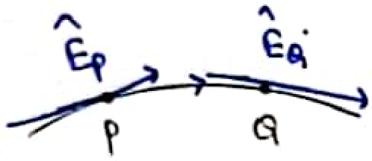
ELECTRIC FIELD LINES AND ITS PROPERTIES

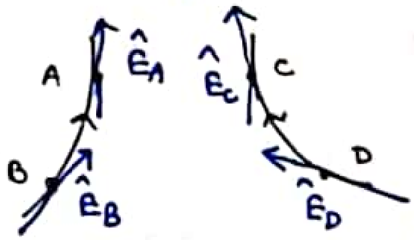
- Electric field lines are smooth, continuous curve or lines that are used to visualize the pattern of electric field Intensity due to charges distribution in 3-D space pictorically.
- Concept of field lines was introduced by faraday. And this concept is based on Non-mathematical and Intutive approach.

PROPERTIES OF ELECTRIC FIELD LINES :

(1) To get the direction of field Intensity at any point 'P' in the given pattern of field lines. We draw a tangent at that point 'P'.

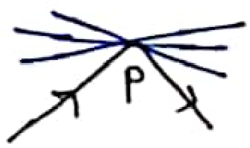
"Direction of tangent give the direction of field Intensity"





(a) In the pattern of electric field "no sharp corner" is obtained.

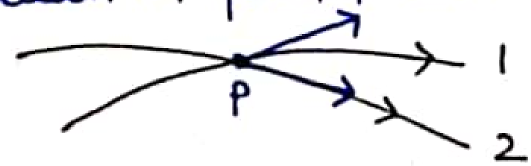
Reason: If sharp corner is obtained then: at that point we can draw multiple lines that represents multiple field Intensity direction at that point and it is not possible.



(Not possible).

(b) Two Electric field line curve never intersect each other.

Reason: If two curve intersect each other then: at intersection point we can draw two tangent that represents two field Intensity direction at point 'P'. and it is not possible.



(Not possible).

<u>Note:</u> If we put a "test charge" at any point 'p' in a 'given pattern of electric field ~~of~~ lines, and this test charge is free to move.

Then direction of tangent drawn at any point 'P' gives

<u>(a)</u> Direction of field Intensity at point 'P'.

(b) Direction of Electric force experienced by charge particle at point 'P'.

If test charge is positive then direction of force is in same direction of field intensity and if test charge is negative then direction of force is in opposite direction of field Intensity. $\boxed{\text{i) } Q>0:\ \vec{F} \uparrow\uparrow \vec{E} \qquad \text{(ii) } Q<0:\ \vec{F} \uparrow\downarrow \vec{E}.}$

(C) Direction of acceleration at point 'P'. i.e. direction of change in velocity at point P.

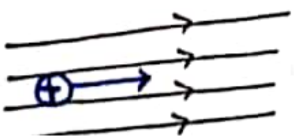
if $q_T > 0$ then: $\hat{a}$ is along $\hat{E}$. i.e. $\hat{a} \uparrow\uparrow \hat{E}$.

$q_T < 0$ then $\hat{a}$ is opposite to $\hat{E}$ i.e. $\hat{a} \uparrow\downarrow \hat{E}$.

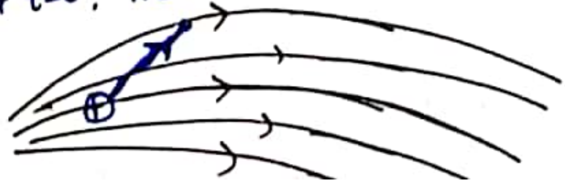
<u>(d)</u> Electric field lines doesn't give direction of motion always <u>i.e.</u> if a test charge is free to move in electric field it may or may not follow the ~~to~~ path of lines of force.

<u>i.e.</u> Trajectory of charged particle is not always same as that of field line

<u>e.g.</u> at t=0 Rest



at t=0; Rest



(2) In a given pattern of electric field lines magnitude of electric field Intensity is measured in terms of flux density.

flux density : No. of electric field lines passes through a surface of unit area. normally.

$$\boxed{\text{magnitude of field Intensity} = \text{flux density}}$$

(a) In a region of electric field where the field lines are denser, at those points intensity is relative high.

(b) In a region of field where the field lines are "Rarer" at those points intensity is relative low.

(c) In a region of electric field where the field lines are "equispaced" at those points intensity is equal.

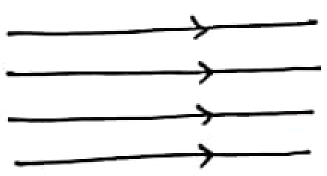
Uniform Electric field: At every point in field.

magnitude and direction of field Intensity is same.

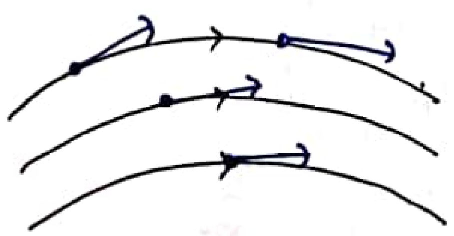
magnitude ⇓ equispaced.

direction ⇓ Straight line

i.e.



equi-spaced parallel straight lines gives representation of uniform electric field.



Non-uniform field:

Direction of field Intensity changes at different points.

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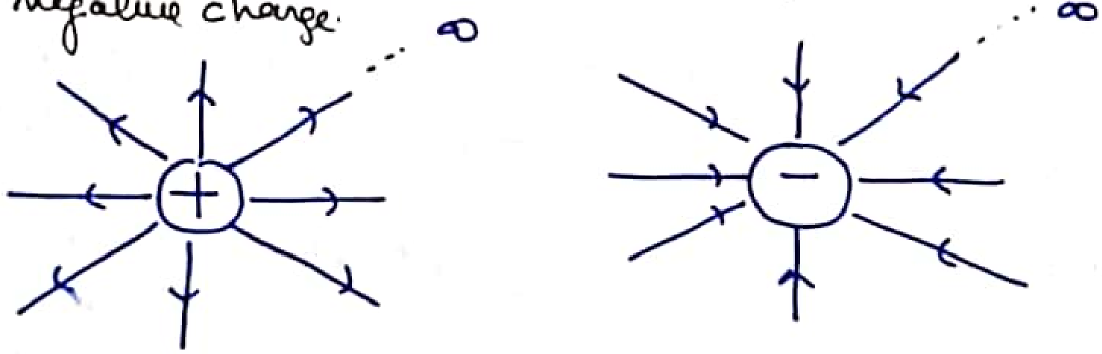
(3) In a given field pattern, Electric field lines are always originate from positive charge and terminate at negative charge. (4)

Note: Electric field lines never form a closed loop i.e. their starting and terminating ends are not on the same point.

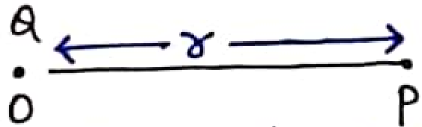
(a) For Point charges only field lines are radial in nature. And point charge is located at the centre.

(i) If $Q > 0$: positive charge
field lines originate from positive charge and terminate at infinity.

(ii) If $Q < 0$: Negative charge:
field lines originate from infinity and terminate at negative charge.



Mathematical Analysis:



field Intensity due to charge 'Q' at point 'P'

$$\vec{E} = \frac{1}{4\pi\varepsilon_0 K} \cdot \frac{Q}{r^2} \hat{r}_{OP}$$

(i) $\hat{E}$ is along $\hat{OP}$.

(ii) $|\vec{E}| = \frac{1}{4\pi\varepsilon_0 K} \cdot \frac{Q}{r^2}$

If $Q < 0$; then: $\hat{E}$ is along $(-\hat{r}_{OP})$ i.e. towards the source charge.

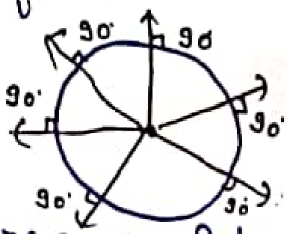
If $Q > 0$; then: $\hat{E}$ is along $(+\hat{r}_{OP})$ i.e. Away from source charge

$$|\vec{E}| = \frac{1}{4\pi\epsilon_0 K}\cdot\frac{Q}{r^2}$$

So:

$$Q = |\vec{E}| \times 4\pi\epsilon_0 K \times r^2$$

(i) $|\vec{E}|$ = No. of field lines passes unit surface area ~~to~~ normally.

(ii) 

In a sphere of radius 'r' m. all the radial lines are normal to spherical surface.

$$Q = \left(|\vec{E}| \times 4\pi r^2\right) \times \epsilon_0 K.$$

→ No. of field lines passes through a spherical surface of area $(4\pi r^2)$.

→ No. of field passes through a unit Area.

So: we can write:

$$|Q| = \begin{pmatrix}\text{No. of Electric field lines} \\ \text{through a spherical Surface}\end{pmatrix} \times (\epsilon_0 K)$$

$(\epsilon_0 K)$ → Property of medium

Conclusions:

1. In a given medium ($\epsilon_0 K$ = Const)

$$\boxed{|Q| \propto \text{No. of field lines}}$$

2. $\frac{|Q|}{\epsilon_0 K}$ = No. of field lines originating or terminating at point charge.

No. of lines originating ~~from~~ / Terminating from a unit charge is $\frac{1}{\epsilon_0 K}$ i.e. $\frac{1}{\epsilon}$. where: $\boxed{\epsilon = \epsilon_0 K}$

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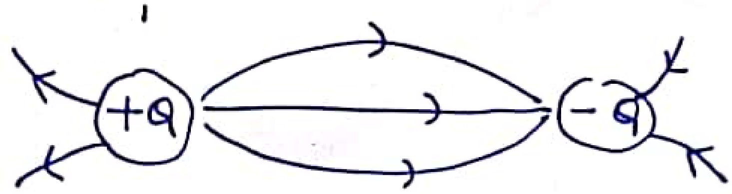
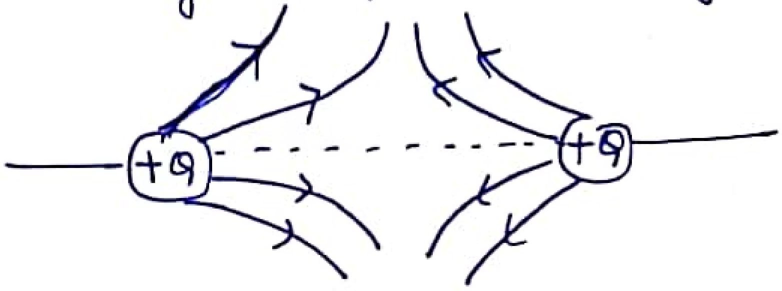
(4) If two opposite nature charges are placed together then: Electric field lines have tendency to contract longitudinally that explain attraction.



If two same nature charges are placed together then: field lines have tendency to expand laterally. that explains repulsion.



(5) Field lines don't pass through conductor. this indicates that Electric field Inside conductor is zero.

(6) Electric field lines **just outside** the surface of conductor is always normal to the surface.

Explanation: let Electric field is not perpendicular to the surface to conductor; then there would be a component of electric field along the surface of conductor and; this component would result an electric current through its surface;
But no current flows through conductor in electrostatic situation thus; we can conclude that there is no component of electric field along the surface of conductor; And; Electric field is always normal to surface of conductor