SHORT QUESTIONS

12.1 The potential is constant throughout a given region of space. Is the electrical field zero or non-zero in this region? Explain.

Ans. When the potential is constant through a given region of space then electric field in this region will be zero.

Reason: We know the relation between electric intensity and potential difference is

$$E = -\frac{\Delta V}{\Delta r} \qquad \ldots\ldots \text{(i)}$$

As potential is constant.

$$\therefore \qquad \Delta V = 0$$

Put in (i) eq. we get

$$E = 0$$

So electric field will be zero.

12.2 Suppose that you follow an electric field line due to a positive point charge. Do electric field and the potential increases or decreases?

Ans. If we follow an electric field line due to a positive point charge then electric field and potential both will decrease.

Reason: The formula for electric intensity and electric potential are

$$E = \frac{1}{4\pi\epsilon_o}\frac{q}{r^2} \quad \text{and} \quad V = \frac{1}{4\pi\epsilon_o}\frac{q}{r}$$

From these formulae we see that electric intensity is inversely proportional to square of distance and electric potential is inversely proportional to the distance therefore both will decrease.

12.3 How can you identify that which plate of a capacitor is positively charged?

Ans. There are different methods by which we can identify that which plate of a capacitor is positively charged.

(i) The plate of a capacitor connected with the positive terminal of battery will be positively charged.

(ii) A device called gold leaf electroscope can also be used for this purpose. We will bring a positively charged electroscope close to the plate of a capacitor, if the leaves will diverge then that plate will be positively charged.

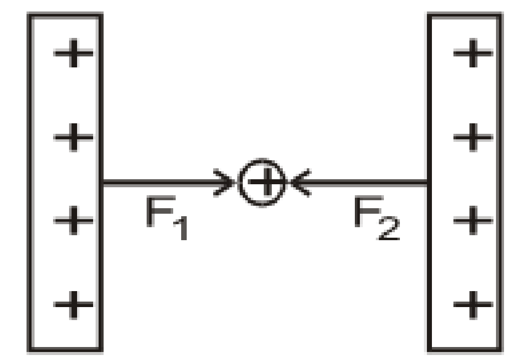
(iii) If a positive test charge is brought near the plate and if test charge will repel then that plate will be positively charged.

12.4 Describe the force or forces on a positive point charge when placed between parallel plates.

(a) With similar and equal charges.

(b) With opposite and equal charges.

Ans. (a) When a positive point charge is placed between parallel plates with similar and equal charge plates then net force will be zero.



Reason: We know that the expression of electric force is

$$F = qE$$

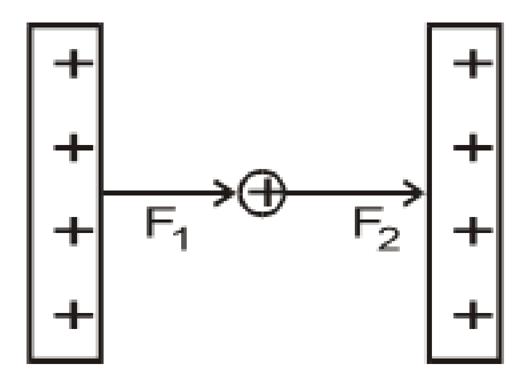
Here, $|F_1| = |F_2| = F$

i.e., magnitude of force is equal but in opposite direction.

Net force $= F_1 + (F_2)$

Net force $= 0$

(b) When a positive point charge is placed between two parallel plates with opposite and equal charges then force will be double i.e., 2F.



As $|F_1| = |F_2| = F$

Net force $= F_1 + F_2$

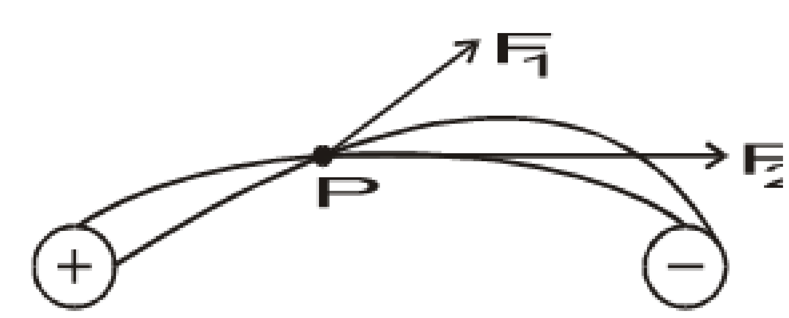
Net force $= 2F$

In this case both forces are equal in magnitude and are in same direction.

12.5 Electric lines of force never cross. Why?

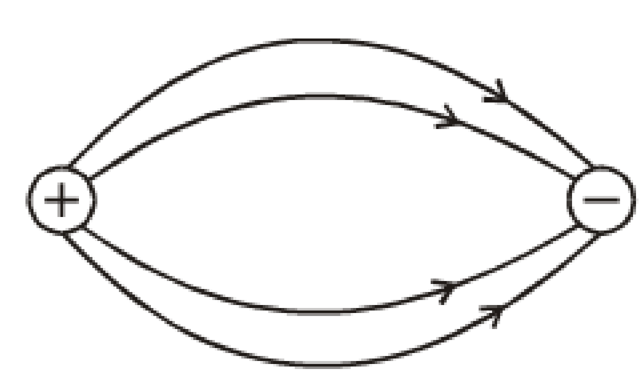
Ans. Electric lines of forces can never cross each other.

Reason: As electric intensity is a vector quantity and if two electric lines of forces cross each other at a single point then electric intensity will have two different direction at a single point which is not possible because electric intensity is a vector quantity and vector has only one direction.

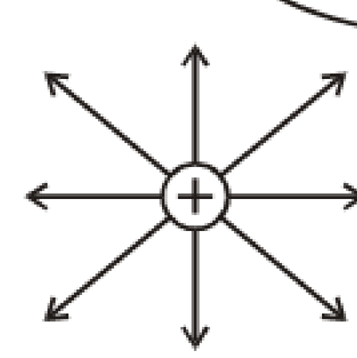


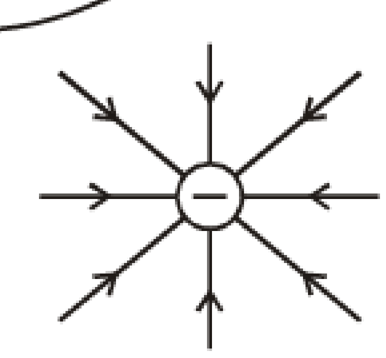
12.6 If a point charge q of mass m is released in a non-uniform electric field with field lines in the same direction pointing, will it make a rectilinear motion?

Ans. If a point charge q of mass m is released in a non-uniform electric field then there are two possibilities:



(i) If a point charge is released in a non-uniform field produced by positive and negative charges then it will move in curved path.



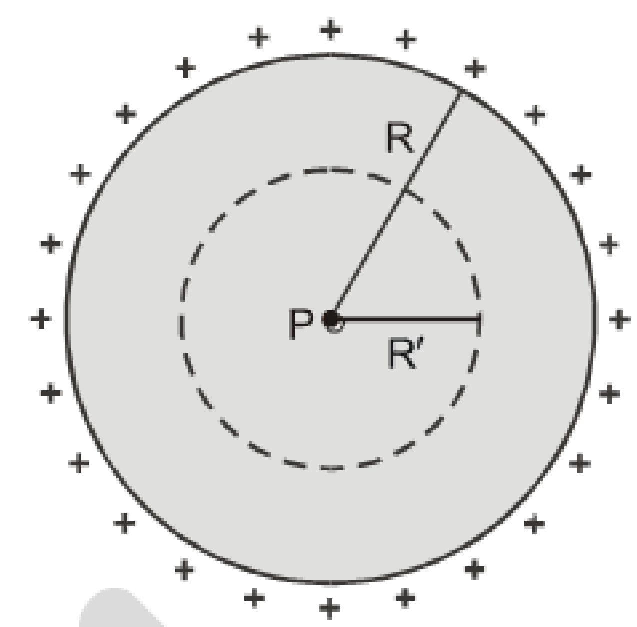


(ii) If a point charge is placed in non-uniform field produced by a positive or negative charge then it will make a rectilinear motion.

12.7 Is E necessarily zero inside a charged rubber balloon if balloon is spherical? Assume that charge is distributed uniformly over the surface.

Ans. Electric intensity inside a charged rubber balloon will be zero.

Reason: Consider a Gaussian surface inside the charged rubber balloon. As there is no charge at the centre therefore q = 0.



According to Gauss's law

$$\phi_e = \frac{1}{\epsilon_o}\text{(Charge)}$$

$$\phi_e = \frac{1}{\epsilon_o}(q)$$

$$\phi_e = \frac{1}{\epsilon_o}\,0$$

$$\therefore \quad \phi_e = 0 \qquad \text{...... (i)}$$

But according to definition of electric flux.

$$\phi_e = \vec{E}\,.\,\vec{A} \qquad \text{...... (ii)}$$

Comparing equations (i) and (ii) we get:

$$\vec{E}\,.\,\vec{A} = 0$$

$$\text{As} \quad \vec{A} \neq 0$$

$$\therefore \quad \vec{E} = 0$$

So the electric intensity inside a charged rubber balloon is zero.

12.8 Is it true that Gauss's law states that the total number of lines of forces crossing any closed surface in the outward direction is proportional to the net positive charge enclosed within surface?

Ans. We know that according to Gauss's law, total flux passing through any closed surface is equal to $\frac{1}{\epsilon_o}$ times the total charge enclosed within the surface.

$$\text{i.e.,} \quad \phi = \frac{1}{\epsilon_o} \text{ (total charge)}$$

$$\text{Here,} \quad \frac{1}{\epsilon_o} = \text{Constant}$$

$$\text{So,} \quad \phi \propto \text{Total charge}$$

Here ϕ = flux which is total number of lines passing through a certain area and we see that it is directly proportional to charge enclosed within the surface therefore given statement is true that the total number of lines of forces crossing any closed surface in the outward direction is proportional to net positive charge enclosed within the surface.

12.9 Do electrons tend to go to region of high potential or of low potential?

Ans. As electrons are negatively charged particle therefore when they enter the electric field they will tend to go the region of high potential (positive terminal) from the region of low potential (negative terminal).

PROBLEMS WITH SOLUTIONS

PROBLEM 12.1

Compare magnitudes of electrical and gravitational forces exerted on an object (mass = 10.0 g, charge = 20.0 μC) by an identical object that is placed 10.0 cm from the first. ($G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2})

Data

Mass of one object $= m_1 = 10.0\ \text{g} = \frac{10.0}{1000}\ \text{kg} = 0.01\ \text{kg}$

Mass of 2nd object $= m_2 = 10.0\ \text{g} = \frac{10.0}{1000}\ \text{kg} = 0.01\ \text{kg}$

Charge on one object $= q_1 = 20.0\ \mu\text{C}$

$= 20 \times 10^{-6}$ C

Charge on 2nd object $= q_2 = 20 \times 10^{-6}$ C

Distance between the charges = 10.0 cm = 0.1 m

To Find

Comparison of forces $= \frac{F_e}{F_g} = ?$

SOLUTION

For electrical force

$$\boxed{F_e = k\frac{q_1 q_2}{r^2}}$$

But $k = 9 \times 10^9\ \text{N.m}^2/\text{C}^2$

$$F_e = \frac{9 \times 10^9 \times 20.0 \times 10^{-6} \times 20.0 \times 10^{-6}}{(0.1)^2}$$

$$= \frac{3600 \times 10^{9-6-6}}{0.01}$$

$$= \frac{3600}{0.01} \times 10^{-3}$$

$$F_e = 360000 \times 10^{-3}$$

$$= 360\text{N}$$

For gravitational force

$$\boxed{F_g = \frac{Gm_1 m_2}{r^2}}$$

But $G = 6.673 \times 10^{-11}\ \text{N.m}^2/\text{Kg}^2$

So,
$$F_g = \frac{6.673 \times 10^{-11} \times 0.01 \times 0.01}{(0.1)^2}$$

$$F_g = \frac{6.673 \times 10^{-11} \times (0.01)^2}{(0.01)}$$

$$F_g = 6.673 \times 10^{-13}\text{N}$$

Therefore, $\frac{F_e}{F_g} = \frac{360}{6.673 \times 10^{-13}}$

$= 53.9 \times 10^{13}$

$= 5.4 \times 10^{14}$

Result

Comparison of Force $= \frac{F_e}{F_g} = 5.4 \times 10^{14}$

PROBLEM 12.2

Calculate the net electrostatic force on q as shown in the figure.

Data

Charge $= q = 4.0\ \mu C$

$= 4.0 \times 10^{-6}$ C

Charge $= q_1 = 1.0\ \mu C$

$= 1.0 \times 10^{-6}$ C

Charge $= q_2 = -1.0\ \mu C$

$= -1.0 \times 10^{-16}$ C

Distance between the charges q and $q_1 = r_1 = 1.0$ m

Distance between the charges q and $q_2 = r_2 = 1.0$ m

To Find

Electrostatic force on charge $q = \vec{F}_e = ?$

SOLUTION

Using $F = \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1 q_2}{r^2}$

Force on q exerted by q_1 is

$F_1 = \frac{1}{4\pi\epsilon_o} \cdot \frac{qq_1}{r^2}$

$F_1 = 9 \times 10^9 \times \frac{1 \times 10^{-6} \times 4 \times 10^{-6}}{(1)^2}$

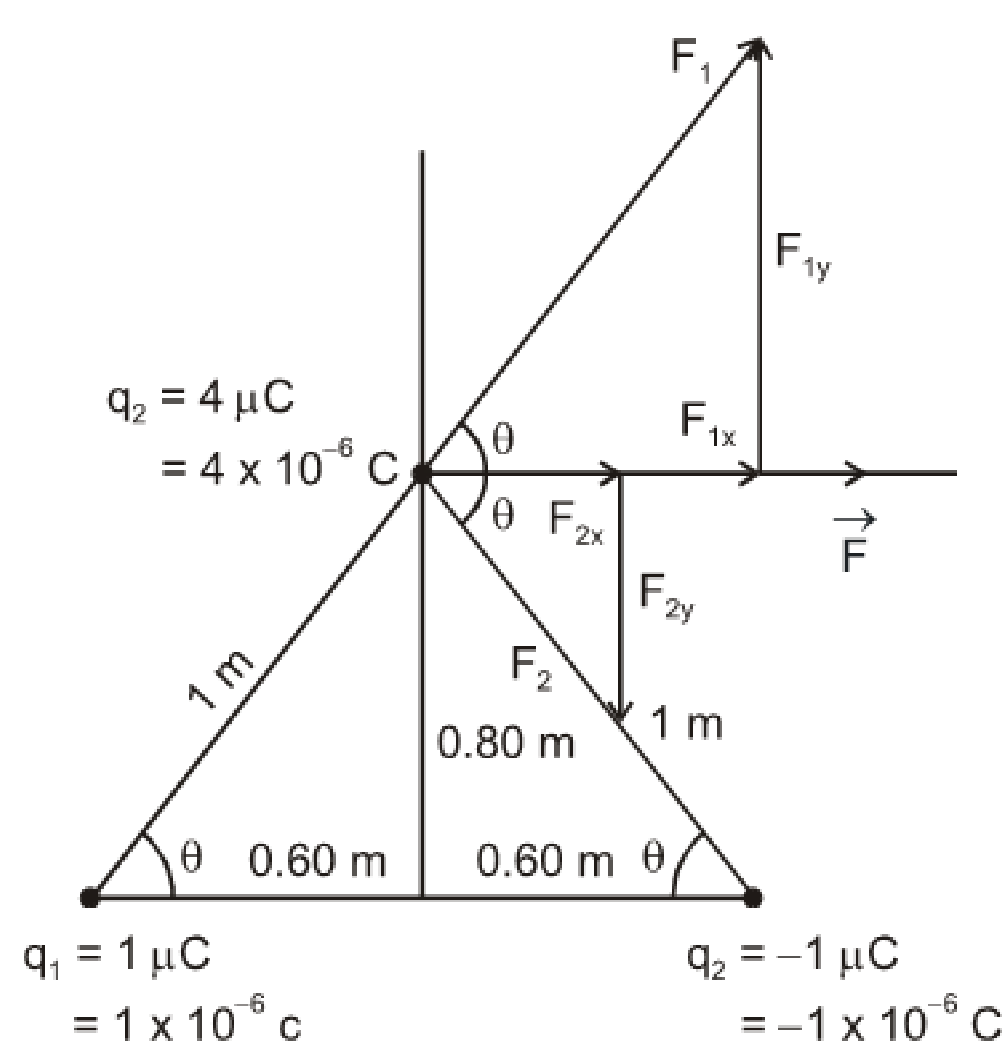
$F_1 = 36 \times 10^{-3}$ N

Now force on q exerted by q_2 is

$F_2 = \frac{1}{4\pi\epsilon_o} \cdot \frac{qq_2}{r^2}$

$F_2 = 9 \times 10^9 \times \frac{4 \times 10^{-6} \times 1 \times 10^{-6}}{(1)^2}$

$F_2 = 36 \times 10^{-3}$ N



Now using

$$F_x = F_{1x} + F_{2x}$$

$$F_x = F_1 \cos\theta + F_2 \cos\theta \qquad \ldots\ldots \text{(i)}$$

From figure

$$\cos\theta = \frac{0.60}{1}$$

$$\cos\theta = 0.60$$

Putting this value in eq. (i)

$$F_x = 36 \times 10^{-3} \times 0.60 + 36 \times 10^{-3} \times 0.60$$

$$= 2 \times 36 \times 0.60 \times 10^{-3}$$

$$= 0.043 \text{ N}$$

$$F_y = F_{1y} + (-F_{2y})$$

Also $\quad F_y = F_1 \sin\theta - F_2 \sin\theta$

$$= 36 \times 10^{-3} \sin\theta - 36 \times 10^{-3} \sin\theta$$

From figure

$$\sin\theta = \frac{0.80}{1}$$

$$\sin\theta = 0.80$$

$\therefore \quad F_y = 36 \times 10^{-3}\,(0.80) - 36 \times 10^{-3}\,(0.80)$

$$F_y = 0 \text{ N}$$

Now $\quad \vec{F} = F_x\hat{i} + F_y\hat{j}$

$$F = \sqrt{F_x^2 + F_y^2}$$

$$= \sqrt{(0.043)^2 + (0)^2}$$

$$= \sqrt{(0.043)^2}$$

$$= 0.043 \text{ N}$$

Since F_x and F_y both lie in 1st quadrant because F_x and F_y are positive.

Now using

$$\tan\phi = \frac{F_y}{F_x}$$

$$\phi = \tan^{-1}\left(\frac{0}{0.043}\right)$$

$$= \tan^{-1}(0)$$

$$= 0^\circ$$

$\therefore$ Net force on q is

$$\vec{F} = 0.043\,\hat{i}\text{ N}$$

Result

The force acting on the charge q is

$$\vec{F} = 0.043\,\hat{i}\text{ N}$$

PROBLEM 12.3

A point charge $q = -8.0 \times 10^{-8}$ C is placed at the origin. Calculate electric field at a point 2.0 m from the origin on the z-axis.

Data

Point charge = $q = -8.0 \times 10^{-8}\text{C}$

Distance between charge and origin $= r = 2.0\text{m}$

To Find

Electric intensity $= \vec{E} = ?$

SOLUTION

The magnitude of the electric intensity at a point along z-axis is

$$\boxed{E = \frac{1}{4\pi\epsilon_o}\frac{q}{r^2}}$$

But $\quad \dfrac{1}{4\pi\epsilon_o} = 9 \times 10^9\text{ Nm}^2/\text{C}^2$

So, $\quad \vec{E} = 9 \times 10^9 \times \dfrac{8.0 \times 10^{-8}}{(2.0)^2}(-\hat{k})$

$$= \frac{-72 \times 10^{9-8}}{4}\hat{k}$$

$$= \frac{-72 \times 10}{4}\hat{k}$$

$$= -18 \times 10\,\hat{k}$$

$$\vec{E} = -180\text{ N/C}\,\hat{k}$$

or $\quad \vec{E} = -1.8 \times 10^2\,\hat{k}\text{ N/C}$

Result

Electric intensity $= E = -1.8 \times 10^2\,\hat{k}\text{ N/C}$

PROBLEM 12.4

Determine the electric field at the point r = $(4\hat{i} + 3\hat{j})$ m caused by a point charge q = 5.0×10^{-6} C placed at origin.

Data

Point charge = $q = 5.0 \times 10^{-6}$ C

Position vector = $\vec{r} = (4\hat{i} + 3\hat{j})$m

To Find

Electric field intensity= $\vec{E}$ = ?

SOLUTION

By formula

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_o}\frac{q}{r^2}\hat{r}} \quad \ldots\ldots \text{(i)}$$

But $\quad \dfrac{1}{4\pi\epsilon_o} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$

Since $\quad \vec{r} = (4\hat{i} + 3\hat{j})$ m

So the magnitude of the given point from the origin is

$$|\vec{r}| = \sqrt{(4)^2 + 5^2}$$
$$r = \sqrt{16 + 5}$$
$$r = \sqrt{25}$$
$$r = 5$$

And $\quad \hat{r} = \dfrac{\vec{r}}{r} = \dfrac{4\hat{i} + 3\hat{j}}{5}$

Putting in equation (i)

$$\vec{E} = 9 \times 10^9 \times \frac{5.0 \times 10^{-6}}{5^2}\left(\frac{4\hat{i} + 3\hat{j}}{5}\right)$$
$$= \frac{45 \times 10^{9-6}}{125}\,(4\hat{i} + 3\hat{j})$$
$$= 0.36 \times 10^3\,(4\hat{i} + 3\hat{j})$$
$$= 360\,(4\hat{i} + 3\hat{j})$$
$$\vec{E} = (1440\hat{i} + 1080\hat{j}) \text{ N/C}$$

Result

Electric field intensity = $\vec{E} = (1440\hat{i} + 1080\hat{j})$ N/C

PROBLEM 12.5

Two point charges, $q_1 = -1.0 \times 10^{-6}$ C and $q_2 = +4.0 \times 10^{-6}$ C, are separated by a distance of 3.0 m. Find and justify the zero-field location.

Data

Charge $= q_1 = -1.0 \times 10^{-6}$ C

Charge $= q_2 = +4.0 \times 10^{-6}$ C

Distance between the charges $= r = 3.0$ m

To Find

Distance where the electric intensity is zero $= x = ?$

SOLUTION

Let P be the any point at a distance x from the charge q_1. So the electric intensity E_1 due to the charge q_1 is

$$\boxed{E_1 = \frac{1}{4\pi\epsilon_o}\frac{q_1}{x^2}}$$

$$E_1 = 9 \times 10^9 \times \frac{1.0 \times 10^{-6}}{x^2}$$

And the electric intensity due to the charge q_2 is

$$\boxed{E_2 = \frac{1}{4\pi\epsilon_o}\frac{q_2}{(3+x)^2}}$$

$$E_2 = 9 \times 10^9 \times \frac{4.0 \times 10^{-6}}{(3+x)^2}$$

Since at point P, the two electric intensities are equal and opposite in direction therefore

$$E_1 = E_2$$

$$\frac{1}{4\pi\epsilon_o}\frac{1.0 \times 10^{-6}}{x^2} = \frac{1}{4\pi\epsilon_o}\frac{4.0 \times 10^{-6}}{(3+x)^2}$$

$$\frac{1}{x^2} = \frac{4}{(3+x)^2}$$

Taking square root

$$\sqrt{\frac{1}{x^2}} = \sqrt{\frac{4}{(3+x)^2}}$$

$$\frac{1}{x} = \frac{2}{3+x}$$

$$2x = 3 + x$$

$$2x - x = 3$$

$$x = 3\text{m}$$

Result

Distance where electric intensity is zero $= x = 3.0$m.

PROBLEM 12.6

Find the electric field strength required to hold suspended a particle of mass 1.0×10^{-6} kg and charge $1.0\ \mu C$ between two plats 10.0 cm apart.

Data

Mass of particle $= m = 1.0 \times 10^{-6}$ kg

Charge on particle $= q = 1.0\ \mu C$

$= 1.0 \times 10^{-6}$ C

Distance between the plates $= r = 10$ cm

$= 0.1$ m

To Find

Electric field strength $= E = ?$

SOLUTION

By formula

$$\boxed{E = \frac{F}{q}}$$

But $F = mg$

$$E = \frac{mg}{q}$$

$$E = \frac{1.0 \times 10^{-6} \times 9.8}{1.0 \times 10^{-6}}$$

$$E = 9.8\ N/C$$

Result

Electric field strength $= E = 9.8$ N/C

PROBLEM 12.7

A particle having a charge of 20 electrons on it falls through a potential difference of 100 volts. Calculate the energy acquired by it in electron volts (eV).

Data

Number of electrons $= N = 20$

Potential difference $= \Delta V = 100$ volt

To Find

Energy acquired $= \Delta(K.E) = ?$

SOLUTION

By using the formula

$$\boxed{\Delta(K.E) = q\,\Delta V}$$

But $q = Ne$

$= 20 \times 1.6 \times 10^{-19}C$

$= 32 \times 10^{-19}C$

$= 3.2 \times 10^{-18}C$

Therefore, $\Delta(K.E) = 3.2 \times 10^{-18} \times 100$

$= 3.2 \times 10^{-16}$ J

Since, $1\text{ eV} = 1.6 \times 10^{-19}$ J

Therefore, $\Delta(K.E) = \dfrac{3.2 \times 10^{-16}}{1.6 \times 10^{-19}}$

$= 2 \times 10^{-16+19}$ eV

$= 2.0 \times 10^{3}$ eV

Result

Energy acquired $= 2.0 \times 10^{3}$ eV

PROBLEM 12.8

In Millikan's experiment, oil droplets are introduced into the space between two flat horizontal plates, 5.00 mm apart. The plate voltage is adjusted to exactly 780V so that the droplet is held stationary. The plate voltage is switched off and the selected droplet is observed to fall a measured distance of 1.50 mm in 11.2 s. Given that the density of the oil used is 900kg m^{-3}, and the viscosity of air at laboratory temperature is 1.80 × 10^{-5} Nm^{-2} s, calculate

(a) the mass, and

(b) the charge on the droplet (assume g = 9.8 ms^{-2})

Data

Distance between the plates $= d = 5.00$ mm

$= 5 \times 10^{-3}$m

Potential difference $= V = 780$ volt

Distance covered by the droplet $= S = 1.50$ mm

$= 1.50 \times 10^{-3}$ m

Time taken $= t = 11.2$ sec.

Density of oil $= \rho = 900$ kg/m^3

Viscosity of Air $= \eta = 1.80 \times 10^{-5}$ Ns/m^2

To Find

(a) Mass of droplet $= m = ?$

(b) Charge on droplet $= q = ?$

SOLUTION

(a) For mass of the droplet

$$\boxed{m = \frac{4}{3}\pi r^3 \times \rho} \quad \ldots\ldots \text{(i)}$$

But $$r^2 = \frac{9\eta v_t}{2\rho g}$$

$$v_t = \text{Terminal velocity} = \frac{\text{Distance covered}}{\text{Time taken}}$$

$$v_t = \frac{1.50 \times 10^{-3}}{11.2}$$

$$v_t = 1.34 \times 10^{-4} \text{ m/s}$$

Therefore,

$$r^2 = \frac{9 \times 1.80 \times 10^{-5} \times 1.34 \times 10^{-4}}{2 \times 900 \times 9.8}$$

$$r^2 = \frac{21.708 \times 10^{-5-4}}{17640}$$

$$\sqrt{r^2} = \sqrt{1.23 \times 10^{-12}}$$

$$r = 1.10 \times 10^{-6}$$

Putting in equation (i)

$$m = \frac{4}{3} \times 3.14\,(1.10 \times 10^{-6})^3 \times 900$$

$$m = 5153.2 \times 10^{-18}$$

$$= 5.15 \times 10^{-15} \text{ kg}$$

(b) For charge using the formula

$$q = \frac{mgd}{v}$$

$$q = \frac{5.15 \times 10^{-15} \times 9.8 \times 5.00 \times 10^{-3}}{780}$$

$$q = 0.323 \times 10^{-18}$$

$$q = 3.23 \times 10^{-19} \text{ C}$$

Result

(a) Mass of droplet $= m = 5.15 \times 10^{-15}$ kg

(b) Charge on droplet $= q = 3.23 \times 10^{-19}$ C

PROBLEM 12.9

A proton placed in uniform electric field of 5000 NC^{-1} directed to right is allowed to go a distance of 10.0 cm from A to B. Calculate

(a) Potential difference between the two points

(b) Work done

(c) The change in P.E. of proton

(d) The change in K.E. of the proton

(e) Its velocity (mass of proton is 1.67×10^{-27} kg)

Data

Uniform electric field intensity	=	E	=	5000 N/C
Distance travelled	=	Δr	=	10.0 cm
			=	0.1 m

To Find

(a)	Potential difference	=	ΔV	=	?
(b)	Work done	=	W	=	?
(c)	Change in P.E of proton	=	ΔU	=	?
(d)	Change in K.E of proton	=	Δ(K.E)	=	?
(e)	Velocity of proton	=	V	=	?

SOLUTION

(a) For potential difference by using the formula

$$\boxed{\Delta V = -E\Delta r}$$

$$= -5000 \times 0.1$$

$$= -500 \text{ volt}$$

–ve sign shows that potential decreases because proton is moving along $\vec{E}$.

(b) For work done

$$\boxed{W = q\,\Delta V}$$

But $q = 1.6 \times 10^{-19}$C

So, $W = 1.6 \times 10^{-19} \times 500$ J

In electron volt

$$W = \frac{1.6 \times 10^{-19} \times 500}{1.6 \times 10^{-19}}$$

$$W = 500 \text{ eV}$$

(c) For change in P.E of the proton

Change in P.E $= \Delta U = -\Delta W$

$$\boxed{\Delta U = -q\,\Delta V}$$

$$= -1.6 \times 10^{-19} \times 500 \text{ J}$$

$$= -\frac{1.6 \times 10^{-19} \times 500}{1.6 \times 10^{-19}} \text{ eV}$$

$$\Delta U = -500 \text{ eV}$$

–ve sign shows that potential energy decreases because proton is moving along $\vec{E}$.

(d) For change in K.E of the proton

$$\Delta(\text{K.E}) = \text{Work done}$$

$$\boxed{\Delta(\text{K.E}) = q\,\Delta V}$$

$$= 1.6 \times 10^{-19} \times 500 \text{ J}$$

$$= \frac{1.6 \times 10^{-19} \times 500}{1.6 \times 10^{-19}} \text{ eV}$$

$$\Delta(\text{K.E}) = 500 \text{ eV}$$

+ve sign shows that kinetic energy increases.

(e) For the velocity of the proton

$$\Delta(\text{K.E}) = \frac{1}{2}\,mV^2$$

$$\boxed{V^2 = \frac{2\Delta(\text{K.E})}{m}}$$

$$V^2 = \frac{2 \times 1.6 \times 10^{-19} \times 500}{1.67 \times 10^{-27}}$$

$$V^2 = 958.08 \times 10^{-19+27}$$

$$\sqrt{V^2} = \sqrt{958.08 \times 10^8}$$

$$V = 30.9 \times 10^4$$

$$V = 3.09 \times 10^5 \text{ m/s}$$

Result

(a) Potential difference $= \Delta V = -500$ volt

(b) Work done $= W = 500$ eV

(c) Change in P.E of proton $= \Delta U = -500$ eV

(d) Change in K.E of proton $= \Delta(\text{K.E}) = 500$ eV

(e) Velocity of proton $= V = 3.09 \times 10^5$ m/s

PROBLEM 12.10

Using zero reference point at infinity, determine the amount by which a point charge of 4.0×10^{-8} C alters the electric potential at a point 1.2 m away, when

(a) Charge is positive (b) Charge is negative

Data

Point charge = $q = 4.0 \times 10^{-8}$ C

Distance = $r = 1.2$ m

To Find

(a) Electric potential when the charge is positive = V_1 = ?

(b) Electric potential when the charge is negative = V_2 = ?

SOLUTION

(a) Electric potential when the charge is positive

$$V_1 = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

But $$\frac{1}{4\pi\epsilon_o} = 9 \times 10^9 \text{ N.m}^2/\text{C}^2$$

$$V_1 = 9 \times 10^9 \times \frac{4.0 \times 10^{-8}}{1.2}$$

$$= \frac{36 \times 10^{9-8}}{1.2}$$

$$= +3.0 \times 10^2 \text{ volt}$$

(b) Electric potential when the charge is negative

$$V_2 = \frac{1}{4\pi\epsilon_o}\frac{-q}{r}$$

$$V_2 = \frac{-9 \times 10^9 \times 4 \times 10^{-8}}{1.2}$$

$$V_2 = \frac{-36}{1.2} \times 10^1$$

$$= -3.0 \times 10^2 \text{ volt}$$

Result

(a) Electric potential when change is positive

$$V_1 = +3.0 \times 10^2 \text{ volt}$$

(b) Electric potential when charge is negative

$$V_2 = -3.0 \times 10^2 \text{ volt}$$

PROBLEM 12.11

In Bohr's atomic model of hydrogen atom, the electron is in an orbit around the nuclear proton at a distance of 5.29×10^{-11} m with a speed of 2.18×10^{6} ms^{-1}. e = 1.6×10^{-19} C, mass of electron = 9.1×10^{-31} kg. Find

(a) The electric potential that a proton exerts at this distance

(b) Total energy of the atom in eV

(c) The ionization energy for the atom in eV

Data

Distance = $r = 5.29 \times 10^{-11}$ m

Speed of electron = $V = 2.18 \times 10^{6}$ m/s

Charge on electron = $\rho = 1.6 \times 10^{-19}$ C

Mass of electron = $m = 9.10 \times 10^{-31}$ kg

To Find

(a) Electric potential = V = ?

(b) Total energy of the atom in eV = E_n = ?

(c) Ionization energy for the atom in eV = E_i = ?

SOLUTION

(a) The electric potential that a proton exerts at this distance is

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

But $$\frac{1}{4\pi\epsilon_o} = 9 \times 10^{9}\ \text{N.m}^2/\text{C}^2$$

$$V = 9 \times 10^{9} \times \frac{1.6 \times 10^{-19}}{5.29 \times 10^{-11}}$$

$$= 2.727 \times 10^{9-19+11}$$

$$= 2.727 \times 10^{1}$$

$$V = 27.27 \text{ volt}$$

(b) For total energy of the atom is

Total energy = E_n = P.E + K.E …… (i)

Therefore for P.E of an electron

$$\boxed{\text{P.E} = -q\,V}$$

$$= -1.6 \times 10^{-19} \times 27.27\text{J}$$

$$= \frac{-1.6 \times 10^{-19} \times 27.27}{1.6 \times 10^{-19}}\ \text{eV}$$

$$= -27.27 \text{ eV}$$

And the K.E of the electron is

$$\boxed{K.E = \frac{1}{2}mv^2}$$

$$= \frac{1}{2} \times 9.10 \times 10^{-31} \times (2.18 \times 10^6)^2$$

$$= 21.62 \times 10^{-31+12}$$

$$= 21.62 \times 10^{-19} J$$

$$K.E = \frac{21.62 \times 10^{-19}}{1.6 \times 10^{-19}} eV$$

$$= 13.51 \text{ eV}$$

So putting in eq (i)

$$E_n = -27.27 + 13.51$$

$$E_n = -13.75 \text{ eV}$$

(c) For ionization energy of the electron

E_i = Energy of electron at outermost orbit – Energy of electron at ground state

$$E_i = E_\infty - E_{ground}$$

$$= 0 - (-13.75)$$

$$= 13.75 \text{ eV}$$

Result

(a) Electric potential that a proton exerts at this distance = V = 27.27 volt

(b) Total energy of the atom = E_n = −13.75 eV

(c) Ionization energy for the atom = E_i = 13.75 eV

PROBLEM 12.12

The electronic flash attachment for a camera contains a capacitor for storing the energy used to produce the flash. In one such unit, the potential difference between the plates of a 750 μF capacitor is 330 V. Determine the energy that is used to produce the flash.

Data

Potential difference between the plates = V = 330 Volt

Capacitance of the capacitor = C = 750μF

$= 750 \times 10^{-6}$F

To Find

Energy to produce the flash = E = ?

SOLUTION

By using the formula

$$\boxed{E = \frac{1}{2}CV^2}$$

$$= \frac{1}{2} \times 750 \times 10^{-6} (330)^2$$

$$= 40837500 \times 10^{-6}$$

$$= 40.83 \text{ J}$$

Result

Energy to produce flash = E = 40.83J

PROBLEM 12.13

A capacitor has a capacitance of 2.5×10^{-8} F. In the charging process, electrons are removed from one plate and placed on the other one. When the potential difference between the plates is 450 V, how many electrons have been transferred?

Data

Capacitance of capacitor = C = 2.5×10^{-8} F

Potential difference between plates = V = 450 V

To Find

Number of electrons = N = ?

SOLUTION

By formula

$$\boxed{q = Ne}$$

$$N = \frac{q}{e} \quad \text{...... (i)}$$

Therefore,

$$q = CV$$

$$= 2.5 \times 10^{-8} \times 450$$

$$= 1123 \times 10^{-8} \text{ C}$$

Putting in eq (i)

$$N = \frac{1125 \times 10^{-8}}{1.6 \times 10^{-19}}$$

$$= 703.1 \times 10^{-8+19}$$

$$N = 703.1 \times 10^{11}$$

$$N = 7.03 \times 10^{13} \text{ electrons}$$

Result

Number of electron = N = 7.03×10^{13}