Electric Charges and Fields

EXERCISE

ELEMENTRY

Q.1 (1)

$Q = ne = 10^{14} \times 1.6 \times 10^{-19} \Rightarrow Q = 1.6 \times 10^{-5}\ C = 16\ \mu C$

Electrons are removed, so chare will be positive.

Q.2 (3)

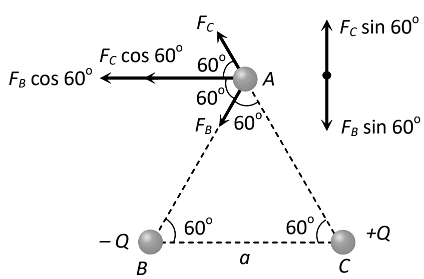
The force will still remain $\dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$.

Q.3 (3)

We put a unit positive charge at O. Resultant force due to the charge placed at A and C is zero and resultant force due to B and D is towards D along the diagonal BD.

Q.4 (3)

$$|\overrightarrow{F_B}| = |\overrightarrow{F_C}| = k.\frac{Q^2}{a^2}$$

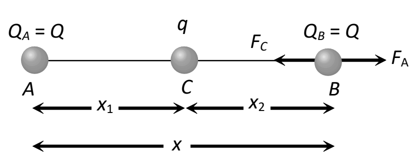


Hence force experienced by the charge at A in the direction normal to BC is zero.

Q.5 (2)

Suppose in the following figure, equilibrium of charge B is considered. Hence for it's equilibrium $|F_A| = |F_C|$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{4x^2} = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{x^2} \Rightarrow q = \frac{-Q}{4}$$



Short Trick : For such type of problem the magnitude of middle charge can be determined if either of the extreme charge is in equilibrium by using the following formula.

If charge A is in equilibrium then $q = -Q_B\left(\dfrac{x_1}{x}\right)^2$

If charge B is in equilibrium then $q = -Q_A\left(\dfrac{x_2}{x}\right)^2$

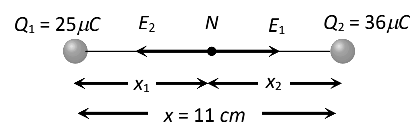
If the whole system is in equilibrium then use either of the above formula.

Q.6 (2)

According to the question, $eE = mg \Rightarrow E = \dfrac{mg}{e}$

Q.7 (1)

Suppose electric field is zero at point N in the figure then



At N $|E_1| = |E_2|$

which gives $x_1 = \dfrac{x}{\sqrt{\dfrac{Q_2}{Q_1}}+1} = \dfrac{11}{\sqrt{\dfrac{36}{25}}+1} = 5\ cm$

Q.8 (2)

For balance $mg = eE \Rightarrow E = \dfrac{mg}{e}$

Also $m = \dfrac{4}{3}\pi r^3 d = \dfrac{4}{3} \times \dfrac{22}{7} \times (10^{-7})^3 \times 1000\ kg$

$$\Rightarrow E = \frac{\frac{4}{3} \times \frac{22}{7} \times (10^{-7})^3 \times 1000 \times 10}{1.6 \times 10^{-19}} = 260\ N/C$$

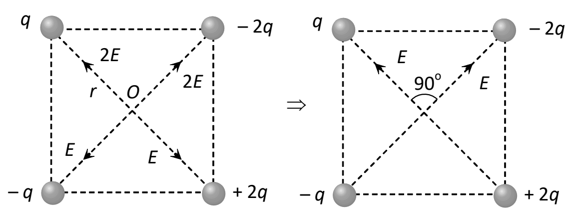
Q.9 (3)

At A and C, electric lines are equally spaced and dense that's why $E_A = E_C > E_B$

Q.10 (1)

Side a = 5×10^{-2} m

Half of the diagonal of the square $r = \frac{a}{\sqrt{2}}$



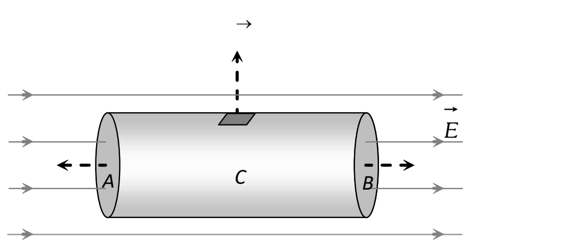
Electric field at centre due to charge q , $E = \frac{kq}{\left(\frac{a}{\sqrt{2}}\right)^2}$

Now field at O = $\sqrt{E^2 + E^2} = E\sqrt{2} = \frac{kq}{\left(\frac{a}{\sqrt{2}}\right)^2} \cdot \sqrt{2}$

$= \frac{9\times10^9 \times 10^{-6} \times \sqrt{2} \times 2}{(5\times10^{-2})^2}$ = 1.02×10^7 N/C (upward)

Q.11 (4)

Flux through surface A, $\phi_A = E \times \pi R^2$ and $\phi_B = -E \times \pi R^2$



Flux through curved surface C = $\int \vec{E}.\vec{ds} = \int E ds \cos 90° = 0$

$\therefore$ Total flux through cylinder = $\phi_A + \phi_B + \phi_C = 0$

Q.12 (3)

Q.13 (2)

Charge enclosed by cylindrical surface (length 100 cm) is Q_{enc} = 100 Q.

By applying Gauss's law $\phi = \frac{1}{\varepsilon_0}(Q_{enc}) = \frac{1}{\varepsilon_0}(100\ Q)$

Q.14 (2)

$\phi = \frac{1}{\varepsilon_0} \times Q_{enc} = \frac{1}{\varepsilon_0}(2q)$

Q.15 (1)

Electric field due to a hollow spherical conductor is governed by following equation E = 0,

for r < R ...(i)

and $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ for $r \geq R$ ....(ii)

i.e. inside the conductor field will be zero and outside the conductor will vary according to $E \propto \frac{1}{r^2}$

Q.16 (3)

Electric field outside of the sphere $E_{out} = \frac{kQ}{r^2}$ ...(i)

Electric field inside the dielectric sphere $E_{in} = \frac{kQx}{R^3}$ ...(ii)

From (i) and (ii),

$E_{in} = E_{out} \times \frac{r^2 x}{R}$

At 3 cm,

$E = 100 \times \frac{3(20)^2}{10^3} = 120\ V/m$

Q.17 (2)

Since potential inside the hollow sphere is same as that on the surface.

Q.18 (3)

ABCDE is an equipotential surface, on equipotential surface no work is done in shifting a charge from one place to another.

Q.19 (2)

Electrostatic energy density $\frac{dU}{dV} = \frac{1}{2}K\varepsilon_0 E^2$

$\therefore \frac{dU}{dV} \propto E^2$

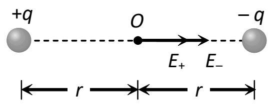
Q.20 (2)

Using $v = \sqrt{\frac{2QV}{m}} \Rightarrow v \propto \sqrt{Q}$

$\Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{Q_A}{Q_B}} = \sqrt{\frac{q}{4q}} = \frac{1}{2}$

Q.21 (3)

At O, E ¹ 0, V = 0



Q.22 (1)

Potential at the centre of square

$$V = 4\times\left(\frac{9\times10^9\times50\times10^{-6}}{2/\sqrt{2}}\right) = 90\sqrt{2}\times10^4\,V$$

Work done in bringing a charge (q = 50 mC) from ∞ to centre (O) of the square is $W = q\,(V_0 - V_\infty) = qV_0$

$$\Rightarrow W = 50\times10^{-6}\times90\sqrt{2}\times10^4 = 64\,J$$

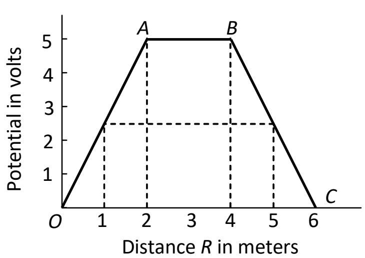
Q.23 (2)

Net electrostatic energy $U = \frac{kQq}{a} + \frac{kq^2}{a} + \frac{kQq}{a\sqrt{2}} = 0$

$$\Rightarrow \frac{kq}{a}\left(Q + q + \frac{Q}{\sqrt{2}}\right) = 0 \qquad \Rightarrow Q = -\frac{2q}{2+\sqrt{2}}$$

Q.24 (1)

Intensity at 5m is same as at any point between B and C because the slope of BC is same throughout (i.e., electric field between B and C is uniform). Therefore electric field at R = 5m is equal to the slope of line BC hence by $E = \frac{-dV}{dr}$;



$$E = -\frac{(0-5)}{6-4} = 2.5\frac{V}{m}$$

Q.25 (1)

The electric potential $V(x, y, z) = 4x^2$ volt

Now $\vec{E} = -\left(\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right)$

Now $\frac{\partial V}{\partial x} = 8x$, $\frac{\partial V}{\partial y} = 0$ and $\frac{\partial V}{\partial z} = 0$

Hence $\vec{E} = -8x\hat{i}$, so at point (1m, 0, 2m)

$\vec{E} = -8\hat{i}$ volt / metre or 8 along negative X-axis.

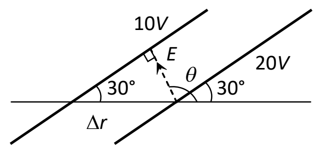
Q.26 (1)

In non-uniform electric field. Intensity is more, where the lines are more denser.

Q.27 (1)

$$F = QE = \frac{QV}{d} \Rightarrow 5000 = \frac{5\times V}{10^{-2}} \Rightarrow V = 10\text{ volt}$$

Q.28 (3)



Using $dV = -\vec{E}.\vec{dr}$

$\Rightarrow \Delta V = -E.\Delta r\cos\theta$

$\Rightarrow E = \frac{-\Delta V}{\Delta r\cos\theta}$

$\Rightarrow$

$$E = \frac{-(20-10)}{10\times10^{-2}\cos120°} = \frac{-10}{10\times10^{-2}(-\sin30°)} = \frac{-10^2}{-1/2} = 200$$

V/m

Direction of E be perpendicular to the equipotential surface i.e. at 120° with x-axis.

Q.29 (3)

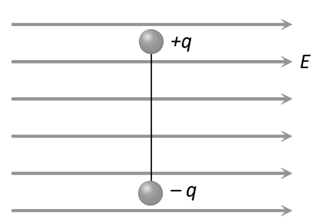
Q.30 (3)

Potential energy = – pE cosθ

When θ = 0. Potential energy = – pE (minimum)

Q.31 (4)

$$\text{Work done} = \int_{90}^{270} pE\sin\theta\,d\theta = \left[-pE\cos\theta\right]_{90}^{270} = 0$$



Q.32 (2)

Q.33 (4)
Potential due to dipole in general position is given by

$$V=\frac{k.p\cos\theta}{r^2}\Rightarrow V=\frac{k.p\cos\theta r}{r^3}=\frac{k\cdot(\vec{p}\cdot\vec{r})}{r^3}$$

Q.34 (3)
Electric field near the conductor surface is given by

$\frac{\sigma}{\varepsilon_0}$ and it is perpendicular to surface.

JEE-MAIN
OBJECTIVE QUESTIONS

Q.1 (2)

Q.2 (1)

Q.3 (4)

Q.4 (4)

$$F=\frac{Kq_1q_2}{r^2}$$

$$F_1=\frac{Kq_1q_2}{(r/2)^2}=\frac{4.Kq_1q_2}{r^2}=4F$$

Q.5 (3)
Attraction is possible between a charged and a neutral object.

Q.6 There is no point near electric dipole having E = 0.

Q.7 (1)

$$F=\frac{Kq_1q_2}{r^2}=\frac{Kq_1q_2}{\varepsilon r r_1^2}$$

$$\frac{1}{(20cm)^2}=\frac{1}{5r_1^2}$$

$$r_1^2=\frac{20\times20\times10^{-4}}{5}=80\times10^{-4}$$

$$r_1=8.94\times10^{-2}m$$

Q.8 (2)

$$F=\frac{Kq(Q-q)}{r^2}$$

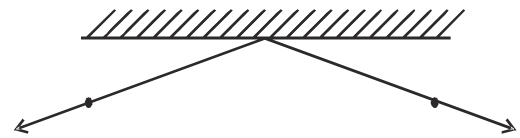
$$\frac{dF}{dq}=\frac{K}{r^2}[q(-1)+(Q-q)1]=0$$

$$-q+Q-q=0$$

$$Q=2q$$

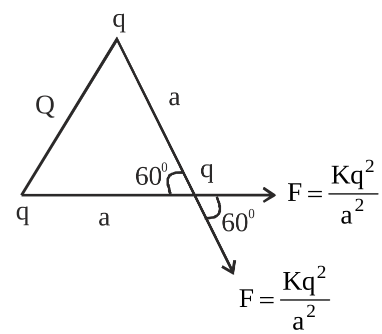
$$\frac{Q}{q}=\frac{2}{1}$$

Q.9 (3)



$$F=\frac{Kq_1q_2}{(2L)^2} \qquad F=\frac{Kq_1q_2}{(2L)^2}$$

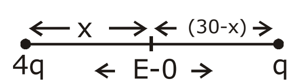
Q.10 (2)



$$F_{net}=\sqrt{F^2+F^2+2F^2\cos60^0}$$

$$=\sqrt{3}F=\sqrt{3}\frac{Kq^2}{a^2}$$

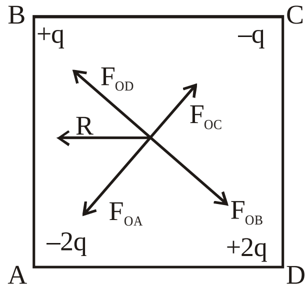
Q.11 (1)



$$\frac{K(4q)}{x^2}=\frac{Kq}{(30-x)^2}$$

x = 20 cm from 4q
10 cm away from q

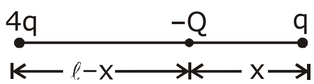
Q.12 (4)
Length of the arrow showes magnitude



Resultant R is $\perp$ to surface AB

Q.13 (1)

Negative charge is placed to achieve equilibrium.



Net force on Q is zero

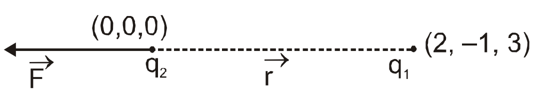
$$\Rightarrow \frac{K4qQ}{(\ell - x)^2} = \frac{kqQ}{x^2}$$

$\Rightarrow$ x = ℓ/3

Net force on q is also zero

$$\Rightarrow \frac{kQq}{(\ell/3)^2} = \frac{k4qq}{\ell^2}; \qquad Q = \frac{4q}{9}$$

Q.14 (4)



$$\vec{F} = \frac{k q_1 q_2}{r^3}(\vec{r}) \text{ ; (By definition)}$$

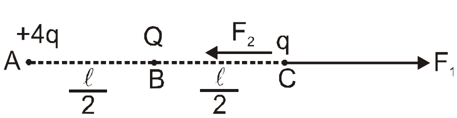
$$\therefore \quad \vec{F} = \frac{1}{4\pi\varepsilon_0}$$

$$\frac{q_1 q_2 [(0-2)\hat{i} + \{0-(-1)\}\hat{j} + (0-3)\hat{k}]}{\left[\sqrt{(0-2)^2 + \{0-(-1)\}^2 + (0-3)^2}\right]^3}$$

$$= \frac{q_1 q_2}{4\pi\varepsilon_0} \cdot \frac{(-2\hat{i} + \hat{j} - 3\hat{k})}{(\sqrt{4+1+9})^3}$$

$$= \frac{q_1 q_2 (-2\hat{i} + \hat{j} - 3\hat{k})}{56\sqrt{14}\pi\varepsilon_0}$$

Q.15 (1)



Charges are placed as shown on line AC.

For net force on q to be zero, Q must be of –ve sign.

If F_1 is force on q due ot 4q & F_2 due to Q

Then, $F_1 = F_2$ (magnitudewise)

$$\text{or} \quad \frac{k4q \cdot q}{\ell^2} = \frac{kQq}{\left(\frac{\ell}{2}\right)^2}$$

$\therefore$ 4q = 4Q

or Q = q (in magnitude)

$\therefore$ Q = –q (with sign)

Q.16 (1)

Final charge on both spheres = $\frac{40-20}{2}$ μC = 10μC

(each) [Distibution by conducting]

$$\therefore \frac{F_i}{F_f} = \frac{(q_1 q_2)_i}{(q_1 q_2)_f} = \frac{800}{100} = 8 : 1$$

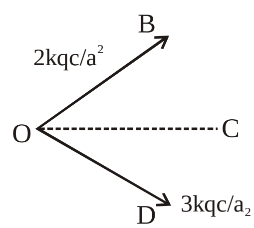
Q.17 (3)

Initially, $F = \frac{k q_1 q_2}{r^2}$ ....(1)

Finally, $4F = \frac{k q_1 q_2}{16R^2}$ ....(2)

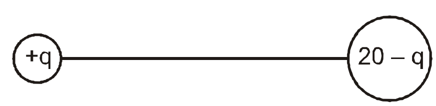
$$\Rightarrow \frac{4kq_1q_2}{r^2} = \frac{4kq_1q_2}{16R^2} \qquad \text{or } R = \frac{r}{8}$$

Q.18 (4)



Resultant lie in between region COD

Q.19 (2)



Let the two charges are q & (20 – q) μC

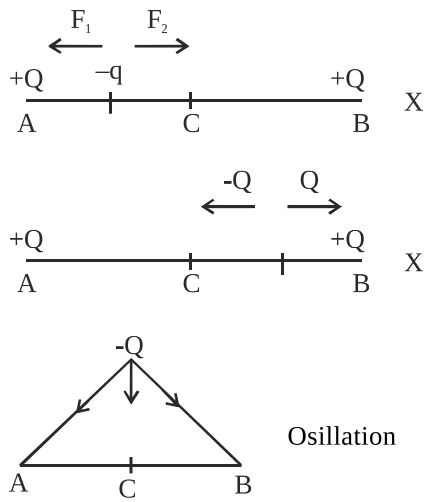
$$\therefore F_e = \frac{K(q)(20-q)}{r^2}$$

F_e will be max, when $\frac{dF_e}{dq} = 0$

or $\frac{dFe}{dq} = \frac{K}{r^2}(20 - 2q) = 0$

$\Rightarrow \therefore q = 10\ \mu C.$

Q.20 (3)

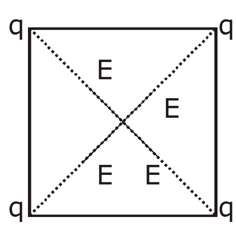


Q.21 (2)

F= qE

$$E = \frac{100}{2} = 50 N/C$$

Q.22 (1)



$E_{Net} = 0$

Q.23 (2)

qE = mg

$$E = \frac{mg}{q} = \frac{9.1\times10^{-31}\times 9.8}{1.6\times10^{-19}}$$

$$= 5.6\times10^{-11} N/C$$

Q.24 (4)

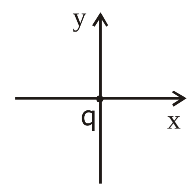
$$|\vec{E}| = \frac{kq}{|\vec{r}|^2}$$

$$\vec{r} = (8-2)\hat{i} + (-5-3)\hat{j}$$

Now $E = \frac{9\times10^9\times50\times10^{-6}}{100} \Rightarrow E = 4500$ v/m

Q.25 (3)

$$\vec{E}_A = \frac{Kq(\hat{i}+2\hat{j}+2\hat{k})}{(\sqrt{14})^3}$$

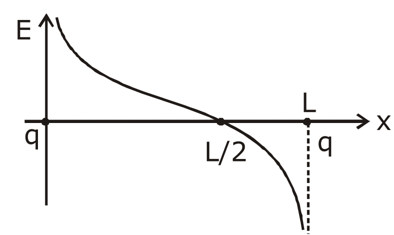


$$\vec{E}_B = \frac{Kq(\hat{i}+\hat{j}-\hat{k})}{(\sqrt{13})^3}$$

$$\vec{E}_c = \frac{Kq(2\hat{i}+2\hat{j}+2\hat{k})}{(\sqrt{12})^3}$$ Now $\vec{E}_A.\vec{E}_B = 0$

$\Rightarrow \vec{E}_A \perp \vec{E}_B$

Q.26 (4)



Q.27 (2)

Force on charge = qE = $qE_0 \sin \omega t$

acceleration = $\frac{q\varepsilon_0}{m} \sin \omega t$

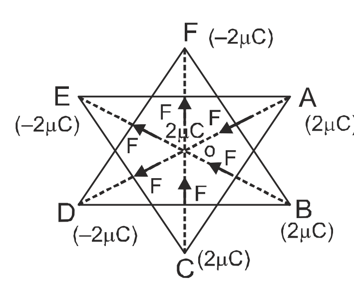
...(1)

In SHM $a = A\omega^2 \sin \omega t$ ...(2)

Comare (1) & (2)

$$A\omega^2 = \frac{q\varepsilon_0}{m} \Rightarrow A = \frac{q\varepsilon_0}{m\omega^2}$$

Q.28 (4)



The given figure shows force diagram for charge at O due to all other charges with r = $\frac{10}{\sqrt{3}}$ cm

$\therefore$ F_{net} = 2F + 4F cos 60º = 4F

$$= \frac{4k(2\mu c)(2\mu c)}{\left(\frac{10}{\sqrt{3}100}\right)^2} = \frac{4\times 9\times 10^9\times 2\times 2\times 10^{-12}}{\left(\frac{1}{300}\right)}$$

= 36 × 4 × 300 × 10^{-3} N = 43.2 N.(Towards E)

Q.29 (2)

$$a = \frac{qE}{m}$$

After time t

$$v = \frac{qE}{m}t$$

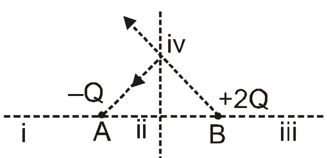
$$KE = \frac{1}{2}mv^2 = \frac{E^2q^2t^2}{2m}$$

Q.30 (4)

W = Fr cos θ ⇒∴ 4 = (0.2) E (2) cos 60º

⇒ ∴ E = 20 N/C.

Q.31 (2)



The electric field due to a point charge ‘q’ at distance ‘r’ from it is given as :

E = $\frac{kq}{r^2}$;more is q, more is r for E to have same magnitude

∴ By this mathematical analogy, electric field cannot be zero in the region iii

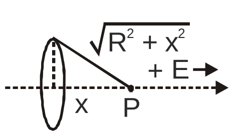
In region ii, electric field due to both charges is added & net electric field is towards left

Along ⊥. bisector line IV electric field due to both charges will be added vectorially & can ‘t be zero

∴ E.F (net) can be zero in region I only (by mathematical analogy explained)

Q.32 (3)

At point P on axis, E = $\frac{kqx}{(R^2+x^2)^{3/2}}$



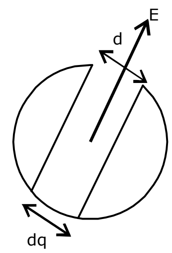
For max E, $\frac{dE}{dx}$ = 0 ⇒ or x = $\frac{R}{\sqrt{2}}$

∴ Putting x in (i)E_{max} = $\frac{2kq}{3\sqrt{3}R^2}$

Q.33 (1)

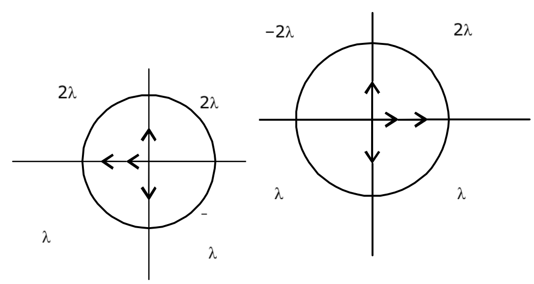
$$E = \frac{Kdq}{R^2}$$

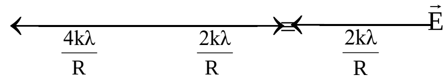
$$dq = \frac{d}{2\pi R}.d$$



$$E = \frac{K\phi}{2\pi R^3}.d \Rightarrow E \times \frac{1}{R^3}$$

Q.34 (1)

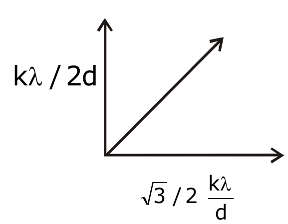




$$\vec{E} = \frac{-2k\lambda\hat{i}}{R}$$

$$= \frac{-\lambda}{2\pi\epsilon_0 R}\hat{i}$$

Q.35 (1)



θ_1 = 0, θ_2 = 60°

$$E_{\perp} = \frac{k\lambda}{d}[\sin 60^\circ + \sin 0^\circ] = \frac{\sqrt{3}}{2}\frac{k\lambda}{d}$$

$$E_{||} = \frac{k\lambda}{d}[\cos 60^\circ - \cos 0^\circ] = \frac{-k\lambda}{2d}$$

$$\tan\theta = \frac{1}{\sqrt{3}} \Rightarrow \theta = 30^\circ$$

Q.36 (1)
a & b can't be both +ve or both – ve otherwise field would have been zero at their mid point.
b can't be positive even, otherwise the field would have been in –ve direction to the right of mid point answer is (1)

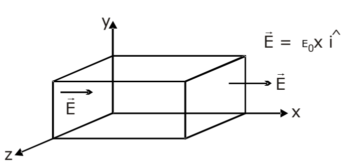
Q.37 (1)
By definition

Q.38 (4)

Q.39 (2)
Density of electric field lines at a point i.e. no. of lines per unit area shows magnitude of electric field at that point.

Q.40 (3)

Q.41 (2)
(2)



Incoming flux $\phi_{in} = E_0\,(0) = 0$
Out going flux $\phi_{out} = E_0\,(a^2)$

$$\Rightarrow \phi_{out} - \phi_{in} = \frac{q}{\varepsilon_0}$$

$q = \varepsilon_0 E_0 a^2$

Q.42 (3)

$$\vec{A} = 100\,\hat{k},\ \vec{E} = \hat{i} + \sqrt{2}\,\hat{j} + \sqrt{3}\,\hat{k}$$

$$\phi = \vec{E} \bullet \vec{A}$$

$$\phi = 100\sqrt{3}$$

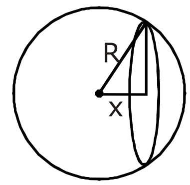
Q.43 (4)
Incoming flux = Outgoing flux

Q.44 (1)

$$\phi = \int \vec{E}\,d\vec{s},\ = \pi R^2 E$$

Q.45 (4)
Radius of the cutting

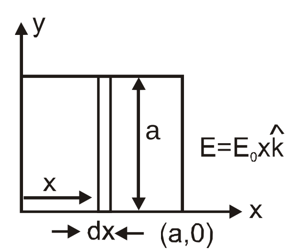
disc = $\sqrt{R^2 - x^2}$



charge on disc
$q = \sigma A$
$q = \sigma\pi\,(R^2 - x^2)$

$$\text{Now } \phi = \frac{q}{\varepsilon_0} = \frac{\sigma\pi(R^2 - x^2)}{\varepsilon_0}$$

Q.46 (2)



flux through differential element $d\phi = E_0\,x\,a\,dx$.
$\therefore$ Net flux

$$\Rightarrow \phi = E_0\,a \int_0^a x.\,dx = \frac{E_0 a^3}{2}$$

Q.47 (1)
If charge is at A or D, its all field lines cut the given surface twice which means that net flux due to this charge remains zero and flux through given surface remains unchanged.

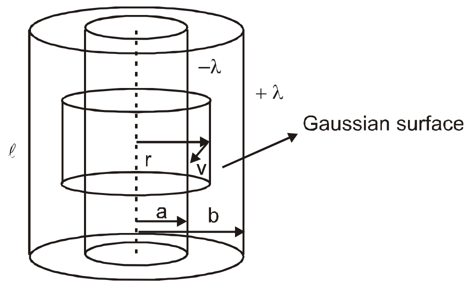
Q.48 (3)

$$\text{Net flux} = \phi_2 - \phi_1 = \frac{q_{in}}{\varepsilon_0}\quad q_{in} = \varepsilon_0\,(\phi_2 - \phi_1)$$

Q.49 (1)

since same no of field lines are passing through both spherical surfaces, so flux has same value for both.

Q.50 (1)



Using Gauss's law for Gaussian surface shown in figure.

$\oint \vec{E}.\vec{dA} = \frac{q_{in}}{\varepsilon_0}$; E. $2\pi r\ell = \frac{\lambda\ell}{\varepsilon_0}$

$\therefore\ E = \frac{\lambda}{2\pi\varepsilon_0 r}$

For circular motion.

$$qE = \frac{mV^2}{r} = \frac{q\lambda}{2\pi\varepsilon_0 r} \quad \therefore\ V = \sqrt{\frac{q\lambda}{2\pi\varepsilon_0 m}}$$

Q.51 (3)

For the closed surface made by disc and hemisphere

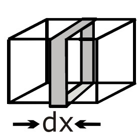
$q_{in} = 0$

$\therefore\ \phi_{net} = 0\ \phi_{disc} + \phi_{H.S} = 0$

$\therefore\ \phi_{HS} = -\phi_{disc} = -\phi$

Q.52 (3)

Flux $\phi = \frac{\Sigma q}{\epsilon_0}$



$\Sigma q = \rho a^2 dx$

$q = a^2 \int \rho dx$

$= a^2$ (area under curve)

$q = a^2 \left(\frac{\rho_0}{8} + \frac{\rho_0}{2} + \frac{\rho_0}{8}\right)$

$q = \frac{3}{4} a^2 \rho_0$

$\phi = \frac{3/4 a^2 \rho_0}{\varepsilon_0} = \frac{3}{4}$

Q.53 (2)

$\phi = \frac{q_{in}}{\varepsilon_o} = \frac{q_2 + q_3}{\varepsilon_o}$

$= -36\pi \times 10^3$

Q.54 (4)

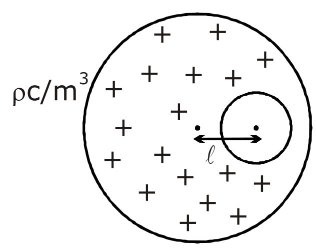
$q_{in} = 0$

$\phi = 0$

Q.55 (1)

From notes electric field in a cavity

$E = \frac{\rho}{3\varepsilon_0}\vec{\ell}$



$F = q\varepsilon = \frac{q\rho\vec{\ell}}{3\varepsilon_0}$

Q.56 (4)

By M.E. conservation between initial & final point :

$U_i + K_i = U_f + K_f$

$\therefore$ Answer is (4)

Q.57 (3)

Q.58 (2)

Q.59 (4)

$V = \frac{K(-2\times10^{-6})}{1/2}$

$\frac{K(-3\times10^{-6})}{1/2} + \frac{K(-6\times10^{-6})}{\sqrt{3}/2}$

$-1.52\times10^5 V$

Q.60 (2)

$\therefore\ \frac{1}{2}mV_A^2 = qV,\ \frac{1}{2}mV_B^2 = 4\ qV \Rightarrow \therefore\ \frac{V_A^2}{V_B^2} = \frac{1}{4}$

$\Rightarrow \frac{V_A}{V_B} = \frac{1}{2}$

Q.61 (4)

Comparison can be shown as :

$V \to 2V \Rightarrow k \to 4k \Rightarrow PE_{max} \to 4PE_{max} \Rightarrow r \to \frac{r}{4}$

Q.62 (1)

$\therefore\ V = Er,\ \therefore\ r = \frac{V}{E} = 6m.$

Q.63 (2)

Apply the formula $V = \frac{kQ}{r}$

Q.64 (1)

$\because\ V_C = \frac{kQ}{r}\ \therefore\ V_C = \frac{9\times10^9\times1.5\times10^{-9}}{(0.5)} = 27$ V.

Q.65 (2)

Q.66 (3)

K.E. = VQ and momentum = $\sqrt{2m(KE)} = \sqrt{2mVQ}$

Q.67 (2)

Potential at 5cm.

$\Rightarrow$ 5cm $= V = \frac{kq}{(10cm)}$

($\because$ point lying inside the sphere)

Pontential at 15 cm $V' \Rightarrow$ 15 cm $V' = \frac{kq}{15cm} = \frac{2}{3}$ V.

Q.68 (1)

$\because\ V = \frac{kq}{r} - \frac{kq}{3r}\ V = \frac{2kq}{3r}$

$\therefore$ Field intensity at distance 3r from centre =

$\frac{kq}{9r^2} = \frac{V}{6r}$

Q.69 (2)

The whole volume of a uniformly charged spherical shell is equipotential.

Q.70 (3)

PE = q $(V_{final} - V_{initial})$

PE = qΔV PE decreases if q is +ve increases if q is –ve.

Q.71 (2)

By conservation of machenical energy

$\frac{1}{2}mv^2 = \frac{kq_1q_2}{r_1} - \frac{kq_1q_2}{r_2}\ \frac{1}{2}(2\times10^{-3})\ v^2$

$= 9 \times 10^9 \times 10^{-6} \times 10^{-3} \left(\frac{1}{1} - \frac{1}{10}\right)$

or $v^2 = 9 \times 10^3 \times \frac{9}{10}$ or v = 90 m/sec

Q.72 (3)

PE may increase may decrease depending on sign of charges.

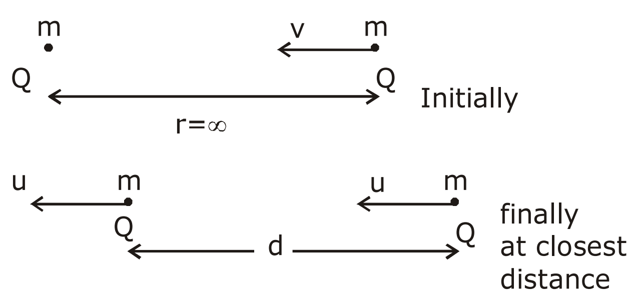
Q.73 (1)

P.E. of system $= \frac{2Kq^2}{a} + \frac{2xkq^2}{a} + \frac{xkq^2}{a} = 0$

where a is distance between charges.

or $2 + 3x = 0$ $\therefore\ x = -\frac{2}{3}$

Q.74 (2)



from E.C.

$\frac{1}{2}mv^2 = 2\left(1/2\,mv^2\right) + \frac{kq^2}{d}$

...(1)

from

M.C. $mv = 2mu \Rightarrow u = v/2$

...(2)

from (1) and (2)

$$\frac{1}{2}mv^2 = \frac{mv^2}{4} + \frac{kq^2}{d}$$

$$d = \frac{4kq^2}{mv^2}$$

Q.75 (2)
U =– QV

Q.76 (4)
Let q is charge and a is radius of single drop.

$$\therefore \quad U_{\text{single drop}} = \frac{3kq^2}{5a}$$

Now, charge on big drop = nq.
& let Radius of big drop is R.

∴ By conservation of volume

$$\Rightarrow \frac{4}{3}\pi R^3 = n.\frac{4}{3}\pi a^3 \Rightarrow R = an^{1/3}.$$

∴ P.E. of big drop

$$= \frac{3}{5}\frac{k(qn)^2}{R} = \frac{3}{5}\frac{k.q^2n^2}{an^{1/3}} = Un^{\frac{5}{3}}$$

Q.77 (2)

$$E = \frac{Kq}{r^2} \; ; V = \frac{Kq(n-1)}{r}$$

$$\frac{V}{E} = r(n-1)$$

Q.78 (4)

q_1 ← d → q_2

Seperation increase then

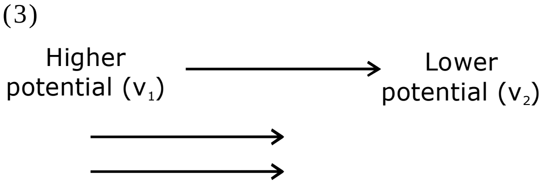
$$U = \frac{Kq_1q_2}{d}\downarrow$$

But

q_1 ← d → $-q_2$

if d ↑ then $U = \frac{-kq_1q_2}{d}\uparrow$

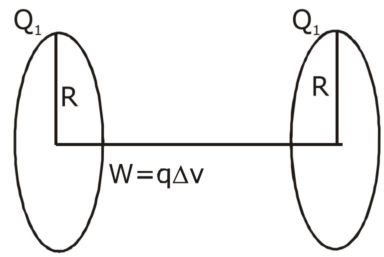
Q.79 (3)



$U_1 = -qV_1$ —qE ←• −q→ $U_2 = -qV_2$

$U_1 < U_2$

Q.80 (2)



$$v_A = \frac{KQ_1}{R} + \frac{KQ_2}{\sqrt{2}R} \qquad v_B = \frac{KQ_2}{R} + \frac{KQ_1}{\sqrt{2}R}$$

$$W = q\left[\frac{kQ_2}{R} + \frac{KQ_1}{\sqrt{2}R} - \frac{kQ_1}{R} - \frac{kQ_2}{\sqrt{2}R}\right]$$

$$W = \frac{q}{R4\pi\varepsilon_0}\left[\left(Q_2 + \frac{Q_1}{\sqrt{2}}\right) - \left(Q_1 + \frac{Q_2}{\sqrt{2}}\right)\right]$$

$$W = q(Q_1 - Q_2)(\sqrt{2} - 1)|(\sqrt{2}\,4\pi\varepsilon_0 R)$$

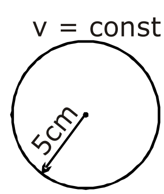
Q.81 (2)

$$\frac{1}{2}mv^2 = eV \therefore v = \sqrt{\frac{2eV}{m}}$$

Q.82 (2)

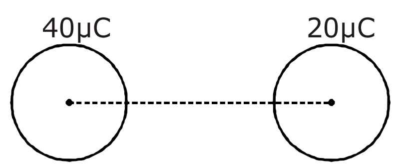
$$\frac{1}{2}mv^2 = eV \therefore v = \sqrt{\frac{2eV}{m}}$$

Q.83 (2)



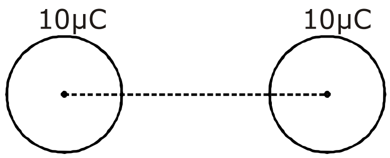
$\frac{kQ}{R} = 10V \Rightarrow v_{in} = 10V$

Q.84 (1)



$F_1 = \frac{k(40)(20)}{d^2}$

After touching the charge on sphere = 10μC



$F_2 = \frac{k(10)(10)}{d^2}$

$F_1 : F_2 = 8 : 1$

Q.85 (1)

Q.86 (4)

$V_C = \frac{kQ}{1} - \frac{kQ}{2} + \frac{kQ}{4} - \frac{kQ}{8} + ...$

$= kQ\left[1 - \frac{1}{2} + \frac{1}{4} - \frac{1}{8}.....\right]$

$= kQ\left[1 + \frac{1}{4} + \frac{1}{16} + ...\right] - kQ\left[\frac{1}{2} + \frac{1}{8} + \frac{1}{32} + ...\right]$

$= kQ\left\{\frac{1}{1-1/4} + \frac{1/2}{1-1/4}\right\}$

$V_C = \frac{Q}{6\pi\varepsilon_0}$

Q.87 (1)

$\Delta V = E.R$

$\Delta V = 1000 \times 1 \times 10^{-2} = 10\text{Volt}$

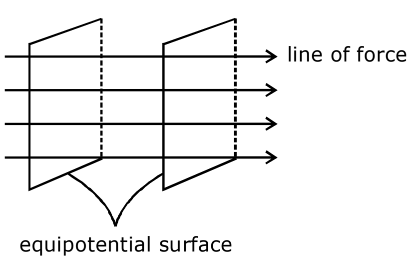
Q.88 (4)

When E = 0

$E = -\frac{dv}{dx}$

V = constant

Q.89 (4)



Angle between both = 90°

Q.90 (3)

Since B and C are at same potential (lying on a line ⊥ to electric field i.e. equipotential surface)

$\therefore \ \Delta V_{AB} = \Delta V_{AC} = Eb.$

Q.91 (4)

Property of equipotential surface.

Q.92 (1)

Q.93 (4)

e.f is perpendicular to equipotential surface

m for e.f = $-\frac{1}{2}$

Now check option Ans - D

Q.94 (3)

Integrate partially one of the term

$v = \int 4a\, xy\sqrt{z}\, dx = \text{const.}$

$4ay\sqrt{z}\,\frac{x^2}{2} = \text{const.}$

$z = \frac{\text{const.}}{x^4 y^2}$

Q.95 (1)

$F = qE$

$\Rightarrow \quad 3000 = 3E$

$\Rightarrow \quad E = 1000$ N/c

$\Delta V = E.\,d = 1000 \times 10^{-2} = 10$ volt

Q.96 (1)

In a given figure

$\vec{E} = E \cos Q\ \hat{i} + E \sin\theta\ \hat{j}$

$d = d\ \hat{i} + d\ \hat{j}$

$v = \vec{E}\cdot\vec{d} = Ed\,(\cos\theta + \sin\theta)$

Q.97 (4)

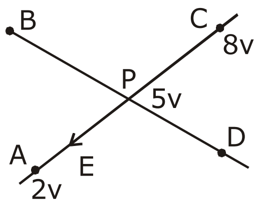
$y = 3 + x \quad \vec{E} = \frac{100}{\sqrt{2}}\left[\hat{i} + \hat{j}\right]$

$dv = -\int \frac{100}{\sqrt{2}}\left[\hat{i} + \hat{j}\right]\cdot[dx\hat{i} + dy\hat{j}]$

$= -\frac{100}{\sqrt{2}}\left[\int_3^1 dx + \int_1^3 dy\right]$

$\Delta v = 0$

Q.98 (2)



$\Delta v = v_A - v_P = 3V$

$$\Rightarrow E = \frac{V}{d} = \frac{3}{\sqrt{(0.1)^2 + (0.1)^2}} = 15\sqrt{2}$$

Q.99 (1)

(i) $E = -\frac{dV}{dr} = -(\text{slope of curve}).$

$\therefore$ At r = 5 cm, slope $= -\frac{5}{2}$ V/cm = – 2.5 V/cm

$\therefore$ $E_{(\text{at sin})} = 2.5$ V/cm

Q.100 (4)

At origin, $E = -\frac{dV}{dr} = -2.5$ V/cm = – 250 V/m

$\therefore$ F = force on 2C = q E = 2 × (– 250) N = – 500 N.

Q.101 (1)

$E = -\frac{dV}{dx} = -10x - 10$

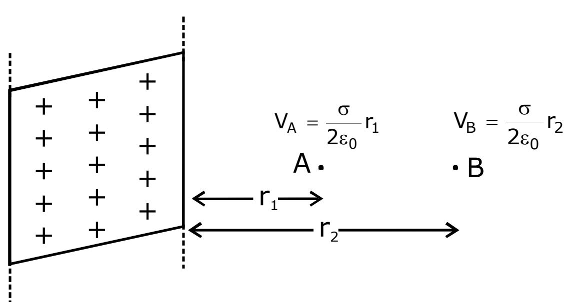
$\therefore$ $E_{(x=1m)}$ – 10 (1) – 10 = – 20 V/m

Q.102 (2)

$\Delta V = -E\Delta x$

$\Rightarrow V_x - 0 = -E_0x.$ or $V_x = -E_0x.$

Q.103 (2)



Given $V_B - V_A = 5$ V

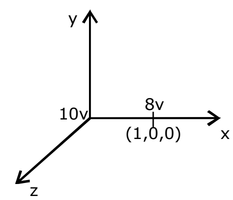
$$\frac{\sigma}{2\varepsilon_0}(r_2 - r_1) = 5V$$

$r_2 - r_1 = 0.88$ mm

Q.104 (2)

$\because E_x = E_y = E_z$

$$E_x = \frac{10-8}{\Delta t} = 2v/m$$



Now $\vec{E} = 2\hat{i} + 2\hat{j} + 2\hat{k}$

$dv = -E.dr = (2\hat{i} + 2\hat{j} + 2\hat{k})(dx\hat{i} + dy\hat{j} + d\hat{k})$

$$v_f - v_i = \left[\int_0^1 2dx + \int_0^1 2dy \int_0^1 2dz\right]$$

$v_f - 10 = -[2 + 2 + 2]$, $v_f = 4v$

Q.105 (2)

$V = k(2x^2 - y^2 + z^2)$

$$E = -\left[\frac{dV}{dx}\hat{i} + \frac{dV}{dy}j + \frac{dV}{dz}\hat{k}\right]K$$

$$E = -\left[4x\hat{i} - 2y\hat{j} + 2z\hat{k}\right]K$$

$$E_{(1,1,1)} = = -\left[4x\hat{i} - 2y\hat{j} + 2z\hat{k}\right]K$$

$|E| = 2k\sqrt{6}$

Q.106 (3)

Q.107 (3)

P = qd

$1 \times 10^{-6} \times 2 \times 10^{-2} = 2\times10^{-8}$

Maximum torque

$\tau = PE = 2 \times 10^{-2}$Nm

Q.108 (2)

$$E_{axis} = \frac{2KP}{r^3}$$

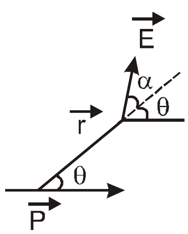
$$E_1 = \frac{KP}{r^3}$$

$$\frac{E_{axis}}{E_1} = \frac{2}{1}$$

Q.109 (1)

Q.110 (3)
Since P & Q are axial & equatorial points, so electric fields are parallel to axis at both points.

Q.111 (3)



In shown diagram, $\vec{E}$ = Net electric field vector due to dipole. (by derivation) & $\tan\alpha = \frac{1}{2}\tan\theta$

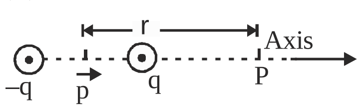
$\therefore$ Angle made by $\vec{E}$ with x-axis is $(\theta + \alpha)$

Q.112 (3)
$\tau_{max} = pE \sin 90^o = 10^{-6} \times 2 \times 10^{-2} \times 1 \times 10^5$ N – m
$= 2 \times 10^{-3}$ N-m

Q.113 (3)
max PE $\Rightarrow$ position of unstable equilibrium $\Rightarrow \theta = \pi$.

Q.114 (4)
$\tau_{max} = PE = 4 \times 10^{-8} \times 2 \times 10^{-4} \times 4 \times 10^8 = 32 \times 10^{-4}$ N-m.
Work done W = $(P.E.)_f - (P.E.)_i$ = PE – (–PE) = 2PE = 64×10^{-4} N-m

Q.115 (3)



At a point 'P' on axis of dipole electric field E = $\frac{2kp}{r^3}$ and electric potential V = $\frac{kp}{r^2}$
both nonzero and electric field along dipole on the axis.

Q.116 (4)
Force on one dipole due to another
$= P\left(\frac{dE}{dr}\right)$ where E is field due to second dipole at first dipole.

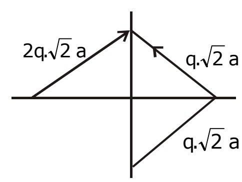
$E \propto \frac{1}{r^3} \quad \therefore \frac{dE}{dr} \propto \frac{1}{r^4}$

$\therefore$ Force $\propto \frac{1}{r^4}$

Q.117 (1)

$$V = \frac{K\vec{p}.\vec{r}}{r^3}$$

Q.118 (1)



x - axis component will cancel out

Q.119 (4)
Since, dipole has net charge zero, so flux through sphere is zero with non-zero electric field at each point of sphere.

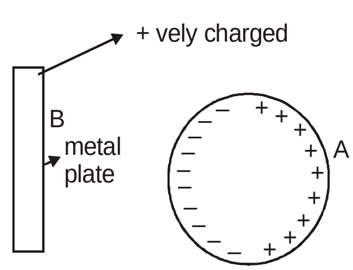
Q.120 (4)

E = Field near sphere $= \frac{V}{R} = \frac{8000}{1\times10^{-2}} = 8 \times 10^5$ V/m

$\therefore$ Energy density $= \frac{1}{2}\varepsilon_0 E^2 = \frac{4\pi\varepsilon_0}{8\pi} E^2$

$$= \frac{8\times8\times10^{10}}{8\pi\times9\times10^9} = \frac{80}{9\pi} = 2.83 \text{ J/m}^3.$$

Q.121 (2)



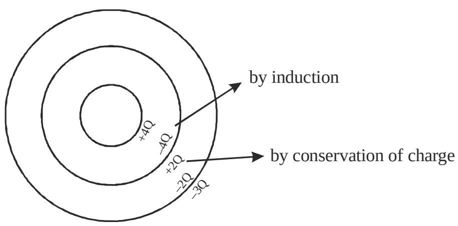
The given diagram shows induction on sphere (metallic) due to metal plate.

Since distance between plate and –ve charge is less than that between plate and +ve charge. electric force acts on object towards plate.

Q.122 (3)

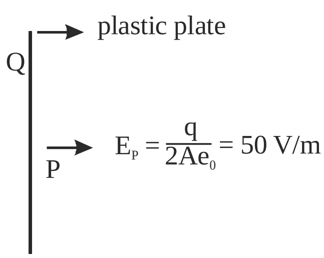
Induction takes place on outer surface of sphere producing non-uniform charge distribution & since external electric field can not enter the sphere, so interior remains charge free.

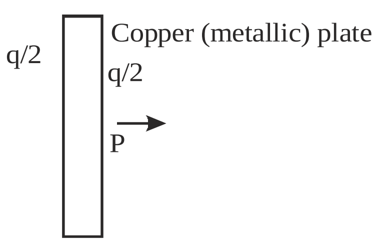
Q.123 (4)



Given diagram shows the charge distribution on shells due to induction & conservation of charge.

Q.124 (3)





$$E_P = \frac{q/2}{2A\varepsilon_0} + \frac{q/2}{2A\varepsilon_0} = \frac{q}{2A\varepsilon_0} = 50V/m$$

Q.125 (3)

Due to outer charge, since there is no charge induced inside the sphere, so no electric field is present inside the sphere.

Q.126 (3)

Since field lines are always perpendicular to conductor surface field lines can' t enter into conductor so only option C is correct.

Q.127 (1)

Car (A conductor) behaves as electric field shield in which a person remains free from shock.

Q.128 (3)

Potential of B = Potintial at the centre of B

= Potential due to induced charges + potential due to A.

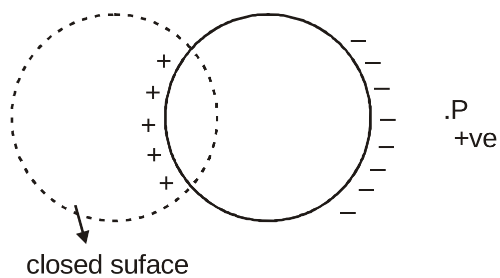
= 0 + (+ ve)

∴ Potential of B is +ve.

Q.129 (1)

Since electric field produced by charge is conservative, so work done in closed path is zero.

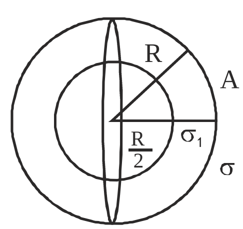
Q.130 (1)



enclosed charge = +ve ⇒ flux through closed suface = +ve.

⇒ Due to induction the charge enclosed in the dotted becomes +ve

Q.131 (1)



Let surface charge density on inner shell is σ_1

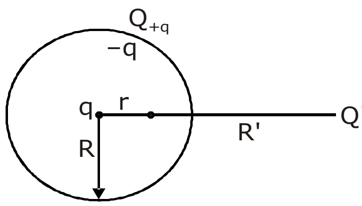
Due to inner sphere, field at A = $\frac{1}{4} \times \frac{\sigma_1}{\varepsilon_0} = \frac{\sigma_1}{4\varepsilon_0}$, and

electrostatic pressure at point A. = $\frac{\sigma^2}{2\varepsilon_0} + \frac{\sigma_1 \sigma}{4\varepsilon_0}$

Net force one hemisphere = $\left(\frac{\sigma^2}{2\varepsilon_0} + \frac{\sigma_1\sigma}{4\varepsilon_0}\right)\pi R^2 = 0$

$\Rightarrow \quad \sigma^2 + \frac{\sigma_1\sigma}{2} = 0$, or $\sigma_1 = -2\sigma$

Q.132 (1)



$E_P = \frac{kq}{r^2}$

Q.133 (1)
(1)

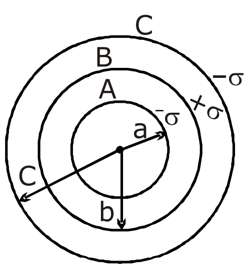
$E = \frac{kq}{r^2}$

Q.134 (1)
In a conductor given charge is distributed uniformly on the surface of sphere

Q.135 (2)
Depends on body either conductor or non-conducting.

Q.136 (3)
Potential of shell A is

$= \frac{kQ_A}{a} + \frac{kQ_B}{b} + \frac{kQ_C}{c}$

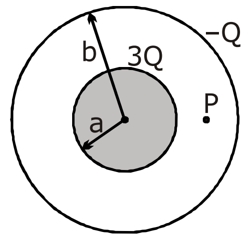


Now $Q_A = -4\pi a^2\sigma$
$Q_B = 4\pi b^2\sigma$
$Q_C = -4\pi c^2\sigma$

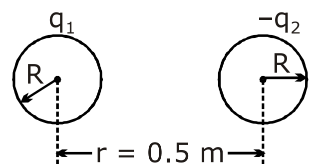
$k = \frac{1}{4\pi\varepsilon_0}$

Q.137 (3)

Electric field at point P = $\frac{k3Q}{r^2}$

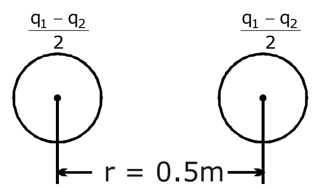


Q.138 (2)



Given $\frac{kq_1q_2}{r^2} = 0.108$ .... (i)

Now after connecting through a wire



Given $\frac{k(q_1 - q_2)^2}{4r^2} = 0.036$ .... (2)

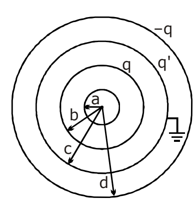
After solving equation (1) & (2) will get the answer.

Q.139 (4)
As we connect A and B through wire with C. Then all the charge on A and B move towards C so
$q_A = 0, q_B = 0$
$q_C = Q + q_1 + q_2$

Q.140 (4)
b = 2a, c = 3a, d = 4a

$\frac{kq}{3a} - \frac{kq}{4a} + \frac{kq'}{3a} = 0$

$q' = -\frac{q}{4}$



Now $v_A = \frac{kq}{2a} - \frac{kq}{4a} + \frac{kq'}{3a} = 0$

$V_A = \frac{kq}{6a}$

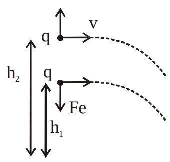
$V_A - V_C = \frac{kq}{6a} - 0 = \frac{kq}{6a}$

JEE-ADVANCED OBJECTIVE QUESTIONS

Q.1 (D)

think x is not small

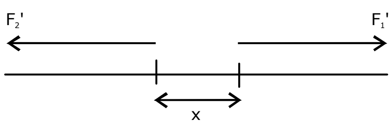
Q.2 (D)



$a_{con.} = g$

Q.3 (B)

If we displaced q lightly then

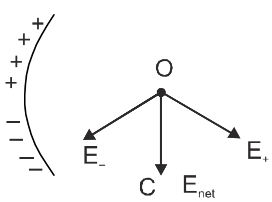


$\because F_2^1 > f_1^1$

$\Rightarrow$ stable equilibrium

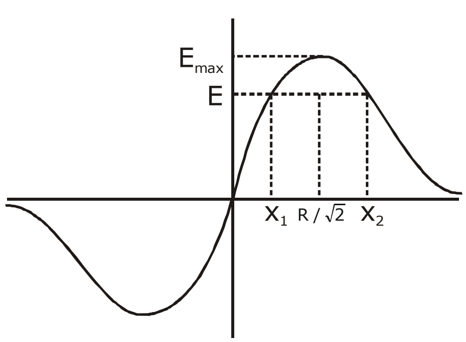
Q.4 (C)

Given diagram shows :



The direction of E_{net} is along OC.

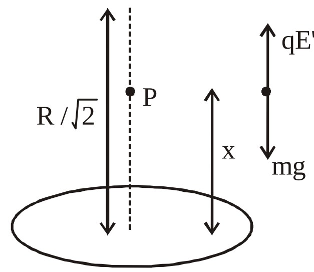
Q.5 (B)



As we displaced upward qE' ↑

qE' > mg So particle move upward

$\Rightarrow$ Unstable equilibrium

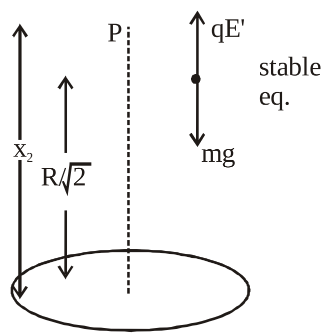


(b) As we displace upward qE' ↓

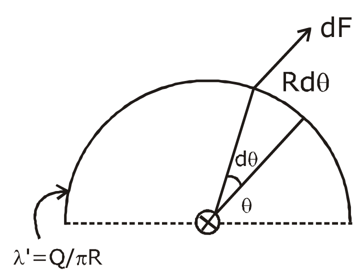
mg > qE' particle comes at point P again

Now we displace down ward from x_2 qE' > mg so particle comes at point P again

$\Rightarrow$ stable equilibrium



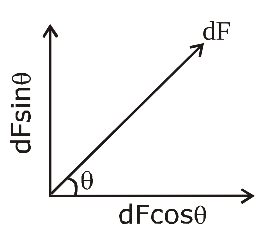
Q.6 (B)



dF = dqE

$dF = \lambda' R d\theta \, \frac{2k\lambda}{R}$

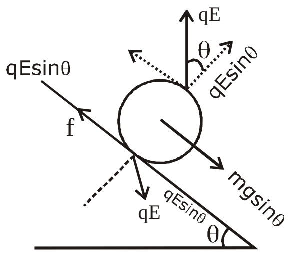
$dF = \frac{2k\lambda}{R} Q \frac{d\theta}{\pi}$



$$F_{net} = \int_0^{\pi} dF \sin\theta = \frac{2k\lambda Q}{\pi R}\int_0^{\pi} \sin\theta d\theta$$

$$F = \frac{\lambda Q}{\pi^2 \varepsilon_0 R}$$

Q.7 (B)



At equilibrium

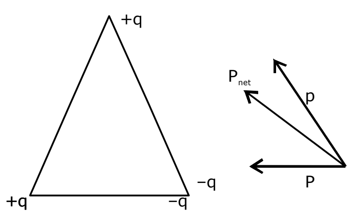
f = mgsinθ

Net τ is also 0

⇒ 2qE sin θ = f.R.

$$E = \frac{mg}{2q}$$

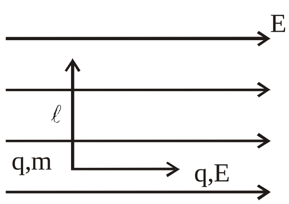
Q.8 (B)

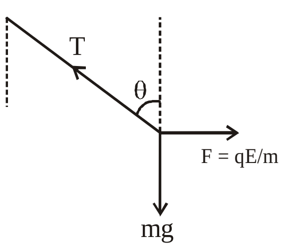


(0, 0, L) is ⊥ to p_{net}

⇒ component along z-direction is zero

Q.9 (D)

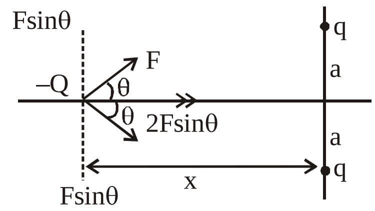




$$g_{eff} = \left[g^2 + \left(\frac{qE}{m}\right)^2\right]^{1/2}$$

$$T = 2\pi\sqrt{\frac{\ell}{g_{eff}}}$$

Q.10 (B)

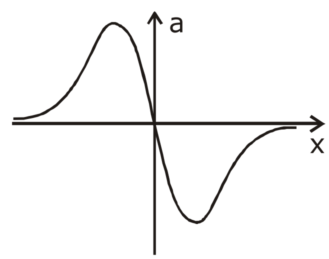


Net force on –Q charge = 2F cos θ

$$a = \frac{2F\cos\theta}{m}$$

$$a = \frac{2kqQx}{m(a^2 + x^2)}$$

for a_{max} $\frac{da}{dx} = 0$

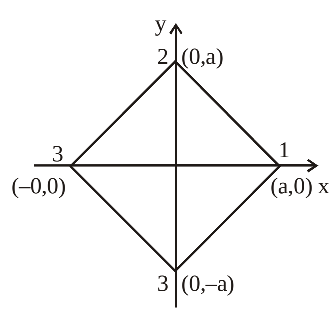


which gives $\pm \frac{a}{\sqrt{2}} = x$

at x → ∞ a = 0

x → 0 a = 0

Q.11 (D)



E.f at (0, 0, z)

$$\vec{E}_1 = \frac{kq(z\hat{k} - a\hat{i})}{(\sqrt{a^2 + z^2})^3}, \quad \vec{E}_2 = \frac{kq(z\hat{k} - a\hat{i})}{(\sqrt{a^2 + z^2})^3}$$

$$\vec{E}_3 = \frac{kq(z\hat{k} + a\hat{i})}{(\sqrt{a^2 + z^2})^3}, \quad \vec{E}_4 = \frac{kq(z\hat{k} + a\hat{i})}{(\sqrt{z^2 + a^2})^3}$$

$$E_{net} = \frac{4kqz\hat{k}}{(\sqrt{z^2 + a^2})^3}$$

$$\text{Magnitude } E = \frac{4kqz}{(\sqrt{z^2 + a^2})^{3/2}}$$

for maxima $\frac{dE}{dz} = 0$

which gives $z = \frac{L}{2}$

Q.12 (C)

$$E = \frac{Kq.x}{(R^2 + x^2)^{3/2}}$$

For x>>R

$$\approx \frac{Kqx}{(x^2)^{3/2}} \approx \frac{Kq}{x^2}$$

Q.13 (B)

– ve charge may move opposite to line of force

Q.14 C

$$\phi = \int \vec{\varepsilon} \,.\, d\vec{s}$$

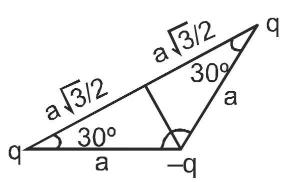
$$= \left(\frac{N}{C}\right) m^2$$

= volt – m

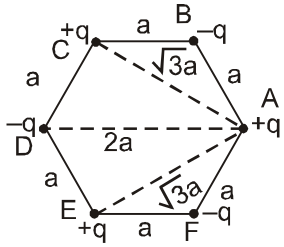
Q.15 (C)

Electric flux due to outside charge will be zero. But elecric field will be due to all the charges.

Q.16 (D)



⇒



(i) E.P.E. of charge +q at point A can be given as :

$$E_A = \frac{-2kq^2}{a} + \frac{-2kq^2}{\sqrt{3}\,a} - \frac{kq^2}{2a} \text{ \& E.P.E. of system}$$

$$\Rightarrow \quad E_S = \frac{E_A + E_B + E_C + E_D + E_E + E_F}{2}$$

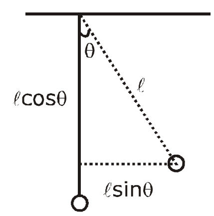
where $E_A = E_B = E_C = E_D = E_E = E_F$

$\therefore \quad E_S = 3\,E_A$

$$\therefore \quad E_S = 6\left(-\frac{kq^2}{a}\right) + 6\left(\frac{kq^2}{a\sqrt{3}}\right) + 3\left(-\frac{kq^2}{2a}\right)$$

$$= \frac{q^2}{\pi \in_0 a}\left[\frac{\sqrt{3}}{2} - \frac{15}{8}\right]$$

Q.17 (B)



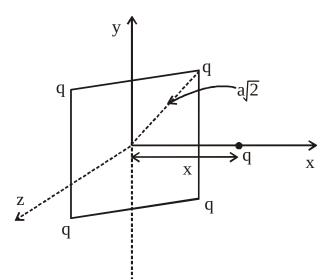
$$(W.D)_E + (W.D.)_{mg} = \Delta K$$

$$(qE\,\ell\sin\theta) + (\ell - \ell\cos\theta)mg = \frac{1}{2}mv^2$$

$$q\left(\frac{mg}{R}\right)\frac{\ell}{\sqrt{2}} + mg\ell\left[1 - \frac{1}{\sqrt{2}}\right] = \frac{1}{2}mv^2$$

$$v = \sqrt{2g\ell}\ , \quad \omega = \frac{v}{R} = \sqrt{\frac{2g}{\ell}}$$

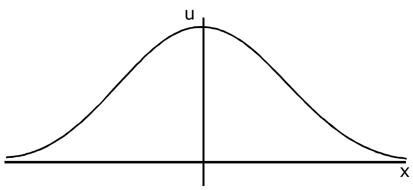
Q.18 (B)



$$U = \frac{Kq^2}{r^2} + \frac{Kq^2}{r^2} + \frac{Kq^2}{r^2} + \frac{Kq^2}{r^2}$$

$$r^2 = x^2 + \frac{a^2}{2}$$

$$U = \frac{4kq^2}{x^2 + a^2/2}$$



Q.19 (B)

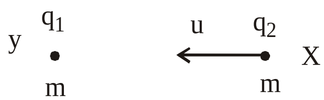
Either y is fixed or not E is conserved but when y is fixed $F_{net} \neq 0$

$\Rightarrow$ P not conserved

when y is free $F_{net} = 0$

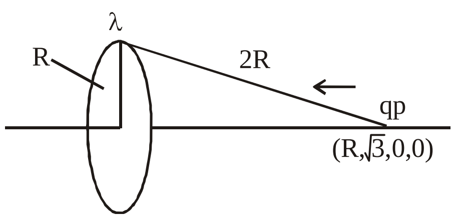
$\Rightarrow$ P = conserved

Q.20 (A)



After long time y will move with velocity u and $v_x = 0$ becouse momentum is conserved

Q.21 (C)



Energy at Point P = $\dfrac{\lambda q}{4\varepsilon_0} + q\left(\dfrac{K\lambda 2\pi R}{2R}\right)$

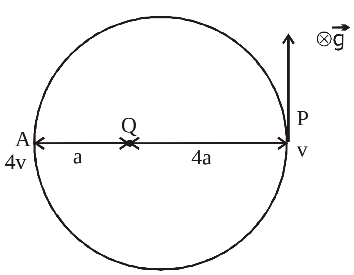
$$= \frac{\lambda q}{4\varepsilon_0} + \frac{q\lambda}{4\varepsilon_0} = \frac{q\lambda}{2\varepsilon_0}$$

Energy at point 0 = $\dfrac{qk\lambda(2\pi R)}{R} = \dfrac{q\lambda}{2\varepsilon_0}$

i.e. particle will reach just point 0.

Q.22 (A)

Energy conservation

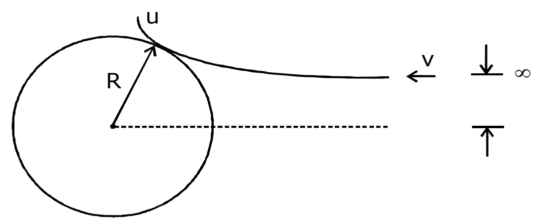


between point P & A

$$\Rightarrow \; qv + \frac{1}{2}mv^2 = 4qv$$

$$\frac{1}{2}mv^2 = 3qV \;\Rightarrow\; v = \sqrt{\frac{6qv}{m}}$$

Q.23 (B)



from AME about point 0

$\Rightarrow$ mvd = mvR

$u = \dfrac{vd}{R}$

...(1)

from E.C. $\dfrac{1}{2}mv^2 = \dfrac{1}{2}mu^2 + \dfrac{kq_1q_2}{R}$

..(2)

from eq. (1) and (2)

$$v = 2\sqrt{\frac{2}{3}} \text{ m/sec.}$$

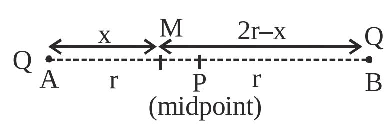
Q.24 (B) from E.C. = $\dfrac{EQq}{r} = \dfrac{EQq}{2r} + \dfrac{1}{2}mv^2$

$$\Rightarrow \; \frac{kQq}{2r} = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{KQq}{mr}}$$

$$\text{Impulse} = mv = \sqrt{\frac{kQqm}{r}}$$

Q.25 (C)



Let the two charges at A & B are separated by distance 2 r.

Let us consider a general point 'M' at distance 'x' from point 'A' in figure.

$$\therefore \; V_m = \text{Potential at M} = \frac{kQ}{x} + \frac{kQ}{(2r-x)}$$

$\therefore \quad V_m = kQ\left[\frac{1}{x}+\frac{1}{(2r-x)}\right] = kQ\left[\frac{(2r)}{x(2r-x)}\right]$

For V_m to be max. or min : $\frac{dV_m}{dx} = 0$

or $\frac{d}{dx}\left[kQ\frac{2r}{x(2r-x)}\right] = 0$

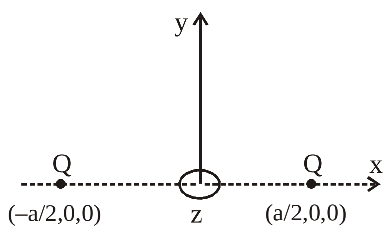
$\therefore \quad \frac{x(2r-x)(0) - kQ(2r)[2r-2x]}{[x(2r-x)]^2} = 0$

$\therefore \quad x = r$

& At $x = r$, $\frac{d^2V_m}{dx^2} > 0 \quad \therefore$ x = r is min.

Hence potential continuously decreases from A to P and then increases

Q.26 (C)



Let –Q charge is placed at (0,y,z)

Now total potential energy of the system

$U = \frac{KQ^2}{a} + \frac{KQ(-Q)}{r} + \frac{KQ(-Q)}{r} = 0$

$r = \sqrt{\frac{a^2}{4} + y^2 + z^2}$

According to problem U = 0

$\frac{KQ^2}{a} = \frac{KQ^2}{\sqrt{\frac{a^2}{4}+y^2+z^2}} + \frac{KQ^2}{\sqrt{\frac{a^2}{4}+y^2+z^2}}$

$\frac{a^2}{4} + y^2 + z^2 = 4a^2$

$y^2 + z^2 = \frac{15a^2}{4}$

Q.27 (B)

Energy conservation between surface and point C

$\Rightarrow q\,(V_c - V_s) = \frac{1}{2}mv^2$

$\Rightarrow q\left(\frac{3kq}{2R} - \frac{kq}{R}\right) = \frac{1}{2}mv^2, \qquad u = \frac{q}{(4\pi\varepsilon_0 mR)^{1/2}}$

Q.28 (B)

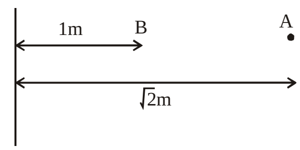
$qV = \frac{1}{2}mv^2 = K.E \Rightarrow V = \sqrt{\frac{2qv}{m}}$

Q.29 (B)

Movement is parallel to x-axis

$\therefore$ w.d. by 2λ is zero.

$(W.D.)_{AB} = \int_{\sqrt{2}}^{1} \vec{E}.dr$



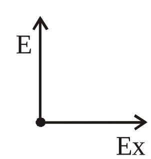
$= \int_{\sqrt{2}}^{1} \frac{2k(3\lambda)}{r}dr = 3 \times 2k\lambda \ln\left(\frac{1}{\sqrt{2}}\right) = 3k\lambda \ln 2$

(W.D.) due to wire λ is $k\lambda \ln(2) = \frac{\lambda \ell_n(2)}{\pi\varepsilon_0}$

Q.30 (C)

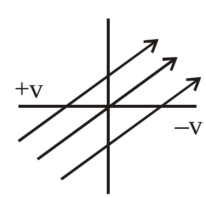
$E = -\frac{dv}{dx}$

Q.31 (B)



in y, $E_y = 0$

$E_x = E_0 = \frac{v}{x_0}$

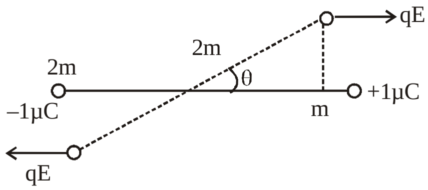


Q.32 (D)

$Ex = \frac{-\partial v}{\partial x}$

check slope

Q.33 (A)



$\tau_{net} = qE\, 2\sin\theta + qE \sin\theta = 3qE \sin\theta$

$\tau_{net} = 3qE\,\theta$

$$W = \sqrt{\frac{K_{shm}}{I}} = \sqrt{\frac{3\times1\times10^{-6}\times20\times10^{-3}}{6}}$$

$$= \sqrt{\frac{1}{100}} = 0.1 \text{ rad /sec}$$

Q.34 (B)

Potential energy $= -\vec{P}_1\cdot\vec{E}$; where, $\vec{E}$ = Electric field due to dipole P_2.

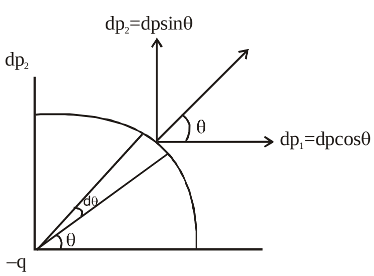
$\therefore \quad U_{12} = -(P_1)(E_2)$

$$U_{12} = -(P_1)\left(\frac{2K\,P_2\cos\theta}{r^3}\right)$$

Q.35 (A)

$$\lambda = \frac{q}{\pi R/2} = \frac{2q}{\pi R}$$

$$dP_1 = \int_0^{\pi/2} dP\cos\theta$$



$$= \int_0^{\pi/2} (\lambda R d\theta)\, R\cos\theta$$

$$= \lambda R^2 \int_0^{\pi/2} \cos\theta\, d\theta = \lambda R^2 \left[\sin\theta\right]_0^{\pi/2}$$

$$= \lambda R^2 .1 = \frac{2q}{\pi R}.R^2 = \frac{2qR}{\pi}$$

$$dP_2 = \int_0^{\pi/2} dP\sin\theta = \frac{2qR}{\pi}$$

$$P = \frac{2\sqrt{2}qR}{\pi}$$

Q.36 (D)

$$F = \left|P\frac{dE}{dr}\right|$$

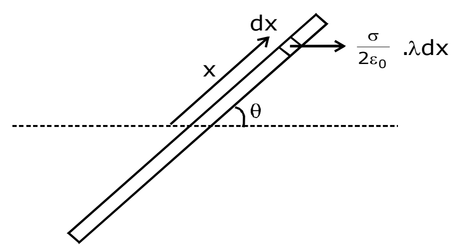
and $\dfrac{dE}{dr} = 0$ at $r = \dfrac{R}{\sqrt{2}}$

$\Rightarrow F = 0$

Q.37 (B)

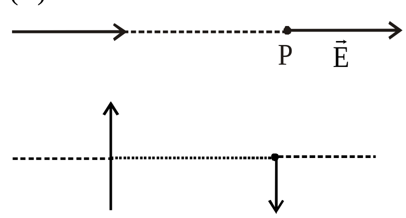
$$d\tau = \frac{2\sigma}{2\varepsilon_0}.\lambda\, x dx$$

$$= \frac{\sigma}{\varepsilon_0}\lambda\sin\theta\int_0^l x.dx$$



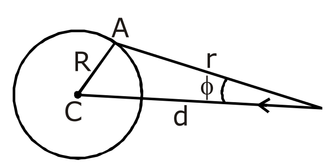
$$= \frac{\sigma\lambda l^2 \sin\theta}{2\varepsilon_0}$$

Q.38 (A)



Q.39 (D)

Q.40 (B)



$d \cos \phi = r$

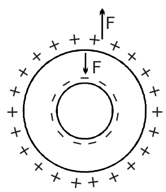
$$v_A = v_C = \frac{kp}{d^2} = \frac{kp \cos^2 \phi}{r^2}$$

Q.41 (A)

Balancing occur only when –ve charge occur in inside conductor.

$$P_{elec.} = \frac{\sigma^2}{2\varepsilon_0}$$

$$F = \frac{\sigma^2}{2\varepsilon_0} A$$



at equilibrium

$$\frac{\sigma^2}{2\varepsilon_0}(4\pi R^2) = \frac{\sigma^2}{2\varepsilon_0}\left(4\pi \frac{R^2}{4}\right)$$

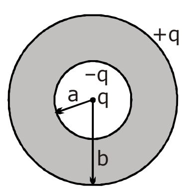
$\sigma' = 2\sigma$ (–ve)

Q.42 (C)

$(W.D.)_{ext} = U_f - U_i$

$U_i = 0$ (at ∞)

Self energy of a conducting sphere = $\frac{kQ^2}{2R}$



$$\Rightarrow U_f = \frac{kq^2}{2b} - \frac{kq^2}{2a} \quad \Rightarrow W.D. = \frac{kq^2}{2b} - \frac{kq^2}{2a}$$

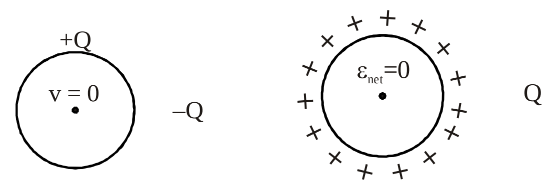
Q.43 (D)

Electric field inside the conductor will be zero. Either external electric field is present or not.

Hence potential at every point must be same.

Charge distribution depends on external field and $\sigma \propto \frac{1}{r}$ (when no electric field)

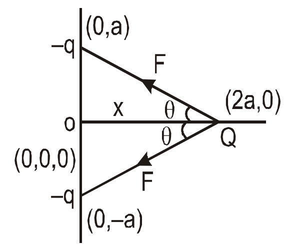
Q.44 (D)



JEE-ADVANCED

MCQ/COMPREHENSION/COLUMN MATCHING

Q.1 (B,D)



(i) From diagram, force on Q at general position x, is given by

$$F_{net} = -2F\cos\theta = -\frac{kQqx}{(a^2 + x^2)^{3/2}} \text{ (Towards origin)}$$

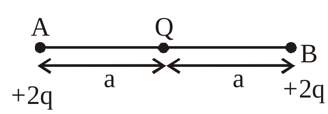
(ii) When charge moves from (2a, 0) to origin O, force keeps on acting on Q and becomes zero at O.

$\therefore$ Velocity of Q is max. at O.

(iii) $\because$ Motion is SHM for very small displacements. & 2a is not very small os motion is periodic but not SHM.

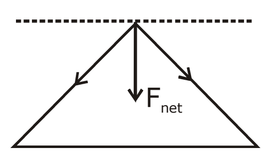
Q.2 (C,D)

If we slightly displaced –Q charge towards B thus force on –Q due to B increses



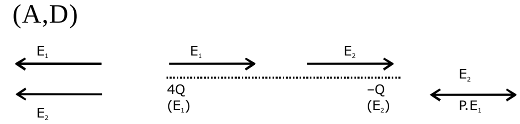
$\Rightarrow$ –Q moves towards BC (unstable equillibrium)

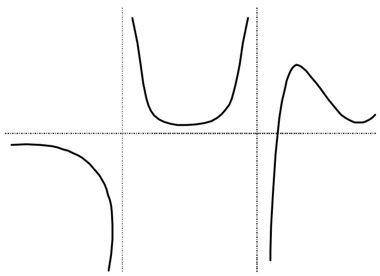
If we displaced to wards y axis



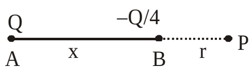
(stable equilibrium)

Q.3 (A,D)





Q.4 (A,B,C)



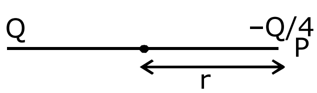
$$V_p = \frac{KQ}{x+r} - \frac{KQ/4}{r} = 0$$

$$\Rightarrow \frac{1}{x+r} - \frac{1}{4r} = 0 \Rightarrow 4r - x - r = 0$$

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

$$v_p = \frac{-KQ/4}{r} + \frac{KQ}{(x-r)} = 0$$

$$\Rightarrow -\frac{1}{4r} + \frac{1}{x-r} = 0 \Rightarrow r = \frac{x}{5}$$

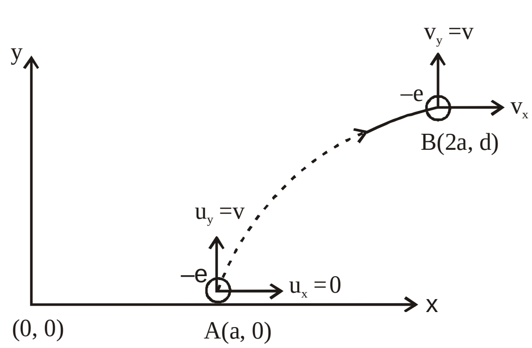


$$Ep = \frac{KQ}{(x+r)^2} - \frac{K(Q/4)}{r^2} = 0$$

$r > 0$

Q.5 (A,B,C,D)

As velocity along y-axis remains unchanged, so there should not be any electric field along y axis.



As velocity along x axis is increasing, so force on the electron must be along +x direction, so electric field must be towards –x direction.

So force on the electron is :

F = qE = eE

acceleration, $a = \frac{eE}{m}$ towards +x direction

From $A \rightarrow B$

$S_y = u_y t$

or $d = vt \Rightarrow \therefore t_{A\rightarrow B} = \frac{d}{V}$

From : $A \rightarrow B$

$$S_x = u_x t + \frac{1}{2} a_x t^2$$

$$\text{or} \quad a = 0 + \frac{1}{2}\left(\frac{eE}{m}\right)\left(\frac{d}{V}\right)^2$$

$$\Rightarrow E = \frac{2amV^2}{ed^2} \text{ toward-x direction ....(1)}$$

(A) Velocity along x axis at B :

From $A \rightarrow B$

$V_x = u_x + a_x t$

$$\text{or} \quad V_x = 0 + \left(\frac{eE}{m}\right)\left(\frac{d}{V}\right)$$

$$\Rightarrow V_x = \frac{eEd}{mV}$$

$$\text{where, } E = \frac{2amv^2}{ed^2} \Rightarrow \therefore V_x = \frac{2aV}{d}$$

(D) Net velocity vector at B

$$\vec{V}_B = V_x\hat{i} + V_y\hat{j}$$

$$\vec{V}_B = \frac{2aV}{d}\hat{i} + V\hat{j}$$

(B) Rate of work done at B = Power = $\vec{F}\cdot\vec{V}_B$

$$= \left(eE\ \hat{i}\right) \cdot \left(\frac{2aV}{d}\hat{i} + V\hat{j}\right)$$

$$= eE\left(\frac{2aV}{d}\right); \text{ where, } E = \frac{2amV^2}{ed^2}$$

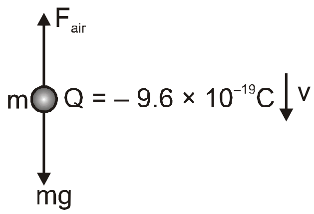
$$\Rightarrow \therefore P = \frac{4ma^2V^3}{d^3}$$

(C) Rate of work done at A :

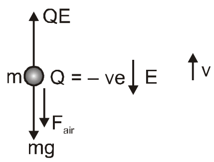
$$P_A = \vec{F}\cdot\vec{V}_A$$

$= \left(e\vec{E}\,\hat{i}\right)\cdot\left(V\,\hat{j}\right) = 0$

Q.6 (B,C)



$\therefore \quad mg = f_{air}$

(ii)


(finelly)

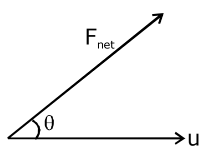
$\therefore$ QE = mg + f_{air} = 2mg

$\therefore$ charge is –ve, so electric field 'E' is directed downwards.

& QE = 2 mg

$$\therefore E = \frac{2mg}{Q} = \frac{2\times1.6\times10^{-18}\times10}{9.6\times10^{-19}} = \frac{1}{3}\times10^{2}\ \text{NC}^{-1}$$

Q.7 (A,C)



In constant force field path may be straight line

Fnet $\rightarrow$

u $\rightarrow$ or Parabola

Q.8 (A,C)

(i) At any point P inside the sphere, electric field

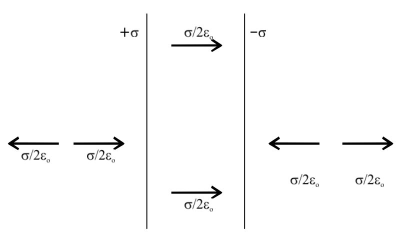
$\Rightarrow E_P = \dfrac{kQr}{R^3}$.

$\therefore$ E_P increases as r increases .

(ii) At any point M outside the sphere, $E_M = \dfrac{kQ}{r^2}$

$\therefore$ E_M decreases as r increases.

Q.9 (A,C)



Q.10 (A,D)

AD

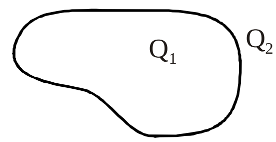
Flux due to charge which is outside will be zero.

$$\oint \vec{\varepsilon}\,.\,d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

electric field due to all the charges.

Q.11 (A,B,C)

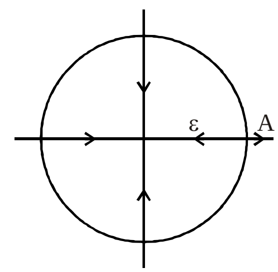
$$\oint \vec{\varepsilon}\,.\,d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$



Flux electric field due to charge lie inside or out side the surface. But ϕ is only due to charge lie inside the surface.

Q.12 (A,B,C)

E = 100 r



$$\oint \vec{\varepsilon}\,.\,d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

$$\varepsilon dA \cos 180° = \frac{q_{in}}{\varepsilon_0}$$

$\Rightarrow q_{in}$ = –ve

$|q_{in}| = EdA\,\varepsilon_0 = 3 \times 10^{-13}$ C

Q.13 (A,C)

Q.14 (A,B,C,D)

$$\frac{kQ}{(r+5cm)} = 100V \qquad \& \quad \frac{kQ}{(r+10cm)} = 75\ V$$

$$\therefore \quad Q = \frac{5}{3}\times10^{-9}\,C,\ \ r = 10\ cm$$

$$\therefore \quad V_{surface} = \frac{kQ}{2} = 150V$$

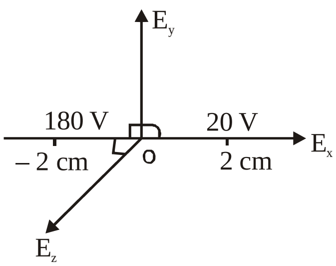
$$E_{surface} = \frac{kQ}{r^2} = 1500\ V/m$$

$$V_{centre} = \frac{3}{2}\ V_{surface} = \frac{3}{2} \times 150 = 225\ V$$

Q.15 (C,D)

(A) Charging by conduction has charge distribution depending on size of bodies.
(B) Charge is invariant with velocity.
(C) Charge requires mass for existence
(D) Repulsion shows charge of both bodies because attraction can be there between charged and uncharged body.

Q.16 (B,C)



from given data $E_x = \frac{160}{4}$ V/cm = 40 V/cm

but $E = \sqrt{E_x^2 + E_y^2 + E_z^2}$ $\Rightarrow$ E may be equal or greater than 40 V/cm ie.

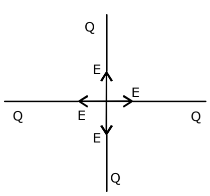
As shown, there can be electric fields ⊥ to x axis, which will not affect the electric potential difference but can increase net field.

Q.17 (A.B,C,D)

(A) $V = \frac{KQ}{r} = 0$ b/w z $\theta = 0$

(B) Depends on distribution of charge .
(C) Depends on distribution of charge .
(D) F_{net} is zero but τ_{net} may be non zero

Q.18 (B,D)



$v_c = \frac{4KQ}{r}$

At Z axis horizontal component of E cancelled but vertical is added.

Q.19 (A,D)

higher density $\Rightarrow$ Higher E

$E_A > E_B$

Electric field lines from higher potential to lower potential.

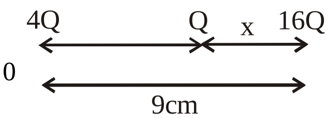
$V_B > V_A$

Q.20 (B,C)

To reduce potential energy

$F = -\frac{dU}{dx}$

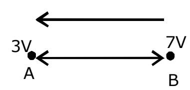
F = 0



$$\frac{16Q^2K}{x^2} = \frac{4Q^2K}{(9-x)^2}$$

2(9–x) =x
18–2x =x
x = 6 cm

Q.21 (A,C)



$F = eE \rightarrow$
k.E. = e (7–3) = 4ev

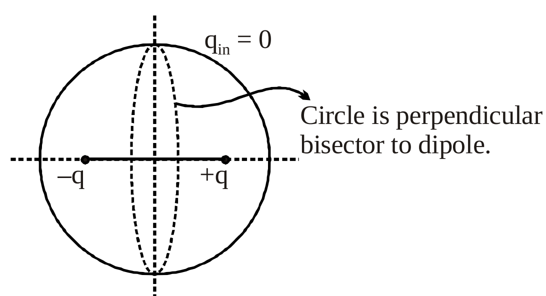
Q.22 (B,C,D)

mA V + mB V = mAV1

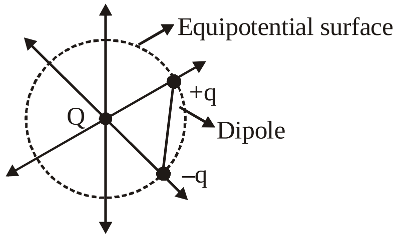
$$E.C\ \frac{1}{2} m_A V_2 = \frac{1}{2}(m_A + m_B)V_2 + \frac{kq_1q_2}{r_{min}}$$

Momentum is concerved because
$F_{net} = 0$

Q.23 (A,C)



Q.24 (A,C)



In all orientations, dipole experiences force, but does not experience torque if dipole has its dipole moment along or opposite to ELOF.

Dipole can never be in stable equilibrium & work done in moving dipole along an EPS of point charge Q will be zero.

Q.25 (A,B,D)

Dimension theory

Q.26 (A,B,D)

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

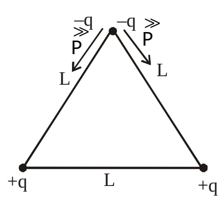
$= \left(2\hat{i} + 3\hat{j}\right) \times \left(3\hat{i} + 2\hat{k}\right) \times 10^{-6} \times 10^{5}$

$= (0.6\,\hat{i} - 0.4\,\hat{j} - 0.9\,\hat{k})$

P.E. $= -\vec{P}.\vec{E}$

Max P.E. $= |\vec{P}||\vec{E}|$

Q.27 (A,D)



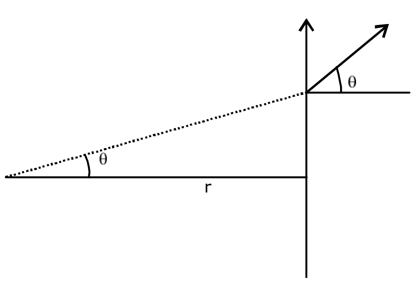
$P_{net}^{2} = P^2 + P^2 + 2P^2 \text{ Cos}60$

$= \sqrt{3}\, qL$

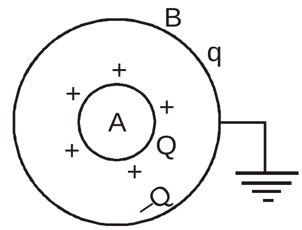
Q.28 (B,C)

$F_{net} = 2F \sin\theta$

$= 2.\dfrac{kqQ}{(r^2 + d^2)} \times \dfrac{d}{(r^2 + d^2)^{1/2}} = \dfrac{2 \times kqQ}{r^3} = \dfrac{KPQ}{r^3}$



Q.29 (A,C,D)



(i) Due to earthing

Let total charge on B is q.

$V_B = 0 \;\; \therefore \;\; \dfrac{kq}{b} + \dfrac{kQ}{b} = 0$ or $q = -Q$.

(ii) $\therefore$ All charge $q = -Q$ appears on inner surface of B due to induction

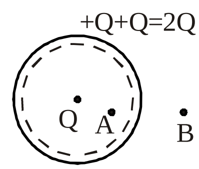
$\Rightarrow$ Charge on outer surface of B = 0

$\Rightarrow$ Field between A and B due to B = 0

Field between A and B due to A $\neq$ 0

Net field between A and B $\neq$ 0.

Q.30 (A,C,D)



$\sigma = \dfrac{2Q}{4\pi R^2}$

$\sigma = \dfrac{Q}{2\pi R^2}$

ε_A only due to inside charge

$\propto \dfrac{1}{r^2}$

ε_B due to charge (inside + outside)

Q.31 (A,B)

In conductor given charge inside on its outer surface.

$\sigma \propto \dfrac{1}{r_c} \Rightarrow$ Potential will be same

Electric field near the surface $= \dfrac{\sigma}{\varepsilon_0}$

Where σ = Local charge density $\sigma \propto \dfrac{1}{r}$

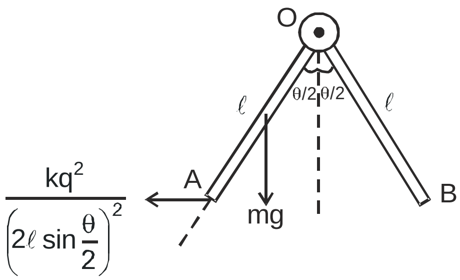
Q.32 (C)

For 30 C charge, angle $\in$ (5°, 9°) $\Rightarrow$ 7°

Q.33 (C)

In (iii) most of the positive charge with run away to the metal knob. So due to less charge on the leaves, the leaves will come closer than before.

Q.34 (A)



Applying torque balance about hinge point O.

$$\frac{kq^2}{\left(2\ell\sin\frac{\theta}{2}\right)^2}\left(\ell\cos\frac{\theta}{2}\right) = mg\left(\frac{\ell}{2}\right)\sin\frac{\theta}{2}$$

for small θ , $\sin\frac{\theta}{2} \to \frac{\theta}{2}$, $\cos\frac{\theta}{2} \to 1$

$$\therefore\quad \theta = \sqrt{\frac{4kq^2}{mg\ell^2}}$$

Q.35 (C)

$\because\ \phi = \frac{Q}{\epsilon_0}$

$\therefore\quad = 2 \times 10^5 \times 8.85 \times 10^{-12}$ C

$= 1.77\ \mu$C

Q.36 (B)

$$\frac{(1.77 \times 10^{-6} + Q_A)}{\epsilon_0} = -4 \times 10^5$$

$\Rightarrow Q_A = -5.31 \times 10^{-6}$ C

Q.37 (D)

For all values of r, flux ϕ is non-zero i.e. no Gaussian sphere of radius r is possible in which net enclosed charge is zero.

Q.38 (B)

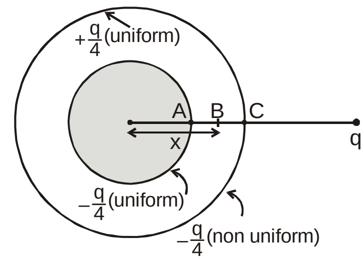
The inner sphere is grounded, hence its potential is zero. The net charge on isolated outer sphere is zero. Let the charge on inner sphere be q'.

∴ Potential at centre of inner sphere is

Q.39 (C)

The region in between conducting sphere and shell is shielded from charges on and outside the outer surface of shell. Hence, charge distribution on surface of sphere and inner surface of shell is uniform.

The distribution of induced charge on outer surface of shell depends only on point charge q, hence is nonuniform. The charge distribution on all surfaces, is as shown.



Q.40 (A)

The electric field at B is $= \frac{1}{4\pi\varepsilon_o}\cdot\frac{q}{4x^2}$ towards left.

$$\therefore V_C = V_C - V_A = -\int_{2a}^{a}\frac{1}{4\pi\varepsilon_o}\frac{q}{4x^2}dx = \frac{1}{32\pi\varepsilon_o}\cdot\frac{q}{a}$$

Q.41 (A) p, q (B) p, q (C) p, q, s (D) r, s

In situation A, B and C, shells I and II are not at same potential. Hence charge shall flow from sphere I to sphere II till both acquire same potential.

If charge flows, the potential energy of system decreases and heat is produced.

In situations A and B charges shall divide in some fixed ratio , but in situation C complete charge shall be transferred to shell II for potential of shell I and II to be same.

∴ (A) → p, q , (B) → p, q , (C) → p, q, s

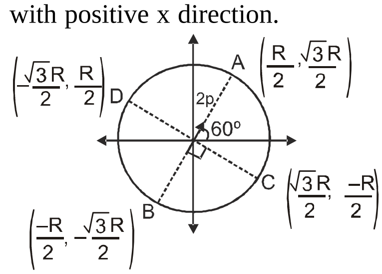
In situation D, both the shells are at same potential, hence no charge flows through connecting wire.

∴ (D) → r, s

Q.42 (A) p (B) r,s (C) p,q (D) r,s

The resultant dipole moment has magnitude $\sqrt{(\sqrt{3}\,P)^2 + P^2} = 2P$ at an angle $\theta = \tan^{-1}\frac{\sqrt{3}\,P}{P}$ = 60°

with positive x direction.



Diameter AB is along net dipole moment and diameter CD is normal to net dipole moment.

$\therefore$ Potential at A $\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$ is maximum

Potential is zero at C $\left(\frac{\sqrt{3}R}{2}, -\frac{R}{2}\right)$ and D $\left(-\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$

Magnitude of electric field is $\frac{1}{4\pi\varepsilon_0}\frac{4p}{R^3}$ at A $\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$ and B $\left(-\frac{R}{2}, -\frac{\sqrt{3}R}{2}\right)$

Magnitude of electric field is $\frac{1}{4\pi\varepsilon_0}\frac{2p}{R^3}$ at C $\left(\frac{\sqrt{3}R}{2}, -\frac{R}{2}\right)$ and D $\left(-\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$

NUMERICAL VALUE BASED

Q.1 [40]

Electric field on particle

E = $E = \frac{-\Delta V}{\Delta x}$ = $E = \frac{-[250-(-250)]}{20\times10^{-2}}$ = – 2500 V/m

Acceleration of charge particle =

$$\frac{qE}{m} = \frac{1.6\times10^{-19}\times2500}{16\times10^{-31}} = 2500\times10^{11}\ \text{m/s}^2$$

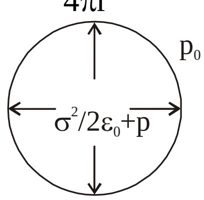
thus time taken = $\sqrt{\frac{2\times5}{a}}$ {S = $\frac{1}{2}$ at^2)

= $\sqrt{\frac{2\times20\times10^{-2}}{2500\times10^{11}}}$ = 4 × 10^{-8} sec. = 40 nS

Q.2 [96]

V = $\frac{4}{3}\pi r^3$ .... (1)

$\sigma = \frac{Q}{4\pi r^2}$ .... (2)



$\frac{\sigma^2}{2\epsilon_0} + p - p_0 = \frac{4s}{r}$ .... (3)

$p - p_0 = 0$ .... (4)

$\Rightarrow \quad \frac{1}{2\varepsilon_0}\cdot\frac{Q^2}{16\pi^2 r^4} = \frac{4s}{r}$

$\Rightarrow \quad \frac{1}{2\varepsilon_0}\cdot\frac{n\pi\varepsilon_0 s}{16\pi^2 r^3}\cdot\frac{4}{3}\pi r^3 = 4s$;

n = 96

Q.3 [6]

$\frac{\lambda}{2\pi\epsilon_0 r} = E_{break}$

$r = \frac{\lambda}{2\pi\epsilon_0 E_{break}}$

$= \frac{10^{-3}}{2\times3.14\times8.85\times10^{-12}\times3\times10^6}$

$= \frac{1}{2\times3.14\times8.85}\times10^3$

= 5.99 m ≈ 6 m **Ans.**

Q.4 [3]

Along z axis $\vec{E}\cdot d\vec{A} = 0$

Along x axis $\vec{E}$ = cont.

$\therefore$ $\phi_x = 0$

for y = 0

$\int\vec{E}\cdot d\vec{A} = \int 3(0+2)\hat{j}\cdot dA(-\hat{j}) = 6\int dA = -6$

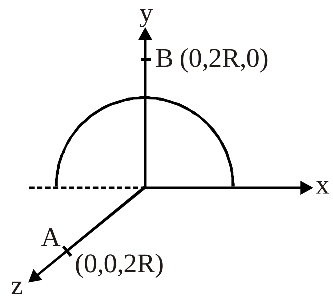
for y = 1

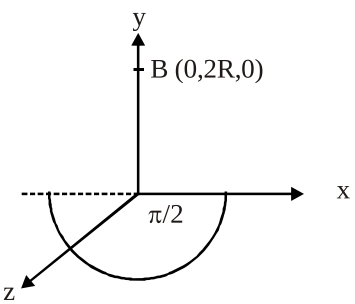
$\int\vec{E}\cdot d\vec{A} = \int 3(1+2)\hat{j}\cdot dA(\hat{j}) = 9\int dA = 9$

$\therefore$ $\phi_{net} = +3\epsilon_0$ **Ans.**

Q.5 [4]

$W_{A\to B}^{ex.} = W = U_B - U_A$





$$W = U_B - \frac{Q^2}{4\pi\varepsilon_0\sqrt{5}R} \qquad \text{............ (1)}$$

At new position

$$U'_B = \frac{Q^2}{4\pi\varepsilon_0\sqrt{5}R}$$

Work done = $U'_B = U_B = -W = -4J$

Q.6 [9]

In uniform electric in vertical direction if (+ve) charge feels extra acceleration in downward direction, then (-ve) charge will feel acceleration in upward direction.

$v_{uncharged} = 5\sqrt{5}\ m/sec$

v = 0, h = height

$v^2 - u^2 = -2(g)\,h$

$-(5\sqrt{5})^2 = -2gh$

$u_{q+} = 13$ m/sec

v = 0, h = h

$$v^2 - u^2 = 2\left(g + \frac{F_E}{m}\right)h$$

$$0 - (13)^2 = -2\left(g + \frac{F_E}{m}\right)h$$

Let u_{q-} = u(say)

v = 0 h = ht

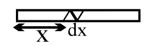
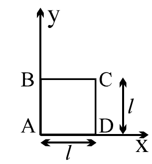
$$v^2 - u^2 = -2\left(g - \frac{F_E}{m}\right)h$$

$$-u^2 = -2\left(g - \frac{F_E}{m}\right)h \ ; \ u = 9 \text{ m/sec}$$

Q.7 [6]

$$F_{AB} = \frac{a}{l}(0 + l) \times \lambda l \qquad = a\lambda l$$

$$\rightarrow F_{CD} = \frac{a}{l}(l + l) \times \lambda l \qquad = 2a\lambda l$$

→  

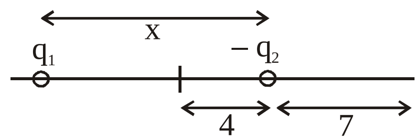
For $F_{AD} = F_{BC}$

$$F = \int \frac{a}{l}(x + l)\lambda dx = \frac{a\lambda}{l}\left[\frac{x^2}{2} + lx\right]_0^l = \frac{3}{2}a\lambda l$$

$6a\lambda l = 6 \times 5 \times 10^5 \times 20 \times 10^{-6} \times 0.1$

= 6N (ans)

Q.8 [44]



$$\frac{q_1}{x-4} - \frac{q_2}{4} = 0 \quad \frac{q_1}{x+7} - \frac{q_2}{7} = 0$$

$$\frac{q_1}{q_2} = \frac{x-4}{4}$$

$$\frac{q_1}{q_2} = \frac{x+7}{7}$$

$$\frac{x-4}{4} = \frac{x+7}{7}$$

7x – 28 = 4x + 28

3x = 56

$$x = \frac{56}{3}$$

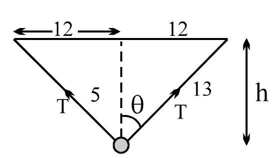
$$\frac{q_1}{q_2} = \frac{\frac{56}{3} + 7}{7} = \frac{11}{3}$$

$|q_2| = +12\ \mu c$

$$\Rightarrow \qquad q_1 = 12 \times \frac{11}{3} = 44\ \mu c$$

Q.9 [17]

Initially, $2T\cos\theta = mg$ ...(1)



here $T = k(26 - 24)$

$T = 2k$

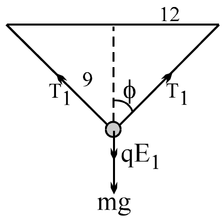
So, $2 \times 2k \times \dfrac{5}{13} = mg$ ...(A)

1^{st} Case

Now length of string = 30 cm

$T_1 = k(30 - 24)$

$\therefore$ $2T_1\cos\phi = qE_1 + mg$



$2 \times 6k \times \dfrac{9}{15} = qE_1 + mg$

$\therefore$ $\dfrac{36}{5}k - \dfrac{20}{13}k = qE_1$

$\therefore$ $\dfrac{(468-100)k}{65} = qE_1$

$\therefore$ $\dfrac{368k}{65} = qE_1$ ...(B)

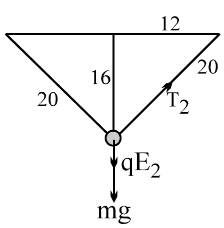
2^{nd} Case

$T_2 = k(40 - 24) = 16k$

$2 \times 16k \times \dfrac{16}{20} = qE_2 + mg$

$\therefore$ $qE_2 = \dfrac{128k}{5} - \dfrac{20k}{13}$

$= \dfrac{(1664-100)k}{65}$



$qE_2 = \dfrac{1564}{65}k$ ...(C)

$\therefore$ $\dfrac{E_2}{E_1} = \dfrac{1564}{368} = 4.25$]

Q.10 [45]

$$\overrightarrow{OP} = (8\hat{i} - k\hat{i}) - (2\hat{i} - 3\hat{j})$$

$$\overrightarrow{OP} = 6\hat{i} - 8\hat{j}) \Rightarrow OP = 10$$

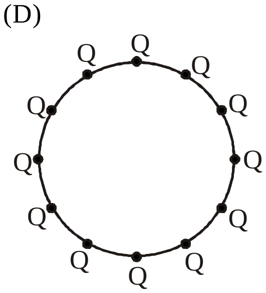
$$\vec{E}_p = K\frac{Q}{OP^3}\overrightarrow{OP} = \frac{KQ}{OP^2}\hat{OP}$$

$$E_p = \frac{9\times10^9\times50\times10^{-6}}{(10)^2} = 4500 \text{ V/m}$$

KVPY

PREVIOUS YEAR'S

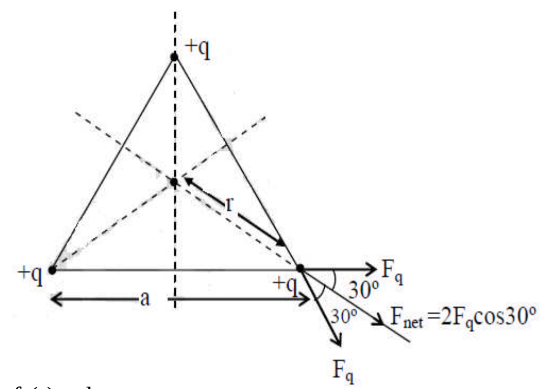
Q.1 (D)



If one charge is removed then net force on Q is $\dfrac{q\times Q}{4\pi\varepsilon_0R^2}$

Towards the position of removed charge

Q.2 (B)



f (r) = kr

now F_{net} on a particle is $2F_q \cos 30°$ due to the other two charges

$$F_{net} = \frac{2kq^2}{a^2}\times\frac{\sqrt{3}}{2}$$

$$\text{also } r = \frac{2}{3}\left(\frac{\sqrt{3}}{2}a\right)$$

$\therefore a = \sqrt{3}\,r$ replacing it in F_{net} we get

$$F_{net} = \frac{2kq^2}{(\sqrt{3}r)^2}\times\left(\frac{\sqrt{3}}{2}\right) = \frac{kq^2}{\sqrt{3}r^2}$$

this is balanced by F (r)

$$\therefore F(r) = F_{net} \Rightarrow kr = \frac{1 \times q^2}{4\pi\varepsilon_0 \times \sqrt{3}r^2}$$

$$\therefore r = \left(\frac{\sqrt{3}q^2}{12\pi\varepsilon_0 k}\right)^{1/3}$$

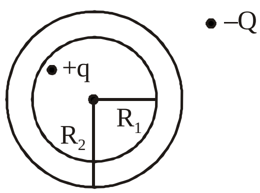
Q.3 (B)

Using law of conservation of mechanical energy

Initial K.E. = Final P.E.

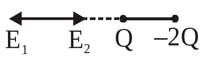
$$\frac{1}{2}mv^2 + \frac{1}{2}mv^2 = \frac{kq^2}{r} \quad \therefore r = \frac{q^2}{4\pi\varepsilon_0 mv^2}$$

Q.4 (D)



For a conductor electric field inside its cavity is only due to inside charge and not due to outside charge.

Q.5 (B)



Q.6 (C)

For uncharged particle

$$L = \frac{u^2 \sin 2\theta}{g} \quad .....(i)$$

Range for particle of mass m and charge q.

$$\frac{L}{2} = \frac{u^2 \sin 2\theta}{g + \frac{qE}{m}} \quad .....(ii)$$

From (i) and (ii)

$$\frac{u^2 \sin 2\theta}{g} = \frac{u^2 \sin 2\theta}{g + \frac{qE}{m}}$$

$\Rightarrow$ mg = qE

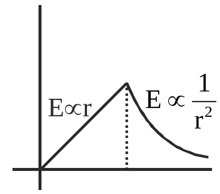
Range of particle of mass m & charge 2q.

$$R = \frac{u^2 \sin 2\theta}{g + \frac{2qE}{m}} = \frac{u^2 \sin 2\theta}{g\left(1 + \frac{2qE}{mg}\right)} = \frac{L}{3}$$

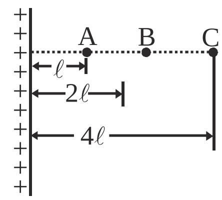
Q.7 (B)

When r < R $\quad E = \frac{\rho r}{3\pi \in_0 r^2}$

When r > R $\quad E = \frac{Q}{4\pi \in_0 r^2}$



Q.8 (A)



energy conservation at A & B

$$qV_A + \frac{1}{2}mu^2 = qV_B + \frac{1}{2}m \times 2u^2$$

$$q[V_A - V_B] = \frac{1}{2}mu^2$$

$$q \times \frac{\lambda}{2\pi \in_0} In_2 = \frac{1}{2}mu^2$$

energy conservation at A & C

$$qV_A + \frac{1}{2}mu^2 = qV_B + \frac{1}{2}mv^2$$

$$q\,[V_A - V_C] + \frac{1}{2}mu^2 = \frac{1}{2}mv^2$$

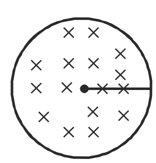
$$\frac{q\lambda}{2\pi \in_0} In 4 + \frac{1}{2}mu^2 + \frac{1}{2}mv^2$$

$$\frac{q\lambda}{2\pi \in_0} In 2 + \frac{1}{2}mu^2 + \frac{1}{2}mv^2$$

$$mu^2 \frac{1}{2}mu^2 = \frac{1}{2}mv^2$$

$$\frac{3}{2}u^2 = \frac{1}{2}v^2 \Rightarrow v = \sqrt{3}\,u$$

Q.9 (A)

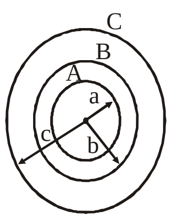


outside the nucleus electric potential decreases
e^- is negativity charged
$\therefore$ its PE is negative even outside the nucleus where nuclear attractive force is negligible
(3) $\rightarrow e^-$
outside the nucleus
neutron will not
experience electric force
as it is neutral. So no potential energy associated with it outside nucleus
1 $\rightarrow$ neutron

Q.10 (A)
Due to induction, bend in same direction

Q.11 (C)

Q.12 (1)



$$V_B \frac{kq}{b} + \frac{k(-q)}{c} = V \quad \text{(Given)}$$

$$q = \frac{4\pi\varepsilon_0 .bc}{c-b}.V$$

Charge on C = – q

Q.13 (D)

$$qV = \frac{1}{2}mv^2$$

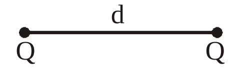
$$V = \frac{1}{2}\frac{mv^2}{q}$$

$$V = \frac{1}{2} \times \frac{9\times10^{-31}\times\left(4\times10^{6}\right)^2}{1.6\times10^{-19}} = 45V$$

45 V from higher to lower potential.

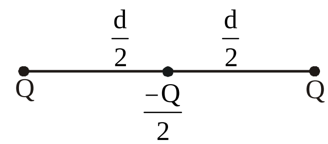
Q.14 (D)
Charge on outer most surface is zero
Hence force on q is also ‘0’

Q.15 (B)



$$\text{Energy } E = \frac{kQ\times Q}{d} = \frac{kQ^2}{d} \qquad ....(1)$$

Third charge is put between them



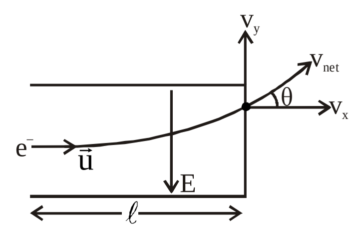
$$\text{Energy of system} = \frac{kQ\times Q}{d} + \frac{kQ}{\frac{d}{2}}\left(\frac{-Q}{2}\right) + \frac{kQ}{\frac{d}{2}}\left(\frac{-Q}{2}\right)$$

$$= \frac{kQ^2}{d} + \left(\frac{-kQ^2}{d}\right) + \left(\frac{-kQ^2}{d}\right)$$

$$= -\frac{kQ^2}{d}$$

From (1)
Energy of system = E

Q.16 (A)



Horizontal displacement = ℓ

$$t = \frac{\ell}{u}$$

$v_y = u_y + at$

$$= 0 + \frac{eE}{m} \times \frac{\ell}{u}$$

$$vy = \frac{eE}{m} \times \frac{\ell}{u}$$

vx remain same and it is equal to u

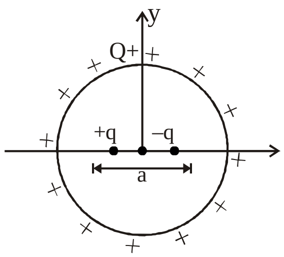
$$\tan\theta = \frac{v_y}{v_x} = \frac{eE}{m}\frac{\ell}{u} \times \frac{1}{u} = \frac{eE\ell}{mu_2}$$

$$\tan\theta \propto \frac{1}{u_2}$$

when speed u is doubled then θ will become $\frac{1}{4}$th.

$$\therefore \tan\theta \frac{0.4}{4} = 0.1$$

Q.17 (C)



PEi = Initial energy of system $= \frac{Q^2}{8\pi\varepsilon_0 R}$ (self energy of sheel)

PE_f = Final energy of system $= \frac{Q^2}{8\pi\varepsilon_0 R} + \frac{q\times(-q)}{4\pi\varepsilon_0 a} + \frac{kQ\times q}{R} + \frac{kQ(-q)}{R} \Rightarrow \frac{Q^2}{8\pi\varepsilon_0 R} - \frac{q^2}{4\pi\varepsilon_0 R}$

(self energy of shell) (Interaction energy between various charges)

Work done $= PE_f - PE_i$

$= \frac{-q^2}{4\pi\varepsilon_0 a}$

Magnitude of work done $= \frac{q^2}{4\pi\varepsilon_0 a}$

Q.18 (A)

$F = \frac{dU}{dr} = \frac{-d}{dr}[qV]$ $\quad q \to$ constant

$F = -q\left[\frac{dU}{dr}\right]$

$F = -qk \quad \leftarrow \begin{pmatrix} v = kr \\ \frac{dV}{dr} = k \end{pmatrix}$

$m\omega^2 R = -qk$

$m\left(\frac{2\pi}{T}\right)^2 R = -qk$

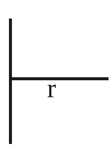
$\frac{m(4\pi^2)R}{T^2} = -qk$

$\Rightarrow T^2 \propto R$

$\Rightarrow T \propto R^{1/2}$

Q.19 (B)

$E = \frac{K}{r}$



$\therefore$ $\boxed{F = qE}$

for 1st electron

$(q)\frac{1}{r_1} = \frac{mv_1^2}{r_1}$

$\Rightarrow \quad q = mv_1^2$

$\boxed{v_1^2 = \frac{q}{M}}$

$v_1 = \sqrt{\frac{q}{M}}$

$\therefore$ Similarly $v_2 = \sqrt{\frac{q}{M}}$

$v_1 = v_2$

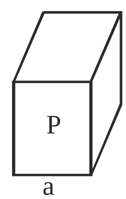
$\frac{T_1}{T_2} = \frac{\frac{2nR_1}{v_1}}{\frac{2nR_2}{v_2}} = \frac{2nR_1}{v_1} \times \frac{v_2}{2nR_2}$

$= \frac{R_1}{v_1} \times \frac{v_2}{R_2} = \frac{1}{2}$

Q.20 (B)

Electric field lines should be perpendicular to surface of metal.

Q.21 (A)



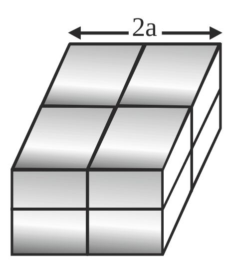
Let at the corner of cube potential = V_0

Potential $\propto \frac{Q}{\text{Side of cube}}$

$Q = \rho \times a^3$

So potential $\propto \frac{\rho a^3}{a}$

Potential $\propto a^2$



Big cube consist of 8 cube

At centre of big cube of side 2a, potential is $8V_0$

Potential at corner of big cube = $V_0 \times (2)^2 = 4V_0$

Required ratio $= \frac{8V_0}{4V_0} = 2:1$

Q.22 (D)

If coloumb's force $\propto \frac{1}{r^3}$ gauss's law is not valid

$\therefore \ \phi \neq \frac{q_{en}}{\varepsilon_0}$

For static condition E = 0 in both of conductor $\therefore$ ϕ through a Gaussian surface just under the surface of conductor = 0 but as

$\phi = \frac{q_{en}}{\varepsilon_0}$ is not valid.

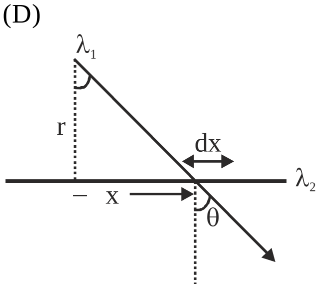
So $q_{en} = 0$ is not correct statement. Some charge will present insider bulk of conductor.

Q.23 (A)
Option 'A' is correct option. According charge conservation & Gauss's law.

Q.24 (B)
q = +2e
$1\alpha V = +2ev.$

Q.25 (C)
$q_1(1-\cos\alpha) = q_2\,(1-\cos\beta)$ solving we get $30° < \beta \le 60°$

Q.26 (D)



$$\frac{x}{r} = \tan\theta \Rightarrow dx = r\sec^2\theta\, d\theta$$

$$dF = \frac{2K\lambda_1}{r\sec\theta}\lambda_2 dx$$

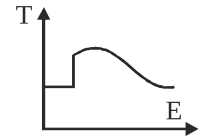
$$dF = \frac{2K\lambda_1\lambda_2}{r\sec\theta} r\sec^2\theta\, d\theta$$

$= 2K\lambda_1\lambda_2 \sec\theta d\theta$

$$F_{net} = 2\int_0^{\pi/2} dF\cos\theta$$

$= 2K\lambda_1\lambda_2$ Ans.

Q.27 (B)



Q.28 (C)

$$E = \frac{dv}{dr}$$

$$\phi = 4\pi r^2 E = \frac{q_{enc.}}{\varepsilon_0}$$

$q_{enclosed} = q/e$

Q.29 (B)

$$Q = -K\ 4\pi R^2 \frac{dT}{dR}$$

$Q \propto R^2$

Q.30 (D)

$am_1 > am_2$

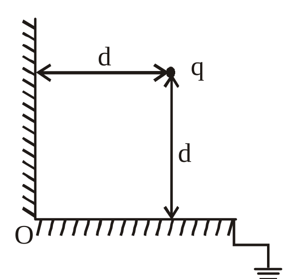
$$\frac{M_1 g - Q_1 E}{M_1} > \frac{M_2 g - Q_2 E}{M_2}$$

$$g - \frac{Q_1 E}{M_1} > g - \frac{Q_1 E}{M_2}$$

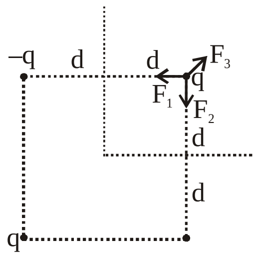
$$\frac{Q_2 E}{M_2} > \frac{Q_1 E}{M_1}$$

$M_1 Q_2 > M_2 Q_1$

Q.31 (C)



By method of image, the given arrangement is equivalent to



$$F_1 = \frac{1}{4\pi \in_0}\frac{q^2}{(2d)^2}, F_2 = \frac{1}{4\pi \in_0}\frac{q^2}{(2d)^2},$$

$$F_3 = \frac{1}{4\pi \in_0}\frac{q^2}{(2\sqrt{2}d)^2}$$

$$\therefore\ F_{net} = \sqrt{2}\frac{q^2}{16\pi \in_0 d^2} - \frac{q^2}{32\pi \in_0 d^2}$$

$$= \frac{q^2}{32\pi \in_0 d^2}(2\sqrt{2}-1)[\text{towards O}]$$

Q.32. (B)

Potential inside uniformly charged solid sphere is given by

$$V = \frac{kQ}{2R^3}\left[3R^2 - r^2\right]$$

$$= \frac{kQ}{R}\left[\frac{3R^2}{2R^2} - \frac{r^2}{2R^2}\right]$$

$$= \frac{Q}{4\pi \in_0 R}\left[\frac{3}{2} - \frac{1}{2}\left(\frac{r}{R}\right)^2\right]$$

Compare with given formula, i.e.,

$$\frac{Q}{4\pi \in_0 R}\left[a + b\left(\frac{r}{R}\right)^C\right]$$

$$a = \frac{3}{2}, b = -\frac{1}{2}, c = 2$$

Q.33 (A)

As charge is increased in discrete manner. (A) graph should be correct option

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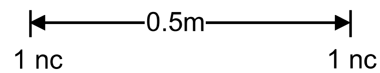
Q.1 (1)

$$\Phi_{P1} = \frac{3}{5}{}_0\ (0.2)$$

$$\Phi_{P2} = \frac{4}{5}E_0\ (0.3)$$

$$\therefore\ \frac{\Phi_{P_1}}{\Phi_{P_2}} = \frac{0.6}{1.2} = \frac{1}{2}$$

Q.2 (36)



$$F = \frac{K(1\times 10^{-9})(1\times 10^{-9})}{(0.5)^2} = 36 \times 10^{-9}N$$

$x = 36$

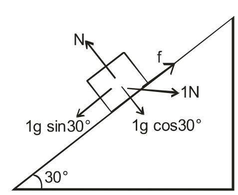
Q.3 (1)

$$E = \frac{K\lambda}{r}(\sin\theta_1 + \sin\theta_2)$$

$$\theta_1 = \theta_2 = 30^o,\ r = \frac{\sqrt{3}\ell}{2},\ \lambda = \frac{Q}{\ell}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{\frac{Q}{\ell}\left(\frac{1}{2}+\frac{1}{2}\right)}{\frac{\sqrt{3}\ell}{2}} = \frac{Q}{2\sqrt{3}\varepsilon_0\pi\ell^2}$$

Q.4 (2)



$$t = \left(\frac{1}{2} + 9.8\frac{\sqrt{3}}{2}\right) \times 0.2$$

$$t = \sqrt{\frac{2s}{a}}$$

$$a = \frac{9.8}{2} = (0.2)\left(\frac{1}{2} + 9.8\frac{\sqrt{3}}{2}\right)$$

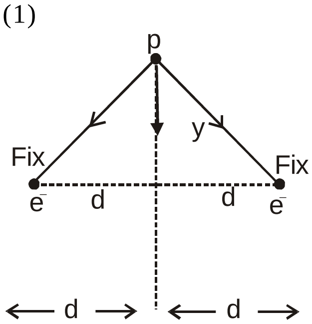
$= 4.9 - 1.79 \approx 3.1$

$= \frac{2}{\sqrt{a}} = \frac{2}{\sqrt{3.1}}$

≈ 1.13 sec

Q.5 (3)

Q.6 (1)



Restoring force on proton

$F_r = \frac{2Ke^2y}{(d^2 + y^2)^{3/2}}$ y <<<<<d

$F_r = \frac{2Ke^2y}{d^3} = \frac{e^2y}{2\pi \epsilon_0 d^3}$ ky

$k = \frac{e^2}{2\pi \epsilon_0 d^3}$

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{e^2}{2\epsilon_0 e^2md^3}}$

Q.7 (1)

If we consider two point charges +q and –q at position of –q charge, then after interchanging –q charge with +q charge, net electric field at centre of cube is zero due to symmetry. Now remaining charges are –2q so net electric field at centre is $\left(\frac{-8kq}{3a^2}\right)$.

Q.8 (226)

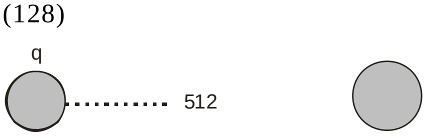
using gues law it is a part of cube of side 12 cm and charge at centre so $\Phi = \frac{Q}{6\varepsilon_0} - \frac{12\mu C}{6\varepsilon_0}$

$x \times 10^3 = 2 \times 4\pi \times 9 \times 10^9 \times 10^{-6}$

$\Phi = 72\pi \times 10^3$ SI units

x = 226

Q.9 (128)



$2 = \frac{Kq}{r}$ R, 512q

$\frac{v'}{2} = \frac{r(512)}{R}$ $v' = \frac{K(512)q}{R}$

$\frac{v'}{2} = \frac{512}{8} = 128$ $(512)\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

v' = 128 volt R = 8r

Q.10. (90)

$v = \frac{kq}{r} = 10v$

$27 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

R = 3r

$v' = \frac{k \times 27q}{3r} = 90$ volt

Q.11 (640)

$\phi = E_x A \Rightarrow \frac{2}{5} \times 4 \times 10^3 \times 0.4 = 640$

Q.12 (2)

qE = Mg

$neE = \rho\left(\frac{4}{3}\pi\ ^3\right) \times g$

$n \times 1.6 \times 10^{-19} \times 3.55 \times 10^5$

$= 3 \times 10^3 \times \frac{4}{3} \times \pi \times (2 \times 10^{-3})^3 \times 9.81$

$n = 173 \times 10^{(3-9-5+19)}$

$n = 1.73 \times 10^{10}$

Q.13 (2)

Q.14 (4)

Q.15 (4)

Q.16 (3)

Q.17 (2)

Q.18 (2)

Q.19 (2)

Q.20 (2)

As electric field is in y-direction so electric flux is only due to top and bottom surface

Bottom surface y = 0

$\Rightarrow E = 0 \Rightarrow \phi = 0$
Tope surface y = 0.5 m

$\Rightarrow E = 150\,(.5)^2 = \dfrac{150}{4}$

Now flux $\phi = EA = \dfrac{150}{4}(.5)^2 = \dfrac{150}{4}$

By Gauss's law $\phi = \dfrac{Q_{in}}{\in_0}$

$\dfrac{150}{16} = \dfrac{Q_{in}}{\in_0}$

$Q_{in} = \dfrac{150}{16} \times 8.85 \times 10^{-12} = 8.3 \times 10^{-11}$ C

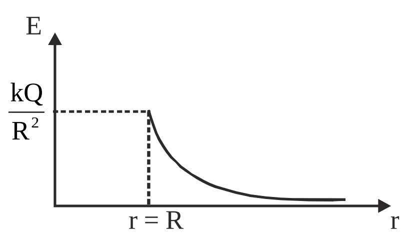
Option (2)

Q.21 (2)

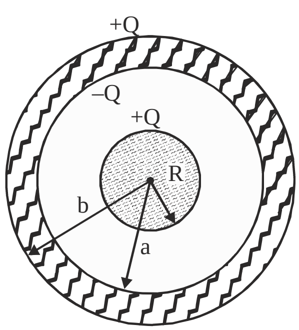
Q.22 (4)

Q.23 (1)
Considering outer spherical shell is non-conducting
Electric field inside a metal sphere is zero.
$r < R \Rightarrow E = 0$

$r > R \Rightarrow E = \dfrac{kQ}{r^2}$



Option (2)
Considering outer spherical shell is conducting

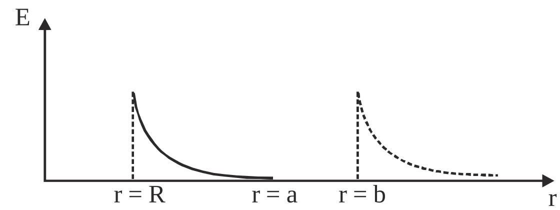


$r < R,\ E = 0$

$R \le r < a \qquad E = \dfrac{kQ}{r^2}$

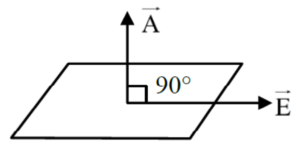
$a \le r < b, \qquad E = 0$

$r \ge b \qquad E = \dfrac{kQ}{r^2}$



Option (1)

Q.24 (3)
Since f = $\vec{E}\cdot\vec{A} = EA\cos\theta$



$\theta = 90^o$
$\therefore\ \phi = 0$

Q.25 (2)

Q.26 (1)

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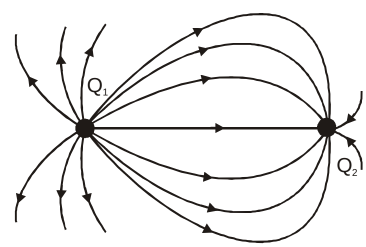
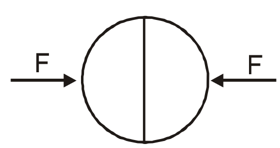
Q.1 (A, D)



From the diagram, it can be observed that Q_1 is positive, Q_2 is negative.
No. of lines on Q_1 is greater and number of lines is directly proportional to magnitude of charge.
So, $|Q_1| > |Q_2|$
Electric field will be zero to the right of Q_2 as it has small magnitude & opposite sign to that of Q_1 .

Q.2 (A)



Electrostatics repulsive force ; $F_{ele} = \left(\dfrac{\sigma^2}{2\varepsilon_0}\right)\pi R^2$;

$F = F_{ele} = \dfrac{\sigma^2 \pi R^2}{2\varepsilon_0}$

Q.3 (D)

In equilibrium, mg = qE

In absence of electric field, mg = 6πηrv

$\Rightarrow$ qE = 6πqrv

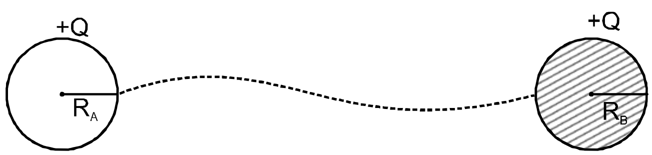
$$m = \frac{4}{3}\pi R r^3 d. = \frac{qE}{g}$$

$$\frac{4}{3}\pi\left(\frac{qE}{6\pi\eta v}\right)^3 d = \frac{qE}{g}$$

After substituting value we get,

$q = 8 \times 10^{-19}$ C **Ans.**

Q.4 (A,B,C,D)



$Q_A + Q_B = 2Q$ ...(i)

$$\frac{KQ_A}{R_A} = \frac{KQ_B}{R_B}$$ ...(ii)

(i) and (ii) $\Rightarrow Q_A = Q_B\left(\frac{R_A}{R_B}\right)$

& $Q_B\left(1+\frac{R_A}{R_B}\right) = 2Q \Rightarrow Q_B = \frac{2Q}{\left(1+\frac{R_A}{R_B}\right)}$

$$= \frac{2Q\,R_B}{R_A + R_B}$$

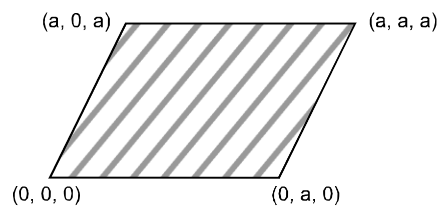
& $Q_A = \frac{2Q\,R_A}{R_A + R_B} \Rightarrow Q_A > Q_B$

$$\frac{\sigma_A}{\sigma_B} = \frac{Q_A / 4\pi R_A^2}{Q_B / 4\pi R_B^2} = \frac{R_B}{R_A} \text{ using (ii)}$$

$E_A = \frac{\sigma_A}{\epsilon_0}$ & $E_B = \frac{\sigma_B}{\epsilon_0}$ $\because \sigma_A < \sigma_B$

$\Rightarrow E_A < E_{B\,\text{(at surface)}}$

Q.5 (C)



flux = (E_0 cos 45°) × area)

$$= \frac{E_0}{\sqrt{2}} \times a \times \sqrt{2}a = E_0 a^2$$

Q.6 (A)

The frequency will be same $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

but due to the constant qE force, the equilibrium position gets shifted by $\frac{qE}{K}$ in forward direction. So Ans. will be (A)

Q.7 (C)

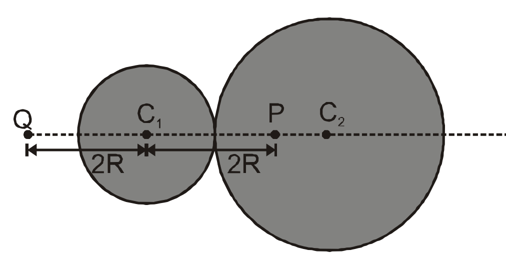
Surface Tension $\gamma = \frac{\text{force}}{\text{length}}$

$$2\left[\frac{\sqrt{2}kq^2}{a^2} + \frac{kq^2}{2a^2}\right] = \gamma \times a\sqrt{2} \times 2$$

a = (Some constant) $\left(\frac{q^2}{\gamma}\right)^{\frac{1}{3}}$ So

N = 3 **Ans.**

Q.8 (B,D)



At point P

If resultant electric field is zero then

$$\frac{KQ_1}{4R^2} = \frac{KQ_2}{8R^3}R$$

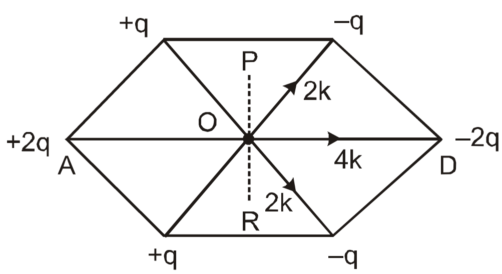
$$\frac{\rho_1}{\rho_2} = 4$$

At point Q
If resultant electric field is zero then

$$\frac{KQ_1}{4R^2} + \frac{KQ_2}{25R^2} = 0$$

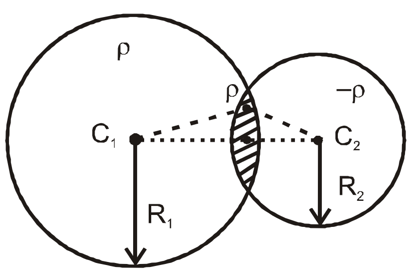
$$\frac{\rho_1}{\rho_2} = -\frac{32}{25}$$ (ρ_1 must be negative)

Q.9 (A,B,C)



$E_0 = 6$ K (along OD)
$V_0 = 0$
Potential on line PR is zero
PR

Q.10 (C, D)



For electrostatic field,

$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$= \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1P} + \frac{(-\rho)}{3\varepsilon_0}\overrightarrow{C_2P}$$

$$= \frac{\rho}{3\varepsilon_0}(\overrightarrow{C_1P} + \overrightarrow{PC_2})$$

$$\vec{E}_P = \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1C_2}$$

Q.11 (C)

$$E_1 = \frac{KQ}{R^2}$$

$$E_2 = \frac{k(2Q)}{R^2} \Rightarrow E_2 = \frac{2kQ}{R^2}$$

$$E_3 = \frac{k(4Q)R}{(2R)^3} \Rightarrow E_3 = \frac{kQ}{2R^2}$$

$E_3 < E_1 < E_2$

Q.12 (C)

$$\frac{Q}{4\pi \in_0 r_0^2} = \frac{\lambda}{2\pi \in_0 r_0} = \frac{\sigma}{2 \in_0}$$

$Q = 2\pi\sigma r_0^2$ A incorrect

$r_0 = \frac{\lambda}{\pi\sigma}$ B incorrect

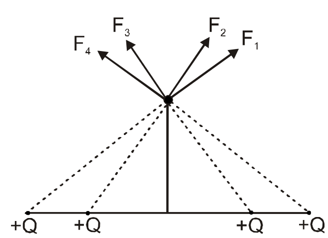
$$E_1\left(\frac{r_0}{2}\right) = \frac{4E_1(r_0)}{1}$$

$E_2\left(\frac{r_0}{2}\right) = 2E_2(r_0) \Rightarrow$ C correct

$E_3\left(\frac{r_0}{2}\right) = E_3(r_0) = E_2(r_0)$ D incorrect

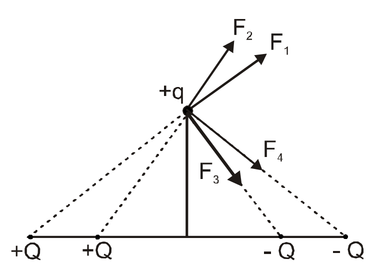
Q.13 (A)

(P)



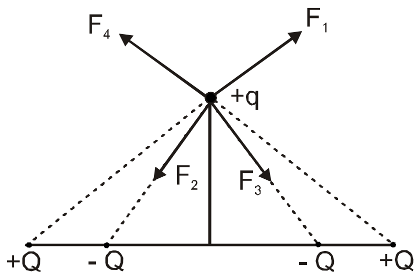
Component of forces along x-axis will vanish. Net force along +ve y-axis

(Q)



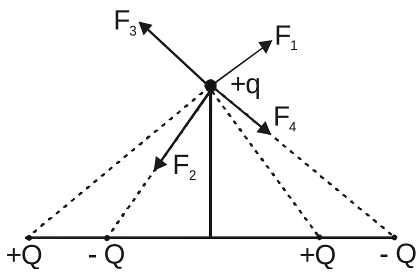
Component of forces along y-axis will vanish. Net force along +ve x-axis

(R)



Component of forces along x-axis will vanish. Net force along -ve y-axis.

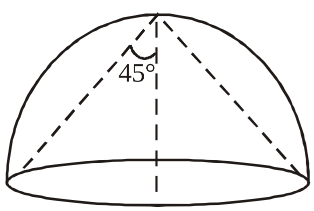
(S)



Component of forces along y-axis will vanish. Net force along -ve x-axis.

(A) P—3, Q—1, R—4,S—2

Q.14 (CD)

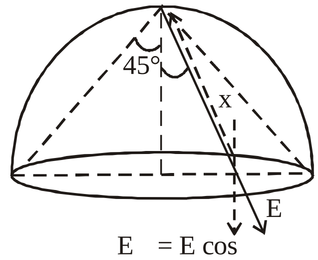


(A) ϕ total due to charge Q is $=\dfrac{Q}{\varepsilon_0}$ so ϕ through the curved and flat surface will be less than $\dfrac{Q}{\varepsilon_0}$

(B) The component of the electric field perpendicular to the flat surface will decrease so we move away from the centre as the distance increase (magnitude of electric field decreases) as well as the angle between the normal and electric field will increase.

2nd Method

$$x=\frac{R}{\cos\theta}$$



$$E=\frac{KQ}{x^2}=\frac{KQ\cos^2\theta}{R^2}$$

$$E\perp=\frac{KQ\cos^3\theta}{R^2}$$

As we move away from centre $\theta\uparrow$ $\cos\theta$ so$\downarrow$ $E\perp\downarrow$

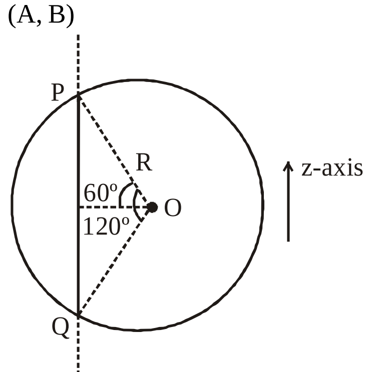
(C) Since the circumference is equidistant from 'Q' it will be equuipotential $V=\dfrac{KQ}{\sqrt{2}R}$

(D) $\Omega=2\pi(1-\cos\theta);\theta=45°$

$$\phi=-\frac{\Omega}{4\pi}\times\frac{Q}{\varepsilon_0}=-\frac{2\pi(1-\cos\theta)}{4\pi}\frac{Q}{\varepsilon_0}$$

$$=-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$$

Q.15 (A, B)



Field due to straight wire is perpendicular to the wire & radially outward. Hence $E_z = 0$

Length, PQ = 2R sin 60 = $\sqrt{3}R$ According to Gauss's law

total flux = $\oint \vec{E}.\vec{ds}=\dfrac{q_{in}}{\epsilon_0}=\dfrac{\lambda\sqrt{3}R}{\epsilon_0}$

Q.16 (B)

(i) $E = \frac{KQ}{d^2} \Rightarrow E \propto \frac{1}{d^2}$

(ii) Dipole

$$E = \frac{2kp}{d^3}\sqrt{1+3\cos^2\theta}$$

$$E \propto \frac{1}{d^3} \text{ for dipole}$$

(iii) For line charge

$$E = \frac{2k\lambda}{d}$$

$$E \propto \frac{1}{d}$$

(iv) $E = \frac{2K\lambda}{d-\ell} - \frac{2K\lambda}{d+\ell}$

$$= 2K\lambda\left[\frac{d+\ell-d+\ell}{d^2-\ell^2}\right]$$

$$E = \frac{2K\lambda(2\ell)}{d^2\left[1-\frac{\ell^2}{d^2}\right]}$$

$$E \propto \frac{1}{d^2}$$

(v) Electric field due to sheet

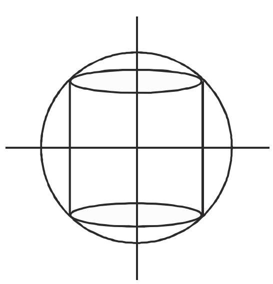
$$\in = \frac{\sigma}{2\in_0}$$

$\in$ = v is independent of r

Q.17 (A,B,D)

For option (1), cylinder encloses the shell, thus option is correct

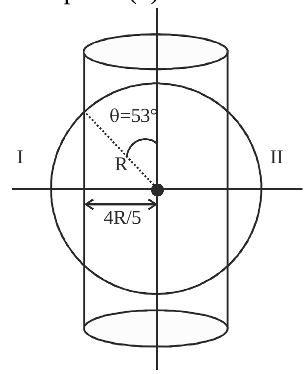
For option (2),



cylinder perfectly enclosed by shell,

thus ϕ = 0, so option is correct.

for option (3)



$$\phi = \frac{2\times Q}{2\in_0}(1-\cos 53^\circ) = \frac{2Q}{5\in_0}$$

For option (4) :

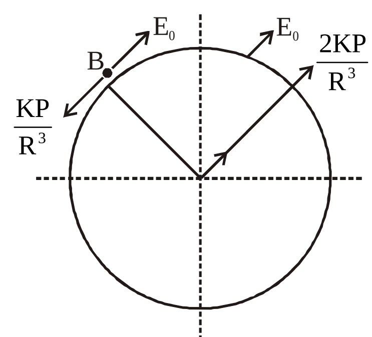
Flux enclosed by cylinder = $\phi = \frac{2Q}{2\in_0}(1-\cos 37^\circ) = \frac{Q}{5\in_0}$

Q.18 (A,D)

(1) $\vec{P} = \frac{P_0}{\sqrt{2}}(\hat{i}+\hat{j})$

E.F. at B along tangent should be zero since circle is equipotential.

So, $E_0 = \frac{K|\vec{P}|}{R^3}$ & $E_B = 0$



So, $R^3 = \frac{KP_0}{E_0} = \left(\frac{P_0}{4\pi\in_0 E_0}\right)$

So $R = \left(\frac{P_0}{4\pi\in_0 E_0}\right)^{1/3}$

So, (1) is correct

(2) Because E_0 is uniform & due to dipole E.F. is different at different points, so magnitude of total E.F. will also be different at different points

So, (2) is incorrect

(3) $E_A = \frac{2KP}{R^3} + \frac{KP}{R^3} = 3\frac{KP}{R^3}\frac{P}{\sqrt{2}}\left(\hat{i}+\hat{j}\right)$

So, (3) is wrong

(4) $E_B = 0$

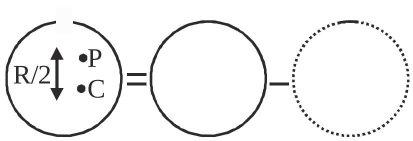
so, (4) is correct

Q.19 (A)

Let charge on the sphere initially be Q.

$\therefore \frac{kQ}{R} = V_0$

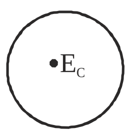
and charge removed = αQ

(1) 

and $V_P = \frac{kQ}{R} - \frac{2kQ\alpha}{R} = \frac{kQ}{R}(1-2\alpha)$

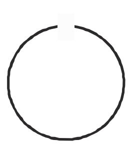
$V_C = \frac{kQ(1-\alpha)}{R}$

$\therefore \frac{V_C}{V_P} = \frac{1-\alpha}{1-2\alpha}$



(2) $(E_C)_{initial}$ = zero

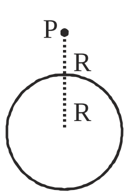
$(E_C)_{initial} = \frac{k\alpha Q}{R^2}$

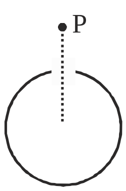


$\Rightarrow$ Electric field increases

(3) $(E_P)_{final} = \frac{kQ}{4R^2} - \frac{k\alpha Q}{R^2}$

$\Delta E_P = \frac{kQ}{4R^2} - \frac{kQ}{4R^2} + \frac{k\alpha Q}{R^2} = \frac{k\alpha Q}{R^2} = \frac{V_0\alpha}{R}$

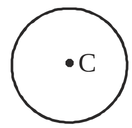


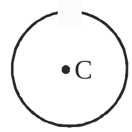


(4) $(V_C)_{initial} = \frac{kQ}{R}$

$(V_C)_{final} = \frac{kQ(1-\alpha)}{R}$

$\Delta V_C \frac{kQ}{R}(\alpha) = \alpha V_0$





Q.20 (B,C)

$a_y = -400\sqrt{3}\times10^{10}$ $[qE_y = ma_y]$

$R = 5 = \frac{40\times10^{12}\sin2\theta}{400\sqrt{3}\times10^{10}}\left[R\left(\text{range}\right) = \frac{u^2\sin2\theta}{a_y}\right]$

$\sin2\theta = \frac{\sqrt{3}}{2}$

$2\theta = 60^\circ, 120$ $\Rightarrow \theta = 30^\circ, 60^\circ$

Time of flight $T_1 = \frac{2\times2\sqrt{10}\times10^6\times\frac{1}{2}}{400\sqrt{3}\times10^{10}} = \sqrt{\frac{5}{6}}\mu s$

(for $\theta=30^\circ$)

Time of flight $T_2 = \frac{2\times2\sqrt{10}\times10^6\times\frac{\sqrt{3}}{2}}{400\sqrt{3}\times10^{10}} = \sqrt{\frac{5}{3}}\mu s$

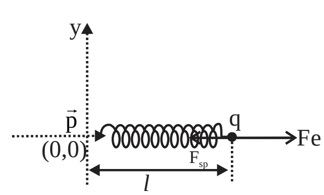
(for $\theta=60^\circ$)

Q.21 (3.14)

$\Delta\ell \to x$

At $\ell : Fe = F_{SP}$

$k\ell = \frac{2kpq}{\ell^3}$



$F_{net} = F_{sp} - Fe = k\left(\ell+x\right) - \frac{q\left(2kp\right)}{\left(\ell+x\right)^3}$

$$= k(x+\ell) - \frac{q(2kp)}{\ell^3 (1 + x/\ell)^3}$$

$$kx + k\ell - q\left(\frac{2kp}{\ell^3}\right)\left(1 - \frac{3x}{\ell}\right)$$

$$= kx + k\ell - q\left(\frac{2kp}{\ell^3}\right) + \frac{2kpq}{\ell^3}\cdot\frac{3x}{\ell}$$

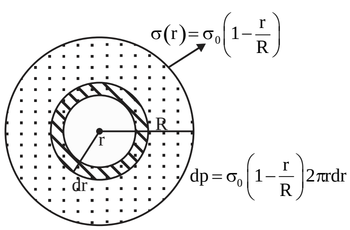
$$F_N = kx + k\ell\left(\frac{3x}{\ell}\right) = 4kx$$

$$k_{eq}=4k \quad T = 2\pi\sqrt{\frac{m}{4k}} = \pi\sqrt{\frac{m}{k}}$$

$$f = \frac{1}{\pi}\sqrt{\frac{k}{m}}$$

So $\delta = \pi = 3.14$

Q.22 (6.40)



$$\phi = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^R \sigma_0\left(1 - \frac{r}{R}\right)2\pi r\,dr}{\varepsilon_0}$$

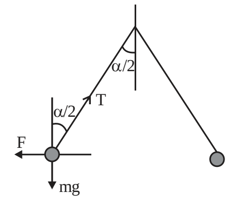
$$\phi = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^{R/4} \sigma_0\left(1 - \frac{r}{R}\right)2\pi r\,dr}{\varepsilon_0}$$

$$\therefore \frac{\phi_0}{\phi} = \frac{\sigma_0 2\pi\int_0^R\left(r - \frac{r^2}{R}\right)dr}{\sigma_0 2\pi\int_0^{R/4}\left(r - \frac{r^2}{R}\right)dr}$$

$$= \frac{\frac{R^2}{2} - \frac{R^2}{3}}{\frac{R^2}{32} - \frac{R^2}{3\times 64}} = \frac{32}{5} = 6.40$$

Q.23 (A,C)

The net electric force on any sphere is lesser but by Coulomb law the force due to one sphere to another remain the same.



In equilibrium

$$T\cos\frac{\alpha}{2} - mg$$

and $T\sin\frac{\alpha}{2} = F$

After immersed is dielectric liquid.
As given no change in angle α.

So $T\cos\frac{\alpha}{2} = mg - V\rho g$

when ρ=800 Kg/m^3

and $T\sin\frac{\alpha}{2} = \frac{F}{e_r}$

$$\therefore \frac{mg}{F} = \frac{mg - V\rho g}{\frac{F}{e_r}}$$

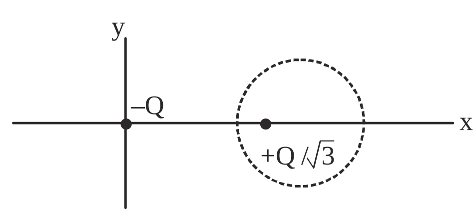
$$\frac{1}{e_r} = 1 - \frac{\rho}{d}$$

d=density of sphere

$$\frac{1}{21} = 1 - \frac{800}{d}$$

d=840

Two point charges –Q and +Q $\sqrt{3}$ are placed in the xy-plane at the origin (0, 0) and a point (2, 0), respectively, as shown in the figure. This results in an equipotential circle of radius R and potential V = 0 in the xy-plane with its center at (b, 0). All lengths are measured in meters.



Q.24 (1.73)

Q.25 (3.00)

ELEMENTRY

Q.1 (4)

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

Q.2 (2)

By using $V_{big} = n^{2/3} v_{small}$

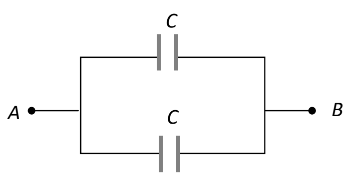
$$\Rightarrow \frac{V_{big}}{v_{small}} = (8)^{2/3} = \frac{4}{1}$$

Q.3 (1)

Q.4 (1)

Q.5 (1)

The given circuit is equivalent to a parallel combination two identical capacitors



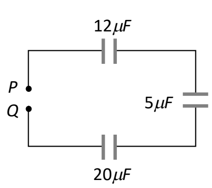
Hence equivalent capacitance between A and B is

$$C = \frac{\varepsilon_0 A}{d} + \frac{\varepsilon_0 A}{d} = \frac{2\varepsilon_0 A}{d}$$

Q.6 (2)

The given circuit can be drawn as

where C = (3 + 2) μF = 5 μF

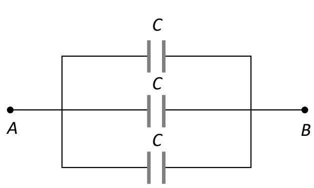


$$\frac{1}{C_{PQ}} = \frac{1}{5} + \frac{1}{20} + \frac{1}{12} = \frac{20}{60} = \frac{1}{3}$$

$\Rightarrow C_{PQ} = 3$ μF

Q.7 (2)

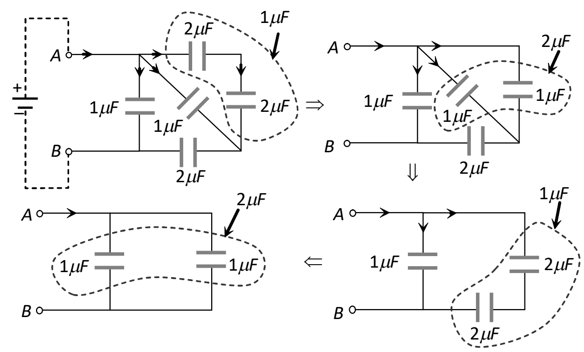
The given circuit can be redrawn as follows



$\Rightarrow C_{AB} = 3C$

Q.8 (2)

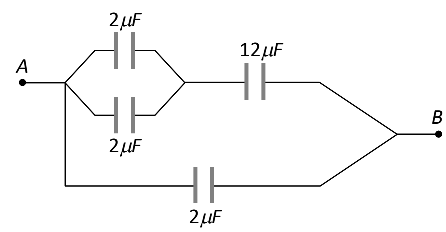
The given circuit can be simplified as follows



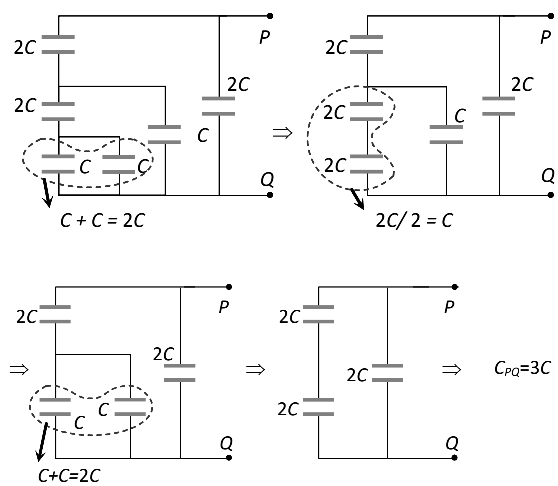
Hence equivalent capacitance between A and B is 2μF.

Q.9 (3)

The circuit can be rearranged as



Q.10 (1)



Q.11 (3)

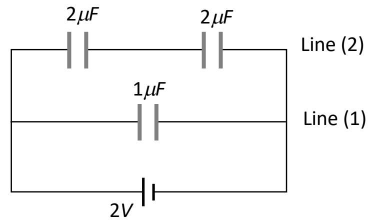
Charge on C_1 = charge on C_2

$\Rightarrow C_1(V_A - V_D) = C_2\,(V_D - V_B)$

$$\Rightarrow C_1(V_1 - V_D) = C_1(V_D - V_2) \Rightarrow V_D = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

Q.12 (4)

Potential difference across both the lines is same i.e. 2 V. Hence charge flowing in line 2



$Q = \left(\frac{2}{2}\right) \times 2 = 2\ \mu C$. So charge on each capacitor in line (2) is 2 μC

Q.13 (3)

Given circuit can be reduced as follows

In series combination charge on each capacitor remain same. So using Q = CV

$\Rightarrow C_1V_1 = C_2V_2 \Rightarrow 3\ (1200 - V_p) = 6\ (V_P - V_B)$

$\Rightarrow 1200 - V_p = 2V_p$ $(\because V_B = 0)$

$\Rightarrow 3V_p = 1200 \Rightarrow V_p = 400$ volt

Q.14 (4)

$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 2 \times 10^{-6} \times (50)^2 = 25 \times 10^{-4} J = 25 \times 10^3$ erg

Q.15 (1)

Let $E = \frac{1}{2}C_0V_0^2$ then, $E_1 = 2E$ and $E_2 = \frac{E}{2}$

So $\frac{E_1}{E_2} = \frac{4}{1}$

Q.16 (2)

In series combination of capacitors, voltage distributes on them, in the reverse ratio of their capacitance

i.e. $\frac{V_A}{V_B} = \frac{3}{2}$ ......(i)

Also $V_A + V_B = 10$ ....(ii)

On solving (i) and (ii) $V_A = 6V$, $V_B = 4V$

Q.17 (2)

$U = \frac{Q^2}{2C}$; in given case C increases so U will decrease

Q.18 (3)

$$C_R = C_1 + C_2 = \frac{k_1\varepsilon_0A_1}{d} + \frac{k_2\varepsilon_0A_2}{d}$$

$$= \frac{2 \times \varepsilon_0 \frac{A}{2}}{d} + \frac{4 \times \varepsilon_0 \frac{A}{2}}{d} = 2 \times \frac{10}{2} + 4 \times \frac{10}{2} = 30\ \mu F$$

Q.19 (4)

$$C_1 = \frac{K_1\varepsilon_0 \frac{A}{2}}{\left(\frac{d}{2}\right)} = \frac{K_1\varepsilon_0A}{d}\ ;\quad C_2 = \frac{K_2\varepsilon_0 \frac{A}{2}}{\left(\frac{d}{2}\right)} = \frac{K_2\varepsilon_0A}{d} \text{ and}$$

$$C_3 = \frac{K_3\varepsilon_0A}{2d} = \frac{K_3\varepsilon_0A}{2d}$$

$$\text{Now, } C_{eq} = C_3 + \frac{C_1C_3}{C_1 + C_2} = \left(\frac{K_3}{2} + \frac{K_1K_2}{K_1 + K_2}\right) \cdot \frac{\varepsilon_0A}{d}$$

JEE-MAIN OBJECTIVE QUESTIONS

Q.1 (1)

$Q_t = Q_1 + Q_2 = 150\mu C$

$\frac{Q_1'}{Q_2'} = \frac{C_1}{C_2} = \frac{1}{2} \Rightarrow Q_1' = 50\mu C$

$Q_2' = 100\mu C$

25μC charge will flow from smaller to bigger sphere .

Q.2 (4)

Charge is flow until potential are equal and in charge flow energy is decrease

$\frac{Q_1}{C_1} = \frac{Q_2}{C_2} \Rightarrow Q_1R_2 = Q_2R_1$.

Q.3 (1)

$C = 4\pi\varepsilon_o R$

$R = \frac{C}{4\pi \in_0} = 1 \times 10^{-6} \times 9 \times 10^9 = 9$ km

Q.4 (4)

Charge / Current flows from higher to lower potential or Q/C ratio.

Q.5 (1)

Charge / Current flows from higher to lower potential or Q/C ratio.

$$V_A = \frac{KQ}{R},\ V_B = \frac{KQ}{2R} \qquad \Rightarrow V_A > V_B$$

$$A \rightarrow B$$

Q.6 (2)

Given $C = \dfrac{\epsilon_0 A}{d}$

If separation is halved d' = d/2

$$C' = \epsilon_0 A/d' = \frac{\epsilon_0 A \times 2}{d} = 2C$$

Q.7 (4)

$$C = \frac{k\epsilon_0 A}{d}$$

where k = dielectric constant of medium between the plates

A = Area, d = distance between the plates

Q.8 (3)

$C_i = 4\pi\epsilon_0 r$

$C_f = 4\pi\epsilon_0 R$

The volume of the n drops is equal to the bigger drop.

$$N\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$R = N^{1/3} r$

$C_f = N^{1/3}\, 4\pi\epsilon_0 r$

Q.9 (3)

$$V_1 : V_2 = \frac{1}{C_1} : \frac{1}{C_2} = C_2 : C_2$$

$$V_1 = \frac{C_2}{C_2 + C_1} V$$

Q.10 (3)

$Q_1 = 900\mu C$

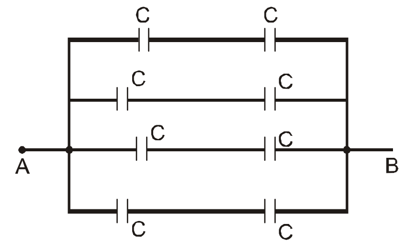
$Q_2 = 2500\mu C$

When the two capacitors are connected together let the common potential is V.

$$900 + 2500 = (3+5)V$$

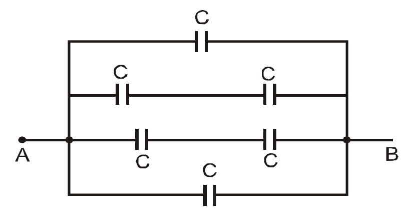
$$V = \frac{3400}{8} = 425V$$

Q.11 (2)



$$C_{eq} = \frac{4C}{2} = 2C.$$

Q.12 (3)



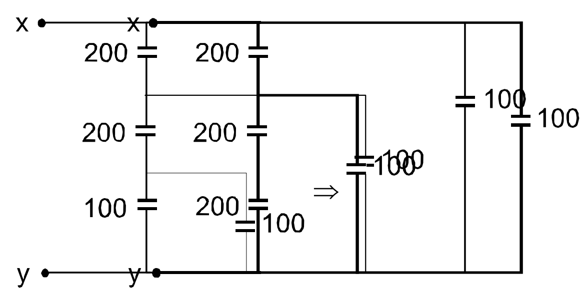
$$C_{eq} = C + \frac{2C}{2} + C = 3C.$$

Q.13 (4)

$$\frac{1}{C_1} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} \Rightarrow C_1 = 1\ \mu F,\ C_2 = 2 + 1 = 3\ \mu F$$

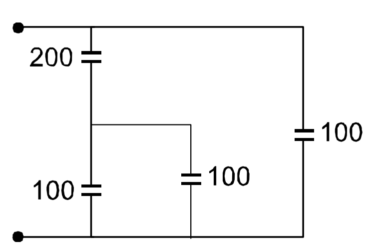
$C_{eq} = 1\mu F.$

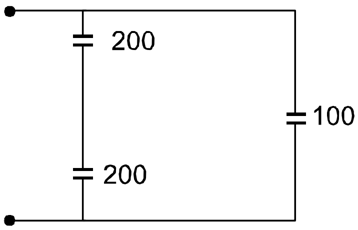
Q.14 (2)

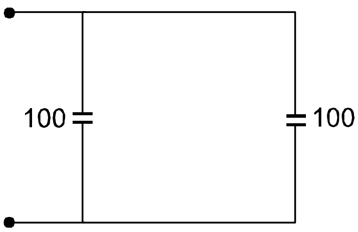


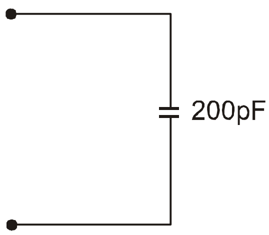
solving by parallel series combinations,

⇒



⇒ 

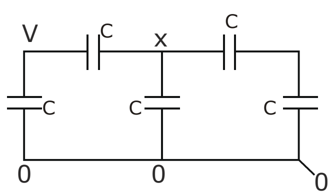
⇒ 

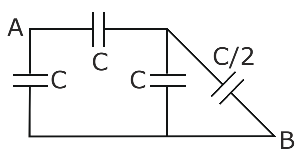
⇒ 

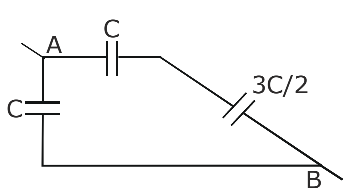
C_{eq} = 200 pF

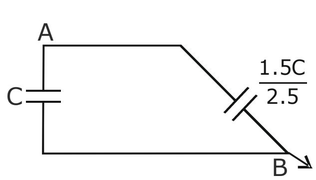
Q.15 (2)

Solving the circuit using following steps



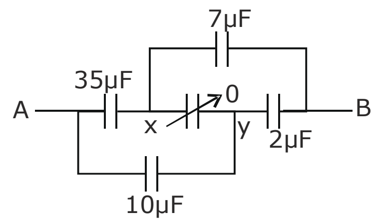


⇒ 

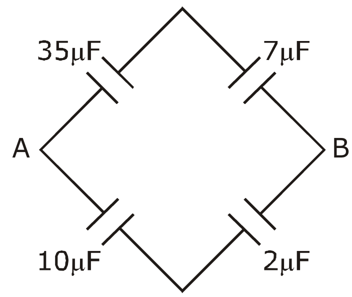
⇒ 

Resultant capacitance of the circuit = 1.6C

Q.16 (2)

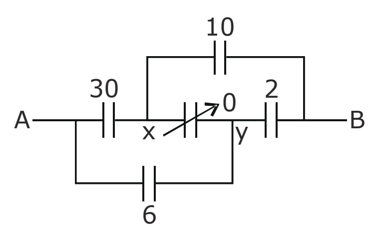


As the resulting circuit is a Wheat stone bridge hence current in 13μF capacitor is zero. Hence the circuit now reduces to

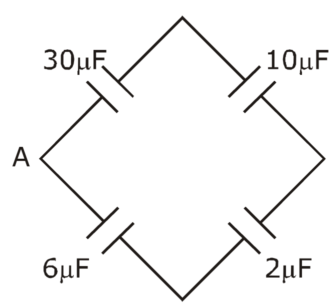


The resultant capacitance is $\frac{35}{6} + \frac{10}{6} = \frac{45}{6} = \frac{15}{2}$ μF

Q.17 (2)

⇒ 

As the resulting circuit is a Wheat stone bridge hence current in 5μF capacitor is zero. Hence the circuit now reduces to



The resultant capacitance is $\frac{30}{4} + \frac{6}{4}$ = 9μF

Q.18 (2)

Isolated capacitor ⇒ Q = constant

separation d increase ⇒ C = decrease

Q = CV ⇒ V = increase

Q.19 (4)

The curve shown is for a function xy = constant

Q = CV

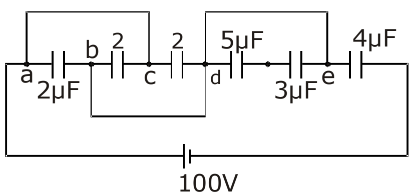
Q.20 (1)

$$E = \frac{1}{2}\varepsilon_o E^2$$

$$2.2 \times 10^{-10} = \frac{1}{2}\ 8.8 \times 10^{-12}\ E^2$$

$E = 7\ NC^{-1}$

Q.21 (4)



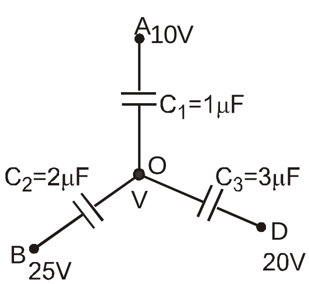
Since potential of point d & e is same. No charge will be stored on 5μF capacitor.

Q.22 (3)

Force between plates = qE

$$= \frac{q\sigma}{2\epsilon_0} = \left(\frac{q}{2A\varepsilon_0}\right) q = kx,\ x = \frac{q^2}{2A\varepsilon_0 K}$$

Q.23 (1)



From junction law

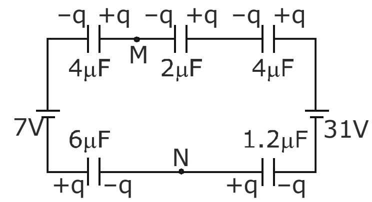
(V – 10)1 + (V – 20)3 + (V + 25)2 = 0

6V = 120

V = 20 Volt

Q.24 (2)

Let q be the charge on all the capacitor



Apply KVL

$$31 - \frac{q}{4} - \frac{q}{2} - \frac{q}{4} - 7 - \frac{q}{6} - \frac{q}{12} = 0$$

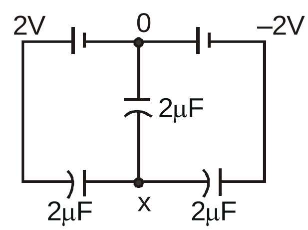
$$24 = \left[\frac{3+6+3+2+10}{12}\right] q$$

q = 12 μC

$$\text{Now } V_N + \frac{q}{6} + 7 + \frac{q}{4} = V_M$$

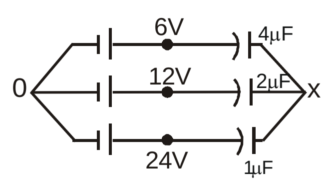
$V_M - V_N = 12$ V

Q.25 (4)



Applying junction law

$(x - 2)2 + (x - 0)2 + [x - (-2)]2 = 0 \Rightarrow x = 0$



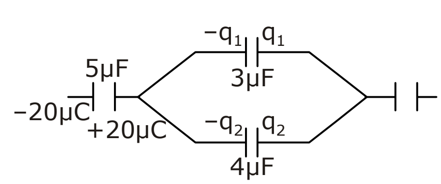
Applying junction law

(x – 6)4 + (x – 12)2 + (x – 24)1 = 0

$$7x = 72 \Rightarrow x = \frac{72}{7} \text{ volt}$$

$$\text{So, } V_a - V_b = 0 - x = -\frac{72}{7} \text{ Volt}$$

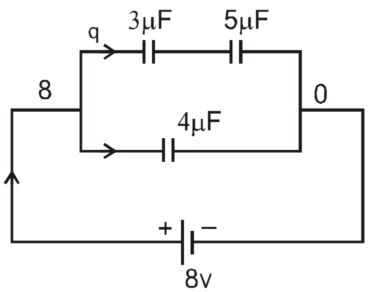
Q.26 (1)



$q_1 : q_2 = 3 : 4$

$q_1 = \frac{3}{7} \times 20\mu C$

Q.27 (2)



$C_{eq} = \frac{15}{8} + 4 = \frac{47}{8}\ \mu F$

$\frac{q}{3} + \frac{q}{5} = 8 \Rightarrow q = 15\mu C$

Charge on 2μF

$\frac{q_1}{2} = \frac{15 - q_1}{3} \Rightarrow q_1 = \frac{30}{5} = 6.0\mu C$

Q.28 (1)

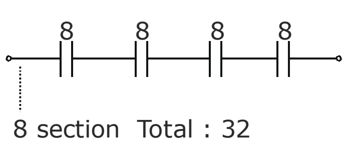
$V_1 : V_2 = \frac{1}{C_1} : \frac{1}{C_2} = C_1 : C_2$

$\frac{V_1}{V_2} = \frac{C_1}{C_2} = \frac{1}{4}$

Q.29 (4)

To form a composite of 1000 V we need 4 capacitance in series.

4 capacitance in series means in each branch capacitance is 2 μF. So 8 branches are needed in parallel. So a total of 8 × 4 = 32 capacitors are required.



Q.30 (3)

For charge in 5μF capacitor

$C_1 : C_2 = 2 : 5$

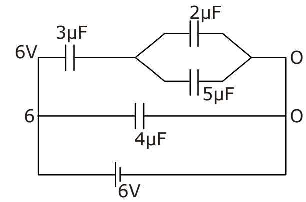
$\frac{q_1}{q_2} = \frac{C_1}{C_2}$

$q_2 = \frac{5 \times 18}{10}$

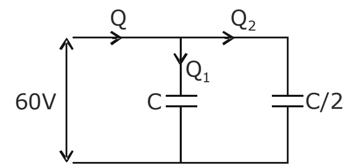
charge on 5μF capacitor is 9μC

charge on 4μF capacitor is 24μC

Ratio of charges = 9 : 24 = 3 : 8



Q.31 (4)



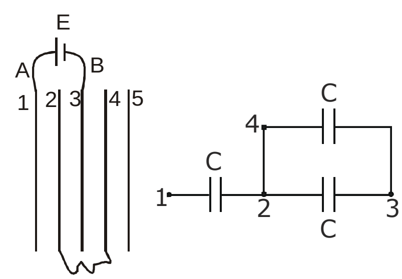
$Q = \frac{3}{2} C \times 60 = 90C$

$Q_1 : Q_2 = C_1 : C_2 = 2 : 1$

$Q_2 = \frac{1}{3} \times 90 = 30\ C$

Potential difference across C = $\frac{30C}{C}$ = 30 V

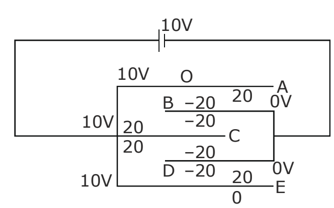
Q.32 (2)



$C_{eq} = \frac{2C \times C}{3C} = \frac{2 \in_0 A}{3d}$

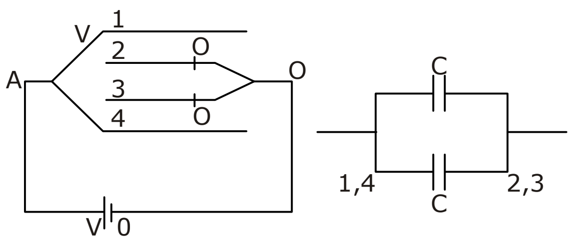
$Q = \frac{2}{3} \times \frac{\in_0 A}{d} \times E$

Q.33 (2)



Total charge on plate C = 40 μC

Q.34 (2)



$C_{eq} = 2C = \frac{2\varepsilon_0 A}{d}$

Q.35 (1)

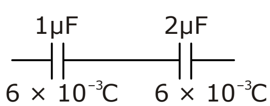
Maximum charge on first capacitor $q_{1_{max}} = 160\mu C$

Maximum charge on second capacitor $q_{2_{max}} = 1280$ μC.

As capacitors are connected in series. Hence maximum charge they can store is $160\mu C$.

Q.36 (4)

Maximum charge on 1st capacitor = 6×10^{-3}C.
Maximum charge on 2nd capacitor = 8×10^{-3}C.
In series the maximum charge they can have is 6×10^{-3}C



Hence maximum voltage =

$$V = \frac{6\times10^{-3}}{1\times10^{-6}} + \frac{6\times10^{-3}}{2\times10^{-6}} = 9KV$$

Q.37 (1)

$Q_{1max} = 3\ C \times 10^3$ C.
$Q_{2max} = 4\ C \times 10^3$ C.
Q_{max} for first branch $3\ C \times 10^3$ C

$$V_{max_1} = \frac{3C\times10^3\times5C}{6C^2} = \frac{5}{2}KV$$

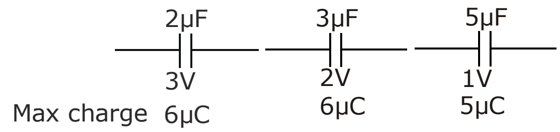
Similarly for second branch

$Q_{3_{max}} = 7C \times 10^3$ C $\quad Q_{4_{max}} = 6C \times 10^3$C

$$V_{max_2} = \frac{6C\times10^3}{21C^2}\times10C = \frac{20}{7}kV$$

The two branches are in parallel. So in order to find max value of voltage for which no capacitor breaks down $V_{max_1} < V_{max_2}$.

Q.38 (2)



Hence maximum charge that the series can with stand is 5 μC. So break down voltage = $5 \times \frac{31}{30} = \frac{31}{6}$ volt

Q.39 (1)

Force between capacitor plates is equal to $\frac{\sigma^2 A}{2\epsilon_0}$.

As the system is in equilibrium

$$\frac{\sigma^2 A}{2\epsilon_0} = mg$$

Q.40 (2)

Force between the plates is given by

$\frac{\sigma^2 A}{2\epsilon_0}$ or

$$F = q\frac{E}{2} = \frac{1\times10^{-6}\times10^5}{2}$$

[$\frac{E}{2}$ as electric field is due to charges on a single plate is to be written] $\frac{0.1}{2}N = 0.05Nt$

Q.41 (3)

We know that force between plates is

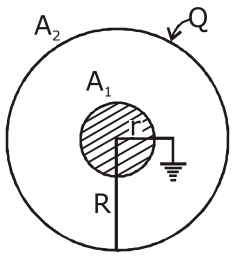
$$\frac{\sigma^2 A}{2\epsilon_0} = \frac{Q^2}{2A\epsilon_0} = \frac{C^2V^2}{2A\epsilon_0}$$

$$= \frac{\epsilon_0^2 A^2V^2}{2A\epsilon_0 d^2} = \frac{\epsilon_0 AV^2}{2d^2}$$

$$C_i = \frac{\epsilon_0 Av^2}{2d^2} \quad C_f = \frac{\epsilon_0 Av^2\times4}{2d^2}$$

Q.42 (3)

Let us assume charge on A_1 is q and potential of A_1 is zero as it is earthed.

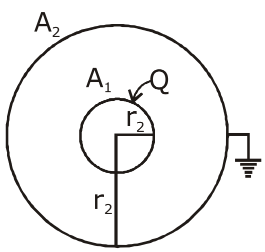


Potential of A_1 is due to charges Q & q. So we can write the equation as

$$V = \frac{KQ}{r}q + \frac{KQ}{R} = 0$$

$$\frac{q}{r} = \frac{-Q}{R} \Rightarrow q = \frac{-Qr}{R}$$

Q.43 (1)



The system from a sperical capacitor and for a spherical capacitor capacitance is given by :

$$C = \frac{4\pi\varepsilon_o r_1 r_2}{r_2 - r_1}$$

Q.44 (3)

$$U = \frac{1}{2}CV^2$$

$$= \frac{1}{2} \times 4 \times 10^{-6} \times (1 \times 10^3)^2$$

= 2 Joules.

Q.45 (1)

Charge carries electrical energy so capacitor stores electrical energy.

Q.46 (2)

$$W = U_f - U_i = \frac{1}{2}CV_f^2 - \frac{1}{2}CV_i^2 = \frac{1}{2}\ C\ (40^2 - 20^2)$$

W = 600 C

$$W_1 = \frac{1}{2}\ C\ (50^2 - 40^2) = \frac{900}{2}\ C$$

$$W_1 = \frac{900}{2} \cdot \frac{W}{600} = \frac{3}{4}\ W$$

Q.47 (4)

As battery is disconnected, charge remains constant in the work process.

Work done = final potential energy – initial potential energy

$$= \frac{Q^2}{2C'} - \frac{Q^2}{2C}$$

$$= \frac{Q^2}{2}\left\{\frac{1}{C'} - \frac{1}{C}\right\}$$

Where, $Q = CV = \frac{A \epsilon_o V}{d}$, $C = \frac{A \epsilon_o}{d}$ & $C' = \frac{A \epsilon_o}{2d}$

Now, work done = $\frac{\epsilon_0 AV^2}{2d}$

Q.48 (1)

Initially

$$U_i = \frac{1}{2}CV^2 = \frac{1}{2} \times 0.5 \times 10^{-6} \times 10^4 = 0.25 \times 10^{-2}\,J$$

When the 0.5 μF capacitor is connected to an uncharged capacitor let the common potential is V.

0.5 × 100 = 0.7 V

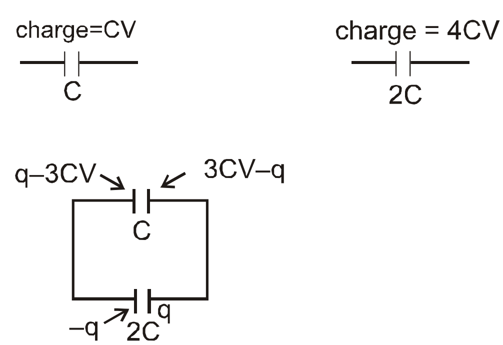
$$V = \frac{0.5 \times 100}{0.7} = \frac{500}{7}\,\text{Volt}$$

$$U_f = \frac{1}{2} \times 0.7 \times 10^{-6} \times \frac{500}{7} \times \frac{500}{7}$$

$= 1.78 \times 10^{-3}$ J

Loss = $U_f - U_i = 0.72 \times 10^{-3}$ J

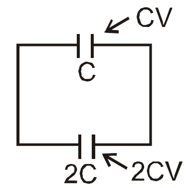
Q.49 (3)



Total charge = 4 CV – CV = 3 CV

Now, let it is distributed as shown, potential across the capacitors is same

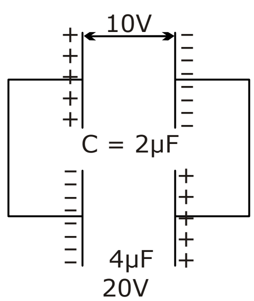
So, $\frac{q}{2C} = \frac{3CV - q}{C}$ $\Rightarrow q = 2\text{ CV}$



Total potential energy = $\frac{Q_1^2}{2C_1} + \frac{Q_2^2}{2C_2} = \frac{C^2V^2}{2C} +$

$\frac{4C^2V^2}{2\times 2C} = \frac{3CV^2}{2}$

Q.50 (2)



Before connection

$Q_1 = 2 \times 10 = 20$, $Q_2 = 4 \times 20 = 80$

$U_i = \frac{1}{2}\, 2(10)^2 + \frac{1}{2} 4\,(20)^2 = 900$ J

Since connected as shown

After $Q_{net} = -20 + 80$

Connection =60

$V = \frac{60}{2+4} = 10$ Volt

$U_f = \frac{1}{2} 6(10)^2 = 300$ J

Heat generated = $-U_f + U_i = 600$ J

Q.51 (3)

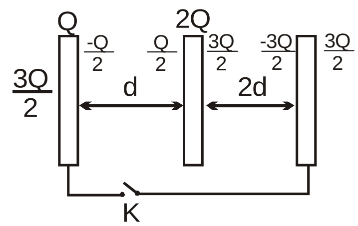
$V_1 : V_2 = \frac{1}{3} : \frac{1}{6} = 2 : 1$

$V_2 = \frac{1}{3} \times 24 = 8$

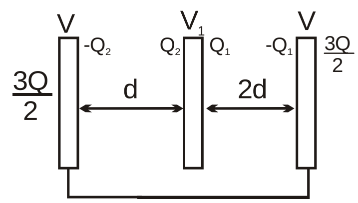
$E = \frac{1}{2}(1)\,(8)^2 = 32\mu J$

Q.52 (1)

Initially



After closing key first and third plate come at same potential.



$E_1 \times 2d = E_2 \times d$

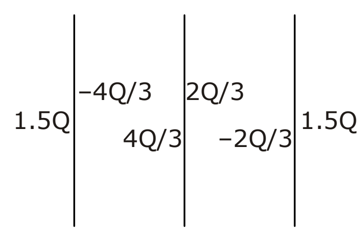
$E_1 = \frac{\sigma_1}{\epsilon_0}$, $V_1 - V = \frac{\sigma_1}{\epsilon_0}\, 2d = \frac{\sigma_2}{\epsilon_0}\, d$

$2\sigma_1 = \sigma_2$

$2Q_1 = Q_2$

$Q_1 + Q_2 = 2Q$

$\Rightarrow 3Q_1 = 2Q \Rightarrow Q_1 = \frac{2Q}{3}$ and $Q_2 = \frac{4Q}{3}$

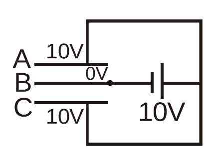


Initial charge on third plate = 0

Final Charge = $\frac{3Q}{2} - \frac{2Q}{3} = \frac{5Q}{6}$

$\therefore$ Charge flown = $\frac{5Q}{6}$

Q.53 (2)



$C = \frac{\epsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 0.1 m^2}{0.885 \times 10^{-3}} = 1 \times 10^{-9}$ F

Energy stored $= \frac{1}{2}(C_1 + C_2)V^2 = 10^{-9} \times 100 = 10^{-7}$ Joule

$\frac{1}{2}$ Ceq. $V^2 = \frac{1}{2} 2CV^2$

Q.54 (2)

$C' = \frac{\epsilon_0 A}{d/2} = \frac{2\epsilon_0 A}{d} = 2C.$

Q.55 (3)
Q = constant
New capacitance = KC (increases)

$V' = \frac{V}{K}$ (decreases)

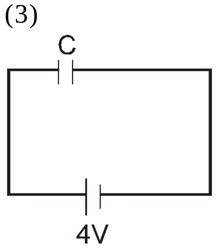
$U' = \frac{Q^2}{2CK}$ (decreases)

$E = \frac{Q}{A\epsilon_0} \Rightarrow E' = \frac{Q}{KA\epsilon_0}$ (decreases)

Q.56 (1)

$V_{C_2} = V_{C_2} = V$
$C_1 = C$
$C_2 = KC$
$q_1 = C_1 V_{C_1} = CV$
$q_2 = C_2 V_{C_2} = KCV$
$q_1 < q_2$.

Q.57 (3)



Here, Potential difference on the capacitor will depend on emf of battery i.e., 4V

Q.58 (1)
Charge or battery = Q = CV = 4 C
Now charge remains same, as battery is disconnected
new capacitance = C´ = KC = 8C
C´V´ = Q

$V' = \frac{Q}{C'} = \frac{4C}{8C} = \frac{1}{2}$ V

Q.59 (1)

$U_0 = \frac{1}{2}CV^2$ (given)

Now energy $= U' = \frac{1}{2}C'V^2$

C´ = CK

$U' = \frac{1}{2}CV^2K = U_oK$

Q.60 (3)
Now, charge remains same on the plates.

$U_0 = \frac{Q^2}{2C}$ (given)

Now energy $= U' = \frac{Q^2}{2C'} = \frac{Q^2}{2CK} = \frac{U_0}{K}$

Q.61 (3)
The charge stored in the capacitor before and after the dielectric is inserted is same so
$Q_i = CV$

$Q_f = (KC)\left(\frac{V}{8}\right)$

$Q_i = Q_f$

Hence $CV = \frac{KCV}{8}$; K = 8

Q.62 (3)
For metal k = ∞
Hence from formula.

$C_{eq} = \frac{\epsilon_0 A}{d - t + t/k}$

$C = \frac{\epsilon_0 A}{(d-t)}$

Q.63 (3)

$V_i = E_i d = \frac{\sigma}{\epsilon_0} d = 3000$

$V_f = E_f d = \frac{\sigma}{\epsilon} d = 1000$

$$\Rightarrow \frac{\in}{\in_0} = 3 \Rightarrow \in = 3\in_0 = 27 \times 10^{-12}\ C^2/Nm^2$$

Q.64 (2)

$$C = \frac{\in_0 A}{d - t + \frac{t}{k}}$$

$$\text{Now } \frac{\in_0 A}{d - t + \frac{t}{k}} = \frac{3}{2}\frac{\in_0 A}{d}$$

$$\left(d - \frac{t}{2}\right) = \frac{2d}{3} \Rightarrow \frac{t}{d} = \frac{2}{3}$$

Q.65 (1)

$V_{max} = E_{max}\, d_{max} = 4000$

$$d = \frac{4000}{18 \times 10^6}$$

$$\text{Now, } C = \frac{\in_0 KA_{min}}{d_{max}} = 7 \times 10^{-2}\ \mu f$$

$$A = \frac{7 \times 10^{-2} \times 10^{-6} \times 4000}{8.85 \times 10^{-12} \times 2.8 \times 18 \times 10^6} = 0.63\ m^2$$

Q.66 (2)

$$\text{Initially } C_{eq} = \frac{C}{2}$$

$$\text{So, } Q_1 = C_{eq} V = \frac{C}{2} E$$

$$\text{Finally } C_{eq} = \frac{C(KC)}{C + CK} = \frac{KC}{1 + K}$$

$$\text{So, } Q_2 = C'_{eq} E = \frac{KCE}{1 + K}$$

So, change flow throw battery = $Q_2 - Q_1$

$$\Delta q = C\,E\left[\frac{K}{1+K} - \frac{1}{2}\right]$$

$$\Delta q = \frac{CE(K-1)}{2(1+K)}$$

Q.67 (1)

$$\text{Charge on capacitor } Q = CV = \frac{\in_0 A}{d} V$$

$$\text{Initial energy} = \frac{1}{2}CV^2 = \frac{\in_0 A}{2d} V^2$$

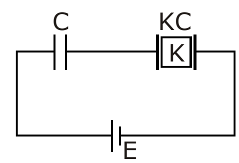
$$\text{Final energy} = \frac{Q^2}{2CK} = \frac{C^2V^2}{2CK} = \frac{1}{2}\frac{CV^2}{K}$$

So,
work done = [Final energy – Initial energy]

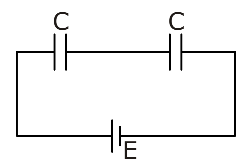
$$= \frac{1}{2}CV^2\left[\frac{1}{K} - 1\right] = \frac{\in_0 AV^2}{2d}\left[\frac{1}{K} - 1\right]$$

Q.68 (3)

$$\frac{Q_1}{Q_2} = K$$



$$C_{eq} = \frac{KC}{K + 1}$$



$$Q_2 = C_{eq}V = \frac{KCE}{K+1},\quad Q_2' = EC/2$$

$$\frac{Q_2'}{Q_2} = \frac{EC}{2\left(\frac{KCE}{K+1}\right)} = (K + 1)/2K$$

Q.69 (3)

As the potential difference is constant hence we can say that

$Q_1 = 60\ \mu C = V \times C$ ....(1)

Now there is already 60 μC on the capacitor.

More 120 μC charge flows from battery. Hence net charge on capacitor is

$Q_2 = 180\ \mu C = V \times KC$ ....(2)

(2) / (1) ⇒ 3 = K

Q.70 (3)

$$U_i = \frac{1}{2}\frac{\left(60 \times 10^{-6}\right)^2}{2 \times 10^{-6}}$$

$= 900 \times 10^{-6}$ J

$$U_f = \frac{1}{2}\frac{\left(180\times10^{-6}\right)^2}{3\times2\times10^{-6}}$$

$$= \frac{180\times180\times10^{-6}}{6\times2} = 2700 \times 10^{-6}\ \text{J}$$

V = 30 volts

Heat produced = 1800 × 10^{-6} J

Q.71 (2)

Charge on 15 μF capacitor A = 1500 μC.

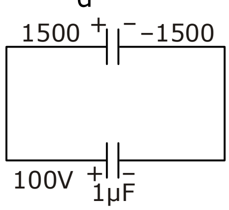
Charge on capacitor B = 100 μC.

When they are connected with dielectric removed from A the capacitor.

Capacitance of A now becomes 1 μF.

$$C_i = \frac{\varepsilon_0 A.15}{d} = 15C = 15\mu F,$$

$$C_f = \frac{\varepsilon_0 A}{d}\ \ C = 1\mu F$$



Q remains constant

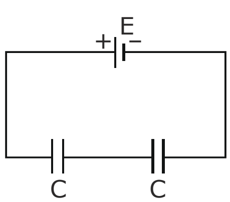
$Q_{net} = C_{eq} \times V_{common}$

1500 + 100 = 2V

V = 800 Volt

Q.72 (4)

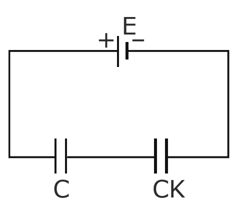
Initially



$$C_{eq}^{n} = \frac{C}{2}$$

$$q_i = \frac{CE}{2}$$

Finally



$$C_{eq}^{n} = \frac{CK}{K+1}$$

$$q_f = \frac{CEK}{K+1}$$

$$q_f - q_i = q_{flown} = \frac{CEK}{K+1} - \frac{CE}{2}$$

$$= \frac{CE(K-1)}{2(K+1)}$$

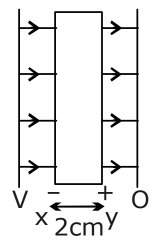
$$\frac{CE}{2} < \frac{CEK}{K+1}$$

So charge flows from C to B.

Q.73 (3)

$$\text{Initially } E = \frac{\sigma}{\epsilon_0} = \frac{q}{A\epsilon_0}$$

= 200 × 10^2 V/m



$$C = \frac{Q}{V} = \frac{Q}{E.d}$$

$$C = \frac{Q}{200\times10^2\times0.05}$$

.... (1)

In final situation

charge remains uncharged

$$C' = \frac{Q}{V'}$$

.... (2)

From (1) & (2)

$$\frac{\epsilon_0 A}{3\times10^{-2}} V = \frac{\epsilon_0 A}{5\times10^{-2}} \times 200\times10^2\times0.05$$

V = 3 × 10^{-2} × 200 × 10^2

= 600 V

Q.74 (4)

The two capacitance C_1 & C_2 behave as a series arrangment as both the capacitors have equal charge on them

$$C_1 = \epsilon_0 \frac{AK_1}{d/2}$$

$$C_2 = \epsilon_0 \frac{AK_2}{d/2}$$

$$C_{eq} = \frac{C_1C_2}{C_1+C_2}$$

$$= \frac{\frac{\varepsilon_o A K_1}{d/2} \times \frac{\varepsilon_o A K_2}{d/2}}{\left(\frac{\varepsilon_o A K_1}{d/2}\right) + \left(\frac{\varepsilon_o A K_2}{d/2}\right)} = \frac{2\varepsilon_o A}{d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)$$

Q.75 (2)

Initially

$$C = 2.5 = \frac{\varepsilon_o A}{d}$$

The two capacitanes act as a paralllel connection

$$C' = \frac{\varepsilon_o A/2}{d} + \frac{K\varepsilon_o A/2}{d}$$

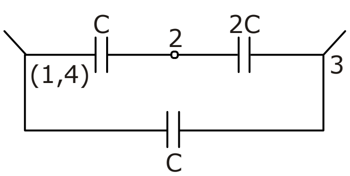
$$5\mu F = \frac{\varepsilon_o A}{2d} + \frac{K\varepsilon_o A}{2d}$$

$$5 = \frac{2.5}{2} + K\frac{2.5}{2}$$

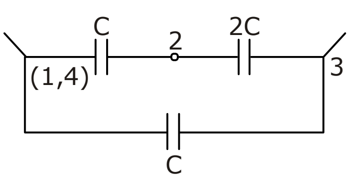
$$\frac{10}{2.5} = K + 1 \Rightarrow K = 3$$

Q.76 (2)

We can express this arrangement as circuit

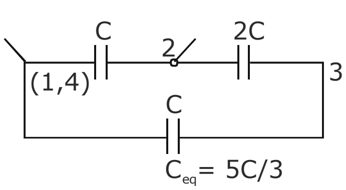


When equivalent capacitance is calculated between 1 & 3 then



$C_1 = \frac{2C}{3} + C = \frac{5C}{3}$

When equivalent capacitance calculated between 2 & 4.



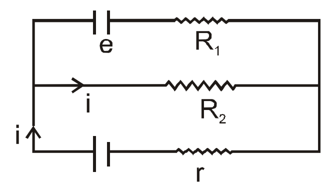
Hence $C_2 = \frac{2C}{3} + C = \frac{5C}{3}$

So $C_1 : C_2$ equal to 1 : 1.

Q.77 (3)

Charge on capacitor = CV = capacitance × (voltage across it)

In steady state, there will be no current through capacitor.



voltage across capacitor $V = iR_2 = \frac{E\ R_2}{R_2 + r}$

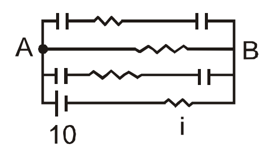
Charge on capacitor $= CiR_2 = \frac{C E R_2}{R_2 + r}$

Q.78 (3)

If S_1 is closed and S_2 is open then, condenser C is fully charged at potential V.

Q.79 (4)

Charge on each capacitor will be same. In steady state current through capacitor will be zero



current in steady state = i = $\frac{10}{5}$ = 2 amp

potential across AB = iR = 2 × 4 = 8 V.

Potential across each capacitor = 4 V

on each plate Q = C V = 3 × 4 = 12 μC

Q.80 (3)

$$q = \frac{q_1}{2} = \frac{8\times10^{-6}\times10}{2}\left(1 - e^{-\frac{0.16\times10^{-3}}{8\times10^{-6}\times20}}\right)$$

$q = 40(1 - e^{-1})\mu C = 40\ (1 - 0.37) = 25.2\mu C$

Q.81 (2)

For capacitors in series $C_{eq} = \frac{C_1C_2}{C_1 + C_2}$

As $C_1 = C_2$ .... $= C_n$ hence

$$C_{eq} = \frac{C}{n}$$

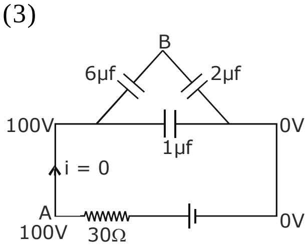
For capacitors in parallel

$$C_{eq} = C_1 + C_2 + C_3 + ...C_n$$

$$C_{eq} = 1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + ...$$

$$= \frac{1}{1 - \frac{1}{2}} = 2\mu F$$

Q.82 (3)



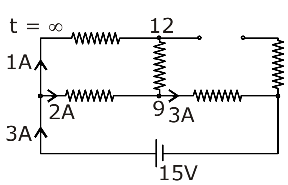
By dividing protential across 6μF & 2μF

$$V_A - V_B = V_{6\mu f} = \frac{100}{(6 + 2)} \times 2$$

$V_A - V_B = V_{6\mu f} = 25V$
Now, $V_B - V_C = V_{2\mu f} = 100 - 25 = 75$ Volt

Q.83 (4)
After steady state capacitor acts as an open circuit.

Q.84 (3)
After steady state capacitor acts as an open circuit.



$R_{eq} = 5\Omega$

$$i = \frac{15}{5} = 3A$$

Hence potential across capacitor is 12 volt.

Q.85 (1)
In steady state $i_1 = 0$

$$\text{So } i_2 = i_3 = \frac{2}{10 + 20} = \frac{1}{15} \text{ Amp.}$$

Q.86 (1)
In steady state $i_1 = 0$

$$\text{So } i_2 = i_3 = \frac{2}{10 + 20} = \frac{1}{15} \text{ Amp.}$$

$$\text{So } V_C = i_2 \times 10 = \frac{2}{3} \text{ Volt} = Q/c$$

$$Q = \frac{2}{3} \times 6 = 4\mu C$$

Q.87 (4)

$$V = V_o e^{-t/RC}$$

$$\frac{V_o}{2} = V_o e^{-t/RC}$$

$$\frac{1}{2} = e^{-t/10\times10^6\times0.1\times10^{-6}}$$

$$e^t = 2$$

t = ln2 = 0.693se

Q.88 (2)

$$\text{As } E = \frac{\sigma}{\epsilon_0}$$

$$\text{And given that } \frac{E_i}{E_f} = 3 \Rightarrow \frac{\sigma_i}{\sigma_f} = 3$$

$$\sigma_i = \frac{Q_0}{A} = 3\frac{Q_f}{A}$$

$\Rightarrow Q_0 = 3Q_f$ Now $Q_f = Q_0e^{-t/RC}$

$$\frac{Q_0}{3} = Q_0e^{-4.4/2R}, \; 3 = e^{2.2/R}$$

$$\Rightarrow R = \frac{2.2}{\ln 3}\,\Omega = 2.0\,\Omega$$

Q.89 (1)
$Q = Q_0e^{-t/RC}$
$Q = [20e^{-t/5\times5}]\mu C$
Here t is in μs.
Now,

$Q_{25} = 20e^{-25/25} = \frac{20}{e}\ \mu C$

$Q_{50} = \frac{20}{e^2}\ \mu C$

so, Heat = [Initial energy – Final energy] of capacitance

$= \frac{1}{2C}\left[Q_{25}^2 - Q_{50}^2\right] = \frac{50}{e^2}\left[1-\frac{1}{e^2}\right]\ \mu J = 4.7\mu J$

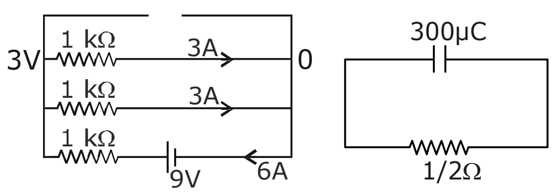
Q.90 (1)
We know that

$i = i_0\ e^{-t/R_{eq}C} \Rightarrow i = i_0/2$

$\frac{1}{2} = e^{-\frac{(\ln 2)10^{-6}}{R_{eq}\times 0.5\times 10^{-6}}}$

$\ln 2 = \ln 2/R_{eq} \times 0.5$
$\Rightarrow R_A + R = 2$
$R_A = 0$

Q.91 (4)
To calculate charge on capacitor consider that capacitor acts as open circuit when completely charged and calculate drop across it which comes out to be 3V.
When s is opened i.e. discharging circuit



$\tau = R_{eq}C$

$= \frac{1}{2}\times 100\times 10^{-6}\times 10^3 = 50\times 10^{-3}$ = 50 ms.

Q.92 (3)
Steps to calculate time constant.
Replace battery by simple wire to find R_{eq}.
Apply formula $\Rightarrow \tau = R_{eq}C$.

$\frac{3R}{4} + R = \frac{7R}{4} = R_{eq}$

Q.93 (2)

$i_1 = \frac{V}{R}\ e^{-t/RC_1}$, $i_2 = \frac{V}{R}\ e^{-t/RC_2}$

$\frac{i_1}{i_2} = e^{-t/R}\left(\frac{1}{C_1}-\frac{1}{C_2}\right) = e^{-t/R}\left(\frac{C_2-2C_2}{2C_2^2}\right) = e^{\frac{t}{2RC_2}}$

With increase in time i_1/i_2 also increases.

Q.94 (4)
Initally the capacitor acts a closed circuit

$i = \frac{2}{1000} = 2$ mA

After steady state capacitor acts as an open circuit i =

$\frac{2}{2000} = 1$ mA

at t = 0, I = 2mA and at t = ∞ ⇒ I = 1mA

Q.95 (2)
The energy dissipated in the 10Ω resistor is equal to initial energy stored is capacitor

$3.6\times 10^{-3} = \frac{Q^2}{2\times 2\times 10^{-6}}$

Q = 120 μC

JEE-ADVANCED OBJECTIVE QUESTIONS

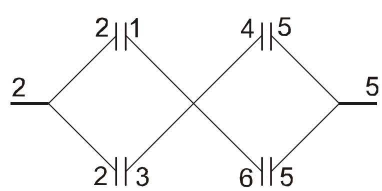
Q.1 (B)
$x = Vt, \Rightarrow d \propto t$

$C = \frac{\epsilon_0 A}{Vt}$

$\frac{dc}{dt} = -\frac{\epsilon_0 A}{V}\frac{1}{t^2}$

$\frac{dc}{dt} \propto \frac{1}{d^2}$

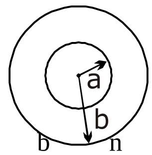
Q.2 (B)



$C_{eq.} = \frac{C}{2}+\frac{C}{2} = C = \frac{\epsilon_0 A}{d}$

Q.3 (A)
$C_1 = 4\pi\varepsilon_0 a$

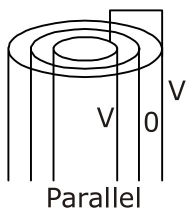
$C_{final} = \dfrac{4\pi\varepsilon_0 ab}{b-a}$



$= \dfrac{4\pi\varepsilon_0 ab}{b\left(1-\dfrac{a}{b}\right)} = \dfrac{4\pi\varepsilon_0 a}{\left[1-\left(\dfrac{n-1}{n}\right)\right]}$ $\dfrac{b}{a} = \dfrac{n}{n-1}$

$= n4\pi\varepsilon_0 a = nc_1$

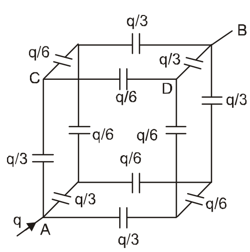
Q.4 (B)



$C = \dfrac{2\pi\epsilon_0}{\ell n b/a} = \dfrac{2\pi\epsilon_0}{\ell n\ 2R/R} + \dfrac{2\pi\epsilon_0}{\ell n\ \dfrac{2\sqrt{2}}{2R}R}$

$= \dfrac{2\pi\epsilon_0}{\ell n\ 2}[1+2] = \dfrac{6\pi\epsilon_0}{\ell n\ 2}$

Q.5 (A)



Due to symmetric charge distribution as shown for loop ACDB

$V_A - \dfrac{q}{3C} - \dfrac{q}{6C} - \dfrac{q}{3C} = V_B \Rightarrow V_A - V_B = \dfrac{5q}{6C} \Rightarrow V_A - V_B$

$= \dfrac{q}{C_{eq}} \Rightarrow C_{eq} = \dfrac{6C}{5}$

Q.6 (D)

Theoritical capacitance = ∞, because d become zero

Q.7 (B)

Charge on C_0, $Q_1 = C_0V_0$,

Initial charge on C_1, $Q_2 = 0$

Common potential $V_1 = \dfrac{Q_1+Q_2}{C_1+C_2} = \dfrac{C_0V_0}{C+C_0} \Rightarrow Q_1 =$

$C_0V_1 = \dfrac{C_0^2}{C+C_0}V_0$

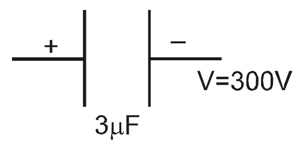
Similarly $V_2 = \dfrac{C_0V_1}{C+C_0} = \left(\dfrac{C_0}{C+C_0}\right)^2 V_0 \Rightarrow Q_2 = C_0V_2$

$= \dfrac{C_0^3}{(C+C_0)^2}V_0$

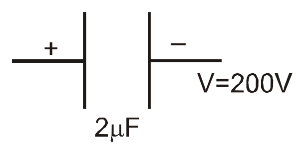
for n times $V_n = \left(\dfrac{C_0}{C+C_0}\right)^n V_0 = V$

$\Rightarrow C = \left[\left(\dfrac{V_0}{V}\right)^{1/n} - 1\right]C_0$

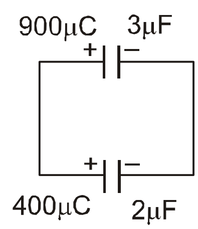
Q.8 (D)



$Q_1 = C_1V_1 = 900\mu C$

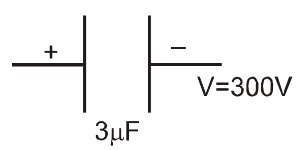


$Q_2 = C_2V_2 = 400\mu C$

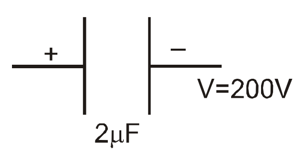


$V = \dfrac{Q_1+Q_2}{C_1+C_2} = \dfrac{900+400}{3+2} = 260V$

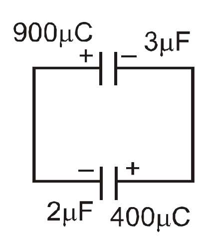
Q.9 (A)



$Q_1 = C_1V_1 = 900\mu C$



$Q_2 = C_2V_2 = 400\mu C$

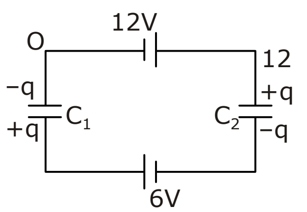


$$V = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{900 - 400}{3 + 2} = 100V$$

Charge on 3μF = C_1V= 300μC

amount of charge flow is = 900μC – 300μC = 600μC
= 6×10^{-4} C

Q.10 (B)



In series charge will be same

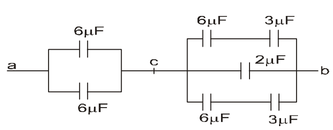
$$12 - \frac{q}{8} + 6 - \frac{q}{4} = 0$$

q = 48 μC

$$V_{C_2} = \frac{48}{8} = 6V$$

$$V_{C_1} = \frac{48}{4} = 12\ V$$

Q.11 (A)

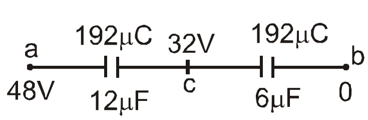


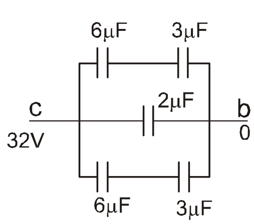
C_{ac} = 6 + 6 = 12μF

$$C_{cb} = 2\left(\frac{6.3}{6+3}\right) + 2 = 6\mu F$$

$$C_{eq} = \frac{12 \times 6}{12 + 6} = 4\mu F$$

Q.12 (D)



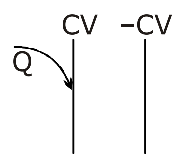


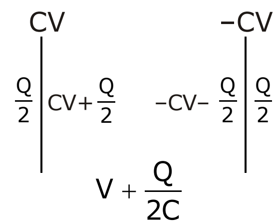
Charge on 2μF capacitor
⇒ Q = CV

Q = 2 × 32 = 64μC

Q.13 (D)
Electric field remains constant but
d↑ ∴ V↑

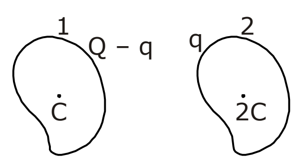
Q.14 (C)





Q.15 (A)

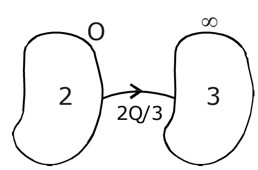
$$V_1 = \frac{Q}{C}$$



$$\therefore\ Q - q = \frac{2Q}{3} \qquad \frac{Q-q}{C} = \frac{q}{2C}$$

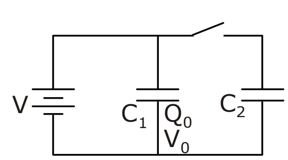
2Q = 3q

$$q = \frac{2Q}{3}$$



$$\therefore\ \frac{Q}{3^N}$$

Q.16 (D)



Correct statement
C_1 and C_2 are parallel So, $V_1 = V_2$

$C_1 = C_2$ and $V_1 = V_2 \Rightarrow Q_1 = Q_2$
Initial change $Q_0 = CV$
Now, $Q_1 = CV$, $Q_2 = CV$

$$\Rightarrow \ Q_0 = \frac{Q_1 + Q_2}{2}$$

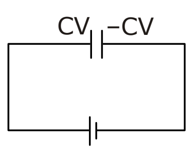
Initial energy $U_0 = \frac{1}{2}CV^2 = U_1 = U_2$

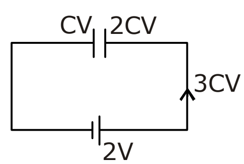
But $U_1 + U_2 \neq U_0$
$U_1 + U_2 = CV^2$

Q.17 (B)
Negative W.D. by external agent

$$\text{Energy} = \frac{Q^2}{2C} \downarrow$$

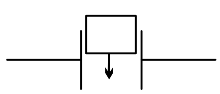
Q.18 (B)





$$\text{Heat} = 6CV^2 - \left\{\frac{1}{2}C(2V)^2 - \frac{1}{2}CV^2\right\}$$

Q.19 (B)



Q = const.

$$\text{Energy} = \frac{Q^2}{2C} = v_i$$

$$U_f = \downarrow ;\ V = \frac{Q}{C} \downarrow$$

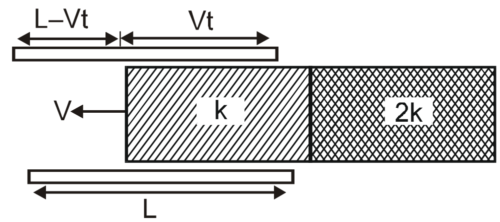
$$\varepsilon = \frac{V}{d} \downarrow$$

Q.20 (A)
After insertion the slab C ↑
but battery is still connected $V = V_0$
$Q > Q_0$

$$\varepsilon = \frac{V}{d} = \text{const.}$$

$$U = \frac{1}{2}CV^2 = \text{const.}$$

Q.21 (B)
Case – I When dielectric slab of dielectric constant K enters in to the capacitor.



At any time t, there will be two capacitors are in parallel combination - one with air and other with dielectric slab.

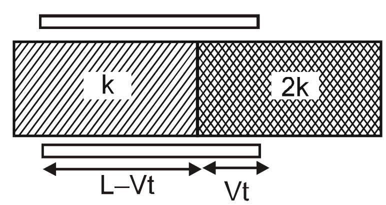
$C(t) = C_{air} + C_{slab}$

$$= \frac{\epsilon_0 A(L - Vt)}{Ld} + \frac{K\epsilon_0 A(Vt)}{Ld}$$

$$= \frac{\epsilon_0 A}{Ld}\,[\,L - (K-1)\,Vt]$$ (linear function of t)

its slope $= M\ C(t) = \frac{\epsilon_0 A}{Ld}(K-1)\,V$

Case – II When dielectric slab of dielectric constant 2K also enters into the capacitor.



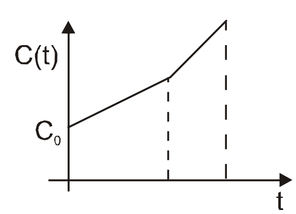
$C'(t) = C_{slab\ 1} + C_{slab\ 2}$

$$= \frac{\epsilon_0 AK(L - Vt)}{Ld} + \frac{\epsilon_0 A2KVt}{Ld}$$

$$= \frac{K\epsilon_0 A}{Ld}\,[L + Vt]$$ (linear function of t)

Its slope $= C'(t) = \frac{\epsilon_0 AKV}{Ld}$

$\Rightarrow C'(t) > C(t)$
and both C(t) and C'(t) are linear function of 't' hence variation of capacitance with time be best represented by (B)



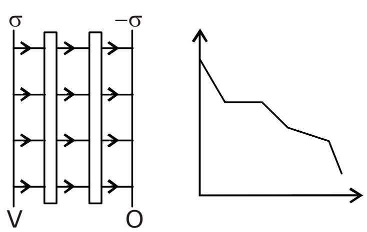
Q.22 (B)

Electric field between two plates of capacitor is given by $\frac{\sigma}{K\epsilon_0}$

When K = 1 then $E = \frac{\sigma}{\epsilon_0}$

then K = K then $E = \frac{\sigma}{K\epsilon_0}$

When K= ∞ then E = 0. From the formula V = E.d.
Now positive plate at x = 0 is at higher potential and potential drops linearly as E is constant.
But as E is the slope of potential v/s distance curve hence inside the dielectric as E decreases hence slope of v v/s x curve for the interval x = 3d to x = 4d also decreases.



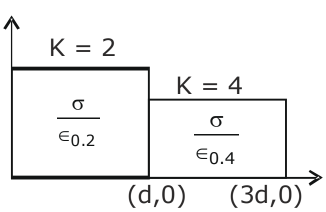
Q.23 (A)

Electric field between two plates of capacitor is given by $\frac{\sigma}{K\epsilon_0}$

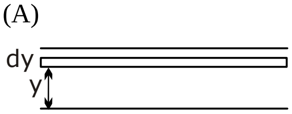
When K = 1 then $E = \frac{\sigma}{\epsilon_0}$

then K = K then $E = \frac{\sigma}{K\epsilon_0}$

On increasing dielectric constant electric field decreases.



Q.24 (A)



$$dc = \frac{\varepsilon_0 A\lambda \sec(\pi y/2d)}{dy}$$

All the elements are in series

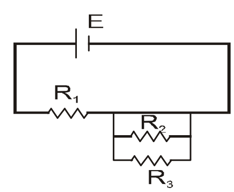
Hence $\frac{1}{C^n_{eq}} = \int_0^d \frac{dy}{\varepsilon_0 A\lambda}\cos\left(\frac{\pi y}{2d}\right)$

$$= \frac{2d}{\varepsilon_0 A\lambda\pi}\left[\sin\left(\frac{\pi y}{2d}\right)\right]_0^d$$

$$C_{eq} = \frac{\varepsilon_0 A\lambda\pi}{2d}$$

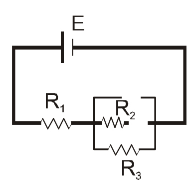
Q.25 (A)

Immediately after the key is closed, capacitor behave like a conducting wire, therefore.



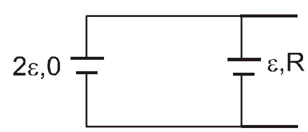
$$i = \frac{E}{R_1}$$

After a long time interval, capacitor behave like a open circuit. Therefore.



$$i = \frac{E}{R_1 + R_3}$$

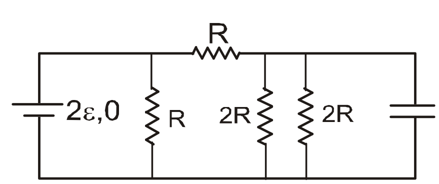
Q.26 (A)



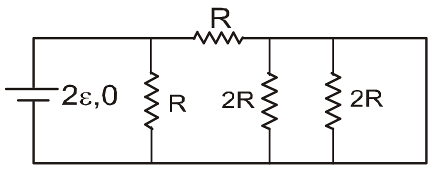
$$\Rightarrow E = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \frac{2\varepsilon R + \varepsilon \times 0}{0 + R}$$

$$\Rightarrow E = 2\varepsilon,\ r_{eq} = \frac{r_1 r_2}{r_1 + r_2} = 0$$

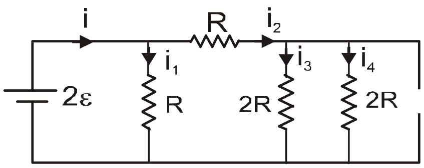
Equivalent battery



$i_{max} = \frac{2\varepsilon}{R}$



for $Q_{max} \Rightarrow$



$i = \frac{2\varepsilon}{2R/3} = \frac{3\varepsilon}{R}$

$i_2 = \frac{\varepsilon}{R}$, $i_1 = \frac{2\varepsilon}{R}$, $i_3 = i_4 = \frac{\varepsilon}{2R}$

potential on C = potential on 2R resistance $= i_3 \times 2R$
$= \varepsilon$

charge on capacitor, $Q_{max} = CV = C\varepsilon$

$\tau = \frac{Q_{max}}{i_{max}} = \frac{C\varepsilon}{2\varepsilon/R} = \frac{RC}{2}$

Q.27 (B)

Just after switch S is closed capacitor act as conducting wire.

$i_1 = \frac{6}{2} = 3A$

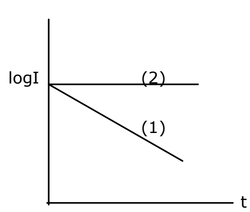
$i_3 = i_2 = 0$

After long time capacitor act as open circuit

$I_1 = I_3 = 0.6$ A

Q.28 (B)

$i = \frac{V}{R} e^{-t/RC}$

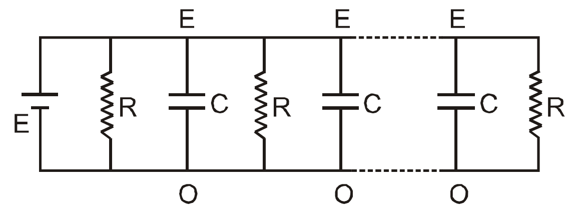


$\log I = \log \frac{V}{R} - \frac{t}{RC}$

at t = 0, log I = const.

For both only one quantity is changed V, R are constant and C changes from 1 to 2. Slope increases magnitude wise and hence C increases.

Q.29 (D)

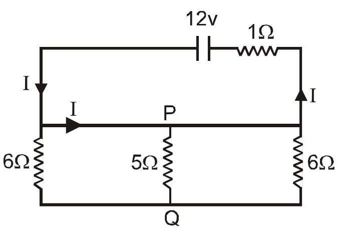


$Q_{first} = Q_{last} = CE$

Ratio $= \frac{Q_{first}}{Q_{last}} = 1.$

Q.30 (D)

Just after switch closing



current through resistor PQ is zero just after closing the switch.

JEE-ADVANCED

MCQ/COMPREHENSION/COLUMN MATCHING

Q.1 (A,B,D)

Magnitude of charge on the charged capacitor decreases and total charge is conserved.

At $V_1 = V_2 \Rightarrow$ no further flow of charge occurs i.e. condition of steady state.

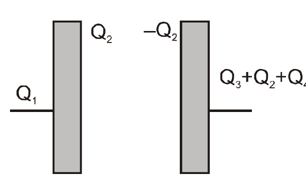
In charge flow energy is consumed in heat.

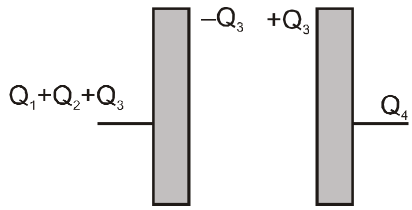
Q.2 (B,C)

Electric field in the capacitor is same at every where which is equal to V/d. so that force at C and B point is same.

Electric field out side the capacitor is zero so that force at A point is zero.

Q.3 (B,C)





Charge on outer surfaces are equal so $Q_1 = Q_3 + Q_2 + Q_4$ ....(i)

and $Q_1 + Q_2 + Q_3 = Q_4$ ....(ii)

$V = \left|\frac{Q_2}{C}\right|$ or $V = \left|\frac{Q_1 - Q_3 - Q_4}{C}\right|$

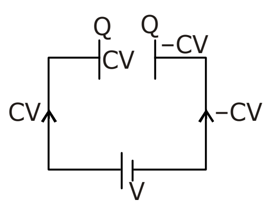
$V = \left|\frac{Q_3}{C}\right|$ or $V = \left|\frac{Q_1 - Q_2 - Q_4}{C}\right|$

Adding (i) and (ii)

$Q_1 = Q_4$ and $Q_2 = -Q_3$

Q.4 (A,C,D)

When two plates of capacitor are connected to a battery. The charges get distributed so that the charges on facing surface are equal & opposite. Also the battery does not create or destroy charges it distributes it.



$Q_1 = Q + CV$

$Q_2 = Q - CV$

Q.5 (A,D)

equivalent capacitance before switch closed is $C_{eq} = \frac{2C}{3}$,

Total charge flow through the cell is $q = \frac{2CE}{3}$

equivalent capacitance after switch S closed is $C_{eq} = 2C$

Total charge flow through the cell is q = 2CE

Therefore some positive charge flow through the cell after closing the switch is $= q_f - q_i = 2CE - \frac{2CE}{3} = \frac{4CE}{3}$

Q.6 (A,B,C,D)

$\frac{1}{C_{eq}} = \frac{1}{20} + \frac{1}{30} + \frac{1}{15} = \frac{3+2+4}{60}$ $C_{eq} = \frac{60}{9} = \frac{20}{3}$ μF

Total charge in this series combination is

$= \frac{20}{3} \times 90$

$q = 600 \mu C$

Potential difference between the plate of C_1 is

$= \frac{q}{C_1} = \frac{600}{20} = 30V$

Potential difference between the plate of C_2 is $= \frac{q}{C_2}$

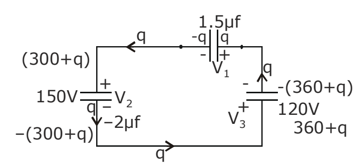
$= \frac{600}{30} = 20V$

Potential difference between the plate of C_3 is $= \frac{q}{C_3}$

$= \frac{600}{15} = 40V$

$\frac{1}{C_{eq}} = \frac{1}{20} + \frac{1}{30} + \frac{1}{15} = \frac{3+2+4}{60}$ $C_{eq} = \frac{60}{9} = \frac{20}{3}$ μF

Q.7 (A,B,C)



$V_1 + V_2 + V_3 = 0$

$\frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3} = 0$

$\frac{300+q}{2} + \frac{q}{1.5} + \frac{360+q}{3} = 0$

$\frac{900 + 3q + 4q + 720 + 2q}{6} = 0$

9q = –1620

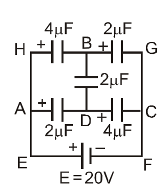
q = –180

$Q_1 = 120\mu C$

$Q_2 = 180\mu C$

Flow of charge from right to left through A

Q.8 (A,B,C,D)



given $V_C = 0$ in AEFC $V_A - 20 = V_C \Rightarrow V_A = 20$ V **Ans.**

by KCL, at point D

$2(V_A - V_D) + 2(V_B - V_D) + 4(V_C - V_D) = 0$

$2(V_A - V_D) + 2(V_B - V_D) = 4V_D$ ...(i) **Ans**

by KCL, at point B

$4(V_A - V_B) + 2(V_D - V_B) + 2(V_C - V_B) = 0$

$4(V_A - V_B) + 2(V_B - V_D) = 2V_B$ ....(ii) **Ans**

adding eq (i) and (ii)

$2(V_A - V_D) + 2(V_B - V_D) + 4(V_A - V_B) + 2(V_B - V_D) = 4V_D + 2V_B$

$\Rightarrow 6V_A = 6V_D + 6V_B \Rightarrow V_A = V_D + V_B$

Q.9 (A,D)

As the capactitance are in series hence charge on both of them will be same.

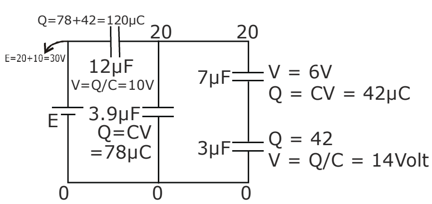
$E = \frac{Q^2}{2C}$

$V_1 : V_2 = \frac{1}{1} : \frac{1}{2}$, $\quad V_1 = \frac{2}{3} \times 15 = 10V$

$V_2 = 5V$

Q.10 (B,C,D)

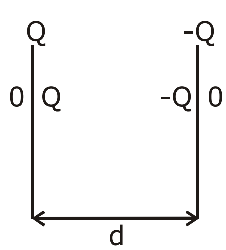
From the diagram



Q.11 (A,B,C,D)

Initially

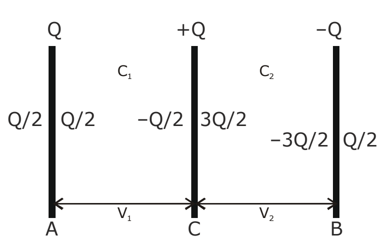
$\Rightarrow C = \frac{\epsilon_0 A}{d}$



$V = \frac{Q}{C}$

$= \frac{Qd}{\epsilon_0 A}$

Finally



$C_1 = C_2 = \frac{2\epsilon_0 A}{A}$

$V_1 = \frac{Qd}{2.2\epsilon_0 A}$

$V_2 = \frac{3Qd}{2.2\epsilon_0 A}$

$V = V_1 + V_2 = \frac{d}{\epsilon_0 A}$

$V_f = V_i$

Q.12 (A,B,C)

In shown fig. C_2 and C_3 are parallel capacitor therefore $V_2 = V_3$.

Charge Q_1 flow through battery and gone to C_1 and divided into C_2 and C_3

$Q_1 = Q_2 + Q_3$, total potential $V = V_1 + V_2 = V_1 + V_3 = V_1 + \frac{V_2 + V_3}{2}$

Q.13 (B,C)

$C_i = \frac{\epsilon_0 A}{d} = C$, $\quad C_f = \frac{\epsilon_0 A}{2d} = \frac{C}{2}$

During pulling charge remains same.

Q.14 (B,C)

Isolated $\rightarrow$ Q = constant C $\downarrow$

Energy $= \frac{Q^2}{2C} \uparrow$, $E = \frac{\sigma}{\epsilon_0}$ = constant

Energy density $= \frac{1}{2}\epsilon_0 E^2$ = constant

Q.15 (A,C)

$C = 2\mu F$

$C_{eq} = C + \frac{C}{2} + \frac{C}{4} + \frac{C}{8} + \frac{C}{16} + ...$

$C_{eq} = C\left(\frac{1}{1-1/2}\right) = 2\left(\frac{1}{1/2}\right) = 4\mu F$ **Ans**

Charge on first row capacitor is $q_1 = 2 \times 10\mu C = 20\mu C$

Charge on second row capacitor is

$q_2 = 1 \times 10\mu C = 10\mu C$

Charge on third row capacitor is

$q_3 = \frac{1}{2} \times 10\mu C = 5\mu C$

Therefore charge on the capacitor in the first row is more than on any other capacitor.

Energy stored in all capacitor is = $\frac{1}{2}$ C_{eq} V^2 = $\frac{1}{2}$ × 4 × 10^{-6} × $(10)^2$ = 0.2 mJ **Ans**

C = 2μF

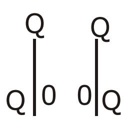
$$C_{eq} = C + \frac{C}{2} + \frac{C}{4} + \frac{C}{8} + \frac{C}{16} + ...$$

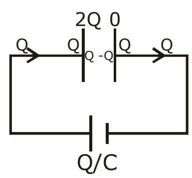
$$C_{eq} = C\left(\frac{1}{1-1/2}\right) = 2\left(\frac{1}{1/2}\right) = 4\mu F$$ **Ans**

Q.16 (A,B,C,D)

Initially

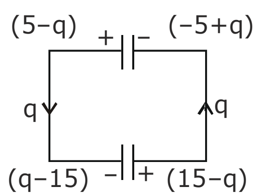
After connecting battery





Energy supplied by cell = QE = CE^2

Q.17 (B,D)



$$V = \frac{C_1V_1 - C_2V_2}{C_1 + C_2} = \frac{(1-3)5}{4} = 2.5V$$

(common potential)

$$\Delta H = \frac{1}{2}(C_1 + C_2)V^2 - \left[\frac{1}{2}C_1V^2 + \frac{1}{2}C_2V^2\right]$$

$$= \frac{1}{2}(1 + 3)\ (2.5)^2 - \left[\frac{1}{2}(1+3)(5)^2\right]$$

$$= \frac{1}{2} \times 4\ [6.25 - 25]$$

= 2 × 18.75 = 37.5 {W.D. by battery = 0}

Q.18 (A,C)

Charge will be stored but some energy will be lost in form of heat.

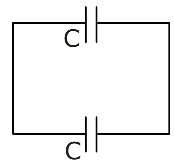
A → Correct, $V = \frac{Q}{C}$ Increase rapidly initially

C → Correct

Q.19 (B,C,D)

$Q_1 = CV_1$

$Q_2 = CV_2$



Net charge = const.

[B correct]

$2CV = C(V_1 + V_2)$

$$V = \frac{V_1 + V_2}{2}$$

[C correct]

As charge flows energy will certainly be lost.

[D correct]

Net charge on the connected plates is equal sum of initial charges because charge is conserved.

Q.20 (A,B,C,D)

(a) $V_i = \frac{kQ}{3R}$ $V_0 = \frac{kQ}{3R}$

(b) Earthing means V = 0

(c) $\frac{kq'}{R} + \frac{kQ}{3R} = 0 \Rightarrow q' = -q/3$

(d) energy between the spheres increases.

Q.21 (A,C)

4 × 500 – 2 × 500 = 6 × V

Q.22 (A,B,C)

$E = \frac{V}{d}$ ⇒ remains constant

C′ = KC ⇒ Increase

Q’ = KQ ⇒ Increase

$U = \frac{1}{2}KCV^2 = KU$ ⇒ Increase

Q.23 (A,C,D)

Battery connected V = constant

$U' = \frac{1}{2}KCV^2 = KU$ ⇒ Increase by K–times

$E = \frac{V}{d}$ = constant

$F = \frac{Q^2}{2 \in_0 A} \Rightarrow F = \frac{C^2V^2}{2 \in_0 A} \Rightarrow F' = \frac{K^2C^2V^2}{2 \in_0 A} = K^2F$

$\Rightarrow$ Increase by K^2–times

$Q = CV \Rightarrow Q' = KCV = KQ \Rightarrow$ Increase by K–times.

Q.24 (B,C,D)

In PQS process charge on capacitor is $Q = CV$

In PSQ process charge on capacitor is $Q' = KCV$

Electric energy stored in PQS is $= \frac{1}{2} CV^2$

Electric energy stored in PSQ is $= \frac{1}{2} KCV^2$

$U_{PSQ} > U_{PQS}$

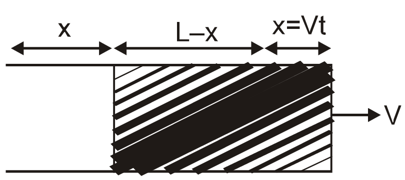
Electric field in PS is $E = \frac{V}{d}$

Electric field in SP is $E = \frac{V}{d}$

$E_{PS} = E_{SP}$

Q.25 (A,B,C,D)

Capacitance of capacitor is $= C_0 = \frac{k \in_0 a.L}{d}$



$C = \frac{\in_0 ax}{d} + \frac{k \in_0 a(L-x)}{d}$

$C = \frac{a \in_0}{d}[x + k(L-x)]$

$= \frac{a \in_0}{d}[kL - (k-1)x] = \frac{a \in_0}{d}[kL - (k-1)vt]$

So, C decreases linearly with time

Charge on capacitor $Q = C_0V_0 = \frac{k \in_0 aL}{d} V_0 =$ constant.

Potential difference across plate is $V = \frac{Q}{C} = \frac{C_0V_0}{C}$

$\Rightarrow V \propto \frac{1}{C}$

$V = \frac{V_0}{\frac{a \in_0}{d}[kL - (k-1)vt]}$

Potential energy $U = \frac{1}{2} QV = \frac{1}{2} C_0V_0 V$

$\Rightarrow U \propto V$ **Ans**

Q.26 (A,C,D)

$C = \frac{\in_0 A}{d}$, $C' = \frac{K \in_0 A}{d}$ $Q = CV = \frac{\in_0 KAV}{d}$ **Ans**

$Q = CV = C_1V_1 \Rightarrow V_1 = \frac{V}{K}$ $E = \frac{V_1}{d} = \frac{V}{Kd}$

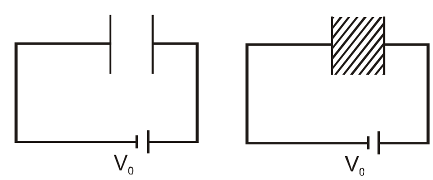
Ans

$W = U_f - U_i = \frac{1}{2} CV^2 - \frac{1}{2} C_1V_1^2 =$

$\frac{1}{2}\frac{\in_0 AV^2}{d^2} - \frac{1}{2}\frac{K \in_0 A}{d}\left(\frac{V}{K}\right)^2 = \frac{\in_0 AV^2}{2d}\left(1 - \frac{1}{K}\right)$

Ans

Q.27 (A,D)



Potential difference $= V_0$

Potential difference $= V_0$

Capacitance = C

Capacitance = KC

[K is the dielectric constant of Slab K > 1]

$Q_0 = CV_0$

New charge = $KC V_0$

Potential Energy $= \frac{1}{2} CV_0^2$

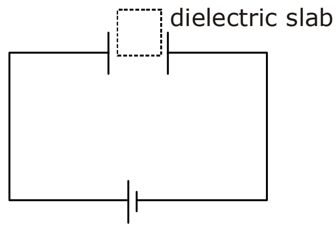
New potential energy = $\frac{1}{2} KC V_0^2$

Correct options are (A), (D).

Q.28 (B,C)

$30C_0 = (C_0 + KVC_0).V$

Q.29 (BC)



V = const.

$C = \frac{\varepsilon_0 kA}{d}$ $\qquad$ $C\uparrow$,

$Q = CV\uparrow$

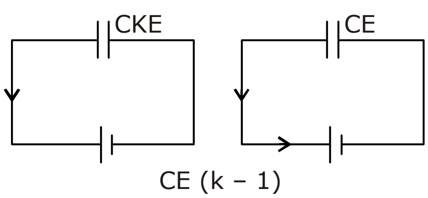
$e = \frac{V}{d}$ = const.

Q.30 (C,D)

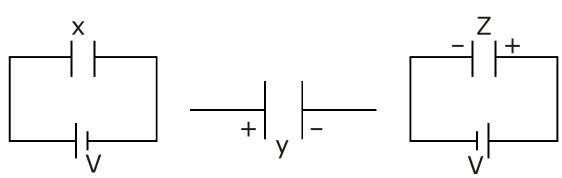
$C = \frac{\epsilon_0 A}{d - t + t/K}$

Independent of Position

Q.31 (A,B,D)

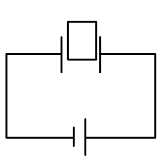


Q.32 (B,C,D)

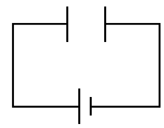


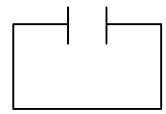
$\varepsilon = \frac{1}{2}CV^2$ $\qquad$ $\varepsilon = \frac{1}{2}CV^2$

$\varepsilon = \frac{1}{2}CV^2$

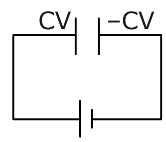


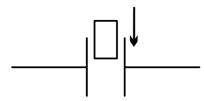
(B) In XWY charge increases





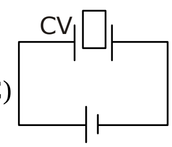
In XYW





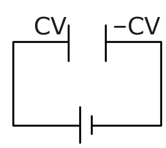
Q = const.

(C)



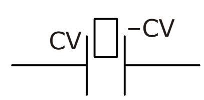
$\varepsilon = \frac{Q^2}{2C}$

$\varepsilon = \frac{k^2C^2V^2}{2KC} = \frac{1}{2}KCV^2$



$\varepsilon = \frac{Q^2}{2C} = \frac{C^2V^2}{2KC} = \frac{1}{2}\frac{CV^2}{K}$

Now insert dielectric



W.D. $= U_f - U_i = -\frac{\varepsilon_0 AV^2}{2d}\left(1 - \frac{1}{k}\right)$

Q.33 (A,C)

$t_1 > t_2$

$R_1C_1 > R_2C_2$ $\qquad$ for same q_{max}

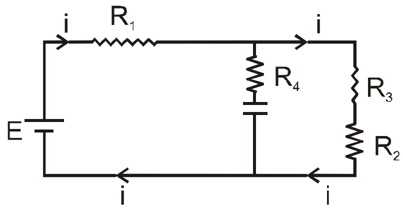
$q_{01} = q_{02} \Rightarrow E_1C_1 = E_2C_2$

If $E_1 = E_2 \Rightarrow C_1 = C_2 \Rightarrow R_1 = R_2$.

Q.34 (B,C,D)

A long time after closing the switch, system comes in steady state and no current flow through capacitor..

Circuit : -



$i = \dfrac{E}{R_1 + R_2 + R_3}$

energy stored in battery $= \dfrac{1}{2}\ CV^2 = \dfrac{1}{2}\ C$

$\left(\dfrac{E\ (R_3 + R_2)}{R_1 + R_2 + R_3}\right)^2$

Q.35 (A,C)

$q_{max} = q_{01} = q_{02}$ = Both capacitors are charged up to the same magnitude of charge

$t_2 > t_1$

$R_2C_2 > R_1C_1$

$q_{01} = C_1V_1 = q_{02} = C_2\ V_2$

$C_1 \neq C_2$

So $V_1 \neq V_2$.

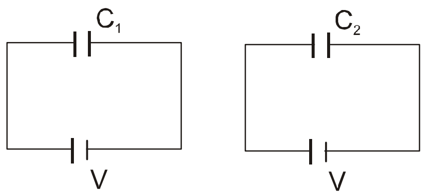
Q.36 (B,D)

During decay of charge in RC circuit

$I = I_0e^{-t/RC}$

where $I_0 = \dfrac{q_0}{RC}$

when $t = 0, I = I_0 = \dfrac{q_0}{RC}$



Since potential difference between the plates is same initially therefore I same in both the cases at t = 0 and is equal to

$I = \dfrac{q_0}{RC} = \dfrac{V}{R}$

Also $q = q_0e^{-t/RC}$. When $q = \dfrac{q_0}{2}$ then $\dfrac{q_0}{2} = q_0\ e^{-t/RC}$

$\Rightarrow e^{+t/RC} = 2$.

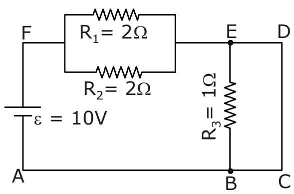
$\dfrac{t}{RC} = \ell n2$

$\Rightarrow t = RC\ \log_e 2$

$\Rightarrow t \propto C$. Therefore time taken for the first capacitor (1μF) for discharging 50% of Initial charge will be less.

(B), (D) are the correct options.

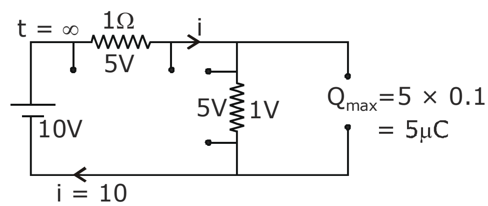
Q.37 (A,B,C,D)



Just afterclosing switch DC will act as wire

i = 10 A

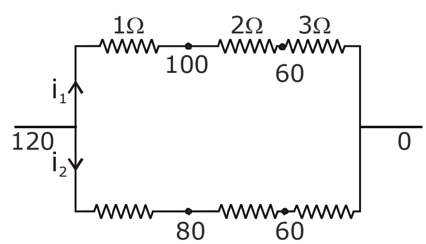
After t = ∞ DC will be open circuit



Q.38 (B,D)

$R_{eq} = 3\Omega$

i = 40 A



$i_1 = i_2 = 20A$

At t = ∞ capacitor act as open circuit

$R_{eq} = 3\Omega$

i = 10 A

Charge stored in $C_1 = VC_1 = 20 \times 2\mu c = 40\ \mu C$

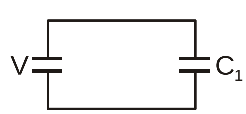
Q.39 (A)

Q.40 (C)

Q.41 (A)

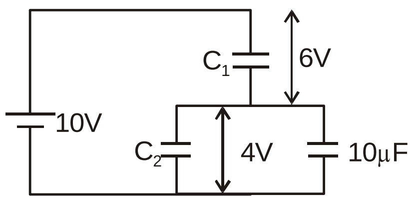
(Q.39 to Q.41)

When $C_3 = \infty$, there will be no charge on C_2



As $V_1 = 10$ V therefore V = 10 V

From graph when $C_3 = 10\ \mu F$, $V_1 = 6\ V$



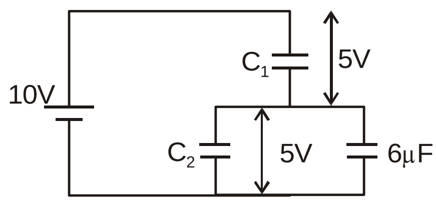
Charge on C_1 = Charge on C_2 + Charge on C_3

$6C_1 = 4C_2 + 40\ \mu C$

.... (1)

Also when $C_3 = 6\ \mu F$, $V_1 = 5V$

Again using charge equation



$5C_1 = 5C_2 + 30\ \mu C$

....(2)

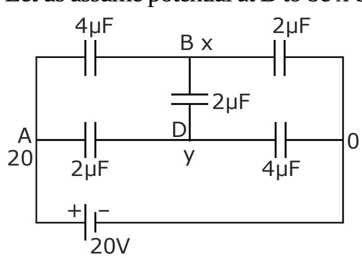
Solving (1) and (2)

$C_1 = 8\ \mu F$

$C_2 = 2\ \mu F$.

Q.42 (B,C)

Let us assume potential at B to be x & D to be y.



$(x - 20)4 + (x - y)2 + 2x = 0$

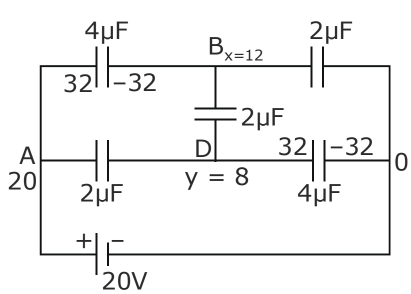
$4x - y = 40$ ....(1)

$2(y - x) + (y - 20)2 + y(4) = 0$

$\Rightarrow 4y - x = 20$ ....(2)

Solving (1) and (2)

$x = 12$; $y = 8$



$V_B - V_D = 12 - 8 = 4 > 0$

Q.43 (A,B,C,D)

(A) As from figure $V_A = 20V$

(B) $4(V_A - V_B) + 2(V_D - V_B)$

$= 4(20 - 12) + 2(8 - 12)$

$= 32 - 8 = 24 = 2V_B$

(C) $2(V_A - V_D) + 2(V_B - V_D)$

$= 2(20 - 8) + 2(12 - 8)$

$= 24 + 8 = 32 = 4V_D$

(D) $V_B + V_D = 12 + 8 = 20 = V_A$

Q.44 (B,C)

$V_B = 12$ $\qquad$ $V_D = 8$

Q.45 (C)

$q_1 = 4(20 - 12) = 32\mu C$

$q_2 = 2(20 - 8) = 24\mu C$

$q_3 = 2(12 - 8) = 8\mu C$

Q.46 (C)

Q.47 (D)

Q.48 (C)

(Q. 46 to 48)

For t = 0 to t_o = RC seconds, the circuit is of charging type. The charging equation for this time is

$$q = CE\left(1 - e^{-\frac{t}{RC}}\right)$$

Therefore the charge on capacitor at time t_0 = RC is

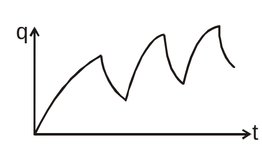
$$q_o = CE\left(1 - \frac{1}{e}\right)$$

For t = RC to t = 2RC seconds, the circuit is of discharging type. The charge and current equation for this time are

$$q = q_o e^{-\frac{t - t_o}{RC}} \qquad \text{and } i = \frac{q_o}{RC} e^{-\frac{t - t_o}{RC}}$$

Hence charge at t = 2 RC and current at t = 1.5 RC are

$$q = q_o e^{-\frac{2RC - RC}{RC}} = \frac{q_o}{e} = \frac{1}{e} CE\left(1 - \frac{1}{e}\right)$$



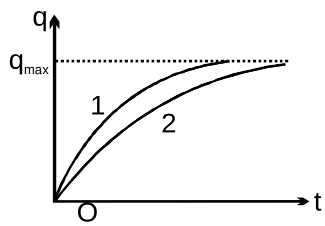
and $$i = \frac{q_o}{RC} e^{-\frac{1.5RC - RC}{RC}} = \frac{q_o}{\sqrt{e}RC} = \frac{E}{\sqrt{e}R}\left(1 - \frac{1}{e}\right)$$

respectively

Since the capacitor gets more charged up from t = 2RC to t= 3RC than in the interval t=0 to t=RC, the graph representing the charge variation is as shown in figure

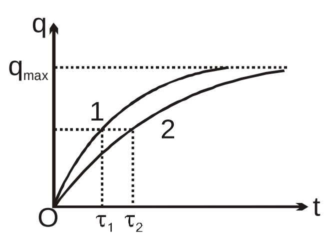
Comprehension Type Questions # 4 (Q. No. 49 to 50)

The charge across the capacitor in two different RC circuits 1 and 2 are plotted as shown in figure.



Q.49 (A,C)

$C_2V_1 = C_2V_2$



As q_{max} for both is same hence A is corrent

As $C_1V_1 = C_2V_2$ Hence EMF's of the cells may be different

Q.50 (D)

$R_2C_2 > R_1C_2$

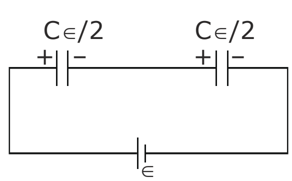
Q.51 (A)

Q.52 (B)

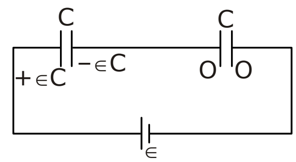
Q.53 (C)

Q.54 (C)

Initial (when S is open)



Finally (When S is closed)



So charge flown = [charge finally – charge initially]

$= \in C - \in C/2$

$= \in C/2$

Work done by battery $= \in \frac{C}{2} \times \in = \frac{\in^2 C}{2}$

(52) Initial energy

$$U_i = \frac{1}{2}\frac{Q^2}{C} + \frac{1}{2}\frac{Q^2}{C}$$

$$= \left(\frac{C\in}{2}\right)^2 \frac{1}{C} = \frac{1}{4} C \in^2$$

$$U_f = \frac{1}{2} C \in^2$$

Change $= \frac{1}{4} C \in^2$

(53) Heat = Work done by battery - $(U_f - U_i)$

$$= \frac{1}{2} C \in^2 - \left(\frac{1}{4} C \in^2\right) = \frac{1}{4} C \in^2$$

Q.55 (B)

at t_0 ; $q = q_0 = 60\ \mu C$

Q.56 (C)

$q = q_0 e^{-t/RC} = 60 \times 10^{-6}\ e^{-100\times10^{-6}/10\times10^{-6}\times10} = \frac{60}{e}$

$\mu C = 22\ \mu C$.

Q.57 (A)

$q = q_0 e^{-t/RC} = 60 \times 10^{-6}\ e^{-1\times10^{-3}/10\times10^{-6}\times10} = \frac{60}{e^{10}}$

$\mu C = 0.003\ \mu C$.

Q.58 (C)

$i = \frac{100}{10}\ e^{-10^{-4}/10^{-4}}$ amp

$= \frac{10}{e} = 3.7$ amp

Q.59 (B)

P = V.i = 100 × 3.7 = 370 W

Q.60 (C)

$\frac{dH}{dt} = i^2R$

$= (3.7)^2 \times 10 = 136.9$ W

Q.61 (D)

$P_{battery} = P_{Heat} + P_C$

$P_C = P_{battery} - P_{Heat}$

= 370 – 136.9 = 233.1 W.

Q.62 (A)

$i_0 = \frac{V}{R} = \frac{6}{24} = 0.25$ A

Q.63 (B)

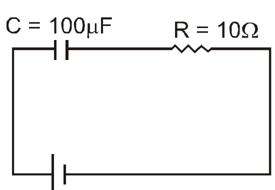
$i = i_0\, e^{-t/RC}$

$= 0.25\, e^{-1}$

$= \frac{0.25}{e} = 0.09$ A.

Q.64 (A)

Q.65 (C)



energy stored in capacitor = $\frac{Q^2}{2C}$

Rate at which energy is stored $= \frac{d}{dt}\left(\frac{Q^2}{2C}\right) = \frac{Q}{C}$.

$\frac{dQ}{dt} = \frac{Qi}{C}$

$Q = \varepsilon C\{1 - e^{-t/RC}\}$

$i = \frac{\varepsilon e^{-t/RC}}{R}$

Rate of energy storage $= \frac{\varepsilon^2}{R}\{1 - e^{-t/RC}\}\{e^{-t/RC}\} =$

$\frac{\varepsilon^2}{R}\{e^{-t/RC} - e^{-2t/RC}\}$ .... (1)

It will be maximum when, $e^{-t/RC} - e^{-2tRC}$ will be maximum let $y(t) = e^{-t/RC} - e^{-2t/RC}$

for maximum, $y'(t) = 0$

$y'(t) = \frac{-e^{-t/RC}}{RC} + \frac{2e^{-2t/RC}}{RC}$

$e^{-t/RC} = \frac{1}{2}$

putting it back in eq. (1)

(1) maximum rate of energy storage $= \frac{\varepsilon^2}{R}$

$\left\{\frac{1}{2} - \left(\frac{1}{2}\right)^2\right\} = \frac{\varepsilon^2}{4R} = \frac{(20)^2}{4\times 10} = 10$ J/s

(2) This will occur when, $e^{-t/RC} = \frac{1}{2}$

$\frac{-t}{RC} = \ell n\, \frac{1}{2}$

$t = RC\, \ell n\, 2 = 10 \times 100 \times 10^{-6} \times \ell n2 = (\ell n\, 2)$ ms

Q.66 (C)

$q_0 = 4\mu C$

$i = \frac{dq}{dt} = \frac{q_0}{RC}\, e^{-t/RC}$

$= \frac{4\times 10^{-6}}{1\times 10^{-6}\times 3\times 10^{6}} e^{-1/3} = \frac{4}{3} e^{-1/3}$ μC/sec

Q.67 (A)

$U = \frac{q_0^2}{2C}(1 - e^{t/RC})^2$

$\frac{dU}{dt} = \frac{q_0^2}{RC^2}(1 - e^{-t/RC})\, e^{-t/RC}$

$= \frac{(4\times 10^{-6})^2}{3\times 10^6 \times (1\times 10^{-6})^2}(1 - e^{-1/3})\, e^{-1/3}$

$= \frac{16}{3}(1 - e^{-1/3})\, e^{-1/3}$ μJ/sec.

Q.68 (C)

$H = \int i^2R\,dt \Rightarrow \frac{dH}{dt} = i^2R$

$$\frac{dH}{dt} = i_0^2 Re^{-2t/RC} = \left(\frac{4}{3\times10^6}\right)^2 3 \times 10^6\ e^{-2/3} =$$

$$\frac{16}{3} e^{-2/3}\ \mu J/s$$

Q.69 (C)

$$U = qV \Rightarrow \frac{dU}{dt} = V\frac{dq_0}{dt}(1 - e^{-t/RC})$$

$$\frac{dU}{dt} = \frac{q_0 V}{RC} e^{-t/RC}$$

$$= \frac{4\times10^{-6}\times4}{3\times10^6\times1\times10^6} e^{-1/3}$$

$$= \frac{16}{3} e^{-1/3}\ \mu J/sec.$$

Q.70 (D)

$$E = \frac{V}{d} = \frac{300}{5\times10^{-2}} = 6 \times 10^3\ V/m$$

Q.71 (B)

$$\Delta U = U_f - U_i = \frac{1}{2}C_f V^2 - \frac{1}{2}C_i V^2$$

$$= \frac{1}{2}\left(\frac{\epsilon_0 A}{d_f} - \frac{\epsilon_0 A}{d_i}\right) V^2 \qquad = \frac{1}{2}\left(\frac{1}{5} - \frac{1}{2}\right)$$

$$\frac{9\times10^{-12}\times100\times10^{-4}}{10^{-2}} (300)^2$$

$$= -12.15 \times 10^{-8}\ J = -1215 \times 10^{-10} J.$$

Q.72 (D)

$$E = \frac{Q}{A\epsilon_0} = \text{Constant}$$

$$= \frac{V}{d_i} = \frac{300}{2\times10^{-2}} = 15 \times 10^3\ V/m.$$

Q.73 (A)

$$Q = \frac{A\epsilon_0}{d_i} V = \text{constant}$$

$$\Delta U = \frac{1}{2}\frac{Q^2}{C_f} - \frac{Q^2}{C_i} = \frac{1}{2} A\epsilon_0 V^2 \left(\frac{d_f}{d_i^2} - \frac{d_i}{d_i^2}\right)$$

$$= \frac{1}{2}\frac{A\epsilon_0}{d_i^2} V^2 (d_f - d_i)$$

$$= \frac{1}{2}\frac{100\times10^{-4}\times9\times10^{-12}\times(300)^2(5-2)\times10^{-2}}{(2\times10^{-2})^2}$$

$$= 30.375 \times 10^{-9}\ J$$

Q.74 (A)

$Q_1 = C_1V = 2 \times 10 = 20\mu F$

$Q_2 = C_2V = 4 \times 10 = 40\mu F$

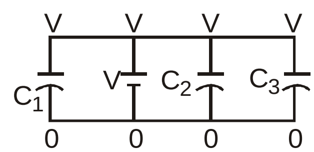
$Q_3 = C_3V = 6 \times 10 = 60\mu F$

Q.75 (B)

Total charge flown = $Q_1 + Q_2 + Q_3 = 120\mu C$

So W.D. = $(120 \times 10^{-6}) \times 10 = 1200\ \mu J$

Q.76 (C)



Total energy stored = $\frac{1}{2}(C_1 + C_2 + C_3)V^2$

$$= \frac{1}{2}(2 + 4 + 6) \times 10^{-6} \times 10^2$$

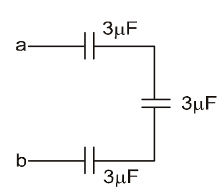
$= 600\ \mu J$

Q.77 (A)

$$\frac{1}{C_1'} = \frac{1}{C_1} + \frac{1}{C_1} + \frac{1}{C_2} \qquad \Rightarrow C_1' = 1\mu F$$

$C_2' = C_2 + C_1' = 3\mu F \Rightarrow C_{eq} = 1\mu F$

Q.78 (D)



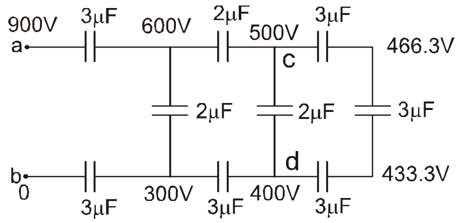
$C_{eq} = 1\mu F$

$Q = C_{eq} V = 900\mu F$

charge on nearest capacitor = $900\mu F$

Q.79 (B)

from point potential method



$V_c - V_d = 100V$

Q.80 (A)

$$V = \frac{Q}{C} = \frac{30}{5} = 6 \text{ Volt}$$

Q.81 (A)

$$\frac{1}{2}CV^2 = \frac{1}{2}(5 \times 10^{-6})(6)^1 = 90\mu J$$

Q.82 (B)

Let V then

$$(C_1 + C_2)V = Q_1 + Q_2$$

$$V = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{(30+50)\times 10^{-6}}{(5+10)\times 10^{-6}}$$

$$V = \frac{16}{3} \text{ volt}$$

Q.83 (A)

(Initial – final) energy

$$= \left(\frac{1}{2}\frac{Q_1^2}{C_1^2} + \frac{1}{2}\frac{Q_2^2}{C_2}\right) - \left(\frac{1}{2}(C_1 + C_2)V^2\right)$$

$$= \frac{1}{2}\left[180 + 250 - 5\times 10\times \frac{16}{3}\right] \times 10^{-6} \text{ J}$$

$$= \frac{5}{3} \times 10^{-6} \text{ J}$$

Q.84 (A)

$$\frac{Q_1'}{Q_2'} = \frac{C_1V}{C_2V} = \frac{C_1}{C_2} = \frac{5}{10} = \frac{1}{2}$$

Q.85 (B)

$$Q'_1 = C_1V = 5 \times \frac{16}{3} \mu C = \frac{80}{3} \mu C$$

$$Q'_2 = C_2V = 10 \times \frac{16}{3} = 160/3 \mu C$$

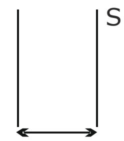
Q.86 (B)

Q.87 (C)

Charge is constant

$$E = \frac{q}{2S\varepsilon_0}$$

So, $F = qE = \dfrac{q^2}{2S\varepsilon_0}$



So, W.D. $= F[x_2 - x_1]$

$$= \frac{q^2}{2S\varepsilon_0}(x_2 - x_1)$$

$$C = \frac{\varepsilon_0 S}{x}$$

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{\varepsilon_0 S}{x}\right)V^2$$

$$F = -\frac{dU}{dx} = \frac{1}{2}\frac{\varepsilon_0 SV^2}{x^2}$$

$$W = \int_{x_1}^{x_2} F \,.\, dx = \frac{1}{2}\varepsilon_0 SV^2 \left[-\frac{1}{x}\right]_{x_1}^{x_2}$$

$$W = \frac{1}{2}\varepsilon_0 SV^2 \left[\frac{1}{x_1} - \frac{1}{x_2}\right]$$

Q.88 (C)

outer sphere is earthed

$$C = \frac{4\pi\epsilon_0 kab}{b-a} =$$

$$\frac{4\times 3.14\times 8.85\times 10^{-12}\times 5\times 10\times 10^{-2}\times 120\times 10^{-2}}{(12-10)\times 10^{-2}}$$

$$C = 3.34 \times 10^{-10} = \frac{10}{3} \times 10^{-10} \text{ F}$$

Q.89 (A)

inner sphere is earthed

$$C = \frac{4\pi\epsilon_0 ab}{b-a} + 4\pi\epsilon_0 b$$

$= \frac{10}{3} \times 10^{-10}$ F + 4 × 3.14 × 8.85 × 10^{-12} × 12 × 10^{-2}

= 3.34 × 10^{-10} + 0.13338 × 10^{-10}

$= \left(\frac{10}{3} + \frac{1.4}{10}\right) \times 10^{-10}$ $= \frac{104}{30} \times 10^{-10}$ F

Q.90 (A) p (B) r (C) q (D) p

The initial charge on capacitor = CV_i = 2 × 1 μC = 2 μC

The final charge on capacitor = CV_f = 4 × 1 μC = 4 μC

∴ Net charge crossing the cell of emf 4V is

$q_f - q_i$ = 4 – 2 = 2 μC

The magnitude of work done by cell of emf 4V is

W = $(q_f - q_i)$ 4 = 8 μJ

The gain in potential energy of capacitor is ΔU = $\frac{1}{2}C(V_f^2 - V_i^2) = \frac{1}{2}$ 1 × [$4^2 - 2^2$] μJ = 6 μJ

Net heat produced in circuit is ΔH = W – ΔU = 8 – 6 = 2 μJ

Q.91 (A) p,q,s (B) p,r,s (C) p,q (D) p,r

(A) For potential difference across each cell to be same

$E_1 - ir = E_2 + ir$ or $i = \frac{E_1 - E_2}{2r}$

$\left(< \frac{E_1 - E_2}{2r + R}\right)$

Hence potential difference across both cells cannot be same.

Cell of lower emf charges up.

For potential difference across cell of lower emf to be zero

$E_2 + ir = 0$

which is not possible.

Current in the circuit cannot be zero

$\because E_1 \neq E_2$.

(B) For potential difference across each cell to be same

$E_1 - ir = E_2 - ir$ which is not possible

No cell charges up.

For potential difference across cell of lower emf to be zero

$E_2 - ir = 0$ and

$E_1 - i(r + R) = 0$

or $\frac{E_1}{r + R} = \frac{E_2}{r}$ which is possible.

$\because E_1 > E_2$.

Current in the circuit cannot be zero.

(C) Situation is same as in (A) except current decreases from $\frac{E_1 - E_2}{2r + R}$ to zero.

Hence the only option that shall changes is 'current shall finally be zero.'

(D) Situation is same as in (B) except current decreases from $\frac{E_1 + E_2}{2r + R}$ to zero.

Hence the only option that shall changes is 'current shall finally be zero.'

NUMERICAL VALUE BASED

Q.1 [119]

Q = CV

$V = -\int_{-3}^{4} E\,dx = -20 \int_{-3}^{4} \left(x^2 + \frac{4}{3}\right) dx$

$V = -2Q \left[\frac{x^3}{3} + \frac{4x}{3} \Big|_{-3}^{4}\right]$

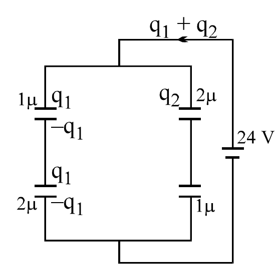
$V = -2Q \left[\frac{1}{3}[64 + 27] + \frac{4}{3}[7]\right]$

$\frac{Q}{C} = 3Q \left[\frac{119}{3}\right]$

$\frac{1}{C} = 119\ F^{-1}$

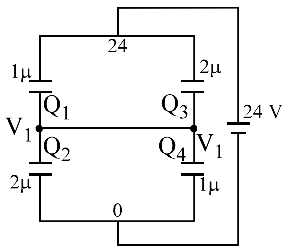
Q.2 [12]

Initially,



$$q_1 = 24\left(\frac{2}{3}\mu F\right) = 16\ \mu C \qquad \&\ q_2 = 16\ \mu C$$

Finally,



$(V_1 - 24) \times 1 + (V_1 - 0) \times 2 + (V_1 - 24) \times 2 + (V_1 - 0) \times 1 = 0$

$V_1(1 + 2 + 2 + 1) - 24 \times 3 = 0$

$$\Rightarrow\ V_1 = \frac{24\times3}{6} = 12\text{ V}$$

$Q_1 + Q_2 = (12 - 24) \times 1 + (12 - 0) \times 2 = -12 + 24 = 12\ \mu C$

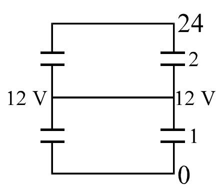
$Q_3 + Q_4 = (12 - 24) \times 2 + (12 - 0) \times 1 = -24 + 12 = -12\ \mu C$

Initial net charge on plates left of S = 0

Final net charge on plates left of S = $Q_1 + Q_2$ = 12 μC

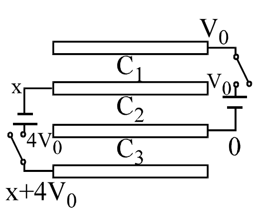
Charge flowing through S = 12 μC towards left

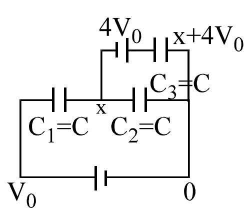
Alternative:—



$-2 \times 12 + 1 \times 12 = 0 = -12 = 12\ \mu C$

Q.3 [3]



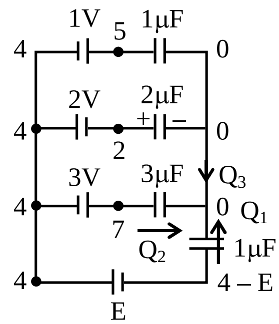


$C(x - V_0) + C(x - 0) + C(x + 4V_0) = 0$

$3Cx = -3CV_0$

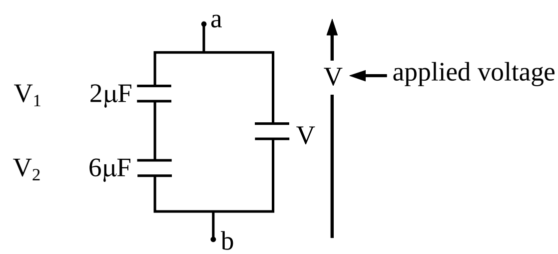
$$Q = \frac{3V_0\varepsilon_0 A}{L}\ \Rightarrow\ x = 3$$

Q.4 [2]



$$\text{Potential across } 2\mu F = \frac{4}{2} = 2\text{ volt}$$

Q.5 [4]



$$V_1 = \frac{6}{8}\times V = \frac{3}{4}V$$

$$V_2 = \frac{1}{4}V$$

$$\text{Now } \frac{3}{4}V < 100 \quad \Rightarrow \quad V < \frac{400}{3}$$

$$\frac{V}{4} < 50 \quad \Rightarrow \quad V < 200\text{ V}$$

$$V < 400 \quad \Rightarrow \quad V < 400$$

$$\text{Common solution } V < \frac{400}{3}$$

Q.6 [9]

$$C_1 = 4\pi\in R_1 = \frac{1}{9\times10^9}0.1 = \frac{1}{9\times10^{10}}\text{F}$$

$$U_1 = \frac{Q^2}{2C_1} = \frac{(20\times10^{-6})^2}{2\times\frac{1}{9\times10^{10}}} = 18\text{J}$$

$C_2 = 4\pi \in R_2$ and $C_2 = 2C_1$

$U_2 = \frac{U_1}{2} = 9J$

$H = \Delta U = 9J$

Q.7 [5]

$q = q'$

$C_0V_0 = CV$

$C_0 = C$ as $V = V_0$ given

$$C_0 = \frac{\in_0 A}{d}$$

$$C_1 = \frac{\in_0 A}{d - t + \frac{t}{K}}$$

But by increasing d to d + 0.24 cm then

$$C_1 \text{ becomes } C = \frac{\in_0 A}{(d + 0.24 - t) + \frac{t}{K}}$$

$$d = d + 0.24 - t + \frac{t}{K}$$

$$K = \frac{t}{t - 0.24} = 5$$

Q.8 [0750]

Just after closing switch no current flows through R_2 so $I_1 = 3mA$

Long time after closing switch no current flows through C so $I_2 = 2mA$

Directly after re-opening the switch no current flows through R_1 and the capacitor will discharge through R_2 so $I_3 = 2mA$

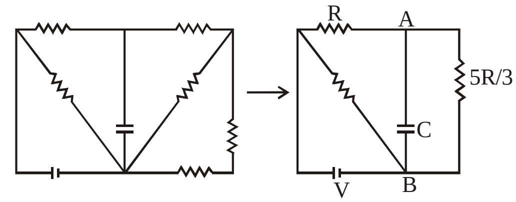
KVPY PREVIOUS YEAR'S

Q.1 (D)

Discharging -

$$Q = Q_0 e^{-t/RC}, \; U' = \frac{U}{2} \Rightarrow \frac{Q_0^2}{2C} e^{-2t/RC} = \frac{Q_0^2}{2C}$$

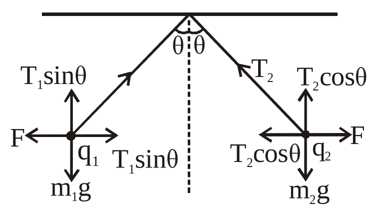
Q.2 (D)



$$V_{AB} = \frac{5\frac{R}{3}}{\frac{5R}{3} + R} \times V = \frac{5}{8}V$$

$$Q = \frac{5}{8}CV$$

Q.3 (B)



For equilibrium of m_1

$T_1 \cos\theta = m_1 g$

$T_1 \sin\theta = F$

$$\tan\theta = \frac{F}{m_1 g} \quad ....(1)$$

For equilibrium of m_2

$T_2 \cos \theta = m_2 g$

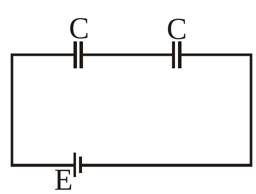
$T_2 \sin \theta = F$

$$\tan\theta = \frac{F}{m_1 g} \quad ....(2)$$

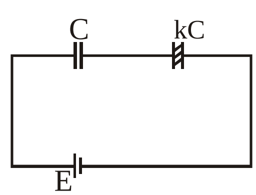
from (1) & (2)

$m_1 = m_2$

Q.4 (B)



Initial charge on both $C = \frac{CE}{2}$



New charge on each $C = \left(\frac{kC}{k+1}\right)E$

Change in charge on C is supplied by battery

$$\therefore \text{ Charge supply by battery} = \left(\frac{kC}{k+1}\right)E - \frac{CE}{2}$$

$$\Rightarrow CE\left[\frac{k}{k+1} - \frac{1}{2}\right]$$

$$\Rightarrow CE\left[\frac{k-1}{2(k+1)}\right]$$

Charge passes through battery is change supply by battery

$$\therefore \text{ Ans. } CE\left[\frac{k-1}{2(k+1)}\right]$$

Q.5 (C)

$$V = \frac{Q}{C} = \frac{Q}{\varepsilon_0 A}(x)$$

V = mx (straight line)

JEE MAIN

PREVIOUS YEAR'S

Q.1 (1)

$v_1 \cos\alpha = v_2 \cos\beta$

$$v_1^2 \cos^2\alpha = v_2^2 \cos^2\beta$$

$$\frac{K_1}{K_2} = \frac{\cos^2\beta}{\cos^2\alpha}$$

Q.2 Bonus

$$C_1 + C_2 = \frac{15}{4}\left(\frac{C_1C_2}{C_1 + C_2}\right)$$

$4(C_1 + C_2)^2 = 15C_1C_2$

$4C^2_1 + 4C^2_2 - 7C_1C_2 = 0$

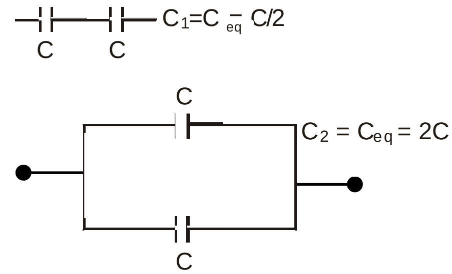
$$4 + 4\left(\frac{C_2}{C_1}\right)^2 - 7\frac{C_2}{C_1} - 7 = 0$$

$$4\left(\frac{C_2}{C_1}\right)^2 - 7\frac{C_2}{C_1} + 4 = 0$$

$\frac{C_2}{C_1}$ has not real value.

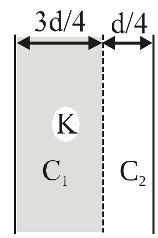
$\frac{C_2}{C_1}$ = Imaginary.

Q.3 (4)



$$\frac{C_1}{C_2} = \frac{1}{4}$$

Q.4 (3)



$$C_0 = \frac{\epsilon_0 A}{d}$$

C' = C_1 and C_2 in series.

$$\text{i.e. } \frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C'} = \frac{(3d/4)}{\epsilon_0 KA} + \frac{d/4}{\epsilon_0 A}$$

$$\frac{1}{C'} = \frac{d}{4\epsilon_0 A}\left(\frac{3+K}{K}\right)$$

$$C' = \frac{4KC_0}{(3+K)}$$

Q.5 (1)

$$\frac{2K\lambda}{r} = \frac{\sigma}{\varepsilon_0} \qquad (x = 3m)$$

$$\sigma = 0.424 \times 10^{-9}\frac{C}{m^2}$$

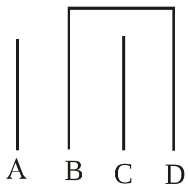
Q.6 (3)

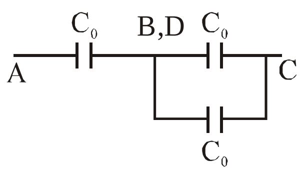
$$C = \frac{\varepsilon_0 A}{\frac{d}{2K} + \frac{d}{2}} = \frac{2\varepsilon_0 A}{\frac{d}{K} + d}$$

$$= \frac{2\times 2\varepsilon_0}{\frac{1}{3.2}+1} = \frac{4\times 3.2}{4.2}\varepsilon_0$$

$= 3.04\ \varepsilon_0$

Q.7 (2)





$$C_{eq} = \frac{2C_0}{3} = \frac{2}{3}\frac{\in_0 A}{d}$$

$$C_{eq} = \frac{2\in_0}{3d}\times\left(2\times\frac{3}{2}\right) = 2 \ (\because\ A = lb = 2\times\frac{3}{2})$$

Q.8 (864)

$U_i = \frac{1}{2}\times 14\times 12\times 12$ pJ $\quad (\because\ U = \frac{1}{2}CV^2)$

$= 1008$ pJ

$U_f = \frac{1008}{7}$ pJ $= 144$ pJ $\quad (\because\ C_m = kC_0)$

Mechanical energy $= \Delta U$

$= 1008 - 144$

$= 864$ pJ

Q.9 (16)

$20 = (C_1 + C_2)\ V \Rightarrow V = 2$ volt.

$Q_2 = C_2V = 16\mu C$

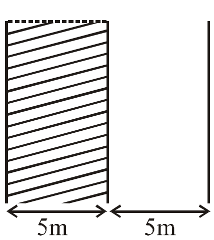
$= 16$

Q.10 (2)

$$i_0 = \frac{V}{R} = \frac{30/3}{5\times 10^6} = 2\times 10^{-6}$$

$\therefore$ Ans. = 2.00

Q.11 (161)



A = 100 m2

Using $C = \frac{k\in_0 A}{d}$

$$C_1 = \frac{10\in_0(100)}{5}$$

$= 200\ \in_0$

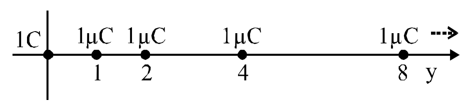
$$C_2 = \frac{\in_0(100)}{5} = 20\ \in_0$$

C1 & C2 are in series so Ceqv.$= \frac{C_1C_2}{C_1+C_2}$

$$= \frac{4000\in_0}{220}$$

$= 160.9\times 10^{-12} \simeq 161$ pF

Q.12 (12)



$$F = k(1C)(1\mu C)\left[1+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+...\right]$$

$$= 9\times 10^3\left[\frac{1}{1-\frac{1}{4}}\right] = 12\times 10^3 N$$

Q.13 (2)

Q.14 (3)

Q.15 (1)

Q.16 (3)

Q.17 (3)

Q.18 (3)

Q.19 (1)

Q.20 (3)

$\rho = 200\Omega m$

$C = 2\times 10^{-12}$ F

$V = 40$ V

$K = 56$

$$i = \frac{q}{\rho k\varepsilon_0} = \frac{q_0}{\rho k\varepsilon_0}e^{\frac{1}{\rho k\varepsilon_0}}$$

$$i_{max} = \frac{2\times 10^{-12}\times 40}{200\times 50\times 8.85\times 10^{-12}}$$

$$= \frac{80}{10^4\times 8.85} = 903\mu A = 0.9 mA$$

Q.21 [4]

$$\Delta U = \frac{1}{2}(\Delta C)V^2$$

$$\Delta U = \frac{1}{2}(KC - C)V^2$$

$$\Delta U = \frac{1}{2}(2-1)CV^2$$

$$\Delta U = \frac{1}{2} \times 200 \times 10^{-6} \times 200 \times 200$$

$\Delta U = 4$ J

Q.22 (2)

$V = V_0(1 - e^{-t/RC})$

$2 = 20\ (1 - e^{-t/RC})$

$$\frac{1}{10} = 1 - e^{-t/RC}$$

$$e^{-t/RC} = \frac{9}{10}$$

$$e^{t/RC} = \frac{10}{9}$$

$$\frac{t}{RC} = \ell n\left(\frac{10}{9}\right) \Rightarrow C = \frac{t}{R\ell n\left(\frac{10}{9}\right)}$$

$$C = \frac{10^{-6}}{10 \times .105} = .95\mu F$$

JEE-ADVANCED PREVIOUS YEAR'S

Q.1 [2]

Equation of charging of capacitor,

$V = V_0\left(1 - e^{-t/R_{eq}C_{eq}}\right)$

$C_{eq} = 2 + 2 = 4\ \mu F$

$R_{eq} = 1\ M\Omega$

$$4 = 10\left(1 - e^{-\frac{t}{10^6 \times 4 \times 10^{-6}}}\right)$$

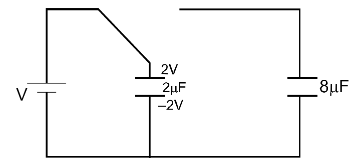
$e^{-t/4} = 0.6 \quad \Rightarrow \quad e^{t/4} = \frac{5}{3}$

$\Rightarrow \frac{t}{4} = \ell n\ 5 - \ell n\ 3 \qquad \Rightarrow t = 0.5 \times 4$

t = 2 sec. **Ans.**

Q.2 (D)

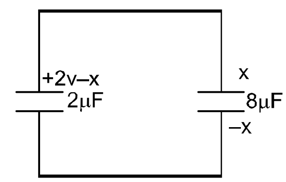
$U_i = \frac{1}{2}(2)V^2$, $V_{common} = \frac{V}{5}$



$$U_f = \frac{1}{2}(2+8)\left(\frac{V}{5}\right)^2$$

$$\frac{U_i - U_f}{U_i} \times 100 = \frac{V^2 - \frac{V^2}{5}}{V^2} \times 100$$

$\frac{4}{5} \times 100 = 80\%$ Ans.



Q.3 (C)

$$q_3 = \frac{C_3}{C_2 + C_3}.Q$$

$$q_3 = \frac{3}{3+2} \times 80 = \frac{3}{5} \times 80 = 48\ \mu C$$

Q.4 (B,D)

When switch S_1 is released charge on C_1 is $2CV_0$ (on upper plate)

When switch S_2 is released charge on C_1 is CV_0 (on upper plate) and charge on C_2 is CV_0 (on upper plate)

When switch S_3 is released charge on C_1 is CV_0 (on upper plate) and charge on C_2 is $-CV_0$ (on upper plate)

Q.5 (A), (D)

$$C = \frac{K\varepsilon_0 A}{3d} + \frac{2\varepsilon_0 A}{3d}$$

$$C_1 = \frac{K\varepsilon_0 A}{3d}$$

$$\frac{C}{C_1} = \frac{2+K}{K} \text{ Ans. (D)}$$

$$E_1 = E_2 = \frac{V}{d}$$

$$\Rightarrow \frac{E_1}{E_2} = 1 \text{ Ans. (A)}$$

$$Q_1 = C_1 V = \frac{K\varepsilon_0 A}{3d} V$$

$$Q_2 = C_2V = \frac{2\varepsilon_0 A}{3d}V$$

$$\Rightarrow \frac{Q_1}{Q_2} = \frac{K}{2}$$

Q.6 (C)
The line charge & cylinder will behave as capacitor filled with conductor i.e. resistance. It will be like a discharging *RC* circuit.
Hence, (B)

Q.7 (A,B,C,D)

Q.8 (D)

$$E_C = \frac{1}{2}CV_0^2 \quad ;$$

$$E_D = V_0CV_0 - \frac{1}{2}CV_0^2 = \frac{1}{2}CV_0^2$$

$\therefore E_C = E_D$

Q.9 (B)

$$E_{D_1} = \frac{V_0}{3}\frac{CV_0}{3} - \frac{1}{2}C.\left(\frac{V_0}{3}\right)^2 = \frac{CV_0^2}{9} - \frac{CV_0^2}{18}$$

$$= \frac{CV_0^2}{18}$$

$$E_{D_2} = \frac{2V_0}{3}\left[\frac{2CV_0}{3} - \frac{CV_0}{3}\right]$$

$$-\left[\frac{1}{2}C\left(\frac{2V_0}{3}\right)^2 - \frac{1}{2}C.\left(\frac{V_0}{3}\right)^2\right]$$

$$= \frac{2V_0}{3}\left[\frac{CV_0}{3}\right] - \frac{1}{2}C\left[\frac{4V_0^2}{9} - \frac{V_0^2}{9}\right]$$

$$= \left(\frac{2}{9} - \frac{1}{2\times 9}\times 3\right)CV_0^2 = \left(\frac{2}{9} - \frac{1}{6}\right)CV_0^2$$

$$= \left(\frac{12-9}{9\times 6}\right)CV_0^2$$

$$E_{D_2} = \frac{1}{18}CV_0^2$$

$$E_{D_3} = V_0\left[CV_0 - \frac{2CV_0^2}{3}\right] - \left[\frac{1}{2}CV_0^2 - \frac{1}{2}C\left(\frac{2V_0}{3}\right)^2\right]$$

$$= \frac{1}{3}CV_0^2 - \frac{1}{2}CV_0^2\left[1 - \frac{4}{9}\right]$$

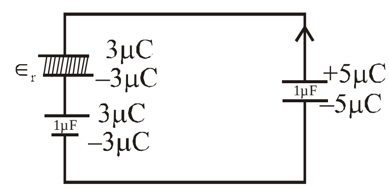
$$= \left(\frac{1}{3} - \frac{5}{18}\right)CV_0^2 = \left(\frac{6-5}{18}\right)CV_0^2 = \left(\frac{1}{18}\right)CV_0^2$$

$$\text{Total} = \left(\frac{1}{18} + \frac{1}{18} + \frac{1}{18}\right)CV_0^2$$

$$= \frac{3}{18}CV_0^2$$

$$E_D = \frac{3}{9}\left[\frac{1}{2}CV_0^2\right] = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$$

Q.10 [1.50]



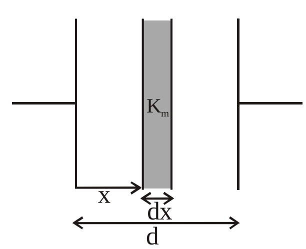
Applying loop rule

$$\frac{5}{1} - \frac{3}{\epsilon_r} - \frac{3}{1} = 0$$

$$\frac{3}{\epsilon_r} = 2$$

$$\epsilon_r = 1.50$$

Q.11 (1.00)



$$\delta = dx = \frac{d}{N} \;\&\; \frac{m}{N} = \frac{x}{d}$$

$$K_m = K\left(1 + \frac{m}{N}\right)$$

$$\Rightarrow K_m = K\left(1+\frac{x}{d}\right)$$

$$C' = \frac{K_m A \in_0}{dx}$$

$$\frac{1}{C_{eq}} = \int_0^d \frac{dx}{K_m A \in_0} = \frac{1}{KA \in_0}\int_0^d \frac{dx}{\left(1+\frac{x}{d}\right)}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{d}{KA \in_0}\left[\ell n\left(1+\frac{x}{d}\right)\right]_0^d$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{d}{KA \in_0}\left[\ell n 2 - \ell n(1)\right]$$

$$\Rightarrow C_{eq} = \frac{KA \in_0}{d \ell n 2} \Rightarrow \alpha = 1$$

Current Electricity

EXERCISES

ELEMENTRY

Q.1 (2)

Q.2 (2)

Q.3 (2)
Order of drift velocity = 10^{-4} m/sec = 10^{-2} cm/sec

Q.4 (4)
In case of stretching of wire $R \propto l^2$
$\Rightarrow$ If length becomes 3 times so Resistance becomes 9 times i.e. $R' = 9 \times 20 = 180\Omega$

Q.5 (1)
Because with rise in temperature resistance of conductor increase, so graph between *V* and *i* becomes non linear.

Q.6 (2)

$$R = \frac{\rho L}{A} \Rightarrow 0.7 = \frac{\rho \times 1}{\frac{22}{7}(1 \times 10^{-3})^2}$$

$\rho = 2.2 \times 10^{-6}$ ohm-m.

Q.7 (2)

$$R \propto \frac{1}{A} \Rightarrow R \propto \frac{1}{A^2} \propto \frac{1}{d^2}$$

[*d* = diameter of wire]

Q.8 (2)
In the absence of external electric field mean velocity of free electron (V_{rms}) is given by $V_{rms} = \sqrt{\frac{3KT}{m}} \Rightarrow$

$V_{rms} \propto \sqrt{T}$.

Q.9 (2)

Specific resistance $k\frac{E}{i}$

Q.10 (3)
Ohm's Law is not obeyed by semiconductors.

Q.11 (4)
$R = 91 \times 10^2 \approx 9.1\ k\Omega$.

Q.12 (2)

Resistance of parallel group $= \frac{R}{2}$

$\therefore$ Total equivalent resistance $= 4 \times \frac{R}{2} = 2R$.

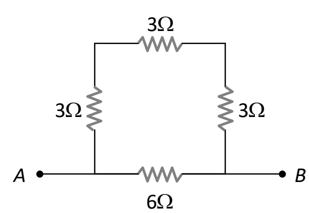
Q.13 (3)

Resistance of 1 *ohm* group $= \frac{R}{n} = \frac{1}{3}\Omega$

This is in series with $\frac{2}{3}\Omega$ resistor.

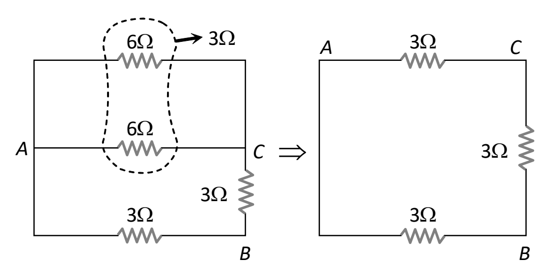
$\therefore$ Total resistance $= \frac{2}{3} + \frac{1}{3} = \frac{3}{3}\Omega = 1\Omega$.

Q.14 (4)
The circuit reduces to



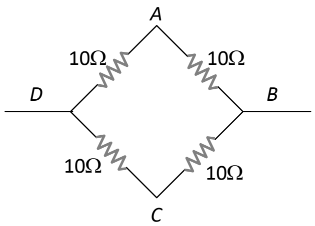
$$R_{AB} = \frac{9 \times 6}{9+6} = \frac{9 \times 6}{15} = \frac{18}{5} = 3.6\Omega$$

Q.15 (2)
Given circuit is equivalent to



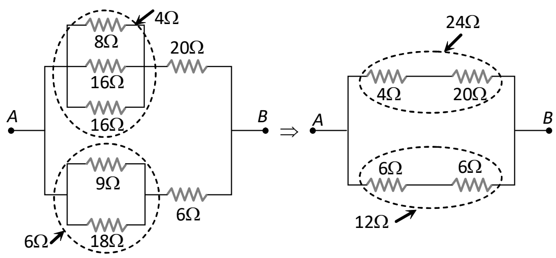
So the equivalent resistance between points *A* and *B* is equal to $R = \frac{6 \times 3}{6+3} = 2\Omega$.

Q.16 (1)
According to the problem, we arrange four resistance as follows



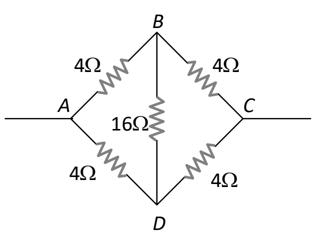
Equivalent resistance $= \dfrac{20 \times 20}{40} = 10\Omega$.

Q.17 (2)



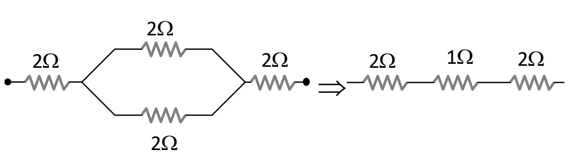
$$R_{AB} = \frac{24 \times 12}{(24+12)} = 8\Omega$$

Q.18 (4)
According to the principle of Wheatstone's bridge, the effective resistance between the given points is 4Ω.



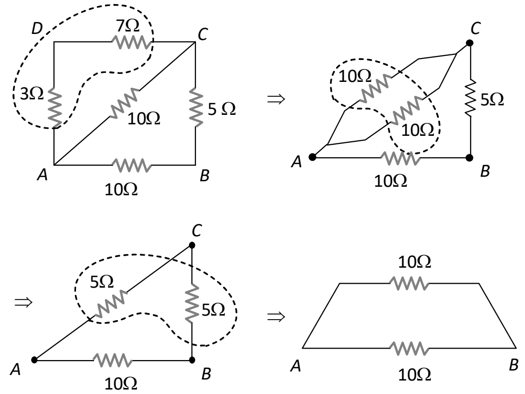
Q.19 (3)

Q.20 (3)
The given circuit can be redrawn as follows



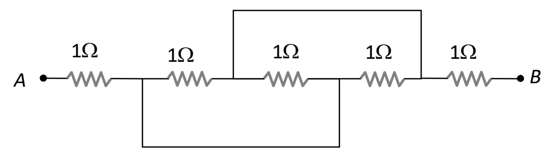
$\Rightarrow R_{eq} = 5\Omega$.

Q.21 (2)
The figure can be drawn as follows



$\Rightarrow R_{AB} = 5\Omega$.

Q.22 (3)



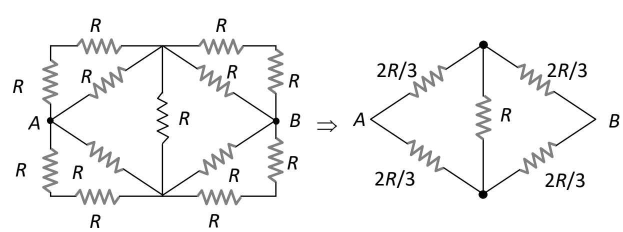
$$R_{AB} = 2 + \frac{1}{3} = 2\frac{1}{3}\Omega.$$

Q.23 (2)

By balanced Wheatstone bridge condition $\dfrac{16}{X} = \dfrac{4}{0.5}$

$$\Rightarrow X = \frac{8}{4} = 2\Omega.$$

Q.24 (3)



Hence $R_{eq} = \dfrac{2R}{3}$.

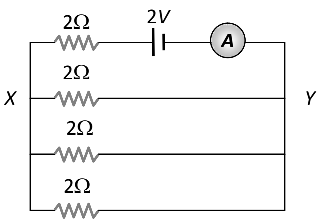
Q.25 (2)

For balanced Wheatstone bridge $\dfrac{P}{Q} = \dfrac{R}{S}$

$$\Rightarrow \frac{12}{(1/2)} = \frac{x+6}{(1/2)} \Rightarrow x = 6\Omega.$$

Q.26 (2)

Resistance across XY $=\frac{2}{3}\Omega$



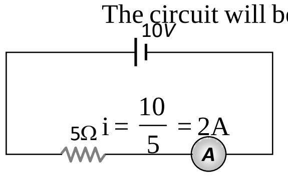
Total resistance

$$= 2+\frac{2}{3}+\frac{8}{3}\Omega$$

Current through ammeter $=\frac{2}{8/3}=\frac{6}{8}=\frac{3}{4}A$

Q.27 (2)

The circuit will be as shown



$i=\frac{10}{5}=2A$

Q.28 (3)

Current through 6Ω resistance in parallel with 3Ω resistance = 0.4 *A*

So total current = 0.8 + 0.4 = 1.2 *A*

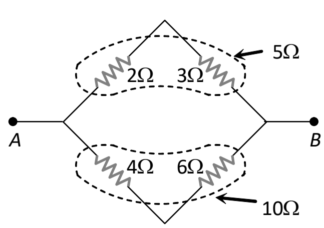
Potential drop across 4Ω = 1.2 × 4 = 4.8V.

Q.29 (4)

Given circuit is a balanced Wheatstone bridge circuit. So there will be no change in equivalent resistance. Hence no further current will be drawn.

Q.30 (1)

The given circuit is a balanced Wheatstone bridge type, hence it can be simplified as follows



$\Rightarrow \quad R_{AB}=\frac{10}{3}\Omega$

Q.31 (2)

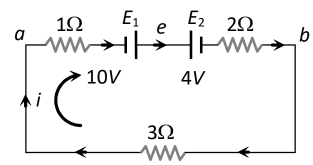
Let current through 5Ω resistance be *i*. Then

$i \times 25 = (2.1 - i)10 \quad \Rightarrow \quad i=\frac{10}{35}\times 2.1 = 0.6$ A.

Q.32 (4)

Since $E_1(10\,V) > E_2(4V)$

So current in the circuit will be clockwise.



Applying Kirchoff's voltage law

$-1\times i+10-4-2\times i-3i=0$

$\Rightarrow i = 1A$(a to b via e)

$\therefore$ Current $=\frac{V}{R}=\frac{10-4}{6}=1.0$ ampere

Q.33 (3)

In short circuiting $R = 0$, so $V = 0$

Q.34 (1)

Total e.m.f. = nE, Total resistance $R + nr \Rightarrow i=\frac{nE}{R+nr}$.

Q.35 (1)

Applying Kirchhoff law

$(2+2)=(0.1+0.3+0.2)i \Rightarrow i=\frac{20}{3}A$

Hence potential difference across *A*

$=2-0.1\times\frac{20}{3}=\frac{4}{3}V$ (less than 2V).

and similarly across B will be zero.

Q.36 (4)

$V_{AB}=4=\frac{5X+2\times 10}{X+10} \quad \Rightarrow \quad X = 20\Omega.$

Q.37 (3)

Since the current coming out from the positive terminal is equal to the current entering the negative terminal, therefore, current in the respective loop will remain confined in the loop itself.

$\therefore$ current through 2Ω resistor = 0.

Q.38 (3)

By Kirchhoff's current law.

Q.39 (1)

Potential gradient $= \frac{e}{(R+R_h+r)} \cdot \frac{R}{L}$

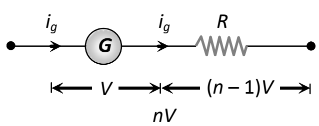
$= \frac{2}{(15+5+0)} \times \frac{5}{1} = 0.5\frac{V}{m} = 0.005\frac{V}{cm}$.

Q.40 (3)

$S = \frac{i_g G}{(i-i_g)} = \frac{1\times 0.018}{10-1} = \frac{0.018}{9} = 0.002\Omega$.

Q.41 (2)

Suppose resistance R is connected in series with voltmeter as shown.



By Ohm's law

$i_g.R = (n-1)V$

$\Rightarrow R = (n-1)G$ (where $i_g = \frac{V}{G}$).

Q.42 (3)

If resistance of ammeter is r then

$20 = (R + r)4 \Rightarrow R + r = 5 \Rightarrow R < 5\Omega$.

Q.43 (3)

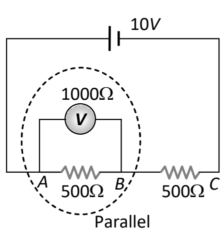
By Wheatstone bridge, $\frac{R}{80} = \frac{AC}{BC} = \frac{20}{80} \Rightarrow R = 20\Omega$.

Q.44 (3)

$2R > 20 \Rightarrow R > 10\Omega$

Q.45 (4)

Resistance between A and B = $\frac{1000\times 500}{(1500)} = \frac{1000}{3}$



So, equivalent resistance of the circuit

$R_{eq} = 500 + \frac{1000}{3} = \frac{2500}{3}$

∴ Current drawn from the cell

$i = \frac{10}{(2500/3)} = \frac{3}{250}$ A

Reading of voltmeter i.e.

potential difference across 500Ω resistor is 4V.

Q.46 (4)

$E = \frac{e}{(R+R_h+r)} \cdot \frac{R}{L} \times l$

$\Rightarrow \mathbf{0.4} = \frac{5}{(5+45+0)} \times \frac{5}{10} \times l$ **0**

$\Rightarrow l = 8$ m.

JEE-MAIN
OBJECTIVE QUESTIONS

Q.1 (3)

The drift velocity of electrons in a conducting wire is of the order of 1mm/s. But electric field is set up in the wire very quickly, producing a current through each cross section, almost instantaneously.

Q.2 (4)

In the presence of an applied electric field ($\vec{E}$) in a metallic conductor. The electrons also move randomly but slowly drift in a direction opposite to $\vec{E}$.

Q.3 (1)

Q.4 (4)

Q.5 (3)

Given that $v_{d_1} = v$, $v_{d_2} = ?$

We know that

$I = neAv_d$

$\Rightarrow \quad V_d \propto \frac{1}{A} \propto \frac{1}{\frac{\pi d^2}{4}} \propto \frac{1}{d^2}$

$\frac{V_{d_1}}{V_{d_2}} = \frac{(d/2)^2}{d^2} = \frac{1}{4}$

$V_{d_2} = 4V$

Q.6 (2)

$v = \sqrt{\frac{3RT}{m}}$

$v \propto \sqrt{T}$

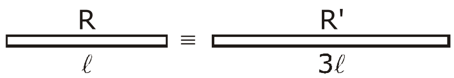
Q.7 (3)

$j = \frac{i}{A}$ current density inversely proportional to area of cross section

Q.8 (4)
Copper is metal and germanium is semiconductor. Resistance of a metal decreases and that of a semiconductor increases with decrease in temperature.

Q.9 (2)

Q.10 (4)



During stretching volume is constant
$Al = A'(3l)$

$\Rightarrow A' = A/3$

$\frac{R'}{R} = \frac{\rho\, 3\ell}{A' \frac{\rho\ell}{A}}$, $R' = \frac{3A}{A'} \times R$

Put A' and R from above $R' = R_{new} = 9R = 180\Omega$

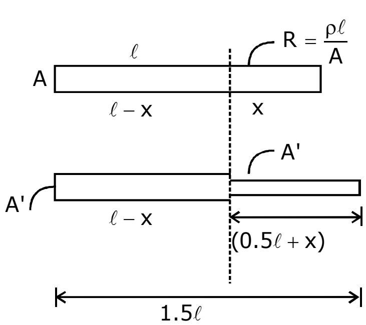
Q.11 (2)

$R \downarrow$ (Resistance decreases which increase of temperature)

Q.12 (2)
Given that l = 5 m, d = 10 cm. = 0.1 m.

$$R = \frac{\rho l}{A} = \frac{17 \times 10^{-8} \times 5}{\frac{\pi \times 0.095^2}{4}} = 5.7 \times 10^{-5}\Omega$$

Q.13 (2)
During stretching volume remains constant



R'= 4R

$Ax = A'(0.5\ell + x)$

$$A' = \frac{Ax}{0.5\ell + x}$$
....(1)

$$\Rightarrow \frac{4\rho\ell}{A} = \frac{\rho(\ell - x)}{A} + \frac{\rho(0.5\ell + x)}{A'}$$
....(2)

Put value of A' in equation (2) from equation (1)

$$\Rightarrow \frac{4\rho\ell}{A} = \frac{\rho(\ell - x)}{A} + \frac{\rho(0.5\ell + x)^2}{Ax}$$

$\Rightarrow 4\ell x = \ell x - x^2 + (0.5\ell)^2 + \ell x + x^2$

After solving $x = (1/8)\ell$

Q.14 (2)
Given that $l = 15$ m, $A = 6.0 \times 10^{-7}$ m^2.
$R = 5\,\Omega$, $\rho = ?$

$$\rho = \frac{RA}{l} = \frac{5 \times 6 \times 10^{-7}}{15} = 0.2 \times 10^{-6}\,\Omega m$$

Q.15 (3)
Given that $l_1 = 20$ cm, $R_1 = 5\,\Omega$,
$l_2 = 40$ cm, $R_2 = ?$
During stretching volume of wire is constant

$20A = 40A' \Rightarrow A' = A/2$

We know that $R = \frac{\rho l}{A}$

$$\frac{R_2}{R_1} = \frac{l_2}{l_1} \times \frac{A}{A'} = \frac{40}{20} \times \frac{A}{\frac{A}{2}}$$

$R_2 = 20\Omega$

Q.16 (3)
In series circuit current is same

$i = n_1 eA\, V_{d_1}$, $i = n_2 eA\, V_{d_2}$, $\frac{n_1}{n_2} = \frac{V_{d_2}}{V_{d_1}} = \frac{4}{1}$

Q.17 (3)
Given that $v_d' = 2v_d$
$I = neAv_d$, $A = \pi r^2$

$I' = neA'v_d'$, $A' = \frac{\pi r^2}{4}$

$I' = ne\dfrac{\pi r^2}{4} v_d'$

$I' = ne\dfrac{\pi r^2}{4} .2V_d$

$I' = I/2$

Q.18 (3)

y : $\rho = \rho_0 (1 + \alpha\Delta T)$

α is –ve for semi conductor

z : temp $\uparrow$ $\tau \downarrow$ Hence rate of collision $\uparrow$

Q.19 (2)

(ii) (3)

(a) $R_1 = R_{01} (1 + \alpha_1 \Delta\theta) = 600 (1 + 0.001 \times 30) = 618\ \Omega$

$R_2 = R_{02} (1 + \alpha_2 \Delta\theta) = 300 (1 + 0.004 \times 30) = 336\ \Omega$

$R_{eq} = R_1 + R_2 = 618 + 336 = 954\ \Omega$

(b) $R_{eq} = R_{0eq} (1 + \alpha_{eq} \Delta\theta)$ $954 = 900 (1 + \alpha\ 30)$ $\alpha = \dfrac{54}{900 \times 30} = \dfrac{1}{500}$ degree^{-1}

Q.20 (4)

$i_1 = neAV$, $i_2 = n(2e) Av/4$

$i = i_1 + i_2 = \dfrac{3neAV}{2}$

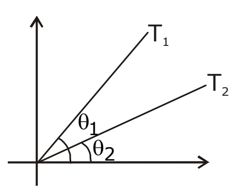
Q.21 (2)

we no that $I = neAv_d$

$V_d = \dfrac{I}{neA} \propto \dfrac{I}{r^2}$

$\dfrac{V_{d_1}}{V_{d_2}} = \left(\dfrac{I_1}{I_2}\right)\left(\dfrac{r_2}{r_1}\right)^2 = \left(\dfrac{4}{1}\right)\left(\dfrac{2}{1}\right)^2 = 16$

Q.22 (2)



$R = \dfrac{V}{I} \Rightarrow \dfrac{I}{V} = \dfrac{1}{R}$

$\tan\theta = 1/R = w + \theta$

$\because$ $\theta_1 > \theta_2$

$\Rightarrow$ $R_1 < R_2 \Rightarrow T_1 < T_2$

$\because$ $T\uparrow R\uparrow$

Q.23 (2)

in this question $n \rightarrow p$

$A \rightarrow s$, $e \rightarrow q$

$i = neAV_d$

$\dfrac{i}{\rho sq} = V_d$

Q.24 (3)

$i = neAV_d$

i is same so

$A\uparrow V_d\downarrow$

Q.25 (1)

$R = \dfrac{\rho\ell}{A}$

$R_{square} = \dfrac{3.5 \times 10^{-5} \times 50 \times 10^{-2}}{(10^{-2})^2}$

$= \dfrac{35}{2} \times 10^{-2}\Omega$

$R_{rectangle} = \dfrac{3.5 \times 10^{-5} \times 2[1 \times 10^{-2}]}{(50 \times 10^{-4})}$

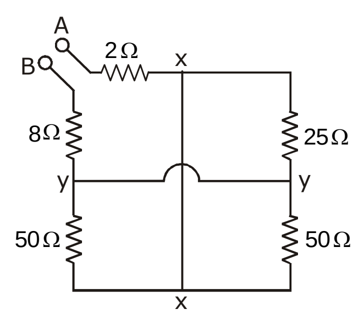
$= 7 \times 10^{-5}$

Q.26 (1)

$\dfrac{1}{R_{eq}} = \dfrac{10}{R} + \dfrac{10}{R} + ...10\text{times}$

$R_{eq} = R / 100$

Q.27 (2)



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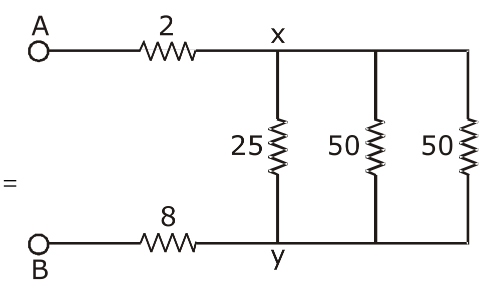
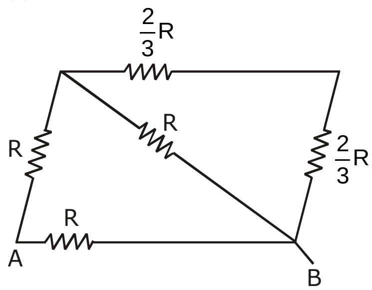


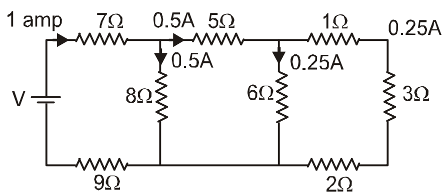
$R_{eq.} = 2 + \frac{25}{2} + 8 = \frac{45}{2}\Omega$

Q.28 (4)



Req. = $\frac{11R}{18}$

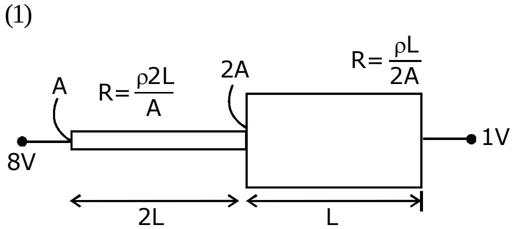
Q.29 (2)

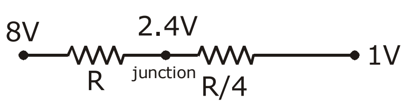


$R_{eq} = 7 + 4 + 9 = 20\Omega$

$V = IR_{eq} = 1 \times 20 = 20$ V

Q.30 (1)





Let I be the current flow

$8 - IR - IR/4 = 1$

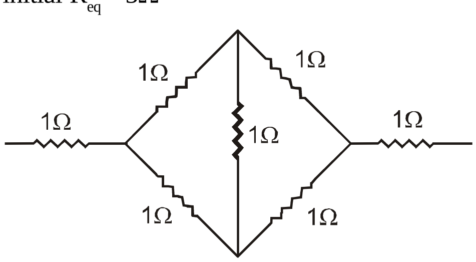
$I = \frac{28}{5R}$

$8 - \frac{28}{5R} \times R = V_j$

$V_j = 2.4V$

Q.31 (1)

initial $R_{eq} = 5\Omega$

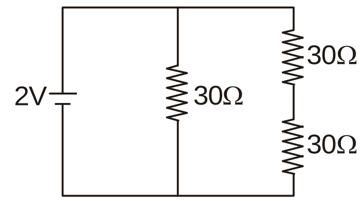


final $R_{eq} = 3\ \Omega$

change in resistance = $5 - 3 = 2\Omega$

Q.32 (3)

This simplified circuit is shown in the figure.



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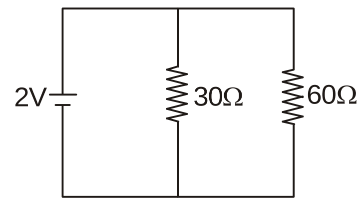

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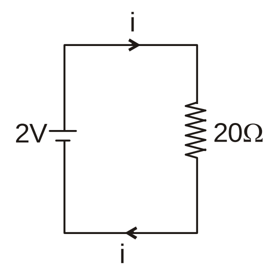
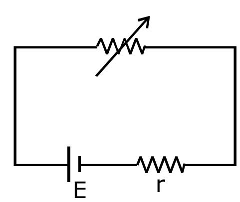


Therefore, current $i = \frac{2}{20} = \frac{1}{10}$ A

Q.33 (4)



$E - ir = V$

$V = E - \frac{E}{R + r}.r$

at $R = 0$

$V = 0$

Q.34 (1)

From V : IR

When S_1 is closed $V_1 = \left(\frac{E}{4R}\right)3R = \frac{3E}{4} = 0.75E$

When S_2 is closed $V_2 = \frac{E}{7R} \cdot 6R = \frac{6E}{7} = 0.85E$

When both S_1 & S_2 are closed

$V_3 = \frac{E}{3R} \times 2R = \frac{2E}{3} = 0.6E$

$V_2 > V_1 > V_3$

Q.35 (3)

For $P_{max} \Rightarrow r = R_{eq}$, $R_{eq} = R/3$

$0.1 = \frac{R}{3} \Rightarrow R = 0.3\,\Omega$

Q.36 (4)

All resistances are parallel so potential is same

$V = 0.3 \times 20 = 6V$

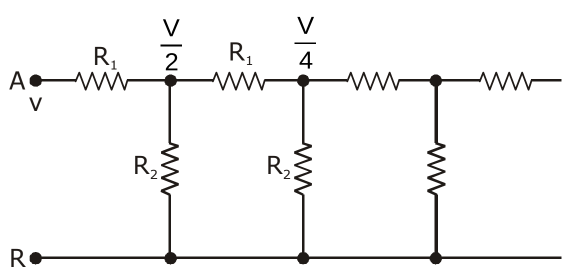
$i_1 : i_1 : i_3 = \frac{1}{R_1} : \frac{1}{20} : \frac{1}{15}$

$= 60 : 3R_1 : 4R_1$

$\Rightarrow 0.3 = \frac{3R_1}{60 + 7R_1} \times (0.8)$

$\Rightarrow R_1 = 60\,\Omega$

Q.37 (2)

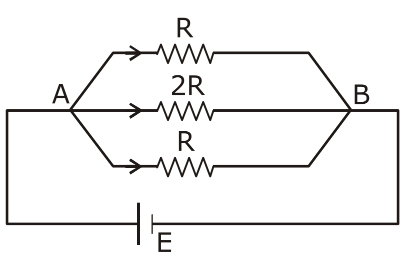


$\frac{V}{2R_1} = \frac{V}{2R_2} + \frac{V}{4R_1}$

$\frac{1}{R_1} = \frac{1}{R_2} + \frac{1}{2R_1} \Rightarrow \frac{R_2}{R_1} = 2$

Q.38 (2)

After redraw circuit all resistances are parellel



Q.39 (1)

$R_{eq} = 2 + \frac{4}{2} + \frac{15}{3} + R_A = 9 + R_A$

$I = \frac{V}{R_{eq}} \Rightarrow 1 = \frac{10}{9 + R_A} \qquad \Rightarrow R_A = 1\Omega$

if 4Ω replace by 2Ω resistance then

$R_{eq} = 2 + \frac{2}{2} + \frac{15}{3} + 1 = 9\Omega$

$I = \frac{10}{9}$ amp

Q.40 (2)

625 (P) = SQ

....(1)

when P,Q is interchanged

Q(676) = PS

....(2)

From eq. (1) & (2)

$\frac{676}{S} = \frac{S}{625}$

$S = 650\,\Omega$

Q.41 (2)

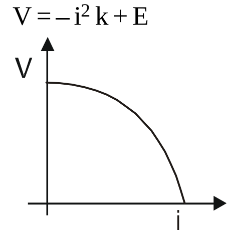
In an electric circuit containing a battery, the positive charge inside the battery may go from the positive terminal to the negative terminal

Q.42 (4)

Given $r \propto i \Rightarrow r = ki$

$V = E - ir = E - i(ki)$

$V = -i^2 k + E$

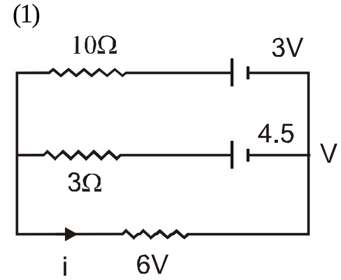


Q.43 (2)

(1) $V = E - ir, V < E$ (2) $V = E + ir, V > E$

(3) $V = E$ (4) $V = E$

Q.44 (1)



$$E_q = \frac{\frac{4.5}{3}+\frac{3}{10}}{\frac{1}{3}+\frac{1}{10}} = \frac{54}{13} = V$$

$$r_{eq} = \frac{3\times 10}{13} = \frac{30}{13}\ \Omega$$

$$i = \frac{54/13}{6+\frac{30}{13}} = \frac{54}{108} = \frac{1}{2}\ \text{amp.}$$

$$V_{6\Omega} = i.R = \frac{1}{2}\times 6 = 3V$$

There fore current in 10Ω is zero.

Q.45 (2)

$$\eta = \frac{E - Ir}{E} = 1 - \frac{r}{r+R} = \frac{R}{r+R} = 0.6 \Rightarrow R = 0.6\,r + 0.6\,R$$

$$r = \frac{4}{6}\ R = \frac{2R}{3}$$

$$\Rightarrow\ \eta = \frac{6R}{r+6R} = \frac{6R}{\frac{2R}{3}+6R} = \frac{18R}{2R+18R} = 0.9 = 90\%$$

Q.46 (3)

$E + ir = 12.5$ Volt

$E + (0.5\times 1) = 12.5$

$E = 12$ volt

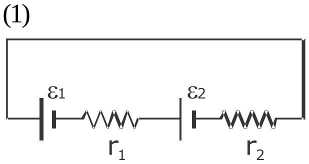
Q.47 (4)

$E - ir = 0$

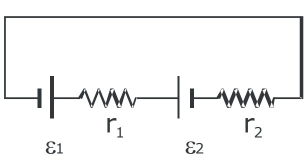
$E - ir = V$ (Discharging)

$E + ir = V$ (Charging)

Q.48 (1)



$$\frac{\varepsilon 1 + \varepsilon 2}{r_1 + r_2} = I_1$$



$$\frac{-(\varepsilon 2 - \varepsilon 1)}{r_1 + r_2} = I_2$$

$$\frac{\varepsilon_1 + \varepsilon_2}{\varepsilon_1 - \varepsilon_2} = \frac{I_1}{I_2}$$

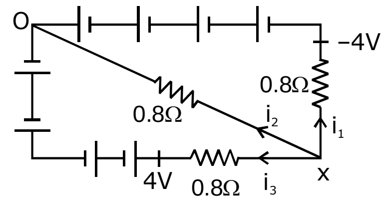
$$\Rightarrow\ \varepsilon_1 = \frac{(I_1 + I_2)}{(I_1 - I_2)}\,\varepsilon_2$$

Q.49 (3)

$$i = \frac{4}{4} = 1\ \text{Amp}$$

$V = E + ir = 2 + 1 \times 3 = 5V$

Q.50 (3)



$i_1 + i_2 + i_3 = 0$

$$\frac{x+4}{0.8} + \frac{x}{0.8} + \frac{x-4}{0.8} = 0$$

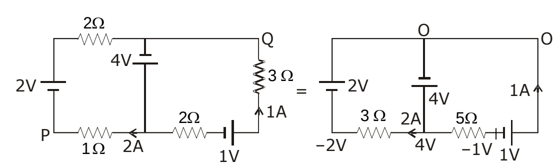
$x = 0$

i.e. there is no curent in 0.8 Ω resistor

$$i_1 = i_3 = i = \frac{4}{0.8} = 5A$$

$\Rightarrow\ V = E - ir = 1 - (5)(0.2) = 0$

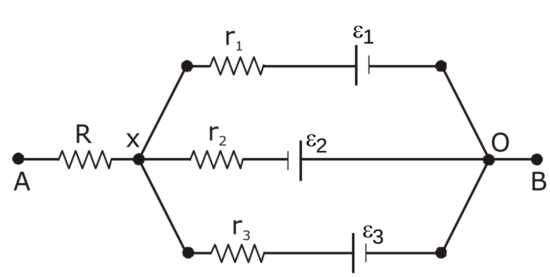
Q.51 (2)



Now $V_p = +2 - 4 + V_Q$

$V_P - V_Q = 2V$

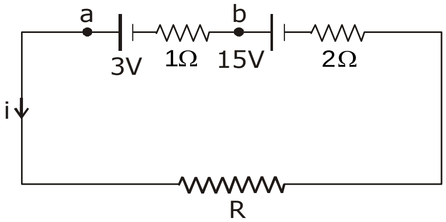
Q.52 (2)



$$\frac{x-\varepsilon_1}{r_1} + \frac{x-\varepsilon_2}{r_2} + \frac{x-\varepsilon_3}{r_3} = 0$$

$x = 2$ volt

Q.53 (3)



From circuit analysis we get

$$i = \frac{18}{R+3}$$

move in the circuit from point b to a

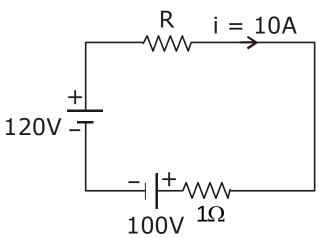
$$V_b = -\frac{-18}{R+3}(1) + 3 + V_a$$

$$V_b - V_a = 0 = -18 + 3R + 9$$

$$\Rightarrow 3R = 9$$

$$R = 3\Omega$$

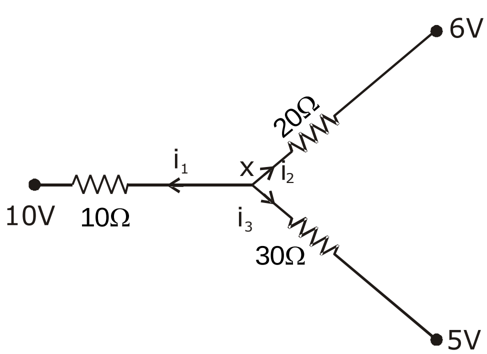
Q.54 (3)



$$I = \frac{20}{R+1} = 10$$

$$R = 1\Omega$$

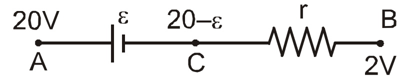
Q.55 (2)
Let potential of junction is x , then current shown in circuit



Now $\frac{x-10}{10} + \frac{x-6}{20} + \frac{x-5}{30} = 0$

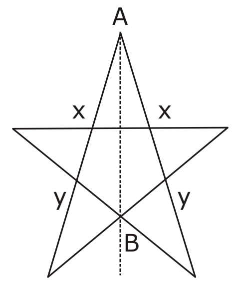
$x = 8V$, $i_1 = \frac{10-8}{10} = 0.2A$

Q.56 (2)



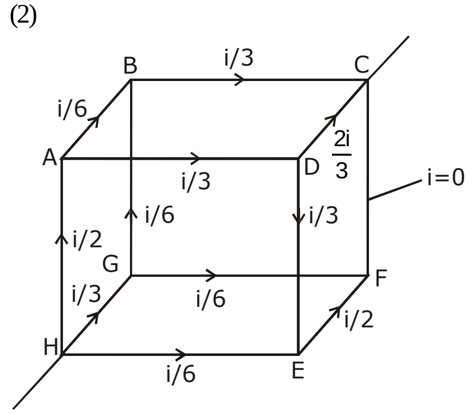
Potential at C point may be greater than potential at point B. Therefore current flow in resistance may be from B to A.

Q.57 (2)

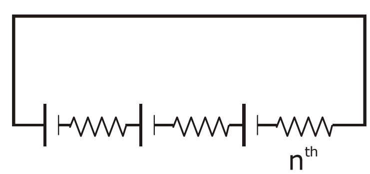


Folding symmetry

Q.58 (2)



Q59 (4)



$$i = \frac{nE}{nr} = \frac{E}{r}$$

Independent of n

Q.60 (1)

$$i = \frac{E}{r/n} = \frac{nE}{r}$$

Q.61 (1)

$$P = \left(\frac{E}{R+5}\right)^2 R$$

$\frac{dP}{dR} = 0$ at R = 5Ω, so power is maximum at R = 5Ω,

Therefore increase continuously till R = 5Ω.

Q.62 (1)

$$R_{2.5\,W} = \frac{(110)^2}{2.5}\ \Omega,\ R_{100W} = \frac{(100)^2}{100} \Rightarrow R_{2.5} > R_{100}.$$

In series current passes through both bulb are same

$P_{2.5} = i^2 R_{2.5}$, $P_{100} = i^2 R_{100}$

$P_{2.5} > P_{100}$ due to $R_{2.5} > R_{100}$ & ∵ $P_{2.5} > 2.5W$ & $P_{100} < 100$ W (can be verified)

Therefore 2.5 W bulb will fuse

Q.63 (1)

$$R = \frac{(220)^2}{100}$$

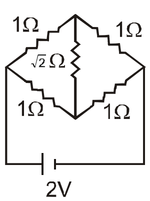
$$R_{eq} = \frac{R}{3} + R = \frac{4R}{3} = \frac{4(220)^2}{300}$$

$$P = \frac{V^2}{R_{eq}} = \frac{(220)^2 \times 300}{4(220)^2} = \frac{300}{4} = 75\ W$$

Q.64 (2)

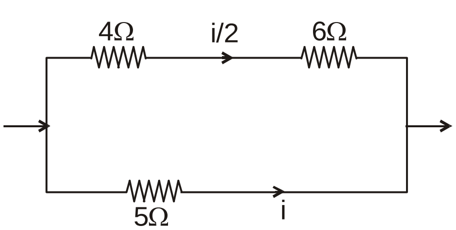
Resistance of one side = 0.1 × 10 = 1Ω

$$R_{eq} = 1\Omega\ \ P = \frac{V^2}{R_{eq}} = \frac{(2)^2}{1} = 4\ \text{watt}$$



Q.65 (2)

Since,resistance in upper branch of the circuit is twice the resistance in lower branch. Hence, current there will be half.



Now, $P_4 = (i/2)^2\,(4)$ $(P = i^2R)$

$P_5 = (i)^2\,(5)$

or $\frac{P_4}{P_5} = \frac{1}{5}$

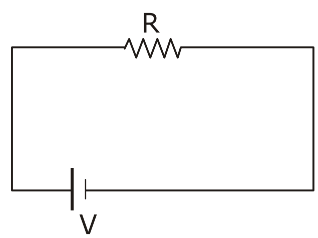
$$\therefore\ P_4 = \frac{P_5}{5} = \frac{10}{5} = 2\ \text{cal/s.}$$

Q.66 (3)

$$P = \frac{V^2}{R} = \frac{240 \times 240}{0.5} = 115.2\,KW$$

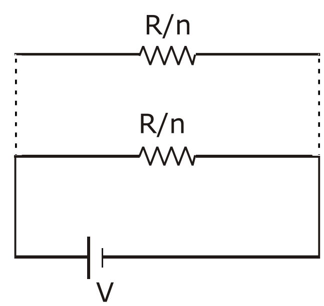
$$\eta = \frac{115.2 - 15}{115.2} \times 100 = 89\%$$

Q.67 (2)



Initially $H = \frac{v^2}{R}$

Now after cutting



Power in one branch

$$= \frac{V^2}{R/n} = \frac{nV^2}{R}$$

$$\text{Total power} = \frac{nV^2}{R} + \frac{nV^2}{R} + \ldots = \frac{n^2V^2}{R}$$

Q.68 (2)

$$H = \frac{v^2}{R}\,\Delta t,\ \&\ R = \frac{\rho\ell}{A}$$

$$H = \frac{AV^2}{\rho \ell} \Delta t$$

$$H \propto \frac{A}{\ell}$$

$$H \propto \frac{r^2}{\ell}$$

Heat is doubled only when r, ℓ doubled

Q.69 (3)

$$R = \frac{V_{rated}^2}{P_{rated}} \Rightarrow R \propto V_{rated}^2$$

$\because$ In series I is same.

$$\text{Power} = I^2 R \propto V_{rated}^2$$

Q.70 (3)

$P = V \cdot i$, $\quad P = E \cdot \ell \cdot JA$

$$\frac{P}{\ell A} = EJ$$

Q.71 (1)

$$i = \frac{dQ}{dt} = 2 - 16t$$

$$\text{Heat} = R \int_0^{1/8} (2 - 16t)^2 . dt, \ \frac{R}{6}$$

Q.72 (2)

$$P = \frac{V^2}{R} \qquad R = \frac{\rho \ell}{A}$$

$$P' = \frac{V^2}{0.9R} \qquad R' = \frac{\rho(\ell - 0.1\ell)}{A}$$

$$P' = \frac{1.11V^2}{R}, \ R' = 0.9 \frac{\rho \ell}{A}$$

$$R' = \frac{0.9\rho\ell}{A}$$

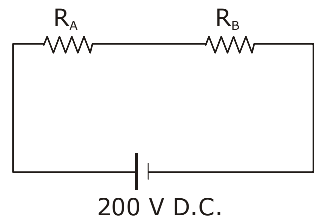
$$P' = \left(1 + \frac{11}{100}\right) P$$

P' increses by 11 %.

Q.73 (4)

We know that $P = \frac{V^2}{R}$

Then $R_A = \frac{(200)^2}{300}$



$$R_B = \frac{(200)^2}{600}$$

In series

$$R_{eq} = R_A + R_B, \ P = \frac{(200)^2}{\frac{(200)^2}{300} + \frac{(200)^2}{600}}$$

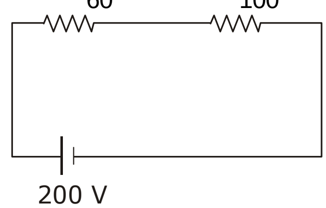
P = 200 Watt

Q.74 (1)

Situation shown in diagram $P = \frac{V^2}{R}$

Case I **Case II**

$$R_1 = \frac{(200)^2}{60} \qquad R_2 = \frac{(200)^2}{100}$$



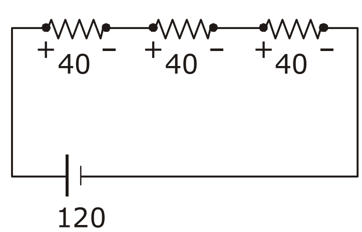
In series combination

$$R_{eq} = R_1 + R_2 = \frac{200^2}{60} + \frac{200^2}{100} = \frac{200^2 \times 160}{60 \times 100}$$

$$P = \frac{200^2 \times 160}{60 \times 100} = 37.5 \text{ W}$$

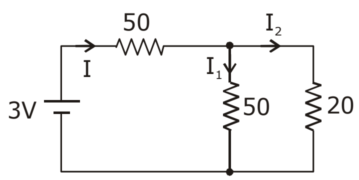
Q.75 (1)

$R = (120)^2/60$



$$P = \frac{(40)^2}{(120)^2} \times 60\ ,\ = 6.7 \text{ Watt}$$

Q.76 (1)
I^2R is maximum for R_1 resistance As $I > I_1$ & I_2



maximum power dissipation in R_1.

Q.77 (2)
As R_{eq} decreases I_{net} increases hence current through X increases but as I_{net} will now be distributed in Y & Z, current in Y decreases.

Q.78 (4)
From Maximum Power Transfer Theorem
$y_{max} = R + 2\Omega$
$\Rightarrow\ 5\Omega = R + 2\Omega \Rightarrow R = 3\Omega$

Q.79 (4)
From graph I = 0 ⇒ Open ckt.
V = y = E

When V = 0 . I_{max}
E = ir
y = xr
r = y/x

Q.80 (3)

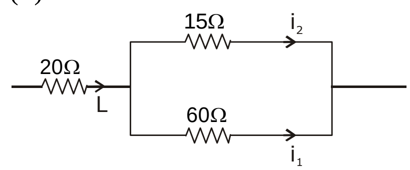
$$R_{eq} = 200 + \frac{300 \times 600}{300 + 600} + 100 = 500\,\Omega$$

$$I = \frac{100}{500} = \frac{1}{5} \text{ amp}$$

$$I_{600} = \frac{\frac{1}{600}}{\frac{1}{300} + \frac{1}{600}} \times \frac{1}{5} = \frac{1}{15} \text{ amp}$$

Reading of volt meter $= I_{600}\,R_{600} = \frac{1}{15} \times 600 = 40$ V

Q.81 (2)



Given $\frac{15 \times i}{75} = 0.75$

Now $i_2 = \frac{60 \times i}{75} = \left[\frac{60 \times 0.75 \times 75}{15}\right] = 3A$

Q.82 (1)

$$R_{eq} = 10 + \frac{480 \times 20}{480 + 20} = 10 + \frac{96}{5} = \frac{146}{5}$$

current passes through the battery.

$$I = \frac{20 \times 5}{146} = \frac{100}{146} = \frac{50}{73} \text{ amp.}$$

Q.83 (3)

Case – I $I_g = \frac{E_1 + E_2}{R_g + R + 2r} \Rightarrow 1 = \frac{3}{R_g + R + 2r}$

$\Rightarrow R_g + R + 2r = 3$ .... (1)

Case – II $E_{eq} = E = 1.5$ V

$$I_g = \frac{E_{eq}}{R_g + R + \frac{r}{2}} \Rightarrow 0.6 = \frac{1.5}{R_g + R + \frac{r}{2}}$$

$\Rightarrow R_g + R + \frac{r}{2} = \frac{1.5}{0.6} = 2.5$ ....(2)

from eq (1) and (2)

$\frac{3r}{2} = 0.5 \Rightarrow r = \frac{1}{3}\,\Omega$

Q.84 (4)

$$i = \frac{2}{10 + R}$$

$$x = \frac{V}{\ell} = \frac{2 \times 10}{(R + 10)} \cdot \frac{1}{100}$$

$$V_1 = x\ell \Rightarrow 10 \times 10^{-3} = \frac{2 \times 10}{(R + 10)} \times \frac{40}{100}$$

$$R + 10 = \frac{8}{10 \times 10^{-3}}$$

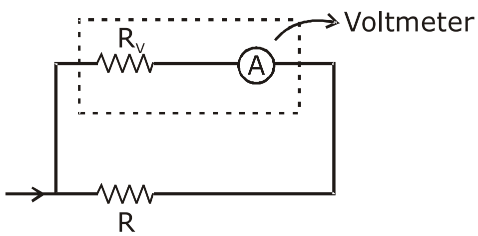
$\Rightarrow R + 10 = 800$ $\Rightarrow R = 790\Omega$

Q.85 (4)

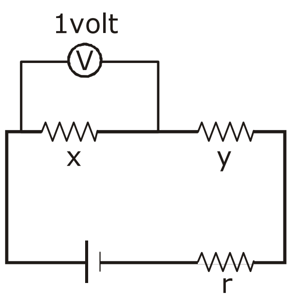
$$\frac{6}{R} = \frac{\ell}{x-\ell}$$

$$\frac{6}{R} = \frac{30}{20} \Rightarrow R = 4\Omega$$

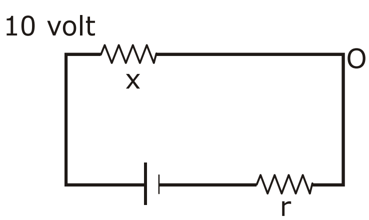
Q.86 (3)
High resistance in series



Q.87 (3)



$$\frac{E}{r+x+y} = 1 \text{ ...(1)}$$



$$E - \frac{Er}{x+r} = 10 \text{ volt}$$

$$\frac{Ex}{x+r} = 10 \text{ volt} \qquad \text{...(2)}$$

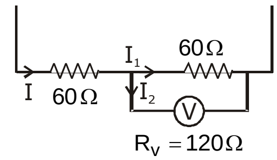
$$\frac{E}{r+x+y} = 1 \text{ volt} \qquad \text{...(3)}$$

$\Rightarrow x = 1\Omega$

$$\frac{12+1}{1+r} = 10$$

$\Rightarrow r = 0.2\Omega$

Q.88 (1)



Net current

$$I = \frac{120}{60+40} = 1.2A$$

$$I_1 : I_2 = \frac{1}{60} : \frac{1}{120}$$

$= 2 : 1$

$$I_1 = \frac{2}{3} \times 1.2 = 0.8 \text{ Amp.}$$

hence Reading $V = 0.8 \times 60 = 48$ V

Q.89 (4)
according to shown network

$$\frac{i}{2} R_g = \frac{i}{2}(20) \Rightarrow R_g = 20$$

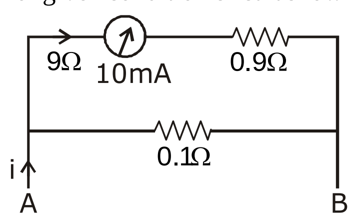
Q.90 (2)

$$i_g = \frac{0.2}{20} = 0.01 \text{ Ampere}$$

$$i = i_g\left(1 + \frac{r_2}{R}\right) \Rightarrow 10 = 0.01\left(1 + \frac{20}{R}\right)$$

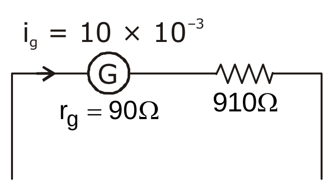
$R \simeq 0.02$

Q.91 (3)
Given for ammeter $i = 10^{-3}$A, $R = 9\Omega$
for given condition circuit shown like



$$10 \times 10^{-3} = \frac{0.1}{10} \times i \Rightarrow i = 1 \text{ Ampere}$$

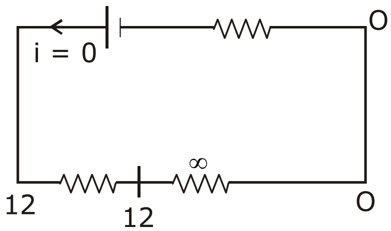
Q.92 (3)
Given for galvanometer $r_g = 90\Omega$, $i = 10$ mA



$V = i_g (R + r_g)$
$V = 10^{-2} (1000)$
$= 10$ Volt

$n = \frac{10}{0.1} = 100$

Q.93 (4)



From circuit diagram voltmeter reading will be 12V

Q.94 (2)
Voltmeter must be connected in parallel and Ammeter in series with the resistance in circuit.

Q.95 (1)
$R_1 \times 60 = R_2 \times 40$
....(1)

$R_1 \times 50 = \frac{R_2 \times 10}{R_2 + 10} \times 50$ ....(2)

Devide (2) by (1) $\frac{50R_1}{60R_1} = \frac{\frac{10R_2 \times 50}{R_2 + 10}}{R_2 \times 40}$

$R_2 = 5\Omega, R_1 = \frac{10\,\Omega}{3}$

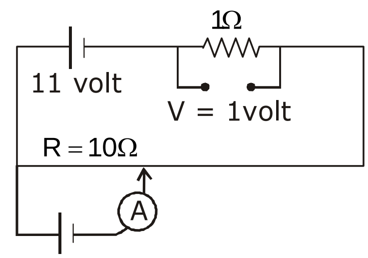
Q.96 (1)

Potential gradient $x = \frac{6}{1}$

$6\ell = 4 \Rightarrow \ell = \frac{2}{3}$ m

Q.97 (2)
case 1
$12 \times (100 - x) = 18 \times x$
$1200 - 12x = 18x$
$30x = 1200$
$x = 40$ cm
case 2
$12 \times (100 - x) = 8\,x$
$1200 - 12x = 8x$
$\Rightarrow x = 60$cm

Q.98 (2)

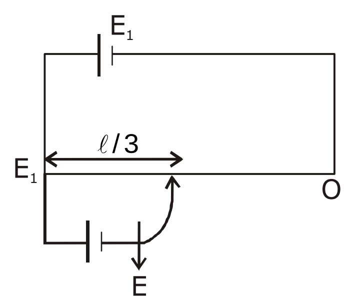


$I = \frac{V}{r + R}$

$I = \frac{11}{10 + 1} = 1$ Amp,

Potential gradient $= x = \frac{11 - 1}{10} = \frac{1\,\text{volt}}{\text{m}}$

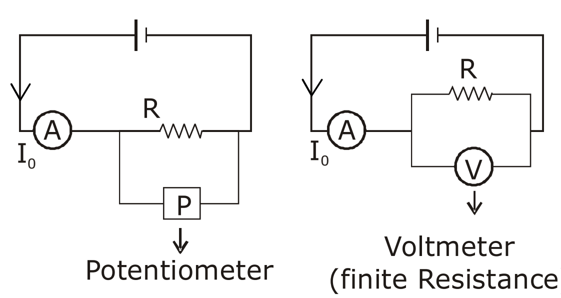
Q.99 (2)



$E_1 = 3E$

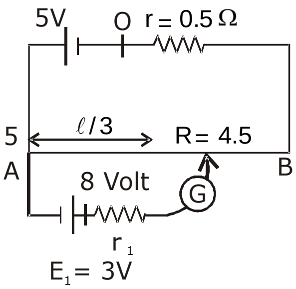
$1.5\ell \rightarrow 3E,\ E \rightarrow \frac{\ell}{2}$

Q.100 (1)



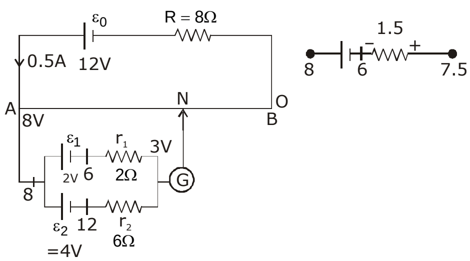
In case of voltmeter $R_{eq} < R$ hence
$I > I_0$
As voltmeter always take some current from the circuit $V < V_0$

Q.101 (4)



As Battery is connected in reverse order E_1 will not be balanced on entire length of wire AB.

Q.102 (3)



$8 \rightarrow 4m$
$1m \rightarrow 2$ Volt
1 Volt $\rightarrow 0.5$ m
0.5 volt $\rightarrow 25$ cm

JEE-ADVANCED OBJECTIVE QUESTIONS

Q.1 (D)

$i = neAV_d$
$V = iR$

Q.2 (A)

$$R_1 = \frac{\rho_B \ell_B}{A}(1 + \alpha_B \Delta T)$$

$$R_2 = \frac{\rho_C \ell_C}{A}(1 + \alpha_C \Delta T)$$

$$\text{Req.} = R_1 + R_2$$

$$R_{eq.} = \frac{\rho_B \ell_B}{A} + \frac{\rho_B \ell_B}{A}\alpha_B \Delta T + \frac{\rho_C \ell_C}{A} + \frac{\rho_C \ell_C}{A}\alpha_C \Delta T$$

Net resistance is independent of temp.

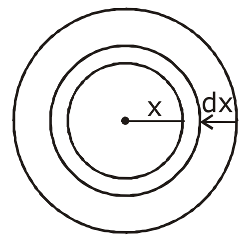
$$\Rightarrow \frac{\rho_B \ell_B \alpha_B \Delta T}{A} + \frac{\rho_C \ell_C \alpha_C \Delta T}{A} = 0$$

$$\Rightarrow \frac{\ell_B}{\ell_C} = \left|\frac{\alpha_C \rho_C}{\rho_B \alpha_B}\right|$$

Q.3 (D)

Apply current density concept

$$I = \int \vec{j} \cdot d\vec{A}$$



$$I = \begin{cases} J_0\left(\frac{x}{R} - 1\right) & \text{for} \quad 0 \le x < R/2 \\ J_0 \frac{x}{R} & \text{for} \quad \frac{R}{2} \le x \le R \end{cases}$$

$$i = \int_0^{R/2} J_0\left(\frac{x}{R} - 1\right) 2\pi x dx + \int_{R/2}^{R} J_0 \frac{x}{R} 2\pi x dx$$

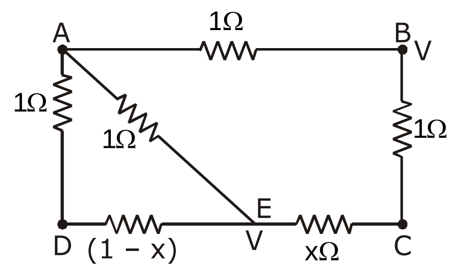
$$i = \frac{5}{12}\pi J_0 R^2$$

Q.4 (C)

In parallel combination equivalent resistance R_{eq} is less then the minimum value of any of resistance $R_1 < R$

In series R_{eq} is greater than maximum of resistance. $R_2 > R$.

Q.5 (D)



$$x = \frac{(2 - x)1}{3 - x}, \; x^2 - 4x + 2 = 0$$

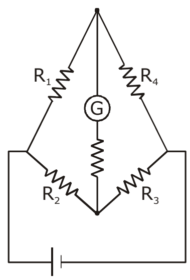
$$x = 2 \pm \sqrt{2}$$

$$\frac{CE}{ED} = \frac{2-\sqrt{2}}{\sqrt{2}-1}$$

$$\frac{CE}{ED} = \frac{(2-\sqrt{2})(\sqrt{2}+1)}{(\sqrt{2}-1)(\sqrt{2}+1)} = \frac{2\sqrt{2}+2-2-\sqrt{2}}{1}$$

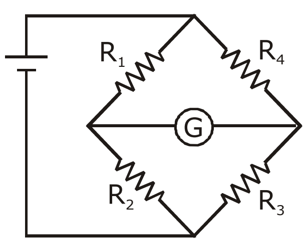
$$\frac{CE}{ED} = \sqrt{2}$$

Q.6 (C)



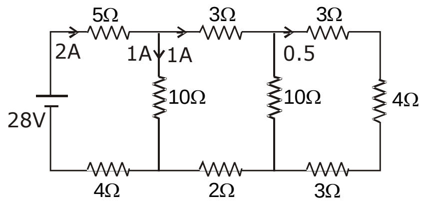
For balanced condition
$R_1R_3 = R_4R_2$
(A) No effect of emf of battery

(B) $(R_1+10)(R_3+10) \neq (R_2+10)(R_4+10)$
Incorrect
(C) $(5R_1)(5R_3) = (5R_2)(5R_4)$
$R_1R_3 = R_2R_4$ correct.
(D)



Balanced

Q.7 (A)



After circuit Analysis we get $R_{eq} = 14\ \Omega$

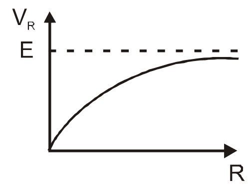
$$I = \frac{28}{14} = 2 \text{ amp.}$$

Q.8 (B)

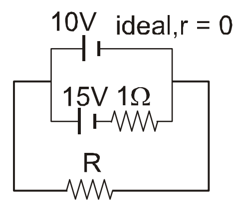
$$V_R = \frac{E}{r+R}\ R = \frac{E}{\frac{r}{R}+1}$$

$R \to 0$ $\quad V_R = 0$

& $R \to \infty$ $\quad V_R = E$



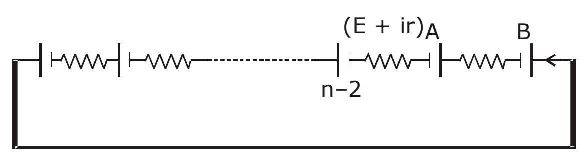
Q.9 (D)
For ideal $r \to 0$



$$E = \frac{\frac{10}{r}+\frac{15}{1}}{\frac{1}{r}+\frac{1}{1}} = \frac{10+15r}{1+r}$$

$E = 10\,V$

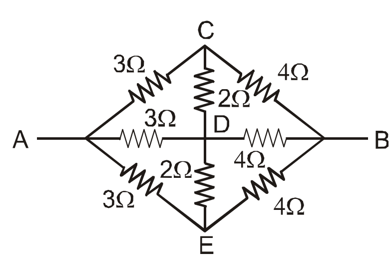
Q.10 (D)



$E^n_{eq} = (n-4)\,.\,E \quad r^n_{eq} = nr$
From circuit analysis we get V = E + ir ....(1)

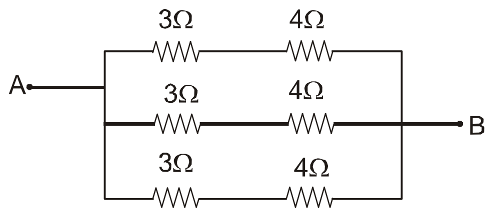
$$i = \frac{(n-4)E}{nr},\quad V = \left[E + \frac{(n-4)E}{nr}.r\right] = 2E\left(1-\frac{2}{n}\right)$$

Q.11 (D)

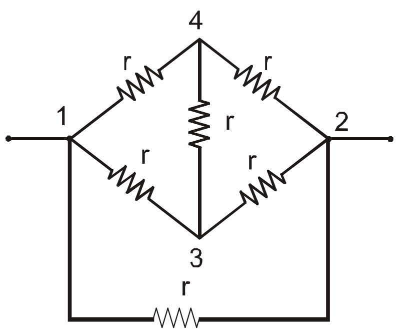


Due to input symmetry potential drop in AC, AD and AE part is same. Therefore potential at C,D and E point is same.

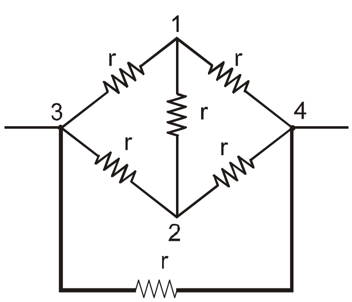
$R_{eq} = \frac{7}{3}\ \Omega$



Q12 (A)

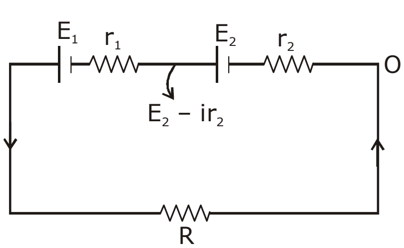


$r_{eq} = r_{12} = \frac{r}{2}$



$r_{eq} = r_{34} = \frac{r}{2}$

Q.13 (B)



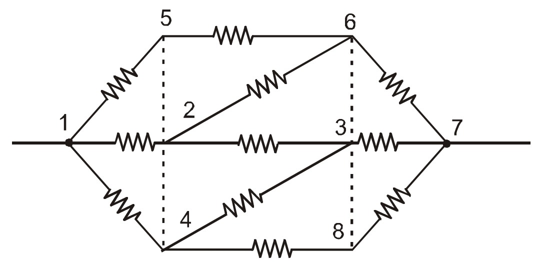
$i = \frac{E_1 + E_2}{R + r_1 + r_2}$

So for $E_2 - ir_2 < 0$ (for increasing i)

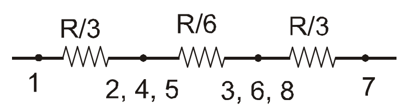
$E_2 - \left(\frac{E_1 + E_2}{R + r_1 + r_2}\right) r_2 < 0$

$\Rightarrow E_2 (R_2 + r_1) < E_1 r_2$

Q.14 (B)

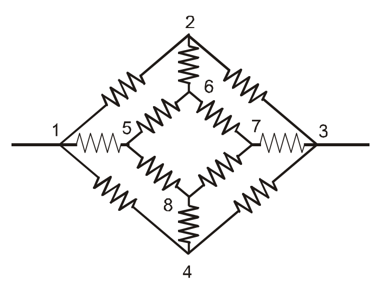


due to input output symmetry potential at point 2, 4, 5, are equal and potential at point 3, 6, 8 are equal



$R_{eq} = \frac{R}{3} + \frac{R}{6} + \frac{R}{3} = \frac{5}{6} R$

Q.15 (A)



due to input output symmetry, here no current passes through resistance 2 to 6 and 4 to 8. Equivalent circuit is

$R_{eq} = \frac{1}{3R} + \frac{1}{2R} + \frac{1}{2R}$

$R_{eq} = \frac{4}{3} R$

Q.16 (B)

For maximum power $r_{eq} = R_{eq}$

$$\Rightarrow 2 + \frac{6x}{6+x} = 4 \Rightarrow \frac{12+8x}{6+x} = 4$$

$$\Rightarrow 12 + 8x = 24 + 4x \Rightarrow 4x = 12$$

$x = 3\Omega$

Q.17 (D)

For maximum power across the resistance, R is equal to equivalent resistance of remaining resistance

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

Q.18 (A)

$i = At\,B$

at $t = \Delta T$, $i = 0$

$\Rightarrow 0 = A\Delta T + B$

$\Rightarrow A\Delta T = -B$

$$q = \int_0^{\Delta T} dq = \int_0^{\Delta T} (\Delta t - A\Delta T)\,dt$$

$$\Rightarrow q = \frac{A\Delta T^2}{2} - B\Delta T^2$$

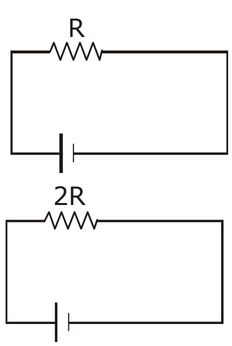
$$\Rightarrow q = -\frac{A\Delta T^2}{2} \Rightarrow A = \frac{-2q}{\Delta T^2}$$

$$\text{Heat} = \int_0^{\Delta T} i^2 R.dt = \int_0^{\Delta T} \left(\frac{-2qt}{\Delta T^2} + \frac{2q}{\Delta T}\right)^2 R dt$$

$$= \frac{4q^2}{\Delta T^2} \int_0^{\Delta T} \left(1 - \frac{t}{\Delta T}\right)^2 .R.dt$$

$$= \frac{4q^2}{\Delta T^2}\left[\Delta T + \frac{(\Delta T)^3}{3(\Delta T)^2} - \frac{2(\Delta T)^2}{2\Delta T}\right] R = \frac{4q^2 R}{3\Delta T}$$

Q.19 (B)



$L \longrightarrow R$

$2L \longrightarrow 2R$

$\Delta Q' = 2\Delta Q$

to raise ΔT temperature in same time t.

$I'^2 R' \Delta t = 2I^2 R \Delta T$

$I'^2 (2R) \Delta T = 2I^2 R \Delta T$

$\Rightarrow I' = I$

$$\frac{nE}{2R} = \frac{3E}{R} \Rightarrow n = 6$$

Q.20 (A)

$$(I_0 - \frac{I_0}{5})\,4 = \frac{I_0}{5}\,G \qquad ...(1)$$

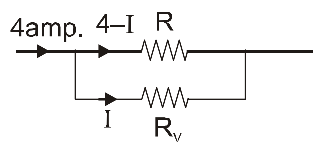
$$(I_0 - I_g)\,\frac{2 \times 4}{2+4} = I_g G \qquad ...(2)$$

from (1) and (2)

$$\frac{16 I_0}{5} \times \frac{6}{8(I_0 - I_g)} = \frac{I_0}{5 I_g}$$

$$12 I_g = I_0 - I_g \Rightarrow I_g = \frac{I_0}{13}$$

Q.21 (C)



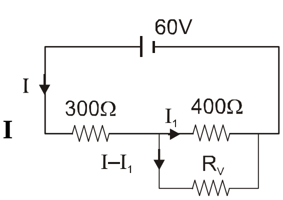
$(4 - I) R = I R_V = 20$ $\qquad (4 - I) R = 20$

$4 - I$ is less than 4

So that, R is greater than 5Ω

Q.22 (C)

case - I



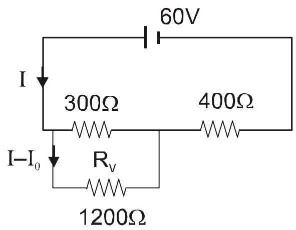
current

$$I = \frac{30}{300} = \frac{1}{10} \text{ amp}$$

$$I_1 = \frac{30}{400} = \frac{3}{40} \text{ amp.}$$

$$30 = (I - I_1) R_V \Rightarrow R_V = \frac{30}{\frac{1}{10} - \frac{3}{40}} = 1200\Omega$$

Case – II



$$I = \frac{60}{400 + \frac{300 \times 1200}{1200 + 300}} = \frac{3}{32} \text{ amp.}$$

$$I_0 300 = (I - I_0) 1200 \Rightarrow I_0 = \frac{1200}{1500} I = \frac{4}{5} \times \frac{3}{32} = \frac{3}{40} \text{ amp}$$

$$\text{Reading of voltmeter} = \frac{3}{40} \times 300 = \frac{900}{40} = 22.5 \text{ V}$$

Q.23 (B)

Current in primary circuit $I = \frac{\varepsilon}{9r + r} = \frac{\varepsilon}{10r}$

Potential drop across length AB = $V_{AB} = I.R$

$$V_{AB} = \frac{\varepsilon}{10r}.9r = \frac{9\varepsilon}{10}$$

$$x = \frac{V_{AB}}{L} = \frac{9\varepsilon}{10L}$$

For balance point $\frac{\varepsilon}{2} = x\ \ell = \frac{9\varepsilon}{10L}\ \ell.\ \ell = \frac{5}{9}\ L$

Q.24 (A)

For I_{max}, R_h is minimum which is zero .

$$I_{max} = \frac{5.5}{20} \text{ Amp.}$$

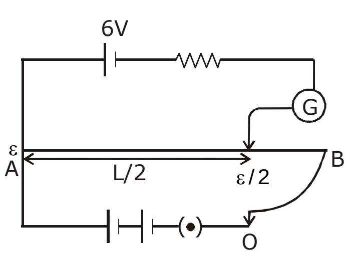
for I_{min}, R_h is maximum which is 30Ω .

$$I_{min} = \frac{5.5}{20 + 30} = \frac{5.5}{50} \text{ Amp.}$$

$$\frac{I_{min}}{I_{max}} = \frac{5.5}{50} \times \frac{20}{5.5} = \frac{2}{5} \text{ Amp.}$$

Q.25 (B)

S_2 is open

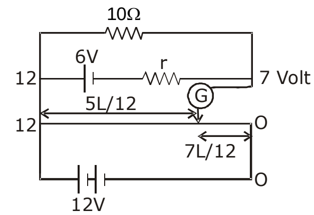


According to diagram

$\frac{\varepsilon}{2} = 6V \quad \varepsilon = 12V$

$L \to 12V$

$\frac{7L}{12} \to 7 \text{ volt}$



$6 - ir = 5$

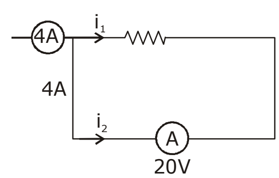
$$6 - \frac{6}{10 + r} r = 5$$

$\Rightarrow 6r = 10 + r \Rightarrow r = 2\Omega$

Q.26 (D)

$r = i_g (R + r_g)$

Q.27 (C)



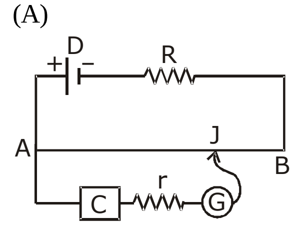
$$R = \frac{V}{i}$$

$i_1 < 4A$

$20 = i_1 R$

$$R = \frac{20}{i_1} > 5\Omega$$

Q.28 (A)



(A) Zero deflection does not depend on r

(B) If $R > R_0$ then drop across potentiometer is negligible

∴ We will not get zero deflection

(C) Notes

(D) Notes

JEE-ADVANCED

MCQ/COMPREHENSION/COLUMN MATCHING

Q.1 (A,D)

In series current remain same $I = neAv_d$, $J = I/A$, for constant current $v_d \propto \frac{1}{A}$ and $J \propto \frac{1}{A}$.

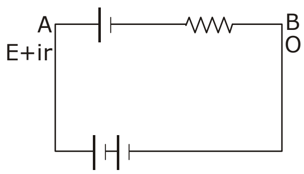
Q.2 (A,D)

$$IR = V = E\ell \Rightarrow I\frac{\rho\ell}{A} = E\ell \Rightarrow \rho = \frac{EA}{I} = \frac{E}{J} = \frac{5\times10^{-2}}{10}$$

$= 5 \times 10^{-3}\ \Omega$–m

$$\sigma = \frac{1}{\rho} = \frac{1}{5\times10^{-3}} = 200 \text{ mho/m.}$$

Q.3 (A,B,C)



Q.4 (A,B,D)

for short circuited, $I = \frac{E}{r}$

$$V = E - Ir = E - \frac{E}{r}.r = 0$$

when current flow from negative terminal to positive terminal

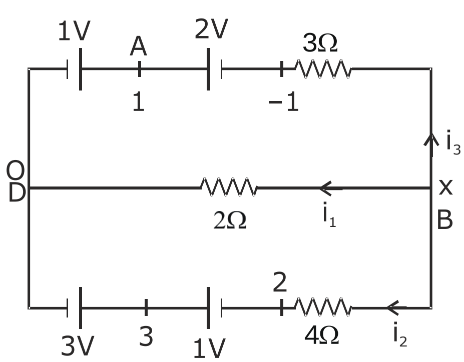
$V = E - Ir$ which is less than E

when current flow from positive terminal to negative terminal

$V = E + Ir$ which is greater than E.

Q.5 (A,C,D)

In parallel resistance $\downarrow \therefore i \uparrow$



Let potention of point B is x then from kirchhoff's first law

$$i_1+i_2+i_3 = 0$$

$$\frac{x}{2} + \frac{x-2}{4} + \frac{x+1}{3} = 0$$

$$\frac{6x+3x-6+4x+4}{12} = 0$$

$\Rightarrow 13x = 2$

$x = \frac{2}{13}$ volt

Q.6 (A,C)

$$E_{eq} = \frac{\frac{KE}{r} + \frac{KE}{r} + \frac{KE}{r} + \text{...........upto } \frac{N}{K}}{\frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \text{........upto } \frac{N}{K}}$$

$E_{eq} = KE$

$$\frac{1}{r_{eq}} = \frac{1}{Kr} + \frac{1}{Kr} \text{ .... upto } \frac{N}{K} \quad r_{eq} = \frac{K^2r}{N}$$

For maximum power $r_{eq} = R \Rightarrow \frac{K^2r}{N} = R \Rightarrow K = \sqrt{\frac{NR}{r}}$

$$P_{max} = \left(\frac{KE}{R + \frac{K^2r}{N}}\right)^2 R \qquad \left(\because R = \frac{K^2r}{N}\right)$$

$$P_{max} = \left(\frac{KE.N}{2K^2r}\right)^2 . \frac{K^2r}{N} \Rightarrow P_{max} = \frac{NE^2}{4r}$$

Q.7 (A,C)

(i) $R_{bulb} = \frac{V}{I} = \frac{10}{10\times10^{-3}} = 1.\ k\Omega$

(ii) $R_{bulb} = \frac{220}{50\times10^{-3}} = 4.4\ k\Omega.$

since increase in temperature increases resistance when it is connected to 220 V mains.

Q.8 (A,B,D)

It is easier to start a car engine on a warm day than on a chilly cold day because the internal resistance of battery decreases with rise in temperature and so current increases.

Power Loss = I^2R, $\Rightarrow$ Power loss $\propto I^2$

Also $P = V.I \Rightarrow I = \frac{P}{V}$

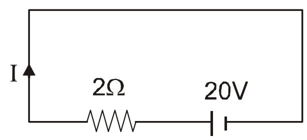
Since for given power & line P & R are constant

Power loss = $I^2R = \frac{P^2R}{V^2}$

$\therefore$ Power loss $\propto \frac{1}{V^2}$

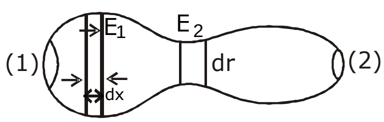
mica is good conductor of heat but bad conductor of electricity

Q.9 (A,C)



current flow in circuit is I = 10 amp
power supplied by the battery is $= I^2R = (10)^2 \times 2 = 200$ W
Potential drop across 4Ω & 6Ω are equal and it is equal to zero.
current in AB wire is 10 amp.

Q.10 (A,B,C,D)



$i = neAV_d$, $R = \frac{\rho l}{A}$

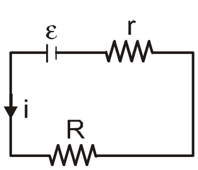
$E_1 = \frac{V}{dx} \Rightarrow = \frac{i.R}{dx} = \frac{i.\rho.dx}{A.dx}$

$\frac{i.\rho}{A}$ = constant $\Rightarrow E_1 \propto \frac{1}{A_1}$

$\frac{E_1}{E_2} = \frac{A_2}{A_1}$

$P = i^2R \Rightarrow i^2 \frac{\rho dx}{A}$

Q.11 (A,C,D)



current $i = \frac{\varepsilon}{R+r}$

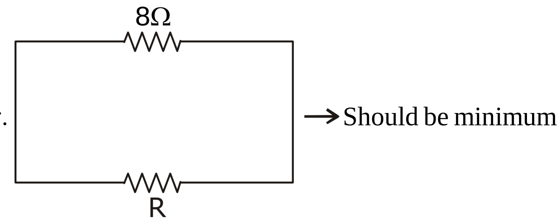
cell generating power = εi
Heat produced in R at the rate

$= i^2R = iR.\frac{\varepsilon}{R+r} = \varepsilon i.\frac{R}{R+r}$

Heat produced in r at the rate $= i^2r = \varepsilon i \frac{r}{R+r}$.

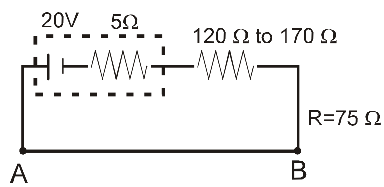
Q.12 (A,C)
Current should be maximum in 2Ω

$\therefore$



$\Rightarrow$ R = 0 (power should be maximum when r = 0)
Power = 72 watt.

Q.13 (A, B, C)



$i_{max} = \frac{20}{5+75+120} = \frac{1}{10}$ amp

$V_{max} = i_{max} R_{75} = \frac{1}{10} \times 75 = 7.5\,V$

range of potentiometer 0 to 7.5 V

Q.14 (A,C,D)
For non ideal ammeter and voltmeter, ammeter have low resistance and voltmeter have high resistance. Therefore the main current in the circuit will be very low and almost all current will flow through the ammeter. It emf of cell is very high then current in ammeter is very high result of this current the devices may get damaged. If devices are ideal that means resistance of voltmeter is infinity. so that current in the circuit is zero. Therefore ammeter will read zero reading and voltmeter will read the emf of cell.

Q.15 (B,C)

for 50 V, $R_V = \frac{50}{50 \times 10^{-6}}$ = 1000 KΩ in series

for 10 V, $R_V = \frac{10}{50 \times 10^{-6}}$ = 200 KΩ in series

for 5 mA, $R_s = \frac{100 \times 50 \times 10^{-6}}{5 \times 10^{-3}} = 1\Omega$ in parallel

for 10 mA, $R_s = \frac{100 \times 50 \times 10^{-6}}{10 \times 10^{-3}} = \frac{1}{2}\Omega$ in parallel

Q.16 (A,C)

$$\left.\begin{array}{l} R_1 = \dfrac{V}{I} = \dfrac{10V}{10mA} = 1k\Omega \\ R_2 = \dfrac{220V}{50mA} = 4.4k\Omega \end{array}\right\} \Rightarrow \text{(A) and (C)}$$

Q.17 (A,D)

To ensure maximum current through ammeter its resistance should be small.

To ensure minimum current through voltmeter its resistance must be very large.

Q.18 (A,B)

As emf of E_1 is distributed over the wire AB. Hence A is correct E_2 is balanced by fraction of length of wire $E_1 > E_2$.

We only balance potential difference hence B is correct.

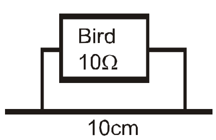
Q.19 (A,C)

In parallel each will take 10A and hence combination requries 10 + 10 = 20 A

In series current will be same in each fuse and that will be equal to required circuit current hence combination requires the same current 10 A

Q.20 (B)

Q.21 (A)

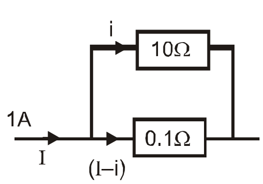


$r = \left(\dfrac{1\Omega}{m}\right)$ (10 cm) $r = 0.1\ \Omega$

$V_{bird} = (R_{II\ combination})$ current

$V_{bird} = \left(\dfrac{10 \times 0.1}{10 + 0.1}\right)(1) \cong 0.1$ V

Q.22 (C)

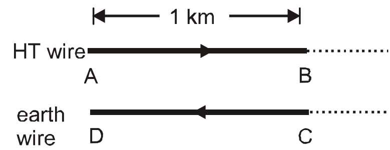


Here $i \times 10 = (I - i)(0.1) \Rightarrow 100\,i = I - i \Rightarrow 101\,i = I$

If I = 1A

$i = \dfrac{1}{101}$ A $\cong$ 0.01 A

Q.23 (C)



$V_{AD} = 11$ KV, $\quad V_{BC} = ?$

$V_{AD} = V_{AB} + V_{BC} + V_{CD}$

V_{AB} = IR = (1 A) (1 km × 1Ω/m) = 1000 V

$V_{CD} = V_{AB} = 1000$ V

$V_{BC} = V_{AD} - V_{AB} - V_{CD} = 11000 - 1000 - 1000.$

$V_{BC} = 9000$ Volt

Q.24 (A)

If critical current through bird is 0.1A then main current

I = 101 i (As Q.No.5)

I = 101 × 0.1 = 10.1 A

P_{max} = (11 KV) (10.1 A) = 111 KW

Q.25 (B)

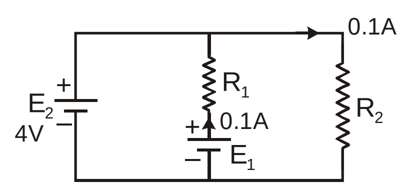
Q.26 (B)

Q.27 (D)

(25 - 27)

As E_2 is increasing it's current also increases, So, increasing graph is of i_2.

$i_1 = 0.1A, E_2 = 4V, i_2 = 0$

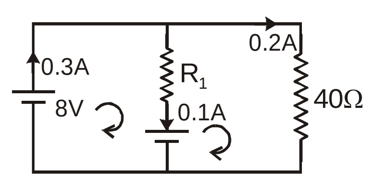


As ;

$0.1\,R_1 + 0.1\,R_2 - E_1 = 0$

$0.1\,R_2 - 4\,V = 0$

$R_2 = 40\ \Omega$



Now; $i_2 = 0.3A$, $i_1 = -0.1$ A, $E_2 = 8V$

Now ; $0.1\,R_1 + E_1 - 8 = 0$

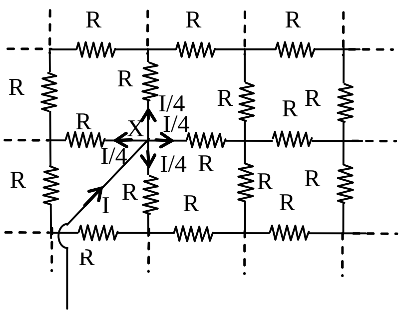
When $E_2 = 6V$, current in E_1 is $i_1 = 0$ (from graph)

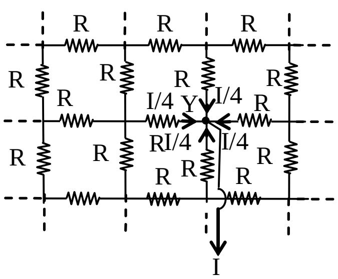
$E_1 = 6V$

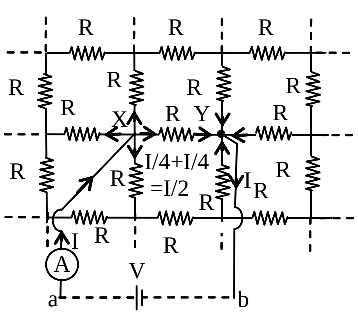
$$\Rightarrow R_1 = \frac{4}{0.2} = 20\ \Omega$$

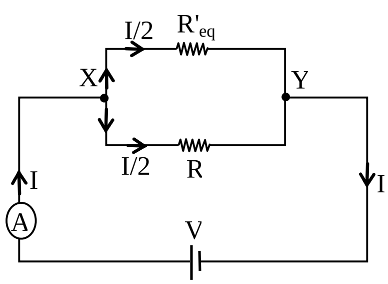
Q.28 (B)

We can consider the network to consist of two resistances connected in parallel between X and Y. One of these is the resistance R between X and Y and the other is the equivalent resistance of the rest of circuit. This is shown in Fig (A).



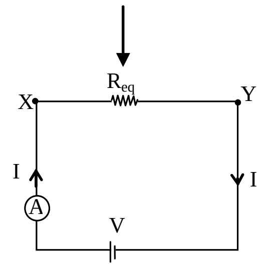






(A)

(Here, R'_{eq} is the equivalent resistance of rest of the circuit, i.e., excluding R)



(Here, R_{eq} is the equivalent of R'_{eq} and R so R_{eq} is the equivalent resistance of total circuit)

Referring to Fig (A),

$$V = \frac{I}{2} R$$

(also $V = I/2\ R'_{eq}$)

and form fig (B), $V = I R_{eq}$

$$\text{So } I R_{eq} = \frac{I}{2} R$$

$$\text{or } R_{eq} = \frac{R}{2}$$

Hence the equivalent resistance of the network between X and Y or any two neighbouring points is R/2.

In Fig. (B)

$$V = I R_{eq}$$

$$\text{or } I = \frac{V}{R_{eq}}$$

but $R_{eq} = R/2$

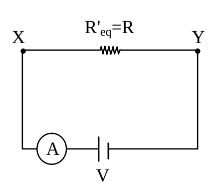
$$\therefore I = \frac{2V}{R}$$

Given V = 1V, R = 4Ω

$$\therefore \quad I = \frac{2}{4} = 0.5\text{ A}$$

So the correct answer is (B).

Q.29 (A)



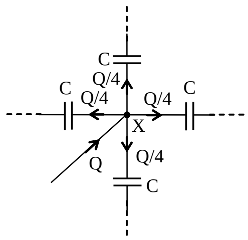
In Fig (A), since सthe current I is equally shared by R and R'_{eq}, so $R'_{eq} = R$. Now if the resistance R is removed, it will be only $R'_{eq} = R$ placed across the battery so that current will now be

$$I = \frac{V}{R} = \frac{1}{4} = 0.25\text{ A}$$

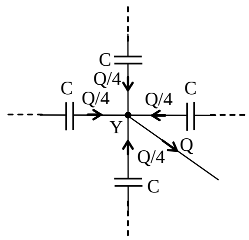
(In this case equivalent resistance of circuit will be $R'_{eq} = R$) Hence the correct option is (A).

Q.30 (C)

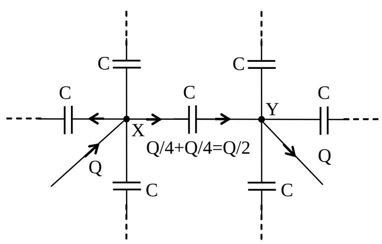
Let us draw the corresponding figures for capacitances.



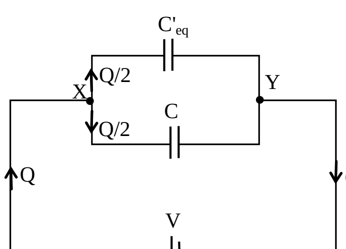
(A)



(B)



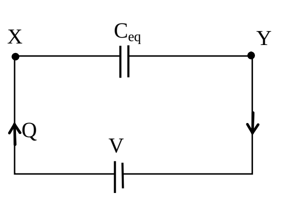
(C)



(D)

(C'_{eq} is the equivalent capacitance of rest of the circuit, i.e., excluding C)

$\downarrow$



(E)

(C_{eq} is the equivalent capacitance of total circuit between X and Y)

In Fig (D)

Potential difference across C,

$$V = \frac{Q/2}{C} = \frac{Q}{2C}$$

in Fig (E) $V = \frac{Q}{C_{eq}}$

$$\therefore \frac{Q}{C_{eq}} = \frac{Q}{2C}$$

or $C_{eq} = 2C$

so the correct option is (C)

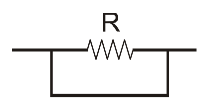
Q.31 (A) q, (B) p, (C) p, (D) q

Drift speed $V_d = \frac{J}{ne} = \frac{i}{neA}$

$i = \frac{V}{R}$ where $R = \frac{\rho L}{A}$

$E = \frac{V}{L}$ and $P = I^2 R$

Q.32 (A) p; (B) q, s; (C) s; (D) p, r, s



short circuited resistor.

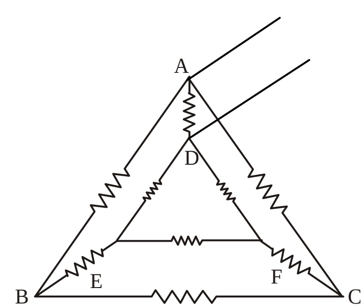
In a resistor current always flows from higher potential to lower potential.

In short circuited resistor or ideal cell, energy dissipated is always zero because in short circuited resistor no current flow and in ideal cell no internal resistance.

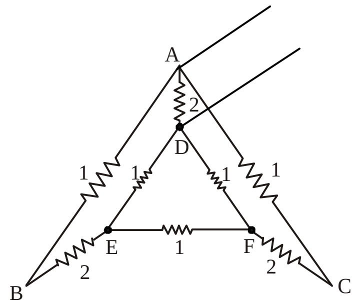
Potential difference may be zero across a resistor, non-ideal cell or short circuited resistor.

NUMERICAL VALUE BASED

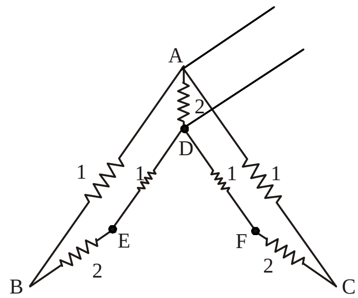
Q.1 [1]

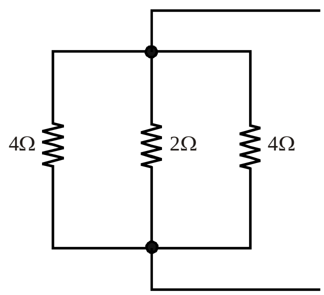


$\Rightarrow$



$\Rightarrow$





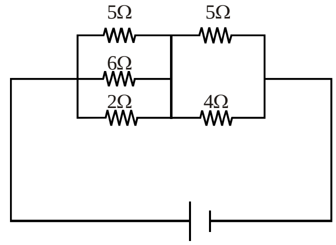
$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{4}+\frac{1}{2}+\frac{1}{4} \Rightarrow R_{eq} = 1\Omega$$

Q.2 [4]

Sol. In combination of 2, 6, 5Ω heat produce will be maximum in 2Ω, while in combination of 5w and 4W heart produce will be maximum in 4Ω $\left(H = \frac{V^2}{R}\right)$

$$I_{2\Omega} : I_{6\Omega} : I_{5\Omega} = \frac{1}{2} : \frac{1}{6} : \frac{1}{5}$$

$$I_{2\Omega} : I_{6\Omega} : I_{5\Omega} = 15 : 5 : 6$$



$$I_{4\Omega} : I_{5\Omega} = 5 : 4$$

$$I_{2\Omega} = \frac{5}{26} I \quad , \quad I_{4\Omega} = \frac{4}{9} I$$

$$H_{2\Omega} = \left(\frac{5}{26} I\right)^2 \times 2J, H_{4\Omega} = \left(\frac{4}{9} I\right)^2 \times 4J$$

$$H_{4\Omega} > H_{2\Omega}$$

Q.3 [3]

$$P = I^2 y = \left(\frac{10}{2+y+R}\right)^2 \; ; \quad y = \frac{100}{(2+y+R)^2} y$$

For P to be maximum

$$\frac{dP}{dy} = 0 \Rightarrow \frac{d}{dy} \frac{100y}{(2+y+R)^2} = 0$$

$R = y - z$ put $y = 5 \Rightarrow R = 3\Omega$

Q.4 [4]

The circuit can be shown as in the figure. The bulb is marked 100W, 220V.

Hence the resistance of filament of bulb.

$$R = \frac{V^2}{P} = \frac{220 \times 220}{100} = 484\Omega$$

Current in the given circuit

$$I = \frac{220}{484+8+8} = 0.44 \text{ A}$$

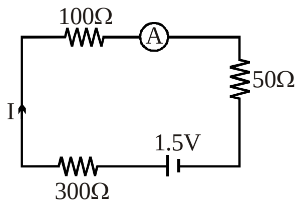
Power delivered to the bulb

$I^2 R_{bulb} = (0.44)^2 (484)$

$= 93.7\ \Omega$

Q.5 [600]

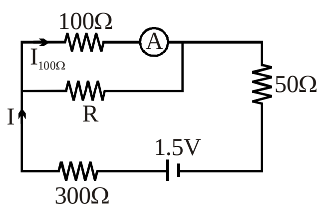
$$I = \frac{1.5}{450}$$



$= \frac{1}{300}$ Amp ...(i)

When both switch are closed

$I_{100\Omega} = \dfrac{1.5}{\dfrac{100R}{100+R}+300} \times \dfrac{R}{100+R}$ ...(ii)



From (i) and (ii)
$R = 600\Omega$

Q.6 [999]

$R = \frac{V}{i_g} - G$

$= \frac{5}{0.005} - 1 = 999\ \Omega$

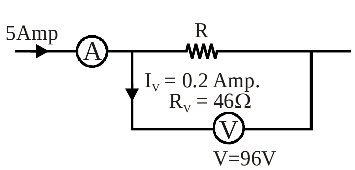
Q.7 [4]
Potentiometer will give terminal potential

$V = E - Ir \Rightarrow V = 5 - \frac{5}{(R+1)} \times 1 = x \times 40$

$5 - \frac{5}{(R+1)} = \frac{10}{100} \times 40 \Rightarrow R = 4\Omega$

Q.8 [20 ohm]

$I_V = \frac{96}{480}$



$I_V = 0.2$ Amp

$R = \frac{96}{(5-0.2)}$

$R = 20\ \Omega$

Q.9 [1]

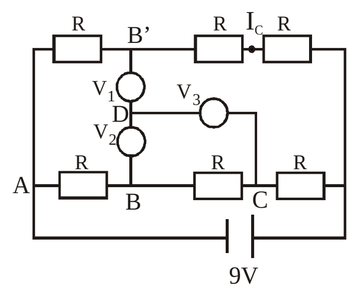
For w_1, $\varepsilon = \frac{l}{2}\left[\left(\frac{\varepsilon_p}{1+2}\right)\frac{2}{l}\right]$ ...(1)

For w_2, $\varepsilon = \frac{2l}{3}\left[\left(\frac{\varepsilon_p}{1+R}\right)\frac{R}{l}\right]$ ...(2)

Dividing eq. (i) by (ii) and on solving, we get

Resistance of wire $w_2 = 1\ \Omega$

Q.10 [0002]
Taking potential at A to be zero potental at B = 3V and potential at B' = 3V and potential at C = 6V so reading of $V_3 = 3V$



Let V_D be potential of point D then sum of charged reaching point D is zero

$$\frac{V_B - V_D}{R_{V_2}} + \frac{V_{B'} - V_D}{R_{V_1}} + \frac{(V_C - V_D)}{R_{V_3}} = 0$$

$[R_{V_1} = R_{V_1} = R_{V_3} = R]$

$\Rightarrow \quad \frac{3-V_D}{R} + \frac{3-V_D}{R} + \frac{6-V_D}{R} = 0$

$\Rightarrow \quad 12 - 3V_D = 0$
$V_D = 4$ volts
reading of $V_3 = 2$ volts.

KVPY
PREVIOUS YEAR'S

Q.1 ( )

For P : $I = I_R + I_V = V / R + V/R_V$

$$R = \frac{V}{I}\left[\frac{R_V}{R_V - V/I}\right]$$

$$= R_{est}\left[\frac{R\nu}{1 - R_{est}/R_\nu}\right]$$

$\approx R_{est}\,[1 + R_{est}/R_V]$ (neglecting higher order terms in R_{est} / R_V)

$$\delta R_P = |R_{est} - R| = R_{est}^2 / R_V \approx \frac{R^2}{R_V}$$

Alternatively,

$$R_{est} = \frac{V}{I} = \frac{R_V R}{R_V + R}$$

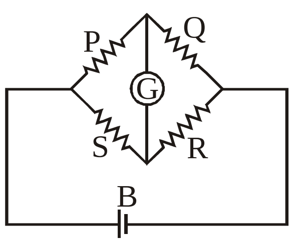
$$\delta R_P = | R_{est} - R | \left[\frac{R_V}{R_V + R} - 1\right] » \frac{R^2}{R_V}$$

For Q : $V = I\,(R + R_A)$
$R = V / I - R_A = R_{est} - R_A$
$\delta R_Q = | R_{est} - R| = R_A$
If $R = \sqrt{R_A R_V}$, then $\delta R_P / \delta R_Q =$

$$R_{est}^2 / (R_A R_V) = R_{est}^2 / R^2 \approx 1$$

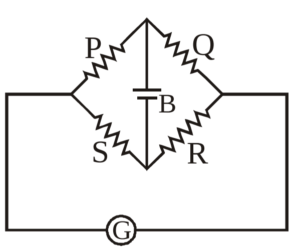
Q.2 (A)
Part of coil turned then resistance decreases
$\therefore$ Power consumption will be more than 1 kW

Q.3 (C)



For null deflection

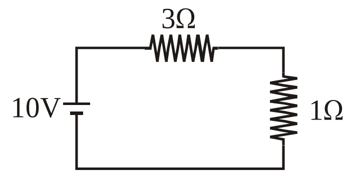
$$\frac{P}{Q} = \frac{S}{R} \text{ or } \frac{P}{S} = \frac{Q}{R}$$



$$\frac{P}{Q} = \frac{S}{R} \text{ still valid}$$

$\therefore$ deflection is zero.

Q.4 (A)



$10 = 4i$

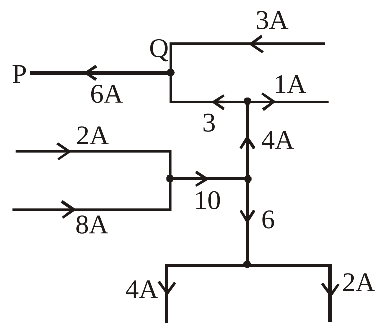
$$i = \frac{5}{2}$$

$$P_i = i^2 R = \left(\frac{5}{2}\right)^2 \times 1 = \frac{25}{4}$$

$$P_f = \left(\frac{10}{12}\right)^2 \times 9 = \frac{100}{12 \times 12} \times 9$$

$P_f = P_i$

Q.5 (D)



Q.6 (C)
Applying volume conservation
$A \times L = A' \times 2L$

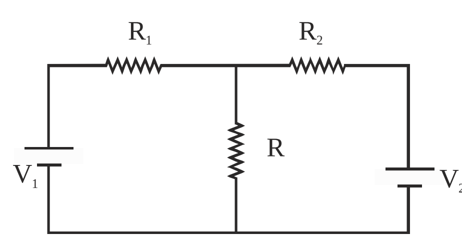
$$A' = \frac{A}{2}$$

$$R = \frac{\rho L}{A}$$

$$R' = \frac{\rho \times 2L}{A'} = \frac{\rho \times 4L}{A}$$

$R' = 4R$

Q.7 (D)



$$V_{eq} = \frac{\frac{V_1}{R_1}+\frac{V_2}{R_2}}{\frac{1}{R_1}+\frac{1}{R_2}} \Rightarrow \frac{V_1R_2+V_2R_1}{R_1+R_2}; R_{eq} = \frac{R_1R_2}{R_1+R_2}$$

$$I = \frac{V_{eq}}{R+R_{eq}}$$

In each case R_{eq} & R is same only V_1 & V_2 is changing

$\therefore V_{eq}$ is changing

$$V_{eq} = \frac{2\times R_2 + 0\times R_1}{R_1+R_2} \qquad [V_1 = 2, V_2 = 0]$$

$$V_{eq} = \frac{2R_2}{R_1+R_2}$$

Case - 2

$$V_{eq} = \frac{4R_1}{R_1+R_2} \qquad [V_1 = 0, V_2 = 4]$$

$$\frac{I_1}{I_2} = \frac{3}{4} = \frac{2R_2}{4R_1} \quad \frac{R_2}{R_1} = \frac{3}{2}$$

Case - 3

$$V_{eq} = \frac{10R_1+10R_2}{R_1+R_2}$$

$$\frac{3}{I'} = \frac{2R_2}{10(R_1+R_2)} \Rightarrow \frac{3}{I'} = \frac{2\times 1.5R_1}{10(2.5R_1)} \text{ or } I' = 25 \text{ mA}$$

Q.8 (B)

$$R = \frac{V}{i} = \frac{V\times i}{i^2} = \frac{P}{i^2}$$

$$\text{energy} = h\nu = \frac{h}{t}$$

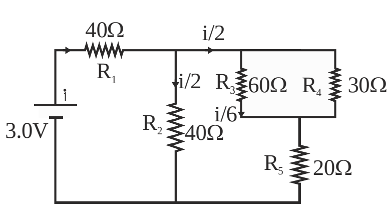
$$\text{Power} = \frac{\text{energy}}{t}$$

$$P = \frac{h}{t^2}$$

$$i = \frac{e}{t}$$

$$\frac{P}{i^2} = \frac{h}{e^2}$$

Q.9 (A)



Power dissipate in R_1 is maximum as its current is maximum and its

resistance is also 40Ω which is higher than R_5R_4.

Q.10 (A)

$$i_1 = \frac{nE}{nR_0+R}, i_2 = \frac{E}{(R_0+nR)}$$

$$P_1 = \frac{nE^2R}{(nR_0+R)^2}, P_2 = \frac{nE^2R}{(R_0+nR)^2}$$

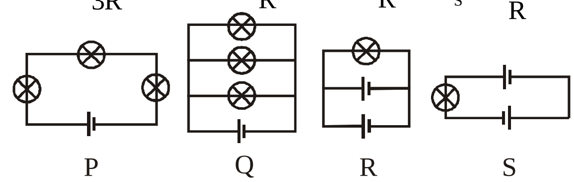
$\because P_1 = P_2$

Hence $R_0/R = 1$

Q.11 (D)

Let R = resistance of each bulb.

$$P_P = \frac{V^2}{3R} \quad P_Q = \frac{3V^2}{R} \quad P_R = \frac{V^2}{R} \quad P_S = \frac{4V^2}{R}$$



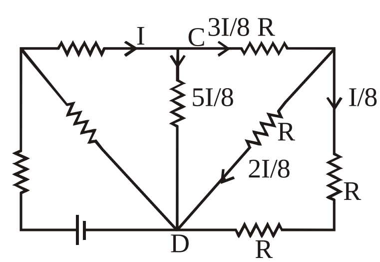
Q.12 (A)

The given circuit can be simplified into two wheatstone bridge in parallel

Q.13 (A)

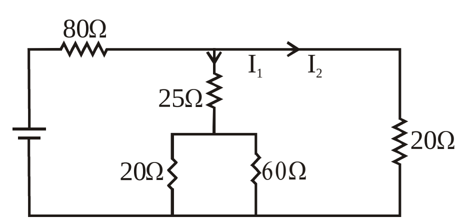
Concept of fuse wire

Q.14 (A)



$$\frac{I}{I'} = 8$$

Q.15 (C)



$$0.1 \times \left(25+\frac{20\times 60}{20+60}\right) = i_2 \times 20$$

$I_2 = 0.2A$

Hence, i through 80Ω

$0.1 + 0.2 = 0.3\,A$

Q.16 (D)

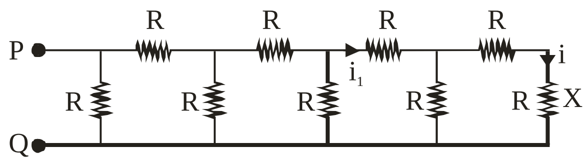
In stready state i through capacitor is zero.

Hence V across 2KΩ = V across capacitor

$$V_{across\ 2k\Omega} = \frac{2}{2+1}\times 6 = 4V$$

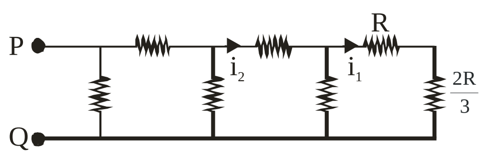
Q.17 (D)

$R = 1k\Omega$, $i = 1\text{ mA} = 1\text{ M}\times 10^{-3}A$

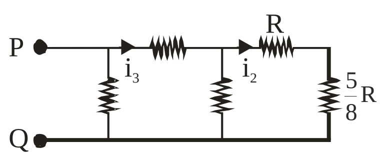


$$i = \frac{i_1 \times R}{3R} = \frac{i_1}{3}$$

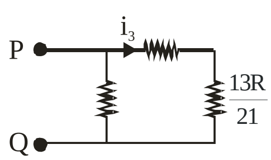
$\therefore \quad i_1 = 3i$



$$i_1 = i_2 \times \frac{3}{8} \quad \Rightarrow \quad \frac{3}{8} \times 3i = 8i$$



$$i_2 = i_3 \times \frac{8}{21}$$



$$i_3 = \frac{21}{8} i_2 = \frac{21}{8} \times 8i = 21i$$

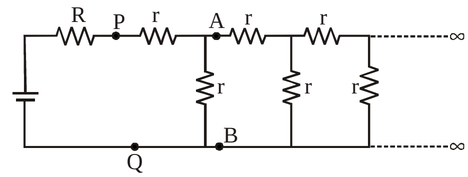
$$V_P - V_Q = i_3 \times \left[R + \frac{13R}{21}\right]$$

$$\Rightarrow \quad 21i \times \frac{34R}{21}$$

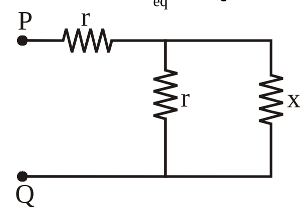
$\Rightarrow$ 34 iR

$\Rightarrow$ $34 \times 1 \times 10^{-3} \times 1 \times 10^{3} = 34$ volt

Q.18 (A)



Let assume $R_{eq} = PQ = x$



$$R_{eqPQ} = r + \frac{rx}{r+x}$$

$$x = \frac{r^2 + rx + rx}{r+x}$$

$rx + x^2 = r^2 + 2rx$

$x^2 - rx - r^2 = 0$

$$x = \frac{+r \pm \sqrt{r^2 + 4r^2}}{2} \Rightarrow \frac{r\left(1+\sqrt{5}\right)}{2}$$

Power in bulb = 1 watt

$i^2 R = 1$

$i^2 \times 16 = 1$

$$i = \frac{1}{4}\text{amp.}$$

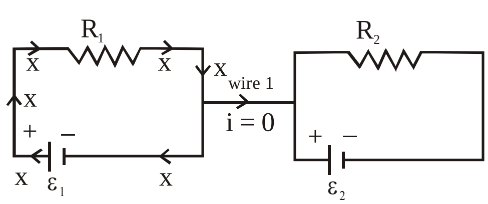
$$i = \frac{10}{R + R_{PQ}}$$

$$\frac{1}{4} = \frac{10}{16 + \frac{r}{2}\left(1+\sqrt{5}\right)}$$

$$16 + \frac{r}{2}\left(1+\sqrt{5}\right) = 40$$

$r = 14.8\,\Omega$

Q.19 (4)



current through wire 1 = 0

Q.20 (D)

$l = neAv$

$$ne = \frac{1}{Av}\ \frac{500\times10^{-6}}{15\times10-7\times3\times10^{7}} = \frac{100}{9}\times10^{-6}\,c/m^3 \sim 10^{-5}\,c/m^3$$

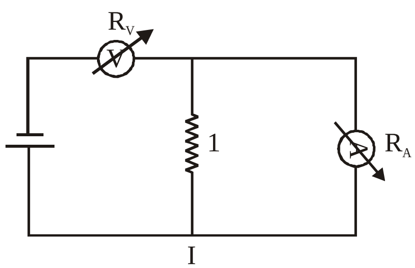
Q.21 (B)

$I = neAv_d$

$$J = \frac{I}{A} = \sigma E$$

Q.22 **(B)**

case –a

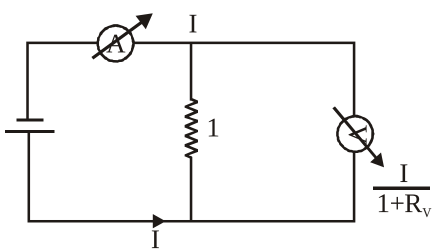


R_V = Resistance of voltmeter

R_A = Resistance of ammeter

$$\frac{V}{A} = \frac{IR_V}{\left(\frac{I}{1+R_A}\right)} = R_v\left(1+R_A\right) = 1000 \quad \text{..... (i)}$$

Case - b



$$\frac{V}{A} = \frac{\left(\frac{I}{1+R_V}\right)R_V}{I} = \frac{R_V}{R_V+1} = 0.999$$

$$R_V = 0.999\,(1+R_V)$$

$\Rightarrow \quad R_V = 999\Omega$

From (i)

$$R_A = 10^{-3}\Omega$$

Q.23 **(C)**

Total power used by laptops is = 90 × 10 = 900 W.

Power delivered by UPS = 1kVA = 1000W

Statement I is correct

Now $\quad P = VI$

$900 = 220\,L$

$$I = \frac{900}{220} = 4.1A$$

So 3A fuse can not used (II is incorrect)

Cost of consumed electricity is

$$\frac{900\times5}{1000}\times5 = Rs.\,22.5$$

Q.24 (C)

Rate of heat gained by water

$$ms\left[\frac{dT}{dt}\right] = i^2R_1 - 4\sigma eAT_0^3[T-T_0]$$

$$\frac{dT}{dt} = \frac{i^2R_1}{ms} - \frac{4\sigma eAT_0^3}{ms}(T-T_0)$$

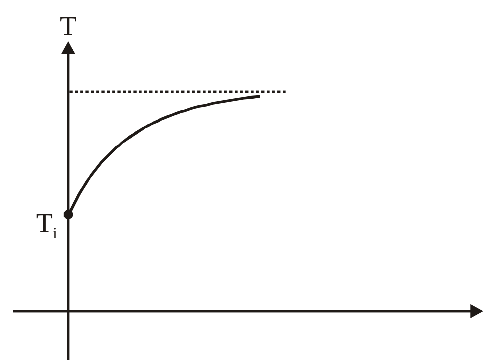
$\frac{dT}{dt} = C_1 - C_2T$ (here C_1 and C_2 are positive constant)

$$\int_{T_i}^{T}\frac{dT}{c_1-c_2} = \int dt$$

$$\frac{1}{-C_2}\ell n\frac{C_1-C_2T}{C_1-C_2T_i} = t$$

$$C_1 - C_2\,T = (C_1 - C_2T_i)\ e^{-c_2t}$$

$$C_2\,T = C_1 - (C_1 - C_2T_i)\ e^{-c_2t}$$



Q.25 (A)

As $\quad I$ = constant

& $\quad V = iR$ & $\quad$ V in general $\quad V = i(R_0 + \Delta R)$

$$R = \frac{\rho\ell}{A}$$

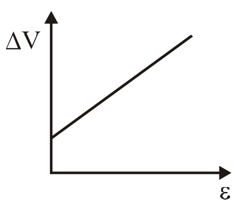
$$\frac{\Delta R}{R} = \rho\left(\frac{\Delta \ell}{\ell} - \frac{\Delta A}{A}\right)$$

$\frac{\Delta A}{A} = -\frac{\Delta \ell}{\ell}$ & ρ = constant as there is no joule heating

So $\Delta R = R\left(\frac{\rho 2\Delta\ell}{\ell}\right) = R\rho(2\varepsilon)$

$\Rightarrow V = i(R + 2\rho R\varepsilon)$

so graph will look like



Q.26 (A)

For circuit (a),

$$i_R = \left(\frac{10}{\frac{300R}{300+R} + 300}\right) \times \frac{300}{300+R}$$

↑ Current through cell

[Note : 300 Ω & R are in parallel which is in series with 100 & 200 Ω]

$$\therefore v_{R_a} = \frac{10 \times 300R}{300R + 300^2 + 300R}$$

[V_{R_a} is potential difference across resistance R]

Fro circuit (b),

$$i_R = \left(\frac{10}{\frac{(200+R)(300)}{200+R+300} + 100}\right) \times \frac{300}{300+200+R}$$

↑ Current through cell

[Note : R & 200 Ω are in series which is in parallel with 300 Ω & again the combination is in series with 100 Ω]

$$\therefore V_{R_b} = \frac{100 \times 300R}{300 \times 200 + 300R + 100 \times 500 + 100R} m$$

[V_{R_b} is potential difference across resistance R]

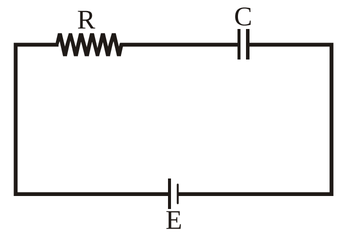
According to given situation

$V_{R_a} = V_{R_b}$

$\therefore 300R + 9 \times 10^4 + 300R = 6 \times 10^4 + 400R + 5 \times 104$

$\Rightarrow 200R = 2 \times 10^4 \Rightarrow R = 100\ \Omega$

Q.27 (C)



$$i = \frac{E}{R} e^{-t/RC}, Q = CE\left(1 - e^{-t/RC}\right)$$

Capacitor is charged to $\frac{E}{2}$,

So $Q = \frac{CE}{2}$

$$\therefore \frac{CE}{2} = CE\left(1 - e^{-t/RC}\right)$$

$$\frac{1}{2} = e^{-t/RC}$$

$t = RC\ \ell n\ 2$

Work done by battery = $(Q_{flown})(\Delta V)$

$$= \left(\frac{CE}{2}\right)(E) = \frac{CE^2}{2}$$

Heat dissipated = $\int_0^{RC\ell n2} i^2 R dt$

$$= \frac{E^2}{0} \int_0^{RC\ell n2} e^{-2t/RC}.dt$$

$$= \frac{3}{4}\left(\frac{CE^2}{2}\right)$$

$$\frac{\text{Work done}}{\text{Heat dissipated}} = \frac{CE^2/2}{\frac{3}{4}\left(\frac{CE^2}{2}\right)} = \frac{4}{3}$$

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Q.1 [2]

$$\frac{E_2}{E_1} = \frac{l_2}{l_1} = \frac{760}{380} = 2$$

Q.2 [2]

Q.3 (4)

It is balanced wheat stone bridge so

$R_{AB} = R$

Q.4 [300]

$\omega = QV$

$= 15 \times 20 = 300$ Joules

Q.5 (1)

$R_i = \dfrac{\rho\ell}{A}$

$R_f = \dfrac{\rho(1.25\ell)}{(A/1.25)} = \dfrac{\rho\ell}{A}(1.25)^2$

$\therefore\ R_f = R_i(1.5625)$

$\therefore\ R_f = R_i(1+0.5625)$

$\therefore\ \dfrac{R_f - R_i}{R_i} = 0.5625$

$\therefore\ \%\dfrac{\Delta R}{R} = 56.25\%$

Q.6 [5]

$J = \sigma E$

$= 5 \times 10^7 \times 10 \times 10^{-3}$

$= 50 \times 10^4\ A/m^2$

$I = J\pi R^2$

$= 50 \times 10^4 \times \pi (0.5 \times 10^{-3})^2$

$= 50 \times 10^4 \times \pi \times 0.25 \times 10^{-6}$

$= 125 \times 10^{-3}\pi$

$x = 5$

Q.7 [11250]

$\dfrac{dq}{dt} = (20t + 8t^2)$

$\int dq = \int_0^{15}(20t + 8t^2)\,dt$

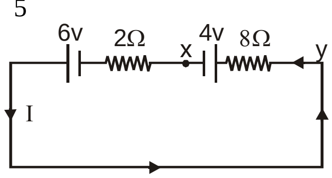
$\Delta q = \left[20\dfrac{t^2}{2} + \dfrac{8t^3}{3}\right]_0^{15}$

$= \dfrac{20 \times (15)^2}{2} + \dfrac{8 \times (15)^3}{3}$

$\Delta q = 11250\ C$

Q.8 (1)

Current $I = \dfrac{6-4}{10} = \dfrac{1}{5}\ A$

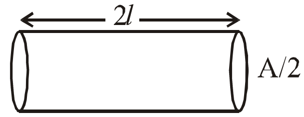


$v_x + 4 + 8 \times \dfrac{1}{5} = vy$

$v_x - v_y = -5.56v$

Q.9 (1)

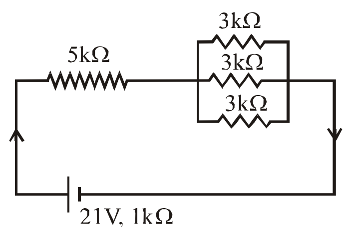
As per the question



Resistance $= \dfrac{\rho(2\ell)}{(A/2)} = \dfrac{4\rho\ell}{A}$

$\Rightarrow$ Current $= \dfrac{V}{R}\dfrac{VA}{4\rho\ell}$

Q.10 (3)



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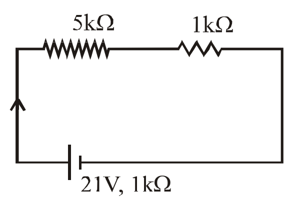


$I = \dfrac{21}{5\ \ 1\ \ 1} = 3\ mA$

Q.11 (4)

$500 = (1.5)_2 \times R \times 20$

$E = (3)_2 \times R \times 20$

$E = 2000$ J

Q.12 [2500]

$Q = i2\,RT$

$R = \dfrac{Q}{i^2 t} = \dfrac{10 \times 10^{-3}}{4 \times 10^{-6} \times 1} = 2500\ \Omega$

Q.13 (2)

$i = 10A$, $A = 5\ mm^2 = 5 \times 10^{-6}\ m^2$

and $v_d = 2 \times 10^{-3}$ m/s

We know, i = neAvd

$\therefore\ 10 = n \times 1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 2 \times 10^{-3}$

$\Rightarrow n = 0.6^{25} \times 10^{28} = 6^{25} \times 10^{25}$

Q.14 (4)

$R_1 + R_2 = s$ ... (1)

$\dfrac{R_1 R_2}{R_1 + R_2} = p$ ... (2)

$R_1 R_2 = sp$

$R_1R_2 = np^2$

$$R_1 + R_2 = \frac{nR_1R_2}{(R_1+R_2)}$$

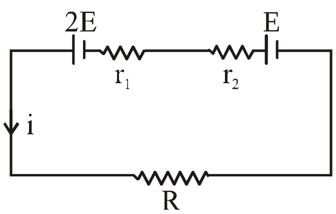
$$\frac{(R_1+R_2)^2}{R_1R_2} = n$$

for minimum value of n

$R_1 = R_2 = R$

$$\therefore\ n = \frac{(2R)^2}{R^2} = 4$$

Q.15 (2)



$$i = \frac{3E}{R+r_1+r_2}$$

TPD = $2E - ir_1 = 0$

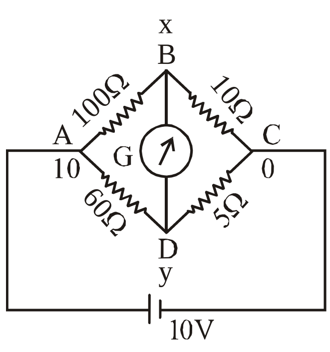
$2E = ir_1$

$$2E = \frac{3E\times r_1}{R+r_1+r_2}$$

$2R + 2r_1 + 2r_2 = 3r_1$

$$R = \frac{r_1}{2} - r_2$$

Q.16 (3)



$$\frac{x-10}{100} + \frac{x-y}{15} + \frac{x-0}{10} = 0$$

$53x - 20y = 30$ .....(1)

$$\frac{y-10}{60} + \frac{y-x}{15} + \frac{y-0}{5} = 0$$

$17y - 4x = 10$ ......(2)

on solving (1) & (2)

x = 0.865

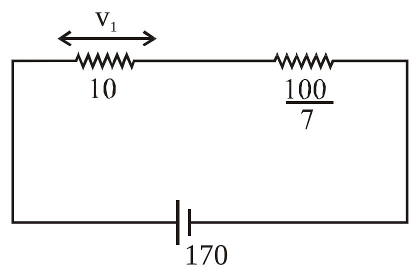
y = 0.792

$\Delta V = 0.073\ R = 15\Omega$

i = 4.87 mA

Q.17 [70]

$$R_{eq_1} = \frac{50\times 20}{70} = \frac{100}{7}$$



$$R_{eq} = \frac{170}{7}$$

$$v_1 = \left[\frac{170}{\frac{170}{7}}\right]\times 10 = 70v$$

Q.18 (48)

In Balanced conditions

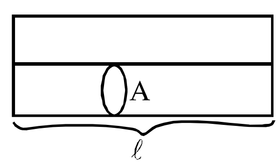
$$\frac{12}{6} = \frac{x}{72-x}$$

x = 48 cm

Q.19 (4)

$\because$ in parallel

$$R_{net} = \frac{R_1R_2}{R_1+R_2}$$



$$\frac{\rho\ell}{2A} = \frac{\rho_1\frac{\ell}{A}\times\rho_2\frac{\ell}{A}}{\rho_1\frac{\ell}{A}+\rho_2\frac{\ell}{A}}$$

$$\frac{\rho}{2} = \frac{6\times 3}{6+3} = 2$$

$\rho = 4$

Q.20 (1)

Q.21 (3)

Q.22 (3)

Q.23 [10]

Q.24 (15)

Q.25 (4)

Q.26 (50)

Q.27 (1)

Q.28 (500)

Q.29 (45)

Q.30 (3)

Q.31 (1)

Q.32 (3)

Q.33 (1)

Q.34 (4)

Q.35 (3)

Q.36 (1)

Q.37 (2)

mass of ice $m = \rho A\ell = 10^3 \times 10^{-4} \times 1 = 10^{-1}$ kg

Energy required to melt the ice

$Q = ms\Delta T + mL$

$= 10^{-1} (2 \times 10^3 \times 10 + 3.33 \times 10^5) = 3.53 \times 10^4$ J

$Q = i^2RT \Rightarrow 3.53 \times 10^4 = \left(\frac{1}{2}\right)^2 (4 \times 10^3)(t)$

Time = 35.3 sec

Option (2)

Q.38 [9]

Q.39 (4)

Q.40 (4)

Q.41 (NTA=2, ALLEN (Bonus))

Q.42 (1)

Q.43 (4)

Q.44 (2)

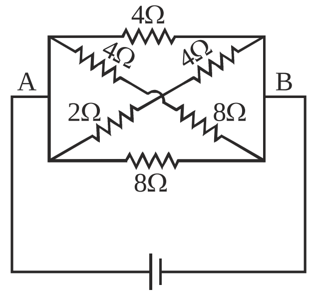
$$\frac{R_1R_2}{R_1 + R_2} = 3$$

$$\frac{\frac{\left(12\times10^{-6}\times10^{-2}\right)\ell\times4}{\pi(2)^2\times10^{-6}}\times\frac{\left(51\times10^{-6}\times10^{-2}\right)\ell\times4}{\pi(2)^2\times10^{-6}}}{\frac{63\times10^{-6}\times10^{-2}\times\ell\times4}{\pi(2)^2\times10^{-6}}}$$

$\Rightarrow \ell = 97$m

Option (2)

Q.45 (3)



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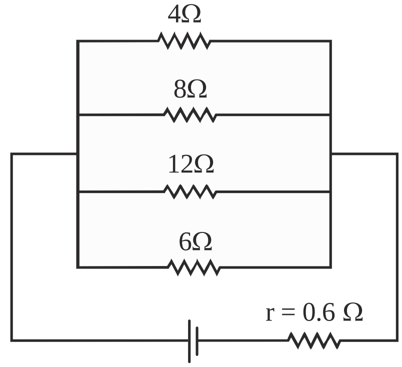


$$\frac{1}{R_{eq}} = \frac{1}{4}+\frac{1}{8}+\frac{1}{12}+\frac{1}{6} = \frac{6+3+2+4}{24} = \frac{15}{24}$$

$$R_{eq} = \frac{24}{15} = 1.6 \Rightarrow R_T = 1.6 + 0.6 = 2.2\Omega$$

$$P = \frac{V^2}{R_T} = \frac{(2.2)^2}{2.2} = 2.2\text{ W}$$

Option (3)

Q.46 (1)

$\Delta Q = \Delta U + \Delta W$

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta U}{\Delta t} + \frac{\Delta W}{\Delta t}$$

$$\frac{6000}{60} = \frac{J}{sec} + \frac{2.5\times10^3}{\Delta t} + 90$$

$\Delta t = 250$ sec

Option (1)

Q.47 [3]

Q.48 (3)

Q.49 [2]

$X_L = 2\pi fL$

f is very large

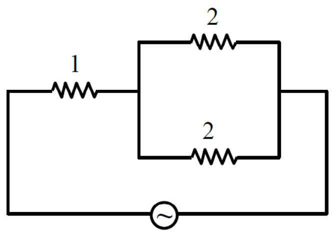
$\therefore$ X_L is very large hence open circuit.

$X_C = \dfrac{1}{2\pi fC}$

f is very large.

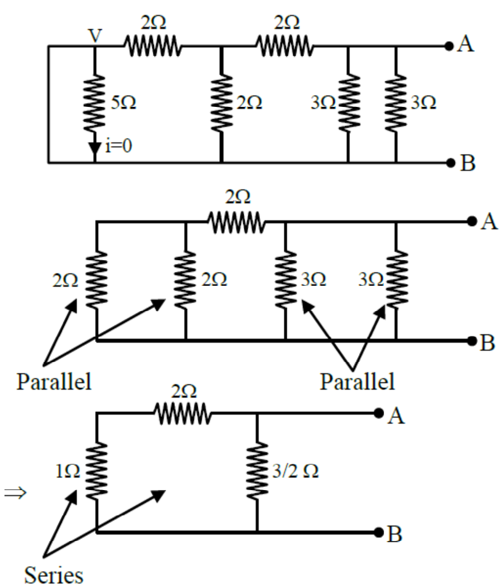
$\therefore X_C$ is very small, hence short circuit.

Final circuit



$Z_{eq} = 1 + \dfrac{2\times 2}{2+2} = 2$

Q.50 (4)



$R_{eq} = \dfrac{3\times 3/2}{3+3/2} = \dfrac{9/2}{9/2} = 1\Omega$

Q.51 [6]
Q.52 [100]
Q.53 (1)
Q.54 (1)
Q.55 [20]

Q.56 (4)

First case $P_1 = \dfrac{V^2}{R} = \dfrac{(240)^2}{36}$

Second case Resistance of each half = 18 Ω

$P_2 = \dfrac{(240)^2}{18} = \dfrac{(240)^2}{18} = \dfrac{(240)^2}{9}$

$\dfrac{P_1}{P_2} = \dfrac{1}{4}$

$x = 4.00$

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Q.1 (C)

$R = \dfrac{\rho l}{A} \Rightarrow R = \dfrac{\rho L}{tL} = \dfrac{\rho}{t}$

Independent of L.

Q.2 (D)

$100 = \dfrac{V^2}{R'_{100}} \Rightarrow \dfrac{1}{R'_{100}} = \dfrac{100}{V^2}$

where R'_{100} is resistance at any temperature corresponds to 100 W

$60 = \dfrac{V^2}{R'_{60}} \Rightarrow \dfrac{1}{R'_{60}} = \dfrac{60}{V^2}$ $\Rightarrow 40 = \dfrac{V^2}{R'_{40}}$

$\Rightarrow \dfrac{1}{R'_{40}} = \dfrac{40}{V^2}$

From above equations we can say

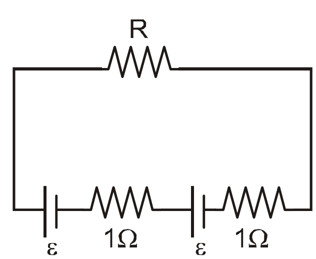
$\dfrac{1}{R'_{100}} > \dfrac{1}{R'_{60}} > \dfrac{1}{R'_{40}}$.

So, most appropriate answer is option (D).

Q.3 (C)

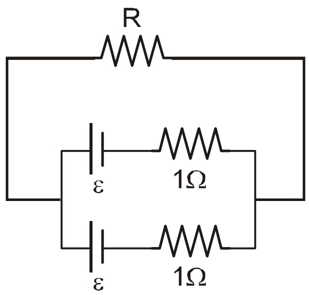
To verify Ohm's law one galvaometer is used as ammeter and other galvanometer is used as voltameter. Voltameter should have high resistance and ammeter should have low resistance as voltameter is used in parallel and ammeter in series that is in option (C).

Q.4 [4]



$i = \dfrac{2\varepsilon}{2+R}$

$J_1 = \left(\dfrac{2\varepsilon}{2+R}\right)^2 R$



$$\varepsilon_{eq} = \frac{\frac{\varepsilon}{1}+\frac{\varepsilon}{1}}{\frac{1}{1}+\frac{1}{1}} = \varepsilon$$

$$r_{eq} = \frac{1}{2} \Rightarrow i = \frac{\varepsilon}{\frac{1}{2}+R} = \frac{2\varepsilon}{2R+1}$$

$$J_2 = \left(\frac{2\varepsilon}{1+2R}\right)^2 R$$

Given $J_1 = \frac{9}{4} J_2$

$$\Rightarrow \left(\frac{2\varepsilon}{2+R}\right)^2 R = \frac{9}{4}\left(\frac{2\varepsilon}{1+2R}\right)^2 R$$

$$\Rightarrow \frac{2}{2+R} = \frac{3}{1+2R}$$

$\Rightarrow 2+4R = 6+3R$

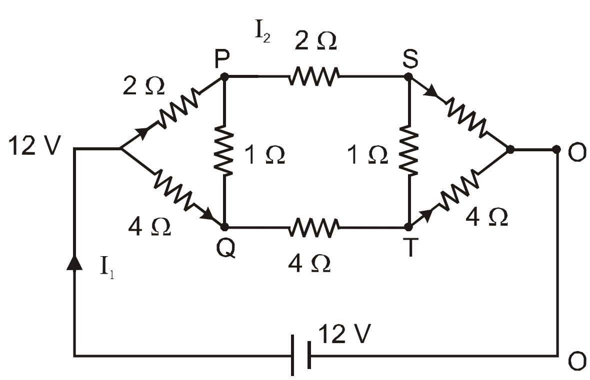
$\Rightarrow R = 4\Omega.$

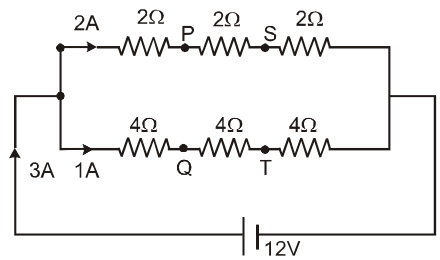
Q.5 [5]

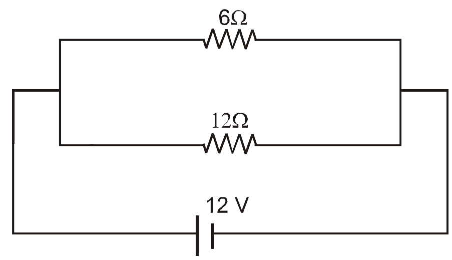
$$\varepsilon = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}} = \frac{\frac{6}{1}+\frac{3}{2}}{\frac{1}{1}+\frac{1}{2}} = \frac{15}{3} = 5 \text{ volt } \textbf{Ans.}$$

Q.6 (A), (B), (C), (D)

Due to input and output symmetry P and Q and S and T have same potential.







$$R_{eq} = \frac{6\times12}{18} = 4\Omega$$

$$I_1 = \frac{12}{4} = 3A$$

$$I_2 = \left(\frac{12}{6+12}\right)\times 3$$

$I_2 = 2A$

$V_A - V_S = 2\times4 = 8V$

$V_A - V_T = 1\times8 = 8V$

$V_P = V_Q \Rightarrow$ Current through PQ = 0 (A)

$V_P = V_Q \Rightarrow V_Q > V_S$ (C)

$I_1 = 3A$ (B)

$I_2 = 2A$ (D)

Q.7 (B), (D)

In given Kettle $R = \rho\frac{L}{\pi\left(\frac{d}{2}\right)^2} = \frac{4\rho L}{\pi d^2}$

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

In second Kettle $R_1 = \rho\frac{L}{\pi d^2}$ $R_2 = \frac{\rho L}{\pi d^2}$

So $R_1 = R_2 = \frac{R}{4}$

If wires are in parallel equivalent resistance

$$R_P = \frac{R}{8}$$

then power $P_P = 8P$

so it will take 0.5 minute

If wires are in series equivalent resistance

$R_S = \frac{R}{2}$

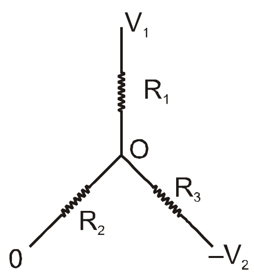
then power $P_S = 2P$

so it will take 2 minutes

Q.8 (A), (B), (D)

Potential of Junction O

$$V_0 = \frac{\frac{V_1}{R_1} + 0 - \frac{V_2}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$



Current through R_2 will be zero if

$$V_0 = 0 \Rightarrow \frac{V_1}{V_2} = \frac{R_1}{R_3}$$

Q.9 [5]

$$\frac{6}{1000}(G + 4990) = 30$$

$$\Rightarrow G + 4990 = \frac{30,000}{6} = 5000 \qquad \Rightarrow G = 10$$

$$\frac{6}{1000} \times 10 = \left(1.5 - \frac{6}{1000}\right)S$$

$$\Rightarrow S = \frac{60}{1494} = \frac{2n}{249}$$

$$\Rightarrow n = \frac{249 \times 30}{1494} = \frac{2490}{498} = 5$$

Q.10 (C)

For balanced meter bridge

$$\frac{X}{R} = \frac{\ell}{(100 - \ell)}$$

$$\frac{X}{40} = \frac{90}{60} \Rightarrow X = 60\Omega$$

$$X = R\,\frac{\ell}{(100 - \ell)}$$

$$\frac{\Delta X}{X} = \frac{\Delta \ell}{\ell} + \frac{\Delta \ell}{100 - \ell} = \frac{0.1}{40} + \frac{0.1}{60}$$

$\Delta X = 0.25$

so $X = (60 \pm 0.25)\,\Omega$

Q.11 (A,C)

For maximum voltage range across a galvanometer, all the elements must be connected in series. For maximum current range through a galvanometer, all the elements should be connected in parallel.

(A, C)

Q.12 (A)

Balls are repelled by lower positive plate and hits upper plate where the balls will get negatively charged and will now get attracted to the lower plate which is positively charged. Therefore motion of the balls will be periodic.

Hence, (A)

Q.13 (C)

$$\frac{K_q}{r} = V_0 \Rightarrow q = \frac{V_0 r}{K}$$

$$\frac{1}{2}\left(\frac{qE}{m}\right)t^2 = h \Rightarrow \frac{1}{2}\frac{V_0 r}{K}\frac{2V_0}{hm}t^2 = h$$

$$t = \frac{h}{V_0}\sqrt{\frac{mK}{r}}$$

Average current, $I_{avg.} = \frac{2q}{t} = \frac{2V_0^2}{h}\frac{r\sqrt{r}}{mK\sqrt{K}}$

Hence, (C)

Q.14 [5.55]

$n = 50$ tunrs $\qquad A = 2 \times 10^{-4}\,m^2$

$B = 0.02\,T \qquad K = 10^{-4}$

$Q_m = 0.2$ rad $\qquad R_g = 50\,\Omega$

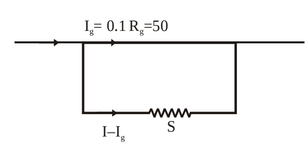
$I_A = 0 - 1.0A \qquad \tau = MB = C\theta,\ M = nIA$

$BINA = Cq$

$0.02 \times 1 \times 50 \times 2 \times 10^{-4} = 10^{-4} \times 0.2\ \ 10$

$I_g = 0.1A$

For galvanometer, resistance is to be connected to ammeter in shunt.



$I_g \times R_g = (I - I_g)S$

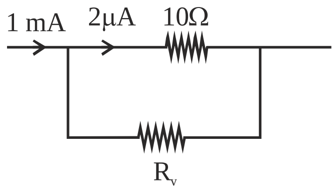
$0.1 \times 50 = (1 - 0.1)\,S$

$$S = \frac{50}{9} = 5.55$$

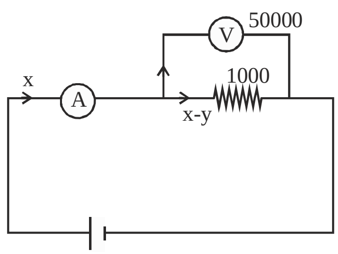
Q.15 (A,C)

$0.1 = 2 \times 10^{-6}(10 + R_v)$

$\therefore R_V = 49990\,\Omega$



$2 \times 10^{-6} \times 10 = 10^{-3} R_A \;\therefore\; = 0.02\,\Omega$

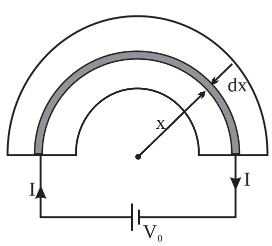


$y\,50000 = (x - y)1000$

$\therefore 51y = x$

$\text{Reading} = \dfrac{y50000}{x} = 980$

Q.16 (A, C, D)



All the elements are in parallel

$$\therefore \int \frac{l}{dr} = \int_{R1}^{R_2} \frac{t\,dx}{\rho\,\pi x}$$

$$\frac{l}{r} = \frac{t}{\pi\rho} \ln\left(\frac{R_2}{R_1}\right)$$

$$\text{Resistance} = \frac{\pi\rho}{t\,\ell n\left(\frac{R_2}{R_1}\right)}$$

$$i = \frac{V_0 t \ln\left(\frac{R_2}{R_1}\right)}{\pi\rho} \qquad \text{(A)}$$

$\left(-e\vec{E}\right)$ will be inward direction in order to provide centripetal acceleration. Therefore electric field will be radially outward

$V_{outer} < V_{inner}$ (C)

$$\frac{mV_d^2}{r} = q\vec{E}$$

$$E = \frac{mV_d^2}{qr} \qquad (I = neAV_d \Rightarrow V_d \propto i)$$

$$\Delta V = \int \vec{E}.\vec{dr}$$

$$\Delta V \propto V_d^2$$

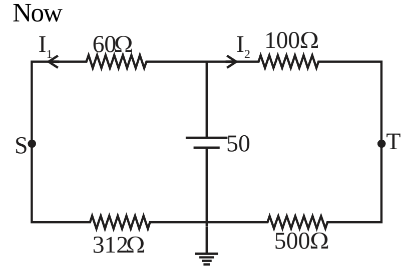
$$\Delta V \propto I^2$$

Q.17 (0.26 to 0.27)

$R_3' = 300(1 + \alpha\Delta T)$

$= 312\,\Omega$

Now



$I_1 = \dfrac{50}{372}$ and $I_2 = \dfrac{50}{600}$

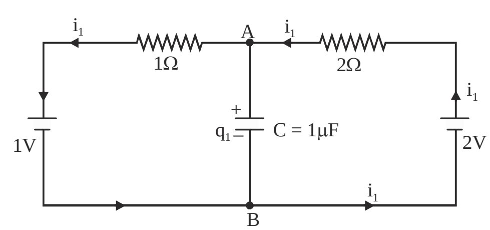
$V_S - V_T = 312\ I_1 - 500I_2$

$= 41.94 - 41.67$

$- 0.27\,V$

Q.18 [1.33]

Q.19 [0.67]



Switch connected to position 'P'

$V_A - 1 \cdot i_1 - 1 + 2 - 2i_1 = V_A$