CHAPTER 1
ELECTRIC CHARGES AND FIELDS

ELECTROSTATICS

Electrostatics is the branch of physics which deals with the electric charges at rest (static charges).

It deals forces , fields and potentials arising from a static charge.

ELECTRIC CHARGES

It was observed that when two glass rods rubbed with silk are brought close to each other, they repel each other while the glass rod and silk attract each other. This is due to bodies acquire electric charges during rubbing.

FRICTIONAL ELECTRICITY

The phenomenon of acquiring electric charges by friction is called **frictional electrification** and the bodies are said to possess **frictional electricity**. This is also called triboelectricity.

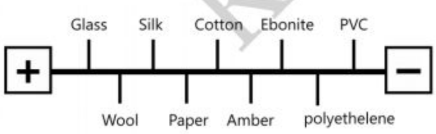
Rubbing of insulators causes transfer of charges from one body to another.

The body which loses electrons gets positive charge and the body which gains electrons gets negative charge.

Ex : When glass rod rubbed with silk, glass rod loses electrons and becomes positively charged and silk gets electrons and becomes negatively charged.

NOTE

The **triboelectric series** is a list that ranks materials according to their tendency to gain or lose electrons



[mnemonic : Good White Silks Produce Clean Attractive Elegant Plastic Pipes]

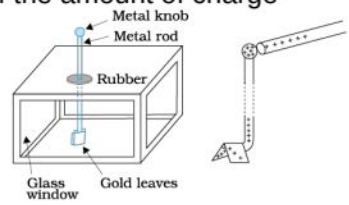
From the above fig. we can understand that the glass is more triboelectrically positive than wool or silk.

NOTE

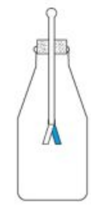
Conductors can not charge by friction

ELECTROSCOPE

An apparatus used to detect the presence of an electric charge. When a charged object touches the metal knob at the top of the electroscope rod, the leaves of the electroscope diverges. The degree of divergence is an indicator of the amount of charge



(a)



(b)

BASIC PROPERTIES OF ELECTRIC CHARGE

1. There are two types of charges , +ve and -ve
2. Like charges repel and unlike charges attract.
3.Charge is a scalar quantity.

4. Charges are additive

If a system contains n charges $q_1, q_2, q_3, \ldots, q_n$, then the total charge of the system is $q_1 + q_2 + \ldots + q_n$.

5. Charge is conserved

It is not possible to create or destroy net charge. ie, the total charge of an isolated system is always conserved .

6. Charge is quantised

Charge of a body is an integral multiple of charge of an electron. That is the basic charge is equal to electronic charge, e = 1.602 x 10^{-19} C.

ie, $\boxed{q = \pm ne}$

Problem 1

How many electrons are present in -1 coulomb of charge ?

Solution

$q = ne$ (or)

$$n = \frac{q}{e} = \frac{1}{1.6 \, x \, 10^{-19}} = 6.25 \, x \, 10^{18}$$

ie, -1 C means 6.25 x 10^{18} electrons are excess. Similarly +1 C means 6.25 x 10^{18} electrons are deficient.

Problem 2 (NCERT Example 1.1)

If 10^9 electrons move out of a body to another body every second, how much time is required to get a total charge of 1 C on the other body?

Solution

1 C = 6.25 x 10^{18} electrons

Time to move out 10^9 electrons = 1 s

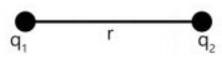
The time to move out 1 electron = $\frac{1}{10^9} s$

Therefore the time to move out 6.25 x 10^{18} electrons=

$$6.25 \, x \, 10^{18} \, x \frac{1}{10^9} s = 6.25 \, x \, 10^9 s = 198.18 \, yrs$$

COULOMB'S LAW

It states that the electrostatic force between two stationary electric charges is directly proportional to the product of the two charges and inversely proportional to the square of the distance between them.



$F \alpha \frac{q_1 q_2}{r^2}$ (Or) $F = \frac{1}{4\pi\varepsilon} \frac{q_1 q_2}{r^2}$

Where 'ε' is a constant called permittivity of the medium.

If the charges are placed in vacuum or air, $\varepsilon = \varepsilon_0$

Therefore $F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$

Where , ε_0 is the permittivity of free space and whose value = $8.85 \, x \, 10^{-12}$ C^2/Nm^2

and $\frac{1}{4\pi\varepsilon_0} = 9 \, x \, 10^9$ Nm^2/C^2

NOTE

If $q_1 = q_2 = 1C$, $r = 1m$ is placed in vacuum, then $F = 9 \, x \, 10^9 N$

ie, One coulomb is defined as that charge which when placed in free space at a distance of 1m with an equal and similar charge, will repel with a force of 9 $x10^9$ N.

RELATIVE PERMITTIVITY (ε_r)

Relative permittivity of a medium is the ratio of permittivity of the medium to the permittivity of free space.

Ie, $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$ Or $\varepsilon = \varepsilon_0 \varepsilon_r$

Therefore $F_{med} = \frac{1}{4\pi\varepsilon_0\varepsilon_r} \frac{q_1 q_2}{r^2} = \frac{F_{air}}{\varepsilon_r}$

Or $\varepsilon_r = \frac{F_{air}}{F_{med}}$

Relative permittivity is also called **dielectric constant.**

NOTE

From the above equation $F_{med} = \frac{F_{air}}{\varepsilon_r}$

For a medium $\varepsilon_r > 1$ ie, $F_{med} < F_{air}$

Problem

Two point charges placed at a distance 'r' in air experience a certain force. Then what's the distance at which they will experience the same force in a medium of dielectric constant K.

Soln) $\frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} = \frac{1}{4\pi K \varepsilon_0} \frac{q_1 q_2}{r_m^2}$

=> $\frac{1}{r^2} = \frac{1}{K r_m^2}$ => $r_m^2 = \frac{r^2}{K}$ => $r_m = \frac{r}{\sqrt{K}}$

Problem

Two point charges placed at a distance 'r' in air exert a force F on each other. The value of distance R at which they experience force 4F when placed in a medium of dielectric constant K = 16 is :

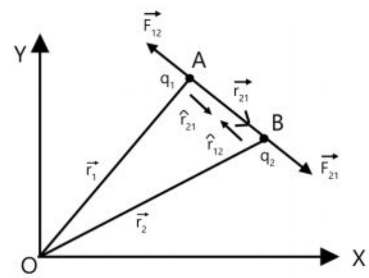
(a) r (b) r/2 (c) r/4 (d) r/8

Soln) $F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$ ....(1)

$4F = \frac{1}{4\pi 16 \varepsilon_0} \frac{q_1 q_2}{R^2}$ ....(2)

(1)/(2)=> $\frac{1}{4} = \frac{16 R^2}{r^2} \Rightarrow R^2 = \frac{r^2}{64} \Rightarrow R = \frac{r}{8}$

COULOMB'S LAW IN VECTOR FORM



The force acting on q_1 due to q_2

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

Where, $\hat{r}_{12}$ is the unit vector drawn from q_2 to q_1.

Similarly The force acting on q_2 due to q_1

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{21}$$

Since $\boxed{\hat{r}_{12} = -\hat{r}_{21}}$ ie, $\vec{F}_{12} = -\vec{F}_{21}$

NOTE

1. Coulomb's law holds good only for point charges
2. The direction of force is always along the line joining the two-point charges q_1 and q_2 . Hence this force is called central force.

Problem 3

An electron and a proton are separated by a distance r . Compare the magnitudes electric force with the gravitational force between them.

Solution

$$\frac{F_e}{F_g} = \frac{\frac{1}{4\pi\varepsilon_0}\frac{e\,e}{r^2}}{G\frac{m_p m_e}{r^2}} = 2.4\,x\,10^{39}$$

ie , $F_e = 2.4\,x\,10^{39}\,x\,F_g$ => $F_e \gg F_g$

FORCES BETWEEN MULTIPLE CHARGES (SUPERPOSITION PRINCIPLE)

The electrostatic force between two charges is not affected by the existence of the other charges and the total electrostatic force on a charge is the vector sum of all the forces due to other charges. This is the superposition principle.

consider a system of n charges q_1, q_2 and q_n

Then the total force acting on q_1 is F_1

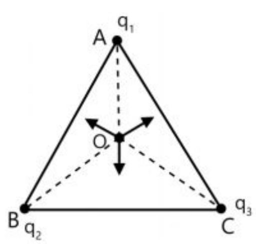
$$F_1 = F_{12} + F_{13} + ...F_{1n}$$

Problem 4

(Example 1.5 NCERT) (Do yourself)

Consider three charges q_1 , q_2 , q_3 each equal to q at the vertices of an equilateral triangle of side l. What is the force on a charge Q (with the same sign as q) placed at the centroid of the triangle, as shown in Fig.

[Ans : 0]



Problem 5

(a) Twelve equal charges, q, are situated at the corners of a regular 12–sided polygon (for instance, one on each numeral of a clock face). What is the net force on a test charge Q at the center?

(b) Suppose one of the 12 q's is removed (the one at "6 o'clock"). What is the force on Q? Explain your reasoning carefully

(c) Now 13 equal charges, q, are placed at the corners of a regular 13–sided polygon. What is the force on a test charge Q at the center?

Answers

(a) 0

(b) $F = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2}$ towards the missing charge

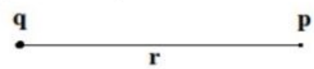
(c) 0

ELECTRIC FIELD

It is the region around an electric charge, where an electrostatic force is experienced on another charge.

ELECTRIC FIELD INTENSITY AT A POINT (E)

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



Let a small test charge 'δq' is placed at P. Then the force experienced by this test charge is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q\,\delta q}{r^2}$$

Therefore, the force experienced on a unit positive charge is $E = \frac{F}{\delta q}$

=> $$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$$

ELECTRIC FIELD LINES (ELECTRIC LINES OF FORCE)

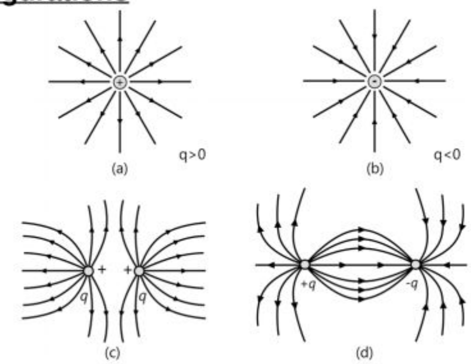
It is the path along which a unit positive charge would move, if it is free to do so. The tangent at any point on the line of force will give the direction of electric intensity at that point.

Properties

1. It start from a positive charge and end in negative charge.
2. Two field lines can never intersect each other.(If they did, the field at the point of intersection will not have a unique direction)
3. Electrostatic field lines do not form any closed loops. (A magnetic dipole forms closed loops magnetic field lines)

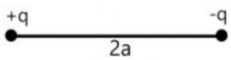
4. Uniform electric field can be represented by parallel lines.

Field lines due to some simple charge configurations



ELECTRIC DIPOLE

Two equal and opposite charges separated by a small distance is called an electric dipole.



Dipole moment (p)

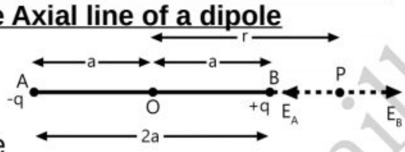
The strength of a dipole is measured by a quantity called dipole moment.

Dipole moment, $\boxed{\vec{p}=q(2a)}$

It is a **vector quantity** , whose direction is from negative charge to positive charge.
Unit : C.m

ELECTRIC FIELD DUE TO A DIPOLE

1. At the Axial line of a dipole



We are going to find out the EF at a point, p which is at a distance 'r' from the centre of the dipole on its axial line .
EF at P due to +q Charge,

$$\vec{E_B}=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$$

E at P due to -q Charge,

$$\vec{E_A}=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}(-\hat{p})$$

So the resultant **E** at P,

$$\vec{E}=\vec{E_B}+\vec{E_A}=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}-\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

=> $$\vec{E}=\frac{q\hat{p}}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2}-\frac{1}{(r+a)^2}\right]$$

=> $$\vec{E}=\frac{q\hat{p}}{4\pi\varepsilon_0}\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2(r+a)^2}\right]$$

=> $$\vec{E}=\frac{q\hat{p}}{4\pi\varepsilon_0}\left[\frac{(r^2+2ra+a^2)-(r^2-2ra+a^2)}{[(r-a)(r+a)]^2}\right]$$

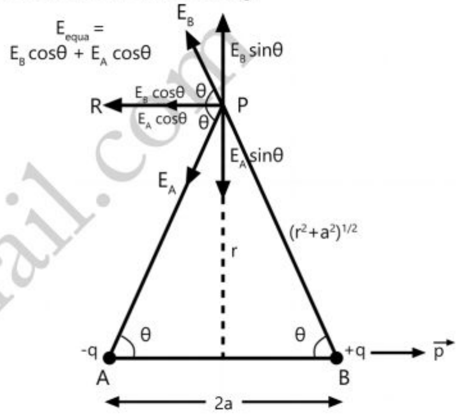
=> $$\vec{E}=\frac{q\hat{p}}{4\pi\varepsilon_0}\left[\frac{4ra}{(r^2-a^2)^2}\right]$$

=> $$\vec{E}=\frac{2q(2a)r\hat{p}}{4\pi\varepsilon_0(r^2-a^2)^2}=\frac{2pr\hat{p}}{4\pi\varepsilon_0(r^2-a^2)^2}$$

For an ideal dipole, $r^2\gg a^2$, a^2 can be neglected.

Therefore $$\boxed{\vec{E_{ax}}=\frac{2p}{4\pi\varepsilon_0 r^3}\hat{p}=\frac{2\vec{p}}{4\pi\varepsilon_0 r^3}}$$

2. At the Equitorial line of a dipole (Perpendicular bisector)



We are going to find out the EF at a point, p which is at a distance 'r' from the centre of the dipole on its equatorial line .

Magnitude of **E** at P due to +q Charge,

$$E_B=\frac{1}{4\pi\varepsilon_0}\frac{q}{(\sqrt{r^2+a^2})^2}$$

=> $$E_B=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$ (direction : B to P)

Magnitude of **E** at P due to -q Charge,

$$E_A=\frac{1}{4\pi\varepsilon_0}\frac{q}{(\sqrt{r^2+a^2})^2}$$

=> $$E_A=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$ (direction : P to A)

Since the magnitude of E_A and E_B are same, the vertical components cancel each other and horizontal components exist.

So the resultant $\vec{E}$ at $p=(E_A\cos\theta+E_B\cos\theta)(-\hat{p})$

=> $\vec{E}$ at $P=2E_A\cos\theta(-\hat{p})$
(since $E_A=E_B$)

Also $\cos\theta = \frac{a}{(r^2+a^2)^{1/2}}$

Therefore $\vec{E} = \frac{2}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\frac{a}{(r^2+a^2)^{1/2}}(-\hat{p})$

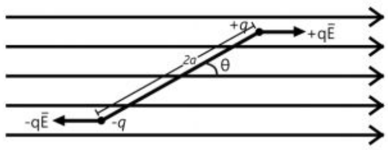
=> $\vec{E} = \frac{p}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}(-\hat{p})$

For an ideal dipole, $r^2 \gg a^2$, a^2 can be neglected.

Therefore, $\boxed{\vec{E}_{eq} = \frac{p}{4\pi\varepsilon_0 r^3}(-\hat{p}) = \frac{-\vec{p}}{4\pi\varepsilon_0 r^3}}$

DIPOLE IN AN EXTERNAL FIELD

1) In a uniform Electric field



$$Net\ force, F = -qE + qE = 0$$

$$Torque, \tau = force\ X\ perpendicular\ distance$$

$$\tau = qE \times 2a\sin\theta \quad , \quad \tau = pE\sin\theta$$

(Or) $\boxed{\vec{\tau} = \vec{p} \times \vec{E}}$

NOTE

- When a dipole is placed in a uniform EF , total force is zero , there is no translational motion.
- Torque will tend to align the dipole with the field E. When p is aligned with E, the torque is zero.

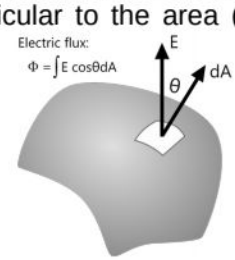
2) In a non uniform Electric field

In non uniform field there is a torque and net force on the dipole. Thus the dipole has rotational and translational motion.

ELECTRIC FLUX

Electric flux through an area is defined as the total number of electric field lines passing normally through the area .

The flux through an area is given by the product of the area and the component of electric field perpendicular to the area (parallel to area vector).



Electric flux through small area dA is given by,

$$d\phi = E\cos\theta\, dA = \vec{E}.\vec{dA}$$

The total electric flux through the area A is given by , $\boxed{\phi = \int \vec{E}.\vec{dA}}$

Unit : Nm^2/C

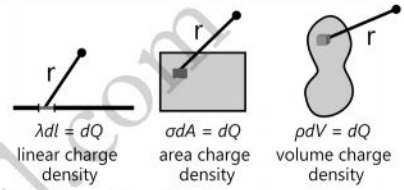
Problem (Do yourself)

Consider a uniform electric field $E = 3\,x\,10^3\,\hat{i}$ N/C.

(a) what is the flux of this field through a square of 10cm 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 60^0 angle with the x-axis?

CONTINUOUS CHARGE DISTRIBUTION



1) Linear charge density(λ)

$$\boxed{\lambda = \frac{dQ}{dl}}$$

2) Surface charge density(σ)

$$\boxed{\sigma = \frac{dQ}{dA}}$$

3) Volume charge density(ρ)

$$\boxed{\rho = \frac{dQ}{dV}}$$

GAUSS'S LAW

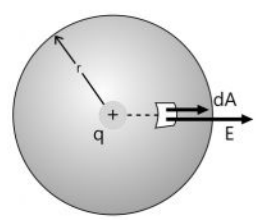
Gauss's law states that " the net electric flux through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the surface"

Proof

A positive charge is located at the centre of a sphere of radius 'r' .

The magnitude of the electric field everywhere on the surface of the sphere is same and it's direction is perpendicular to the surface (parallel to the area vector).

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$



$$Total\ flux\ through\ the\ surface, \phi = \oint \vec{E}.\vec{dA}$$

=> $$\phi = \oint \vec{E}.\vec{dA} = \oint E\,dA$$

(Since $\vec{E}$ and $\vec{dA}$ are in same direction)

$$\phi = \oint E\,dA = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\oint dA = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}4\pi r^2 = \frac{q}{\varepsilon_0}$$

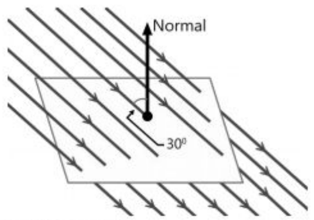
NOTE

Gauss's law is true for any closed surface irrespective of the size and shape.

Problem 5

A square surface with side length 3.7 mm is located in a uniform electric field with magnitude E=2400 N/C, as shown in the above below. What is the electric flux through the surface, assuming that the normal is directed outward?

Solution



$$\phi = \vec{E}.\vec{A} = E\,A\cos\theta$$

=> $$\phi = 2400\,x\,(3.7\,x\,10^{-3})^2\,x\cos 150$$

Problem 6

A cube with edge length 0.90 m is located in the xyz- space as shown in the figure below. If the uniform electric field in the space is given by $-4.00\,\hat{j}\,N/C$, what is the electric flux through the right face of the cube?

Solution

$$\phi = \vec{E}.\vec{A} = E\,A\cos\theta$$

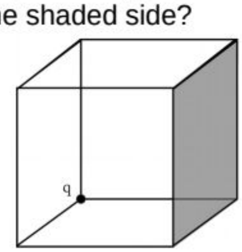
=> $$\phi = 4\,x\,(0.9)^2\,x\cos 180 = -3.24\,N.m^2/C$$

Problem 7 (Do yourself)

Charge q is placed at the centre of a cube. What is the flux through one face of a cube?

Problem 7 (Do yourself)

A charge q is at the back corner of a cube, as shown in Figure . What is the flux of E through the shaded side?

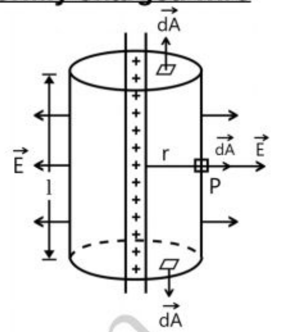


NOTE

Gaussian surface : An imaginary surface enclosing a charge or charge distribution is called a **Gaussian surface**. A Gaussian surface can be a surface of any shape.

APPLICATIONS OF GAUSS ' S LAW

1) Electric field due to an infinitely long straight uniformly charged wire



Consider an infinitely long straight charged wire of linear charge density (charge per unit length) , λ .

To find the electric field at a point P at a distance 'r' from the wire, consider a Gaussian cylinder of radius 'r' and length 'l' coaxial with the wire

Apply Gauss's law to the Gaussian surface

$$\oint_{GS} \vec{E}.\vec{dA} = \frac{q_{enc}}{\varepsilon_0}$$

=> $$\int_{TS} \vec{E}.\vec{dA} + \int_{BS} \vec{E}.\vec{dA} + \int_{CS} \vec{E}.\vec{dA} = \frac{\int \lambda\,dl}{\varepsilon_0}$$ .....(1)

For **top surface** and for the **bottom surface** $\vec{E}$ and $\vec{ds}$ are perpendicular to each other and flux through the surface is zero. For the curved surface $\vec{E}$ and $\vec{ds}$ are in parallel. Therefore

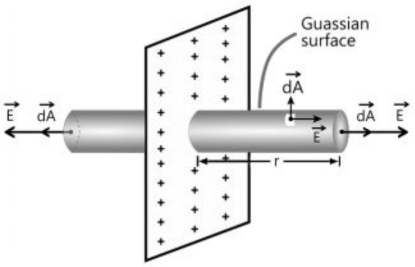
(1)=> $$\int_{CS} E\,dA = \frac{\int \lambda\,dl}{\varepsilon_0} \quad \Rightarrow \quad E\int_{CS} dA = \frac{\lambda \int dl}{\varepsilon_0}$$

=> $$E\,2\pi r\,l = \frac{\lambda l}{\varepsilon_0}$$

=> $$\boxed{E = \frac{\lambda}{2\pi r\,\varepsilon_0}}$$ (or) $$\boxed{\vec{E} = \frac{\lambda}{2\pi r\,\varepsilon_0}\hat{n}}$$,

where $\hat{n}$ is a unit vector in radial direction.

2) Electric field due to a uniformly charged infinite plane sheet



Consider a thin, infinite plane sheet of surface charge density (charge per unit area), σ .

To find the electric field at a distance 'r' from the sheet, consider a Gaussian cylinder as shown in the figure. The electric field points away from the plane and the field has same magnitude at equal distance from the sheet.

Apply Gauss's law to the Gaussian surface

$$\oint_{GS} \vec{E}.\vec{dA}=\frac{q_{enc}}{\varepsilon_0}$$

=> $\int_{RS} \vec{E}.\vec{dA}+\int_{LS} \vec{E}.\vec{dA}+\int_{CS} \vec{E}.\vec{dA}=\frac{\int \sigma\, dA}{\varepsilon_0}$

=> $\int_{RS} E\, dA+\int_{LS} E\, dA+0=\frac{\int \sigma\, dA}{\varepsilon_0}$

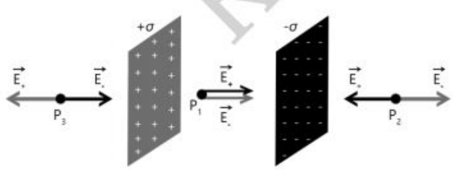
=> $2\int E\, dA=\frac{\int \sigma\, dA}{\varepsilon_0}$

=> $2E\int dA=\frac{\sigma \int dA}{\varepsilon_0}$

=> $\boxed{E=\frac{\sigma}{2\varepsilon_0}}$ (or) $\boxed{\vec{E}=\frac{\sigma}{2\varepsilon_0}\hat{n}}$

where $\hat{n}$ is a unit vector perpendicular to the sheet.

3) EF due to two parallel charged infinite sheets



The magnitude of the electric field due to an infinite charged plane sheet is $\frac{\sigma}{2\varepsilon_0}$ and it points perpendicularly outward if σ is +ve and points inward if σ is -ve.

At the points P_2 and P_3 (outside), the electric field due to both plates are equal in magnitude and opposite in direction .As a result, **electric field at a point outside the plates is zero.**

But inside the plate, electric fields are in same direction i.e., towards the right, the total electric field at a point P_1

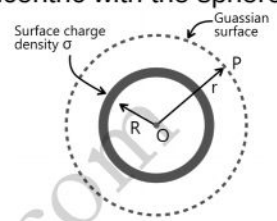
$$\boxed{E_{inside}=\frac{\sigma}{2\varepsilon_0}+\frac{\sigma}{2\varepsilon_0}=\frac{\sigma}{\varepsilon_0}}$$

Direction: from positively charged plate to negatively charged plate and is uniform everywhere inside the plate.

3) EF due to a uniformly charged spherical shell of radius ,R and surface charge density , σ

(i) Field outside the shell:

To find the EF at a point 'p' outside the sphere (at a distance 'r' from the centre of the sphere) , a spherical gaussian sphere of radius 'r' is drawn concentric with the sphere.



Apply Gauss's law, $\oint_{GS} \vec{E}.\vec{dA}=\frac{q_{enc}}{\varepsilon_0}$

=> $\oint_{GS} E\, dA=\frac{4\pi R^2\sigma}{\varepsilon_0}$ (since $\vec{E}\|\vec{dA}$)

=> $E\oint_{GS} dA=\frac{4\pi R^2\sigma}{\varepsilon_0}$

=> $E\, 4\pi r^2=\frac{4\pi R^2\sigma}{\varepsilon_0}$

=> $\boxed{E_{out}=\frac{R^2\sigma}{r^2\varepsilon_0}}$

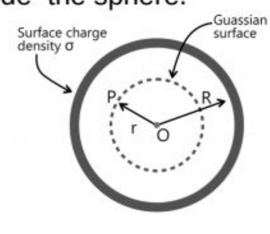
(ii) Field on the surface of the shell

On the surface $r=R$, Therefore

$$\boxed{E_{surf}=\frac{\sigma}{\varepsilon_0}}$$

(iii) Field inside the shell

To find the EF at a point 'p' inside the sphere (at a distance 'r' from the centre of the sphere) , a spherical gaussian sphere of radius 'r' is drawn inside the sphere.

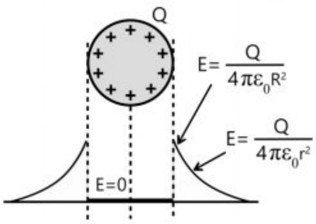


Apply Gauss's law, $\oint_{GS} \vec{E}.\vec{dA}=\frac{q_{enc}}{\varepsilon_0}=0$

Therefore $E_{ins} = 0$

NOTE :

1. The electric field is maximum at the surface of the shell
2. Electric field decreases as $1/r^2$ outside the shell
3. EF is zero inside a spherical shell. Hence a person inside a car is safer than outside during lightning.
4. Variation of EF of a shell with r (Graph)



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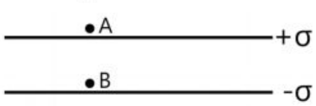
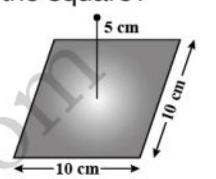
PREVIOUS QUSTIONS

1.	Gauss's theorem is useful in determining the electric field when the source distribution has symmetry.	
a)	The electric field intensity at a distance 'r' from a uniformly charged infinite plane sheet of charge is (i) Proportional to r (ii)Proportional to $\frac{1}{r}$ (iii) Proportional to r^2 (iv) Independent of r	1
b)	A thin spherical shell of radius 'R' is uniformly charged to a surface charge density σ. Using Gauss's theorem derive the expression for the electric field produced outside the shell.	2
2.	Two plane sheets of charge densities +σ and - σ are kept in air as shown in figure. What are the electric field intensities at points A and B? 	2
3.	The idea of 'Electric field lines' is useful in pictorially mapping the electric field around charges.	
a)	Give any two properties of electric lines of force.	1
b)	State Gauss's theorem in electrostatics.	1
c)	Using the Gauss's theorem, derive an expression for electric field due to a uniformly charged spherical shell i) at a point outside the shell ii) at a point inside the shell	3
d)	A point charge of +10 μc is at a distance of 5 cm directly above the centre of a square of side 10 cm as shown in figure. What is the electric flux through the square? 	2
4.a)	The electrostatic force between two charges is governed by Coulomb's law. On which factors does the electrostatic force between two charges depend and how?	2
b)	If the air medium between the two charges is replaced by water what change do you expect in the electrostatic force and why?	2
5.	Two equal and opposite charges +q and-q are separated by a small distance '2a'.	
a)	Name this arrangement.	1
b)	Define its moment. What is its direction?	1
c)	If the above system is placed in a spherical shell. What would be the net electric flux coming out of it?	1
d)	The above system of two charges is placed in an external electric field E, at an angle θ with it. Obtain relation for the torque acting on it.	2
6 a)	Find out the Electric field (i) At the axial line of a dipole ii) At the equitorial line of a dipole	
b)	What is the ratio of the magnitudes of electric field at equitorial and axial line of an electric dipole	
7 a)	All free charges are integral multiple of a basic unit charge e. Then quantization rule of electric charge	1

	implies (i) Q = e (ii) Q = ne (iii) Q = 1/e (iv) Q= ne^2	
b)	Match the following quantities in Column A with their units in Column B:	

A	B
(i) Force	(a) Coulomb(C)
(ii) Charge	(b) N/C or V/m
(iii) Electric field	(c) C.m
(iv)Dipole moment	(d) Newton(N)

8)	How many electrons constitute an electric charge of 1C ? (a) $6.25\,X\,10^{18}$ (b) $6.25\,X\,10^{19}$ (c) $6.25\,X\,10^{-18}$ (d) $6.25\,X\,10^{-19}$	1
1.	The electrostatic force per unit charge is known as (a) Electric current (b) Electric potential (c) Electric Power (d) Electric field	1
2.a) b)	Define electric dipole moment. Write an expression for torque acting on an electric dipole placed in a uniform electric field. When will it become maximum ?	1 2
3.a) b)	State Gauss's law in magnetism. A short bar magnet placed with its axis at 30 0 with a uniform external magnetic field of 0.3T experiences a torque of magnitude equal to 5 x10 $^{-2}$J. What is the magnitude of the magnetic moment of the magnet ?	1 2
4.a) b)	A spherical shell of radius 'R' is uniformly charged with charge '+q'.Using Gauss's law find the electric field intensity at a point (i)Outside the spherical shell. (ii)On the surface of the spherical shell. A point charge causes an electric flux -2 x 10^4 Nm^2/C to pass through a spherical Gaussian surface. Where, $\varepsilon_0 = 8.85\,x\,10^{-12} C^2 N^{-1} m^2$ (i) Calculate the value of the point charge. (ii) If the radius of the Gaussian surface is doubled, how much flux would through the surface ?	 2 1 1 1