SQP SOLUTIONS

1. (a)	**2.** (b)	**3.** (a)	**4.** (b)
5. (d)	**6.** (b)	**7.** (a)	**8.** (b)
9. (b)	**10.** (d)	**11.** (a)	**12.** (c)
13. (b)	**14.** (b)	**15.** (a)	**16.** (d)

17. Here, $f_0 = 1.25$ cm, $f_e = 5$ cm, $d = 25$ cm, $L = ?$, $M = 30$

When final image is formed at the near point of eyer the magnifying power of compound microscope is given by

$$M = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right) \; ; \; 30 = \frac{L}{1.25}\left(1 + \frac{25}{5}\right) = \frac{6L}{1.25}$$

$$L = \frac{30 \times 1.25}{6} = 6.25 \text{ cm}$$

18. (I) As the solenoids are identical, the currents in Q and R will be the same and will be half the current in P. The magnetic field within a solenoid is given by $\mu_0 ni$. Hence, the field at Q will be equal to field at R and will be half the field in P *i.e.*, will be 1.0 T.

OR

18. (II) Magnetic field due to current carrying wire AB,

$$\vec{B} = \frac{\mu_0 I}{2\pi x} = 2 \times 10^{-7} \times \frac{4}{0.2}$$

$= 4 \times 10^{-6}$ T inside the plane of paper,

Required force on proton,

$F = qvB \sin 90° = 1.6 \times 10^{-19} \times 4 \times 10^{6} \times 4 \times 10^{-6}$
$= 25.6 \times 10^{-19}$ N

Force on the proton will be away from the wire AB.

19. Given $f = \dfrac{-3R}{4}$,

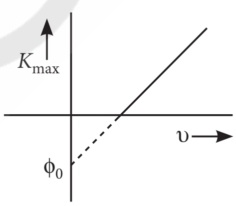
From lens-maker's formula,

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \Rightarrow \frac{1}{\frac{-3R}{4}} = (\mu - 1)\left[\frac{1}{-R} - \frac{1}{R}\right]$$

$$\frac{4}{3R} = \frac{2(\mu - 1)}{R} \Rightarrow \mu = \frac{5}{3}$$

It will behave as a converging lens if $(\mu - 1) < 0$ or $\mu < 1$.

20. (I) According to Einstein's photoelectric equation, $K_{max} = h\upsilon - \phi_0$



So, the graph between K_{max} and υ is a straight line.

(i) Slope of $K_{max} - \upsilon$ graph $= \dfrac{\Delta K_{max}}{\Delta \upsilon} = h$

Slope of $K_{max} - \upsilon$ gives the value of Planck's constant.

(ii) Intercept on the negative K_{max} axis $= \phi_0$

It gives the value of work function.

OR

20. (II) Frequency of violet light (υ_v) > frequency of blue light (υ_b) *i.e.*, $\left(\dfrac{\upsilon_v}{\upsilon_b}\right) > 1$

As both light have same intensity, so

$$n_v \upsilon_v = n_b \upsilon_b \Rightarrow \frac{n_v}{n_b} = \frac{\upsilon_b}{\upsilon_v} < 1$$

$\therefore \quad n_b > n_v$

(i) Since $n_b > n_v$, hence number of electrons emitted per second corresponding to blue light will be more than that for violet light.

(ii) Since $\upsilon_v > \upsilon_b$, hence maximum kinetic energy of the electrons $(K_{max} = h\upsilon - \phi_0)$ for violet light will more than that for blue light.

21. Here, $B_0 = 300\ \mu T = 3 \times 10^{-4}$ T

(i) Maximum value of electric field, $E_0 = c\, B_0$

$\therefore \quad E_0 = (3 \times 10^8) \times (3 \times 10^{-4}) = 9 \times 10^4$ Vm^{-1}

(ii) Average energy density corresponding to electric field is

$$U_E = \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{4} \times (8.85 \times 10^{-12}) \times (9 \times 10^4)^2$$
$$= 179.2 \times 10^{-4} \text{ J m}^{-3}$$

22. (I) (A) Drift velocity : It is the average velocity with which electrons move in a conductor when an external electric field (or potential difference) is applied across the conductors.

The drift velocity controls the net current flowing across any cross section. There is no net transport of charges across any area perpendicular to the applied field.

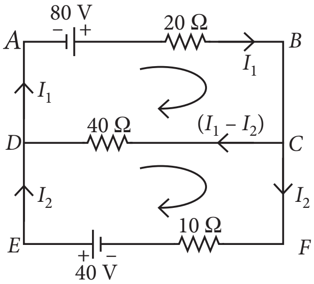
Relaxation time : It is the average time between successive collision for the drifting electrons in the conductor.

It is a factor in determining the electrical conductivity of a conductor at different temperatures.

(B) $v_d = \dfrac{eV}{mL}\tau \Rightarrow v'_d = \dfrac{eV}{m \times 5L}\tau = \dfrac{v_d}{5}$

OR

22. (II) Applying KVL in closed loop *ABCDA*



$-80 + 20I_1 + 40(I_1 - I_2) = 0$

$20I_1 + 40I_1 - 40I_2 = 80$

$60I_1 - 40I_2 = 80$

$3I_1 - 2I_2 = 4$ ...(i)

Applying KVL in closed loop *DCFED*

$-40(I_1 - I_2) + 10I_2 - 40 = 0$

$-40I_1 + 40I_2 + 10I_2 - 40 = 0$ or $-40I_1 + 50I_2 = 40$

or $-4I_1 + 5I_2 = 4$ ...(ii)

From (i) and (ii), $I_2 = 4$ A and $I_1 = 4$ A

$\therefore$ Current flowing through 40 Ω $= I_1 - I_2 = 0$ A

Current flowing through 20 Ω = 4 A

23. (I) Here, $m = 6\ \mathrm{J\,T^{-1}}$, $\theta_1 = 60°$, $B = 0.44$ T

Work done in turning the magnet,

$W = -mB(\cos\theta_2 - \cos\theta_1)$

(A) When the bar magnet is turned normal to the magnetic field, the final angle made by the axis of the bar magnet with the magnetic field is, $\theta_2 = 90°$ and $\theta_1 = 60°$

$\therefore$ $W = -6 \times 0.44(\cos 90° - \cos 60°)$

$$= -6 \times 0.44\left(0 - \frac{1}{2}\right) = 1.32\ \mathrm{J}$$

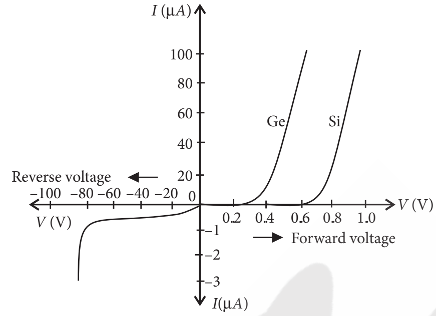
(B) When the bar magnet is turned opposite to the magnetic field, the final angle made by the axis of the bar magnet with the magnetic field is $\theta_2 = 180°$ and $\theta_1 = 60°$

$\therefore$ $W = -6 \times 0.44(\cos 180° - \cos 60°)$

$$= -6 \times 0.44\left(-1 - \frac{1}{2}\right) = 3.96\ \mathrm{J}$$

(II) $\tau = mB\sin\theta = mB\sin 180° = 0$

24. (I) *I-V* characteristics of a *p-n* junction : The *I-V* characteristics of a *p-n* junction do not obey Ohm's law. The *I-V* characteristics of a *p-n* junction are as shown in the figure.



(II) (A) The current of order in reverse bias is due to the drifting of minority charge carriers from one region to another through the junction. A small amount of applied voltage is sufficient to sweep the minority charge carriers through the junction. So, reverse current is almost independent of critical voltage.

(B) During breakdown voltage, enormous covalent bond breaks. As a result large number of charge carriers increases. Therefore, current increases at breakdown voltage.

25. (I)

Nuclear fission	Nuclear fusion
The process of splitting of a heavy nucleus into two nuclei of nearly comparable masses with liberation of energy is called nuclear fission.	When two or more than two light nuclei fuse together to form heavy nucleus with the liberation of energy, the process is called nuclear fusion.
Example: $^{235}_{92}\mathrm{U} + ^{1}_{0}n \rightarrow ^{141}_{56}\mathrm{Ba} + ^{92}_{36}\mathrm{Kr} + 3\,^{1}_{0}n + Q$	Example: $^{2}_{1}\mathrm{H} + ^{2}_{1}\mathrm{H} \rightarrow ^{3}_{2}\mathrm{He} + ^{1}_{0}n$ +3.2 MeV

(II) The release of energy in nuclear fission and fusion can be explained by the concept of binding energy per nucleon. Binding energy per nucleon is the amount of energy required to separate a nucleon from the nucleus of an atom. Nuclei with higher binding energy per nucleon are more stable, meaning that they require more energy to be split apart or combined.

In nuclear fission, the total binding energy per nucleon of the resulting nuclei is greater than the binding energy per nucleon of the original nucleus. This excess energy is released in the form of kinetic energy and radiation.

In nuclear fusion, the total binding energy per nucleon of the resulting nucleus is greater than the binding energy per nucleon of the original nuclei. The excess binding energy is released in the form of kinetic energy and radiation.

26. Clearly, equivalent focal length of equi-convex lens and water lens, $f = x$

Focal length of equi-convex lens, $f_1 = y$

Focal length f_2 of water lens is given by

$$\frac{1}{f_2}=\frac{1}{f}-\frac{1}{f_1}=\frac{1}{x}-\frac{1}{y}=\frac{y-x}{xy} \quad \text{or} \quad f_2=\frac{xy}{y-x}$$

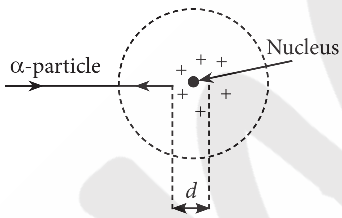
The water lens formed between the plane mirror and the equi-convex lens is a plano-concave lens. For this lens.

Using lens maker's formula,

$$\frac{1}{f_2}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad \text{or} \quad \frac{y-x}{xy}=(\mu-1)\left[\frac{1}{-R}-\frac{1}{\infty}\right]$$

$$\text{or} \quad \mu-1=\frac{(x-y)R}{xy} \quad \text{or} \quad \mu=1+\frac{(x-y)R}{xy}.$$

27. (I) Suppose an α-particle of mass m and initial velocity v moves directly towards the centre of the nucleus of an atom. As it approaches the positive nucleus, it experiences Coulombic repulsion and its kinetic energy gets progressively converted into electrostatic potential energy. At a certain distance d from the nucleus, the α-particle stops for a moment and then begins to retrace its path. The distance d is called the distance of closest approach.



(Distance of closest approach)

Let, initial kinetic energy of α-particle, $K_\alpha=\frac{1}{2}mv^2$

Electrostatic P.E. of α-particle and nucleus at distance d,

$$U=\frac{q_1q_2}{4\pi\varepsilon_0 d}=\frac{2eZe}{d}\frac{1}{4\pi\varepsilon_0}$$

At the distance d, from law of conservation of energy, $K_\alpha = U$

$$\text{or} \quad K_\alpha=\frac{2eZe}{d}\frac{1}{4\pi\varepsilon_0} \Rightarrow d=\frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{K_\alpha}$$

(II) Distance of closest approach, $d=\frac{1}{4\pi\varepsilon_0}\cdot\frac{2Ze^2}{K}$

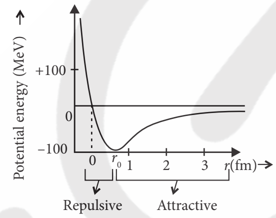
where K is the kinetic energy of the particle.

$$\therefore \quad d=\frac{2(Ze)\times q}{4\pi\varepsilon_0\times\frac{1}{2}mv^2} \Rightarrow d=\frac{(Ze)\times q}{\pi\varepsilon_0\, mv^2} \quad \therefore \quad d\propto\frac{q}{m}$$

For the ratio of distances of closest approach for proton and α-particle, we can write

$$\frac{d_p}{d_\alpha}=\frac{e}{2e}\times\frac{4m}{m}=\frac{2}{1}$$

28. Plot of potential energy of a pair of nucleons as a function of their separation is given in the figure.



Conclusions: (i) The nuclear force is much stronger than the coulomb force acting between charges or the gravitational forces between masses.

(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few fermi.

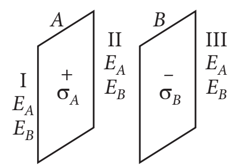
(iii) For a separation greater than r_0, the force is attractive and for separation less than r_0, the force is strongly repulsive.

29. (I) (d) : There are two plates A and B having surface charge densities,

$\sigma_A = 17.0 \times 10^{-22}\ \text{C/m}^2$

on A and $\sigma_B = -17.0 \times 10^{-22}\ \text{C/m}^2$ on B, respectively.

According to Gauss' theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.



$$E_\text{I}=E_A+E_B=\frac{\sigma}{2\varepsilon_0}+\left(-\frac{\sigma}{2\varepsilon_0}\right)=0$$

(II) (d) : The electric field in region III is also zero.

$$E_\text{III}=E_A+E_B=\frac{\sigma}{2\varepsilon_0}+\left(-\frac{\sigma}{2\varepsilon_0}\right)=0$$

(III) (c) : In region II or between the plates , the electric field

$$E_\text{II}=E_A-E_B=\frac{\sigma}{2\varepsilon_0}+\frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$$

$E = 1.9 \times 10^{-10}$ N C^{-1}

(IV) (c) **:** Since, electric field due to an infinite-plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge. So, for the given distances, the ratio of E will be 1 : 1.

30. (I) Given : $R = 12\ \Omega$, $X_C = 14\ \Omega$, $L = 0.1$ H

$X_L = \omega L = 2\pi\upsilon L = 2 \times 3.14 \times 50 \times 0.1 = 31.4\ \Omega$

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

$= \sqrt{(12)^2 + (31.4 - 14)^2} = 21.13\ \Omega$

(III) $I_v = \frac{E_v}{Z} = \frac{200 \text{ V}}{21.13} = 9.46$ A

31. (I) (A) $r = \frac{mv}{Bq} = \frac{m}{Bq}\sqrt{\frac{2K}{m}} = \frac{\sqrt{2mK}}{Bq}$

$m_\alpha = 4m,\ m_d = 2m,\ m_p = m$

$m_\alpha = 2e,\ q_d = e,\ q_p = e$

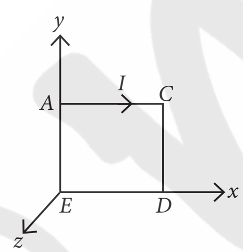
Here, KE is constant, magnetic field is constant

$r \propto \frac{\sqrt{m}}{q}$

$r_\alpha \propto \frac{\sqrt{4m}}{2e} \propto \frac{\sqrt{m}}{e},\quad r_d \propto \frac{\sqrt{2m}}{e},\quad r_p \propto \frac{\sqrt{m}}{e}$

So, $r_\alpha : r_d : r_p = 1 : \sqrt{2} : 1$

(B) The direction of magnetic field is given by Maxwell's right hand thumb rule which is inwards to the plane of paper.



(C) If the resistance of the ammeter would be high, total resistance would be high. Due to which the current decreases so, to avoid change of current we use low resistance ammeter.

OR

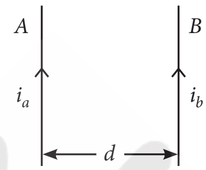
31. (II) (A) Consider two parallel wires A and B placed at a distance d apart and length of each conductor be l. Current in wire A and B is i_a and i_b respectively.

The magnetic field due to the current i_a flowing in conductor A at any point on conductor B is

$B_A = \frac{\mu_0 i_a}{2\pi d}$ ...(i) (acting perpendicular inwards)

So, the force on conductor B due to the field B_A

$\vec{F} = i_b\left(\vec{l} \times \vec{B}_A\right)$



$F = i_b \times l \times \frac{\mu_0 i_a}{2\pi d}$ from (i)

$F = \frac{\mu_0}{2\pi}\frac{i_a i_b l}{d};\ \frac{F}{l} = \frac{\mu_0 I_a I_b}{2\pi d}$

Definition of 1 A : Two straight infinitely long parallel conductors are said to carry 1 A current each when they interact each other with a force of 2×10^{-7} N/m, when kept 1 m apart in vacuum.

(B) $m = 3$ A m^2, $r = 10$ cm, $B = 0.25$ T, $\theta = 30°$

In equilibrium,

Restoring torque = Deflecting torque , $F \times r = mB\sin\theta$

$F \times 10 \times 10^{-2} = 3 \times 0.25 \times \sin 30°$, $F = 3.75$ N

The magnet oscillates for sometime but finally aligns along the original direction of the external magnetic field.

32. (I) (A) Here; $f_0 = 25$ cm,

$f_e = 2.5$ cm,

$\mu_0 = -1.5$ m $= -150$ cm,

$v_e = -25$ cm, $L = ?$

As $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$\therefore \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{u_0} = \frac{1}{25} - \frac{1}{150} = \frac{6-1}{150}$

$v_0 = \frac{150}{5} = 30$ cm

Again, as $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$\therefore \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{2.5} = \frac{-1-10}{25} = \frac{-11}{25}$

$u_e = \frac{-25}{11} = -2.27$ cm

Length of telescope, $L = |v_0| + |u_e|$

$= 30$ cm $+ (-2.27$ cm$)$

$= 27.73$ cm

(B) (i) $P_o = 100$ D

$\therefore f_o = 1$ cm

$P_E = 40$ D

$\therefore f_E = 2.5$ cm.

Since $f_o < f_E$, the instrument is a compound microscope.

(ii) Magnification, $m = \frac{L}{f_0}\left(\frac{D}{F_E}\right) = \frac{20}{1}\left(\frac{25}{2\cdot 5}\right) = 200$

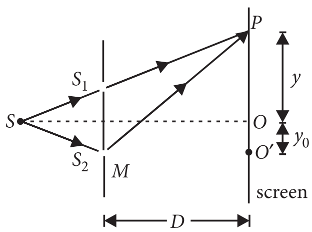
OR

32. (II) (A) Given : $SS_2 - SS_1 = \frac{\lambda}{4}$

Now path difference between the two waves from slit S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$ or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$



(i) For constructive interference at point P, path difference, $\Delta x = n\lambda$

or $\frac{\lambda}{4} + \frac{yd}{D} = n\lambda$ or $\frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ ...(i)

where $n = 0, 1, 2, 3, \ldots,$

(ii) For destructive interference at point P, path difference

$\Delta x = (2n-1)\frac{\lambda}{2}$ or $\frac{\lambda}{4} + \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$

or $\frac{yd}{D} = \left(2n - 1 - \frac{1}{2}\right)\frac{\lambda}{2} = (4n-3)\frac{\lambda}{4}$ ...(ii)

where $n = 1, 2, 3, 4, \ldots$

For central bright fringe, putting $n = 0$ in equation (i), we get

$\frac{yd}{D} = -\frac{\lambda}{4}$ or $y = \frac{-\lambda D}{4d}$

(B) The negative sign indicates that central bright fringe will be observed at a point O' below the centre O of screen.

33. (I) (i) The magnitude of the electric field at point A due to the charge $+ 10^{-8}$ C is

$E_1 = (9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \frac{(10^{-8}\text{ C})}{(0.05\text{ m})^2} = 3.6 \times 10^4 \text{ N C}^{-1}$

(towards right, away from the charge.

Due to the charge -10^{-8} C is

$E_2 = (9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \frac{(10^{-8}\text{ C})}{(0.05\text{ m})^2} = 3.6 \times 10^4 \text{ N C}^{-1}$

towards right, towards the charge.

Since E_1 and E_2 are in the same direction, the magnitude of the total electric field at A is

$EA = E_1 + E_2 = (3.6. \times 10^4) + (3.6. \times 10^4)$
$= 7.2 \times 10^4 \text{ N C}^{-1}$.

$\therefore$ $\vec{E}_A$ is directed towards right.

(ii) The magnitude of the electric field at point B due to the charge $+ 10^{-8}$ C is,

$E_1 = (9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \frac{(10^{-8}\text{ C})}{(0.05\text{ m})^2} = 3.6 \times 10^4 \text{ NC}^{-1}$,

towards left.

Due to the charge -10^{-8} C is,

$E_2 = (9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \frac{(10^{-8}\text{ C})}{(0.15\text{ m})^2} = 0.4 \times 10^4 \text{ N C}^{-1}$,

towards right.

Since E_1 and E_2 are oppositely-directed, the magnitude of the total electric field at B is

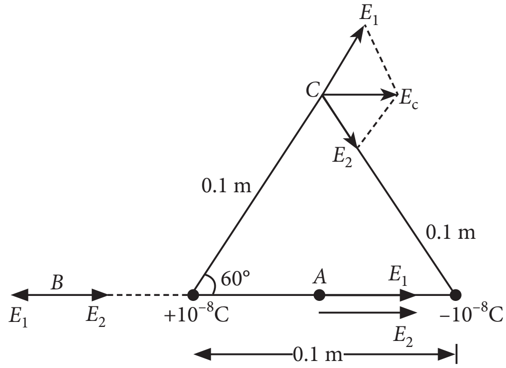
$EB = E_1 - E_2 = (3.6 \times 10^4) - (0.4 \times 10^4)$
$= 3.2 \times 10^4 \text{ N C}^{-1}$.

$\therefore$ $\vec{E}_B$ is directed towards left.

(iii) The magnitude of each of the electric field at point C due to the charge $+ 10^{-8}$ C and $- 10^{-8}$ C is

$E_1 = E_2 = 9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \frac{10^{-8}\text{ C}}{(0.1\text{ m})^2} = 9.0 \times 10^3 \text{ N C}^{-1}$

The directions of E_1 and E_2 at C are as shown in figure. The resultant electric field at C is



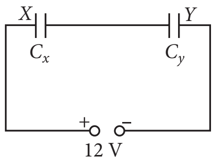
$EC = E_1 \cos 60° + E_2 \cos 60° = 2 \times (9.0 \times 10^3) \times 0.5$
$= 9.0 \times 10^3 \text{ N C}^{-1}$.

$\therefore$ $\vec{E}_C$ is directed towards right.

OR

33. (II) (A) Here, $C_x = \dfrac{\varepsilon_0 A}{d}$

$$C_y = \frac{\varepsilon_0 \varepsilon_r A}{d} = \varepsilon_r C_x = 5\, C_x$$



(i) C_x and C_y are in series, so equivalent capacitance is given by

$$C = \frac{C_x \times C_y}{C_x + C_y}$$

$$\Rightarrow \quad 5 = \frac{C_x \times 5\,C_x}{C_x + 5\,C_x} \qquad (\because\ C = 5\ \mu\text{F})$$

$$\Rightarrow \quad 5 = \frac{5\,C_x}{6} \quad \therefore\ C_x = 6\ \mu\text{F}$$

and $C_y = 5\,C_x = 30\ \mu\text{F}$

(ii) Charge on each capacitor, $Q = CV$

$Q = 5 \times 10^{-6} \times 12 = 60 \times 10^{-6}$ C

Potential difference between the plates of X,

$$V_x = \frac{Q}{C_x} = \frac{60 \times 10^{-6}}{6 \times 10^{-6}} = 10\ \text{V}$$

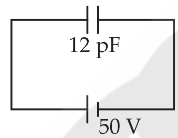
Potential difference between the plates of Y,

$V_y = V - V_x = 12 - 10 = 2$ V

(iii) Ratio of electrostatic energy stored,

$$\frac{U_x}{U_y} = \frac{\dfrac{Q^2}{2C_x}}{\dfrac{Q^2}{2C_y}} = \frac{C_y}{C_x} = \frac{5C_x}{C_x} = 5$$

(B) Electrostatic energy stored in the capacitor,



$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 12 \times 10^{-12} \times (50)^2$$

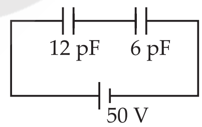
(As C = 12 pF, V = 50 V)

$U = 1.5 \times 10^{-8}$ J

When 6 pF is connected in series with 12 pF, charge stored across each capacitor,

$$Q = \frac{C_1\, C_2}{C_1 + C_2} V$$

$$= \frac{12 \times 6 \times 10^{-24}}{(12+6) \times 10^{-12}} \times 50 = 200\ \text{pC}$$



Now, potential difference across 12 pF is,

$$= \frac{Q}{C_1} = \frac{200 \times 10^{-12}}{12 \times 10^{-12}} = 16.67\ \text{V}$$

Potential difference across 6 pF is,

$$= \frac{Q}{C_2} = \frac{200 \times 10^{-12}}{6 \times 10^{-12}} = 33.33\ \text{V}$$

☺☺☺