DIPOLE

An Electric dipole and flux lines :

An electric dipole is formed when two point charges of equal magnitude but opposite sign are separated by a small distance.

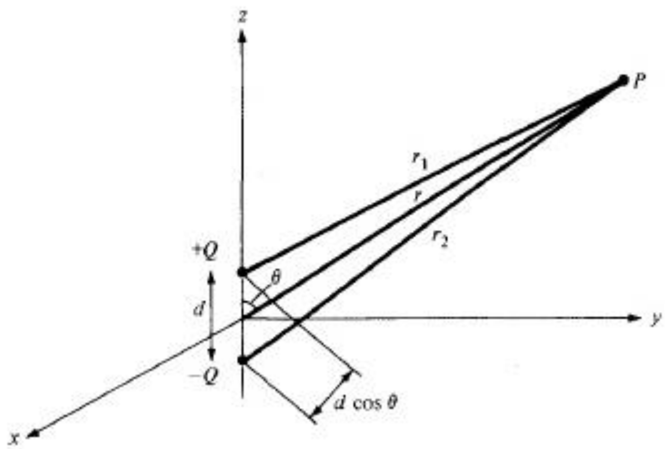


Fig31. An electric dipole

The potential at point $P(r, \theta, \varphi)$ given by

$$V_1 = \frac{Q}{4\pi\varepsilon_0 r_1} \qquad V_2 = \frac{-Q}{4\pi\varepsilon_0 r_2}$$

$$V = V_1 + V_2$$

$$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{r_2 - r_1}{r_1 r_2}\right] \quad \ldots\ldots\ldots\ldots \quad (1)$$

$r_1 \& r_2$ are the distance between $P \;\&\; Q \;\&\; -Q$ respectively $r >> d$

$$\left.\begin{aligned} r_2 - r_1 &\approx d\cos\theta \\ r_2 r_1 &\approx r^2 \end{aligned}\right\} \quad (2)$$

Sub (2) in (1)

(1) $V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{d\cos\theta}{r^2}\right]$ ………… (3)

Since $d\cos\theta = d.ar$, $d = d.az$

$$P = Q.d \quad \text{…….. (4)}$$

Sub (4) in (3) The dipole movement may be written as

$$V = \frac{P.ar}{4\pi\varepsilon_0 r^2} \quad \text{………… (5)}$$

The dipole moment P is directed from $-Q\ to\ +Q$. If the dipole centre is not at the origin but at r'

(5) ⇒

$$V(r) = \frac{P.(r-r')}{4\pi\varepsilon_0|r-r'|^2} \quad \text{…………. (6)}$$

The electric field due to the dipole with center at the origin.

$$E = -\nabla V = -\left[\frac{\partial v}{\partial r}\ ar + \frac{1}{r}\frac{\partial v}{\partial\theta}\ a\theta\right]$$

$$= \left[\frac{Qd\ cos\theta}{4\pi\varepsilon_0}\frac{\partial}{\partial r}(r^{-2})ar + \frac{Qd}{4\pi\varepsilon_0 r^3}\frac{\partial\cos\theta}{\partial\theta}\ a\theta\right]$$

$$= \frac{Qd\ cos\theta}{4\pi\varepsilon_0 r^3}2\ ar + \frac{Qd\ sin\theta}{4\pi\varepsilon_0 r^3}\ a\theta$$

$$= \frac{Qd\ cos\theta}{2\pi\varepsilon_0 r^3}\ ar + \frac{Qd\ sin\theta}{4\pi\varepsilon_0 r^3}\ a\theta$$

$$E = \frac{Qd}{4\pi\varepsilon_0 r^3}\ [2\ cos\theta\ ar + Sin\theta\ a\theta] \quad \text{………… (7)}$$

Where $p = |p| = Qd$

A point charge is a monopole and its electric field varies inversely as r^2. While its potential field varies inversely as r. The electric field due to a dipole varies inversely as r^3, while its potential varies inversely as r^2. The electric fields due to successive higher order multipoles

[quadrupole → two dipoles

Octupole → quadrupoles] vary inversely as r^4, r^5, r^6 potentials vary inversely as r^3, r^4, r^5.

The electric flux lines (or electric lines of force) was introduced by Michael Faraday (1791-1867)

An electric flux line is an imaginary path or line drawn in such a way that its direction at any point is the direction of the electric filed at that point.

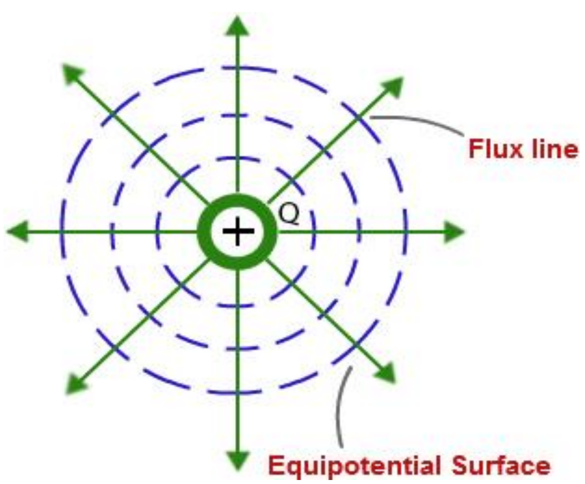
The electric flux density 'D' is tangential at every point of the electric flux lines.

Any surface on which the potential is same throughout is known as equipotential surface. The intersection of an equipotential surface and a plane results in a path or line known as an equipotential line. No work is done in moving a charge from one point to another along an equipotential line $[V_A - V_B = 0]$

$$\oint_l E.dl = 0 \qquad \ldots\ldots\ldots\ldots \qquad (8)$$

The flux lines (direction of E) are always normal to equipotential surfaces.

flux line v>0



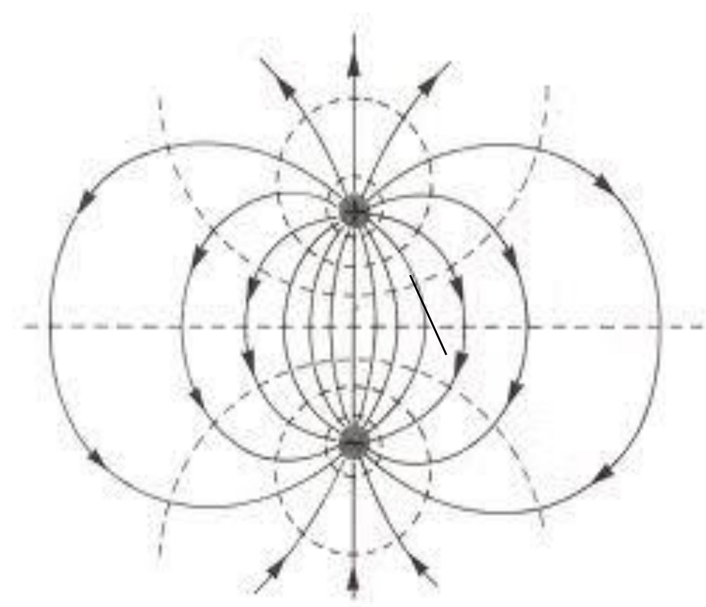


Fig (a) Equipotential surface surface

Fig (b) Electric pole equipotential

Fig 32 : Equipotential surface for an electric pole and a point charge

Applications of electric flux lines & equipotential surface :

- Field mapping
- Diagnosis of the human heart

Heart can be characterized as a dipole with the filed mapping. Shown in fig field mapping detect the abnormal heart position.