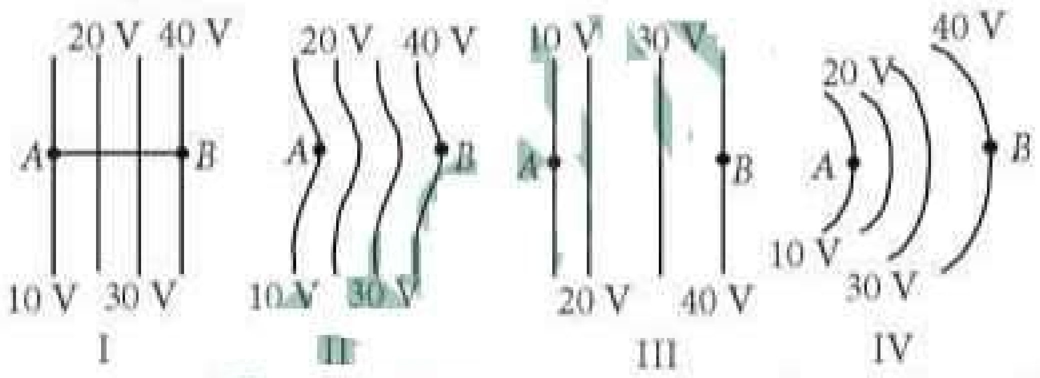
Chapter 12. Electrostatics

1. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system
   (a) decreases by a factor of 2
   (b) remains the same
   (c) increases by a factor of 2
   (d) increases by a factor of 4 *(NEET 2017)*

2. Suppose the charge of a proton and an electron differ slightly. One of them is $-e$, the other is $(e + \Delta e)$. If the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance d (much greater than atomic size) apart is zero, then Δe is of the order of [Given: mass of hydrogen $m_h = 1.67 \times 10^{-27}$ kg]
   (a) 10^{-23} C (b) 10^{-37} C
   (c) 10^{-47} C (d) 10^{-20} C
   (NEET 2017)

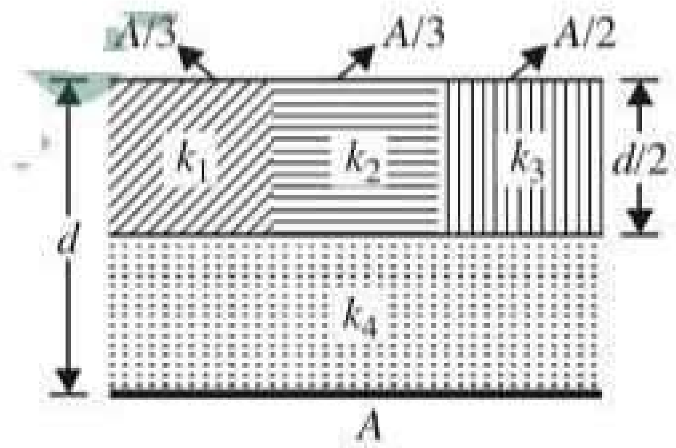
3. The diagrams below show regions of equipotentials.



A positive charge is moved from A to B in each diagram.
   (a) In all the four cases the work done is the same.
   (b) Minimum work is required to move q in figure (I).
   (c) Maximum work is required to move q in figure (II).
   (d) Maximum work is required to move q in figure (III). *(NEET 2017)*

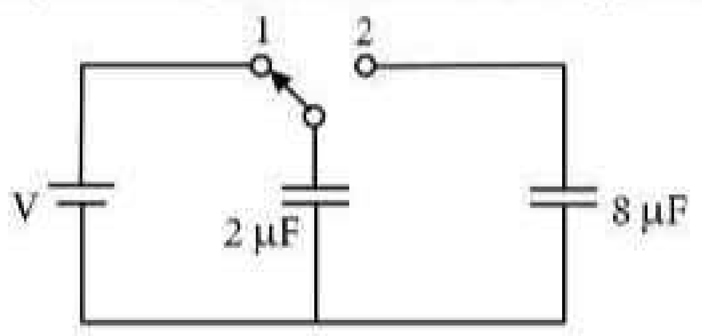
4. An electric dipole is placed at an angle of 30° with an electric field intensity 2×10^5 N C^{-1}. It experiences a torque equal to 4 N m. The charge on the dipole, if the dipole length is 2 cm, is
   (a) 8 mC (b) 2 mC (c) 5 mC (d) 7 μC
   (NEET -II 2016)

5. A parallel-plate capacitor of area A, plate separation d and capacitance C is filled with four dielectric materials having dielectric constants k_1, k_2, k_3 and k_4 as shown in the figure. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant k is given by



   (a) $k = k_1 + k_2 + k_3 + 3k_4$
   (b) $k = \frac{2}{3}(k_1 + k_2 + k_3) + 2k_4$
   (c) $\frac{2}{k} = \frac{3}{k_1 + k_2 + k_3} + \frac{1}{k_4}$
   (d) $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{3}{2k_4}$ *(NEET -II 2016)*

6. A capacitor of 2 μF is charged as shown in the diagram. When the switch S is turned to position 2, the percentage of its stored energy dissipated is



   (a) 75% (b) 80%
   (c) 0% (d) 20%
   (NEET-I 2016)

7. Two identical charged spheres suspended from a common point by two massless strings of lengths l, are initially at a distance d ($d << l$) apart because of their mutual repulsion. The

charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity v. Then v varies as a function of the distance x between the spheres, as

(a) $v \propto x^{-1/2}$ (b) $v \propto x^{-1}$
(c) $v \propto x^{1/2}$ (d) $v \propto x$

(NEET-I 2016)

8. A parallel plate air capacitor has capacity C, distance of separation between plates is d and potential difference V is applied between the plates. Force of attraction between the plates of the parallel plate air capacitor is

(a) $\frac{CV^2}{d}$ (b) $\frac{C^2V^2}{2d^2}$ (c) $\frac{C^2V^2}{2d}$ (d) $\frac{CV^2}{2d}$

(2015)

9. If potential (in volts) in a region is expressed as $V(x, y, z) = 6xy - y + 2yz$, the electric field (in N/C) at point (1, 1, 0) is

(a) $-(2\hat{i}+3\hat{j}+\hat{k})$ (b) $-(6\hat{i}+9\hat{j}+\hat{k})$
(c) $-(3\hat{i}+5\hat{j}+3\hat{k})$ (d) $-(6\hat{i}+5\hat{j}+2\hat{k})$

(2015)

10. The electric field in a certain region is acting radially outward and is given by $E = Ar$. A charge contained in a sphere of radius 'a' centred at the origin of the field, will be given by

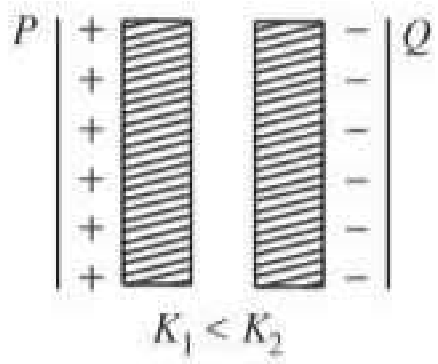
(a) $4\pi\varepsilon_0 Aa^3$ (b) $\varepsilon_0 Aa^3$
(c) $4\pi\varepsilon_0 Aa^2$ (d) $A\varepsilon_0 a^2$

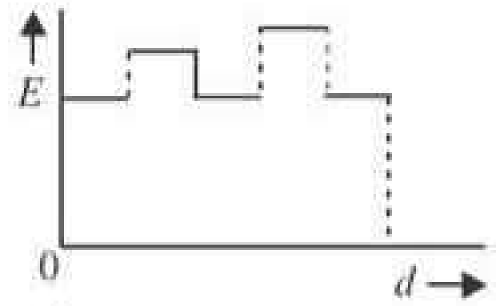
(2015 Cancelled)

11. A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect?

(a) The change in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$.
(b) The charge on the capacitor is not conserved.
(c) The potential difference between the plates decreases K times.
(d) The energy stored in the capacitor decreases K times. *(2015 Cancelled)*

12. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between plates of a parallel plate capacitor, as shown in the figure. The variation of electric field E between the plates with distance d as measured from plate P is correctly shown by



(a)


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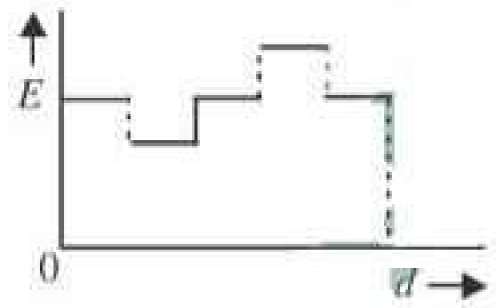
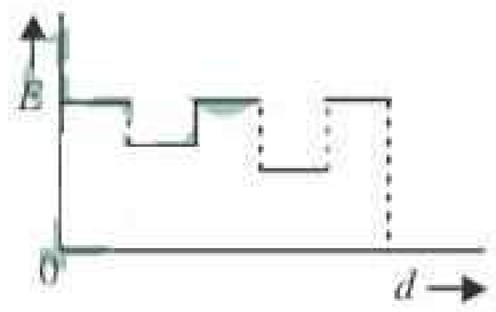
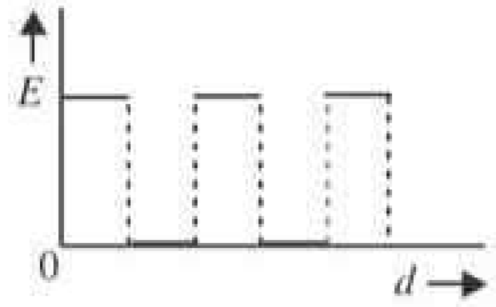


(c)


(d)


(2014)

13. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are

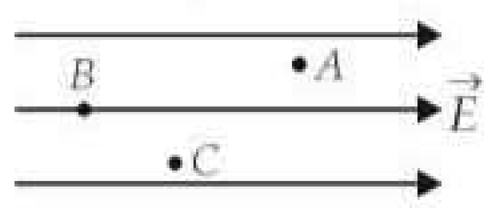
(a) zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (b) $\frac{Q}{4\pi\varepsilon_0 R}$ and zero
(c) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (d) both are zero

(2014)

14. In a region, the potential is represented by $V(x, y, z) = 6x - 8xy - 8y + 6yz$, where V is in volts and x, y, z are in metres. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is

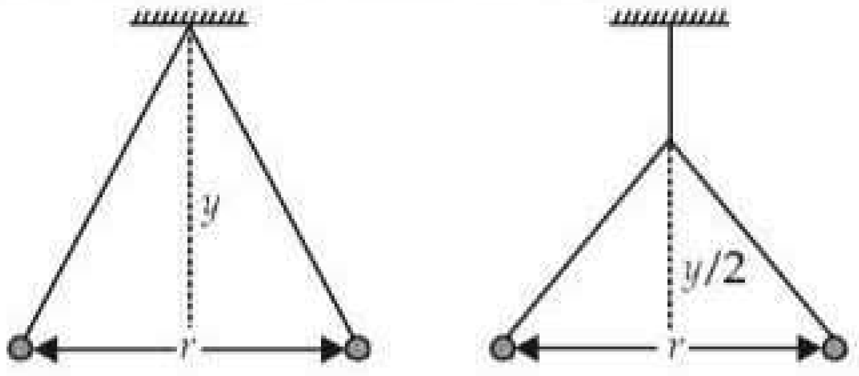
(a) $6\sqrt{5}$ N (b) 30 N
(c) 24 N (d) $4\sqrt{35}$ N *(2014)*

15. A, B and C are three points in a uniform electric field. The electric potential is



(a) maximum at C
(b) same at all the three points A, B and C
(c) maximum at A
(d) maximum at B *(NEET 2013)*

16. Two pith balls carrying equal charges are suspended from a common point by strings of equal length, the equilibrium separation between them is r. Now the strings are rigidly clamped at half the height. The equilibrium separation between the balls now become



(a) $\left(\frac{2r}{\sqrt{3}}\right)$ (b) $\left(\frac{2r}{3}\right)$ (c) $\left(\frac{1}{\sqrt{2}}\right)^2$ (d) $\left(\frac{r}{\sqrt[3]{2}}\right)$

(NEET 2013)

17. An electric dipole of dipole moment p is aligned parallel to a uniform electric field E. The energy required to rotate the dipole by 90° is
(a) p^2E (b) pE
(c) infinity (d) pE^2
(Karnataka NEET 2013)

18. A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to
(a) $-Q/4$ (b) $Q/4$ (c) $-Q/2$ (d) $Q/2$
(Karnataka NEET 2013)

19. An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when $\theta = 90°$, the torque and the potential energy of the dipole will respectively be
(a) $pE\sin\theta, -pE\cos\theta$ (b) $pE\sin\theta, -2pE\cos\theta$
(c) $pE\sin\theta, 2pE\cos\theta$ (d) $pE\cos\theta, -pE\sin\theta$
(2012)

20. Four point charges $-Q, -q, 2q$ and $2Q$ are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero is

(a) $Q = -q$ (b) $Q = -\frac{1}{q}$

(c) $Q = q$ (d) $Q = \frac{1}{q}$ *(2012)*

21. What is the flux through a cube of side a if a point charge of q is at one of its corner?

(a) $\frac{2q}{\varepsilon_0}$ (b) $\frac{q}{8\varepsilon_0}$ (c) $\frac{q}{\varepsilon_0}$ (d) $\frac{q}{2\varepsilon_0}6a^2$

(2012)

22. A parallel plate capacitor has a uniform electric field E in the space between the plates. If the distance between the plates is d and area of each plate is A, the energy stored in the capacitor is

(a) $\frac{1}{2}\varepsilon_0 E^2$ (b) $\frac{E^2Ad}{\varepsilon_0}$

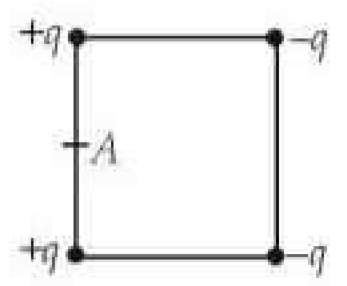
(c) $\frac{1}{2}\varepsilon_0 E^2 Ad$ (d) $\varepsilon_0 EAd$

(Mains 2012, 2011, 2008)

23. Two metallic spheres of radii 1 cm and 3 cm are are given charges of -1×10^{-2} C and 5×10^{-2} C, respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is
(a) 2×10^{-2} C (b) 3×10^{-2} C
(c) 4×10^{-2} C (d) 1×10^{-2} C
(Mains 2012)

24. A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will
(a) increase four times
(b) be reduced to half
(c) remain the same
(d) be doubled *(2011)*

25. Four electric charges $+q, +q, -q$ and $-q$ are placed at the corners of a square of side $2L$ (see figure). The electric potential at point A, midway between the two charges $+q$ and $+q$, is



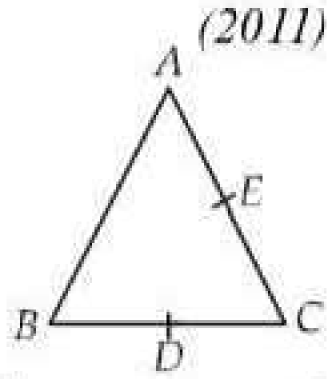
(a) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\sqrt{5}\right)$

(b) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\frac{1}{\sqrt{5}}\right)$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1-\frac{1}{\sqrt{5}}\right)$

(d) zero *(2011)*

26. Three charges, each $+q$, are placed at the corners of an isosceles triangle ABC of sides BC and AC, $2a$. D and E are the mid points of BC and CA. The work done in taking a charge Q from D to E is



(a) $\frac{3qQ}{4\pi\varepsilon_0 a}$ (b) $\frac{3qQ}{8\pi\varepsilon_0 a}$ (c) $\frac{qQ}{4\pi\varepsilon_0 a}$ (d) zero

(Mains 2011)

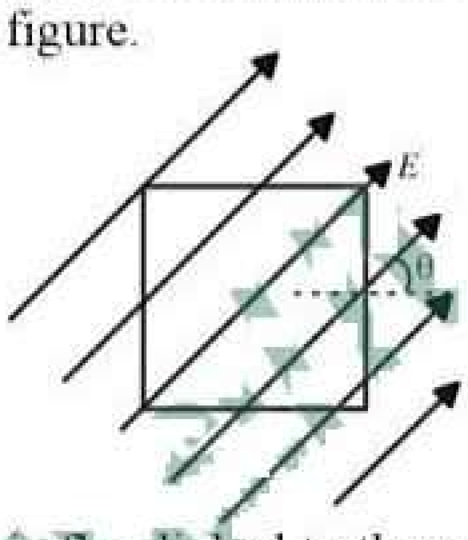
27. The electric potential V at any point (x, y, z), all in metres in space is given by $V = 4x^2$ volt. The electric field at the point (1, 0, 2) in volt/meter, is
(a) 8 along negative X-axis
(b) 8 along positive X-axis
(c) 16 along negative X-axis
(d) 16 along positive X-axis *(Mains 2011)*

28. Two positive ions, each carrying a charge q, are separated by a distance d. If F is the force of repulsion between the ions, the number of electrons missing from each ion will be
(e being the charge on an electron)

(a) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$ (b) $\sqrt{\frac{4\pi\varepsilon_0 Fe^2}{d^2}}$

(c) $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$ (d) $\frac{4\pi\varepsilon_0 Fd^2}{q^2}$ *(2010)*

29. A square surface of side L meter in the plane of the paper is placed in a uniform electric field E(volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure.



The electric flux linked to the surface, in units of volt m is
(a) EL^2 (b) $EL^2\cos\theta$
(c) $EL^2\sin\theta$ (d) zero *(2010)*

30. A series combination of n_1 capacitors, each of value C_1, is charged by a source of potential difference $4V$. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2, in terms of C_1, is then

(a) $\frac{2C_1}{n_1 n_2}$ (b) $16\frac{n_2}{n_1}C_1$

(c) $2\frac{n_2}{n_1}C_1$ (d) $\frac{16C_1}{n_1 n_2}$ *(2010)*

31. Two parallel metal plates having charges $+Q$ and $-Q$ face each other at a certain distance between them. If the plates are now dipped in kerosene oil tank, the electric field between the plates will
(a) become zero (b) increase
(c) decrease (d) remain same
(Mains 2010)

32. The electric field at a distance $\frac{3R}{2}$ from the centre of a charged conducting spherical shell of radius R is E. The electric field at a distance $\frac{R}{2}$ from the centre of the sphere is

(a) zero (b) E (c) $\frac{E}{2}$ (d) $\frac{E}{3}$

(Mains 2010)

33. Three concentric spherical shells have radii a, b and c $(a < b < c)$ and have surface charge densities σ, – σ and σ respectively. If V_A, V_B and V_C denote the potentials of the three shells, then, for $c = a + b$, we have
(a) $V_C = V_B \neq V_A$ (b) $V_C \neq V_B \neq V_A$
(c) $V_C = V_B = V_A$ (d) $V_C = V_A \neq V_B$
(2009)

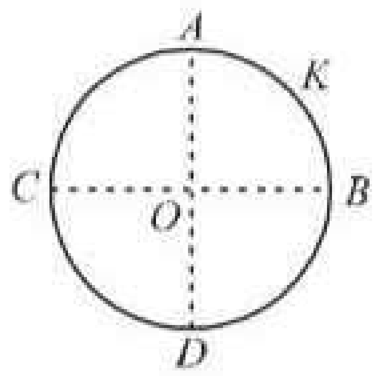
34. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be

(a) $3C, \frac{V}{3}$ (b) $\frac{C}{3}, 3V$

(c) $3C, 3V$ (d) $\frac{C}{3}, \frac{V}{3}$ *(2009)*

35. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$.
The electric field at that point is
(a) $\vec{E} = \hat{i}\,2xy + \hat{j}\,(x^2 + y^2) + \hat{k}\,(3xz - y^2)$
(b) $\vec{E} = \hat{i}\,z^3 + \hat{j}\,xyz + \hat{k}\,z^2$
(c) $\vec{E} = \hat{i}\,(2xy - z^3) + \hat{j}\,xy^2 + \hat{k}\,3z^2x$
(d) $\vec{E} = \hat{i}\,(2xy + z^3) + \hat{j}\,x^2 + \hat{k}\,3xz^2$ *(2009)*

36. A thin conducting ring of radius R is given a charge $+Q$. The electric field at the centre O of the ring due to the charge on the part AKB of the ring is E. The electric field at the centre due to the charge on the part $ACDB$ of the ring is

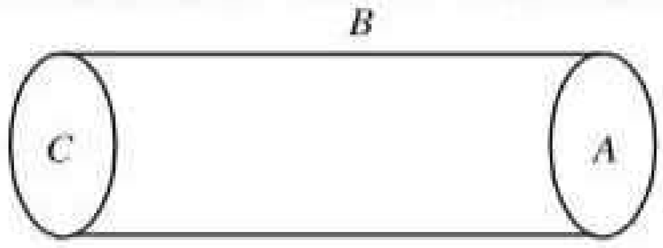


(a) E along KO (b) $3E$ along OK
(c) $3E$ along KO (d) E along OK
(2008)

37. The electric potential at a point in free space due to charge Q coulomb is $Q \times 10^{11}$ volts. The electric field at that point is

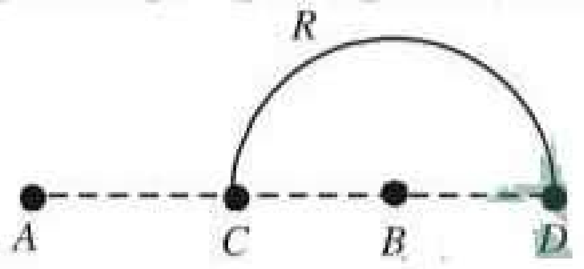
(a) $4\pi\varepsilon_0 Q \times 10^{20}$ volt/m
(b) $12\pi\varepsilon_0 Q \times 10^{22}$ volt/m
(c) $4\pi\varepsilon_0 Q \times 10^{22}$ volt/m
(d) $12\pi\varepsilon_0 Q \times 10^{20}$ volt/m *(2008)*

38. A hollow cylinder has a charge q coulomb within it. If f is the electric flux in units of voltmeter associated with the curved surface B, the flux linked with the plane surface A in units of V-m will be



(a) $\frac{q}{2\varepsilon_0}$
(b) $\frac{\phi}{3}$
(c) $\frac{q}{\varepsilon_0} - \phi$ (d) $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$ *(2007)*

39. Charges $+q$ and $-q$ are placed at points A and B respectively which are a distance $2L$ apart, C is the midpoint between A and B. The work done in moving a charge $+Q$ along the semicircle CRD is

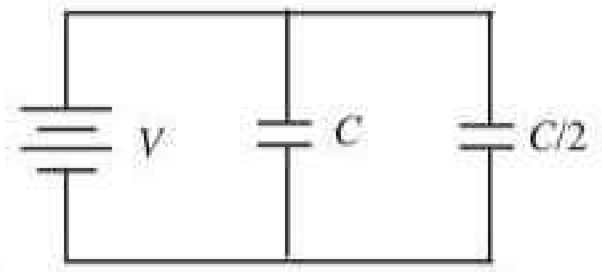


(a) $\frac{qQ}{2\pi\varepsilon_0 L}$ (b) $\frac{qQ}{6\pi\varepsilon_0 L}$
(c) $-\frac{qQ}{6\pi\varepsilon_0 L}$ (d) $\frac{qQ}{4\pi\varepsilon_0 L}$ *(2007)*

40. Three point charges $+q$, $-2q$ and $+q$ are placed at points $(x = 0, y = a, z = 0)$, $(x = 0, y = 0, z = 0)$ and $(x = a, y = 0, z = 0)$ respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are

(a) $\sqrt{2}qa$ along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$
(b) qa along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$
(c) $\sqrt{2}qa$ along $+x$ direction
(d) $\sqrt{2}qa$ along $+y$ direction. *(2007)*

41. Two condensers, one of capacity C and other other of capacity $C/2$ are connected to a V-volt battery, as shown in the figure. The work done in charging fully both the condensers is



(a) $\frac{1}{4}CV^2$ (b) $\frac{3}{4}CV^2$
(c) $\frac{1}{2}CV^2$ (d) $2CV^2$. *(2007)*

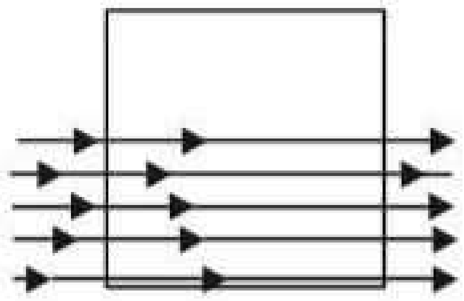
42. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates

(a) increases (b) decreases
(c) does not change (d) becomes zero *(2006)*

43. An electric dipole of moment $\vec{p}$ is lying along a uniform electric field $\vec{E}$. The work done in rotating the dipole by 90° is

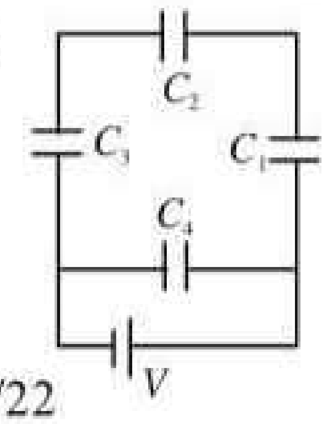
(a) pE (b) $\sqrt{2}pE$
(c) $pE/2$ (d) $2pE$. *(2006)*

44. A square surface of side L metres is in the plane of the paper. A uniform electric field $\vec{E}$ (volt/m), also in the plane of the paper is limited only to the lower half of the square surface (see figure). The electric flux in SI units associated with the surface is



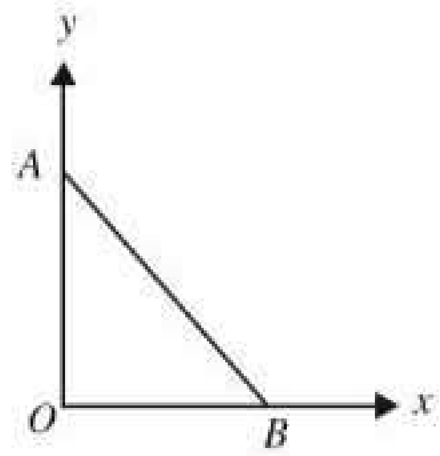
(a) EL^2 (b) $EL^2/2\varepsilon_0$ (c) $EL^2/2$ (d) zero *(2006)*

45. A network of four capacitors of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$ and $C_4 = 4C$ are connected to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is



(a) 4/7 (b) 3/22
(c) 7/4 (d) 22/3 *(2005)*

46. As per the diagram a point charge $+q$ is placed at the origin O. Work done in taking another point charge $-Q$ from the point A [coordinates $(0, a)$] to another point B



[coordinates $(a, 0)$] along the straight path AB is

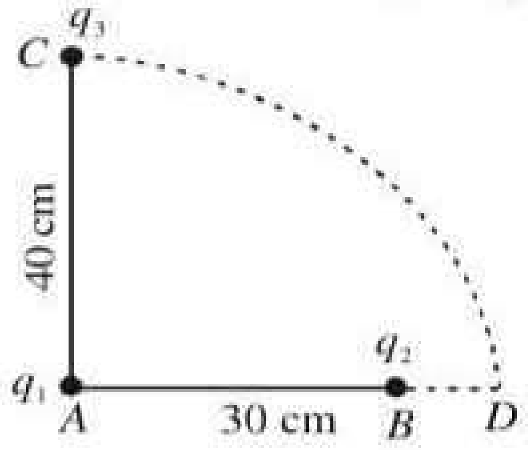
(a) zero

(b) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\cdot\sqrt{2}\,a$

(c) $\left(\frac{-qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\cdot\sqrt{2}\,a$ (d) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\cdot\frac{a}{\sqrt{2}}$

(2005)

47. Two charges q_1 and q_2 are placed 30 cm apart, as shown in the figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D.



The change in the potential energy of the system is $\frac{q_3}{4\pi\varepsilon_0}k$, where k is

(a) $8q_1$ (b) $6q_1$

(c) $8q_2$ (d) $6q_2$. *(2005)*

48. A bullet of mass 2 g is having a charge of 2 μC. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s ?

(a) 5 kV (b) 50 kV

(c) 5 V (d) 50 V *(2004)*

49. An electric dipole has the magnitude of its charge as q and its dipole moment is p. It is placed in a uniform electric field E. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively

(a) $2q\cdot E$ and minimum

(b) $q\cdot E$ and $p\cdot E$

(c) zero and minimum

(d) $q\cdot E$ and maximum *(2004)*

50. Three capacitors each of capacity 4 μF are to be connected in such a way that the effective capacitance is 6 μF. This can be done by

(a) connecting all of them in series

(b) connecting them in parallel

(c) connecting two in series and one in parallel

(d) connecting two in parallel and one in series

(2003)

51. A charge q is located at the centre of a cube. The electric flux through any face is

(a) $\frac{2\pi q}{6(4\pi\varepsilon_0)}$ (b) $\frac{4\pi q}{6(4\pi\varepsilon_0)}$

(c) $\frac{\pi q}{6(4\pi\varepsilon_0)}$ (d) $\frac{q}{6(4\pi\varepsilon_0)}$ *(2003)*

52. Identical charges $(-q)$ are placed at each corners of cube of side b then electrostatic potential energy of charge $(+q)$ which is placed at centre of cube will be

(a) $\frac{-4\sqrt{2}\,q^2}{\pi\varepsilon_0 b}$ (b) $\frac{-8\sqrt{2}\,q^2}{\pi\varepsilon_0 b}$

(c) $\frac{-4\,q^2}{\sqrt{3}\,\pi\varepsilon_0 b}$ (d) $\frac{8\sqrt{2}\,q^2}{4\,\pi\varepsilon_0 b}$ *(2002)*

53. A capacitor of capacity C_1 charged upto V volt and then connected to an uncharged capacitor of capacity C_2. The final potential difference across each will be

(a) $\frac{C_2V}{C_1+C_2}$ (b) $\frac{C_1V}{C_1+C_2}$

(c) $\left(1+\frac{C_2}{C_1}\right)$ (d) $\left(1-\frac{C_2}{C_1}\right)V$.

(2002)

54. Some charge is being given to a conductor. Then its potential is

(a) maximum at surface

(b) maximum at centre

(c) remain same throughout the conductor

(d) maximum somewhere between surface and centre. *(2002)*

55. A dipole of dipole moment $\vec{p}$ is placed in uniform electric field $\vec{E}$ then torque acting on it is given by

(a) $\vec{\tau}=\vec{p}\cdot\vec{E}$ (b) $\vec{\tau}=\vec{p}\times\vec{E}$

(c) $\vec{\tau}=\vec{p}+\vec{E}$ (d) $\vec{\tau}=\vec{p}-\vec{E}$. *(2001)*

56. Energy per unit volume for a capacitor having area A and separation d kept at potential difference V is given by

(a) $\frac{1}{2}\varepsilon_0\frac{V^2}{d^2}$ (b) $\frac{1}{2\varepsilon_0}\frac{V^2}{d^2}$

(c) $\frac{1}{2}CV^2$ (d) $\frac{Q^2}{2C}$. *(2001)*

57. A charge Q μC is placed at the centre of a cube, the flux coming out from each face will be

(a) $\frac{Q}{6\varepsilon_0}\times10^{-6}$ (b) $\frac{Q}{6\varepsilon_0}\times10^{-3}$

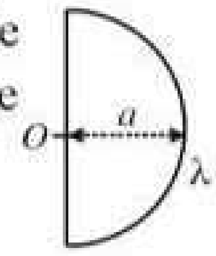
(c) $\frac{Q}{24\varepsilon_0}$ (d) $\frac{Q}{8\varepsilon_0}$ *(2001)*

58. A charge Q is situated at the corner of a cube, the electric flux passed through all the six faces of the cube is

(a) $\frac{Q}{6\varepsilon_0}$ (b) $\frac{Q}{8\varepsilon_0}$ (c) $\frac{Q}{\varepsilon_0}$ (d) $\frac{Q}{2\varepsilon_0}$

(2000)

59. Electric field at centre O of semicircle of radius a having linear charge density λ given as



(a) $\frac{2\lambda}{\varepsilon_0 a}$ (b) $\frac{\lambda\pi}{\varepsilon_0 a}$

(c) $\frac{\lambda}{2\pi\varepsilon_0 a}$ (d) $\frac{\lambda}{\pi\varepsilon_0 a}$ *(2000)*

60. A capacitor is charged with a battery and energy stored is U. After disconnecting battery another capacitor of same capacity is connected in parallel to the first capacitor. Then energy stored in each capacitor is

(a) $U/2$ (b) $U/4$

(c) $4U$ (d) $2U$. *(2000)*

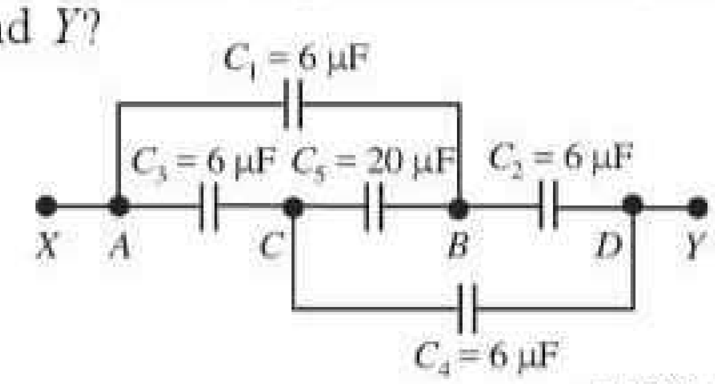
61. What is the effective capacitance between points X and Y?

(a) 12 μF

(b) 18 μF

(c) 24 μF

(d) 6 μF



(1999)

62. When air is replaced by a dielectric medium of constant K, the maximum force of attraction between two charges separated by a distance

(a) increases K times

(b) remains unchanged

(c) decreases K times

(d) increases K^{-1} times. *(1999)*

63. In bringing an electron towards another electron, the electrostatic potential energy of the system

(a) becomes zero (b) increases

(c) decreases (d) remains same *(1999)*

64. A parallel plate condenser with oil between the plates (dielectric constant of oil $K = 2$) has a capacitance C. If the oil is removed, then capacitance of the capacitor becomes

(a) $\frac{C}{\sqrt{2}}$ (b) $2C$ (c) $\sqrt{2}C$ (d) $\frac{C}{2}$ *(1999)*

65. A hollow insulated conduction sphere is given a positive charge of 10 μC. What will be the electric field at the centre of the sphere if its radius is 2 metres?

(a) 20 μC m^{-2} (b) 5 μC m^{-2}

(c) zero (d) 8 μC m^{-2} *(1998)*

66. A particle of mass m and charge q is placed at rest in a uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is

(a) qEy (b) qE^2y (c) qEy^2 (d) q^2Ey *(1998)*

67. A point Q lies on the perpendicular bisector of an electrical dipole of dipole moment p. If the distance of Q from the dipole is r (much larger than the size of the dipole), then the electric field at Q is proportional to

(a) p^2 and r^{-3} (b) p and r^{-2}

(c) p^{-1} and r^{-2} (d) p and r^{-3} *(1998)*

68. A point charge $+q$ is placed at the centre of a cube of side l. The electric flux emerging from the cube is

(a) $\frac{6ql^2}{\varepsilon_0}$ (b) $\frac{q}{6l^2\varepsilon_0}$ (c) zero (d) $\frac{q}{\varepsilon_0}$. *(1996)*

69. The energy stored in a capacitor of capacity C and potential V is given by

(a) $\frac{CV}{2}$ (b) $\frac{C^2V^2}{2}$ (c) $\frac{C^2V}{2}$ (d) $\frac{CV^2}{2}$ *(1996)*

70. Two metallic spheres of radii 1 cm and 2 cm are given charges 10^{-2} C and 5×10^{-2} C respectively. If they are connected by a conducting wire, the final charge on the smaller sphere is

(a) 3×10^{-2} C (b) 4×10^{-2} C

(c) 1×10^{-2} C (d) 2×10^{-2} C *(1995)*

71. There is an electric field E in x-direction. If the work done on moving a charge of 0.2 C through a distance of 2 m along a line making an angle 60° with x-axis is 4 J, then what is the value of E?

(a) 5 N/C (b) 20 N/C

(c) $\sqrt{3}$ N/C (d) 4 N/C. *(1995)*

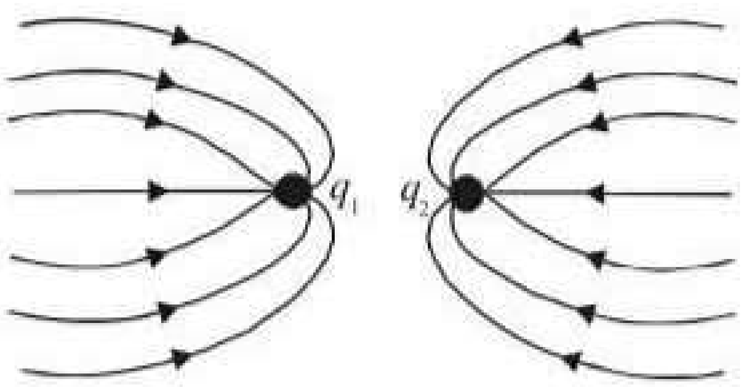
72. A charge q is placed at the centre of the line joining two exactly equal positive charges Q. The system of three charges will be in equilibrium, if q is equal to

(a) $-Q$ (b) $Q/2$ (c) $-Q/4$ (d) $+Q$ *(1995)*

73. An electric dipole of moment p is placed in the position of stable equilibrium in uniform electric field of intensity E. This is rotated through an angle θ from the initial position. The potential energy of the electric dipole in the final position is

(a) $-pE \cos \theta$ (b) $pE (1 - \cos \theta)$
(c) $pE \cos \theta$ (d) $pE \sin \theta$. *(1994)*

74. The given figure gives electric lines of force due to two charges q_1 and q_2. What are the signs of the two charges?



(a) q_1 is positive but q_2 is negative
(b) q_1 is negative but q_2 is positive
(c) both are negative
(d) both are positive. *(1994)*

75. Charge q_2 is at the centre of a circular path with radius r. Work done in carrying charge q_1, once around this equipotential path, would be

(a) $\frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r^2}$ (b) $\frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r}$
(c) zero (d) infinite. *(1994)*

76. A hollow metallic sphere of radius 10 cm is charged such that potential of its surface is 80 V. The potential at the centre of the sphere would be

(a) 80 V (b) 800 V
(c) zero (d) 8 V. *(1994)*

77. Point charges $+4q$, $-q$ and $+4q$ are kept on the X-axis at point $x = 0$, $x = a$ and $x = 2a$ respectively.

(a) only $-q$ is in stable equilibrium
(b) all the charges are in stable equilbrium
(c) all of the charges are in unstable equilibrium
(d) none of the charges is in equilibrium *(1988)*

Answer Key

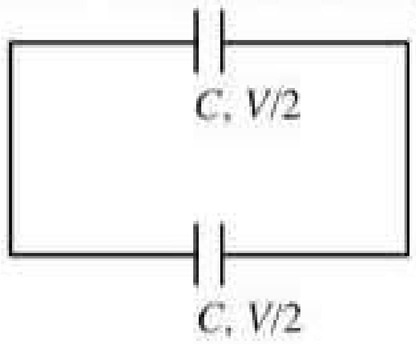
1.	(a)	**2.**	(b)	**3.**	(a)	**4.**	(b)	**5.**	(c)	**6.**	(b)	**7.**	(a)	**8.**	(d)	**9.**	(d)	**10.**	(a)
11.	(b)	**12.**	(c)	**13.**	(b)	**14.**	(d)	**15.**	(d)	**16.**	(d)	**17.**	(b)	**18.**	(a)	**19.**	(a)	**20.**	(a)
21.	(b)	**22.**	(c)	**23.**	(b)	**24.**	(c)	**25.**	(c)	**26.**	(d)	**27.**	(a)	**28.**	(c)	**29.**	(d)	**30.**	(d)
31.	(c)	**32.**	(a)	**33.**	(d)	**34.**	(b)	**35.**	(d)	**36.**	(d)	**37.**	(c)	**38.**	(d)	**39.**	(c)	**40.**	(a)
41.	(b)	**42.**	(a)	**43.**	(a)	**44.**	(d)	**45.**	(b)	**46.**	(a)	**47.**	(c)	**48.**	(b)	**49.**	(c)	**50.**	(c)
51.	(b)	**52.**	(c)	**53.**	(b)	**54.**	(c)	**55.**	(b)	**56.**	(a)	**57.**	(a)	**58.**	(b)	**59.**	(c)	**60.**	(b)
61.	(d)	**62.**	(c)	**63.**	(b)	**64.**	(d)	**65.**	(c)	**66.**	(a)	**67.**	(d)	**68.**	(d)	**69.**	(d)	**70.**	(d)
71.	(b)	**72.**	(c)	**73.**	(b)	**74.**	(c)	**75.**	(c)	**76.**	(a)	**77.**	(c)						

EXPLANATIONS

1. **(a) :** When the capacitor is charged by a battery of potential V, then energy stored in the capacitor,

$$U_i = \frac{1}{2}CV^2 \quad \text{...(i)}$$

When the battery is removed and another identical uncharged capacitor is connected in parallel



Common potential, $V' = \frac{CV}{C+C} = \frac{V}{2}$

$\therefore$ Then the energy stored in the capacitor,

$$U_f = \frac{1}{2}(2C)\left(\frac{V}{2}\right)^2 = \frac{1}{4}CV^2 \quad \text{...(ii)}$$

$\therefore$ From eqns. (i) and (ii)

$$U_f = \frac{U_i}{2}$$

that means the total electrostatic energy of resulting system will decreases by a factor of 2.

2. **(b) :** A hydrogen atom consists of an electron and a proton.

$\therefore$ Charge on one hydrogen atom

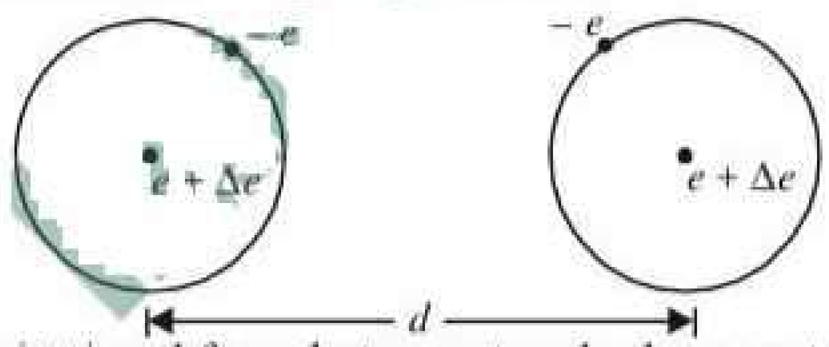
$= q_e + q_p = -e + (e + \Delta e) = \Delta e$

Since a hydrogen atom carry a net charge Δe,

$\therefore$ Electrostatic force,

$$F_e = \frac{1}{4\pi\varepsilon_o}\frac{(\Delta e)^2}{d^2} \quad \text{...(i)}$$

will act between two hydrogen atoms.



The gravitational force between two hydrogen atoms is given as

$$F_g = \frac{Gm_h m_h}{d^2} \quad \text{...(ii)}$$

Since, the net force on the system is zero, $F_e = F_g$

Using eqns. (i) and (ii), we get

$$\frac{(\Delta e)^2}{4\pi\varepsilon_o d^2} = \frac{Gm_h^2}{d^2}$$

$(\Delta e)^2 = 4\pi\varepsilon_o G m_h^2$

$= 6.67 \times 10^{-11} \times (1.67 \times 10^{-27})^2/(9 \times 10^9)$

$\Delta e \approx 10^{-37}$ C

3. **(a) :** Work done is given as $W = q\Delta V$

In all the four cases the potential difference from A to B is same.

$\therefore$ In all the four cases the work done is same.

4. **(b) :** Here, $\theta = 30°$, $E = 2 \times 10^5$ N C^{-1}

$\tau = 4$ N m, $l = 2$ cm $= 0.02$ m, $q = ?$

$\tau = pE\sin\theta = (ql)E\sin\theta$

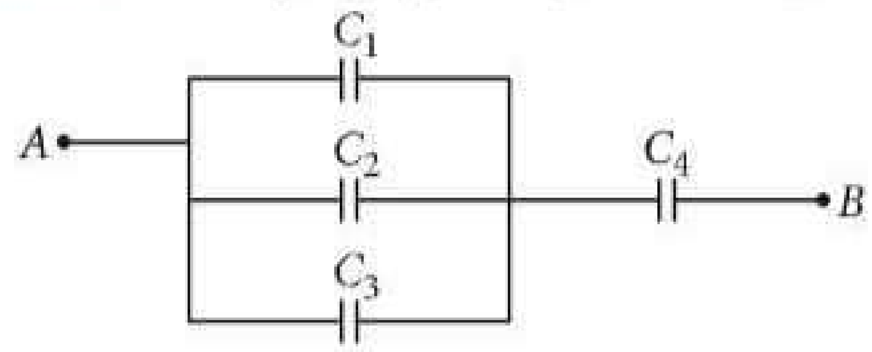
$$\therefore \quad q = \frac{\tau}{El\sin\theta} = \frac{4}{2\times10^5\times0.02\times\frac{1}{2}}$$

$$= \frac{4}{2\times10^3} = 2\times10^{-3}\,\text{C} = 2\,\text{mC}$$

5. **(c) :** Here, $C_1 = \frac{2\varepsilon_0 k_1 A}{3d}$, $C_2 = \frac{2\varepsilon_0 k_2 A}{3d}$

$C_3 = \frac{2\varepsilon_0 k_3 A}{3d}$, $C_4 = \frac{2\varepsilon_0 k_4 A}{d}$

Given system of C_1, C_2, C_3 and C_4 can be simplified as



$$\therefore \quad \frac{1}{C_{AB}} = \frac{1}{C_1 + C_2 + C_3} + \frac{1}{C_4}$$

Suppose, $C_{AB} = \frac{k\varepsilon_0 A}{d}$

$$\frac{1}{k\left(\frac{\varepsilon_0 A}{d}\right)} = \frac{1}{\frac{2}{3}\frac{\varepsilon_0 A}{d}(k_1 + k_2 + k_3)} + \frac{1}{\frac{2\varepsilon_0 A}{d}k_4}$$

$$\Rightarrow \quad \frac{1}{k} = \frac{3}{2(k_1 + k_2 + k_3)} + \frac{1}{2k_4}$$

$$\therefore \quad \frac{2}{k} = \frac{3}{k_1 + k_2 + k_3} + \frac{1}{k_4}$$

6. **(b) :** Initially, the energy stored in 2 μF capacitor is

$$U_i = \frac{1}{2}CV^2 = \frac{1}{2}(2 \times 10^{-6})V^2 = V^2 \times 10^{-6}\text{ J}$$

Initially, the charge stored in 2 μF capacitor is $Q_i = CV = (2 \times 10^{-6})V = 2V \times 10^{-6}$ coulomb. When switch S is turned to position 2, the charge flows and both the capacitors share charges till a common potential V_c is reached.

$$V_C = \frac{\text{total charge}}{\text{total capacitance}} = \frac{2V\times10^{-6}}{(2+8)\times10^{-6}} = \frac{V}{5}\text{ volt}$$

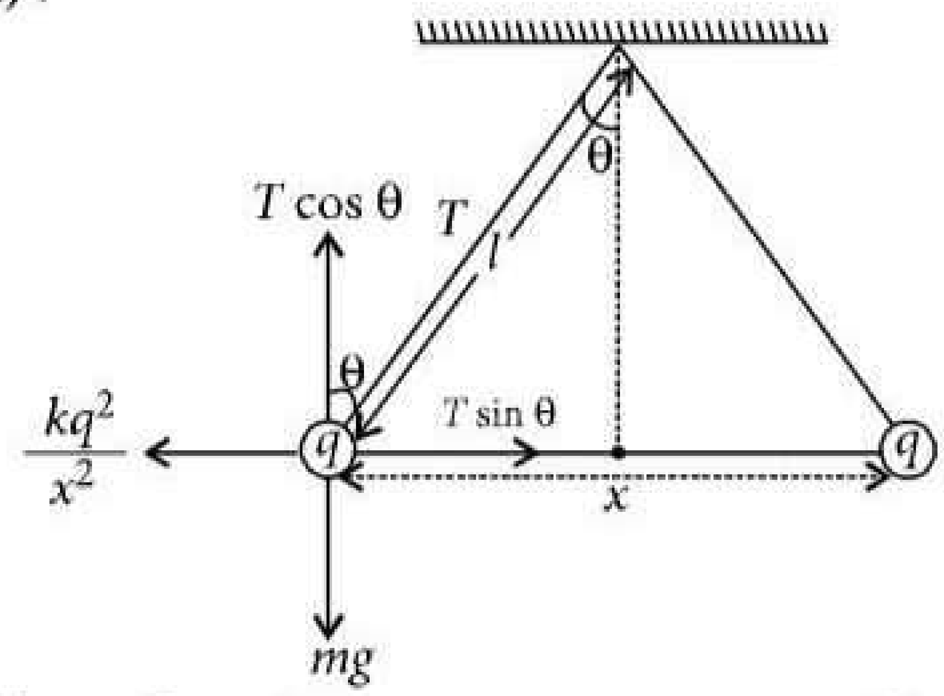
Finally, the energy stored in both the capacitors

$$U_f = \frac{1}{2}[(2+8)\times 10^{-6}]\left(\frac{V}{5}\right)^2 = \frac{V^2}{5}\times 10^{-6}\ \text{J}$$

% loss of energy, $\Delta U = \dfrac{U_i - U_f}{U_i}\times 100\%$

$$= \frac{(V^2 - V^2/5)\times 10^{-6}}{V^2 \times 10^{-6}}\times 100\% = 80\%$$

7. **(a) :**



From figure, $T\cos\theta = mg$ ...(i)

$$T\sin\theta = \frac{kq^2}{x^2} \quad \text{...(ii)}$$

From eqns. (i) and (ii), $\tan\theta = \dfrac{kq^2}{x^2 mg}$

Since θ is small, $\therefore \tan\theta \approx \sin\theta = \dfrac{x}{2l}$

$$\therefore \frac{x}{2l} = \frac{kq^2}{x^2 mg} \Rightarrow q^2 = x^3\frac{mg}{2lk} \text{ or } q \propto x^{3/2}$$

$$\Rightarrow \frac{dq}{dt} \propto \frac{3}{2}\sqrt{x}\frac{dx}{dt} = \frac{3}{2}\sqrt{x}v$$

Since, $\dfrac{dq}{dt}$ = constant

$$\therefore v \propto \frac{1}{\sqrt{x}}$$

8. **(d) :** Force of attraction between the plates of the parallel plate air capacitor is

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

where Q is the charge on the capacitor, ε_0 is the permittivity of free space and A is the area of each plate.

But $Q = CV$

and $C = \dfrac{\varepsilon_0 A}{d}$ or $\varepsilon_0 A = Cd$

$$\therefore F = \frac{C^2V^2}{2Cd} = \frac{CV^2}{2d}$$

9. **(d) :** The electric field $\vec{E}$ and potential V in a region are related as

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

Here, $V(x, y, z) = 6xy - y + 2yz$

$$\therefore \vec{E} = -\left[\frac{\partial}{\partial x}(6xy - y + 2yz)\hat{i} + \frac{\partial}{\partial y}(6xy - y + 2yz)\hat{j} + \frac{\partial}{\partial z}(6xy - y + 2yz)\hat{k}\right]$$

$$= -[(6y)\hat{i} + (6x - 1 + 2z)\hat{k} + (2y)\hat{k}]$$

At point (1, 1, 0),

$$\vec{E} = -[(6(1))\hat{i} + (6(1) - 1 + 2(0))\hat{j} + (2(1))\hat{k}]$$

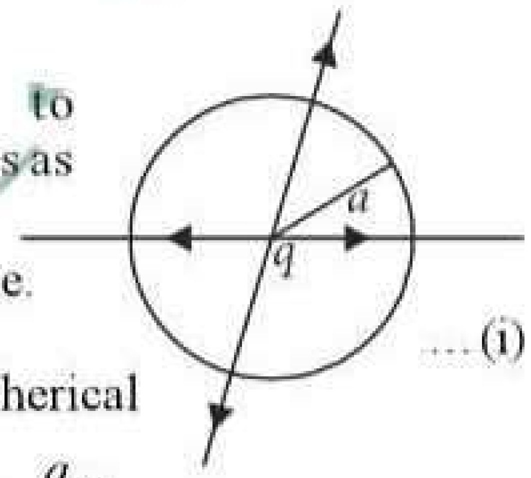
$$= -(6\hat{i} + 5\hat{j} + 2\hat{k})$$

10. **(a)** : According to question, electric field varies as

$E = Ar$

Here r is the radial distance.

At $r = a$, $E = Aa$ ...(i)

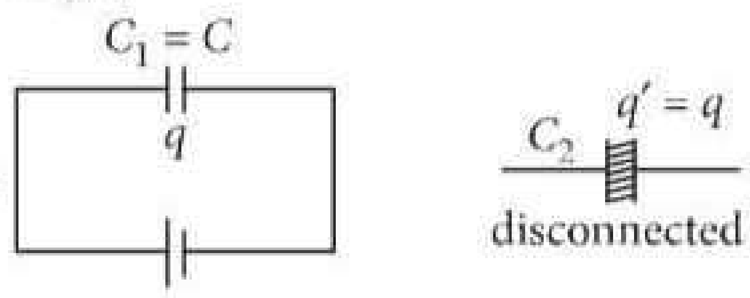


Net flux emitted from a spherical surface of radius a is $\phi_{\text{net}} = \dfrac{q_{en}}{\varepsilon_0}$

$$\Rightarrow (Aa)\times(4\pi a^2) = \frac{q}{\varepsilon_0} \quad \text{[Using equation (i)]}$$

$\therefore q = 4\pi\varepsilon_0 A a^3$

11. **(b) :**



$q = CV \Rightarrow V = q/C$

Due to dielectric insertion, new capacitance

$C_2 = CK$

Initial energy stored in capacitor, $U_1 = \dfrac{q^2}{2C}$

Final energy stored in capacitor, $U_2 = \dfrac{q^2}{2KC}$

Change in energy stored, $\Delta U = U_2 - U_1$

$$\Delta U = \frac{q^2}{2C}\left(\frac{1}{K} - 1\right) = \frac{1}{2}CV^2\left(\frac{1}{K} - 1\right)$$

New potential difference between plates

$$V' = \frac{q}{CK} = \frac{V}{K}$$

12. **(c)**

13. **(b) :** For the conducting sphere,

Potential at the centre = Potential on the sphere

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

Electric field at the centre = 0

14. (d) : Here, $V(x, y, z) = 6x - 8xy - 8y + 6yz$
The x, y and z components of electric field are

$$E_x = -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}(6x - 8xy - 8y + 6yz)$$
$$= -(6 - 8y) = -6 + 8y$$
$$E_y = -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial y}(6x - 8xy - 8y + 6yz)$$
$$= -(-8x - 8 + 6z) = 8x + 8 - 6z$$
$$E_z = -\frac{\partial V}{\partial z} = -\frac{\partial}{\partial z}(6x - 8xy - 8y + 6yz) = -6y$$
$$\vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k}$$
$$= (-6 + 8y)\hat{i} + (8x + 8 - 6z)\hat{j} - 6y\hat{k}$$

At point (1, 1, 1)

$$\vec{E} = (-6 + 8)\hat{i} + (8 + 8 - 6)\hat{j} - 6\hat{k} = 2\hat{i} + 10\hat{j} - 6\hat{k}$$

The magnitude of electric field $\vec{E}$ is

$$\vec{E} = \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{(2)^2 + (10)^2 + (-6)^2}$$
$$= \sqrt{140} = 2\sqrt{35}\ \text{N C}^{-1}$$

Electric force experienced by the charge

$$F = qE = 2\ \text{C} \times 2\sqrt{35}\ \text{N C}^{-1} = 4\sqrt{35}\ \text{N}$$

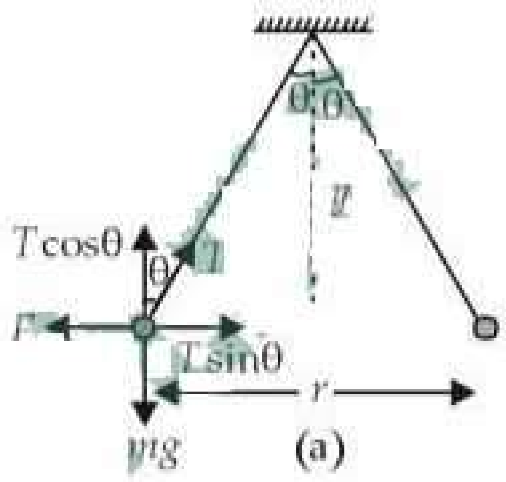
15. (d) : In the direction of electric field, electric potential decreases.

$\therefore\ V_B > V_C > V_A$

16. (d) : Let m be mass of each ball and q be charge on each ball.

Force of repulsion,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$$



In equilibrium

$$T\cos\theta = mg \qquad \text{...(i)}$$
$$T\sin\theta = F \qquad \text{...(ii)}$$

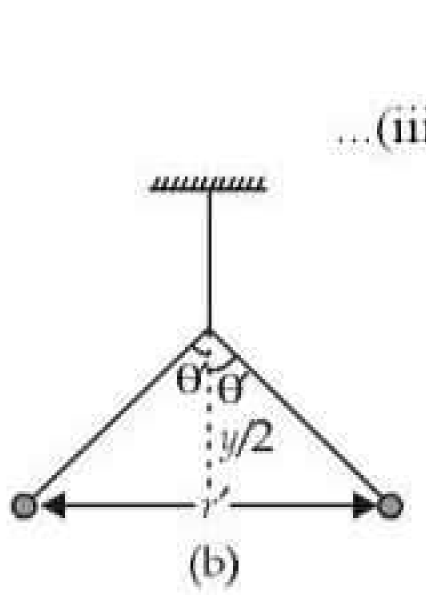
Divide (ii) by (i), we get, $\tan\theta = \dfrac{F}{mg} = \dfrac{\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}{mg}$

From figure (a),

$$\frac{r/2}{y} = \frac{\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}{mg} \qquad \text{...(iii)}$$

$$\tan\theta' = \frac{\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r'^2}}{mg}$$

From figure (b)



$$\frac{r'/2}{y/2} = \frac{\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r'^2}}{mg} \qquad \text{...(iv)}$$

Divide (iv) by (iii), we get

$$\frac{2r'}{r} = \frac{r^2}{r'^2}$$
$$r'^3 = \frac{r^3}{2} \Rightarrow r' = \frac{r}{\sqrt[3]{2}}$$

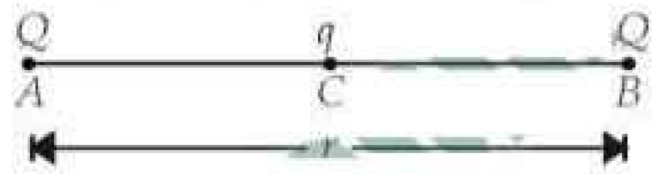
17. (b) : Potential energy of dipole,

$U = -pE(\cos\theta_2 - \cos\theta_1)$

Here, $\theta_1 = 0°$, $\theta_2 = 90°$

$\therefore\ U = -pE(\cos 90° - \cos 0°) = -pE(0 - 1) = pE$

18. (a) : The situation is as shown in the figure.



Let two equal charges Q each placed at points A and B at a distance r apart. C is the centre of AB where charge q is placed.

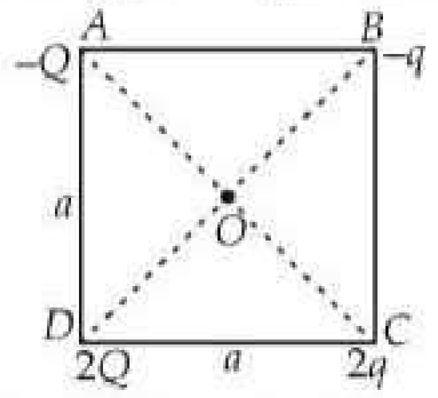
For equilibrium, net force on charge $Q = 0$

$$\therefore\ \frac{1}{4\pi\varepsilon_0}\frac{QQ}{r^2} + \frac{1}{4\pi\varepsilon_0}\frac{Qq}{(r/2)^2} = 0$$
$$\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{r^2} = -\frac{1}{4\pi\varepsilon_0}\frac{4Qq}{r^2} \text{ or } Q = -4q \text{ or } q = -\frac{Q}{4}$$

19. (a) : Torque, $\tau = pE\sin\theta$

Potential energy, $U = -pE\cos\theta$

20. (a) :



Let a be the side length of the square $ABCD$.

$$\therefore\ AC = BD = \sqrt{a^2 + a^2} = a\sqrt{2}$$
$$OA = OB = OC = OD = \frac{a\sqrt{2}}{2} = \frac{a}{\sqrt{2}}$$

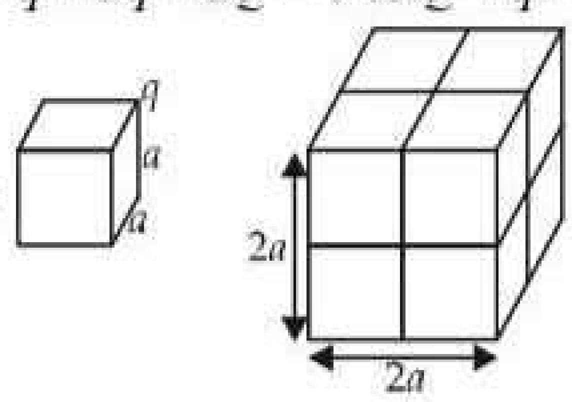
Potential is a scalar quantity.

Potential at the centre O due to given charge configuration is

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{(-Q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{(-q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{(2q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{2Q}{\left(\frac{a}{\sqrt{2}}\right)}\right] = 0$$

$\Rightarrow\ -Q - q + 2q + 2Q = 0$ or $Q + q = 0$ or $Q = -q$

21. (b) :



Eight identical cubes are required so that the given charge q appears at the centre of the bigger cube.

Thus, the electric flux passing through the given cube is

$$\phi = \frac{1}{8}\left(\frac{q}{\varepsilon_0}\right) = \frac{q}{8\varepsilon_0}$$

22. (c) : Capacitance of a parallel plate capacitor is

$$C = \frac{\varepsilon_0 A}{d} \quad \text{...(i)}$$

Potential difference between the plates is

$$V = Ed \quad \text{...(ii)}$$

The energy stored in the capacitor is

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2 \quad \text{(Using (i) and (ii))}$$

$$= \frac{1}{2}\varepsilon_0 E^2 Ad$$

23. (b) : When the given metallic spheres are connected by a conducting wire, charge will flow till both the spheres acquire a common potential which is given by

Common potential,

$$V = \frac{q_1 + q_2}{C_1 + C_2} = \frac{-1\times10^{-2} + 5\times10^{-2}}{4\pi\varepsilon_0 R_1 + 4\pi\varepsilon_0 R_2}$$

$$= \frac{4\times10^{-2}}{4\pi\varepsilon_0(1\times10^{-2} + 3\times10^{-2})}$$

$$= \frac{4\times10^{-2}}{4\pi\varepsilon_0 \times 4\times10^{-2}} \quad \text{...(i)}$$

$\therefore$ Final charge on the bigger sphere is

$$= 4\pi\varepsilon_0 \times 3\times10^{-2} \times \frac{4\times10^{-2}}{4\pi\varepsilon_0 \times 4\times10^{-2}} \quad \text{(Using (i))}$$

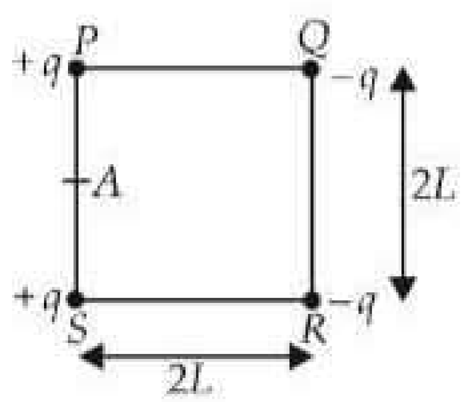
$$= 3\times10^{-2}\ \text{C}$$

24. (c) : According to Gauss's law

$$\phi_E = \frac{Q_{enclosed}}{\varepsilon_0}$$

If the radius of the Gaussian surface is doubled, the outward electric flux will remain the same. This is because electric flux depends only on the charge enclosed by the surface.

25. (c) : A is the midpoint of PS



$\therefore \quad PA = AS = L$

$$AR = AQ = \sqrt{(SR)^2 + (AS)^2}$$

$$= \sqrt{(2L)^2 + (L)^2} = L\sqrt{5}$$

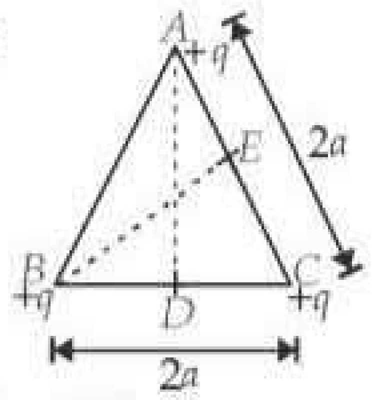
Electric potential at point A due to the given charge configuration is

$$V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{PA} + \frac{q}{AS} + \frac{(-q)}{AQ} + \frac{(-q)}{AR}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L} + \frac{q}{L} - \frac{q}{L\sqrt{5}} - \frac{q}{L\sqrt{5}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{L} - \frac{2q}{L\sqrt{5}}\right] = \frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left[1 - \frac{1}{\sqrt{5}}\right]$$

26. (d) :



Here, $AC = BC = 2a$

D and E are the midpoints of BC and AC.

$\therefore \quad AE = EC = a$ and $BD = DC = a$

In ΔADC, $(AD)^2 = (AC)^2 - (DC)^2$

$$= (2a)^2 - (a)^2 = 4a^2 - a^2 = 3a^2$$

$$AD = a\sqrt{3}$$

Similarly, potential at point D due to the given charge configuration is

$$V_D = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{BD} + \frac{q}{DC} + \frac{q}{AD}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} + \frac{1}{a} + \frac{1}{\sqrt{3}a}\right] = \frac{q}{4\pi\varepsilon_0 a}\left[2 + \frac{1}{\sqrt{3}}\right] \quad \text{...(i)}$$

Potential at point E due to the given charge configuration is

$$V_E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AE} + \frac{q}{EC} + \frac{q}{BE}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} + \frac{1}{a} + \frac{1}{a\sqrt{3}}\right] = \frac{q}{4\pi\varepsilon_0 a}\left[2 + \frac{1}{\sqrt{3}}\right] \quad \text{...(ii)}$$

From the (i) and (ii), it is clear that

$$V_D = V_E$$

The work done in taking a charge Q from D to E is

$$W = Q(V_E - V_D) = 0 \qquad (\because V_D = V_E)$$

27. (a) : $\vec{E} = -\vec{\nabla}V$

where $\vec{\nabla} = \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$

$$\therefore \quad \vec{E} = -\left[\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right]$$

Here, $V = 4x^2 \quad \therefore \quad \vec{E} = -8x\hat{i}$

The electric field at point (1, 0, 2) is

$$\vec{E}_{(1,0,2)} = -8\hat{i}\ \text{V m}^{-1}$$

So electric field is along the negative X-axis.

28. (c) : According to Coulomb's law, the force of repulsion between the two positive ions each of charge q, separated by a distance d is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(q)(q)}{d^2}$$

$$F = \frac{q^2}{4\pi\varepsilon_0 d^2}$$

$$q^2 = 4\pi\varepsilon_0 F d^2$$

$$q = \sqrt{4\pi\varepsilon_0 F d^2} \quad \text{...(i)}$$

Since, $q = ne$

where,

n = number of electrons missing from each ion

e = magnitude of charge on electron

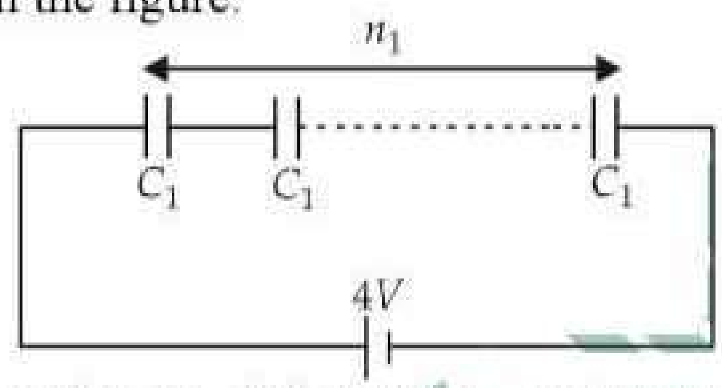
$$\therefore \quad n = \frac{q}{e}$$

$$n = \frac{\sqrt{4\pi\varepsilon_0 F d^2}}{e} \quad \text{(Using (i))}$$

$$= \sqrt{\frac{4\pi\varepsilon_0 F d^2}{e^2}}$$

29. (d)

30. (d) : A series combination of n_1 capacitors each of capacitance C_1 are connected to $4V$ source as shown in the figure.



Total capacitance of the series combination of the capacitors is

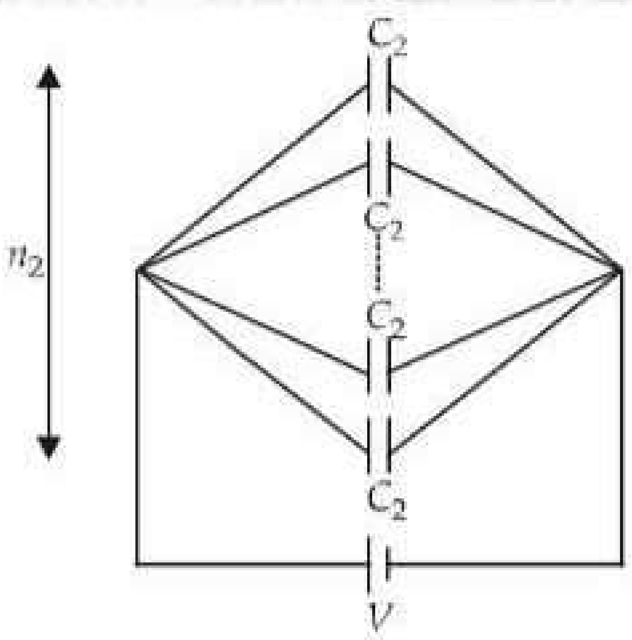
$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_1} + \frac{1}{C_1} + \text{.........upto } n_1 \text{terms} = \frac{n_1}{C_1}$$

$$\text{or } C_s = \frac{C_1}{n_1} \quad \text{...(i)}$$

Total energy stored in a series combination of the capacitors is

$$U_s = \frac{1}{2}C_s(4V)^2 = \frac{1}{2}\left(\frac{C_1}{n_1}\right)(4V)^2 \quad \text{(Using (i))} \quad \text{...(ii)}$$

A parallel combination of n_2 capacitors each of capacitance C_2 are connected to V source as shown in the figure.



Total capacitance of the parallel combination of capacitors is

$$C_p = C_2 + C_2 + \text{..........+ upto } n_2 \text{ terms} = n_2C_2$$

$$\text{or } C_p = n_2C_2 \quad \text{...(iii)}$$

Total energy stored in a parallel combination of capacitors is

$$U_p = \frac{1}{2}C_pV^2$$

$$= \frac{1}{2}(n_2C_2)(V)^2 \quad \text{(Using (iii)) (iv)}$$

According to the given problem,

$$U_s = U_p$$

Substituting the values of U_s and U_p from equations (ii) and (iv), we get

$$\frac{1}{2}\frac{C_1}{n_1}(4V)^2 = \frac{1}{2}(n_2C_2)(V)^2$$

$$\text{or } \frac{C_1 16}{n_1} = n_2C_2 \text{ or } C_2 = \frac{16C_1}{n_1n_2}$$

31. (c) : Electric field between two parallel plates placed in vacuum is given by

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

In a medium of dielectric constant K, $E' = \dfrac{\sigma}{\varepsilon_0 K}$

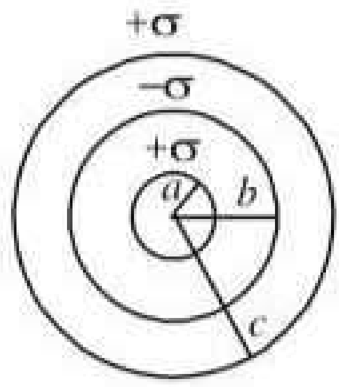
For kerosene oil $K > 1 \Rightarrow E' < E$

32. (a) : Electric field inside a charged conductor is always zero.

33. (d) : $V_A = \dfrac{1}{4\pi\varepsilon_0}\left\{\dfrac{q_A}{a} + \dfrac{q_B}{b} + \dfrac{q_C}{c}\right\}$

$$= \frac{4\pi}{4\pi\varepsilon_0}\left\{\frac{a^2\sigma}{a} - \frac{b^2\sigma}{b} + \frac{c^2\sigma}{c}\right\}$$

$$V_A = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{a} - \frac{b^2\sigma}{b} + \frac{c^2\sigma}{c}\right\}$$



$$V_B = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{b} - \frac{b^2\sigma}{b} + \frac{c^2\sigma}{c}\right\}$$

$$V_C = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{c} - \frac{b^2\sigma}{c} + \frac{c^2\sigma}{c}\right\}$$

Given $c = a + b$.

If $a = a$, $b = 2a$ and $c = 3a$ for example, as $c > b > a$,

$$V_A = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{a} - \frac{4a^2\sigma}{2a} + \frac{c^2\sigma}{c}\right\}$$

$$V_B = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{2a} - \frac{4a^2\sigma}{2a} + \frac{c^2\sigma}{c}\right\}$$

$$V_C = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{3a} - \frac{4a^2\sigma}{3a} + \frac{c^2\sigma}{c}\right\}$$

It can seen by taking out common factors that

$V_A = V_C > V_B$ i.e., $V_A = V_C \neq V_B$

34. (b) : Three capacitors of capacitance C each are in series.

$\therefore$ Total capacitance, $C_{\text{total}} = \dfrac{C}{3}$

The charge is the same, Q, when capacitors are in series.

$$V_{\text{total}} = \frac{Q}{C} = \frac{Q}{C/3} = 3V.$$

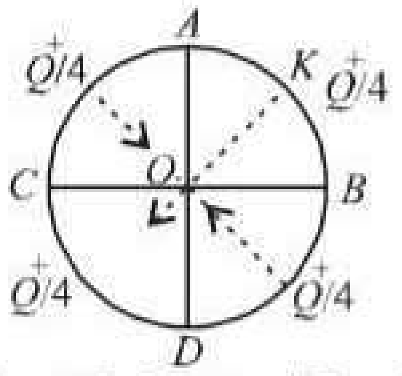
35. (d) : The electric potential at a point,

$V = -x^2y - xz^3 + 4.$

The field $\vec{E} = -\vec{\nabla}V = -\left(\dfrac{\partial V}{\partial x}\hat{i} + \dfrac{\partial V}{\partial y}\hat{j} + \dfrac{\partial V}{\partial z}\hat{k}\right)$

$\therefore\ \vec{E} = \hat{i}(2xy + z^3) + \hat{j}x^2 + \hat{k}(3xz^2)$

36. (d) :



The fields at O due to AC and BD cancel each other. The field due to CD is acting in the direction OK and equal in magnitude to E due to AKB.

37. (c) : $V = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{Q}{r} = Q.10^{11}$ volts

$\therefore\ \dfrac{1}{r} = 4\pi\varepsilon_0\,10^{11}$

$$E = \frac{\text{potential}}{r} = Q\cdot 10^{11} \times 4\pi\varepsilon_0\cdot 10^{11}$$

$\Rightarrow\ E = 4\pi\varepsilon_0\cdot Q\cdot 10^{22}$ volt/m

38. (d) : Let ϕ_A, ϕ_B and ϕ_C are the electric flux linked with A, B and C.

According to Gauss theorem,

$$\phi_A + \phi_B + \phi_C = \frac{q}{\varepsilon_0}$$

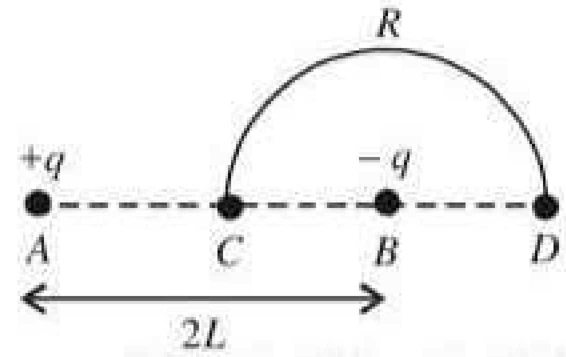
Since $\phi_A = \phi_C$,

$\therefore\ 2\phi_A + \phi_B = \dfrac{q}{\varepsilon_0}$ or $2\phi_A = \dfrac{q}{\varepsilon_0} - \phi_B$

or, $2\phi_A = \dfrac{q}{\varepsilon_0} - \phi$ (Given $\phi_B = \phi$).

$\therefore\ \phi_A = \dfrac{1}{2}\left(\dfrac{q}{\varepsilon_0} - \phi\right).$

39. (c) :



From figure, $AC = L$, $BC = L$, $BD = BC = L$

$AD = AB + BD = 2L + L = 3L$

Potential at C is given by

$$V_C = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AC} + \frac{(-q)}{BC}\right] = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L} - \frac{q}{L}\right] = 0$$

Potential at D is given by

$$V_D = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AD} + \frac{(-q)}{BD}\right] = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{3L} - \frac{q}{L}\right]$$

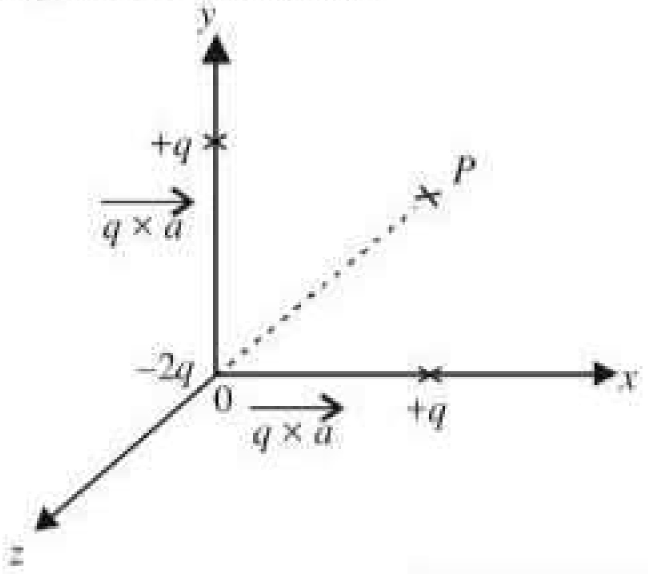
$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{L}\left[\frac{1}{3} - 1\right] = -\frac{q}{6\pi\varepsilon_0}.$$

Work done in moving charge $+Q$ along the semicircle CRD is given by

$$W = [V_D - V_C](+Q) = \left[\frac{-q}{6\pi\varepsilon_0} - 0\right](Q) = \frac{-qQ}{6\pi\varepsilon_0 L}$$

Comments : Potential at C is zero because the charges are equal and opposite and the distances are the same. Potential at D due to $-q$ is greater than that at A ($+q$), because D is closer to B. Therefore it is negative.

40. (a) : This consists of two dipoles, $-q$ and $+q$ with dipole moment along with the $+y$-direction and $-q$ and $+q$ along the x-direction.



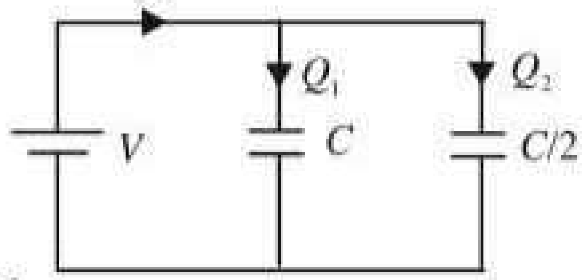
$\therefore$ The resultant moment $= \sqrt{q^2a^2 + q^2a^2} = \sqrt{2}qa.$

Along the direction 45° that is along OP where P is $(+a, +a, 0)$.

41. (b) : As the capacitors are connected in parallel, therefore potential difference across both the condensors remains the same.

$\therefore\ Q_1 = CV$;

$Q_2 = \dfrac{C}{2}V$



Also, $Q = Q_1 + Q_2$

$= CV + \dfrac{C}{2}V = \dfrac{3}{2}CV.$

Work done in charging fully both the condensors is given by

$$W = \frac{1}{2}QV = \frac{1}{2}\times\left(\frac{3}{2}CV\right)V = \frac{3}{4}CV^2.$$

42. **(a) :** Capacitance of a parallel plate capacitor

$$C = \frac{\varepsilon_0 A}{d} \quad \text{... (i)}$$

Also capacitance = $\frac{\text{potential difference}}{\text{charge}}$ ... (ii)

When battery is disconnected and the distance between the plates of the capacitor is increased then capacitance increases and charge remains constant.

Since capacitance = $\frac{\text{potential difference}}{\text{charge}}$

$\therefore$ Potential difference increases.

43. **(a) :** Work done in deflecting a dipole through an angle θ is given by

$$W = \int_0^\theta pE\sin\theta d\theta = pE(1-\cos\theta)$$

Since $\theta = 90°$

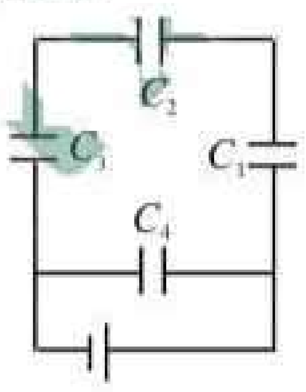
$\therefore$ $W = pE(1 - \cos 90°)$ or, $W = pE$.

44. **(d) :** Electric flux, $\phi_E = \int \vec{E}\cdot d\vec{S}$

$= \int EdS\cos\theta = \int EdS\cos 90° = 0.$

The lines are parallel to the surface.

45. **(b) :** C_1, C_2 and C_3 are in series



$$\frac{1}{C'} = \frac{1}{C} + \frac{1}{2C} + \frac{1}{3C}$$

or, $\frac{1}{C'} = \frac{6+3+2}{6C} = \frac{11}{6C}$

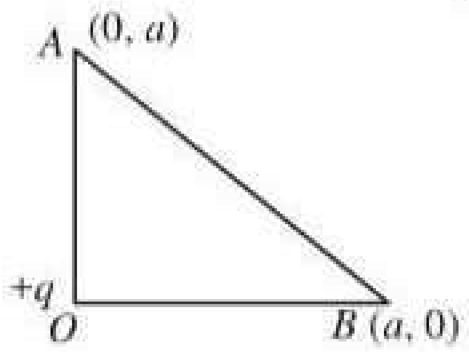
or, $C' = \frac{6C}{11}$

All the capacitors in branch 1 is in series so the charge on each capacitor is $Q' = \frac{6}{11}CV$

Also charge on capacitor C_4 is $Q = 4CV$

$\therefore$ Ratio = $\frac{Q'}{Q} = \frac{6CV}{11\times 4CV} = \frac{3}{22}$.

46. **(a) :** Work done is equal to zero because the potential of A and B are the same = $\frac{1}{4\pi\varepsilon_0}\frac{q}{a}$



No work is done if a particle does not change its potential energy.

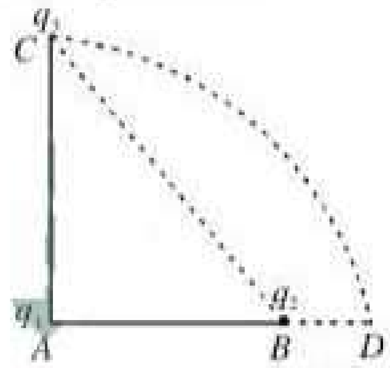
i.e. initial potential energy = final potential energy.

47. **(c) :** The potential energy when q_3 is at point C

$$U_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{0.40} + \frac{q_2q_3}{\sqrt{(0.40)^2+(0.30)^2}}\right]$$

The potential energy when q_3 is at point D

$$U_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{0.40} + \frac{q_2q_3}{0.10}\right]$$



Thus change in potential energy is

$\Delta U = U_2 - U_1$

$$\Rightarrow \frac{q_3}{4\pi\varepsilon_0}k = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{0.40} + \frac{q_2q_3}{0.10} - \frac{q_1q_3}{0.40} - \frac{q_2q_3}{0.50}\right]$$

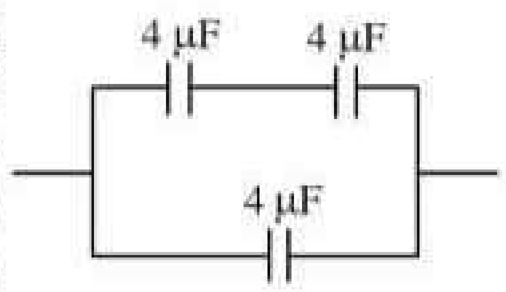
$$\Rightarrow k = \frac{5q_2 - q_2}{0.50} = \frac{4q_2}{0.50} = 8q_2.$$

48. **(b) :** Using $\frac{1}{2}mv^2 = qV$

$$V = \frac{1}{2}\times\frac{2\times10^{-3}\times10\times10}{2\times10^{-6}} = 50 \text{ kV}$$

49. **(c) :** The total force on dipole is zero because $F = qE$ is applied on each charge but in opposite direction. The potential energy is $U = -\vec{p}\cdot\vec{E}$, which is minimum when $\vec{p}$ and $\vec{E}$ are parallel.

50. **(c) :** To get equivalent capacitance 6 μF. Out of the 4 μF capacitance, two are connected in series and third one is connected in parallel.



$$C_{eq} = \frac{4\times4}{4+4} + 4 = 2 + 4 = 6\,\mu\text{F}.$$

51. **(b) :** The total flux through the cube $\phi_{total} = \frac{q}{\varepsilon_0}$

$\therefore$ the electric flux through any face

$$\phi_{face} = \frac{q}{6\,\varepsilon_0} = \frac{4\pi q}{6(4\pi\varepsilon_0)}.$$

52. **(c) :** There are eight corners of a cube and in each corner there is a charge of $(-q)$. At the centre of the corner there is a charge of $(+q)$. Each corner is equidistant from the centres of the cube and the distance (d) is half of the diagonals of the cube.

Diagonal of the cube = $\sqrt{b^2+b^2+b^2} = \sqrt{3}\,b$

$\therefore$ $d = \sqrt{3}\,b/2$

Now, electric potential energy of the charge $(+q)$ due to a charge $(-q)$ at one corner = U

$$= \frac{q_1 q_2}{4\pi\varepsilon_0 r} = \frac{(+q)\times(-q)}{4\pi\varepsilon_0(\sqrt{3}b/2)} = -\frac{q^2}{2\pi\varepsilon_0(\sqrt{3}b)}$$

∴ Total electric potential energy due to all the eight identical charges $= 8U = -\frac{8q^2}{2\pi\varepsilon_0\sqrt{3}b} = \frac{-4q^2}{\sqrt{3}\,\pi\varepsilon_0 b}$.

53. (b) : Charge on first capacitor $= q_1 = C_1 V$
Charge on second capacitor $= q_2 = 0$
When they are connected, in parallel the total charge
$q = q_1 + q_2$. ∴ $q = C_1 V$.
and capacitance, $C = C_1 + C_2$
Let V' be the common potential difference across each capacitor, then $q = CV'$.

∴ $V' = \frac{q}{C} = \frac{C_1}{C_1 + C_2} V$.

54. (c) : Electric field intensity E is zero within a conductor due to charge given to it.

Also, $E = -\frac{dV}{dx}$ or $\frac{dV}{dx} = 0$. (inside the conductor)
∴ V = constant. [V is potential]
So potential remains same throughout the conductor.

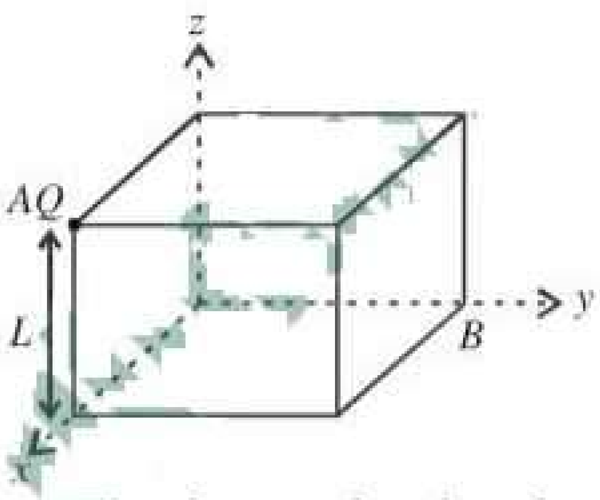
55. (b) : When an electric dipole is placed in a uniform electrical field $\vec{E}$, the torque on the dipole is given by $\vec{\tau} = \vec{p} \times \vec{E}$

56. (a) : Energy density $= \frac{1}{2}\varepsilon_0 \frac{V^2}{d^2}$

57. (a) : For complete cube $\phi = \frac{Q}{\varepsilon_0} \times 10^{-6}$

For each face $\phi = \frac{1}{6}\frac{Q}{\varepsilon_0} \times 10^{-6}$

58. (b) :



As at a corner, 8 cubes can be placed symmetrically, flux linked with each cube (due to a charge Q at the corner) will be $\frac{Q}{8\varepsilon_0}$.

Now for the faces passing through the edge A, electric field E at a face will be parallel to area of face and so flux for these three faces will be zero. Now as the cube has six faces and flux linked with three faces (through A) is zero, so flux linked with remaining three faces will be $\frac{Q}{8\varepsilon_0}$

Hence, electric flux passed through all the six faces of the cube is $\frac{Q}{8\varepsilon_0}$

59. (c)

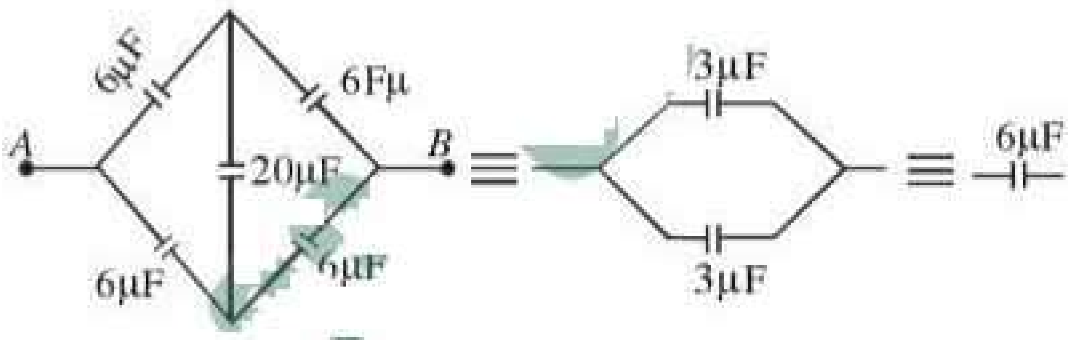
60. (b) : Let q be the charge on each capacitor.

∴ Energy stored, $U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{q^2}{C}$

Now, when battery is disconnected and another capacitor of same capacity is connected in parallel to the first capacitor, then voltage across each capacitor, $V = \frac{q}{2C}$

∴ Energy stored $= \frac{1}{2}C\left(\frac{q}{2C}\right)^2 = \frac{1}{4}\cdot\frac{1}{2}\frac{q^2}{C} = \frac{1}{4}U$.

61. (d) : Reconstruction of circuits gives



62. (c) : $F_m = \frac{F_0}{K}$ *i.e.*, decreases K times

63. (b) : In bringing an electron towards another electron, work has to be done (since same charges repel each other). The work done stored as electrostatic potential energy, and hence, electrostatic potential energy of the system increases.

64. (d) : Capacitance of capacitor with oil between the plate, $C = \frac{K\varepsilon_0 A}{d}$

If oil is removed capacitance, $C' = \frac{\varepsilon_0 A}{d} = \frac{C}{K} = \frac{C}{2}$

65. (c) : Field inside a conducting sphere = 0.

66. (a) : As $v^2 = 0^2 + 2ay = 2\,(F/m)\,y = 2\left(\frac{qE}{m}\right)y$

K.E. $= \frac{1}{2}mv^2$

∴ K.E. $= \frac{1}{2}m\left[2\frac{(qE)}{m}y\right]$ ⇒ K.E. $= qEy$

67. (d) : The electric field at a point on equatorial line (perpendicular bisector) of dipole at a distance r is given by, $E = \frac{p}{4\pi\varepsilon_0}\cdot\frac{1}{(r^2+a^2)^{3/2}}$

where $2a$ = length of dipole
For, $r >> a$,

∴ $E = \frac{p}{4\pi\varepsilon_0}\cdot\frac{1}{r^3}$. *i.e.*, $E \propto p$ and $E \propto r^{-3}$.

68. (d) : Electric flux emerging from the cube does not depend on size of cube.

Total flux $= \frac{q}{\varepsilon_0}$

69. (d)

70. (d) : Radii of sphere $(R_1) = 1$ cm $= 1 \times 10^{-2}$ m; $(R_2) = 2$ cm $= 2 \times 10^{-2}$ m and charges on sphere; $(Q_1) = 10^{-2}$C and $(Q_2) = 5 \times 10^{-2}$ C.

Common potential $(V) = \dfrac{\text{Total charge}}{\text{Total capacity}} = \dfrac{Q_1 + Q_2}{C_1 + C_2}$

$$= \frac{(1\times10^{-2})+(5\times10^{-2})}{4\pi\varepsilon_0 10^{-2} + 4\pi\varepsilon_0(2\times10^{-2})} = \frac{6\times10^{-2}}{4\pi\varepsilon_0(3\times10^{-2})}$$

Therefore final charge on smaller sphere (C_1V)

$$= 4\pi\varepsilon_0 \times 10^{-2} \times \frac{6\times10^{-2}}{4\pi\varepsilon_0 \times 3\times10^{-2}} = 2 \times 10^{-2}\text{ C.}$$

71. (b) : Charge $(q) = 0.2$ C; Distance $(d) = 2$ m; Angle $\theta = 60^\circ$ and work done $(W) = 4$ J.

Work done in moving the charge (W)

$= F.d \cos\theta = qEd\cos\theta$

or, $$E = \frac{W}{qd\cos\theta} = \frac{4}{0.2\times2\times\cos 60^\circ} = \frac{4}{0.4\times0.5}$$

$= 20$ N/C.

72. (c) : For equilibrium of charge Q, the force of repulsion due to similar charges Q should be balanced by the force of attraction due to charge q and

$$\frac{1}{4\pi\varepsilon_0}\times\frac{Qq}{(r/2)^2} + \frac{1}{4\pi\varepsilon_0}\times\frac{Q^2}{r^2} = 0$$

or $\quad 4\times\dfrac{Q}{r^2}q = -\dfrac{Q^2}{r^2}$ or $4q = -Q$ or $q = -\dfrac{Q}{4}$.

73. (b) : To orient the dipole at any angle θ from its initial position, work has to be done on the dipole from $\theta = 0^\circ$ to θ

$\therefore$ Potential energy $= pE(1 - \cos\theta)$

74. (c) : Electric lines of force start from the positive charge and end at the negative charge. Since the electric lines for both the charges are ending, therefore both q_1 and q_2 are negative charges.

75. (c) : Work done on carrying a charge from one place to another on an equipotential surface is zero.

76. (a) : Potential inside the sphere is the same as that on the surface *i.e.*, 80 V.

77. (c) : Net force on each of the charge due to the other charges is zero. However, disturbance in any direction other than along the line on which the charges lie, will not make the charges return.