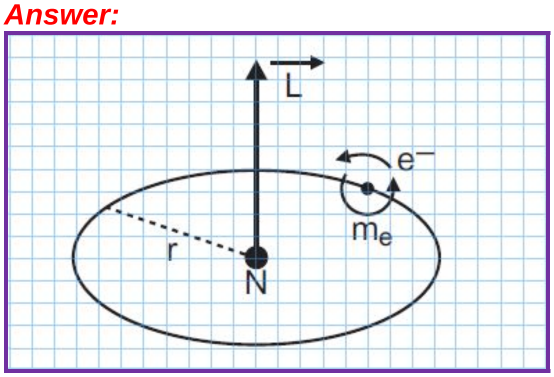
If the loop contains N-turns, then π NI AB sin θ

In vector form $\vec{\pi} = NI\ \vec{A} \times \vec{B}$

OR

Deduce the expression for magnetic dipole moment of an electron revolving around the nucleus in a circular orbit of radius 'r'. Indicate the direction of the magnetic dipole moment. [3]

Answer:



Magnetic moment of an electron moving in a circle:

Consider an electron revolving around a nucleus (N) in circular path of radius r with speed v.

The revolving electron is equivalent to electric current

$$I = \frac{e}{T}$$

where T is period of revolution = $\frac{2\pi r}{v}$

$$\therefore \quad I = \frac{e}{2\pi r / v} = \frac{ev}{2\pi r} \quad \ldots\ldots\ldots\ldots\ldots\ldots(i)$$

Area of current loop (electron orbit), $A = \pi r^2$

Magnetic moment due to orbital motion,

$$M_l = IA = \frac{ev}{2\pi r}(\pi r^2) = \frac{evr}{2} \quad \ldots\ldots\ldots(ii)$$

This equation gives the magnetic dipole moment of a revolving electron. The direction of magnetic moment is along the axis.

Relation between magnetic moment and angular momentum

Orbital angular momentum of electron

$L = m_e vr$..............................(iii)

where me is mass of electron,

Dividing (ii) by (iii), we get

$$\frac{M_1}{L} = \frac{evr/2}{m_e vr} = \frac{e}{2m_e} \text{ ....(iv)}$$

This is expression of magnetic moment of revolving electron in terms of angular momentum of electron.

In vector form

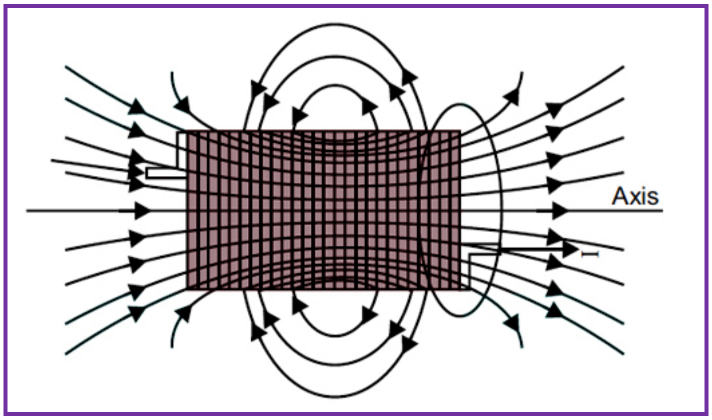
$$\vec{Ml} = -\frac{e}{2m_e}\vec{L} \text{ ....(v)}$$

Question 23

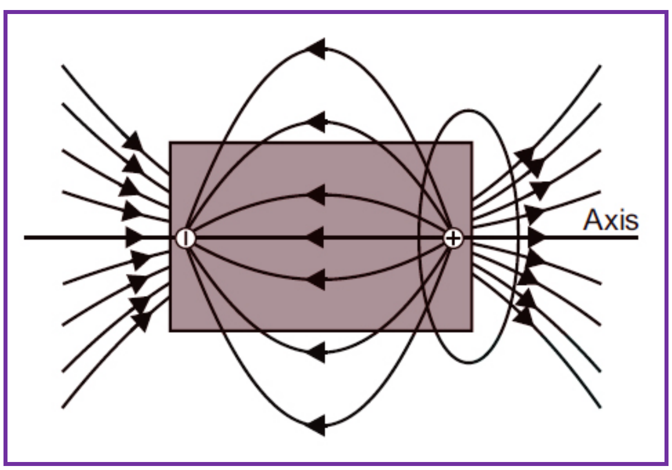
Depict the field-line pattern due to a current carrying solenoid of finite length. [3]

i. In what way do these lines differ from those due to an electric dipole?
ii. Why can't two magnetic field lines intersect each other?

Answer:



Field fines of a current carrying solenoid



Field fines of an electric dipole

a. Difference: Field lines of a solenoid form continuous current loops, while in the case of an electric dipole the field lines begin from a positive charge and end on a negative charge or escape to infinity.

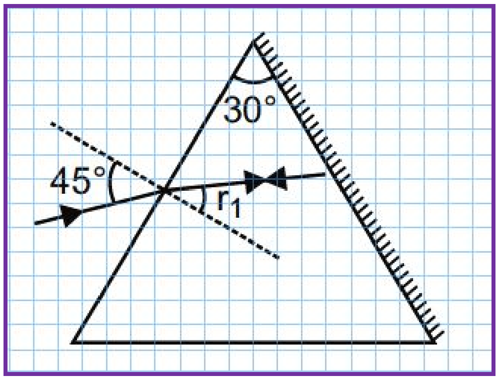
b. Two magnetic field lines cannot intersect because at the point of intersection, these will be two directions of magnetic field which is impossible.

Question 24

State the conditions under which total internal reflection occurs.

One face of a prism with a refracting angle of 30° is coated with silver. A ray incident on another face at an angle of 45° is refracted and reflected from the silver coated face and retraces its path. Find the refractive index of the material of the prism. [3]

Answer:



(i) The conditions for total internal reflection are

(*a*) The ray must travel from a denser into a rarer medium.

(*b*) The angle of incidence *i* > critical angle *C*.

(ii) Numerical: Given *A* = 30°

When ray is incident normally on the other face, it retraces its path, so

$r_2 = 0$.

As $r_1 + r_2 = A$ Þ $r_1 = A - r_2 = 30° - 0 = 30°$

$i_1 = 45°$

Refractive index, $n = \frac{\sin i_1}{\sin r_1} = \frac{\sin 45^0}{\sin 30^0}$

$\Rightarrow \quad n = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \sqrt{2} = 1.414$

Question 25

a. Why do we not encounter diffraction effects of light in everyday observations?

Answer:

We do not encounter diffraction effects of light in everyday observations. To observe diffraction, size of obstacle/aperture must be comparable with wavelength of light but in daily observations size of obstacle/aperture is much larger than the wavelength of light. Angular width of central fringe $\beta_\theta = \frac{2\lambda}{a}$

b. In the observed diffraction pattern due to a single slit, how will the width of central maximum be affected if

i. The width of the slit is doubled;

Answer:

If the width of slit is doubled, the (angular) width of central fringe $\left(\propto \frac{1}{a}\right)$ is halved.

ii. The wavelength of the light used is increased?

Justify your answer in each case. [3]

Answer:

When wavelength of light used is increased $\left(\beta_{\theta} \propto \lambda\right)$, the width of central fringes increases.

Question 26

a. What is meant by half-life of a radioactive element?

Answer:

The half-life of a radioactive sample is defined as the time in which the mass of sample is left one half of the original mass.

b. The half-life of a radioactive substance is 30 s. Calculate

i. The decay constant

ii. Time taken for the sample to decay by $\frac{3}{4}$th of the initial value. [3]

Answer:

Give T = 30 s

i. Decay constant, $\lambda = \frac{0.6931}{T} = \frac{0.6931}{30} s^{-1} = 0.0231 s^{-1}$

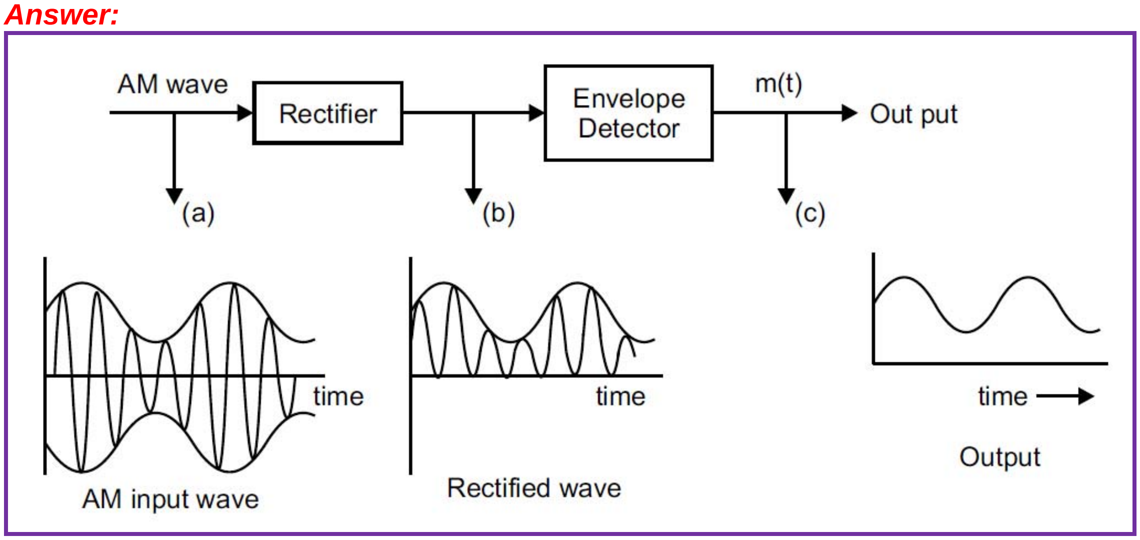
ii. $\frac{N}{N_0} = (\frac{1}{2})^n \qquad \Rightarrow 1 - \frac{3}{4} = \left(\frac{1}{2}\right)^n$ or $\left(\frac{1}{2}\right)^n$

This gives $n = \frac{t}{T} = 2$ or $t = 2T = 2 \times 30 = 60$ s

Question 27

What is meant by detection of a signal in a communication system? With the help of a block diagram explain the detection of A.M. signal. [3]

Answer:



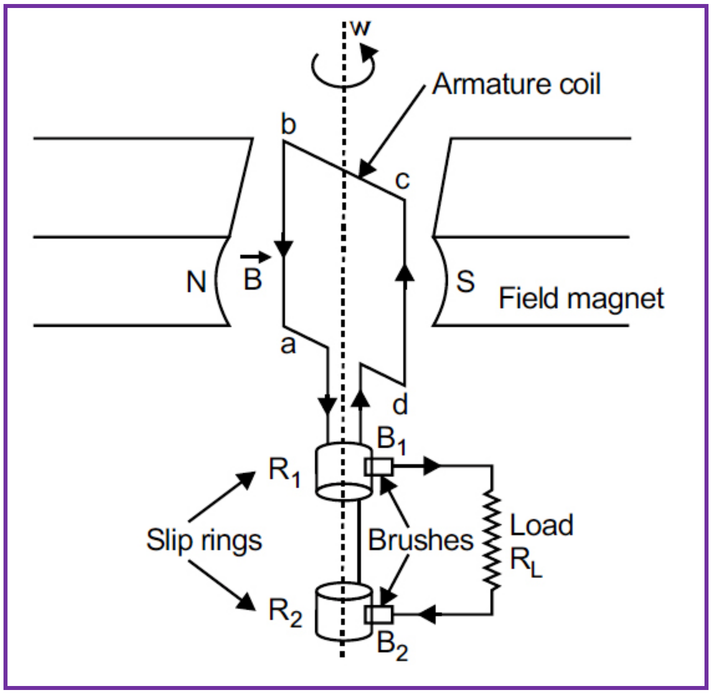
Detection: Detection is the process of recovering the modulating signal from the modulated carrier wave.
Explanation of Detection with the help of a block diagram:
The modulated carrier wave contains frequencies wc ± wm. The detection means to obtain message signal m(t) of frequency wm. The method is shown in the form of a block diagram.
The modulated signal is passed through a rectifier. It produces rectified wave [fig. (b)];' the envelope of which is the message signal.
The rectified wave is passed through an envelope detector; whose output is the required message signal m(t).

Question 28

State the working principle of an A.C. generator with the help of a labelled diagram. Derive an expression for the instantaneous value of the emf induced in coil.

Why is the emf maximum when the plane of the armature is parallel to the magnetic field? [5]

Answer:



AC generator: A dynamo or generator is a device which converts mechanical energy into electrical energy. It is based on the principle of electromagnetic induction.
Construction: It consists of the four main parts:
(i) Field Magnet: It produces the magnetic field. In the case of a low power dynamo, the magnetic field is generated by a permanent magnet, while in the case of large power dynamo, the magnetic field is produced by an electromagnet.

(ii) Armature: It consists of a large number of turns of insulated wire in the soft iron drum or ring. It can revolve round an axle between the two poles of the field magnet. The drum or ring serves the two purposes: (i) It serves as a support to coils and (ii) It increases the magnetic field due to air core being replaced by an iron core.

(iii) Slip Rings: The slip rings R1 and R2 are the two metal rings to which the ends of armature coil is connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.

(iv) Brushes: These are two flexible metal plates or carbon rods (B_1 and B_2) which are fixed and constantly touch the revolving rings. The output current in external load RL is taken through these brushes.
Working: When the armature coil is rotated in the strong magnetic field, the magnetic flux linked with the coil changes and the current is induced in the coil, its direction being given by Fleming's right-hand rule. Considering the armature to be in vertical position and as it rotates in anticlockwise direction, the wire ab moves upward and downward, so that the direction of induced currencies shown in fig. In the external circuit, the current flows along B_1R_L B_2 .

The direction of current remains unchanged during the first half turn of armature. During the second half revolution, the wire ab moves downward and cd upward, so the direction of current is reversed and in external circuit it flows along B_2R_L B_1. Thus the direction of induced emf and current changes in the external circuit after each half revolution. If N is the number of turns in coil, f the frequency of rotation, A area of coil and B the magnetic induction, then induced emf

$$e = -\frac{d\varnothing}{dt} = \frac{d}{dt}\{NBA(\cos 2\pi f\, t)\} = 2\pi N B A f \sin 2\pi f\, t$$

Obviously, the emf produced is alternating and hence the current is also alternating.
Current produced by an ac generator cannot be measured by moving coil ammeter; because the average value of ac over full cycle is zero.

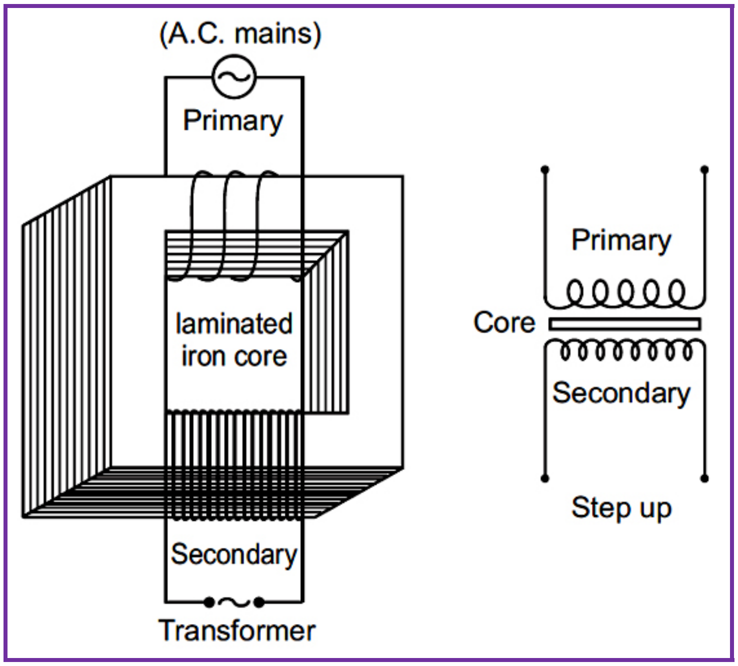
The source of energy generation is the mechanical energy of rotation of armature coil. When plane of armature coil is parallel to magnetic field, then sin wt = 1, so emf is maximum, the maximum value is e0 = NB Aw

OR

Draw a labelled diagram of a step-up · transformer and explain briefly its working. Deduce the expressions for the secondary voltage and secondary current in terms of the number of turns of primary and secondary windings.

How is the power transmission and distribution over· long distances done with the use of transformers? [5]

Answer:



Transformer: Transformer is a device by which an alternating voltage may be decreased or increased. This is based on the principle of mutual-induction.

Construction: It consists of laminated core of soft iron, on which two coils of insulated copper wire are separately wound. These coils are kept insulated from each other and from the iron-core, but are coupled through mutual induction.

The number of turns in these coils are different. Out of these coils one coil is called primary coil and other is called the secondary coil. The terminals of primary coils are connected to AC mains and the terminals of the secondary coil are connected to external circuit in which alternating current of desired voltage is required.

Step up Transformer: It transforms the alternating low voltage to alternating high voltage and in this the number of turns in secondary coil is more than that in primary coil.
(i.e, NS > Np).

Working: When alternating current source is connected to the ends of primary coil, the current changes continuously in the primary coil; due to which the magnetic flux linked with the secondary coil changes continuously, therefore the alternating emf of same frequency is developed across the secondary.

Let N_p be the number of turns in primary coil, NS the number of turns in secondary coil and f the magnetic flux linked with each turn. We assume that there is no leakage of flux so that the flux linked with each turn of primary coil and secondary coil is the same. According to Faraday's laws the emf induced in the primary coil

$\varepsilon_p = -N_p \frac{\Delta\varnothing}{\Delta t}$ ....(i)

and emf induced in the secondary coil

$\varepsilon_s = -N_s \frac{\Delta\varnothing}{\Delta t}$ ....(ii)

From (1) and (ii)

$\frac{\varepsilon_S}{\varepsilon_P} = \frac{N_S}{N_P}$ ………………..(iii)

If the resistance of primary coil is negligible, the emf (ε_p) induced in the primary coil, will be equal to the applied potential difference (V_p) across its ends. Similarly if the secondary circuit is open, then the potential difference VS across its ends will be equal to the emf (e_S) induced in it; therefore

$\frac{V_S}{V_P} = \frac{\varepsilon_S}{\varepsilon_P} = \frac{N_S}{N_P}$ = r (say)……….(iv)

where r = $\frac{N_S}{N_P}$ is called the transformation ratio. If i_p and i_s are the instantaneous currents in primary and secondary coils and there is no loss of energy;

For about 100% efficiency, Power in primary = Power in secondary

$V_P i_P = V_S i_S$

$\therefore \frac{i_S}{i_P} = \frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{1}{r}$ ………..(v)

In step up transformer, Ns > Np $\rightarrow$ r >1;

So $V_s > V_p$ and $i_s < i_p$

i.e., step up transformer increases the voltage.

Power Transmission Over Long Distances

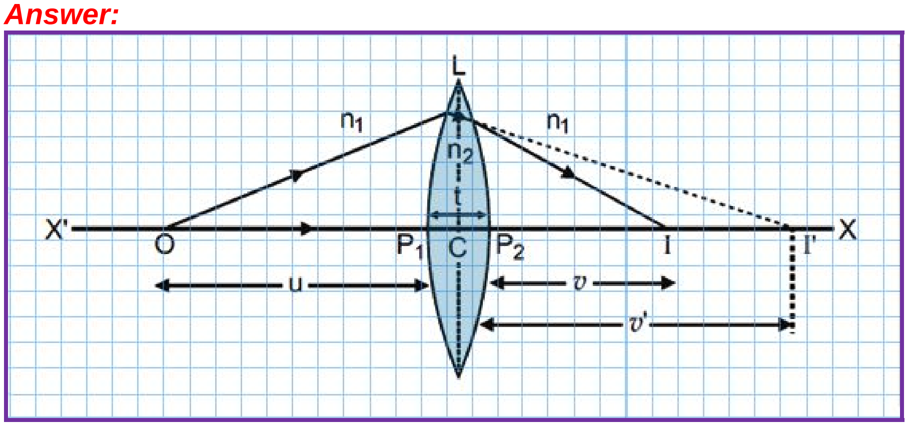
The power (electrical energy) is transmitted to long distances by the use of transformers. The voltage output of the generator is stepped up by means of step up transformer, this steps down the current, so power loss $I^2R$is significantly reduced. At the receiving station the voltage is stepped down to 220 V for domestic supply.

Question 29

Draw a ray diagram for formation of image of a point object by a thin double convex lens having radii of curvatures R_1 and R_2 and hence derive lens maker's formula.

Define power of a lens and give its S.I. units. If a convex lens of focal length 50 cm is placed in contact coaxially with a concave lens of focal length 20cm, what is the power ·of the combination? [5]

Answer:



(a) Lens Maker's Formula: Suppose L is a thin lens. The refractive index of the material of lens is n2 and it is placed in a medium of refractive index n_1. The optical centre of lens is C and X 'X is principal axis. The radii of curvature of the surfaces of the lens are R_1 and R_2 and their poles are P_1 and P_2 . The thickness of lens is t, which is very small. O is a point object on the principal axis of the lens. The distance of O from pole P_1 is u. The first refracting surface forms the image of O at I ' at a distance v' from P_1. From the refraction formula at spherical

Surface

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \text{ ....(i)}$$

The image I 'acts as a virtual object for second surface and after refraction at second surface, the final image is formed at I. The distance of I from pole P_2 of second surface is v. The distance of virtual object (I ') from pole P_2 is (v' - t).

For refraction at second surface, the ray is going from second medium (refractive index n_2) to first medium (refractive index n_1), therefore from refraction formula at spherical surface

$$\frac{n_1}{v} - \frac{n_2}{(v'-t)} = \frac{n_1 - n_2}{R_2} \text{ ....(ii)}$$

For a thin lens t is negligible as compared to v', therefore from (ii)

$$\frac{n_1}{v} - \frac{n_2}{(v')} = \frac{n_2 - n_1}{R_2} \text{ ....(iii)}$$

Adding equations (i) and (iii), we get

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Or $$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

i.e. $$\frac{1}{v} - \frac{1}{u} = ({}_1n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ ....(iv)}$$

where ${}_1n_2 = \frac{n_2}{n_1}$ is refractive index of second medium (i.e. medium of lens) with respect to first medium.

If the object O is at infinity, the image will be formed at second focus i.e.

if $u = \infty$, $v = f_2 = f$

Therefore, from equation (iv)

$$\frac{1}{f} - \frac{1}{\infty} = ({}_1n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

i.e. $$\frac{1}{f} = ({}_1n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ ....(v)}$$

This is the formula of refraction for a thin lens. This formula is called **Lens-Maker's formula.**

If first medium is air and refractive index of material of lens be n, then ${}_1n_2 = n$, therefore equation (v) may be written as

$$\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ ....(vi)}$$

(b) Power of a Lens: The power of a lens is its ability to deviate the rays towards its principal axis. It is defined as the reciprocal of focal length in metres.

Power of a lens, $P = \frac{1}{f(\text{in metres})}$ diopters $= \frac{100}{f(\text{in cm})}$ diopters

The SI unit for power of a lens is dioptre (D).

Numerical:

Power of convex lens, $p_1 = \frac{1}{F_1} D = \frac{1}{0.50} = 2.0\,D$

Power of concave lens, $p_2 = \frac{1}{F_2} D = \frac{1}{-0.20} = -5.0\,D$

$\therefore$ Power of combination of lenses in contact

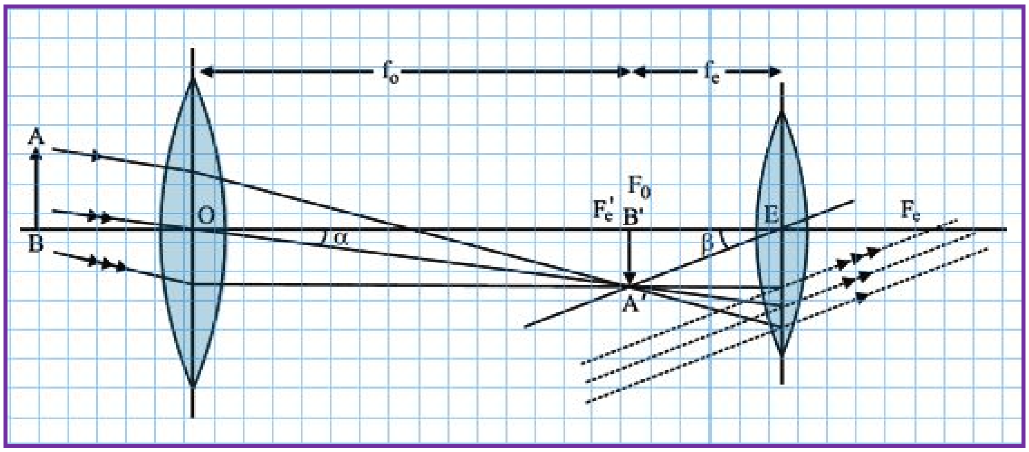
$P = P_1 + P_2 = 2.0D - 5.0D = -3.0D$

OR

Draw a labelled ray diagram to show the image formation by an astronomical telescope.

Derive the expression for its magnifying power in normal adjustment. Write two basic features which can distinguish between a telescope and a compound microscope. [5]

Answer:



Astronomical Telescope: Magnifying power of astronomical telescope in normal adjustment is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye, by the object directly, when the final image and the object both lie at infinite distance from the eye.

Magnifying power, $m = \frac{\beta}{\alpha}$

As angles α and β are small, therefore, $\alpha \approx \tan\alpha$ and $\beta \approx \tan\beta$.

From equation (1), $m = \frac{\tan\beta}{\tan\alpha}$

In $\Delta A'B'C_2'$ $\tan\beta = \frac{A'B'}{C_2B'}$

In $\Delta A'B'C_1'$ $\tan\alpha = \frac{A'B'}{C_1B'}$

Put in equation (2), $m = \frac{A'B'}{C_2B'} \times \frac{C_1B'}{A'B'} = \frac{C_1B'}{C_2B'}$

Or $m = \frac{f_0}{-f_e}$

where $C_1B = f_0$ = focal length of objective lens,
$C_2B' = -f_e$ = focal length of eye lens.
Negative sign of m indicates that final image is inverted.

The diameter of objective is kept large to increase (i) intensity of image, (ii) resolving power of telescope.

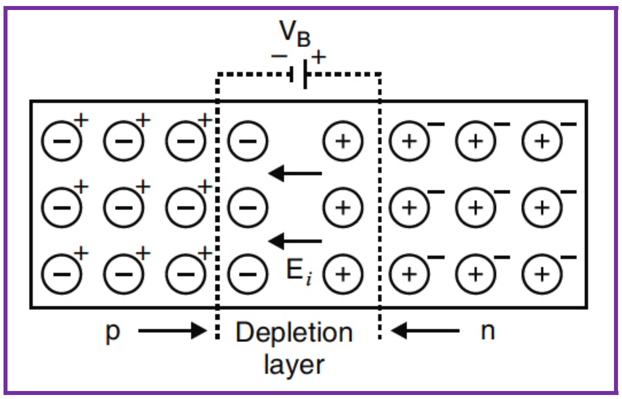
	Telescope	Compound Microscopes
1	Objective lens is of large focal length and eye lens is of small focal length.	Both objective and eye lenses are of small focal lengths but focal length of eye lens is larger than that of objective lens.
2.	Objective is of very large aperature.	Objective is of small aperture.

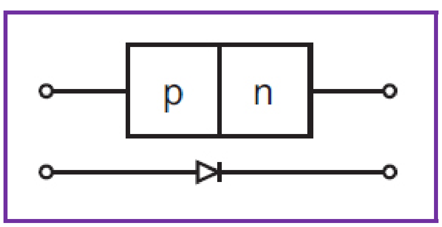
Question 30

a. Explain the formation of 'depletion layer' and barrier potential in a p-n junction.

Answer:

At the junction there is diffusion of charge carriers due to thermal agitation; so that some of electrons of n-region diffuse to p-region while some of holes of p-region diffuse into n-region. Some charge carriers combine with opposite charges to neutralize each other. Thus near the junction there is an excess of positively charged ions in n-region and an excess of negatively charged ions in p-region. This sets up a **potential difference** called potential barrier and hence an internal electric field E_i across the junctions. The field E_i is directed from n-region to p-region. This field stops the further diffusion of charge carriers. Thus the layers ($\approx 10^{-4}$ cm to 10^{-6} cm) on either side of the junction becomes free from mobile charge carriers and hence is called the depletion layer. The symbol of p-n junction diode is shown in Figure.

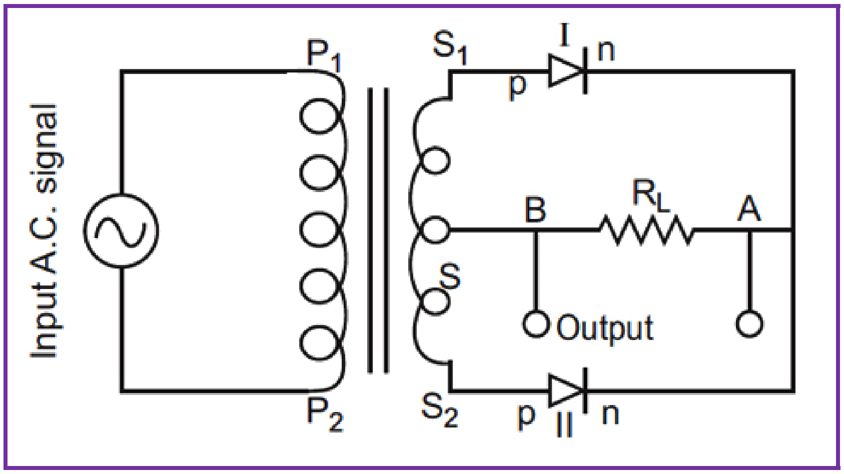


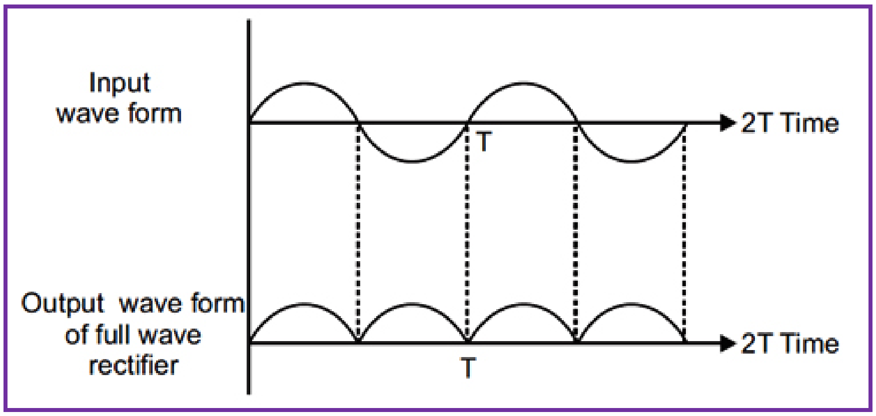


b. With the help of a labelled circuit diagram explain the use of a p-junction diode as a full wave rectifier. Draw the input and output waveforms. [5]

Answer:

(b) Full Wave Rectifier: For full wave rectifier we use two junction diodes. The circuit diagram for full wave rectifier using two junction diodes is shown in figure.





Suppose during first half cycle of input ac signal the terminal S_1 is positive relative to S and S_2 is negative relative to S, then diode **I** is forward biased and diode **II** is reverse biased. Therefore, current flows in diode **I** and not in diode **II**.

The direction of current i_1 due to diode **I** in load resistance R_L is directed from A to B. In next half cycle, the terminal S_1 is negative relative to S and S_2 is positive relative to S. Then diode **I** is reverse biased and diode **II** is forward biased. Therefore, current flows in diode **II** and there is no current in diode **I**.

The direction of current i_2 due to diode **II** in load resistance is again from A to B. Thus for input a.c. signal the output current is a continuous series of unidirectional pulses. This output current may be converted in fairly steady current by the use of suitable filters.

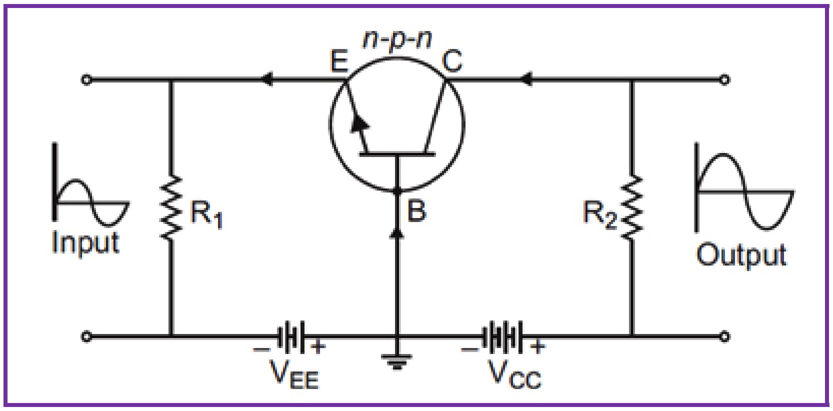
OR

Draw a circuit diagram of an n-p-n transistor with its emitter base junction forward biased and base collector junction reverse biased. Describe briefly it's working.

Explain how a transistor in active state exhibits a low resistance at its emitter base junction and high resistance at its base collector junction.

Draw a circuit diagram and explain the operation of a transistor as a switch. [5]

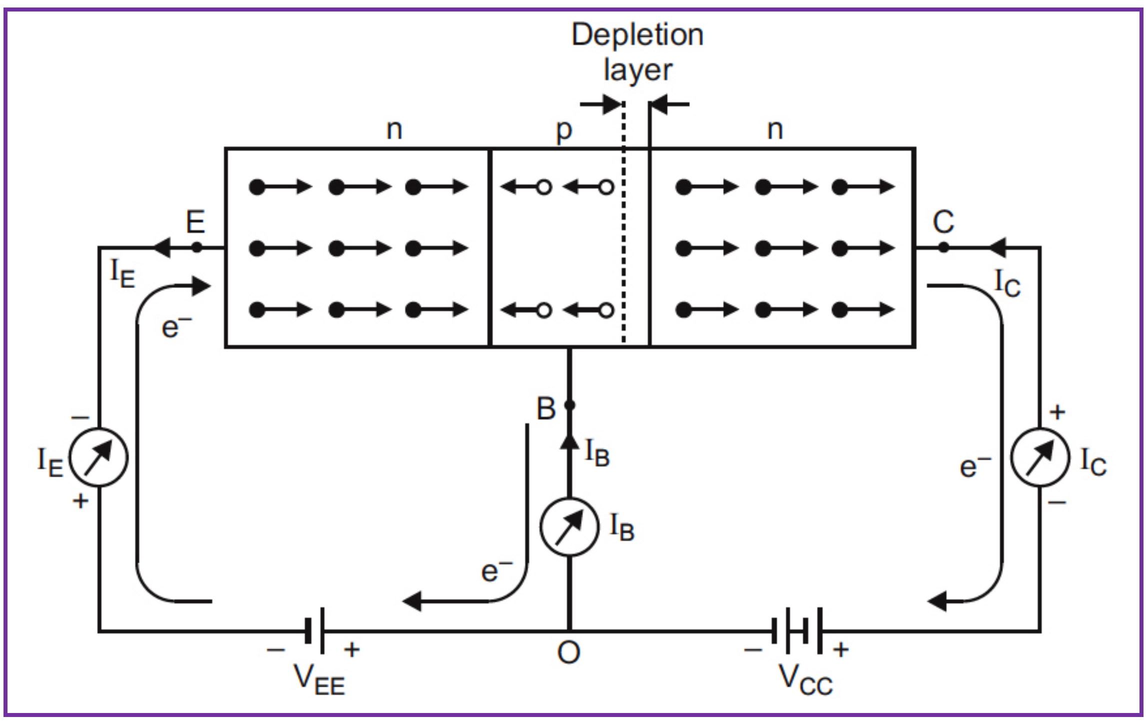
Answer:



Base Current and Collector Current: Under forward bias of emitter-base junction, the electrons in emitter and holes in base are compelled to move towards the junction, thus the depletion layer of emitter-base junction is eliminated.

As the base region is very thin, most electrons (about 98%) starting from emitter region cross the base region and reach the collector while only a few of them (about 2%) combine with an equal number of holes of base-region and get neutralized. As soon as a hole (in P-region) combines with an electron, a covalent bond of crystal atom of base region breaks releasing an electron-hole pair.

The electron released is attracted by positive terminal of emitter battery V_{EE}, giving rise to a feeble base current (I_B). Its direction in external circuit is from emitter to base. The hole released in the base region compensates the loss of hole neutralized by electrons.



The electrons crossing the base and entering the collector, due to reverse biasing of collector-base junction, are attracted towards the positive terminal of collector battery V_{CC} . In the process an equal number of electrons leave the negative terminal of battery V_{CC} and enter the positive terminal of battery V_{EE}. This causes a current in collector circuit, called the collector current. In addition to this the collector current is also due to flow of minority charge carriers under reverse bias of base-collector junction. This current is called the leakage current.

Thus, collector current is formed of two components:
(i) Current (Inc) due to flow of electrons (majority charge carriers) moving from emitter to collector.

(ii) leakage current ($I_{leakage}$) due to minority charge carriers, i. e., $I_c = I_{nc} + I_{leakage}$.

Emitter Current: When electrons enter the emitter battery V_{EE} from the base causing base current or electrons enter the collector battery V_{CC} from the collector causing collector current, an equal number of electrons enter from emitter battery V_{EE} to emitter, causing the emitter current. The process continues.

Relation between Emitter, Base and Collector Currents:
Applying Kirchhoff's I law at terminal O, we get

$I_E = I_B + I_C$

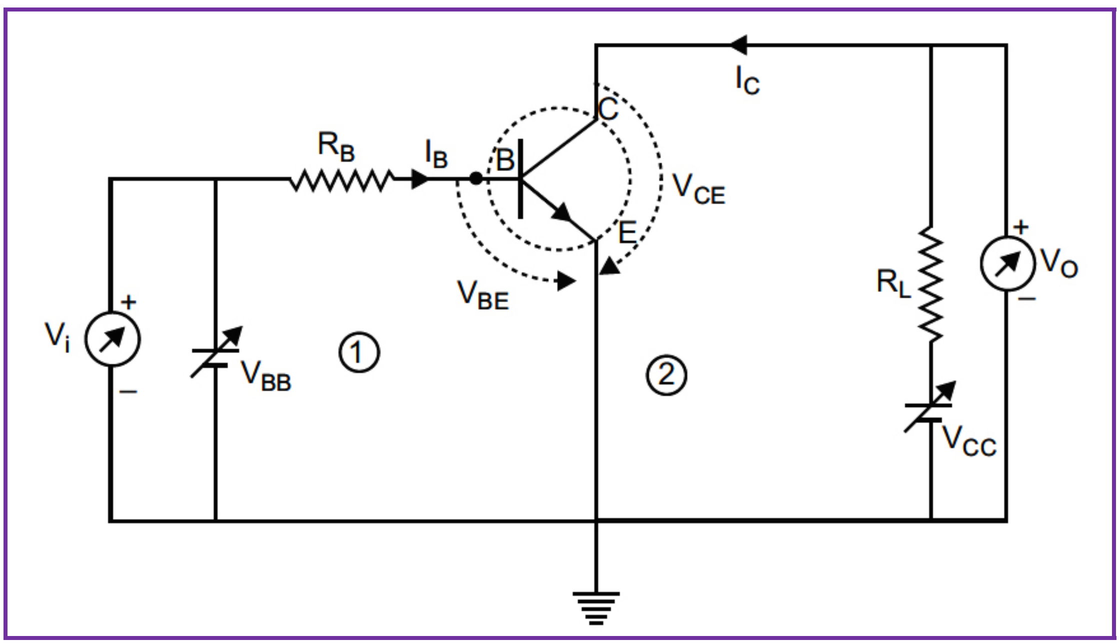
That is, the emitter current IE is the sum of base current I_B and the collector current I_C. This is the fundamental relation between currents in the bipolar transistor circuit.

Transistor as a Switch

- A switch is a device which can turn ON and OFF current is an electrical circuit.
- A transistor can be used to turn current ON or OFF rapidly in electrical circuits.

Operation: The circuit diagram of n-p-n transistor in CE configuration working as a switch is shown in fig. V_{BB} and V_{CC} are two dc supplies which bias base-emitter and emitter collecter junctions respectively.

Let V_{BB} be the input supply voltage. This is also input dc voltage (V_C). The dc output voltage is taken across collector-emitter terminals, R_L is the load resistance in output circuit.



Applying Kirchhoff's second law to input and output meshes (1) and (2), we get

$$V_{BB} = I_B R_B + V_{BE} \ldots\ldots\ldots\ldots\ldots\ldots(i)$$

and $$V_{CC} = I_C R_L + V_{CE} \ldots\ldots\ldots\ldots(ii)$$

We have $V_{BB} = V_i$ and $V_{CE} = V_0$, so above equations take the form

$$Vi = V_{BE} + I_B R_B \ldots\ldots\ldots\ldots\ldots(iii)$$

and $$V_0 (= V_{CE}) = V_{CC} - I_C R_L \ldots\ldots\ldots\ldots(iv)$$

Let us see the change in V_0 due to a change in Vi. In case of Si transistor; the barrier voltage across base-emitter junction is 0. 6 V. Therefore, when V_i is less than 0 .6 V, there is no collector current ($I_C = 0$), so transistor will be in cut off state. Hence, from (iv) with $I_C = 0$; $V_0 = V_{CC}$.
When V_i becomes greater than 0. 6 V, I_C begins to flow and increase with increase of Vi. Thus, from (iv), V_0 decreases upto $V_i = 1$ V; the increase in I_C is linear and so decrease in output voltage V_0 is **linear.**

Beyond $V_i = 1$ V, the change in collector current and hence in output voltage V_0 is non-linear and the transistor goes into saturation. With further increase in V_i, the output voltage further decrease towards zero (though it never becomes zero).

If we plot V_0 versus V_i, we get the graph as shown in fig. [This characteristics curve is also called transfer characteristic curve of base biased transistor.]

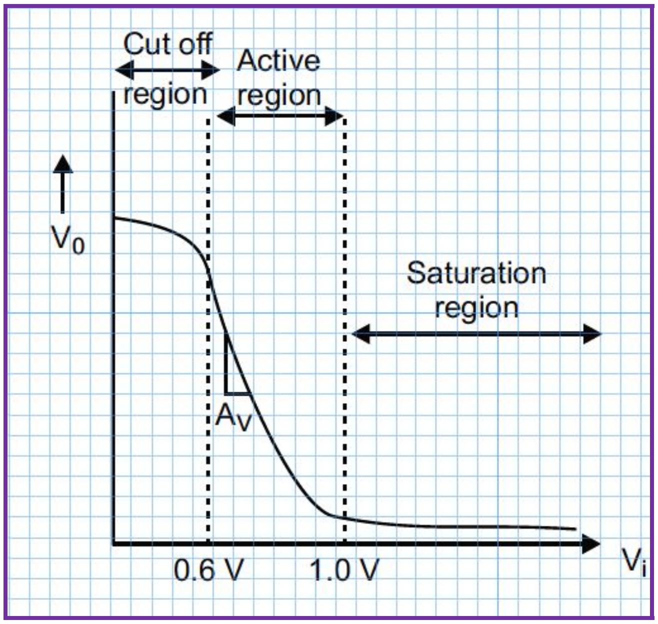
The curve shows that there are non-linear regions.

(i) Between cut off state and active state
(ii) Between active state and saturation state; thus showing that the transitions (i) from cut off to active state and from active to saturation state are not sharply defined.

Now we are in the position to explain the action of **transistor as a switch.** When transistor is non-conducting ($I_C = 0$), it is said to be **'switched off'** but when it is conducting (I_C is not zero); it is said to be **'switched ON'.**

As long as input voltage V_i is low and unable to overcome the barrier voltage of the emitter base junction, V_0 is high ($I_C = 0$ and $V_0 = V_{CC}$), so the transistor is 'switched OFF' and if it is high enough to derive the transistor into saturation (I_C is high and so V_0 (= $V_{CC} - I_C R_L$) is low, very near to zero, so the transistor is 'switched ON'.

Thus we can say low input switches the transistor is **OFF state** and high input switches it ON. The switching circuits are designed in such a way that the transistor does not remain in active state.


Cut off region
Active region
Saturation region
V_0
A_V
0.6 V
1.0 V
V_i