2012

Question 1
Why the potential inside a hollow is spherical charged conductor constant and has the same value as on its surface? . [1]

Answer:
Electric field inside a hollow charged conductor is zero and there is no tangential component on the surface of the conductor. So, work done is zero to moving a charge inside and on the surface of the conductor.

From this we conclude that potential inside the spherical charged conductor is constant and it is same on the surface.

Question 2
A magnetic needle, free to rotation in a vertical plane, orients itself vertically at a certain place on the Earth. What are the values of-

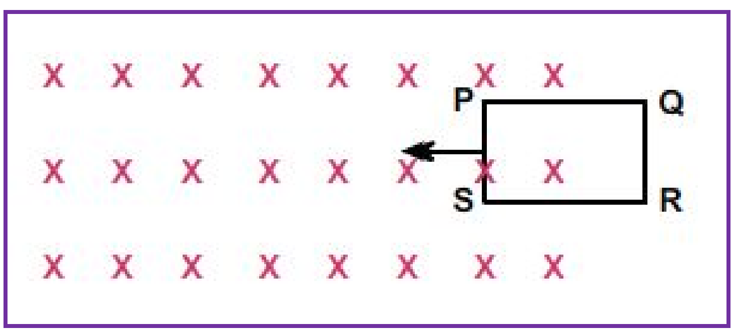
i. Horizontal component of Earth's magnetic field

Answer:
The horizontal component of earth's magnetic field is 0°.

ii. Angle of dip at this place. [1]

Answer:
The angle of dip is 90°

Question 3
The closed loop (PQRS) of wire is moved into a uniform magnetic field at right angles to the plane of the paper as shown in the figure. Predict the direction of the induced current in the loop.



[1]

Answer:
By Lenz's law, the direction of induced current is such that it opposes its own cause of production. The induced current opposes the increase in magnetic flux. Hence the direction of induced current is PSRQP (anticlockwise).

Question 4
Name the electromagnetic waves, which [1]

i. Maintain the Earth's warmth

Answer:
Infrared rays maintain the earth's warmth.

ii. Which are used in aircraft navigation.

Answer:
Microwaves are used in aircraft navigation due to their short wavelength.

Question 5
How does focal length of a lens change when red light incident on it is replaced by violet light? Given reason for your answer. [1]

Answer:
The refractive index of the material of a lens increases with the decrease in wavelength of the incident light. So, focal length will decrease with decrease in wavelength according to formula

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

$f \propto \frac{1}{(\mu-1)}$ and $\mu_\upsilon > \mu_R$

The increase in refractive index would result in decrease of focal length of lens. Hence, we can say by replacing red light with violet light, decreases the focal length of the lens used.

Question 6
Write the relationship between the size of a nucleus and its mass number (A) [1]

Answer:
The relationship is

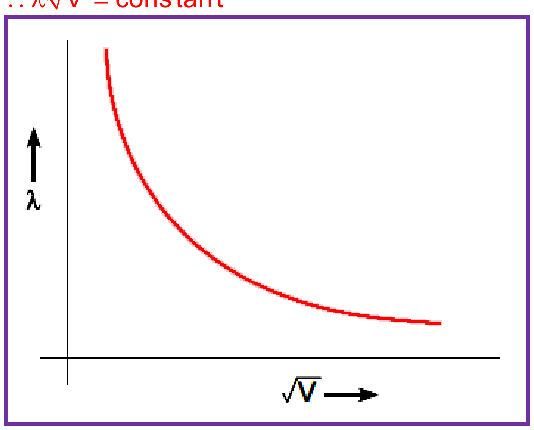
$$R = R_o A^{\frac{1}{3}}$$

where
R = radius of nucleus
Ro = 1.2 x 10^{-15} m
A = mass number

Question 7
Show on a graph the variation of the de Broglie wavelength (λ) associated with an electron, with the square root of accelerating potential (V). [1]

Answer:
We know $\lambda = \frac{1.22}{\sqrt{V}} \overset{o}{A}$

$\therefore \lambda\sqrt{V} = \text{constant}$



The nature of the graph between λ and $\sqrt{V}$ is hyperbola.

Question 8
Define dipole moment of an electric dipole. Is it a scalar or a vector? [1]

Answer:
Dipole moment of an electric dipole is the product of either of charge and the length of dipole. It is a vector quantity.
$\vec{P} = q(2\vec{a})$

Question 9
A conductor of length 'l' is connected to a dc source of potential 'V'. if the length of the conductor is triple by gradually stretching it, keeping 'V' constant, how will

i. Drift speed of electrons

Answer:
We know that $\upsilon_d = -\frac{eV\tau}{ml} \propto \frac{1}{l}$ when length is tripled, the drift velocity becomes one-third.

ii. Resistance of the conductor be affected?

Justify your answer. [2]

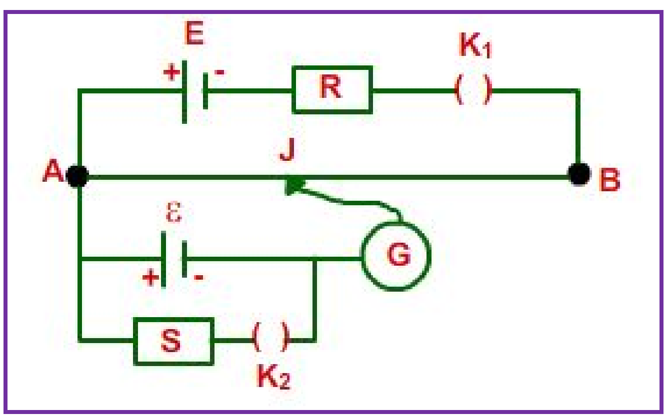
Answer:
$R = \rho\frac{l}{A'} \quad l' = 31$

New resistance

$R' = \rho\frac{l'}{A'} = \rho \text{ x} \frac{3l}{\frac{A}{3}} = 9R$

R' = 9R
Hence, the new resistance will be 9 times the original.

Question 10
Two student 'X' and 'Y' perform an experiment on potentiometer separately using the circuit given below. [2]



Keeping other parameters unchanged, how will the position of the null point be affected if

i. "X" increases the value of resistance R in the set-up by keeping the key K_1 closed and the key K_2 open?

Answer:
By increasing resistance R the current through AB decreases, so potential gradient decreases. Hence a greater length of wire would be needed for balancing the same potential difference. So the null point would shift towards B.

ii. 'Y' decreases the value of resistance S in the set-up, while the key K_2 remains open and the key K_1 closed?

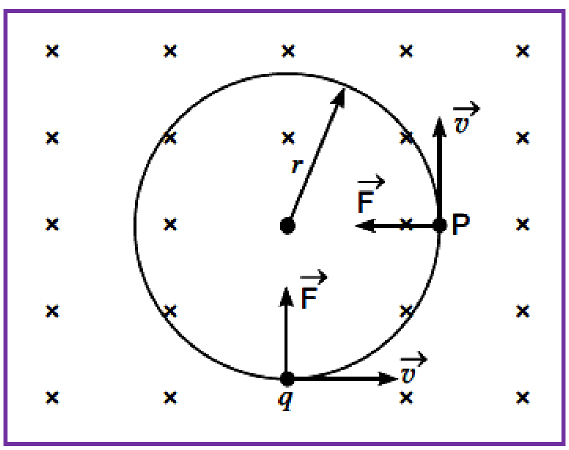
Justify.

Answer:
By decreasing resistance S, the current through AB remains the same, potential gradient does not change. As K_2 is open so there is no effect of S on null point.

Question 11
A particle of charge 'q' and mass 'm' is moving with velocity $\vec{V}$. It is subjected to a uniform magnetic field $\vec{B}$ directed perpendicular to its velocity. Show that it describes a circular path. Write the expression for its radius. [2]

Answer:
When a particle of charge 'q' of mass 'm' is directed to move perpendicular to the uniform magnetic field 'B' with velocity '$\vec{\upsilon}$'.

The force on the charge $\vec{F} = q(\vec{v} \times \vec{B})$



This magnetic force acts always perpendicular to the velocity of charged particle. Hence magnitude of velocity remains constant but direction changes continuously. Consequently the path of the charged particle in a perpendicular magnetic field becomes circular. The magnetic force ($q\upsilon B$) provides the necessary centripetal force to move along a circular path.

Then $q\upsilon B = \dfrac{m\upsilon^2}{r} \Rightarrow r = \dfrac{m\upsilon}{qB}$

Here r = radius of the circular path followed by the charge.

Question 12

Calculate the quality factor of a series LCR circuit with L=2.0 H, C=2μF and R = 10Ω. Mention the significance of quality factor in LCR circuit. [2]

Answer:

We have, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{2}{2 \times 10^{-6}}} = 100$

It signifies the sharpness of resonance.

Question 13

Explain briefly how electromagnetic waves are produced by an oscillating charge. How the frequency of the em waves is produced related to that of the oscillating charge? [2]

Answer:

An oscillating or accelerated is supposed to be source of an electromagnetic wave. An oscillating change produces an oscillating electric field in space which further produces an oscillating magnetic field which in turn is a source of electric field. These oscillating electric and magnetic field, hence, keep on regenerating each other and an electromagnetic wave is produced The frequency of em wave = Frequency of oscillating charge

Question 14

In a given sample, two radioisotopes, A and B, are initially present in the ratio of 1:4. The half-lives of A and B are respectively 100 years and 50 years. Find the time after which the amounts of A and B become equal. [2]

Answer:

We have $N = N_0 e^{-\lambda t}$

For radio isotopes A and B, we can write

$N_A = N_0 e^{-\lambda_A t_A}$ .... (i)

$N_B = 4N_0 e^{-\lambda_B t_B}$ .... (ii)

Let t be the time after which $N_A = N_B$

$t_A = t_B = t(\text{say})$

$\therefore N_0 e^{-\lambda_A t} = 4N_0 e^{-\lambda_B t} \Rightarrow 4 = e^{-\lambda_B t - \lambda_A t}$

$\Rightarrow \log_e 4 = (-\lambda_B t - \lambda_A t)\log_e e$

$$\Rightarrow 2\log_e 2 = \left[\frac{\log_e 2}{T_{B_{\frac{1}{2}}}} - \frac{\log_e 2}{T_{A_{\frac{1}{2}}}}\right]t \qquad \because \lambda = \frac{\log_e 2}{T}$$

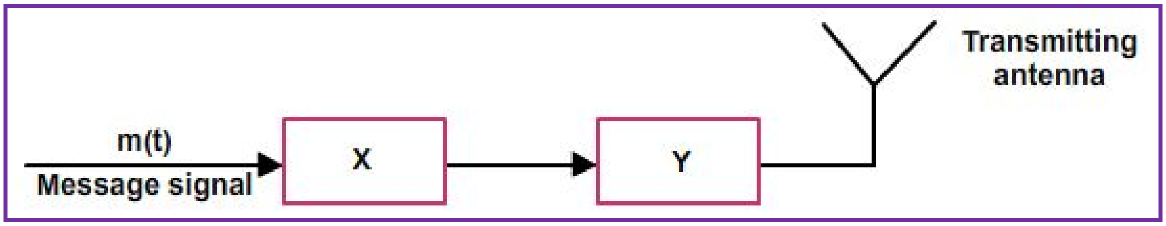
$$\Rightarrow 2 = \left[\frac{1}{50} - \frac{1}{100}\right]t$$

$$\Rightarrow 2 = \left[\frac{2-1}{100}\right]t$$

$\Rightarrow$ t = 200 years

Question 15

Figure shows a block diagram of a transmitter. Identify the boxes 'X' and 'Y' and write their functions. [2]



Answer:

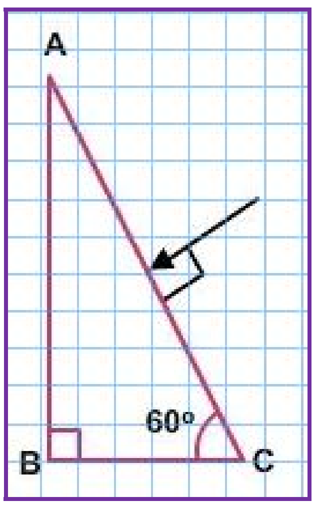
X → Amplitude Modulator
Y → Power Amplifier

Function of X: The original message signal has very small energy and dies out very soon if transmitted directly as such. Hence, these signals are modulated by mixing with very high frequency waves (carrier wave) by modulator power.

Function of Y: The signal cannot be transmitted as such because they get weaken after travelling long distance. Hence, use of power amplifier provides them necessary power before feeding the signal to the transmitting antenna.

Question 16

Trace the path of a ray of light passing through a glass prism (ABC) as shown in the figure. If the refractive index of glass is $\sqrt{3}$, find out the value of the angle of emergence from the prism. [2]



Answer:

Given $n_8 = \sqrt{3}$

i = 0

At the interface AC,

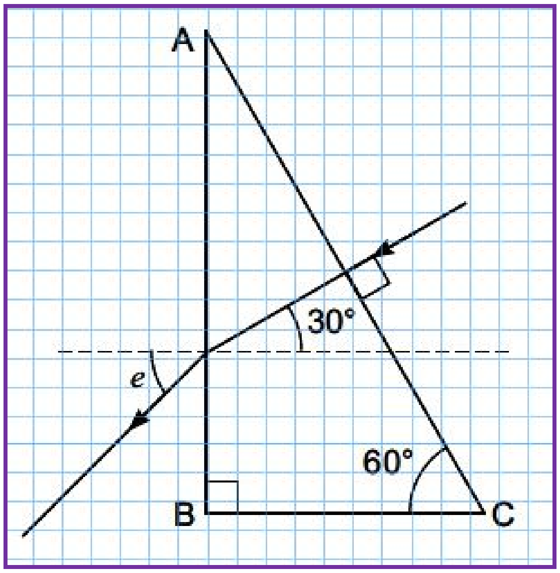
By Snell's Law $\frac{\sin i}{\sin r} = \frac{n_g}{n_\alpha}$

But sin i = sin 0° = 0, hence r = 0

At the interface AB, i =30°

Applying Snell's Law

$$\frac{\sin 30^0}{\sin e} = \frac{n_\alpha}{n_g} = \frac{1}{\sqrt{3}} \Rightarrow \sin e = \sqrt{3}\sin 30^0 \quad \Rightarrow e = 60^0$$



Question 17 [2]

Write two characteristic feature to distinguish between n-type and p-type semiconductors.

Answer:

n–type Semiconductor	p–type Semiconductor
i. It is formed by doping pentavalent impurities.	i. It is doped with trivalent impurities.
ii. The electrons are majority carriers and holes are minority carriers ($n_e >> n_h$).	ii. The holes are majority carriers and electrons are minority carriers ($n_h >> n_e$).

OR

How does a light emitting diode (LED) work? Give two advantages of LED's over the conventional incandescent lamps.

Answer:

A light emitting diode is simply a forward biased p-n junction which emits spontaneous light radiation. At the junction, energy is released in the form of photons due to the recombination of the excess minority charge carrier with the majority charge carrier.

Advantages

i. Low operational voltage and less powder.
ii. Fast action and no warm up time required.

Question 18

A short bar magnet of magnetic moment 0.9 $\frac{J}{T}$ is placed with its axis at 30^0 to a uniform magnetic field. It experiences a torque of 0.063 J. [2]

a. Calculate the magnitude of the magnetic field.

Answer:

We know $\vec{\tau} = \vec{M} \times \vec{B}$

or, $\tau = MB \sin\theta$

$0.063 = 0.9 \times B \times \sin 30°$

or $B = 0.14$ T

b. In which orientation will the bar magnet be in stable equilibrium in the magnetic field?

Answer:

The position of minimum energy corresponds to position of stable equilibrium.

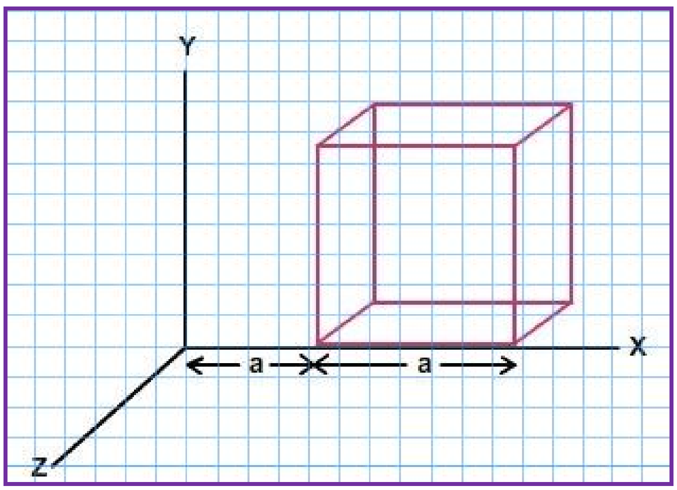
The energy (U) = $-MB\cos\theta$

When $\theta = 0° \Rightarrow U = -MB$ = Minimum energy

Hence, when the bar magnet is placed parallel to the magnetic field, it is the state of stable equilibrium.

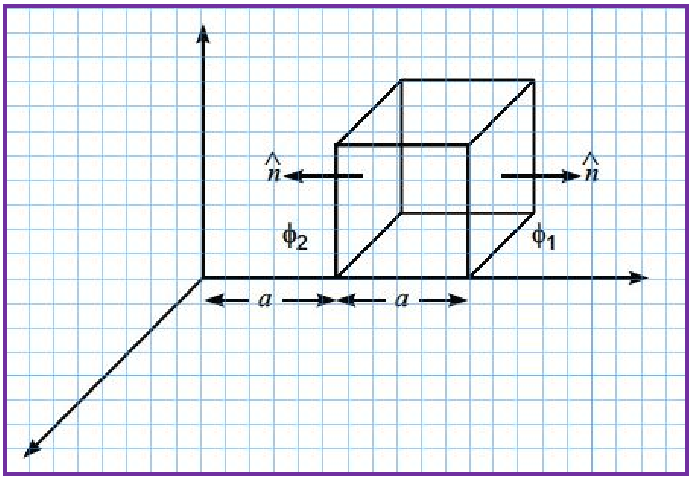
Question 19

State Gauss's law in electrostatics. A cube with each side 'a' is kept in an electric field given by $\vec{E} = Cx\hat{i}$, (as show in the figure) where C is a positive dimensional constant. Find out. [3]



Answer:

Gauss's Law in electrostatics states that the total electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of that charge. $\phi = \oint_s \vec{E}.\vec{dS} = \frac{q}{\varepsilon_0}$



a. The electric flux through the cube

Answer:

Net flux $\phi = \phi_1 + \phi_2$

where $\phi_1 = \vec{E}.\vec{d}S$

$= 2aC\ dS \cos 0° = 2\ aC \times a^2 = 2a^3C$

$\phi_2 = aC \times a^2 \cos 180° = -a^3C$

$\phi = 2a^3C + (-a^3C) = a^3C\ Nm^2\ C^{-1}$

b. The net charge inside the cube.

Answer:

Net charge (q) = $\varepsilon_0 \times \phi = a^3C\ \varepsilon_0$ coulomb

$q = a^3C\ \varepsilon_0$ coulomb.

Question 20

A capacitor of 200 pF is charged by a 300 V battery. The battery is then disconnected and the charged capacitor is connected to another uncharged capacitor of 100 pF. Calculate the difference between the final energy store in the combination system and the initial energy stored in the single capacitor. [3]

Answer:

Initial energy of capacitor (Ui) = $\frac{1}{2}CV^2$

$U_i = \frac{1}{2} \times 200 \times 10^{-12} \times (300)^2 = 9 \times 10^{-6}\ J$

Charge on capacitor 'Q' = CV = $200 \times 10^{-12} \times 300 = 6 \times 10^{-8}$ C

When both capacitors are connected then let V be common potential difference across the two capacitors.

The charge would be shared between them.

Hence, Q = q + q' , $\frac{q}{C} = \frac{q'}{C'}$

q → charge on capacitor (first)

q' → charge on capacitor (second)

C = 200 pF, C' =100 pF

$$\frac{q}{200 \text{ x } 10^{-12}} = \frac{q}{100 \text{ x } 10^{-12}} \Rightarrow q = 2q'$$

Then Q = 2q' + q' =3q' $\Rightarrow q' = \frac{Q}{3} = \frac{60nC}{3} = 20nC$

and q = 2q' = 40 nC

Hence, total final energy $U_f = \frac{1}{2} x \frac{(40 x 10^{-9})^2}{200 x 10^{-12}} + \frac{1}{2} x \frac{(20 x 10^{-9})^2}{10010^{-12}}$

$U_f = 6 x 10^{-6}$ J

Energy difference (ΔU) = $U_f - U_i$ = $6x10^{-6}$ $-9x10^{-6}$ = $-3x10^{-6}$ J

$\Rightarrow$ $\Delta U = 3x10^{-6}$ J (in magnitude)

Question 21

Draw a labelled diagram of a moving coil galvanometer and explain its working. What is the function of radial magnetic field inside the coil? [3]

Answer:

Moving coil galvanometer: A galvanometer is used to detect current in a circuit.

Construction: It con sists of a rectangular coil wound on a non-con ducting metallic frame and is suspended by phosphor bronze strip between the pole-pieces (N and S) of a strong permanent magnet.

A soft iron core in cylindrical form is placed between the coils. One end of coil is attached to suspension wire which also serves as one terminal (T_1) of galvanometer. The other end of coil is connected to a loosely coiled strip, which serves as the other terminal (T_2).

The other end of the suspension is attached to a torsion head which can be rotated to set the coil in zero position. A mirror (M) is fixed on the phosphor bronze strip by means of which the deflection of the coil is measured by the lamp and scale arrangement. The levelling screws are also provided at the base of the instrument.

The pole pieces of the permanent magnet are cylindrical so that the magnetic field is radial at any position of the coil.

Principle and working: When current (I) is passed in the coil, torque t acts on the coil, given by $\tau = NIAB \sin\theta$ where θ is the angle between the normal to plane of coil and the magnetic field of strength B, N is the number of turns in a coil.

When the magnetic field is radial, as in the case of cylindrical pole pieces and soft iron core, then in every position of coil the plane of the coil, is parallel to the magnetic field lines, so that θ = 90° and sin 90° =1

Deflecting torque, τ = NIAB

If C is the torsional rigidity of the wire and θ is the twist of suspension strip, then restoring torque =C θ

For equilibrium, deflecting torque = restoring torque

i.e. NIAB = C θ

$\therefore \theta = \frac{NAB}{C} I$ .... (i)

i.e. $\theta \propto I$

Deflection of coil is directly proportional to current flowing in the coil and hence we can construct a linear scale.

Question 22

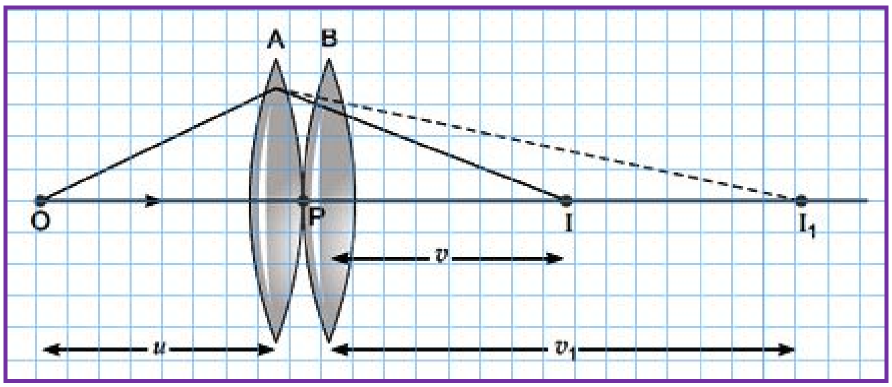
Define power of a lens. Write its units. Deduce the relation $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ for two thin lenses kept in contact coaxially. [3]

Answer:

Power of lens: It is the reciprocal of focal length of a lens.

$P = \frac{1}{f}$(f is in meter)

Unit of power of lens: Diopter.



An object is placed at point O. The lens A produces an image at I_1 which serves as a virtual object for lens B which produces final image at I.

Given, the lenses are thin. The optical centres (P) of the lenses A and B is co-incident.

For lens A, we have $\frac{1}{\upsilon_1} - \frac{1}{u} = \frac{1}{f_1}$ .... (i)

For lens B, we have $\frac{1}{\upsilon} - \frac{1}{\upsilon_1} = \frac{1}{f_2}$ .... (ii)

Adding equations (i) and (ii),

$\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$ .... (iii)

If two lenses are considered as equivalent to a single lens of focal length f, then

$\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$ .... (iv)

From equation (iii) and equation (iv), we can write $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

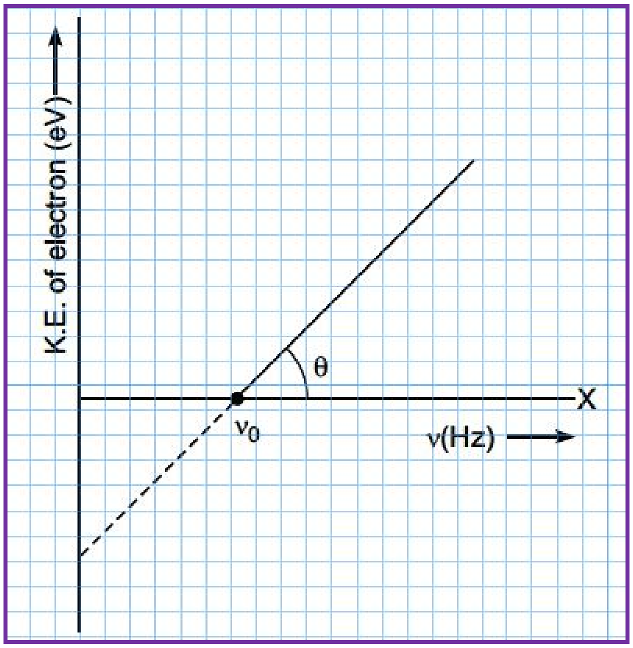
Question 23

Write two characteristic features observed in photoelectric effect which support the photon picture of electromagnetic radiation.

Draw a graph between the frequency of incident radiation (v) and the maximum kinetic energy of the electrons emitted from the surface of a photosensitive material. State clearly how this graph can be used to determine (i) Planck's constant and (ii) work function of the material. [3]

Answer:

All photons of light of a particular frequency 'n' have same energy and momentum whatever the intensity of radiation may be.



Photons are electrically neutral and are not affected by presence of electric and magnetic fields,

i. From this graph, the Planck constant can be calculated by the slope of the current
$h = \frac{\Delta(KE)}{\Delta v}$

ii. Work function is the minimum energy required to eject the photo-electron from the metal surface
$\phi = hv_0$ where v_0 = Threshold frequency

Question 24

Define modulation index. Given its physical significance.

For an amplitude modulated wave, the maximum amplitude is found to be 10 V while the minimum amplitude is 2 V. determine the modulation index μ. [3]

Answer:

Modulation index: It is the ratio of peak value of modulating signal to the peak value of carrier wave. $\mu = \frac{A_m}{A_c}$

Physical significance: It signifies the level of distortion or noise. A lower value of modulation index indicates a lower distortion in the transmitted signal.

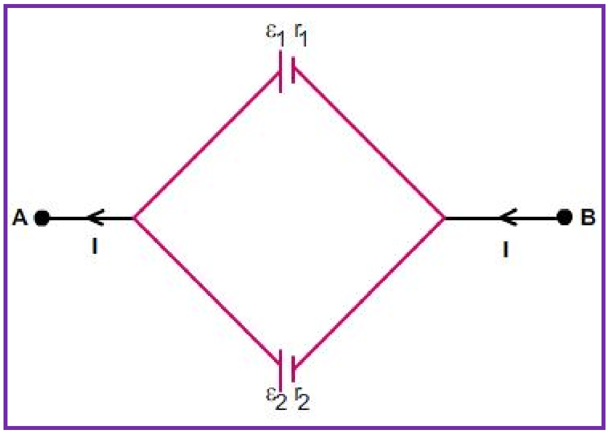
Maximum amplitude, $A_{max} = A_c + A_m$

Minimum aptitude, $A_{min} = A_c - A_m = 2V$

Modulation index = $\frac{A_{max} - A_{min}}{A_{max} + A_{min}} = \frac{10-2}{10+2} = \frac{8}{12} = \frac{2}{3}$

Question 25

Two cells of emfs ε_1, ε_2 and internal resistance r_1 and r_2 respectively are connected in parallel as shown in the figure. [3]



Deduce the expressions for

i. The equivalent e.m.f of the combination,
ii. The equivalent resistance of the combination
iii. The potential difference between the points A and B.

Answer:

Here, $I = I_1 + I_2$ .... (i)

Let V = Potential difference between A and B.

For cell ε_1

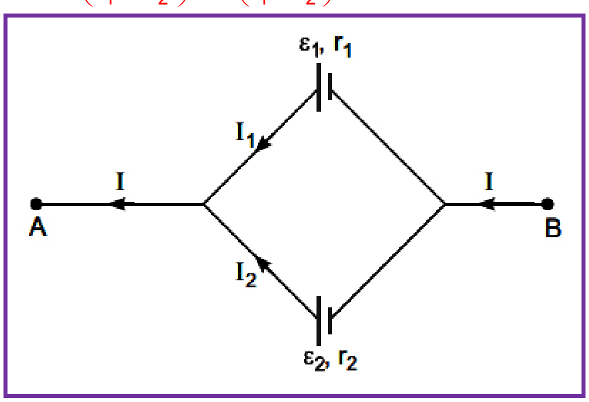
Then, $V = \varepsilon_1 - I_1 r_1 \Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1}$

Similarly, for cell ε_2 $I_2 = \frac{\varepsilon_2 - V}{r_2}$

Putting these values in equation (i)

$$I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2}$$

or, $I = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$



or, $V = \left(\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ .... (ii)

Comparing the above equation with the equivalent circuit of emf 'ε_{eq}' and internal resistance 'r_{eq}' then,

$V = \varepsilon_{eq} - I r_{eq}$ .... (iii)

Then,

i. $\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$

ii. $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

iii. The potential difference between A and B $V = \varepsilon_{eq} - I r_{eq}$

Question 26

Using Bohr's postulates for hydrogen atom, show that the total energy (E) of the electron in the stationary states can be expressed as the sum of kinetic energy (K) and potential energy (U), where K=-2U. Hence deduce the expression for the total energy in the n^{th} energy level of hydrogen atom. [3]

Answer:

Energy of an electron in the stationary orbits of the hydrogen atom can be obtained by adding its kinetic and potential energies.

For electron revolving in an orbit of radius r hydrogen (z = 1) atom with speed v.

$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$ (from first postulate of Bohr's atom model)

$\Rightarrow KE = \frac{1}{2}mv^2 = \frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r}$ .... (ii)

The potential energy is due to the presence of charge (+e) on the nucleus and is given by
PE = Potential × charge

$= \frac{1}{4\pi\varepsilon_0}, \frac{e}{r}.(-e) = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$ .... (iii)

Total energy = KE + PE

$E_n = \frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r} + \left(-\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}\right)$

$E_n = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r}$ .... (iv)

According to Bohr's second postulate

$mvr = \frac{nh}{2\pi} \Rightarrow v = \frac{nh}{2\pi mr}$ .... (v)

From equation (i)

$\frac{m}{r}\frac{n^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$

$\Rightarrow r = \frac{n^2h^2\varepsilon_0{}^2}{m\pi e^2}$

Substituting the value of r in equation (iv), we have $En = -\frac{me^4}{8n^2\varepsilon_0{}^2h^2}$

Question 27

Define a wavefront. Using Huygen's geometrical construction to show the propagation of a plane wavefront from a rare medium (1) to a denser medium (2) undergoing refraction.

Hence derive Snell's law of refraction. [3]

Answer:

Wavefront: A wave front is a locus of all particles of medium vibrating in the same phase.

Huygen's Principle: There are some phenomena like interference, diffraction and polarization which could not be explained by Newton's corpuscular theory. They were explained by wave theory first proposed by Huygen.

The assumptions of Huygen's theory are:

A source sends waves in all possible directions. The locus of particles of a medium vibrating in the same phase is called a wavefront. For a point source, the wavefront is spherical; while for a line source the wavefront is cylindrical. The distant wavefront is plane.

Each point of a wave front acts as a source of secondary wavelets. The envelope of all wavelets at a given instant gives the position of a new wavefront.

Proof of Snell's law of Refraction using Huygen's wave theory: When a wave starting from one homogeneous medium enters another homogeneous medium, it is deviated from its path. This phenomenon is called refraction. In transversing from first medium to another medium, the frequency of wave remains unchanged but its speed and the wavelength both are changed. Let XY be a surface separating the two media '1' and '2'. Let υ_1 and υ_2 be the speeds of waves in these media.

Suppose a plane wave front AB in first medium is incident obliquely on the boundary surface XY and its end A touches the surface at A at time t = 0 while the other end B reaches the surface at point B' after time-interval t. Clearly BB' $= \upsilon_1 t$. As the wave front AB advances, it strikes the points between A and B' of boundary surface.

According to Huygen's principle, secondary spherical wavelets originate from these points, which travel with speed υ_1 in the first medium and speed υ_2 in the second medium. First of all secondary wavelet starts from A, which traverses a distance AA' ($= \upsilon_2 t$) in second medium in time t. In the same time-interval t, the point of wavefront traverses a distance BB' ($= \upsilon_1 t$) in first medium and reaches B', from, where the secondary wavelet now starts. Clearly BB' $= \upsilon_1 t$ and AA' $= \upsilon_2 t$.

Assuming A as center, we draw a spherical arc of radius AA' ($= \upsilon_2 t$) and draw tangent B¢ A' on this arc from B'. As the incident wave front AB advances, the secondary wavelets start from points between A and B', one after the other and will touch A' B' simultaneously. According to Huygen's principle A' B' is the new position of wave front AB in the second medium. Hence A¢ B¢ will be the refracted wave front.

First law: As AB, A' B' and surface XY are in the plane of paper, therefore the perpendicular drawn on them will be in the same plane. As the lines drawn normal to wave front denote the rays, therefore we may say that the incident ray, refracted ray and the normal at the point of incidence all lie in the same plane. This is the first law of refraction.

Second law: Let the incident wave front AB and refracted wave front A' B' make angles i and r respectively with refracting surface XY.

In right-angled triangle AB' B, $\angle$ABB' = 90°

$$\therefore \sin i = \sin \angle BAB' = \frac{BB'}{AB'} = \frac{\upsilon_1 t}{AB'} \ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Similarly in right-angled triangle AA' B' , $\angle$AA' B' = 90°

$$\therefore \sin r = \sin \angle AB'A' = \frac{AA'}{AB'} = \frac{\upsilon_2 t}{AB'} \ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Dividing equation (i) by (ii), we get

$$\frac{\sin i}{\sin r} = \frac{\upsilon_1}{\upsilon_2} = \text{constant} \ldots\ldots\ldots\ldots\ldots\ldots (iii)$$

As the rays are always normal to the wavefront, therefore the incident and refracted rays make angles i and r with the normal drawn on the surface XY i.e. i and r are the angle of incidence and angle of refraction respectively. According to equation (3):

The ratio of sine of angle of incidence and the sine of angle of refraction is a constant and is equal to the ratio of velocities of waves in the two media. This is the second law of refraction, and is called the Snell's law.

When a light wave travels from rarer to denser medium, the speed decreases. It does not imply reduction its energy. This is because energy of wave depends on its frequency and not on its speed.

OR

a. Use Huygen's geometrical construction to show the behaviour of a plane wave front.
   i. Passing through a biconvex lens.
   ii. Refracting by a concave mirror.

Answer:

Wave Nature of Light : Huygen's Theory

There are some phenomena like interference, diffraction and polarisation which could not be explained by Newton's corpuscular theory. They were explained by wave theory first proposed by Huygen.

The assumptions of Huygen's theory are:

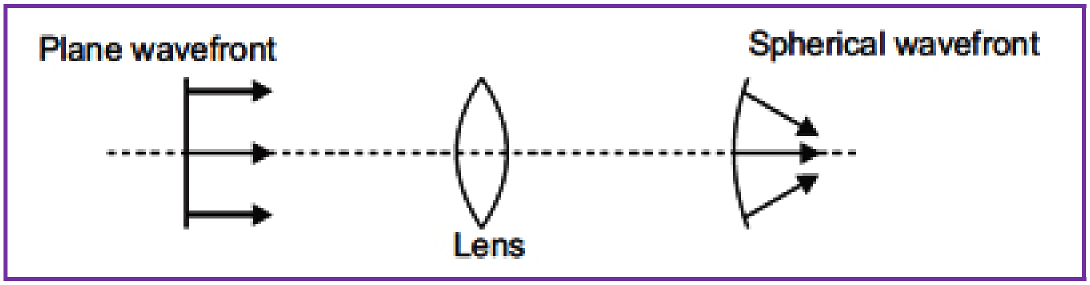
i. A source sends waves in all possible directions. The locus of particles of a medium vibrating in the same phase is called a wavefront. For a point source, the wavefront is spherical; while for a line source the wavefront is cylindrical. The distant wavefront is plane.

ii. Each point of a wavefront acts as a source of secondary wavelets. The envelope of all wavelets at a given instant gives the position of a new wavefront.

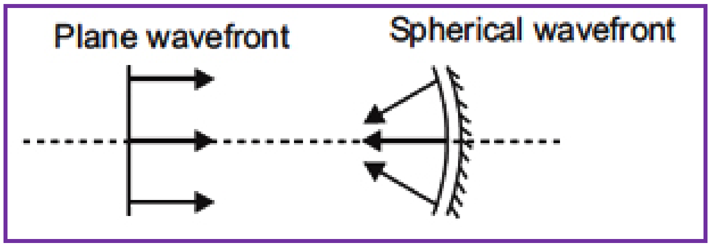
Rectilinear Propagation of Light:

According to Newton's corpuscular theory, the path of light is a straight line, but according to wave theory the rectilinear propagation of light is only approximate.

i. ***The action of a convex lens:*** A plane wavefront becomes spherical convergent wavefront after refraction.



ii. ***Action of concave mirror:*** A plane wavefront becomes spherical convergent after reflection



b. When monochromatic light is incident on a surface separating two media, why does the refracted light have the same frequency as that of the incident light?

Answer:
As frequency of light is the characteristic of its source, light reflects and refracts due to the interaction of incident light with the atoms of the medium. These atoms always take up the frequency of the incident light which forces them to vibrate and emit light of same frequency. Hence, frequency remains same.

Question 28 [5]

a. What is the effect on the interference fringes in a Young's double slit experiment when

i. The separation between the two slits is decreased?

Answer:

Fringe width $(\beta) = \frac{\lambda D}{d}$ If d decreases, β increases.

ii. The width of the source slit is increased?

Answer:

For interference fringe, the condition is $\frac{s}{D} < \frac{\lambda}{d}$

where s = size of source, D = distance of source from slits.

If the source slit width increases, fringe pattern gets less sharp or faint. When the source slit is made wide which does not fullfil the above condition and interference pattern not visible.

iii. The monochromatic source is replaced by a source of white light?

Justify your answer in each case.

Answer:
The central fringes are white. On the either side of the central white fringe the colored bands (few colored maxima and minima) will appear. This is because fringes of different colors overlap.

b. The intensity at the central maxima in Young's double slit experimental set-up is I_o. Show that the intensity at a point where the path difference is $\frac{\lambda}{3}$ is $\frac{I_o}{4}$.

Answer:

Intensity at a point is $I = I_0 \cos^2 \frac{\phi}{2}$

At path difference $\frac{\lambda}{3}$ the phase difference $\phi = \frac{2\pi}{\lambda}.\frac{\lambda}{3} = \frac{2\pi}{3}$

$\therefore I = I_0 \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right) = I_0 \cos^2\left(\frac{\pi}{3}\right) = \frac{I_0}{4}$

OR

a. Obtain the conditions for the bright and dark fringes in diffraction pattern due to a single narrow slit illuminated by a monochromatic source.

Explain clearly why the secondary maxima go on becoming weaker with increasing n.

Answer:
Diffraction of light at a single slit: When monochromatic light is made incident on a single slit, we get diffraction pattern on a screen placed behind the slit. The diffraction pattern contains bright and dark bands, the intensity of central band is maximum and goes on decreasing on both sides.

Explanation: Let AB be a slit of width 'a' and a parallel beam of monochromatic light is incident on it. According to Fresnel the diffraction pattern is the result of superposition of a large number of waves, starting from different points of illuminated slit.

Let θ be the angle of diffraction for waves reaching at point P of screen and AN perpendicular dropped from A on wave diffracted from B.

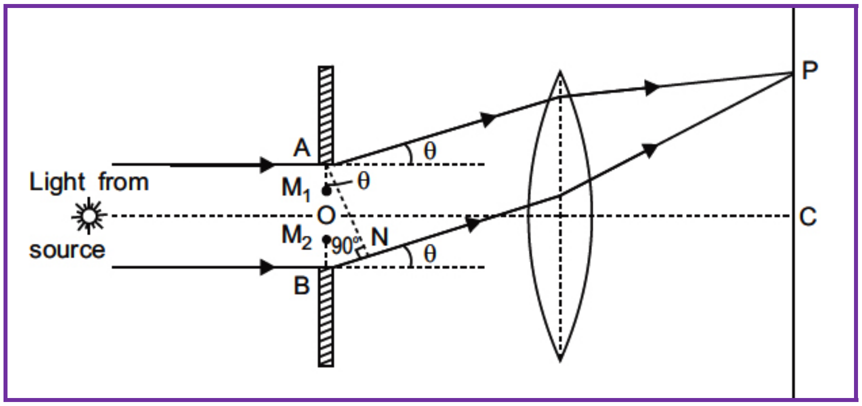
The path difference between rays diffracted at points A and B,
Δ=BP-AP=BN

In Δ ANB, $\angle$ANB = 90° $\therefore$ and $\angle$BAN = θ

$\therefore \sin\theta = \frac{BN}{AB}$ or, $BN = AB \sin\theta$

As AB =width of slit = α
$\therefore$ Path difference, $\Delta=\alpha \sin\theta$.

To find the effect of all coherent waves at P, we have to sum up their contribution, each with a different phase. This was done by Fresnel by rigorous calculations, but the main features may be explained by simple arguments given below:



At the central point C of the screen, the angle q is zero. Hence the waves starting from all points of slit arrive in the same phase. This gives maximum intensity at the central point C.

If point P on screen is such that the path difference between rays starting from edges A and B is λ, then path difference

$$\alpha \sin\theta = \lambda \Rightarrow \sin\theta = \frac{\lambda}{\alpha}$$

If angle θ is small, $\sin\theta = \theta = \frac{\lambda}{\alpha}$ .... (ii)

Minima: Now we divide the slit into two equal halves AO and OB, each of width $\frac{\alpha}{2}$. Now for every point, M_1 in AO, there is a corresponding point M_2 in OB, such that $M_1M_2 = \frac{\alpha}{2}$; Then path difference between waves arriving at P and starting from M_1 and M_2 will be $\frac{\alpha}{2}\sin\theta = \frac{\lambda}{2}$. This means that the contributions from the two halves of slit AO and OB are opposite in phase and so cancel each other. Thus equation (2) gives the angle of diffraction at which intensity falls to zero. Similarly it may be shown that the intensity is zero for $\sin\theta = \frac{n\lambda}{\alpha}$. with n as integer. Thus the general condition of minima is
$\alpha \sin\theta = n\lambda$ .... (ii)

Secondary Maxima: Let us now consider angle θ such that $\sin\theta = \theta = \frac{3\lambda}{2\alpha}$ which is midway between two dark bands given by $\sin\theta = \theta = \frac{\lambda}{\alpha}$ and $\sin\theta = \theta = \frac{2\lambda}{\alpha}$

Let us now divide the slit into three parts. If we take the first two of parts of slit, the path difference between rays diffracted from the extreme ends of the first two parts

$$\frac{2}{3}\alpha \sin\theta = \frac{2}{3}\alpha \times \frac{3\lambda}{2\alpha} = \lambda$$

Then the first two parts will have a path difference of $\frac{\lambda}{\alpha}$ and cancel the effect of each other. The remaining third part will contribute to the intensity at a point between two minima. Clearly there will be a maxima between first two minima, but this maxima will be of much weaker intensity than central maximum. This is called first secondary maxima. In a similar manner we can show that there are secondary maxima between any two consecutive minima; and the intensity of maxima will go on decreasing with increase of order of maxima. In general the position of nth maxima will be given by

$\alpha \sin \theta = \left(n + \frac{1}{2}\right)\lambda$, [n = 1, 2, 3, 4, …] …………………(iv)

The intensity of secondary maxima decrease with increase of order n because with increasing n, the contribution of slit decreases.

For n = 2, it is one-fifth, for n = 3, it is one-seventh and so on.

b. When the width of the slit is made double, how would this affected the size and intensity of the central diffraction band? Justify. [5]

Answer:

Width of central Maxima 'β' = $\frac{2D\lambda}{\alpha}$

$\alpha \rightarrow$ size of slit

If size of slit is doubled, width of central maxima becomes half. Intensity varies as square of slit width. It width of slit is doubled, intensity gets four times.

Question 29 [5]

a. State the principle on which AC generator works. Draw a labelled diagram and explain its working.

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:

- It serves as a support to coils
- It increases the magnetic field due to air core being replaced by an iron core.

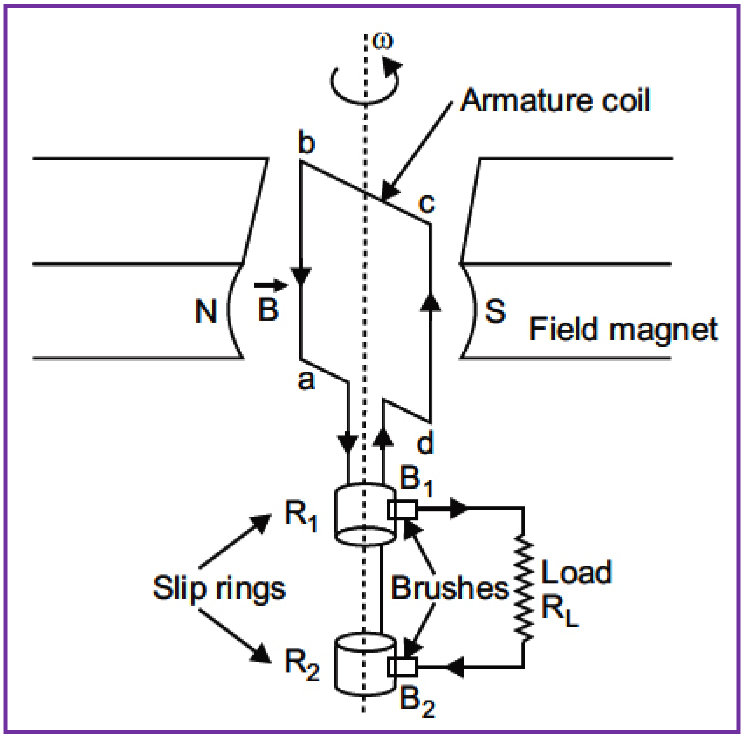
iii. ***Slip Rings:*** The slip rings R_1 and R_2 are the two metal rings to which the ends of armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.

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 R_L 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 cd downward, so that the direction of induced current is 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.



Expression for Induced emf: 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

$$e = -\frac{d\phi}{dt} = \frac{d}{dt}\{NBA(\cos 2\pi f\ t)\}$$

$= 2\pi$ NBA f sin 2πf 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.

b. A conducting rod held horizontally along East-West direction is dropped from rest from a certain higher near the Earth's surface. Why should there be an induced emf across the ends of the rod? Draw a plot showing the instantaneous variation of emf as a function of time from the instant it begins to fall.

Answer:

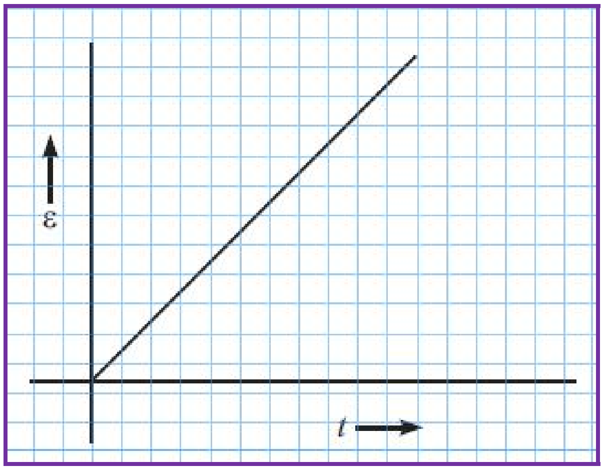
As the earth's magnetic field lines are cut by the falling rod, the change in magnetic flux takes place. This change in flux induces an emf across the ends of the rod. Since the rod is falling under gravity,

$v = gt \quad (\because u = 0)$

Induced emf, $\varepsilon = Blv$

$\varepsilon = Blgt$

$\therefore \varepsilon \propto t$



OR

a. State the principle of a step-up transformer, explain, with the help of a labelled diagram, its working.

Answer:

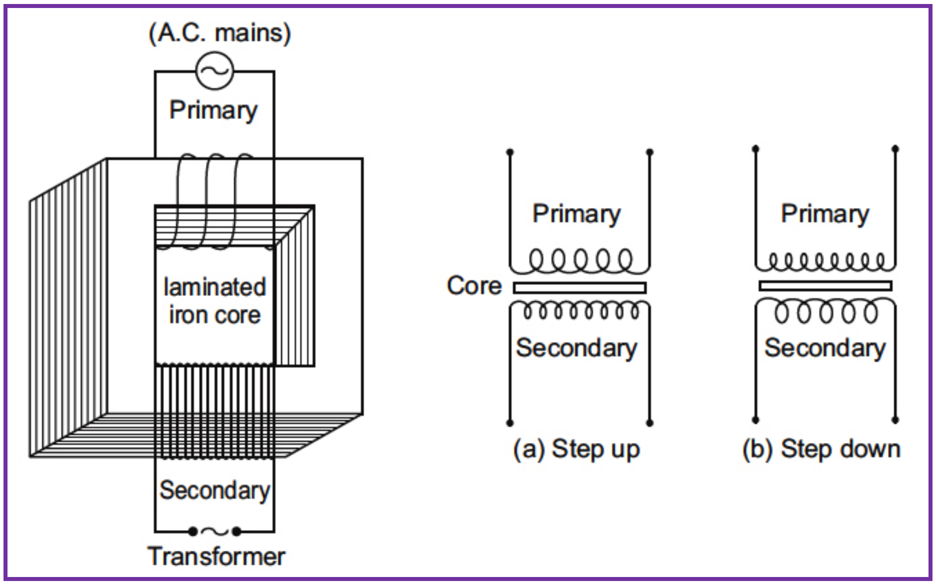
Transformer: Transformer is a device by which an alternating voltage may be decreased or increased. This is based on the principle of mutual-induction.

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. Transformers are of two types:

- ***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. $N_s > N_p$)

- ***Step down Transformer:*** It transforms the alternating high voltage to alternating low voltage and in this the number of turns in secondary coil is less than that in primary coil (i.e. $N_s < N_p$)



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, N_S the number of turns in secondary coil and ϕ 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.

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

and emf induced in the secondary coil

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

From (i) and (ii)

$$\frac{\varepsilon_p}{\varepsilon_s} = \frac{N_s}{N_p} \text{ .... (iii)}$$

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 V_S across its ends will be equal to the emf (ε_s) induced in it; therefore

$$\frac{V_s}{V_p} = \frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p} = r\,(\text{say}) \text{ .... (iv)}$$

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; then for about 100% efficiency,
Power in primary = Power in secondary

$V_p\, i_p = V_s\, i_s$

$$\therefore \frac{i_s}{i_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{1}{r} \ldots\ldots\ldots\ldots\ldots \text{(v)}$$

In step up transformer, $N_s > N_p \rightarrow r > 1$

So, $V_S > V_p$ and $i_S < i_p$ i.e. step up transformer increases the voltage.

b. Describe briefly any two energy losses, giving the reasons for their occurrence in actual transformers.

Answer:

i. ***Flux leakage:*** There is always some flux leakage, that is, not all of the flux due to primary passes through the secondary due to poor design of the core or the air gaps in the core.

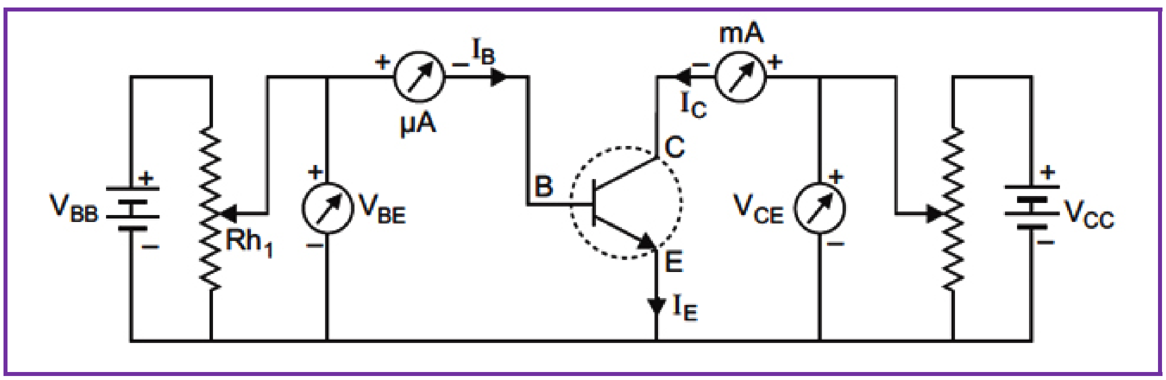
ii. ***Eddy currents:*** The alternating magnetic flux induces eddy currents in the iron core and causes heating.

Question 30 [5]

a. Draw the circuit for studding the input and output characteristics of an n-p-n transistor in CE configuration. Show, how from the output characteristics, the information about the current amplification factor (β_{ac}) can be obtained.

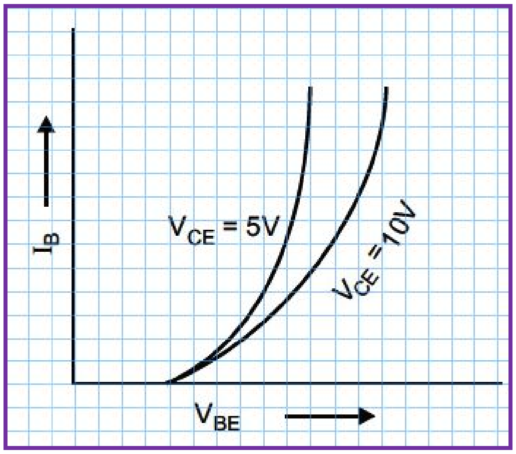
Answer:

Characteristic Curves: The circuit diagram for determining the static characteristic curves of an n-p-n transistor in common-emitter configuration is shown in figure.

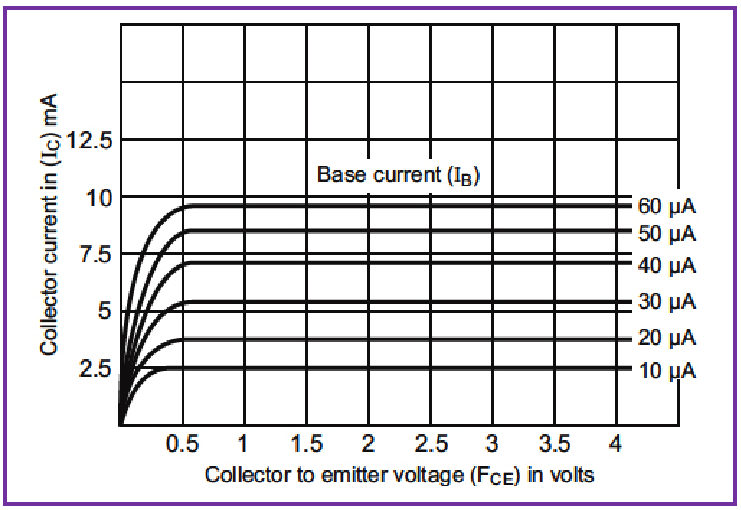


Output characteristics: These characteristics are obtained by plotting collector current I_C versus collector-emitter voltage V_{CE} at a fixed value of base current I_B. The base current is changed to some other fixed value and the observations of I_C versus V_{CE} are repeated represents the output characteristics of a common-emitter circuit.

The characteristic curves show:



When collector-emitter voltage V_{CE} is increased from zero, the collector current I_C increases as V_{CE} increases from 0 to 1 V only and then the collector current becomes almost constant and independent of V_{CE}. The value of V_{CE} upto which collector current I_C changes is called the knee voltage V_{knee}.



Determination of Current Gain:

Current gain $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$

We take the active region of output characteristics i, the region where collector current (I_C) is almost independent of V_{CE}.

Now we choose any two characteristic curves for given values of I_B and find the two corresponding values of I_C.

Then $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right) = \frac{(I_C)_2 - (I_C)_1}{(I_B)_2 - (I_B)_1}$

From graph $(I_C)_1$ =5.2 mA, $(I_C)_2$ =7.3 mA
$(I_B)_1$ =30 μA, $(I_B)_2$ = 40 μA

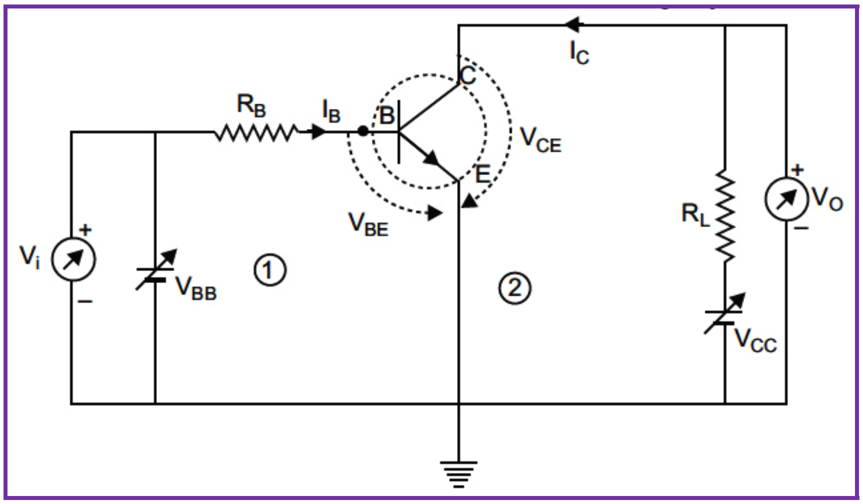
$\beta = \frac{(7.3-5.2)mA}{(40-30)\mu A} = \frac{2.1 \times 10^{-3}}{10 \times 10^{-6}} = 210$

Using any two curves from output characteristics current amplification factor $\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}$

b. Draw a plot of the transfer characteristic (V_o versus V_i) for a base-biased transistor in CE configuration. Show for which regions in the plot, the transistor can operate as a switch.

Answer:

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. VBB and VCC 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

$V_{BB} = I_B R_B + V_{BE}$ …………….. (i)

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

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

$V_i = V_{BE} + I_B R_B$ …………. (iii)

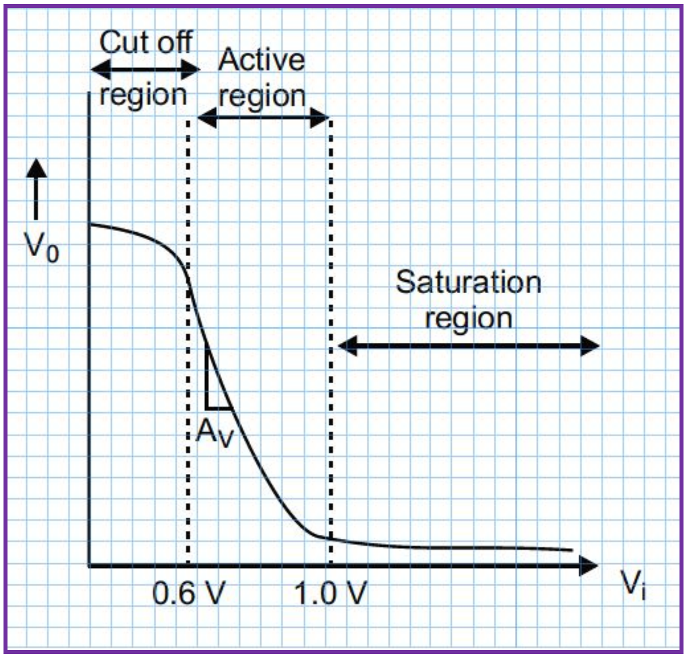
and $V_0 (= V_{CE}) = V_{CC} - I_C R_L$ ……….. (iv)

Let us see the change in V_0 due to a change in V_i. 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 V_i. 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.

- Between cut off state and active state and
- 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 Vi is low and unable to overcome the barrier voltage of the emitter base junction, V0 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.

The transistor can operate as a switch in cut off region and saturation region.

OR

Why is a zener diode considered as a special purpose semiconductor diode?

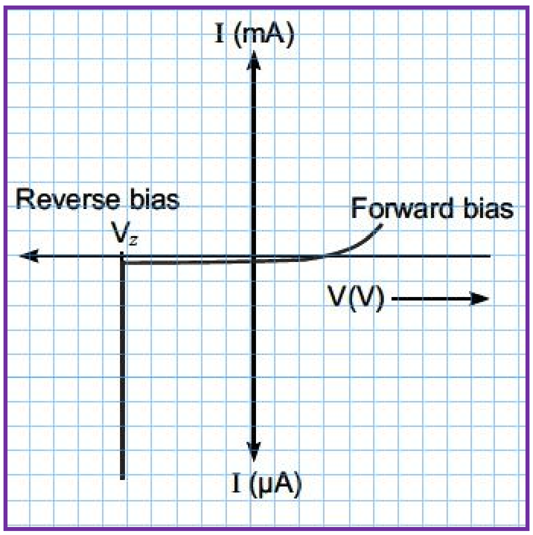
Draw the I_V characteristic of a zener diode and explain briefly how reverse current suddenly increase at the breakdown voltage.

Describe briefly with the help of a circuit diagram how a zener diode works to obtain a constant dc voltage the unregulated dc output of a reactifier.

Answer:

A zener diode is considered as a special purpose semiconductor diode because it is designed to operate under reverse bias in the breakdown region.

We know that reverse current is due to the flow of electrons (minority carriers) from p →n and holes from n → p. As the reverse bias voltage is increased, the electric field at the junction becomes significant. When the reverse bias voltage V =Vz, then the electric field strength is high enough to pull valence electrons from the host atoms on the p-side which are accelerated to n-side. These electrons causes high current at breakdown.



Working:

The unregulated dc voltage output of a rectifier is connected to the zener diode through a series resistance R_s such that the zener diode is reverse biased. Now, any increase/decrease in the input voltage results in increase/decrease of the voltage drop across R_s without any change in voltage across the zener diode. Thus, the zener diode acts as a voltage regulator.