Electrostatics

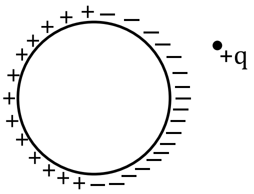
SOLUTIONS

Exercise-I (Conceptual Questions)

1. $N = \frac{Q}{e}$, if N is not an integer then Q is not possible.

2. Charge is quantized it always present in integral multiple of elementary charge.

3.



Net charge = 0

4. $F \propto q_1 q_2$

$F \propto q_2$ ...(i) $[q_1 = q_2]$

50% charge, transferred from one to another sphere.

$$q_1' = q + \frac{q}{2} = \frac{3q}{2} \Rightarrow q_2' = q - \frac{q}{2} = \frac{q}{2}$$

$$F' \propto \left(\frac{3q}{2}\right)\left(\frac{q}{2}\right) \propto \frac{3}{4}q^2 \quad ...(ii)$$

From (i) & (ii)

$$F' = \frac{3}{4}F$$

5. $F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$ .....(1)

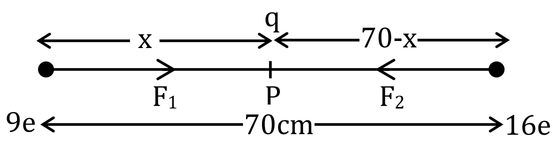
$F' = \frac{1}{4\pi\epsilon_0 K}\frac{q_1q_2}{r'^2}$ .....(2)

F' = F

$$\frac{1}{4\pi\epsilon_0 K}\frac{q_1q_2}{r'^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

$$r' = \frac{r}{\sqrt{k}}$$

6.



For charge, which placed at point P :-

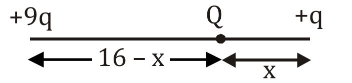
$F_{net} = 0$

$F_1 = F_2$

$$\frac{k(9e)(q)}{x^2} = \frac{k(16e)(q)}{(70-x)^2}$$

$\Rightarrow$ x = 30 cm from 9e or 40 cm from 16e.

7.



$$\frac{kqQ}{x^2} = \frac{k(9q)Q}{(16-x)^2};\ \frac{1}{x} = \frac{3}{16-x}$$

x = 4 cm from (+q) and 12 cm from (+9q)

8.

$$F = \frac{k(7\mu C)(-5\mu C)}{x^2}$$

After adding $(-2\mu C)$ charge

$$F' = \frac{k(5\mu C)(-7\mu C)}{x^2} = F$$

9. $F = \frac{kQ^2}{r^2} \Rightarrow 0.144 = \frac{9\times10^9 Q^2}{(5\times10^{-2})^2}$

$$Q^2 = \frac{0.144\times25\times10^{-4}}{9\times10^9} = \frac{144\times25}{9}\times10^{-16}$$

$$Q = \frac{12\times5}{3}\times10^{-8} = 0.2 \times 10^{-6}\text{ C.}$$

10. $F_1 = \frac{k(2\mu C)(6\mu C)}{x^2}$ = 12N repulsion

After adding charge $(-4\mu C)$

$F_2 = \frac{k(-2\mu C)(2\mu C)}{x^2}$ = –4N attractive

11. $\frac{kq^2}{R^2} = \frac{GM_eM_m}{R^2}$

$q = \sqrt{\frac{6.67\times10^{-11}\times10^{25}\times10^{23}}{9\times10^9}}$ = 8.6×10^{13} C

12. Electrostatic force b/w two charge particles does not affected due to presence or absence of another charges.

13. $Q = Q_1 + Q_2$

$$F = \frac{kQ_1Q_2}{R^2} = \frac{kQ_1(Q-Q_1)}{R^2}$$

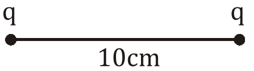
For maximum repulsion $\frac{dF}{dQ_1} = 0$

$$\therefore \frac{k}{R^2}\frac{d}{dQ_1}(Q_1Q - Q_1^2) = \frac{k}{R^2}(Q - 2Q_1) = 0$$

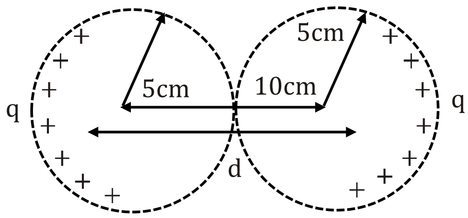
$Q - 2Q_1 = 0$; $Q_1 = \frac{Q}{2}$

$Q_2 = Q - Q_1 = \frac{Q}{2}$

14.



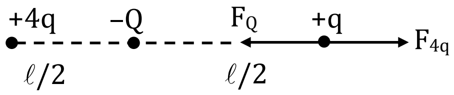
$$f=\frac{Kq^2}{(0.1)^2}$$



$$f'=\frac{Kq^2}{\left(d\times10^{-2}\right)^2}<f$$

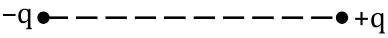
charges moves away from each other due to repulsion force thats why separation b/w them increases and force decreases

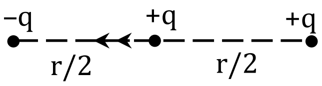
15.



$$\Rightarrow\frac{k.4q.q}{\ell^2}=\frac{kqQ}{(\ell/2)^2}\Rightarrow Q=q\text{ (but unlike)}$$

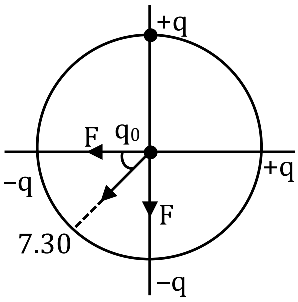
16. $F=\frac{kq^2}{r^2}$.



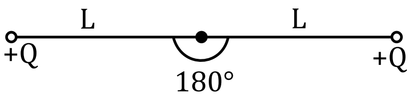


$$F'=\frac{kq.q}{(r/2)^2}+\frac{kq.q}{(r/2)^2}=8\frac{kq^2}{r^2}=8F\ \text{(towards }-q)$$

17.



18.

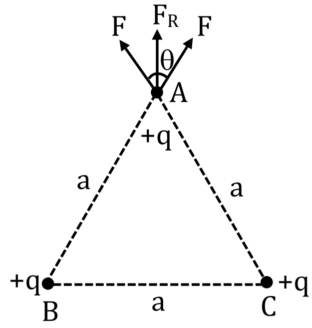


$F=\frac{kQ^2}{4L^2}$ (No. gravitational effect)

19. Wrong statement $\rightarrow$ 2

Proton and Neutron bound by neuclear force which is most powerful force in short range.

20.



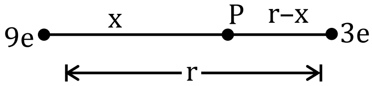
F_R = 2F Cos θ/2,

where θ = 60°

$$=2\left(\frac{kq^2}{a^2}\right)\cos30°$$

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

21.

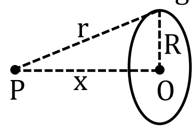


$$x=\frac{\sqrt{9}}{\sqrt{9}+\sqrt{3}}\quad r=\frac{3r}{3+\sqrt{3}}$$

$$x=\frac{r}{1+\sqrt{3}/3}=\frac{r}{1+1/\sqrt{3}}$$

From 9e charge

22.



$$E=\frac{kQx}{\left(R^2+x^2\right)^{3/2}}$$

$r^2 = R^2 + x^2$

$x^2 = r^2 - R^2$

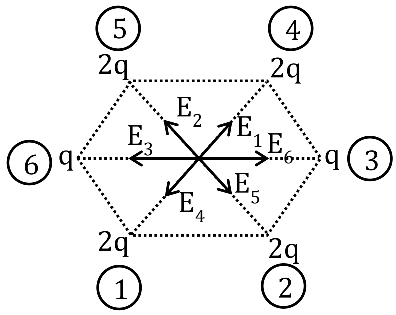
23. $E=\frac{k(2\mu C)}{(1/2)^2}-\frac{k(1\mu C)}{(1/2)^2}$

$= 8 \times 9 \times 10^9 \times 10^{-6} - 4 \times 9 \times 10^9 \times 10^{-6}$

$= 3.6 \times 10^4$ N/C

24. $E=\frac{K}{x^3}, K=Ex^3=\frac{N}{C}\times m^3$

25.



In case III

$$E_1 = E_2 = E_4 = E_5 = \frac{2kq}{r^2}$$

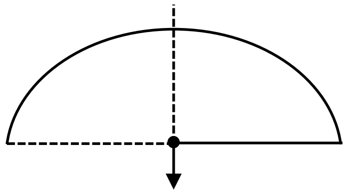
$$E_3 = E_6 = \frac{kq}{r^2}$$

$E_{net} = 0$

26. $E = \frac{2k\lambda}{a}\sin\alpha/2$, where $\alpha = 180°$

$$= \frac{2k\lambda}{a}\sin 90° = \frac{\lambda}{2\pi\epsilon_0 a}$$

27.

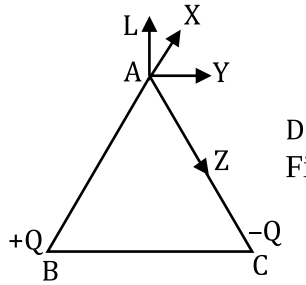


$\leftarrow \lambda = \frac{Q}{\pi R}$

$$= \frac{2k\lambda}{R} = \frac{2\times 9\times 10^{9}\times 1.4\times 10^{-9}}{3.14\times 0.5\times 0.5}$$

$= 32$ v/m

28.



Direction of electric Field towards AY

29. For balancing cond^n

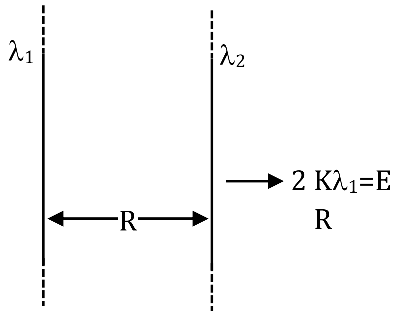
qE = mg

$$E = \frac{mg}{q} = \frac{10^{-6}\times 10}{1\times 10^{-6}}$$

$E = 10\frac{V}{m}$ downward

30. $\tan\theta = \frac{F_e}{mg} = \frac{kQ^2}{x^2 mg}$

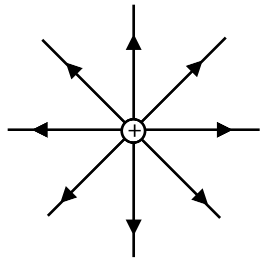
31.



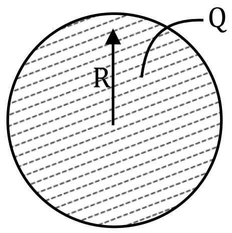
Force per unit length

$$\frac{F}{\ell} = E\lambda_2 = \frac{2k\lambda_1\lambda_2}{R}$$

32.



33.



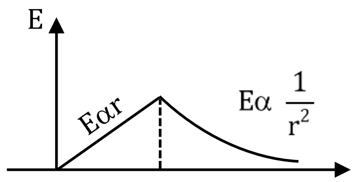
inside $E = \frac{kQr}{R^3}$; outside $E = \frac{kQ}{r^2}$

34. Electrostatic field lines never make closed loop.

35. $Q = \frac{q_{in}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$

36. $E_{inside} = \frac{kQr}{R^3}$ $\quad E \propto r \quad 0 < r < R$

$E_{outside} = \frac{kQ}{r^2}$ $\quad E \propto \frac{1}{r^2} \quad R < r < \infty$



37. $\phi \propto q$ ...(i)

After addition flux becomes ϕ'.

$\phi' \propto \theta'$ ...(ii)

$$\frac{\phi'}{\phi} = \frac{q^1}{q} = \frac{100}{20} = 5$$

$\phi' = 5\phi$

change influx $\Delta\phi = \phi' - \phi = 4\phi$

38. $\vec{E} = 8\hat{i} + 4\hat{j} + 3\hat{k}$

$\vec{A} = 100\,\hat{k}$

$\phi = \vec{E}\cdot\vec{A} = (8\hat{i}+4\hat{j}+3\hat{k})\cdot(100\hat{k})$

$\phi = 300$ unit

i & $\hat{j}$ component of E.F. do not give flux in the given area.

39. $\phi = \frac{\text{total enclosed charge}}{\epsilon_0} = \frac{100Q}{\epsilon_0}$

40. In case of net charge is zero then incoming lines = outgoing lines

41. $E_1 = \dfrac{kQ}{r_1^2}$

$E_2 = \dfrac{kQr_2}{R^3}$

$\dfrac{E_2}{E_1} = \dfrac{r_2 . r_1^2}{R^3} = 120\ V/m$

42. $\phi = \dfrac{q_{in}}{\varepsilon_0}$

$q_{in} = (\phi_2 - \phi_1) \times \varepsilon_0$

43. $\vec{E} = (5\hat{i} + 2\hat{j})\ N/C$

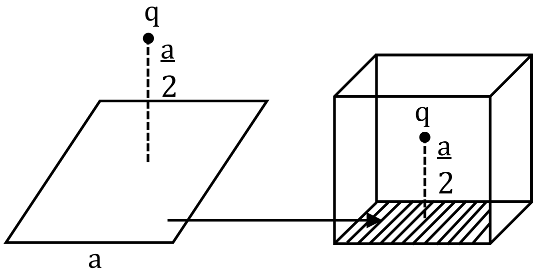
$\vec{A}$ = $2m^2$ in y-z plane = $2m^2\ \hat{i}$

$\phi = \vec{E} \cdot \vec{A}$ = 10 units

44. $\phi = \dfrac{1}{8\epsilon_0}(\Sigma q) = \dfrac{1}{8\epsilon_0}(36\mu C)$

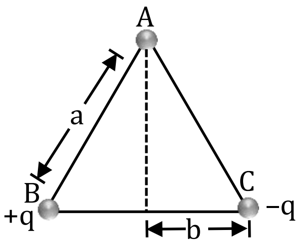
$= \dfrac{4\pi \times 9 \times 10^9}{8} \times 36 \times 10^{-6}$

= $162\pi \times 10^3 Nm^2/C$

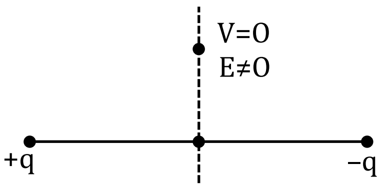
45. 

net flux through cube = $\dfrac{q}{\varepsilon_0}$

than flux through base = $\dfrac{q}{6\varepsilon_0}$

46. 

$V_A = \dfrac{k(+q)}{a} + \dfrac{k(-q)}{a} = 0$

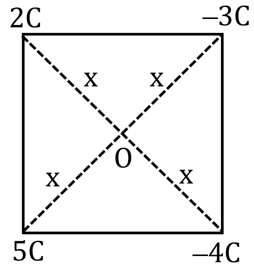
47. 

48. Inside potential = potential at surface

49. remain same (equipotential surface)

50. uniform

51. Potential difference between outer and inner spheres doesn't depend upon the charge given to outer sphere hence remain same.

52. 

$V_0 = \dfrac{k(2C)}{x} + \dfrac{k(-3C)}{x} + \dfrac{k(-4C)}{x} + \dfrac{k(5C)}{x}$

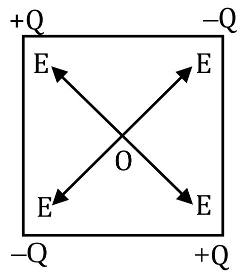
$V_0 = 0,\ E_0 \neq 0$

53. $\displaystyle\int_{\ell=-\infty}^{0} -\vec{E}.d\vec{\ell} = \dfrac{kq}{R} = V_0$

$V_0 = \dfrac{kq}{R} = \dfrac{9 \times 10^9 \times 1.11 \times 10^{-10}}{0.5} = 2\ volt$

54. E inside = 0

55. $V = \dfrac{kQ}{R}$ $(V_{in} = V_S)$

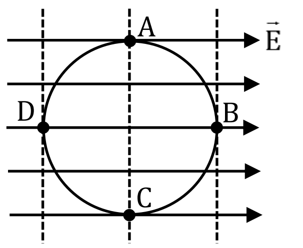
56. 

E = 0 ; V = 0

57. $V_{10} - V_{20} = -\displaystyle\int_{20}^{10} \vec{E}.d\vec{x}$

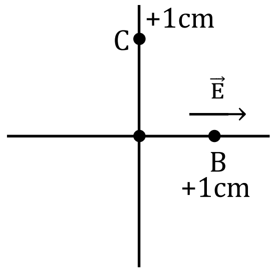
$V_{10} - V_{20} = -\displaystyle\int_{20}^{10} \left(\dfrac{100}{x^2}\right) dx = 100\left[\dfrac{1}{x}\right]_{20}^{10}$

$= 100\left[\dfrac{1}{10} - \dfrac{1}{20}\right] = 5\ volt$

58. 

$V_D > V_A = V_C > V_B$

Along the direction of E.F., potential decreases.

59. 

Along direction of E.F. potential decrease then $(V_A = V_C > V_B)$

60. $E = -\frac{dV}{dx} = -10x + 10 = 0$

61. $\frac{kQ}{r} = 600$ ...(i) $\qquad \frac{KQ}{r^2} = 200$ ...(ii)

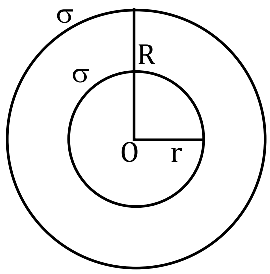
From (i) & (ii)

$200r^2 = 600r$

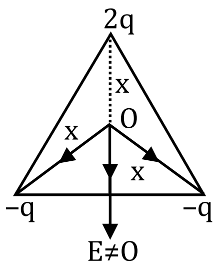
$r = 3$

from (i)

$Q = \frac{600\times3}{9\times10^9} = 2 \times 10^{-7}\ C = 0.2\mu C$

62. 

$V_0 = \frac{k(\sigma 4\pi r^2)}{r} + \frac{k(\sigma 4\pi R^2)}{R} = \frac{\sigma}{\varepsilon_0}(r+R)$

63. 

$V = \frac{k(2q)}{x} + \frac{k(-q)}{x} + \frac{k(-q)}{x}$

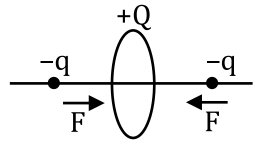
$V = 0$

But $E \neq 0$

64. $\Delta V = -\vec{E}\cdot\vec{dx} = Ed\cos 60$

65. $\vec{E} = -\frac{dV}{dx}\hat{i} - \frac{dV}{dy}\hat{j} - \frac{dV}{dz}\hat{k} = -6\hat{i} + 8\hat{j}$

$\Rightarrow |\vec{E}| = 10 \Rightarrow |\vec{F}| = q|\vec{E}| = 20N$

66. 

(i) Displacement is not small so no SHM execution

(ii) e^-s move from lower to higher potential.

67. $E_1 = \frac{KQ_1}{r_1^2} \qquad E_2 = \frac{KQ_2}{r_2^2}$

$\because \ E_1 = E_2$

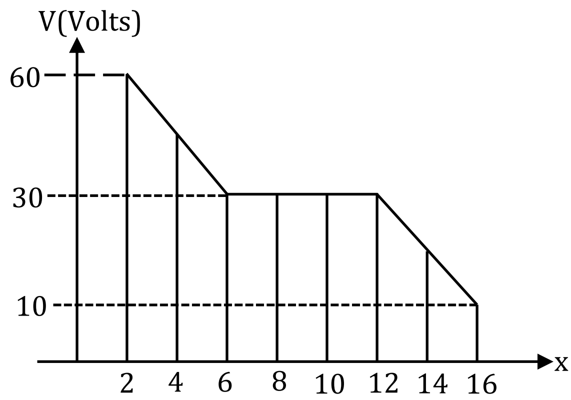
$\frac{Q_1}{r_1^2} = \frac{Q_2}{r_2^2}$

$V_1 = \frac{kQ_1}{r_1} \qquad V_2 = \frac{kQ_2}{r_2}$

$\frac{V_1}{V_2} = \frac{Q_1}{r_1}\left(\frac{r_2}{Q_2}\right) = \frac{r_2}{r_1}\left(\frac{r_1}{r_2}\right)^2 = \frac{r_1}{r_2}$

68. $\Delta V = \left|\frac{KQ}{3r} - \frac{KQ}{r}\right| = \frac{2KQ}{3r} = V \Rightarrow KQ = \frac{3Vr}{2}$

$E = \frac{KQ}{9r^2} = \frac{3Vr}{2(9r^2)} = \frac{V}{6r}$

69. 

$E = -\frac{dV}{dx}$ (–ve slope of V-x curve)

electric field at 13m is

$= \frac{30-10}{16-12} = \frac{20}{4} = 5(V/m)$

70. Electric field is directed from high potential to low potential.

71. Points A,B, C,D, E are equal distance from charge Q (at centre) so :- (Equipotential points)

$V_A = V_B = V_C = V_D = V_E = V$

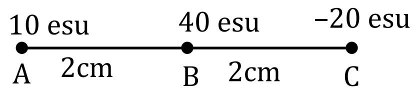
$W = q\,(V_f - V_i)$

$= q\,(V - V)$

$= 0$

72. Option (4) is incorrect

73.



$U_A = q_A V_A = 10\left[\dfrac{kq_B}{r_1}+\dfrac{kq_C}{r_2}\right]$

$=10\left[\dfrac{1\times(40)}{2}+\dfrac{1\times(-20)}{4}\right]=150\text{ ergs}$

74. For closed path : -

$W_{AB} + W_{BC} + W_{CA} = 0$

$2 + (-3) + W_{CA} = 0$

$W_{CA} = +1\text{ J}$

75. $W = Q\,(V_B - V_A)$

$15 = 0.01\,(V_B - V_A)$

$V_B - V_A = 1500\text{ V}$

76. $F = qE = q\dfrac{\Delta V}{d}$

$2000 = 5 \times \dfrac{\Delta V}{2\times10^{-2}} \Rightarrow \Delta V = 8\text{ volt}$

77. Depending upon nature of charges, may increase or may decrease.

78. Velocity will be decreased.

79. $qE = mg$

$a = \dfrac{qE}{m}$ $\quad(q,E \rightarrow \text{constant})$

$\boxed{a \propto \dfrac{1}{m}} \Rightarrow \dfrac{a_e}{a_p} = \dfrac{m_p}{m_e}$

80. speed of charge after time 't'

$v = u + at$, where $u = 0$ and $a = \dfrac{qE}{m}$

$v = \left(\dfrac{qE}{m}\right)t$

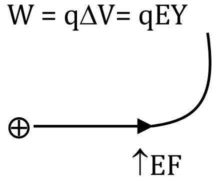
so $KE = \dfrac{1}{2}mv^2 = \dfrac{1}{2}m\left(\dfrac{qEt}{m}\right)^2$

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

81. $\Delta V = EY$

$W = q\Delta V = qEY$

82.



direction of E.F. will be down to top

$3\oplus \Rightarrow \uparrow$

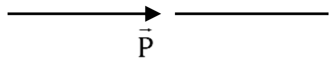
$2\ominus \Rightarrow \downarrow$ $\qquad 4\ominus \Rightarrow \downarrow$

83. $P = q\,d$

$= 10^{-10} \times 1 \times 10^{-8}$

$= 10^{-18} = 1\text{ debye}$

84.



$V = \dfrac{kP}{r^2}$ $\qquad E = \dfrac{2kP}{r^3}$

$V \propto \dfrac{1}{r^2}$ $\qquad E \propto \dfrac{1}{r^3}$

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

$\tau = PE\sin\theta$

for maximum value $\theta = 90°$

86. $E_{axial} = \dfrac{2kp}{r^3}$

$E_{equitorial} = \dfrac{kp}{r^3}$

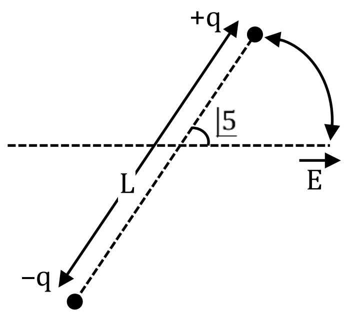
$\dfrac{E_{axial}}{E_{equtorial}} = \dfrac{2}{1}$

87. $P = qd = 2 \times 10^{-8}$ (C–m)

for maximum $\theta = 90° \Rightarrow \sin\theta = 1$

$\tau = PE = 10 \times 10^{-3}$ Nm

88.



$I\alpha = -pE\sin\theta$

for small angle $\sin\theta \simeq \theta$

$I\alpha = -pE\theta$

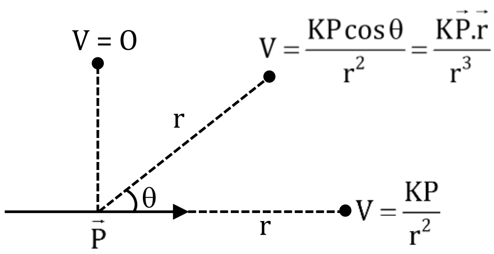
$\alpha = -\left(\dfrac{pE}{I}\right)\theta = -\omega^2\theta$

Hence $\omega = \sqrt{\dfrac{pE}{I}}$

$T = 2\pi\sqrt{\dfrac{I}{pE}}$

$= 2\pi\sqrt{\dfrac{ML^2/2}{qLE}} = 2\pi\sqrt{\dfrac{ML}{2qE}}$

89.



90. $F \propto \frac{1}{d^3}$

$F' = F/8$

91. $V = \frac{kp\cos\theta}{r^2}$

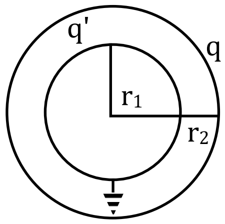
92. τ may be zero because it depends upon angle.

93. Same charge induced in both spheres.

($\varepsilon_r \to$ same)

94. Direction of charge flow from inside to outside in conducting concentric hollow metallic spheres.

95.



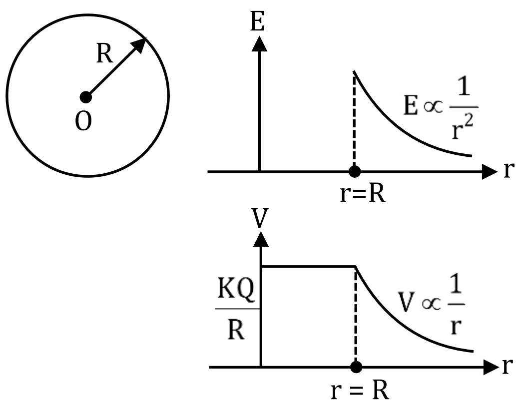
Potential of inner sphere in zero due to earthing V = 0

$$\frac{Kq}{r_2} + \frac{Kq'}{r_1} = 0 \Rightarrow q' = -\frac{qr_1}{r_2}$$

96. Minimum PE $\to$ more stability

97. electric field lines perpendicular to the conducting material.

98.



Exercise-II (Previous Year Questions)

1. For conducting sphere

At centre, E = 0 & V = $\frac{Q}{4\pi\epsilon_0 R}$

2. $\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$

$= -[(6 - 8y)\,\hat{i} + (-8x - 8 + 6z)\,\hat{j} + (6y)\,\hat{k}\,]$

At (1, 1, 1), $\vec{E} = 2\hat{i} + 10\hat{j} - 6\hat{k}$

$\Rightarrow \quad (\vec{E}) = \sqrt{2^2 + 10^2 + 6^2} = \sqrt{140} = 2\sqrt{35}$

Force = qE = 2 × $2\sqrt{35}$ = $4\sqrt{35}$ N

3. Flux linked with sphere $= \vec{E}.d\vec{s}$

since electric field is radial. It is always perpendicular to the surface.

so $\quad \phi = Ar.(4\pi r^2)$

$\phi = A(a)(4\pi r^2) \qquad$ (as r = a)

$\phi = A4\pi a^3$

Now according to gauss law

$\phi = \frac{q_{in}}{\epsilon_0} \Rightarrow q_{in} = \phi.\epsilon_0$

So $q_{in} = A4\pi a^3\,\epsilon_0$

4. $\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$

$\vec{E} = -(6y)\hat{i} - (6x - 1 + 2z)\hat{j} - (2y)\hat{k}$

at point (1,1,0)

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

5. τ = pE sinθ

τ = qℓ E sin θ

$4 = q \times 2 \times 10^{-2} \times 2 \times 10^5 \sin 30°$

$\Rightarrow$ q = 2 mC

6. W = qΔV

as ΔV is same in all conditions, work will be same.

7. $\frac{K \times (\Delta e)^2}{r^2} = \frac{Gm^2}{r^2}$

$\Delta e = m\sqrt{\frac{G}{K}} = 1.67 \times 10^{-27}\sqrt{\frac{6.67 \times 10^{-11}}{9 \times 10^9}}\,C$

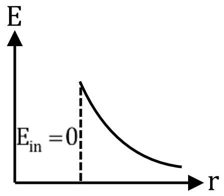
$= 1.436 \times 10^{-37}$ C

8. $S = ut + \frac{1}{2}at^2$

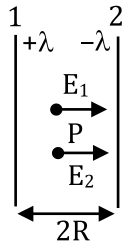
$h = 0 + \frac{1}{2}\left(\frac{qE}{m}\right)t^2 \Rightarrow t = \sqrt{\frac{2hm}{qE}} \Rightarrow t \propto \sqrt{m}$

as mass of proton is heavier than electron, hence electron will take less time.

9. For a metal sphere $E_{in} = 0$ and $\vec{E}_{out} = \frac{Kq}{r^2}\hat{r}$



10.



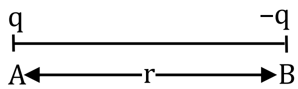
$\vec{E} = \vec{E}_1 + \vec{E}_2$

$E = E_1 + E_2$

$E = \frac{\lambda}{2\pi\epsilon_0 R} + \frac{\lambda}{2\pi\epsilon_0 R}$

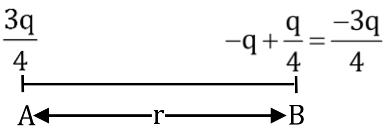
$E = \frac{\lambda}{\pi\epsilon_0 R}$ N/C

11.



$F = \frac{-Kq^2}{r^2}$

25% charge from A is transferred to B



New force (F') = $\frac{K\left(\frac{3q}{4}\right)\left(\frac{-3q}{4}\right)}{r^2} = \frac{-9}{16}\frac{kq^2}{r^2} = \frac{9F}{16}$

12. $\phi = \frac{q_{in}}{\epsilon_0} = 0$

13. $V = \frac{kP\cos\theta}{r^2} = \frac{9\times10^9\times16\times10^{-9}(1/2)}{(0.6)^2} = 200V$

14. Potential is constant throughout the volume

$\therefore$ Electric field is zero.

15. $E = \frac{kQ}{r^2} = \frac{9\times10^9\times3.2\times10^{-7}}{(15\times10^{-2})^2}$

$E = 1.28 \times 10^5$ N/C

16. Electric field in equatorial plane

$\vec{E} = -\frac{k\vec{p}}{r^3}$

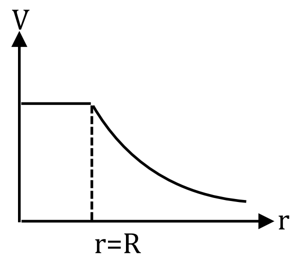
$\vec{E} = -\frac{\vec{p}}{4\pi\epsilon_0 r^3}$

17. $F = K\frac{e^2}{r^2} \Rightarrow a = K\frac{e^2}{mr^2}$

$\Rightarrow a = 9\times10^9\frac{(1.6\times10^{-19})^2}{(1.6\times10^{-10})^2(9\times10^{-31})}$

$\Rightarrow a = 10^{-29} \times 10^{51} = 10^{22}$ m/s²

18. $V_{in} = V_S = \frac{KQ}{R}$ and $V_{out} = \frac{KQ}{r}(r > R)$

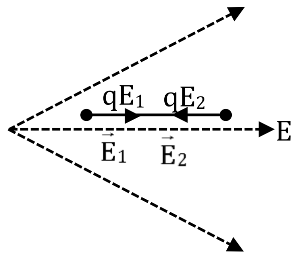


19. $|\vec{E}_1| > |\vec{E}_2|$

as field lines are closer at charge +q,

So, net force on the dipole acts towards right side.

Also, a system always moves to decrease its potential energy.



20. For a conducting sphere

$E = \frac{\sigma}{\epsilon_0}$

$V = \frac{\sigma R}{\epsilon_0}$

as both spheres have same potential after connecting with wire,

$V_1 = V_2$

$\sigma_1 R_1 = \sigma_2 R_2$

$\Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$

21. Volume conservation

$$\frac{4}{3}\pi R^3 = 27\left(\frac{4}{3}\pi r^3\right) \Rightarrow R = 3r \qquad ...(1)$$

and $V = \frac{Kq}{r} \Rightarrow \frac{V_1}{V_2} = \left(\frac{q_1}{q_2}\right)\left(\frac{r_2}{r_1}\right)$

$$\Rightarrow \frac{220}{V_2} = \left(\frac{q}{27q}\right)\left(\frac{3r}{r}\right)$$

$$\Rightarrow \frac{220}{V_2} = \frac{1}{9}$$

$\Rightarrow V_2 = 220 \times 9 = 1980$ Volt

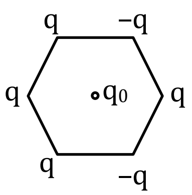
22. Electric field is always perpendicular to EPS.

23. It is electric dipole at large distance electric field intensity

$$E = \frac{KP}{R^3}\sqrt{1+3\cos^2\theta}$$

$$\therefore\ E \propto \frac{1}{R^3}$$

24.



Work = $U_f - U_i$

= 0 – 0

Work = 0

25. τ on a dipole = $\vec{p} \times \vec{E}$

$\tau = pE\sin\theta$

$4 = q \times \ell \times E \times \sin 30°$

$$4 = q \times 2 \times 10^{-2} \times 2 \times 10^{5} \times \frac{1}{2}$$

$q = 2 \times 10^{-3}$

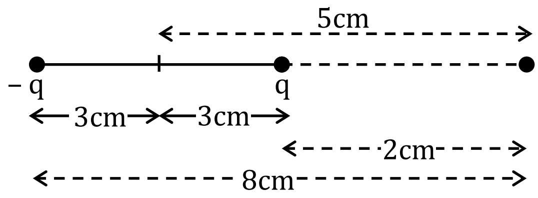
q = 2 mC

26. $\phi_{closed} = 0$

So $\phi_{in} = \phi_{out}$

Number of field lines entering is equal number of field lines leaving.

27.



$$v = \frac{Kq}{2\times10^{-2}} - \frac{Kq}{8\times10^{-2}}$$

$$= Kq\left[\frac{3}{8}\right] \times 10^{2}$$

28. $\phi = \frac{q_{inside}}{\varepsilon_0}$

only depends on charge enclosed by surface.

29. Total flux from cube = $\frac{q}{\varepsilon_0}$

$\therefore$ So flux of any one surface of cube

$$= \frac{q}{6\varepsilon_0} = \frac{Q\times10^{-6}}{6\varepsilon_0}$$

30. $\therefore V = \frac{KQ}{R}$

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

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

31. $V_{dipole} = \frac{kp\cos\theta}{r^2}$

at axis ($\theta = 0°$ or $180°$)

$$V_{Axis} = \pm\frac{kp}{r^2} = \pm\frac{9\times10^{9}\times4\times10^{-6}}{2^2}$$

$$= \pm 9\times10^{3}\,V$$

A $\rightarrow$ Correct

R $\rightarrow$ False. $\because V = \pm\frac{p}{4\pi\varepsilon_0 r^2}$

32. Shell is equipotential surface

So, $V_p = V_c$

$\therefore$ Potential Difference = 0

33. $\sigma = \frac{Q}{A} = \frac{6\times10^{-6}}{6\times5\times5\times10^{-4}}$

$$= \frac{1}{25}\times10^{-2}$$

$= 4 \times 10^{-4}$

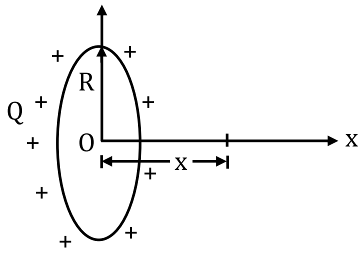
$= 0.4 \times 10^{-3}$ C/m²

34. $V = \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{r}$

$V = \dfrac{9\times10^{9}\times4\times10^{-7}}{9\times10^{-2}}$

V = 4 × 10^4 Volt

Exercise-III (Analytical Questions)

1. 

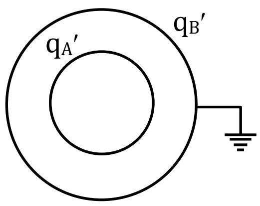
$E = \dfrac{KQx}{\left(R^2+x^2\right)^{3/2}}$, for (x, 0, 0)

E = 0 & $V = \dfrac{KQ}{R}$ at centre/origin.

2. |q| ∝ No. of ELF

Neutral point of system of two unlike charges is outside the line joining the two charges near to & near the charge of smaller magnitude.

3. ∵ Both are unlike so neutral point exist outside & near the smaller charge.

4. 

$2V = \dfrac{kq_A}{R} + \dfrac{kq_B}{2R}$

$\dfrac{3V}{2} = \dfrac{k(q_A+q_B)}{2R}$

on solving

$\dfrac{q_A}{q_B} = \dfrac{1}{2}$

$V_B = 0$

$\dfrac{kq'_A}{b} + \dfrac{kq'_B}{b} = 0$

$q'_B = -q_A'$

$\dfrac{|q'_A|}{|q'_B|} = 1$

5. Charge particle is in stable equilibrium if it is displaced along y-axis.

6. Think according to options.

7. For infinite non-conducting sheet ; $E = \dfrac{\sigma}{2\varepsilon_0}$

For infinite conducting sheet ; $E = \dfrac{\sigma}{\varepsilon_0}$

For non conducting sphere (at surface) ;

$E = \dfrac{\rho R}{3\varepsilon_0}$

For non conducting sphere at centre ; E = 0

8. Charge can't exist without mass, but mass can exist without charge. Charge is conserved but mass is not conserved.

9. $[F] = [MLT^{-2}]$

∵ $F = \dfrac{E}{q}$

∴ $E = \dfrac{MLT^{-2}}{AT}$ ⇒ $E = [MLT^{-3}A^{-1}]$

ε_r is dimensionless

$F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{r^2} \Rightarrow \varepsilon_0 = \dfrac{[A^2T^2]}{[MLT^{-2}][L^2]}$

$= [M^{-1}L^{-3}A^2T^4]$

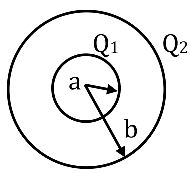
10. $V_{R/2} = \dfrac{kQ}{2R^3}\left[3R^2 - \left(\dfrac{R}{2}\right)^2\right] = \dfrac{kQ}{2R^3}\left(\dfrac{11R^2}{4}\right)$

$V_{R/2} = \dfrac{11kQ}{8R} = \dfrac{11V}{8}$; $V_S = \dfrac{kQ}{R}$

$V_{2R} = \dfrac{kQ}{2R} = \dfrac{V}{2}$

$E_{R/2} = \dfrac{kQ}{R^3}\dfrac{R}{2} = \dfrac{kQ}{2R^2} = \dfrac{V}{2}$ (R = 1m)

$E_{2R} = \dfrac{kQ}{(2R)^2} = \dfrac{V}{4}$

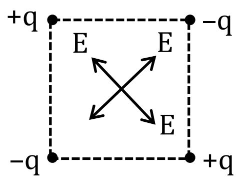
11. 

$\Delta V = KQ_1\left(\dfrac{1}{a} - \dfrac{1}{b}\right)$ does not depends on outer charge.

$E_{in} = \dfrac{KQ_1}{a^2}$ does not depends on outer charge.

12. Direction of force depends on nature of charge.

13. Potential depends on frame of reference while potential difference is a absolute.

14. 

$E = 0, V = \frac{Kq}{x} + \frac{Kq}{x} - \frac{Kq}{x} - \frac{Kq}{x} = 0$

It is not necessary that if potential is zero then electric field is also zero.

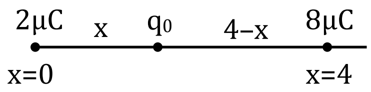
15. Extra charge on aircraft body due to air friction is transferred to ground.

16. Electric field can not enter in conductor.

17. Charge of isolated body can not be changed.

18. Net flux is due to inside charges but electric field is due to all charges.

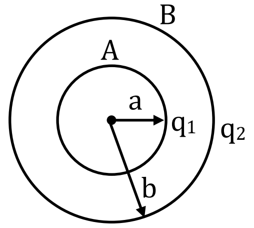
19. There is loss / gain of electrons so mass may decrease or increase.

22. 

$\frac{k2q_0}{x^2} = \frac{k8q_0}{(4-x)^2}; \quad \frac{1}{x} = \frac{2}{4-x}$

4−x = 2x; 3x=4

$x = \frac{4}{3} = \frac{\alpha}{\beta} \Rightarrow \alpha + \beta = 4 + 3 = 7$

24. 

$V_A = \frac{q_2}{b} + \frac{q_1}{a}$

$V_B = \frac{q_1}{b} + \frac{q_2}{b}$

$V_A - V_B = q_1\left[\frac{1}{a} - \frac{1}{b}\right]$

25. $V = \frac{kQ}{r}$ & $E = \frac{kQ}{r^2}$

27. Centre of mass is taken but there is no concept of centre of charge.