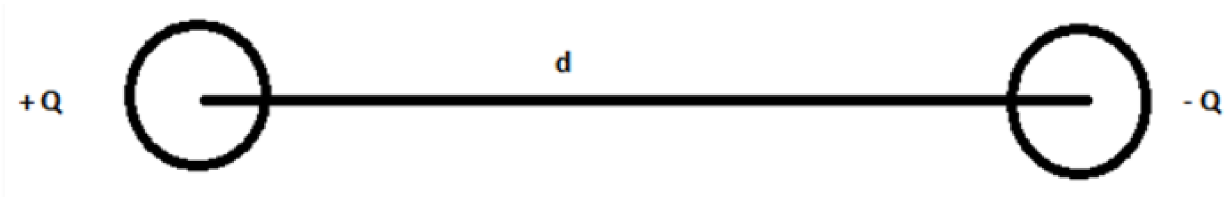
What is Electric Dipole?

An electric dipole is defined as a couple of opposite charges q and –q separated by a distance d. By default, the direction of electric dipoles in space is always from negative charge -q to positive charge q. The midpoint q and –q is called the centre of the dipole. The simplest example of an electric dipole is a pair of electric charges of two opposite signs and equal magnitude separated by distance.

Visualizing Electric Dipole

Suppose there are two charges of equal magnitude 'q', separated by a distance, d. Let the first charge be negative and the second charge is positive. This combination can be called an electric dipole. Therefore, we can say that an electric dipole is created by the combination of equal and opposite charges by a separation of a certain distance.



Electric dipole moment:- The dipole moment of an electric field is a vector whose magnitude is charge times the separation between two opposite charges.

- Direction of dipole moment is along the dipole axis from negative charge to positive charge.

Direction of Electric Dipole Moment:

The electric dipole moment is a vector quantity; it has a defined direction which is from the negative charge to the positive charge. Though, it is important to remember that this convention of direction is only followed in Physics. In Chemistry, the convention is taken to be opposite i.e. from positive to negative. The line along the direction of an electric dipole is called the axis of the dipole.

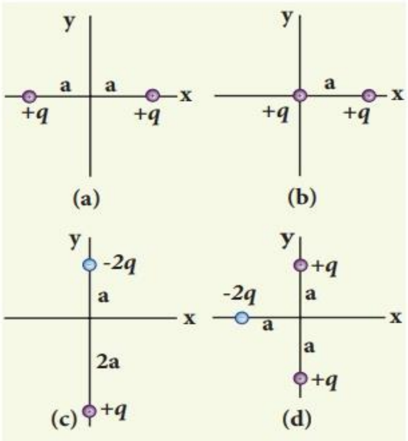
Mathematically,

Dipole Moment=either one of charges × separation vector from -ive to +ive

- $\vec{P}$=q($\vec{d}$) C.m Above equation gives *Electric dipole moment formula*

- Magnitude of dipole moment is
  $|\vec{P}|$=q$|\vec{d}|$ C.m

Calculate the electric dipole moment for the following charge configurations.



Solution

Case (a) The position vector for the +q on the positive x-axis is ai and position vector for the +q charge the negative x axis is -a i ^ . So the dipole moment is,

$$\vec{p} = (+q)(a\hat{i}) + (+q)(-a\hat{i}) = 0$$

Case (b) In this case one charge is placed at the origin, so its position vector is zero. Hence only the second charge +q with position vector ai contributes to the dipole moment, which is $\vec{p}$ = qa $\hat{i}$.

From both cases (a) and (b), we can infer that in general the electric dipole moment depends on the choice of the origin and charge configuration. But for one special case, the electric dipole moment is independent of the origin. If the total charge is zero, then the electric dipole moment will be the same irrespective of the choice of the origin. It is because of this reason that the electric dipole moment of an electric dipole (total charge is zero) is always directed from –q to +q, independent of the choice of the origin.

Case (c) $\vec{p} = (-2q)a\hat{j} + q(2a)(-\hat{j}) = -4qa\hat{j}$. . Note that in this case p is directed from -2q to +q.

Case (d) $\vec{p} = -2qa(-\hat{i}) + qa\hat{j} + qa(-\hat{j}) = 2qa\hat{i}$

A neutral water molecule (H_2O) in its vapor state has an electric dipole moment of 6.2×10^{-30} c-m.

(a) How far apart are the molecule's centres of positive and negative charge?

$p = 6.2 \times 10^{-30}$ C-m $\quad d = ?$

Magnitude of Charge on electron or proton $= e = 1.60 \times 10^{-19}$ C

There are 10 electrons and 10 protons in the water molecule (H_2O).

$q = 10e$

Magnitude of dipole moment $= p = qd$

$\therefore p = (10e)\, d$

or $d = p/10e$

$$d = \frac{6.2 \times 10^{-30}}{10 \times 1.60 \times 10^{-19}} = 3.9 \times 10^{-12} \text{ m}$$

($\because$ 1 Pico-meter (Pm) $= 10^{-12}$ m)

$\therefore \quad d = 3.9$ Pm

~x~

PROBLEM: 6

An electric dipole, Consisting of charges of magnitude 1.50 nc separated by 6.20 μm, is in an electric field of strength 1100 N/C.
(a) What is the magnitude of electric dipole moment?
(b) What is the difference in potential energy corresponding to dipole orientations parallel to and antiparallel to the field?

<u>SOLUTION: (a)</u>

$q = 1.50\ nC$ $\qquad$ $(1\ \text{Nano-Coul.} = 10^{-9}\ C$

$q = 1.50 \times 10^{-9}\ C$

$d = 6.20\ \mu m$ $\qquad$ $(1\ \mu m = 10^{-6}\ m)$

$d = 6.20 \times 10^{-6}\ m$, $\quad E = 1100\ N/C$

Electric dipole moment $= p = ?$

$p = qd$ $\qquad$ $\therefore p = 1.50 \times 10^{-9} \times 6.20 \times 10^{-6}$