DAA College

Dharmapuram

Department of PHYSICS

Class : II B.Sc., (Physics)

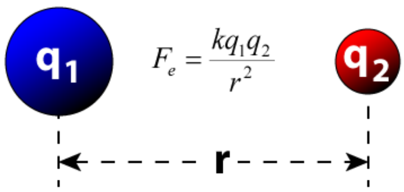
Title of the paper: Electricity magnetism and electromagnetism

UNIT I

Points to remember:

Coulomb's law:

The magnitude of the electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distance between them. The force is along the straight line joining them.

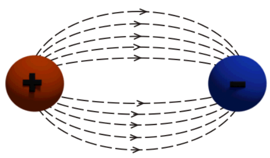


Electric field:

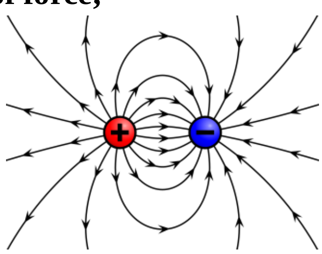
Electric field at a point is defined as the force that acts on the unit positive charge placed at that point.

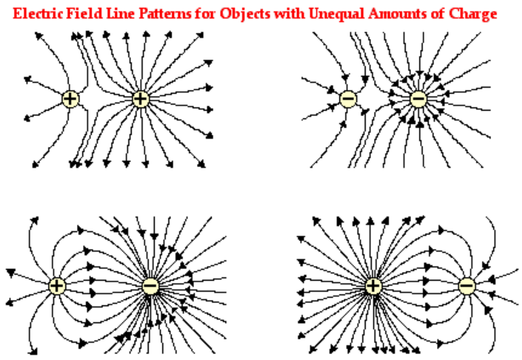
Electrostatic lines of force;

The paths, along which the unit positive charge will move due to electrostatic force in the field are called electric lines of force. We consider the direction of electric lines of force as the direction of the movement of unit positive charge in the field. We represent the direction of lines of force with arrowheads



Properties of electrostatic lines of force;





They start from positive charge and terminate at negative charge.

Never intersect each other.

They are perpendicular to the surface charge.

The field is strong - the lines are close together, and it is weak-lines move apart from each other.

The number of field lines is directly proportional to the magnitude of the charge.

Gauss's law:

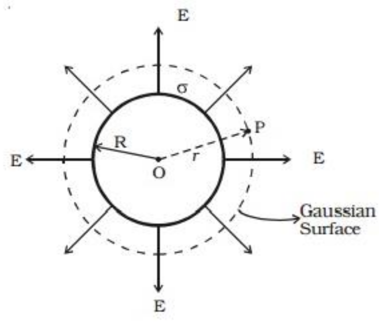
The net outward normal electric flux through any closed surface of any shape is equal to $1/\varepsilon_0$ times the total charge contained within it.

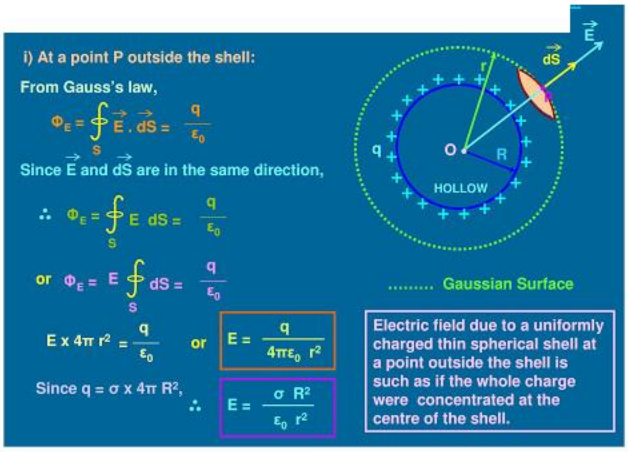
$$\phi = \oint E \, .dS = 1/\varepsilon_0 \, (q)$$

Applications of gauss theorem

Electric Field due to a Uniformly Charged Sphere

A spherically symmetric charge distribution means the distribution of charge where the charge density ρ at any point depends only on the distance of the point from the centre and not on the direction. Consider a total charge q distributed uniformly throughout a sphere of radius R. Note that the sphere cannot be a conductor or, as we have seen, the excess charge will reside on its surface.





In a spherically symmetric charge distribution, the charge density ρ at any point depends only on the distance of the point from the centre and not on the direction.

Case (i) When the point P lies outside the sphere:

Electric field intensity $E = (1/4\pi\varepsilon_o)\, q/r^2$

Case (ii) When the point P lies on the sphere:

Electric field intensity $E = (1/4\pi\varepsilon_o)\, q/R^2$

Case (iii) When the point P lies inside the sphere:

Electric field intensity $E = (1/4\pi\varepsilon_o)\, qr/R^3$

Electric field intensity due to infinitely cylindrical charge

For any point r < R or r > R, the Gaussian surface will be cylindrical.

$$E(2\pi r l) = \frac{q_{\text{in}}}{\varepsilon_0} = \frac{(\rho\pi r^2 l)}{\varepsilon_0}$$

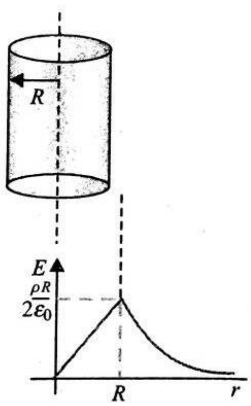
$$E = \frac{\rho r}{2\varepsilon_0} \Rightarrow E \propto r$$

For any point outside the cylinder ($r > R$), we have

$$E(2\pi r l) = \frac{q_{\text{in}}}{\varepsilon_0} = \frac{(\rho\pi R^2 l)}{\varepsilon_0}$$

$$E = \frac{\rho R^2}{2\varepsilon_0 r} \Rightarrow E \propto \frac{1}{r}$$

Electric field inside the long uniformly charged cylinder varies lineary, i.e., $E \propto r$ and outside the cylinder the electric field varies inversely to the distance from the axis, i.e., $E \propto 1/r$

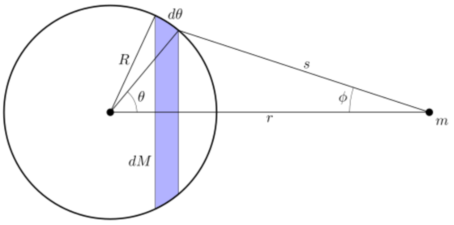


Electric potential:

An electric potential is the amount of work needed to move a unit of charge from a reference point to a specific point inside the field without producing an acceleration.

Potential at a point due to a uniformly charged conducting sphere:

When a conducting sphere is given a charge, the charge is distributed uniformly on the surface of the sphere. Radius R and charge +q.



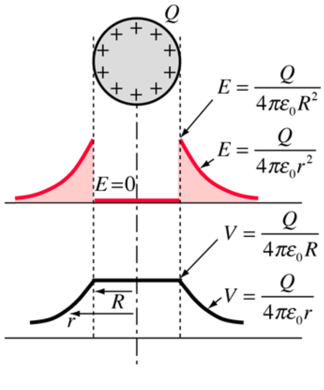
Potential at an external point

$$V = \frac{kQ}{r} = \frac{Q}{4\pi\varepsilon_0 r}$$

Potential at a point on the surface of the sphere and at an internal point will be the same.

$$V = \frac{Q}{4\pi\varepsilon_0 R}$$

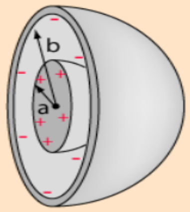
Figure shows variation of electric field E as a function of radial distance R.



Capacitance: the amount of charge given to a conductor to increase its potential by unity. Unit: Farad.

Capacitance of a spherical condenser

Spherical Capacitor



The capacitance for spherical or cylindrical conductors can be obtained by evaluating the voltage difference between the conductors for a given charge on each. By applying Gauss' law to an charged conducting sphere, the electric field outside it is found to be

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

The voltage between the spheres can be found by integrating the electric field along a radial line:

$$\Delta V = \frac{Q}{4\pi\varepsilon_0}\int_a^b \frac{1}{r^2}dr = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a}-\frac{1}{b}\right]$$

From the definition of capacitance, the capacitance is

$$C = \frac{Q}{\Delta V} = \frac{4\pi\varepsilon_0}{\left[\frac{1}{a}-\frac{1}{b}\right]}$$

Capacitance of a cylindrical capacitor:

Consider a cylindrical capacitor of length L. The radius of inner cylinder a and outer cylinder b respectively. Charge +q on the centre of the cylinder and –q on the outer cylinder.

Potential

$$V_{ba} = -\int_a^b \left(\frac{Q}{2\pi\varepsilon_o rL}\hat{r}\right)\cdot(dr\hat{r}) = -\frac{Q}{2\pi\varepsilon_o L}\int_a^b \frac{dr}{r} = -\frac{Q}{2\pi\varepsilon_o L}\ln\left(\frac{b}{a}\right)$$

Therefore capacitance

$$C = \frac{Q}{V} = \frac{2\pi\varepsilon_0 L}{\ln\left(\frac{b}{a}\right)}$$

Energy stored in a capacitor:

Total work done to charge a capacitor to a charge q is

$$W = ½(q^2/C)$$

This work done is stored as the electrostatic potential energy in the capacitor.

Energy $E = ½\, cV^2$

Energy loss due to sharing of charges

During the sharing of charges between the different bodies no net loss of charge takes place. During this process some energy is disappeared in the form of heat. But some amount of energy is scattered in sharing between these charges.Now if we want to calculate the total loss of energy during the process then we have to take two capacitors having capacity C_1, C_2.These also have their distinct potentials say V_1 and V_2. As we have discussed above that the charge always flows from the capacitor having higher potential to the capacitor having less potential.

So, their common potential is given by the equation below:

$V=(C_1V_1+C_2V_2) / C_1+C_2$