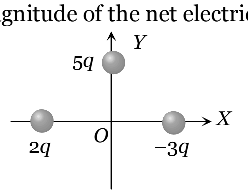
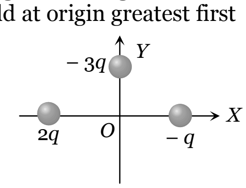
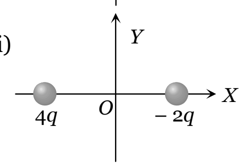
Electrostatics

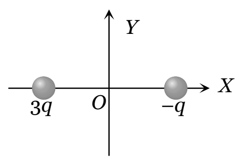
SET Self Evaluation Test -18

1. In the following four situations charged particles are at equal distance from the origin. Arrange them the magnitude of the net electric field at origin greatest first

(i)


(ii)


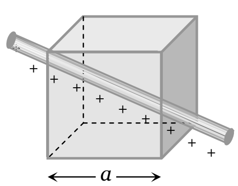
(iii)


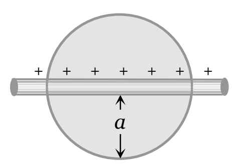
(iv)


(a) (i) > (ii) > (iii) > (iv) (b) (ii) > (i) > (iii) > (iv)

(c) (i) > (iii) > (ii) > (iv) (d) (iv) > (iii) > (ii) > (i)

2. A linear charge having linear charge density λ, penetrates a cube diagonally and then it penetrate a sphere diametrically as shown. What will be the ratio of flux coming cut of cube and sphere





(a) $\frac{1}{2}$ (b) $\frac{2}{\sqrt{3}}$

(c) $\frac{\sqrt{3}}{2}$ (d) $\frac{1}{1}$

3. Two charges each equal to $\eta q(\eta^{-1} < \sqrt{3})$ are placed at the corners of an equilateral triangle of side a. The electric field at the third corner is E_3 where $(E_0 = q / 4\pi\varepsilon_0 a^2)$

(a) $E_3 = E_0$ (b) $E_3 < E_0$

(c) $E_3 > E_0$ (d) $E_3 \geq E_0$

4. An electron falls through a small distance in a uniform electric field of magnitude $2 \times 10^4\ NC^{-1}$. The direction of the field is reversed keeping the magnitude unchanged and a proton falls through the same distance. The time of fall will be

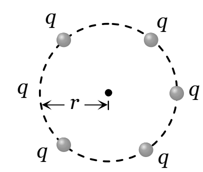
(a) Same in both cases

(b) More in the case of an electron

(c) More in the case of proton

(d) Independent of charge

5. A point charge is surrounded symmetrically by six identical charges at distance r as shown in the figure. How much work is done by the forces of electrostatic repulsion when the point charge q at the centre is removed at infinity



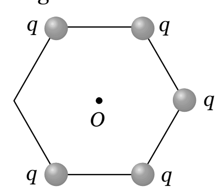
(a) Zero

(b) $6q^2 / 4\pi\varepsilon_0 r$

(c) $q^2 / 4\pi\varepsilon_0 r$

(d) $12q^2 / 4\pi\varepsilon_0 r$

6. Five point charge each having magnitude 'q' are placed at the corner of hexagon as shown in fig. Net electric field at the centre 'O' is $\vec{E}$. To get net electric field at 'O' be $6\vec{E}$, charge placed on the remaining sixth corner should be



(a) $6\,q$

(b) $-6\,q$

(c) $5\,q$

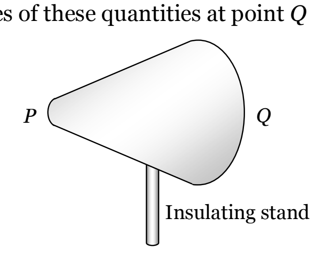
(d) $-5\,q$

7. An infinite non-conducting sheet has a surface charge density $\sigma = 0.10\ \mu C/m^2$ on one side. How far apart are equipotential surfaces whose potentials differ by 50 V

(a) 8.85 m (b) 8.85 cm

(c) 8.85 mm (d) 88.5 mm

8. Figure shows a charged conductor resting on an insulating stand. If at the point P the charge density is σ, the potential is V and the electric field strength is E, what are the values of these quantities at point Q



	Charge density	Potential	Electric intensity
(a)	$> \sigma$	$> V$	$> E$
(b)	$> \sigma$	V	$> E$
(c)	$< \sigma$	V	E
(d)	$< \sigma$	V	$< E$

9. Two point charge – q and $+q/2$ are situated at the origin and at the point $(a, 0, 0)$ respectively. The point along the X-axis where the electric field vanishes is

(a) $x = \frac{a}{\sqrt{2}}$ (b) $x = \sqrt{2}a$

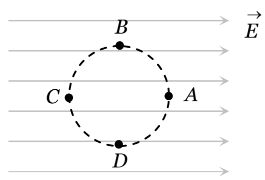
(c) $x = \frac{\sqrt{2}a}{\sqrt{2}-1}$ (d) $x = \frac{\sqrt{2}a}{\sqrt{2}+1}$

10. Two identical balls having like charges and placed at a certain distance apart repel each other with a certain force. They are brought in contact and then moved apart to a distance equal to half their initial separation. The force of repulsion between them increases 4.5 times in comparison with the initial value. The ratio of the initial charges of the balls is

(a) 2 (b) 3

(c) 4 (d) 6

11. The electric field in a region surrounding the origin is uniform and along the x-axis. A small circle is drawn with the centre at the origin cutting the axes at points A, B, C, D having co-ordinates $(a, 0)$, $(0, a)$, $(-a, 0)$, $(0, -a)$; respectively as shown in figure then potential in minimum at the point



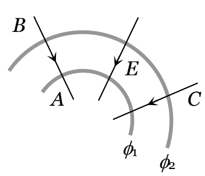
(a) A

(b) B

(c) C

(d) D

12. In moving from A to B along an electric field line, the electric field does 6.4×10^{-19} J of work on an electron. If ϕ_1, ϕ_2 are equipotential surfaces, then the potential difference $(V_C - V_A)$ is



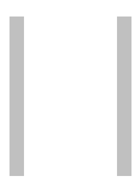
(a) – 4V

(b) 4V

(c) Zero

(d) 64 V

13. In the following figure two parallel metallic plates are maintained at different potential. If an electron is released midway between the plates, it will move



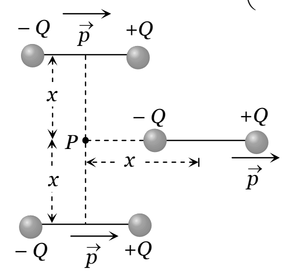
(a) Right ward at constant speed

(b) Left ward at constant speed

(c) Accelerated right ward

(d) Accelerated left ward

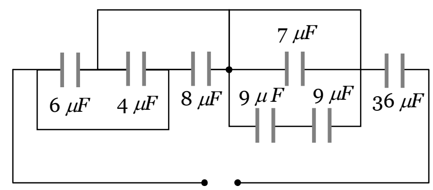
14. Three identical dipoles are arranged as shown below. What will be the net electric field at P $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$



(a) $\frac{k.p}{x^3}$ (b) $\frac{2kp}{x^3}$

(c) Zero (d) $\frac{\sqrt{2}\,kp}{x^3}$

15. In the following diagram, the charge and potential difference across 8 μF capacitance will be respectively



(a) 320 μC, 40 V (b) 420 μC, 50 V

(c) 214 μC, 27 V (d) 360 μC, 45 V

16. A conducting sphere of radius R, and carrying a charge q is joined to a conducting sphere of radius $2R$, and carrying a charge $-2q$. The charge flowing between them will be

(a) $\frac{q}{3}$ (b) $\frac{2q}{3}$

(c) q (d) $\frac{4q}{3}$

17. An arc of radius r carries charge. The linear density of charge is λ and the arc subtends a angle $\frac{\pi}{3}$ at the centre. What is electric potential at the centre

(a) $\frac{\lambda}{4\varepsilon_0}$ (b) $\frac{\lambda}{8\varepsilon_0}$

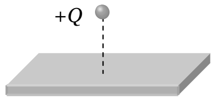
(c) $\frac{\lambda}{12\varepsilon_0}$ (d) $\frac{\lambda}{16\varepsilon_0}$

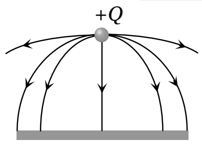
18. A neutral water molecule (H_2O) in it's vapor state has an electric dipole moment of magnitude 6.4×10^{-30} C-m. How far apart are the molecules centres of positive and negative charge

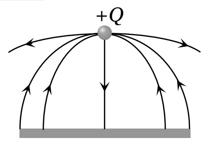
(a) 4 m (b) 4 mm

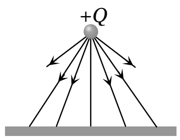
(c) 4 μm (d) 4 pm

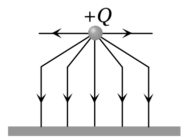
19. A charge Q is fixed at a distance d in front of an infinite metal plate. The lines of force are represented by



(a) 

(b) 

(c) 

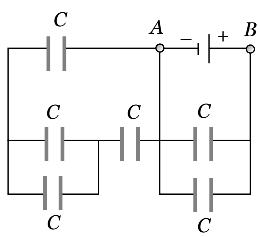
(d) 

20. A 500 μF capacitor is charged at a steady rate of 100 $\mu C/sec$. The potential difference across the capacitor will be 10 V after an interval of

(a) 5 *sec* (b) 20 *sec*

(c) 25 *sec* (d) 50 *sec*

21. Find equivalent capacitance between A and B



(a) 6C

(b) 5C

(c) 3C

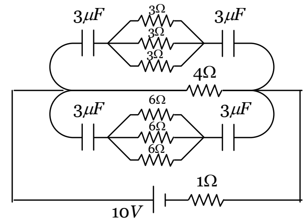
(d) 2C

22. The radii of the inner and outer spheres of a condenser are $9cm$ and $10cm$ respectively. If the dielectric constant of the medium between the two spheres is 6 and charge on the inner sphere is 18×10^{-9} *coulomb*, then the potential of inner sphere will be, if the outer sphere is earthed

(a) 180 *volts* (b) 30 *volts*

(c) 18 *volts* (d) 90 *volts*

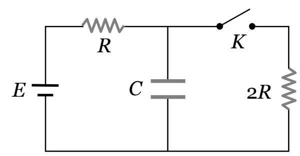
23. In the following figure, the charge on each condenser in the steady state will be



(a) 3μC (b) 6 μC

(c) 9μC (d) 12μC

24. In the circuit, shown in fig. 'K' is open. The charge on capacitor C in steady state is q_1. Now key is closed and at steady state, the charge on C is q_2. The ratio of charges $\left(\frac{q_1}{q_2}\right)$ is



(a) $\frac{3}{2}$ (b) $\frac{2}{3}$

(c) 1 (d) $\frac{1}{2}$

25. In a parallel plate capacitor the separation between the plates is $3mm$ with air between them. Now a $1mm$ thick layer of a material of dielectric constant 2 is introduced between the plates due to which the capacity increases. In order to bring its capacity to the original value the separation between the plates must be made

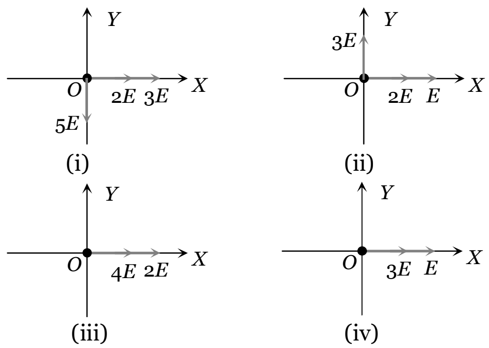
(a) 1.5 *mm* (b) 2.5 *mm*

(c) 3.5 *mm* (d) 4.5 *mm*

Answers and Solutions

(SET -18)

1. (c) If electric field due to charge $|q|$ at origin is E then electric field due to charges $|2q|$, $|3q|$, $|4q|$ and $|5q|$ are respectively $2E$, $3E$, $4E$ and $5E$



$E_{(i)} = \sqrt{(5E)^2 + (5E)^2} = 5\sqrt{2}E$,

$E_{(ii)} = \sqrt{(3E)^2 + (3E)^2} = 3\sqrt{2}E$,

$E_{(iii)} = 4E + 2E = 6E$ and $E_{(iv)} = 3E + E = 4E$

$\Rightarrow E_{(i)} > E_{(iii)} > E_{(ii)} > E_{(iv)}$

2. (c) Flux coming out of the cube $\phi_1 = \dfrac{\lambda . a\sqrt{3}}{\varepsilon_0}$ ......(i)

and from sphere $\phi_2 = \dfrac{\lambda \cdot 2a}{\varepsilon_0}$ ......(ii)

$\therefore \dfrac{\phi_1}{\phi_2} = \dfrac{\sqrt{3}}{2}$

3. (c) $E_1 = \dfrac{\eta q}{4\pi\varepsilon_0 a^2}, E_2 = \dfrac{\eta q}{4\pi\varepsilon_0 a^2}$. Therefore $E = \vec{E}_1 + \vec{E}_2$

$= \sqrt{E_1^2 + E_2^2 + 2E_1E_2 \cos 60^o} = \dfrac{\sqrt{3}\eta q}{4\pi\varepsilon_0 a^2}$.

Since $\eta^{-1} < \sqrt{3}, 1 < \sqrt{3}\eta, \sqrt{3}\eta > 1$.

$\Rightarrow \dfrac{\sqrt{3}\eta q}{4\pi\varepsilon_0 a^2} > \dfrac{q}{4\pi\varepsilon_0 a^2} \Rightarrow E_3 > E_0 \left(E_0 = \dfrac{q}{4\pi\varepsilon_0 a^2} \right)$.

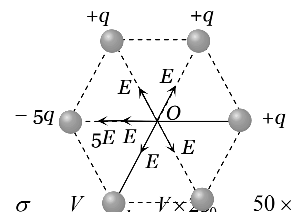
4. (c) The time required to fall through distance d is $d = \dfrac{1}{2}\left(\dfrac{qE}{m}\right)t^2$ or $t = \sqrt{\dfrac{2dm}{qE}}$

Since $t^2 \propto m$, a proton takes more time.

5. (b) Total potential at the centre $V = \dfrac{6q}{4\pi\varepsilon_0 r}$

Required work done $= q.V = \dfrac{6q^2}{4\pi\varepsilon_0 r}$

6. (d) To obtained net field $6E$ at centre O, the charge to be placed at remaining sixth corner is – $5q$. (see following figure)



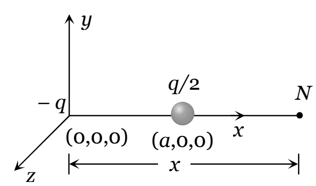
7. (c) $E = \dfrac{V}{d} \Rightarrow \dfrac{\sigma}{2\varepsilon_0} = \dfrac{V}{d} \Rightarrow d = \dfrac{V \times 2\varepsilon_0}{\sigma} = \dfrac{50 \times 2 \times 8.85 \times 10^{-12}}{0.1 \times 10^{-6}}$

$= 8.85 \times 10^{-3}\ m = 8.88\ mm$

8. (d) The surface of the conductor is an equipotential surface since there is free flow of electrons within the conductor. Thus potential at Q is the same as that at P. That is $V_P = V_Q = V$. The electric field E at a point on the equipotential surface of the conductor is inversely proportional to the square of the radius of curvature r at that point. That is $E \propto r^{-2}$

Since point Q has a larger radius of curvature than that at point P, the electric field at Q is less than that at P. That is $E_Q < E_P = E$

9. (c)

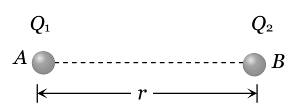


Suppose the field vanishes at a (distance x), we have $\dfrac{kq}{x^2} = \dfrac{kq/2}{(x-a)^2}$ or $2(x-a)^2 = x^2$ or $\sqrt{2}(x-a) = x$

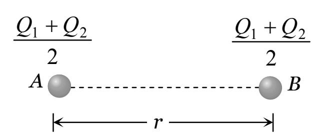
or $(\sqrt{2}-1)x = \sqrt{2}\,a$ or $x = \left(\dfrac{\sqrt{2}\,a}{\sqrt{2}-1}\right)$

10. (a) Suppose the balls having charges Q_1 and Q_2 respectively.

Initially :



Finally :



$F' = \dfrac{k\left(\dfrac{Q_1+Q_2}{2}\right)^2}{\left(\dfrac{r}{2}\right)^2} = \dfrac{k(Q_1+Q_2)^2}{r^2}$

It is given that $F' = 4.5F$ so $\dfrac{k(Q_1+Q_2)^2}{r^2} = 4.5\,k.\dfrac{Q_1Q_2}{r^2}$

$\Rightarrow (Q_1+Q_2)^2 = 4.5\,Q_1Q_2$. On solving it gives $\frac{Q_1}{Q_2}=\frac{2}{1}$.

11. (a) In the direction of electric field, potential decreases.

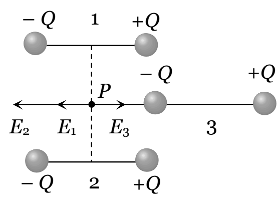
12. (b) Work done by the field $W = q(-dV) = -e(V_A - V_B)$

$= e(V_B - V_A) = e(V_C - V_A)$ $(\because V_B = V_C)$

$\Rightarrow (V_C - V_A) = \frac{W}{e} = \frac{6.4\times10^{-19}}{1.6\times10^{-19}} = 4\,V$

13. (d) Electric field is directed right ward (higher potential of – 200 V to lower potential of – 400 V). When electron left free in an electric it accelerates opposite to the electric field. Hence in the given case electron accelerates left ward.

14. (c) Point P lies at equatorial positions of dipole 1 and 2 and axial position of dipole 3.



Hence field at P due to dipole 1

$E_1 = \frac{k.p}{x^3}$ (towards left)

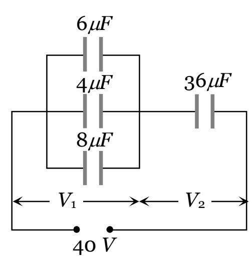
due to dipole 2

$E_2 = \frac{k.p}{x^2}$ (towards left)

due to dipole 3 $E_3 = \frac{k.(2p)}{x^3}$ (towards right)

So net field at P will be zero.

15. (c) Given circuit can be redrawn as follows capacitors, $9\mu F$, $9\mu F$ and $7\mu F$ are short circuited. So they are deleted.



$V_1 + V_2 = 40\,V$

and $\frac{V_1}{V_2} = \frac{36}{18} = 2$

Hence $V_1 = \frac{80}{3}\,V$

and $V_2 = \frac{40}{3}\,V$

Charge on $8\mu F$ capacitor

$= 8\times\frac{80}{3} = 213.3\,\mu F \approx 214\,\mu F$

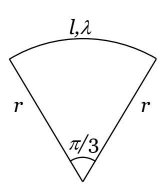
16. (d) Initial charge on sphere of radius $R = q$

Charge on this sphere after joining

$q' = \frac{(q+(-2q))\times R}{R+2R} = \frac{-q\times R}{3R} = -\frac{q}{3}$

Now charge flowing between them $= q - \left(-\frac{q}{3}\right) = \frac{4q}{3}$

17. (c) Length of the arc $= r\theta = \frac{r\pi}{3}$



Charge on the arc $= \frac{r\pi}{3}\times\lambda$

$\therefore$ Potential at center $= \frac{kq}{r}$

$= \frac{1}{4\pi\varepsilon_0}\times\frac{r\pi}{3}\frac{\lambda}{r} = \frac{\lambda}{12\varepsilon_0}$

18. (c) There are 10 electrons and 10 protons in a neutral water molecule.

So it's dipole moment is $p = q\,(2l) = 10\,e\,(2l)$

Hence length of the dipole *i.e.* distance between centres of positive and negative charges is

$2\,l = \frac{p}{10e} = \frac{6.4\times10^{-20}}{10\times1.6\times10^{-19}} = 4\times10^{-12}\,m = 4\,pm$

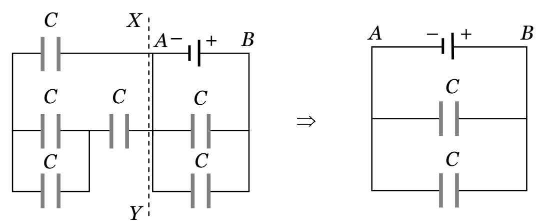
19. (a) Metal plate acts as an equipotential surface, therefore the field lines should enter normal to the surface of the metal plate.

20. (d) Charge required to reach the capacitor upto 10 V is

$Q = 500\times10^{-6}\times10 = 5\times10^{-3}\,C$

Now required time $= \frac{5\times10^{-3}}{100\times10^{-6}} = 50\,sec$

21. (d) All capacitor lying in left side of line XY are short circuited so circuit can be reduced as follows



$C_{AB} = 2C$

22. (b) Given system is a spherical capacitor

So capacitance of system $C = K\times4\pi\varepsilon_0\left[\frac{r_1r_2}{r_2-r_1}\right]$

$= \frac{6}{9\times10^9}\left[\frac{9\times10}{1}\right]\times10^{-2} = 6\times10^{-10}\,Farad$

Now potential of inner sphere will be equal to potential difference of the capacitor.

So $V = \frac{q}{C} = \frac{18\times10^{-9}}{6\times10^{-10}} = 30\,V$

23. (d) In steady state current flows through 4Ω resistance only and it is $i = \frac{10}{(4+1)} = 2amp$. Potential difference across 4Ω resistance is $V = 2\times4 = 8\,volt$

Hence, potential difference across each capacitor is 4V

So charge on each capacitor $Q = 3\times4 = 12\mu C$.

24. (a) When key is open, charge in steady state will be $q_1 = CE$.

When key is closed, potential difference across capacitor will be $V = \frac{2R}{R+2R}E = \frac{2}{3}R$

Charge in steady state will be $q_2 = \frac{2}{3}CE \Rightarrow \frac{q_1}{q_2} = \frac{3}{2}$.

25. (c) $K = \frac{t}{t-d'} \Rightarrow 2 = \frac{1}{1-d'} \Rightarrow d' = \frac{1}{2}mm$

So new distance $= 3 + \frac{1}{2} = 3.5\,mm$

***