BYJU'S Home Learning Program

Topic covered:

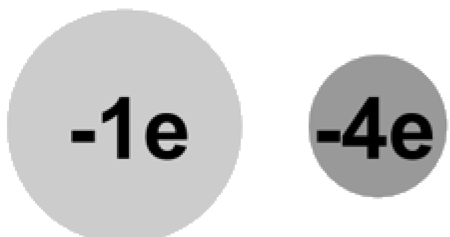
- **Electrostatics (Session - 1)**

Daily Practice Problems

1. When 10^{19} electrons are removed from a neutral metal plate, the electric charge on it is

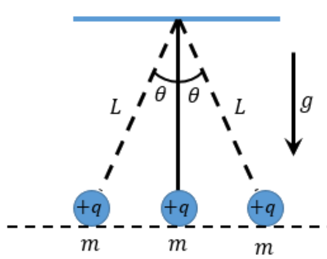
   a. – 1.6 C
   b. + 1.6 C
   c. 10^{+19} C
   d. 10^{-19} C

2. A metal disk with a charge $Q_1 = -1e$ sits near a metal sphere that has a charge $Q_2 = -4e$. If the disk touched the sphere, what is the possible final charge on each object?



   a. $Q_1 = -2e, Q_2 = -3e$
   b. $Q_1 = -3e, Q_2 = -3e$
   c. $Q_1 = -1e, Q_2 = +7e$
   d. $Q_1 = -2e, Q_2 = -2e$

3. Three identical point charges, each of mass m and charge q, hang from three strings as shown in the given figure. The value of q in terms of m, L and θ is



   a. $q = \sqrt{\left(\frac{16}{5}\right)\pi\varepsilon_o mgL^2 sin^2\theta \tan\theta}$
   b. $q = \sqrt{\left(\frac{16}{15}\right)\pi\varepsilon_o mgL^2 sin^2\theta \tan\theta}$
   c. $q = \sqrt{\left(\frac{15}{16}\right)\pi\varepsilon_o mgL^2 sin^2\theta \tan\theta}$
   d. none of these

4. A polythene piece rubbed with wool is found to have a negative charge of $3\times 10^{-7} C$.
   (a)Estimate the number of electrons transferred (from which to which)
   (b)Is there a transfer of mass from wool to polythene?

5. A charge Q is placed at each of the two opposite corners of a square. A charge q is placed at the each of the other two corners. If the resulatant force on each charge q is zero, then:
   a. $q = \sqrt{2}Q$
   b. $q = -\sqrt{2}Q$
   c. $q = 2\sqrt{2}Q$
   d. $q = -2\sqrt{2}Q$

6. F_g and F_e represents gravitational and electrostatic force respectively on electrons situated at a distance of 10 cm. The ratio of $\frac{F_g}{F_e}$ is of the order of
   a. 10^{42}
   b. 10
   c. 1
   d. 10^{-43}

7. Three charges $4q, Q$ and q are in a straight line in the position of 0, $\frac{l}{2}$ and l respectively. The resultant force on q will be zero, if $Q =$
   a. $-q$
   b. $-2q$
   c. $-\frac{q}{2}$
   d. $4q$

8. Two charges each having a charge of 1 C are at a distance 1 km apart. The force between them is
   a. $9 \times 10^3\ N$
   b. $9 \times 10^{-3}\ N$
   c. $1.1 \times 10^{-4}\ N$
   d. $10^4\ N$

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

10. Two identical charged spheres suspended from a common point by two massless strings of length l, are initially at a distance d $(d \ll l)$ apart because of their mutual repulsion. The charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity v. Then v varies as a function of the distance x between the spheres, as
    a. $v \propto x^{-\frac{1}{2}}$
    b. $v \propto x^{-1}$
    c. $v \propto x^{\frac{1}{2}}$
    d. $v \propto x^{\frac{1}{3}}$

Answer Key

Question Number	1	2	3	4	5
Answer Key	(b)	(a)	(a)	a. 1.875×10^{12} b. 17×10^{-19}	(d)

Question Number	6	7	8	9	10
Answer Key	(d)	(a)	(a)	(b)	(a)

Solutions

1. (b)

   Charge on an electron is a constant i.e., $-1.6 \times 10^{-19}\ C$. So, if we remove an electron from a substance, we remove a charge of $-1.6 \times 10^{-19}\ C$. Therefore, by quantization of charge, the charge gained by the substance is equal to $+1.6 \times 10^{-19}\ C$ and if 10^{19} electrons are removed then the charge gain by the metal plate is

$$Q = ne$$
$$Q = 10^{19} \times 1.6 \times 10^{-19}\ C$$
$$Q = 1.6\ C$$

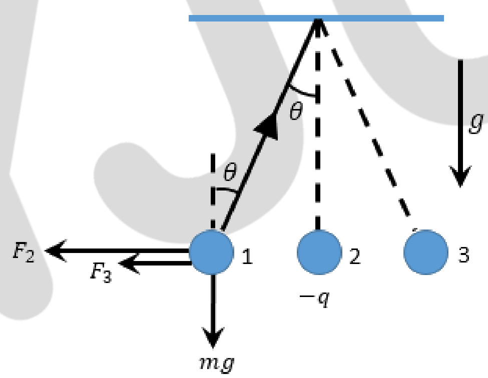
2. (a)

   Total charge initially $= -1e + (-4e) = -5e$

   Using the quantization of charges, the only possibility is option (a)

   Total charge finally $= -2e + (-3e) = -5e$

3. (a)



$$F = F_2 + F_3 = \frac{kq^2}{(L\sin\theta)^2} + \frac{kq^2}{(2L\sin\theta)^2}$$
$$= \frac{5}{4}\frac{kq^2}{L^2 sin^2\theta} \text{ .... (1)}$$
$$T\sin\theta = Fe \text{ ..... (2)}$$
$$T\cos\theta = mg \text{ .... (3)}$$

From (1), (2) and (3), $q = \sqrt{\left(\frac{16}{5}\right)\pi\varepsilon_o mgL^2 sin^2\theta \tan\theta}$

4.

Given,

$q = 3 \times 10^{-7} C, e = 1.6 \times 10^{-19}\ C$

(a) To estimate the number of the electron transferred,

$q = ne$

$n = \frac{3\times10^{-7}}{1.6\times10^{-19}} = 1.875 \times 10^{12}$ electrons

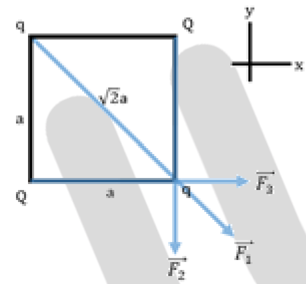
(b) Yes, mass is transferred from wool to polythene.

We know that the mass of electron, $m = 9.1 \times 10^{-31}\ kg$

The mass transferred is $M = nm$

$M = 1.875 \times 10^{12} \times 9.1 \times 10^{-31} = 17 \times 10^{-19}\ kg$

5. (d)



The net force on q at one corner is zero if $\vec{F_1} + \vec{F_2} + \vec{F_3} = 0$

Or $F_1 \cos 45°\ \hat{\imath} - F_1 \sin 45\,°\hat{\jmath} - F_2\hat{\jmath} + F_3\hat{\imath}$

So, $F_1 \cos 45° = -F_3$...(1) and $F_1 \sin 45° = -F_2$...(2)

Using (1), $\frac{kq^2}{(\sqrt{2}a)^2} \times \frac{1}{2} = -\frac{kqQ}{a^2}$

Or $q = -2\sqrt{2}Q$

6. (d)

Gravitational force between electrons $F_g = \frac{G(m_e)^2}{r^2}$

Electrostatic force between electrons $F_e = \frac{k(e)^2}{r^2}$

$\frac{F_g}{F_e} = \frac{G(m_e)^2}{k(e)^2} = \frac{6.67\times10^{-11}\times(9.1\times10^{-31})^2}{9\times10^{9}\times(1.6\times10^{-19})^2} = 2.39\times 10^{-43}$

7. (a)

The force between $4q$ and q: $F_1 = \frac{1}{4\pi\varepsilon_o}\frac{4q\times q}{l^2}$

The force between Q and q: $F_2 = \frac{1}{4\pi\varepsilon_o}\frac{Q\times q}{\left(\frac{l}{2}\right)^2}$

Given $F_1 + F_2 = 0$

$\frac{4q^2}{l^2} = \frac{4Qq}{l^2} \Longrightarrow Q = -q$

8. (a)

$$F = \frac{kQ^2}{r^2} = 9\times10^9\times1^2\times\frac{1}{(1000)^2} = 9\times10^3\ N$$

9. (b)

A hydrogen atom consists of an electron and a proton

$\therefore$ Charge on one hydrogen atom $= q_e + q_p = -e + (e+\Delta e) = \Delta e$

Since a hydrogen atom carry a net charge Δe,

Electrostatic force, $F_e = \frac{1}{4\pi\varepsilon_o}\frac{(\Delta e)^2}{d^2}$ will act between the two hydrogen atoms.

The gravitational force between them is given as $F_g = \frac{Gm_hm_h}{d^2}$

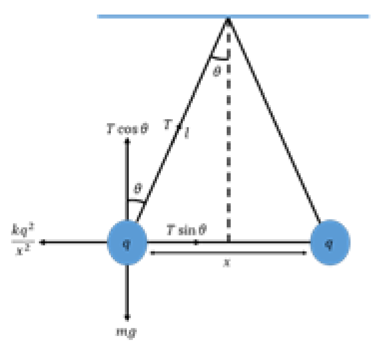
Since the net force on the system is zero, $F_e = F_g$

$$\frac{1}{4\pi\varepsilon_o}\frac{(\Delta e)^2}{d^2} = \frac{Gm_hm_h}{d^2}$$

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

$$= 9\times10^9\times6.67\times10^{-11}\times(1.67\times10^{-27})^2 = 10^{-37}\ C$$

10. (a)



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

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

From equations (i) and (ii), $\tan\theta = \frac{kq^2}{x^2mg}$

Since θ is small, $\tan\theta \cong \sin\theta = \frac{x}{2l}$

$$\therefore \frac{x}{2l} = \frac{kq^2}{x^2mg}$$

$$q^2 = x^3\frac{mg}{2lk} \Longrightarrow \frac{dq}{dt} \propto \frac{3}{2}\sqrt{x}\frac{dx}{dt} = \frac{3\sqrt{x}v}{2}$$

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

From the above equation, $\boldsymbol{v} \propto \frac{\mathbf{1}}{\sqrt{\boldsymbol{x}}}$