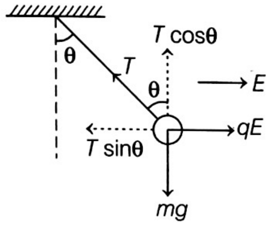
# PHYSICS

## ELECTROSTATICS

1. (4)

Forces on the bob are shown




For equilibrium,

$T\cos\theta = mg$ … (i) and

$T\sin\theta = qE$ … (ii)

Dividing Eq. (ii) by Eq.(i), we get

$$\tan\theta = \frac{qE}{mg}$$

Here, $q = 5\ \mu C = 5 \times 10^{-6}$ C,

$E = 2000\ V\ m^{-1}$

$M = 2\ g = 2 \times 10^{-3}$ kg,

$g = 10\ m\ s^{-2}$

$$\therefore \tan\theta = \frac{5\times10^{-6}\times2000}{2\times10^{-3}\times10} = \frac{1}{2} = 0.5$$

So, the angle made by the string of the pendulum with the vertical is

$$\theta = \tan^{-1}(0.5)$$

2. (1)

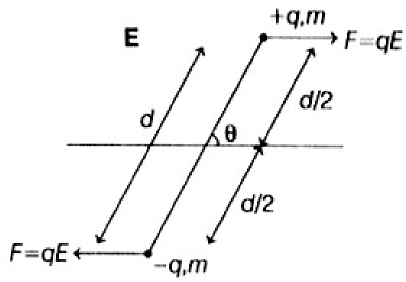
$\therefore$ Torque on the dipole can also be given as

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

where, I is the moment of inertia and $\alpha$ is angular acceleration. For small angles, $\sin\theta \approx \theta$

$$\therefore \alpha = -\left(\frac{pE}{I}\right)\theta \quad \dots (i)$$

Moment of inertia of the given system is




$$I = m\left(\frac{d}{2}\right)^2 + m\left(\frac{d}{2}\right)^2$$

$$= \frac{2md^2}{4} = \frac{md^2}{2}$$

Substituting the value of I in Eq. (i) we get

$$\Rightarrow \alpha = -\left(\frac{2pE}{md^2}\right)\cdot\theta \quad \dots (ii)$$

The above equation is similar to the equation for a system executing angular SHM.

Comparing Eq. (ii), with the general equation of angular SHM , i.e. $\alpha = \omega^2\theta$ where, $\omega$ is the angular frequency, we get

$$\omega^2 = \frac{2pE}{md^2} \text{ or } \omega = \sqrt{\frac{2pE}{md^2}}. \text{ As, } p = qd$$

$$\therefore \omega = \sqrt{\frac{2qdE}{md^2}} = \sqrt{\frac{2qE}{md}}$$

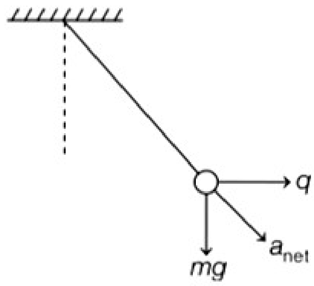
3. (1)

(a) When pendulum is oscillating between capacitor plates, it is subjected to two forces

(i) Weight downwards = mg

(ii) Electrostatic force acting horizontally = qE

So, net acceleration of pendulum bob is resultant of accelerations produced by these two perpendicular forces.




Net acceleration is $\alpha_{net} = \sqrt{a_1^2 + a_2^2}$

$= \sqrt{g^2 + \left(\frac{qE}{m}\right)^2}$

So, time period of oscillations of pendulum is

$$T = 2\pi\sqrt{\frac{I}{a_{net}}} = 2\pi\sqrt{\frac{L}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$$

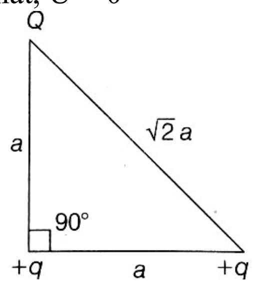
4. (4)
Electrostatic energy between two charges $q_1$ and $q_2$ such that the distance between them is rgiven as

$$U = \frac{Kq_1q_2}{r}$$

In accordance to the principle of superposition, total energy of the charge system as shown in the figure below is

$$U = \frac{Kq^2}{a} + \frac{KQq}{a} + \frac{KQq}{\sqrt{2}a}$$

It is given that, U = 0




$$\therefore \frac{Kq}{a}\left[q + Q + \frac{Q}{\sqrt{2}}\right] = 0$$

$$\Rightarrow Q = \frac{-\sqrt{2} \times q}{\left(\sqrt{2}+1\right)}$$

5. (2)
For a uniformly charged spherical shell,electric potential inside it is given by

$$V_{inside} = V_{surface} = \frac{kq}{r_0} = \text{constant},$$

(where $r_0$ = radius of the shell)
and electric potential outside the shell at a distance r is

$$V_{outside} = \frac{kq}{r}$$

$$\Rightarrow V \propto \frac{1}{r}$$

Therefore, the given graph represents the variation of r and potential of a uniformly charged spherical shell.

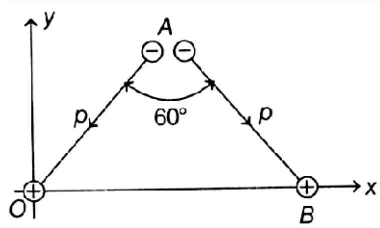
6. (4)
Given, E=1000 V $m^{-1}$
θ =45°andp= $10^{-29}$ C-m
We know that, electric potential energy stored in an electric dipole kept in uniform electric field is given by the relation

$U = -p.E = -pcos\theta$

$= -10^{-29} \times 1000 \times \cos 45°$

$U = -7 \times 10^{-27}$ J

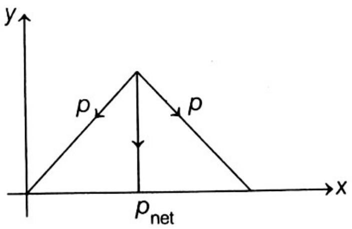
7. (3)
Given system is equivalent to two dipoles inclined at 60° to each other shown in the figure below




Now, magnitude of resultant of these dipole moments is

$$P_{net} = \sqrt{p^2 + p^2 + 2p \cdot p\cos 60°}$$

$$= \sqrt{3}p = \sqrt{3}ql$$




As, resultant is directed along negative y-direction.

$p_{net} = -\sqrt{3}p\hat{j} = -\sqrt{3}ql\hat{j}$

8. (3)

As we know, potential difference $V_A - V_O$ is

$dV = -Edx$

$$\int_{V_O}^{V_A} dV = -\int_0^2 30x^2 dx$$

$$V_A - V_O = -30 \times \left[\frac{x^3}{3}\right]_0^2$$

$$= -10 \times [2^3 - (0)^3]$$

$$= -10 \times 8 = -80 \text{ J}$$

9. (2)

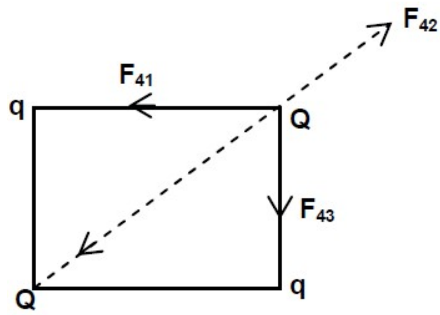
Electric field inside the uniformly charged sphere varies linearly, $E = \frac{kQ}{R^3} \cdot r, \ (r \le R)$, while outside the sphere, it varies as inverse square of distance, $E = \frac{kQ}{r^2}; \ (r \ge R)$

10. (1)

Three forces $F_{41}, F_{42}$ and $F_{43}$ acting on Q as shown.

Resultant of $F_{41} + F_{43} = \sqrt{2}F_{each}$

$$= \sqrt{2}\frac{1}{4\pi\varepsilon_0}\frac{Qq}{d^2}$$




Resultant on Q becomes zero only when q charges are of negative nature.

$$\therefore F = \frac{1}{4\pi\varepsilon_0}\frac{Q \times Q}{(\sqrt{2}d)^2}$$

$$\Rightarrow \sqrt{2}\frac{dQ}{d^2} = \frac{Q \times Q}{2d^2}$$

$$\Rightarrow \sqrt{2} \times q = \frac{Q \times Q}{2}$$

$$\therefore q = \frac{Q}{2\sqrt{2}}$$

or $\frac{Q}{q} = -2\sqrt{2}$