Sure shots (1 Mark) Solution

1.

Option (C) is correct.

Detailed Answer:

For uniform electric field equipotential surfaces are plane.

2.

Option (C) is correct

Detailed Answer:

$$q = \frac{\tau}{[(2a)E\sin\theta]}$$

$$= \frac{4}{2\times10^{-2}\times2\times10^{5}\sin30^\circ}$$

$$= 2\times10^{-3}\,C = 2\,mC$$

3.

Option (D) is correct

Detailed Answer:

Higher the frequency, greater is the stopping potential

4.

Option (C) is correct.

Detailed Answer:

There is large vacant space between the nucleus and the orbiting electrons. Alpha particles pass through the space.

5.

Option (B) is correct.

Detailed Answer:

Applying Fleming's left hand rule, the direction of force can be evaluated.

6.

Option (D) is correct.

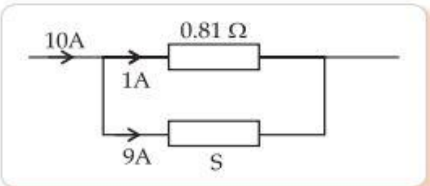
Detailed Answer:

Relative permeability of diamagnetic substance is less than 1 and that of paramagnetic substance is slightly greater than 1.

7.

Option (B) is correct.

Detailed Answer:



$$9\times S = 1\times 0.81$$

$$S = \frac{0.81}{9} = 0.09\,\Omega$$

8.

Option (A) is correct.

Detailed Answer:

$$\text{Magnetic moment} = \left(\frac{ev}{2\pi r}\right)\times \pi r^2$$

$$= \frac{evr}{2}$$

$$= \frac{evmr}{2m}$$

$$= \frac{eL}{2m}$$

9.

Option (D) is correct.

Detailed Answer:

Since voltage is stepped up, the current is stepped down.

Power loss varies with square of the current. Since current decreases, power loss also decreases significantly.

10.

Option (A) is correct.

Detailed Answer:

Direction of propagation of electromagnetic wave is given by $\overline{E}\times\overline{B}$.

Here $\overline{B}$ is along + X axis. $\overline{E}$ is along – Y axis. So, applying right hand rule, the propagation of em wave is perpendicular to $\overline{E}$ and $\overline{B}$ and out of plane of the paper.

11.

Option (D) is correct.

$$e = \frac{\Delta\varphi}{\Lambda t},\ I = \frac{1}{R}\frac{\Delta\varphi}{\Delta t}$$

$$I\,\Delta t = \frac{\Delta\varphi}{R}$$

$$= \text{Area under } I - t \text{ graph},$$

$$R = 100\text{ ohm}$$

$$\therefore \quad \Delta\varphi = 100\times\frac{1}{2}\times10\times0.5 = 250\text{ Wb.}$$

12.

Option (B) is correct.

13.
Option (C) is correct.
Explanation: When a capacitor is linked to a voltage source "V" it stores electrical energy as it becomes charged. A capacitor's ability to store electrical energy is determined by its capacitance, which is indicated by "C_0." When a dielectric material is placed between the capacitor plates while it is still connected to the voltage source, the capacitance of the capacitor changes. The dielectric material reduces the electric field inside the capacitor, resulting in a decrease in the voltage across the capacitor.

14.
Option (D) is correct.
Explanation: $E = -\frac{dV}{dx} = -4x$, electric potential varies with position as $v(x) = 3 + 2x^2$. So the electric field in the given region is non-uniform along x-axis. which is non- uniform.

15.
Option (A) is correct.
Explanation: When a photon strikes a metal surface, the surface electrons come out with maximum speed and maximum kinetic energy. But if the electron emission takes place from inner side of metal, then some energy of the electron is lost due to collision with other electrons and so their speed becomes less. So, ultimately the electrons come out with different speeds.

16.
Option (B) is correct.
Explanation: Alpha and Deuteron both have the same kinetic energy

Since, the centripetal force $= \frac{mv^2}{r}$ and Magnetic Force $= qvB$
Here, Centripetal Force = Magnetic Force
Therefore,

$$\frac{mv^2}{r} = qvB$$

$$r = \frac{\sqrt{2mK.E.}}{qB}$$

Now the radius ratio for deuteron and alpha particle

So, $$\frac{r_d}{r_\alpha} = \sqrt{\frac{m_d}{m_\alpha} \times \frac{q_\alpha}{q_d}}$$

$$\Rightarrow \quad \frac{r_d}{r_\alpha} = \sqrt{\frac{2}{4} \times \frac{2}{1}}$$

Ratio of radii $= \frac{r_d}{r_a} = \sqrt{2}$

17.
Option (B) is correct.
Explanation: Given,

Distance $= \frac{r}{2}$, Magnetic field $= B$

$$B \propto \frac{1}{r}$$

(Magnetic field is inversely proportional to radius)

$$\frac{B_1}{B_2} = \frac{r_2}{r_1} = \frac{r/2}{r}$$

$$\therefore \quad B_2 = 2B_1 = 2B$$

18.
Option (D) is correct.
Explanation: Sample I is a diamagnetic substance. Sample II is a paramagnetic or ferromagnetic substance.
Hence, For I: $\mu_r < 1, \chi < 0$, For II: $\mu_r > 1, \chi > 0$

19.
Option (A) is correct.
Explanation: To convert a galvanometer into a voltmeter, a high-value resistance is to be connected in series with it.

20.
Option (A) is correct.
Explanation: The angular momentum of an electron in stationary orbits always remains constant and is an integral multiple of $\frac{h}{2\pi}$ where h is Planck's constant.

21.
Option (D) is correct.
Explanation: Power = $\text{Voltage}_{\text{rms}}$ × $\text{Current}_{\text{rms}}$ × cosine of Phase Difference.

So, $$P = V_{\text{rms}} \times I_{\text{rms}} \times \cos\phi$$

Here, magnetic flux, $\phi = \frac{\pi}{2}$

So, Power = 0

22.
Option (D) is correct.

23.
Option (D) is correct.
Explanation: Mutual Inductance is directly proportional to R_1

$$M = \frac{\mu_0 \pi R_2^2}{2R_1}$$

$$= \frac{\mu_0 \pi (0.01R_1)^2}{R_1}$$

$$= \mu_0 \pi (0.01)^2 R_1$$

24.

Option (C) is correct.

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

Or, $-1.51 = \frac{-13.6}{n^2}$

$\therefore$ $n = 3$

25.

Option (A) is correct.

Explanation: Given: Voltage = 200 V, Capacitance $= 2\,\mu F$

Energy $= \frac{1}{2} CV^2$

In case (I): $E_1 = \frac{1}{2} \times 2 \times 10^{-6} \times 200^2$

$= 4 \times 10^{-2}$ J

In case (II): $E_2 = \frac{1}{2} \times X \times 10^{-6} \times 200^2$ J

(X is unknown capacitance)

Energy Decrement $= E_1 - E_2$

Or, $2 \times 10^{-2} = 4 \times 10^{-2} - \frac{1}{2} \times X \times 10^{-6} \times 200^2$

Or, $2 = 4 - 2X$

$\therefore$ $X = 1\,\mu$F

26.

Option (D) is correct.

Explanation: Potential on equatorial line of a dipole is always zero.

27.

Option (C) is correct.

Explanation: Work function $= 4.14$ eV $= \frac{hc}{\lambda_0}$

(h = Planck's constant, c = speed of light, λ_0 = threshold wavelength)

$\therefore \lambda_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.14 \times 1.6 \times 10^{-19}}$

$= 2.989 \times 10^{-7} \approx 3000$Å

28.

Option (B) is correct.

Explanation: Nuclear force is the strongest force.

29.

Option (B) is correct.

Explanation: Applying right hand thumb rule only in region II and IV magnetic fields are in same direction. In region II the directions are outward and in region IV the directions are inwards.

30.

Option (D) is correct.

Explanation: Given: $i_1 = 4.0$ A, $i_2 = 10.0$A, $r = 2.5$ cm

$$F = \frac{\mu_0 i_1 i_2}{2\pi r}$$

(F= force per unit length, μ_0 = Permeability, i_1 = Current 1, i_2 = Current 2, and r = distance)

$$= \frac{4\pi \times 10^{-7} \times 4 \times 10}{2\pi \times 2.5 \times 10^{-2}}$$

$= 3.2 \times 10^{-4}$ N/m

31.

Option (A) is correct.

Explanation: Given: Radius = R, Magnetic field at centre $= B_1$, Magnetic field on axis at a distance $R = B_2$

Magnetic field at the centre

$$B_1 = \frac{\mu_0 i}{2R} \quad ...(1)$$

Magnetic field on the axis

$$B_2 = \frac{\mu_0 i R^2}{2(x^2 + R^2)^{3/2}} \quad ...(2)$$

$$= \frac{\mu_0 i}{2^{5/2} R}$$

$$\frac{B_1}{B_2} = 2^{3/2} = 2\sqrt{2}$$

32.

Option (A) is correct.

Explanation: $F = Bil \sin\theta$

θ is the angle between the direction of current and the direction of magnetic field, B is the magnetic field, l is the length, I is flowing current.

So, when $\theta = 90°$, the force is maximum.

33.

Option (A) is correct.

Explanation: Given: $I_{rms} = 15A$, Frequency = 50Hz,

Current in circuit flowing time $= \frac{1}{600}$ s

$$I = I_0 \sin \omega t$$

Or, $$I = I_{rms} \times \sqrt{2} \times \sin(2\pi ft)$$

Or, $$I = I_{rms} \times \sqrt{2} \times \sin\left(\frac{2\times\pi\times 50}{600}\right)$$

Or, $$I = 15 \times \sqrt{2} \times \sin\left(\frac{\pi}{6}\right)$$

$\therefore$ $$I = \frac{15}{\sqrt{2}} \text{ A}$$

34.

Option (D) is correct.

Explanation: Electric field and magnetic field of electromagnetic field are mutually perpendicular to one another, and also to the direction of propagation of the electromagnetic wave.

Hence, direction of propagation is along $\vec{E} \times \vec{B}$.

35.

Option (D) is correct.

Explanation: Given: $N_1 = 600$ turns, $N_2 = 500$ turns, Self-inductance of coil $L_1 = 108$ mH

$$L = \frac{\mu_0 N^2 A}{l}$$

So, $$L \propto N^2$$

$\therefore$ $$\frac{L_1}{L_2} = \frac{N_1^2}{N_2^2}$$

Or, $$\frac{108}{L_2} = \frac{600^2}{500^2}$$

$\therefore$ $$L_2 = 108 \times \frac{25}{36} = 75 \text{ mH}$$

36.

Option (A) is correct.

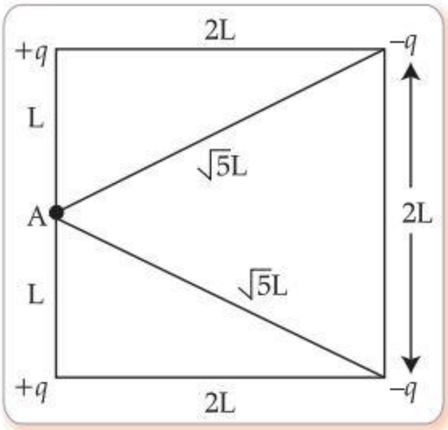
Explanation: Nuclear forces are simply too powerful in short range. It decreases to zero with distance.

The distance between oxygen atoms in an oxygen molecule is greater than the distance between nucleons in a nucleus. Because nuclear forces are short-ranged, the force between the nuclei of two oxygen atoms is negligible.

37.

Option (A) is correct.

Explanation:



Given: Four charges $-q$, $-q$, $+q$ and $+q$.

Distance between any two charges = 2L

And we know that electric potential due to two point charges is at a given distance r is given by

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

So, Electric potential due to two $+q$ charges

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{2q}{L}$$

And,

Electric potential due to two $-q$ charges

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{-2q}{\sqrt{5}L}$$

Thus, total potential at $A = \frac{1}{4\pi\varepsilon_0} \times \frac{2q}{L}\left(1 - \frac{1}{\sqrt{5}}\right)$

38.

Option (C) is correct.

Explanation: For an equipotential surface we can write, $V_A = V_B$

So, when a particle is transferred from one place on an equipotential surface to another position on the same equipotential surface, no work is done.

39.

Option (C) is correct.

Explanation: Given: Voltage drop of Silicon and Germanium diodes is 0.7V and 0.3V respectively.

Also, Source voltage = 10 V

Germanium diode provides an easier path of the flow of current. Hence no current will flow through Silicon diode.

So, $V_0 = 10V - 0.3V = 9.7V$

40.

Option (C) is correct.

Explanation: Given: $r_0 = 53$ pm

In accordance with Bohr's atomic model, an atom's radius in its ground state is

$$r = \frac{r_0}{Z}$$

(r_0 = Bohr radius, Z = Atomic number)

Now, $r_0 = 53$ pm, $Z = 3$ (Atomic number of Lithium)

$$r = \frac{53}{3} = 17.67 \text{ pm} = 18 \text{ pm}$$

41.

Option (D) is correct.

Explanation: Given: Ratio of radii in loop P and $Q = 2 : 3$, $i_Q = 9$ A

The magnetic field will be the same strength and facing the opposite direction at the centre.

μ_0 = Permeability, i_Q = Current in loop Q, i_P = Current in loop P

So, $$\frac{\mu_0 i_P}{2r_P} = \frac{\mu_0 i_Q}{2r_Q}$$

Or, $$\frac{i_P}{i_Q} = \frac{r_P}{r_Q}$$

Or, $$\frac{i_P}{9} = \frac{2}{3}$$

$\therefore$ $i_P = 6A$

in the opposite direction i.e., clock-wise.

42.

Option (C) is correct.

Explanation: Torque = $\tau = MB \sin \theta$ (where, M = magnetic moment, B = magnetic field, θ = Angle between M and B)

Since, M and B are parallel, then $\theta = 0$,

$$\tau = 0$$

Torque is 0.

So, in this case force is also zero since the distance is not equal to zero.

43.

Option (D) is correct.

Explanation: Torque is directly proportional to the magnetic field.

$$\tau = MB \sin \theta$$

(τ = Torque, M = magnetic moment, B = magnetic field, θ = Angle between M and B)

$$\tau \propto B$$

44.

Option (B) is correct.

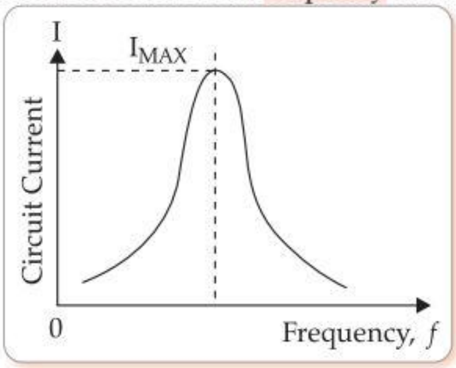
Explanation: (T = Time period, M = magnetic moment, B = magnetic field I = Current)

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

45.

Option (A) is correct.

Explanation: In series LCR circuit frequency vs. circuit current graph looks like the following, with initial spikes in current followed by maximum current and then falls off as frequency rises.



46.

Option (C) is correct.

Explanation: Changing electric field produces displacement current which produces magnetic field.

47.

Option (C) is correct.

Explanation: Given, an X-Y plane in which a square of side L is located in $\vec{B}$.

So, $\vec{A} = L^2\hat{k}$

$$\phi = \vec{B}.\vec{A}$$

$$= B_0(2\hat{i} + 3\hat{j} + 4\hat{k}).(L^2\hat{k})$$

$$= B_0[2 \times \hat{i}.\hat{k} + 3 \times \hat{j}.\hat{k} + 4 \times \hat{k}.\hat{k}]$$

$$= B_0L^2[0 + 0 + 4]$$

$$= 4B_0L^2 \text{ Wb.}$$

48.

Option (C) is correct.

Explanation: The rotating electrons around a stationary proton nucleus in a hydrogen atom experience some centripetal acceleration. Its frame of reference is therefore non-inertial. The given expression is false in the frame of reference where the electron is at rest because it is an inertial frame of reference.

49.

Option (A) is correct.

Explanation: Given: electric field intensity E, Electric potential V, distance x

$$E = -\frac{dV}{dx}$$

For $0 < x < 2$

The slope is positive, $\frac{dV}{dx} > 0$

So, electric field intensity = $-E$

For $2 < x < 4$

The slope is positive, $\frac{dV}{dx} = 0$

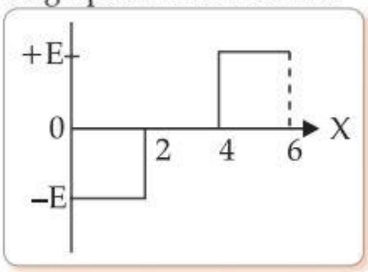
So, electric field intensity = 0

For $4 < x < 6$

The slope is positive, $\frac{dV}{dx} < 0$

So, electric field intensity = $+E$

So, E versus x graph will be as below: **1**



50.

Option (A) is correct.

Explanation: The collection of charges, whose total sum is not zero, at great distance may be considered as a point charge. So, electric potential is inversely proportional to the distance from the charge.

So, electric potentials due to point charge are the same for all equidistant points. The locus of these equidistant points, which are at same potential, is a sphere.

51.

Option (B) is correct.

Explanation: Given: Energy of photon = 1 MeV

Energy of the photon must be equal to the binding energy of proton.

So, energy of photon = E = 1MeV

$= 10^6 \times 1.6 \times 10^{-19}$ J

$$\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-13}} = \frac{6.63\times3}{1.60}\times10^{-26+13}$$

$$= \frac{19.89}{1.60}\times10^{-13} = 12.4\times10^{-13} = 1.24\times10^{1}\times10^{-13}$$

$$= 1.24\times10^{-9}\times10^{-3} = 1.24\times10^{-3}\text{ nm}$$

After rounding off, we get the wavelength 1.2×10^{-3} nm.

52.

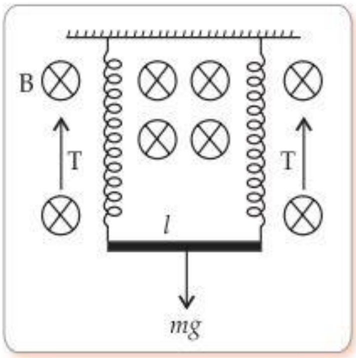
Option (A) is correct.

Explanation: A set of atoms in an excited state decays in general to any of the states with lower energy since lower energy state is more stable.

53.

Option (C) is correct.

Explanation: From the given figure, we can say that:



Force = mass × gravitational force

$F = mg = T$

Magnetic force = $F_{mag} = ilB$

To remove the tension,

$T = F_{mag}$

Or, $mg = ilB$

$\therefore$ $i = \frac{mg}{lB}$

54.

Option (A) is correct.

Explanation: $\mu \propto 1/H$

So, as magnetising field (H) increase, permeability ($\propto$) decreases.

55.

Option (D) is correct.

Explanation: Ammeter and voltmeter are basically galvanometer.

When a high resistance is connected in series with the galvanometer it works as a voltmeter and when a low resistance is connected in parallel with the galvanometer it works as a ammeter.

56.

Option (C) is correct.

Explanation: Since, the current remains constant, the rate of heating will not increase.

57.

Option (C) is correct.

Explanation: The resultant voltage in the LCR series circuit is calculated as,

$$V = \sqrt{V_R^2 + (V_C \sim V_L)^2}$$

Here, all alphabets are in their usual meanings.

$V_R = 20\,V, V_C = 30\,V$ and $V_L = 15\,V$

So, $V = \sqrt{(20)^2 + (30 \sim 15)^2}$

$$V = \sqrt{400 + 225} = \sqrt{625}$$

$$V = 25\,V$$

Therefore, the resultant voltage is 25 V.

58.

Option (A) is correct.

Explanation: Peaks of magnetic and electric waves of electromagnetic wave form at the same time. Hence, there is no phase difference between these two waves.

59.

Option (A) is correct.

Explanation: Induced emf = $|\varepsilon| = M\frac{di}{dt}$

$$= 0.5 \times \left(\frac{40}{0.4}\right)$$

$$= 50\,V$$

60.

Option (A) is correct.

Explanation: Total energy of two H-atom in ground state = 2(–13.6) = –27.2 eV.

The maximum amount by which their combined kinetic energy is reduced when any one H-atom goes into first excited state after the inelastic collision, that is, the total energy of two H-atom after inelastic collision:

$$E = \frac{13.6}{n^2} + 13.6$$

$$= \frac{13.6}{2^2} + 13.6 \text{ [For excited state } (n = 2)]$$

$$= 3.4 + 13.6 = 17.0\,eV$$

So, that the loss in the kinetic energy due to inelastic collision will be,

$$= 27.2 - 17.0 = 10.2\,eV$$

61.

Option (B) is correct.

Explanation: The incident ray PQ must become parallel after striking the point Q as it passes through the focus of the mirror. So, rays 1 and 3 must be neglected.

Now, since the mirror is a concave mirror, the ray cannot go behind the mirror. So, the correct answer is Ray 2.

62.

Option (B) is correct.

Explanation: If an object is placed between the f and $2f$ of a concave mirror, the resulting image will be located beyond $2f$. This image will be real and magnified in comparison to the original object.

63.

Option (C) is correct.

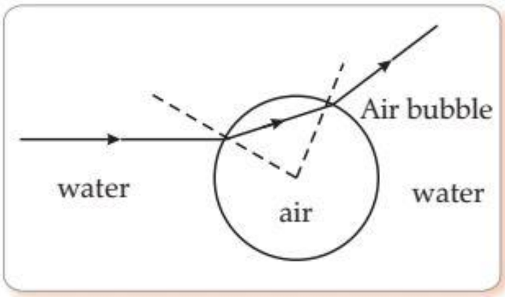
Explanation: The minor charge carriers in an n-type silicon are the holes.

Pentavalent elements, such as phosphorus, are doped into silicon to produce an n-type semiconductor.

64.

Option (B) is correct.

Explanation:

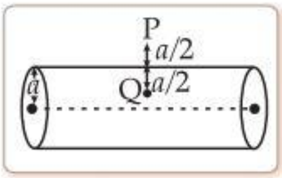


Since, light passes through denser medium (water) to rarer medium (air) and then to denser medium (water) again, the light ray gets diverged. Hence, its behaviour is like a concave lens.

65.

Option (C) is correct.

Explanation:



Magnetic field is given by,

$$B = \frac{\mu_0}{2\pi} \times \frac{I}{r} \qquad \text{(for } r > a\text{)}$$

And $$B = \frac{\mu_0}{2\pi} \times \frac{Ir}{a^2} \qquad \text{(for } r < a\text{)}$$

At point P, $r > a$

So, $$r_1 = a + \frac{a}{2}$$

Or, $$r_1 = \frac{3a}{2}$$

So, $$B_P = \frac{\mu_0}{2\pi} \times \frac{I}{r_1}$$

Or, $$B_P = \frac{\mu_0}{2\pi} \times \frac{I \times 2}{3a}$$

Or, $$B_P = \frac{\mu_0 I}{3\pi a}$$

At point Q, $r < a$

So, $$r_2 = a - \frac{a}{2}$$

Or, $$r_2 = \frac{a}{2}$$

Or, $$B_Q = \frac{\mu_0}{2\pi} \times \frac{Ir_2}{a^2}$$

Or, $$B_Q = \frac{\mu_0}{2\pi} \times \frac{I \times a}{a^2 \times 2}$$

$\therefore$ $$\frac{B_P}{B_Q} = \frac{\frac{\mu_0 I}{3\pi a}}{\frac{\mu_0 I}{4\pi a}}$$

$$= \frac{4}{3} = 4:3$$

66.

Option (A) is correct.

Explanation: The non-uniform field will exert non-uniform forces on the needle's poles. As a result, the needle experiences both a force and a torque.

67.

Option (B) is correct.

Explanation: Magnetic field at the end of a current carrying solenoid is half of the magnetic field inside it.

68.

Option (C) is correct.

Explanation: X is charged negatively. It repels Y, indicating that Y is also negatively charged because like charges repel each other. If Z is positively charged or neutral, then only Y will attract Z.

69.

Option (C) is correct.

Explanation: Given: $L_1 = 5$ mH, $C = 5$ μF,

Resonant frequency $= \omega_0 = \dfrac{1}{\sqrt{(LC)}}$

Case-1

$$\omega_1 = \frac{1}{\sqrt{(5 \times 10^{-3} \times 5 \times 10^{-6})}}$$

$$= \frac{1}{\sqrt{(25 \times 10^{-9})}}$$

Case-2

$$\omega_2 = \frac{1}{\sqrt{(20 \times 10^{-3} \times 5 \times 10^{-6})}}$$

$$= \frac{1}{\sqrt{(100 \times 10^{-9})}}$$

So, the ratio,

$$\frac{\omega_1}{\omega_2} = \sqrt{\left[\frac{(100 \times 10^{-9})}{(25 \times 10^{-9})}\right]} = 2$$

70.

Option (B) is correct.

Explanation: Photoelectric effect allows us to perceive the quantum nature electromagnetic radiation. This effect cannot be explained by wave theory of light.

71.

Option (A) is correct.

Explanation: Magnetic flux, $\phi = 5t^2 + 2t + 3$ (given)

Induced e.m.f. $\varepsilon = -\dfrac{d\phi}{dt}$

Or, $$|\varepsilon| = \frac{d\phi}{dt}$$

$$|\varepsilon| = \frac{d(5t^2 + 2t + 3)}{dt}$$

$$= 10t + 2$$

$$|\varepsilon|_{t=3\text{ sec}} = 32 \text{ units}$$

72.

Option (C) is correct.

Explanation:

$$\theta = \frac{D}{u} \text{ (}u\text{ = distance of the Sun)}$$

Image will be formed on the focal plane. Hence $v = f$.

$$\text{Magnification} = m = \frac{\text{Diameter of image}}{\text{Diameter of the Sun}} = \frac{v}{u}$$

$$= \frac{f}{\left(\frac{D}{\theta}\right)}$$

$$= \frac{f\theta}{D}$$

$\therefore$ Diameter of image = $f\theta$

73.

Option (C) is correct.

Explanation: Potential of small drop = $V_1 = \frac{Kq}{r}$

Charge on large drop = $64q$

Volume of large drop : Volume of small drop = 64:1

So, Radius of large drop : Radius of small drop = $R : r = 4 : 1$

Potential of small drop = $V_2 = K64q/R$

$$\therefore \quad V_2 : V_1 = (K64q/R) / (Kq/r)$$

$$= 64 \times \left(\frac{r}{R}\right)$$

$$= 64 \times \left(\frac{1}{4}\right)$$

$$= 16 : 1$$

74.

Option (B) is correct.

Explanation: As the electric field inside a conductor is zero. So, the potential at any point is constant.

75.

Option (C) is correct.

Explanation: K.E. = $h\nu - \phi$ (where h is Planck's constant, ν is the frequency of the incident photon and ϕ is the work function of the metal)

From the above equation we can conclude that kinetic energy is independent of the intensity of incident light.

76.

Option (A) is correct.

Explanation: The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons because when we derive the formula for radius/energy levels, etc., we assume that centripetal force is provided only by electrostatic force of attraction by the nucleus.

So that, this will only work for single electron atoms. In multi-electron atoms, there will also be repulsion due to other electrons. For this reason, the simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons.

77.

Option (D) is correct.

Explanation: The work done to rotate the loop in the magnetic field, $W = MB(\cos\theta_1 - \cos\theta_2)$. When current carrying coil is rotated then there will be no change in angle between magnetic moment and magnetic field.

Here, $\theta_1 = \theta_2 = \alpha$

$\Rightarrow W = MB(\cos\alpha - \cos\alpha) = 0$

78.

Option (B) is correct.

Explanation: Voltage and current will be in phase when capacitive reactance is equal to inductive reactance.

i.e., $X_C = X_L$

$$\Rightarrow \quad \frac{1}{\omega C} = \omega L$$

$$\Rightarrow \quad \frac{1}{2\pi fC} = 2\pi fL$$

$$\Rightarrow \quad C = \frac{1}{4\pi^2 f^2 L}$$

$$\Rightarrow \quad C = \frac{1}{4 \times (3.14)^2 \times (50)^2 \times 80 \times 10^{-3}}$$

$$\therefore \quad C = 127\ \mu F$$

79.

Option (D) is correct.

Explanation: The core of a transformer is laminated to increase the resistance and hence reduce the eddy current.

80.

Option (D) is correct.

Explanation: Ultraviolet rays are used for water purification and eye surgery.

81.

Option (B) is correct.

Explanation: As the iron piece is taken out of the self-inductance of the coil decreases.

So, ωL i.e., X_L decreases.

So, the current in the circuit increases.

Hence, the brightness of the bulb increases.

82.

Option (C) is correct.

Explanation: Microwave frequency ranges from 10^{13} to 10^{9} Hz.

83.

Option (A) is correct.

Explanation: Flux through the coil $\phi = BA\cos\theta$

Or, $\phi = 10^{-1} \times (100 \times 10^{-4}) \times \cos 30°$

$\therefore \quad \phi = 10^{-3} \times \sqrt{3/2}$ Wb

Thus, induced emf in the coil is given by $\varepsilon = \frac{-d\phi}{dt}$

$$= \frac{-(\phi_f - \phi_i)}{\Delta t}$$

$$= \frac{-\left(0 - 10^{-3} \times \frac{\sqrt{3}}{2}\right)}{10^{-4}}$$

$$= 5\sqrt{3}\ \text{V}$$

84.

Option (B) is correct.

Explanation: The relation between the refractive index of turpentine, water and water is given by:

$\mu_A < \mu_T > \mu_W$ (μ_A, μ_T and μ_W where represents refractive index of air, turpentine and water respectively)

As the incident ray moves from air to turpentine to water, it represents a transition from rarer to denser, then denser to rarer. As a result, it first bends towards normal, then

away from normal, so the path shown for ray (2) is correct.

85.

Option (B) is correct.

Explanation: Expression of capacitance: $C = \frac{A\varepsilon_0}{d}$

The cross-sectional area is represented by A, the permittivity of free space is represented by ε_0, and the distance between the plates is represented by d.

Due to the fact that the capacitance and plate separation are inversely related, decreasing the plate separation results in an increase in capacitance.

86.

Option (C) is correct.

Explanation: The potential difference between the two plates of a capacitor must remain constant since it remains connected to the battery.

87.

Option (D) is correct.

Explanation: The incident wavelength needs to be below the threshold wavelength. The wavelength of IR is more than 600 nm. The wavelength of UV is below 600 nm.

Therefore, either a 100 W or 10 W UV light will release photoelectrons.

88.

Option (A) is correct.

Explanation: According to Bohr model, angular momentum of revolving electron must be integral multiple of $\frac{h}{2\pi}$ i.e., $mvrn = \frac{nh}{2\pi}$. Angular momentum is a vector. The above equation gives only the magnitude of angular momentum and not the direction. Hence, it does not give the correct value of angular momentum of revolving electron.

89.

Option (B) is correct.

Explanation: Ferromagnetic domains randomly organise when heated above the Curie temperature, turning the material into a paramagnetic one.

90.

Option (A) is correct.

Explanation: Given:

$$V = 50\sqrt{2}\sin\omega t$$

Root mean squared value of V

$$\therefore \quad V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{50\sqrt{2}}{\sqrt{2}} = 50\text{V}$$

Formula, $V_{rms} = \sqrt{V_2^2 + V_1^2}$

$$50 = \sqrt{V_2^2 + 40^2}$$

$$V_2^2 = 2500 - 1600 = 900$$

$$\therefore \quad V_2 = 30\text{V}$$

91.

Option (C) is correct.

Explanation: To produce the $\frac{\pi}{2}$ phase difference, only pure C and L are capable. But the phase difference departs from $\frac{\pi}{2}$ if R is also present there.

92.

Option (A) is correct.

Explanation: Frequency range of Gamma rays: $10^{22} - 10^{19}$ Hz

Frequency range of UV rays: $10^{17} - 10^{15}$ Hz

Frequency range of IR rays: $10^{14} - 10^{12}$ Hz

Frequency range of Microwave: $10^{13} - 10^{9}$ Hz

93.

Option (D) is correct.

Explanation: RMS value of voltage is obtained by dividing the instantaneous value by the square root of 2.

$$V_{rms} = 0.707\, V_0$$

Or, $$V_{rms} = \frac{V_0}{\sqrt{2}}$$

94.

Option (C) is correct.

Explanation: In a vacuum, velocity, also known as propagation speed, is the physical quantity that does not change for microwaves of wavelength of 1 mm and UV radiation of wavelength 1600 Å.

95.

Option (B) is correct.

Explanation: Equal areas won't be traced in equal amounts of time when the circular and elliptical loops move out from the field.

Thus, induced emfs for these two loops won't be constant.

96.

Option (D) is correct.

Explanation: Velocity of wave = $v = \nu \times \lambda$

(ν = frequency, λ = wavelength)

Larger the wavelength, faster the speed because the frequency of light remains constant when it travels from one medium to another. Red colour appears first after passing through the slab because it has the highest wavelength and speed compared to all colours of light.

97.

Option (A) is correct.

Explanation: Given: capacitor = 10 μF

$C' = KC$ (K = dielectric constant)

$$V = \frac{Q}{C}$$

$$\therefore \quad V' = \frac{Q}{C'}$$

$$V' = \frac{V}{4} = \frac{V}{K'}$$

$$\therefore \quad K = 4$$

98.

Option (A) is correct.

Explanation: The object already has a charge of 2C, and now it has gained 10^{19} electrons, each of which has a charge of -1.6×10^{-19} C, making the total charge obtained equal to $10^{19} \times -1.6 \times 10^{-19}$ C = -1.6C.

Charge of the object is $2 + (-1.6)$ C = 0.40 C.

99.

Option (C) is correct.

Explanation: The electrons' kinetic energy is zero at the stopping potential.

100.

Option (A) is correct.

Explanation: Two H atoms in their ground state have a combined energy of 2(13.6) = 27.2 eV.

The total energy of two H-atoms following an inelastic collision is equal to 3.4 + 13.6 = 17.0 eV, which is the greatest amount by which their combined kinetic energy is lowered when any one H-atom enters the first excited state.

Loss in KE from an inelastic collision is therefore = 27.2 – 17.0 = 10.2 eV.

101.

Option (D) is correct.

Explanation: By definition, if a charge of 1C encounters a force of 1N while moving at a speed of 1 m/s perpendicular to the magnetic field, the field strength at that location is equal to 1 Tesla (1T).

102.

Option (D) is correct.

Explanation: For an L-C-R AC circuit, the impedance is

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

103.

Option (C) is correct.

Explanation: The power dissipation is highest in a pure resistive circuit since the current and voltage are in phase.

104.

Option (A) is correct.

Explanation: Given: Frequency 5×10^{19} Hz

Wavelength: $\lambda = \frac{c}{\nu}$

(c = speed of light in vacuum, ν = wave frequency)

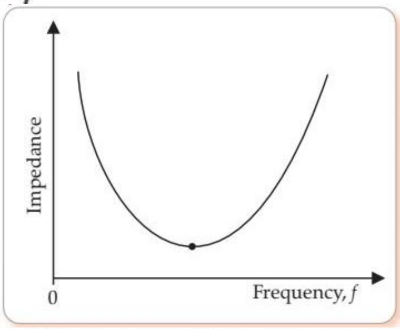
$$\lambda = \frac{3 \times 10^8}{5 \times 10^{19}}$$

$$\lambda = 6 \times 10^{-12}\text{ m}$$

105.

Option (D) is correct.

Explanation:



As observed from Impedance vs. frequency graph, the impedance of a series L-C-R circuit decreases at first, becomes minimum and then increases.

106.

Option (B) is correct.

Explanation: $\lambda = \frac{c}{\nu}$

(c =speed of light in vacuum, ν = wave frequency)

$$5 \times 10^{-5} = \frac{3 \times 10^8}{\nu}$$

$$\nu = 6 \times 10^{12}\text{ Hz}$$

107.

Option (C) is correct.

Explanation: The law of conservation of energy leads to Lenz's law.

In reality, the Lenz law states that an induced current always tends to oppose the source that generates it. So we must use more effort to work against an opposing force. More current is induced as a result of the periodic shift in magnetic flux caused by this additional labour. The extra work is simply converted into electrical energy as a result, in accordance with the rule of conservation of energy.

108.

Option (A) is correct.

Explanation: Given: v = 3 cm, μ_1 = 1, u = ∞, R = 0.78 cm

$$\frac{\mu_2}{\nu} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{\mu^2}{3} - \frac{1}{\infty} = \frac{\mu_2 - 1}{0.78}$$

$$\therefore \qquad \mu_2 = 1.35$$

109.

Option (D) is correct.

Explanation: Given A = 20 cm² = $20 \times 10^4 \text{m}^2$, E = 20 N/C and $\theta = 30°$

$\phi = EA\cos\theta$ (E = electric field, A = area, θ = angle between the surface and the electric-field)

$$\phi = 20 \times 20 \times 10^{-4} \times \cos 30°$$

$$\phi = 20 \times 20 \times 10^{-4} \times \frac{\sqrt{3}}{2}$$

$$\phi = 346.41 \times 10^{-4}$$

$$\phi = 0.03464\text{ Vm}$$

110.

Option (A) is correct.

Explanation: Given: Charge = 10 C,

Work done = 1 Joule, distance = 1cm

Potential difference between two points in an electric field is:

$$V_A - V_B = \frac{W}{q_0}$$

$$V_A - V_B = \frac{1}{10} = 0.1\text{ V}$$

111.

Option (D) is correct.

Explanation: Velocity due to free fall,

$$v = \sqrt{2gH}$$

(g = gravitational constant)

de-Broglie wavelength: $\lambda = \frac{h}{p}$

(h = Planck's constant, p = momentum)

$$\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{2gH}}$$

(h, m, and g are constant)

$$\lambda \propto \frac{1}{\sqrt{H}}$$

Or, $$\lambda \propto H^{-\frac{1}{2}}$$

112.

Option (B) is correct.

Explanation:

$$\text{Power} = \text{Energy evolved per fission} \times \text{number of fission per second}$$
$$= 200 \times 10^{20} \text{ MeV/s}$$
$$= (200 \times 10^6)(1.6 \times 10^{-19})(10^{20}) \text{ J/s}$$
$$= 32 \times 10^8 \text{ W}$$

113.

Option (B) is correct.

Explanation: We know $B \propto \frac{1}{y}$. As, distance y is changed to (y/2) distance is halved hence by above relation field will be doubled. Hence new field = 2B.

114.

Option (C) is correct.

Explanation: For transformers, Frequency at input = frequency at output.

115.

Option (A) is correct.

Explanation: Transformers are static devices that transfer power via electromagnetic induction from one circuit to another. Electrical transformers have no friction since there are no moving parts. Transformer efficiency, which ranges from 95% to 98%, is extremely high because losses in the transformer are relatively low compared to those in any other rotating equipment.

116.

Option (B) is correct.

117.

Option (B) is correct.

Explanation: Power factor of a purely resistive circuit is 1. LCR circuit behaves as a resistive circuit at resonance.

118.

Option (D) is correct.

119.

Option (C) is correct.

Explanation: Current or induced emf in a circuit has polarity which opposes the cause which produced it. It is also referred to as Lenz's law.

120.

Option (D) is correct.

Explanation: The objective lens and eyepiece lens's focal lengths determine the microscope's magnification power. $m \propto \frac{1}{f_0 f_e}$ (f_0 and f_e are the focal lengths of objective lens and eyepiece lens.)

121.

Option (A) is correct.

Detailed Answer:

Photoelectric current is proportional to the intensity of the radiation when the frequency of incident radiation is greater than the threshold frequency. So, the assertion is true.

As the intensity increases, greater number of energy quanta is available. Greater number of electrons are emitted by absorbing greater number of energy quanta. Greater number of electrons means greater amount of current. Thus photoelectric current becomes proportional to the intensity of the radiation.

So, reason is also true and it explains the assertion properly.

122.

Option (A) is correct.

Detailed Answer:

Putting p type semiconductor slab directly in physical contact with n type semiconductor slab cannot form a pn junction.

The roughness at contact does not match with inter atomic crystal spacing which is around 2-3 Å and hence there remains a discontinuity. So, continuous flow of charge carriers is not possible.

So, the assertion and reason both are true and the reason explains the assertion.

123.

Option (C) is correct.

Detailed Answer:

When an electron is at a location associated with a negative value of potential, say –V, its potential energy is U = $(-e)(-V) = eV$. When an electron is at a location associated with a positive potential, say +V, its potential energy is

U= $(-e)(+V) = -eV$.

So, the assertion is true.

Current flows from higher to lower potential. According to convention, the electrons flow in opposite direction i.e. from lower to higher potential.

So, the reason is false.

124.

Option (C) is correct.

Detailed Answer:

Propagation of light through an optical fibre is due to total internal reflection taking place at the core-cladding interface. The assertion is true.

One essential condition for total internal reflection is that the light should travel from denser to rarer medium. In optical fibre when light travels from core to cladding, total internal reflection takes place. Hence the refractive index of core should be greater than that of cladding. So, the reason is false.

125.

Option (A) is correct.

Explanation: Photoelectrons produced by monochromatic light have different velocities and hence different energies. Actually, all the electrons do not occupy the same level of energy. So, electrons coming out from different levels have different velocities and hence different energies. So, the assertion is true. The electrons coming out from inside the metal surface, face collisions with the other atoms in the metal. So, energies become different. Hence the reason is true and it explains the assertion.

126.

Option (C) is correct.

Explanation: On doping number of free carriers increases, hence the electrical conductivity of a semiconductor increases on doping. So, the assertion is true.

Doping may increase the number of electrons or holes in the semiconductor depending on the type of doping. If the dopant is donor type then number of electrons increases and if the dopant is acceptor type then the number of holes increases. So, the reason is false.

127.

Option (A) is correct.

Explanation: Heat produced is proportional to Resistance.

Since, resistance of filament >> resistance of wire so, more heat is produced in filament. Therefore, Assertion is true. Filament is made of material having high resistance like tungsten so that heat produced is more. Melting point of the material also should be high so that it can sustain more heat. Hence, reason is also true. Reason properly explains the assertion.

128.

Option (C) is correct.

Explanation: Convex mirror always form virtual image. So, the assertion is true.

Parallel rays, incident on convex mirror do not actually meet. They get reflected in such a manner that their extensions meet at a point. So, the reason is false.

129.

Option (B) is correct.

Explanation: Electrons in constant orbits around the nucleus do not emit radiation, according to Bohr's theory. Hence, the assertion is true.

According to classical physics, all moving charged particle radiate electromagnetic radiation. So moving electrons will also radiate energy. Hence the reason is also true. But it does not explain the assertion.

130.

Option (A) is correct.

Explanation: As the temperature of a semiconductor increases, its resistance decreases. Hence the assertion is true. The electrons in the valence band gain enough thermal energy as the temperature rises to move into the conduction band. So more free carriers are available for carrying current. Hence the resistance decreases. Hence the reason is also true and explains the assertion.

131.

Option (A) is correct.

Explanation: Negative charge will usually gravitate towards higher electric potentials due to the strong Coulomb attraction. As a result, it moves towards a point of a higher electric potential. The work required by an external agent to bring each charge from an infinite distance equals the potential energy of a system of fixed-point charges. As a result, the charge will try to migrate in the direction of low potential energy.

132.

Option (A) is correct.

Explanation: f = focal length, u = object distance, v = image distance, $u = f + x$

Using mirror formula:

$$\frac{1}{v}+\frac{1}{u} = \frac{1}{f}$$

Or, $$\frac{1}{v}-\frac{1}{f+x} = -\frac{1}{f}$$

$\therefore$ $$v = -f\frac{(f+x)}{x}$$

$$\text{Magnification } (m) = \frac{\text{size of image}}{\text{size of object}}$$

$$= \frac{-v}{u}$$

$$|m| = \frac{f(f+x)}{x}\times\frac{1}{f+x} = \frac{f}{x}$$

Hence, assertion and reason both are correct and reason explains the assertion.

133.

Option (A) is correct.

Explanation: The majority of the α-particles travel within 1° of a straight line.

This indicates that no force is exerted against them. Therefore, the assertion is true.

The majority of the atom's space is empty. Only 0.14% of α-particles are scattered more than 1°. Thus, the reason is also true and explains the assertion.

134.

Option (A) is correct.

Explanation: When a diode is used for rectification, it has to face both the positive and negative half cycles of alternating voltage. The amplitude of the negative half cycle should not cross the break down voltage of the diode. If it so happens, the diode gets permanently damaged. So, the assertion and reason both are correct and the reason explains the assertion.

135.

Option (A) is correct.

Explanation: Placing an electric dipole in a uniform electric field the dipole feels a torque and no net force.

Torque generated by two parallel forces = qE.

The force acting on the two ends of the dipole will not be equal in a non-uniform field.

There will therefore be a couple and a net force working together.

Dipole will have both rotational and linear translational motion. So, the assertion and reason both are correct and the reason explains the assertion..

136.

Option (C) is correct.

Explanation: When light rays pass through water and enter an air bubble, they experience total internal reflection and reflect just like from a mirror. As a result, the air bubble seems to be shiny. Hence the assertion is true but the reason is false.

137.

Option (D) is correct.

Explanation: According to Rutherford, "the entire positive charge and most of the mass of the atom is concentrated in a small volume called the nucleus, with electrons revolving around the nucleus just as planets revolve around the Sun." So, the assertion is false.

Energy is emitted by electrons orbiting the nucleus. As a result, the radius of the orbit gradually shrinks, and the electron falls into the nucleus. As a result, the stability of an atom is not explained. So, the reason is also false.

138.

Option (B) is correct.

Explanation: At critical temperature, the resistance of a superconductor reduces to zero. This characteristic is particularly important for power transfer with no loss. Both assertion and reason are correct, but reason does not explain the assertion.

139.

Option (A) is correct.

Explanation: Electric field intensity E, Electric potential V, distance r are related as,

$$\vec{E} = -\frac{dV}{dr}$$

So, the electric field is always perpendicular to equipotential surface. So, the assertion is true. The electric field is the negative gradient of electric potential. As a result, the direction of the electric field must be in the direction of the decreasing order of electric potential.

So, the reason is also true and is the correct explanation of assertion too.

140.

Option (C) is correct.

Explanation: The mirror formula is derived under the consideration that the incident rays are paraxial which means that the rays lie very close to the principal axis. Hence the mirror aperture is considered to be small. So, the assertion is true. Laws of reflection is valid for any surface plane or spherical. Hence the reason is false.

141.

Option (A) is correct.

Explanation: For H and He^+ containing only one electron, the Bohr model performs well. However, since, it is unable to take into account electron spin and sub-level (s, p, d, and f) orbitals, it is not applicable to multi-electron atoms.

142.

Option (A) is correct.

Explanation: Reverse bias prevents the majority charge carriers from passing through a p-n junction. Thus, there is no forward current flow. The reverse saturation current, on the other hand, is a weak current that flows in the opposite direction. Therefore, the assertion is true.

Few holes serve as minority charge carriers in the n-side and few electrons serve as such in the p-side. In a reverse bias condition, the negative polarity of the voltage source attached to the p-side pulls on the holes to the n-side. Similar to this, the positive polarity of the voltage source attached to the n-side pulls the electrons to the p-side. Therefore, these minority carriers can now pass the junction and cause a weak current in the opposite direction.

143.

Option (A) is correct.

Explanation: Relation between current and magnetic moment of a current carrying loop is:

$M = IA$ (I = current, M = magnetic moment, A = Area of the coil)

If the current is kept constant then, $M \propto A$

Now, Magnetic moment when radius is doubled, $M' = I\pi(2r)^2 = 4I(\pi r^2) = 4M$

So, magnetic moment becomes four times when radius is doubled.

Hence, assertion and reason both are true and reason is the correct explanation of assertion.

144.

Option (C) is correct.

Explanation: Convex mirror is used as rear view mirror in automobile. The assertion is true.

Convex mirror has wide file of view. Hence, the reason is false.

145.

Option (D) is correct.

Explanation: When a double convex air bubble forms within a glass slab, the refractive index of the bubble's medium is less than that of the surrounding medium. As a result, the lens will not behave as a converging lens. It will behave similarly to a diverging lens. As a result, the assertion is false.

When compared to air, the speed of light in glass is slower. As a result, the refractive index of glass is greater than that of air. So the reason is false.

146.

Option (B) is correct.

Explanation: When a diode is used in a half wave rectifier, it has to face both forward bias and reverse bias. During reverse bias, if the applied voltage is greater than the break down voltage of the diode, it will get permanently damaged. So, the break down voltage should be greater than the amplitude of the input ac supply which is to be rectified. So, the assertion is true.

In reverse bias majority carriers cannot cross the junction. Only the minority carriers are capable to cross the junction and thus yield a feeble current. So, the reason is also true. But it does not explain the assertion.

147.

Option (B) is correct.

Explanation: The electric lines of force cannot cross each other because if they cross, there would be two directions of electric field at that point, which is not possible. Hence the assertion is true. Electric lines of force are imaginary lines. The reason is also true. But it does not explain the assertion.

148.

Option (D) is correct.

Explanation: Magnification of microscope is inversely proportional to focal lengths of objective lens and the eyepiece lens. Hence, both the focal lengths of both the lenses are small. On the other hand, magnification of telescope is inversely proportional to focal lengths of eyepiece lens and directly proportional to the focal length objective lens. So, the focal length of the objective lens is large and the focal length of the eyepiece lens is small.

Hence, if the objective lens and the eyepiece lens of a microscope are interchanged that will not meet the criterion of the telescope.

So, assertion and reason both are false.

149.

Option (A) is correct.

Explanation: A simple microscope is composed of a single convex lens. The object distance is less than the focal length of the lens. The image formed in virtual, erect and magnified. So, the assertion is true.

When an object is placed in between the focus and the optical centre of a convex lens the image formed is virtual, erect and magnified. So, the reason is also true and explains the assertion.

150.

Option (C) is correct.

Explanation: As temperature increases, more and more electrons jump from valance band to conduction band. Hence, the resistivity decreases. Hence, the assertion is true, but the reason is false.

151.

Option (B) is correct.

Explanation: Charge on conductors be q_1 and q_2 respectively.

Radii of the conductors be r_1 and r_2 respectively.

Surface charge density $= \dfrac{\text{Total Charge}}{\text{Area}}$

Change density $= \dfrac{q_1}{\pi r_1^2} = \dfrac{q_2}{\pi r_2^2}$

$$\therefore \quad \frac{q_1}{q_2} = \left(\frac{r_1^2}{r_2^2}\right) \quad \text{...(i)}$$

Electric field $= E_1 = \dfrac{q_1}{4\pi r_1^2}$

Electric field $= E_2 = \dfrac{q_2}{4\pi r_2^2}$

$$\frac{E_1}{E_2} = \left(\frac{q_1}{q_2}\right) \times \left(\frac{r_2^2}{r_1^2}\right)$$

Applying equation (i),

$$\frac{E_1}{E_2} = \left(\frac{q_1}{q_2}\right) \times \left(\frac{q_2}{q_1}\right) = 1$$

$\therefore \quad E_1 = E_2$

Hence, the assertion and reason both are true but the reason does not explain the assertion.

152.

Option (A) is correct.

Explanation: Huygen's theory states that every point on a wavefront generates secondary wavelets that do not propagate backward. Kirchhoff explained that the amplitude of these secondary wavelets is proportional to (1 + cos θ), where θ represents the angle between the ray at a given point and the secondary wavelet direction. The value of 1 + cos θ equals zero in the case of a backward direction (θ = 180°), supporting the fact that secondary wavelets do not propagate in the backward direction.

153.

Option (A) is correct.

Explanation: The wave-front emitted by a point source in an isotropic medium is spherical because the wave travels in all directions at the same speed. Hence, the assertion is true. The medium which has the same refractive index at every point in all directions is known as an isotropic medium. Hence the reason is true and it explains the assertion.

154.

Option (D) is correct.

Explanation: When an electron jumps from valance band to conduction band, a hole is created in the valance band. Hence, the assertion is false.
In *p*-type semiconductor, holes are majority carriers. Hence, the reason is also false.

155.

Option (A) is correct.

Explanation: Gaussian surface surrounding a cavity encloses no charge. The electric field is therefore zero. The assertion therefore true.
Only the surface of a conductor contains charges. Therefore, the reason is also true and explains the assertion.

156.

Option (D) is correct.

Explanation: A light wave's speed drops when it moves from a rarer to a denser medium. However, this decrease in speed does not indicate that the energy that the light wave carries has been lost. Hence, the assertion is false.
Energy of wave is directly proportional to the frequency since $E = h\nu$.
So, the reason is also false.

157.

Option (A) is correct.

Explanation: Fringe width, which is proportional to $\frac{1}{d}$, may grow too big when d is negligibly small.

The entire screen may be covered by a single fringe. As a result, the pattern cannot be found. Hence, the assertion and reason both are true and the reason explains the assertion.

158.

Option (A) is correct.

Explanation: A diode must face both the positive and negative sides of the alternating voltage while being employed as a rectifier.
The reverse breakdown voltage of the diode is defined, and care is made to ensure that the amplitude of the negative half cycle of the alternating voltage does not exceed that value. Thus, the assertion is true.
When employed as a rectifier, typical p-n junction diodes have a high reverse breakdown voltage. Reverse voltage that is greater than this stated break down voltage irreversibly damages the diode. Hence the reason is also true and explains the assertion.

159.

Option (D) is correct.

Explanation: Gauss's law does not follow inverse square law. So, the assertion is false.
Gauss's law is not a consequence of conservation of charges. Hence, the reason is also false.

160.

Option (B) is correct.

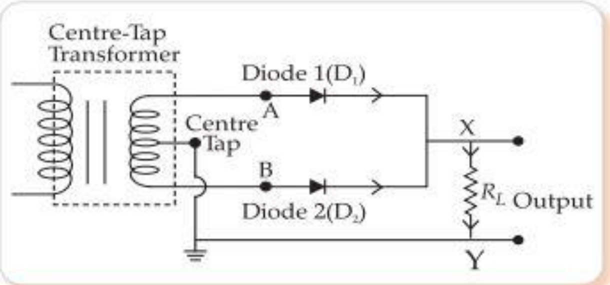
Explanation: Diffraction is the propagation of waves around an obstruction. It occurs with all different forms of waves (mechanical, non-mechanical, transverse, and longitudinal). The assertion is true.
When the wave's wavelength and the dimension of diffracting device are comparable, diffraction is detectable. Hence the reason is also true but it does not explain the assertion.

Sure shots (1 Mark) Solution

1.

(a) Rectifier

(b) Circuit diagram of full wave rectifier



2.

As $\lambda = \frac{h}{mv}, v = \frac{h}{m\lambda}$ ...(i)

Energy of photon $E = \frac{hc}{\lambda}$

& Kinetic energy of electron

$$K = \frac{1}{2}mv^2 = \frac{1}{2}\frac{mh^2}{m^2\lambda^2} \quad ...(ii)$$

Simplifying equation (i) & (ii) we get $\frac{E}{K} = 2\lambda mc/h$

3.

Here angle of prism A = 60°, angle of incidence i = angle of emergence e and under this condition angle of deviation is minimum

$\therefore i = e = \frac{3}{4}A = \frac{3}{4}\times 60° = 45°$ and $i + e = A + D$,

hence $\delta_m = 2i - A = 2 \times 45° - 60° = 30°$

∴ Refractive index of glass prism

$$n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$= \frac{\sin 45°}{\sin 30°} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \sqrt{2}$$

4.

Given: V = 230 V, I_0 = 3.2A, I = 2.8A, T = 27°C, $\alpha = 1.70 \times 10^{-4}$ °C^{-1}.

Using equation $R = R_0(1 + \alpha\Delta T)$

i.e $\frac{V}{I} = \left\{\frac{V}{I_0}\right\}[1+\alpha\Delta T]$

and solving ΔT = 840°C, i.e. T = 840 + 27 = 867°C

[CBSE SQP Marking Scheme 2023-24]

Detailed Answer:

$$R = R_0(1 + \alpha\Delta T)$$

Or, $\frac{V}{I} = \left(\frac{V}{I_0}\right)(1+\alpha\Delta T)$

Or, $\frac{230}{I} = \left(\frac{230}{I_0}\right)(1+\alpha\Delta T)$

Or, $\frac{1}{2.8} = \left(\frac{1}{3.2}\right)(1+1.7\times10^{-4}\Delta T)$

Or, $\frac{8}{7} - 1 = 1.7 \times 10^{-4}\Delta T$

Or, $\frac{1}{7} = 1.7 \times 10^{-4}\Delta T$

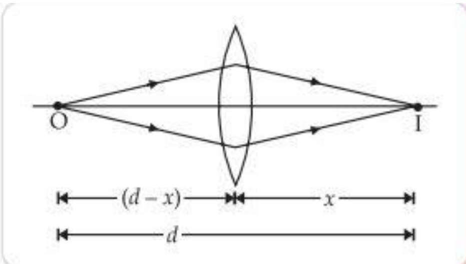
∴ ΔT = 840.336°C

∴ T = 27 + ΔT

= 27 + 840.336 = 867.336°C

5.

Let d be the least distance between object and image for a real image formation.



$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, $\frac{1}{f} = \frac{1}{x} + \frac{1}{d-x} = \frac{1}{x(d-x)}$

$fd = xd - x^2$, $x^2 - dx + fd = 0$, $x = \frac{d \pm \sqrt{d^2 - 4fd}}{2}$

For real roots of x, $d^2 - 4fd \geq 0$

$d \geq 4f$.

OR

Let f_o and f_e be the focal length of the objective and eyepiece respectively. For normal adjustment the distance from objective to eyepiece is $f_o + f_e$.

Taking the line on the objective as object and eyepiece as lens

$u = -(f_o + f_e)$ and $f = f_e$

$\frac{1}{v} - \frac{1}{[-\{f_o + f_e\}]} = \frac{1}{f_e} \Rightarrow v = \left(\frac{f_o + f_e}{f_o}\right)f_e$

Linear magnification (eyepiece) $= \frac{v}{u}$

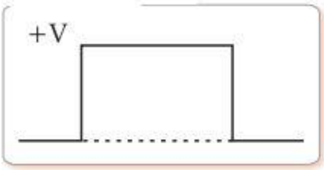
$= \frac{\text{Image size}}{\text{Object size}} = f = \frac{l}{L} = \frac{f_e}{f_o}$

∴ Angular magnification of telescope

$M = \frac{f_o}{f_e} = \frac{L}{l}$

6.

(i)



(ii) Since, the p end of the p-n diode is earthed, the p-n diode will be forward-biased and conduct only during the time the input waveform the voltage $= -V$

When the input waveform is $+V$, the diode will be reverse-biased.

Since, the diode is ideal, during the forward bias, its resistance will be zero and hence no voltage drops across it. During reverse bias, its resistance will be infinite and hence the voltage drop will be $+V$ which is the same as the input.

7.

Whether emission of photoelectron will occur or not it depends on the energy of photon.

As the intensity of light increases, the energy of photons does not increase; only the number of photons increases.

As the frequency of light increases, energy of photons increases.

Hence, the frequency and not the intensity of light source determines whether emission photoelectrons will occur or not.

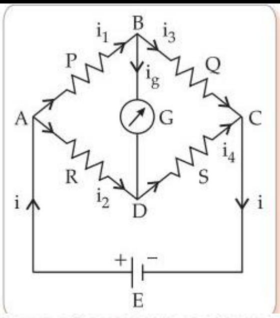
(i) Correct. As the critical angle is $\sin i_c = \frac{n_2}{n_1}$, where n_2 is the refractive index of the surrounding medium and n_1 is the absolute refractive index of the diamond.

Now as, n_2 for air $< n_2$ for water, $\sin i_c$ for the diamond in water will be more than $\sin i_c$ for the diamond in air.

(ii) Incorrect. As the critical angle for the total internal reflection of a diamond when surrounded by water is more than that when in air, the extent of total internal reflection that occurs in water is less than that occurs when in air. So, the diamond sparkles more in the air than when immersed in water.

9.

We will apply Kirchhoff's current law in the below circuit.



The flow of current at junction B,

$$i_1 = i_g + i_3 \quad \text{...(i)}$$

The flow of current at junction D,

$$i_2 = i_g + i_4 \quad \text{...(ii)}$$

If current through the galvanometer is zero, then

$$i_g = 0$$

Thus, from equation (i), $i_1 = i_3$

And,from equation (ii), $i_2 = i_4$

Now, applying Kirchhoff's voltage law for loop $ABDA$,

$$i_1P + i_gG = i^2R \quad \text{...(iii)}$$

Applying Kirchhoff's voltage law for loop $BCDB$,

$$i_3Q = i_4S + i_gG \quad \text{...(iv)}$$

When, $i_g = 0$

Then equation (iii) and (iv) will be,

$$i_1P = i_2R$$

and $$i_3Q = i_4S$$

But, we have seen above that, $i_1 = i_3$ and $i_2 = i_4$

Therefore, $\frac{P}{Q} = \frac{R}{S}$

10.

Given, transparent material of refractive index, 1.25, immersed in water of refractive index, 1.33.

Focal length (f), Refractive index (μ), Radius of curvature (R)

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

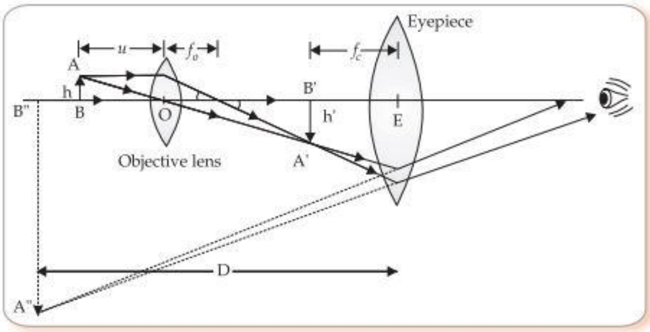
$$\frac{1}{f} = \left(\frac{\mu_m}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{\mu_m}{\mu_w} = \frac{1.25}{1.33}$$

$$\frac{\mu_m}{\mu_w} = 0.98$$

So, $1/f$ is negative. So, the lens will behave like a

OR



Here, f_0 = focal length of objective, f_e = focal length of the eyepiece.

11.

(i) Group 5 element is added to form n type extrinsic semiconductor.

Group 3 element is added to form p type extrinsic semiconductor.

Group 5 elements added as impurity are known as donors.

Group 3 elements added as impurity are known as acceptors.

(ii) Forward Bias: This bias condition incorporates by connecting of a positive potential to the P-type material and a negative potential to the N-type material across the diode.

Reverse Bias: Reverse biasing condition involves the connection of a negative potential to the P-type material and a positive potential to the N-type material across the diode.

Zero Bias: This is a bias condition in which there is no external potential applied to a diode.

12.

(i) For electron:

$$\lambda_e = \frac{h}{\sqrt{2mE}}$$

For Photon:

$$E = pc$$

$$\lambda_{photon} = \frac{hc}{E}$$

(c = speed of light, E = energy of photon)

Ratio of wavelength electron and photon

$$= \frac{\lambda_e}{\lambda_{photon}} = \frac{h}{\sqrt{2mE}} \times \frac{E}{hc}$$

$$= \left(\frac{E}{2m}\right)^{1/2} \frac{1}{c}$$

(ii) The wave lengths of matter waves for macroscopic bodies are extremely small. According to de broglie's equation, the relationship between wavelength and object mass is inverse. Because macroscopic bodies have a higher mass than micro things, they cannot exhibit wave behaviour.

13.

Mirror Equation:

f = focal length, u = object distance, v = image distance

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad (f \text{ is } -ve)$$

If, $u = -f$

$\Rightarrow \quad \frac{1}{v} = 0$

$\Rightarrow \quad v = \infty$

If, $u = -2f$

$\Rightarrow \quad \frac{1}{v} = \frac{-1}{2f}$

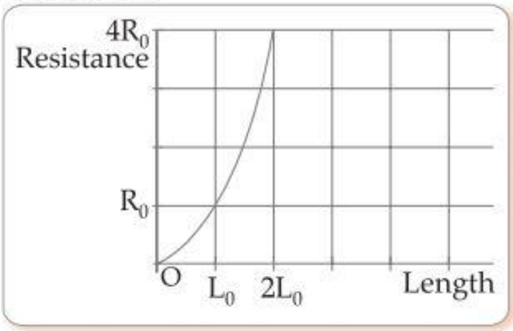
$\Rightarrow \quad v = -2f$

Hence, if $\quad -2f < u < -f$

then, $\quad -2f < v < \infty$

14.

(a) R vs. L graph:



(b) Length = L_0

Area = A_0

Resistance = R_0

$$R_0 = \rho \frac{L_0}{A_0}$$

When, length = $2L_0$

Area = $\frac{A_0}{2}$

Then $R = \rho\frac{L}{A}$

Or, $R = \rho\frac{2L_0}{A_0/2} = 4\rho\frac{L_0}{A_0} = 4R_0$

15.

No, it will not change. The focal length of a narrow aperture mirror is half of its radius. It is not affected by the refractive index of the surrounding medium.

OR

The ratio of the angle the image occupies at the eye to the angle the object occupies (at the unaided eye) is known as the magnifying power.

$$m = m_0 \times m_e = \frac{L}{f_0}\times\frac{D}{f_e}$$

Short focal lengths are required for the objective and eyepiece in order to maximise the magnifying power = $m = \frac{L}{f_o}\times\frac{D}{f_o}$

16.

(i) In a *p-n* junction at two sides of the depletion region immobile ions get so arranged that they prevent further diffusion of free charge carriers. They act as a barrier. Thus a potential difference developed across the junction is known as the potential barrier.

When a *p-n* junction is forward biased, the potential barrier reduces.

(ii) When a *p-n* junction diode is reverse biased, the initial increase in current is very small and steady until the voltage reaches a specific level known as the reverse breakdown voltage. At this voltage, a large number of covalent bonds rupture, number of free charge carriers drastically increases and the circuit current becomes extremely high.

17.

(i) The transition from $n_i = 2$ to $n_f = 3$ produces absorption spectra. This is because absorption spectra are created when an electron moves to a higher energy level by absorbing a photon with energy equal to the difference between the original and final energy levels.

(ii) The transition from $n_i = 3$ to $n_f = 1$ produces the Lyman spectral line. This is because transitions from higher energy levels to the $n = 1$ energy level are represented by the Lyman series.

The transition from $n_i = 4$ to $n_f = 2$ results in the Balmer spectral line. This is because transitions from higher energy levels to the $n = 2$ energy level are represented by the Balmer series.

The transition from $n_i = 4$ to $n_f = 3$ creates the Brackett spectral line. This is because transitions from higher energy levels to the $n=4$ energy level are represented by the Paschen series.

18.

(i)

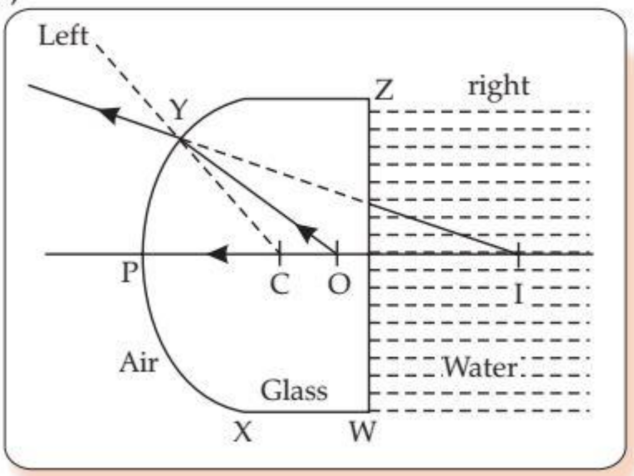


Image is virtual.

(ii) If we switch the objective and eyepiece lenses on a refracting telescope, magnifying power decreases since

$m = -\frac{f_O}{f_E}$ for normal adjustment and

$m = -\frac{f_O}{f_E}\left(1+\frac{f_E}{D}\right)$ for near point adjustment.

19.

Given: Ratio of the resistance of the bulbs = 1 : 2

$P = I^2R$ (P = Power, I = current, R = resistance)

The current, in the two bulbs, will be same as they are connected in series.

Ratio of the power dissipation:

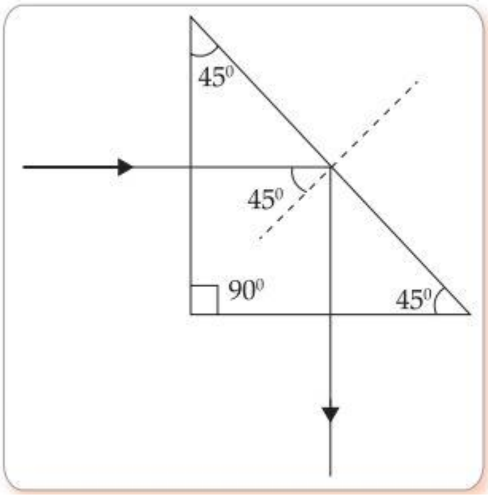
$$\therefore \quad \frac{P_1}{P_2} = \frac{I^2R_2}{I^2R_2} = \frac{R_1}{R_2}$$

$$= \frac{1}{2}$$

20.

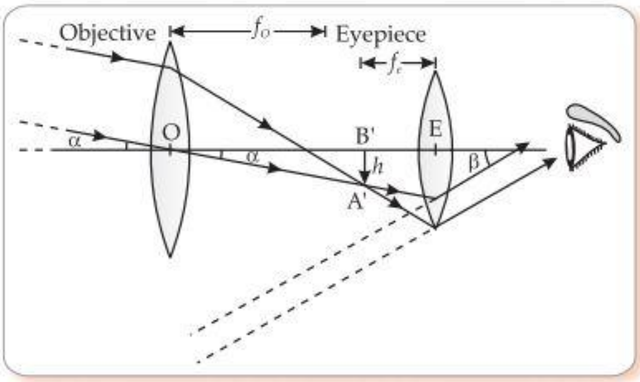
When a light ray travels from a medium with a higher refractive index to a medium with a lower refractive index at an angle of incidence greater than the critical angle, the phenomenon of total internal reflection occurs.
The critical angle is the angle of incidence at which the angle of refraction equals 90°.

Ray Diagram :



OR

Ray-Diagram :



Magnification (m): f_0 = Focal length of objective, f_e = Focal length of eyepiece

$$m = \frac{f_o}{f_e}$$

Or, $$m = \frac{\beta}{\alpha}$$

21.

B - Reverse biased : When an external voltage (V) is placed across a semiconductor diode, such that n side is positive and p side is negative, then the direction of applied voltage is same as the direction of barrier potential. As a result of the shift in the electric field, the barrier height rises and the depletion region expands.

C – Forward biased : When an external voltage (V) is placed across a semiconductor diode, such that p side is positive and n side is negative, then the direction of applied voltage is opposite to the direction of barrier potential. As a result, the width of the depletion layer decreases and the barrier height reduces.

22.

The mass of the target atom in the α-particle scattering experiment should be substantially larger than the mass of the bombarding particle. If a thin sheet of solid hydrogen is employed instead of gold foil, the mass of the target atom is less than the mass of the bombarding particle. As a result α-particle can't bounce back.

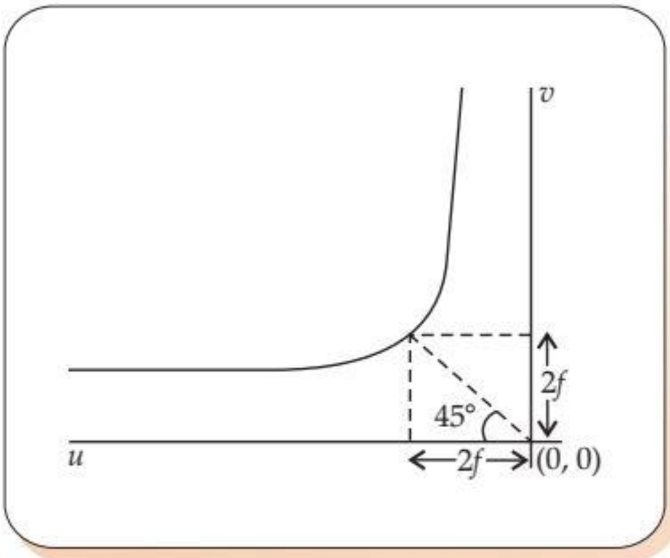
23.

Characteristics of the image formed

(i) Virtual

(ii) Enlarged

(iii) On the same side of the object



24.

Junction rule : At any junction, the sum of currents entering the junction equals the sum of currents leaving the junction.

$$\sum i = 0$$

Loop rule : The algebraic total of potential changes around every closed loop containing resistors and cells is zero.

$$\sum(\Delta V) = 0$$

Justification : The junction rule follows the law of charge conservation whereas the loop rule follows the law of energy conservation.

25.

A concave mirror forms a magnified image of an object when:

Case-1: Object is in between centre of curvature (C) and principal focus (F) of the mirror.

Case-2: Object is in between principal focus (F) and pole (P) of the mirror.

Difference: In first case the image is real and inverted while in second case, the image is virtual and erect.

OR

Given:

Refractive index of material of the lens = 1.5,

Refractive index of medium = 1.4,

Power of the lens = –5 D

$$f = \frac{1}{P} = \frac{1}{-5}\text{ m} = -\frac{100}{5}\text{ cm} = -20\text{ cm}$$

Formula: $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\mu_2 = 1.5,\ \mu_1 = 1.4,\ R_1 = -R,\ R_2 = R$

$$\frac{1}{-20} = \left(\frac{1.5}{1.4} - 1\right)\left(-\frac{1}{R} - \frac{1}{R}\right)$$

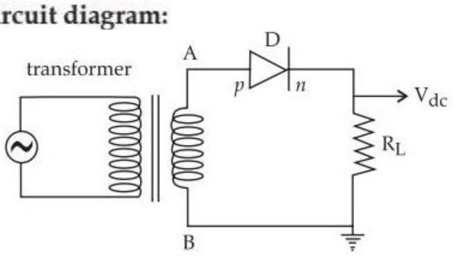
$$\frac{1}{-20} = \left(\frac{0.1}{1.4}\right)\left(-\frac{2}{R}\right)$$

$$R = \frac{20}{7}\text{ cm } (= 2.86\text{ cm})$$

26.

Half-Wave Rectifier: A half-wave rectifier is a rectifier that only transforms one half of an ac current into direct current.

Circuit diagram:

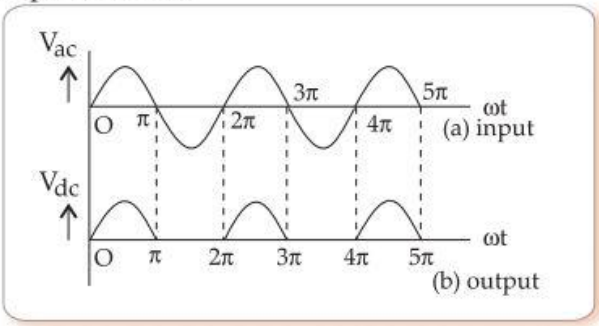


Working: AC input signal is fed to the primary coil of a transformer for rectification. The secondary coil is connected in series with a load resistance R_L, and a junction diode.

During the positive half cycle of the AC input, point A of the secondary coil is positive while point B has zero potential. Since, A is connected to *p*-region of the junction diode, the junction diode is forward biased and it conducts.

Conversely, during the negative half cycle of the AC input, point A is negative while point B remains at zero potential, causing the junction diode to be reverse biased and therefore non-conductive.

The output variation corresponding to input is depicted below:



27.

(i) Energy of incident photon = $E = \frac{hc}{\lambda}$

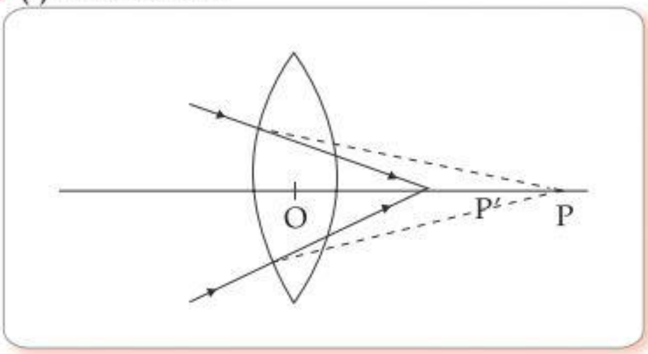
$$= \frac{(6.6 \times 10^{-34} \times 3 \times 10^{8})}{(600 \times 10^{-9} \times 1.6 \times 10^{-19})}$$

$= 2.06$ eV

Since, the energy of photon is less than the work function there will be no emission of photoelectrons.

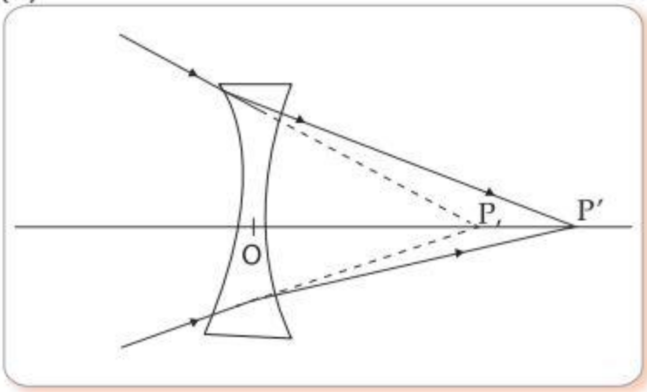
28.

(i) Convex lens:



When a convex lens is placed, the beam will converge at point P' whose distance is less than the distance of point P.

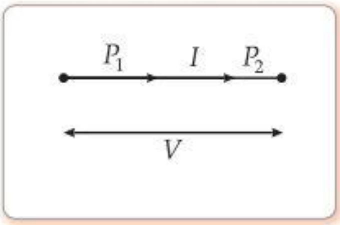
(ii) Concave lens:



When a concave lens is placed, the beam will converge at point P' whose distance is more than the distance of point P.

29.

(i) In series connection, current remains constant.



$$I = neA_1 v_{d_1} = neA_2 v_{d_2}$$

$$\therefore \quad \frac{v_{d1}}{v_{d2}} = \frac{A_2}{A_1}$$

(ii) In parallel connection, current is different, but potential difference is same.

$$V = I_1 R_1 = neA_1 v_{d1} \frac{\rho l}{A_1}$$

$$= ne\rho v_{d1} l$$

And $\quad V = I_2 R_2 = ne\rho v_{d2} l$

Now, $\quad I_1 R_1 = I_2 R_2$

$$\therefore \quad \frac{v_{d1}}{v_{d2}} = 1$$

30.

$$Q_1 + Q_2 = 0.8\text{C}$$

Force acting between them,

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$$

$$= \frac{Q_1(0.8 - Q_1)}{4\pi\varepsilon_0 \times (30 \times 10^{-2})^2}$$

The force will be maximum when $\frac{dF}{dQ_1} = 0$

Or, $$\frac{d}{dQ_1}\left[\frac{Q_1(0.8 - Q_1)}{4\pi\varepsilon_0 \times (30 \times 10^{-2})^2}\right] = 0$$

$$\therefore \quad Q_1 = 0.4\text{C}$$

$$Q_2 = 0.4\text{C}$$

OR

$$C = \frac{\varepsilon_0 A}{d}$$

d is same for both the capacitors as per the question.

Thus, $C \propto A$.

And, Plate area of C_2 is greater than C_1.

So, $(C_2 > C_1)$ ...(i)

Also, $C = \frac{q}{V}$ which is the slope of the graph. ...(ii)

From (i) and (ii),

We can say that Line A of the graph corresponds to C_2 and line B corresponds to C_1.

31.

As the temperature of a semiconductor rises, its resistance decreases and the current flowing through it rises. To maintain a constant reading on the ammeter, the value of the resistor R, is to be increased.

32.

(a) Since, surface A does not emit electrons, the frequency of the incident radiation is lower than the threshold frequency.

(b) Since, photoelectrons are just emitted from surface B, the frequency of the incident radiation is equal to the threshold frequency of surface B.

(c) Surface C emits photoelectrons with a certain kinetic energy, indicating that the frequency of the incident radiation is greater than the threshold frequency of surface C.

The threshold frequency is the minimum frequency of light required to cause electron emission from a metal surface. If there is no electron emission, it means that the frequency of the light is below the threshold frequency, whereas electron emission implies that the frequency of the light exceeds the threshold frequency.

33.

Magnifying power of a telescope = $\frac{f_o}{f_e}$

So, for higher magnification focal length of the objective should be large.

34.

Total resistance = 0.5 × 150 = 7.5Ω.

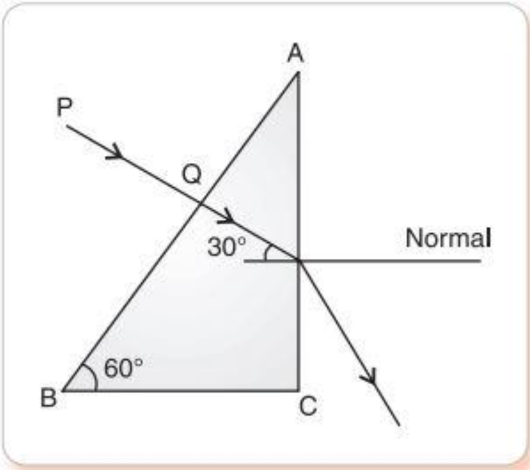
Total voltage drop = 8 × 150 = 1200V

$$\text{Power} = \frac{V^2}{R}$$

$$= \frac{1200^2}{75}$$

$$= 19200\text{W}$$

35.



$\theta_c = \sin^{-1}\frac{2}{3}$ where θ_c is the critical angle

$$\theta_c = 41.8°$$

$\angle i$ on face AC is 30° which is less than θ_c. Hence the ray will refract out from face AC.

OR

The width of the central bright band $= 2D \times \frac{\lambda}{d}$

Where d = width of the slit.

(i) As the width of the slit is increased, the size of the central diffraction band will be reduced.

(ii) On increasing the size of slit more light passes through it and the size of central bright band is reduced. Therefore, it is clear that intensity of central bright band will definitely increase.

36.

(i) N-type semiconductor, C_1
P-type semiconductor, C_2

(ii) Doping of intrinsic semiconductors is necessary to increase the concentration of the majority charge carrier so that it can be used as a P or N semiconductor in the diode.

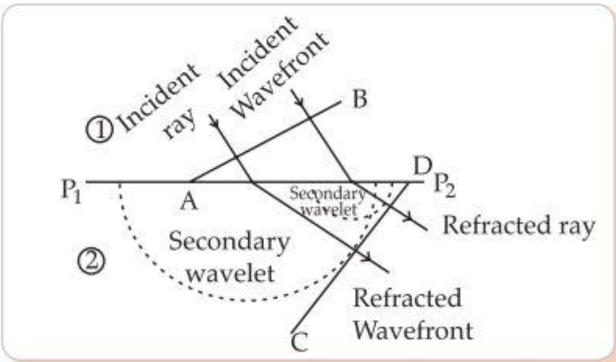
37.

(i) $E_K = h\nu + \phi_0$ (Einstein's photoelectric equation)
E_K = Maximum kinetic energy of emitted electron,
ϕ_0 = work function,
$h\nu$ = energy of incident radiation
If frequency increases, with work function (ϕ_0) remaining the same, the kinetic energy of the electron increases.

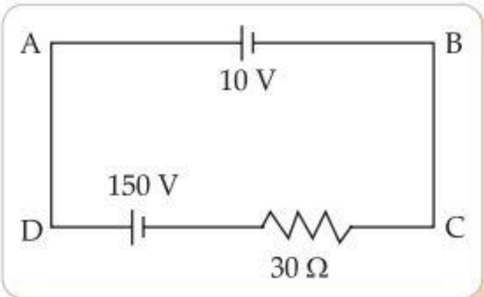
(ii) No changes will occur to photocurrent.
Photocurrent is dependent on light intensity rather than frequency.

38.

Wave front of light is an imaginary surface over which an optical wave has a fixed phase is known as a wave-front.



39.



In the above diagram net emf of the combination of cell $\varepsilon = 150 - 10 = 140$ V

Total resistance in the given circuit, $R = 30\ \Omega$

Thus, current in the circuit, $I = \frac{\varepsilon}{R} = \frac{140}{30}$

$\therefore I = 4.67$ A.

40.

(i) As, $\mu_2 > \mu_1$, the upper half of the lens will become diverging. As, $\mu_1 > \mu_3$, the lower half of the lens will become converging.

(ii) When a biconvex lens of focal length f is cut into two halves, the focal length of each part will be $2f$.

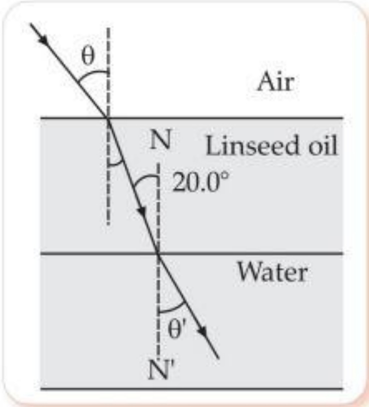
OR

(i) The power of a lens is defined as the reciprocal of its focal length and it is the measure of its ability to refract light.

It is given by the expression, $P = \frac{1}{f}$, where f is the focal length in metres.

Dioptre (D) is the SI unit of power.

(ii)



Applying Snell's law at the air-oil interface,

$$n_{air} \sin\theta = n_{oil} \sin 20.0°$$

Which gives θ = 30.4°.

Again, applying Snell's law at the oil-water interface

$$n_{water} \sin\theta = n_{oil} \sin 20.0°$$

Which gives θ′ = 22.3°.

41.

Doping of an Intrinsic Semiconductor: Doping is the mixing of a small quantity of trivalent (such as aluminium) or pentavalent (such as phosphorus) substance as an impurity in a pure semiconductor (such as Ge, Si). Conductivity of semiconductor is increased through doping. Pentavalent phosphorus is used to dope pure Si, Ge, making it an *n*-type semiconductor. In order to transform pure Si, Ge into a *p*-type semiconductor, trivalent aluminium is needed.

42.

The energy of a photon of incident radiation is given by:

$$E = \frac{hc}{\lambda}$$

(h = Planck's constant, c = speed of light in vacuum, λ= wavelength)

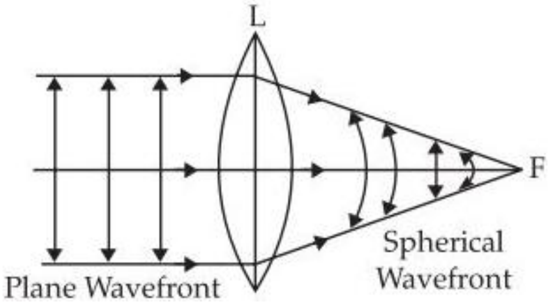
$$E = \frac{6.63\times10^{-34}\times3\times10^{8}}{(412.5\times10^{-9})\times(1.6\times10^{-19})}\,\text{eV}$$

E = 3.01 eV

Only Na and K will therefore exhibit photoelectric emission since their work functions are less than the energy of incident photon.

43.

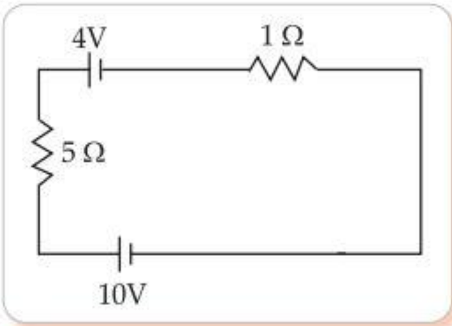
Plane wavefront after being refracted through convex lens:



44.

Given: emf of cell = 4V, Internal resistance of cell = 1 ohm, d.c. source voltage = 10V

Total current through the circuit:

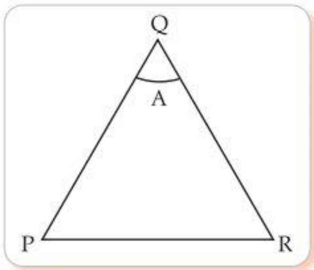


$$I = \frac{10-4}{6} = 1A$$

During charging, the terminal voltage across the cell is,

$$V = E - IR$$
$$= 4 - 1\times1$$
$$= 3V$$

45.



The angle that the emergent ray makes with the incident ray after refraction through a prism is the angle of deviation. Refractive index of the prism is given by,

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where A is the angle of prism and is its refractive index is μ. $A = 60°$ for an equilateral prism. The prism has a 1.6 refractive index when kept in air.

$$1.6 = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$1.6 = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin(30°)}$$

$$\Rightarrow \quad 1.6 \sin 30° = \sin\left(\frac{60° + \delta_m}{2}\right)$$

$$\sin^{-1}0.8 = 30° + \frac{\delta_m}{2}$$

$$53.1° = 30° + \frac{\delta_m}{2}$$

$$\therefore \quad \frac{\delta_m}{2} = 46.26°$$

When the prism is kept in a medium of refractive index of $\frac{4\sqrt{2}}{5}$

$$\frac{\mu_{prism}}{\mu_{medium}} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$\frac{1.6}{4\sqrt{2}/5} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin 30°}$$

$$\frac{60 + \delta_m}{2} = 45°$$

OR

Given: Height of the needle = h_1 = 4.5 cm, object distance (u) = –12 cm, focal length of convex mirror (f) = 15 cm, image distance = v

Using mirror formula:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\frac{1}{v} = \frac{1}{15} + \frac{1}{12} = \frac{9}{60}$$

$$v = \frac{60}{9} = 6.7 \text{ cm}$$

Image of the needle is 6.7 cm away from the mirror.

Magnification formula:

$$m = \frac{h_2}{h_1} = -\frac{v}{u}$$

$$h_2 = -\frac{v}{u} \times h_1$$

$$= \frac{-6.7}{-12} \times 4.5$$

$$= +2.5 \text{ cm}$$

$$m = \frac{2.5}{4.5} = 0.56$$

46.

In Germanium diodes the reverse saturation current is in micro-ampere order. But in Silicon diodes the reverse saturation current is in nano-ampere order. Hence, behavior of Silicon diodes are more close to ideal diode. Hence, Silicon diodes are more preferable than Germanium diodes.

47.

Given: Retarding potential = 3.3 V, frequency at which photoelectron emission starts = 8×10^{14} Hz

Work function = $W = h\nu_0$ (h = Planck's constant, ν_0 = frequency)

$$= \frac{6.63 \times 10^{-14} \times 8 \times 10^{14}}{1.6 \times 10^{-19}} \text{ eV}$$

$$= 3.315 \text{ eV}$$

Here, $h\nu = W + eV$

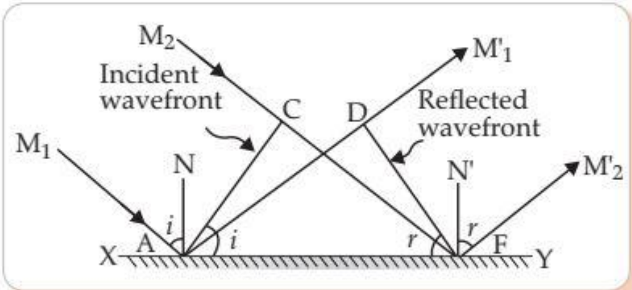
$$= (3.315 + 3.3) \text{ eV} = 6.615$$

$\therefore \quad \nu = \dfrac{6.615 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$

$\nu = 1.596 \times 10^{15}$ Hz

48.

A wave-front is a surface with a fixed phase. Secondary wavelets emanating from various locations on the wave-front allow the wave to travel perpendicular to it.



XY is the reflecting surface.

AC is the incident wavefront.

DF is the reflected wavefront.

M_1A and M_2F are the perpendiculars to incident wavefront and are incident rays.

M'_1A and M'_2F are the perpendiculars to reflected wavefront and are reflected rays.

NA and *N'A* are perpendiculars on the reflecting surface at the points of incidence.

$\therefore \quad M_1AN$ = Angle of incidence

$\therefore \quad M'_2FN'$ = Angle of reflection

$\therefore \quad CAF = 90° - \angle NAC$

$= \angle M_1AC - \angle NAC$

$= \angle M_1AN$

$= \angle i$

Similarly, $\angle AFD = \angle r$

Now in ΔAFC and ΔAFD

$\angle FCA = \angle ADF = 90°$

$CF = AD$ [Since, Time taken by light to travel *C* to *F* is equal to the time taken to travel *A* to *D*]

AF is the common side.

So, the triangles are congruent.

$\therefore \quad \angle CAF = \angle AFD$

i.e., $\quad \angle i = \angle r$

Thus law of reflection is proved.

49.

(i) $E_{net} = E_1 - E_2 = 100 - 10 = 190$ V

Current in the given circuit: $I = \dfrac{E_{net}}{R_{eq}} = \dfrac{190}{38} = 5A$

(ii) The current flowing through galvanometer is zero in a balanced wheat stone bridge.

50.

Given: Angular width decreases by 30%, $\lambda = 6000$ Å

Angular width $2\theta = \dfrac{2\lambda}{d}$

New angular width $= 0.70 \times 2\theta$

Or $\quad \lambda' = 0.7 \times 2\lambda/d$

Or, $\quad \lambda' = 0.7 \times 6000$Å

$\therefore \quad \lambda' = 4200$Å

OR

(i) (a) The wavefront generated from a line source is a cylindrical wavefront.

(b) The wave-front that emerges from a point source is spherical.

When the source is so far away that it is thought to be at infinity, the wave-front is therefore a plane wave-front.

(ii) Since, the wavelength differs, there will be no interference fringe.

Sure shots (3 Mark) Solution

1.

Number of atoms in 3 gram of Cu coin

$$= \frac{(6.023 \times 10^{23} \times 3)}{63} = 2.86 \times 10^{22}$$

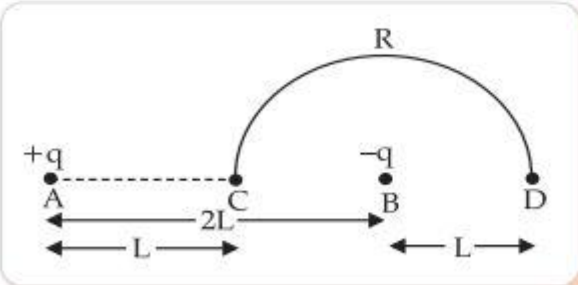
Each atom has 29 Protons & 34 Neutrons

Thus Mass defect $\Delta m = 29 \times 1.00783 + 34 \times 1.00867 - 62.92960 \text{ u} = 0.59225\text{u}$

Nuclear energy required for one atom $= 0.59225 \times 931.5$ MeV

Nuclear energy required for 3 gram of Cu $= 0.59225 \times 931.5 \times 2.86 \times 10^{22}$ MeV $= 1.58 \times 10^{25}$ MeV

2.



$$V_C = 0,$$

$$V_D = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{3L} - \frac{q}{L}\right] = \frac{-q}{6\pi\varepsilon_0 L}$$

$$W = Q[V_D - V_C] = \frac{-Qq}{6\pi\varepsilon_0 L}$$

3.

Formula K =–E , U = –2K

(a) K = 3.4 eV &

(b) U= –6.8 eV

(c) The kinetic energy of the electron will not change. The value of potential energy and consequently, the value of total energy of the electron will change. **[CBSE SQP Marking Scheme 2023-24]**

Detailed Answer:

(a) $KE = 13.6\, Z^2/n^2$

Or, $KE = \frac{13.6 \times 1^2}{2^2}$

Or, $KE = \frac{13.6}{4}$

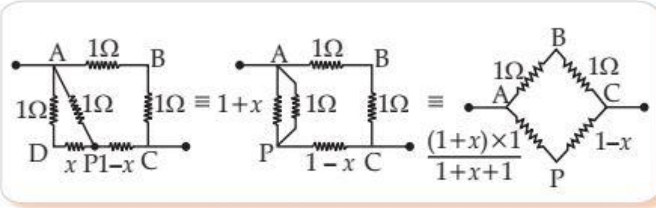
$\therefore$ $KE = 3.4\, eV$

(b) $TE = KE + PE$

Or, $-3.4 = 3.4 + PE$

$\therefore$ $PE = -6.8\, eV$

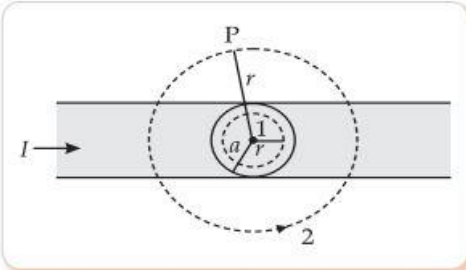
4.



As the points B and P are at the same potential the bridge is in balanced condition.

$$\frac{1}{1} = \frac{\frac{(1+x)}{(2+x)}}{(1-x)} \Rightarrow x = (\sqrt{2} - 1)\text{ohm}$$

5.



(a) Consider the case $r > a$. The Amperian loop, labelled 2, is a circle concentric with the cross-section. For this loop, $L = 2\pi r$

Using Ampere circuital Law, we can write,

$$B(2\pi r) = \mu_0 I,\ B = \frac{\mu_0 I}{2\pi r},\ B \propto \frac{1}{r}\ (r > a)$$

(b) Consider the case $r < a$. The Amperian loop is a circle labelled 1. For this loop, taking the radius of the circle to be r, $L = 2\pi r$

Now the current enclosed I_e is not I, but is less than this value. Since the current distribution is uniform, the current enclosed is,

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

Using Ampere's law, $B(2\pi r) = \mu_0 \frac{Ir^2}{a^2}$

$$B = \left(\frac{\mu_0 I}{2\pi a^2}\right) r^2 \qquad B \propto r \qquad (r < a)$$

6.

(a) Infrared

(b) Ultraviolet

(c) X rays

Any one method of the production of each one

Detailed Answer:

Method of production:

Infrared: By Nernst lamp.

Ultraviolet: By arc of mercury.

Xray: By Coolidge tube.

7.

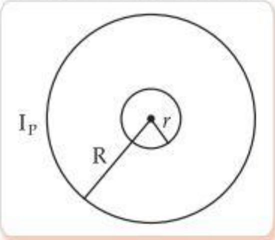
(a) Definition and S.I. Unit.

Detailed Answer:

Mutual inductance of two coils is equal to the e.m.f induced in one coil when rate of changes of current through the other coil is unity.

SI unit of mutual inductance is Henry.

(b)



Let a current I_P flows through the circular loop of radius R. The magnetic induction at the centre of the loop is

$$B_P = \frac{\mu_0 I_P}{2R}$$

As, $r << R$, the magnetic induction B_P may be considered to be constant over the entire cross sectional area of inner loop of radius r. Hence magnetic flux linked with the smaller loop will be

$$\Phi_S = B_P A_S = \frac{\mu_0 I_P}{2R} \pi r^2$$

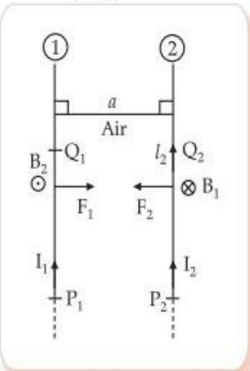
Also, $\Phi_S = MI_P$

$$\therefore \quad M = \frac{\Phi_S}{I_P} = \frac{\mu_0 \pi r^2}{2R}$$

OR

The magnetic induction B_1 is set up by the current I_1 flowing in first conductor at a point somewhere in the middle of second conductor is

$$B_1 = \frac{\mu_0 I_1}{2\pi a} \quad ...(i)$$



The magnetic force acting on the portion P_2Q_2 of length l_2 of second conductor is

$$F_2 = I_2 l_2 B_1 \sin 90° \quad ...(ii)$$

From equation (i) and (ii),

$$F_2 = \frac{\mu_0 I_1 I_2 l_2}{2\pi a}, \text{ towards first conductor}$$

$$\frac{F_2}{l_2} = \frac{\mu_0 I_1 I_2}{2\pi a} \quad ...(iii)$$

The magnetic induction B_2 set up by the current I_2 flowing in second conductor at a point somewhere in the middle of first conductor is

$$B_2 = \frac{\mu_0 I_2}{2\pi a} \quad ...(iv)$$

The magnetic force acting on the portion P_1Q_1 of length l_1 of first conductor is

$$F_1 = I_1 l_1 B_2 \sin 90° \quad ...(v)$$

From equation (iii) and (v)

$$F_1 = \frac{\mu_0 I_1 I_2 l_2}{2\pi a}, \text{ towards second conductor}$$

$$\frac{F_1}{l_1} = \frac{\mu_0 I_1 I_2}{2\pi a} \quad ...(vi)$$

The standard definition of 1A

$$I_1 = I_2 = 1A$$

$$l_1 = l_2 = 1m$$

$$a = 1m \text{ then}$$

$$\frac{F_1}{l_1} = \frac{F_2}{l_2} = \frac{\mu_0 \times 1 \times 1}{2\pi \times 1} = 2 \times 10^{-7} \text{ N/m}$$

$\therefore$ One ampere is that electric current which when flows in each one of the two infinitely long straight parallel conductors placed 1m apart in vacuum causes each one of them to experience a force of 2×10^{-7} N/m.

8.

(i) *S, W, X*

(ii) $Z = Z_1 + Z_2$

$A = A_1 + A_2$

(iii) In heavier nuclei, the Colombian repulsive force increases considerably and affects the attractive nuclear force. Thus nuclei become unstable.

9.

(i) The force on the charge Q at the point C force due to other charge Q (at A)

$$\vec{F_1} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{\left(a\sqrt{2}\right)^2}$$

$$\vec{F_1} = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q^2}{2a^2}\right) \qquad \text{(along } AC\text{)}$$

Force due to the charge q (at B),

$$\vec{F_2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{a^2} \qquad \text{(along } BC\text{)}$$

Force due to the charge q (at D),

$$\vec{F_3} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{a^2} \qquad \text{(along } DC\text{)}$$

Resultant of these two equal forces $\vec{F_2}$ & $\vec{F_3}$,

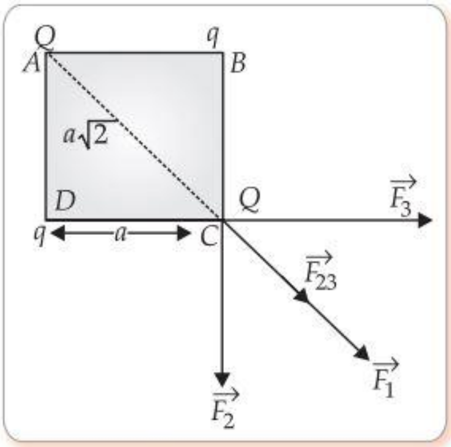
$$\vec{F_{23}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ\left(\sqrt{2}\right)}{a^2} \qquad \text{(along } AC\text{)}$$

∴ Net force on charge Q (at point C)

$$\vec{F} = \vec{F_1} + \vec{F_{23}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{a^2}\left[\frac{Q}{2} + \sqrt{2}q\right]$$

This force is directed along AC.

(For the charge Q, at the point A, the force will have the same magnitude but will be directed along CA)



(ii) Potential energy of the system

$$= \frac{1}{4\pi\varepsilon_0}\left[4\frac{qQ}{a} + \frac{q^2}{a\sqrt{2}} + \frac{Q^2}{a\sqrt{2}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0 a}\left[4qQ + \frac{q^2}{\sqrt{2}} + \frac{Q^2}{\sqrt{2}}\right]$$

10.

The necessary centripetal force for the rotation of electron is supplied by the electrostatic force between the electron and nucleus.

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

[putting Z =1]

Or, $$mv^2 = \frac{e^2}{4\pi\varepsilon_0 r} \qquad \text{...(i)}$$

From Bohr's theory,

$$mvr = \frac{nh}{2\pi}$$

∴ $$v = \frac{nh}{2\pi mr}$$

Putting in equation (i)

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{e^2}{4\pi\varepsilon_0 r}$$

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

In general, $$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2}$$

∴ $$r_n \propto n^2$$

11.

Electrical resistance	Resistivity
It is the property of material due to which it opposes the flow of electricity through the conductor.	The resistivity is defined as the resistance of a material of 1 metre length and 1 square metre area of cross section.
Unit : Ohm	Unit : Ohm-metre
Symbol : R	Symbol : ρ
Depends on length, cross-section area of conductor and temperature	Depends on temperature and material of the conductor

(ii) For resistor R_1, Resistivity = ρ_1, Length = L and Area = A_1

$$\therefore R_1 = \rho_1 \times \frac{L}{A_1}$$

For resistor R_2, Resistivity = ρ_2, Length = L and Area = A_2

$$\therefore R_2 = \rho_2 \times \frac{L}{A_2}$$

For the equivalent resistor,

Resistivity = ρ

Length = L

Area = $A = A_1 + A_2$

$\therefore \quad R = \rho \times \frac{L}{A}$

Since, the resistors are connected in parallel,

Equivalent resistance $= R = \frac{R_1 R_2}{R_1 + R_2}$

Or, $\rho \times \frac{L}{A} = \frac{\frac{\rho_1 L}{A_1} \times \frac{\rho_2 L}{A_2}}{\frac{\rho_1 L}{A_1} + \frac{\rho_2 L}{A_2}}$

$\therefore \rho$ = Effective resistivity $= \frac{\rho_1 \rho_2 (A_1 + A_2)}{\rho_1 A_2 + \rho_2 A_1}$

12.

(a) No force will be experienced by the charge.

(b) $B = \frac{\mu_0 N i}{2r}$

Or, $B = \frac{(4\pi \times 10^{-7})(100)(10)}{2 \times 25 \times 10^{-2}}$

$\therefore \quad B = 2.5 \times 10^{-3}$ T

13.

(i) Arranging in ascending order of frequency:

Radio waves, Microwaves, X-rays, Gamma ray

(ii) Uses of X-ray:

- to view bones and teeth, for diagnosing fractures.
- to check for cracks or flaws in industrial materials.

Uses of infra-red:

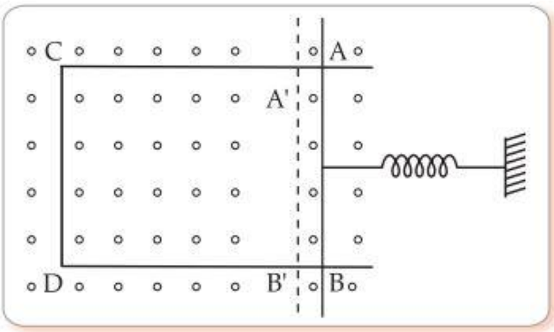
- In heat-sensitive thermal imaging cameras.
- In home remote controls.

14.

(i) Self-inductance of a coil of wire = $L = \frac{\mu N^2 A}{l}$

As the number of turns become 5 times, the self-inductance must become 25 times of the initial value. Thus, new self-inductance = 25 × 15 mH = 375mH

(ii)



The wire AB would oscillate in a simple harmonic way

We can write

$$x = -a \cos \omega t$$

As $\quad x = -a$ at $t = 0$

Therefore instantaneous magnetic Flux

$$\phi(t) = Blx \qquad (l = AB)$$

Instantaneous induced emf,

$$e(t) = -\frac{d\phi}{dt} = aBl\omega \sin \omega t \qquad ½$$

OR

Flux through the coil = $BA \cos \theta$

$$= 10^{-1} \times 100 \times 10^{-4} - \cos(90° - 60°)$$

$$= 10^{-1} \times 100 \times 10^{-4} \times \left(\frac{\sqrt{3}}{2}\right)$$

$$= \left(\frac{\sqrt{3}}{2}\right) \times 10^{-3} \text{ Wb}$$

Induced e.m.f. $= -\frac{d\phi}{dt}$

$$= -\frac{\left[0 - \left(\frac{\sqrt{3}}{2}\right) \times 10^{-3}\right]}{10^{-3}}$$

$$= \left(\frac{\sqrt{3}}{2}\right)$$

$$= 0.866 \text{ V}$$

15.

(i) Since, mass numbers are same for both, the radii are also same.

$$r \propto A^{1/3}$$

(ii) (a) Mass defect = Mass of 2 neutrons – Actual mass of particle

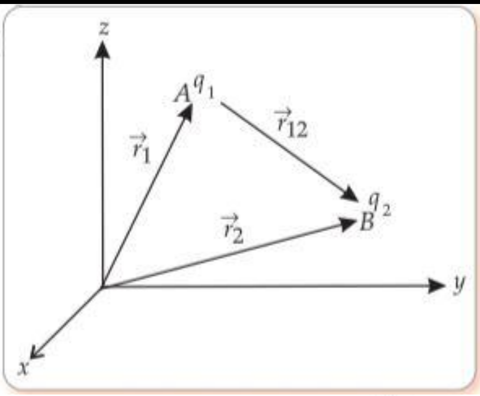
$= 2(1.0086 \text{ u}) - 2.0272 \text{ u}$

$= 2.0172 \text{ u} - 2.0272 \text{ u} = -0.0100 \text{ u}$

(b) Negative mass defect is not possible. This would imply the creation of mass as well as the binding energy, both of which would violate the principle of energy conservation. So this particle cannot exist.

16.

(i)



Potential due to q_1 at $B = V = k\frac{q_1}{r_{12}}$

When point charge q_2 is brought from infinity to r_2, then work done to bring this charge against the field of q_1 is

$$W = q_2 V$$

$$q_2 = \frac{q_1}{r_{12}}$$

This work done is stored as potential energy

$$U = k\frac{q_1 q_2}{r_{12}}$$

(b) An external field E is applied on the system:

Work done in bringing q_1 from infinity to $r_1 = W_1 = q_1 V_{r1}$

Work done on q_2 for bringing it from infinity to r_2 against the external field $(E) = W_2 = q_2 V r_2$

Work done on q_2 against the field due to $q_1 = W_{12} = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$

(q_1 and q_2 = charges, ε_0 = permittivity of free space, r_{12} = distance between q_1 and q_2)

Potential energy of the whole system

$$U = W_1 + W_2 + W_{12}$$

$$U = q_1 V_{r_1} + q_2 V_{r_2} + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

17.

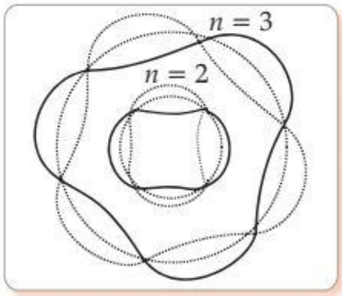
(i) Radiation emitted by transition of an electron to ground state of Bohr hydrogen atom:

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

$$\frac{\lambda_{min}}{\lambda_{max}} = \frac{R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)}{R\left(\frac{1}{1^2} - \frac{1}{\infty}\right)} = \frac{3}{4}$$

The ratio of the emitting radiation's minimum to maximum wavelength is $\frac{3}{4}$

(ii)



(iii) According to de Broglie $\lambda = \frac{h}{mv}$ ...(1)

(h = Planck's constant, m = mass of electron, v = velocity of electron)

Conservation of Angular momentum = $mvr = \frac{nh}{2\pi}$ ...(2)

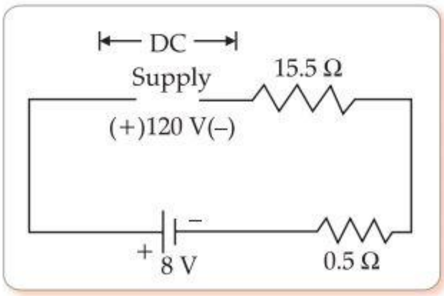
Put equation (2) in (1):

$$\frac{h}{mv} = \frac{2\pi r}{n}$$

For $n = 2$, $\lambda = \frac{2\pi r}{2}$

18.

(a)



(b) Emf of storage battery = E = 8 V

Internal resistance = r = 0.5 Ω

DC supply voltage = V_a = 120 V

Charging through R = 15.5 Ω

Current on the circuit = $I = (V_a - E)/(R + r)$

Or, $I = (120 - 8)/(15.5 + 0.5)$

∴ I = 7A

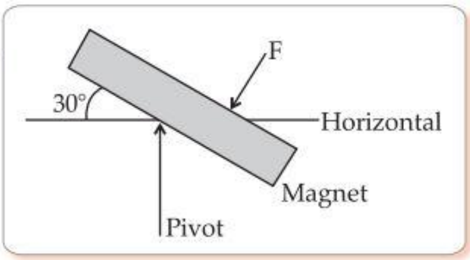
Potential across the storage battery : $V = E + Ir$

Or, $V = 8 + 7 \times 0.5$

∴ V = 11.5 V

(c) The purpose of series resistor in the circuit is to limit the current drawn from DC source.

19.



Dipole moment of the magnet = M = 3 Am^2

F = force applied at a distance 10 cm from the centre

It is now in equilibrium at an angle = θ = 30°

External magnetic field strength = B = 0.25 T

The magnet will be at rest when the total torque acting on it is 0.

It means that the torque due to applied force F is equal to the torque due to magnetic force.

Torque due to applied force = $F \times 10$

Torque due to magnetic force = $MB \sin\theta$

$$= 3 \times 0.25 \times \sin 30°$$

Given that torque caused by an applied force F equals torque caused by a magnetic force,

$$F \times 10 = 3 \times 0.25 \times \sin 30°$$

$$F = \frac{1}{10} \times 3 \times 0.25 \text{ x } \sin 30° = \frac{1}{10} \times 3 \times 0.25 \times 0.5$$

$$= 0.0375 \text{ N}$$

If F is withdrawn, the magnet will go back to its original position.

20.

(i) According to Einstein Photoelectric Equation

$$K_{max} = h\nu - h\nu_0$$

Or, $$K_{max} = h\nu - \Phi_0$$

For a constant frequency of incident radiation (ν), K_{max} is more for metal 1 than metal 2.

Or, $$K_{max} = h\nu - \Phi_0$$

From the above equation it is clear that K_{max} is higher for lower Φ_0.

Hence, metal 1 must represent Potassium of lower work function 2.3 eV. While the metal 2 must represent Aluminium of higher work function 4.3 eV.

(ii) According to Einstein Photoelectric Equation,

$$K_{max} = h\nu - h\nu_0$$

Or, $$K_{max} = h\nu + (-h\nu_0)$$

On comparing the above equation with $y = mx + c$

We get,

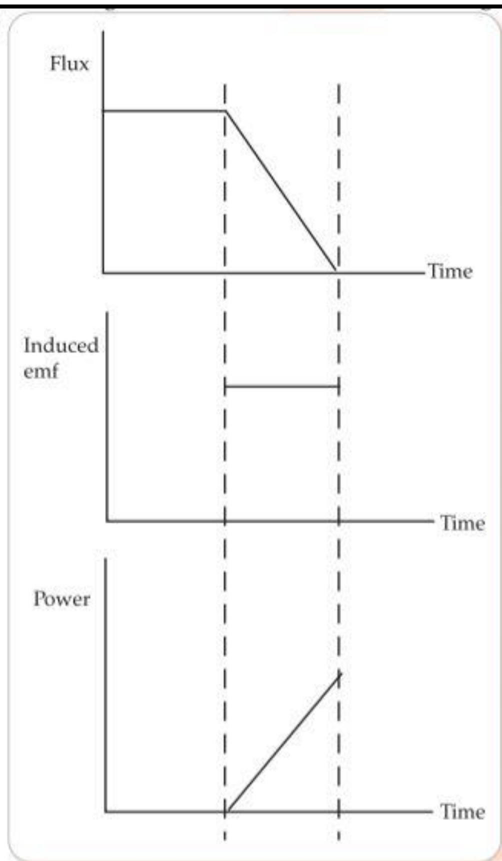
The slope of the K_{max} versus 'ν' graph

Slope = h (Plank's constant)

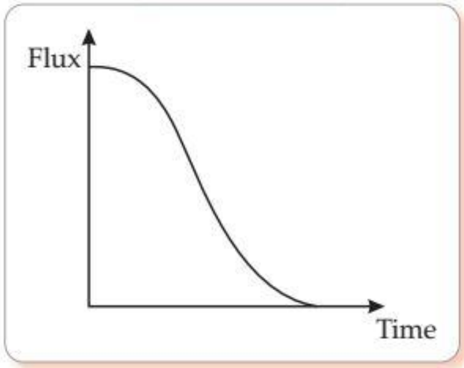
(iii) The frequency of incident radiation should be higher than the threshold frequency of wavelength less than the threshold wavelength.

21.

(a)



(b) When a circular coil is used, the rate at which the loop's area changes as it exits the field is not constant, and the induced current varies as a result.



OR

OR

Given: Resistance = 8.5 Ω, Radius = 12 cm

Area of the circular loop = πr^2

$$= 3.14 \times (0.12)^2 \text{ m}^2 = 4.5 \times 10^{-2} \text{ m}^2$$

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(BA) = -A\frac{dB}{dt} = -A.\frac{B_2 - B_1}{t_2 - t_1}$$

For $0 < t < 2s$

$$\varepsilon_1 = -4.5 \times 10^{-2} \times \left\{\frac{1-0}{2-0}\right\} = -2.25 \times 10^{-2} \text{ V}$$

$$\therefore I_1 = \frac{\varepsilon_1}{R} = \frac{-2.25 \times 10^{-2}}{8.5} \text{A} = -2.6 \times 10^{-3} \text{A} = -2.6 \text{ mA}$$

For 2s < t < 4s,

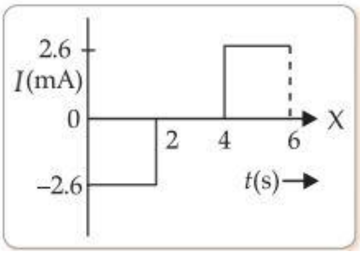
$$\varepsilon_2 = -4.5\times10^{-2}\times\left\{\frac{1-1}{4-2}\right\}=0$$

$$\therefore I_2 = \frac{\varepsilon_2}{R}=0$$

For 4s < t < 6s,

$$I_3 = -\frac{4.5\times10^{-2}}{8.5}\times\left\{\frac{0-1}{6-4}\right\}\text{A} = 2.6\text{ mA}$$

	$0 < t < 2s$	$2 < t < 4s$	$4 < t < 6s$
$\varepsilon(V)$	–0.023	0	+0.023
I(mA)	–2.6	0	+2.6



22.

(i) The energy necessary to disassemble a nucleus into its component protons and neutrons and to separate them to such a great distance that they cannot interact with one another is known as the binding energy. It can also be described as the extra energy that nucleons release as a result of their attraction to one another as they come together to form a nucleus. Binding energy per nucleon is calculated by dividing the binding energy by the mass number.

(ii) Mass number has no dependence on mass density.

(iii) Given x_1 and x_2 are the binding energy per nucleons for deutrons and alpha particle.

Binding energy for deutrons = $4 \times x_1 = 4x_1$

Binding energy for alpha particle = $4 \times x_2 = 4x_2$

Energy released Q = Binding energy of product part(deutrons) – Binding energy of reactant part(alpha particle) = $4x_2 - 4x_1 = 4(x_2 - x_1)$

23.

(i) The charge placed at the centre of the hollow sphere is $-q$. Therefore, $+q$ will induce on the inner surface. As a result, the inner surface of the shell has a total charge of $+q$.

Density of surface charges on the inner surface:

$$\sigma_{inner} = \frac{\text{Total charge}}{\text{Inner surface area}} = \frac{+q}{4\pi r_1^2}$$

On the outside of the sphere, a charge of $-q$ is induced. On the outer surface of the sphere, there is a charge of Q magnitude. As a result, the outer surface of the sphere has a total charge of $Q-q$.

Density of surface charges on the outer sphere:

$$\sigma_{outer} = \frac{\text{Total charge}}{\text{Outer surface area}} = \frac{Q-q}{4\pi r_2^2}$$

(ii) Electric field at a point r distance from the sphere's centre and outside the sphere:

Using the Gauss theorem:

$$\text{Flux} = \phi = \frac{\text{charge enclosed}}{\varepsilon_0}$$

Or, $$E\times 4\pi r^2 = \frac{Q-q}{\varepsilon_0}$$

$$E = \frac{Q-q}{4\pi r^2\varepsilon_0}$$

24.

Given: Ground state energy of hydrogen atom is –13.6 eV, kinetic energy of photoelectron = 9 eV

For a transition from $n = 3$ to $n = 1$ state, the energy of the emitted photon,

$$h\nu = E_2 - E_1 = 13.6\left[\frac{1}{1^2}-\frac{1}{3^2}\right]\text{eV},$$

$= 12.1$ eV

From Einstein's photoelectric equation,

$$h\nu = K_{max} + W_0$$

$$\therefore \quad W_0 = h\nu - K_{max}$$

$$= 12.1 - 9 = 3.1 \text{ eV}$$

Threshold wavelength,

$$\lambda_0 = \frac{hc}{W_0} = \frac{6.62\times10^{-34}\times3\times10^{8}}{3.1\times1.6\times10^{-19}}$$

$$\lambda_0 = 4\times10^{-7}\text{ m}$$

25.

(i) A material's conductivity is equal to the reciprocal of its resistivity

$$\text{SI Unit} = \frac{1}{\text{Ohm.metre}}$$

(ii) Acceleration: $\vec{a} = -\frac{e}{m}\vec{E}$

Average drift velocity: $v_d = -\frac{eE}{m}\tau$

(τ = relaxation time)

If n is the number of free electrons per unit volume, then current I is given by:

$$I = neA|v_d| = \frac{e^2A}{m}\tau n|E|$$

Or, $$\frac{I}{A} = \frac{e^2\tau nE}{m}$$

Or, $$J = \sigma E$$

$\therefore$ $$\sigma = \frac{J}{E}$$

Where $\sigma = e^2\tau n/m$

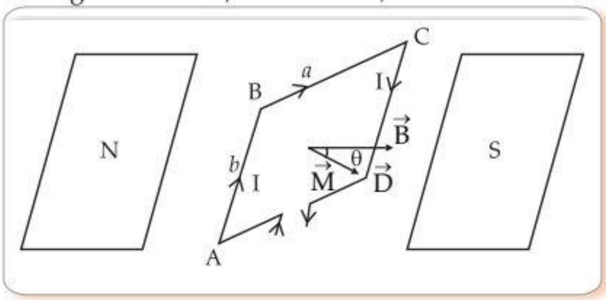
26.

In a magnetic field $\vec{B}$, the force on a wire of length l carrying a current I is given by:

$$\vec{F} = IlB\sin\theta = I\vec{l}\times\vec{B}$$

(F = force, I = current, B = magnetic field)

When a rectangular loop is positioned in the magnetic field $\vec{B}$, as indicated,



Where θ is the angle formed by the sides BC and $\vec{B}$,

|Force on arm BC| = |Force on arm DA| = $IaB \sin 0° = 0$.

$IbB \sin 90° = IbB$ = |Force on arm AB| = |Force on arm CD|

These two forces constitute a torque.

The separation between their lines of action at right angles is:

$\therefore$ Torque acting on the coil, has a magnitude τ,

$= IbBa\sin\theta$

$= IBA \sin\theta$ (A = area of the coil)

In vector form:

$$\vec{\tau} = I\vec{A}\times\vec{B}$$

But $$I\vec{A} = \vec{M}$$

$\therefore$ $$\vec{\tau} = \vec{M}\times\vec{B}$$

27.

(i) During one half cycle, D_1 is forward biased, D_2 is reversed biased. During the next half cycle, D_2 is forward biased, D_1 is reversed biased. It repeats.

(ii) Both the diodes are safe. Diode D_2 is reverse biased. No current will flow through it. So, it is safe. D_1 is forward biased. Current through it is

$$I = \frac{5V}{(30+100+70)\Omega} = 25 \text{ mA.}$$

So, this is also safe.

28.

(a) An electric circuit's ability to modify the current that flows through it in order to induce a voltage inside the same circuit is known as self-inductance. This phenomenon happens when a coil's current varies, causing the same coil to produce an opposite voltage that counteracts the changing current. L stands for self-inductance, which is measured in henry (H).

An electric circuit's ability to generate a voltage in an adjacent coil by altering the current flowing through one coil is known as mutual inductance. When two coils are put close to one another, this phenomenon happens when the changing current in one coil causes a voltage to change in the other coil. M stands for mutual inductance, which is also measured in henry (H).

(b) Given: Mutual Inductance = 2H, Change in current = 0.5A, Change in time = 100 ms = 0.1s.

(i) Flux through other coils = $\Delta\phi_2 = M\Delta I_1$

$= 2 \times 0.5 = 1$ Wb

(ii) Induced emf in other coil = $M\left(\frac{\Delta I_1}{\Delta t}\right)$

$= 2 \times \left(\frac{0.5}{0.1}\right)$

$= 10$V

OR

OR

Given: magnetic field (B) = 0.5, Length (l) = 20cm = 0.2 m

Velocity (v) = 10 ms^{-1}, Resistance (R) = 5 Ω

Emf induced in the loop:

$$\varepsilon = Blv$$
$$= 0.5 \times 0.2 \times 10 = 1 \text{ V}$$

∴ Current flow :

$$I = \frac{\varepsilon}{R} = \frac{1}{5} = 0.2 \text{ A}$$

29.

(i) The distinguishing feature of nuclear force are:

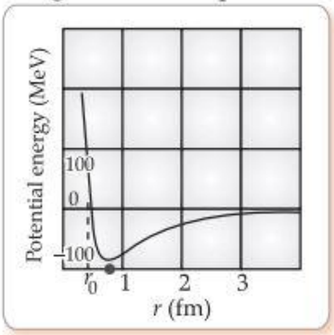
(1) Short range force

(2) Strongest force

(3) Attractive in nature

(4) Does not depend on charge. **(any two)**

(ii) Plot showing variation of potential energy:



Marking the regions:

(a) $r < r_0$: repulsive force

(b) $r > r_0$: attractive force.

30.

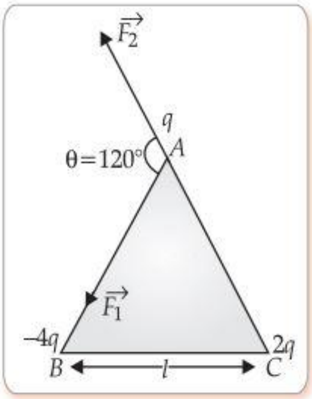
(i) Force on charge q due to the charge $-4q$

$$\vec{F_1} = \frac{1}{4\pi\varepsilon_0}\left(\frac{4q^2}{l^2}\right), \text{ along AB}$$

Force on the charge q, due to the charge $2q$

$$\vec{F_2} = \frac{1}{4\pi\varepsilon_0}\left(\frac{2q^2}{l^2}\right), \text{ along CA}$$

The forces $\vec{F_1}$ and $\vec{F_2}$ are inclined to each other at an angle of 120°



Hence, resultant electric force on charge q

$$F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$
$$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos 120°}$$
$$= \sqrt{F_1^2 + F_2^2 - F_1F_2}$$
$$= \left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{l^2}\right)\sqrt{16+4-8}$$
$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{2\sqrt{3}q^2}{l^2}\right)$$

(ii) Net potential energy of the system:

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{l}[-4+2-8]$$
$$= \frac{(-10)}{4\pi\varepsilon_0}\cdot\frac{q^2}{l}$$

Therefore, amount of work done $= \frac{10}{4\pi\varepsilon_0}\cdot\frac{q^2}{l}$

$$= \frac{5q^2}{2\pi\varepsilon_0 l}$$

31.

(i) Given: Total energy = – 1.51 eV

So, Potential energy = 2 × Total energy = – 3.02 eV

Kinetic energy = – Total energy = 1.51 eV

(ii) Radius of atom = $R = 5.3 \times 10^{-11}$ m,

Diameter of nucleus = $r = 1.0 \times 10^{-15}$ m

Volume of nucleus = $\frac{4}{3}\pi r^3$

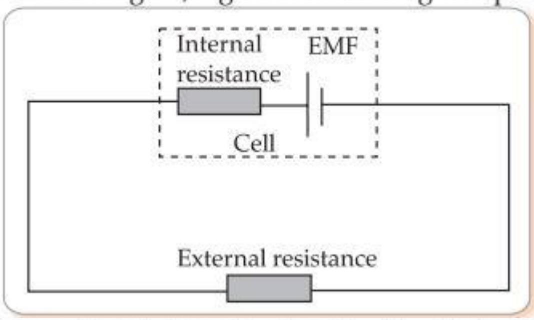
Volume of atom = $\frac{4}{3}\pi R^3$

Fraction of volume occupied by the nucleus

$$= \frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi R^3} = \frac{(0.5\times10^{-15})^3}{(5.3\times10^{-11})^3} = 8.4\times10^{-16}.$$

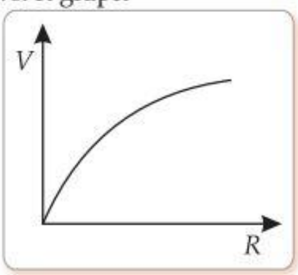
32.

(i) Internal resistance of a cell is the resistance within the cell that resists current flow when it is coupled to an external circuit with some external resistance. As a result, when current flows through it, it generates a voltage drop.

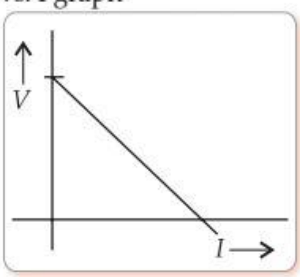


In a cell, resistance is given by the electrolyte and electrodes. As a result, the electrodes and electrolyte provide internal resistance by opposing current flow within the cell.

(ii) (a) V vs. R graph



(b) V vs. I graph



33.

(i) $\vec{F} = q(\vec{v}\times\vec{B})$ (Force $\vec{F}$ acting on a particle of mass m and charge q moving with velocity $\vec{v}$ in a magnetic field)

(a) When the velocity of charge particle and magnetic field are perpendicular to each other.

(b) When velocity is neither parallel nor perpendicular to the magnetic field.

(ii) The force, experienced by the charged particle, is perpendicular to the instantaneous velocity $\vec{v}$, at all instants. Hence, the magnetic force cannot bring any change in the speed of the charged particle. Since, speed remains constant, the kinetic energy also stays constant.

34.

(i) When Beryllium nuclei were blasted with alpha-particles, James Chadwick noticed the emission of neutral radiation in 1932. This neutral radiation was revealed to be capable of knocking protons from light nuclei such as helium, carbon, and nitrogen. Photons were the only type of neutral radiation known at the time. The principles of conservation of energy and momentum demonstrated that if the neutral radiation comprised of photons, the energy of the photons would have to be substantially larger than what was available from the bombardment of Beryllium nuclei with particles. As a result, Chadwick postulated that neutral radiation is composed of a new sort of neutral particle known as neutrons.

(ii) Radius of nucleus depends on the total number of neutrons and protons.

Let assume one nucleus has n_1 neutrons and p_1 protons. The second nucleus has n_2 neutrons and p_2 protons. If,

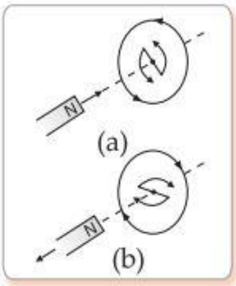
$$n_1 + p_1 = n_2 + p_2$$

then the radius of the two nuclei will be equal even though they are having different number of neutrons and different number of protons.

35.

Statement: The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

Explanation:

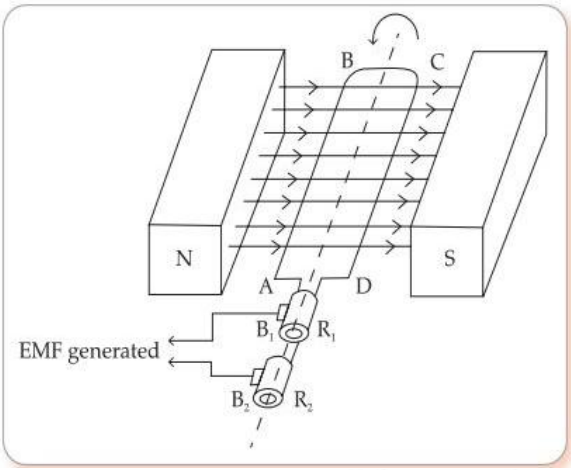


When the north pole of a bar magnet is pushed towards a close coil, the magnetic flux through the coil increases, and current is induced in the coil in a direction that opposes the increase in flux. This is achievable when the induced current in the coil rotates anti-clockwise. When the North Pole is moved away from the coil, the reverse phenomenon occurs.

In either case, it is the work done against the force of magnetic repulsion/attraction that gets 'converted' into the induced emf.

OR

AC generator:



Construction: An external force (such as steam, rushing water, etc.) rotates an n-turn coil, known as the armature, between the magnetic poles. Through the use of carbon brushes and slip rings, the ends of the coils are connected to an external circuit.

Principle of working: The laws electromagnetic induction of Faraday provide the basis for how an AC generator operates. According to it, an emf is induced across the ends of a conducting loop whenever the magnetic flux through the loop changes.

$$\varepsilon = -\frac{d\phi_B}{dt}$$

Working: The strong magnetic field is created between the poles. In this field, the coil ABCD is rotated by an outside source. The angle between the magnetic field and the coil fluctuates as the coil rotates, causing an alternating electromagnetic field to be produced. By using carbon brushes (B_1 & B_2) and slip rings (R_1 & R_2), the coil's ends are connected to an external circuit. An alternating current flows through the coil when the external circuit is closed.

Expression for emf produced: Here, B is the magnetic field produced by the magnet.

The coil is placed such that at $t = 0$, the angle between the surface area vector of the coil and the magnetic field is $\frac{\pi}{2}$.

ω = Angular speed of the coil angle between surface area vector of the coil and the magnetic field after time t is given by:

$$\theta = \theta_0 + \omega t$$

Magnetic flux through the coil is then:

$$\phi_B = \int B.dA$$

Or, $\phi_B = BA\cos\theta$

Or, $\phi_B = BA\cos(\theta_0 + \omega t)$

By Faraday's law of electromagnetic induction, magnitude of induced emf through a coil of n–turns is given by:

$$|\varepsilon| = n\frac{d\phi_B}{dt}$$

Or, $|\varepsilon| = n\frac{d}{dt}[BA\cos(\theta_0 + \omega t)]$

$\therefore$ $|\varepsilon| = nBA\omega\sin(\theta_0 + \omega t)$

36.

(i) The mass defect of a nucleus is the difference between the mass of a nucleus and the sum of the masses of its individual protons and neutrons. This difference arises due to the conversion of some mass into energy during the formation of the nucleus.

(ii) Nuclear radius of Al = 3.6 fermi (given)

Nuclear radius is given by: $R = R_0 A^{\frac{1}{3}}$ (where, A = mass number of the nucleus R_0 = Constant.)

$$\frac{R_{Fe}}{R_{Al}} = \left(\frac{A_{Fe}}{A_{Al}}\right)^{1/3}$$

$$= \left(\frac{125}{27}\right)^{1/3}$$

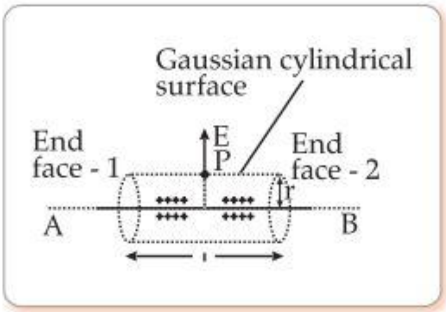
$$R_{Fe} = \frac{5}{3} R_{Al}$$

$$= \frac{5}{3} \times 3.6$$

$$= 6 \text{ fermi}$$

37.

(i)



The wire in AB is infinitely long.
E is the electric field. P is a position at a distance r from the axis of the wire.
The radius of a Gaussian cylinder is "r."
l stands for the Gaussian cylinder's length.
Let 'q' represent the charge contained within the Gaussian cylinder.
Let 'λ' represent the linear charge density of the wire.
Due to the absence of any electric field components along the normal to the end faces, there is no flux through the end faces.
ϕ = flux through curved surface
$\phi = E \times$ area of curved surface (ϕ = E × area)
'E' is pointed away from the wire in a direction that is perpendicular to it.

$$\phi = E \times 2\pi rl \quad ...(1)$$

From Gauss' Theorem,

$$\phi = \frac{q}{\varepsilon_0} \quad ...(2)$$

$$\because \quad \lambda = \frac{q}{l} \quad ...(3)$$

From (1), (2) and (3), we have;

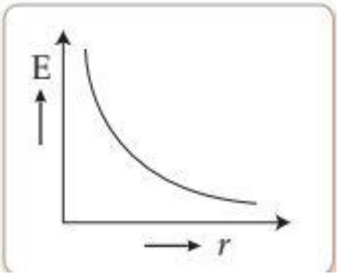
$$E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{1}{2\pi\varepsilon_0} \times \frac{\lambda}{r}$$

(ii) From the derived equation we can say that,

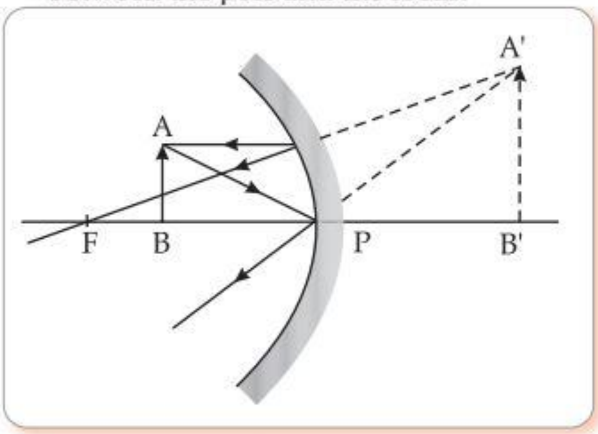
$$E \times r = \text{constant.}$$

Thus, the graph will be a rectangular hyperbola as shown below:

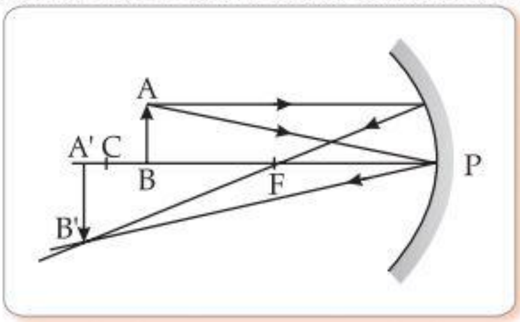


38.

(i) A magnified, virtual, and erect image is given by a concave mirror when the object is placed between the pole and the focus.



Concave mirrors produce an enlarged, real, and inverted image of the object when it is placed between the centre of curvature and the focus.



(ii) Given: focal length = 12 cm
Case I: For virtual image;

$$\frac{h'}{h} = -\frac{v}{u} = 3$$

$$\therefore \quad v = -3u$$

Using mirror formula:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

(f = focal length, u = object distance, v = image distance)

Or, $\frac{1}{-3u}+\frac{1}{u}=\frac{1}{-12}$

$\Rightarrow u = -8$ cm

Case II: For real image;

$$\frac{h'}{h}=-\frac{v}{u}=-3$$

$\therefore \quad v = 3u$

Again, putting in the mirror formula:

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

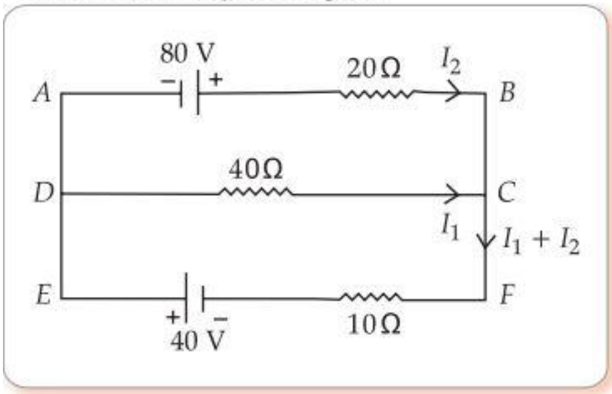
Or, $\frac{1}{3u}+\frac{1}{u}=\frac{1}{-12}$

$\therefore \quad u = -16$ cm

The distance between the two positions is 8 cm.

39.

Applying Kirchhoff's loop law in the two circuits shown in the adjacent figure:



In loop *ABCDA*,

$$+80 - 20I_2 + 40I_1 = 0$$

$$4 = I_2 - 2I_1 \quad ...(i)$$

In loop *FCDEF*,

$$-40I_1 - 10(I_1 + I_2) + 40 = 0$$

$$-50I_1 - 10I_2 + 40 = 0$$

$$5I_1 + I_2 = 4 \quad ...(ii)$$

Solving these two equations, we get

$$I_1 = 0\,A$$

$$I_2 = 4\,A$$

40.

Three points of difference

Paramagnetic	Diamagnetic	Ferromagnetic
These are substances in which each individual atom possesses a magnetic moment that is not zero.	These substances lack any net magnetic moments inside their individual atoms.	These are the substances that contain atoms that have a net magnetic moment that is not zero.
Positive and low magnetic susceptibility is present.	Low and negative magnetic susceptibility	Positive and strong magnetic susceptibility is present.
It weakly attracts and tends to move from weaker sections of the field to stronger parts when there is a non-uniform magnetic field present.	It repels and tends to move from stronger sections of the field to weaker parts when there is a non-uniform magnetic field present.	It strongly attracts and moves readily from weaker sections of the magnetic field to stronger parts when there is an uneven magnetic field present.
For example: Titanium	For example: Copper	For example: Iron

41.

(i) Primary conduction factor of semiconductors is the quantity of free electrons present. The kinetic energy of the unbound electrons is temperature-dependent. At 0 K the kinetic energy is zero and the free electrons can no more conduct. So, a semiconductor behaves as an insulator.

(ii) **(a)** **Forward bias:** The P side of a PN junction has at higher positive potential than the N side of the *pn*-junction.

(b) **Reverse bias:** *P* side is at zero potential (lower) and the *N* side is at positive potential (higher) of the *pn*-junction.

(c) **Forward bias:** While the *N* side has a higher negative potential, the *P* side has a lower negative potential of the *pn*-junction.

(d) **Reverse bias :** *P* is at lower (negative) potential and the *N* side is at zero potential (higher) of the *pn*-junction.

42.

(i) In Circuit (a)

If ω is lowered, then capacitive reactance $\frac{1}{\omega C}$ increases.

Also, the R.M.S value of the current is given by $I_{r.m.s.}=\frac{V_{r.m.s.}}{\sqrt{R^2+X_C^2}}$ becomes low.

Thus, the bulb glows dimmer.

In Circuit (b)

Because X_c is greater for lower ω, less current passes through the capacitor arm. The majority of the current, however, passes via the inductor arm since inductive reactance ($X_L = \omega L$) is small.

Thus, lamp glows brighter.

(ii) In Circuit (a)

If ω is increased, then capacitive reactance $X_C = \frac{1}{\omega C}$ decreases.

Also, the R.M.S value of the current is given by $I_{r.m.s.}=\frac{V_{r.m.s.}}{\sqrt{R^2+X_C^2}}$ increases.

Thus, the bulb glows brighter.

In Circuit (b)

The inductive reactance increases and the capacitive reactance decreases as ω rises. As a result, the capacitive arm experiences greater current flow than the inductive arm. The bulb dims as a result.

(iii) If $\omega = 0$ the power supply becomes dc.

In Circuit (a)

$$X_C = \infty$$

$$\therefore \qquad I_{rms} = 0$$

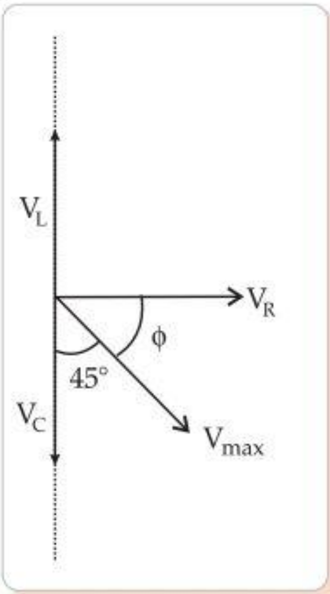
And, hence, bulb does not glow at all.

In Circuit (b)

The capacitive arm conducts no current. The inductor arm receives the maximum current. The bulb grows the brightest.

OR

(i) Phasor Diagram:



(ii) Given: Voltage across the capacitor lags input voltage by 45°

Phase angle (ϕ) = 90° – 45° = –45°

(iii) Inductor = L, Resistor = R, Capacitance = C

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R}$$

$$\tan(-45°) = -\tan 45° = -1$$

So, $$\frac{\omega L - \frac{1}{\omega C}}{R} = -1$$

$$L = \frac{97}{9} = 10.7 \text{ H}$$

43.

When fast moving neutrons hit Uranium, the following reaction takes place:

$$^{238}_{92}\text{U} + ^{0}_{1}n \rightarrow ^{238}_{92}\text{U} \rightarrow ^{140}_{58}\text{Ce} + ^{99}_{44}\text{Ru} + 10\ ^{0}_{-1}e$$

Mass defect Δm = [Initial mass – Final mass]

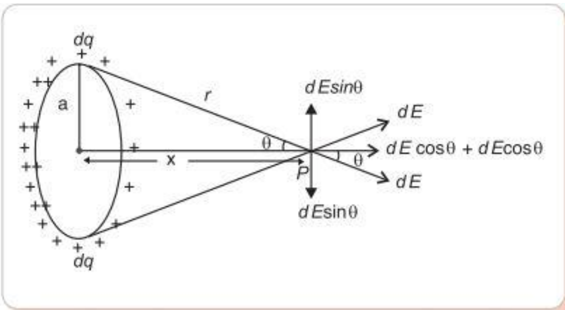
$\Delta m = (238.05079 + 1.008665 - 139.90543 - 98.90549)u$

[neglecting mass of electron]

Or, $\Delta m = 0.24835$ u

Thus, $Q = 0.24835 \times 931 = 231.386085 = 231.386$ MeV

44.



Net Electric Field at point $P = \int_0^{2\pi a} dE\cos\theta$

(Where dE = Electric field due to a small element having charge dq)

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$$

Let λ = Linear charge density

$$= \frac{dq}{dl}$$

$$dq = \lambda dl$$

Hence, $$E = \int_0^{2\pi a}\frac{1}{4\pi\varepsilon_0}\cdot\frac{\lambda dl}{r^2}\times\frac{x}{r} \quad \left(\text{where } \cos\theta = \frac{x}{r}\right)$$

$$= \frac{\lambda x}{4\pi\varepsilon_0 r^3}(2\pi a)$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(x^2+a^2)^{\frac{3}{2}}},$$

where total charge $Q = \lambda \times 2\pi a$

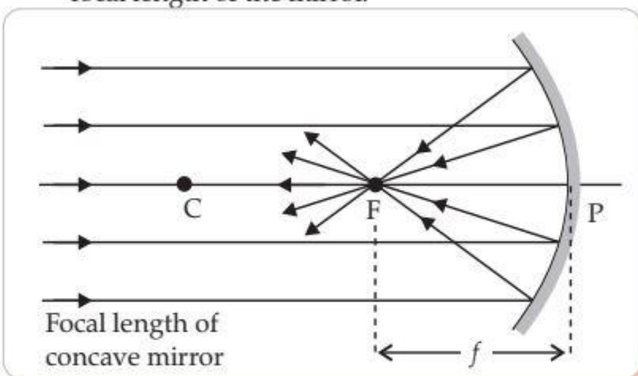
Now, for large distance i.e., $x >> a$

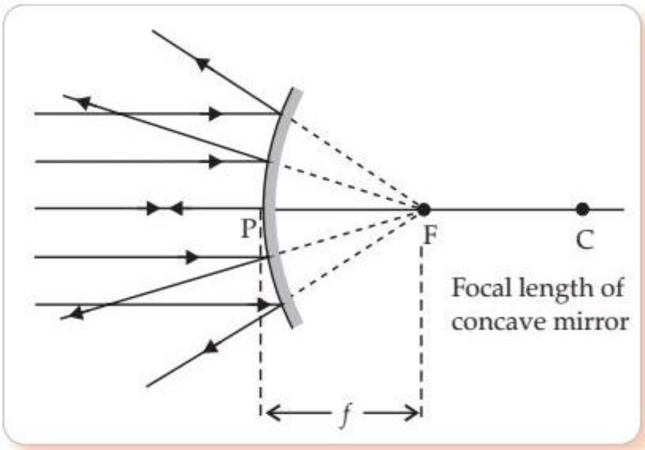
$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{x^2}$$

This is the electric field due to a point charge at distance x.

45.

Focal length of mirror: When rays of light parallel to the principal axis of a mirror is incident on it, the rays after reflection, either converge at a point or appear to diverge from a point. The distance of this point from the pole of the mirror is known as the focal length of the mirror.





Relation between focal length and radius of curvature:

A ray of light BP′ travelling parallel to the principal axis PC is incident on a spherical mirror PP′. It reflects along P′R.

For concave mirror, it passes through the focus. For convex mirror while extending the ray backward, it appears to pass through the focus.

P is the pole and F is the focus of the mirror.

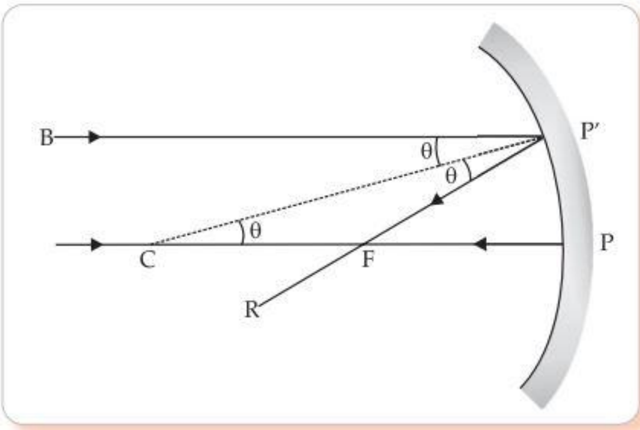
$PF = f$.

C is the centre of curvature.

PC = Radius of curvature = R

P′C is the normal to the mirror at the point of incidence P′.

For concave mirror,



and $\angle BP'C = \angle P'CF = \theta$ (alternate angles)

$\angle BP'C = \angle CP'F = \theta$ (law of reflection, $\angle i = \angle r$)

Again, $\angle P'CF = \angle CP'F$

$\therefore \Delta FP'C$ is isosceles.

Hence, $P'F = FC$

If the aperture of the mirror is small, the point P′ is very close to the point P,

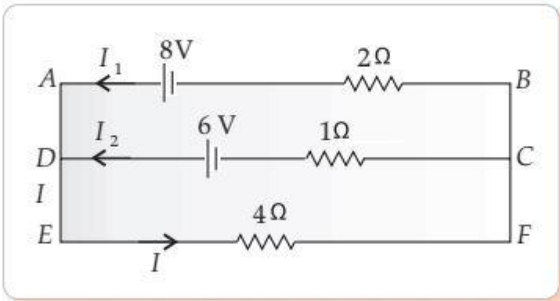
Then $P'F = PF$

$\therefore \quad PF = FC$

$$= \frac{1}{2} PC$$

$$\therefore \quad f = \frac{1}{2} R$$

46.



$$I = I_1 + I_2 \quad \text{...(i)}$$

In loop $ABCDA$,

$$-8 + 2I_1 - 1 \times I_2 + 6 = 0 \quad \text{...(ii)}$$

In loop $DEFCD$,

$$-4I - 1 \times I_2 + 6 = 0$$

$$4I + I_2 = 6$$

$$4(I_1 + I_2) + I_2 = 6$$

$$4I_1 + 5I_2 = 6 \quad \text{...(iii)}$$

From equations (i), (ii) and (iii), we get

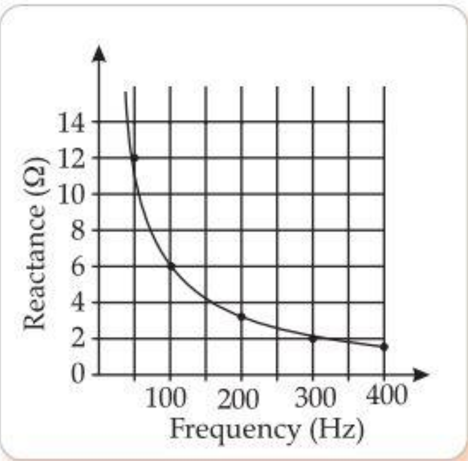
$$I_1 = \frac{8}{7}\text{ A},\ I_2 = \frac{2}{7}\text{ A},\ I = \frac{10}{7}\text{ A}$$

Potential difference across resistor 4 Ω is :

$$V = \frac{10}{7} \times 4 = \frac{40}{7}\text{ volt}$$

47.

(i)



We know that for AC source capacitor reactance,

$$X_C = \frac{1}{\omega C}$$

$$\Rightarrow \quad X_C = \frac{1}{2\pi f C} \quad \text{...(i)}$$

(Where f = frequency in hertz)

Here, a point on the graph is (100, 6).

So, when f = 100 Hz, $X_C = 6$

Putting these values in equation (i)

$$\Rightarrow \quad 6 = \frac{1}{2\pi \times 100 \times C}$$

$$\Rightarrow \quad 2\pi \times 100 \times C = \frac{1}{6}$$

$$\Rightarrow \quad C = \frac{7}{1200 \times 22} F$$

$$\Rightarrow \quad C = 2.65 \times 10^{-4} F$$

(ii) The inductance of inductor is L.

So, $6 = 2\pi \times 100 \times L$

$$\Rightarrow \quad L = \frac{6}{200\pi} H$$

$$\therefore \quad L = 0.954 \times 10^{-2} H$$

48.

From the observations made (surfaces A and B) based on Einstein's photoelectric equation ($K.E. = h\nu - \varphi_0$), we can draw following conclusions:

(i) For surface A, the threshold frequency is more than 10^{15} Hz, hence no photo-emission is possible.

(ii) For surface B the threshold frequency is equal to the frequency of given radiation. Thus, photo-emission takes place but kinetic energy of photoelectrons is zero.

(iii) For surface C, the threshold frequency is less than 10^{15} Hz. So, photo-emission occurs and photoelectrons have some kinetic energy.

49.

(i) Since, at point N, the angle of refraction is 90°, then $\angle r_2$ is the critical angle for the glass-air pair of media.

And we know that, $\sin \theta_c = \frac{1}{\mu}$

(where μ is the refractive index of medium)

$$\sin \angle r_2 = \frac{1}{\mu}$$

$$= \frac{1}{\sqrt{2}}$$

$$\angle r_2 = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$$

(ii) The expression for angle of minimum deviation of the prism is given by:

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

(where A = prism angle, δ_m = angle of minimum deviation)

Or, $$\sqrt{2} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin\frac{60°}{2}}$$

Or, $$\sqrt{2} = \frac{\sin\left(30° + \frac{\delta_m}{2}\right)}{\frac{1}{2}}$$

Or, $$0.7 = \sin\left(30° + \frac{\delta_m}{2}\right)$$

Or, $$\sin^{-1} 0.7 = 30° + \frac{\delta_m}{2}$$

Or, $$44.4° = 30° + \frac{\delta_m}{2}$$

$$\therefore \quad \delta_m = 28.8°$$

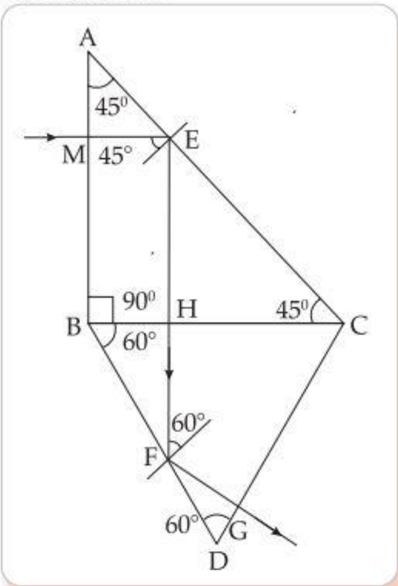
OR

(i) Necessary conditions for total internal reflection:

(a) Light should travel from denser to rarer medium.

(b) Angle of incidence should be greater than the critical angle for the pair of media and the colour of light used.

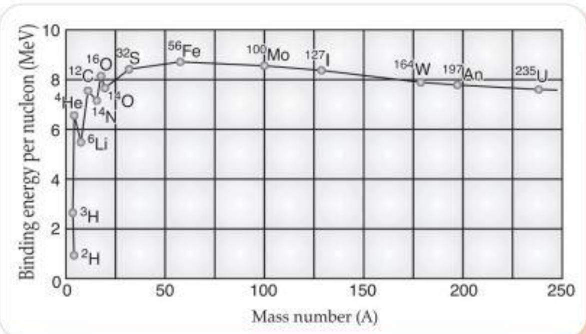
(ii) A ray of light enters normally at point M, but at point E, where the angle of incidence is 45° and exceeds the critical angle, the ray undergoes total internal reflection.



When the light ray reaches point H and enters prism BDC normally, it continues undeviated. The ray, however, undergoes internal reflection at point F, where the angle of incidence is 60 degrees and exceeds the critical angle. Finally, when the ray arrives at point G, it enters and exits the prism normally.

50.

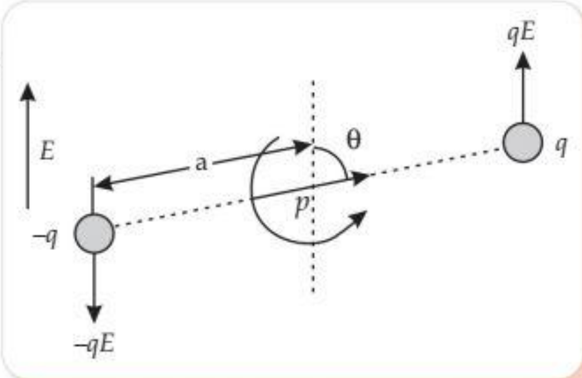
The value of binding energy per nucleon provides a measure of a stability of nucleus.; higher the binding energy per nucleon, more stable is the nucleus.



From the graph we find that there is gain in binding energy when we move from the heavy nuclei region to the middle region. This indicates that energy can be released when a heavy nucleus breaks into two roughly equal fragments. This process is called nuclear fission. Similarly, when we move from lighter nuclei to heavier nuclei, we again find that there is a gain in the binding energy. This indicates that energy can be released when two or more lighter nuclei fuse to form a heavy nucleus. This process is called nuclear fusion.

51.

(i)



Let us suppose a dipole as shown in the above figure:

Then, force on $+q$, $\overline{F} = q\overline{E}$

Force on $-q$, $\overline{F} = -q\overline{E}$

Then, magnitude of torque is given by,

$$\tau = qE \times 2a \sin\theta$$
$$= 2qa\,E \sin\theta$$
$$\vec{\tau} = \vec{p} \times \overline{E}$$

(ii) If the electric field is non-uniform, the dipole experiences a translatory force as well as a torque.

52.

The mirror formula is: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Where, v is the image distance, u is the object distance and f is the focal length of the mirror, for plane mirror, $f = \infty$.

Hence, $$\frac{1}{v} + \frac{1}{u} = \frac{1}{\infty}$$

$$\frac{1}{v} + \frac{1}{u} = 0$$

$\Rightarrow$ $$v = -u$$

From the above result we can conclude that the image distance is equal to the object distance and image lies to the opposite side of the object.

This is true particularly in the case of a plane mirror.

Hence, we can say that spherical mirror formula holds equally true for a plane mirror.

53.

Using Kirchhoff's voltage rule, we have :

For loop *DABD*,

$(1 \times I_1) + (1) + (-2) + 2I_1 + 2(I_1 + I_2) = 0$

Or, $5I_1 + 2I_2 = 1$ ...(i)

For loop *DCBD*,

$(I_2 \times 3) + (3) + (-1) + (1 \times I_2) + 2(I_1 + I_2) = 0$

Or, $2I_1 + 6I_2 = -2$ ...(ii)

Solving (i) and (ii), we get

$$I_1 = \frac{5}{13}\text{A}$$

$$I_2 = \frac{-6}{13}\text{A}$$

∴ Current through *DB*

$$= I_1 + I_2$$
$$= \frac{-1}{13}\text{A}$$

(here, the –ve sign denotes that the direction of current is opposite to the direction we have assumed)

∴ Potential difference between *B* and $D = (I_1 + I_2)R$

$$= \frac{1}{13} \times 2 = 0.154\text{ V}$$

54.

(i) (a) Impedance of an LCR circuit is given by

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

For the impedance to be minimum $(X_L - X_C)^2 = 0$

Or, $X_L = X_C$

(b) For wattless current to flow, the circuit should not have any Ohmic resistance i.e., $R = 0$.

(ii) Selectivity depends on quality factor.

Quality factor (Q) of LCR circuit is

$$Q = \frac{\omega_0 L}{R}$$

Q will be large when R is low and L is large and then the circuit will be more selective.

55.

(i) Energy $= E = \dfrac{hc}{\lambda}$

Or, $E = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{331.5 \times 10^{-9}}$

∴ $E = 6 \times 10^{-19}$ J

Momentum $= p = \dfrac{h}{\lambda}$

Or, $p = \dfrac{6.6 \times 10^{-34}}{331.5 \times 10^{-9}}$

∴ $p = 2 \times 10^{-27}$ kg.m/s

(ii) Momentum of Hydrogen atom $= p = 2 \times 10^{-27}$ kg.m/s

$p = mv$

Or, $v = \dfrac{p}{m}$

Or, $v = \dfrac{2 \times 10^{-27}\text{ kg.m/s}}{1\text{ a.m.u.}}$

Or, $v = \dfrac{2 \times 10^{-27}\text{ kg.m/s}}{1.66 \times 10^{-27}\text{ kg}}$

∴ $v = 1.2$ m/s

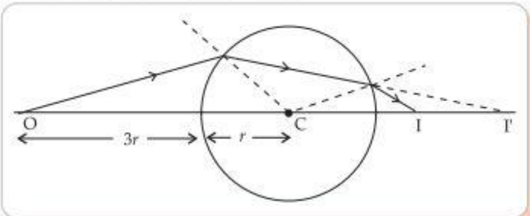
56.

(i) The conditions for a converging lens are:

(a) Magnification is negative for real image formed by convex lens.

(b) Magnification is positive for virtual image formed by convex lens.

(ii)



OR

(i) The prism angle of a prism is the angle made by the two refracting faces of the prism with each other.

(ii) **(a)** Refractive index = $\mu = 1.5$

Radius of curvature of convex side = 25 cm

$$= \frac{25}{100}\text{ m}$$

Radius of curvature of plane side = ∞

Applying lens maker's formula,

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

Where f is the focal length of the lens; μ is refractive index and R_1 and R_2 are the radii of the curvature of both surfaces.

Or, $$\frac{1}{f} = (1.5-1)\left(\frac{1}{\infty} + \frac{100}{25}\right)$$

Or, $$\frac{1}{f} = 0.5 \times \left(\frac{100}{25}\right)$$

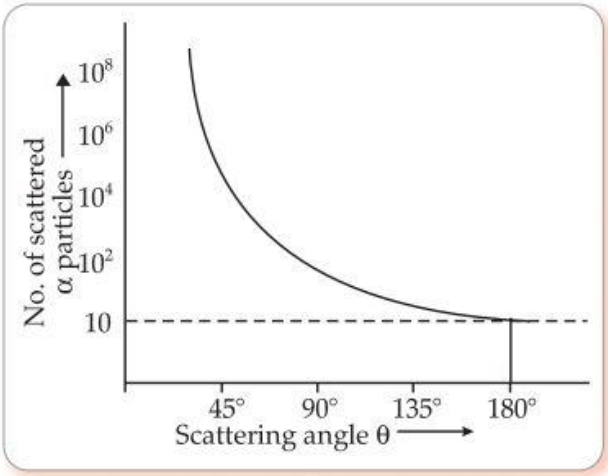
$\therefore$ $$f = \frac{25}{50}\text{ m} = 50\text{ cm}$$

(b) Focal length $= f = 50$ cm

Object distance $= u = -50$ cm

When the object distance = focal length, then the image is formed at infinity. The image is real, inverted and highly magnified.

57.

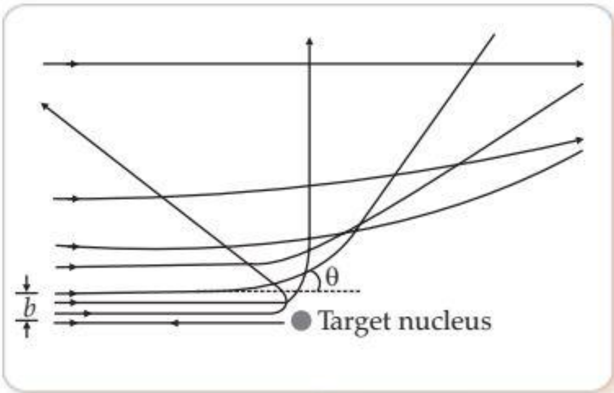


The graph shows that a large number of α-particle do not suffer large angle scattering and very few number of alpha particle suffers large angle scattering. Thus it is concluded that

(a) the massive positively charged nucleus concentrated in a small region

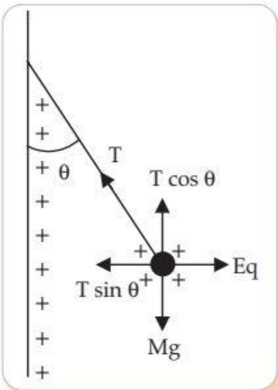
(b) most of the space is empty in an atom

Impact parameter picture:



The trajectory traced by an α-particle depends on the impact parameter, b. The impact parameter is the perpendicular distance of the initial velocity vector of the α-particle from the centre of the nucleus. So, the measurement of b gives a powerful idea for the upper limit of the size of the target nucleus. A given beam of α-particles has a distribution of impact parameters b, so that the beam is scattered in various directions. It is seen that an α-particle close to the nucleus (small impact parameter) suffers large scattering. In case of head-on collision, the impact parameter is minimum and the α-particle rebounds back ($\theta \approx \pi$). So, measurement of the minimum impact parameter for these α-particles gave the upper limit of the size of the target nucleus.

58.



Mg = Weight of the ball acting downward.

Eq = Electrostatic repulsive force (where $E = \sigma/2\varepsilon_0$)

T = Tension of the string.

$T\cos\theta$ component balances Mg.

$\therefore$ $$T\cos\theta = Mg \quad \text{...(i)}$$

$T\sin\theta$ component balances Eq.

$\therefore$ $$T\sin\theta = Eq = \frac{\sigma q}{2\varepsilon_0} \quad \text{...(ii)}$$

Dividing equation (ii) by (i)

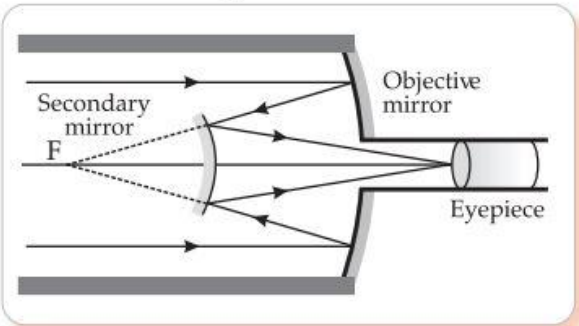
$$\frac{T\sin\theta}{T\cos\theta} = \frac{\sigma q}{2\varepsilon_0 Mg}$$

Or, $$\tan\theta = \frac{\sigma q}{2\varepsilon_0 Mg}$$

∴ $$\theta = \tan^{-1}\left(\frac{\sigma q}{2\varepsilon_0 Mg}\right)$$

59.

Initially, parallel light rays from an infinite distance strike the concave objective mirror.



These are incident on a secondary convex mirror after reflection. At F, a virtual image develops. The rays meet at a spot to create a true image that is seen through the eyepiece after reflection by the convex mirror.

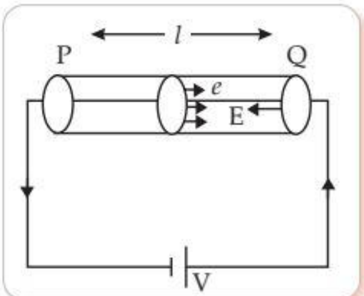
Advantages of reflecting telescope over refracting telescopes:

- Mirrors can be manufactured to be larger than lenses.
- Chromatic aberrations don't exist.

60.

(i) The capacity of a metallic wire to transmit heat or electric charges is known as its conductivity. Numerically conductivity is reciprocal of resistivity. Its SI unit is mho m^{-1} (U/m).

(ii) The total number of free electrons in conductor *PQ* of length *l* and cross section A is $N = n \times$ volume of conductor *PQ*, where *n* is the number of electrons per unit volume in a conductor.



Expression for the conductivity of a wire in terms of current density and relaxation time:

Relation between drift velocity and current,

$$i = neAv_d$$

Or, $$\frac{V}{R} = neAv_d \qquad \left[\text{since } i = \frac{V}{R}\right]$$

Or, $$V = neAv_dR$$

Or, $$El = \frac{neAv_d\rho l}{A}$$

[since $V = El$ and $R = \rho l/A$]

Or, $$E = nev_d\rho$$

Or, $$E = ne\rho\left(\frac{eE\tau}{m}\right)$$

[since $v_d = eE\tau/m$]

Or, $$1 = \frac{ne^2\rho\tau}{m}$$

Or $$\frac{1}{\rho} = \frac{ne^2\tau}{m}$$

∴ $$\sigma = \frac{ne^2\tau}{m} \qquad [\text{since } 1/\rho = \sigma]$$

Relation between current density and electric field:

$$i = neAv_d$$

Or, $$\frac{i}{A} = nev_d$$

Or, $$j = nev_d \qquad [\text{since } i/A = j]$$

Or, $$j = ne\left(\frac{eE\tau}{m}\right)$$

[since $v_d = eE\tau/m$]

Or, $$j = \frac{ne^2\tau E}{m}$$

∴ $$j = \sigma E \qquad [\text{since } \sigma = ne^2\tau/m]$$

61.

(i) (a) Resonance frequency, $\omega_0 = \frac{1}{\sqrt{LC}}$

Or, $$\omega_0 = \frac{1}{\sqrt{50\times10^{-3}\times80\times10^{-6}}}$$

Or, $$\omega_0 = 500$$

Or, $$2\pi f = 500$$

∴ $$f = \frac{500}{2\pi} = 80\text{ Hz}$$

(b) Quality factor $= Q = \frac{\omega_0 L}{R}$

Or, $$Q = \frac{500\times50\times10^{-3}}{40}$$

∴ $$Q = 0.625$$

(ii) The power factor of a series LCR circuit at resonance is unity.

62.

(i) Speed of the alpha particle can be found from the expression

$$\frac{1}{2}mv^2 = qV$$

Or, $$\frac{1}{2}mv^2 = 2e \times 100$$

(Since, potential difference is 100 V)

Or, $$mv^2 = 400 \text{ eV}$$

$$v = \sqrt{\frac{400\text{ eV}}{m}}$$

$$v = \sqrt{\frac{400 \times 1.6 \times 10^{-19}}{6.4 \times 10^{-27}}}$$

$$v = 10^5 \text{ m/s}$$

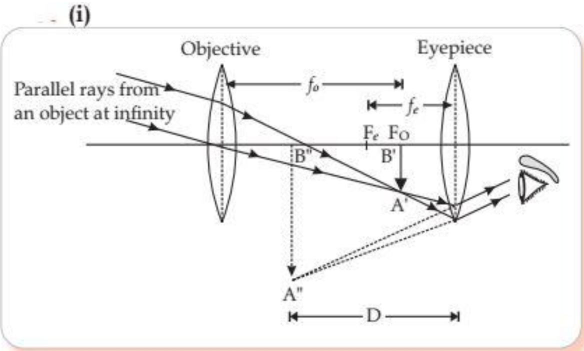
(ii) de-Broglie wavelength = $\lambda = \frac{h}{\sqrt{2mqV}}$

Or, $$\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 6.4 \times 10^{-27} \times 2 \times 1.6 \times 10^{-19} \times 100}}$$

$\therefore$ $$\lambda = 1.03 \times 10^{-12} \text{ m}$$

63.

(i)



(ii) Angular magnification of the telescope = $\frac{f_o}{f_e}$

(where f_o and f_e are the focal length of the objective and eyepiece respectively).

Angular magnification = $\frac{15}{0.01} = 1500$

For objective lens, $\tan\alpha = \frac{3.48 \times 10^6}{3.8 \times 10^8}$

For eyepiece, $\tan\theta = \frac{\text{diameter of moon}}{\text{distance of moon from earth}}$

$$= \frac{h_i}{f_e} = \frac{h_i}{10^{-2}}$$

$\therefore$ Magnifying power = $\frac{\beta}{\alpha} = \frac{\frac{h_i}{10^{-2}}}{\frac{3.48 \times 10^6}{3.8 \times 10^8}}$

$$1500 = \frac{h_i \times 3.8 \times 10^8}{3.48 \times 10^6 \times 10^6}$$

$$h_i = 15 \text{ cm}$$

OR

(i) Condition of two light sources to be coherent:

- The two sources of light must be derived from a single source.
- The source must be monochromatic in nature.

(ii) Distance between two consecutive bright bands = fringe width.

Fringe width = $\frac{D\lambda}{2d}$

$$= \frac{(100) \times (6 \times 10^{-5})}{(0.1)}$$

$$= 0.06 \text{ cm}$$

64.

(i) Limitation of Bohr's atomic model:

(a) It can not explain the line spectrum of multi electron atoms.

(b) This model fails to explain Zeeman effect and Stark effect.

(ii) $\bar{\nu}$ = antineutrino is the elementary particle emitted along with proton and electron in nuclear reaction.

$p+$ = proton e^- = electron $n°$ = free neutron

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

65.

(i) The torque on a dipole is given:

$\tau = pE \sin\theta$ (p = dipole moment, E = electric field)

Integrate the work done from θ_1 to θ_2 to find the work done:

$$W = \int_{\theta_1}^{\theta_2} pE\sin\theta$$

$$= pE(\cos\theta_1 - \cos\theta_2) \quad \text{...(i)}$$

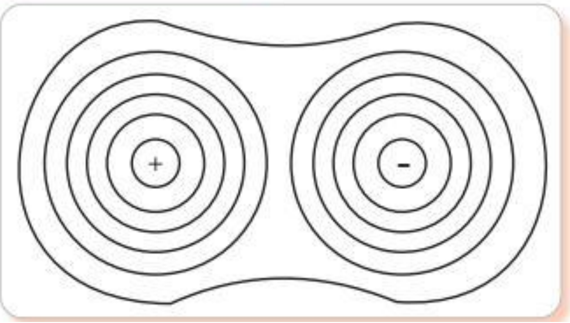
According to the question $\theta_1 = 0°$ & $\theta_2 = 180°$

On Substituting the values, in above equation 1

$$W = pE(\cos 0° - \cos 180°)$$

$$= pE(1 + 1) = 2pE$$

(ii) Equipotential surfaces for an electric dipole:



66.

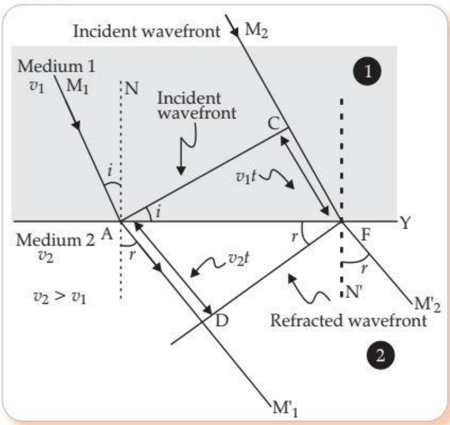
The ratio of the sine of the angle of incidence in medium 1 to the sine of the angle of refraction in medium 2 represents the refractive index of medium 2 in relation to medium 1.

Refractive index of medium 2 with respect to medium 1:

$$_1\mu_2 = \frac{\sin i}{\sin r}$$

$$= \frac{\text{Velocity of light in medium 1}}{\text{Velocity of light in medium 2}}$$

Verification of Snell's law of refraction when a plane wavefront is propagating from a denser to a rarer medium:



AB is the plane wavefront incident on XY, the plane of separation of two media.

Medium 1 is denser. Velocity of light = v_1.

Medium 2 is rarer. Velocity of light = v_2.

When wavelet from C reaches F, by that time wavelet from A reaches D.

So, $AD = v_2 t$ and $CF = v_1 t$

M_1A and M_2F are the perpendiculars to the incident waveform and are the incident rays.

M'_1A and M'_2F are the perpendiculars to the refracted waveform and are the refracted rays.

$$\angle M_1AN = \text{angle of incidence}$$
$$\angle M'_2FN' = \text{angle of refraction}$$
$$\angle CAF = 90° - \angle NAC$$
$$= \angle M_1AC - \angle NAC$$
$$= \angle M_1AN$$
$$= \angle i$$

Similarly, $\angle AFD = \angle r$

In ΔACF,

$$\sin i = \frac{CF}{AF} = \frac{v_1 t}{AF}$$

In ΔADF,

$$\sin r = \frac{AD}{AF} = \frac{v_2 t}{AF}$$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \text{constant} = {}_1\mu_2$$

This is Snell's law.

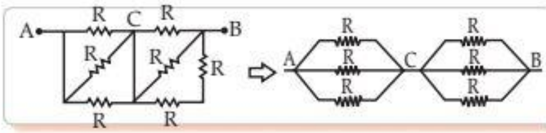
67.

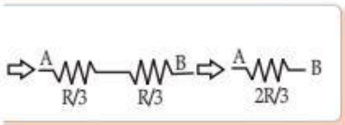
(i) Between A and C points three resistors each of value R are connected in parallel.

$$R_{AC} = \frac{R}{3}$$

Between C and B points three resistors each of value R are connected in parallel.

$$R_{BC} = \frac{R}{3}$$





These two $R/3$ resistors are connected in series. Hence, the equivalent resistance between A and B is $2R/3$.

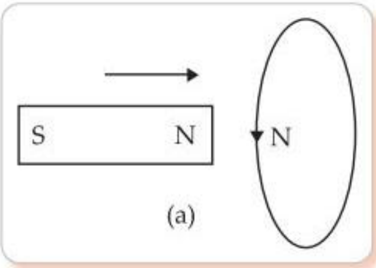
(ii) For very low resistance measurement, the value of unknown resistance becomes almost equal to the resistance of the connecting wires and hence, errors may creep into the measurement.

For very high value resistance measurement, the current through the branch becomes very low and hence it becomes difficult to find the null point (zero deflection of the galvanometer).

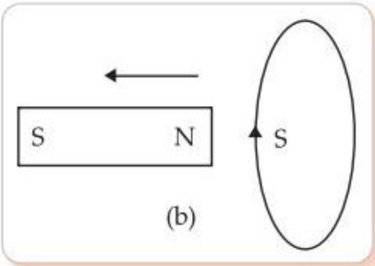
For these reasons, very high and very low resistance cannot be measured correctly by using Wheatstone bridge.

68.

Lenz's law: According to this law, the direction of an induced current in a closed circuit is always in such a way as to create a magnetic field that opposes the change that caused it. For instance, when the north pole of a magnet is brought near a closed coil, the induced current in the coil will flow in a direction that creates a magnetic field that opposes the approaching north pole. Consequently, the side of the coil facing the magnet will behave as a north pole, requiring an anticlockwise current flow in the coil when observed from the side of the magnet.



Similarly, when the north pole of a magnet is moved away from a coil, the induced current in the coil will flow in a direction that creates a magnetic field that attracts the magnet. As a result, the side of the coil facing the magnet will behave as a south pole, leading to a clockwise current flow in the coil when observed from the side of the magnet.



According to the conservation of energy in Lenz's Law, whenever there is relative motion between a coil and a magnet, a force arises that opposes this motion. As a result, to sustain the relative motion, mechanical work must be performed, which is then converted into electric energy in the coil. Therefore, Lenz's law is founded on the principle of energy conservation.

69.

(i) Frequency of incident radiaton

$$\nu = 6.4 \times 10^{14} \text{ Hz}$$

Energy of the incident radiation,

$$E = h\nu = 6.6 \times 10^{-34} \times 6.4 \times 10^{14}$$
$$= 42.24 \times 10^{-20} \text{J}$$

(ii) $KE_{max} = h\nu - \phi_0$

$\therefore$ $KE_{max} = 42.24 \times 10^{-20} - 2.31 \times 1.6 \times 10^{-19}$

$$= 5.28 \times 10^{-20} \text{ J}$$

(iii) If stopping potential $= V_S$, then

$$eV_S = KE_{max}$$

$$\therefore \quad V_S = \frac{KE_{max}}{e}$$

$$= \frac{5.28 \times 10^{-20}}{1.6 \times 10^{-19}}$$

$$= 3.3 \times 10^{-1} = 0.33 \text{ V}$$

70.

The angular width of the central maximum in a single slit diffraction pattern can be expressed as

$$2\theta = \frac{2\lambda}{a}$$

(i) The angular width of the central maximum in a single slit diffraction pattern is proportional to the wavelength of the light used. When comparing orange light, which has a longer wavelength, to green light, which has a shorter wavelength, the angular width of the central maximum will be greater when orange light is used instead of green light.

(ii) The angular width of the central maximum in a single slit diffraction pattern remains constant regardless of the distance between the slit and the screen. Therefore, if the screen is moved closer to the slit, there will be no change in the angular width of the central maximum.

(iii) Angular width of central maxima $\propto \dfrac{1}{\text{slit width}}$

So, if the slit width is decreased, the angular width of the central maxima will increase.

OR

(i) Both the Maxwell's electromagnetic theory and Huygens' wave theory consider light as a wave phenomenon. However, they differ in their explanation of how light propagates. According to the Maxwell's electromagnetic theory, light is a transverse wave and can propagate through empty space without the need for a medium. In contrast, Huygens' wave theory suggests that light is a longitudinal wave and a medium is required for the propagation of light waves. To account for this, Huygens introduced the concept of a hypothetical medium called "ether" through which light waves were assumed to travel even in a vacuum. But later this idea was discarded.

(ii) The angle formed between the incident wavefront and the interface is known as the angle of incidence of light.

Sure shots (5 Marks) Solution

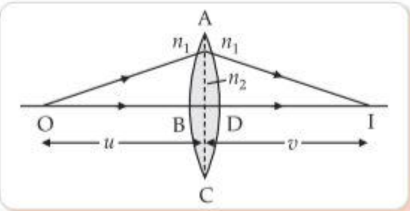
1.

31. **(i)** DIAGRAM/S :

DERIVATION :

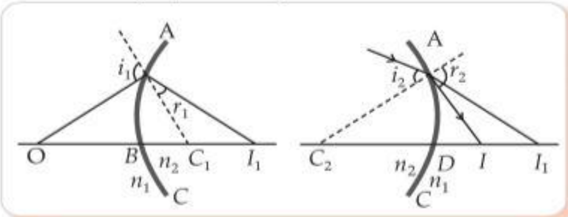
NUMERICAL :

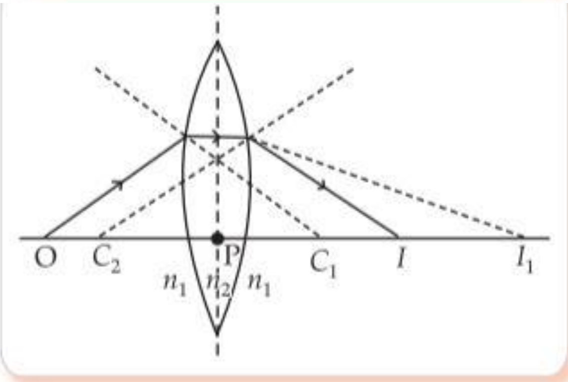
Lens maker's Formula



When a ray refracts from a lens (double convex), in above figure, then its image formation can be seen in term of two steps:

Step 1: The first refracting surface forms the image I_1 of the object O





Step 2: The image of object O for first surface acts like a virtual object for the second surface. Now for the first surface ABC, ray will move from rarer to denser medium, then

$$\frac{n_2}{B_1} + \frac{n_1}{OB} = \frac{n_2 - n_1}{BC_1} \quad ...(i)$$

Similarly for the second interface, ADC we can write.

$$\frac{n_1}{DI} - \frac{n_2}{DI_1} = \frac{n_2 - n_1}{DC_2} \quad ...(ii)$$

DI_1 is negative as distance is measured against the direction of incident light.

Adding equation (i) and equation (ii), we get

$$\frac{n_2}{BI_1} + \frac{n_1}{OB} + \frac{n_1}{DI} - \frac{n_2}{DI_1} = \frac{n_2 - n_1}{BC_1} + \frac{n_2 - n_1}{DC_2}$$

or $$\frac{n_1}{DI} + \frac{n_1}{OB} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \quad ... (iii)$$

($\because$ for thin lens $BI_1 = DI_1$)

Now, if we assume the object to be at infinity i.e. $OB \to \infty$, then its image will form at focus F (with focal length f), i.e.

$DI = f$, thus equation (iii) can be rewritten as

$$\frac{n_1}{f} + \frac{n_1}{\infty} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right)$$

or $$\frac{n_1}{f} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \quad ... (iv)$$

Now according to the sign conventions

$$BC_1 = +R_1 \text{ and } DC_2 = -R_2 \quad ...(v)$$

Substituting equation (v) in equation (iv), we get

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

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

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

(ii) $$\frac{1}{f_a} = (1.6 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ...(i)$$

$$\frac{1}{f_l} = \left[\frac{1.6}{1.3} - 1\right]\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ...(ii)$$

From equation (i) and (ii)

$$\frac{f_l}{f_a} = \left[\frac{0.6}{0.3} \times 1.3\right]$$

$\Rightarrow f_l = 2.6 \times 10$ cm

$\Rightarrow f_l = 26$ cm

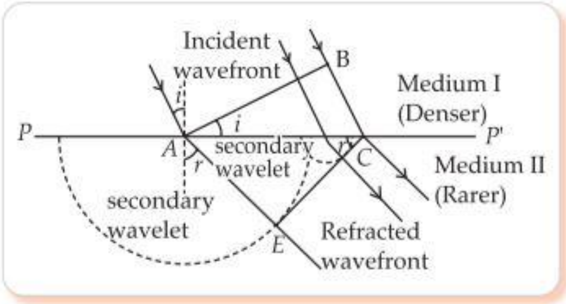
OR

(i) A wave front is defined as a surface of constant phase.

(a) The ray indicates the direction of propagation of wave while the wave front is the surface of constant phase.

(b) The ray at each point of a wave front is normal to the wave front at that point.

(ii) Diagram showing the passage of a plane wavefront from a denser to a rarer medium using Huygens's construction of secondary wavelets:



Verification of Snell's law:

AB is the Incident Plane Wave Front

CE is Refracted Wave front .

$$\sin i = \frac{BC}{AC}$$

$$\sin r = \frac{AE}{AC}$$

$$\frac{\sin i}{\sin r} = \frac{BC}{AE}$$

Time t is taken to reach the wave front to reach B to C in medium I.

If v_1 is velocity of light in medium I, then BC = $v_1 t$.

Time t is taken to reach the wave front to reach reach A to E in medium II.

If v_2 is velocity of light in medium II, then AC = $v_2 t$.

So, $\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2}$

This is Snell's law.

(iii) $d = \frac{\lambda}{\theta} = \frac{6 \times 10^{-7}}{0.1 \times \frac{\pi}{180}} = 3.4 \times 10^{-4}$ m

(iv) Two differences between interference pattern and diffraction pattern

(a) Diffraction occurs due to superposition of secondary wavelets.

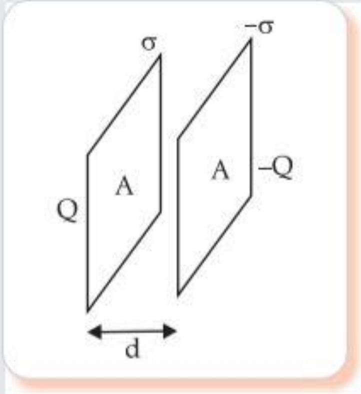
Interference occurs due to the superposition of light waves from two coherent sources.

(b) In diffraction pattern, the central maximum is widest and thereafter width of the fringes decreases.

In interference pattern, all the fringe widths are equal.

2.

(i)Derivation of the expression for the capacitance



Let the two plates be kept parallel to each other separated by a distance d and cross-sectional area of each plate is A.

Electric field by a single thin plate = $\frac{\sigma}{2\epsilon_0}$

Total electric field between the plates

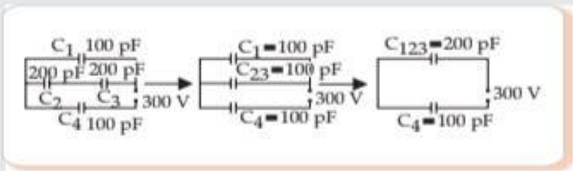
$$= \frac{\sigma}{\epsilon_0}$$

Potential difference between the plates V = Ed

$$= \frac{\sigma d}{\varepsilon_0}.$$

Capacitance C $= \frac{Q}{V} = \frac{\sigma A}{d\varepsilon_0}$

(ii)



The equivalent capacitance = $\frac{200}{3}$pF

Charge on $C_4 = \frac{200}{3} \times 10^{-12} \times 300 = 2 \times 10^{-8}$ C,

potential difference across C_4

$$= \frac{200 \times 10^{-12} \times 300}{3 \times 100 \times 10^{-12}} = 200 \text{ V}$$

potential difference across C_1 = 300 – 200 = 100 V

charge on $C_1 = 100 \times 10^{-12} \times 100 = 1 \times 10^{-8}$ C potential difference across C_2 and C_3 series combination = 100 V

potential difference across C_2 and C_3 each = 50 V

charge on C_2 and C_3 each = $200 \times 10^{-12} \times 50$

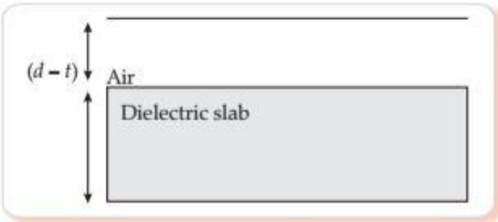
$= 1 \times 10^{-8}$ C

Detailed Answer:

(i) P and Q are two parallel plates. Distance between them is d.

A dielectric material of thickness $t(t < d)$ and dielectric constant K is inserted in between the plates.

In the remaining space $(d - t)$ there is air.



Electric field in the dielectric filled portion =

$$E_1 = \frac{\sigma}{\varepsilon_0 K}$$

Electric field in the air filled portion = $E_2 = \frac{\sigma}{\varepsilon_0}$

Potential difference between the plates = V

$V = E_2 \times (d-t) + E_1 \times t$

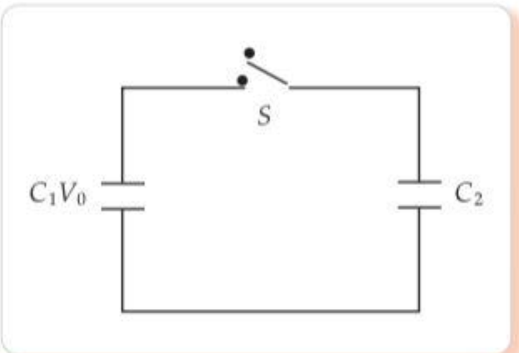
$$\text{Or, } V = \frac{\sigma}{2\varepsilon_0} \times (d-t) + \frac{\sigma}{\varepsilon_0 K} \times t$$

$$\text{Or, } V = \frac{q}{A\varepsilon_0} \times \left[(d-t) + \frac{t}{K}\right]$$

Now, capacitance = $C = \frac{q}{V}$

$$\text{Or, } C = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{K}}$$

(ii)



Before the connection of switch S,

$$\text{Initial energy} \quad U_i = \frac{1}{2}C_1V_0^2 + \frac{1}{2}C_2 \times 0^2$$

$$= \frac{1}{2}C_1V_0^2$$

After the connection of switch S

$$\text{common potential } V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{C_1V_0}{C_1 + C_2}$$

Final energy $= U_f$

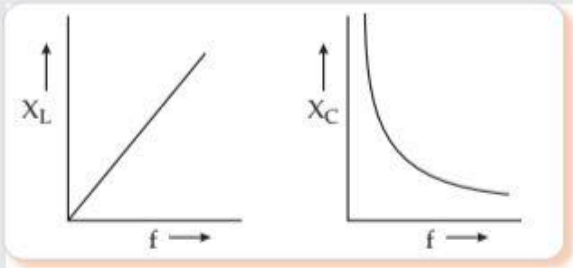
$$= \frac{1}{2}(C_1 + C_2)\frac{(C_1V_0)^2}{(C_1 + C_2)^2}$$

$$= \frac{1}{2}\frac{C_1^2V_0^2}{(C_1 + C_2)}$$

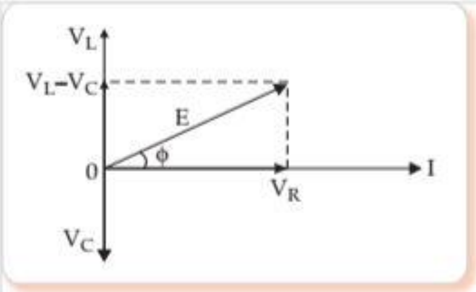
$$U_f : U_i = \frac{C_1}{(C_1 + C_2)}$$

3.

(a)



(b)



(c) **(i)** In device X, Current lags behind the voltage by $\frac{\pi}{2}$, X is an inductor

In device Y, Current in phase with the applied voltage, Y is resistor

(ii) We are given that

$$0.25 = \frac{220}{X_L}, X_L = 880\ \Omega,$$

Also $0.25 = \frac{220}{R}$, R = 880 Ω

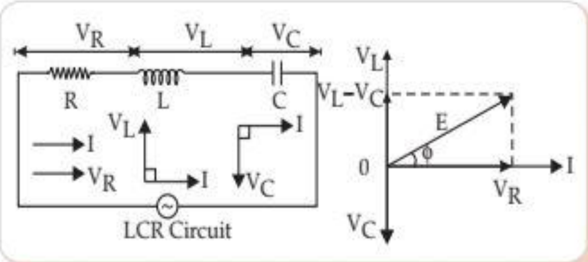
For the series combination of X and Y,

Equivalent impedance $Z = 880\sqrt{2}\Omega$,

I = 0.177 A

OR

(a)



$E = E_0 \sin\omega t$ is applied to a series LCR circuit. Since all three of them are connected in series the current through them is same. But the voltage across each element has a different phase relation with current.

The potential difference V_L, V_C and V_R across L, C and R at any instant is given by $V_L = IX_L$, $V_C = IX_C$ and $V_R = IR$, where I is the current at that instant.

V_R is in phase with I. V_L leads I by 90° and V_C lags behind I by 90° so the phasor diagram will be as shown Assuming $V_L > V_C$, the applied emf E which is equal to resultant of potential drop across R, L & C is given as

$$E^2 = I^2[R^2 + (X_L - X_C)^2]$$

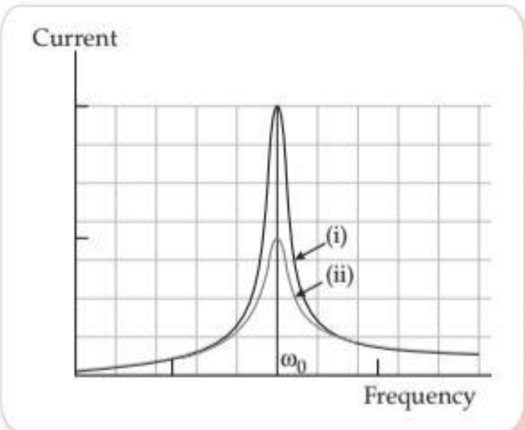
Or, $I = \frac{E}{\sqrt{[R^2 + (X_L - X_C)^2]}} = \frac{E}{Z}$, where Z is

Impedance.

Emf leads current by a phase angle φ as tan φ

$$= \frac{V_L - V_C}{R} = \frac{X_L - X_C}{R}$$

(b) The curve (i) is for R_1 and the curve (ii) is for R_2



4.

(i) For magnified virtual image, focal length should be greater than the object distance.

When lens is immersed in water, then

$$f_{water} > f_{air}$$

So, for $f_{air} > d$ may not form a virtual image.

Hence, $d < f_{water}$ will certainly form a virtual image.

(ii) Given $A_0/A = 2$ and deviation produced by each prism

$$\delta = (\mu - 1)A$$

$$\delta_{net} = \delta - \delta_0 + \delta$$
$$= 2\delta - \delta_0$$

For $\delta_{net} = 0$

$$2\delta = \delta_0$$
$$2(\mu - 1) A = (\mu_0 - 1) A_0$$

As, $A_0/A = 2$

So $2(\mu - 1) = (\mu_0 - 1) \times 2$

$$(\mu - 1) = (\mu_0 - 1)$$
$$\mu = \mu_0$$

(iii) For downward refraction as in *P*, the surrounding medium should have a refractive index less than that of the prism.

So, the medium surrounding the prism can be Benzene and aqueous Sodium Chloride.

And for the upward refraction as in *Q*, the surrounding medium should have a refractive index more than that of the prism.

So, the medium surrounding the prism can be that of carbon disulphide and ethyl alcohol.

OR

(i)
- Waves on a string propagate in only one dimension while the light-wave interference pattern exists in three dimensions.
- The standing-wave pattern represents no net energy flow, while there is a net energy flow from the slits to the screen in an interference pattern.

(ii) (a) Most spread-out fringes imply greater fringe width. Fringe width, $\beta = \lambda D/d$.

For greater β, higher λ and small *d* is required. So, slits S_1 and wavelength λ_2 will produce a fringe pattern that is most spread out.

(b) Least spread-out fringes imply smaller fringe width. Since fringe width, $\beta = \lambda D/d$ for smaller β, lower λ and greater *d* is required. So, slits S_2 and wavelength λ_1 will produce a fringe pattern that is most spread out.

(iii) $I_1 : I_2 = 1 : 4$

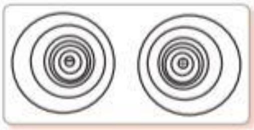
∴ $a_1 : a_2 = 1 : 2$

Maximum Intensity : Minimum Intensity

$$= (a_1 + a_2)^2 : (a_1 - a_2)^2$$
$$= 9 : 1$$

5.

(i) (a)



(b)

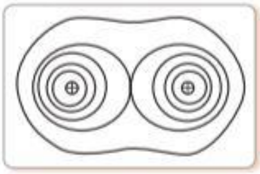


Figure: equipotential surface for
(a) a dipole
(b) two identical positive charge.

(ii) Here, $A = 6 \times 10^{-3}\ m^2$, $d = 3$ mm $= 3 \times 10^{-3}$ m

(a) Capacitance, $C = \varepsilon_0 A/d$
$= (8.85 \times 10^{-12} \times 6 \times 10^{-3}/3 \times 10^{-3})$
$= 17.7 \times 10^{-12}$ F

(b) Charge, $Q = CV$
$= 17.7 \times 10^{-12} \times 100$
$= 17.7 \times 10^{-10}\ C$

(c) New charge $Q' = \kappa Q$
$= 6 \times 17.7 \times 10^{-10}$
$= 1.062 \times 10^{-8}\ C$

OR

(i) Energy stored in a capacitor $= \frac{1}{2}CV^2$

$\therefore$ Energy stored in the charged capacitors,

$$E_1 = \frac{1}{2}C_1V_1^2$$

And $$E_2 = \frac{1}{2}C_2V_2^2$$

$\therefore$ Total energy stored $= \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$

(ii) Let V be the potential difference across the parallel combination.

Equivalent capacitance $= (C_1 + C_2)$

Since, charge is a conserved quantity, we have

$$(C_1 + C_2)V = C_1V_1 + C_2V_2$$

$$\Rightarrow \quad V = \left[\frac{C_1V_1 + C_2V_2}{(C_1 + C_2)}\right]$$

$\therefore$ Total energy stored in the parallel combination

$$= \frac{1}{2}(C_1 + C_2)V^2$$

$$= \frac{1}{2}\frac{(C_1V_1 + C_2V_2)^2}{(C_1 + C_2)}$$

(iii) The total energy of the parallel combination is different (less) from the total energy before the capacitors are connected. This is because some energy gets used up due to the movement of charges.

6.

(i) Power dissipation $= P = V_{rms}I_{rms}\cos\phi$

$$\cos\phi = \frac{R}{Z}.$$

For ideal inductor $R = 0$

$\therefore \quad \cos\phi = 0$

$\therefore \quad P = V_{rms}I_{rms}\cos\phi = 0$

Thus, ideal inductor does not dissipate power in an ac circuit.

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

$$\therefore \quad L = \frac{X_L}{2\pi f}$$

From graph, at $f = 100$ Hz

$$X_L = 20\ \Omega$$

$$\therefore \quad L = \frac{X_L}{2\pi f} = \frac{20}{2\pi \times 100}$$

$= 0.032$ H $= 32$ mH

(b) Power dissipation is maximum when

$$2\pi fL = \frac{1}{2\pi fC}$$

$$f = 300\ s^{-1}$$

$$L = 0.032\ H$$

$$2\pi fL = \frac{1}{2\pi fC}$$

Or, $$2\pi \times 300 \times 0.032 = \frac{1}{2\pi \times 300 \times C}$$

$$\therefore \quad C = 8.8 \times 10^{-6}\ F = 8.8\ \mu F$$

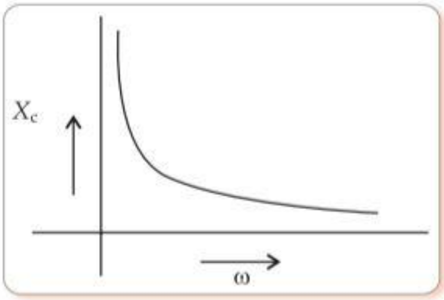
OR

(i) The device X is a capacitor

(ii) Curve B : voltage
Curve C : current
Curve A : power

Reason: The current leads the voltage in phase, by $\pi/2$ for a capacitor.

(iii)



$$X_c = \frac{1}{\omega C}$$

$$X_c \propto \frac{1}{\omega}$$

(iv) $V = V_o \sin \omega t$

$q = CV = CV_o \sin \omega t$

$$I=\frac{dq}{dt}=\omega cV_o\cos\omega t$$

$$=I_o\sin\left(\omega t+\frac{\pi}{2}\right)$$

7.

(i) Formula for refractive index of prism in terms of angle of minimum deviation:

$$n=\frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

Refractive index of the material decreases when immersed in water. Hence, angle of minimum deviation also decreases.

(ii) Refractive index of the material of the prism is different for different colour. Hence, critical angle is also for different for different colour. So, the when blue light undergoes total internal reflection, red light does not undergo total internal reflection.

(iii) Given : Refractive index of prism = 1.6,

Refractive index of medium = $\frac{4\sqrt{2}}{5}$

$$\mu=\frac{\mu_1}{\mu_2}=\frac{1.6}{\frac{4}{5}\sqrt{2}}=\frac{8}{4\sqrt{2}}=\sqrt{2}$$

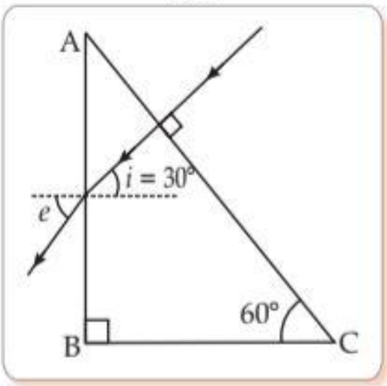
$$\sqrt{2}=\frac{\sin\left(\frac{60^\circ+\delta_m}{2}\right)}{\sin\frac{60^\circ}{2}}=\frac{\sin\left(\frac{60^\circ+\delta_m}{2}\right)}{\sin 30^\circ}$$

$$\therefore\quad \sin\left(\frac{60^\circ+\delta_m}{2}\right)=\sqrt{2}\times\frac{1}{2}=\frac{1}{\sqrt{2}}=\sin 45^\circ$$

$$\therefore\quad \frac{60^\circ+\delta_m}{2}=45^\circ$$

$$\therefore\quad \delta_m=30^\circ$$

OR



From Snell's law,

$$\mu_1\sin i=\mu_2\sin e$$

For $\mu_2 = 1$ for air

Or, $\sqrt{3}\sin 30^\circ = 1\times\sin e$

$\therefore$ $e = 60^\circ$

For $\mu_2 = 1.3$ for given liquid

$\sqrt{3}\sin 30^\circ = 1.3\times\sin e'$

$\therefore$ $e' = 41.83^\circ$

So, the angle of emergence reduces from 60° to 41.83°.

8.

(i) Capacitors C_2, C_3 and C_4 are in parallel

$\therefore$ $C_{234} = C_2 + C_3 + C_4$

$\therefore$ $C_{234} = 6\ \mu F$

Capacitors C_1, C_{234} and C_5 are in series

$$\therefore\quad \frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_{234}}+\frac{1}{C_5}$$

$$=\frac{1}{2}+\frac{1}{6}+\frac{1}{2}=\frac{7}{6}$$

$$C_{eq}=\frac{6}{7}\mu F$$

(ii) Charge drawn from the source

$$Q=C_{eq}V$$

$$=\frac{6}{7}\times 7\ \mu C=6\ \mu C$$

Energy stored, $U=\frac{Q^2}{2C_{eq}}$

$$=\frac{6\times 6\times 10^{-12}\times 7}{2\times 6\times 10^{-6}}J$$

$$=21\ \mu J$$

(iii) 6 μF and 3 μF are connected in series. Hence their equivalent capacitance is 2 μF. 4 μF and 2 μF are connected in series. Hence their equivalent capacitance is $\frac{4}{3}$ μF. Again, 2 μF and $\frac{4}{3}$ μF capacitors are connected in parallel.

So, the equivalent capacitance

$$=\frac{10}{3}\mu F=\frac{10}{3}\times 10^{-6}\ \mu F$$

Since, $Q = CV$

$$\therefore\quad Q=\frac{10}{3}\times 10^{-6}\times 3=10^{-5}C$$

$$=10\mu C$$

OR

(i) Given: Battery emf = 50V, C_1 = 12 pF, C_2 = 6pF

Energy stored, in the capacitor of capacitance 12 pF,

$$U=\frac{1}{2}CV^2$$

$$= \frac{1}{2}\times 12\times 10^{-12}\times 50\times 50 \text{J}$$

$$= 1.5 \times 10^{-8} \text{ J}$$

C = Equivalent capacitance of 12 pF and 6 pF, in series, is given by

$$\frac{1}{C} = \frac{1}{12}+\frac{1}{6}=\frac{1+2}{12}$$

$\therefore$ $C = 4$ pF

Charge stored across each capacitor

$$q = CV$$
$$= 4 \times 10^{-12} \times 50 \text{ C}$$
$$= 2 \times 10^{-10} \text{ C}$$

$\therefore$ Potential difference across capacitor C_1

$$\therefore \quad V_1 = \frac{2\times 10^{-10}}{12\times 10^{-12}}$$

$$= \frac{50}{3}\text{V}$$

$\therefore$ Potential difference across capacitor C_2

$$\therefore \quad V_2 = \frac{2\times 10^{-10}}{6\times 10^{-12}}$$

$$= \frac{100}{3}\text{V}$$

(ii) Given: Q_1 = 360 μC, Q_2 = 120 μC, V = 120 V

Capacitance, $C = \frac{Q_1}{V_1}$

$$C = \frac{Q_2}{V_2}$$

$$\frac{360\mu C}{V} = \frac{120\mu C}{(V-120)}$$

So, $3V - 360V = V$

$$V = 180\ V$$

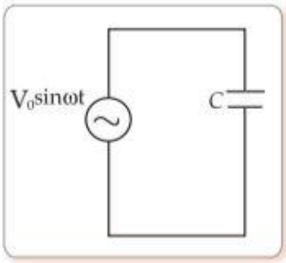
$$C = \frac{360\ \mu C}{180\ V} = 2\ \mu F$$

$$2\mu F = \frac{Q_3}{300}$$

$$Q_3 = 600\ \mu C$$

9.

(i)



At any moment, charge (q) on the capacitor is given by

$q = CV = CV_0\sin\omega t$

Then, Current in the circuit (i) is given by:

$$i = \frac{dq}{dt} = \frac{d}{dt}CV_0 \sin\omega t$$

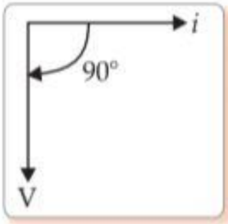
$$= \omega CV_0\sin\omega t$$

$$= \frac{V_0}{\frac{1}{\omega C}}\sin\left(\omega t + \frac{\pi}{2}\right)$$

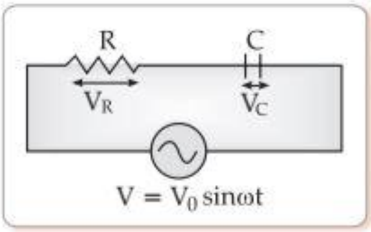
$$= \frac{V_0}{X_C}\sin\left(\omega t + \frac{\pi}{2}\right)$$

$$= i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

(ii) Phasor diagram:



(iii) Resistor is now connected with the capacitor in series:



Peak voltage drop across R is i_0R

i_0X_C is the maximum voltage drop across C.

The current is in phase with the voltage at cross R.

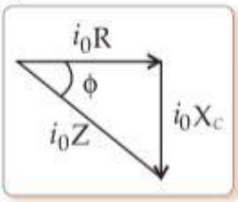
The voltage across C is 90° behind the current.

As a result, the voltage across R and C are not in phase. They are 90 degrees out of phase.

$$V_0 = \sqrt{(i_0R)^2 + (i_0X_C)^2}$$

$$\therefore \quad i_0 = \frac{V_0}{\sqrt{R^2 + X_C^2}}$$

The phase angle by which the current leads the applied voltage is:



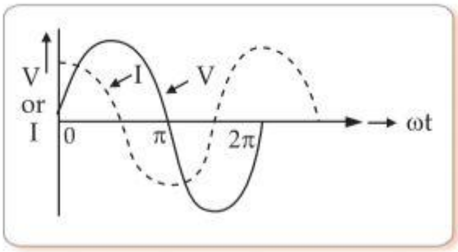
$$\text{Phase Angle} = \phi = \tan^{-1}\frac{X_C}{R}$$

OR

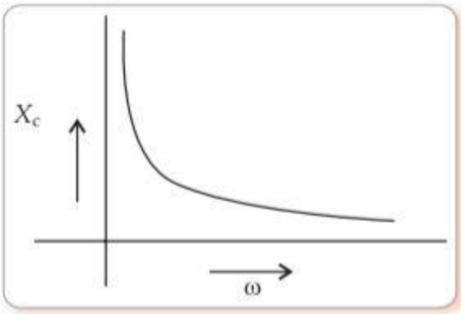
(i) X: Capacitor

Reactance, $X_c = \dfrac{1}{\omega C} = \dfrac{1}{2\pi f C}$

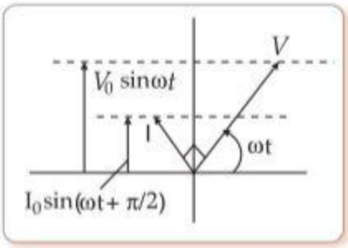
(ii)



(iii) Reactance of the capacitor varies in inverse proportion to the frequency, i.e., $X_c \propto \dfrac{1}{f}$

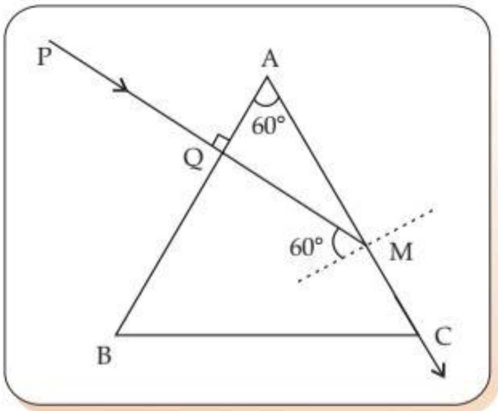


(iv)



10.

(i)



Given : $\angle A = 60°, \angle i = 0°$

At point M:

$$\sin C = \frac{1}{\mu} = \frac{\sqrt{3}}{2} = \sin 60°$$

$\therefore \quad C = 60°$

So, the ray PM after refraction from the face AC grazes along AC.

$$\angle e = 90°$$

$\therefore \quad \angle i + \angle e = \angle A + \angle\delta$

Or, $\quad 0° + 90° = 60° + \angle\delta$

$\Rightarrow \quad \delta = 90° - 60° = 30°$

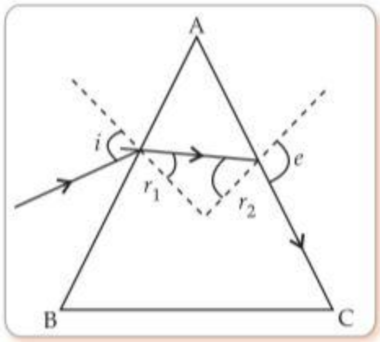
(ii) (a) Given: Minimum deviation = 30°, Refractive index = $\dfrac{2}{\sqrt{3}}$

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \sqrt{2}$$

$$\text{Also, } \mu = \frac{c}{v} \Rightarrow v = \frac{3\times10^8}{\sqrt{2}} \text{ m/s}$$

(b) Given: At face AC, let the angle of incidence be r_2. For grazing ray, $e = 90°$

$$\Rightarrow \mu = \frac{1}{\sin r_2} \Rightarrow r_2 = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$$



Assume an angle of refraction at face AB be r_1.

$$r_1 + r_2 = A$$

Or, $\quad r_1 = A - r_2 = 60° - 45° = 15°$

Let angle of incidence at this face be i,

$\Rightarrow \quad \mu = \dfrac{\sin i}{\sin r_1} \Rightarrow \sqrt{2} = \dfrac{\sin i}{\sin 15°}$

$\therefore \quad i = \sin^{-1}(\sqrt{2}.\sin 15°)$

$= 21.5°$

OR

(i) (a) Given: Width = 0.6 mm, Wavelengths = 480 nm and 600 nm

Distance of 2^{nd} bright fringe from central maximum = $\dfrac{2\lambda D}{d}$

$$= \frac{2\times600\times10^{-9}\times1}{0.6\times10^{-3}}$$

$= 20 \times 10^{-4}$ m

(b) If n^{th} bright fringe due to 600 nm coincides with $(n+1)^{th}$ bright fringe due to 480 nm, then

$$\frac{n\lambda_1 D}{d} = \frac{(n+1)\lambda_2 D}{d}$$

$$n\lambda_1 D = (n+1)\lambda_2 D$$

$$\frac{n}{(n+1)} = \frac{\lambda_2}{\lambda_1}$$

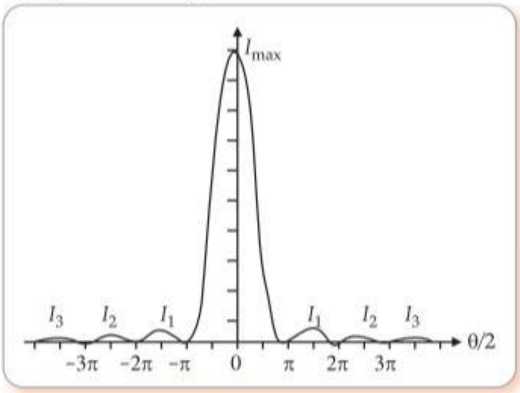
$$\frac{n}{(n+1)} = \frac{480}{600}$$

$\therefore \quad n = 4$

So, the least distance from central maximum

$$= \frac{4\times 600\times 10^{-9}\times 1}{0.6\times 10^{-3}} = 40\times 10^{-4}\text{ m}$$

(ii) Plot of diffraction intensity distribution with apropriate marking:



11.

(i)(a) Given: Dielectric constant = 4, Equivalent capacitance = 4 μF

Assume $C_X = C$

$C_Y = 4C$ (as it has a dielectric medium of $\varepsilon_r = 4$)

For series combination of two capacitors

$$\frac{1}{C} = \frac{1}{C_X} + \frac{1}{C_Y}$$

$$\Rightarrow \quad \frac{1}{4\ \mu F} = \frac{1}{C} + \frac{1}{4C}$$

$$\frac{1}{4\ \mu F} = \frac{5}{4C}$$

$\Rightarrow \quad C = 5\ \mu F$

Hence, $\quad C_X = 5\ \mu F$

$C_Y = 20\ \mu F$

(b) Total charge, Q(C = Capacitance, V = Potential)

$Q = CV$

$Q = 4\ \mu F \times 15\ V = 60\ \mu C$

$$\Rightarrow \quad V_X = \frac{Q}{C_X} = \frac{60\ \mu C}{5\ \mu F} = 12\text{ V}$$

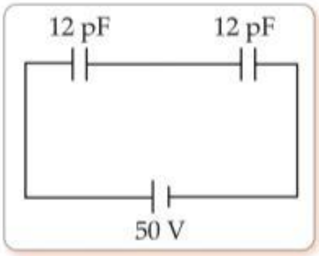
$$\Rightarrow \quad V_Y = \frac{Q}{C_Y} = \frac{60\ \mu C}{20\ \mu F} = 3\text{V}$$

(c) Ratio of electrostatic energy :

$$\frac{E_x}{E_y} = \frac{\frac{Q^2}{2C_X}}{\frac{Q^2}{2C_Y}} = \frac{C_Y}{C_X}$$

$$= \frac{20}{5} = 4:1$$

(ii) In series combination :



Given : Two capacitors = 12 pF (each), emf of Battery = 50V

$$\frac{1}{C_s} = \left(\frac{1}{12} + \frac{1}{12}\right)$$

$C_s = 6 \times 10^{-12}$F

Potential energy, $U_s = \frac{1}{2}C_s V^2$

$$U_s = \frac{1}{2}\times 6\times 10^{-12}\times 50^2$$

$U_s = 75 \times 10^{-10}\ J$

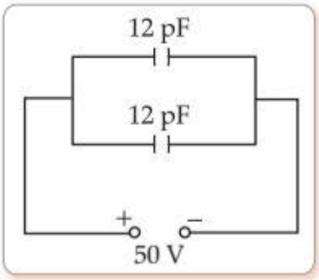
Charge drawn, $q_s = C_s V$

$= 6 \times 10^{-12} \times 50$

$= 300 \times 10^{-12}\ C$

$= 3 \times 10^{-10}\ C$

In parallel combination:



$C_p = (12 + 12)$ pF

$C_p = 24 \times 10^{-12}$ F

Potential energy, $U_P = \frac{1}{2}C_P V^2$

$$U_p = \frac{1}{2}\times 24\times 10^{-12}\times 2500\text{ J}$$

$U_P = 3 \times 10^{-8}\ J$

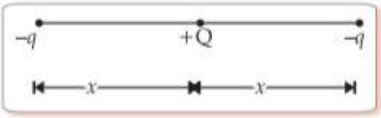
Charge drawn, $q_p = C_p V$

$q_p = 24 \times 10^{-12} \times 50\ C$

$q_p = 1.2 \times 10^{-9}\ C$

OR

(i)



Potential energy = $\frac{Kq_1q_2}{r}$

Potential energy of charges $(-q)$, $(+Q)$, $(-q)$:

According to question:

$$\frac{K(-q)Q}{x} + \frac{kQ(-q)}{x} + \frac{k(-q)(-q)}{2x} = 0$$

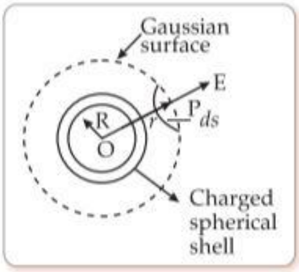
Or, $$\frac{-2kqQ}{x} + \frac{kq^2}{2x} = 0$$

Or, $$\frac{kq^2}{2x} = \frac{2kqQ}{x}$$

Or, $$q = 4Q$$

Or, $$\frac{Q}{q} = \frac{1}{4}$$

(ii) Electric field due to a uniformly charged thin spherical shell:



(a) When point P lies outside the spherical shell: Suppose that we have to calculate field at the point P at a distance $r(r > R)$ from its centre. A Gaussian surface is drawn through point P so as to enclose the charged spherical shell.

Let $\overline{E}$ be the electric field at point P, then the electric flux through area element of area $\overline{ds}$ is given by

$$d\phi = \overline{E}.\overline{ds}$$

Since, $\overline{ds}$ is also along normal to the surface

$$d\phi = E\, dS$$

$\therefore$ Total electric flux through the Gaussian surface is given by

$$\phi = \oint E ds = E \oint ds$$

Or, $$\oint ds = 4\pi r^2$$

$\therefore$ $$\varphi = E \times 4\pi r^2 \quad \text{...(i)}$$

Since, the charge enclosed by the Gaussian surface is q, according to the Gauss's theorem,

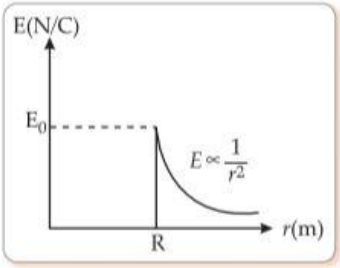
$$\phi = \frac{q}{\varepsilon_0} \quad \text{...(ii)}$$

From equation (i) and (ii) we obtain

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2} \text{ (for } r > R)$$

(b) Graph showing the variation of electric field as a function of r :



12.

(i) (a) Impedance = $Z = \sqrt{R^2 + X_C^2}$

$$R = \frac{V_R}{I_R} = 30\ \Omega$$

$$X_C = \frac{V_C}{I_C} = \frac{120}{3} = 40\ \Omega$$

$$Z = \sqrt{30^2 + 40^2} = 50\ \Omega$$

(b) Value of inductance :

$$X_C = X_L \quad (\because \text{ As power factor } = 1)$$

$$100\pi L = 40$$

$$L = \frac{2}{5\pi} \text{ H}$$

(ii) (a) Using the Q factor, which describes how quickly energy decays in an oscillating system, one can determine the sharpness of resonance.

Resonance's sharpness is influenced by damping which is a condition that causes vibrations to have less amplitude.

(b) $$V_L = V_C \neq V_R$$

So, $$X_L = X_C$$

$\therefore$ $Z = \sqrt{R^2 + (X_L - X_C)^2}$ (Z denotes impedance)

$$Z = \sqrt{R^2} = R$$

$$\text{Power factor} = \cos\phi = \frac{R}{Z}$$

$\Rightarrow$ $$\cos\phi = \frac{R}{Z} = \frac{R}{R} = 1$$

OR

(i) Given,

Inductance (L) = 100 mH

Capacitance (C) = 2 μF

Resistance (R) = 400 Ω
Voltage (V) = $V_0 \sin(1000t + \phi)$
Inductive reactance (X_L)

$$X_L = \omega L = (1000 \times 100 \times 10^{-3})\ \Omega$$
$$= 100\ \Omega$$

Capacitive reactance

$$X_C = \frac{1}{\omega C} = \left(\frac{1}{1000 \times 2 \times 10^{-6}}\right)\Omega$$
$$= 500\ \Omega$$

Thus, Phase angle :

$$\tan\phi = \frac{X_L - X_C}{R}$$
$$\tan\phi = \frac{100 - 500}{400} = -1$$
$$\phi = -\frac{\pi}{4}$$

As $X_C > X_L$, ϕ phase angle is negative, hence current leads voltage.

(ii) To make power factor unity,

$$X_C' = X_L$$

(where X_C' is new capactive reactance and X_L inductive reactance)

$$\frac{1}{\omega C'} = 100$$
$$\therefore \quad C' = 10\ \mu F$$
$$C' = C + C_1$$
$$10 = 2 + C_1$$
$$C_1 = 8\ \mu F$$

(iii) For LR circuit

$$\frac{X_L}{R} = \tan 45° = 1$$

So, $X_L = R$

For CR circuit also

$$X_C = R$$

So, For LCR circuit
When L, C and R are connected in series, then actually three R are connected in series. Thus, circuit is resistive.

$$V = V_0 \sin \omega t$$
$$I = I_0 \sin \omega t$$

(a) Average power dissipation, $P = VI$

$$P = V_0 \sin\omega t \times I_0 \sin \omega t$$

Overall full cycle,

$$P_{avg} = \frac{V_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}}$$

(b) Instantaneous current, $I = I_0 \sin \omega t$.

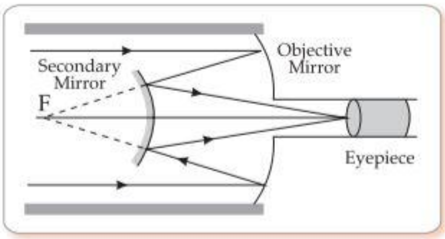
13.

(i) The main considerations with an astronomical telescope:

(a) The diameter of the objective on which the brightness of the image and resolving power depend.

(b) The focal length of the objective on which the magnification $\left(m = \frac{f_o}{f_E}\right)$ depends.

(ii)



At first, parallel light rays from an infinite distance strike the concave objective mirror.
These are incident on a secondary convex mirror following reflection. At F, a virtual image starts is formed. The rays meet at a spot to create a real image that is seen through the eyepiece after reflection by the convex mirror.

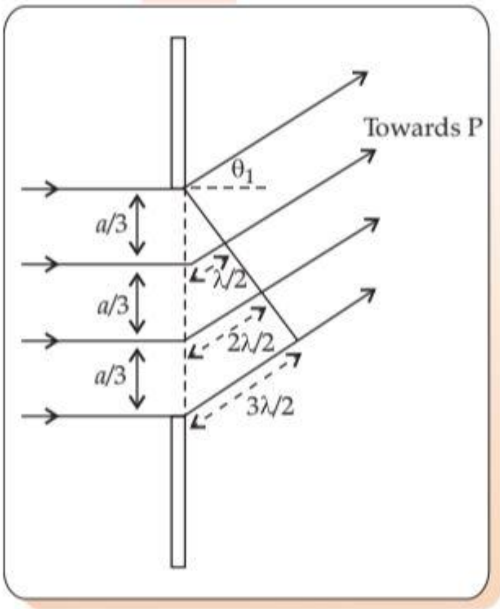
(iii) Advantages of a reflecting telescope over a refracting telescope:

- Mirrors can be made larger in size than lenses.
- There is no chromatic aberrations.

OR

(i) If all the bands are of equal width and intensity, then patterns is produced by double slit. Bands of the pattern produced by single slit have the width and intensity both varying.

(a) Derivation of expression for angular position of bright fringe produced by single slit diffraction: The single slit may be considered to be divided into three equal parts. If waves from two parts of the slit cancel each other, the wave from the third part will produce a maxima at a point between two minima.



So, $\sin\theta_1 = \frac{3\lambda}{2a}$

Similarly, if the slit is divided in five equal parts, then another maxima will be produced at

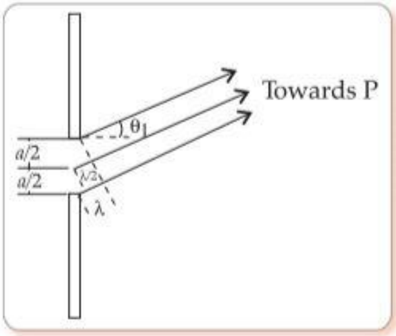
$$\sin\theta_2 = \frac{5\lambda}{2a}$$

Similarly, for other fringes, $\sin\theta_n = \frac{(2n+1)\lambda}{2a}$

Or, $\theta_n = \frac{(2n+1)\lambda}{2a}$

For, central maxima, $\theta = 0°$

(b) Derivation of expression for angular position of dark fringe produced by single slit diffraction:



The single slit is divide into two equal halves. For every point in one half has a corresponding point in the other half. The path difference between two waves arriving at point P is

$$\frac{a}{2\sin\theta_1} = \frac{\lambda}{2}$$

This means the contributions are in opposite in phase, so cancel each other and the intensity falls to zero.

So, for first dark fringe, $\sin\theta_1 = \frac{\lambda}{a}$

Similarly for other dark fringes, $\sin\theta_n = \frac{n\lambda}{a}$

$$\theta_n = \frac{n\lambda}{a}$$

(ii) Given: $\lambda = 6000$ Å

Angular width $2\Phi = \frac{2\lambda}{d}$

In case of λ' angular width decreases by 30%

New angular width = 0.70 (2Φ)

$$\frac{2\lambda'}{d} = 0.70 \cdot \left(\frac{2\lambda}{d}\right)$$

$$\lambda' = 4200 \text{ Å}$$

14.

(i) The amount of charge required on each plate to increase the potential difference between them by unity is the capacitance of the capacitor.

Capacitance of a air filled parallel plate capacitor $= \frac{A\varepsilon_0}{d}$

(ii) Capacitance without dielectric,

$$C = \frac{A\varepsilon_0}{d}$$

Capacitance when filled with dielectric having thickness $\frac{3d}{4}$

$$C' = \frac{A\varepsilon_0}{\left(d - t + \frac{t}{\kappa}\right)}$$

$$= \frac{A\varepsilon_0}{\left(d - \frac{3d}{4} + \frac{3d}{4\kappa}\right)}$$

$$= \frac{4\varepsilon_0\kappa A}{d(\kappa+3)}$$

Ratio $\frac{C'}{C} = \frac{A\varepsilon_0 4\kappa}{d(\kappa+3)} \times \frac{d}{A\varepsilon_0}$

$$= \frac{4\kappa}{(\kappa+3)}$$

OR

(i) (a) 2μF and 4μF capacitors are to be connected in series. So, the effective capacitor will be

$$C_{eff} = \frac{2\times 4}{2+4} = \frac{4}{3}\,\mu F$$

With C_{eff}, the 3μF capacitor is to be connected in parallel. So, the equivalent capacitor will be

$$C_{eqv} = \frac{4}{3} + 3 = \frac{13}{3}\mu F$$ 1

(b) Maximum value of capacitance may be obtained by connecting the capacitors in parallel. In that case, the equivalent capacitance will be, (2 + 3 + 4) = 9 μF.

Minimum value of capacitance may be obtained by connecting the capacitors in series. In that case, the equivalent capacitance will be C_S.

$$\frac{1}{C_S} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4} = \frac{13}{12}$$

$\therefore \quad C_S = \frac{12}{13}\ \mu F$

(ii) (a) Capacitance of the capacitor, $C = 200\ \mu F$

Potential of *dc* source, $V = 100$ V

Let 'A' be the area of the plate and 'd' be the separation between the plates,

The capacitance of the capacitor is given as,

$$C = \frac{\varepsilon_0 A}{d}$$

Or, $\quad \varepsilon_0 A = Cd$

When the capacitor remains connected with the *dc* source, then there will be no change in potential difference.

Now, according the problem

Separation between the plates = $2d$

Thickness of dielectric slab, $t = 5$ mm

$= 5.0 \times 10^{-3}$ m

Dielectric constant, $\kappa = 10$

New capacitance of the capacitor

$$C' = \frac{A\varepsilon_0}{(d'-t) + \frac{t}{\kappa}}$$

Here, $d' = 2d$ and $t = d$

$$C' = \frac{A\varepsilon_0}{(2d-d) + \frac{d}{\kappa}}$$

$$= \frac{A\varepsilon_0}{d\left(1 + \frac{1}{\kappa}\right)}$$

$$= \frac{Cd}{d\left(1 + \frac{1}{\kappa}\right)}$$

$$= \frac{C\kappa}{\kappa + 1}$$

$$= \frac{10 \times 200\ \mu F}{(10+1)}$$

$= 182\ \mu$F.

Hence, new capacitance of the capacitor will decrease.

(b) Since, there in no change in the potential difference, Hence, there would not be any change in electric field. It will be $\frac{100}{5.5 \times 10^{-3}} = 18182$ V/m .

(c) The Energy will decrease because

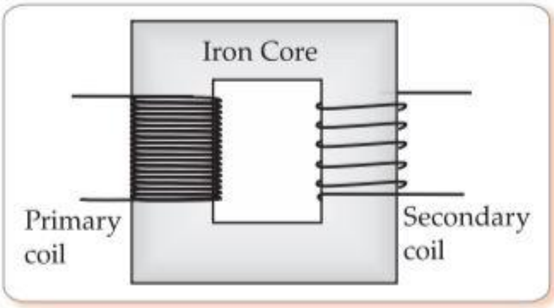
$$E = \frac{1}{2} CV^2$$

Or, $\quad E \propto C \quad$ [V is constant]

Since, the capacitance decreases, the energy density will also decrease.

15.

(i) Working of a step-down transformer: A step-down transformer converts a high voltage a.c. at the primary side to a low voltage a.c. at the secondary side.



Transformer works on the principle of "Faraday's law of electromagnetic induction".

The number of turns in the primary and secondary windings affects the induced emf. Turns ratio (or transformation ratio) is the name given to this ratio.

Ability of step-down transformer to reduce voltage is based on the primary and secondary turns ratio. The quantity of flux transmitted to the secondary coil of transformer decreases as secondary coil turns are kept less than primary coil turns. As a result, turns induced emf in secondary coil is less than primary.

$$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$

Here,

N_S = Number of turns in secondary coil

N_p = Number of turns in primary coil

V_S = Voltage in secondary coil

V_p = Voltage in primary coil

For step-down transformer, the number of turns in secondary winding is always less than the number of turns in the primary winding of the transformer, i.e., $N_p > N_S$.

As the number of turns is less in secondary coil, so the induced emf (output voltage) in the secondary coil is less than the primary input voltage.

(ii) For an ideal transformer,

$$i_p V_p = i_s V_s$$

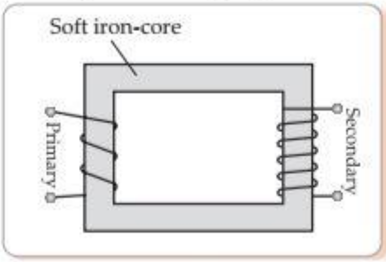
$$\therefore \quad \frac{i_p}{i_s} = \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

(iii) We have

$$i_pV_p = i_sV_s = 500 \text{ W}$$
$$V_p = 220 \text{ V}$$
$$i_p = \frac{550}{220} = \frac{5}{2} = 2.5 \text{ A}$$

OR

(i) Labelled diagram of step-up transformer :



Working principle: Transformer works on the principle of "Faraday's law of electromagnetic induction".

Relation: $\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{i_p}{i_s}$

Here,

N_S = Number of turns in secondary coil

N_p = Number of turns in primary coil

V_S = Voltage in secondary coil

V_p = Voltage in primary coil

i_S = Current in secondary coil

i_p = Current in primary coil

(ii) Input power, $P_P = I_PV_P = 15 \times 100 = 1500$ W

Power output, $P_S = P_P.\frac{90}{100} = 1350$ W

Or, $I_SV_S = 1350$W

Output voltage $= V_S = \frac{1350}{3} = 450$ V

16.

(i) Kinetic energy of an electron is given by the expression:

$$K.E. = 13.6\frac{Z^2}{n^2} \text{eV}$$

For Hydrogen, $Z = 1$

Thus, $K.E. = \frac{13.6}{n^2}$eV

For $n = 1$;

$$(K.E.)_1 = \frac{13.6}{(1)^2} \text{ eV}$$
$$= 13.6 \text{ eV} \qquad ...(i)$$

For $n = 2$;

$$(K.E.)_3 = \frac{13.6}{(3)^2} \text{ eV}$$
$$= \frac{13.6}{9} \text{ eV} \qquad ...(ii)$$

From (i) and (ii) we can say that:

$$(K.E.)_3 = \frac{(K.E.)_1}{9}$$

Thus, kinetic energy decreases by a factor one over nine.

Now, potential energy of an electron is given by the expression:

$$P.E. = -27.2\frac{Z^2}{n^2} \text{ eV}$$

For Hydrogen, $z = 1$

Thus, $P.E. = \frac{-27.2}{n^2}$eV

For $n = 1$:

$$(P.E.)_1 = \frac{-27.2}{(1)^2} \text{ eV}$$
$$= -27.2 \text{ eV} \qquad ...(iii)$$

For $n = 2$;

$$(P.E.)_3 = \frac{-27.2}{(3)^2} \text{eV}$$
$$= \frac{-27.2}{9} \text{ eV} \qquad ...(iv)$$

From (iii) and (iv), we can say that:

$$(P.E.)_3 = \frac{(P.E.)_1}{9}$$

Since, potential energy is associated with a negative sign.

Thus, potential energy increase by a factor of nine.

(ii) Wavelength range of Lyman series: 912Å – 1216Å (approximately)

Wavelength range of Balmer series: 3646Å – 6566Å (approximately)

Wavelength range of Paschen series: 8212Å – 18769Å (approximately)

Energy of Hydrogen in ground state $= E = -\frac{13.6}{n^2}$ eV

For $n = 1$, $E_1 = -13.6$eV

For $n = 2$, $E_2 = -3.4$eV

Maximum energy required for excitation $= \Delta E$

$$\Delta E = E_2 - E_1 = 10.2 \text{ eV}$$

So, maximum wavelength radiation for excitation = λ_{max}

$$\lambda_{max} = 12375/\Delta E \text{ Å}$$
$$= 12375/10.2 \text{ Å}$$
$$= 1213.235 \text{ Å}$$

So, only Lyman series will be absorbed. So, absorption spectral lines would correspond Lyman series will be available.

(iii) **(a)** For 3rd excited state $n = 4$.

When a photon with shortest wavelength is emitted, the energy is maximum.

Maximum energy is emitted when electron jumps from $n = 4$ to $n = 1$.

$$E_4 = -0.85 \text{ eV}$$
$$E_1 = -13.6 \text{ eV}$$

So, energy of photon = $E_4 - E_1$ = 12.75 eV

Final quantum no., $n = 1$.

(b) When a photon with longest wavelength is absorbed, the energy is minimum.

Minimum energy is absorbed when electron jumps from $n = 4$ to $n = 5$.

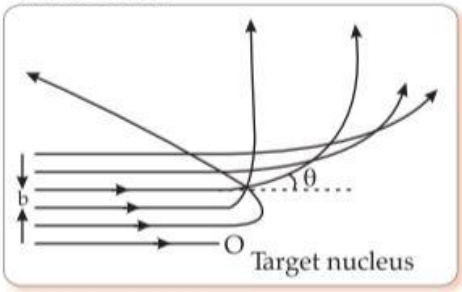
$$E_4 = -0.85 \text{ eV}$$
$$E_5 = -0.54 \text{ eV}$$

So, energy of photon = $E_5 - E_4$ = 0.31 eV

Final quantum no., $n = 5$.

OR

(i) The trajectory, traced by the α-particles in the Coulomb field of target nucleus, has the form as shown below:



The size of the nucleus was estimated by observing the distance (d) of closest approach, of the α-particles. This distance is given by:

$$d = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2eZe}{K}$$

where, K = kinetic energy of the α-particles when they are far away from the target nuclei.

(ii) Neutrons having kinetic energy around 10^{-2} eV are known as thermal neutrons.

(iii) λ = wavelength, m = mass, v = velocity, h = Planck's constant

$$\lambda = \frac{h}{p}$$

$$\lambda = \frac{h}{mv} \qquad (\because p = mv)$$

$$\lambda = \frac{h}{\sqrt{2mqV}} \qquad \left(\because \frac{1}{2}mv^2 = qV\right)$$

Thus, ratio of de-Broglie wavelength of deuterons and α-particles when accelerated through same potential is given by:

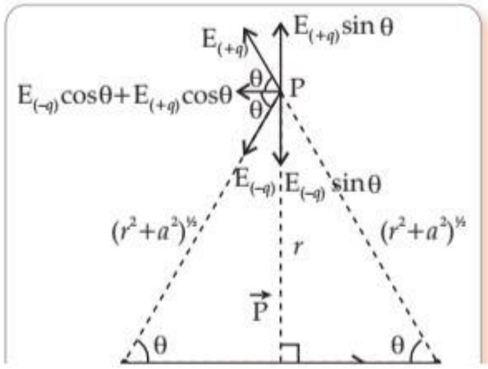
$$\frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_d q_d}}$$

$$\frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{4\times 2}{2\times 1}} = 2$$

Thus, wavelength associated with deuterons is twice the wavelength associated with α-particles.

17.

(i) Due to the positive q charge electric field at point P,



$$\bar{E}(+q) = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \qquad \text{...(i)}$$

Due to the negative q charge electric field at point P,

$$\bar{E}(-q) = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \qquad \text{...(ii)}$$

$\bar{E}(+q) = \bar{E}(-q)$ and they can be resolved in two components each.

$E(+q)\sin\theta$ and $E(-q)\sin\theta$ cancel out since their magnitudes and directions are opposite.

So, Net electric field at point P

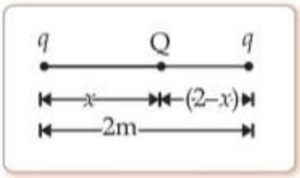
$$E = 2E(+q)\cos\theta$$

$$E = 2 \times \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \times \frac{a}{(r^2 + a^2)^{\frac{1}{2}}}$$

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{p}{(r^2 + a^2)^{3/2}}$$

(P = electric dipole moment)

(ii) Charges in equilibrium and there is no net force acting on it. So,



$$\frac{1}{4\pi\varepsilon_0}\frac{qQ}{(x)^2} - \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(2-x)^2} = 0$$

$$\frac{qQ}{x^2} = \frac{qQ}{(2m-x)^2}$$

$$x = 2 - x$$

$$2x = 2$$

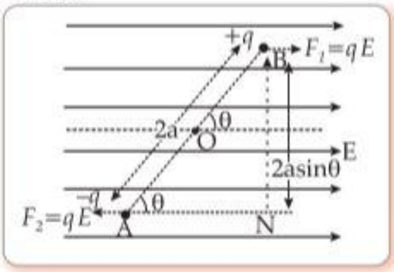
$$x = 1$$

Q is therefore located in the middle of the line connecting the charges q and q.

If it is assumed that charge Q is positive, the force on it may be zero. But the forces on charge q at two ends will not be zero. It is because the forces on a charge q due to the other two charges will act in the same direction. If charge Q is negative, then the forces on q due to the other two charges will act in opposite direction and equilibrium will be achieved. Hence, Q will be negative in nature.

OR

(i) An electric dipole AB consisting of charge $+q$ and $-q$ and of length $2a$ is placed in uniform electric field E making an angle θ with the direction of electric field.



Force acting on $-q$ is $-q$E

Force acting on $+q$ is qE

These two forces are equal and opposite to each other.

Hence, a torque on the dipole is developed.

Torque = Force × perpendicular distance between the forces

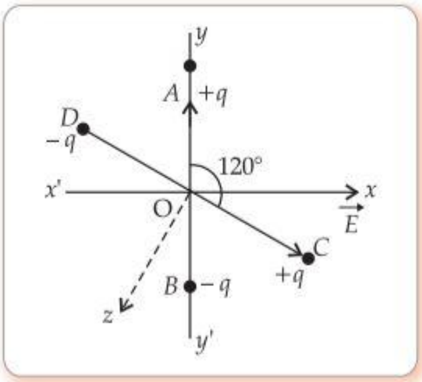
Or, $\tau = qE \times 2a\sin\theta$

Or, $\tau = (q \times 2a)E\sin\theta$

∴ $\tau = pE\sin\theta$ (where p is dipole moment)

When the dipole is pointed in the direction of the electric field, it will reach a stable equilibrium.

(ii)



(a) Dipole moment of the dipole $AB = (\vec{p})_{AB} = p\hat{j}$

Dipole moment of dipole $CD = (\vec{p})_{CD}$

$$= p\cos 30°\hat{i} - p\cos 60°\hat{j}$$

$$(\vec{p})_{CD} = \frac{\sqrt{3}p}{2}\hat{i} - \frac{p}{2}\hat{j}$$

∴ Net dipole moment $= (\vec{p})_{AB} + (\vec{p})_{CD}$

$$= p\hat{j} + \frac{\sqrt{3}p}{2}\hat{i} - \frac{p}{2}\hat{j}$$

$$= \frac{\sqrt{3}p}{2}\hat{i} + \frac{p}{2}\hat{j}$$

$$\therefore \quad |\vec{p}| = \sqrt{\frac{3p^2}{4} + \frac{p^2}{4}} = \sqrt{p^2}$$

$$\Rightarrow \quad |\vec{p}| = p$$

Therefore, magnitude of dipole moment = p

$$\tan\theta = \frac{\frac{1}{2}}{\frac{\sqrt{3}}{2}} = \frac{1}{\sqrt{3}}$$

Therefore, angle made by the dipole with the positive x-axis is 30°.

(b) Torque acting on a dipole of dipole moment in an electric field is given by

$$\tau = \vec{p} \times \vec{E}$$

For AB, dipole moment $= p\hat{j}$

Electric field $= E\hat{i}$

∴ Torque, $\tau_{AB} = (p\hat{j} \times E\hat{i}) = pE(-\hat{k})$

Similarly, for CD dipole moment $= \left(\frac{\sqrt{3}p}{2}\hat{i} - \frac{p}{2}\hat{j}\right)$

Electric field $= E\hat{i}$

∴ Torque, $\tau_{CD} = \left(\frac{\sqrt{3}p}{2}\hat{i} - \frac{p}{2}\hat{j}\right) \times E\hat{i}$

$$= pE\frac{\sqrt{3}}{2} \times 0 - \frac{p}{2}E(-\hat{k})$$

$$= -\frac{pE}{2}(-\hat{k})$$

Magnitude of net torque $= \frac{pE}{2}$; Direction: into the plane of the paper.

18.

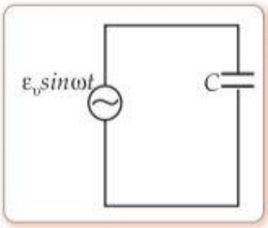
(i) $V_0 = 200V$

$$V_{rms} = \frac{200}{\sqrt{2}} = 141.4V$$

Angular frequency = 314 rad

So, frequency $= \frac{314}{2\pi} = 50Hz$

(ii)



Given, Voltage $\varepsilon = \varepsilon_0 \sin \omega t$ and capacitance $= C$

At any moment charge on the capacitor is

$q = C\varepsilon = C\varepsilon_0 \sin\omega t$

Current in the circuit,

$$i = \frac{dq}{dt} = \frac{d}{dt}CV_0\varepsilon_0 \sin\omega t$$

$$= \omega C\varepsilon_0 \cos\omega t$$

$$= \frac{V_0}{\frac{1}{\omega C}}\sin\left(\omega t + \frac{\pi}{2}\right)$$

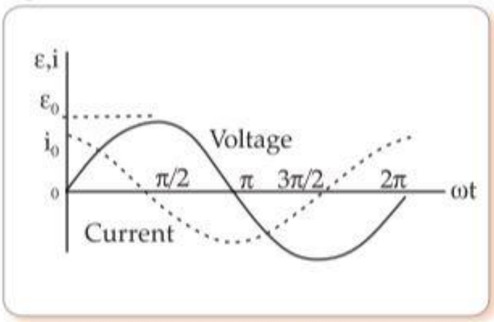
$$= \frac{V_0}{X_C}\sin\left(\omega t + \frac{\pi}{2}\right)$$

$$= \frac{V_0}{Z}\sin\left(\omega t + \frac{\pi}{2}\right)$$

$$= i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

So, the current is ahead of the voltage by $\frac{\pi}{2}$.

Graph of ε and I versus ωt:



OR

(i) To reduce the current from 2A to 1A, the impedance is to be doubled.

When only R is present, then

$R = V/I = 220/2 = 110\ \Omega$

Now a capacitor C is connected in series and the impedance becomes 220 Ω.

So, we can apply $Z = \sqrt{R^2 + X_C^2}$

Or, $220 = \sqrt{110^2 + X_C^2}$

Or, $220^2 = 110^2 + X_C^2$

Or, $X_C = 110\sqrt{3}$

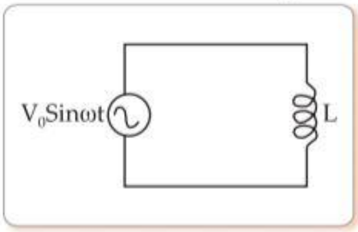
Or, $\frac{1}{2\pi fC} = 110\sqrt{3}$

$$\left(\because X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}\right)$$

Or, $C = \frac{1}{2\pi 110\sqrt{3}}$

$\therefore$ $C = 11.93\ \mu F$

(ii)



Given $V = V_0 \sin \omega t$ and Inductance $= L$

Applying Kirchhhoff's rule,

$$V - L\frac{di}{dt} = 0$$

Or, $V_0 \sin\omega t = L\frac{di}{dt}$

Or, $di = \frac{V_o}{L}\sin\omega t\, dt$

On integrating both sides we get,

$$\int di = \frac{V_o}{L}\int \sin\omega t\, dt$$

$\Rightarrow$ $i = -\frac{V_o}{\omega L}\cos\omega t$

$\Rightarrow$ $i = -\frac{V_o}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$

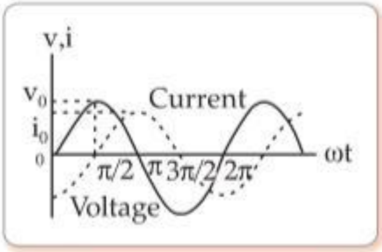
$\Rightarrow$ $i = -\frac{V_o}{Z_L}\sin\left(\omega t - \frac{\pi}{2}\right)$

$\Rightarrow$ $i = -\frac{V_o}{Z}\sin\left(\omega t - \frac{\pi}{2}\right)$

$\therefore$ $i = -i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

So, the current flowing through it lags behind the applied voltage by a phase angle of $\frac{\pi}{2}$.

Graph of V and i versus ωt:



19.

(i) The Bohr Model of the Hydrogen atom is based on three postulates.

- The first postulate states that electrons orbit the nucleus in circular paths, with the electrostatic force between the positively charged nucleus and negatively charged electrons providing the necessary centripetal force.
- The second postulate asserts that electrons can only occupy certain fixed orbits, in which their angular momentum is an integral multiple of Planck's constant. These stationary orbits do not result in the emission of energy.
- The third postulate states that when an electron transitions from a higher energy orbit to a lower energy orbit, it emits a quantum of energy (a photon) equal to the difference in energy between the two orbits.

Expression for Bohr radius:

Let us consider

m = Mass of an electron

r = Radius of the circular orbit in which the electron is revolving

v = Speed of electron

$-e$ = Charge of electron

From 1st postulate

Centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$\therefore \quad v^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{mr} \quad \text{... (i)}$$

From 2nd postulate

Angular momentum is an integral multiple of $\frac{h}{2\pi}$

$$mvr = \frac{nh}{2\pi}$$

(here mvr is the angular momentum)

$$\text{Or,} \quad v = \frac{nh}{2\pi mr}$$

$$\text{Or,} \quad v^2 = \frac{n^2h^2}{4\pi^2m^2r^2} \quad \text{... (ii)}$$

On comparing equations (i) and (ii),

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

$$\therefore \text{ Bohr radius, } r = \frac{\varepsilon_0 n^2h^2}{\pi me^2}$$

(ii) The shortest wavelength in Balmer series can be found using the expression:

$$\frac{1}{\lambda_S} = R\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$$

$$\therefore \quad \lambda_S = \frac{4}{R}$$

Longest wavelength in Balmer series can be found using the expression:

$$\therefore \quad \frac{1}{\lambda_L} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\therefore \quad \lambda_L = \frac{36}{5R}$$

$$\text{So,} \quad \frac{\lambda_L}{\lambda_S} = \frac{\frac{36}{5R}}{\frac{4}{R}} = \frac{9}{5}$$

OR

(i) $$mvr = \frac{nh}{2\pi} \quad \text{...(i)}$$

(here mvr is the angular momentum)

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

(Since, Centripetal force = Electrostatic force)

On comparing equations (i) and (ii), we get

$$\text{Bohr' radius,} \quad r = \frac{\varepsilon_0 n^2h^2}{\pi me^2}$$

$$\text{Potential energy, } U = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}$$

$$= -\frac{me^4}{4\varepsilon_0^2n^2h^2}$$

$$\text{Kinetic energy, } K.E. = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{nh}{2\pi mr}\right)^2$$

$$= \frac{n^2h^2\pi^2m^2e^4}{8\pi^2m\varepsilon_0{}^2n^4h^4}$$

$$K.E. = \frac{me^4}{8\varepsilon_0^2n^2h^2}$$

$$T.E. = K.E. + P.E.$$

$$= -\frac{me^4}{8\varepsilon_0^2n^2h^2} + \left(-\frac{me^4}{4\varepsilon_0^2n^2h^2}\right)$$

$$= -\frac{me^4}{8\varepsilon_0^2 n^2 h^2}$$

(ii) Rydberg's formula: For first member of Lyman series,

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

$$\lambda = \frac{4}{3R} = \frac{4}{3} \times 912\,\text{Å}$$

$$= 1216\,\text{Å}$$

For first member of Balmer Series.

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\lambda = \frac{36}{5R}$$

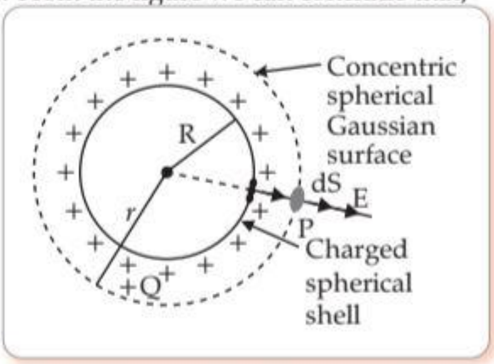
$$\lambda = \frac{36}{5} \times 912\,\text{Å}$$

$$= 6566.4\,\text{Å}$$

20.

(i) Let a point charge Q is situated in a region. Electric field due to charge Q at a radial distance r is given by $\frac{kQ}{r^2} = \frac{Q}{4\pi\varepsilon_0 r^2}$

Now, consider a uniformly charged spherical shell of radius R, containing charge Q.
Let us take a spherical Gaussian surface of radius $r > R$, coinciding with the centre of shell, say O.
∴ From the figure we can conclude that,



The angle between electric field and area vector is also constant.
So, using Gauss' law for a sphere of radius r,

$$\oint \vec{E}.\vec{ds} = \frac{Q_{enclosed}}{\varepsilon_0}$$

(here $\vec{E}$ is the electric field vector $\vec{ds}$ is the area field vector)

$$\oint E\, ds \cos\theta = \frac{Q}{\varepsilon_0}$$

Electric field vector and area vector are parallel to each other.

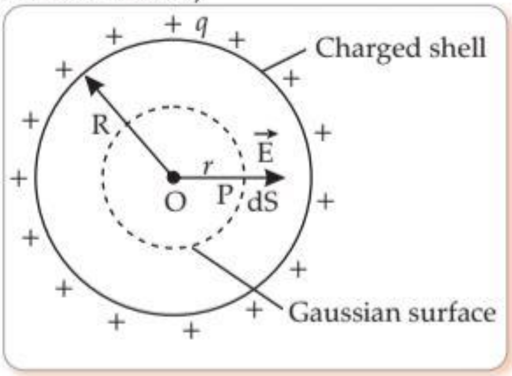
So, $E\oint ds = \frac{Q}{\varepsilon_0} (\cos\theta = \cos 0° = 1)$

And for a sphere $\oint ds = 4\pi r^2$

So, $E \times 4\pi r^2 = \frac{Q}{\varepsilon_0}$

$\Rightarrow \quad E = \frac{Q}{4\pi\varepsilon_0 r^2}$

Hence, the field at a distance r is equal to the field as if whole charge Q is placed at its center O.
Now, again taking Gaussian surface of radius $r < R$ inside the shell,



$$\oint \vec{E}.\vec{ds} = \frac{Q_{enclosed}}{\varepsilon_0}$$

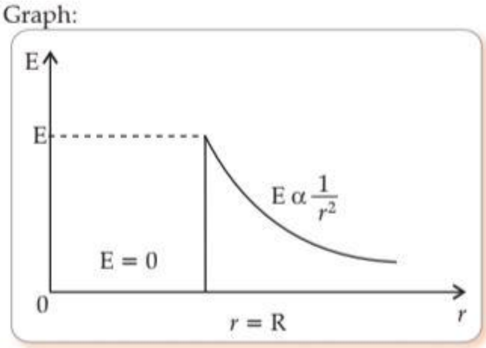
Since, the whole charge of the shell is distributed on the surface.

∴ $Q_{enclosed} = 0$

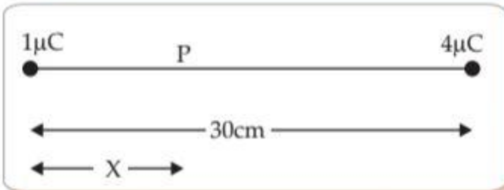
Thus, $\oint \vec{E}.\vec{ds} = 0$

Or, $\vec{E} = 0$

Graph:



(ii)



The electric field is zero at distance x cm form 1μC charge. Let the point be P.

Field at P due to the $1\mu C$ charge $\frac{k \times 1\mu C}{x^2}\hat{i}$

Field at P due to $4\mu C$ charge $\frac{k \times 4\mu C}{(30-x)^2}(-\hat{i})$

Since, net field is 0,

$$\therefore \quad \frac{k \times 1\mu C}{x^2} = \frac{k \times 4\mu C}{(30-x)^2}$$

$$\frac{x^2}{(30-x)^2} = \frac{1}{4}$$

$$\frac{x}{(30-x)} = \frac{1}{2}$$

$$2x = 30 - x$$

Or, $x = 10$ cm

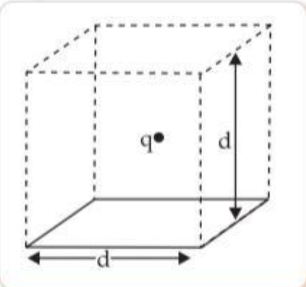
Thus, electric field is 0 at 10 cm from $1\mu C$ charge.

OR

(i) Electric flux through a given surface is defined as the dot product of electric field and area vector over that surface.

Mathematically, $\phi = \int \vec{E}.\vec{ds}$ (where ϕ is the flux associated with a given surface, $\vec{E}$ is the electric field vector and is the area vector)

Electric flux, through a surface equals the surface integral of the electric field over that surface. It is a scalar quantity.



Let us draw a cube of side 'd' so that charge 'q' gets placed within of this cube (Gaussian surface).

According to Gauss' law the Electric flux is given by,

$$\phi = \frac{\text{Charge enclosed}}{\varepsilon_0}$$

$$\Rightarrow \quad \phi = \frac{q}{\varepsilon_0}$$

This is the total flux associated with all the six faces of the cube.

Hence, electric flux through the square is given by:

$$\frac{1}{6} \times \frac{q}{\varepsilon_0} = \frac{q}{6\varepsilon_0}$$

(ii) If the charge is moved to a distance d and the side of the square is doubled, the cube which will now be constructed will have a side length $2d$. But, the total charge enclosed in it will remain the same. Hence, the total flux through the cube and therefore the flux through the square will remain same as before.

21.

(i) Let magnetic needle is suspended in the uniform external magnetic field B and making angle θ with it and is slightly disturbed to oscillate in this field.

As magnetic moment $\vec{M}$ is directed along the axis of needle, torque τ on the needle is

$$\vec{\tau} = \overline{M} \times \overline{B}$$
$$= MB \sin\theta \quad ...(i)$$

We also know that

$$\tau = I\alpha$$

Where I is moment of inertia of needle and α angular acceleration.

Angular acceleration,

$$\alpha = \frac{d^2\theta}{dt^2} \quad ...(ii)$$

Hence, equation (ii) can be written as

$$\tau = I\frac{d^2\theta}{dt^2} = -MB\sin\theta$$

This derived equation is similar to equation of simple harmonic motion,

$$\frac{d^2\theta}{dt^2} = -\omega^2\theta$$

where, $\omega^2 = \frac{MB}{I}$

Hence, it is proved that it executes simple harmonic motion.

We know that $\omega = \frac{2\pi}{T}$

where, T is period of oscillation.

$$\therefore \quad \sqrt{\frac{MB}{I}} = \frac{2\pi}{T}$$

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

(ii) The magnetic potential energy

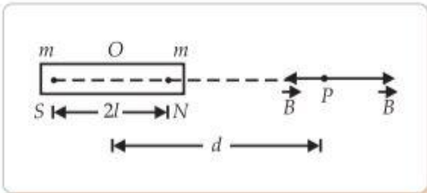
$$= U = \int \tau d\theta$$
$$= \int MB \sin\theta \, d\theta$$
$$= -MB\cos\theta$$
$$= -\vec{M}.\vec{B}$$

OR

Magnetic moment M : Magnetic moment M of a magnetic dipole is defined as the product of the pole strength (m) and the magnetic length ($2l$).

$$M = m \times 2l = 2ml$$

(i) Magnetic field intensity due to magnetic dipole at a point on its axis:



Due to North pole of the magnet (N)

$$B_1 = \frac{\mu_0(m)}{4\pi(d-l)^2}$$

Due to South pole of the magnet (S)

$$B = \frac{\mu_0(m)}{4\pi(d+l)^2}$$

B_1 and B_2 are oppositely directed.

Hence, resultant magnetic field at point P when $2l << d$:

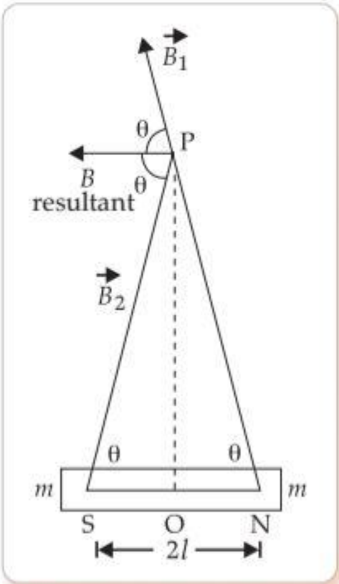
$$B = \frac{\mu_0 2M}{4\pi d^3}$$

where, $M = m \times 2l$.

(ii) Magnetic field intensity due to magnetic dipole at a point on its equator:

Let's assume that length of dipole = $2l$, magnetic strength of each pole = m, Magnetic permeability of free space = μ_0, then magnetic field at point P due to:

N pole $$B_1 = \frac{\mu_0(m)}{4\pi(d^2+l^2)}$$



Due to S pole

$$B_2 = \frac{-\mu_0 m}{4\pi(d^2+l^2)}$$

$$B_2 = \frac{-\mu_0 m}{4\pi(d^2+l^2)}$$

B_1 and B_2 both have two components. Sin θ components balance each other. Cos θ components are added up. So, the resultant magnetic field at P is

$$B = \frac{\left(\frac{2\mu_0}{4\pi}\right)}{\left[\frac{M}{(d^2+l^2)^{3/2}}\right]}$$

Hence, resultant at point P when $2l << d$:

$$B = \frac{\mu_0 M}{4\pi d^3}$$

where, $M = m \times 2l$

22.

(i) **(a)** During the experiment, many alpha particles were able to pass through the foil, while only very few were deflected at angles greater than 90 degrees. Based on these observations, Rutherford concluded that the deflected alpha particles must have encountered a significant repulsive force in order to be repelled and deflected backwards. Other alpha particles were undeflected since in atoms there are mostly empty space, with the majority of their positive charge concentrated tightly at a central point.

(b) Radius of the nucleus of mass number A is given by $R = R_0 A^{\frac{1}{3}}$, where R_0 is constant.

Volume of the nucleus (V) = $\frac{4}{3}\pi R^3$

$$= \frac{4}{3}\pi\left(R_0 A^{\frac{1}{3}}\right)^3$$

$$= \frac{4}{3}\pi A R_0^3$$

$$\text{Density } (\rho) = \frac{\text{mass}}{\text{volume}} = \frac{mA}{\left(\frac{4}{3}\pi R_0^3 A\right)}$$

$$= \frac{3m}{4\pi R_0^3}$$

From above result, we can conclude that density is independent of mas number (A).

(ii) Shortcomings of Rutherford's atomic model:

(a) Rutherford's atomic model can not explain the sharply defined discrete lines in the hydrogen spectrum.

(b) Rutherford's atomic model cannot explain the stability of an atom. According to electron dynamics an accelerated electron radiate energy, so the radius of orbit goes on decreasing and finally, the electron will fall into the nucleus and the atom will not be stable. But practically this does not happen.

Bohr atomic model removes these drawbacks of the Rutherford model.

(a) According to Bohr atomic model, electron can revolve only in well defined energy levels in which its angular momentum is integral multiple of $(h/2\pi)$.

(b) According to Bohr atomic model, electrons revolving in a definite orbit do not radiate energy, it radiates energy only when changing the orbits.

Thus the stability of atom and appearance of line spectra both were explained.

OR

(i) Spectral lines in Balmer series is given by,

$$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

Spectral lines in Paschen series is given by

$$\frac{1}{\lambda_P} = R\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$$

In both the cases $n = \infty$, as the most energetic line corresponds to the transition from the highest energy level.

In Balmer series,

$$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2}-\frac{1}{\infty}\right)$$

$$\frac{1}{\lambda_B} = \frac{R}{2^2} \Rightarrow \lambda_B = \frac{4}{R}$$

In Paschen series

$$\frac{1}{\lambda_P} = R\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$$

$$\frac{1}{\lambda_P} = R\left(\frac{1}{3^2}-\frac{1}{\infty}\right)$$

$$\frac{1}{\lambda_P} = \frac{R}{3^2} \Rightarrow \lambda_P = \frac{9}{R}$$

Hence, the ratio

$$\frac{\lambda_B}{\lambda_P} = \frac{\frac{4}{R}}{\frac{9}{R}} = 4:9$$

(ii) Bohr's quantization condition : Electron revolves around the nucleus only in those orbits for which the angular momentum is some integral of $h/2\pi$. (where, h is Planck's constant)

i.e., $$mvr = \frac{nh}{2\pi}$$

For Brackett Series,

shortest wavelength is for the transition of electrons from $n_i = \infty$ to $n_f = 4$

$$\frac{1}{\lambda} = R\left(\frac{1}{4^2}\right) = \frac{R}{16}$$

$$\lambda = \frac{16}{R}\text{m}$$

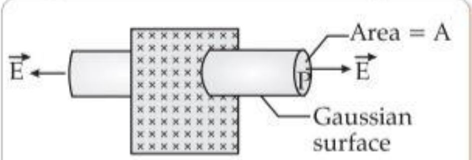
On substituting the value of $R = 1.0973 \times 10^7$ m^{-1}.

$$\lambda = 1458.5 \text{ nm}$$

23.

(i) Gauss Theorem : The electric flux ϕ across any closed surface is proportional to the net electric charge q enclosed by the surface i.e., is, $\phi = q/\varepsilon_0$, where ε_0 is the electric permittivity of free space.

Let us suppose a cylindrical Gaussian surface passing through the infinitely large, thin, plane charged sheet as shown in the diagram below:



Plane sheet of charge

Over all curved surface, the electric field is perpendicular to the surface.

Hence, electric flux associated with region is 0.

i.e., $\vec{E}.\vec{ds} = 0$

If Δs is the area of the flat surface of the cylinder, then

$$\int \vec{E}.\vec{ds} = 2E\Delta s \text{ (for both the flat surface)}$$

According the Gauss' theorem,

$$\int \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0} = \frac{\sigma\Delta s}{\varepsilon_0}$$

(where σ is the surface charge density)

So, $$2E\Delta s = \frac{\sigma\Delta s}{\varepsilon_0}$$

$\therefore$ $$E = \frac{\sigma}{2\varepsilon_0}$$

(ii) The expression for the work done to bring charge q from infinity to r is given by

$$W = -q\int_{\infty}^{r} \vec{E}.\vec{dr}$$

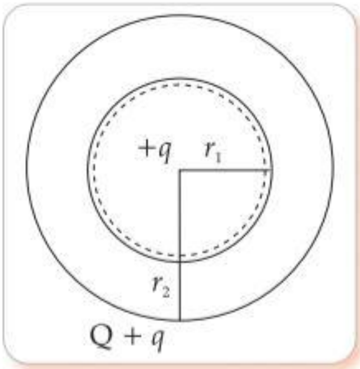
$$= -q\int_{\infty}^{r}\left(\frac{\sigma}{2\varepsilon_0}\right)dr$$

$$= \frac{q\sigma}{2\varepsilon_0}|\infty - r|$$

$$= (\infty)$$

OR

(i) (a)



In the above figure consider a shell with inner radius r_1 and outer radius r_2 having charge Q.

The charge induced on the inner surface of the shell will be $-q$.

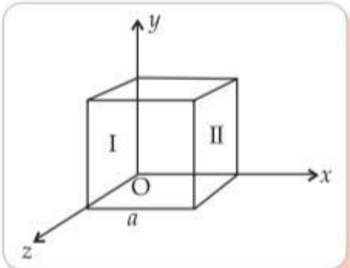
The surface charge density on inner surface of the shell is $\sigma_1 = -\frac{q}{4\pi r_1^2}$

The surface charge density on the outer shell is $\sigma_2 = -\frac{Q+q}{4\pi r_2^2}$

(b) Yes, the electric field inside the cavity is zero even when the shape spherical or not. Let us suppose a Gaussian surface inside the shell, net flux is zero since $q_{net} = 0$.

And according to Gauss' law, it is independent of the shape and size of the shell.

(ii)



From the given diagram,

Only the face perpendicular to the direction of x-axis, contribute to the electric flux. The remaining faces of the cube gives zero contribution since electric field vector is along the +ve x-axis.

Total flux, $\phi = \phi_1 + \phi_2$

Where ϕ_1 and ϕ_2 are the flux associated with region I and II respectively.

$$\varphi = \oint_{I} \bar{E}.\overline{ds} + \oint_{II} \bar{E}.\overline{ds}$$

$$= 0 + 2(a).\,a^2$$

$$= 2a^3$$

Charge enclosed, $q = \phi\varepsilon_0 = 2a^3\varepsilon_0$

24.

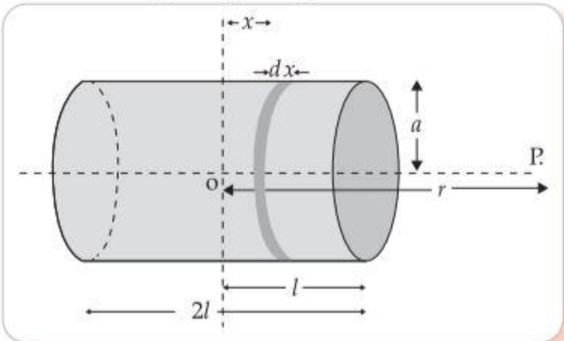
(i) Let us consider a solenoid, whose

radius = a

length = $2l$

Number of turns per unit length = n

Current passing through the solenoid = I.



Let us consider a small element dx at distance x from O.

Magnetic field at P (a point at a distance r from O) is

$$dB = \frac{\mu_0 n dx I a^2}{2\left[(r-x)^2 + a^2\right]^{3/2}}$$

Integrating both sides of the equation, we get:

$$B = \int_{-l}^{+l} \frac{\mu_0 n dx I a^2}{2\left[(r-x)^2 + a^2\right]^{3/2}} \quad \text{...(i)}$$

Putting $\left[(r-x)^2 + a^2\right]^{3/2} = r^3$

Now, magnetic moment, $M = n \times 2l \times I \times \pi a^2$

$$\therefore \quad n \times 2l \times I = \frac{M}{\pi a^2} \quad \text{...(ii)}$$

Putting in the equation (i), we get;

$$B = \frac{\mu_0 a^2 M}{2r^3 \pi a^2} = \frac{\mu_0 M}{2r^3 \pi} = \frac{\mu_0 2M}{4\pi r^3}$$

The same magnetic field is produced by a bar magnet.

Hence, a current carrying solenoid behaves like a bar magnet.

(ii) Magnitude of magnetic dipole moment M with the circular current loop having n number of turns, carrying a current I and of area A is $|M| = nIA$. The direction of the magnetic dipole moment is perpendicular to the plane of the loop.

Here, $n = 5$

$I = 2\text{A}$

r = (radius) = 7 cm = 0.07 m

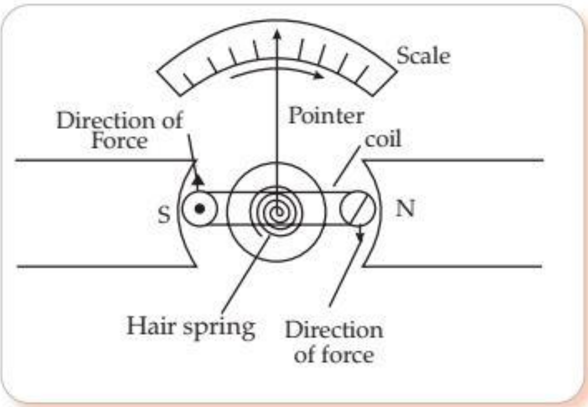
$\therefore$ Area = $A = \pi r^2 = 3.14 \times (0.07)^2\ \text{m}^2$

$\therefore$ Magnetic dipole moment = $5 \times 2 \times 3.14 \times (0.07)^2$

$= 0.154\ \text{Am}^2$

OR

Moving coil galvanometer: It is a device used for detecting and measuring feeble electric currents.



Principle: The working of a moving coil galvanometer is based upon the principle that a current carrying coil when suspended in a magnetic field experiences a torque.

Working: When a current flows through the coil it experiences a magnetic torque. The torque is proportional to the current. Thus it rotates through an angle proportional to the current flowing through it. There is a hair spring (restoring spring) attached to the coil and the frame of the galvanometer and it exerts a restoring force on the coil that helps to keep the coil and hence, the pointer stable and in a fixed position. The spring also helps to bring back the coil to its initial position and hence, the pointer to zero when current is withdrawn.

(a) Because of its ferromagnetic properties, a soft iron core concentrates magnetic field lines within the core. This concentration increases the magnetic field strength generated by the field magnet, increasing the galvanometer's sensitivity.

(b) Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit current flows through it.

Current sensitivity, $I_S = \frac{\theta}{I} = \frac{nBA}{K}$ ...(i)

Voltage sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit voltage is applied across two terminals.

Voltage sensitivity,

$$V_S = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{nBA}{KR} \quad ...(ii)$$

Where n = number of turns in the coil of galvanometer.

B = magnetic field around coil

A = area of coil

K = restoring torque per unit twist

R = galvanometer resistance

From equation (i) and (ii) we can say that increasing a galvanometer's current sensitivity does not always increase its voltage sensitivity. This is due to the fact that the galvanometer's current sensitivity is primarily determined by the strength of the magnetic field produced by the external field magnet and the number of turns in the coil. Voltage sensitivity, on the other hand, is determined by the resistance of the coil and the overall design of the galvanometer. If the other factors are not properly adjusted, simply increasing the current sensitivity may not directly affect the voltage sensitivity. As a result, changes in current sensitivity may not have a direct relationship with changes in voltage sensitivity.

25.

(i) Bohr's postulates are:

1. Bohr's first postulate states that electrons in an atom can occupy stable orbits without emitting radiant energy, and each atom can exist in specific stable states with definite total energy.
2. In his second postulate, Bohr described these stable orbits as circular paths around the nucleus, where the angular momentum of revolution is quantized and given by an integral multiple of $h/2\pi$, with h representing Planck's constant.
3. Bohr's third postulate states that electrons can transition from one non-radiating orbit to another with lower energy. During this transition, a photon is emitted, and the energy of the photon corresponds to the difference in energy between the two states.

Expression for Bohr radius:

Let us consider

m = Mass of an electron

r = Radius of the circular orbit in which the electron is revolving

v = Speed of electron

$-e$ = Charge of electron

From 1st postulate

Centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$\therefore \quad v^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{mr} \quad ...(i)$$

From 2nd postulate:

Angular momentum is an integral multiple of $\frac{h}{2\pi}$

$$mvr = \frac{nh}{2\pi}$$

Or, $$v = \frac{nh}{2\pi mr}$$

Or, $$v^2 = \frac{n^2h^2}{4\pi^2m^2r^2} \quad ...(ii)$$

From equations (i) and (ii),

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

∴ Bohr radius, $r = \frac{\varepsilon_0 n^2h^2}{\pi me^2}$

(ii) The shortest wavelength in Balmer series is:

$$\frac{1}{\lambda_S} = R\left(\frac{1}{2^2}-\frac{1}{\infty}\right)$$

∴ $$\lambda_S = \frac{4}{R}$$

Longest wavelength in Balmer series is:

$$\frac{1}{\lambda_L} = R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

$$\lambda_L = \frac{36}{5R}$$

So, $$\frac{\lambda_1}{\lambda_2} = \frac{\frac{36}{5R}}{\frac{4}{R}} = \frac{9}{5}$$

26.

(i) $$\overline{OA} = \vec{r_1} = (2-0)\hat{i}+(1-0)\hat{j}+(2-0)\hat{k}$$
$$= 2\hat{i}+\hat{j}+2\hat{k}$$

Similarly,

$$\vec{r_2} = \hat{i}+\hat{j}+2\hat{k}$$

Electric field at A due to charge q,

$$\vec{E_1} = \frac{kq}{r_1^2}\vec{r_1}$$

Or, $$\vec{E_1} = \frac{kq}{(\sqrt{2^2+1^2+2^2})^3}\vec{r_1}$$

∴ $$\vec{E_1} = \frac{kq}{27}\vec{r_1}$$

Similarly, electric field at A due to charge 1 nC,

$$\vec{E_2} = \frac{k\times10^{-9}}{r_2^3}\vec{r_2}$$

Or, $$\vec{E_2} = \frac{k\times10^{-9}}{(\sqrt{1^2+1^2+2^2})^3}\vec{r_2}$$

∴ $$\vec{E_2} = \frac{k\times10^{-9}}{6\sqrt{6}}\vec{r_2}$$

So, net electric field at A,

$$\vec{E} = \vec{E_1}+\vec{E_2}$$

Or, $$\vec{E} = \frac{kq}{27}\vec{r_1}+\frac{k\times10^{-9}}{6\sqrt{6}}\vec{r_2}$$

Or, $$\vec{E} = \frac{kq}{27}(2\hat{i}+\hat{j}+2\hat{k})+\frac{k\times10^{-9}}{6\sqrt{6}}(\hat{i}+\hat{j}+2\hat{k})$$

Or, $$\vec{E} = k\left[\frac{2q}{27}+\frac{10^{-9}}{6\sqrt{6}}\right]\hat{i}+k\left[\frac{q}{27}+\frac{10^{-9}}{6\sqrt{6}}\right]\hat{j} +k\left[\frac{2q}{27}+\frac{2\times10^{-9}}{6\sqrt{6}}\right]\hat{k}$$

According to the given condition,

$$k\left[\frac{2q}{27}+\frac{10^{-9}}{6\sqrt{6}}\right] = 0$$

∴ $$q = -\frac{27\times10^{-9}}{2\times6\sqrt{6}}$$
$$= 0.92\times10^{-9}\text{ C} = 0.92\text{ nC}$$

(ii) (a) From graph it is clear that the potential is maximum at the centre of the sphere.

(b) For conducting sphere, the potential is constant and maximum everywhere inside the sphere. The magnitude is,

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

Charge will be distributed on the surface of the sphere only.

OR

(a) Capacitance decreases since $C \propto 1/d$.

(b) Charge decreases. $Q = CV$. V remains constant. C decreases. So, Q decreases.

(c) Potential difference remains same since the battery remains connected.

(d) Electric field decreases. $E = V/d$. V remains same. d increases. So, E decreases.

(e) Energy stored decreases. $U = \frac{1}{2}CV^2$. V remains same. C decreases. So, U decreases.

27.

(i) (a) diamagnetic (since the number of magnetic field lines passing through it decreases)

(b) paramagnetic (since the number of magnetic field lines passing through it increases)

(ii) The magnetic susceptibility of A is small negative and that of B is small positive.

(iii) The four properties of magnetic field lines are:

(a) Magnetic field lines always form continuous closed loops.

(b) The tangent to the magnetic field line at a given point represents the direction of the net magnetic field at that point.

(c) The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field.

(d) Magnetic field lines do not intersect.

(iv) For an oscillating magnet, $T = 2\pi\sqrt{\frac{I}{MB}}$

Where $I = \frac{ml^2}{12}$, $M = xl$, x = pole strength

When the magnet is divided into two equal parts, the magnetic dipole moment:

$$M' = \text{Pole strength} \times \text{length}$$

$$= \frac{x \times l}{2} = \frac{M}{2} \qquad \text{...(i)}$$

$$I' = \frac{\text{Mass} \times (\text{length})^2}{12}$$

$$= \frac{\frac{m}{2} \times \left(\frac{l}{2}\right)^2}{12}$$

$$= \frac{ml^2}{12 \times 8} = \frac{I}{8}$$

$$\therefore \text{Time period } T' = \sqrt{\frac{I'}{M'B'}}$$

$$\frac{T}{T'} = \sqrt{\frac{I'}{M'} \times \frac{M}{I}}$$

$$= \sqrt{\frac{I'}{I} \times \frac{M}{M'}}$$

$$\therefore \quad \frac{T}{T'} = \sqrt{\frac{1}{8} \times \frac{2}{1}} = \frac{1}{2}$$

OR

(i) Time period of original magnet

$$= T_1 = 2\pi\sqrt{\frac{I_1}{M_1 B}}$$

Time period of oscillation of combination magnet

$$T_2 = 2\pi\sqrt{\frac{I_2}{M_2 B}}$$

$$I_1 = \frac{ml^2}{12}$$

$$I_2 = \frac{1}{12} \times \frac{m}{3} \times \left(\frac{l}{3}\right)^2 \times 3$$

$$= \frac{I_1}{9}$$

$$M_2 = \frac{M_1}{3} \times 3 = M_1$$

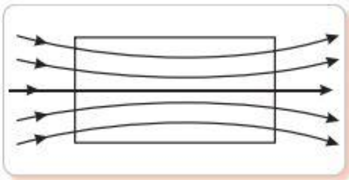
Substituting these values, we get;

$$\frac{T_2}{T_1} = \sqrt{\frac{I_2}{I_1}} = 1:3$$

(ii) Magnetic susceptibility = 0.9853 (given)

The value is positive and magnitude is less than unity.'

Thus, the material is paramagnetic.



(iii) When the angle between the magnetic dipole moment and magnetic field is 0° i.e., both are parallel to each other, then the magnetic dipole is said to be in stable equilibrium.

28.

(i) $En = -\frac{13.6}{n^2} eV$

So, energy level – 1.51eV corresponds to $n = 3$

And energy level – 3.4eV corresponds to $n = 2$

So, electron transfer takes place from $n = 3$ to $n = 2$. Radiation emitted corresponds to Balmer series.

$$\therefore \quad \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$\therefore \quad \lambda = 6563 \text{Å}$$

(ii) Binding energy of p

= 240 × 7.6 MeV = 1824 MeV

Q heavy nucleus

= 110 × 8.5 MeV = 935 MeV

Binding energy of R

= 130 × 8.4 MeV = 1092 MeV

Energy released = [(935 + 1092) – 1824] MeV

= [2027 – 1824] MeV

= 203 MeV

(iii) The mass defect is the difference of mass of all the nucleons and the mass of the nucleus.

OR

(i)

Isotopes	Isobars
Isotopes have the same atomic number but different mass numbers.	Isobars have the same mass number but different atomic numbers.
Isotopes of an element are placed in the same place as that of the element in the periodic table.	Isobars of elements are placed at different places in the periodic table.
The physical properties of isotopes are different. The chemical properties of isotopes are the same.	The physical properties of isobars are nearly the same. The chemical properties of isobars are different.

(ii) No, two nuclei are only considered to be isotopes if they share the same atomic number.

(iii) Since, the atomic number decreases. Therefore, the particles X will be electron.

$${}^{22}_{11}\text{Na} + \left({}^{0}_{-1}e^{-}\right) \rightarrow {}^{22}_{10}\text{Ne} + \nu_e$$

$({}^{0}_{-1}e^{-})$ is beta particle (electron)

29.

(i) The total electric flux through a closed Gaussian surface is provided by Gauss' theorem,

$$\phi = \frac{q}{\varepsilon_0}$$

Substituting the values of $\varphi = -3 \times 10^{-14}$ and $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m we get

$$-3 \times 10^{-14} = \frac{q}{8.85 \times 10^{-12}}$$

$$q = (-3 \times 10^{-14}) \times (8.85 \times 10^{-12})$$

$$q = 2.655 \times 10^{-25}\text{ C}$$

Therefore, the magnitude of point charge is -2.655×10^{-25} C.

(ii) The given value of electric field intensity is

$$|E| = 5 \times 10^3 \text{ N/C}$$

The length of one side of the square is 10 cm or 0.1 m. So, the area of the square will be 0.01 m^2. The plane of the square is parallel to the YZ-plane. So, $\theta = 0°$.

Substituting $|E| = 5 \times 10^3$ N/C

$A = 0.01$ m^2 and $\theta = 0°$

$$\phi = |E|\, A \cos\theta$$

$$\phi = 5 \times 10^3 \times (0.01) \cos 0°$$

$$= 5 \times 10^3 \times (0.01)$$

$$= 50 \text{ N-m}^2/\text{C}$$

Therefore, the flux when the square's plane is parallel to the YZ-plane is 50 N-m^2/C.

When the plane makes a 30° angle with the x axis then, $\theta = 60°$.

Again, substituting the values in the equation,

$$\varphi = 5 \times 10^3 \times 0.01 \times \cos 60°$$

$$= 25 \text{ N-m}^2/\text{C}$$

Therefore, the flux when the plane of the square makes an angle 30° with x-axis is 50 N-m^2/C.

(iii) Electric flux, $\phi = \frac{q_{enclosed}}{\varepsilon_0}$

So, flux is not affected by radius of the Gaussian surface.

OR

(i) Given, surface charge density is 4×10^{-6} C/m^2 and the mass of the particle is 5×10^{-6} g.

The electric field, $E = \frac{\sigma}{2\varepsilon_0}$

$$= \frac{4 \times 10^{-6}}{2(8.85 \times 10^{-12})}$$

$$= 2.26 \times 10^5 \text{ N/C}$$

Therefore, the electric field is 2.26×10^5 N/C

The electric force qE acts in the upward direction if the particle is given a charge q. The particle's weight is balanced by this force, $F = qE$.

The force F is downward force. So, $mg = qE$.

Substitute the values into the formula,

$$(5 \times 10^{-6})(9.8) = q(2.26 \times 10^5)$$

$$q = \frac{(5 \times 10^{-6})(9.8)}{(2.26 \times 10^5)}$$

$$= 2.2 \times 10^{-10}\text{ C}$$

Therefore, charge applied is 2.21×10^{-10} C.

(ii) It is not feasible to construct a symmetric Gaussian surface that completely encloses a charged cube, which makes it challenging to calculate the electric field using Gauss' law. The charge distribution of a cube appears asymmetric from any chosen Gaussian surface, resulting in fluctuating electric field values. Hence, Gauss' law cannot be applied to determine the electric field of a charged cube.

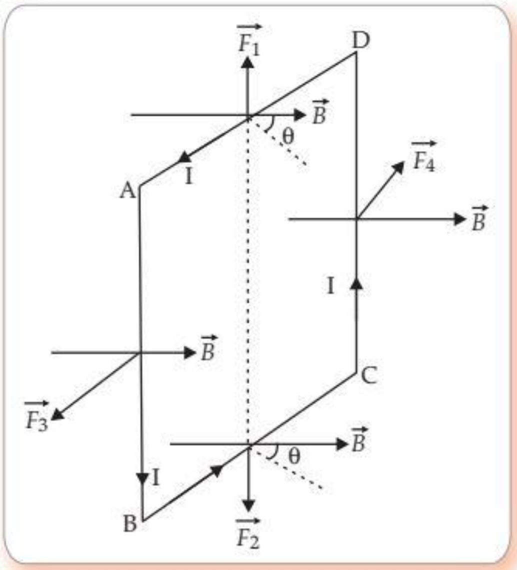
(iii) According to the Gauss theorem,

$$\phi = \frac{q_{enclosed}}{\varepsilon_0}$$

Thus, electric flux depends upon the charge enclosed and the permittivity of the medium.

30.

(i)



A rectangular current carrying loop is placed in a magnetic field $\vec{B}$.

$$AD = BC = b$$

$$AB = CD = l$$

Current I flowing through the loop.

Loop is making an angle θ with the direction of magnetic field.

Force acting on DA,

$$F_1 = IbB \sin(90° + \theta)$$
$$= IbB \cos\theta$$

It will be acting in the upward direction.

Similarly force acting on BC,

$$F_2 = IbB \cos\theta$$

It will be acting in the downward direction.

So, net resultant force of F_1 and F_2 is zero.

AB being perpendicular to $\vec{B}$, force on AB is,

$$F_3 = IlB \sin 90° = BIl$$

It will be acting perpendicular outward to the plane of the paper.

Similarly force acting on CD,

$$F_3 = BIl$$

It will be acting perpendicular inward to the plane of the paper.

These two forces are equal and opposite and lines of action are different. Hence, they will constitute a torque.

Perpendicular distance between the forces = $b \sin\theta$.

So, torque $= \tau = BIl \times b \sin\theta$

Or, $\tau = BIA \sin\theta$

If there are N number of turns in the loop, then

$$\tau = NBIA \sin\theta$$

(ii) In a radial magnetic field, the rectangular coil maintains two sides that are parallel to the magnetic field lines, while the other two sides remain perpendicular to the magnetic field lines. This characteristic remains consistent for all positions of the coil within the magnetic field.

(iii) Given resistance of galvanometer (G) = 100 Ω

External resistance (S) = 0.1 Ω

Current for maximum deflection (I_G) = 100 μA

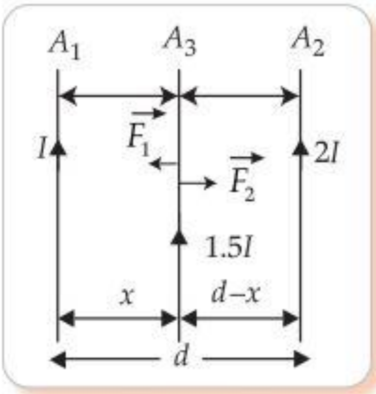
$$i = \frac{I_g(G+S)}{S}$$
$$= \frac{100 \times 10^{-6}(100 + 0.1)}{0.1}$$
$$i = 100.1\ mA$$

(iv) In order for a galvanometer to function as a voltmeter, its inherent resistance needs to be increased. Since the coil in the galvanometer has a low resistance, it is necessary to increase the resistance to transform it into a voltmeter. This is achieved by connecting an appropriate high resistance in series with the galvanometer.

OR

(i) Since, we know the force per unit length on two infinitely current-carrying wires is given by $\frac{\mu_0 I_a I_b}{2\pi d}$.

where I_a is current flowing through wire A and I_b by wire A_2 and d is the distance between parallel wires.



Now, force per unit length on wire A_3 due to A_1

$$(F_1) = \frac{\mu_0 I \times 1.5I}{2\pi x} \text{ (in –ve } x\text{-direction)} \quad ...(i)$$

And, force per unit length on wire A_3 due to A_2

$$(F_2) = \frac{\mu_0 2I \times 1.5I}{2\pi(d-x)} \text{ (in +ve } x\text{-direction)} ...(ii)$$

So, net force on A_3 to be zero, both the forces should be equal.

Therefore, $\frac{\mu_0 I \times 1.5I}{2\pi x} = \frac{\mu_0 2I \times 15I}{2\pi(d-x)}$

Or, $2x = d - x$

$3x = d$

So, $x = \frac{d}{3}$

The net force acting on A_3 is zero only when current through is 1.5 I. So, it depends on the current flowing through it.

(ii) Given, $I_1 = 2A$

$I_2 = 1A$

$d_1 = 10$ cm

$d_2 = 30$ cm

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

Force on AB,

$$F_{AB} = \frac{\mu_0 \times 2 \times 1 \times 20 \times 10^{-2}}{2\pi \times 10 \times 10^{-2}}$$

Force on CD,

$$F_{CD} = \frac{\mu_0 \times 2 \times 1 \times 20 \times 10^{-2}}{2\pi \times 30 \times 10^{-2}}$$

Net force

$$= \frac{\mu_0 \times 2 \times 1 \times 20 \times 10^{-2}}{2\pi \times 10 \times 10^{-2}} - \frac{\mu_0 \times 2 \times 1 \times 20 \times 10^{-2}}{2\pi \times 30 \times 10^{-2}}$$

$$= 5.3 \times 10^{-7}\,\text{N}$$