Electric dipole - An electric dipole consist of a pair of equal and opposite point charges separated by small distance .

Let two charges of equal magnitude but opposite sign(q and -q) are separated by distance 2a , then the arrangement is known as electric dipole .

Dipole moment ($\vec{p}$) – Dipole moment of an electric dipole is the measurement of the strength of the electric dipole its magnitude is the product of magnitude of either charge and separation between them .

i.e. Magnetic moment $\vec{P}$ = q (2 $\vec{a}$) or | $\vec{P}$ | = q (2a)

Direction of magnetic field is given as negative to positive charge i.e. -q to +q ;

Its SI unit is C-m (coulomb meter) and dimension is [$M^0 L^1 T^1 A^1$] :

** **Dipole field** – It is the space around the dipole in which electric effect of the dipole can be experienced . For electric dipole electric field E α $1/r^3$ but for a point charge Eα $1/r^2$

Electric field intensity on axial line of electric dipole (electric field at a point on the axis of a dipole) –

Let , AB is an electric dipole with charges -q and +q as shown in figure having dipole length 2a , p is the point at distance r from the dipole (centre of dipole) . so AP = r+a and BP= r-a ;

E_B is the field at P due to B and E_A is the field at p due to A

So we can write ;

$$E_B = \frac{1}{4\pi \epsilon_0} \cdot \frac{q}{(r-a)^2} \text{ along } BP$$

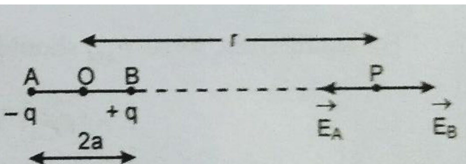


Fig. 1.37

and electric field due to $-q$ charge at A is

$$E_A = \frac{1}{4\pi \epsilon_0} \cdot \frac{q}{(r+a)^2} \text{ along } PB$$

∴ Net electric field at point P is given by

$$E = E_B - E_A = \frac{q}{4\pi \epsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right] = \frac{q.4ar}{4\pi \epsilon_0 (r^2-a^2)^2}$$

$$\Rightarrow \qquad E = \frac{2pr}{4\pi \epsilon_0 (r^2-a^2)^2}, \text{ where } p = q.2a = \text{dipole moment of given dipole.}$$

For a short dipole or if the point P is situated far away, then $a << r$ and hence

$$E = \frac{1}{4\pi \epsilon_0} \cdot \frac{2p}{r^3} \text{ along } ABP$$

Vectorially $$\vec{E} = \frac{1}{4\pi \epsilon_0} \cdot \frac{2\vec{p}}{r^3}$$

Electric field intensity on equatorial line of electric dipole –

Let , AB is an electric dipole and P is the point on the equatorial line where we have to find the electric field intensity due to the dipole as shown in fig .

Glance.

Dipole moment is a vector. Let us calculate the electrostatic field at a point P on the equatorial line at a distance 'r' from mid-point O of an electric dipole AB.

Obviously, $|\vec{E}_A| = |\vec{E}_B| = \dfrac{1}{4\pi \epsilon_0} \cdot \dfrac{q}{(a^2+r^2)}$

Resultant field at point P is $\vec{E} = \vec{E}_A + \vec{E}_B$.

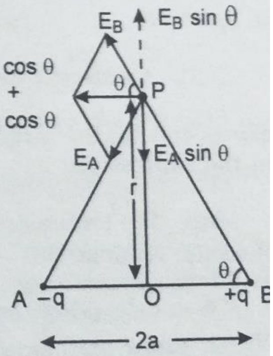
Let us resolve $\vec{E}_A$ and $\vec{E}_B$ along and perpendicular to the dipole axis. We find that components $E_A \sin\theta$ and $E_B \sin\theta$ nullify each other and hence

$$|\vec{E}| = (E_A + E_B)\cos\theta = 2 \cdot \frac{1}{4\pi \epsilon_0} \cdot \frac{q}{(a^2+r^2)} \cdot \frac{a}{\sqrt{a^2+r^2}}$$

$$= \frac{2qa}{4\pi \epsilon_0 (a^2+r^2)^{3/2}} = \frac{p}{4\pi \epsilon_0 (a^2+r^2)^{3/2}}$$

where $p = q.2a$ = dipole moment of electric dipole.

The direction of $\vec{E}$ is opposite to that of $\vec{p}$ *i.e.,* $\vec{E} = -\dfrac{\vec{p}}{4\pi\epsilon_0 (r^2+a^2)^{3/2}}$



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If $r >> a$, then the above relation may be modified as

$$\vec{E} = -\frac{\vec{p}}{4\pi \epsilon_0 r^3}$$

Therefore it is clear from the result that the ratio of electric field intensity at axial to the equatorial point is given as $E_{axial}/E_{equatorial} = 2/1$;