Contents of Physics Class XII

PART-1

PHYSICS

Class XII

Chapter 1-Electric Charges and Fields

1 Marks Questions

1. Which orientation of an electric dipole in a uniform electric field would correspond tostable equilibrium ?

A. When dipole moment vector is parallel to electric field vector
$\vec{P} \parallel \vec{E}$

2. If the radius of the Gaussian surface enclosing a charge is halved, how does theelectric flux through the Gaussian surface change ?

A. Electic flux ϕE is given by
$\phi E = \oint \vec{E} \cdot \vec{ds} = \frac{Q}{\varepsilon 0}$

…. where [Q is total charge inside the closed surface
∴ On changing the radius of sphere, the electric flux through the Gaussian surface remains same.

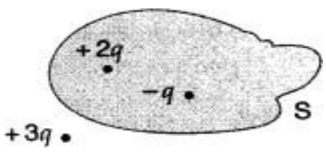
3. Define the term electric dipole moment of a dipole. State its S.I. unit

A. τ = OE sin θ
If E = 1 unit, θ = 90°, then τ = P
Dipole moment may be defined as the torque acting on an electric dipole, placed perpendicular to a uniform electric dipole, placed perpendicular to a uniform electric field of unit strength.
or Strength of electric dipole is called dipole moment.
$|\vec{P}| = q|2a|$
∴ SI unit is Cm.

4. In which orientation, a dipole placed in a uniform electric field is in stable, unstable equilibrium ?

A. For stable equilibrium, a dipole is placed parallel to the electric field.
For unstable equilibrium, a dipole is placed antiparallel to the electric field.

5. Figure shows three point charges, +2q, -q and + 3q. Two charges +2q and -q are enclosed



within a surface ‘S’. What is the electric flux due to this configuration throughthe surface.

A. Electric flux $= \oint_S \vec{E} \cdot \vec{dS}$

According to *Gauss's law*, $\phi = \oint_S \vec{E} \cdot \vec{dS} = \frac{q_1}{\varepsilon_0}$

...where [q_1 is the total charge enclosed by the surface S

$$\phi = \frac{2q - q}{\varepsilon_0} = \frac{q}{\varepsilon_0} \quad \therefore \quad \textbf{Electric flux, } \phi = \frac{q}{\varepsilon_0}$$

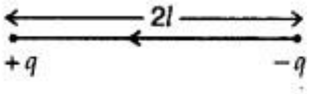
6. Name the physical quantity whose S.I. unit is JC^{-1}. Is it a scalar or a vector quantity?

A. Physical quantity whose S.I. unit is JC^{-1} is Electric potential.
It is a Scalar quantity.

7. Define electric dipole moment. Write its S.I. unit.

A. Electric dipole moment of an electric dipole is defined as the product of the magnitude of either charge and dipole length.

$\vec{p} = q(2\vec{l})$



S.I. unit of dipole ($\vec{p}$) is coulomb metre (Cm).

8.Why should electrostatic field be zero inside a conductor?

A. Electrostatic field inside a conductor should be zero because of the absence of charge. As in a static condition, charge remains only on the surface.

9. Why must electrostatic field be normal to the surface at every point of a chargedconductor?

A. So that tangent on charged conductor gives the direction of the electric field at that point.

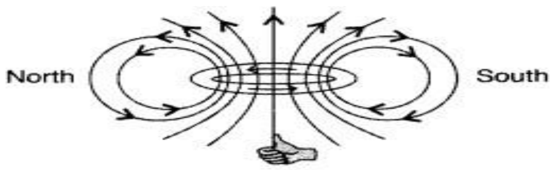
10. A charge 'q' is placed at the centre of a cube of side l. What is the electric flux passingthrough each face of the cube?

A. Electric flux through each phase of the cube

$$= \frac{1}{6}\phi_E = \frac{1}{6}\frac{q}{\varepsilon_0} = \frac{q}{6\varepsilon_0}$$

11. Depict the direction of the magnetic field lines due to a circular current carrying loop.

A. Direction of the magnetic field lines is given by right hand thumb rule.

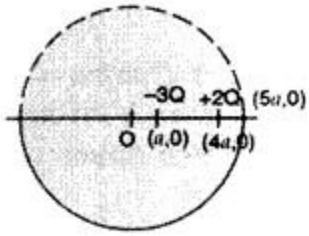


Magnetic field lines

12. Two charges of magnitudes -3Q and + 2Q are located at points (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius'5a' with its centre at the origin?

A.

$$\text{Flux} = \frac{\text{Charge enclosed}}{\varepsilon_0} = \frac{+2Q - 3Q}{\varepsilon_0} = \frac{-Q}{\varepsilon_0}$$



13. Write the expression for the work done on an electric dipole of dipole moment p in turning it from its position of stable equilibrium to a position of unstable equilibrium ina uniform electric field E.

A. Torque, acting on the dipole is, $\tau = pE \sin \theta$

Torque, acting on the dipole is, $\tau = pE \sin \theta$

$$\omega = \int_{\theta_1}^{\theta_2} pE \sin \theta \, d\theta \Rightarrow \omega = pE\,[\cos \theta_1 - \cos \theta_2]$$

$$\therefore \quad \omega = pE\,[\cos 0^\circ - \cos 180^\circ]$$

$$= pE\,[1 - (-1)] = 2pE \quad \therefore \boxed{\omega = 2pE}$$

2 Mark Questions

1. Derive an expression for the torque experienced by an electric dipole kept in auniform electric field.

A. Consider an electric dipole consisting of charges + q and — q and of length 2a placed in a uniform electric field E→ making an angle θ with it. It has a dipole moment of magnitude,Hence the net translating

$p = q \times 2a$

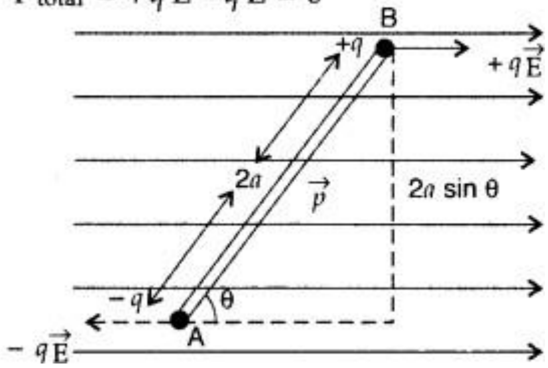
Force exerted on charge $+q$ by field,

$\vec{E} = q\vec{E}$ (along $\vec{E}$)

Force exerted on charge $-q$ by field,

$\vec{E} = q\vec{E}$ (opposite to $\vec{E}$)

$\therefore \quad \vec{F}_{total} = +q\vec{E} - q\vec{E} = 0$



force on a dipole in a uniform electric field is zero. But the two equal and

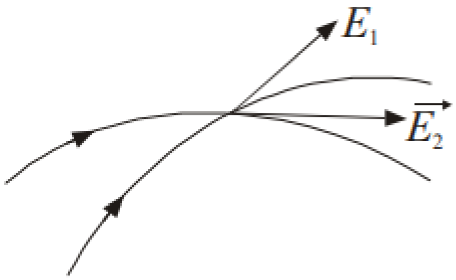
opposite forces act at different points of the dipole. They form a couple which exerts a torque.
Torque = Either force × Perpendicular distance between the two forcesx =
qE × 2a sin θ
X = pE sin θ [∵ p = q × 2a; p is dipole moment]
As the direction of torque $\vec{\tau}$ is perpendicular to $\vec{p}$ and $\vec{E}$, so we can write $\vec{\tau} = \vec{p} \times \vec{E}$

2. (a) Explain the meaning of the statement 'electric charge of a body is quantised'.
(b) Why can one ignore of electric charge when dealing with macroscopic i.e., large scale charges?

A. **(a)** Electric charge of a body is quantized. This means that only integral (1, 2, …., *n*) number of electrons can be transferred from one body to the other. Charges are not transferred in fraction. Hence, a body possesses total charge only in integral multiples of electric charge.
(b) In macroscopic or large scale charges, the charges used are huge as compared to the magnitude of electric charge. Hence, quantization of electric charge is of no use on macroscopic scale. Therefore, it is ignored and it is considered that electric charge is continuous.

3. A free proton and a free electron are placed in a uniform field. Which of the two experience greater force and greater acceleration?

A. As F = q E and a = F/m as charge on both e-1 and proton are equal and opposite in nature, so force on them would be equal but as mass of proton is more than that of electron, so acceleration of electron would be more.



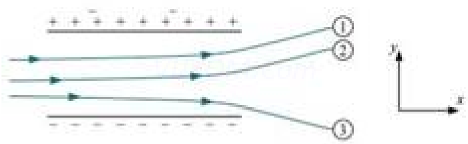
4. **When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.**

A. Rubbing produces charges of equal magnitude but of opposite nature on the two bodies because charges are created in pairs. This phenomenon of charging is called charging by friction. The net charge on the system of two rubbed bodies is zero. This is because equal amount of opposite charges annihilates each other. When a glass rod is rubbed with a silk cloth, opposite natured charges appear on both the bodies. This phenomenon is in consistence with the law of conservation of energy. A similar phenomenon is observed with many other pairs of bodies.

5. (a) An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?
(b) Explain why two field lines never cross each other at any point?

A. (a) An electrostatic field line is a continuous curve because a charge experiences a continuous force when traced in an electrostatic field. The field line cannot have sudden breaks because the charge moves continuously and does not jump from one point to the other.
(b) If two field lines cross each other at a point, then electric field intensity will show two directions at that point. This is not possible. Hence, two field lines never cross each other.

5.1. Figure 1.33 shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to mass ratio?



A. Opposite charges attract each other and same charges repel each other. It can be observed that particles 1 and 2 both move towards the positively charged plate and repel away from the negatively charged plate. Hence, these two particles are negatively charged. It can also be observed that particle 3 moves towards the negatively charged plate and repels away from the positively charged plate. Hence, particle 3 is positively charged.
The charge to mass ratio (emf) is directly proportional to the displacement or amount of deflection for a given velocity. Since the deflection of particle 3 is the maximum, it has the highest charge to mass ratio.

6. What is the net flux of the uniform electric field of Exercise 1.15 through a cube of side 20 cm oriented so that its faces are parallel to the coordinate planes?

A. All the faces of a cube are parallel to the coordinate axes. Therefore, the number of field lines entering the cube is equal to the number of field lines piercing out of the cube. As a result, net flux through the cube is zero.

7. Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is 8.0×10^3 N m^2 / C . (a) What is the net charge inside the box?

(b) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box? Why or Why not?

A. (a) Net outward flux through the surface of the box, $\Phi = 8.0\times10^3\ N\ m^2 / C$
For a body containing net charge *q*, flux is given by the relation,

$$\phi = \frac{q}{\epsilon_0}$$

ϵ_0 = Permittivity of free space

$= 8.854\times 10^{-12}\ N^{-1}C^2\ m^{-2}$ $q = \epsilon 0\Phi$

$= 8.854\times10^{-12} \times 8.0\times10^3$

$= 7.08\times10^{-8}$

= 0.07 μC

Therefore, the net charge inside the box is 0.07 μC .
(b) No
Net flux piercing out through a body depends on the net charge contained in the body. If net flux is zero, then it can be inferred that net charge inside the body is zero. The body may have equal amount of positive and negative charges.

4 Mark Questions

1. **A particle of mass m and charge q is released form rest in a uniform electric field of intensity E. calculate the kinetic energy it attains after moving a distances between the plates?**

A. Since F = qE

$\therefore \quad a = \frac{F}{m} = \frac{qE}{m}$ —1

Using third equation of motion

$v^2 - u^2 = 2as$

Initially charged particle is at rest $\therefore$ u = o

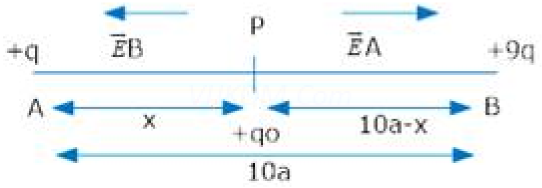
$\Rightarrow v^2 = 2as$

$KE = \frac{1}{2} mv^2 = \frac{1}{\cancel{2}} m (\cancel{2} as) = mas$............2

Substituting 1 in eq. 2

$KE = \cancel{m} \times \frac{qE}{\cancel{m}} \times S$

$KE = qES$



2. **Two point charges +q and +9q are separated by a distance of 10 a. Find the point on the line joining the two changes where electric field is zero?**

A. Let P be the pt where test charge (+qo) is present then electric field at pt. P will be zero if Field at pt. P due to +q = field at p+. P due to + 9q————1

$\vec{E} \Rightarrow E\vec{A} = \frac{K(+q)}{x^2} \; E\vec{B} = \frac{K(+9q)}{(10a-x)^2}$

Substituting in eq. 1

$\frac{\cancel{K}(+\cancel{q})}{x^2} = \frac{\cancel{K}(+9\cancel{q})}{(10a-x)^2}$

$(10a-x)^2 = 9x^2 \Rightarrow 10a - x = 3x$

$10a = 4x \quad \Rightarrow \quad x = \frac{10}{4} 9$

$x = 2.5$ a from change (+q)

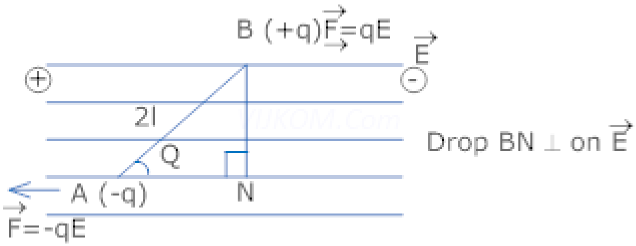
Or

$10\ a - x = 10a - 2.5a = 7.5$ a from change (+9q)

3. Define the term dipole moment $\vec{P}$ of an electric dipole indicating its direction. Write its S.I unit. An electric dipole is placed in a uniform electric field $\vec{E}$. Deduce the expression for the Torque acting on it.

A. Electric dipole moment is defined as the product of the magnitude of either charge and the length of dipole. Its direction is from –ve to +ve charge.

$\vec{P} = q(\vec{2l})$ Its S.I. unit is coulomb meter (Cm)



Consider a dipole placed in uniform electric field and makes an angle (θ) with the electric field $(\vec{E})$ Since two forces acts on the charges constituting an electric dipole which are equal and opposite in direction, thus a torque acts on the dipole which makes the dipole rotate.

And Torque $\tau = Ethier\ force \times \perp distance$

Here force (F) = qE

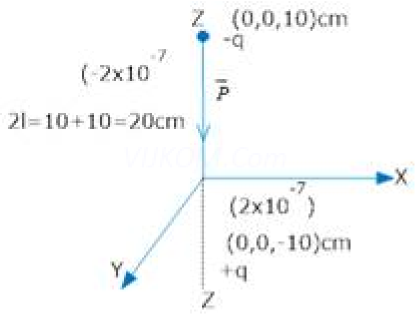
$And\ \frac{BN}{AB} = \sin\theta \quad \Rightarrow BN = AB \sin\theta = 2\ell \sin\theta$

$(\tau) = qE \times 2sin$

(τ) = PE Sinθ $(\because \vec{P} = q(\vec{2l}))$

$\vec{\tau} = \vec{P} \times \vec{E}$

In vector form



4. A sphere of radius r_1 encloses a change Q. If there is another concentric sphere S_2 of radius $r_2 (r_2 > r_1)$ and there is no additional change between $S_1 and\ S_2$. Find the ratio of electric flux through $S_1 and\ S_2$?

A. $\theta = q/\in o$ (where θ=electric flux)

$$\theta_{S1} = \frac{Q}{Eo}$$

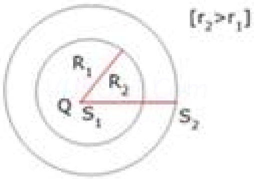
For sphere S_2

$$\theta_{S2} = \frac{Q}{\in o} \text{ (since no additional charge is given)}$$

$$\text{So } \frac{\theta_{S1}}{\theta_{S2}} = \frac{Q/\in o}{Q/\in o} = 1:1$$

$$So\ \theta_{s1}:\theta_{s2} = 1:1$$

5. Electric charge is uniformly distributed on the surface of a spherical balloon. Show how electric intensity and electric potential vary (a) on the surface (b) inside and (c) outside.

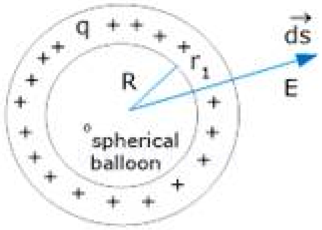


A. Electric field intensity on the surface of a shell

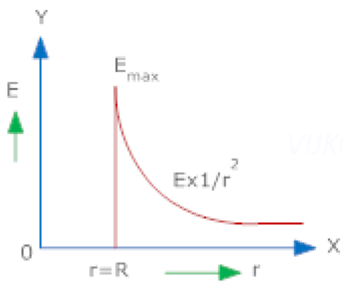
E = $\sigma/\in o$& V = Kq/R

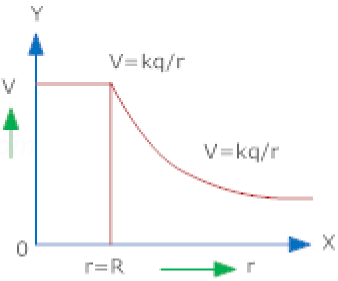
Inside E = o& V = Kq/R

Outside E = $\frac{\sigma}{\in o}\frac{R^2}{r^2}$ & V = Kq/r

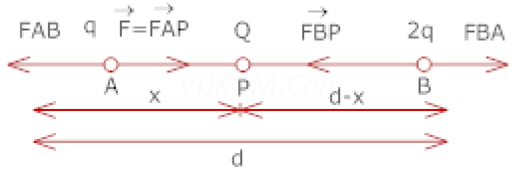


Graphically





6. Two point electric charges of value q and 2q are kept at a distance d apart from each other in air. A third charge Q is to be kept along the same line in such a way that the net force acting on q and 2q is zero. Calculate the position of charge Q in terms of q and d.



A. Net force on charge q and 2q will be zero if the third charge is negative (i.e. of opposite sign) and q and 2q are positive, Force on change q will be zero if

$$\left|\vec{FAB}\right| = \left|\vec{FAP}\right|$$

$$\frac{\cancel{K}\cancel{q}(2q)}{d^2} = \frac{\cancel{K}\cancel{q}(Q)}{x^2}$$

$$\frac{Q}{q} = \frac{2x^2}{d^2} - - - - (1)$$

Force on charge 2q to be zero

if $\left|F\vec{B}A\right| = \left|F\vec{B}P\right|$

$$\frac{\cancel{K}\cancel{q}(\cancel{2}q)}{d^2} = \frac{\cancel{K}(\cancel{2}\cancel{q})Q}{(d-x)^2}$$

$$\frac{Q}{q} = \frac{(d-x)^2}{d^2} - - - - (2)$$

comparing equation 1 and 2

$$\frac{2x^2}{\cancel{d^2}} = \frac{(d-x)^2}{\cancel{d^2}}$$

$$x^2 = \frac{(d-x)^2}{2}$$

$$x^2 = \frac{(d-x)^2}{(\sqrt{2})^2}$$

$$\Rightarrow x = \frac{d-x}{\sqrt{2}} or \Gamma 2x + x = d$$

$$x(\sqrt{2}+1) = d$$

$$\Rightarrow x = \frac{d}{\sqrt{2}+1}$$

7. What is the force between two small charged spheres having charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air?

A.Repulsive force of magnitude $6\times10^{-3}\ N$

Charge on the first sphere, $q_1 = 2\times10^{-7}\ C$

Charge on the second sphere, $q_2 = 3 \times 10^{-7}\ C$

Distance between the spheres, *r* = 30 cm = 0.3 m

Electrostatic force between the spheres is given by the relation,

$$F = \frac{q_1 q_2}{4\pi \in_0 r^2}$$

Where, $\in 0$ = Permittivity of free space

$$\frac{1}{4\pi \in_0} = 9\times10^9\ Nm^2C^2$$

s

$$F = \frac{9\times10^9 \times 2\times10^{-7} \times 3\times10^{-7}}{(0.3)^2} = 6\times10^{-3} N$$

Hence, force between the two small charged spheres is $6\times10^{-3}\ N$. The charges are of same nature. Hence, force between them will be repulsive.

8. The electrostatic force on a small sphere of charge $0.4\ \mu C$ due to another small sphere of charge – $0.8\ \mu C$ in air is 0.2 N. (a) What is the distance between the two spheres? (b) What is the force on the second sphere due to the first?

A. (a) Electrostatic force on the first sphere, *F* = 0.2 N

Charge on this sphere, $q^1 = 0.4\ \mu C = 0.4\times10^{-6}\ C$

Charge on the second sphere, $q^2 = -\ 0.8\ \mu C = -0.8\times10^{-6}\ C$

Electrostatic force between the spheres is given by the relation,

$$F = \frac{q_1 q_2}{4\pi \in_0 r^2} \quad And\ \frac{1}{4\pi \in_0} = 9\times10^9\ Nm^2C^{-2}$$

Where, $\in_0$ = Permittivity of free space

$$And, \frac{1}{4\pi \in_0} = 9\times10^9\ Nm^{-2}C^{-2}$$

$$r^2 = \frac{q_1 q_2}{4\pi \in_0 F}$$

$$= 144\times10^{-4}$$

$$r = \sqrt{144\times10^{-4}} = 0.12m$$

The distance between the two spheres is 0.12m.

(b) Both the spheres attract each other with the same force. Therefore, the force on the second sphere due to the first is 0.2N.

9. A polythene piece rubbed with wool is found to have a negative charge of $3\times10^{-7}\ C$
(a) Estimate the number of electrons transferred (from which to which?)
(b) Is there a transfer of mass from wool to polythene?

A. (a) When polythene is rubbed against wool, a number of electrons get transferred from wool to polythene. Hence, wool becomes positively charged and polythene becomes negatively charged.

Amount of charge on the polythene piece, $q = -3\times10^{-7}\ C$

Amount of charge on an electron, $e = -1.6\times10^{-19}\ C$

Number of electrons transferred from wool to polythene = n

n can be calculated using the relation,

$q = ne$

$n = \frac{q}{e}$

$= \frac{-3\times10^{-7}}{-1.6\times10^{-19}}$

$= 1.87 \times 10^{12}$

Therefore, the number of electrons transferred from wool to polythene is 1.87×1012.

(b) Yes.

There is a transfer of mass taking place. This is because an electron has mass,

$me = 9.1 \times 10^{-3}\ kg$

Total mass transferred to polythene from wool,

$m = me \times n$

$= 9.1\times10^{-31} \times 1.85 \times 10^{12}$

$= 1.706 \times 10^{-18}\ kg$

Hence, a negligible amount of mass is transferred from wool to polythene.

10. Consider a uniform electric field $E = 3\times10^{3}\ \hat{i}\ N/C$. (a) What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the *yz* plane? (b) What is the flux through the same square if the normal to its plane makes a $60°$ angle with the *x*-axis?

A. (a) Electric field intensity, $\vec{E} = 3\times10^{3}\ \hat{i} N/C$

Magnitude of electric field intensity, $|\vec{E}| = 3\times10^{3}\ N/C$

Side of the square, s = 10 cm = 0.1 m

Area of the square, $A = s^2 = 0.01\ m2$

The plane of the square is parallel to the y-z plane. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 0°$

Flux (Φ) through the plane is given by the relation,

$\Phi = |\vec{E}| A\cos\theta$

$= 3\times10^{3}\times0.01\times\cos0°$

$= 30\ N\ m^2 / C$

(b) Plane makes an angle of 60° with the *x*-axis. Hence, $\theta = 60°$

Flux, $\Phi = |\overline{E}| A \cos\theta$

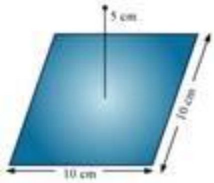
$= 3 \times 10^3 \times 0.01 \times cos 60°$

$= 30 \times \frac{1}{2}$

$= 15\ N\ m^2 / C$

11. A point charge +10 μC is a distance 5 cm directly above the centre of a square of side 10 cm, as shown in Fig. 1.34. What is the magnitude of the electric flux through the square? (*Hint:* Think of the square as one face of a cube with edge 10 cm.)

A. The square can be considered as one face of a cube of edge 10 cm with a centre where charge *q* is placed. According to Gauss's theorem for a cube, total electric flux is through all its six faces.



$\phi_{Total} = \frac{q}{\epsilon_0}$

Hence, electric flux through one face of the cube i.e., through the square, $\phi = \frac{\phi_{Total}}{6}$

$= \frac{1}{6}\frac{q}{\epsilon_0}$

Where,

ϵ_0 = Permittivity of free space

$= 8.854 \times 10^{-12}\ N^{-1} C^2\ m^{-2}$

$q = 10\ \mu C$

$= 10 \times 10^{-6}\ C$

$\therefore \phi = \frac{1}{6} \times \frac{10 \times 10^{-6}}{8.854 \times 10^{-12}}$

$= 1.88 \times 10^5\ N\ m^2\ C^{-1}$

Therefore, electric flux through the square is $1.88 \times 10^5\ N\ m^2\ C^{-1}$.

12. A point charge of 2.0 μC is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface?

A. Net electric flux (Φ_{Net}) through the cubic surface is given by,

ϕNet=qϵ0ϕNet=qϵ0
Where, $\in_0$ = Permittivity of free space
= 8.854×10^{-12} $N^{-1}C^2$ m^{-2}
q = Net charge contained inside the cube = 2.0 μC = 2×10^{-6} C
∴ ϕNet=2×10−68.854×10−12ϕNet=2×10−68.854×10−12
= 2.26×10^5 N m^2 C^{-1}
The net electric flux through the surface is 2.26×10^5 N m^2C^{-1}.

13.A point charge causes an electric flux of -1.0×10^3 Nm^2/C to pass through a spherical Gaussian surface of 10.0 cm radius centered on the charge. (a) If the radius of the Gaussian surface were doubled, how much flux would pass through the surface? (b) What is the value of the point charge?

A. (a) Electric flux, $\Phi = -1.0\times10^3\ N\,m^2/C$
Radius of the Gaussian surface,
r = 10.0 cm
Electric flux piercing out through a surface depends on the net charge enclosed inside a body. It does not depend on the size of the body. If the radius of the Gaussian surface is doubled, then the flux passing through the surface remains the same i.e., $-10^3\ Nm^2/C$.
(b) Electric flux is given by the relation,

$$\phi = \frac{q}{\in_0}$$

Where,
q = Net charge enclosed by the spherical surface
$\in_0$= Permittivity of free space = $8.854\times10^{-12}N^{-1}C^2\ m^{-2}$
∴ $q = \phi \in_0$
$= -1.0\times10^3 \times 8.854\times10^{-12}$
$= -8.854\times10^{-9}\ C$
= – 8.854 nC
Therefore, the value of the point charge is –8.854 nC.

14. A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5×10^3 N/C and points radially inward, what is the net charge on the sphere?

A. Electric field intensity (*E*) at a distance (*d*) from the centre of a sphere containing net charge *q* is given by the relation,

$E = \frac{q}{4\pi \epsilon_0 d^2}$

Where,

q = Net charge = $1.5 \times 10^3\ N/C$

d = Distance from the centre = 20 cm = 0.2 m

ϵ_0 = Permittivity of free space

And, $\frac{1}{4\pi \epsilon_0}$ = 9 × 109 N m^2 C – 2

∴

$= \frac{1.5 \times 10^3 \times (0.2)^2}{9 \times 10^9}$

$= 6.67 \times 10^9\ C$ = 6.67 nC

Therefore, the net charge on the sphere is 6.67 nC.

15. A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 μC /m². (a) Find the charge on the sphere. (b) What is the total electric flux leaving the surface of the sphere?

A. (a) Diameter of the sphere, d = 2.4 m

Radius of the sphere, r = 1.2 m

Surface charge density, σ = 80.0 $\mu C/m^2$ $= 80 \times 10^{-6}\ C/m^2$

Total charge on the surface of the sphere,

Q = Charge density × Surface area

$= \sigma \times 4\pi r^2$

$= 80 \times 10^{-6} \times 4 \times 3.14 \times (1.2)^2 = 1.447 \times 10^{-3}\ C$

Therefore, the charge on the sphere is $1.447 \times 10^{-3}\ C$.

(b) Total electric flux (ϕ_{Total}) leaving out the surface of a sphere containing net charge Q is given by the relation,

$\phi_{Total} = \frac{Q}{\epsilon_0}$

Where,

ϵ_0 = Permittivity of free space

$= 8.854 \times 10^{-12}\ N^{-1} C^2 m^{-2}$

$Q = 1.447 \times 10^{-3}\ C$

$\phi_{Total} = \frac{1.44 \times 10^{-3}}{8.854 \times 10^{-12}}$

$= 1.63 \times 10^8\ N\ C^{-1}\ m^2$

Therefore, the total electric flux leaving the surface of the sphere is $1.63 \times 10^8\ N\ C^{-1}\ m^2$.

7 Marks Questions

Question 1.
(a) Using Gauss' law, derive an expression for the electric field intensity at any point outside a uniformly charged thin spherical shell of radius R and charge density a C/m2. Draw the field lines when the charge density of the sphere is
(i) positive,
(ii) negative.
(b) A uniformly charged conducting sphere of 2.5 m in diameter has a surface charge density of 100 μC/m². Calculate the
(i) charge on the sphere
(ii) total electric flux passing through the sphere

Answer:
(a) (i) To find out electric field at a point outside a spherical charged shell we imagine a symmetrical Gaussian surface in such a way that the point lies on it.

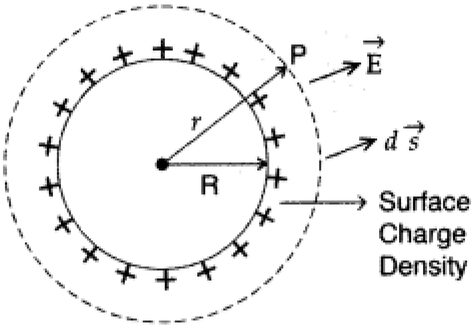
From Gauss's theorem, $\phi = \oint_S \vec{E}.d\vec{S} = \frac{q_m}{\varepsilon_0}$

Flux ϕ through S′

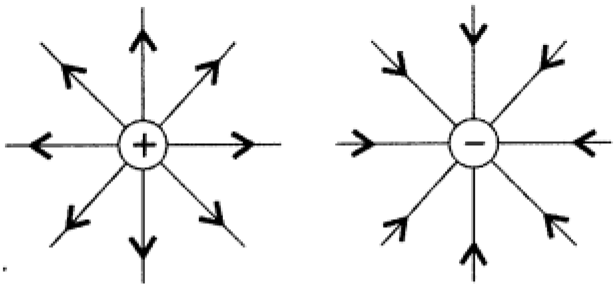
$$\phi = \oint_{S'} \vec{E}.d\vec{S} = \oint_{S'} EdS = E.4\pi r^2$$

$$\Rightarrow \quad E.4\pi r^2 = \frac{q_m}{\varepsilon_0}$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_0}.\frac{q_m}{r^2}$$



(*ii*)



for $q > 0$ for $q < 0$

(*b*) (*i*) **Given** : $r = \frac{2.5}{2}$ m, $\sigma = 100\ \mu C/m^2$

Charge on the sphere, $Q = \sigma.4\pi r^2$

or $\quad Q = 100 \times 10^{-6} \times 4 \times 3.14 \times \left(\frac{2.5}{2}\right)^2$

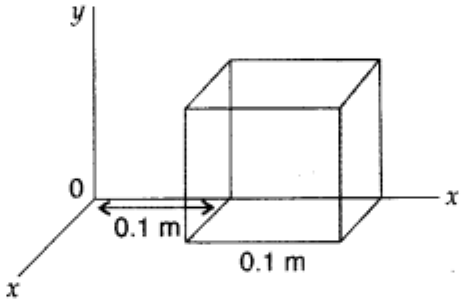
$= 19.6 \times 10^{-4}$ C $= \mathbf{1.96 \times 10^{-3}C}$

(*ii*) Flux passing through the sphere

$$\phi = \frac{Q}{\varepsilon_0} \quad \text{or} \quad \phi = \frac{19.6 \times 10^{-4}}{8.85 \times 10^{-12}}$$

$$\therefore \quad \phi = \mathbf{2.2 \times 10^8\ Nm^2/C}$$

Question 2.
(a) Define electric flux. Write its SI units.
(b) The electric field components due to a charge inside the cube of side 0.1 m are as shown :
E_x = ax, where α = 500 N/C^{-m}
$E_y = 0, \qquad E_z = 0.$



Calculate
(i) the flux through the cube, and
(ii) the charge inside the cube.
Answer:
(a) Electric flux through a surface represents the total number of electric lines of force crossing the surface.
∴ S.I. unit is $Nm^2\ C^{-1}$.
(b) (i) Flux through R.H.S. of the cube is

$$\begin{aligned} \phi_1 &= Ex_1 . A \\ &= (\alpha x) . (l)^2 \\ &= (500 \times 0.2)\ (0.1)^2 \\ &= 1 Nm^2\ C^{-1} \end{aligned} \quad \left[\begin{aligned} \because\ &\theta = 0^\circ \\ &\alpha = 500\ N/C^{-m} \\ &x = 0.2\ m \\ &l = 0.1\ m \end{aligned} \right.$$

(*ii*) Flux through L.H.S. of the cube is

$$\begin{aligned} \phi_2 &= Ex_2 . A \\ &= -(\alpha x) . l^2 \\ &= -(500 \times 0.1)\ (0.1)^2 \\ &= -0.5\ Nm^2/C \end{aligned} \quad \left[\begin{aligned} \because\ &\theta = 180^\circ \\ &x = 0.1\ m \\ &l = 0.1\ m \\ &\alpha = 500 N/C^{-m} \end{aligned} \right.$$

$$\text{Net flux } \phi = \phi_1 + \phi_2 = 1 - 0.5 = \mathbf{0.5\ Nm^2/C}$$

(*iii*) As $\phi = \dfrac{q}{\varepsilon_0} \qquad \therefore \quad q = \varepsilon_0\ \phi$

$$\Rightarrow q = 8.854 \times 10^{-12} \times 0.5 = \mathbf{4.4 \times 10^{-12}\ C}$$

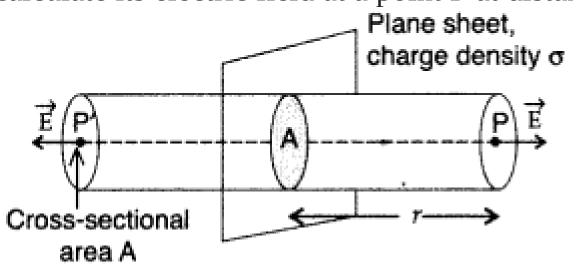
Question 3.
(a) Define electric flux. Write its S.I. units.
(b) Using Gauss’s law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it.
(c) How is the field directed if
(i) the sheet is positively charged,
(ii) negatively charged?

Answer:
(a) Electric flux: The electric flux through a given area held inside an electric field is the measure of the total number of electric lines of force passing normally through that area.

S.I. units of electric flux = $NC^{-1}m^2$ = **Nm^2C^{-1} or Vm**

Mathematically, $\phi_E = \oint_s \vec{E}\,\Delta\,\vec{s}$

(b) Consider a thin, infinite plane sheet of charge with uniform surface charge density 0. We wish to calculate its electric field at a point P at distance r from it.



By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P anel F equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross¬sectional area A and length 2r with its axis perpendicular to the sheet.

As the lines of force are parallel to the curved surface of the cylinder, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is :

$\phi E = EA + EA = 2EA$

Charge enclosed by the *Gaussian surface*,

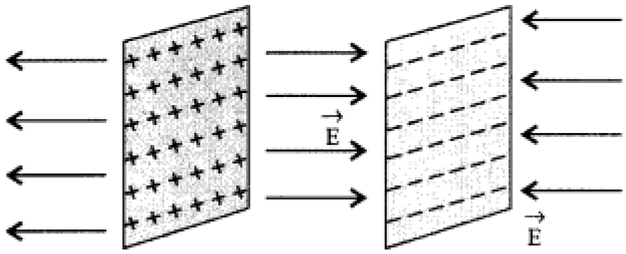
$q = \sigma A$

According to *Gauss's theorem*,

$$\phi_E = \frac{q}{\varepsilon_0} \quad \therefore\ 2EA = \frac{\sigma A}{\varepsilon_0} \text{ or } E = \frac{\sigma}{2\varepsilon_0}$$

Clearly, E is independent of *r*, the distance from the plane sheet.

(*c*)



(*i*) (*ii*)

(i) For positively charged sheet → away from the sheet

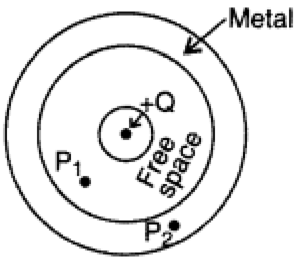
(ii)For negatively charged sheet →towards the sheet

Question 4.

(a) Define electric flux. Write its S.I. unit.

(b) A small metal sphere carrying charge +Q is located at the centre of a spherical cavity inside a large uncharged metallic spherical shell as shown in the figure the expressions for the electric field at points P_1 and P_2.

(c) Draw the pattern of electric field lines in this arrangement.



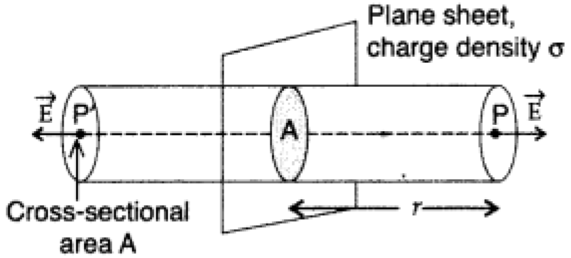
Answer:

(a) Electric flux: The electric flux through a given area held inside an electric field is the measure of the total number of electric lines of force passing normally through that area.

S.I. units of electric flux = $NC^{-1}m^2$ = $\mathbf{Nm^2C^{-1}}$ **or Vm**

Mathematically, $\phi_E = \oint_s \vec{E}\, \Delta \vec{s}$

(b) Consider a thin, infinite plane sheet of charge with uniform surface charge density 0. We wish to calculate its electric field at a point P at distance r from it.



By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P anel F equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross-sectional area A and length 2r with its axis perpendicular to the sheet.

As the lines of force are parallel to the curved surface of the cylinder, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is :

$$\phi E = EA + EA = 2EA$$

Charge enclosed by the *Gaussian surface,*

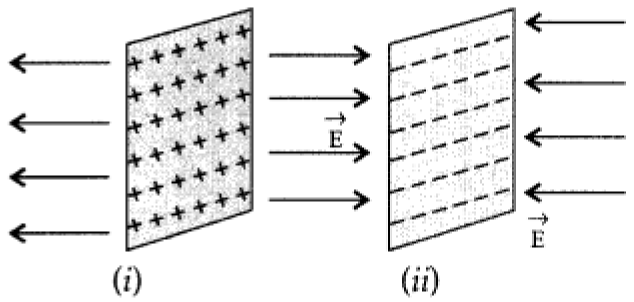
$$q = \sigma A$$

According to *Gauss's theorem,*

$$\phi_E = \frac{q}{\varepsilon_0} \quad \therefore\ 2EA = \frac{\sigma A}{\varepsilon_0} \text{ or } E = \frac{\sigma}{2\varepsilon_0}$$

Clearly, E is independent of *r*, the distance from the plane sheet.

(*c*)



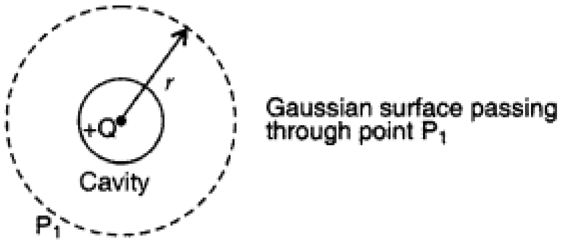
(i) For positively charged sheet → away from the sheet

(ii)For negatively charged sheet →towards the sheet

(b) Calculation of electric field at point Pt:

Net charge enclosed by the Gaussian surface is +Q

$$\therefore\ \phi = \oint \vec{E}.d\vec{s} = \frac{Q}{\varepsilon_0}$$



As electric field of positive charge is radially outwards, it is parallel to the area vector on the surface chosen.

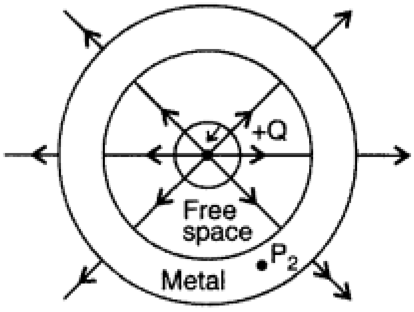
$$\therefore \oint \vec{E}.d\vec{s} = \oint E.\,ds\cos 0° = \frac{Q}{\varepsilon_0}$$

$$E\oint ds = \frac{Q}{\varepsilon_0} \quad \Rightarrow E \times 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

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

As point P_2 lies inside the metal, therefore electric field at point P_2 is zero.

(*c*)



Electric field lines

Fill in the Blanks

Choose the correct option and fill in the blanks.

(always repulsion, always attraction, displacement of negative charge, displacement of positivecharge, atom, molecule, steel, copper, plastic, inflated balloon, charged object, gold)

(a) There is ....between like charges.**(always repulsion)**

(b)is responsible for generation of electric charge in an object.**(displacement of negative charge)**

(c) A lightning conductor is made of a.............................. strip.**(copper)**

(d)does not get electrically charged easily by rubbing.**(copper/ gold)**

(e) There is .... when opposite electric charge come near each other.**(always attraction)**

(f) A.........................can be detected with an electroscope.**(charged object)**

Multiple Choices

1. If the sizes of charged bodies are very small compared to the distances between them, we treatthem as_.

   a. Zero charges
   b. Point charges
   c. Single charge
   d. No charges

Answer: (b) Point charges

Explanation: If the sizes of charged bodies are very small compared to the distances between them, we treat them as point charges.

2. The force per unit charge is known as_________________.

   a. Electric current
   b. Electric potential
   c. Electric field
   d. Electric space

Answer: (c) Electric field

Explanation: The force per unit charge is known as the electric field.

3. State true or false: The total charge of the isolated system is NOT conserved.

   a. True (b) False

Answer: (b) False

Explanation: As per the conservation of charges, it is said that the total charge of the isolatedsystem is always conserved.

4. What is the dielectric constant of a metal?

   a. -1
   b. 0
   c. 1

d. Infinite

Answer: (d) Infinite

Explanation: The dielectric constant of metals is infinite. The dielectric constant of metal is infinite,as the net electric field inside the metal is zero.

5. If the charge of 1 C is placed at a distance of 1 m from another charge of the same magnitudein a vacuum, it experiences an electrical force repulsion of magnitude________________________.

a. $9 * 10^{-9} N$

b. $9 * 10^{9} N$

c. $10 * 10^{9} N$

d. $10 * 10^{-9} N$

Answer: (b)

$9 * 10^{9} N$

Explanation: If the charge of 1 C is placed at a distance of 1 m from another charge of the same magnitude in a vacuum, it experiences an electrical force repulsion of magnitude

$9 * 10^{9} N$

$$F = \frac{1}{4\pi\epsilon_0} \frac{q1q2}{r^2}$$

$$= (9 \times 10^{9} Nm^{2} C^{-2}) \frac{(1C)(1C)}{(1m)^2}$$

$= 9 \times 10^{9} N$

6. The quantisation of charge indicates that

a. Charge, which is a fraction of charge on an electron, is not possible
b. A charge cannot be destroyed
c. Charge exists on particles
d. There exists a minimum permissible charge on a particle

Answer: (a) Charge, which is a fraction of charge on an electron, is not possible

Explanation: The quantisation of charge means that when we say something has some charge, we mean by that that how many times the charge of electrons it has. Because the whole charge is associated with an electron.

7. The property which differentiates two kinds of charges is called__________________.

a. Equality of charge
b. Polarity of charge
c. Fraction of charge
d. None of the option

Answer: (b) Polarity of charge

Explanation: The property which differentiates two kinds of charges is called polarity of charge.

8. ————— gives the information on field strength, direction, and nature of the charge.

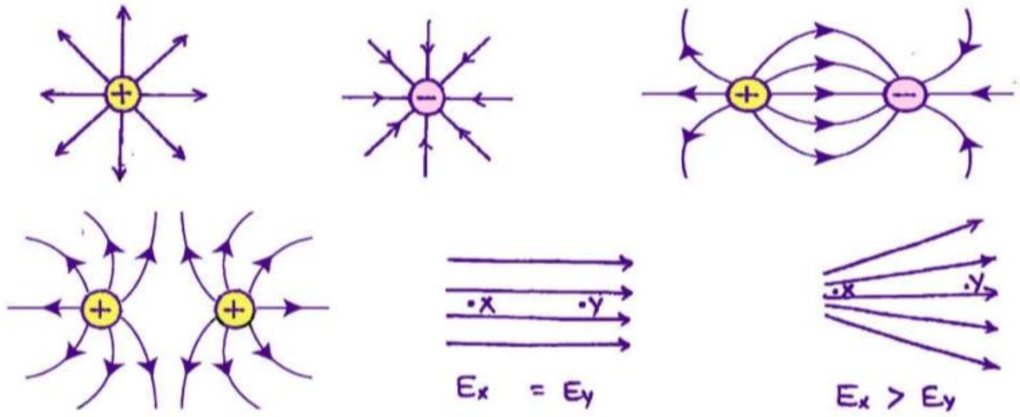
a. Electric current
b. Electric flux
c. Electric field
d. Electric potential

Answer: (c) Electric field

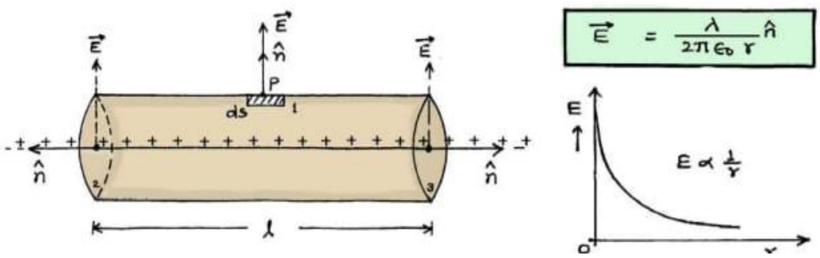
Explanation: Electric field gives the information on field strength, direction, and nature of the charge.

Diagrams

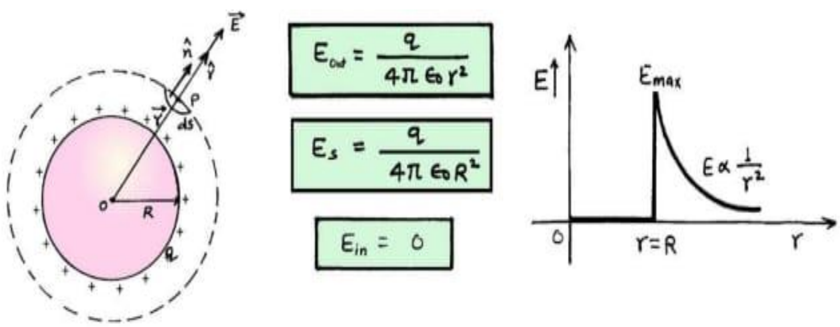
Properties of Electric Field Lines



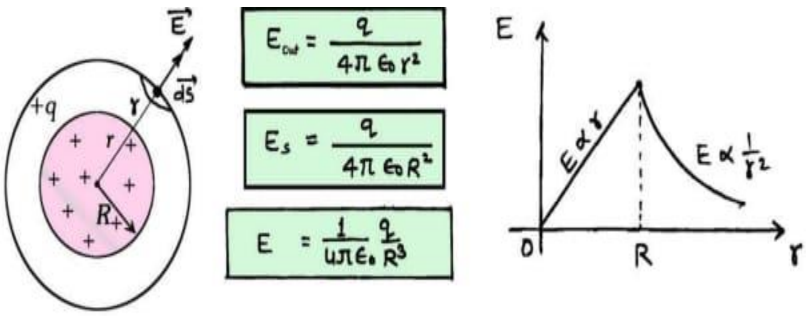
(1)Field due to an infinitely Long straight Uniformly charged wire



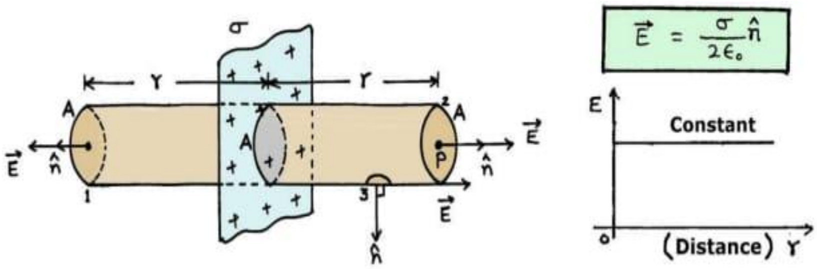
(2) Electric Field Intensity due to a Uniformly charged spherical shell



(3) Electric Field due to a Uniformly charged Non-conducting sphere

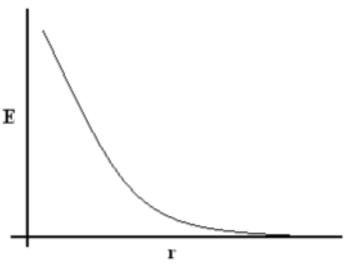


(4) Electric Field intensity due to a thin infinite plan sheet of charge



SUMMARY

- **Like Charges and Unlike Charges:**
  Like charges repel and unlike charges attract each other.
- **Conductors and Insulators:**
  Conductors allow movement of electric charge through them, insulators do not.
- **Quantization of Electric Charge:**
  It means that total charge (q) of a body is always an integral multiple of a basic quantum of charge (e)
  $$q = ne$$
  where n = 0, ±1, ±2, ±3, ….
- **Additivity of Electric Charges:**
  Total charge of a system is the algebraic sum of all individual charges in the system.
- **Conservation of Electric Charges:**
  The total charge of an isolated system remains uncharged with time.
- **Superposition Principle:**
  It is the properties of forces with which two charges attract or repel each other are not affected by the presence of a third (or more) additional charge(s).
- **The Electric Field E at a Point due to a Charge Configuration:**
  It is the force on a small positive test charges q placed at the point divided by a magnitude
  $$\frac{|q|}{4\pi\varepsilon_0 r^2}$$
  It is radially outwards from q, if q is positive and radially inwards if q is negative.
  E at a point varies inversely as the square of its distance from *Q*, the plot of *E* versus *r* will look like the figure given below.



- **Coulomb's Law:**
  The mutual electrostatic force between two point charges q_1 and q_2 is proportional to the product q_1q_2 and inversely proportional to the square of the distance r_{21} separating them.
  $$\vec{F}_{21}(\textit{force}\text{ on } q_2 \text{ due to } q_1) = \frac{k(q_1q_2)}{r_{21}^2}\hat{r}_{21}$$
  Where $\hat{r}_{21}$ is a unit vector in the direction from q_1 to q_2 and $k = \frac{1}{4\pi\varepsilon_0}$ is the proportionality constant.
- **An Electric Field Line:**
  It is a curve drawn in such a way that the tangent at each point on the curve gives the direction of electric field at that point.

- **Important Properties of Field Lines:**
  These are:
  (i) Field lines are continuous curves without any breaks.
  (ii) Two field lines cannot cross each other.
  (iii) Electrostatic field lines start at positive charges and end at negative charges – they cannot form closed loops.
- **Electric Field at a Point due to Charge q:**

$$\vec{E} = \frac{\vec{F}}{q}$$

- **Electric Field due to an Electric Dipole in its Equatorial Plane at a Distance r from the Centre:**

$$E = \frac{-p}{4\pi\varepsilon_0}\frac{1}{(a^2 + r^2)^{\frac{3}{2}}}$$

$$\cong \frac{-p}{4\pi\varepsilon_0}, \textit{ for } r>>a$$

- **Electric Field due to an Electric Dipole on the Axis at a Distance r from the Centre:**

$$E = \frac{2pr}{4\pi\varepsilon_0 (r^2 - a^2)^2}$$

$$\cong \frac{2p}{4\pi\varepsilon_0 r^3}, \textit{ for } r>>a$$

- **A Dipole Placed in Uniform Electric Field E experiences:**
  Torque $\vec{\tau}$,

$$\vec{\tau} = \vec{p} x \vec{E}$$

- **The Electric Flux:**
  $\phi = \int d\phi = \int \vec{E}.\vec{ds}$ is a ‘dot’ product, hence it is scalar.
  $\Delta\phi$ is positive for all values of $\theta < \frac{\pi}{2}$
  $\Delta\phi$ is negative for all values of $\theta > \frac{\pi}{2}$
- **Gauss’s Law:**
  The flux of electric field through any closed surface S is 1/ε0 times the total charge enclosed by S.
  $\phi = \int \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$
- Electric field outside the charged shell is as though the total charge is concentrated at the centre. The same result is true for a solid sphere of uniform volume charge density.
- The electric field is zero at all points inside a charged shell.

- **Electric field E, due to an infinitely long straight wire of uniform linear charge density λ:**

  $$E = \frac{\lambda}{2\pi\varepsilon_0 r} \cdot \hat{n}$$

  where r is the perpendicular distance of the point from the wire and is the radial unit vector in the plane normal to the wire passing through the point.

- **Electric field E, due to an infinite thin plane sheet of uniform surface charge density σ:**

  $$E = \frac{\sigma}{2\varepsilon_0} \cdot \hat{n}$$

  Where $\hat{n}$ is a unit vector normal to the plane, outward on either side.

- **Electric field E, due to thin spherical shell of uniform surface charge density σ:**

  $$E = \frac{q}{4\pi\varepsilon_0 r^2} \cdot \hat{r} \qquad (r \geq R)$$

  $$E = 0 \qquad (r < R)$$

  where r is the distance of the point from the centre of the shell and R the radius of the shell, q is the total charge of the shell & $q = 4\pi R^2\sigma$.

- Electric field E along the outward normal to the surface is zero and σ is the surface charge density. Charges in a conductor can reside only at its surface. Potential is constant within and on the surface of a conductor. In a cavity within a conductor (with no charges), the electric field is zero.