Electric Field Definition:

An electric field is a region of space in which an electric charge “feels” a force.

Electric field strength can be calculated using the equation:

$$E = \frac{F}{Q}$$

Where:

E = electric field strength (N/C)

F = electrostatic force on the charge (N)

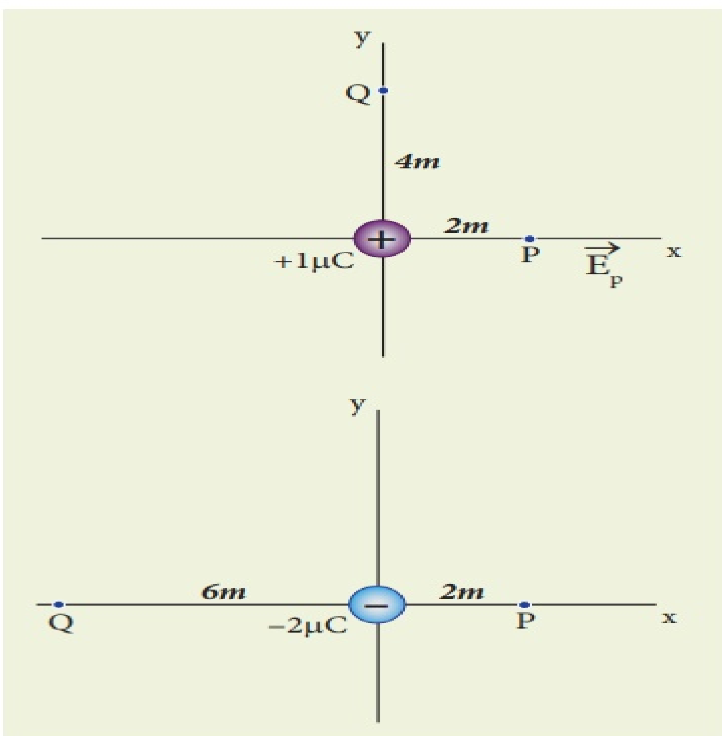
Q = charge (C)

EXAMPLE-1

Calculate the electric field at points P, Q for the following two cases, as shown in the figure.

(a) A positive point charge +1 μC is placed at the origin

(b) A negative point charge -2 μC is placed at the origin



Solution

Case (a)

The magnitude of the electric field at point P is

$$E_P = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{9\times10^9\times1\times10^{-6}}{4}$$
$$= 2.25\times10^3 NC^{-1}$$

Since the source charge is positive, the electric field points away from the charge. So the electric field at the point P is given by

$$\vec{E}_P = 2.25\times10^3 NC^{-1}\,\hat{i}$$

For the point Q

$$\left|\vec{E}_Q\right| = \frac{9\times10^9\times1\times10^{-6}}{16} = 0.56\times10^3\ NC^{-1}$$

Hence $\vec{E}_Q = 0.56\times10^3\,\hat{j}$

Case (b)

The magnitude of the electric field at point P

$$\left|\vec{E}_P\right| = \frac{kq}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{9\times10^9\times2\times10^{-6}}{4}$$
$$= 4.5 \times 10^3\ N\ C^{-1}$$

Since the source charge is negative, the electric field points towards the charge. So the electric field at the point P is given by

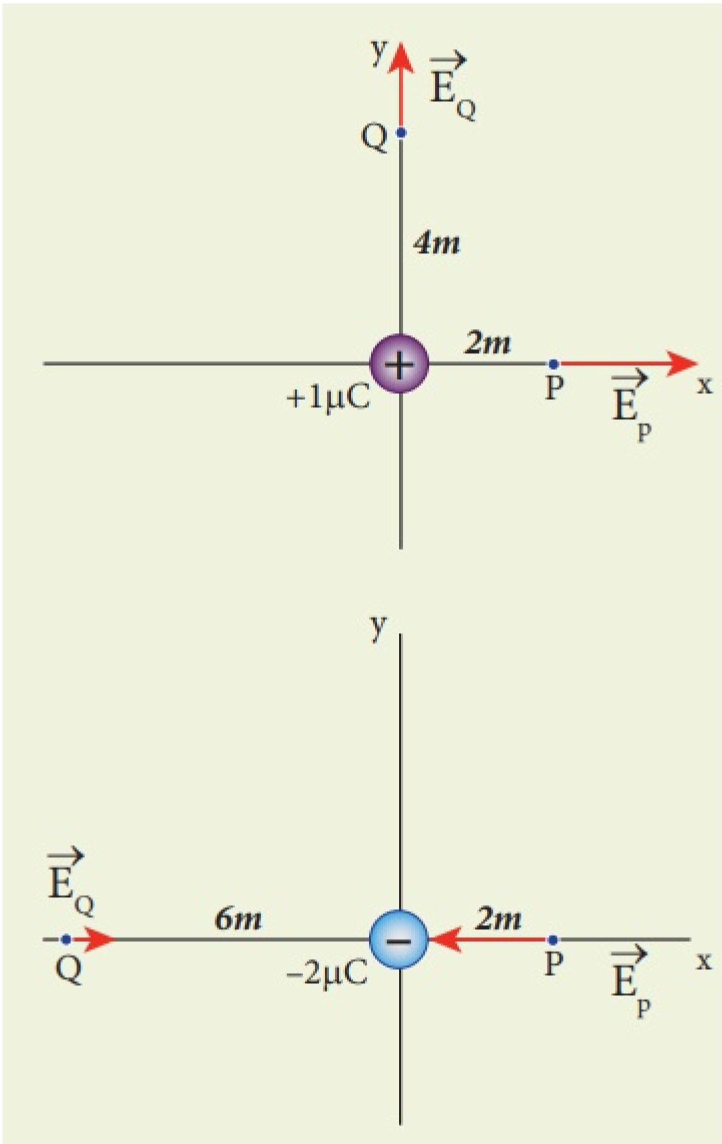
$$\vec{E}_P = -4.5\times10^3\,\hat{i}\ NC^{-1}$$

For the point Q, $\left|\vec{E}_Q\right| = \frac{9\times10^9\times2\times10^{-6}}{36}$

$= 0.5 \times 10^3\ N\ C^{-1}$

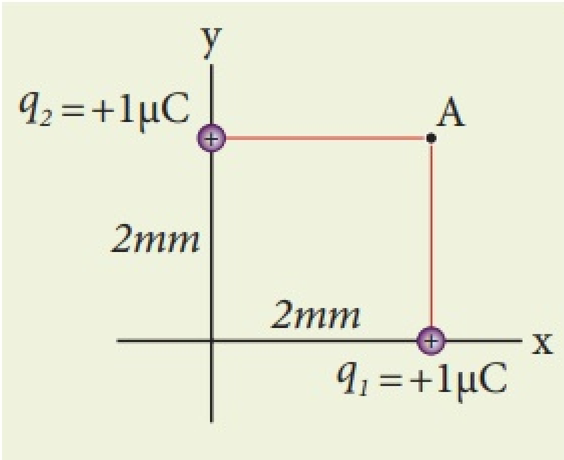
$$\vec{E}_R = 0.56\times10^3\,\hat{i}\ NC^{-1}$$

At the point Q the electric field is directed along the positive x-axis.



EXAMPLE-2

Consider the charge configuration as shown in the figure. Calculate the electric field at point A. If an electron is placed at points A, what is the acceleration experienced by this electron? (Mass of the electron = 9.1×10^{-31} kg and charge of electron = -1.6×10^{-19} C)



Solution

By using superposition principle, the net electric field at point A is

$$\vec{E}_A = \frac{1}{4\pi\varepsilon_\circ}\frac{q_1}{r_{1A}^2}\hat{r}_{1A} + \frac{1}{4\pi\varepsilon_\circ}\frac{q_2}{r_{2A}^2}\hat{r}_{2A},$$

where r1A and r2A are the distances of point A from the two charges respectively.

$$\vec{E}_A = \frac{9\times10^9\times1\times10^{-6}}{\left(2\times10^{-3}\right)^2}(\hat{j}) + \frac{9\times10^9\times1\times10^{-6}}{\left(2\times10^{-3}\right)^2}(\hat{i})$$

$$= 2.25\times10^9\ \hat{j} + 2.25\times10^9\hat{i} = 2.25\times10^9(\hat{i} + \hat{j})$$

The magnitude of electric field

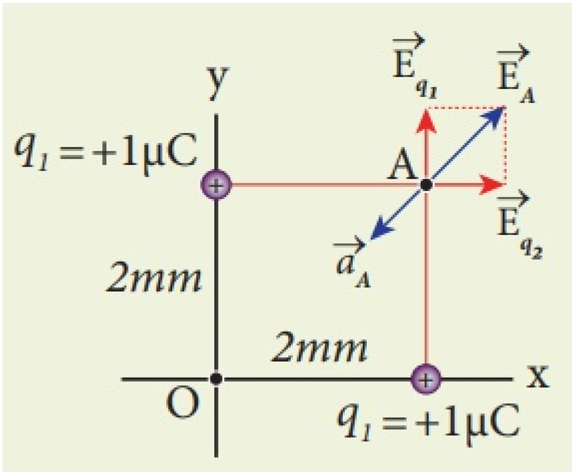
$$\left|\vec{E}_A\right| = \sqrt{\left(2.25\times10^9\right)^2 + \left(2.25\times10^9\right)^2}$$

$$= 2.25\times\sqrt{2}\times10^9\ NC^{-1}$$

The direction of $\vec{E}_A$ is given by

$$\frac{\vec{E}_A}{\left|\vec{E}_A\right|} = \frac{2.25\times10^9(\hat{i} + \hat{j})}{2.25\times\sqrt{2}\times10^9} = \frac{(\hat{i} + \hat{j})}{\sqrt{2}},$$

which is the unit vector along OA as shown in the figure.



The acceleration experienced by an electron placed at point A is

$$\vec{a}_A = \frac{\vec{F}}{m} = \frac{q\vec{E}_A}{m}$$

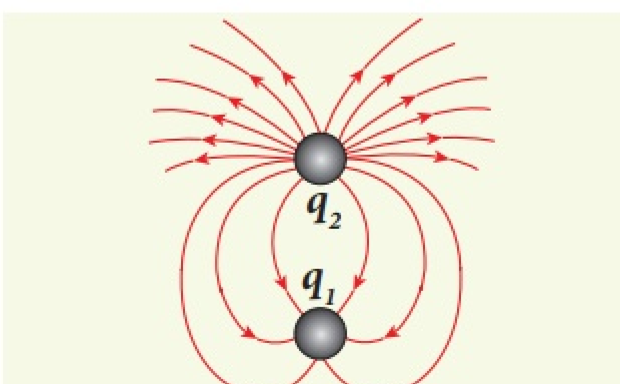
$$= \frac{\left(-1.6\times10^{-19}\right)\times\left(2.25\times10^{9}\right)\left(\hat{i}+\hat{j}\right)}{9.1\times10^{-31}}$$

$$= -3.95\times10^{20}\left(\hat{i}+\hat{j}\right)N$$

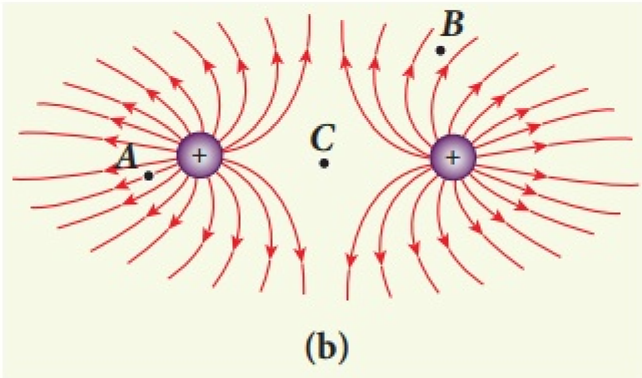
The electron is accelerated in a direction exactly opposite to $\vec{E}_A$.

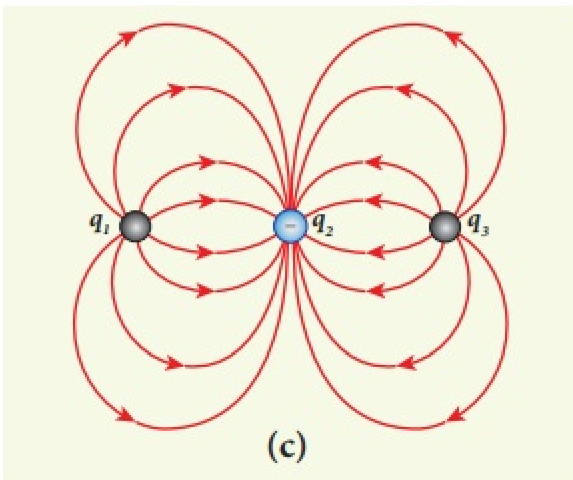
EXAMPLE -3

The following pictures depict electric field lines for various charge configurations.



(a)





(i) In figure (a) identify the signs of two charges and find the ratio |q1 / q2|

(ii) In figure (b), calculate the ratio of two positive charges and identify the strength of the electric field at three points A, B, and C

(iii) Figure (c) represents the electric field lines for three charges. If q2 = -20 nC, then calculate the values of q1 and q3

Solution

(i) The electric field lines start at q2 and end at q1. In figure (a), q2 is positive and q1 is negative. The number of lines starting from q2 is 18 and number of the lines ending at q1 is 6. So q2 has greater magnitude. The ratio of |q1/ q2| = N1/ N2 = 6/18 = 1/3 . It implies that |q2| = 3|q1|

(ii) In figure (b), the number of field lines emanating from both positive charges are equal (N=18). So the charges are equal. At point A, the electric field lines are denser compared to the lines at point B. So the electric field at point A is greater in magnitude compared to the field at point B. Further, no electric field line passes through C, which implies that the resultant electric field at C due to these two charges is zero.

(iii) In the figure (c), the electric field lines start at $q1$ and $q3$ and end at $q2$. This implies that $q1$ and $q3$ are positive charges. The ratio of the number of field lines is $| q1 / q2 | = 8/16 = | q3 / q2 | = 1/2$, implying that q1and q3are half of the magnitude of q2. So $q1 = q3 = +10$ nC.

s around a uniform spherical conductor are identical to those on a point charge