Electric field and electric intensity

i) The space around an electric charge in which its influence can be felt is known as **electric field**.
ii) The **intensity of electric field (E)** at a point is the force experienced by a unit positive charge placed at that point.
iii) It is a vector quantity.
iv) $E = F/q$, unit of E is NC^{-1} or Vm^{-1}
v) Due to a point charge q, the intensity at a point *r* units away from it is given by the expression

$E = \dfrac{q}{4\pi\varepsilon r^2}$ NC^{-1}. Another unit is volt/metre.

vi) The electric field due to a positive charge is always directed away from the charge.
vii) The electric field due to a negative charge is always directed towards the charge.
viii) The intensity of electric field at any point due to a number of charges is equal to the vector sum of the intensities produced by the separate charges.

Force experienced by a charge Q in an electric field.

$\vec{F} = Q\vec{E}$ where E is the electric intensity.

i) If Q is positive charge, the force $\vec{F}$ acts in the direction of $\vec{E}$.

Acceleration $a = \dfrac{F}{m} = \dfrac{QE}{m}$

ii) If Q is negative charge, the force $\vec{F}$ acts in a direction opposite to $\vec{E}$

Acceleration $a = \dfrac{F}{m} = \dfrac{QE}{m}$

iii) A charge in an electric field experiences a force whether it is at rest or moving.
iv) The electric force is independent of the mass and velocity of the charged paerticle, it depends upon the charge.
v) A proton and an electron in the same electric field experience forces of samemagnitude but in opposite directions.
vi) Force on proton is accelerating force where as force on electron is retarding force. If the proton and electron are initially moving in the direction of electric field.

$$\frac{\text{Acceleration of Proton}}{\text{Retardation of electron}} = \frac{\text{mass of electron}}{\text{mass of proton}}$$

Dielectric Strength :

It is the minimum field intensity that should be applied to break down the insulating property of insulator.

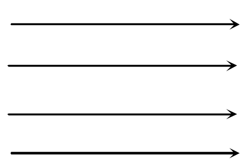
i) Dielectric strength of air = 3×10^6 V/m
Dielectric strength of Teflon = 60×10^6 Vm^{-1}
ii) The maximum charge a sphere can hold depends on size and dielectric strength of medium in which sphere is placed.

ii) The maximum charge a sphere of radius 'r' can hold in air = $4\pi\epsilon_0 r^2 \times$ dielectric strength of air.

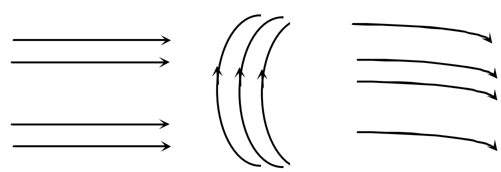
When the electric field in air exceeds its dielectric strength air molecules become ionised and are accelerated by fields and the air becomes conducting.

Electric lines of force :

i) Line of force is the path along which a unit +ve charge, accelerates in electric field.
ii) The tangent at any point to the line of force gives the direction of the field at that point.
iii) Two lines of force never intersect.
iv) Number of lines of force passing normally through unit area around a point is numerically equal to E, the strength of the field at the point.
v) Lines of force always leave or end normally on a charged conductor.
vi) Electric lines of force can never be closed loops.
vii) Lines of force have tendency to contract **longitudinally** and exert a force of repulsion on one another laterally.
viii) If in a region of space there is no electric field, there will be no lines of force. Inside a conductor there cannot be any line of force.
ix) Number of lines of force passing normally through unit area around a point is numerically equal to E.
x) In uniform field, lines of force are parallel to one another.



Uniform field



Magnitude is not constant

Direction is not constant

Both magnitude and not constant

Non uniform magnetic field

. Motion of a charged particle in an electric field.

i) If a charged particle of charge Q is placed in an electric field of strength E, the force experienced by the charged particle = EQ.

ii) The acceleration of the charged particle in the electric field, $a = \frac{EQ}{m}$

iii) The velocity of charged particle after time "t" is $V = at = \left(\frac{EQ}{m}\right)t$ if the initial velocity is zero.

iv) The distance travelled by the charged particle is $S = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{EQ}{m}\right)t^2$ if the initial velocity is zero

v) When a charged particle is projected into a uniform electric field with some velocity perpendicular to the field, the path traced by it is **parabola**.

vi) The trajectory of a charged particle projected in a different direction from the direction of a uniform electric field is a **parabola.**

vii) When a charged particle of mass m and charge Q remains suspended in an vertical electric field then mg=EQ.

viii) When a charged particle of mass m and charge Q remains suspended in an electric field, the number of fundamental charges on the charged particle is n then

$$mg = E(ne)$$

$$n = \frac{mg}{Ee}$$

xi) The bob of a simple pendulum is given +ve charge and it is made to oscillate in vertically upward electric field, then the time period of oscillation is $T = 2\pi\sqrt{\dfrac{\ell}{g - \dfrac{EQ}{m}}}$

x) In the above case, if the bob is given a –ve charge then the time period is given by $T = 2\pi\sqrt{\dfrac{\ell}{g + \dfrac{EQ}{m}}}$

xi) A charged particle of charge ±Q is projected with an initial velocity u making an angle θ to the horizontal in an electric field directed vertically upward. Then

a) Time of flight = $\dfrac{2u\sin\theta}{g \mp \dfrac{EQ}{m}}$

b) Maximum height = $\dfrac{u^2\sin^2\theta}{2\left(g \mp \dfrac{EQ}{m}\right)}$

c) Range = $\dfrac{u^2\sin 2\theta}{\left(g \mp \dfrac{EQ}{m}\right)}$

xii) Intensity of electric field inside a charged hollow conducting sphere is zero

xiii) A sphere is given a charge of 'Q' and is suspended in a horizontal electric field. The angle made by the string with the verticle is, $\theta = \tan^{-1}\left(\dfrac{EQ}{mg}\right)$

xiv) The tension in the string is $\sqrt{(EQ)^2 + (mg)^2}$

xv) A bob carrying a +ve charge is suspended by a silk thread in a vertically upward electric field,
then the tension in the string is, T = mg - EQ.

xvi) If the bob carries –ve charge, tension in the string is T = mg + EQ

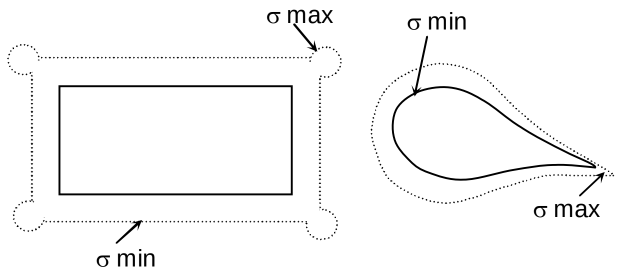
Surface charge density (σ)

i) The charge per unit area of a conductor is defined as surface charge density.

ii) $\sigma = \frac{q}{A} = \frac{\text{total charge}}{\text{area}}$, when A=1 m^2 then σ = q

iii) Its unit is coulomb/ meter and its dimensions are ATL^{-2}.

iv) It is used in the formulae for charged disc, charged conductor and infinite sheet of charge etc.



v) $\sigma \propto \frac{1}{r^2}$,i.e. $\frac{\sigma_1}{\sigma_2} = \frac{r_2^2}{r_1^2}$

vi) σ is maximum at pointed surfaces and for plane surfaces it is minimum.

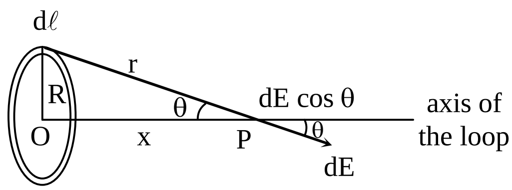
vii) σ depends on the shape of the conductor and presence of other conductors and insulators in the vicinity of the conductor.

viii) σ is maximum at the corners of rectangular laminas and at the vertex of conical conductor

Electric field due to charged ring : Q charge is distributed over a ring of radius R.

(i) Intensity of electric field at a distance x from the centre of ring along it's axis -

$$E = \frac{1}{4\pi\varepsilon_0} \frac{Qx}{(R^2 + x^2)^{3/2}}$$

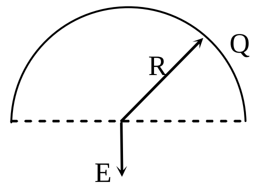


(ii) Intensity will be zero at the centre of the ring.

(iii) Intensity will be maximum at a distance $\frac{R}{\sqrt{2}}$ from the centre and

$$E_{max} = \frac{2}{3\sqrt{3}} \cdot \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R^2}$$

Uniformly charged semi - circular arc



$$E_{centre} = \frac{\lambda}{2\pi\varepsilon_0 R}$$

where l = linear charge density = $\frac{Q}{\pi R}$