LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNMENT PAPER 4**

Section A

1. (D) **2.** (A) **3.** (B) **4.** (D) **5.** (D) **6.** (C) **7.** (A) **8.** (B) **9.** (B) **10.** (C) **11.** (C) **12.** (B) **13.** (A) **14.** (B) **15.** (B) **16.** (B) **17.** (B) **18.** (C) **19.** (D) **20.** (C) **21.** (D) **22.** (D) **23.** (B) **24.** (B) **25.** (A) **26.** (C) **27.** (D) **28.** (B) **29.** (B) **30.** (C) **31.** (C) **32.** (D) **33.** (A) **34.** (C) **35.** (B) **36.** (C) **37.** (A) **38.** (D) **39.** (B) **40.** (D) **41.** (B) **42.** (C) **43.** (D) **44.** (B) **45.** (A) **46.** (C) **47.** (A) **48.** (C) **49.** (D) **50.** (B)

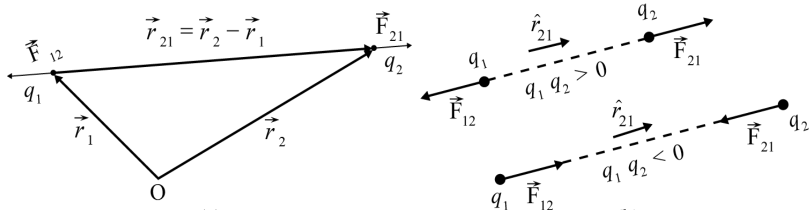
Section A

➢ **Write the answer of the following questions : (Each carries 2 Mark)**

1.

➥ The electric force (Coulomb force) between two point stationary charges is proportional to the product of the values of the charges and inversely proportional to the square of the distance between them. The direction of this force is in the direction of the line joining the two charges.

➥ Let the position vectors of charges q_1 and q_2 be $\vec{r}_1$ and $\vec{r}_2$ respectively [see Fig. (a)].



(a) (b)

➥ We denote force on q_1 due to q_2 by $\vec{F}_{12}$ and force on q_2 due to q_1 by $\vec{F}_{21}$. The two point charges q_1 and q_2 have been numbered 1 and 2 for convenience and the vector leading from 1 to 2 is denoted by $\vec{r}_{21}$:

$$\vec{r}_{21} = \vec{r}_2 - \vec{r}_1$$

➥ In the same way, the vector leading from 2 to 1 is denoted by $\vec{r}_{12}$:

$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2 = -\vec{r}_{21}$$

➥ The magnitude of the vectors $\vec{r}_{21}$ and $\vec{r}_{12}$ is denoted by r_{21} and r_{12}, respectively ($r_{12} = r_{21}$).

➥ The direction of a vector is specified by a unit vector along the vector. To denote the direction from 1 to 2 (or from 2 to 1), we define the unit vectors :

$$\hat{r}_{21} = \frac{\vec{r}_{21}}{r_{21}},\ \hat{r}_{12} = \frac{\vec{r}_{12}}{r_{12}},\ \hat{r}_{21} = -\hat{r}_{12}$$

➥ Coulomb's force law between two point charges q_1 and q_2 located at $\vec{r}_1$ and $\vec{r}_2$, respectively is then expressed as

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21} \quad \text{... (1)}$$

➥ Equation is valid for any sign of q_1 and q_2 whether positive or negative.

➥ If q_1 and q_2 are of the same sign (either both positive or both negative), F_{21} is along $\hat{r}_{21}$, which denotes repulsion, as it should be for like charges.

➥ If q_1 and q_2 are of opposite signs, F_{21} is along $-\hat{r}_{21} = \hat{r}_{12}$, which denotes attraction, as expected for unlike charges.

➥ The force $\vec{F}_{12}$ on charge q_1 due to charge q_2 is obtained from Eq. by simply interchanging 1 and 2, i.e.,

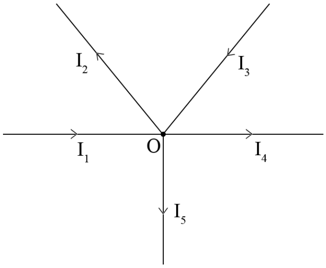
$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12} = -\vec{F}_{21}$$

➥ Thus, Coulomb's law agrees with Newton's third law.

2.

➥ Kirchhoff's junction rule : *"At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction."*

➥ Consider junction O of a network as shown in the figure.



➥ The currents meeting at the junction point O are I_1, I_2, I_3, I_4 and I_5 respectively. Their directions are represented by arrows in the figure.

➥ Let Q_1, Q_2, Q_3, Q_4, and Q_5 be charges flowing through the cross- sectional area of conductors at time *t* respectively.

➥ Thus, $I_1 = \frac{Q_1}{t}$ $\therefore Q_1 = I_1 t$

$I_2 = \frac{Q_2}{t}$ $\therefore Q_2 = I_2 t$ ...

$I_3 = \frac{Q_3}{t}$ $\therefore Q_3 = I_3 t$

$I_4 = \frac{Q_4}{t}$ $\therefore Q_4 = I_4 t$

$I_5 = \frac{Q_5}{t}$ $\therefore Q_5 = I_5 t$

➥ From the figure, the total electric charge entering the junction is $Q_1 + Q_3$ while $Q_2 + Q_4 + Q_5$ amount of electric charge is leaving the junction in time t.

➥ According to the law of conservation of charge,

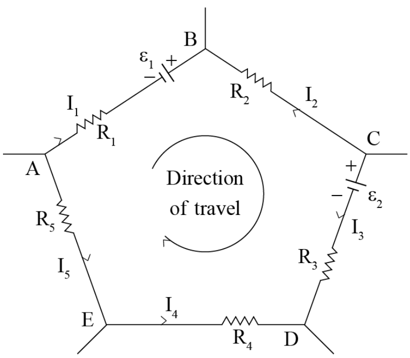
$Q_1 + Q_3 = Q_2 + Q_4 + Q_5$

$\therefore I_1 t + I_3 t = I_2 t + I_4 t + I_5 t$

$\therefore I_1 + I_3 = I_2 + I_4 + I_5$

➥ Thus at the junction the sum of the currents entering the junction is equal to the sum of currents leaving the junction.

➥ Kirchhoff's loop rule : *"The algebric sum of changes in potential around any closed loop involving resistors and cells in the loop is zero."*



➥ Let us consider a closed path ABCDEA as shown in figure.

➥ This circuit consists of resistors R_1, R_2, R_3, R_4, R_5 as well as batteries of *emfs* ε_1 and ε_2 with negligible internal resistances.

Remember

While going from positive to negative terminal of the battery the drop in the potential across the battery is equal to the *emf* of the battery.

The potential difference across the resistance is equal to the product of the resistor and the current flowing through it.

- If V_A is the electric potential at point A and if we measure the changes in the electric potential while moving in clockwise or anticlockwise direction in a closed circuit and come back to point A the potential V_A remains constant.

- The electric potential drops by I_1R_1 when we move in a clockwise direction from A through the resistor R_1. The direction of current is arbitrarily taken from A to B i.e. current flows through resistor R_1 from a point of higher potential A to lower potential B. Hence there will be a drop in potential by I_1R_1 as we move from A to B.

- There is a rise in the potential ε_1 while going from the negative to positive terminal of a battery of *emf* ε_1.
- The potential rises by I_2R_2 when we go from B to C through the resistor R_2.
- In a similar way, there is a potential drop equal to ε_2 when we go from positive to negative terminal of a battery of emf ε_2. There is a potential drop I_3R_3 while passing through R_3, rise in potential I_4R_4 and I_5R_5 through resistor R_4 and R_5 respectively.

- Taking the algebric sum of all the potential at point A should remain V_A

$$\therefore V_A - I_1R_1 + \varepsilon_1 + I_2R_2 - \varepsilon_2 - I_3R_3 + I_4R_4 + I_5R_5 = V_A$$

$$\therefore - I_1R_1 + \varepsilon_1 + I_2R_2 - \varepsilon_2 - I_3R_3 + I_4R_4 + I_5R_5 = 0$$

3.

- If the transformer is assumed to be 100% efficient (no energy losses), the input power is equal to the output power,

$$\therefore I_p\upsilon_p = I_s\upsilon_s$$

$$\therefore \frac{\upsilon_s}{\upsilon_p} = \frac{I_p}{I_s} \quad \dots (1)$$

- But $\frac{\upsilon_s}{\upsilon_p} = \frac{N_s}{N_p}$

  we get $\frac{\upsilon_s}{\upsilon_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$.

- From this equation

$\frac{\upsilon_s}{\upsilon_p} = \frac{N_s}{N_p}$	$\frac{N_s}{N_p} = \frac{I_p}{I_s}$
$\therefore \upsilon_s = \left(\frac{N_s}{N_p}\right) \cdot \upsilon_p \dots (2)$	$\therefore I_s = \frac{N_p}{N_s} \cdot I_p \dots (3)$

From eq. (2) and (3)

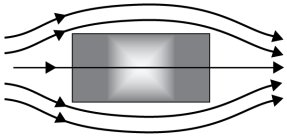
(i) If $N_s > N_p$ then $\upsilon_s > \upsilon_p$ which means the voltage is stepped up. Such a transformer is called step up transformer.

(ii) If $N_s < N_p$ then $\upsilon_s < \upsilon_p$ which means the voltage reduces (or voltage is stepped down). Such a transformer is called step down transformer.

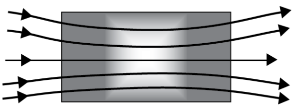
4.

- Simple explanation of dia-magnetism :
- Electrons in an atom orbiting around nucleus possess orbital angular momentum. These orbiting electrons are equivalent to current carrying loop and thus possess orbital magnetic moment.
- Diamagnetic substances are the ones in which the resultant magnetic moment in an atom is zero. When magnetic field is applied, those electrons having orbital magnetic moment in the same direction slow down and those in the opposite direction speed up.

- This happens due to induced current in accordance with Lenz's law.
- Thus, the substance develops a net magnetic moment in direction opposite to that of applied field and hence repulsion.
- This is a simple explanation of diamagnetism.



- Fig. shows a bar of diamagnetic material placed in an external magnetic field. The field lines in it are repelled and field inside the material is reduced.
- In most cases, this reduction is slight, being one part in 10^5.
- When placed in a non-uniform magnetic field, a diamagnetic substance experiences net force from stronger to weaker field and tends to move from high to low field. Which means they experience repulsion.
- Some diamagnetic materials are bismuth, copper, lead, silicon, nitrogen (at STP), water and sodium chloride.
- Value of χ (magnetic susceptibility) is negative ($-1 \le \chi < 0$) for diamagnetic materials.
- Paramagnetic substances are those which get weakly magnetised when placed in external magnetic field.
- Atoms (or ions or molecules) of paramagnetic materials possess a permanent magnetic dipole moment, but due to continuous (ceaseless) random thermal motion of atoms, net magnetisation is zero. So in normal condition, such substances do not behave as a magnet.
- When such substances are placed in sufficiently strong external magnetic field ($\vec{B}_0$) at low temperature, the atomic dipole moments of individual atoms are aligned in the direction of magnetic field ($\vec{B}_0$), and they get weakly magnetised.



- Therefore, as shown in Fig., magnetic field inside a paramagnetic substance is enhanced, and the field lines get concentrated inside the material. This enhancement is slight, generally one part in 10^5.
- When placed in a non-uniform magnetic field, they tend to move from weak field to strong, i.e. get weakly attracted to a magnet.
- This effect (property) is known as paramagnetism and such materials are known as paramagnetic materials.
- Some examples of paramagnetic materials are : aluminium, sodium, calcium, oxygen (at STP) and copper chloride.
- For a paramagnetic material both χ and $\propto_r$ depend not only on the material, but also on the sample temperature. As the field is increased or the temperature is lowerd the magnetisation increases until it reaches the saturation value at which point all the dipoles are perfectly aligned with the field.

5.

- For a solenoid having length l and area of cross-section A,

  I = electric current passed

  N = total number of turns

  n = number of turns per unit length

  $\therefore N = nl$
- Magnetic field produced in solenoid,

  $B = \propto_0 n I$
- Total magnetic flux linked,

  $N\varphi_B = (nl)\,AB = (nl)\,(A)\,(\propto_0 n\, I)$ ... (1)
- Self inductance of solenoid,

  $L = \dfrac{N\,\phi_B}{I}$ ... (2)

  From equation (1) & (2),

$$L = \frac{\mu_0 n^2 A l\, I}{I}$$

$$\therefore L = \propto_0 n^2 A l \ \ldots (3)$$

- Equation (3) is expression for self inductance of solenoid.
- If substance having relative permeability $\propto_r$ is filled inside the solenoid then,

  self inductance $L = \propto_r \propto_0 n^2 A l \ \ldots (4)$
- Self inductance of coil depends on its shape, size and permeability of medium on which coil is wound.

6.

- The centripetal force on the electron in the hydrogen atom is provided by Coulomb force exerted by the proton.
- Centripetal force = Coulomb force

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

$$\therefore m\upsilon^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\therefore \frac{1}{2} m\upsilon^2 = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{r}$$

$$K = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{r} \ \ldots (1)$$

- The electrostatic potential energy of the electron in hydrogen atom is

$$U = \frac{k(e)(-e)}{r}$$

$$\therefore U = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \ \ldots (2)$$

- Thus, the total energy of the electron in a hydrogen atom is,

$$E = K + U$$

$$E = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\therefore E = -\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r} \ \ldots (3)$$

- The total energy of the electron is negative which implies that the electron is bound to the nucleus.

7.

- Sun continuously emits energy due to thermonuclear fusion. The interior of the Sun has a temperature of $1.5 \cdot 10^7$ K.
- The thermonuclear fusion process in the Sun is known as proton-proton cycle.
- This process is a multi-step process in which the hydrogen is burned into helium. Thus the fuel in the Sun is the hydrogen in its core.
- The proton-proton cycle is represented by the following sets of reactions :

$${}^1_1H + {}^1_1H \rightarrow {}^2_1H + e^+ + \nu + 0.42 \text{ MeV} \ \ldots\text{(i)}$$

$$e^+ + e^- \rightarrow \gamma + \gamma + 1.02 \text{ MeV} \ \ldots\text{(ii)}$$

$${}^2_1H + {}^1_1H \rightarrow {}^3_2He + \gamma + 5.49 \text{ MeV} \ \ldots\text{(iii)}$$

$${}^3_2He + {}^3_2He \rightarrow {}^4_2He + {}^1_1H + {}^1_1H + 12.86 \text{ MeV} \ \ldots\text{(iv)}$$

- In this reaction, the first three reactions must occur twice and in the fourth reaction two light helium nuclei unite to form ordinary helium nucleus.
- If we consider the combination

  2(i) + 2(ii) + 2(iii) + (iv), the net effect is

$4\,{}_1H^1 + 2e^- \rightarrow {}_2He^4 + 2\nu + 6\gamma + 26.7$ MeV

OR

$4\,{}_1H^1 + 4e^- \rightarrow [{}_2He^4 + 2e^-] + 2\nu + 6\gamma + 26.7$ MeV

➥ Thus four hydrogen atoms combine to form an ${}_2He^4$ atom with a release of 26.7 MeV of energy.

8.

➥ number of atoms in pure Si = 5×10^{28} m^{-3}

➥ Concentration of As = 1 ppm

Impurity proportion is kept as 1 in 10^6 pure atoms.

Total atoms of As = $\dfrac{5\times10^{28}}{10^6} = 5 \times 10^{22}$ m^{-3}

➥ As is pentavalent impurity. Thus As is donating one extra electron. So electron number density due to As atom,

$n_e = n_D = 5 \times 10^{22}$ m^{-3}

➥ Now $n_i^2 = n_e n_h$

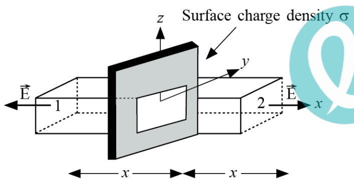
$\therefore n_h = \dfrac{n_i^2}{n_e}$

$\therefore n_h = \dfrac{(1.5\times10^{16})^2}{5\times10^{22}}$

$\therefore n_h = \dfrac{2.25\times10^{32}}{5\times10^{22}}$

$\therefore n_h = 4.5 \times 10^9$ m^{-3}

9.

➥ 

➥ Let σ be the uniform surface charge density of an infinite plane sheet (Fig.). We take the x-axis normal to the given plane.

➥ By symmetry, the electric field will not depend on y and z coordinates and its direction at every point must be parallel to the x-direction.

➥ We can take the Gaussian surface to be a rectangular parallelpiped of cross-sectional area A, as shown. (A cylindrical surface will also do.)

➥ As seen from the figure, only the two faces 1 and 2 will contribute to the flux; electric field lines are parallel to the other faces and they, therefore, do not contribute to the total flux.

➥ Total flux passing through Gaussian surface.

ϕ = Electric flux passing through Surface 1 + Electric flux passing through surface 2

$\therefore \phi = EA\cos 0 + EA \cos 0$

$= EA + EA = 2EA$ ... (1)

➥ According to Gauss's law = $\varphi = \dfrac{q}{\varepsilon_0}$ ... (2)

Thus, $2EA = \dfrac{q}{\varepsilon_0}$ ... (3)

Where, q = electric charge enclosed by Gaussian surface

q = Surface charge density · Area

$\therefore q = \sigma A$

➥ Put the value in equation (3),

$$\therefore 2EA = \frac{\sigma A}{\varepsilon_0}$$

$$\therefore E = \frac{\sigma}{2\varepsilon_0}$$

$$2EA = \frac{\sigma A}{\varepsilon_0}$$

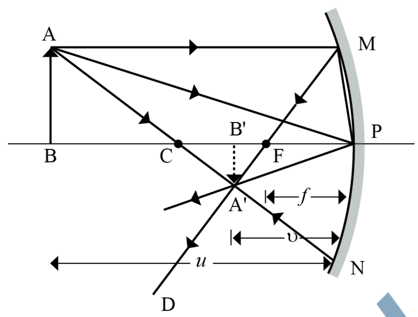
$$\text{or, } E = \frac{\sigma}{2\varepsilon_0}$$

➥ Vectorically,

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$$

➥ Where $\hat{n}$ is a unit vector normal to the plane and going away from it, E is directed away from the plate if σ is positive and toward the plate if σ is negative.

10.

➥ 

➥ A mirror with small aperture is shown in figure. An object AB is placed in front of the mirror at some distance from the centre of curvature.

➥ Three rays emanating from A are reflected by a mirror and converge at point A'. So the image of the object AB is given by A'B' between C and F.

➥ From figure the two right-angled triangles ΔA'B'F and ΔMPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP.)

➥ Therefore, $\frac{A'B'}{MP} = \frac{B'F}{FP}$

But, AB = MP

$$\frac{A'B'}{AB} = \frac{B'F}{FP} \quad \ldots (1)$$

➥ The right angled triangles ΔABP and ΔA'B'P are similar.

Therefore, $\frac{A'B'}{AB} = \frac{B'P}{BP}$ ... (2)

➥ Comparing equations (1) and (2),

We get,

$$\therefore \frac{B'F}{FP} = \frac{B'P}{BP}$$

But, B'F = PB' – FP

$$\therefore \frac{PB' - FP}{FP} = \frac{B'P}{BP} \quad \ldots (3)$$

➥ But, $B'P = -\upsilon$, $FP = -f$, $BP = -u$

(according to sign convention all three have negative signs)

➥ using these in equation (3), we get

$$\frac{-\upsilon + f}{-f} = \frac{-\upsilon}{-u}$$

$$\therefore \frac{-\upsilon}{-f} - \frac{f}{f} = \frac{\upsilon}{u}$$

$$\therefore \frac{\upsilon}{f} - 1 = \frac{\upsilon}{u}$$

➥ Now dividing by υ,

$$\therefore \frac{\upsilon}{f\upsilon} - \frac{1}{\upsilon} = \frac{\upsilon}{u\upsilon}$$

$$\therefore \frac{1}{f} - \frac{1}{\upsilon} = \frac{1}{u}$$

$$\therefore \frac{1}{f} = \frac{1}{\upsilon} + \frac{1}{u}$$

➥ It is called mirror equation.

11.

➥

	Interference pattern	Diffraction pattern
(1)	In an interference pattern, there are many bright and dark bands at equal distance from each other.	In a diffraction pattern, the central maximum has width double the width of other secondary maxima.
(2)	Intensity of all the bright fringes is same.	Intensity of the central maximum is the highest and intensity gradually keeps reducing for successive secondary maxima.
(3)	An interference pattern is seen because of super position of two waves created from two narrow slits.	A difference pattern is seen because of super position of continuous wave fronts created from each point of the single slit.
(4)	For constructive interference phase difference is $\pm 2n\pi$ (where $n = 0, 1, 2, ...$) For destructive interference phase diff. is $\pm(2n+1)\pi$ (where $n = 0, 1, 2, 3 ...$)	For central maxima $\theta \approx 0$ secondary maxima phase diff. is $\left(n+\frac{1}{2}\right)\frac{\lambda}{a}$ (where $n = \pm 1, \pm 2, \pm 3$ ....) Secondary minima phase diff. is $\frac{n\lambda}{a}$ (where $n = \pm 1, \pm 2, \pm 3$ ...)

12.

➥ $v_0 = 3.3 \times 10^{14}$ Hz

$v = 8.2 \times 10^{14}$ Hz

$V_0 = ?$

➥ Einstein's equation

$K_{max} = hv - \varphi_0$

$eV_0 = hv - hv_0$ ($\because K_{max} = eV_0, \varphi_0 = hv_0$)

$$\therefore V_0 = \frac{h(v - v_0)}{e}$$

$$V_0 = \frac{6.625 \times 10^{-34} \times (8.2 \times 10^{14} - 3.3 \times 10^{14})}{1.6 \times 10^{-19}}$$

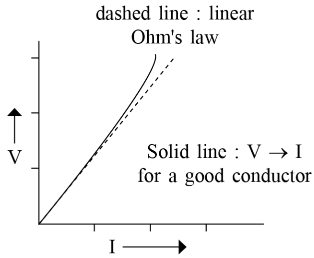
$V_0 = 2$ V

Section B

➢ **Write the answer of the following questions : (Each carries 3 Mark)**

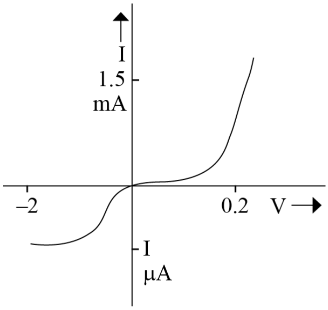
13.

➥ (1) In some devices V and I are not proportional to each other.



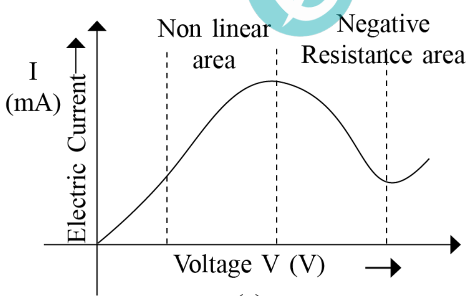
(a)

(2) The relation between V and I depends on the sign of V. In other words, if I is the current for a certain value of V, then reversing the direction of V keeping its magnitude fixed, does not produce a current of the same magnitude as I in the opposite direction. This happens in case of diode.



(b)

(3) The relation between V and I is not unique means there are more than one value of V for the same current I. for example, GaAs (Gallium Arsenide).



(c)

14.

➥ N = 100 R = 10 cm = 0.1 m

$I = 3.2$ A $B = 2$T

$\theta_1 = 0°$

$\theta_2 = 90°$

i (moment of inertia) = 0.1 kg m^2

(a) The magnetic field at the centre of the coil,

$$B_c = \frac{\mu_0 NI}{2R}$$

$$= \frac{4\pi \times 10^{-7} \times 100 \times 3.2}{2 \times 0.1}$$

(Taking $\pi \times 3.2 = 10$)

$= 2 \times 10^{-3}$ T

➥ The direction is given by right hand thumb rule

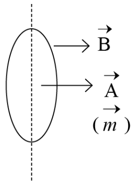
(b) The magnetic moment

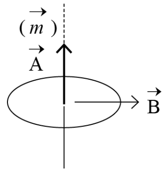
$m = NAI$

$= N(\pi R^2)\, I$

$= 100 \times 3.2 \times 3.14 \times (10^{-1})^2$

$m = 10\ Am^2$





(c) Torque acting on the coil

➥ Torque acting on coil in the initial position

$\vec{\tau} = \vec{m} \times \vec{B}$.

$\tau = mB \sin\theta$

➥ But initially the coil is in the direction of magnetic field.

$\theta_1 = 0°$, Thus,

$\tau_1 = mB \sin 0$

$\tau_1 = 0$

➥ Torque acting on coil in the final position $\theta_2 = 90°$

$\tau_2 = mB \sin 90° = 10 \times 2 \times 1$

$\tau_2 = 20\ Nm$

(d) We know that

$\tau = mB \sin\theta$... (1)

and $\tau = i\alpha$

$\tau = i \dfrac{d\omega}{dt} \left(\because \alpha = \dfrac{d\theta}{dt}\right)$ ... (2)

By comparing eq. (1) & (2)

$\therefore i \dfrac{d\omega}{dt} = mB \sin\theta$

$\therefore i \dfrac{d\omega}{d\theta} \times \dfrac{d\theta}{dt} = mB \sin\theta$

$\therefore i \dfrac{d\omega}{d\theta} \cdot \omega = mB \sin\theta \left(\because \dfrac{d\theta}{dt} = \omega\right)$

$\therefore i\,\omega\, d\omega = mB\, \sin\theta\, d\theta$

➥ Integrating both sides

$$\int_{\omega_2}^{\omega_1} i\,\omega\, d\omega = \int_{\theta_1}^{\theta_2} mB\, \sin\theta\, d\theta$$

$$\therefore i \int_{\omega_2}^{\omega_1} \omega\, d\omega = mB \int_{\theta_1}^{\theta_2} \sin\theta\, d\theta$$

$$\therefore i \left[\frac{\omega^2}{2}\right]_{\omega_1}^{\omega_2} = mB\, [-\cos\theta]_{\theta_1}^{\theta 2}$$

$$\therefore i \left[\frac{\omega_2^{\,2}}{2} - \frac{\omega_1^{\,2}}{2}\right] = mB\, [-\cos\theta_2 + \cos\theta_1]$$

At $\theta_1 = 0$, $\omega_1 = 0$ So

$$\therefore i\,\frac{\omega_2^2}{2} = mB\, [-\cos 90 + \cos 0°]$$

$$\therefore i\,\frac{\omega_2^2}{2} = mB\ (\because \cos 90 = 0, \cos 0 = 1)$$

$$\therefore \omega_2^{\,2} = \frac{2\, mB}{i}$$

$$\therefore \omega_2^{\,2} = \frac{2 \times 2 \times 10}{0.1}$$

$$\therefore \omega_2 = \sqrt{400}$$

$$\therefore \omega_2 = 20 \text{ rad/s}$$

➥ Second Method :

➥ Change in Kinetic energy of rotation = change in potential energy of rotation (or work done)

$$\therefore \frac{1}{2}\, i\omega^2 = mB\, (\cos\theta_1 - \cos\theta_2)$$

$\theta_1 = 0°$, $\theta_2 = 90°$, $i = 0.1$ kg m^2

$$\therefore \frac{1}{2}\, i\omega^2 = mB\, (\cos 0° - \cos 90°)$$

$$\therefore \frac{1}{2}\, i\omega^2 = mB\ (\because \cos 90 = 0, \cos 0 = 1)$$

$$\therefore \omega^2 = \frac{2\, mB}{i}$$

$$\therefore \omega^2 = \frac{2 \times 10 \times 10}{0.1}$$

$$\therefore \omega_2 = \sqrt{400}$$

$$\therefore \omega_2 = 20 \text{ rad s}^{-1}$$

15.

➥ $\lambda_1 = 650$ nm, $\lambda_2 = 520$ nm

➥ (a) $n = 3$ (bright fringe)

D = 90 cm, $d = 0.15$ cm

➥ path difference for constructive

interference = $n\lambda$ where, $n = 0, 1, 2, 3$ ...

but path difference = $\frac{xd}{D}$

$\therefore \frac{xd}{D} = n\lambda_1$

$\therefore x = \frac{n\lambda_1 D}{d}$

$\therefore x = \frac{3 \times 650 \times 10^{-9} \times 90 \times 10^{-2}}{0.15 \times 10^{-2}}$

$\therefore x = 1170000 \times 10^{-9}$

$\therefore x = 1.17 \times 10^{-3}$ m

$\therefore x = 1.17$ mm

➥ (b) Suppose, at some minimum distance x on the screen, from its central bright (central maximum) fringe, the n_1^{th} order bright fringe of light with wavelength $\lambda_1 = 650$ nm superposes on the n_2^{th} order bright fringe of light with wavelength $\lambda_2 = 520$ nm.

➥ Hence, the path difference for both is same.

$\therefore n_1\lambda_1 = n_2\lambda_2$

$\therefore \frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{520}{650}$

$\therefore \frac{n_1}{n_2} = \frac{4}{5}$ ... (1)

since, $\frac{n_1}{n_2} = \frac{4}{5}$, to find the minimum.

(/ least) distance, we must take the values of n_1 and n_2 minimum, which must satisfy the above equation.

Thus, we get $n_1 = 4$ and $n_2 = 5$.

➥ Now, for the light having wavelength λ_1,

Path difference $= n_1\lambda_1 = \frac{xd}{D}$

$x = \frac{n_1\lambda_1 D}{d}$

$\therefore x = \frac{4 \times 650 \times 10^{-9} \times 90 \times 10^{-2}}{0.15 \times 10^{-2}}$

$\therefore x = 1560000 \times 10^{-9}$

$\therefore x = 1.56 \times 10^{-3}$ m

$\therefore x = 1.56$ mm

➥ Thus, both the bright fringes will superpose on each other at distance 1.56 mm from the central maximum.

16.

➥ Wavelength of light $\lambda = 632.8$ nm

power $P = 9.42$ mW $= 9.42 \times 10^{-3}$ W

(a) Energy of each photon

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

$\therefore E = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{632.8 \times 10^{-9}}$

$\therefore E = 0.03141 \times 10^{-17}$

$E = 3.141 \times 10^{-19}$ J

$E = \frac{3.141 \times 10^{-19}}{1.6 \times 10^{-19}}$ eV

$= 1.963$ eV

➡ Momentum of each photon

$P = \frac{hv}{c}$ ($\because c = v\lambda$)

$P = \frac{h}{\lambda}$

$P = \frac{6.625 \times 10^{-34}}{632.8 \times 10^{-9}}$

$P = 0.01047 \times 10^{-25}$

$P = 1.047 \times 10^{-27}$ kg m/s

(b) Number of photons emitted per second

$P = \frac{NE}{t}$

$N = \frac{Pt}{E} = \frac{9.42 \times 10^{-3} \times 1}{3.14 \times 10^{-19}}$

$= 3 \times 10^{16}$ photons / sec

(c) The speed of H-atom for the same momentum $p = mv$

$\therefore v = \frac{p}{m} = \frac{1.05 \times 10^{-27}}{1.66 \times 10^{-27}} = 0.63\ ms^{-1}$

➥ Thus, Hydrogen atom has to move with speed of 0.63 ms^{-1}.

17.

➥ B = 0.3 T

$l = 8$ cm $= 8 \times 10^{-2}$ m

b = 2 cm $= 2 \times 10^{-2}$ m

Speed of loop $\upsilon = 1$ cm/sec $= 10^{-2}$ m/sec

(a) In direction perpendicular to longer side : ($\vec{\upsilon}$ as per fig. a)

➠ As shown in figure, a small cut is between B and C. AB side is outside magnetic field, thus no induced *emf* is obtained in it.

➠ Here, for sides AE and CD, $\vec{\upsilon} \parallel \vec{B}$. Thus, no induced *emf* obtained in these sides.

➠ Only for side DE, $\vec{\upsilon} \perp \vec{B}$

Thus, induced *emf*

$\varepsilon = B\upsilon l$

$= 0.3 \times 10^{-2} \times 8 \times 10^{-2}$

$= 2.4 \times 10^{-4}$ V

$= 2.4 \times 10^{-3}$ V

= 0.24 mV

➠ Induced *emf* will be produced till small side comes out of magnetic field.

➠ Suppose, time is t,

$t_1 = \frac{\text{length of smaller side}}{\text{Speed}} = \frac{b}{\upsilon}$

$= \frac{2 \times 10^{-2}}{10^{-2}}$

= 2 sec

Thus, induced *emf* will remain for 2 sec.

(b) In direction perpendicular to shorter side : ($\vec{\upsilon}$ as per fig. b)

➠ Smaller side CD is outside magnetic field. Thus, no *emf* is induced in it.

➠ Sides AB and DE have $\vec{\upsilon} \parallel \vec{B}$. Thus, no *emf* induced in these sides.

➠ Only for side AE, $\vec{\upsilon} \perp \vec{B}$

Thus, induced *emf*

$\varepsilon = B\upsilon b$

$= 0.3 \times 10^{-2} \times 2 \times 10^{-2}$

$= 0.6 \times 10^{-4}$ V

$= 0.06 \times 10^{-3}$ V

$= 0.06$ mV

➠ Induced *emf* will be produced till longer side comes out of magnetic field suppose, time is t_2

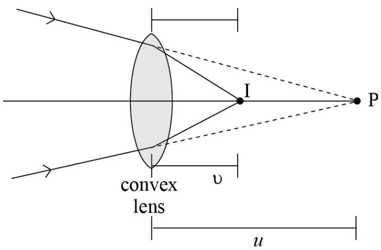
$$t_2 = \frac{\text{length of longer side}}{\text{Speed}} = \frac{l}{\upsilon}$$

$$= \frac{8 \times 10^{-2}}{10^{-2}} = 8 \text{ sec}$$

Thus, induced *emf* will remain for 8 sec.

18.

➥ (a) for convex lens,



➠ As shown in the figure, placing a convex lens in the path of a beam of light, it concentrates at point I. ($\because$ it is converging lens.)

➠ Here the point P behaves as a virtual object.

$\therefore$ object-distance $u = 12$ cm

image-distance $\upsilon = ?$

focal length $f = 20$ cm

➠ from lens formula,

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

$$\therefore \frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$$

$$\therefore \frac{1}{\upsilon} = \frac{1}{20} + \frac{1}{12}$$

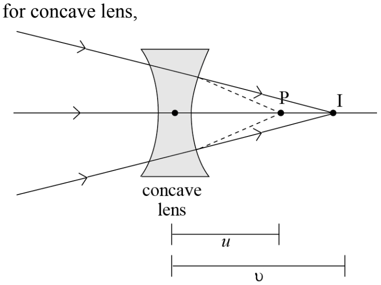
$$\therefore \frac{1}{\upsilon} = \frac{3+5}{60}$$

$$\therefore \upsilon = \frac{60}{8}$$

$= 7.5$ cm

➠ This beam of light is concentrated near point I at a distance of 7.5 cm as shown in figure.

➥ (b) for concave lens,



As shown in figure, placing a concave lens in the path of a beam of light is concentrated near I.

∴ object distance u = 12 cm

image distance υ = ?

focal length f = –16 cm

from lens formula,

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

$$\therefore \frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$$

$$\therefore \frac{1}{\upsilon} = \frac{-1}{16} + \frac{1}{12}$$

$$\therefore \frac{1}{\upsilon} = \frac{-3+4}{48}$$

$\therefore \upsilon = 48$ cm

This beam of light is concentrated near point I at a distance of 48 cm as shown in figure.

19.

Series Connection and Parallel Connection :

	Series Connection	Parallel Connection
1	Charge on each capacitor is same.	Charge on each capacitor is different.
2	p.d. across two terminals of each capacitor is different.	p.d. across two terminals of each capacitor is same.
3	Equivalent capacitance of series connection $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$	Equivalent capacitance for parallel connection $C = C_1 + C_2 + C_3 + \ldots$
4	Value of equivalent capacitance is smaller than the smallest capacitance.	Value of equivalent capacitance is more than the largest (/ greatest) capacitance.

20.

V = 220 V, P = 100 W

(a) Resistance of bulb (R)

$$\therefore P = \frac{V^2}{R}$$

$$\therefore R = \frac{V^2}{P}$$

$$= \frac{220 \times 220}{100}$$

$\therefore R = 484\ \Omega$

(b) Maximum value of source voltage (υ_m)

$$\therefore \upsilon_m = \sqrt{2}\ V$$

$$\therefore \upsilon_m = (1.414)(220)$$

$$\therefore \upsilon_m = 311\ V$$

(c) rms value of current flowing through bulb,

$$\therefore I = \frac{V}{R}$$

$= \frac{220}{484}$

$\therefore I = 0.454$ A

21.

- Let d be the distance of closest approach for the α-particle.
- At this time, according to the law of conservation of energy, the kinetic energy of the α-particle is converted into potential energy.
- The kinetic energy of α-particle = Potential energy of a system consisting of α-particle and a gold nucleus

$$\therefore 7.7 \text{ MeV} = \frac{1}{4\pi\varepsilon_0} \frac{(2e)(Ze)}{d}$$

$$\therefore d = \frac{1}{4\pi\varepsilon_0} \frac{(2e)(Ze)}{7.7 \text{ MeV}}$$

$$\therefore d = \frac{9 \times 10^9 \times 2 \times (1.6 \times 10^{-19})^2 (79)}{7.7 \times 10^6 \times 1.6 \times 10^{-19}}$$

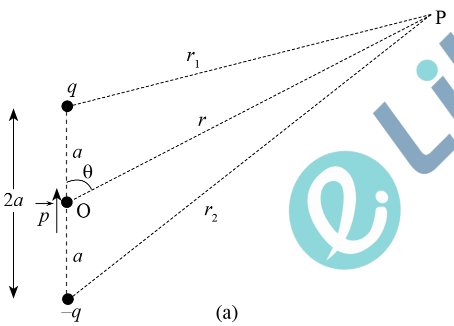
$d = 3.0 \times 10^{-14}\ m$

$= 30\ fm$.

Section C

- **Write the answer of the following questions : (Each carries 4 Mark)**

22.



(a)

- As shown in fig. point P is given at a distance 'r' from the midpoint 'O' of electric dipole and at an angle θ (with the electric dipole moment $\vec{p}$).
- We want to find electric potential at this point P.
- Electric potential at point P due to charge $+q$,

$$V_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_1}$$

- Electric potential at point P due to charge $-q$,

$$V_2 = \frac{1}{4\pi\varepsilon_0} \frac{(-q)}{r_2}$$

$$= -\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_2}$$

- Total electric potential at point P as per super position principle,

$$V = V_1 + V_2$$

$$\therefore V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_2}$$

$$\therefore V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \ldots (1)$$

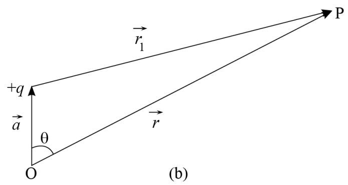
➥ As shown in the figure (a), position vector of point P with respect to origin O is $\vec{r}$.

Position vector of point P with respect to

$+q$ is $\vec{r_1}$.

Position vector of point P with respect to

$-q$ is $\vec{r_2}$.



(b)

➥ From figure (b),

$$\vec{r} = \vec{a} + \vec{r_1}$$

$$\therefore \vec{r_1} = \vec{r} - \vec{a}$$

$\therefore r_1^2 = r^2 + a^2 - 2ra \cos\theta$ (θ is angle between $\vec{r}$ and $\vec{a}$)

$$\therefore r_1^2 = r^2\left(1 + \frac{a^2}{r^2} - \frac{2a\cos\theta}{r}\right)$$

➥ But value of $\frac{a^2}{r^2}$ is very less for $r >> a$,

so it can be neglected from equation.

$$\therefore r_1^2 = r^2\left(1 - \frac{2a\cos\theta}{r}\right)$$

$$\therefore r_1 = r\left(1 - \frac{2a\cos\theta}{r}\right)^{\frac{1}{2}}$$

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{2a\cos\theta}{r}\right)^{-\frac{1}{2}}$$

➥ **Note ...**

Binomial Theorem :

$$(1-x)^n = 1 - \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \ldots.(x^2 < 1)$$

$$(1-x)^{-n} = 1 \mp \frac{nx}{1!} + \frac{n(n+1)x^2}{2!} + \ldots.(x^2 < 1)$$

➥ Using the binomial theorem to expand the equation,

$$\frac{1}{r_1} = \frac{1}{r}\left[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r} + \ldots.. + \text{other higher order terms of } \frac{2a\cos\theta}{r}\right)$$

➥ But the terms having more than 1 power will be very small and hence they can be neglected in the above equation,

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{1}{2}\cdot\frac{2a\cos\theta}{r}\right)$$

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{a\cos\theta}{r}\right) \quad \ldots (2)$$

➥ Similarly,

$$\frac{1}{r_2} = \frac{1}{r}\left(1 - \frac{a\cos\theta}{r}\right) \quad \ldots (3)$$

can be derived.

➥ Substituting values of $\frac{1}{r_1}$ and $\frac{1}{r_2}$ from equation (2) and (3) in equation (1),

$$\therefore V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1+\frac{a\cos\theta}{r}\right)-\frac{1}{r}\left(1-\frac{a\cos\theta}{r}\right)\right]$$

$$\therefore V = \frac{q}{4\pi\varepsilon_0 r}\left(1+\frac{a\cos\theta}{r} - 1+\frac{a\cos\theta}{r}\right)$$

$$\therefore V = \frac{q}{4\pi\varepsilon_0 r}\cdot\frac{2a\cos\theta}{r}$$

$$\therefore V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p\cos\theta}{r^2} \quad \text{... (4)}$$

($\because p = 2aq$ Electric dipole moment)

$$\therefore V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}\cdot\hat{r}}{r^2} \quad (r >> a) \text{ ... (5) } (\because p\cos\theta = \vec{p}\,.\,\hat{r})$$

Where, $\hat{r}$ is the unit vector along the position vector $\vec{r}$.

OR

$$V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}\cdot\vec{r}}{r^3} \quad \text{... (6)}$$

➥ Equations (4), (5) and (6) show electric potential of dipole.

23.

➥ $V_m = 283$ V

$R = 3\ \Omega$

$C = 796\mu F$

$\nu = 50$ Hz

$L = 25.48$ mH

➥ (a) Impedence of the circuit (Z),

➠ Inductive reactance (X_L)

$X_L = \omega L = 2\pi\nu L$

$\therefore X_L = 2 \times 3.14 \times 50 \times 25.48 \times 10^{-3}$

$\therefore X_L = 8000.72 \times 10^{-3}$

$\therefore X_L = 8\ \Omega$

➠ Capacitive reactance (X_C)

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$

$$\therefore X_C = \frac{1}{2\times 3.14\times 50\times 796\times 10^{-6}}$$

$$\therefore X_C = \frac{1000000}{249944}$$

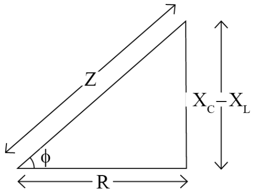
$\therefore X_C = 4\ \Omega$

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

$\therefore Z = \sqrt{3^2 + (4-8)^2}$

$\therefore Z = 5\ \Omega$

(b) Phase difference (φ)



(impedance diagram)

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

$$\tan \varphi = \frac{4 - 8}{3}$$

$$\tan \varphi = -\frac{4}{3}$$

$\tan \varphi = -1.3333$

$\varphi = -53.1°$

($\because \tan(-\theta) = -\tan\theta$)

Note : Here φ is negative. So the current in the circuit is lagging behind the voltage between two terminals of the source.

(c) Power dissipated in the circuit :

$P = I^2 R$

$$\text{But } I = \frac{I_m}{\sqrt{2}}$$

$$\therefore I = \frac{V_m}{Z\sqrt{2}}$$

$$\therefore P = \frac{V_m^2}{Z^2(2)} \cdot R$$

$$\therefore P = \frac{(283)^2 \times 3}{25 \times 2}$$

$\therefore P = 4800$ W

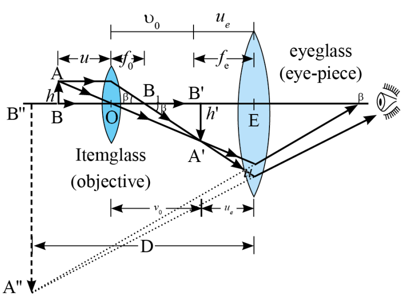
(d) Power factor,

$\cos \varphi = \cos(-53.1°)$ ($\because \cos(-\theta) = \cos\theta$)

$= \cos 53.1°$

$= 0.6$

24.

➥ 

➥ $f_0 = 2.0$ cm

$f_e = 6.25$ cm

(a) final image is at near point

➠ $\upsilon_e = -25$ cm

➠ Lens formula for eye-piece,

$\therefore \frac{1}{\upsilon_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$\therefore \frac{1}{\upsilon_e} - \frac{1}{f_e} = \frac{1}{u_e}$

$\therefore \frac{1}{u_e} = \frac{-1}{25} - \frac{1}{6.25}$

$\therefore \frac{1}{u_e} = \frac{-1-4}{25}$

$\therefore u_e = -5$ cm

- Thus, the object distance for the eye-piece is 5 cm.
- The distance between two lens,

$\upsilon_0 + |u_e| = 15$ cm (which can be understood from the figure)

$\therefore \upsilon_0 + 5 = 15$

$\therefore \upsilon_0 = 10$ (image distance for objective)

- Applying lens formula for the objective,

$\frac{1}{\upsilon_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$\therefore \frac{1}{\upsilon_0} - \frac{1}{f_0} = \frac{1}{u_0}$

$\therefore \frac{1}{u_0} = \frac{1}{10} - \frac{1}{2}$

$\therefore \frac{1}{u_0} = \frac{1-5}{10}$

$\therefore \frac{1}{u_0} = -\frac{4}{10}$

$\therefore u_0 = -2.5$ cm

- Thus, object should be kept at a distance of 2.5 cm from the objective.
- Magnification of microscope,

$m = m_0 \times m_e$

$\therefore m = \frac{\upsilon_0}{|u_0|} \times \left(1 + \frac{D}{f_e}\right)$

$\therefore m = \frac{10}{2.5} \times \left(1 + \frac{25}{6.25}\right)$

$\therefore m = 4(1 + 4)$

$\therefore m = 20$

(b) final image is formed at infinite distance.

$\upsilon_e = \infty \, f_e = 6.25$ cm

- Applying the lens formula for eye-piece,

$\therefore \frac{1}{\upsilon_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$\therefore \frac{1}{\upsilon_e} - \frac{1}{f_e} = \frac{1}{u_e}$

$\therefore \frac{1}{\infty} - \frac{1}{6.25} = \frac{1}{u_e}$

$\therefore \frac{1}{u_e} = 0 - \frac{1}{6.25}$

$\therefore u_e = -6.25$ cm

- Thus, the object distance for eye-piece is 6.25 cm.

- For eye-piece :
- Distance between two lenses

  $\upsilon_0 + |u_e| = 15$ cm (which can be understood from the figure)

  $\therefore \upsilon_0 + 6.25 = 15$

  $\therefore \upsilon_0 = 8.75$ cm (which is image distance for the objective)
- Applying lens formula for objective,

  $$\frac{1}{\upsilon_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

  $$\therefore \frac{1}{\upsilon_0} - \frac{1}{f_0} = \frac{1}{u_0}$$

  $$\therefore \frac{1}{u_0} = \frac{1}{8.75} - \frac{1}{2}$$

  $$\frac{1}{u_0} = \frac{2 - 8.75}{8.75 \times 2}$$

  $$\therefore \frac{1}{u_0} = \frac{-6.75}{17.5}$$

  $$\therefore u_0 = \frac{-17.5}{6.75}$$

  $\therefore u_0 = -2.59$ cm
- Thus, object should be kept at a distance of 2.59 cm from the objective.
- Magnification of microscope,

  $m = m_0 \times m_e$

  $$\therefore m = \frac{\upsilon_0}{|u_0|} \times \left(\frac{D}{f_e}\right)$$

  $$\therefore m = \frac{8.75}{2.59} \times \frac{25}{6.25} = 13.5$$

25.

- atomic weight of deuteron = 2 g/mol

  Mass of deuteron No. of atoms

  2 g $6.023 \cdot 10^{23}$

  $\therefore$ 2000 g (?)
- No. of atoms

  $$N = \frac{2000 \times 6.023 \times 10^{23}}{2}$$

  $\therefore N = 6.023 \cdot 10^{26}$
- When two atoms of deuteron fuse, the energy released = 3.27 MeV

  $\therefore$ The energy released by fusion of N atoms

  $$E = \frac{N \times 3.27}{2} \text{ MeV}$$

  $$E = \frac{6.023 \times 10^{26} \times 3.27 \times 10^{6} \times 1.6 \times 10^{-19}}{2}$$

  $\therefore E = 15.75 \cdot 10^{13}$ J
- Power of electric lamp = 100 W. It means the energy consumed by the lamp per second = 100 J

  $\therefore$ time required to consumed $15.75 \cdot 10^{13}$ J

$$t = \frac{15.75 \times 10^{13}}{100}$$

$\therefore t = 15.75 \cdot 10^{11}$ s

$$\therefore t = \frac{15.75 \times 10^{11}}{3.154 \times 10^{7}}$$

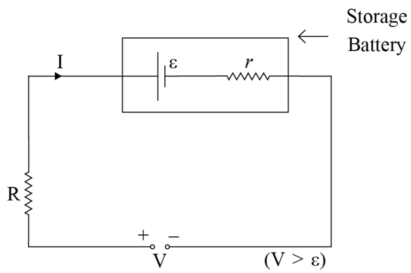
$\therefore t = 4.99 \cdot 10^{4}$ years

➥ Thus, an electric bulb can glow for about 50,000 years.

26.

➥ $\varepsilon = 8$ V $r = 0.5\ \Omega$

$V = 120$ V $R = 15.5\ \Omega$



(Battery in charging condition)

➥ The current flowing through the circuit when the battery is being charged is called the charging current.

$$\therefore \text{Charging current } I = \frac{V - \varepsilon}{R + r}$$

$$\therefore I = \frac{120 - 8}{15.5 + 0.5}$$

$$\therefore I = \frac{112}{16}$$

$\therefore I = 7$ A

➥ The terminal voltage of battery during its charging,

$V' = \varepsilon - (-I)r$

$\therefore V' = \varepsilon + Ir$

$= 8 + (7)(0.5)$

$= 8 + 3.5$

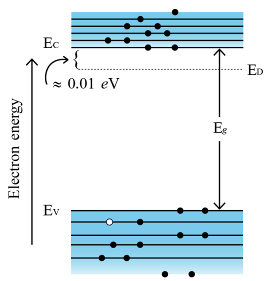
$= 11.5$ V

➥ The series resistor controls the current drawn from the external DC supply. By controlling charging current, heat energy loss can be reduced.

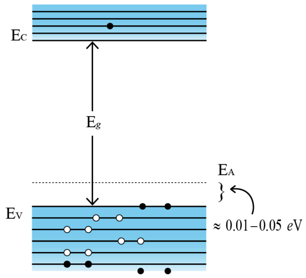
27.

➥ The semiconductor's energy band structure is affected by doping. In the case of extrinsic semi-conductors, additional energy states due to donor impurities (E_D) and acceptor impurities (E_A) also exist.

➥



(a) T > 0 K



(b) T > 0 K

one thermally generated electron-hole pair +9 electrons from donor atoms

- In the energy band diagram of *n*-type S*i* semiconductor, the donor energy level E_D is slightly below the bottom E_C of conduction band and the electrons from this level move into the conduction band with very small supply of energy. At room temperature, most of the donor atoms get ionised but very few ($\sim 10^{-12}$) atoms of S*i* get ionised. So the conduction band will have most electrons coming from the donor impurities as shown in fig. (a).
- Similarly for *p*-type semiconductor, the acceptor energy level E_A is slightly above the top of E_V the valence band as shown in fig (b).
- At room temperature, most of the acceptor atoms get ionised, which create holes in the valence band.
- Thus at room temperature, the density of holes in the valence band is pre-dominantly due to impurity in the extrinsic semiconductor. The electron and hole concentration in a semiconductor in thermal equilibrium is given by,

$$n_e \cdot n_h = n_i^2.$$