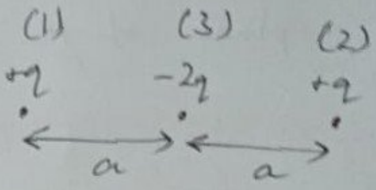
CBSE 12th grade Physics Paper - Solutions

Section A



1) P.E. of the system = Sum of P.E.'s b/w each pair of charges

$$U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_1 q_3}{r_{13}}\right)$$

$q_1 = q_2 = q$, $q_3 = -2q$, $r_{12} = 2a$, $r_{23} = r_{13} = a$

$$\therefore U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a} + \frac{q(-2q)}{a} + \frac{q(-2q)}{a}\right) = \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a} - \frac{2q^2}{a} - \frac{2q^2}{a}\right)$$

$$= \frac{q^2}{4\pi\varepsilon_0 a}\left(\frac{1}{2} - 2 - 2\right) = \frac{q^2}{4\pi\varepsilon_0 a}\left(\frac{1-4-4}{2}\right) = \boxed{\frac{-7q^2}{8\pi\varepsilon_0 a}} \quad (C)$$

2) Ball B_1 : $q_1 = -7pC$
Ball B_2 : $q_2 = +4pC$
Ball B_3 : $q_3 = q$ (say)

Final charge on each ball = $-2pC$

Conservation of charge : Total initial charge = Total final charge

$-7 + 4 + q = -2 - 2 - 2$ (q is in pC)

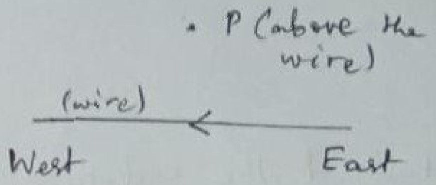
$-3 + q = -6 \Rightarrow q = 3 - 6 = \boxed{-3pC}$ = initial charge on B_3
(B)

3) (A) [theoretical]

4) $r_n = 0.529 \frac{n^2}{Z} \mathring{A} \Rightarrow \boxed{r_n \propto n^2}$ (C)

5) Point P is above the wire. By the right-hand thumb rule, the magnetic field at P will be into the plane of the paper, i.e., $\boxed{\text{North}}$.

(C)



North → into the plane
South → out of the plane

6) (A) [theoretical]

7) In conversion of a galvanometer to an ammeter, the shunt resistance is: $S = \dfrac{I_g G}{I - I_g}$

G → resistance of galvanometer

I → max. current to be measured by the ammeter

I_g → current (through the galvanometer) needed to cause a full scale deflection in the galvanometer

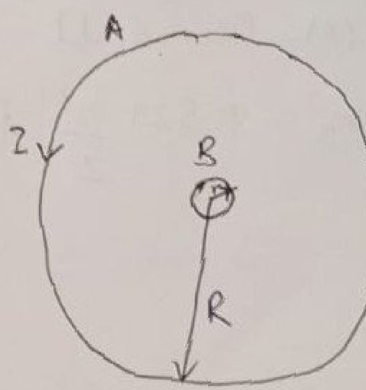
Here, $S = 0.1\,\Omega$, $I = 1\,A$, $G = 100\,\Omega$

$$0.1 = \frac{100 I_g}{1 - I_g} \Rightarrow 0.1 - 0.1 I_g = 100 I_g \Rightarrow 100.1 I_g = 0.1$$

$$I_g = \frac{0.1}{100.1} \approx \frac{0.1}{100} = 10^{-3}\,A = 1\,mA$$

$\therefore I_g \approx \boxed{1\,mA} \rightarrow (B)$

8) For the current loop A, the magnetic field near the centre of the loop is (approximately): $B \simeq \dfrac{\mu_0 I}{2R}$



To find the flux through loop B, note that its radius $r = R/20$ so that $R >> r$.

Assume the field is constant throughout loop B.

$$\phi = BA = \left(\frac{\mu_0 I}{2R}\right)\pi r^2 = \frac{\mu_0 I}{2R}\cdot \pi \frac{R^2}{400} = \left(\frac{\mu_0 \pi I}{800}\right) R,$$

So $\boxed{\phi \propto R}$. (A)

9) $X_L = \omega L$. Thus, in a plot of X_L vs ω, the slope of the line is L.

Slope of L_1-plot $= L_1 = \tan 30^\circ = \frac{1}{\sqrt{3}}$ units

Slope of L_2-plot $= L_2 = \tan 60^\circ = \sqrt{3}$ units

$$\therefore \frac{L_1}{L_2} = \frac{1/\sqrt{3}}{\sqrt{3}} = \boxed{\frac{1}{3}} \rightarrow (D)$$

10) (A) [theoretical]

11) $B = B_0 \cos\left(\frac{2\pi}{T}t\right)$, $\phi = BA = B_0 A \cos\left(\frac{2\pi}{T}t\right)$

(A = area of coil)

$$|\varepsilon| = \left|\frac{d\phi}{dt}\right| = \left|-B_0 A \frac{2\pi}{T} \sin\left(\frac{2\pi}{T}t\right)\right| = B_0 A \frac{2\pi}{T}\left|\sin\left(\frac{2\pi}{T}t\right)\right|$$

For maximum EMF,

$$\left|\sin\left(\frac{2\pi}{T}t\right)\right| = 1 \Rightarrow \sin\left(\frac{2\pi}{T}t\right) = \pm 1$$

$$\frac{2\pi}{T}t = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \frac{7\pi}{2}, \ldots$$

$$t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \frac{7T}{4}, \ldots = (\text{odd no.}) \times \frac{T}{4}$$

Answer is (B) but n should be an odd number only, not any natural number.

12) (D) [theoretical]

13) Both (A) and (R) are false, check the "Dual Nature ..." chapter in NCERT. → (D)

14) Both (A) and (R) are true but (R) is not an explanation for (A) [correct explanation is in "Current Electricity" chapter in NCERT]. → (B)

15) Both (A) and (R) are true, and (R) is a correct explanation for (A) ["Current Electricity", NCERT]. → (A)

16) (A) is correct but (R) is wrong, as energy conservation principle cannot be violated. → (C)

Section B

17) [theoretical]

18) If a particle of mass m and charge q is accelerated through a potential V, then kinetic energy $K = qV = \frac{p^2}{2m}$

$\therefore\ p = \sqrt{2mqV}$; de Broglie wavelength $(\lambda) = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$

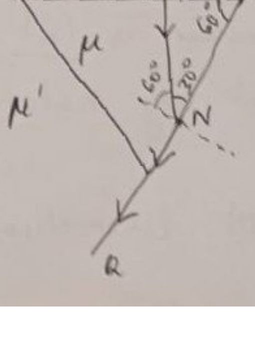
Proton : $m = m_p,\ q = e,\ V = V_1$

Alpha particle : $m \approx 4m_p,\ q = 2e,\ V = V_2$

$$\lambda_1 = \lambda_2 \Rightarrow \frac{h}{\sqrt{2m_p e V_1}} = \frac{h}{\sqrt{2(4m_p)(2e)V_2}} \Rightarrow m_p e V_1 = 8 m_p e V_2$$

$$\boxed{V_1 / V_2 = 8}$$

19) Let the R.I. of the surrounding medium be μ'. From the figure, angle of incidence at the second face $= 60°$.



Snell's law : $\mu \sin 60° = \mu' \sin 90° = \mu'$

$$\boxed{\mu' = \frac{\sqrt{3}\mu}{2}}$$ = R.I. of surrounding medium.

20) $P = V^2/R \Rightarrow R = V^2/P$, [V = voltage rating of appliance, P = power rating of appliance]

If the heaters are connected in series,

$$R_1 = \frac{V^2}{P_1}, \quad R_2 = \frac{V^2}{P_2}, \quad R_{eq} = V^2\left(\frac{1}{P_1} + \frac{1}{P_2}\right)$$

As they are connected to a source of voltage V,

$$I = \frac{V}{R_{eq}} = \frac{1}{V\left(\frac{1}{P_1}+\frac{1}{P_2}\right)} = \frac{P_1P_2}{V(P_1+P_2)}$$

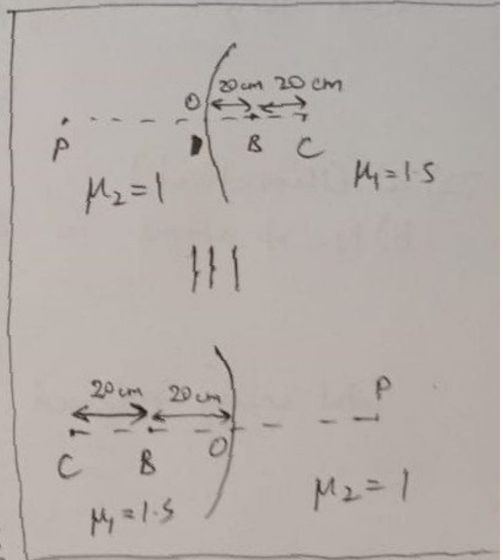
$$\text{Total power consumed} = I^2R_1 + I^2R_2 = I^2R_{eq} = \frac{P_1^{\cancel{2}}P_2^{\cancel{2}}}{\cancel{V^2}(P_1+P_2)^{\cancel{2}}}\cancel{V^2}\left(\frac{\cancel{P_1+P_2}}{\cancel{P_1P_2}}\right)$$

$$= \boxed{\frac{P_1P_2}{P_1+P_2}}$$

If they are ~~conne~~ connected in parallel, each heater is connected to a source at exactly the rated voltage (V).

Total power consumed = sum of rated powers = $\boxed{P_1 + P_2}$ which is not the same as the power consumed in series.

21) a) Here, B is the object. The figure has been redrawn below for convenience.



$R = -40$ cm, $u = -20$ cm, $\mu_1 = 1.5$, $\mu_2 = 1$, $v = ?$

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

$$\frac{1}{v} - \frac{1.5}{(-20)} = \frac{1-1.5}{(-40)} \Rightarrow \frac{1}{v} + \frac{1.5}{20} = \frac{0.5}{40}$$

$$\frac{1}{v} = \frac{0.5}{40} - \frac{1.5}{20} = \frac{1}{80} - \frac{3}{40} = \frac{1-6}{80} = \frac{-5}{\underset{16}{\cancel{80}}} = -\frac{1}{16}$$

$v = -16$ cm, i.e., 16 cm to the right of the point O in the first figure (i.e., inside the glass sphere).

In the original figure, the image of the bubble is formed 4 cm to the left of the point B in the original figure. It is virtual and erect.

(OR)

b) ~~Length of~~ Distance b/w objective and eyepiece lens $= f_o + f_e = 1$ m

Magnifying power $= \frac{f_o}{f_e} = 19$

(f_o = objective focal length, f_e = eyepiece focal length)

$f_o + f_e = 100$ cm and $f_o = 19 f_e$

$19 f_e + f_e = 100$ cm $\Rightarrow 20 f_e = 100$ cm $\Rightarrow f_e = 5$ cm

$f_o = 19 f_e = 95$ cm

$\therefore$ Focal length of objective $= \boxed{95 \text{ cm}}$

Focal length of eyepiece $= \boxed{5 \text{ cm}}$

Section C

22) a) [Theoretical]

b) No. of atoms in 1g of Pu-239 $= \frac{1 g}{239 g/mol} \times 6.022 \times 10^{23}$ atoms/mol

Total energy released in fission $= \frac{6.022 \times 10^{23}}{239} \times 180$ MeV

$= 4.535 \times 10^{29}$ eV

$= 4.535 \times 10^{29} \times 1.6 \times 10^{-19}$ J

$= 7.257 \times 10^{10}$ J

$= \boxed{72.57 \text{ GJ}}$

23) $\vec{E} = (10x+4)\hat{i}$, $V = -\int \vec{E}\cdot\vec{dr} = -\int (E_x\,dx + E_y\,dy + E_z\,dz)$

$= -\int E_x\,dx$ as $E_y = E_z = 0$

$V = V(x) = -\int (10x+4)\,dx = -5x^2 - 4x + C$ J/C

i) Work done $= V(10\,m, 0) - V(5\,m, 0) = (-5(10)^2 - 4(10) + C) - (-5(5)^2 - 4(5) + C)$

$= (-500 - 40 + \cancel{C}) - (-125 - 20 + \cancel{C})$

$= 145 - 540 = \boxed{-395\ J}$

ii) Work done $= V(5m, 10m) - V(5m, 0) = (-5(5)^2 - 4(5) + C) - (-5(5)^2 - 4(5) + C)$

$= \boxed{0}$

24) [Theoretical]

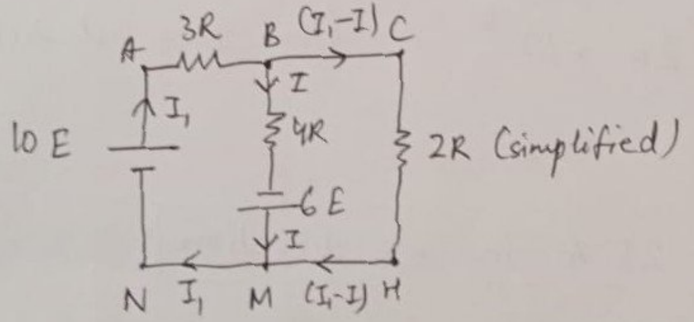
25) Simplify the mesh CDEFGHC in the given circuit.

$R_{DG} = \dfrac{4R\,(R+2R+R)}{4R+(R+2R+R)} = \dfrac{4R \times 4R}{8R} = 2R$

~~$R_{CG} = R_{CD} + R_{DG} = 2R + 2R = 4R$~~

$R_{CH} = \dfrac{4R\,(2R+R_{DG})}{4R+(2R+R_{DG})} = \dfrac{4R \times 4R}{8R} = 2R$

The simplified circuit is:



Loop ABMNA : $I_1(3R) + I(4R) - 6E - 10E = 0$

Loop BCHMB : $(I_1 - I)(2R) + 6E - I(4R) = 0$

$\therefore \quad 3RI_1 + 4RI = 16E \quad \text{...(i)}$

$\quad -2RI_1 + 6RI = 6E \quad \text{...(ii)}$

(i)×2 : $6RI_1 + 8RI = 32E \quad \text{...(iii)}$

(ii)×3 : $-6RI_1 + 18RI = 18E \quad \text{...(iv)}$

(iii)+(iv) : $26RI = 50E \Rightarrow I = \frac{\cancel{50}^{25}}{\cancel{26}_{13}} \frac{E}{R} = \boxed{\frac{25}{13}\frac{E}{R}}$ = current through branch BM.

26) At point O, $\vec{B}(\text{loop}) = \frac{\mu_0 I}{2R}(-\hat{k}) = \frac{\cancel{4}^{2}\pi \times 10^{-7} \times 1}{2 \times 0.1}(-\hat{k})\,T$

$= 2\pi \times 10^{-6}\,(-\hat{k})\,T$

For zero net field at O, $\vec{B}$ (wire) must be in the $\hat{k}$ direction. By right hand thumb rule, current must flow in the ~~direction~~ $+x$ direction (i.e., $\vec{dl}$ must be along $\uparrow$).

Let the current in the wire be I'.

$\vec{B}(\text{wire}) = \frac{\mu_0 I'}{2\pi r'}(\hat{k})$, where $r' = 20$ cm $= 0.2$ m

$$\frac{\cancel{4}^{2}\pi \times \cancel{10^{-7}}^{10^{-6}} \times I'}{\cancel{2}\pi \times \cancel{0.2}_{0.1}} = 2\pi \times \cancel{10^{-6}}$$ (for zero net field)

$I' = 2\pi$ A $\approx \boxed{6.28 \text{ A in } +x \text{ direction}}$

27),28) [Theoretical]

SECTION D

29) i) (B) 0.01 eV [Theoretical]

ii) $n_i = 2 \times 10^{10}\ cm^{-3}$, $n_h = 8 \times 10^{3}\ cm^{-3}$, $n_e = ?$

$$n_i^2 = n_e n_h \Rightarrow n_e = \frac{n_i^2}{n_h} = \frac{\overset{10^{17}}{\cancel{4 \times 10^{20}}}}{\underset{2}{\cancel{8 \times 10^{3}}}}\ cm^{-3} = 0.5 \times 10^{17}\ cm^{-3}$$
$$= 5 \times 10^{16}\ cm^{-3}$$

$$1\ cm^{-3} = \frac{1}{(10^{-2}\ m)^3} = \frac{1}{(10^{-6})}\ m^{-3} = 10^{6}\ m^{-3}$$

$$n_e = 5 \times 10^{16}\ cm^{-3} = 5 \times 10^{16} \times 10^{6}\ m^{-3} = \boxed{5 \times 10^{22}\ m^{-3}}$$

(D)

iii) a) (C) [Theoretical]

OR

b) (A) [Theoretical]

iv) $V = 0.5 \sin(100\pi t) = V_0 \sin(2\pi \nu t)$

$V_0 = 0.5\ V$, $2\pi\nu = 100\pi \Rightarrow \nu = 50\ Hz$

For half wave rectifier, freqnency remains the same but for full wave, freqnency doubles (refer to the input and output waveforms in NCERT).

$\therefore \boxed{\nu_{\text{half wave}} = \nu = 50\ Hz, \quad \nu_{\text{full wave}} = 2\nu = 100\ Hz}$

(D)

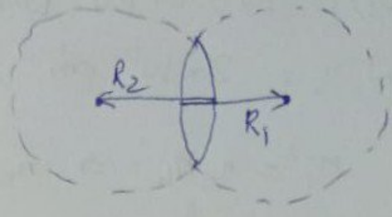
30) i) $f_1 = +20\ cm$, $f_2 = -15\ cm$

$f_1 = +0.2\ m$, $f_2 = -0.15\ m$

$$P_1 = +\frac{1}{0.2}\ D = +5\ D, \quad P_2 = -\frac{1}{0.15}\ D = -\frac{\overset{20}{\cancel{100}}}{\underset{3}{\cancel{15}}}\ D = -\frac{20}{3}\ D$$

$P_{net} = P_1 + P_2 = 5 - \frac{20}{3}\ D = \frac{15-20}{3}\ D = \boxed{\frac{-5}{3}\ D}$ (B)

ii) $R_1 = +R$, $R_2 = -2R$, $f = \frac{4}{3}R$



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

$$\frac{3}{4R} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{(-2R)}\right) = (\mu - 1)\left(\frac{1}{R} + \frac{1}{2R}\right) = (\mu - 1)\cdot\frac{3}{2R}$$

$$\frac{\cancel{3}}{\cancel{4R}_{\,2}} = (\mu - 1)\frac{\cancel{3}}{2\cancel{R}} \Rightarrow \mu - 1 = 0.5 \Rightarrow \boxed{\mu = 1.5 = \frac{3}{2}}$$

(C)

iii) (A) [theoretical]

iv) a) For lens, $u = -\infty$, $f = +10$ cm

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{10} = \frac{1}{v} - \frac{1}{(-\infty)} = \frac{1}{v} \Rightarrow v = +10 \text{ cm}$$

from L
[on the right]

For mirror, $|u| = 40 - 10$ cm $= 30$ cm
and $u = -30$ cm (Why ?)

$f = -15$ cm (Why -ve ?)

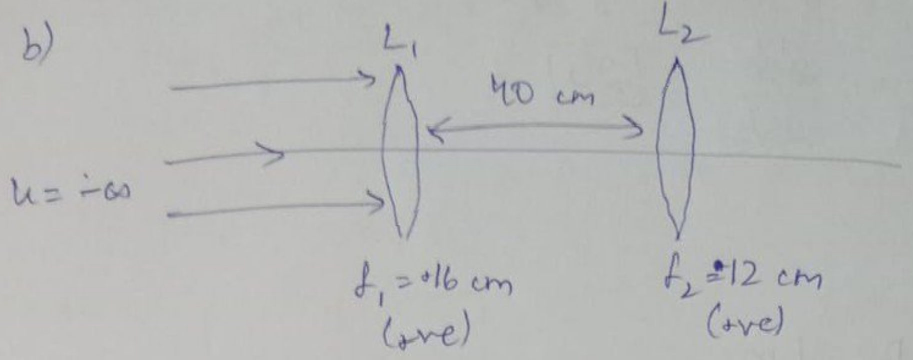
$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow -\frac{1}{15} = \frac{1}{v} - \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{15} = -\frac{1}{30}$$

$v = u = -30$ cm (same position as the object for the mirror)

Final image is formed 30 cm to the left of the mirror, which is $(40 - 30)$ cm $=$ 10 cm to the right of the lens. (B)

OR

b)



For lens L_1 : $u = -\infty$, $f = +16$ cm

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{16} = \frac{1}{v} - \frac{1}{(-\infty)} = \frac{1}{v} \Rightarrow v = +16$ cm (to the right of L_1)

For lens L_2 : $|u| = (40 - 16)$ cm $= 24$ cm , $u = -24$ cm (Why?)

$f = +12$ cm

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{12} = \frac{1}{v} - \frac{1}{(-24)} = \frac{1}{v} + \frac{1}{24} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{24}$

$= \frac{1}{24}$

$\underline{v = +24 \text{ cm}}$ (to the right of L_2)

Since the image is formed on the right side of the lens, it will be real. (A)

SECTION E

31) a) i), ii) [theoretical]

iii) For a compound microscope, $m = m_o m_e = 200$ (given)

$f_e = 2$ cm, final image at infinity

$\therefore m_e = \frac{D}{f_e}$ where $D = 25$ cm

$m_e = \frac{25}{2}$.

$m_o m_e = 250 \Rightarrow m_o$ (magnification by objective) $= \frac{250}{m_e}$

$$= \frac{\cancel{250}^{10}}{\cancel{25}/2} = \boxed{20}$$

OR

b) i), ii) [theoretical]

iii) $d = 3\,mm$, $D = 1\,m$

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

Fourth bright fringe is formed at a distance

$y_1 = 4\beta = \frac{4\lambda D}{d}$ from the central fringe

Second <u>dark</u> fringe is formed at a distance

$y_2 = 2\beta - \frac{\beta}{2} = \frac{3\lambda D}{2d}$ from the central fringe

(note : the first dark fringe is formed at $y = \beta/2$)

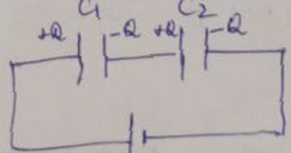
Now, $y_1 - y_2 = 5\,mm \Rightarrow \left(4 - \frac{3}{2}\right)\frac{\lambda D}{d} = 5 \times 10^{-3}\,m$

$$\frac{5}{2} \times \frac{1\,\cancel{m}}{3 \times 10^{-3}\,\cancel{m}} \times \lambda = 5 \times 10^{-3}\,m$$

$$\lambda = 6 \times 10^{-6}\,m = \boxed{6000\,nm}$$

32) a) i) [theoretical]

ii) Case 1:



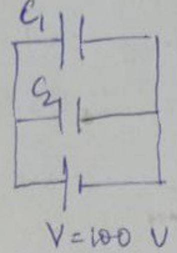
$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$, $Q = C_{eq} V$

$$E = E_1 + E_2 = \frac{Q^2}{2C_1} + \frac{Q^2}{2C_2} = \frac{Q^2}{2}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) = \frac{Q^2}{2C_{eq}} \quad \left[\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}\right]$$

$$= \frac{C_{eq}^{\cancel{2}} V^2}{2\cancel{C_{eq}}} = \frac{1}{2} C_{eq} V^2 = \frac{\overset{50}{\cancel{100}} \times 100}{\cancel{2}} \cdot \frac{C_1 C_2}{C_1 + C_2} = 40 \times 10^{-3} \text{ (Given)}$$

$$\frac{C_1 C_2}{C_1 + C_2} = \frac{40 \times 10^{-3}}{5000} = 0.8 \times 10^{-5} = 8 \times 10^{-6} \quad \text{... (i)}$$

Case 2:



$$E = E_1 + E_2 = \frac{1}{2} C_1 V^2 + \frac{1}{2} C_2 V^2$$

$$= \frac{\overset{50}{\cancel{100}} \times 100}{\cancel{2}} \times (C_1 + C_2) = 250 \times 10^{-3} \text{ (Given)}$$

$$(C_1 + C_2) = \frac{\overset{50}{\cancel{250}} \times 10^{-3}}{\underset{1000}{\cancel{5000}}} = 50 \times 10^{-6} \quad \text{... (ii)}$$

Putting (ii), in (i), $C_1 C_2 = 8 \times 10^{-6} \times 50 \times 10^{-6}$

$$= 400 \times 10^{-12} \quad \text{... (iii)}$$

$$(C_1 + C_2)^2 - (C_1 - C_2)^2 = 4C_1C_2 \Rightarrow (C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2$$

$$= 2500 \times 10^{-12} - 1600 \times 10^{-12}$$

$$= 900 \times 10^{-12}$$

$C_1 - C_2 = 30 \times 10^{-6}$ (assuming $C_1 > C_2$)

... (iv)

(ii) + (iv) : $2C_1 = 80 \times 10^{-6} \Rightarrow C_1 = 40 \times 10^{-6}$

(ii) - (iv) : $2C_2 = 20 \times 10^{-6} \Rightarrow C_2 = 10 \times 10^{-6}$

∴ The capacitances are $\boxed{40\ \mu F}$ and $\boxed{10\ \mu F}$.

OR

b) i) [Theoretical]

ii) $\vec{E} = (5x^2 + 2)\hat{i}$, which is normal to the side faces of the cube only. Since it is parallel to the other four faces, the flux through them is zero.

Now for the side faces, since $\vec{E}$ does not depend on y or z, it will be constant over each of the side faces.

The first side face is at $x = 0$ where $\vec{E} = (5 \times 0^2 + 2)\hat{i}$ N/C
$= 2\hat{i}$ N/C

The second side face is at $x = 10$ cm $= 0.1$ m
where $\vec{E} = (5 \times (0.1)^2 + 2)\hat{i}$ N/C $= 2.05\hat{i}$ N/C

Area of the side faces (A) $= (0.1)^2\ m^2 = 0.01\ m^2$

Inward flux through left side face $= 2 \times 0.01 = 2 \times 10^{-2}\ \frac{Nm^2}{C}$

Outward flux through right side face $= 2.05 \times 0.01$
$= 2.05 \times 10^{-2}\ \frac{Nm^2}{C}$

Net outward flux $= (2.05 - 2) \times 10^{-2}\ \frac{Nm^2}{C} = 0.05 \times 10^{-2}\ \frac{Nm^2}{C}$
$= \boxed{5 \times 10^{-4}\ \frac{Nm^2}{C}}$ ~~or 5×10^{-4} V~~

By Gauss' law, net outward flux $= \frac{q_{enclosed}}{\varepsilon_0}$

$5 \times 10^{-4}\ \frac{Nm^2}{C} = \frac{q_{enclosed}}{\varepsilon_0} \Rightarrow q_{enclosed} = 5 \times 10^{-4} \times 8.85 \times 10^{-12}$
$= 44.25 \times 10^{-16}$ C
$= \boxed{4.425 \times 10^{-15}\ C}$

33) [all parts are theoretical]