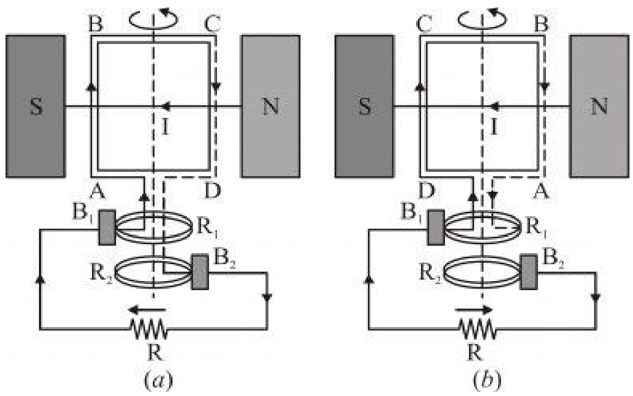
LONG ANSWER QUESTIOS(SURE SHOT)

Q1) (a) State the working of a.c. generator with the help of a labelled diagram.
(b) The coil of an a.c. generator having N turns, each of area A, is rotated with a constant angular velocity ω. Deduce the expression for the alternating emf generated in the coil.
(c) What is the source of energy generation in this device?

Ans) Principle - Based on the phenomenon of electromagnetic induction
Construction:

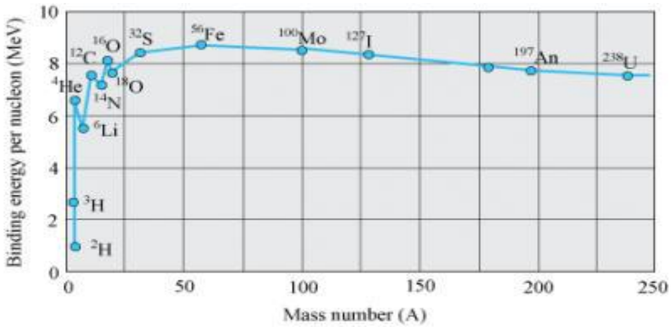


Main parts of an ac generator:
- Armature - Rectangular coil ABCD
- Filed Magnets - Two pole pieces of a strong electromagnet
- Slip Rings - The ends of coil ABCD are connected to two hollow metallic rings R_1 and R_2.
- Brushes - B_1 and B_2 are two flexible metal plates or carbon rods. They are fixed and are kept in tight contact with R_1 and R_2 respectively.

Theory and Working - As the armature coil is rotated in the magnetic field, angle θ, between the field and normal to the coil changes continuously. Therefore, magnetic flux linked with the coil changes. An *emf* is induced in the coil. According to Fleming's right hand rule, current induced in AB is from A to B and it is from C to D in CD. In the external circuit, current flows from B_2 to B_1.

Q2) Draw the plot of binding energy per nucleon (BE/A) as a function of mass number A. Write two important conclusions that can be drawn regarding the nature of nuclear force.
(b) Use this graph to explain the release of energy in both the processes of nuclear fusion and fission.
(c) Write the basic nuclear process of neutron undergoing β^--decay.
Why is the detection of neutrinos found very difficult?

Ans) Plot of binding energy per nucleon as the function of mass number A is given as below:



Following are the two conclusions that can be drawn regarding the nature of the nuclear force:
(i) The force is attractive and strong enough to produce a binding energy of few MeV per nucleon.
(ii) The constancy of the binding energy in the range A= 30 to 170

(b) Nuclear fission: A very heavy nucleus (say A = 240) has lower binding energy per nucleon as compared to the nucleus with A = 120. Thus if the heavier nucleus breaks to the lighter nucleus with high binding energy per nucleon, nucleons are tightly bound. This implies that energy will be released in the process which justifies the energy release in fission reaction.
Nuclear fusion: When two light nuclei (A<10) are combined to form a heavier nuclei, the binding energy of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. Thus the final system is more tightly bound than the initial system. Again the energy will be released in fusion reaction.

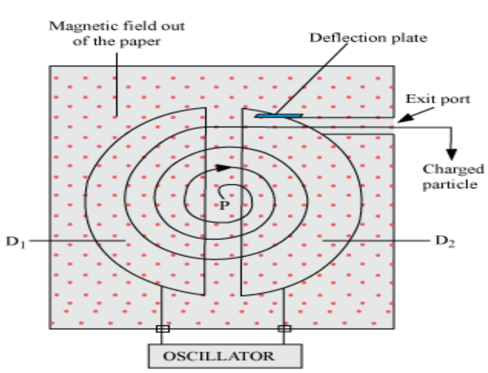
(c) The basic nuclear process of neutron undergoing β^--decay is given as:

$$n \rightarrow p + e^- + \bar{v}$$

Neutrinos interact very weakly with matter so, they have a very high penetrating power. That's why the detection of neutrinos is found very difficult.

Q3)(a) Draw a schematic sketch of a cyclotron. Explain clearly the role of crossed electric and magnetic field in accelerating the charge. Hence derive the expression for the kinetic energy acquired by the particles.
(b) An Alpha particle and a proton are released from the centre of the cyclotron and made to accelerate.
(i) Can both be accelerated at the same cyclotron frequency?
Give reason to justify your answer.
(ii) When they are accelerated in turn, which of the two will have higher velocity at the exit slit of the does?

Ans)Schematic sketch of cyclotron



of crossed electric and magnetic fields is used to The combination increase the energy of the charged particle. Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy. Inside the dees the particle is shielded from the electric field and magnetic field acts on the particle and makes it to go round in a circular path inside a dee. Every time the particle moves from one dee to the other it comes under the influence of electric field which ensures to increase the energy of the particle as the sign of the electric field changed alternately. The increased energy increases the radius of the circular path so the accelerated particle moves in a spiral path.

(b) (i) Let us consider: Mass of proton = m, Charge of proton = q,

Mass of alpha particle = 4m

Charge of alpha particle = 2q

Cyclotron frequency, $\nu = \frac{Bq}{2\pi m} \Rightarrow \nu \propto \frac{q}{m}$

For proton:Frequency, $\nu_p \propto \frac{q}{m}$

For alpha particle:Frequency, $\nu_a \propto \frac{2q}{4m}$ or $\nu_a \propto \frac{q}{2m}$

Thus, particles will not accelerate with same cyclotron frequency. The frequency of proton is twice than the frequency of alpha particle.

(ii)

Velocity, $\mathrm{v} = \frac{Bqr}{m} \Rightarrow \mathrm{v} \propto \frac{q}{m}$

For proton:Velocity, $v_p \propto \frac{q}{m}$

For alpha particle:Velocity, $v_a \propto \frac{2q}{4m}$ or $v_a \propto \frac{q}{2m}$

Thus particles will not exit the dees with same velocity. The velocity of proton is twice than the velocity of alpha particle.

Q4) (a) State the importance of coherent sources in the phenomenon of interference.
(b) In Young's double slit experiment to produce interference pattern, obtain the conditions for constructive and destructive interference. Hence deduce the expression for the fringe width.
(c) How does the fringe width get affected, if the entire experimental apparatus of Young is immersed in water?
Ans)(a)Two sources are called coherent sources, if the phase difference between them is either zero or constant. And this is essential for interference of light. We can never be obtained, even if the sources emit waves of equal wavelengths and equal amplitudes. This is because the waves emitted by a source undergo rapid and irregular changes of phase, so that the intensity at any point is never constant. Naturally the phase difference between the waves emitted by the two sources cannot remain constant.

(b)

Let d be the distance between two coherent sources A and B of wavelength λ. A screen XY is placed parallel to AB at a distance D from the coherent sources. C is the mid point of AB. O is a point on the screen equidistant from A and B. P is a point at a distance x from O, as shown in Fig 5.17. Waves from A and B meet at P in phase or out of phase depending upon the path difference between two waves.

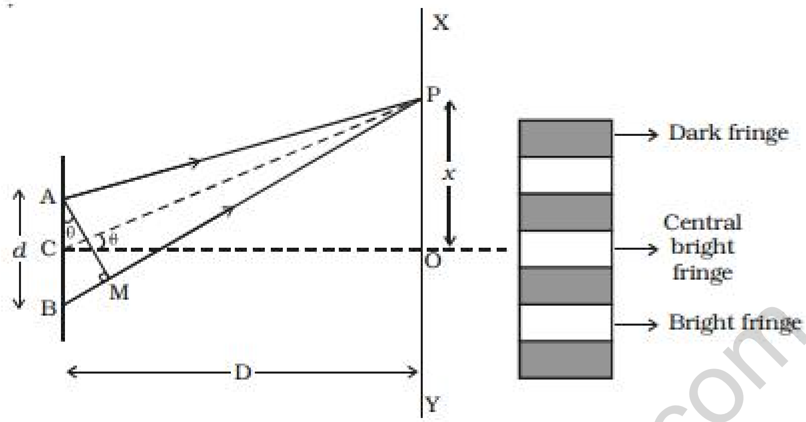


Fig 5.17 Interference band width

Draw AM perpendicular to BP

The path difference δ = BP – AP

AP = MP

$\therefore$ δ = BP – AP = BP – MP = BM

In right angled Δ ABM, BM = d sin θ

If θ is small, sin θ = θ

$\therefore$ The path difference $\delta = \theta.d$

In right angled triangle COP, $\tan\theta = \frac{OP}{CO} = \frac{x}{D}$

For small values of θ, $\tan\theta = \theta$

$\therefore$ The path difference $\delta = \frac{xd}{D}$

For bright frindge

$\therefore \quad \frac{xd}{D} = n\lambda$

where $n = 0,1,2$ ... indicate the order of bright fringes.

$\therefore \quad x = \frac{D}{d} n\lambda$

This equation gives the distance of the n^{th} bright fringe from the point O.

Dark fringes

By the principle of interference, condition for destructive interference is the path difference $= (2n-1)\frac{\lambda}{2}$

where $n = 1,2,3$ ... indicate the order of the dark fringes.

$\therefore \quad x = \frac{D}{d}(2n-1)\frac{\lambda}{2}$

This equation gives the distance of the n^{th} dark fringe from the point O. Thus, on the screen alternate dark and bright bands are seen on either side of the central bright band.

Band width (β)

The distance between any two consecutive bright or dark bands is called bandwidth.

The distance between $(n+1)^{th}$ and n^{th} order consecutive bright fringes from O is given by

$$x_{(n+1)} - x_n = \frac{D}{d}(n+1)\lambda - \frac{D}{d}n\lambda = \frac{D}{d}\lambda$$

Bandwitdth, $\beta = \frac{D}{d}\lambda$

(c) If the whol

$$\beta_\omega = \frac{\lambda_\omega d}{D} = \frac{\lambda}{nD}$$

$$\boxed{\beta_\omega = \frac{1}{n}\beta}$$

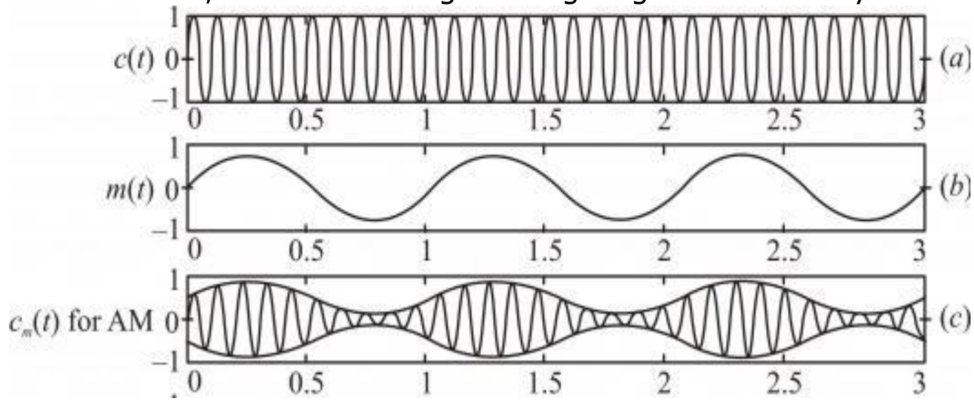
This shows fringe width will be reduced by the factor of the refractive index of water

Q5)(a)Write briefly any two factors which demonstrate the need for modulating a signal. Draw a suitable diagram to show amplitude modulation using a sinusoidal signal as the modulating signal.

(b) A transmitting antenna at the top of a tower has a height of 20 m and the height of the receiving antenna is 45 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4 X 10^6 m)

Ans)(a)The need for modulation can be summarized as follows:
(1) The antenna needed for transmitting signals should have size at least $\lambda/4$, where, λ is the wavelength. The information signal, also known as baseband signal is of low frequency (and therefore the wavelength is high). If we need to transmit such a signal directly, the size of the antenna will be very large and impossible to build.

(2) The radiated power by an antenna is inversely proportional to the square of the wavelength. So, if we use high frequency signals, the power radiated will be increased.
(3) If we transmit the baseband signals directly, the signals from different transmitters will get mixed up and the information will be lost. Because of these reasons, we use the technology of modulation, for transmitting message signals effectively for long distances.



(b) We have, height of transmitting antenna, h_T = 20 m and height of receiving antenna, h_R = 45 m

Then, Maximum distance between the two antennas,

$$d_m = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

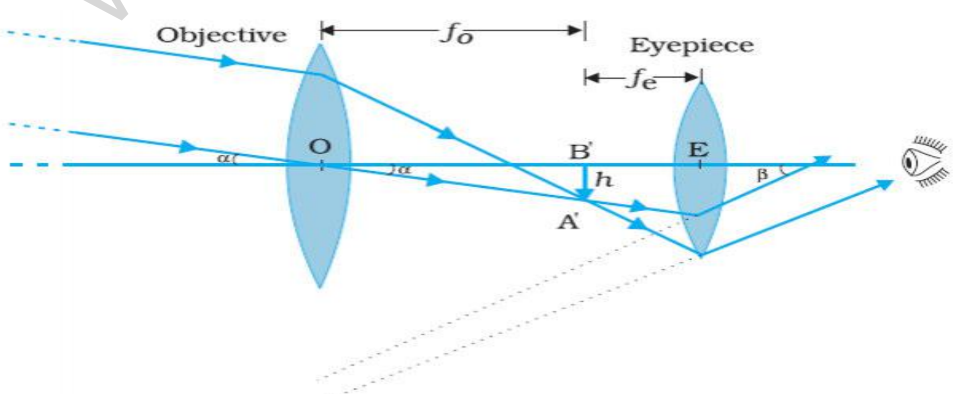
$$\Rightarrow d_m = \sqrt{2 \times 6.4 \times 10^6 \times 20} + \sqrt{2 \times 6.4 \times 10^6 \times 45} = 2 \times 8 \times 10^3 + 3 \times 8 \times 10^3 = 40 \text{ km.}$$

Thus, the maximum distance between the antennas is 40 km.

Q6)(a) Draw a labelled ray diagram of a refracting telescope. Define its magnifying power and write the expression for it.
(b) Write two important limitations of a refracting telescope over a reflecting type telescope.

(c) A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 cm is used, find the angular magnification of the telescope.

Ans) **Refracting telescope:**



Magnifying Power: The magnifying power *m* is the ratio of the angle subtended at the eye by the final image to the angle which the object subtends at the lens or the eye.

$$m \approx \frac{\beta}{\alpha} \approx \frac{h}{f_e} \cdot \frac{f_o}{h} = \frac{f_o}{f_e}$$

(b)Limitations of refracting telescope over reflecting type telescope:

(NOTE: Write any two)

(i) Refracting telescope suffers from chromatic aberration as it uses large sized lenses.

(ii) The requirements of big lenses tend to be very heavy and therefore difficult to make and support by their edges.

(iii) It is also difficult and expensive to make such large sized lenses.

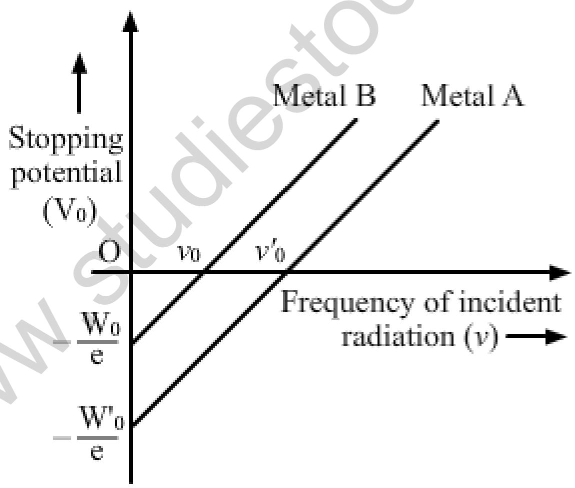
(c)

$$\text{Angular magnification } = -\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right) = -\frac{1500}{1}\left(1+\frac{1}{25}\right) = -1560$$

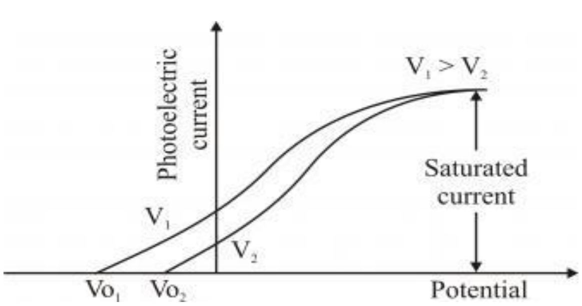
Negative sign indicates that the image is inverted.

Q7)(a) **Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_1 > \nu_2$, of incident radiation having the same intensity. In which case will the stopping potential be higher? Justify your answer.**

(b) The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which one of the two has higher value of work-function? Justify your answer.



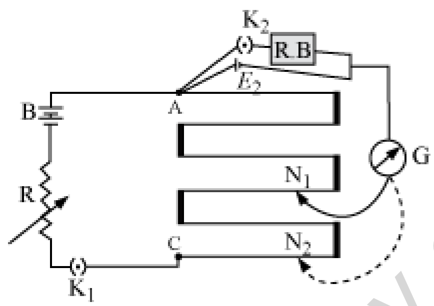
Ans) Taking radiations of different frequencies but of same intensity, the variation between photoelectric current and potential of plate *A* is obtained and shown in graph given below:



From the graph, we note:
(i) The value of stopping potential is different for radiation of different frequency.
(ii) The value of stopping potential is more negative **for radiation of higher incident frequency**.
(iii) The value of saturation current depends on the intensity of incident radiation, but is independent of the frequency of the incident radiation.

(b) From the graph, the threshold frequency for metal A is greater than that for metal B. Hence, the work function for metal A is greater than that for metal B.

Q8)Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a cell.
Ans) Measurement of internal resistance of a cell using potentiometer:



The cell of emf, *E* (internal resistance *r*) is connected across a resistance box (*R*) through key K_2.

When $K_2$is open, balance length is obtained at length $AN_1 = l_1$

$E = kl_1$................................ (1)

When $K_2$is closed:

Let *V* be the terminal potential difference of cell and the balance is obtained at $AN_2 = l_2$

$\therefore V = kl_2$ .... (2)

From equations (1) and (2), we get

$$\frac{E}{V} = \frac{l_1}{l_2} \quad ...(3)$$

$$E = I(r+R)$$
$$V = IR$$
$$\therefore \frac{E}{V} = \frac{r+R}{R} \quad ...(4)$$

From (3) and (4), we get $\frac{R+r}{R} = \frac{l_1}{l_2}$

$$\therefore \frac{E}{V} = \frac{l_1}{l_2}$$

$$\because r = R\left(\frac{E}{V}-1\right) \therefore r = R\left(\frac{l_1}{l_2}-1\right)$$

Q9)(a)Derive the expression for the radius of the nth orbit of hydrogen atom using Bohr's postulates. Show graphically the (nature of) variation of the radius of orbit with the principal quantum number, n.
(b)The ground state energy of hydrogen atom is – 13.6 eV.

What are the potential and kinetic energy of an electron in the 3rd excited state?

Ans)(a)
(b) Energy of ground state of H atom May be given as
$E_n = -13.6/n^2 = -13.6/1^2 = -13.6$ eV
In third excited state, $E_4 = -0.85$ eV

So K.E. = 0.85 eV and P.E. = 2 (- 0.85) = - 1.7 eV

Q10)(a)Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker?
(b)Define mobility of electron in a conductor. How does electron mobility change when (i) temperature of conductor is decreased (ii) Applied potential difference is doubled at constant temperature?

Ans) (a)

For copper, $R_c = \rho_c \frac{l_c}{A_c}$

and for magnanin $R_m = \rho_m \frac{l_m}{A_m}$

As,

$\rho_m > \rho_c$

or $\frac{\rho_m}{\rho_c} > 1$

As $l_c = l_m$

Dividing $\frac{R_c}{R_m} = \frac{\rho_c A_m}{\rho_m A_c}$

Again $R_c = R_m$

$\therefore \rho_c A_m = \rho_m A_c$

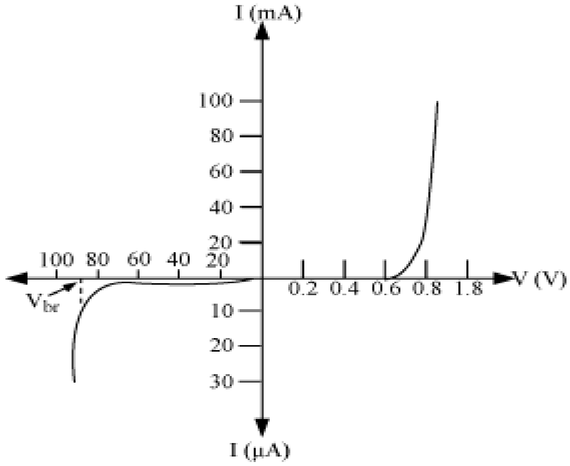
$\frac{\rho_m}{\rho_c} = \frac{A_m}{A_c} > 1$

Hence $A_m > A_c$ Or, Manganin wire is thicker

(b)definition (i) electron mobility decreased (ii) electron mobility not change

Q11) Draw V I characteristics of a p-n junction diode. Answer the following questions, giving reasons:
(i) Why is the current under reverse bias almost independent of the applied potential up to a critical voltage?
(ii) Why does the reverse current show a sudden increase at the critical voltage?
(iii) Name any semiconductor device which operates under the reverse bias in the breakdownregion.

Ans) V-I characteristic of p-n junction diode



i) Under the reverse bias condition, the holes of p-side are attracted towards the negative terminal of the battery and the electrons of the n-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However the minority charge carriers are drifted across the junction producing a small current. At any temperature the number of minority carriers is constant so there is the small current at any applied potential. This is the reason for the current under reverse bias to be almost independent of applied potential. At the critical voltage, avalanche breakdown takes place which results in a sudden flow of large current.

(ii) At the critical voltage, the holes in the n-side and conduction electrons in the p-side are accelerated due to the reverse bias voltage. These minority carriers acquire sufficient kinetic energy from the electric field and collide with a valence electron. Thus the bond is finally broken and the valence electrons move into the conduction band resulting in enormous flow of electrons and thus formation of hole-electron pairs. Thus there is a sudden increase in the current at the critical voltage.

(iii)Zener diode is a semiconductor device which operates under the reverse bias in the breakdown region.

Q12) The magnetic field in a plane electromagnetic wave is given by tesla.

$B_y = 2\times10^{-7}\sin\left(0.5\times10^{3}x + 1.5\times10^{11}t\right)$**tesla.**

(a) What is the wavelength and frequency of the wave?

(b) Write an expression for the electric field.

(c) A parallel plate capacitor is being charged. Show that the displacement current across an area in the region between the plates and parallel to it is equal to the conduction current in the connecting wires.

Ans)

Given

$$B_y = 2\times10^{-7}\sin\left(0.5\times10^{3}x + 1.5\times10^{11}t\right)\text{tesla}$$

On comparing with the standard equation, $B_Y = B_0 \sin\left[2\pi\left(\frac{x}{\lambda} - vt\right)\right]$

We get , $\frac{2\pi}{\lambda} = 0.5\times 10^{3}$

$\therefore \quad \lambda = \frac{2\pi}{0.5\times 10^{3}} = \frac{2\times 3.14}{0.5\times 10^{3}} = 1.26\times 10^{-2}\, m$

Also , $2\pi\nu = 1.5\times 10^{11}$

$\therefore \quad \nu = \frac{1.5\times 10^{11}}{2\pi} = \frac{1.5\times 10^{11}}{2\times 3.14} = 23.9\times 10^{9}\, Hz = 23.9\, GHz$.

(b) $E_0 = cB_0 = 3\times 10^{8}\times 2\times 10^{-7} = 60 \;\; Vm^{-1}$.

The electric field is perpendicular to the direction of propagation (x-axis) and the direction of magnetic field (y-axis). So the expression for electric field is

$$E_z = E_0 \sin\left(0.5\times 10^{3} x + 1.5\times 10^{11} t\right) Vm^{-1}$$

(c) The conduction current $I_c = \frac{dq}{dt}$ is not continuous across the capacitor gap as no charge is transported across this gap.The displacement current I_d is zero outside the capacitor plates and in the gap, it has the value

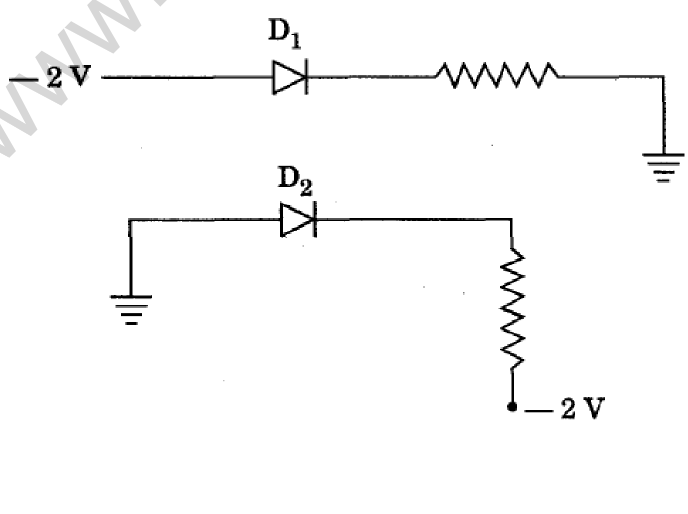
$$I_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(EA) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0}\right) = \frac{dq}{dt}$$

It is exactly the value of the conduction current in the lead wires. Thus the displacement current satisfies the basic condition that the current is continuous.

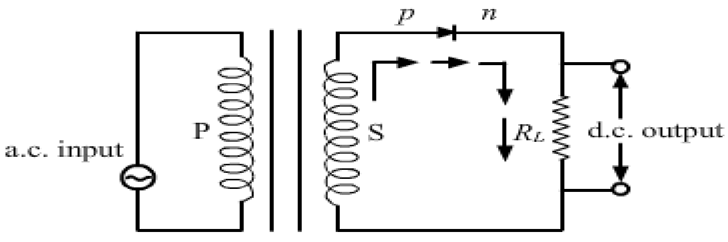
The sum $I_c + I_d$ has the same value along the entire path (both inside and outside the capacitor plates), although individually the two currents are discontinuous.

Q13)(i) With the help of a circuit diagram and input and output waveform explain working of half wave Rectifier.

(ii) From the diagram shown below identify whether the diode D_1 and D_2 is forward or reverse biased and why?



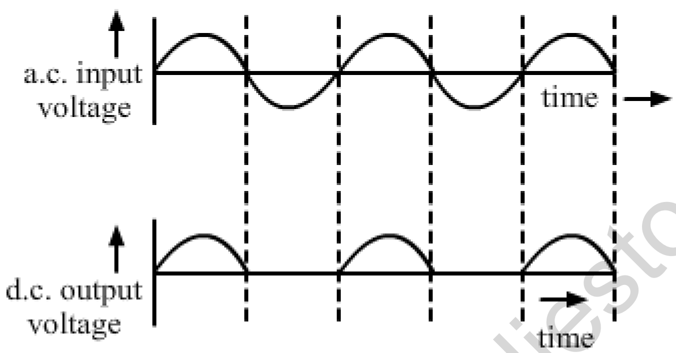
Ans)(i) The circuit diagram for a *p-n* junction diode as a half wave rectifier is shown below:



(a)

Working: During the positive half cycle of the input a.c. The *p-n* junction is forward biased i.e the forward current flows from *p* to *n*, the diode offers a low resistance path to the current. Thus we get output across-load i.e. a.c input will be obtained as d.c output

During the negative half cycle of the input a.c. The *p-n* junction is reversed biased i.e the reverse current flows from *n* to p, the diode offers a high resistance path to the current. Thus we get no output across-load. This principle is shown in the diagram given below.



(b)

(ii) D_1 reverse biased

D_2 forward biased

Q14) (a)With the help of the diagram explain the principle and working of a moving coil galvanometer.

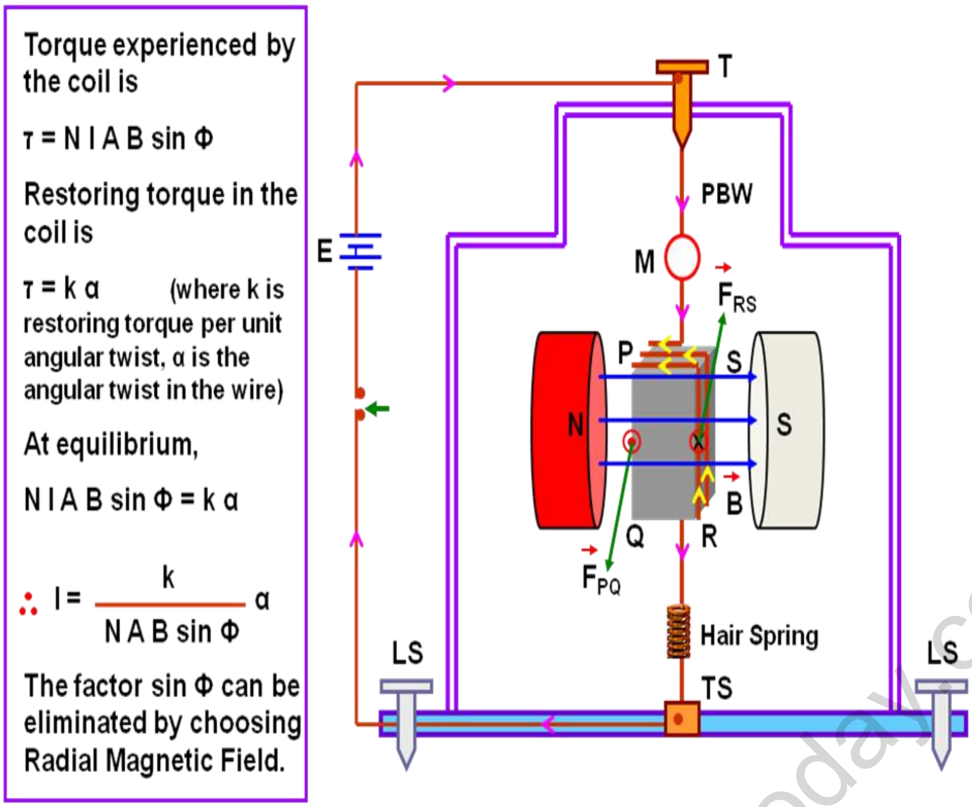
(b) What is the importance of the radial magnetic field and how is it produced?

(c) Why is it that while using a moving coil galvanometer as a voltmeter a high

resistance in series is required in series whereas in an ammeter a shunt is used.

Ans) (a)Labelled diagram, Principle of working

Moving Coil or Suspended Coil or D' Arsonval Type Galvanometer:



T – Torsion Head, TS – Terminal screw, M – Mirror, N,S – Poles pieces of a magnet,
LS – Levelling Screws, PQRS – Rectangular coil, PBW – Phosphor Bronze Wire

(b) For radial magnetic field $\varphi = 0^0$ => I = (k/ NAB) ɵ => I αɵ

(c) Reason:

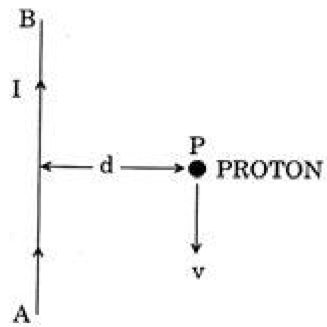
Voltmeter: This ensures that a very low current passes through the voltmeter and hence does not change (much) the original potential difference to be measured.

Ammeter: This ensures that the total resistance of the circuit does not change much and the current flowing remains (almost) at its original value..

Q15) (a)Drive an expression for the force between two long parallel current carrying conductors.

(b) Use this expression to define *S.I.* unit of current.

(c)A long straight wire AB carries a current *I*. A proton P travels with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the force experienced by the proton and what is its direction?



Ans) (a)

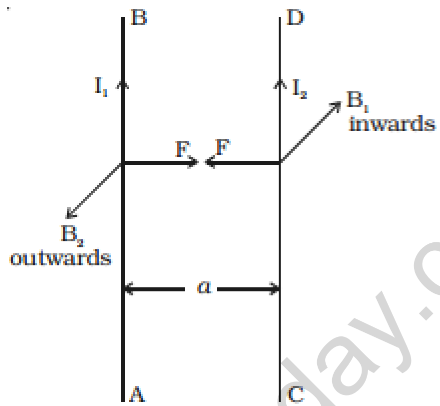


Fig. 3.23 Force between two long parallel current-carrying conductors

AB and CD are two straight very long parallel conductors placed in air at a distance a. They carry currents I_1 and I_2 respectively. (Fig 3.23). The magnetic induction due to current I_1 in AB at a distance a is

$$B_1 = \frac{\mu_o I_1}{2\pi a} \quad ...(1)$$

This magnetic field acts perpendicular to the plane of the paper and inwards. The conductor CD with current I_2 is situated in this magnetic field. Hence, force on a segment of length l of CD due to magnetic field B_1 is

$$F = B_1 I_2 l$$

substituting equation (1)

$$F = \frac{\mu_o I_1 I_2 l}{2\pi a} \quad ...(2)$$

By Fleming's Left Hand Rule, F acts towards left. Similarly, the magnetic induction due to current I_2 flowing in CD at a distance a is

$$B_2 = \frac{\mu_o I_2}{2\pi a} \quad ...(3)$$

This magnetic field acts perpendicular to the plane of the paper and outwards. The conductor AB with current I_1, is situated in this field. Hence force on a segment of length l of AB due to magnetic field B_2 is

$$F = B_2 I_1 l$$

substituting equation (3)

$$\therefore \quad F = \frac{\mu_o I_1 I_2 l}{2\pi a} \quad ...(4)$$

By Fleming's left hand rule, this force acts towards right. These two forces given in equations (2) and (4) attract each other. Hence, two parallel wires carrying currents in the same direction attract each other and if they carry currents in the opposite direction, repel each other.

(b) The force between two parallel wires carrying currents on a segment of length l is

$$F = \frac{\mu_o I_1 I_2}{2\pi a} l$$

$\therefore$ Force per unit length of the conductor is

$$\frac{F}{l} = \frac{\mu_o I_1 I_2}{2\pi a}$$

If $I_1 = I_2 = 1A$, $a = 1m$

$$\frac{F}{l} = \frac{\mu_o}{2\pi}\ \frac{1 \times 1}{1} = \frac{4\pi \times 10^{-7}}{2\pi} = 2 \times 10^{-7}\ Nm^{-1}$$

The above conditions lead the following definition of ampere.

Ampere is defined as that constant current which when flowing through two parallel infinitely long straight conductors of negligible cross section and placed in air or vacuum at a distance of one metre apart, experience a force of 2×10^{-7} newton per unit length of the conductor.

(c) $F = evB = ev(\mu_0 I/ 2\pi d)$, towards right.

Q16) A point object is placed in front of a double convex lens(of refractive in

$n=n_2/n_1$ with respect to air) with its spherical faces of radii of curvature R_1 and R_2. Show the path of rays due to refraction at first and subsequently at the second surface to obtain the formation of the real image of the object. Hence obtain the lens- maker's formula for a thin lens. Write the assumptions and sign convention used.

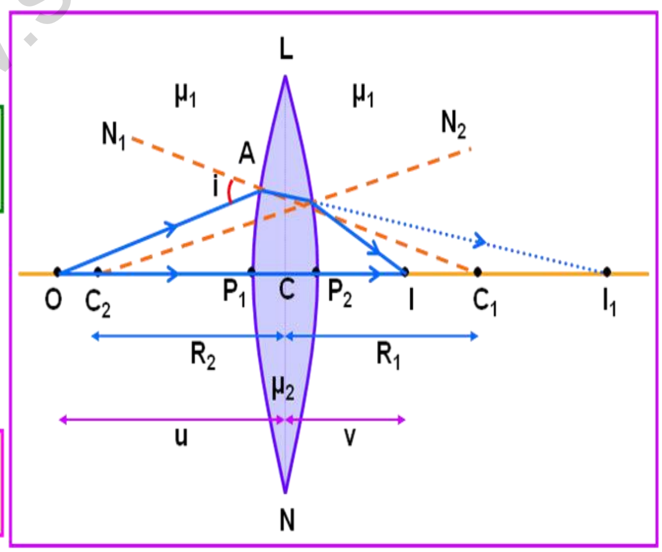
Ans)

Lens Maker's Formula:

For refraction at LP_1N,

$$\frac{\mu_1}{CO} + \frac{\mu_2}{CI_1} = \frac{\mu_2 - \mu_1}{CC_1}$$

(as if the image is formed in the denser medium)



For refraction at LP_2N,

$$\frac{\mu_2}{-CI_1} + \frac{\mu_1}{CI} = \frac{-(\mu_1 - \mu_2)}{CC_2}$$

(as if the object is in the denser medium and the image is formed in the rarer medium)

Combining the refractions at both the surfaces,

$$\frac{\mu_1}{CO} + \frac{\mu_1}{CI} = (\mu_2 - \mu_1)\left(\frac{1}{CC_1} + \frac{1}{CC_2}\right)$$

Substituting the values with sign conventions,

$$\frac{1}{-u} + \frac{1}{v} = \frac{(\mu_2 - \mu_1)}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Since $\mu_2 / \mu_1 = \mu$

$$\frac{1}{-u} + \frac{1}{v} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or

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

When the object is kept at infinity, the image is formed at the principal focus.

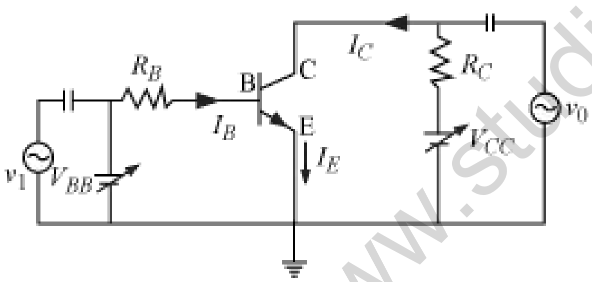
i.e. $u = -\infty$, $v = +f$.

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

This equation is called 'Lens Maker's Formula'.

Also, from the above equations we get, $$\boxed{\frac{1}{-u} + \frac{1}{v} = \frac{1}{f}}$$

Q17)(a)Draw a circuit diagram of n-p-n transistor amplifier in CE configuration. Under what condition does the transistor act as an amplifier?
(b) Draw input, output wave form.
(c) Define Trans-conductance.
Ans)
The circuit diagram of an NPN transistor amplifier in CE configuration is given below



The transistor acts as an amplifier when the input circuit (emitter–base) is forward biased with low voltage V_{BB} and the output circuit (collector–base) is reverse biased with high voltage V_{CC} .When transistor is in active state.

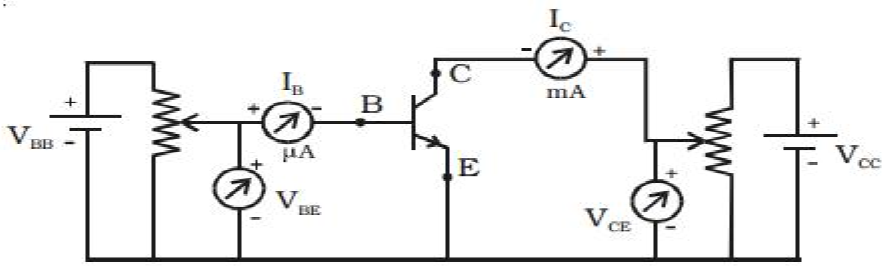
(b) waveform

(c) Ratio of small change in collector current to small change in emitter base voltage.

$$g_m = \frac{\Delta Ic}{\Delta Vbe}$$

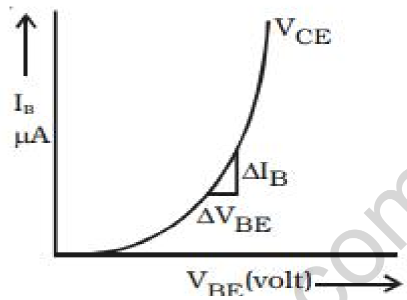
Q18) Draw the circuit arrangement for studying the input and output characteristics of anpn transistor in CE configuration. Draw the input and output curves.With the help of these characteristic curves define
(a) nput resistance
(b)Output resistance
(c)Current amplification factor.

Ans)



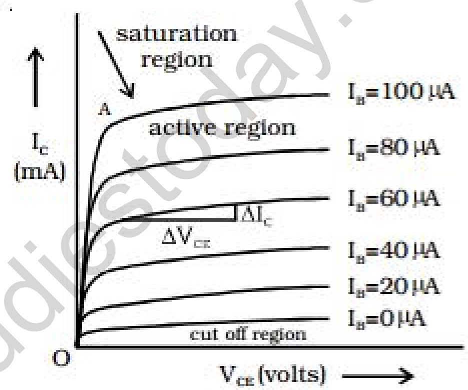
Input characteristics curve

Input impedance, $r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$

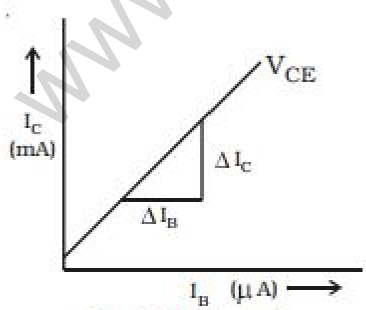


Output characteristics curve

output impedence, $r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$



Current amplification



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

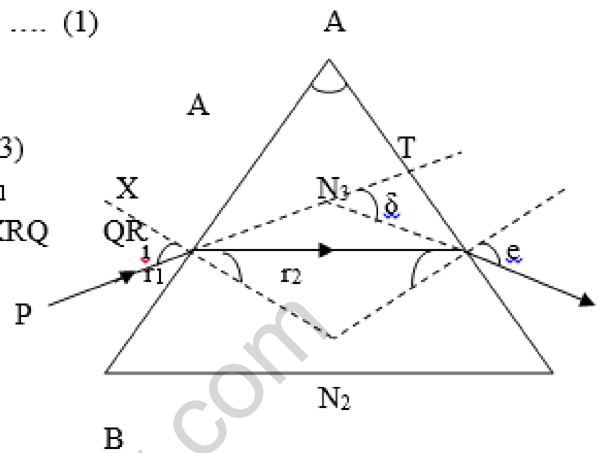
Fig 9.31 Transfer characteristic curve

Q19)Draw a graph to show the variation of the angle of deviation 'δ' with that of angle ofincidence 'i' for a monochromatic ray of light passing through a glass prism of refractingangle A. hence deduce the expression for the

refractive index of the material of the prismin terms of the angle of prism and the angle of minimum deviation.

Ans)

Diagram shows section ABC of a prism taken by a vertical plane perpendicular to the edge. BC is base of the prism and AB & AC are its two refracting surfaces. PQ is incident ray, QR is refracted ray and RS is emergent ray.



In quadrilateral AQN_2R, $\angle AQN_2 + \angle ARN_2 = 180^\circ$ .... (1)

$\angle A + \angle QN_2R = 180^\circ$

In Δ QRN_2, $\angle r_1 + \angle r_2 + \angle QN_2R = 180^\circ$ .... (2)

From equations (1) and (2), $\angle A = \angle r_1 + \angle r_2$ ..... (3)

In Δ XQR, $\angle XQR = \angle i - \angle r_1$ & $\angle XRQ = \angle e - \angle r_2$ N_1

Since exterior $\angle TXR$ = interior $\angle XQR$ + interior $\angle XRQ$

$\therefore \angle \delta = (\angle i - \angle r_1) + (\angle e - \angle r_2)$

$= (\angle i + \angle e) - \angle A$

S

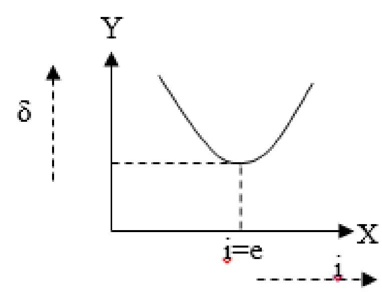
Or, $\angle A + \angle \delta = \angle i + \angle e$ .... (4)

A graph between $\angle i$ and $\angle \delta$ shows that,

C

$\angle \delta$ is more when $\angle i$ is either small or large.

$\angle \delta$ is minimum for some intermediate value of $\angle i$.



From graph, when $\angle \delta = \angle \delta_m$, then $\angle i = \angle e$ & $\angle r_1 = \angle r_2$

Now, from equations (3) and (4), we get, δ_m

$\angle A = 2r \Rightarrow r = \frac{\angle A}{2}$ & $\angle A + \angle \delta_m = \angle i + \angle i \Rightarrow \angle i = \frac{\angle A + \delta m}{2}$

From Snell's law, $n = \frac{\sin\left(\frac{\angle A + \delta m}{2}\right)}{\sin\left(\frac{\angle A}{2}\right)}$ This is the required expression.

Q20) With the help of a ray diagram, show the formation of image of a point object by refraction of light at a convex spherical (convex) surface separating two media of refractive indices n_1 and n_2(n_2> n_1) respectively. Using this diagram, derive the relation.

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}.$$

Also write the sign conventions used and assumptions

Ans) Sign Convention used:-

a) All the distances are measured from the pole.
b) The distances measured in the direction of incident light are taken as positive.
c) The distances measured in the direction opposite to the direction of light are taken as negative.

Assumptions:-

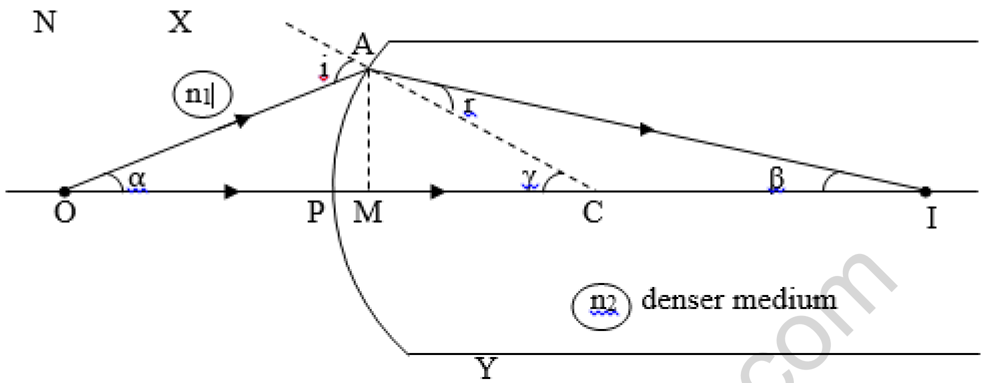
a) The aperture of the spherical refracting surface is small.
b) The object is a point object and lies on the principal axis.

c) The incident ray, the refracted ray and the normal to the spherical surface make small angles with the principal axis.

d) Let XPY = convex spherical refracting surface

O = point object in rarer medium

I = real image in denser medium



From ray diagram, from ΔAOC, $i = \alpha + \gamma$

From ΔAIC, $\gamma = r + \beta \Rightarrow r = \gamma - \beta$

According to Snell's law, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \Rightarrow n_1 \sin i = n_2 \sin r$

Since the angles are small, $\therefore n_1\, i = n_2\, r$ or, $n_1 \tan i = n_2 \tan r$

Substituting for i & r, in the above equation, we get

$n_1 \tan(\alpha + \gamma) = n_2 \tan(\gamma - \beta)$

Or, $n_1\{\tan\alpha + \tan\gamma\} = n_2\{\tan\gamma + \tan\beta\}$

Or, $n_1\left\{\frac{AM}{PO} + \frac{AM}{MC}\right\} = n_2\left\{\frac{AM}{MC} - \frac{AM}{MI}\right\}$

Since the aperture is small, $\therefore$ MC = PC, MI = PI

$\therefore \left\{\frac{n_1}{PO} + \frac{n_1}{PC}\right\} = \left\{\frac{n_2}{PC} - \frac{n_2}{PI}\right\}$

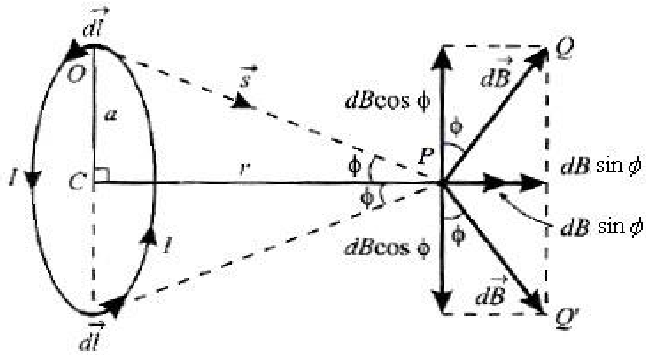
According to sign convention, PO = $-u$, $PC = R$, PI = v

$\therefore \left\{\frac{n_1}{-u} + \frac{n_1}{R}\right\} = \left\{\frac{n_2}{R} - \frac{n_2}{v}\right\}$

Or, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ This is the required equation.

Q21)StateBiot Savart's law .Using it, derive the expression for the magnetic field in the vector form at a point on the axis of a circular current loop.

Ans) Consider a circular loop of wire of radius *a* and carrying current *I*, as shown in figure.



Let the plane of the loop be perpendicular to the plane of paper. We wish to find field $\vec{B}$ at an axial point P at a distance r from the centre C.

Consider a current element $d\vec{l}$ at the top of the loop. It has an outward coming current.
If $\vec{s}$ be the position vector of point P relative to the element $d\vec{l}$, then from Biot-Savart law, the field at point P due to the current element is

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$$

Since $d\vec{l} \perp \vec{s}$, i.e., $\theta = 90°$, therefore

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{s^2}$$

The field $d\vec{B}$ lies in the plane of paper and is perpendicular to $\vec{s}$, as shown by PQ.Let ϕ be the angle between OP and CP. Then dB can be resolved into two rectangular components.

1. $dB\sin\phi$ along the axis, 2. $dB\cos\phi$ perpendicular to the axis.

For any two diametrically opposite elements of the loop, the components perpendicular to the axis of the loop will be equal and opposite and will cancel out. Their axial components will be in the same direction, i.e., along CP and get added up.

Therefore, total magnetic field at the point P in the direction CP is

$$B = \int dB\sin\phi$$

$$But\sin\phi = \frac{a}{s} \text{ and } dB = \frac{\mu_0}{4\pi}\frac{Idl}{s^2}$$

$$\therefore B = \int\frac{\mu_0}{4\pi}.\frac{Idl}{s^2}.\frac{a}{s}$$

Since μ_0 and I are constant, and s and $a$are same for all points on the circular loop, we have

$$B = \frac{\mu_0 Ia}{4\pi s^3}\int dl = \frac{\mu_0 Ia}{4\pi s^3}.2\pi a = \frac{\mu_0 I a^2}{2s^3} \qquad [\because \int dl = Circumference = 2\pi a]$$

$$As, \quad s = (r^2+a^2)^{1/2}$$

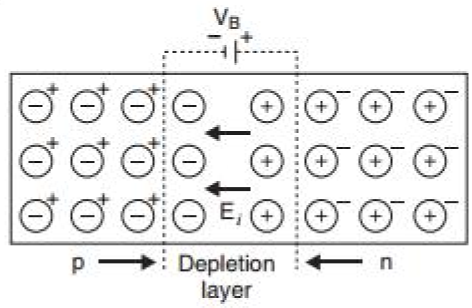
$$\therefore \quad B = \frac{\mu_0 I a^2}{2(r^2+a^2)^{3/2}}$$

If the coil consists on N turns, then $B = \dfrac{\mu_0 N I a^2}{2(r^2+a^2)^{3/2}}$.

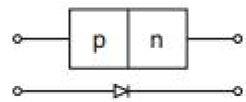
Q22) What is a p-n junction diode? Explain the formation of depletion region and barrier potential set up in a p-n junction?

Ans)

Formation of depletion layer and potential barrier:



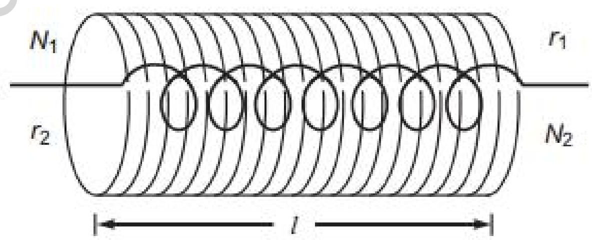
At the junction there is diffusion of charge carriers due to thermal agitation; so that some of electrons of n-region diffuse to p-region while some of holes of p-region diffuse into n-region. Some charge carriers combine with opposite charges to neutralise each other. Thus near the junction there is 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 Fig.



Q23) Define mutual inductance. Derive an expression for mutual inductance of two long coaxial solenoids of same lengths wound over each other.

Ans) Definition

Mutual Inductance of Two Co-axial Solenoids : Consider two long co-axial solenoid each of length l with number of turns N_1 and N_2 wound one over the other. Number of turns per unit length in order (primary) solenoid, $n = \frac{N_1}{l}$. If I_1 is the current flowing in primary solenoid, the magnetic field produced within this solenoid.



$$B_1 = \frac{\mu_0 N_1 I_1}{l} \quad \text{...(ii)}$$

The flux linked with each turn of inner solenoid coil is $\phi_2 = B_1 A_2$, where A_2 is the cross-sectional area of inner solenoid. The total flux linkage with inner coil of N_2-turns.

$$\Phi_2 = N_2 \phi_2 = N_2 B_1 A_2 = N_2 \left(\frac{\mu_0 N_1 I_1}{l} \right) A_2 = \frac{\mu_0 N_1 N_2}{l} A_2 I_1$$

By definition **Mutual Inductance,** $M_{21} = \frac{\Phi_2}{I_1} = \frac{\mu_0 N_1 N_2 A_2}{l}$

If n_1 is number of turns per unit length of outer solenoid and r_2 is radius of inner solenoid, then $M = \mu_0 n_1 N_2 \pi r_2^2$.

Q24)Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f). When electron in hydrogen atom jumps from energy state n_i =4 to n_f = 3, 2, 1, identify the spectral series to which the emission lines belong.

(3) Total energy : From eq (i) $\frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{r} = mv^2$ so kinetic energy $\boxed{K = \frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{r}}$.

Electrostatic potential energy, $\boxed{U = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r}}$

Total energy (E) is the sum of potential energy and kinetic energy *i.e.*

$$E = K + U = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} + \frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{r}$$

Ans) $\boxed{E = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}}$ From eq (iii) $r_n = \frac{n^2h^2\varepsilon_0}{\pi m z e^2}$. Hence $\boxed{E = -\left(\frac{me^4}{8\varepsilon_0^2h^2}\right)\frac{z^2}{n^2}}$ —(iv)

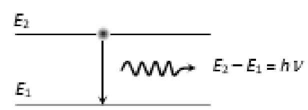
(a) Energy of emitted radiation :– From eq (iv)

$$\Delta E = E_2 - E_1 = -\left(\frac{me^4}{8\varepsilon_0^2h^2}\right)\frac{z^2}{n_2^2} - -\left(\frac{me^4}{8\varepsilon_0^2h^2}\right)\frac{z^2}{n_1^2}$$

$$\boxed{\Delta E = \frac{mZ^2e^4}{8\varepsilon_0^2h^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)} \quad \text{OR}$$

$$\Delta E = 13.6Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(b) Frequency of emitted radiation;– $\Delta E = h\nu \Rightarrow h\nu = \frac{mZ^2e^4}{8\varepsilon_0^2h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ The frequency of the emitted radiations can be found from the following relation $\nu = \frac{mZ^2e^4}{8\varepsilon_0^2h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$



Wave number/wavelength:– If c be the velocity of light and λ its wavelength, then $\nu = c/\lambda$

$$\nu = \frac{c}{\lambda} = \frac{me^4}{8\varepsilon_0^2h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \quad \text{or} \quad \frac{1}{\lambda} = \frac{me^4}{8\varepsilon_0^2h^3c}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Where $R = \frac{me^4}{8\varepsilon_0^2h^3c}$, R is known as Rydberg's constant and its value is $1.097\times10^7\ m^{-1}$.

Wave number $\bar{\nu}$ is the number of waves in unit length. It is reciprocal of wavelength is given by

$$\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

This equation is the general expression for the wave number of radiation emitted by the electron when it jumps from higher orbit n_2 to lower orbit n_1.

When n_f = 3, Paschen Series
When n_f = 2, Balmer Series

When n_f = 1, Lyman Series

Q25)State Huygen's principle and deduce the laws ofrefraction on the basis of this principle.

Ans)(a)

Principle:

(*i*) Every point on a given wavefront may be regarded as a source of new disturbance.

(*ii*) The new disturbances from each point spread out in all directions with the velocity of light and are called the ***secondary wavelets.***

(*iii*) The surface of tangency to the secondary wavelets in forward direction at any instant gives the new position of the wavefront at that time.

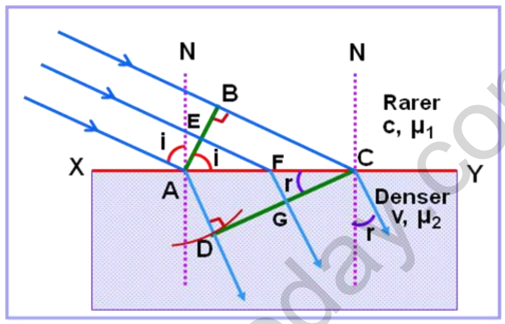
Laws of Refraction at a Plane Surface (On Huygens' Principle):

If c be the speed of light, t be the time taken by light to go from B to C or A to D or E to G through F, then

$$t = \frac{EF}{c} + \frac{FG}{v}$$

$$t = \frac{AF \sin i}{c} + \frac{FC \sin r}{v}$$

$$t = \frac{AC \sin r}{v} + AF\left(\frac{\sin i}{c} - \frac{\sin r}{v}\right)$$



AB – Incident wavefront
CD – Refracted wavefront
XY – Refracting surface

For rays of light from different parts on the incident wavefront, the values of AF are different. But light from different points of the incident wavefront should take the same time to reach the corresponding points on the refracted wavefront.

So, t should not depend upon AF. This is possible only

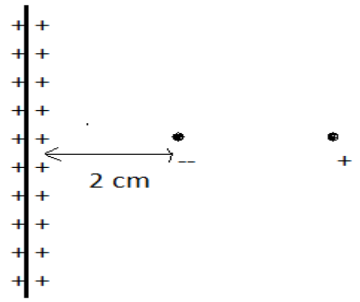
if $\frac{\sin i}{c} - \frac{\sin r}{v} = 0$ or $\frac{\sin i}{c} = \frac{\sin r}{v}$ or $\frac{\sin i}{\sin r} = \frac{c}{v} = \mu$

Q26)(a) Using the Gauss' Law deduce the expression for the electric field due to a uniformly charged spherical conducting shell of the radius R at a point(i)outside and (ii)inside the shell. Plot a graph showing variation of electric field as a function of r>R and r<R.

(r being the distance from the centre of the shell).

(b)An electric dipole consist charges $\pm$ 2.0x10^{-8} C separated by a distance of 2.0x10^{-3} m.it is placed near a long line charge of linear charge density 4.0x10^{-4} Cm^{-1}

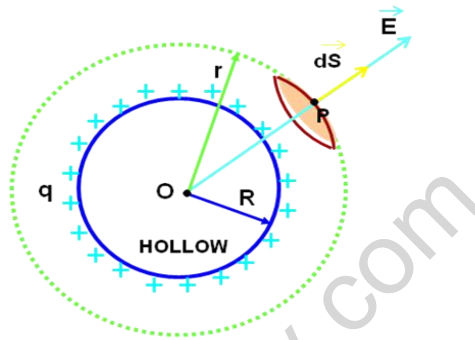
As shown in figure, such that negative charge is at 2.0 cm from the line charge. Find the force acting on the dipole.



Ans)

4. **Electric Field Intensity due to a Uniformed Charged This Spherical Shell:**

i) At a point P outside the shell:



.... Gaussian Surface

From Gauss's law,

$$\Phi_E = \oint_S \vec{E} \cdot \vec{dS} = \frac{q}{\varepsilon_0}$$

Since $\vec{E}$ and $\vec{dS}$ are in the same direction,

$$\therefore \quad \Phi_E = \oint_S E \ dS = \frac{q}{\varepsilon_0}$$

$$\text{or} \quad \Phi_E = E \oint_S dS = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0} \quad \text{or} \quad \boxed{E = \frac{q}{4\pi\varepsilon_0 \ r^2}}$$

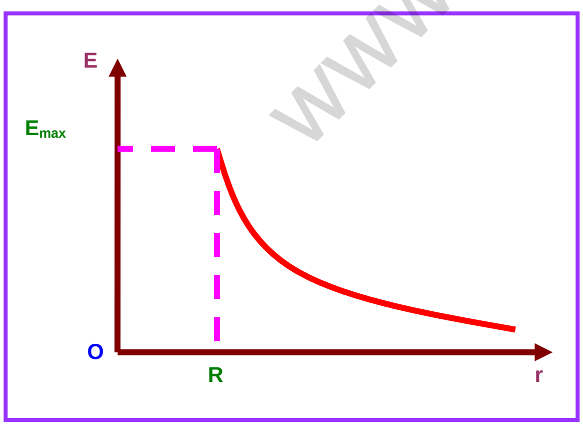
Since $q = \sigma \times 4\pi R^2$,

$$\therefore \quad \boxed{E = \frac{\sigma \ R^2}{\varepsilon_0 \ r^2}}$$

Electric field due to a uniformly charged thin spherical shell at a point outside the shell is such as if the whole charge were concentrated at the centre of the shell.

ii)At surface r =R , $E = \sigma/\varepsilon_0$

iii) Inside the shell q= o , E = 0.



(b) $E_1 = \frac{1}{4\pi\varepsilon 0} \cdot \frac{2\lambda}{r1}$ towards line charge

And $E_2 = \frac{1}{4\pi\varepsilon 0} \cdot \frac{2\lambda}{r2}$ away from line charge

So $F_{net} = q(E_1 - E_2) = \left(\frac{1}{4\pi\varepsilon 0}\right) \text{X}2 \text{ X } 10^{-8} \text{ X } 2 \text{ X } (4 \text{ X } 10^{-4})(1/r_1 - 1/r_2)$

Q 27) Find the electric field due to a dipole at equatorial line.
Ans)

$$E_2 = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+d^2)}$$

The magnitudes of E_1 and E
heir horizontal and vertical c
omponents E_1 sin θ and E_2 si
hey cancel each other.

The horizontal components $E_1 \cos\theta$ and $E_2 \cos\theta$ will get added along PR.

Resultant electric field at the point P due to the dipole is

$$E = E_1 \cos\theta + E_2 \cos\theta \text{ (along PR)}$$

$$= 2\, E_1 \cos\theta \quad (\because E_1 = E_2)$$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+d^2)} \times 2\cos\theta$$

But $\cos\theta = \dfrac{d}{\sqrt{r^2+d^2}}$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+d^2)} \times \frac{2d}{(r^2+d^2)^{1/2}} = \frac{1}{4\pi\varepsilon_o}\frac{q2d}{(r^2+d^2)^{3/2}}$$

$$= \frac{1}{4\pi\varepsilon_o}\frac{p}{(r^2+d^2)^{3/2}} \quad (\because p = q2d)$$

For a dipole, d is very small when compared to r

$$\therefore \quad E = \frac{1}{4\pi\varepsilon_o}\frac{p}{r^3}$$

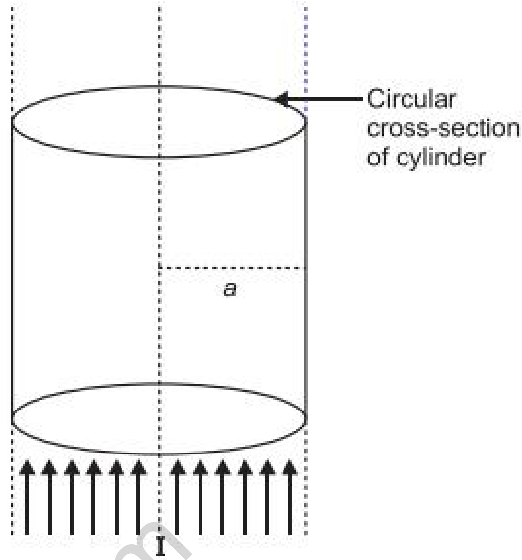
The direction of E is along PR, parallel to the axis of the dipole and directed opposite to the direction of dipole moment.

Q28) A long straight wire of a circular cross-section of radius 'a' carries a steady current 'I'. The current is uniformly distributed across the cross-section. Apply Ampere's circuital law to calculate the magnetic field at a point 'r' in the region for (i) r < a and (ii) r > a.

Ans.

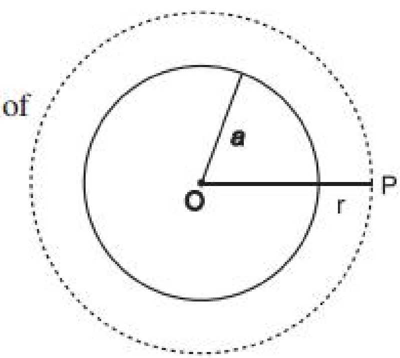
Magnetic Field due to a straight thick wire of uniform cross-section: Consider an infinitely long cylinderical wire of radius *a*, carrying current *I*. Suppose that the current is uniformly distributed over whole cross-section of the wire. The cross-section of wire is circular. Current per unit cross-sectional area.

$$i = \frac{I}{\pi a^2} \qquad \ldots(i)$$



Magnetic Field at External Points: We consider a circular path of radius r ($> a$) passing through external point P concentric with circular cross-section of wire. By symmetry the strength of magnetic field at every point of circular path is same and the direction of magnetic field is tangential to path at every point. So line integral of magnetic field $\vec{\mathbf{B}}$ around the circular path

$$\oint \vec{\mathbf{B}} \cdot \vec{dl} = \oint B\, dl \cos 0° = B\, 2\pi r$$



Current enclosed by path = Total current on circular cross-section of cylinder = I

By Ampere's circuital law

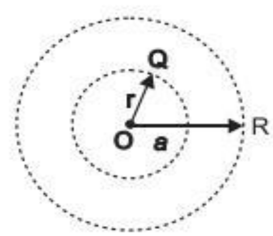
$$\oint \vec{\mathbf{B}} \cdot \vec{dl} = \mu \times \text{current enclosed by path}$$

$$\Rightarrow \qquad B\, 2\pi r = \mu_0 \times I$$

$$\Rightarrow \qquad B = \frac{\mu_0 I}{2\pi r}$$

Magnetic field at Internal Point: Consider a circular path of radius

r ($< a$), passing through internal point Q, concentric with circular cross-section of the wire. In this case the assumed circular path encloses only a path of current carrying circular cross-section of the wire.



$\therefore$ Current enclosed by path

$$= \text{current per unit cross-section} \times \text{cross section of assumed circular path}$$

$$= i \times \pi r^2 = \left(\frac{I}{\pi a^2}\right) \times \pi r^2 = \frac{I r^2}{a^2}$$

$\therefore$ By Ampere's circuital law

$$\oint \vec{\mathbf{B}} \cdot \vec{dl} = \mu_0 \times \text{current closed by path}$$

$$\Rightarrow \qquad B \cdot 2\pi r = \mu_0 \times \frac{Ir^2}{a^2}$$

$$B = \frac{\mu_0 I r}{2\pi a^2}$$

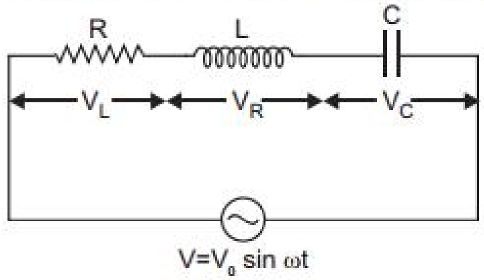
Clearly, magnetic field strength inside the current carrying wire is directly proportional to distance of the point from the axis of wire.

At surface of cylinder $r = a$, so magnetic field at surface of wire

$$B_s = \frac{\mu_0 I}{2\pi a} \qquad \text{(maximum value)}$$

Q29) A series LCR circuit is connected to an ac source having voltage v = vm sin wt. Derive the expression for the instantaneous current J and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define 'power factor'. State the conditions under which it is (i) maximum and (ii) minimum.

Suppose resistance R, inductance L and capacitance C are connected in series and an alternating source of voltage $V = V_0 \sin \omega t$ is applied across it. (fig. a) On account of being in series, the current (i) flowing through all of them is the same.



(a)

Suppose the voltage across resistance R is V_R, voltage across inductance L is V_L and voltage across capacitance C is V_C. The voltage V_R and current i are in the same phase, the voltage V_L will lead the current by angle 90° while the voltage V_C will lag behind the current by angle 90° (fig. b). Clearly V_C and V_L are in opposite directions, therefore their resultant potential difference $= V_C - V_L$ (if $V_C > V_C$).

Thus V_R and $(V_C - V_L)$ are mutually perpendicular and the phase difference between them is 90°. As applied voltage across the circuit is V, the resultant of V_R and $(V_C - V_L)$ will also be V. From fig.

$$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2} \qquad ...(i)$$

Ans

But $V_R = R\,i, V_C = X_C\,i$ and $V_L = X_L\,i$ ...(ii)

where $X_C = \frac{1}{\omega C}$ = capacitance reactance and $X_L = \omega L$ = inductive reactance

$$\therefore \quad V = \sqrt{(R\,i)^2 + (X_C\,i - X_L\,i)^2}$$

$\therefore$ Impedance of circuit, $Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$

i.e. $$Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$$

Instantaneous current $I = \dfrac{V_0 \sin(\omega t + \phi)}{\sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}}$

Condition for resonance to occur in series *LCR* ac circuit:

For resonance the current produced in the circuit and emf applied must always be in the same phase.

Phase difference (ϕ) in series *LCR* circuit is given by

$$\tan\phi = \frac{X_C - X_L}{R}$$

For resonance $\phi = 0 \Rightarrow X_C - X_L = 0$

or $X_C = X_L$

If ω_r is resonant frequency, then $X_C = \frac{1}{\omega_r C}$

and $X_L = \omega_r L$

$$\therefore \quad \frac{1}{\omega_r C} = \omega_r L \Rightarrow \omega_r = \frac{1}{\sqrt{LC}}$$

Power factor is the cosine of phase angle ϕ, *i.e.*, $\cos\phi = \frac{R}{Z}$.

For maximum power

$\cos\phi = 1$ or $Z = R$

i.e., circuit is purely resistive.

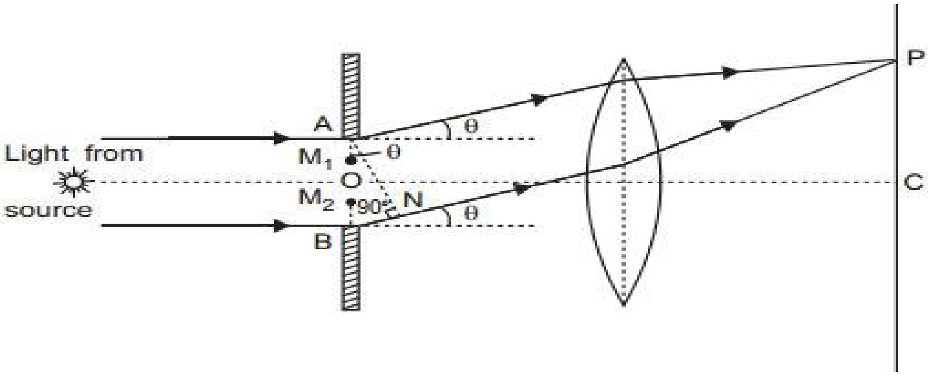
For minimum power

$\cos\phi = 0$ or $R = 0$

i.e., circuit should be free from ohmic resistance.

Q30) Show, with the help of a suitable diagram, how Huygen's principle is used to obtain the diffraction pattern by a single slit. Draw a plot of intensity distribution and explain clearly why the secondary maxima become weaker with increasing order (n) of the secondary maxima.

Ans)



Let AB be a slit of width 'a' and a parallelbeam of monochromatic light is incident onit. According to Fresnel the diffraction pattern is the result of superposition of large number of waves, starting fromdifferent points of illuminated slit.

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

The path difference between rays diffracted at points A and B,

$$\Delta = BP - AP = BN$$

In ΔANB, $\angle ANB = 90°$ $\quad\therefore$ and $\angle BAN = \theta$

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

As $AB =$ width of slit $= a$

$\therefore$ Path difference,

$$\Delta = a \sin\theta \qquad ....(i)$$

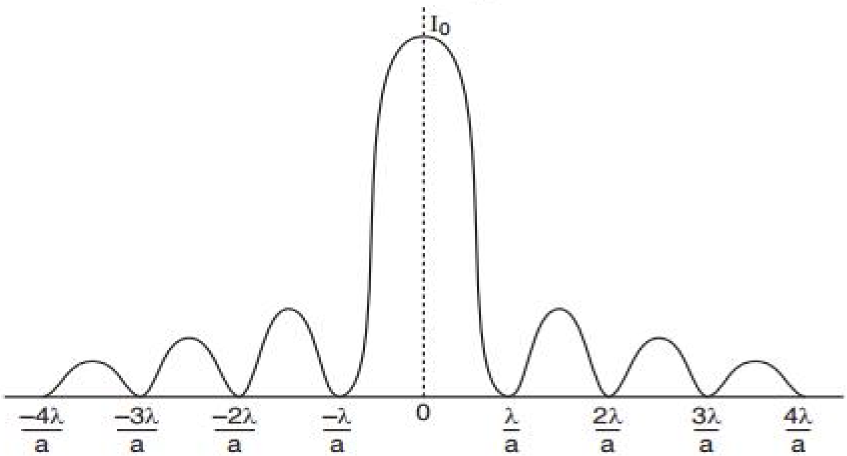
To find the effect of all coherent waves at P, we have to sum up their contribution, each with a different phase. This was done by Fresnel by rigorous calculations, but the main features may be explained by simple arguments given below:

At the central point C of the screen, the angle θ 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

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

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



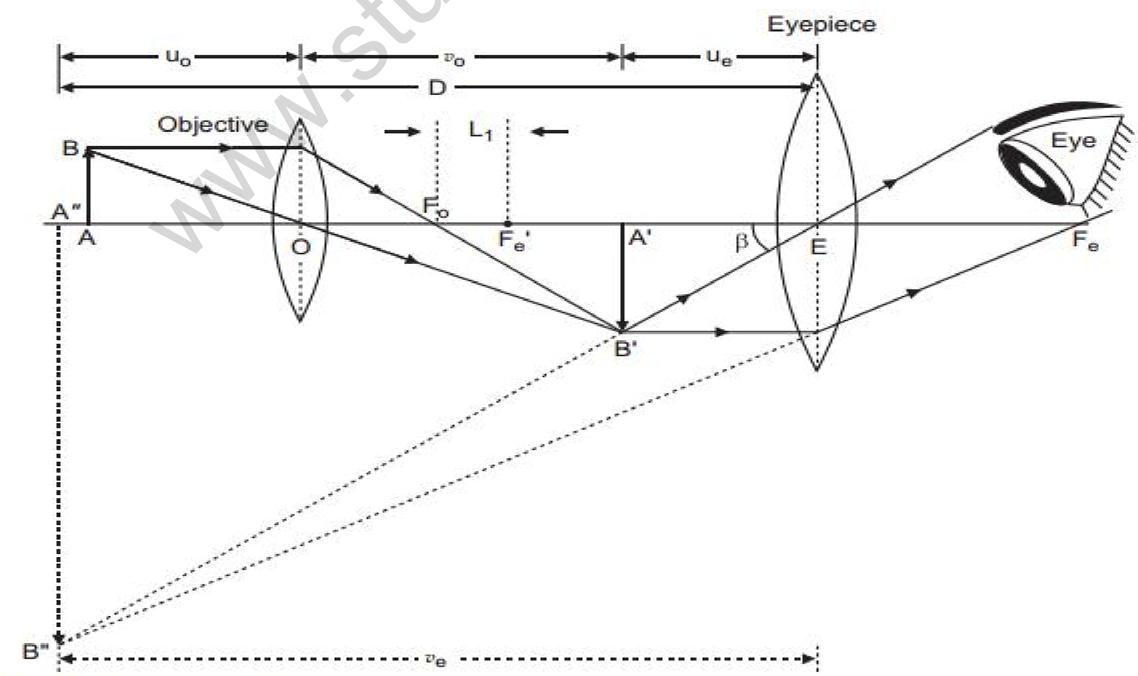
The intensity of secondary maxima decreases with increase of order n because with increasing n, the contribution of slit decreases.

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

Q31) Draw a ray diagram to show the working of a compound microscope. Deduce an expression forthe total magnification when the final image is formed at the near point.

In a compound microscope, an object is placed at a distance of 1×5 cm from the objective of focallength 1× 25 cm. If the eye piece has a focal length of 5 cm and the final image is formed at thenear point, estimate the magnifying power of the microscope.

Ans)



Magnifying power of microscope,

$$M = -\frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

Given $u_0 = -1\cdot5$ cm, $f_0 = 125$ cm, $f_e = 5$ cm, $D = 25$ cm

Formula $\dfrac{1}{f_0} = \dfrac{1}{v_0} - \dfrac{1}{u_0}$ gives

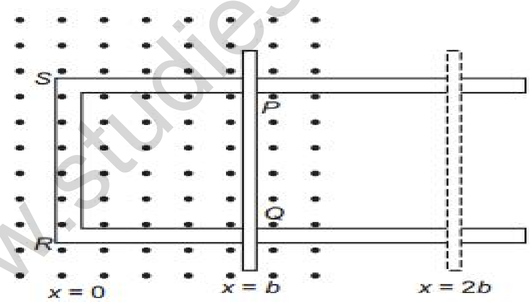
$$\frac{1}{1\cdot25} = \frac{1}{v_0} + \frac{1}{1\cdot5} \quad \Rightarrow \quad \frac{1}{v_0} = \frac{1}{1\cdot25} - \frac{1}{1\cdot5}$$

$$\Rightarrow \qquad v_0 = 7\cdot5 \text{ cm}$$

$$M = -\frac{7\cdot5}{1\cdot5}\left(1 + \frac{25}{5}\right) = -5 \times 6 = -\mathbf{30}$$

Q32)State Faraday's law of electromagnetic induction. Figure shows a rectangular conductor PQRS in which the conductor PQ is free to move in a uniform magnetic field B perpendicular to the plane of the paper. The field extends from x = 0 to x = b and is zero for x > b. Assume that only the arm PQ possesses resistance r. When the arm PQ is pulled outward from x = 0 to x = 2b and is then moved backward to x = 0 with constant speed v,obtain the expressions for the flux and the induced emf.

Sketch the variations of these quantities with distance $0 \le x \le 2b$.



Ans)

Faraday's law of electromagnetic induction states that whenever there is a change in magnetic flux linked with of a coil, an emf is induced in the coil. The induced emf is proportional to the rate of change of magnetic flux linked with the coil.

$$i.e.,\ e \propto \frac{\Delta\phi}{\Delta t}$$

If the coil contains N-turns, then $e = -N\frac{\Delta\phi}{\Delta t}$

Let length of conductor $PQ = l$

As $x = 0$, magnetic flux $\phi = 0$.

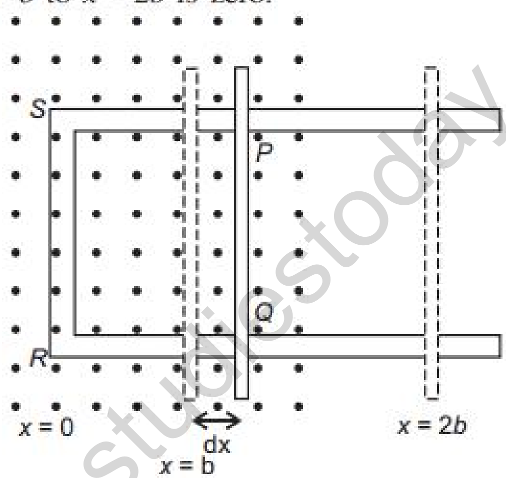
When PQ moves a small distance from x to $x + dx$, then magnetic flux linked $= BdA = Bldx$

The magnetic field is from $x = 0$ to $x = b$, so final magnetic flux $= \Sigma Bldx = Bl\,\Sigma\,dx$

$= Blb$ (increasing)

Mean magnetic flux from $x = 0$ to $x = b$ is $\frac{1}{2}Blb$.

The magnetic flux from $x = b$ to $x = 2b$ is zero.



Induced emf, $\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(Bldx)$

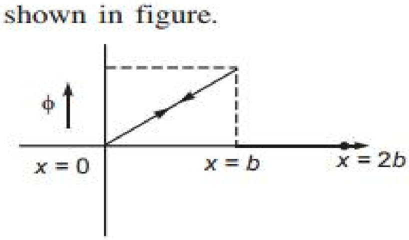
$$= -Bl\frac{dx}{dt} = -Blv$$

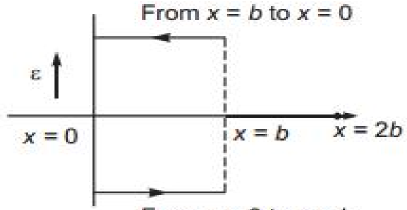
where $v = \frac{dx}{dt}$ = velocity of arm PQ from $x = 0$ to $x = b$.

During return from $x = 2b$ to $x = b$, the induced emf is zero; but now area is decreasing so magnetic flux is decreasing, and induced emf will be in opposite direction.

$$\varepsilon = Blv$$

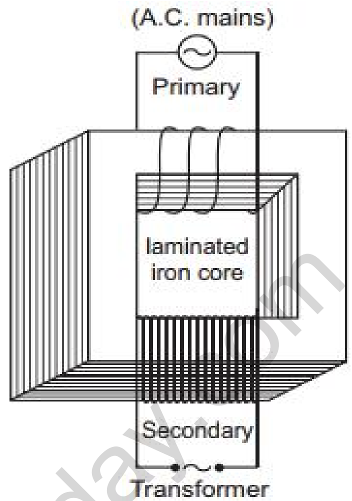
Graph is shown in figure.

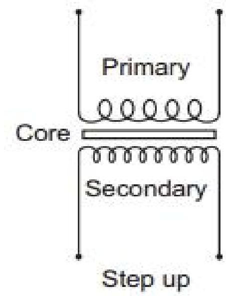




Q33) Draw a schematic diagram of a step-up transformer. Explain its working principle. Deduce theexpression for the secondary to primary voltage in terms of the number of turns in the two coils.In an ideal transformer, how is this ratio related to the currents in the two coils?
How is the transformer used in large scale transmission and distribution of electrical energy overlong distances?
Ans.

Principle: 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

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

and emf induced in the secondary coil

$$\varepsilon_S = -N_S \frac{\Delta\phi}{\Delta t} \quad ...(ii)$$

From (*i*) and (*ii*)

$$\frac{\varepsilon_S}{\varepsilon_p} = \frac{N_S}{N_p} \quad ...(iii)$$

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

$$\frac{V_S}{V_p} = \frac{\varepsilon_S}{\varepsilon_p} = \frac{N_S}{N_p} = r \text{ (say)} \qquad ...(iv)$$

where $r = \dfrac{N_S}{N_p}$ 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

$$V_p\, i_p = V_S\, i_S$$

$$\therefore \qquad \frac{i_S}{i_p} = \frac{V_p}{V_S} = \frac{N_p}{N_S} = \frac{1}{r} \qquad ...(v)$$

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

So $\qquad V_S > V_p$ and $i_S < i_p$

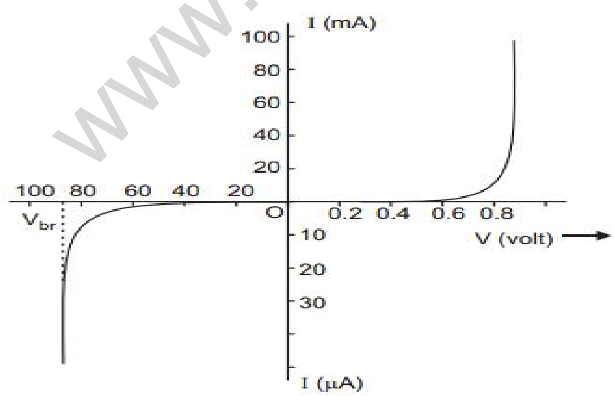
i.e., step up transformer increases the voltage.

When output voltage increases, the output current automatically decreases to keep the power same. Thus, there is no violation of conservation of energy in a step up transformer.

Step up transformer is used at power house to transmit power at high voltage 11000 V or 33000 V. The current in wires at this voltage is quite small, so power loss I^2R is negligible. At town, the step down transformer is used to supply power at 220 V. This saves enormous electrical energy.

Q34) (a) Draw I-V characteristics of a Zener diode. (b) Explain with the help of a circuit diagram, the use of a Zener diode as a voltage-regulator. (c) A photodiode is operated under reverse bias although in the forward bias the current is known to be more than the current in the reverse bias. Explain giving reason.

Ans. (*a*) I-V Characteristics of Zener diode:



(b) Zener diode as a Voltage Regulator

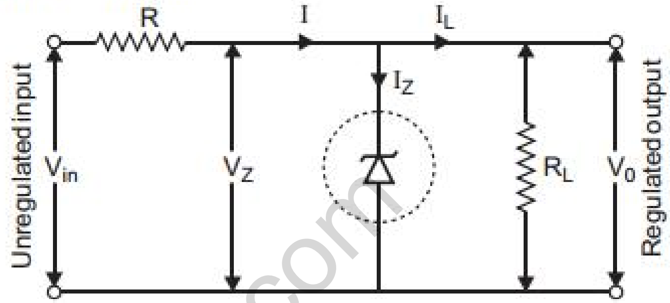
The Zener diode makes its use as a voltage regulator due to the following property :

When a Zener diode is operated in the breakdown region, the voltage across it remains practically constant for a large change in the current.

A simple circuit of a voltage regulator using a Zener diode is shown in the Fig. The Zener diode is connected across load such that it is reverse biased.

The series resistance R absorbs the output voltage fluctuations so as to maintain constant voltage across the load.

The operation of the circuit may be explained as follows :



Let V_{in} be the unregulated input *dc* voltage and V_0 be the output voltage across R_L to be regulated and V_Z be the Zener voltage of the diode. The value of the series resistance is so chosen that the diode operates in the breakdown region under the Zener voltage V_Z across it.

Let I be the current drawn from supply, I_Z the current through Zener diode and I_L the current through load. Then obviously

$$I = I_Z + I_L \quad \text{or} \quad I_Z = I - I_L$$

If R_Z is Zener diode resistance, then

$$V_0 = V_Z = I_Z \cdot R_Z = I_L R_L$$

Applying Kirchhoff's law to the mesh containing resistance R, Zener diode and supply voltage V_{in}, we have

$$RI + V_Z = V_{in}$$

i.e., $V_Z = V_{in} - RI.$ ...(*i*)

When the input voltage V_{in} is lower than the Zener voltage V_Z of diode, there is no current conduction

i.e., $I_Z = 0.$

This implies $V_0 = V_{in}.$

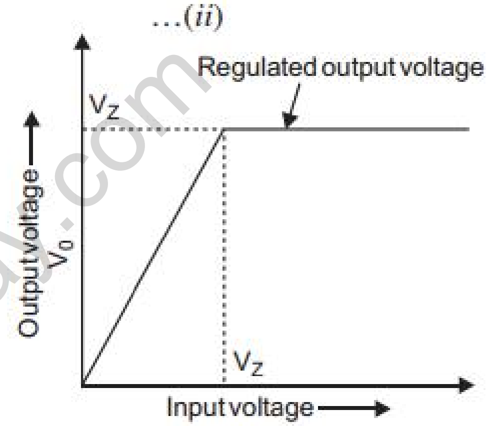
As input voltage V_{in} is increased so that it becomes equal to V_Z, the breakdown point is reached and the voltage across the diode $V_Z = (V_{in} - RI)$ becomes constant.

A further increase of input voltage V_{in} does not result in the corresponding increase in V_0 or V_Z but merely increases the voltage drop across R.

Thus in breakdown region, we have

$$V_0 = V_Z = V_{in} - RI \quad ...(ii)$$

Fig. represents the plot of output voltage V_0 versus input voltage V_{in}. It is clear from the graph that the output voltage remains constant when the diode is in Zener region.



It may be pointed out that for maintaining constant regulated output, the series resistance R for a given range of input voltage be so chosen that

(*i*) the diode operates in Zener region and

(*ii*) current should not exceed a certain value to cause burn out of diode.

(*c*) A photodiode is used in reverse bias, although in forward bias current in more, then current in reverse bias because in reverse bias it is easier to observe change in current with change in light intensity.

Q35) (a) State and derive the law of radioactive decay. Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half life $T_{1/2}$. Depict in the plot the number of undecayed nuclei at (i) t = $3T_{1/2}$ and (ii) t = $5T_{1/2}$

(b) Define the activity of a given radioactive substance. Write its S.I. unit.

Ans(a) Let N_0 be the number of radioactive atoms present initially and N, the number of atoms at a given instant t. Let dN be the number of atoms undergoing disintegration in a small interval of time dt. Then the rate of disintegration is

$$-\frac{dN}{dt} \propto N$$

$$\frac{dN}{dt} = -\lambda N \qquad \text{...(1)}$$

where λ is a constant known as decay constant or disintegration constant. The negative sign indicates that N decreases with increase in time.

Equation (1) can be written as

$$\frac{dN}{N} = -\lambda\, dt$$

Integrating, $\log_e N = -\lambda t + C$ ...(2)

where C is a constant of integration.

At $t = 0$, $N = N_0$

$\therefore$ $\log_e N_o = C$

Substituting for C, equation (2) becomes

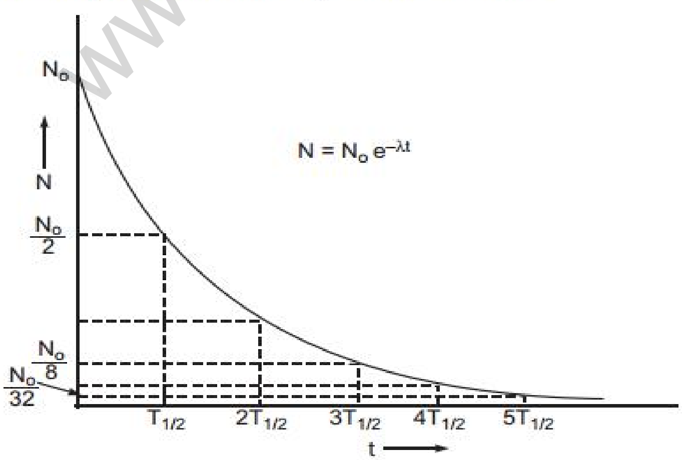
$$\log_e N = -\lambda t + \log_e N_0$$

$$\log_e\left(\frac{N}{N_o}\right) = -\lambda t$$

$$\frac{N}{N_o} = e^{-\lambda t}$$

$$N = N_0\, e^{-\lambda t} \quad \text{...}$$

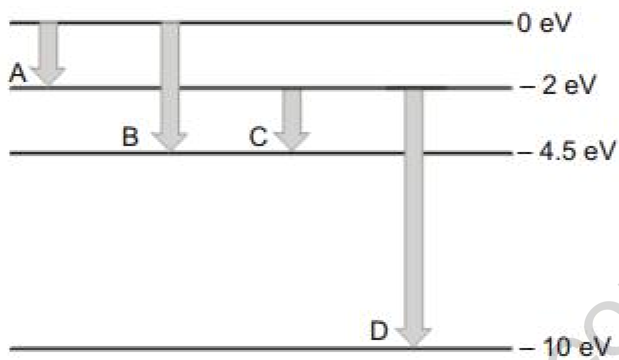
The number of nuclei undergoing the decay per unit time, at any instant, is proportional to the total number of nuclei present in the sample at that instant.



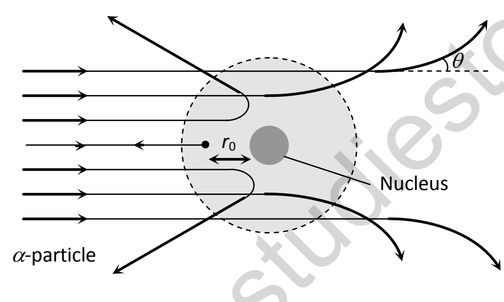
Number of undecayed nuclei at $t = 3T_{1/2}$ is $\frac{N_o}{8}$ and at $t = 5T_{1/2}$, it is $\frac{N_o}{32}$.

(b) The total decay rate of a radioactive sample is called the activity of the sample. The S.I. unit of activity is Becquerel (Bq).

Q36) The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm? Which of these transitions correspond to emission of radiation of (i) maximum and (ii) minimum wavelength?



(b)The trajectories, traced by different α-particle , n Geiger-Marsden experiment were observed as shown in figure.



(i)What names are given to symbols 'b' and 'θ' shown here.

(ii) What can we say about the value of b for (1)θ=0^0,(2)θ=π radians

Ans.

Energy of photon wavelength 275 nm

$$E = \frac{hc}{\lambda} = \frac{6 \cdot 63 \times 10^{-34} \times 3 \times 10^{8}}{275 \times 10^{-9} \times 1 \cdot 6 \times 10^{-19}} \text{ eV} = 4.5 \text{ eV}.$$

This corresponds to transition 'B'.

(*i*) $\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$

For **maximum wavelength** ΔE should be minimum. This corresponds to transition *A*.

(*ii*) For *minimum wavelength* ΔE should be maximum. This corresponds to transition *D*.

(b) (i)The symbol 'b' represents impact parameter & 'θ' represents the scattering angle.

(ii) (1) when θ=0^0, the impact parameter will be maximum & represent the atomic size.

(2)When θ=π radians, the impact parameter 'b' will be minimum & represent the nuclear size

Q37)(a) State de Broglie's hypothesis. Write the expression for the de Broglie wave. State Bohr's postulate on angular momentum of a revolving electron and use the same to show that the nth Bohr orbit has an integral number of de Broglie waves.
(b) Write three basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

Ans) (a) De Broglie hypothesis of matter wave
A moving particle of matter should display wave like property under certain condition. The wavelength of wave associated with a particle of momentum p is given as
$\lambda = \frac{h}{p} = \frac{h}{mv}$

Bohr's postulate
An electron revolves about the nucleus in which its angular momentum is integral multiple of $\frac{h}{2\pi}$.
Now according to this postulate
$mvr_n = n\frac{h}{2\pi}$ or $2\pi r_n = n\frac{h}{mv}$

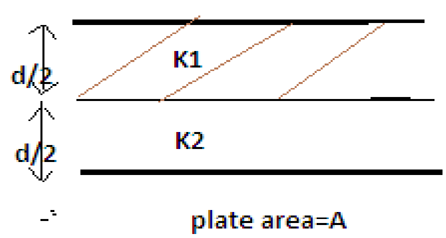
(b)
According to Einstein's photoelectric equation we have
$$h\nu - \varphi = E_{max}$$

Features of the photons:

(*i*) Photons are particles of light having energy E = hν and momentum $p = \frac{h}{\lambda}$, where h is planck constant.
(*ii*) Photons travel with the speed of light in vacuum, independent of the frame of reference.
(*iii*) Intensity of light depends on the number of photons crossing unit area in a unit time.

Q38)(a) Net capacitance of three identical capacitors in series is 1 μF. What will be their net capacitance, if connected in parallel? Find the ratio of energy stored in the two configurations, if they are both connected to the same source ?

(b) A parallel plate capacitor is filled with dielectrics as shown in diagram. Find the capacitance of the system.



Ans) (a) Hint ; $C_S = C/n$ and $C_p = nC$ ratio , $U_S/U_p = 1/9$

(b) The two capacitors formed by inserting the dielectric slabs are in series.

$C_1=(2K_1\varepsilon_0 A)/d$, $C_2=(2K_2\varepsilon_0 A)/d$

$C_s= C_1C_2/C_1+C_2$, we get $C_s = =(2K_1K_2\varepsilon_0 A)/d(K_1+K_2)$

Q39) In young's double slit experiment, what is the effect of the following operation on interference fringes?

(i) The screen is moved away from the plane of the slits.
(ii) The mono chromatic source is replaced by another monochromatic source of shorter wavelength.
(iii) The monochromatic source is replaced by a source of white light.
(iv) The width of source slit is made wider.
(v) The separation between the slits is increased.
(vi) The distance between the source slit and plane slit is increased.
(vii) The width of each of the two slits is of the order of wavelength of light source.

Ans) (I) Angular separation ($\theta=\lambda/d$) of the fringes remains constant. The fringe width increases in proportion to the distance of the screen from the plane of the two slits.

(II) Fringe width decreases. The angular separation also decreases.
(III) Colored fringes will be obtained. But the Centre of the pattern will be white
(IV) Overlapping of fringes will occur. The interference pattern will not be distinct.
(V) Fringe width will decrease. The angular separation will also decrease.
(VI) Overlapping of fringes will occur. The interference pattern will not be distinct.
(vii) Diffraction effect will superimpose on the interference pattern.

Q40)(a) What does a Polaroid consist of? Show, using a single Polaroid, that sunlight is transverse in nature. Intensity of light coming out of a Polaroid does not change irrespective of the orientation of the pass axis of the Polaroid. Explain why?

(b) Find an expression for intensity of transmitted light when a Polaroid sheet is rotated between two crossed plaroids. In which position of the Polaroid sheet will the transmitted intensity is maximum?

(c) Name three phenomena in which polarization of light take place.

Ans)(a)A polaroid consist of long chain molecule aligned in a particular direction. Sunlight after scattering is already plane polarized, when light is passed through a Polaroid there is intensity variation. As unploarised light have electric vectors in all directions therefore no variation in intensity of transmitted ray is observed.

(b)$I = (I_0\cos^2\Theta_1)\,(I_0\cos^2\Theta_2)$; if $\Theta_1=\Theta$, then $\Theta_2 = 90 - \Theta_1$

$I = (I_0\cos^2\Theta)\,(I_0\cos^2(90-\Theta)) = I = (I_0^2\cos^2\Theta)\,(\sin^2\Theta)$

(c)(i) Reflection of light (ii) Scattering of light (ii) Multiple refraction.

Q41) What is space wave propagation? Which two communication methods make use of this mode of propagation? If the sum of the heights of transmitting and receiving antennae in line of sight of communication is fixed at *h*, show that the range is maximum when the two antennae have a height h/2 each.

(b) A message signal of frequency 10 kHz and peak value of 8 volts is used to modulate a carrier of frequency 1MHz and peak voltage of 20 volts. Calculate: (i) Modulation index (ii) The side bands produced.

Ans)(a) Satellite communication and line of sight (LOS) communication make use of space waves.

Here $d_1=\sqrt{2Rh_2}$ and $d_2=\sqrt{2Rh_2}$

For maximum range,

$D_m=\sqrt{2Rh_1}+\sqrt{2Rh_2}$

where $d_m = d_1 + d_2 = d$

Given $h_1 + h_2 = h$

Let $h_1 = x$ then $h_2 = h-x$

Then $d_m = \sqrt{2Rx} + \sqrt{2R(h-x)}$,

$dd_m/dx = \sqrt{R/2x} - \sqrt{R/2(h-x)} = 0$

i.e., $1/2x = 1/2(h-x)$ i.e., $x = h/2$

=> $h_1 = h_2 = h/2$.

(b) Modulation index, $a_m = E_m/E_c$

Maximum amplitude of modulated wave $a=E_c + E_m$.

Minimum amplitude of modulated wave $b = E_c - E_m$

From (2) and (3), $E_c = a+b/2$, $E_m = a-b/2$

From (1), modulation index, $a_m = E_m/E_c = (a-b)/2 / (a+b)/2 = a-b/ a+b$

Q42) Explain the spectral lines of hydrogen atom.

Ans) The wavelength of different members of the series can be found from the following relation.

$$\bar{v} = \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

This relation explains the complete spectrum of hydrogen

(a) Lyman series - The series consists of all wavelengths which are emitted when electron jumps from an outer orbit to the first orbit *i.e.*, the electronic jumps to *K* orbit gives rise to Lyman series.

Here $n_1 = 1$ and $n_2 = 2, 3, 4, \ldots,\infty$

The wavelengths of different members of Lyman series are :

(i) *First member* - In this case $n_1 = 1$ and $n_2 = 2$, it is called α–line of Lyman series, hence

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4} \text{ or } \lambda = \frac{4}{3R} \quad \text{or} \quad \lambda = \frac{4}{3\times 1.097\times 10^7} = 1216\times 10^{-10}\, m =$$

$1216\ \mathring{A}$

(ii) *Second member* - In this case $n_1 = 1$ and $n_2 = 3$, it is called β–line of Lyman series, hence

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8R}{9} \text{ or } \lambda = \frac{9}{8R} \quad \text{or} \quad \lambda = \frac{9}{8\times 1.097\times 10^7} = 1026\times 10^{-10}\, m =$$

$1026\ \mathring{A}$

Similarly, the wavelengths of other members can be calculated.

(iii) *Limiting member* - In this case $n_1 = 1$ and $n_2 = \infty$, hence

$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right] = R$ or $\lambda = \frac{1}{R}$ or $\lambda = \frac{1}{1.097 \times 10^7} = 912 \times 10^{-10}\, m = 912\, Å$

This series lies in ultraviolet region.

(b) Balmer series - This series consists of all wavelengths which are emitted when an electron jumps from an outer orbit to the second orbit *i.e.*, the electron jumps to L orbits give rise to Balmersereis.

Here $n_1 = 2$ and $n_2 = 3, 4, 5, \ldots, \infty$.

The wavelengths of different members of Balmer series are :

(i) *First member* - In this case $n_1 = 2$ and $n_2 = 3$, it is called α–line of Balmer series, hence

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$ or $\lambda = \frac{36}{5R}$ or $\lambda = \frac{36}{5 \times 1.097 \times 10^7} = 6563 \times 10^{-10}\, m =$ 6563 $Å$.

(ii) *Second member* - In this case $n_1 = 2$ and $n_2 = 4$, it is called β–line of Balmer series hence

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3R}{16}$ or $\lambda = \frac{16}{3R}$ or $\lambda = \frac{16}{3 \times 1.097 \times 10^7} = 4861 \times 10^{-10}\, m =$ 4861 $Å$.

Similarly the wavelengths of other members can be calculated.

(iii) *Limiting case* - In this case $n_1 = 2$ and $n_2 = \infty$, hence

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{\infty}\right] = \frac{R}{4}$ or $\lambda = \frac{4}{R} = 3646\, Å$.

This series lies in visible and near ultraviolet region.

(c) Paschen series - This series consists of all wavelengths which are emitted when an electron jumps from an outer orbit to the third orbit *i.e.*, the electronic jumps to M orbit give rise to Paschen series.

Here $n_1 = 3$ and $n_2 = 4, 5, 6, \ldots, \infty$. The different wavelengths of this series can be obtained from the formula

$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$ where $n_2 = 4, 5, 6, \ldots, \infty$.

For the first member, the wavelength is 18750 $Å$. This series lies in infra-red region.

(d) Brackett series - This series consists of all wavelengths which are emitted when an electron jumps from an outer orbit to the fourth orbit *i.e.*, the electronic jumps to N orbit give rise to Brackett series.

Here $n_1 = 4$ and $n_2 = 5, 6, 7, \ldots, \infty$. The different wavelengths of this series can be obtained from the formula

$$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2^{\,2}}\right]$$ where $n_2 = 5, 6, 7, \ldots, \infty$. This series lies in infra-red region.

(e) Pfund series - The series consists of all wavelengths which are emitted when an electron jumps from an outer orbit to the fifth orbit *i.e.*, the electronic jumps to *O* orbit give rise to Pfund series.

$$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2^{\,2}}\right]$$ where $n_2 = 6, 7, 8, \ldots, \infty$. This series lies in the infra-red region of the spectrum.

Q43) (a)What are the Faraday's Laws of electromagnetic induction.

(b)Show that Lenz's law is in accordance with the law of conservation of energy.
(c) Define eddy currents.

Ans) (a) Faraday's law of electromagnetic induction was based on his experimental observations.According to this law,

Whenever the magnetic flux through a coil or loop of wire is changed, an emf is induced in the coil or loop. The magnitude of the induced emf is proportional to the rate of change of flux through the coil.

Mathematically, the induced emf is given by $\varepsilon = -\frac{d\phi_B}{dt}$

The negative sign indicates the direction of induced emf ε and hence the direction of current in a closed loop. It will be explained on the basis of Lenz's law.

If the loop is replaced by a coil of N turns, then the induced emf is given by $\varepsilon = -N\frac{d\phi_B}{dt}$

(b) **The direction of induced emf is such that it tends to produce a current which opposes the change (in magnetic flux) that causes the induction.**

Conservation of energy :

The fact that electromagnetic induction in accordance with Lenz's law represents the conservation of energy can be easily explained. . A repulsive force acts on the bar magnet due to the current induced in the coil. We have to do work in moving the North-pole of the magnet towards the coil. What happens to this work done by us (or the energy supplied by us)? This energy is converted into electrical energy and then dissipated as heat in the loop by Joule heating produced by the induced current

(C) When large pieces of conductors are placed in changing magnetic flux, small circulating currents are induced in them. These currents are called eddy currents

Q44)(a)A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

(b)A parallel plate is charged by a battery, When the battery remains connected. A dielectric slab is inserted in the space between the plates. Explain what changes, if any, occur in the values of:

(i) Electric field strength between the plates

(ii) Capacitance

(iii) Charge on the plate

(iv) Energy stored in the capacitor? Justify your answer in each case.

Ans) (a) Capacitance with dielectric of thickness't'

$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$ put t = d/2

$$C = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2K}}$$

$$C = \frac{\varepsilon_0 A}{\frac{d}{2} + \frac{d}{2K}}$$

$$C = \frac{\varepsilon_0 A}{\frac{d}{2}(1 + \frac{1}{K})}$$

$$C = \frac{2\varepsilon_0 AK}{d\,(K + 1)}$$

(b) (i)When battery remains connected, the potential difference remain the same.

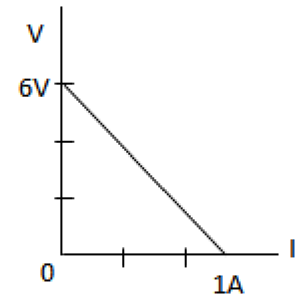
(ii) As electric field E $= \frac{V}{d}$ and V = constant, d = constant; therefore ,electric field strength remains the same.

(iii) The capacitance of capacitor increases as K > 1

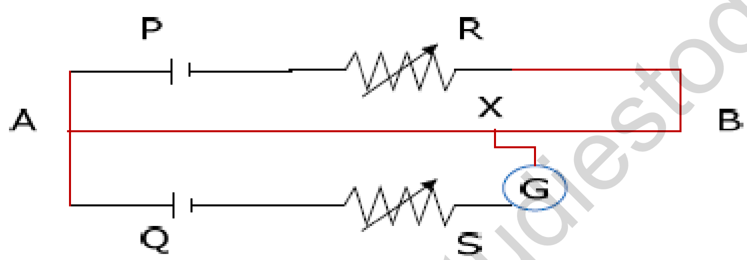
(iv) The charge Q $= CV$, V = same , C increases ; therefore , charge on plates increases.

(v) Energy stored by capacitor $U = \frac{1}{2}CV^2$, also increases.

Q45)
(a)Theplotofthevariationofpotentialdifferenceacrossacombinationofthreeidenticalcellsin series,versuscurrentisasshownbelow.Whatistheemfofeachcell?



(b) The potentiometer circuit shown, the balance (null) point is at X. State with reason, where the balance point will be shifted when



(1) Resistance R is increased, keeping all parameters unchanged.

(2) Resistance S is increased, keeping R constant.

(3) Cell P is replaced by another cell whose emf is lower than that of cell Q.

Ans) (a) Let Ebe emf of each celland *r* bethe totalinternal resistance of circuit. The equationofterminal potential difference

$V = 3E - Ir$ ....(1)

At V = 6V, I = 0. Therefore from eq (1), $6 = 3E - 0 \Rightarrow E = 2V$

(b)(1) When resistance R is increased, the current through potentiometer wire AB will decrease, hence potential difference across A will decrease, so balance point shifts towards B.

(2)When resistance S is increased terminal potential difference of the battery will decrease, so balance point will be obtained at smaller length and hence shifts towards A.

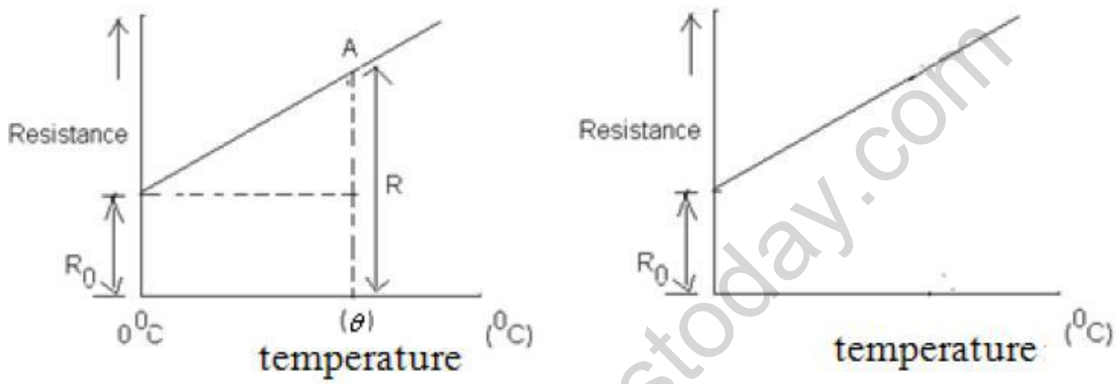
(3) When cell P is replaced by another cell whose emf is lower than that of cell Q, the P.D. across AB will be less than that of emfQ so balance point will not be obtained.

Q46)(a) Explain with the help of a circuit diagram, how the value of an unknown resistance can be determined using a wheat stone bridge?

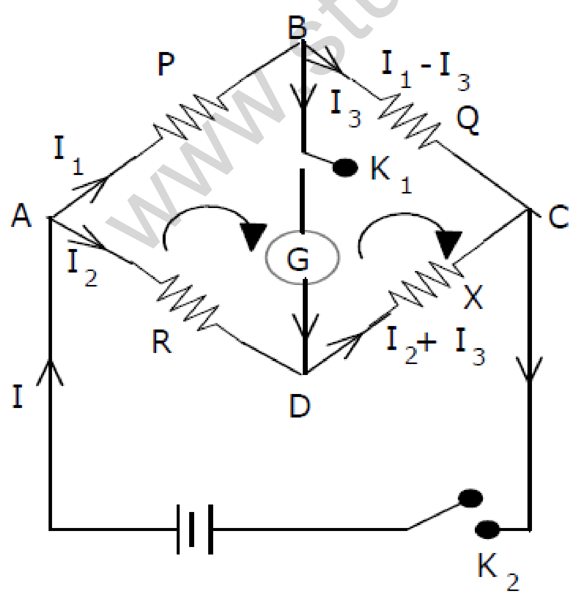
(b)The variation of resistance of a metallic conductor with temperature is given in figure.

(a) Calculate the temperature coefficient of resistance from the graph.

(b) State why the resistance of the conductor increases with the rise in temperature.



Ans)(a)



Here P , Q , R are known resistance and X is an unknown resistance. Applying kirchoff's law for closed path ABDA .

$I_1P + I_3 G - I_2 R = 0$ ------ (1)

For closed path BCDB

$(I_1 - I_3) Q - (I_2+I_3)\times -I_3G$ ------(2)

Now the bridge is said to be balanced when no current flows through the galvanometer

$\Rightarrow Ig = 0$

$\therefore$ Eg. (1) & (2) becomes

$I_1P = I_2R$

$$\boxed{\frac{I_1}{I_2} = \frac{R}{P}} \text{ -------- (3)}$$

$I_1, Q = I_2 X$

$$\boxed{\frac{I_1}{I_2} = \frac{X}{Q}} \text{ ----------- (4)}$$

Equating (3) & (4)

$$\frac{R}{P} = \frac{X}{Q} \Rightarrow \boxed{X = \frac{RQ}{P}}$$

(b)

(a) Temperature coefficient of Resistance

$$\alpha = \frac{R - R_0}{R_0\theta}$$

Where R is the resistance of the conductor and Ω is the temperature corresponding to pt.A

(b) Since $R = p\frac{l}{A} = \frac{m}{ne^2\tau}\left(\frac{t}{A}\right)$ P=Resistivity

When temperature increases, no of collisions increases average relaxation time decreases, hence resistance Increases.

Q47) A series L-C-R circuit is connected to an a.c. source of 220V – 50Hz. If the readings of volt meter across resistor, capacitor, and inductor 65 V, 415 V, 204 V. calculate

- **i) current in the circuit**
- **ii) Value of L**
- **iii) Value of C and**
- **iv) capacitance required to produce resonance with the given inductor L.**

Ans) HereE_r=200V

Frquency = ν = 50Hz
R= 100 Ohms
V_R=65 V, V_c=415V, V_l=204V

i) If I_r is the current in the circuit then

$V_R = I_r \times R$
I_r= 65/100 =0.65Amp

II) $V_L = I_r \times X_l$

Then $X_L = \omega L = 2\pi\nu = 313.85$ Ohms
Then $L = X_L / \omega = X_L / 2\pi\nu$
= 313.85 / 2x 3.14 x 50 = 1H

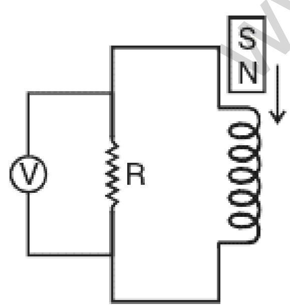
III) $Vc = I_r . X_c$

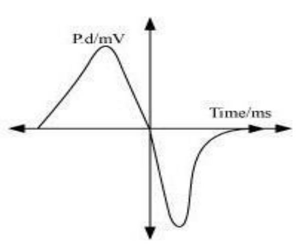
$Xc = Vc / I_r = 415 / 0.65 = 638.5$ Ohms
Then $Xc = 1/ \omega c = 1/ 2\pi\nu C$
$C = 1/ 2\pi\nu Xc = 1/ 2 \times 3.14 \times 50 \times 638.5 = 4.99 \times 10^{-6}$ F

IV) Let C be the capacitance that would produce resonance with L= 1H then

$\nu_r = 1 / 2\pi\sqrt{L C'}$
$C' = 1 / 4 \pi^2\nu^2 L = 1 / 4 \times (3.14)^2 \times (50)^2 \times 1 = 10.1\mu F$

Q48)A bar magnet M is dropped so that is falls vertically through the coil C. The graph obtained for voltage produced across the coil Vs time is shown in diagram





(b)

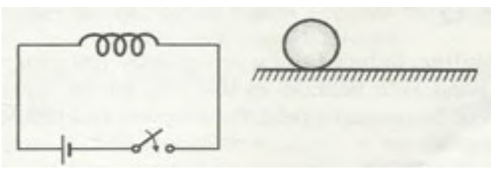
Ans) Theemf is proportional to dφ/dt , and this is proportional to the velocity but not to the acceleration. Since the velocity increases, the flux increases, causing a a-symmetrical peak.

When magnet falls through the coil as the rate of change of flux increases the emf in coil increases.As the magnet come inside coil no flux change takes place across coil and emf falls to zero.

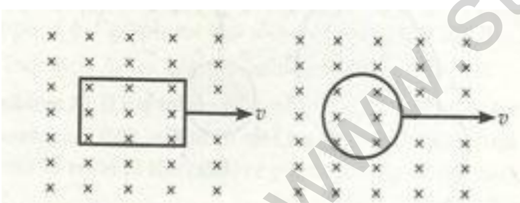
After magnet comes out of coil the emf developed in the coil is in opposite direction relative to when it falls inside coil

(c) negative peak is greater than positive peak as rate of flux is more when magnet comes out of coil as compare to when it fall inside the coil

Q49)(a)The following figure shows a horizontal solenoid connected to a battery and a switch. A copper ring is placed on a friction less track, the axis of the ring being along the axis of the solenoid. What happens to the ring as switch is closed?



(b) A rectangular loop and a circular loop are moving out of a uniform magnetic field region to a field free region with a constant velocity. In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is the normal to the loops.



(c) What is electrical inertia.

Ans)(a)The ring moves away from the coil, because the current induces in the ring opposes the growth of current in the solenoid.

(b)In a rectangular loop, the induced emf will be constant. It is because rate of change of the area of the rectangular loop is uniform, whereas that of a circular circular loop is not constant.

(c) The self inductance of a coil is defined as electrical inertia.

Q50) (a) what is earth's magnetism.
(b) What are the three components of earth's magnetic field.
(c) What is the value of dip angle at the poles of the earth.
(d) Angle of dip at a certain place is 30˚. If the horizontal component of earth's magnetic field at the place is 0.4 G. Find total intensity of earth's magnetic field at that place.

Ans) (a) The magnetism possessed by the molten metallic fluid of the earth and magnetic materials of the earth.

(b) Angle of declination, Angle of Dip, Horizontal component of earth's magnetic field.

(c) 90°.

(d) Using, $B_H = B_E \sin\Theta$

$B_E = 0.8$ Gauss

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