24. (b) With temperature rise, dielectric constant of liquid decreases.

25. (d) In the presence of medium force becomes $\frac{1}{K}\, times$.

26. (a) Separation between the spheres is not too large as compared to their radius so due to induction effect redistribution of charge takes place. Hence effective charge separation decreases so force increases.

27. (a) $Q = ne = 10^{14} \times 1.6 \times 10^{-19} \Rightarrow Q = 1.6 \times 10^{-5} C = 16\mu C$

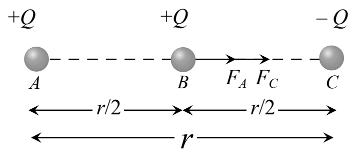
Electrons are removed, so chare will be positive.

28. (a) When put 1 *cm* apart in air, the force between *Na* and *Cl* ions = *F*. When put in water, the force between *Na* and *Cl* ions $= \frac{F}{K}$

29. (d) Positive charge shows the deficiency of electrons. Number of electrons $= \frac{14.4 \times 10^{-19}}{1.6 \times 10^{-19}} = 9$

30. (c)

31. (c) Initially, force between *A* and *C* $F = k\frac{Q^2}{r^2}$



When a similar sphere *B* having charge +*Q* is kept at the mid point of line joining *A* and *C*, then Net force on *B* is $F_{net} = F_A + F_C$

$= k\frac{Q^2}{(r/2)^2} + \frac{kQ^2}{(r/2)^2} = 8\frac{kQ^2}{r^2} = 8F$.

(Direction is shown in figure)

32. (a) Let separation between two parts be $r \Rightarrow F = k.q\frac{(Q-q)}{r^2}$

For *F* to be maximum $\frac{dF}{dq} = 0 \Rightarrow \frac{Q}{q} = \frac{2}{1}$

33. (b) $n = \frac{Q}{e} = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$

34. (a) $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = \frac{F}{K}$

If *F* is the force in air, then F is less than *F* since $K > 1$.

35. (b) Charge on glass rod is positive, so charge on gold leaves will also be positive. Due to *X*-rays, more electrons from leaves will be emitted, so leaves becomes more positive and diverge further.

36. (d) Negative charge means excess of electron which increases the mass of sphere *B*.

37. (b) $F \propto \frac{1}{r^2} \Rightarrow \frac{F_1}{F_2} = \left(\frac{r_2}{r_1}\right)^2 \Rightarrow$

$\frac{5}{F_2} = \left(\frac{0.04}{0.06}\right)^2 = F_2 = 11.25\ N$

38. (a) $F \propto \frac{1}{K}$ *i.e.* $\frac{F_{medium}}{F_{air}} = K$

39. (a) In second case, charges will be $-2\mu C$ and $+3\mu C$

Since $F \propto Q_1 Q_2$ *i.e.* $\frac{F}{F} = \frac{Q_1 Q_2}{Q_1\, Q_2}$

$\therefore\ \frac{40}{F} = \frac{3 \times 8}{-2 \times 3} = -4 \Rightarrow F = 10\ N$ (Attractive)

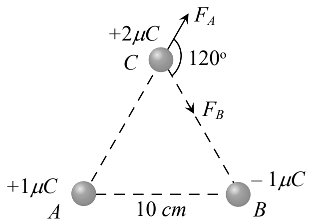
40. (b) By using $Q = ne \Rightarrow Q = 10^{19} \times 1.6 \times 10^{-19} = +1.6\,C$.

41. (b) F_A = force on *C* due to charge placed at *A*

$= 9 \times 10^9 \times \frac{10^{-6} \times 2 \times 10^{-6}}{(10 \times 10^{-2})^2} = 1.8\ N$

F_B = force on *C* due to charge placed at *B*

$= 9 \times 10^9 \times \frac{10^{-6} \times 2 \times 10^{-6}}{(0.1)^2} = 1.8\,N$



Net force on *C*

$F_{net} = \sqrt{(F_A)^2 + (F_B)^2 + 2F_A F_B \cos 120^o} = 1.8\ N$

42. (c) By using $Q = ne \Rightarrow Q = +2e = +3.2 \times 10^{-19}\,C$

43. (b) $F \propto Q_1 Q_2 \Rightarrow \frac{F_1}{F_2} = \frac{Q_1 Q_2}{Q_1' Q_2'} = \frac{10 \times -20}{-5 \times -5} = -\frac{8}{1}$

44. (c) By using $F = 9 \times 10^9 . \frac{Q^2}{r^2}$

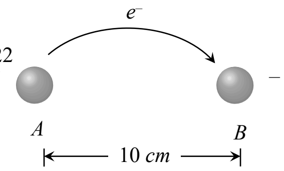
$\Rightarrow F = 9 \times 10^9 . \frac{(2 \times 10^{-6})^2}{(0.5)^2} = 0.144\,N$

45. (c) Effective air separation between them becomes infinite so force becomes zero.

46. (a) $F = 9\times10^9 \times \frac{Q^2}{r^2} = 9\times19^9 \times \frac{(1.6\times10^{-19})^2}{(10^{-10})^2} = 2.3\times10^{-8}\,N$

47. (c) Number of atoms in given mass $= \frac{10}{63.5}\times 6.02\times10^{23}$

$= 9.48 \times 10^{22}$



Transfer of electron between balls

$= \frac{9.48\times10^{22}}{10^6}$

$= 9.48 \times 10^{16}$

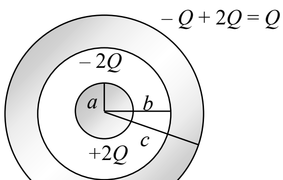
Hence magnitude of charge gained by each ball.

$Q = 9.48\times10^{16}\times1.6\times10^{-19} = 0.015\,C$

Force of attraction between the balls

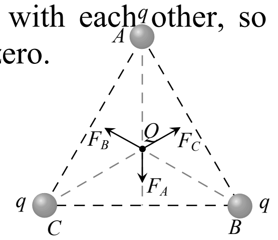
$F = 9\times10^9\times\frac{(0.015)^2}{(0.1)^2} = 2\times10^8\,N.$

48. (a) Surface charge density (σ) $= \frac{\text{Charge}}{\text{Surfacearea}}$



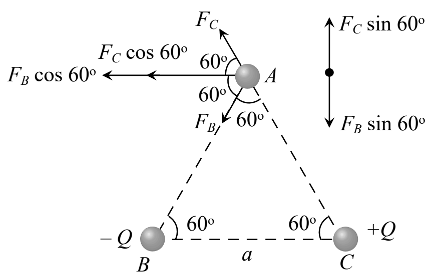
So $\sigma_{inner} = \frac{-2Q}{4\pi b^2}$ and $\sigma_{Outer} = \frac{Q}{4\pi c^2}$

49. (a) In the following figure since $|\vec{F_A}| = |\vec{F_B}| = |\vec{F_C}|$ and they are equally inclined with each other, so their resultant will be zero.



50. (d) By using $K = \frac{F_a}{F_m} \Rightarrow K = \frac{10^{-4}}{2.5\times10^{-5}} = 4$

51. (c) $|\vec{F_B}| = |\vec{F_C}| = k.\frac{Q^2}{a^2}$



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

52. (d) They will not experience any force if $|\vec{F_G}| = |\vec{F_e}|$

$\Rightarrow G\frac{m^2}{(16\times10^{-2})^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{(16\times10^{-2})^2} \Rightarrow$

$\frac{q}{m} = \sqrt{4\pi\varepsilon_0 G}$

53. (b) On rubbing glass rod with silk, excess electron transferred from glass to silk. So glass rod becomes positive and silk becomes negative.

54. (c) $\vec{F} = -k\frac{e^2}{r^2}\hat{r} = -k.\frac{e^2}{r^3}\vec{r}$ $\left(\because \hat{r} = \frac{\vec{r}}{r}\right)$

55. (c) By $Q = Ne$ or $N = \frac{Q}{e} \therefore N = \frac{80\times10^{-6}}{1.6\times10^{-19}} = 5\times10^{14}$

56. (c) $F = F'$ or $\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2} = \frac{Q_1Q_2}{4\pi\varepsilon_0 r'^2 K} \Rightarrow r' = \frac{r}{\sqrt{K}}$

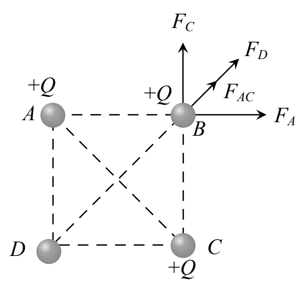
57. (b) Dielectric constant $K = \frac{\varepsilon}{\varepsilon_0}$

Permittivity of metals (ε) is assumed to be very high.

58. (c) Potential energy depends upon the charge at peaks of irregularities. Since every event in the universe leads to the minimisation of energy.

59. (c) Let us consider 1 ball has any type of charge. 1 and 2 must have different charges, 2 and 4 must have different charges *i.e.* 1 and 4 must have same charges but electrostatics attraction is also present in (1, 4) which is impossible.

60. (c) After following the guidelines mentioned above



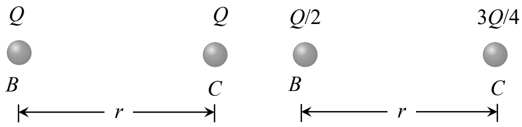
$$F_{net} = F_{AC} + F_D = \sqrt{F_A^2 + F_C^2} + F_D$$

Since $F_A = F_C = \frac{kq^2}{a^2}$ and $F_D = \frac{kq^2}{(a\sqrt{2})^2}$

$$F_{net} = \frac{\sqrt{2}kq^2}{a^2} + \frac{kq^2}{2a^2} = \frac{kq^2}{a^2}\left(\sqrt{2} + \frac{1}{2}\right) = \frac{q^2}{4\pi\varepsilon_0 a^2}\left(\frac{1+2\sqrt{2}}{2}\right)$$

61. (c) Since both are metals so equal amount of charge will induce on them.

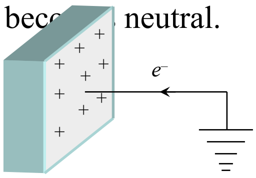
62. (d) Initially $F = k.\frac{Q^2}{r^2}$ (fig. A). Finally when a third spherical conductor comes in contact alternately with B and C then removed, so charges on B and C are $Q/2$ and $3Q/4$ respectively (fig. B)



(A) (B)

Now force $F' = k.\frac{\left(\frac{Q}{2}\right)\left(\frac{3Q}{4}\right)}{r^2} = \frac{3}{8}F$

63. (b) When a positively charged body connected to earth, electrons flows from earth to body and body becomes neutral.



64. (a) $F = \frac{1}{4\pi\varepsilon_0}\frac{(+7\times10^{-6})(-5\times10^{-6})}{r^2} = -\frac{1}{4\pi\varepsilon_0}\frac{35\times10^{12}}{r^2}N$

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{(+5\times10^{-6})(-7\times10^{-6})}{r^2} = -\frac{1}{4\pi\varepsilon_0}\frac{35\times10^{12}}{r^2}N$$

65. (a) Gravitational force $F_G = \frac{Gm_e m_p}{r^2}$

$$F_G = \frac{6.7\times10^{-11}\times9.1\times10^{-31}\times1.6\times10^{-27}}{(5\times10^{-11})^2} = 3.9\times10^{-47}N$$

Electrostatic force $F_e = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$

$$F_e = \frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{(5\times10^{-11})^2} = 9.22\times10^{-8}N$$

So, $\frac{F_e}{F_G} = \frac{9.22\times10^{-8}}{3.9\times10^{-47}} = 2.36\times10^{39}$

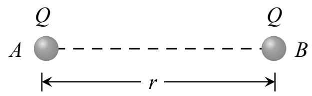
66. (d) $F \propto Q_1Q_2 \Rightarrow \frac{F_1}{F_2} = \frac{Q_1Q_2}{Q_1'Q_2'}$

$$= \frac{3\times10^{-6}\times8\times10^{-6}}{(3\times10^{-6}-6\times10^{-6})(8\times10^{-6}-6\times10^{-6})} = \frac{3\times8}{-3\times2} = -\frac{4}{1}$$

$$\Rightarrow F_2 = -\frac{F_1}{4} = -\frac{6\times10^{-3}}{4} = -1.5\times10^{-3}N$$

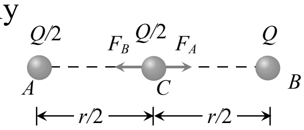
(Attractive)

67. (a) Initially



$F = k\frac{Q^2}{r^2}$ .... (i)

Finally



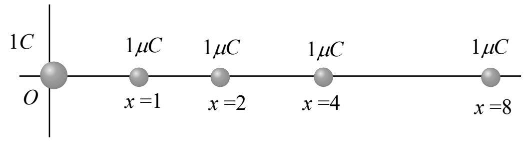
Force on C due to A, $F_A = \frac{k(Q/2)^2}{(r/2)^2} = \frac{kQ^2}{r^2}$

Force on C due to B, $F_B = \frac{KQ(Q/2)}{(r/2)^2} = \frac{2KQ^2}{r^2}$

$\therefore$ Net force on C, $F_{net} = F_B - F_A = \frac{kQ^2}{r^2} = F$

68. (d) $F = k.\frac{Q^2}{r^2}$. If Q is halved, r is doubled then $F \to \frac{1}{16}$ times

69. (b) The schematic diagram of distribution of charges on x-axis is shown in figure below :



Total force acting on 1 C charge is given by

$$F = \frac{1}{4\pi\varepsilon_0}\left[\frac{1\times1\times10^{-6}}{(1)^2} + \frac{1\times1\times10^{-6}}{(2)^2} + \frac{1\times1\times10^{-6}}{(4)^2} + \frac{1\times1\times10^{-6}}{(8)^2} + ...\infty\right]$$

$$= \frac{10^{-6}}{4\pi\varepsilon_0}\left(\frac{1}{1} + \frac{1}{4} + \frac{1}{16} + \frac{1}{64} + ...\infty\right) = 9\times10^9\times10^{-6}\left(\frac{1}{1-\frac{1}{4}}\right)$$

$= 9\times10^9 \times 10^{-6}\times\frac{4}{3} = 9\times10^3\times\frac{4}{3} = 12000\ N$

70. (a) $n = \frac{q}{e} = \frac{1.6}{1.6\times10^{-19}} = 10^{19}$

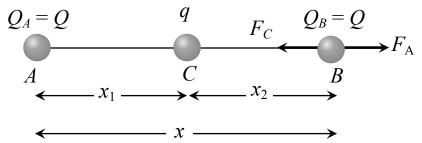
71. (a) In case of spherical metal conductor the charge quickly spreads uniformly over the entire surface because of which charges stay for longer time on the spherical surface. While in case of non-spherical surface, the charge concentration is different at different points due to which the charges do not stay on the surface for longer time.

72. (b) Nuclear force binds the protons and neutrons in the nucleus of an atom.

Electric Field and Potential

1. (b) 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 $q = -Q_B\left(\frac{x_1}{x}\right)^2$

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

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

2. (a) Inside the hollow sphere, at any point the potential is constant.

3. (d) The force is perpendicular to the displacement.

4. (c) A movable charge produces electric field and magnetic field both.

5. (b) Because current flows from higher potential to lower potential.

6. (a) All charge resides on the outer surface so that according to Gauss law, electric field inside a shell is zero.

7. (a) 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 $\frac{\partial V}{\partial z} = 0$

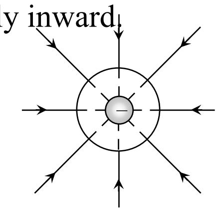
Hence $\vec{E} = -8x\hat{i}$, so at point $(1m, 0, 2m)$

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

8. (b) Since potential inside the hollow sphere is same as that on the surface.

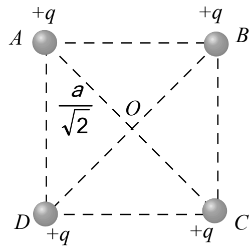
9. (d) On the equipotential surface, electric field is normal to the charged surface (where potential exists) so that no work will be done.

10. (c) Electric lines force due to negative charge are radially inward.



11. (b) Potential at the centre O, $V = 4\times\frac{1}{4\pi\varepsilon_0}.\frac{Q}{a/\sqrt{2}}$

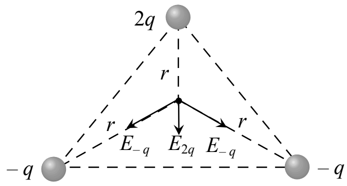
where $Q = \frac{10}{3}\times10^{-9}\ C$ and $a = 8\ cm = 8\times10^{-2}\ m$



So $V = 5\times9\times10^9\times\frac{\frac{10}{3}\times10^{-9}}{\frac{8\times10^{-2}}{\sqrt{2}}} = 1500\sqrt{2}\ volt$

12. (b) $\because E = -\frac{dV}{dX} \Rightarrow V_x = -xE_0$

13. (b) Obviously, from charge configuration, at the centre electric field is non-zero. Potential at the centre due to $2q$ charge $V_{2q} = \frac{2q}{r}$



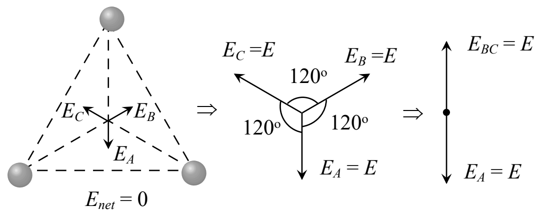
and potential due to – q charge

$V_{-q} = -\frac{q}{r}$ (r = distance of centre point)

$\therefore$ Total potential $V = V_{2q} + V_{-q} + V_{-q} = 0$

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

15. (c)



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

17. (b) According to the question, $eE = mg \Rightarrow E = \frac{mg}{e}$

18. (d) May be at positive, zero or negative potential, it is according to the way one defines the zero potential.

19. (c) $a = \frac{qE}{m} \Rightarrow \frac{a_e}{a_p} = \frac{m_p}{m_e}$

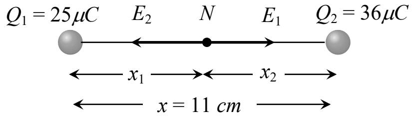
20. (c) $K = \frac{E_{\text{without dielectric}}}{E_{\text{with dielectric}}} = \frac{2 \times 10^5}{1 \times 10^5} = 2$

21. (b) $E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2} = 9 \times 10^9 \times \frac{q}{r^2}$

$\therefore\ q = \frac{E \times r^2}{9 \times 10^9} = \frac{3 \times 10^6 \times (2.5)^2}{9 \times 10^9} = 2.0833 \times 10^{-3}$

q should be less than 2.0833×10^{-3}. In the given set of options 2×10^{-3} is the maximum charge which is smaller than 2.0833×10^{-3}.

22. (a) Suppose electric field is zero at point N in the figure then



At $N\ |E_1| = |E_2|$

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

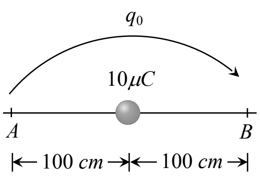
23. (d) Total charge $Q = 80 + 40 = 120\,\mu C$. By using the formula $Q_1' = Q\left[\frac{r_1}{r_1 + r_2}\right]$. New charge on sphere A is $Q_A' = Q\left[\frac{r_A}{r_A + r_B}\right]$ $= 120\left[\frac{4}{4+6}\right] = 48\,\mu C$. Initially it was $80\mu C$ *i.e.,* $32\,\mu C$ charge flows from A to B.

24. (b) Because E points along the tangent to the lines of force. If initial velocity is zero, then due to the force, it always moves in the direction of E. Hence will always move on some lines of force.

25. (b) Electrostatic energy density $\frac{dU}{dV} = \frac{1}{2}K\varepsilon_0 E^2$

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

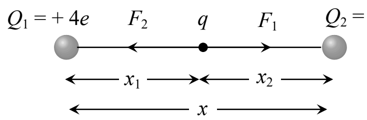
26. (a)



Since $V_A = V_B$ so $W_{A \to B} = 0$

27. (c) For equilibrium of q

$|F_1| = |F_2|$



Which gives $x_2 = \frac{x}{\sqrt{\frac{Q_1}{Q_2}} + 1} = \frac{x}{\sqrt{\frac{4e}{e}} + 1} = \frac{x}{3}$

28. (c) Electric lines of force never intersect the conductor. They are perpendicular and slightly curved near the surface of conductor.

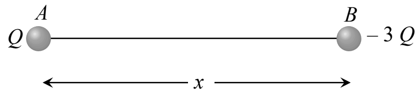
29. (a) Since $qE = mg$ or $E = \frac{mg}{q} = \frac{1.7 \times 10^{-27} \times 9.8}{1.6 \times 10^{-19}}$

$= 10.0 \times 10^{-8} = 1 \times 10^{-7}\ V/m$

30. (c) Since charge Q moving on equipotential surface so work done is zero.

31. (b) The field produced by charge $-3Q$ at A, this is E as mentioned in the Example.

$\therefore E = \frac{3Q}{x^2}$ (along AB directed towards negative charge)



Now field at location of $-3Q$ *i.e.* field at B due to charge Q will be $E' = \frac{Q}{x^2} = \frac{E}{3}$ (along AB directed away from positive charge)

32. (c) $E = \frac{1}{4\pi\varepsilon_0}.\frac{ne}{r^2} \Rightarrow n = \frac{Er^2}{e}.4\pi\varepsilon_0$

$\Rightarrow n = \frac{0.036 \times 0.1 \times 0.1}{9 \times 10^9 \times 1.6 \times 10^{-19}} = \frac{360}{144} \times 10^5 = 2.5 \times 10^5$ N/C.

33. (b) $E = \frac{V}{d} = \frac{10}{2 \times 10^{-2}} = 500\ N/C$

34. (b) For balance $mg = eE \Rightarrow E = \frac{mg}{e}$

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

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

35. (a) Electric field inside a conductor is zero.

36. (c) For pair of charge $U = \frac{1}{4\pi\varepsilon_0}.\frac{q_1 q_2}{r}$

$$U_{System} = \frac{1}{4\pi\varepsilon_0}\left[\frac{10 \times 10^{-6} \times 10 \times 10^{-6}}{10/100} + \frac{10 \times 10^{-6} \times 10 \times 10^{-6}}{10/100} + \frac{10 \times 10^{-6} \times 10 \times 10^{-6}}{10/100}\right]$$

$= 3 \times 9 \times 10^9 \times \frac{100 \times 10^{-12} \times 100}{10} = 27\ J$

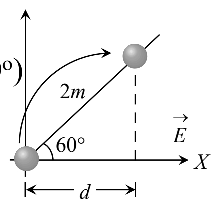
37. (c) Electric field near the conductor surface is given by $\frac{\sigma}{\varepsilon_0}$ and it is perpendicular to surface.

38. (d) $W = qV = qE.d$

$\Rightarrow 4 = 0.2 \times E \times (2 \cos 60^o)$

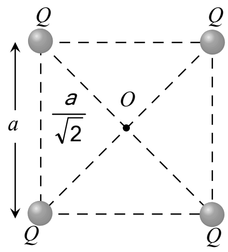
$= 0.2\ E \times (2 \times 0.5)$

$\therefore E = \frac{4}{0.2} = 20\ NC^{-1}$



39. (c) Potential at centre O of the square

$V_O = 4\left(\frac{Q}{4\pi\varepsilon_0(a/\sqrt{2})}\right)$



Work done in shifting $(-Q)$ charge from centre to infinity

$W = -Q(V_\infty - V_O) = QV_0$

$= \frac{4\sqrt{2}\,Q^2}{4\pi\varepsilon_0 a} = \frac{\sqrt{2}Q^2}{\pi\varepsilon_0 a}$

40. (b) Using $v = \sqrt{\frac{2QV}{m}} \Rightarrow v \propto \sqrt{Q} \Rightarrow$

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

41. (c) Due to deutron, intensity of electric field at 1 Å distance,

$E = \frac{1}{4\pi\varepsilon_0}.\frac{e}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-19}}{10^{-20}} = 1.44 \times 10^{11}\ N/C.$

42. (c) Lines of force is perpendicular to the equipotential surface. Hence angle = 90°

43. (a) Magnetic lines of force always makes a closed loop.

44. (b)

45. (d)

46. (a) $V = E \times r \Rightarrow r = \frac{V}{E} = \frac{3000}{500} = 6\ m$

47. (c) The magnitude of electric field in the annular region of a charged cylindrical capacitor is given by $E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}$ where λ is the charge per unit length and r is the distance from the axis of the cylinder. Thus $E \propto \frac{1}{r}$

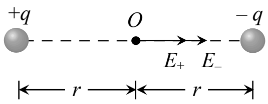
48. (d) The electric field is always perpendicular to the surface of a conductor. On the surface of a metallic solid sphere, the electrical field is oriented normally (*i.e.* directed towards the centre of the sphere).

49. (d) $E = \frac{q}{4\pi\varepsilon_0 r^2} = 9 \times 10^9 \times \frac{1.6 \times 10^{-19}}{(10^{-10})^2} = 1.44 \times 10^{11}\ N/C$

50. (a) Electric field due to a point charge $E = \frac{q}{4\pi\varepsilon_0 r^2}$

$\therefore q = E \times 4\pi\varepsilon_0 r^2 = 2 \times \frac{1}{9 \times 10^9} \times \left(\frac{30}{100}\right)^2 = 2 \times 10^{-11}\ C$

51. (c) At $O, E \neq 0, V = 0$



52. (d) At neutral point

$$k \times \frac{20}{(20\times10^{-2})^2} = k \times \frac{Q}{(40\times10^{-2})^2} \Rightarrow Q = 80\ C$$

53. (a) Work done in moving a charge from P to L, P to M and P to N is zero.

54. (b) $a = \frac{QE}{m} = \frac{3\times10^{-3}\times 80}{20\times10^{-3}} = 12\, m/sec^2$

Hence $v = u + at \Rightarrow v = 20 + 12 \times 3 = 56$ m/s.

55. (a) Potential at the centre of square

$$V = 4 \times \left(\frac{9\times10^9\times 50\times10^{-6}}{2/\sqrt{2}}\right) = 90\sqrt{2}\times10^4\ V$$

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

$$\Rightarrow W = 50\times10^{-6}\times 90\sqrt{2}\times10^4 = 64\ J$$

56. (b) In balance condition

$$\Rightarrow QE = mg \Rightarrow Q\frac{V}{d} = \left(\frac{4}{3}\pi r^3 \rho\right) g$$

$$\Rightarrow Q \propto \frac{r^3}{V} \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^3 \times \frac{V_2}{V_1}$$

$$\Rightarrow \frac{Q}{Q_2} = \left(\frac{r}{r/2}\right)^3 \times \frac{600}{2400} = 2 \Rightarrow Q_2 = Q/2$$

57. (a) $F = QE = \frac{QV}{d} \Rightarrow 5000 = \frac{5\times V}{10^{-2}} \Rightarrow V = 10\ volt$

58. (c) After redistribution, charges on them will be different, but they will acquire common potential

i.e. $k\frac{Q_1}{r_1} = k\frac{Q_2}{r_2} \Rightarrow \frac{Q_1}{Q_2} = \frac{r_1}{r_2}$

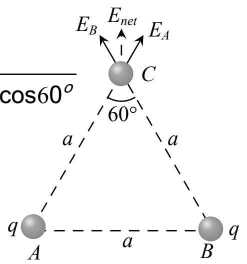
As $\sigma = \frac{Q}{4\pi r^2} \Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{Q_1}{Q_2}\times\frac{r_2^2}{r_1^2} \Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1} \Rightarrow$ $\sigma \propto \frac{1}{r}$

i.e. surface charge density on smaller sphere will be more.

59. (c) $|E_A| = |E_B| = k.\frac{q}{a^2}$

So, $E_{net} = \sqrt{E_A^2 + E_B^2 + 2E_A E_B \cos 60^o}$

$$= \frac{\sqrt{3}\, k.q}{a^2}$$



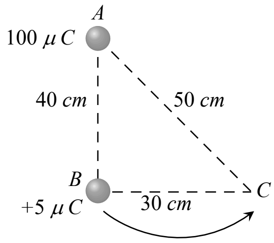
$$\Rightarrow E_{net} = \frac{\sqrt{3}\, q}{4\pi\varepsilon_0 a^2}$$

60. (c) $U_{system} = \frac{1}{4\pi\varepsilon_0}\frac{(q)(-2q)}{a} + \frac{1}{4\pi\varepsilon_0}\frac{(-2q)(q)}{a} + \frac{1}{4\pi\varepsilon_0}\frac{(q)(q)}{2a}$

$$U_{system} = -\frac{7q^2}{8\pi\varepsilon_0 a}$$

61. (d) Work done in displacing charge of 5 μ C from B to C is

$W = 5\times10^{-6}(V_C - V_B)$ where



$$V_B = 9\times10^9 \times \frac{100\times10^{-6}}{0.4} = \frac{9}{4}\times10^6\ V$$

and $V_C = 9\times10^9\times\frac{100\times10^{-6}}{0.5} = \frac{9}{5}\times10^6\ V$

So $W = 5\times10^{-6}\times\left(\frac{9}{5}\times10^6 - \frac{9}{4}\times10^6\right) = -\frac{9}{4}\ J$

62. (a) $E = \frac{F}{q_0} \longrightarrow Newton/\ Coulomb$

63. (a) $V = \frac{kq}{R}$ *i.e.* $V \propto \frac{1}{R}$

$\therefore$ Potential on smaller sphere will be more.

64. (b) $K = qV = 2e\times10^6\ J = \frac{2e\times10^6}{e}\ eV = 2MeV$

65. (a) Since $W = qV \Rightarrow 20 = 5 \times V \Rightarrow V = 2$ *volts*

66. (a) $E = -\frac{dV}{dx} = -\frac{d}{dx}(5x^2 + 10x - 9) = -10x - 10$

$\therefore (E)_{x=1} = -10\times1 - 10 = -20\ V/m$

67. (b) For equilibrium $mg = qE$

$$\therefore 1.96\times10^{-15}\times 9.8 = q\times\left(\frac{800}{0.02}\right)$$

$$\Rightarrow q = \frac{1.96\times10^{-15}\times9.8\times0.02}{800}$$

$$\Rightarrow n\times1.6\times10^{-19} = \frac{1.96\times10^{-15}\times9.8\times0.02}{800} \Rightarrow n = 3.$$

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

69. (b) Joined by a wire means they are at the same potential. For same potential $\frac{kQ_1}{a_1}=\frac{kQ_2}{a_2}\Rightarrow$

$\frac{Q_1}{Q_2}=\frac{a}{b}$

Further, the electric field at the surface of the sphere having radius R and charge Q is $\frac{kQ}{R^2}$.

$\therefore\ \frac{E_1}{E_2}=\frac{kQ_1/a^2}{kQ_2/b_2}=\frac{Q_1}{Q_2}\times\frac{b^2}{a^2}=\frac{b}{a}$

70. (c) Kinetic energy = Force × Displacement = qEy

71. (a) The intensity of electric field inside a hollow conducting sphere is zero.

72. (b) For electron $s=\frac{eE}{m_e}\times t_1^2$, For proton $s=\frac{eE}{m_p}\times t_2^2$

$\therefore\ \frac{t_2^2}{t_1^2}=\frac{m_p}{m_e}\Rightarrow\frac{t_2}{t_1}=\sqrt{\frac{m_p}{m_e}}=\left(\frac{m_p}{m_e}\right)^{1/2}$

73. (d) Due to symmetric charge distribution.

74. (c) In balance condition $QE=mg=\left(\frac{4}{3}\pi r^3\rho\right)g$

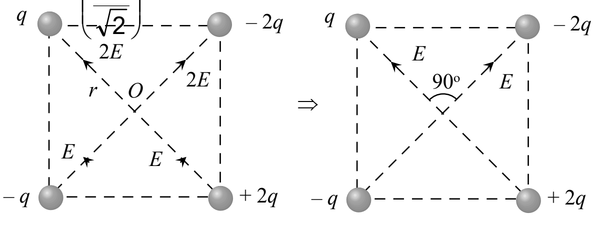
$\Rightarrow E=\frac{4\times(3.14)(0.1\times10^{-6})^3\times10^3\times10}{3\times1.6\times10^{-19}}=262\ N/C$

75. (a) Side $a=5\times10^{-2}\ m$

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 $O=\sqrt{E^2+E^2}=E\sqrt{2}=\frac{kq}{\left(\frac{a}{\sqrt{2}}\right)^2}.\sqrt{2}$

$=\frac{9\times10^9\times10^{-6}\times\sqrt{2}\times2}{(5\times10^{-2})^2}=1.02\times10^7\ N/C$

(upward)

76. (d) Energy density $u_e=\frac{1}{2}\varepsilon_0E^2=\frac{1}{2}\times8.86\times10^{-12}\times\left(\frac{V}{r}\right)^2$

$=2.83\ J/m^3$

77. (c) Force on each charge is zero. But if any of the charge is displaced, the net force starts acting on all of them.

78. (c) Let neutral point be obtained at a distance x from 20 μC charge. Hence at neutral point

$\frac{20}{(x)^2}=\frac{80}{(10-x)^2}\Rightarrow x=+0.033\ m$

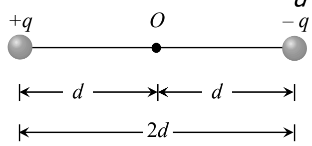
79. (a) $KE=q(V_1-V_2)=2\times1.6\times10^{-19}\times(70-50)=40\ eV$

80. (b) Potential inside the sphere will be same as that on its surface *i.e.* $V=V_{surface}=\frac{q}{10}\ statvolt$,

$V_{out}=\frac{q}{15}\ statvolt$

$\therefore\ \frac{V_{out}}{V}=\frac{2}{3}\Rightarrow V_{out}=\frac{2}{3}V$

81. (a) Potential at mid point O, $V=\frac{kq}{d}+\frac{k(-q)}{d}=0$



82. (a) By using $U=9\times10^9\frac{Q_1Q_2}{r}$

$\Rightarrow U=9\times10^9\times\frac{10^{-6}\times10^{-6}}{1}=9\times10^{-3}\ J$

83. (b) In equilibrium $QE=mg\Rightarrow$ $Q.\frac{V}{d}=mg=\left(\frac{4}{3}\pi r^3\rho\right)g$

$\Rightarrow 2\times1.6\times10^{-19}\times\frac{12000}{2\times10^{-2}}=\frac{4}{3}\pi r^3\times900\times10$

$\Rightarrow r=1.7\times10^{-6}\ m$

84. (d) Momentum $p=\sqrt{2mK}$; where K = kinetic energy = $Q.V$

$\Rightarrow p=\sqrt{2mQV}\Rightarrow p\propto\sqrt{mQ}\Rightarrow\frac{p_e}{p_\alpha}=\sqrt{\frac{m_eQ_e}{m_\alpha Q_\alpha}}$

$=\sqrt{\frac{m_e}{2m_\alpha}}$

85. (b) Kinetic energy $K=Q.V\Rightarrow K=(+e)\ (50000\ V)$

$=50000\ eV=50000\times1.6\times10^{-19}\ J=8\times10^{-15}\ J$

86. (c) $\Delta KE=qV=eV=e\times1=1eV$

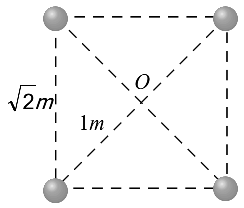
87. (b) Force on electron $F = QE = Q\left(\frac{V}{d}\right)$

$\Rightarrow F = (1.6\times10^{-19})\left(\frac{1000}{2\times10^{-3}}\right) = 8\times10^{-14}\ N$

88. (b) Spheres have same potential

i.e. $k\frac{Q_1}{R_1} = k\frac{Q_2}{R_2} \Rightarrow \frac{Q_1}{Q_2} = \frac{R_1}{R_2}$

89. (c) Length of each side of square is $\sqrt{2}\,m$ so distance of it's centre from each corner is $\frac{\sqrt{2}}{\sqrt{2}} = 1m.$



Potential at the centre

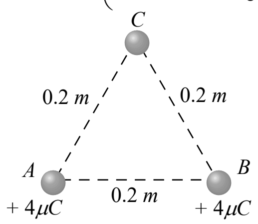
$V = 9\times10^{9}\left[\frac{10\times10^{-6}}{1} + \frac{5\times10^{-6}}{1} - \frac{3\times10^{-6}}{1} + \frac{8\times10^{-6}}{1}\right]$

$= 1.8\times10^{5}\ V$

90. (a) $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2} \Rightarrow 2 = 9\times10^{9}\times\frac{Q}{(0.6)^2} \Rightarrow Q = 8\times10^{-11}\ C$

91. (d) $E = 9\times10^{9}\times\frac{Q}{r^2} \Rightarrow 500 = 9\times10^{9}\times\frac{Q}{(3)^2} \Rightarrow Q = 0.5\ \mu C$

92. (c) Potential at $C = \left(9\times10^{9}\times\frac{4\times10^{-6}}{0.2}\right)\times 2 = 36\times10^{4}\ V$



93. (b) $E = 9\times10^{9}.\frac{Q}{r^2} = 9\times10^{9}\times\frac{5\times10^{-6}}{(0.8)^2} = 7\times10^{4}\ N/C$

94. (b) At centre $E = 0$, $V \neq 0$

95. (c) $W = U_f - U_i = 9\times10^{9}\times Q_1 Q_2\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$

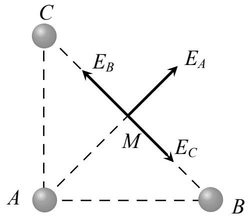
$\Rightarrow W = 9\times10^{9}\times12\times10^{-6}\times8\times10^{-6}\left[\frac{1}{4\times10^{-2}} - \frac{1}{10\times10^{-2}}\right]$

$= 12.96\ J \approx 13\ J$

96. (b) E_A = Electric field at M due to charge placed at A

E_B = Electric field at M due to charge placed at B

E_C = Electric field at M due to charge placed at C



As seen from figure $|\vec{E_B}| = |\vec{E_C}|$, so net electric field at M, $E_{net} = E_A$; in the direction of vector 2.

97. (a) By using $W = Q(\vec{E}.\Delta\vec{r})$

$\Rightarrow W = Q[(e_1\hat{i} + e_2\hat{j} + e_3\hat{k}).(a\hat{i} + b\hat{j})] = Q(e_1 a + e_2 b)$

98. (b) By using $V = 9\times10^{9}\times\frac{Q}{r}$

$= 9\times10^{9}\times\frac{100\times10^{-6}}{9} = 10^{5}\ V$

99. (c) $E = \frac{1}{4\pi\varepsilon_0}.\frac{Qr}{R^3} \Rightarrow E \propto \frac{1}{R^3}$

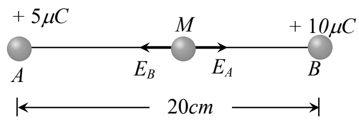
100. (a) From following figure,

E_A = Electric field at mid point M due to $+5\mu C$ charge

$= 9\times10^{9}\times\frac{5\times10^{-6}}{(0.1)^2} = 45\times10^{5}\ N/C$

E_B = Electric field at M due to $+10\mu C$ charge

$= 9\times10^{9}\times\frac{10\times10^{-6}}{(0.1)^2} = 90\times10^{5}\ N/C$



Net electric field at $M = |\vec{E_B}| - |\vec{E_A}|$

$= 45\times10^{5}\ N/C = 4.5\times10^{6}\ N/C,$

in the direction of E_B *i.e.* towards $+5\mu C$ charge

101. (d) α-particles are charged particles, so they can deflect by electric field.

102. (b) Potential at A = Potential due to $(+q)$ charge + Potential due to $(-q)$ charge

$= \frac{1}{4\pi\varepsilon_0}.\frac{q}{\sqrt{a^2+b^2}} + \frac{1}{4\pi\varepsilon_0}\frac{(-q)}{\sqrt{a^2+b^2}} = 0$

103. (a,d) When two opposite charge separated by a certain distance then at two points potential is zero. One point exist between the charges and other exists outside them. Also no point, exists between the opposite charges. Where electric field is zero.

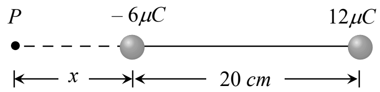
104. (b) $QE = mg \Rightarrow Q = \frac{mg}{E} = \frac{5\times10^{-5}\times10}{10^7} = 5 \times 10^{-5}\mu C$.

Since electric field is acting downward so for balance charge must be negative.

105. (b) Net electrostatic energy $U = \frac{kQq}{a} + \frac{kq^2}{a} + \frac{kQq}{a\sqrt{2}} = 0$

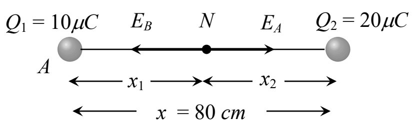
$\Rightarrow \frac{kq}{a}\left(Q + q + \frac{Q}{\sqrt{2}}\right) = 0 \Rightarrow Q = -\frac{2q}{2+\sqrt{2}}$

106. (c) Point P will lie near the charge which is smaller in magnitude *i.e.* $-6\ \mu C$. Hence potential at P



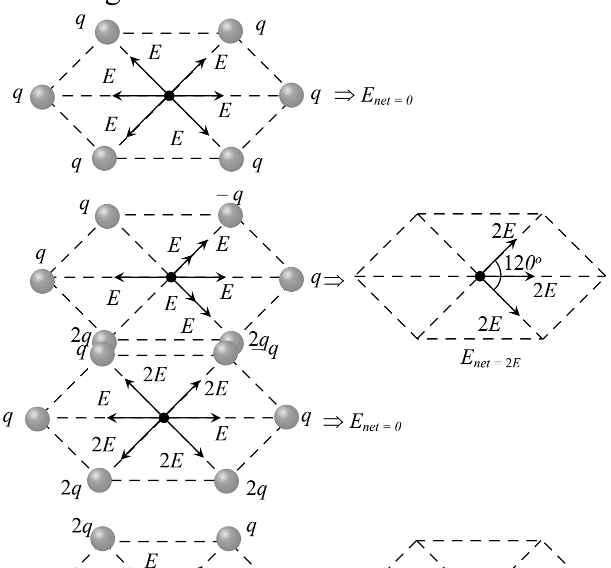
$V = \frac{1}{4\pi\varepsilon_0}\frac{(-6\times10^{-6})}{x} + \frac{1}{4\pi\varepsilon_0}\frac{(12\times10^{-6})}{(0.2+x)} = 0 \Rightarrow x = 0.2\ m$

107. (c) Suppose electric field is zero at N. Hence $|E_A| = |E_B|$



Which gives $x_1 = \frac{x}{\sqrt{\frac{Q_2}{Q_1}}+1} = \frac{80}{\sqrt{\frac{20}{10}}+1} = 33\,cm$

108. (b) Electric field at a point due to positive charge acts away from the charge and due to negative charge it act's towards the charge.



109. (c) When charge enters perpendicularly in electric field, it describe parabolic path.

110. (c) Because electric field applies the force on electron in the direction opposite to it's motion.

111. (c) Kinetic energy $K = \frac{1}{2}mv^2 = eV \Rightarrow v = \sqrt{\frac{2eV}{m}}$

112. (c) Potential $V \propto \frac{1}{r} \Rightarrow V = \frac{V}{2} = 8\,V$

113. (c) Energy density $= \frac{\text{Energy}}{\text{Volume}}$ so it's dimensions are $\frac{ML^2T^{-2}}{L^3} = [ML^{-1}T^{-2}]$

114. (a) Work done $W = 3\times10^{-6}(V_A - V_B)$; where

$V_A = 10^{10}\left[\frac{(-5\times10^{-6})}{15\times10^{-2}} + \frac{2\times10^{-6}}{5\times10^{-2}}\right] = \frac{1}{15}\times10^6\ volt$

and $V_B = 10^{10}\left[\frac{(2\times10^{-6})}{15\times10^{-2}} - \frac{5\times10^{-6}}{5\times10^{-2}}\right] = -\frac{13}{15}\times10^6\ volt$

$\therefore\ W = 3\times10^{-6}\left[\frac{1}{15}\times10^6 - \left(-\frac{13}{15}\times10^6\right)\right] = 2.8\ J$

115. (c) Electric lines of force are always normal to metallic body.

116. (a)

117. (c) Inside a conducting body, potential is same everywhere and equals to the potential of it's surface

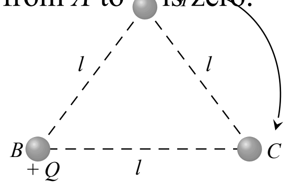
118. (d) If charge acquired by the smaller sphere is Q then it's potential $120 = \frac{kQ}{2}$ ..... (i)

Also potential of the outer sphere

$V = \frac{kQ}{6}$ .....(ii)

From equation (i) and (ii) $V = 40$ *volt*

119. (d) According to figure, potential at A and C are equal. Hence work done in moving $-q$ charge from A to C is zero.



120. (a) $KE = qV$

121. (b) Given electric potential of spheres are same *i.e.* $V_A = V_B$

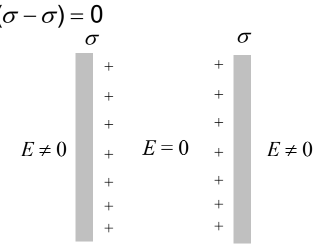
$$\Rightarrow \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1}{a} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_2}{b} \Rightarrow \frac{Q_1}{Q_2} = \frac{a}{b} \qquad ......(i)$$

as surface charge density $\sigma = \frac{Q}{4\pi r^2}$

$$\Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{Q_1}{Q_2}\times\frac{b^2}{a^2} = \frac{a}{b}\times\frac{b^2}{a^2} = \frac{b}{a}$$

122. (a) Potential at any point inside the charged spherical conductor equals to the potential at the surface of the conductor *i.e.* Q/R.

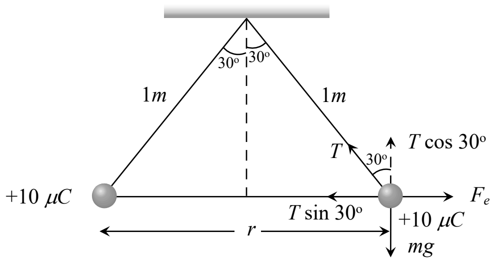
123. (c) Electric field between sheets $E = \frac{1}{2\varepsilon_0}(\sigma - \sigma) = 0$



124. (c) $V = 9\times10^9 \times \frac{Q}{r} = 9\times10^9 \times \frac{(+1.6\times10^{-19})}{0.53\times10^{-10}} = 27.2V$

125. (a)

126. (b) In the following figure, in equilibrium $F_e = T\sin 30^o$, $r = 1m$



$$\Rightarrow 9\times10^9.\frac{Q^2}{r^2} = T\times\frac{1}{2}$$

$$\Rightarrow 9\times10^9.\frac{(10\times10^{-6})^2}{1^2} = T\times\frac{1}{2} \Rightarrow T = 1.8\ N$$

127. (a) By using $\frac{1}{2}m(v_1^2 - v_2^2) = QV$

$$\Rightarrow \frac{1}{2}\times10^{-3}\{v_1^2 - (0.2)^2\} = 10^{-8}(600-0)$$

$$\Rightarrow v_1 = 22.8\ cm/s$$

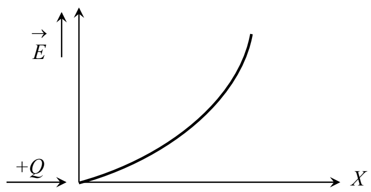
128. (a) $a = \frac{eE}{m} \Rightarrow a = 1.76\times10^{11}\times50\times10^2 = 8.8\times10^{14}\ m/sec^2$

129. (a) Potential energy of the system

$$U = k\frac{Qq}{l} + \frac{kq^2}{l} + \frac{kqQ}{l} = 0$$

$$\Rightarrow \frac{kq}{l}(Q + q + Q) = 0 \Rightarrow Q = -\frac{q}{2}$$

130. (a) Vertical velocity changes due to electric field, but no change in horizontal velocity.



131. (d) $E_x = -\frac{dV}{dx} = -(-5) = 5$; $E_y = -\frac{dV}{dy} = -3$

and $E_z = -\frac{dV}{dz} = -\sqrt{15}$

$$E_{net} = \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{(5)^2 + (-3)^2 + (-\sqrt{15})^2} = 7$$

132. (c) By using $W = Q.\Delta V \Rightarrow \Delta V = \frac{2}{20} = 0.1\ volt$

133. (c) Inside the hollow charged spherical conductor electric field is zero.

134. (b) By using, $KE = QV \Rightarrow 4\times10^{20}\times1.6\times10^{-19} = 0.25\times V \Rightarrow V = 256$ *volt*

135. (a) By using $KE = QV \Rightarrow KE = 1.6\times10^{-19}\times100$

$= 1.6\times10^{-17}\ J$

136. (a) By using $QE = mg$

$\Rightarrow E = \frac{mg}{Q} = \frac{10^{-6}\times10}{10^{-6}} = 10\ V/m$, upward because charge is positive.

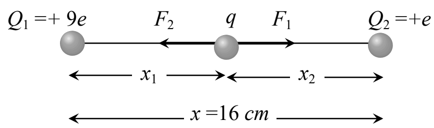
137. (b) By using $QE = mg$

$$\Rightarrow Q = \frac{mg}{E} = \frac{0.003\times10^{-3}\times10}{6\times10^4} = 5\times10^{-10}\ C$$

138. (b) Suppose q is placed at a distance x from

+9*e*, then for equilibrium net force on it must be zero *i.e.* $|F_1| = |F_2|$

Which gives $x_1 = \frac{x}{\sqrt{\frac{Q_2}{Q_1}}+1} = \frac{16}{\sqrt{\frac{e}{9e}}+1} = 12\,cm$

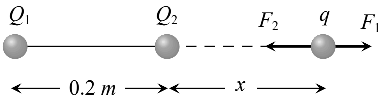


139. (c) $U = \frac{1}{4\pi\varepsilon_0}.\frac{Q_1Q_2}{r}$; net potential energy

$U_{net} = 3 \times \frac{1}{4\pi\varepsilon_0}.\frac{q^2}{l}$

140. (c) If two opposite charges are separated by a certain distance, then for it's equilibrium a third charge should be kept outside and near the charge which is smaller in magnitude.

Here, suppose third charge q is placed at a distance x from $-2.7 \times 10^{-11}C$ then for it's equilibrium $|F_1| = |F_2|$



$\Rightarrow \frac{kQ_1q}{(x+0.2)^2} = \frac{kQ_2q}{x^2} \Rightarrow x = 0.556\ m$

$\left(\text{Here } k = \frac{1}{4\pi\varepsilon_0} \text{ and } Q_1 = 5\times10^{-11}C, Q_2 = -2.7\times10^{-11}C\right)$

141. (d) Length of the diagonal of a cube having each side b is $\sqrt{3}\,b$. So distance of centre of cube from each vertex is $\frac{\sqrt{3}\,b}{2}$.

Hence potential energy of the given system of charge is

$U = 8 \times \left\{\frac{1}{4\pi\varepsilon_0}.\frac{(-q)(q)}{\sqrt{3}\,b/2}\right\} = \frac{-4q^2}{\sqrt{3}\pi\varepsilon_0 b}$

142. (c) $a = \frac{F}{m} = \frac{eE}{m}$

143. (d) Cathode rays (stream of negatively charged particles) deflect in opposite direction of field *i.e.* towards north.

144. (c) $KE = QV \Rightarrow KE = (2e)200\ V = 400\ eV$

145. (b) When a negatively charged pendulum oscillates over a positively charged plate then effective value of g increases so according to $T = 2\pi\sqrt{\frac{l}{g}}$, T decreases.

146. (c) When charge q is released in uniform electric field E then its acceleration $a = \frac{qE}{m}$ (is constant)

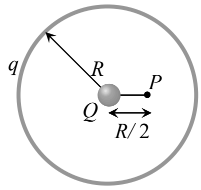
So its motion will be uniformly accelerated motion and its velocity after time t is given by $v = at = \frac{qE}{m}t$

$\Rightarrow KE = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{qE}{m}t\right)^2 = \frac{q^2E^2t^2}{2m}$

147. (c) $KE = QV = e \times 10^3\ V = 1KeV$.

148. (c) Electric field inside a conductor is always zero.

149. (d) Electric potential at P



$V = \frac{k.Q}{R/2} + \frac{k.q}{R}$

$= \frac{2Q}{4\pi\varepsilon_0 R} + \frac{q}{4\pi\varepsilon_0 R}$

150. (d) Conducting surface behaves as equipotential surface.

151. (c)

152. (c) Electric force $qE = ma \Rightarrow a = \frac{QE}{m}$

$\therefore a = \frac{1.6\times10^{-19}\times1\times10^3}{9\times10^{-31}} = \frac{1.6}{9}\times10^{15}$

$u = 5\times10^6$ and $v = 0$

$\therefore$ From $v^2 = u^2 - 2as \Rightarrow s = \frac{u^2}{2a}$

$\therefore$ Distance $s = \frac{(5\times10^6)^2\times9}{2\times1.6\times10^{15}} = 7\ cm(\text{approx})$

153. (a) Electron is moving in opposite direction of field so field will produce an accelerating effect on electron.

154. (b) $V = 9\times10^9\times\frac{50\times1.6\times10^{-19}}{9\times10^{-15}} = 8\times10^6\ V$

155. (b) Energy $= 0.5\times2000 = 1000\ J$

156. (b) $\Delta E = 2e\times5V = 10eV \Rightarrow$ Final kinetic energy $= 10eV$

157. (d) Energy $= 1.6\times10^{-19}\times100000 = 1.6\times10^{-14}\ J$

158. (a) Potential is to be determined at a distance of 4 *cm* from centre of sphere *i.e.* inside the sphere.

159. (c) Work done $=(\Delta V)Q$

For an equipotential surface.

160. (d) Energy $=\frac{10\times 40}{2}+\frac{10\times 20}{4}=250\ erg$

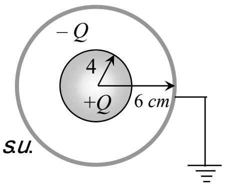
161. (c) Firstly being a conductor it is attracted by the high voltage plate, when charge is shared, ball is repelled until it goes to other plate and whole of the charge is transferred to the earth and the process is repeated.

162. (d) Suppose charge on inner sphere is $+Q$ as shown.

Potential on inner sphere

$V=\frac{Q}{4}-\frac{Q}{6}$

$\Rightarrow 3=Q\left(\frac{1}{4}-\frac{1}{6}\right) \Rightarrow Q=36\ e.s.u.$



163. (a)

164. (b) $\Delta P.E.=$ Work done by external agent

$=(V_f q-V_i q)\ V_f>V_i \Rightarrow \Delta P.E.>0\ i.e. P.E.$ will increase

165. (b) It is assumed that charge on earth is $10^6\,C$ hence by taking away a negative charge from the earth, potential energy will increase.

166. (a) $V=Ed=\frac{3000}{3}\times 10^{-2}=10\,V$

167. (d) The work done is given by $=q(V_2-V_1)=0$

168. (b) Potential energy of the system will be given by $=\frac{(-e)(-e)}{4\pi\varepsilon_0 r}=\frac{e^2}{4\pi\varepsilon_0 r}$

As r decreases, potential energy increases.

169. (b) At a point inside the sphere, the potential is same everywhere and is equal to that of the surface.

170. (a) Work done $W=Q(V_B-V_A)\Rightarrow (V_B-V_A)=\frac{W}{Q}$

$=\frac{10\times 10^{-3}}{5\times 10^{-6}}\,J/C=2\,kV$

171. (c) $V=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r} \Rightarrow V\propto\frac{1}{r}$

172. (b)

173. (a) The work done in moving a charge on equipotential surface is zero.

174. (a) $a=\frac{qE}{m}=\frac{q}{m}\left(\frac{V}{d}\right)=\frac{10^{-11}}{10^{-15}}\times\frac{50}{5\times 10^{-3}}=10^8\,m/sec^2$

175. (a)

176. (c) For non-conducting sphere $E_{in}=\frac{k.Qr}{R^3}=\frac{\rho r}{3\varepsilon_0}$

177. (a) $E=\frac{V}{d}=\frac{30-(-10)}{(2\times 10^{-2})}=2000\,V/m.$

178. (c) Electric potential inside a conductor is constant and it is equal to that on the surface of conductor.

179. (d)

180. (a) $E=9\times 10^9\frac{Q}{r^2}\Rightarrow$

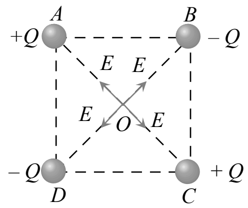
$Q=\frac{E\times r^2}{9\times 10^9}=\frac{1\times(0.1)^2}{9\times 10^9}=1.11\times 10^{-12}\,C$

181. (a) In equilibrium

$QE=mg \Rightarrow n=\frac{mg}{Ee}=\frac{9.6\times 10^{-16}\times 10}{20{,}000\times 1.6\times 10^{-19}}=3$

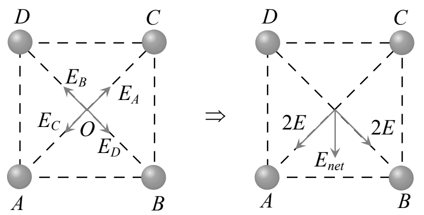
182. (c) Potential inside the conducting sphere is same as that of surface *i.e.* $\frac{Q}{4\pi\varepsilon_0 R}$

183. (a) At centre
$E=0$
and $V=0$



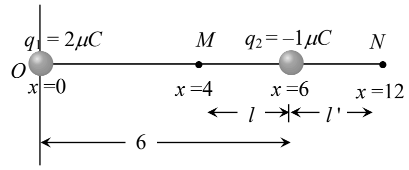
184. (a) $V=\frac{1}{4\pi\varepsilon_0}\cdot\frac{(Ze)}{r}=9\times 10^9\times\frac{47\times 1.6\times 10^{-19}}{3.4\times 10^{-14}}=1.99\times 10^6\,V$

185. (b)



$E_A=E, E_B=2E, E_C=3E, E_D=4E$

186. (c) Potential will be zero at two points



At internal point (M) :
$\frac{1}{4\pi\varepsilon_0}\times\left[\frac{2\times 10^{-6}}{(6-l)}+\frac{(-1\times 10^{-6})}{l}\right]=0$

$\Rightarrow l=2$

So distance of M from origin; $x = 6 - 2 = 4$

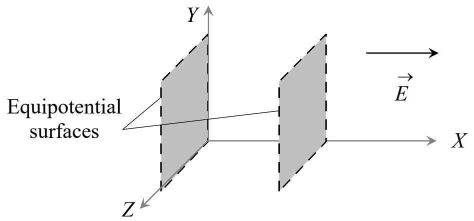
At exterior point (N) :

$$\frac{1}{4\pi\varepsilon_0}\times\left[\frac{2\times10^{-6}}{(6-l)}+\frac{(-1\times10^{-6})}{l}\right]=0$$

$\Rightarrow l = 6$

So distance of N from origin, $x = 6 + 6 = 12$

187. (a)



188. (b) By using $\frac{1}{2}mv^2 = QV$

$$\Rightarrow \frac{1}{2}\times2\times10^{-6}\times(10)^2 = 2\times10^{-6}\,V \Rightarrow V = 50\,kV$$

189. (c)

190. (b) In the direction of electric field potential decreases.

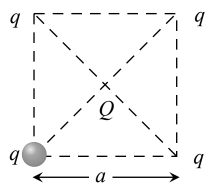
191. (c) A free positive charge move from higher (positive) potential to lower (negative) potential. Hence, it must cross S at some time.

192. (a) Net field at origin $E=\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{4^2}+....\infty\right]$

$$=\frac{q}{4\pi\varepsilon_0}\left[1+\frac{1}{4}+\frac{1}{16}+.....\infty\right]$$

$$=\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{1-\frac{1}{4}}\right]=12\times10^9 q\ N/C$$

193. (a) From symmetry of the figure all corner have same electric potential. Therefore work done in moving the charge q from the corner to the diagonally opposite corner is zero.



194. (c) $T=\sqrt{(mg)^2+(QE)^2}$

$$=\sqrt{(30.7\times10^{-6}\times9.8)^2+(2\times10^{-8}\times20000)^2}=5\times10^{-4}\,N$$

195. (b) Relation for electric field is given by $E=\frac{\lambda}{2\pi\varepsilon_0 r}$

(Given : $E = 7.182\times10^8\ N/C$)

$r = 2\ cm = 2\times10^{-2}\ m$

$$\frac{1}{4\pi\varepsilon_0}=9\times10^{-9}\Rightarrow\lambda=2\pi\varepsilon_0 rE=\frac{2\times2\pi\varepsilon_0 rE}{2}$$

$$=\frac{1\times2\times10^{-2}\times7.182\times10^8}{2\times9\times10^9}=7.98\times10^{-4}\,C/m$$

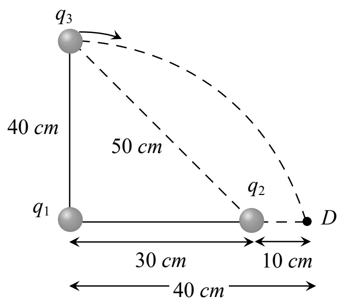
196. (c) $E=\frac{F}{q}=\frac{mg}{e}=\frac{9\times10^{-31}\times9.8}{1.6\times10^{-19}}=5.5\times10^{-11}\,N/C$

197. (b) By using $E=9\times10^9\times\frac{Q}{R^2}$

$$\Rightarrow 3\times10^6=9\times10^9\times\frac{Q}{(3)^2}\Rightarrow Q=3\times10^{-3}\,C$$

198. (a) Since A and B are at equal potential so potential difference between A and B is zero. Hence $W = Q.\Delta V = 0$

199. (a) Change in potential energy $(\Delta U) = U_f - U_i$



$$\Rightarrow \Delta U=\frac{1}{4\pi\varepsilon_0}\left[\left(\frac{q_1q_3}{0.4}+\frac{q_2q_3}{0.1}\right)-\left(\frac{q_1q_3}{0.4}+\frac{q_2q_3}{0.5}\right)\right]$$

$$\Rightarrow \Delta U=\frac{1}{4\pi\varepsilon_0}[8q_2q_3]=\frac{q_3}{4\pi\varepsilon_0}(8q_2)$$

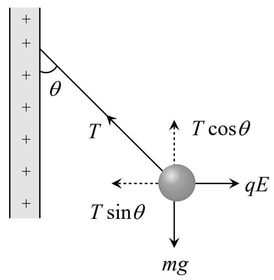
$\therefore k = 8q_2$

200. (b) $T\sin\theta = qE$

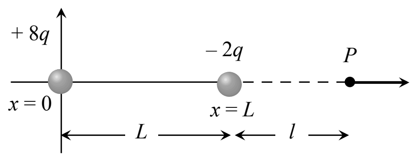
and $T\cos\theta = mg$

$$\Rightarrow \tan\theta=\frac{qE}{mg}=\frac{q}{mg}\left(\frac{\sigma}{2\varepsilon_0}\right)$$

$\Rightarrow \sigma\propto\tan\theta$.



201. (c) The net field will be zero at a point outside the charges and near the charge which is smaller in magnitude.

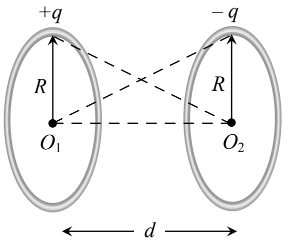


Suppose E.F. is zero at P as shown.

Hence at P; $k.\frac{8q}{(L+l)^2}=\frac{k.(2q)}{l^2} \Rightarrow l = L$.

So distance of P from origin is $L + L = 2L$.

202. (d) Potential at the centre of rings are



$$V_{O_1}=\frac{k.q}{R}+\frac{k(-q)}{\sqrt{R^2+d^2}}, \; V_{O_2}=\frac{k(-q)}{R}+\frac{kq}{\sqrt{R^2+d^2}}$$

$$\Rightarrow \quad V_{O_1}-V_{O_2}=2kq\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$$

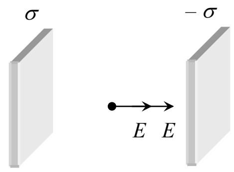
$$=\frac{q}{2\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$$

203. (b) $\vec{E}=-\frac{\sigma}{2\varepsilon_o}\hat{k}-\frac{2\sigma}{2\varepsilon_o}\hat{k}-\frac{\sigma}{2\varepsilon_o}\hat{k}=-\frac{2\sigma}{\varepsilon_o}\hat{k}$

204. (c) Electric field between the plates is

$$=\frac{\sigma}{2\varepsilon_0}-\frac{(-\sigma)}{2\varepsilon_0}$$

$$=\frac{\sigma}{\varepsilon_0}\text{ volt/meter}$$



205. (a) The negative charge oscillates, the resultant force acts as a restoring force and proportional to displacement. When it reaches the plane XY, the resultant force is zero and the mass moves down due to inertia. Thus oscillation is set.

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

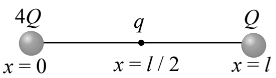
Electric field inside the dielectric sphere $E_{in}=\frac{kQx}{R^3}$ ...(ii)

From (i) and (ii), $E_{in}=E_{out}\times\frac{r^2x}{R}$

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

207. (d) The total force on Q

$$\frac{Qq}{4\pi\varepsilon_0\left(\frac{l}{2}\right)^2}+\frac{4Q^2}{4\pi\varepsilon_0 l^2}=0$$



$$\frac{Qq}{4\pi\varepsilon_0\left(\frac{l}{4}\right)^2}=-\frac{4Q^2}{4\pi\varepsilon_0 l^2} \Rightarrow q=-Q.$$

208. (b) $\text{K.E.}=q_0(V_A-V_B)=1.6\times10^{-19}(70-50)=3.2\times10^{-18}\ J$

209. (b) According to the figure, there is no other charge. A single charge when moved in a space of no field, does not experience any force. No work is done.

$W_A=W_B=W_C=0$

210. (b) Potential V any where inside the hollow sphere, including the centre is $V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$.

Electric Dipole

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

When $\theta = 0$. Potential energy $= -\ pE$ (minimum)

2. (d) Force on charge $F=q(E_a)=q\times\frac{k.2p}{r^3} \Rightarrow F\propto\frac{1}{r^3}$

When $r \to$ doubled; $F \to \frac{1}{8}$ times

3. (b) Electric potential due to dipole in it's general position is given by $V=\frac{k.p\cos\theta}{r^2} \Rightarrow$ $V\propto\frac{1}{r^2}$

4. (d) Potential energy of dipole in electric field $U=-PE\cos\theta$; where θ is the angle between electric field and dipole.

5. (a) As the dipole will feel two forces which are although opposite but not equal.

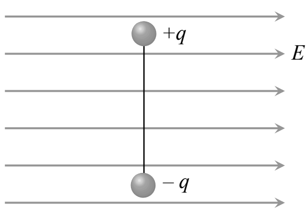
$\therefore$ A net force will be there and as these forces act at different points of a body. A torque is also there.

6. (b) Maximum torque $= pE$

$= 2\times10^{-6}\times3\times10^{-2}\times2\times10^{5}=12\times10^{-3}$ N-m.

7. (d) Work done

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



8. (d) Field along the axis of the dipole

$$E=\frac{1}{4\pi\varepsilon_0}.\frac{2p}{d^3}=\frac{1}{4\pi\varepsilon_0}.\frac{2(q\times r)}{d^3};\ \therefore\ E\propto\frac{qr}{d^3}$$

9. (b) $p = q \times (2l) = 1.6 \times 10^{-19} \times 10^{-10} = 1.6 \times 10^{-29}\ C\text{-}m$

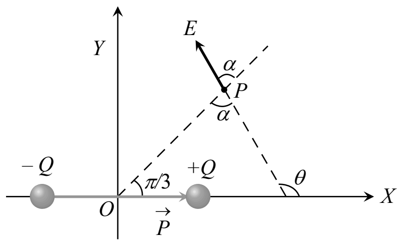
10. (b) $E=\frac{1}{4\pi\varepsilon_0}.\frac{2p}{r^3}$

11. (c) Dipole moment $p = q\ (2l)$

$$= 3.2\times10^{-19}\times(2.4\times10^{-10}) = 7.68\times10^{-29}\ C\text{-}m$$

12. (c)

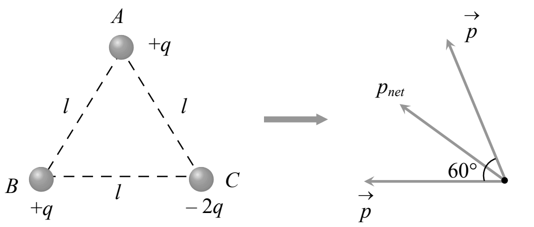
13. (b)



$$\theta=\frac{\pi}{3}+\alpha \text{ where } \tan\alpha=\frac{1}{2}\tan\frac{\pi}{3}$$

$$\Rightarrow \alpha=\tan^{-1}\sqrt{3}/2 \text{ so, } \theta=\frac{\pi}{3}+\tan^{-1}\sqrt{3}/2$$

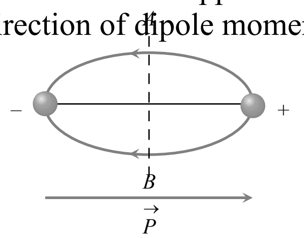
14. (c)



$p_{net}=\sqrt{p^2+p^2+2pp\cos60^\circ}=\sqrt{3}p=\sqrt{3}\,ql$ ($\because$ $p = ql$)

15. (b)

16. (b) The direction of electric field at equatorial point A or B will be in opposite direction, as that of direction of dipole moment.



17. (d) Dipole moment $p = 4 \times 10^{-8} \times 2 \times 10^{-4} = 8 \times 10^{-12}\ m$

Maximum torque $= pE = 8 \times 10^{-12} \times 4 \times 10^{8} = 32 \times 10^{-4}\ Nm$

Work done in rotating through $180^\circ = 2pE = 2 \times 32 \times 10^{-4} = 64 \times 10^{-4}\ J$

18. (b) We have $E_a=\frac{2kp}{r^3}$ and $E_e=\frac{kp}{r^3}$; $\therefore E_a=2E_e$

19. (d) Point charge produces non-uniform electric field.

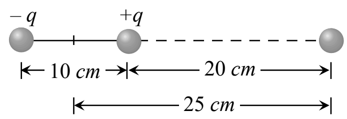
20. (d) $E_{equatorial}=\frac{kp}{r^3}$ *i.e.* $E\propto p$ and $E\propto r^{-3}$

21. (d) $E_{axial}=E_{equatorial}\Rightarrow\quad k.\frac{2p}{x^3}=\frac{k.p}{y^3}\quad\Rightarrow$

$$\frac{x}{y}=\frac{2^{1/3}}{1}=\sqrt[3]{2}:1$$

22. (c) In uniform electric field dipole experience only torque, but no force.

23. (a)



By using $E=9\times10^9.\frac{2pr}{(r^2-l^2)^2}$; where

$p = (500 \times 10^{-6}) \times (10 \times 10^{-2}) = 5 \times 10^{-5}\ c\times m$,

$r = 25\ cm = 0.25\ m$, $l = 5\ cm = 0.05\ m$

$$E=\frac{9\times10^9\times2\times5\times10^{-5}\times0.25}{\{(0.25)^2-(0.05)^2\}^2}=6.25\times10^7\ N/C$$

24. (a)

25. (a) $V=9\times10^9.\frac{p}{r^2}$

$$=9\times10^9\times\frac{(1.6\times10^{-19})\times1.28\times10^{-10}}{(12\times10^{-10})^2}=0.13V$$

26. (d) $V=\frac{p\cos\theta}{r^2}$ If $\theta = 0^\circ$ then $V_a=\max$.

If $\theta=180^\circ$ then $V_e=\min$.

27. (d) Potential due to dipole in general position is given by

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

28. (c) In the given condition angle between $\vec{p}$ and $\vec{E}$ is zero. Hence potential energy $U=-pE\cos0=-pE=\min$.

Also in uniform electric field $F_{net} = 0$.

29. (b)

30. (b) $E_a=k\frac{2p}{r^3}$ and $E_E=\frac{kp}{r^3}\Rightarrow\frac{E_a}{E_E}=\frac{2}{1}$

31. (c) $\tau_{max}=pE=q(2l)E=2\times10^{-6}\times0.01\times5\times10^5$

$$=10\times10^{-3}\ N\text{-}m$$

32. (d) $W=PE(1-\cos\theta)$ here $\theta = 180^\circ$

$\therefore W = PE(1-\cos180^\circ) = PE[1-(-1)]=2PE$

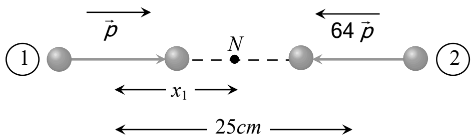
33. (a) $U = -PE\cos\theta$

It has minimum value when $\theta = 0^o$

i.e. $(U)_{\min} = -PE \times \cos 0^o = -PE$

34. (b) Stationary electric dipole has electric field only.

35. (a) Suppose neutral point N lies at a distance x from dipole of moment p or at a distance x_2 from dipole of 64 p.



At N |E. F. due to dipole ①|= |E. F. due to dipole ②|

$\Rightarrow \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{x^3} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2(64\,p)}{(25-x)^3}$

$\Rightarrow \frac{1}{x^3} = \frac{64}{(25-x)^3} \Rightarrow x = 5\ cm.$

36. (a)

37. (b) Potential energy of electric dipole

$U = -pE\cos\theta \ = -(q \times 2l)E\cos\theta$

$U = -(3.2\times10^{-19}\times 2.4\times 10^{-10})4\times10^5\cos\theta$

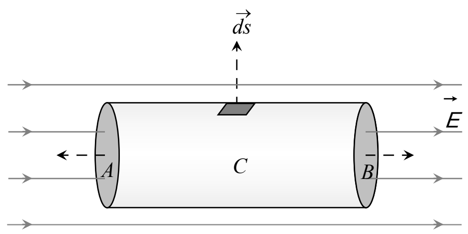
$U = -3\times10^{-23}$ (approx.)

38. (c) The direction of electric field intensity at a point on the equatorial line of the dipole is opposite to the direction of dipole moment.

39. (c) When the dipole is rotated through at an angle of 90° about it's perpendicular axis then given point comes out to be on equator. So field will become E / 2 at the given point.

Electric Flux and Gauss's Law

1. (d) Flux through surface A $\phi_A = E\times\pi R^2$ and $\phi_B = -E\times\pi R^2$



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

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

2. (c) $E = \sigma/(2\varepsilon_0)$

3. (a) By Gauss's theorem.