

Section A

1.

(c) Van der Waals

Explanation:

Vander walls bond is the weakest kind of bonding in solids.

2.

(b) 0.592 A

Explanation:

To find the current flowing in the tube, we need to calculate the total charge per second due to the movement of protons and electrons.

i. **Charge of Protons and Electrons:** The charge of a proton (or electron) is approximately 1.6×10^{-19} coulombs.

ii. **Current from Protons:** The current due to protons can be calculated using the formula: $I_p = n_p \times e$ where n_p is the number of protons per second and e is the charge of a proton. Substituting the values:

$$I_p = 1.0 \times 10^{18} \times 1.6 \times 10^{-19} = 0.16 \text{ A}$$

iii. **Current from Electrons:** The current due to electrons is calculated similarly: $I_e = n_e \times e$ where n_e is the number of electrons per second. Substituting the values: $I_e = 2.7 \times 10^{18} \times 1.6 \times 10^{-19} = 0.432 \text{ A}$

iv. **Total Current:** Since the protons and electrons are moving in opposite directions, the total current is the difference between the two: $I_{total} = I_e - I_p = 0.432 \text{ A} - 0.16 \text{ A} = 0.272 \text{ A}$

However, the total current should be calculated by considering the net charge flow. Since electrons are negatively charged and moving in the opposite direction, we consider the absolute value of the current contributions:

$$I_{total} = I_p + I_e = 0.16 \text{ A} + 0.432 \text{ A} = 0.592 \text{ A}$$

Thus, the total current flowing in the tube is 0.592 A, which matches the provided solution.

3.

(b) Full image will be formed but will be less bright

Explanation:

Image will be formed at the same position and same height but intensity of image formed will be less hence its brightness will be less as less number of light rays will form the image. Light rays from the covered portion will not contribute to image formation.

4.

(d) due to spin and orbital motions of electrons both

Explanation:

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5.

(d) $\vec{E} = \hat{i}(2xy + z^3) + \hat{j}x^2 + \hat{k}3xz^2$

Explanation:

$$\begin{aligned} \vec{E} &= -\frac{\partial V}{\partial r} = \left[-\frac{\partial V}{\partial x} \hat{i} - \frac{\partial V}{\partial y} \hat{j} - \frac{\partial V}{\partial z} \hat{k} \right] \\ &= \left[(2xy + z^3) \hat{i} + x^2 \hat{j} + 3xz^2 \hat{k} \right] \end{aligned}$$

6.

(a) remains constant

Explanation:

As the magnetic force is always at right angle to the direction of motion of charged particle. So work done is zero, hence kinetic energy remains constant.

7.

(d) l decreases and A increases

Explanation:

L = self-inductance, A = area of cross-section.

As we know, $L = \mu_r \mu_0 \frac{N^2}{l} Al$

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

as L is constant for a coil

$$L \propto A \text{ and } L \propto \frac{1}{l}$$

As, μ_r and N are constant here so, to increase L for a coil, area A must be increased and l must be decreased.

8.

(d) $\oint \vec{B} \cdot d\vec{s} = 0$

Explanation:

Since magnetic monopoles do not exist, flux entering the closed surface is equal to flux leaving the surface. Hence net magnetic flux through a closed surface is zero.

9. (a) Diffraction

Explanation:

When the light bends round an obstacle it enters into an area of geometrical shadow. This phenomenon is called as diffraction of light.

10.

(d) $7.2 \times 10^7 \text{ NC}^{-1}$

Explanation:

The electric field at the center of a uniformly charged ring is typically zero due to symmetry. However, in this case, the ring has a gap, which disrupts the symmetry. The charge is uniformly distributed along the ring, except for the gap, which means that the electric field will not cancel out completely. To find the electric field at the center, we can use the formula for the electric field due to a charged ring with a gap. The electric field can be calculated by considering the contributions from the charged segments on either side of the gap. The total electric field is then derived from the geometry of the ring and the amount of charge. Given the radius of the ring (0.5 m) and the charge (+1 C), the calculations yield an electric field of approximately $7.2 \times 10^7 \text{ N/C}$ at the center, which matches the provided solution. This value takes into account the effect of the gap and the distribution of charge around the ring.

11.

(b) p-type semiconductor



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Explanation:

One can see in the figure that number of holes are greater than number of electrons. Hence it is p-type semiconductor.

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12.

(d) fitting eye-piece of high power

Explanation:

Magnification of telescope can be increased by using eyepiece of lower focal length (f_e). Since power is inversely proportional to focal length, eyepiece of large power will increase magnification of the telescope.

13. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Explanation:

Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

14. (a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation:

Assertion and reason both are correct statements and reason is correct explanation for assertion.

15.

(b) Both A and R are true but R is not the correct explanation of A.

Explanation:

Both assertion and reason true but the reason is not the correct explanation of assertion. Colours are seen due to interference between light waves reflected by the upper and lower surfaces of the thin oil film.

16.

(c) A is true but R is false.

Explanation:

Both ac and dc produce heat, which is proportional to the square of the current. The reversal of direction of current in ac is immaterial so far as production of heat is concerned.

Section B

17. $t = 30 \text{ minute} = 30 \times 60 = 1800 \text{ sec} = 0.18 \times 10^4 \text{ sec}.$

The total energy falling on the surface is

$$U = (18 \text{ W/cm}^2) \times (20 \text{ cm}^2) \times (30 \times 60 \text{ s}) \\ = 6.48 \times 10^5 \text{ J}$$

Therefore, the total momentum delivered (for complete absorption) is

$$p = \frac{U}{c} = \frac{6.48 \times 10^5 \text{ J}}{3 \times 10^8 \text{ m/s}} = 2.16 \times 10^{-3} \text{ kg m/s}$$

The average force exerted on the surface is

$$F = \frac{p}{t} = \frac{2.16 \times 10^{-3}}{0.18 \times 10^4} = 1.2 \times 10^{-6} \text{ N}$$

18. Let the pole strengths of the two dipoles be q_m and $4q_m$.

Here $F = 5 \text{ gf} = 5 \times 10^{-3} \text{ kgf} = 5 \times 10^{-3} \times 9.8 \text{ N}$, $r = 10 \text{ cm} = 0.1 \text{ m}$

Using Coulomb's law of magnetism,

$$F = \frac{\mu_0}{4\pi} \cdot \frac{q_{m1} q_{m2}}{r^2}$$

$$\therefore 5 \times 10^{-3} \times 9.8 = \frac{10^{-7} \times q_m \times 4q_m}{(0.1)^2}$$

$$\text{or } q_m^2 = \frac{5 \times 9.8 \times (0.1)^2 \times 10^4}{4} = 25 \times 49$$

$$\text{or } q_m = 5 \times 7 = 35 \text{ Am and } 4q_m = 4 \times 35 = 140 \text{ Am}$$

OR

Here $A = 0.2 \text{ cm}^2 = 0.2 \times 10^{-4} \text{ m}^2$, $H = 1200 \text{ Am}^{-1}$, $\chi_m = 599$

Permeability, $\mu = \mu_0 (1 + \chi_m)$

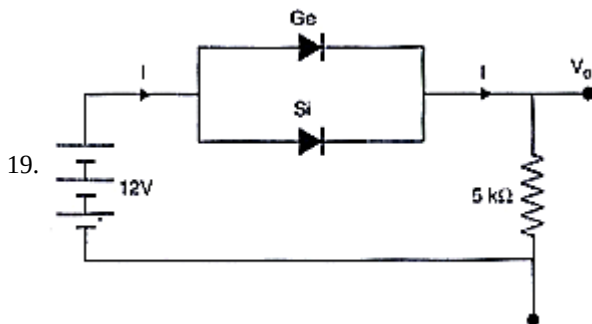
$$= 4\pi \times 10^{-7} \times (1 + 599) = 7.536 \times 10^{-4} \text{ TmA}^{-1}$$

Magnetic induction,

$$B = \mu H = 7.536 \times 10^{-4} \times 1200 = 0.904 \text{ T}$$

Magnetic flux,

$$\phi = BA = 0.904 \times 0.2 \times 10^{-4} = 1.81 \times 10^{-5} \text{ Wb}$$



$$\text{Current, } I = \frac{12 - 0.3}{5 \times 10^3} = 2.34 \text{ mA}$$

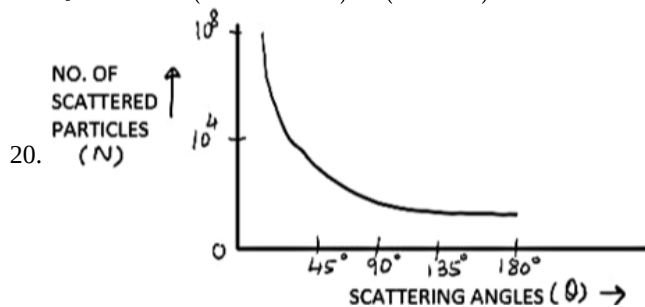
$$\text{Output voltage, } V_o = RI = (5 \times 10^3) \times (2.34 \times 10^{-3}) = 11.7 \text{ V}$$

When the connections of Ge diode are reversed, then current will be through silicon.

In this case, $I' = \frac{12-0.7}{5 \times 10^3} = 2.26 \text{ mA}$

and

$$V'_0 = I'R = (2.26 \times 10^{-3}) \times (5 \times 10^3) = 11.3 \text{ V}$$



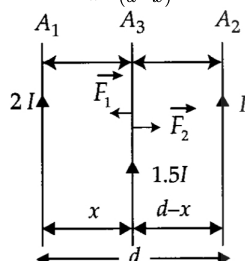
CONCLUSIONS FROM GRAPH:

- Decreasing slope shows that most of the particles pass straight through the gold foil without deflection. So most of the space within the atom must be empty.
- A few particles, about 1 in 800 got deflected through 90 degree or more, depending on the impact parameter.

21. Finding the position of third wire Reason

$$F_1 = \frac{\mu_0}{4\pi} \frac{I \times 1.5I}{x}$$

$$F_2 = \frac{\mu_0}{4\pi} \frac{2I \times 1.5I}{(d-x)}$$



For no force on the conductor, A_3

$$\frac{\mu_0}{4\pi} \frac{I \times 1.5I}{x} = \frac{\mu_0}{4\pi} \frac{2I \times 1.5I}{(d-x)}$$

$$\frac{1}{x} = \frac{2}{(d-x)}$$

$$3x = d$$

$$x = \frac{d}{3}$$

The net force acting on A_3 is zero only when current through is $1.5I$. So, it depends on the current flowing through it.

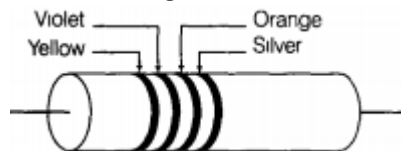
[Note: Also accept in general, it will depend on the value of I_3 .]

Section C

22. i. Given, resistance = $47k\Omega \pm 10\%$

$$= 47 \times 10^3 \Omega \pm 10\%$$

$\therefore$ 1st colour band should be yellow as code for it is 4, 2nd colour band should be violet as code for it is 7, 3rd colour band should be orange as code for it is 3, 4th colour band should be silver because approximation is $\pm 10\%$.



ii. Two properties of manganin are:

- low temperature coefficient of resistance.
- high value of resistivity of material of manganin make it suitable for making a standard resistor.

23. The frequency of ultraviolet radiations is more while that of red light is less than the threshold frequency for a zinc surface, so ultraviolet radiations can cause the emission of electrons and red light cannot.

From Einstein's photoelectric equation, K.E. of a photoelectron is

$$\frac{1}{2} m v^2 = h\nu - W_0 = h\nu - 0 = \frac{hc}{\lambda}$$

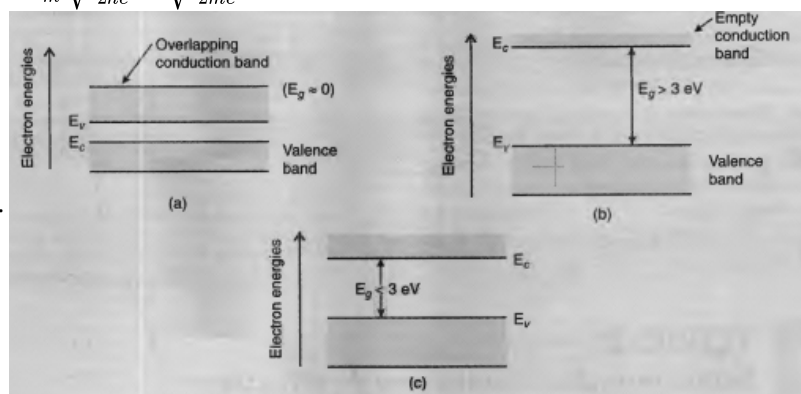
$$\text{or } v = \sqrt{\frac{2hc}{m\lambda}}$$

de Broglie wavelength of electrons,

$$\lambda_e = \frac{h}{mv}$$

$$= \frac{h}{m} \sqrt{\frac{m\lambda}{2hc}} = \sqrt{\frac{h\lambda}{2mc}}$$

24.



Two distinguishing features are given below :

- In conductors, the valence band and conduction band tends to overlap (or nearly overlap) each other , while in insulators they are separated by a large energy gap and in semiconductors they are separated by a small energy gap.
- The conduction band of a conductor, has a large number of electrons available for electrical conduction. However, the conduction band of insulators is almost empty while that of the semi-conductor has only a (very) small number of such electrons available for electrical conduction

25. The number of neutron and Proton both in a $^{56}\text{Fe}_{26}$ atom is respectively 30 and 26.

The mass defect $\Delta m = m_p + m_n - m_{\text{Fe}}$

And Binding energy is given by $E_B = \Delta mc^2$

Mass of a proton = 1.007825 u

Mass of a neutron = 1.008665 u

In this case mass defect $= \Delta m = (26 \times 1.007825 + 30 \times 1.008665 - 55.934939) \text{u} = 0.528461 \text{u}$

We know, $1 \text{a.m. u} = 931.5 \text{ MeV}/c^2$

So, $E = \Delta mc^2 = 0.528461 \times 931.5 (\text{MeV}/c^2) \times c^2 = 492.26 \text{ MeV}$

So, Binding Energy per Nucleon $= \frac{\text{Total Binding Energy}}{\text{Total No Of Nucleon}} = \frac{492.26}{56} = 8.79 \text{ MeV}$

The number of neutron and Proton both in a $^{209}\text{Bi}_{83}$ atom is respectively 126 and 83.

The mass defect $\Delta m = m_p + m_n - m_{\text{Bi}}$

And Binding energy is given by $E_B = \Delta mc^2$

Mass of a proton = 1.007825 u

Mass of a neutron = 1.008665 u

Mass Defect $= \Delta m = 83 \times 1.007825 + 126 \times 1.008665 - 208.980388 = 1.760877 \text{ u}$

We know, $1 \text{a.m.u} = 931.5 \text{ MeV}/c^2$

So, $E = \Delta mc^2 = 1.760877 \times 931.5 (\text{MeV}/c^2) \times c^2 = 1640.26 \text{ MeV}$

Average binding energy per nucleon $= \frac{1640.26}{209} = 7.848 \text{ MeV}$

Hence, these are the required values.

26. The radius of the nth orbit of a hydrogen atom is given by $r = \frac{n^2 h^2}{4\pi^2 m k e^2}$

Radius of the innermost orbit, called Bohr's radius, is obtained by putting $n = 1$ It is denoted by r_0

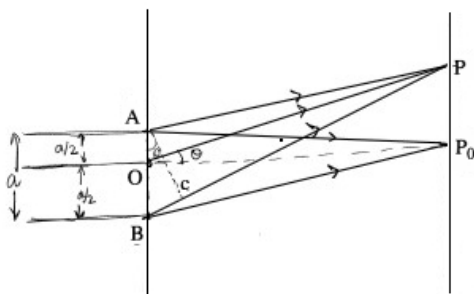
$$\therefore r_0 = \frac{h^2}{4\pi^2 m k e^2}$$

$$= \frac{(6.6 \times 10^{-34})^2}{4\pi^2 \times 9.1 \times 10^{-31} \times 9 \times 10^9 \times (1.6 \times 10^{-19})^2} \text{ m}$$

$$= 0.53 \times 10^{-10} \text{ m} = 0.53 \text{ \AA}$$

27. Let us consider consider a slit AB is made up of two slits each of width $\frac{a}{2}$.

As P_0 is point equidistant from all the huygen's sources therefore all will be in phase to give central maxima for first minima path differences between waves from A and O $= \frac{\lambda}{2}$



Let OP subtends angle θ at the slit then in $\triangle^s ABC$ and OP_0P

With P as the centre and PA as radius, strike an arc intersecting PB at C

AC can be considered as straight line at right angle to PB thus $\triangle^s ABC \sim OP_0P$

$$\therefore BC = a \sin \theta$$

$$(PB - PO) + (PO - PA) = a \sin \theta$$

$$\frac{\lambda}{2} + \frac{\lambda}{2} = \lambda = a \sin \theta$$

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

$$\text{and } \theta \text{ is small so, } \theta_n = \frac{n\lambda}{a}$$

$n = 1, 2, 3$ dark fringes

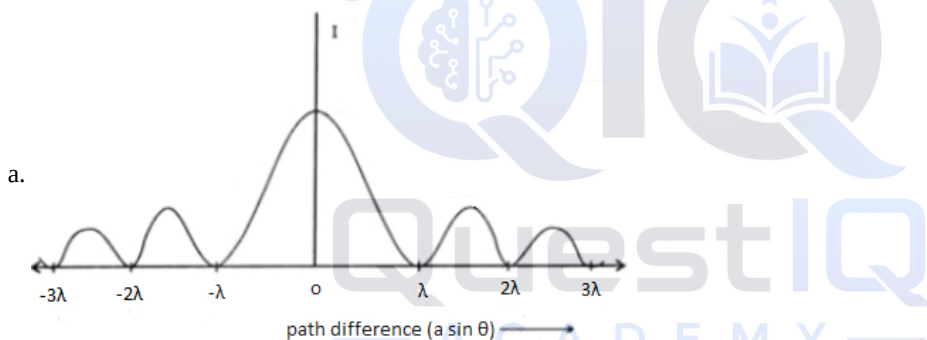
Similarly for secondary maxima

$$a \sin \theta = \frac{\lambda}{2}$$

$$\sin \theta = \frac{\lambda}{2a}$$

$$\theta_n = \left(n + \frac{1}{2}\right) \frac{\lambda}{a}$$

$n = 1, 2, 3, \dots$ bright fringes



a. $\theta_n = \left(n + \frac{1}{2}\right) \frac{\lambda}{a}$

$$\frac{x}{D} = \frac{3}{2} \frac{\lambda}{a}$$

$n = 1$ for first maxima

$$x = \frac{3\lambda D}{2a}$$

28. Rate of work done,

$$\frac{dW}{dt} = |\varepsilon| i$$

$$dW = \left(L I \frac{dI}{dt} \right) dt$$

$$dW = L I dI$$

Total amount of work done,

$$\int dW = \int L I dI$$

$$W = \frac{1}{2} L I^2$$

For the solenoid:

$$\text{Inductance, } L = \mu_0 n^2 A E; B = \mu_0 n I$$

$$\therefore W = U_B = \frac{1}{2} L I^2$$

$$= \frac{1}{2} (\mu_0 n^2 A l) \left(\frac{B}{\mu_0 n} \right)^2$$

$$= \frac{B^2 A l}{2 \mu_0}$$

Magnetic energy per unit volume

$$\text{Electrostatic Energy Stored Per Unit Volume stored in parallel plate capacitor} = \frac{1}{2} \varepsilon_0 E^2$$

OR

$$a. B = \mu_0 n_1 I = \frac{\mu_0 N_1 I}{l} = \frac{\mu_0 N_1 I}{2\pi r}$$

$$\text{Total magnetic flux, } \phi_B = N_1 B A = \frac{\mu_0 N_1^2 I A}{2\pi r}$$

$$\text{But } \phi_B = L I$$

$$\therefore L = \frac{\mu_0 N_1^2 A}{2\pi r}$$

$$\text{Or } L = \frac{4\pi \times 10^{-7} \times 1200 \times 1200 \times 12 \times 10^{-4}}{2\pi \times 0.15}$$

$$= 2.3 \times 10^{-3} H = 2.3 \text{ mH}$$

$$b. |E| = \frac{d}{dt}(\phi_2) \text{ where } \phi_2 \text{ is the total magnetic flux linked with the second coil.}$$

$$|E| = \frac{d}{dt}(N_2 B A) = \frac{d}{dt} \left[N_2 \frac{\mu_0 N_1 I}{2\pi r} A \right]$$

$$|E| = \frac{\mu_0 N_1 N_2 A}{2\pi r} \frac{dI}{dt}$$

$$|E| = \frac{4\pi \times 10^{-7} \times 1200 \times 300 \times 12 \times 10^{-4} \times 2}{2\pi \times 0.15 \times 0.05} = 0.023 \text{ V}$$

Section D

29. Read the text carefully and answer the questions:

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ϵ will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

$$(i) \quad (d) \text{ ML}^{-1}\text{T}^{-2}$$

Explanation:

$$\frac{1}{2} \epsilon_0 E^2 = \text{energy density} = \frac{\text{Energy}}{\text{Volume}}$$

$$\therefore \left[\frac{1}{2} \epsilon_0 E^2 \right] = \frac{\text{ML}^2 \text{T}^{-2}}{\text{L}^3} = [\text{ML}^{-1}\text{T}^{-2}]$$

$$(ii) \quad (c) [\epsilon_0] = \text{M}^{-1}\text{L}^{-3}\text{T}^4\text{A}^2$$

Explanation:

$$\text{As } \epsilon_0 = \frac{q_1 q_2}{4\pi F R^2} \text{ (from Coulomb's law)}$$

$$\epsilon_0 = \frac{C^2}{\text{Nm}^2} \frac{[\text{AT}]^2}{\text{MLT}^{-2} \text{L}^2} = \text{M}^{-1}\text{L}^{-3}\text{T}^4\text{A}^2$$

$$(iii) \quad (d) \text{ wavelength is halved and the frequency remains unchanged.}$$

Explanation:

The frequency of the electromagnetic wave remains same when it passes from one medium to another.

$$\text{Refractive index of the medium, } n = \sqrt{\frac{\epsilon}{\epsilon_0}} = \sqrt{\frac{4}{1}} = 2$$

Wavelength of the electromagnetic wave in the medium,

$$\lambda_{\text{med}} = \frac{\lambda}{n} = \frac{\lambda}{2}$$

OR

$$(a) \text{ the speed of light } c = 3 \times 10^8 \text{ m s}^{-1} \text{ in free space}$$

Explanation:

The velocity of electromagnetic waves in free space (vacuum) is equal to velocity of light in vacuum (i.e., $3 \times 10^8 \text{ m s}^{-1}$).

$$(iv) \quad (b) \beta\text{-rays}$$

Explanation:

β -rays consists of electrons which are not electromagnetic in nature.

30. i. The proportionality constant k depends on the nature of the medium between the two charges.

ii. The dimensional formula for the permittivity constant is $[\text{ML}^{-3}\text{T}^4\text{A}^2]$.

iii. The force of repulsion will be $9 \times 10^9 \text{ N}$.

$$\text{iv. } F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{d^2}$$

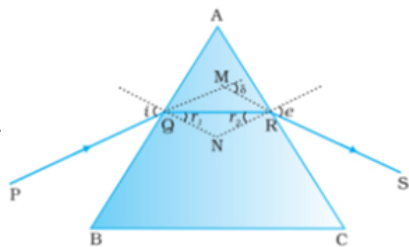
$$\therefore (10 \times 10^{-3}) \times 10 = \frac{(9 \times 10^9) \times q^2}{(0.6)^2}$$

$$\text{or } q^2 = \frac{10^{-1} \times 0.36}{9 \times 10^9} = 4 \times 10^{-12}$$

$$\text{or } q = 2 \times 10^{-6} \text{ C} = 2 \mu\text{C}$$

Section E

31. i.



In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles. Therefore, the sum of the other angles of the quadrilateral is 180° .

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

$$\text{From the triangle QNR, } r_1 + r_2 + \angle QNR = 180^\circ$$

Comparing these two equations, we get

$$r_1 + r_2 = A \dots (i)$$

The total deviation δ is the sum of deviations at the two faces,

$$\delta = (i - r_1) + (e - r_2) \text{ that is, } \delta = i + e - A \dots (ii)$$

When $\delta = \delta_m$; $i = e$ & $r_1 = r_2$

$$\text{From (i); } 2r = A \text{ or } r = \frac{A}{2}$$

$$\text{From (ii); } \delta_m = 2i - A \text{ or } i = \frac{A + \delta_m}{2}$$

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

hence, this is the relation of angle of prism (A) and angle of minimum deviation (δ_m).

ii. Given; P = -5D

$$f \text{ (in cm)} = \frac{100}{(-5)} = -20 \text{ cm}$$

$$\text{Using Lens Maker's formula; } \frac{1}{f} = (\mu - 1) \left[\frac{1}{R_1} - \frac{1}{R_2} \right]$$

$$\frac{1}{(-20)} = (\mu - 1) \left[\frac{1}{(-20)} - \frac{1}{(+20)} \right]$$

$$\frac{1}{(-20)} = (\mu - 1) \left[-\frac{1}{10} \right]; \mu - 1 = \frac{1}{2}$$

$$\Rightarrow \mu = \frac{3}{2} = 1.5$$

- a. i. The interference pattern has a number of equally spaced bright and dark bands. The diffraction pattern has a central bright maximum which is twice as wide as the other maxima. The intensity falls as we go to successive maxima away from the centre, on either side.

- ii. We calculate the interference pattern by superposing two waves originating from the two narrow slits. The diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

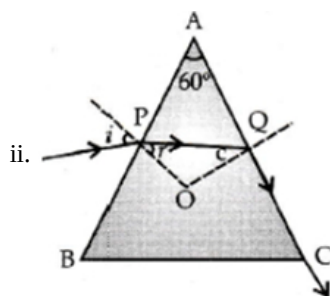
$$\text{b. i. } \mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{90}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \sqrt{2}$$

$$\text{Here } A = 60^\circ, \delta_m = 30^\circ.$$

$$\text{Now } \mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu};$$

$$\Rightarrow v = \frac{3 \times 10^8}{\sqrt{2}} = 2.12 \times 10^8 \text{ ms}^{-1}$$

the speed of light through the prism is $2.12 \times 10^8 \text{ ms}^{-1}$



$$n = \sqrt{2}$$

$$\therefore n = \frac{1}{\sin c} \text{ (for face AC)}$$

$$\sqrt{2} = \frac{1}{\sin c}$$

$$\Rightarrow \sin c = \frac{1}{\sqrt{2}} = \sin 45^\circ$$

$$\Rightarrow c = 45^\circ$$

$$\therefore \angle APQ = 180^\circ - (60^\circ + 45^\circ)$$

$$= 75^\circ$$

$$\therefore r = 90^\circ - 75^\circ = 15^\circ$$

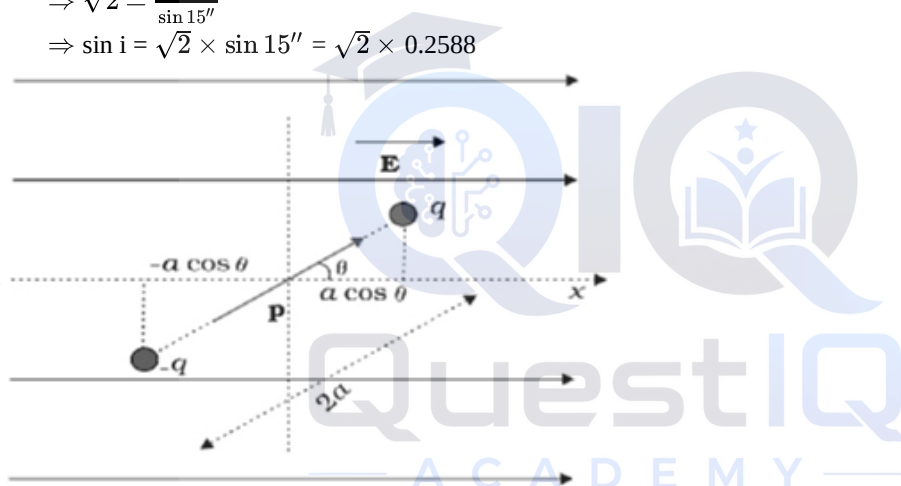
$$i = ?$$

$$n = \frac{\sin i}{\sin r}$$

$$\Rightarrow \sqrt{2} = \frac{\sin i}{\sin 15^\circ}$$

$$\Rightarrow \sin i = \sqrt{2} \times \sin 15^\circ = \sqrt{2} \times 0.2588$$

32. a.



Since torque acting on dipole

$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$\vec{\tau} = pE \sin \theta \cdot \hat{n}$$

$$\text{work done } dW = \tau \cdot d\theta$$

$$= pE \sin \theta d\theta$$

$$W = \int_{\theta_1}^{\theta_2} dW = pE \int_{\theta_1}^{\theta_2} \sin \theta d\theta$$

$$W = pE [-\cos \theta]_{\theta_1}^{\theta_2}$$

$$= pE [\cos \theta_1 - \cos \theta_2]$$

$$\text{if } \theta_1 = 0, \theta_2 = \theta$$

$$W = pE (1 - \cos \theta)$$

Conditions-

For stable equilibrium - When electric dipole is parallel to electric field.

For unstable equilibrium - Anti Parallel to electric field.

b. No.

Inside equipotential surface

OR

Consider origin at the centre of dipole. As per superposition principle, potential due to dipole will be the sum of potentials due to charges q and $-q$

$$V = \frac{1}{4\pi\epsilon_0} \left[\frac{q}{r_1} - \frac{q}{r_2} \right]$$



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Where,

r_1 and r_2 = distances of point P from q and -q.

$$r_1^2 = r^2 + a^2 - 2a \cos \theta$$

$$r_2^2 = r^2 + a^2 + 2a \cos \theta$$

If r is greater than a, and taking terms upto first order in a/r

$$r_1^2 = r^2 \left[1 - \frac{2a \cos \theta}{r} + \frac{a^2}{r^2} \right]$$

$$= r^2 \left[1 - \frac{2a \cos \theta}{r} \right]$$

$$\text{Also, } r_2^2 = r^2 \left[1 + \frac{2a \cos \theta}{r} \right]$$

With the help of Binomial theorem, keeping terms upto first order is shown below:

$$\frac{1}{r_1} \equiv \frac{1}{r} \left[1 - \frac{2a \cos \theta}{r} \right]^{\frac{1}{2}}$$

$$\equiv \frac{1}{r} \left[1 + \frac{a}{r} \cos \theta \right]$$

$$\frac{1}{r_2} \equiv \frac{1}{r} \left[1 + \frac{2a \cos \theta}{r} \right]^{\frac{1}{2}}$$

$$\equiv \frac{1}{r} \left[1 - \frac{a}{r} \cos \theta \right]$$

As $p = qa$

$$V = \frac{1}{4\pi\epsilon_0} \frac{q(2a) \cos \theta}{r^2}$$

$$V = \frac{p}{4\pi\epsilon_0} \cdot \frac{\cos \theta}{r^2}$$

Now, $p \cos \theta = \vec{p} \cdot \hat{r}$

where $\hat{r}$ is unit vector along position vector.

Hence electric potential of dipole for distances large compared to size of dipole is given as below :

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{p} \cdot \hat{r}}{r^2} \text{ for } r \gg a$$

---For potential at any point on axis, $\theta = [0, \pi]$

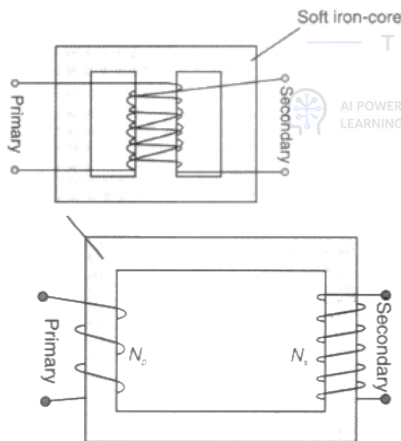
$$V = \pm \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r}$$

potential is positive when $\theta = 0$

potential is negative when $\theta = \pi$

Hence, electric potential falls at large distance, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$

33. i.



Principle: Step-down transformer is made up of two or more coil wound on the iron core of the transformer. It works on the principle of magnetic induction between the coils. When the current flowing through the primary coil changes, an emf is induced in the secondary coil due to the change in magnetic flux linked with it.

ii. $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

iii. For an ideal transformer,

$$i_p V_p = i_s V_s$$

$$\therefore \frac{i_p}{i_s} = \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

iv. We have

$$i_p V_p = i_s V_s = 550 \text{ W}$$

$$V_p = 220 \text{ V}$$

$$i_p = \frac{550}{220} = \frac{5}{2} = 2.5 \text{ A}$$

OR

Inductance, $L = 0.12 \text{ H}$

Capacitance, $C = 480 \text{ nF} = 480 \times 10^{-9} \text{ F}$

Resistance, $R = 23 \Omega$

Supply voltage, $V = 230 \text{ V}$

Peak voltage is given as:

$$V_0 = \sqrt{2} \times 230 = 352.22 \text{ V}$$

a. the source frequency for which the current amplitude is maximum is given by:-Current flowing in the circuit is given by the

$$\text{relation, } I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

Where,

I_0 = maximum at resonance

At resonance, we have

$$\omega_R L - \frac{1}{\omega_R C} = 0$$

Where,

ω_R = Resonance angular frequency

$$\therefore \omega_R = \frac{1}{\sqrt{LC}}$$

$$= \frac{1}{\sqrt{0.12 \times 480 \times 10^{-9}}} = 4166.67 \text{ rad/s}$$

$$\therefore \text{Resonant frequency, } \nu_R = \frac{\omega_R}{2\pi} = \frac{4166.67}{2 \times 3.14} = 663.48 \text{ Hz}$$

$$\text{And, maximum current in the given circuit } (I_0)_{\text{Max}} = \frac{V_0}{R} = \frac{352.22}{23} = 15.31 \text{ A}$$

b. Maximum average power absorbed by the circuit is given as:

$$(P_{\text{av}})_{\text{Max}} = \frac{1}{2} (I_0)_{\text{Max}}^2 R$$
$$= \frac{1}{2} \times (15.31)^2 \times 23 = 2709.3 \text{ W}$$

Also, the resonant frequency (ν_R) is 663.48 Hz.

c. The power transferred to the circuit is half the power at resonant frequency.

Frequencies at which power transferred is half, $= \omega_r \pm \Delta\omega$

$$= 2\pi (\nu_R \pm \Delta\nu)$$

where,

$$\Delta\omega = \frac{R}{2L}$$

$$= \frac{23}{2 \times 0.12} = 95.83 \text{ rad/s}$$

$$\text{Hence, change in frequency, } \Delta\nu = \frac{1}{2\pi} \Delta\omega = \frac{95.83}{2\pi} = 15.26 \text{ Hz}$$

$$\therefore \nu_R + \Delta\nu = 663.48 + 15.26 = 678.74 \text{ Hz}$$

$$\text{And, } \nu_R - \Delta\nu = 663.48 - 15.26 = 648.22 \text{ Hz}$$

Hence, at 648.22 Hz and 678.74 Hz frequencies, the power transferred is half.

At these frequencies, the current amplitude can be given as:

$$I' = \frac{1}{\sqrt{2}} \times (I_0)_{\text{Max}}$$

$$= \frac{15.31}{\sqrt{2}} = 10.8 \text{ A}$$

d. Q -factor of the given circuit can be obtained using the relation, $Q = \frac{\omega_R L}{R}$

$$= \frac{4166.67 \times 0.12}{23} = 21.74$$

Hence, the Q -factor of the given circuit is = 21.74