

## CHAPTER – 29

### ELECTRIC FIELD AND POTENTIAL

#### EXERCISES

1.  $\epsilon_0 = \frac{\text{Coulomb}^2}{\text{Newton m}^2} = \text{I}^1 \text{M}^{-1} \text{L}^{-3} \text{T}^4$

$$\therefore F = \frac{kq_1q_2}{r^2}$$

2.  $q_1 = q_2 = q = 1.0 \text{ C}$  distance between =  $2 \text{ km} = 1 \times 10^3 \text{ m}$

$$\text{so, force} = \frac{kq_1q_2}{r^2} \quad F = \frac{(9 \times 10^9) \times 1 \times 1}{(2 \times 10^3)^2} = \frac{9 \times 10^9}{2^2 \times 10^6} = 2.25 \times 10^3 \text{ N}$$

The weight of body =  $mg = 40 \times 10 \text{ N} = 400 \text{ N}$

$$\text{So, } \frac{\text{wt of body}}{\text{force between charges}} = \left( \frac{2.25 \times 10^3}{4 \times 10^2} \right)^{-1} = (5.6)^{-1} = \frac{1}{5.6}$$

So, force between charges = 5.6 weight of body.

3.  $q = 1 \text{ C}$ , Let the distance be  $\chi$

$$F = 50 \times 9.8 = 490$$

$$F = \frac{Kq^2}{\chi^2} \Rightarrow 490 = \frac{9 \times 10^9 \times 1^2}{\chi^2} \quad \text{or } \chi^2 = \frac{9 \times 10^9}{490} = 18.36 \times 10^6$$

$$\Rightarrow \chi = 4.29 \times 10^3 \text{ m}$$

4. charges 'q' each,  $AB = 1 \text{ m}$

$$\text{wt, of } 50 \text{ kg person} = 50 \times g = 50 \times 9.8 = 490 \text{ N}$$

$$F_c = \frac{kq_1q_2}{r^2} \quad \therefore \frac{kq^2}{r^2} = 490 \text{ N}$$

$$\Rightarrow q^2 = \frac{490 \times r^2}{9 \times 10^9} = \frac{490 \times 1 \times 1}{9 \times 10^9}$$

$$\Rightarrow q = \sqrt{54.4 \times 10^{-9}} = 23.323 \times 10^{-5} \text{ coulomb} \approx 2.3 \times 10^{-4} \text{ coulomb}$$

5. Charge on each proton =  $a = 1.6 \times 10^{-19} \text{ coulomb}$

$$\text{Distance between charges} = 10 \times 10^{-15} \text{ metre} = r$$

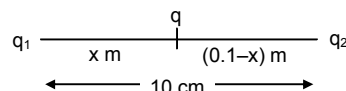
$$\text{Force} = \frac{kq^2}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 1.6 \times 10^{-38}}{10^{-30}} = 9 \times 2.56 \times 10 = 230.4 \text{ Newton}$$

6.  $q_1 = 2.0 \times 10^{-6}$   $q_2 = 1.0 \times 10^{-6}$   $r = 10 \text{ cm} = 0.1 \text{ m}$

Let the charge be at a distance  $x$  from  $q_1$

$$F_1 = \frac{Kq_1q}{\chi^2} \quad F_2 = \frac{kqq_2}{(0.1-\chi)^2}$$

$$= \frac{9.9 \times 2 \times 10^{-6} \times 10^{-9} \times q}{\chi^2}$$



Now since the net force is zero on the charge  $q$ .  $\Rightarrow f_1 = f_2$

$$\Rightarrow \frac{kq_1q}{\chi^2} = \frac{kqq_2}{(0.1-\chi)^2}$$

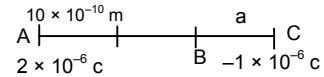
$$\Rightarrow 2(0.1-\chi)^2 = \chi^2 \Rightarrow \sqrt{2}(0.1-\chi) = \chi$$

$$\Rightarrow \chi = \frac{0.1\sqrt{2}}{1+\sqrt{2}} = 0.0586 \text{ m} = 5.86 \text{ cm} \approx 5.9 \text{ cm} \quad \text{From larger charge}$$

7.  $q_1 = 2 \times 10^{-6} \text{ c}$      $q_2 = -1 \times 10^{-6} \text{ c}$      $r = 10 \text{ cm} = 10 \times 10^{-2} \text{ m}$

Let the third charge be a so,  $F_{AC} = -F_{BC}$

$$\Rightarrow \frac{kQq_1}{r_1^2} = \frac{-KQq_2}{r_2^2} \Rightarrow \frac{2 \times 10^{-6}}{(10 + \chi)^2} = \frac{1 \times 10^{-6}}{\chi^2}$$



$$\Rightarrow 2\chi^2 = (10 + \chi)^2 \Rightarrow \sqrt{2}\chi = 10 + \chi \Rightarrow \chi(\sqrt{2} - 1) = 10 \Rightarrow \chi = \frac{-10}{1.414 - 1} = 24.14 \text{ cm}$$

So, distance = 24.14 + 10 = 34.14 cm from larger charge

8. Minimum charge of a body is the charge of an electron

Wo,  $q = 1.6 \times 10^{-19} \text{ c}$      $\chi = 1 \text{ cm} = 1 \times 10^{-2} \text{ cm}$

$$\text{So, } F = \frac{kq_1q_2}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 1.6 \times 10^{-19} \times 10^{-19}}{10^{-2} \times 10^{-2}} = 23.04 \times 10^{-38+9+2+2} = 23.04 \times 10^{-25} = 2.3 \times 10^{-24}$$

9. No. of electrons of 100 g water =  $\frac{10 \times 100}{18} = 55.5 \text{ Nos}$     Total charge = 55.5

No. of electrons in 18 g of  $\text{H}_2\text{O} = 6.023 \times 10^{23} \times 10 = 6.023 \times 10^{24}$

No. of electrons in 100 g of  $\text{H}_2\text{O} = \frac{6.023 \times 10^{24} \times 100}{18} = 0.334 \times 10^{26} = 3.334 \times 10^{25}$

Total charge =  $3.34 \times 10^{25} \times 1.6 \times 10^{-19} = 5.34 \times 10^6 \text{ c}$

10. Molecular weight of  $\text{H}_2\text{O} = 2 \times 1 \times 16 = 16$

No. of electrons present in one molecule of  $\text{H}_2\text{O} = 10$

18 gm of  $\text{H}_2\text{O}$  has  $6.023 \times 10^{23}$  molecule

18 gm of  $\text{H}_2\text{O}$  has  $6.023 \times 10^{23} \times 10$  electrons

100 gm of  $\text{H}_2\text{O}$  has  $\frac{6.023 \times 10^{24}}{18} \times 100$  electrons

So number of protons =  $\frac{6.023 \times 10^{26}}{18}$  protons (since atom is electrically neutral)

Charge of protons =  $\frac{1.6 \times 10^{-19} \times 6.023 \times 10^{26}}{18} \text{ coulomb} = \frac{1.6 \times 6.023 \times 10^7}{18} \text{ coulomb}$

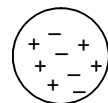
Charge of electrons =  $\frac{1.6 \times 6.023 \times 10^7}{18} \text{ coulomb}$

Hence Electrical force =  $\frac{9 \times 10^9 \left( \frac{1.6 \times 6.023 \times 10^7}{18} \right) \times \left( \frac{1.6 \times 6.023 \times 10^7}{18} \right)}{(10 \times 10^{-2})^2}$

=  $\frac{8 \times 6.023}{18} \times 1.6 \times 6.023 \times 10^{25} = 2.56 \times 10^{25} \text{ Newton}$

11. Let two protons be at a distance be 13.8 femi

$F = \frac{9 \times 10^9 \times 1.6 \times 10^{-38}}{(14.8)^2 \times 10^{-30}} = 1.2 \text{ N}$



12.  $F = 0.1 \text{ N}$

$r = 1 \text{ cm} = 10^{-2}$  (As they rubbed with each other. So the charge on each sphere are equal)

So,  $F = \frac{kq_1q_2}{r^2} \Rightarrow 0.1 = \frac{kq^2}{(10^{-2})^2} \Rightarrow q^2 = \frac{0.1 \times 10^{-4}}{9 \times 10^9} \Rightarrow q^2 = \frac{1}{9} \times 10^{-14} \Rightarrow q = \frac{1}{3} \times 10^{-7}$

$1.6 \times 10^{-19} \text{ c}$  Carries by 1 electron    1 c carried by  $\frac{1}{1.6 \times 10^{-19}}$

$0.33 \times 10^{-7} \text{ c}$  carries by  $\frac{1}{1.6 \times 10^{-19}} \times 0.33 \times 10^{-7} = 0.208 \times 10^{12} = 2.08 \times 10^{11}$

$$13. F = \frac{kq_1q_2}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 1.6 \times 10^{-19} \times 10^{-19}}{(2.75 \times 10^{-10})^2} = \frac{23.04 \times 10^{-29}}{7.56 \times 10^{-20}} = 3.04 \times 10^{-9}$$

14. Given: mass of proton =  $1.67 \times 10^{-27}$  kg =  $M_p$   
 $k = 9 \times 10^9$  Charge of proton =  $1.6 \times 10^{-19}$  C =  $C_p$   
 $G = 6.67 \times 10^{-11}$  Let the separation be 'r'

$$F_e = \frac{k(C_p)^2}{r^2}, \quad F_g = \frac{G(M_p)^2}{r^2}$$

$$\text{Now, } F_e : F_g = \frac{K(C_p)^2}{r^2} \times \frac{r^2}{G(M_p)^2} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times (1.67 \times 10^{-27})^2} = 9 \times 2.56 \times 10^{38} \approx 1.24 \times 10^{38}$$

15. Expression of electrical force  $F = C \times e^{\frac{-kr}{r^2}}$

Since  $e^{-kr}$  is a pure number. So, dimensional formulae of  $F = \frac{\text{dimensional formulae of } C}{\text{dimensional formulae of } r^2}$

$$\text{Or, } [MLT^{-2}][L^2] = \text{dimensional formulae of } C = [ML^3T^{-2}]$$

$$\text{Unit of } C = \text{unit of force} \times \text{unit of } r^2 = \text{Newton} \times m^2 = \text{Newton-m}^2$$

Since  $-kr$  is a number hence dimensional formulae of

$$k = \frac{1}{\text{dimensional formulae of } r} = [L^{-1}] \quad \text{Unit of } k = m^{-1}$$

16. Three charges are held at three corners of an equilateral triangle.

Let the charges be A, B and C. It is of length 5 cm or 0.05 m

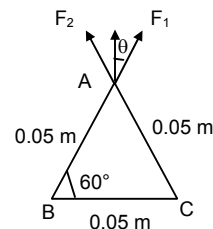
Force exerted by B on A =  $F_1$  force exerted by C on A =  $F_2$

So, force exerted on A = resultant  $F_1 = F_2$

$$\Rightarrow F = \frac{kq_2}{r^2} = \frac{9 \times 10^9 \times 2 \times 2 \times 10^{-12}}{5 \times 5 \times 10^{-4}} = \frac{36}{25} \times 10 = 14.4$$

Now, force on A =  $2 \times F \cos 30^\circ$  since it is equilateral  $\Delta$ .

$$\Rightarrow \text{Force on A} = 2 \times 1.44 \times \frac{\sqrt{3}}{2} = 24.94 \text{ N.}$$



17.  $q_1 = q_2 = q_3 = q_4 = 2 \times 10^{-6}$  C

$$v = 5 \text{ cm} = 5 \times 10^{-2} \text{ m}$$

$$\text{so force on } \bar{c} = \bar{F}_{CA} + \bar{F}_{CB} + \bar{F}_{CD}$$

$$\text{so Force along } \times \text{Component} = \bar{F}_{CD} + \bar{F}_{CA} \cos 45^\circ + 0$$

$$= \frac{k(2 \times 10^{-6})^2}{(5 \times 10^{-2})^2} + \frac{k(2 \times 10^{-6})^2}{(5 \times 10^{-2})^2} \frac{1}{2\sqrt{2}} = kq^2 \left( \frac{1}{25 \times 10^{-4}} + \frac{1}{50\sqrt{2} \times 10^{-4}} \right)$$

$$= \frac{9 \times 10^9 \times 4 \times 10^{-12}}{24 \times 10^{-4}} \left( 1 + \frac{1}{2\sqrt{2}} \right) = 1.44 (1.35) = 19.49 \text{ Force along } \times \text{component} = 19.49$$

$$\text{So, Resultant } R = \sqrt{F_x^2 + F_y^2} = 19.49 \sqrt{2} = 27.56$$

18.  $R = 0.53 \text{ A}^\circ = 0.53 \times 10^{-10} \text{ m}$

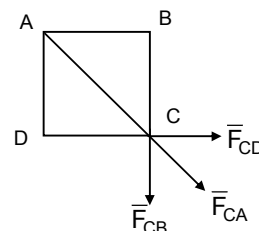
$$F = \frac{Kq_1q_2}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 1.6 \times 10^{-38}}{0.53 \times 0.53 \times 10^{-10} \times 10^{-10}} = 82.02 \times 10^{-9} \text{ N}$$

19.  $F_e$  from previous problem No. 18 =  $8.2 \times 10^{-8}$  N  $V_e = ?$

$$\text{Now, } M_e = 9.12 \times 10^{-31} \text{ kg} \quad r = 0.53 \times 10^{-10} \text{ m}$$

$$\text{Now, } F_e = \frac{M_e v^2}{r} \Rightarrow v^2 = \frac{F_e \times r}{m_e} = \frac{8.2 \times 10^{-8} \times 0.53 \times 10^{-10}}{9.1 \times 10^{-31}} = 0.4775 \times 10^{13} = 4.775 \times 10^{12} \text{ m}^2/\text{s}^2$$

$$\Rightarrow v = 2.18 \times 10^6 \text{ m/s}$$



20. Electric force feeld by 1 c due to  $1 \times 10^{-8}$  c.

$$F_1 = \frac{k \times 1 \times 10^{-8} \times 1}{(10 \times 10^{-2})^2} = k \times 10^{-6} \text{ N.} \quad \text{electric force feeld by 1 c due to } 8 \times 10^{-8} \text{ c.}$$

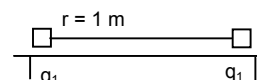
$$F_2 = \frac{k \times 8 \times 10^{-8} \times 1}{(23 \times 10^{-2})^2} = \frac{k \times 8 \times 10^{-8} \times 10^2}{9} = \frac{28k \times 10^{-6}}{4} = 2k \times 10^{-6} \text{ N.}$$

$$\text{Similarly } F_3 = \frac{k \times 27 \times 10^{-8} \times 1}{(30 \times 10^{-2})^2} = 3k \times 10^{-6} \text{ N}$$

$$\text{So, } F = F_1 + F_2 + F_3 + \dots + F_{10} = k \times 10^{-6} (1 + 2 + 3 + \dots + 10) \text{ N}$$

$$= k \times 10^{-6} \times \frac{10 \times 11}{2} = 55k \times 10^{-6} = 55 \times 9 \times 10^9 \times 10^{-6} \text{ N} = 4.95 \times 10^3 \text{ N}$$

21. Force exerted =  $\frac{kq_1^2}{r^2}$
- $$= \frac{9 \times 10^9 \times 2 \times 2 \times 10^{-16}}{1^2} = 3.6 \times 10^{-6} \text{ is the force exerted on the string}$$



22.  $q_1 = q_2 = 2 \times 10^{-7} \text{ C}$        $m = 100 \text{ g}$   
 $l = 50 \text{ cm} = 5 \times 10^{-2} \text{ m}$        $d = 5 \times 10^{-2} \text{ m}$

(a) Now Electric force

$$F = K \frac{q^2}{r^2} = \frac{9 \times 10^9 \times 4 \times 10^{-14}}{25 \times 10^{-4}} \text{ N} = 14.4 \times 10^{-2} \text{ N} = 0.144 \text{ N}$$

(b) The components of Resultant force along it is zero, because  $mg$  balances  $T \cos \theta$  and so also.

$$F = mg = T \sin \theta$$

(c) Tension on the string

$$T \sin \theta = F \quad T \cos \theta = mg$$

$$\tan \theta = \frac{F}{mg} = \frac{0.144}{100 \times 10^{-3} \times 9.8} = 0.14693$$

$$\text{But } T \cos \theta = 10^2 \times 10^{-3} \times 10 = 1 \text{ N}$$

$$\Rightarrow T = \frac{1}{\cos \theta} = \sec \theta$$

$$\Rightarrow T = \frac{F}{\sin \theta},$$

$$\sin \theta = 0.145369; \cos \theta = 0.989378;$$

23.  $q = 2.0 \times 10^{-8} \text{ C}$        $n = ?$        $T = ?$        $\sin \theta = \frac{1}{20}$

Force between the charges

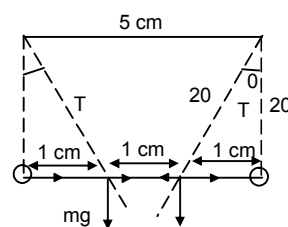
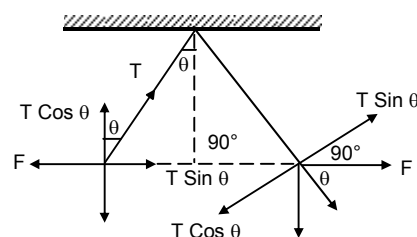
$$F = \frac{Kq_1q_2}{r^2} = \frac{9 \times 10^9 \times 2 \times 10^{-8} \times 2 \times 10^{-8}}{(3 \times 10^{-2})^2} = 4 \times 10^{-3} \text{ N}$$

$$mg \sin \theta = F \Rightarrow m = \frac{F}{g \sin \theta} = \frac{4 \times 10^{-3}}{10 \times (1/20)} = 8 \times 10^{-3} = 8 \text{ gm}$$

$$\cos \theta = \sqrt{1 - \sin^2 \theta} = \sqrt{1 - \frac{1}{400}} = \sqrt{\frac{400 - 1}{400}} = 0.99 \approx 1$$

$$\text{So, } T = mg \cos \theta$$

$$\text{Or } T = 8 \times 10^{-3} \times 10 \times 0.99 = 8 \times 10^{-2} \text{ N}$$



24.  $T \cos \theta = mg \quad \dots(1)$

$T \sin \theta = F_e \quad \dots(2)$

Solving, (2)/(1) we get,  $\tan \theta = \frac{F_e}{mg} = \frac{kq^2}{r} \times \frac{1}{mg}$

$\Rightarrow \frac{2}{\sqrt{1596}} = \frac{9 \times 10^9 \times q^2}{(0.04)^2 \times 0.02 \times 9.8}$

$\Rightarrow q^2 = \frac{(0.04)^2 \times 0.02 \times 9.8 \times 2}{9 \times 10^9 \times \sqrt{1596}} = \frac{6.27 \times 10^{-4}}{9 \times 10^9 \times 39.95} = 17 \times 10^{-16} \text{ C}^2$

$\Rightarrow q = \sqrt{17 \times 10^{-16}} = 4.123 \times 10^{-8} \text{ C}$

25. Electric force =  $\frac{kq^2}{(\ell \sin Q + \ell \sin Q)^2} = \frac{kq^2}{4\ell^2 \sin^2}$

So,  $T \cos \theta = ms$  (For equilibrium)  $T \sin \theta = Ef$

Or  $\tan \theta = \frac{Ef}{mg}$

$\Rightarrow mg = Ef \cot \theta = \frac{kq^2}{4\ell^2 \sin^2 \theta} \cot \theta = \frac{q^2 \cot \theta}{\ell^2 \sin^2 \theta 16\pi\epsilon_0}$

or  $m = \frac{q^2 \cot \theta}{16\pi\epsilon_0 \ell^2 \sin^2 \theta g}$  unit.

26. Mass of the bob = 100 g = 0.1 kg

So Tension in the string =  $0.1 \times 9.8 = 0.98 \text{ N}$ .

For the Tension to be 0, the charge below should repel the first bob.

$\Rightarrow F = \frac{kq_1q_2}{r^2} \quad T - mg + F = 0 \Rightarrow T = mg - f \quad T = mg$

$\Rightarrow 0.98 = \frac{9 \times 10^9 \times 2 \times 10^{-4} \times q_2}{(0.01)^2} \Rightarrow q_2 = \frac{0.98 \times 1 \times 10^{-2}}{9 \times 2 \times 10^5} = 0.054 \times 10^{-9} \text{ N}$

27. Let the charge on C = q

So, net force on c is equal to zero

So  $F_{AC} + F_{BA} = 0$ , But  $F_{AC} = F_{BC} \Rightarrow \frac{kqQ}{x^2} = \frac{k2qQ}{(d-x)^2}$

$\Rightarrow 2x^2 = (d-x)^2 \Rightarrow \sqrt{2}x = d-x$

$\Rightarrow x = \frac{d}{\sqrt{2}+1} = \frac{d}{(\sqrt{2}+1)} \times \frac{(\sqrt{2}-1)}{(\sqrt{2}-1)} = d(\sqrt{2}-1)$

For the charge on rest,  $F_{AC} + F_{AB} = 0$

$(2.414)^2 \frac{kqQ}{d^2} + \frac{kq(2q)}{d^2} = 0 \Rightarrow \frac{kq}{d^2} [(2.414)^2 Q + 2q] = 0$

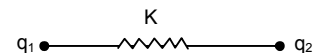
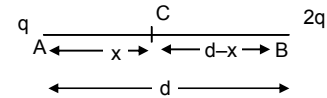
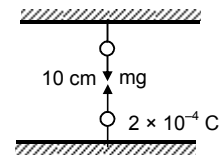
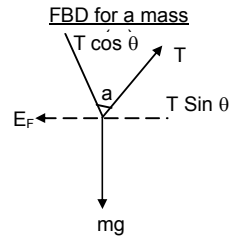
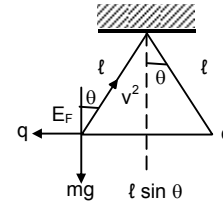
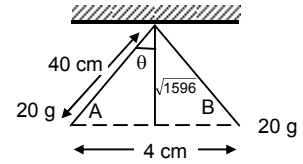
$\Rightarrow 2q = -(2.414)^2 Q$

$\Rightarrow Q = \frac{2}{-(\sqrt{2}+1)^2} q = -\left(\frac{2}{3+2\sqrt{2}}\right) q = -(0.343) q = -(6-4\sqrt{2})$

28.  $K = 100 \text{ N/m} \quad \ell = 10 \text{ cm} = 10^{-1} \text{ m} \quad q = 2.0 \times 10^{-8} \text{ C}$  Find  $\ell = ?$

Force between them  $F = \frac{kq_1q_2}{r^2} = \frac{9 \times 10^9 \times 2 \times 10^{-8} \times 2 \times 10^{-8}}{10^{-2}} = 36 \times 10^{-5} \text{ N}$

So,  $F = -kx$  or  $x = \frac{F}{-K} = \frac{36 \times 10^{-5}}{100} = 36 \times 10^{-7} \text{ cm} = 3.6 \times 10^{-6} \text{ m}$



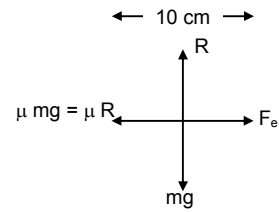
29.  $q_A = 2 \times 10^{-6} \text{ C}$      $M_b = 80 \text{ g}$      $\mu = 0.2$

Since B is at equilibrium, So,  $F_e = \mu R$

$$\Rightarrow \frac{Kq_A q_B}{r^2} = \mu R = \mu m \times g$$

$$\Rightarrow \frac{9 \times 10^9 \times 2 \times 10^{-6} \times q_B}{0.01} = 0.2 \times 0.08 \times 9.8$$

$$\Rightarrow q_B = \frac{0.2 \times 0.08 \times 9.8 \times 0.01}{9 \times 10^9 \times 2 \times 10^{-6}} = 8.7 \times 10^{-8} \text{ C} \quad \text{Range} = \pm 8.7 \times 10^{-8} \text{ C}$$



30.  $q_1 = 2 \times 10^{-6} \text{ C}$     Let the distance be  $r$  unit

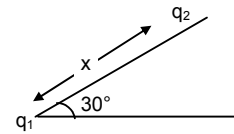
$$\therefore F_{\text{repulsion}} = \frac{kq_1 q_2}{r^2}$$

For equilibrium  $\frac{kq_1 q_2}{r^2} = mg \sin \theta$

$$\Rightarrow \frac{9 \times 10^9 \times 4 \times 10^{-12}}{r^2} = m \times 9.8 \times \frac{1}{2}$$

$$\Rightarrow r^2 = \frac{18 \times 4 \times 10^{-3}}{m \times 9.8} = \frac{72 \times 10^{-3}}{9.8 \times 10^{-1}} = 7.34 \times 10^{-2} \text{ metre}$$

$$\Rightarrow r = 2.70924 \times 10^{-1} \text{ metre from the bottom.}$$



31. Force on the charge particle 'q' at 'c' is only the x component of 2 forces

So,  $F_{\text{on c}} = F_{CB} \sin \theta + F_{AC} \sin \theta$     But  $|F_{CB}| = |F_{AC}|$

$$= 2 F_{CB} \sin \theta = 2 \frac{KQq}{x^2 + (d/2)^2} \times \frac{x}{[x^2 + d^2/4]^{1/2}} = \frac{2k\theta qx}{(x^2 + d^2/4)^{3/2}} = \frac{16kQq}{(4x^2 + d^2)^{3/2}} x$$

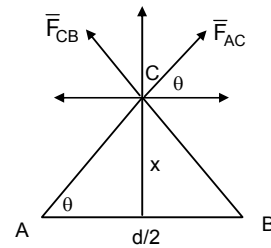
For maximum force  $\frac{dF}{dx} = 0$

$$\frac{d}{dx} \left( \frac{16kQqx}{(4x^2 + d^2)^{3/2}} \right) = 0 \Rightarrow K \left[ \frac{(4x^2 + d^2) - x \left[ 3/2 [4x^2 + d^2]^{1/2} 8x \right]}{[4x^2 + d^2]^3} \right] = 0$$

$$\Rightarrow \frac{K(4x^2 + d^2)^{1/2} [(4x^2 + d^2)^3 - 12x^2]}{(4x^2 + d^2)^3} = 0 \Rightarrow (4x^2 + d^2)^3 = 12x^2$$

$$\Rightarrow 16x^4 + d^4 + 8x^2 d^2 = 12x^2 \quad d^4 + 8x^2 d^2 = 0$$

$$\Rightarrow d^2 = 0 \quad d^2 + 8x^2 = 0 \Rightarrow d^2 = 8x^2 \Rightarrow d = \frac{d}{2\sqrt{2}}$$



32. (a) Let  $Q$  = charge on A & B Separated by distance  $d$

$q$  = charge on c    displaced  $\perp$  to  $-AB$

So, force on  $O = \bar{F}_{AB} + \bar{F}_{BO}$

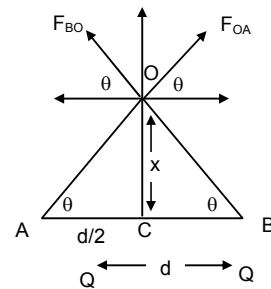
But  $F_{AO} \cos \theta = F_{BO} \cos \theta$

So, force on 'O' in due to vertical component.

$$\bar{F} = F_{AO} \sin \theta + F_{BO} \sin \theta \quad |F_{AO}| = |F_{BO}|$$

$$= 2 \frac{KQq}{(d/2)^2 + x^2} \sin \theta \quad F = \frac{2KQq}{(d/2)^2 + x^2} \sin \theta$$

$$= \frac{4 \times 2 \times kQq}{(d^2 + 4x^2)} \times \frac{x}{[(d/2)^2 + x^2]^{1/2}} = \frac{2kQq}{[(d/2)^2 + x^2]^{3/2}} x = \text{Electric force} \Rightarrow F \propto x$$



(b) When  $x \ll d$   $F = \frac{2kQq}{[(d/2)^2 + x^2]^{3/2}} x$   $x \ll d$

$$\Rightarrow F = \frac{2kQq}{(d^2/4)^{3/2}} x \Rightarrow F \propto x \quad a = \frac{F}{m} = \frac{1}{m} \left[ \frac{2kQqx}{[(d^2/4) + \ell^2]} \right]$$

So time period  $T = 2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{\ell}{a}}$

33.  $F_{AC} = \frac{KQq}{(\ell+x)^2}$   $F_{CA} = \frac{KQq}{(\ell-x)^2}$

Net force =  $KQq \left[ \frac{1}{(\ell-x)^2} - \frac{1}{(\ell+x)^2} \right]$

$$= KQq \left[ \frac{(\ell+x)^2 - (\ell-x)^2}{(\ell+x)^2(\ell-x)^2} \right] = KQq \left[ \frac{4\ell x}{(\ell^2 - x^2)^2} \right]$$

$x \ll \ell = d/2$  neglecting  $x$  w.r.t.  $\ell$  We get

net  $F = \frac{KQq4\ell x}{\ell^4} = \frac{KQq4x}{\ell^3}$  acceleration =  $\frac{4KQqx}{m\ell^3}$

Time period =  $2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}} = 2\pi\sqrt{\frac{xm\ell^3}{4KQqx}} = 2\pi\sqrt{\frac{m\ell^3}{4KQq}}$

$$= \sqrt{\frac{4\pi^2 m\ell^3 4\pi\epsilon_0}{4Qq}} = \sqrt{\frac{4\pi^3 m\ell^3 \epsilon_0}{Qq}} = \sqrt{4\pi^3 md^3 \epsilon_0 8Qq} = \left[ \frac{\pi^3 md^3 \epsilon_0}{2Qq} \right]^{1/2}$$

34.  $F_e = 1.5 \times 10^{-3} \text{ N}$ ,  $q = 1 \times 10^{-6} \text{ C}$ ,  $F_e = q \times E$

$$\Rightarrow E = \frac{F_e}{q} = \frac{1.5 \times 10^{-3}}{1 \times 10^{-6}} = 1.5 \times 10^3 \text{ N/C}$$

35.  $q_2 = 2 \times 10^{-6} \text{ C}$ ,  $q_1^2 = -4 \times 10^{-6} \text{ C}$ ,  $r = 20 \text{ cm} = 0.2 \text{ m}$   
( $E_1$  = electric field due to  $q_1$ ,  $E_2$  = electric field due to  $q_2$ )

$$\Rightarrow \frac{(r-x)^2}{x^2} = \frac{-q_2}{q_1} \Rightarrow \frac{(r-1)^2}{x} = \frac{-q_2}{q_1} = \frac{4 \times 10^{-6}}{2 \times 10^{-6}} = \frac{1}{2}$$

$$\Rightarrow \left( \frac{r}{x} - 1 \right) = \frac{1}{\sqrt{2}} = \frac{1}{1.414} \Rightarrow \frac{r}{x} = 1.414 + 1 = 2.414$$

$$\Rightarrow x = \frac{r}{2.414} = \frac{20}{2.414} = 8.285 \text{ cm}$$

36.  $EF = \frac{KQ}{r^2}$

$$5 \text{ N/C} = \frac{9 \times 10^9 \times Q}{4^2}$$

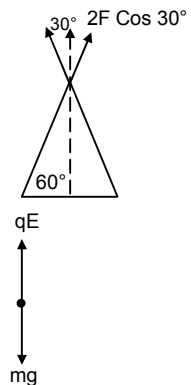
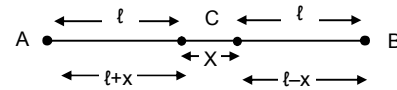
$$\Rightarrow \frac{4 \times 20 \times 10^{-2}}{9 \times 10^9} = Q \Rightarrow Q = 8.88 \times 10^{-11}$$

37.  $m = 10$ ,  $mg = 10 \times 10^{-3} \text{ g} \times 10^{-3} \text{ kg}$ ,  $q = 1.5 \times 10^{-6} \text{ C}$

But  $qE = mg \Rightarrow (1.5 \times 10^{-6}) E = 10 \times 10^{-6} \times 10$

$$\Rightarrow E = \frac{10 \times 10^{-4} \times 10}{1.5 \times 10^{-6}} = \frac{100}{1.5} = 66.6 \text{ N/C}$$

$$= \frac{100 \times 10^3}{1.5} = \frac{10^{5+1}}{15} = 6.6 \times 10^3$$



38.  $q = 1.0 \times 10^{-8} \text{ C}$ ,  $\ell = 20 \text{ cm}$

$E = ?$   $V = ?$

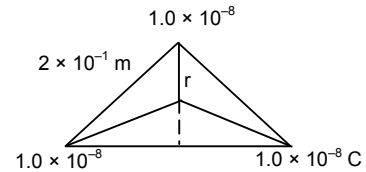
Since it forms an equipotential surface.

So the electric field at the centre is Zero.

$$r = \frac{2}{3} \sqrt{(2 \times 10^{-1})^2 - (10^{-1})^2} = \frac{2}{3} \sqrt{4 \times 10^{-2} - 10^{-2}}$$

$$= \frac{2}{3} \sqrt{10^{-2}(4-1)} = \frac{2}{3} \times 10^{-2} \times 1.732 = 1.15 \times 10^{-1}$$

$$V = \frac{3 \times 9 \times 10^9 \times 1 \times 10^{-8}}{1 \times 10^{-1}} = 23 \times 10^2 = 2.3 \times 10^3 \text{ V}$$



39. We know : Electric field 'E' at 'P' due to the charged ring

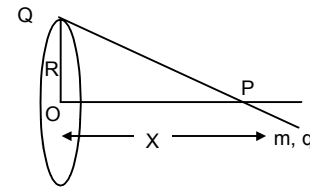
$$= \frac{KQx}{(R^2 + x^2)^{3/2}} = \frac{KQx}{R^3}$$

Force experienced 'F' =  $Q \times E = \frac{q \times K \times Qx}{R^3}$

Now, amplitude = x

$$\text{So, } T = 2\pi \sqrt{\frac{x}{KQqx/mR^3}} = 2\pi \sqrt{\frac{mR^3x}{KQqx}} = 2\pi \sqrt{\frac{4\pi\epsilon_0 mR^3}{Qq}} = \sqrt{\frac{4\pi^2 \times 4\pi\epsilon_0 mR^3}{qQ}}$$

$$\Rightarrow T = \left[ \frac{16\pi^3 \epsilon_0 mR^3}{qQ} \right]^{1/2}$$



40.  $\lambda = \text{Charge per unit length} = \frac{Q}{L}$

$dq_1$  for a length  $d\ell = \lambda \times d\ell$

Electric field at the centre due to charge =  $k \times \frac{dq}{r^2}$

The horizontal Components of the Electric field balances each other. Only the vertical components remain.

$\therefore$  Net Electric field along vertical

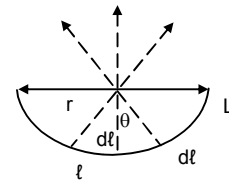
$$dE = 2 E \cos \theta = \frac{Kdq \times \cos \theta}{r^2} = \frac{2k \cos \theta}{r^2} \times \lambda \times d\ell \quad [\text{but } d\theta = \frac{d\ell}{r} = d\ell = r d\theta]$$

$$\Rightarrow \frac{2k\lambda}{r^2} \cos \theta \times r d\theta = \frac{2k\lambda}{r} \cos \theta \times d\theta$$

$$\text{or } E = \int_0^{\pi/2} \frac{2k\lambda}{r} \cos \theta \times d\theta = \int_0^{\pi/2} \frac{2k\lambda}{r} \sin \theta = \frac{2k\lambda}{r} = \frac{2K\theta}{Lr}$$

but  $L = \pi R \Rightarrow r = \frac{L}{\pi}$

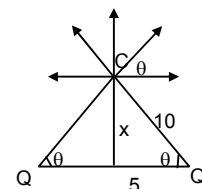
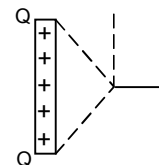
$$\text{So } E = \frac{2k\theta}{L \times (L/\pi)} = \frac{2k\pi\theta}{L^2} = \frac{2}{4\pi\epsilon_0} \times \frac{\pi\theta}{L^2} = \frac{\theta}{2\epsilon_0 L^2}$$



41.  $G = 50 \mu\text{C} = 50 \times 10^{-6} \text{ C}$

We have,  $E = \frac{2KQ}{r}$  for a charged cylinder.

$$\Rightarrow E = \frac{2 \times 9 \times 10^9 \times 50 \times 10^{-6}}{5\sqrt{3}} = \frac{9 \times 10^{-5}}{5\sqrt{3}} = 1.03 \times 10^{-5}$$





42. Electric field at any point on the axis at a distance  $x$  from the center of the ring is

$$E = \frac{xQ}{4\pi\epsilon_0(R^2 + x^2)^{3/2}} = \frac{KxQ}{(R^2 + x^2)^{3/2}}$$

Differentiating with respect to  $x$

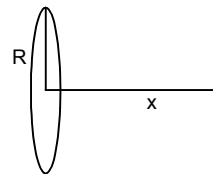
$$\frac{dE}{dx} = \frac{KQ(R^2 + x^2)^{3/2} - KxQ(3/2)(R^2 + x^2)^{1/2}2x}{(R^2 + x^2)^3}$$

Since at a distance  $x$ , Electric field is maximum.

$$\frac{dE}{dx} = 0 \Rightarrow KQ(R^2 + x^2)^{3/2} - Kx^2 Q3(R^2 + x^2)^{1/2} = 0$$

$$\Rightarrow KQ(R^2 + x^2)^{3/2} = Kx^2 Q3(R^2 + x^2)^{1/2} \Rightarrow R^2 + x^2 = 3x^2$$

$$\Rightarrow 2x^2 = R^2 \Rightarrow x^2 = \frac{R^2}{2} \Rightarrow x = \frac{R}{\sqrt{2}}$$



43. Since it is a regular hexagon. So, it forms an equipotential surface. Hence the charge at each point is equal. Hence the net entire field at the centre is Zero.



44. Charge/Unit length =  $\frac{Q}{2\pi a} = \lambda$ ; Charge of  $d\ell = \frac{Qd\ell}{2\pi a}$  C

Initially the electric field was '0' at the centre. Since the element ' $d\ell$ ' is removed so, net electric field must

$$\frac{K \times q}{a^2} \quad \text{Where } q = \text{charge of element } d\ell$$

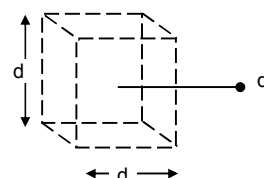
$$E = \frac{Kq}{a^2} = \frac{1}{4\pi\epsilon_0} \times \frac{Qd\ell}{2\pi a} \times \frac{1}{a^2} = \frac{Qd\ell}{8\pi^2\epsilon_0 a^3}$$

45. We know,

Electric field at a point due to a given charge

$$'E' = \frac{Kq}{r^2} \quad \text{Where } q = \text{charge, } r = \text{Distance between the point and the charge}$$

$$\text{So, 'E' = } \frac{1}{4\pi\epsilon_0} \times \frac{q}{d^2} \quad [\because r = 'd' \text{ here}]$$



46.  $E = 20 \text{ kv/m} = 20 \times 10^3 \text{ v/m}$ ,  $m = 80 \times 10^{-5} \text{ kg}$ ,  $c = 20 \times 10^{-5} \text{ C}$

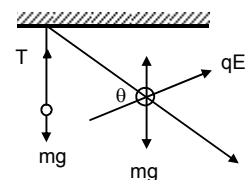
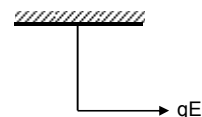
$$\tan \theta = \left( \frac{qE}{mg} \right)^{-1} \quad [T \sin \theta = mg, T \cos \theta = qe]$$

$$\tan \theta = \left( \frac{2 \times 10^{-8} \times 20 \times 10^3}{80 \times 10^{-6} \times 10} \right)^{-1} = \left( \frac{1}{2} \right)^{-1}$$

$$1 + \tan^2 \theta = \frac{1}{4} + 1 = \frac{5}{4} \quad [\cos \theta = \frac{1}{\sqrt{5}}, \sin \theta = \frac{2}{\sqrt{5}}]$$

$$T \sin \theta = mg \Rightarrow T \times \frac{2}{\sqrt{5}} = 80 \times 10^{-6} \times 10$$

$$\Rightarrow T = \frac{8 \times 10^{-4} \times \sqrt{5}}{2} = 4 \times \sqrt{5} \times 10^{-4} = 8.9 \times 10^{-4}$$



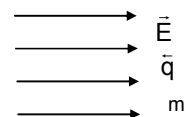
47. Given

$u$  = Velocity of projection,  $\vec{E}$  = Electric field intensity

$q$  = Charge;  $m$  = mass of particle

We know, Force experienced by a particle with charge ' $q$ ' in an electric field  $\vec{E} = q\vec{E}$

$$\therefore \text{acceleration produced} = \frac{qE}{m}$$



As the particle is projected against the electric field, hence deceleration =  $\frac{qE}{m}$

So, let the distance covered be 's'

Then,  $v^2 = u^2 + 2as$  [where a = acceleration, v = final velocity]

$$\text{Here } 0 = u^2 - 2 \times \frac{qE}{m} \times S \Rightarrow S = \frac{u^2 m}{2qE} \text{ units}$$

48.  $m = 1 \text{ g} = 10^{-3} \text{ kg}$ ,  $u = 0$ ,  $q = 2.5 \times 10^{-4} \text{ C}$ ;  $E = 1.2 \times 10^4 \text{ N/C}$ ;  $S = 40 \text{ cm} = 4 \times 10^{-1} \text{ m}$

a)  $F = qE = 2.5 \times 10^{-4} \times 1.2 \times 10^4 = 3 \text{ N}$

So,  $a = \frac{F}{m} = \frac{3}{10^{-3}} = 3 \times 10^3$

$E_q = mg = 10^{-3} \times 9.8 = 9.8 \times 10^{-3} \text{ N}$

b)  $S = \frac{1}{2} at^2$  or  $t = \sqrt{\frac{2a}{g}} = \sqrt{\frac{2 \times 4 \times 10^{-1}}{3 \times 10^3}} = 1.63 \times 10^{-2} \text{ sec}$

$v^2 = u^2 + 2as = 0 + 2 \times 3 \times 10^3 \times 4 \times 10^{-1} = 24 \times 10^2 \Rightarrow v = \sqrt{24 \times 10^2} = 4.9 \times 10 = 49 \text{ m/sec}$

work done by the electric force  $w = F \rightarrow td = 3 \times 4 \times 10^{-1} = 12 \times 10^{-1} = 1.2 \text{ J}$

49.  $m = 100 \text{ g}$ ,  $q = 4.9 \times 10^{-5}$ ,  $F_g = mg$ ,  $F_e = qE$

$\vec{E} = 2 \times 10^4 \text{ N/C}$

So, the particle moves due to the resultant R

$R = \sqrt{F_g^2 + F_e^2} = \sqrt{(0.1 \times 9.8)^2 + (4.9 \times 10^{-5} \times 2 \times 10^4)^2}$

$= \sqrt{0.9604 + 96.04 \times 10^{-2}} = \sqrt{1.9208} = 1.3859 \text{ N}$

$\tan \theta = \frac{F_g}{F_e} = \frac{mg}{qE} = 1$  So,  $\theta = 45^\circ$

$\therefore$  Hence path is straight along resultant force at an angle  $45^\circ$  with horizontal

Disp. Vertical =  $(1/2) \times 9.8 \times 2 \times 2 = 19.6 \text{ m}$

Disp. Horizontal =  $S = (1/2) at^2 = \frac{1}{2} \times \frac{qE}{m} \times t^2 = \frac{1}{2} \times \frac{0.98}{0.1} \times 2 \times 2 = 19.6 \text{ m}$

Net Dispt. =  $\sqrt{(19.6)^2 + (19.6)^2} = \sqrt{768.32} = 27.7 \text{ m}$

50.  $m = 40 \text{ g}$ ,  $q = 4 \times 10^{-6} \text{ C}$

Time for 20 oscillations = 45 sec. Time for 1 oscillation =  $\frac{45}{20} \text{ sec}$

When no electric field is applied,  $T = 2\pi \sqrt{\frac{\ell}{g}} \Rightarrow \frac{45}{20} = 2\pi \sqrt{\frac{\ell}{10}}$

$\Rightarrow \frac{\ell}{10} = \left(\frac{45}{20}\right)^2 \times \frac{1}{4\pi^2} \Rightarrow \ell = \frac{(45)^2 \times 10}{(20)^2 \times 4\pi^2} = 1.2836$

When electric field is not applied,

$T = 2\pi \sqrt{\frac{\ell}{g-a}} \left[ a = \frac{qE}{m} = 2.5 \right] = 2\pi \sqrt{\frac{1.2836}{10-2.5}} = 2.598$

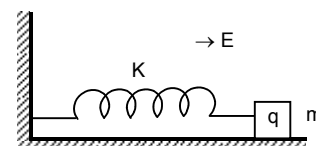
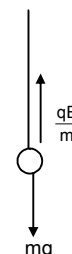
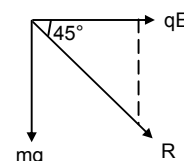
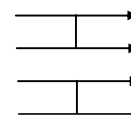
Time for 1 oscillation = 2.598

Time for 20 oscillation =  $2.598 \times 20 = 51.96 \text{ sec} \approx 52 \text{ sec}$ .

51.  $F = qE$ ,  $F = -Kx$

Where x = amplitude

$qE = -Kx$  or  $x = \frac{-qE}{K}$



52. The block does not undergo SHM since here the acceleration is not proportional to displacement and not always opposite to displacement. When the block is going towards the wall the acceleration is along displacement and when going away from it the displacement is opposite to acceleration.

Time taken to go towards the wall is the time taken to go away from it till velocity is

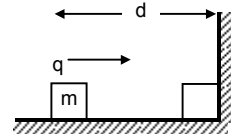
$$d = ut + \frac{1}{2}at^2$$

$$\Rightarrow d = \frac{1}{2} \times \frac{qE}{m} \times t^2$$

$$\Rightarrow t^2 = \frac{2dm}{qE} \Rightarrow t = \sqrt{\frac{2md}{qE}}$$

$\therefore$  Total time taken for to reach the wall and come back (Time period)

$$= 2t = 2\sqrt{\frac{2md}{qE}} = \sqrt{\frac{8md}{qE}}$$



53.  $E = 10 \text{ n/c}$ ,  $S = 50 \text{ cm} = 0.1 \text{ m}$

$$E = \frac{dV}{dr} \text{ or, } V = E \times r = 10 \times 0.5 = 5 \text{ cm}$$

54. Now,  $V_B - V_A = \text{Potential diff} = ?$  Charge =  $0.01 \text{ C}$   
Work done =  $12 \text{ J}$  Now, Work done = Pot. Diff  $\times$  Charge

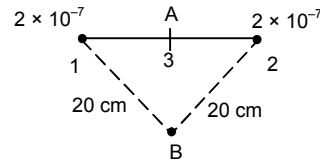
$$\Rightarrow \text{Pot. Diff} = \frac{12}{0.01} = 1200 \text{ Volt}$$

55. When the charge is placed at A,

$$E_1 = \frac{Kq_1q_2}{r} + \frac{Kq_3q_4}{r}$$

$$= \frac{9 \times 10^9 (2 \times 10^{-7})^2}{0.1} + \frac{9 \times 10^9 (2 \times 10^{-7})^2}{0.1}$$

$$= \frac{2 \times 9 \times 10^9 \times 4 \times 10^{-14}}{0.1} = 72 \times 10^{-4} \text{ J}$$



When charge is placed at B,

$$E_2 = \frac{Kq_1q_2}{r} + \frac{Kq_3q_4}{r} = \frac{2 \times 9 \times 10^9 \times 4 \times 10^{-14}}{0.2} = 36 \times 10^{-4} \text{ J}$$

$$\text{Work done} = E_1 - E_2 = (72 - 36) \times 10^{-4} = 36 \times 10^{-4} \text{ J} = 3.6 \times 10^{-3} \text{ J}$$

56. (a)  $A = (0, 0)$   $B = (4, 2)$

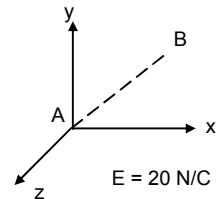
$$V_B - V_A = E \times d = 20 \times \sqrt{16} = 80 \text{ V}$$

- (b)  $A(4\text{m}, 2\text{m})$ ,  $B = (6\text{m}, 5\text{m})$

$$\Rightarrow V_B - V_A = E \times d = 20 \times \sqrt{(6-4)^2} = 20 \times 2 = 40 \text{ V}$$

- (c)  $A(0, 0)$   $B = (6\text{m}, 5\text{m})$

$$\Rightarrow V_B - V_A = E \times d = 20 \times \sqrt{(6-0)^2} = 20 \times 6 = 120 \text{ V}.$$



57. (a) The Electric field is along x-direction

Thus potential difference between  $(0, 0)$  and  $(4, 2)$  is,

$$\delta V = -E \times \delta x = -20 \times (40) = -80 \text{ V}$$

Potential energy  $(U_B - U_A)$  between the points =  $\delta V \times q$

$$= -80 \times (-2) \times 10^{-4} = 160 \times 10^{-4} = 0.016 \text{ J}.$$

- (b)  $A = (4\text{m}, 2\text{m})$   $B = (6\text{m}, 5\text{m})$

$$\delta V = -E \times \delta x = -20 \times 2 = -40 \text{ V}$$

Potential energy  $(U_B - U_A)$  between the points =  $\delta V \times q$

$$= -40 \times (-2 \times 10^{-4}) = 80 \times 10^{-4} = 0.008 \text{ J}$$

- (c)  $A = (0, 0)$   $B = (6\text{m}, 5\text{m})$

$$\delta V = -E \times \delta x = -20 \times 6 = -120 \text{ V}$$

Potential energy  $(U_B - U_A)$  between the points A and B

$$= \delta V \times q = -120 \times (-2 \times 10^{-4}) = 240 \times 10^{-4} = 0.024 \text{ J}$$

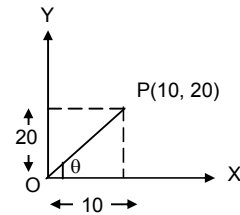
58.  $E = (\hat{i}20 + \hat{j}30) \text{ N/CV} = \text{at } (2\text{m}, 2\text{m}) \text{ } r = (2\hat{i} + 2\hat{j})$

So,  $V = -\vec{E} \times \vec{r} = -(i20 + j30) (2\hat{i} + 2\hat{j}) = -(2 \times 20 + 2 \times 30) = -100 \text{ V}$

59.  $E = \vec{i} \times Ax = 100 \vec{i}$

$$\int_v^0 dv = -\int E \times d\ell \quad V = -\int_0^{10} 10x \times dx = -\int_0^{10} \frac{1}{2} \times 10 \times x^2$$

$$0 - V = -\left[\frac{1}{2} \times 1000\right] = -500 \Rightarrow V = 500 \text{ Volts}$$



60.  $V(x, y, z) = A(xy + yz + zx)$

(a)  $A = \frac{\text{Volt}}{\text{m}^2} = \frac{\text{ML}^2\text{T}^{-2}}{\text{ITL}^2} = [\text{MT}^{-3}\text{I}^{-1}]$

(b)  $E = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k} = -\left[\frac{\partial}{\partial x}[A(xy + yz + zx)] + \frac{\partial}{\partial y}[A(xy + yz + zx)] + \frac{\partial}{\partial z}[A(xy + yz + zx)]\right]$

$$= -[(Ay + Az)\hat{i} + (Ax + Az)\hat{j} + (Ay + Ax)\hat{k}] = -A(y + z)\hat{i} - A(x + z)\hat{j} - A(y + x)\hat{k}$$

(c)  $A = 10 \text{ SI unit, } r = (1\text{m}, 1\text{m}, 1\text{m})$

$$E = -10(2)\hat{i} - 10(2)\hat{j} - 10(2)\hat{k} = -20\hat{i} - 20\hat{j} - 20\hat{k} = \sqrt{20^2 + 20^2 + 20^2} = \sqrt{1200} = 34.64 \approx 35 \text{ N/C}$$

61.  $q_1 = q_2 = 2 \times 10^{-5} \text{ C}$

Each are brought from infinity to 10 cm a part  $d = 10 \times 10^{-2} \text{ m}$

So work done = negative of work done. (Potential E)

$$P.E. = \int_{\infty}^{10} F \times ds \quad P.E. = K \times \frac{q_1 q_2}{r} = \frac{9 \times 10^9 \times 4 \times 10^{-10}}{10 \times 10^{-2}} = 36 \text{ J}$$

62. (a) The angle between potential  $E d\ell = dV$

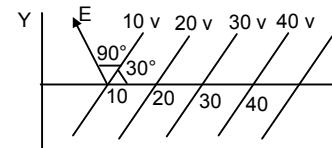
Change in potential = 10 V = dV

As  $E = \perp r dV$  (As potential surface)

So,  $E d\ell = dV \Rightarrow E d\ell \cos(90^\circ + 30^\circ) = -dV$

$\Rightarrow E(10 \times 10^{-2}) \cos 120^\circ = -dV$

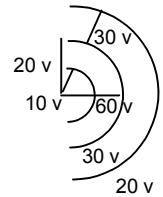
$$\Rightarrow E = \frac{-dV}{10 \times 10^{-2} \cos 120^\circ} = -\frac{10}{10^{-1} \times (-1/2)} = 200 \text{ V/m making an angle } 120^\circ \text{ with y-axis}$$



(b) As Electric field intensity is  $\perp r$  to Potential surface

$$\text{So, } E = \frac{kq}{r^2} r = \frac{kq}{r} \Rightarrow \frac{kq}{r} = 60 \text{ v} \quad q = \frac{6}{K}$$

$$\text{So, } E = \frac{kq}{r^2} = \frac{6 \times k}{k \times r^2} \text{ v.m} = \frac{6}{r^2} \text{ v.m}$$



63. Radius = r So,  $2\pi r = \text{Circumference}$

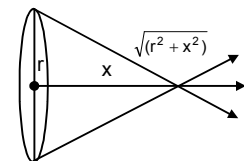
Charge density =  $\lambda$  Total charge =  $2\pi r \times \lambda$

$$\text{Electric potential} = \frac{Kq}{r} = \frac{1}{4\pi\epsilon_0} \times \frac{2\pi r\lambda}{(x^2 + r^2)^{1/2}} = \frac{r\lambda}{2\epsilon_0(x^2 + r^2)^{1/2}}$$

$$\text{So, Electric field} = \frac{V}{r} \cos\theta$$

$$= \frac{r\lambda}{2\epsilon_0(x^2 + r^2)^{1/2}} \times \frac{1}{(x^2 + r^2)^{1/2}}$$

$$= \frac{r\lambda}{2\epsilon_0(x^2 + r^2)^{1/2}} \times \frac{x}{(x^2 + r^2)^{1/2}} = \frac{r\lambda x}{2\epsilon_0(x^2 + r^2)^{3/2}}$$



64.  $\vec{E} = 1000 \text{ N/C}$

(a)  $V = E \times d = 1000 \times \frac{2}{100} = 20 \text{ V}$

(b)  $u = ? \quad \vec{E} = 1000, \quad = 2/100 \text{ m}$

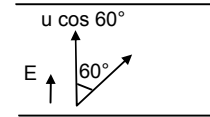
$a = \frac{F}{m} = \frac{q \times E}{m} = \frac{1.6 \times 10^{-19} \times 1000}{9.1 \times 10^{-31}} = 1.75 \times 10^{14} \text{ m/s}^2$

$0 = u^2 - 2 \times 1.75 \times 10^{14} \times 0.02 \Rightarrow u^2 = 0.04 \times 1.75 \times 10^{14} \Rightarrow u = 2.64 \times 10^6 \text{ m/s.}$

(c) Now,  $U = u \cos 60^\circ \quad V = 0, \quad s = ?$

$a = 1.75 \times 10^{14} \text{ m/s}^2 \quad V^2 = u^2 - 2as$

$\Rightarrow s = \frac{(u \cos 60^\circ)^2}{2 \times a} = \frac{\left(2.64 \times 10^6 \times \frac{1}{2}\right)^2}{2 \times 1.75 \times 10^{14}} = \frac{1.75 \times 10^{12}}{3.5 \times 10^{14}} = 0.497 \times 10^{-2} \approx 0.005 \text{ m} \approx 0.50 \text{ cm}$



65.  $E = 2 \text{ N/C}$  in x-direction

(a) Potential at the origin is 0.  $dV = -E_x dx - E_y dy - E_z dz$

$\Rightarrow V - 0 = -2x \Rightarrow V = -2x$

(b)  $(25 - 0) = -2x \Rightarrow x = -12.5 \text{ m}$

(c) If potential at origin is 100 v,  $v - 100 = -2x \Rightarrow V = -2x + 100 = 100 - 2x$

(d) Potential at  $\infty$  is 0,  $V - V' = -2x \Rightarrow V' = V + 2x = 0 + 2\infty \Rightarrow V' = \infty$

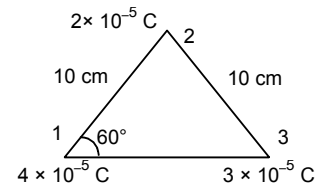
Potential at origin is  $\infty$ . No, it is not practical to take potential at  $\infty$  to be zero.

66. Amount of work done in assembling the charges is equal to the net potential energy

So, P.E. =  $U_{12} + U_{13} + U_{23}$

$= \frac{Kq_1q_2}{r_{12}} + \frac{Kq_1q_3}{r_{13}} + \frac{Kq_2q_3}{r_{23}} = \frac{K \times 10^{-10}}{r} [4 \times 2 + 4 \times 3 + 3 \times 2]$

$= \frac{9 \times 10^9 \times 10^{-10}}{10^{-1}} (8 + 12 + 6) = 9 \times 26 = 234 \text{ J}$



67. K.C. decreases by 10 J. Potential = 100 v to 200 v.

So, change in K.E = amount of work done

$\Rightarrow 10 \text{ J} = (200 - 100) \text{ v} \times q_0 \Rightarrow 100 q_0 = 10 \text{ v}$

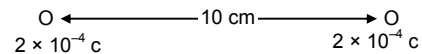
$\Rightarrow q_0 = \frac{10}{100} = 0.1 \text{ C}$

68.  $m = 10 \text{ g}; \quad F = \frac{KQ}{r} = \frac{9 \times 10^9 \times 2 \times 10^{-4}}{10 \times 10^{-2}} \quad F = 1.8 \times 10^{-7}$

$F = m \times a \Rightarrow a = \frac{1.8 \times 10^{-7}}{10 \times 10^{-3}} = 1.8 \times 10^{-3} \text{ m/s}^2$

$V^2 - u^2 = 2as \Rightarrow V^2 = u^2 + 2as$

$V = \sqrt{0 + 2 \times 1.8 \times 10^{-3} \times 10 \times 10^{-2}} = \sqrt{3.6 \times 10^{-4}} = 0.6 \times 10^{-2} = 6 \times 10^{-3} \text{ m/s.}$



69.  $q_1 = q_2 = 4 \times 10^{-5}; \quad s = 1 \text{ m}, \quad m = 5 \text{ g} = 0.005 \text{ kg}$

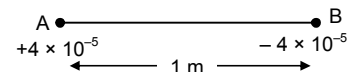
$F = K \frac{q^2}{r^2} = \frac{9 \times 10^9 \times (4 \times 10^{-5})^2}{1^2} = 14.4 \text{ N}$

Acceleration 'a' =  $\frac{F}{m} = \frac{14.4}{0.005} = 2880 \text{ m/s}^2$

Now  $u = 0, \quad s = 50 \text{ cm} = 0.5 \text{ m}, \quad a = 2880 \text{ m/s}^2, \quad V = ?$

$V^2 = u^2 + 2as \Rightarrow V^2 = 2 \times 2880 \times 0.5$

$\Rightarrow V = \sqrt{2880} = 53.66 \text{ m/s} \approx 54 \text{ m/s}$  for each particle



70.  $E = 2.5 \times 10^4$        $P = 3.4 \times 10^{-30}$      $\tau = PE \sin \theta$   
 $= P \times E \times 1 = 3.4 \times 10^{-30} \times 2.5 \times 10^4 = 8.5 \times 10^{-26}$

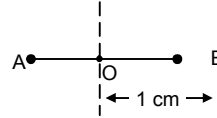
71. (a) Dipole moment =  $q \times \ell$

(Where  $q$  = magnitude of charge     $\ell$  = Separation between the charges)

$= 2 \times 10^{-6} \times 10^{-2} \text{ cm} = 2 \times 10^{-8} \text{ cm}$

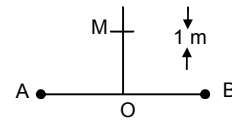
(b) We know, Electric field at an axial point of the dipole

$= \frac{2KP}{r^3} = \frac{2 \times 9 \times 10^9 \times 2 \times 10^{-8}}{(1 \times 10^{-2})^3} = 36 \times 10^7 \text{ N/C}$



(c) We know, Electric field at a point on the perpendicular bisector about 1m away from centre of dipole.

$= \frac{KP}{r^3} = \frac{9 \times 10^9 \times 2 \times 10^{-8}}{1^3} = 180 \text{ N/C}$



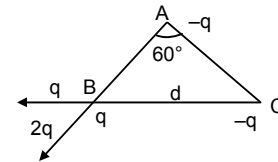
72. Let  $-q$  &  $-q$  are placed at A & C

Where  $2q$  on B      So length of A = d

So the dipole moment =  $(q \times d) = P$

So, Resultant dipole moment

$P = [(qd)^2 + (qd)^2 + 2qd \times qd \cos 60^\circ]^{1/2} = [3q^2d^2]^{1/2} = \sqrt{3} qd = \sqrt{3} P$



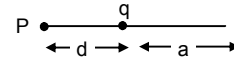
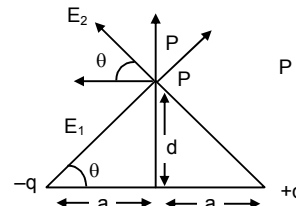
73. (a)  $P = 2qa$

(b)  $E_1 \sin \theta = E_2 \sin \theta$       Electric field intensity

$= E_1 \cos \theta + E_2 \cos \theta = 2 E_1 \cos \theta$

$E_1 = \frac{Kqp}{a^2 + d^2}$  so  $E = \frac{2KPQ}{a^2 + d^2} \frac{a}{(a^2 + d^2)^{1/2}} = \frac{2Kq \times a}{(a^2 + d^2)^{3/2}}$

When  $a \ll d$        $= \frac{2Kqa}{(d^2)^{3/2}} = \frac{PK}{d^3} = \frac{1}{4\pi\epsilon_0} \frac{P}{d^3}$



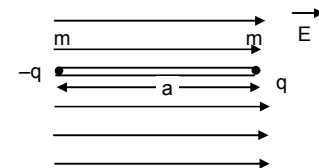
74. Consider the rod to be a simple pendulum.

For simple pendulum       $T = 2\pi\sqrt{\ell/g}$  ( $\ell$  = length,  $g$  = acceleration)

Now, force experienced by the charges

$F = Eq$       Now, acceleration =  $\frac{F}{m} = \frac{Eq}{m}$

Hence length =  $a$       so, Time period =  $2\pi\sqrt{\frac{a}{(Eq/m)}} = 2\pi\sqrt{\frac{ma}{Eq}}$



75. 64 grams of copper have 1 mole

1 mole = No atoms

1 atom contributes 1 electron

6.4 grams of copper have 0.1 mole

0.1 mole = (no  $\times$  0.1) atoms

$= 6 \times 10^{23} \times 0.1 \text{ atoms} = 6 \times 10^{22} \text{ atoms}$

$6 \times 10^{22} \text{ atoms}$  contributes  $6 \times 10^{22}$  electrons.

