Section A

1. **(a)** $\sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$

Explanation: Velocity of light in vacuum, c = $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Velocity of light in medium, v = $\frac{1}{\sqrt{\mu\varepsilon}}$

$\therefore$ Refractive index of the medium

$\mu = \frac{c}{v} = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$

2. **(a)** I, I_2, I_1, I_g
Explanation: I, I_2, I_1, I_g
3. **(a)** rectifier
Explanation: Diode is used as a rectifier.
4. **(d)** 1.68 $(\Omega\text{-m})^{-1}$
Explanation: As we know that conductivity of semiconductor,

$\sigma = e\left(\eta_e\mu_e + \eta_\lambda\mu_h\right)$
$= 1.6 \times 10^{-19}(5 \times 10^{18} \times 2 + 5 \times 10^{19} \times 0.01)$
$= 1.6 \times 1.05$
$= 1.68$
5. **(b)** $\vec{E} \times \vec{B}$
Explanation: Energy flow per unit area per unit time is called Poynting's vector $\vec{S} = \vec{E} \times \vec{B}$.
6. **(d)** $\frac{\pi\mu_0 I_o}{2} \cdot \frac{a^2}{b}\omega\sin(\omega t)$
Explanation: For two concentric circular coil,

Mutual Inductance M = $\frac{\mu_0\pi N_1 N_2 a^2}{2\,b}$

Here, $N_1 = N_2 = 1$

Hence, M = $\frac{\mu_0\pi a^2}{2\,b}$ ...(i)

and given I = $I_0 \cos \omega t$ ...(ii)

Now according to Faraday's second law induced emf

$$e = -M\frac{dI}{dt}$$

From eq. (ii),

$$e = \frac{-\mu_0 \pi a^2}{2\,b}\frac{d}{dt}\left(I_0 \cos\omega t\right)$$

$$e = \frac{\mu_0 \pi a^2}{2\,b} I_0 \sin\omega t(\omega)$$

$$e = \frac{\pi\mu_0 I_0}{2}\cdot\frac{a^2}{b}\omega\sin\omega t$$

7. **(a)** $33\sin\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

Explanation: $\omega = 2\pi v = \frac{2\pi c}{\lambda} = \frac{2\pi \times 3 \times 10^8}{6 \times 10^{-3}}$

$= \pi \times 10^{11}$ rad/sec

The equation for the electric field, along y-axis in the electromagnetic wave, is,

$$E_y = E_0 \sin\omega\left(t - \frac{x}{c}\right)$$

$$= 33\sin\pi \times 10^{11}\left(t - \frac{x}{c}\right)$$

8. **(b)** 6×10^{-5} cm

Explanation: For nth dark fringe,

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

$$\therefore\ 10^{-3} = (2 \times 2 - 1)\frac{1 \times \lambda}{2 \times 0.9 \times 10^{-3}}$$

or $\lambda = 6 \times 10^{-7}$ cm $= 6 \times 10^{-5}$ cm

9. **(d)** 108.8 eV

Explanation: Energy (E) $= 13.6\, Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ eV $= 13.6 \times 9\left[\frac{1}{1} - \frac{1}{3^2}\right]$ eV

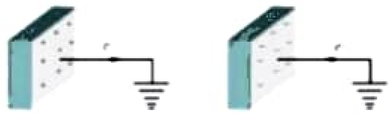
$$= \frac{13.6 \times 9 \times 8}{9}\text{ eV} = 108.8\text{ eV}$$

10. **(d)** There are no free electrons at room temperature

Explanation: At room temperature, few bond breaks and electron-hole pairs generate inside the **semiconductor.**

11. **(d)** Electrons flow from the conductor to the earth

Explanation: After earthing a positively charged conductor electrons flow from earth to conductor and if a negatively charged conductor is earthed then electrons flows from conductor to earth.



12. **(c)** increases

Explanation: By symmetry, the charge will distribute evenly over the surface of the bubble. Because like charges repel, they want to move even further apart, the only which way is outward, taking the soap surface with them. Of course, the increase in restoring force of the soap film (surface tension) will at some point be equal and opposite to the electrostatic force, resulting in a new (larger) equilibrium radius. This will happen to both positive and negatively charged bubbles because of the ionic similarity.

Hence, when the soap bubble is given a negative charge, then its radius will increase.

13. **(b)** decrease by 2 times

Explanation: $\lambda \propto \frac{1}{\sqrt{V}}$

$$\therefore \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{V_1}{V_2}} = \sqrt{\frac{25}{100}} = \frac{1}{2} \text{ or } \lambda_2 = \frac{\lambda_1}{2}$$

14. **(a)** 3.33×10^{-8} N/m^2

Explanation: 3.33×10^{-8} N/m^2

15. **(a)** 1 H

Explanation: N = 100, I = 4A, $\phi = 4 \times 10^{-3}$ Wb

$\phi N = LI$

$$\therefore L = \frac{\phi N}{I}$$

$$= \frac{4 \times 10^{-3} \times 1000}{4} \text{H} = 1 \text{ H}$$

16. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation: Both A and R are true and R is the correct explanation of A.

17. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation: The third pin is used for grounding purposes so that it leaves the user safe while handling the appliance by making the extra charge on it gets discharged.

18. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation: Both A and R are true and R is the correct explanation of A.

Section B

19. In terms of nuclear masses, the 3-value of the reaction is given by

$$Q = \left[m_N\left({}^7_3\text{Li}\right) + m_\text{N}\left({}^1_1\text{H}\right) - 2m_\text{N}\left({}^4_2\text{He}\right)\right]c^2$$

In terms of atomic masses, we can write

$$Q = \left[\left\{m\left({}^7_3\text{Li}\right) - 3m_e\right\} + \left\{m\left({}^1_1\text{H}\right) - m_e - 2\left\{m\left({}^4_2\text{He}\right) - 2m_e\right\}\right]c^2\right\}$$

$$= \left[m\left({}^7_3\text{Li}\right) + m\left({}^1_1\text{H}\right) - 2m\left({}^4_2\text{He}\right)\right] \times c^2$$

$= [7.016 + 1.008 - 2 \times 4.004] \times 931$ MeV

$= 0.016 \times 931 = 14.896$ MeV

Energy of each α-particle $= \dfrac{14.896}{2} = 7.448$ MeV

20. Given,

Intensity of light $= 10^{-5}\ \text{Wm}^{-2}$

Surface area of the sodium photocell, $A = 2\ \text{cm}^2$

Top five layers of sodium absorb the incident energy. (given)

the work function for the metal $\phi_0 = 2\text{eV}$

Therefore,

Number of atoms in 5 layers of sodium is,

$$= \frac{5 \times \text{ area of each layer}}{\text{Effective area of atom}}$$

$$= \frac{5 \times 2 \times 10^{-4}}{10^{-20}} = 10^{17}$$

Assume that there is only one conduction electron per sodium atom.

$\therefore$ Number of electrons in 5 layers = 10^{17}

Energy received by an electron per sec is,

$$= \frac{\text{Power of incident light}}{\text{Number of electrons}}$$

$$\frac{10^{-5} \times 2 \times 10^{-4}}{10^{17}} = 2 \times 10^{-26}\ \text{W}$$

thus the time required for photoemission is,

$$= \frac{2 \times 1.6 \times 10^{-19}}{2 \times 10^{-26}}$$

$$= 1.6 \times 10^{7}\text{s}$$

Thus, it is contrary to the observed fact that there is no time lag between the incidence of light and the emission of photoelectrons.

21. Resistivity of pure germanium,

$$\rho = \frac{1}{\sigma} = \frac{1}{en_i\left(\mu_e + \mu_h\right)}$$

$$\therefore\ n_i = \frac{1}{ep\left(\mu_e + \mu_h\right)} = \frac{1}{1.6 \times 10^{-19} \times 0.52(0.2 + 0.4)}$$

$$= 2 \times 10^{19}\ \text{m}^{-3}$$

When 10^{20} acceptor atoms are further added,

$n_h - n_e = N_a - N_d = 10^{20} - 2 \times 10^{19} = 8 \times 10^{19}\ \text{m}^{-3}$

As $n_h > n_e$, so $n_h = 8 \times 10^{19}$

$$\therefore\ \rho = \frac{1}{en_h\mu_h} = \frac{1}{1.6 \times 10^{-19} \times 8 \times 10^{19} \times 0.4}$$

$$= 0.195\ \Omega m$$

22. No. It may be possible that the magnetic field is present but the electron is moving parallel or anti-parallel to the magnetic field and magnetic force ($F = qvB\sin\theta, \theta = 0^\circ, 180^\circ$) is zero.

OR

we know that, $|dB| = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$

$dl = \Delta x = 1\text{cm} = 10^{-2}$ m, I = 10 A, r = 0.5 m, $\mu_0/4\pi = 10^{-7}\frac{Tm}{A}$

$\theta = 90°$; $\sin\theta = 1$

$$|dB| = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10^{-8} T$$

The direction of the field is in the +z-direction. This is so since,

$dl \times r = \Delta x\hat{i} \times y\hat{j} = y\Delta x(\hat{i} \times \hat{j}) = y\Delta x\hat{k}$

We remind you of the following cyclic property of cross-products,

$\hat{i} \times \hat{j} = \hat{k}; \hat{j} \times \hat{k} = \hat{i}; \hat{k} \times \hat{i} = \hat{j}$

Note that the field is small in magnitude.

23. Here $V_D = 0.5$ V, V = 1.5 V, I = 5 mA = 5×10^{-3}, R = ?

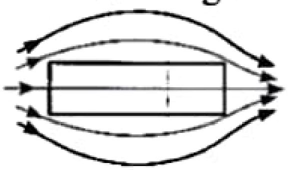
The voltage equation for the diode circuit is

$IR + V_D = V$

or $5 \times 10^{-3} A \times R + 0.5 V = 1.5 V$

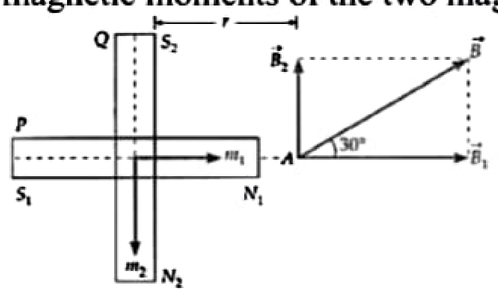
or $R = 200\ \Omega$

24. As the susceptibility has a small negative value, so the given material is diamagnetic in nature. When a specimen of this material is placed in a uniform magnetic field, the lines of force get expelled from it as shown in figure.



OR

Let A be any point on the prolongation of the axis of magnet P. Let $\vec{B}_1$ and $\vec{B}_2$ be the fields of the magnets P and Q respectively at the point A. Let $\vec{m}_1$ and $\vec{m}_2$, be the magnetic moments of the two magnets.



As point A lies on the axial line of P, therefore,

$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{2m_1}{r^3}$$

The point A lies on the broad-side-on position of Q, therefore,

$$B_2 = \frac{\mu_0}{4\pi} \cdot \frac{m_2}{r^3}$$

$$\therefore \frac{B_2}{B_1} = \frac{m_2}{2m_1}$$

But the resultant field B_1 is inclined at 30° with B_1, so

$$\frac{B_2}{B_1} = \tan 30^o = \frac{1}{\sqrt{3}}$$

Hence $\frac{1}{\sqrt{3}} = \frac{m_2}{2m_1}$ or $\frac{m_1}{m_2} = \frac{\sqrt{3}}{2}$

25. Here, $\frac{\Delta\lambda}{\lambda} = \frac{0.032}{100} = 3.2 \times 10^{-4}$

$v = -\frac{\Delta\lambda}{\lambda} c = -3.2 \times 10^{-4} \times 3 \times 10^8$

$= -9.6 \times 10^4 \, ms^{-1} = -96 \, km \, s^{-1}$

The negative sign indicates that the star is moving away from the earth.

Section C

26. The relation $\mu_l = -\left(\frac{e}{2m}\right)l$ is in accordance with result expected from classical physics.

It can be derived as follows: The magnetic moment vectors μ_S and μ_L associated with the intrinsic spin angular momentum $\vec{S}$and orbital angular momentum $\vec{l}$ respectively,

Magnetic moment associated with the orbital motion of the electron is

$\mu_l =$ current $\times$ area of the orbit

$= IA$

$= \frac{-e}{T} \cdot \pi r^2$

and, the angular momentum of the orbiting electron is given by

$l = mvr$

$= m \cdot \frac{2\pi r}{T} \cdot r$

$= \frac{2\pi m r^2}{T}$

Here, r is the radius of the circular orbit which the electron of mass m and charge (-e) completes in time T. $\frac{\mu_l}{l}$

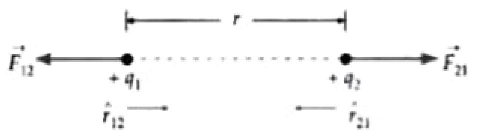
$$= \frac{-e\pi r^2}{2\pi m r^2} = \frac{-e}{2m}$$

As the charge of the electron is negative (-e) it is easily seen that magnetic moment, μ_l and angular momentum, l are antiparallel, both normal to the plane of the orbit.

Therefore, is twice the classically expected value which is $\mu_s / s = \frac{e}{m}$.

This latter result (verified experimentally) is an outstanding consequence of the modem quantum theory.

27. **Coulomb's law in vector form:** As shown in fig., consider two positive point charges q_1 and q_2 placed in vacuum at distance r from each other. They repel each other.



Repulsive coulombian forces for $q_1 q_2 > 0$.

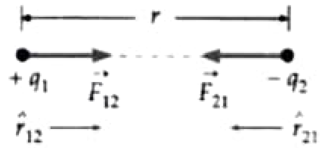
In vector form, Coulomb's law may be expressed as $\vec{F}_{21}$ = Force on charge q_2 due to q_1

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} \hat{r}_{12}$$ where $\hat{r}_{12} = \frac{\vec{r}_{12}}{r}$, is a unit vector in the direction from q_1 to q_2

Similarly, $\vec{F}_{12}$ = Force on charge q_1 due to q_2

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} \hat{r}_{21}$$ where $\hat{r}_{21} = \frac{\vec{r}_{21}}{r}$, is a unit vector in the direction from q_2 to q_1.

The coloumbian forces between unlike charges ($q_1q_2 < 0$) are attractive, as shown in Fig.



Attractive coulombian forces for $q_1 q_2 < 0$.

Importance of vector form. The vector form of coulomb's law gives the following additional information :

i. As $\hat{r}_{21} = -\hat{r}_{12}$, therefore $\vec{F}_{21} = -\vec{F}_{12}$

This means that the two charges exert equal and opposite forces on each other. So Coulombian forces obey Newton's third law of motion.

ii. As the Coulombian forces act along $\vec{F}_{12}$ or $\vec{F}_{21}$, i.e., along the line joining the centres of two charges, so they are central forces.

28. i. Gauss law of electrostatics.

ii. Faraday's law of electromagnetic induction.

iii. Modified Ampere's law, the term on the right-hand side is Maxwell's displacement current.

OR

a. Given, Radius R is = 12 cm = 0.12 m, separation between the plates is given by;

$d = 5.0 \text{ mm} = 5 \times 10^{-3}$ m

$I = 0.15$ A

$\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$

$\therefore$ Area, $A = \pi R^2 = 3.14 \times (0.12)^2 m^2$

Capacitance of parallel plate capacitor is given by

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

$$= \frac{8.85 \times 10^{-12} \times (3.14) \times (0.12)^2}{5 \times 10^{-3}}$$

$$= 80.1 \times 10^{-12} = 80.1 pF$$

Now, q = CV

$$\text{or } \frac{dq}{dt} = C \times \frac{dV}{dt} \text{ or } I = C \times \frac{dV}{dt} \left[\because I = \frac{dq}{dt}\right]$$

$$\text{or } \frac{dV}{dt} = \frac{I}{C} = \frac{0.15}{80.1 \times 10^{-12}}$$

$$= 1.87 \times 10^9 V s^{-1}$$

b. Displacement current is equal to the conduction current i.e. 0.15 A.

c. Yes, Kirchoff's first rule is valid at each plate of the capacitor provided. We take the current to be the sum of the conduction and displacement currents.

29. The distance of nth bright fringe from the central bright fringe is

$$x_n = \frac{nD\lambda}{d} = n\beta$$

$$\therefore\ x_9 = 9\beta$$

The distance of nth dark fringe from the central bright fringe is

$$x'_n = (2n - 1)\frac{D\lambda}{2d} = (2n - 1)\frac{\beta}{2}$$

$$\therefore x'_2 = \frac{3}{2}\beta$$

But $x_9 - x'_2 = 8.835$ mm [Given]

or $9\beta - \frac{3}{2}\beta = 8.835$ mm or $\frac{15}{2}\beta = 8.835$ mm

or $\beta = \frac{8.835 \times 2}{15}$ mm

$= 1.178$ mm $= 1.178 \times 10^{-3}$ m

Hence $\lambda = \frac{\beta d}{D} = \frac{1.178 \times 10^{-3} \times 0.5 \times 10^{-3}}{1.0}$ m

$= 0.5890 \times 10^{-6}$ m $= 5890\ \mathring{A}$

OR

The fringe width in the interference pattern is inversely proportional to the separation between the coherent sources ($\beta = \frac{D\lambda}{d}$. When the distance d between the coherent source is large, the fringe width becomes very small. In such a case, the fringes may overlap and the interference pattern may not be observed.

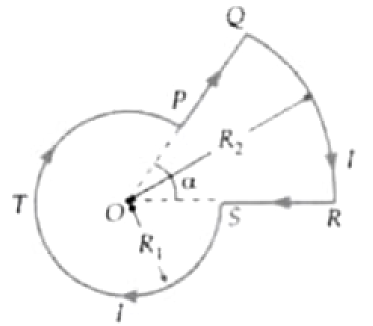
Fringe width in air, $\beta = \frac{D\lambda}{d}$

Fringe width in liquid, $\beta' = \frac{D\lambda'}{d} = \frac{D\lambda}{d\mu}$

$$\Rightarrow \beta' = \frac{\beta}{\mu}$$

or $\beta' = \frac{2.0}{1.33} = 1.5mm$

30. The magnetic field at O due to each of the straight parts PQ and RS is zero because $\theta = 0^o$, for each of them.



Magnetic field at the centre O due to circular segment QR of radius R_2 is

$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{I}{R_2^2} l_2$$

Here,
l_2 = length of circular segment QR = αR_2

$$\therefore\ B_1 = \frac{\mu_0}{4\pi} \cdot \frac{I\alpha}{R_2}, \text{ directed normally downward}$$

Similarly, the magnetic field at O due to the circular segment STP is

$$B_2 = \frac{\mu_0}{4\pi} \frac{I(2\pi - \alpha)}{R_1}, \text{ directed normally downward}$$

Hence the resultant field at O is

$$B = B_1 + B_2 = \frac{\mu_0 I}{4\pi}\left(\frac{\alpha}{R_2} + \frac{2\pi - \alpha}{R_1}\right),$$

directed normally downward.

If $\alpha = 90^{0} = \frac{\pi}{2}$, then

$$B = \frac{\mu_0 I}{4\pi}\left(\frac{\pi}{2R_2} + \frac{3\pi}{2R_1}\right)$$

$$= \frac{\mu_0 I}{8}\left[\frac{1}{R_2} + \frac{3}{R_1}\right]$$

Section D

31. We have, for a point charge, $V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$

(i). At point (0, 0, z) :
Potential due to the charge (+q)

$$V_+ = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(z-a)}$$

Potential due to the charge (~q)

$$V_- = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-q)}{(z+a)}$$

Total Potential at (0 ,0, z) $V=V_+ + V_-$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{-1}{z+a} + \frac{1}{z-a}\right]$$

$$= \frac{2qa}{4\pi\varepsilon_0\left(z^2-a^2\right)}$$

At point (x, y, 0)

Potential due to the charge + q

$$V_+ = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{\sqrt{x^2+y^2+a^2}}$$

Potential due to the charge (- q)

$$V_- = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-q}{\sqrt{x^2+y^2+a^2}}$$

Total potential at (x, y, 0)

$$= \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{\sqrt{x^2+y^2+a^2}} - \frac{1}{\sqrt{x^2+y^2+a^2}}\right) = 0$$

Hence total potential due to them at the given point will be zero.

(ii). Work done = $q[V_1 - V_2]$

$V_1 = 0$ and $V_2 = 0$

$\therefore$ Work done = 0

Where V_1 and V_2 are the total potential due to dipole at point (5, 0, 0) and (-7, 0, 0)

(iii). There would be no change This is because the electrostatic field is a conservative field.

(Alternatively: The work done, in moving a test charge between two given points is independent of the path taken ,it depends only on initial and final value.)

(iv). The two given charges make an electric dipole of dipole moment $\vec{p} = q \cdot 2\vec{a}$

P.E. in the position of unstable equilibrium($\theta=180^o$)(where $\vec{p}$ and $\vec{E}$ are antiparallel to each other) = $pE\cos 180^o$

$\cos 180^o = -1$

Thus potential energy is= + pE = 2aqE

OR

a. During charging of the capacitor, work is done by the battery which is stored in the form of potential energy inside the capacitor.
   Consider a capacitor which is to be charged by charge Q with the help of a battery.
   Let at any instant charge on the capacitor is q and the potential difference between

the two plates of the capacitor is V.

We know that,

$q = CV \Rightarrow V = q/C$

Now small work done to charge the capacitor by small charge dq,

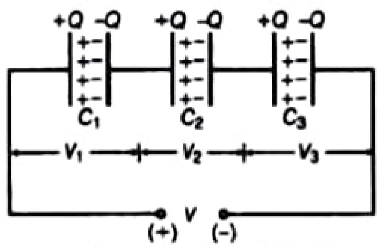
$$dW = Vdq = \frac{q}{C}dq$$

where, q = instantaneous charge, C = capacitance and V = voltage

∴ Total work done in storing charge from 0 to Q(total charge) is given by

$$\Rightarrow W = \int_0^Q \frac{q}{C}dq = \frac{Q^2}{2C}$$

b. In a series combination of capacitors, the same charge lie on each capacitor for any value of capacitances.



Capacitors in series combination

Also, the net potential difference across the combination is equal to the algebraic sum of potential differences across each capacitor

i.e. $V = V_1 + V_2 + V_3$ ....(i)

where V_1, V_2, V_3 and V are the potential differences across C_1, C_2, C_3 and equivalent capacitor, respectively.

Again $q_1 = C_1V_1 \Rightarrow V_1 = \dfrac{q_1}{C_1}$

Similarly, $V_2 = \dfrac{q}{C_2}$ and $V_3 = \dfrac{q}{C_3}$

∴ Total potential difference [From Eq.(i)]

$$\Rightarrow V = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\Rightarrow \frac{V}{q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \left[\frac{V}{q} = \frac{1}{C}\right.$$, where C is equivalent capacitance]

32. Suppose m be the mass of an electron and v be its speed in nth orbit of radius r. The centripetal force for revolution is produced by electrostatic attraction between electron and nucleus.

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

$$\text{or, } mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r} \quad .....(i)$$

$$\text{So, Kinetic energy [K]} = \frac{1}{2}mv^2$$

$$K = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$$

$$\text{Potential energy} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$$

Total energy,

$$E = KE + PE = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r} + \left(-\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}\right)$$

$$E = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$$

$$\text{So, } E_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r_n} \quad ......(ii)$$

Again from Bohr's postulate for quantization of angular momentum,

$$\text{velocity, } v = \frac{nh}{2\pi mr}$$

Substituting this value of v in equation (i), we get

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$$

$$\text{or, } r = \frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2} \text{ or } r_n = \frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2} \quad ....(iii)$$

Substituting this value of r_n in equation (ii), we get

$$E_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2\left(\frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}\right)} = -\frac{mZ^2e^4}{8\varepsilon_0^2 h^2 n^2}$$

$$\text{or, } E_n = -\frac{Z^2 Rhc}{n^2}, \text{ where } R = \frac{me^4}{8\varepsilon_0^2 ch^3}$$

where R is called Rydberg constant.

For hydrogen atom, Z = 1, so

$E_n = \frac{-Rch}{n^2}$

If n_i and n_f are the quantum numbers of initial and final states and E_i & E_f are energies of electron in H-atom in an initial and final state, we have

$E_i = \frac{-Rhc}{n_i^2}$ and $E_f = \frac{-Rhc}{n_f^2}$

If v is the frequency of emitted radiation, we get

$$v = \frac{E_i - E_f}{h}$$

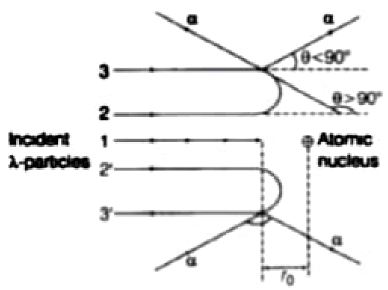
$$v = \frac{-Rch}{n_i^2} - \left(\frac{-Rch}{n_f^2}\right) = \text{Rch}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = \frac{me^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

This is the required expression.

If electron jumps from $n_i = 4$ to $n_f = 3, 2, 1$, radiation belongs to Paschen, Balmer and Lyman series.

OR

Trajectory of an α-particles in the Coulomb field of the target nucleus is given below as



From this experiment, the following is observed.

i. Most of the α-particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.

ii. About one α-particle in every 8000 α-particles deflects by more than 90°. As most of the α-particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty and at the centre of the atom, there is a heavy mass, which is most commonly known as nucleus. Thus, with the help of these observations regarding the deflection of a-particles, the size of the nucleus was predicted.

If m is the average mass of the nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

The volume of the nucleus, $V = 4/3\pi R^3$

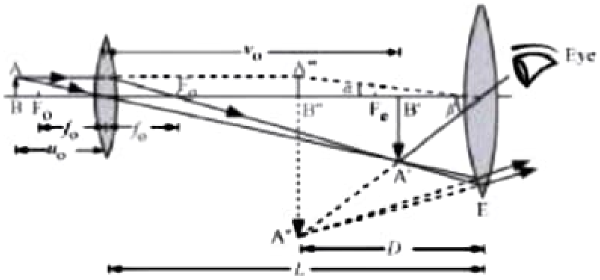
$$\Rightarrow \quad V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 \Rightarrow V = \frac{4}{3}\pi R_0^3 A$$

Density of nuclear matter

$$\rho = \frac{mA}{V} \Rightarrow \rho = \frac{mA}{4/3\pi R_0^3 \cdot A} \Rightarrow \rho = \frac{3m}{4\pi R_0^3}$$

This shows that the nuclear density in independent of mass number A.

33. a.



where AB = object, A'B' = image formed by objective, A"B" = image formed by eyepiece

L is the separation between the eyepiece and the objective,

f_0 is the focal length of the objective,

f_e is the focal length of the eyepiece,

D is the least distance for clear vision

b. For the least distance of clear vision, the total magnification is given by:

$$m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) = m_o \cdot m_e \text{ ...(i)}$$

Also, the given magnification for the eyepiece:

$$m_e = 5 = \left(1 + \frac{D}{f_e}\right)$$

$$\Rightarrow 5 = 1 + \frac{20}{f_e}$$

$$\Rightarrow f_e = 5 \text{ cm}$$

Substituting the value of m and m_e in equation (i), we get:

$m = m_0 \cdot m_e$

$$\Rightarrow m_o = \frac{m}{m_e} = \frac{20}{5} = 4$$

Now, we have:

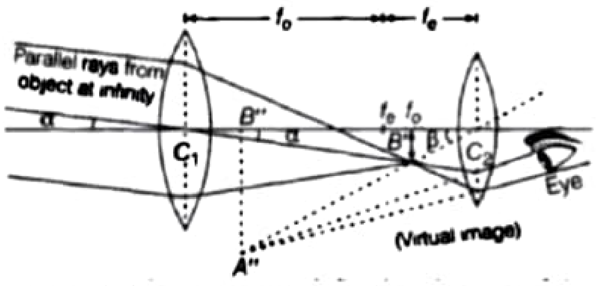
$$m_o = \frac{L}{\left|f_o\right|}$$

$$\Rightarrow f_0 = \frac{14}{4} = 3.5 \text{ cm}$$

OR

i. In astronomical telescope for normal adjustment, final image is formed at infinity and it is virtual.

The labelled ray diagram to obtain one of the real image formed by the astronomical telescope is shown below:



Magnifying power is defined as the ratio of the angle subtended at the eye by the focal image as seen through the telescope to the angle subtended at the eye by the object seen directly, when both the image and the object lies at infinity.

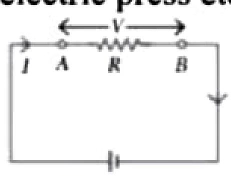
ii. a. We know the objective lens of a telescope should have larger focal length and eyepiece lens should have smaller focal length. And focal length is inverse of power, so lens of power (P = 1/f).
Thus, 10D can be used as eyepiece and lens of power 0.5 D can be used as objective lens.

b. The objective lens of a telescope should have larger aperture, in order to form bright image of distant objects, so that it can gather sufficient light rays from the distant objects.

Section E

34. **Read the text carefully and answer the questions:**

Whenever an electric current is passed through a conductor, it becomes hot after some time. The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc.



(i) **(b)** Heat produced in a conductor varies directly as the square of the current flowing.

Explanation: According to Joule's law of heating.

Heat produced in a conductor, $H = I^2 Rt$

where, I = Current flowing through the conductor

R = Resistance of the conductor

t = Time for which current flows through the conductor.

$\therefore H \propto I^2$

(ii) **(d)** Doubled

Explanation: If the coil is cut into half, its resistance is also halaved.

As $H = \frac{V^2}{R}t$

$\therefore$ H' = 2

(iii)**(d)** 25 W

Explanation: $P = \frac{V^2}{R}$ or $R = \frac{V^2}{P}$

The bulbs are joined in series. Current in both the bulbs will same.

$\therefore$ The heat produced in them is given by $H = I^2 Rt$

or $H \propto R \Rightarrow H \propto \frac{1}{P}$

Therefore the bulb with low wattage or high resistance will glow brighter or we can say the 25 W bulb will glow brighter than the 100 W bulb.

OR

(d) 30 kJ

Explanation: R = 100 Ω; I = 1A; t = 5 min = 5 × 60 = 300s

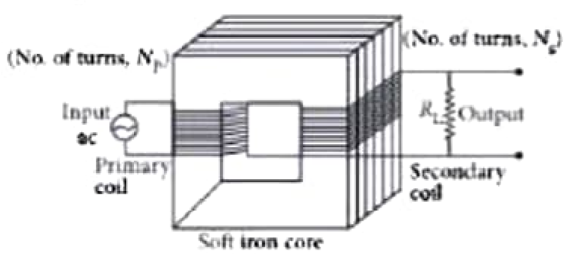
change in internal energy = heat generated in coil

$= I^2 Rt = ((1)^2 \times 100 \times 300)J$

= 30000 J = 30 kJ

35. **Read the text carefully and answer the questions:**

A transformer is an electrical device which is used for changing the a.c. voltages. It is based on the phenomenon of mutual induction i.e. whenever the amount of magnetic flux linked with a coil changes, an e.m.f. is induced in the neighbouring coil. For an ideal transformer, the resistances of the primary and secondary windings are negligible.



It can be shown that $\frac{E_s}{E_p} = \frac{I_p}{I_s} = \frac{n_s}{n_p} = k$

where the symbols have their standard meanings.

For a step-up transformer, $n_s > n_p$; $E_s > E_p$; $k > 1$; $\therefore$ $I_s < I_p$

For a step down transformer, $n_s < n_p$; $E_s < E_p$; $k < 1$

The above relations are on the assumption that efficiency of transformer is 100%.

Infact, efficiency $\eta = \frac{\text{output power}}{\text{intput power}} = \frac{E_s I_s}{E_p I_p}$

(i)

For a transformer, $\frac{V_S}{V_p} = \frac{N_S}{N_p}$

Where N denotes the number of turns and V = voltage.

$$\therefore \quad \frac{V_S}{220} = \frac{10}{20}$$

$$\therefore \ V_S = 110 \text{ ac V}$$

(ii) In a transformer, the primary and secondary currents are related by

$$I_S = \left(\frac{N_p}{N_S}\right) I_p$$

and the voltage are related by

$$V_S = \left(\frac{N_S}{N_p}\right) V_p$$

where subscripts p and s refer to the primary and secondary of the transformer.

Here, $V_p = V \cdot \frac{N_p}{N_S} = 4 \ \therefore \ I_S = 4I_p$

and $V_S = \left(\frac{1}{4}\right) V = \frac{V}{4}$

(iii)

The efficiency of the transformer is $\eta = \frac{\text{Output power } (P_{out})}{\text{Input power } (P_{in})} \times 100$

Here, $P_{out} = 100$ W, $P_{in} = (220 \text{ V})(0.5 \text{ A}) = 110$ W

$$\therefore \ \eta = \frac{100 \text{ W}}{110 \text{ W}} \times 100 = 90\%$$

OR

In an ideal transformer, there is no power loss. The efficiency of an ideal transformer is $\eta = 1$ (i.e 100 %) i.e. input power = output power.