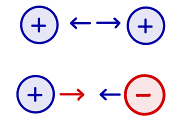
ELECTROSTATICS: ELECTRIC CHARGES AND FIELD

Electrostatics is the study of charges at rest.

Charge (q)

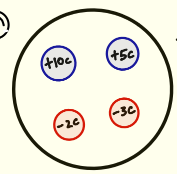
- Charge is an intrinsic property of matter due to which it experiences Electrostatic forces of attraction and repulsion.
- There are two types of charges; positive (e.g. proton) and negative (e.g. electron)
- Charge on a single electron is **$e = 1.6 \times 10^{-19}$C** | **SI** Unit- Coulomb(C)



Properties of charge

1. **Attraction and repulsion:** Like charges repel each other | Unlike charges attract each other

2. **Additive nature of charge:** Charge is additive in nature i.e. total charge on a body is the algebraic sum of all charges present on the body.



Total charge on body = +10C +5C -3C-2C
= 10C –**Ans.**

3. **Quantisation of charge**

- Charge on a body is the integral multiple of charge on a single Electron.

i.e. **$Q = ne$**

(Where e is the charge on a single electron and n= 1, 2, 3……)

Ques: Calculate the no. of electrons in 1C charge

Ans: q= ne; 1= n × 1.6×10^{-19};;n= 6.25×10^{18} electrons.

4. **Invariability of charge**

- Charge is invariable in nature i.e. the charge on a body does not depend on its state of rest or motion.

Principle of conservation of charge

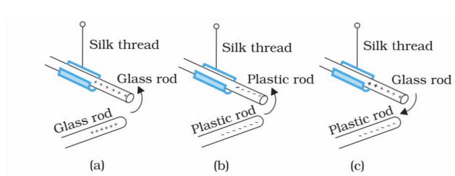
'In an isolated system, charge can neither be created nor destroyed'

Note: If a body has excess electrons, it has a negative charge.
If a body has excess protons, it has a positive charge.

Methods of charging bodies

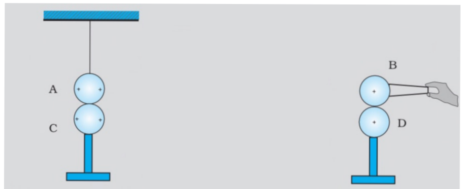
1. **Charging bodies by rubbing/friction**

When two bodies are rubbed together, the friction between the bodies causes transfer of electrons from one body to another and as a result both bodies become charged. The body which loses electrons becomes positively charged and the body which gains electrons becomes negatively charged.
Eg - rubbing glass rod with silk, rubbing plastic rod with fur



- By convention, charge on glass rod and fur is positive and charge on silk cloth and plastic rod is negative.

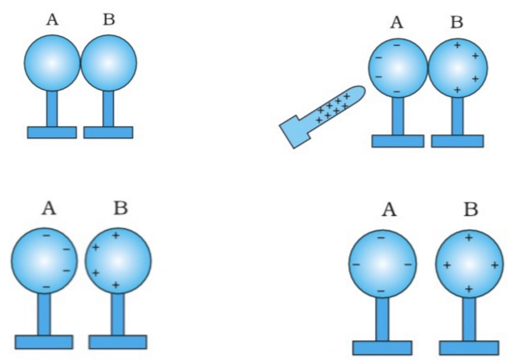
2. **Charging by touch**
   When a charged body is made to touch an uncharged body, some of the charge from the charged body is transferred to the other body. This is called charging by touch.



3. **Charging by induction**
   Let us understand charging by induction through an example.

- Take two metallic spheres A and B (mounted on insulating stands) and bring them together.
- Now, bring a positively charged rod near the left end of sphere A (not touching).
- The positive charge of the rod attracts the electrons of A as a result there is an excessive negative charge on left side of A. At the same time, there is an accumulation of excessive positive charge on right side of sphere B due to repulsive forces.
- So, we see that at the end of this process, both spheres become charged. This process of charging is called charging by induction.

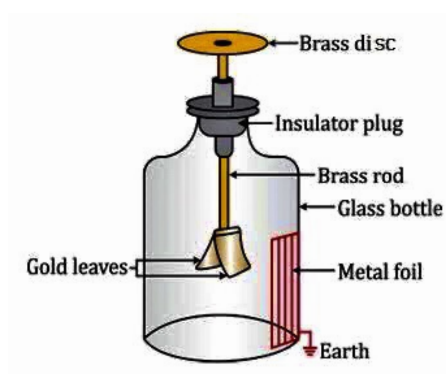
Note: 1. Charges on both spheres will be equal and opposite.
2. Not all the electrons in the sphere accumulate on one side because as electrons keep getting accumulated, the incoming electrons feel a strong force of repulsion from the already accumulated electrons. Over time equilibrium is set up under the force of attraction of the rod and force of repulsion of the electrons.



Gold leaf Electroscope

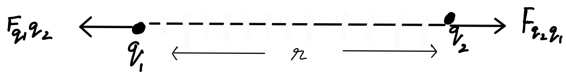
- Used to detect charge on a body.

Working: when a charged body is brought near or touched with the metal knob, charge travels to the leaves through the rod. Since both the leaves have the same charge they diverge(repel) The degree of divergence is an indicator of amount of charge.

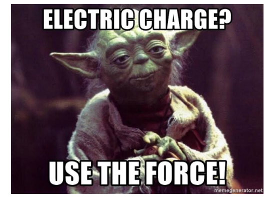


Coulomb's Law **(PYQ 2019, 2014, 2011)**

The magnitude of electrostatic force between two point objects is directly proportional to the product of the two charges and inversely proportional to the square of the distance between them and acts along the line joining their centres.



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



PERMITTIVITY OF FREE SPACE ($\varepsilon_\circ$)

$\boxed{\varepsilon_\circ = 8.85\times10^{-12}\ C^2N^{-1}m^{-2}}$

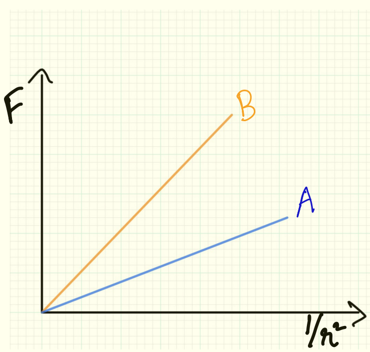
PERMITTIVITY IN MEDIUM (ε)

There exists a relation between permittivity in free space/vacuum and that in a medium.

$\boxed{\varepsilon_r = K = \varepsilon/\varepsilon_\circ}$, where ε_r is the relative permittivity of medium AKA K (dielectric constant of medium)

Ques: Plot a graph showing variation of coulomb force (F) versus $1/r^2$, where r is the distance between the two charges of each pair of charges A(1μC,2μC) and B (1μC, -3μC) **(PYQ 2011)**

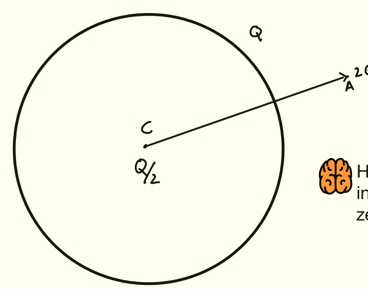
sol^n: We know $F \propto 1/r^2$, therefore,



Since $F \propto q_1q_2$, graph for pair B will have greater slope Than slope of pair A.

Similar PYQs

ques: A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge Q/2 is placed at its center C and another charge +2Q is placed at a distance x from the center. Find force on the charge Q/2 and 2Q. **(PYQ 2015)**



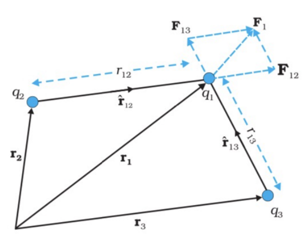
Hint: field inside shell is zero

Force between multiple charges

Principle of superposition

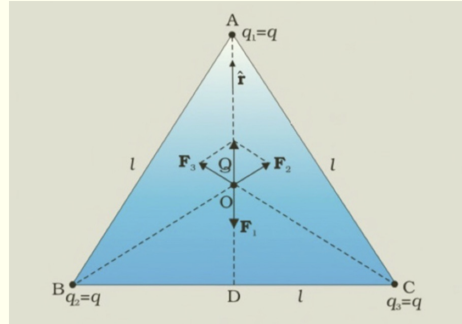
Principle of superposition talks about two things

1. Net force on any charge is the vector sum of all the forces acting on that charge
2. The individual forces between two charges are unaffected due to the presence of other charges



(a)

Ques: **Example 1.6** 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. 1.9?



Sol^n: In ΔABC, we can calculate,

AO=BO=CO= l/2 ÷ cos30 = l/√3

Now, let us calculate the forces between the three charges at the vertices and charge Q at the centroid individually (principle of superposition)

$\mathbf{F_1}$ $=3kq_1Q/l^2(-\hat{j})$

$\mathbf{F_2}$$= 3kq_1Q/l^2\ (\sin60\hat{\imath} + \cos60\hat{j})$

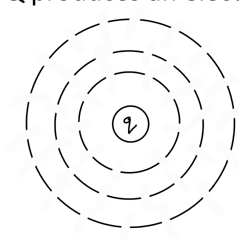
$\mathbf{F_3}$$= 3kq_1Q/l^2\ (-\sin60\hat{\imath} + \cos60\hat{j})$

Now to calculate net force on Q we find the vector sum of the forces $\mathbf{F_1 + F_2 + F_3}$ which amounts to zero.

We can also see by symmetry that net force on Q is zero.

Electric Field

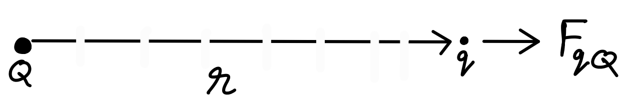
Electric field can be defined as the space around a charge in which another charge experiences an electrostatic force of attraction and repulsion. An electric charge Q produces an electric field 'everywhere' in its surrounding.



Electric field strength/ field intensity (E)

- Electric field strength at a point is defined as the force that a unit charge experiences when kept at that point.
- Mathematically , lim q→0 **E=F/q**
- It is a vector quantity | SI Unit- N/C or V/m

General expression for field strength:



Let us take a charge Q. at a distance r from it, there is another unit charge q. the force on q due to Q can be written as-

$$F = k\ Q.q/r^2$$
$$E = F/q$$
$$\boxed{E = k\ Q/r^2}$$

Note: Electric field strength also follows law of superposition i.e. net electric field strength at a point is the vector sum of all field strengths due to individual charges.

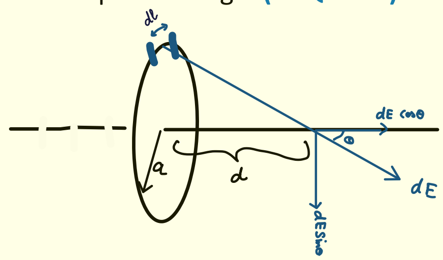
Characteristics of Electric field

1. Electric field at a point doesn't depend on charge q as the ratio F/q is independent of q.
2. For a positive point charge electric field is directed radially outwards.
3. For a negative point charge electric field is directed radially inwards.
4. Magnitude of E due to a charge Q depends inversely on R^2, so at equal distances from the charge Q, E will have same magnitude i.e. it shows radial symmetry.

Ques: A charge is uniformly distributed over a ring of radius a. Obtain an expression for the electric field at its center. Hence show that for large distances it behaves like a point charge. **(PYQ 2016)**

Ans.

Consider a differential
Element of length dl
And charge dq



$$\lambda = \frac{Q}{2\cdot\pi a} d,$$

$$dq = \lambda \mathrm{dl}$$

i) **Field along x-axis**

$$dE_x = dE\cos\theta$$

$$dE = \frac{1}{4\ \pi\varepsilon_0}\ \frac{dq}{a^2+d^2}\ \cos\theta$$

$$dE = \frac{1}{4\times\pi\varepsilon_0}\times\frac{\lambda \mathrm{dl}}{a^2+d^2}\ \frac{d}{\sqrt{a^2+d^2}}$$

$$\Rightarrow E = \frac{\lambda}{4\times\pi\varepsilon_0}\times\frac{d}{\left(d^2+a^2\right)^{3/2}}\int_0 dl$$

$$\Rightarrow \frac{1}{4\times\pi\varepsilon_0}\times\frac{Qd}{\left(d^2+a^2\right)^{\frac{3}{2}}}\times\frac{1}{2\times\pi a}\times 2\times\pi a$$

$$\Rightarrow E_x = \frac{1}{4\times\pi\varepsilon_0}\times\frac{Qd}{\left(d^2+a^2\right)^{3/2}}$$

2) **Field along y-axis**

$E_y = 0$ **(Due to symmetry)**

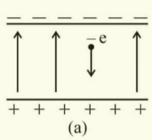
$$\therefore \quad \Rightarrow E = \frac{1}{4\times\pi\varepsilon_0}\ \frac{Qd}{\left(d^2+a^2\right)^{3/2}}$$

So, field at center

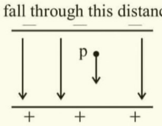
$E_c = 0$

Similar PYQs

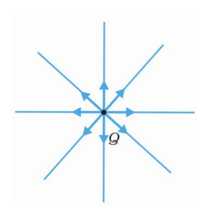
An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N/C (Fig. a)

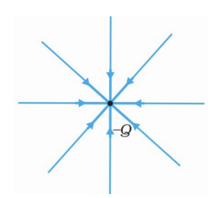


Calculate the time it takes to fall through this distance starting from rest.



PYQ 2018 (Ans = 2.9×10^{-9} s)



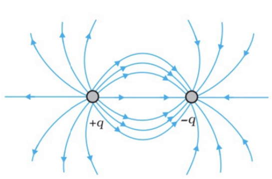


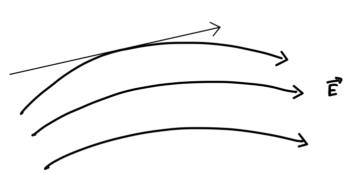
Electric Field lines (PYQ 2020,2019,2018,2017,2016,2015,2014,2013,2012,2011,2010)

- The concept of electric field lines was given by Faraday to visualise the strength of electric fields.
- Electric field lines are imaginary, straight or curved lines around charged bodies such that tangent to it at a point gives direction of electric field at that point.

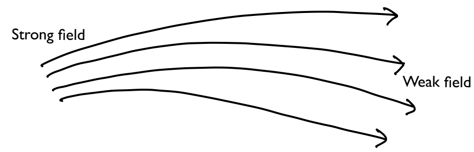
Properties of Electric Field lines

1. Field lines originate from a positive charge and terminate at a negative charge.





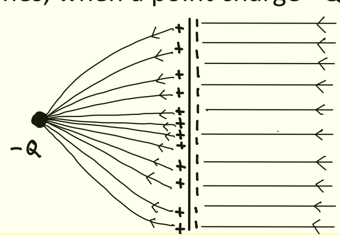
2. Two field lines can never intersect each other. (This is because at the point of intersection we can draw two tangents which means electric field at the point of intersection will have two directions, which is not possible.) **(PYQ)**
3. Greater is the density of field lines, greater is the strength of electric field in the region



4. Electrostatic field lines do not form closed loops because of the conservative nature of electric field (i.e. work done by electric field depends on final and initial position and not the path followed.)
5. Electric field lines do not have any breaks; they are continuous in nature.

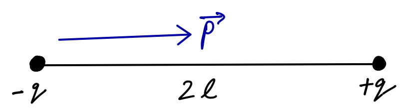
Ques: Draw pattern of electric field lines, when a point charge –Q is kept near an uncharged conducting plate. **(PYQ 2019)**

Ans.



Electric Dipole

An electric dipole is an arrangement of 2 equal and opposite charges kept at some finite distance.



Dipole Moment (P)

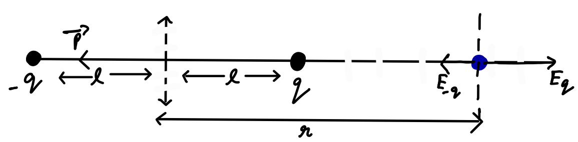
- The dipole moment (vector quantity) of an electric dipole measures the strength of the dipole
- Its magnitude is equal to the product of the charge and the separation between the two charges

$$\boxed{P = q.(2l)}$$

- Its direction is along the dipole axis, from the negative charge to the positive charge.

Electric field due to dipole (PYQ 2019,2018,2017,2016,2015,2011)

A. Field on axial positon/ End on position (PYQ 2015)



$$E = \frac{1}{4\times\pi\varepsilon_0}\times\frac{q}{(r-l)^2} - \frac{1}{4\times\pi\varepsilon_0}\times\frac{q}{(r+l)^2}$$

$$E = \frac{q}{4\times\pi\varepsilon_0}\times\left(\frac{(r+l)^2-(r-l)^2}{(r+l)^2\times(r-l)^2}\right)$$

$$E = \frac{q}{4\times\pi\varepsilon_0}\times\frac{(r+l-r+l)\times(r+l+r-l)}{(r+l)^2\times(r-l)^2}$$

$$E = \frac{q}{4\times\pi\varepsilon_0}\times\frac{4rl}{(r+l)^2\times(r-l)^2}$$

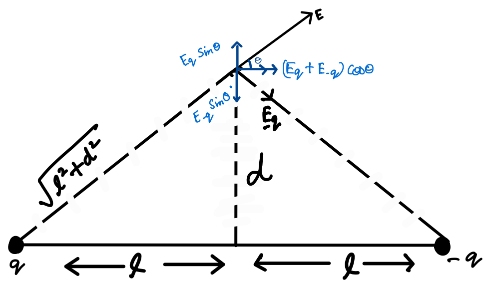
$$E = \frac{1}{4\times\pi\varepsilon_0}\times\frac{2\times(2ql)r}{(r+l)^2\times(r-l)^2}$$

$$E = \frac{1}{4\times\pi\varepsilon_0}\times\frac{2pr}{(r+l)^2\times(r-l)^2}$$

For r $\gg l$

$$\boxed{\vec{E} = \frac{1}{4\times\pi\varepsilon_0}\times\frac{2\vec{p}}{r^3} \quad (\because \vec{E} \text{ is } \parallel \text{ to } \vec{p})}$$

B. Electric field on equatorial position/ Broad on position (PYQ 2017)



1) Field along x-axis

$$E_x = 2 \times \frac{1}{4 \times \pi\varepsilon_0} \times \frac{q}{l^2+d^2} \times \cos\theta$$

$$E_x = \frac{1}{4 \times \pi\varepsilon_0} \times \frac{2ql}{(l^2+d^2)^{3/2}}$$

For d >> l

$$\vec{E}_x = \frac{-1}{4 \times \pi\varepsilon_0} \times \frac{\vec{p}}{d^3}$$

($\because \vec{E}$ is anti // to $\vec{p}$)

2) Field along y axis

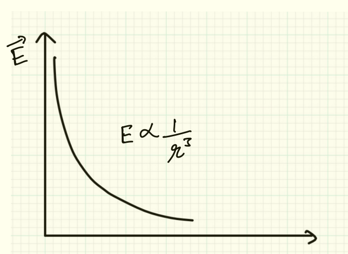
$$E_y = (E_q - E_{-q}) \times \sin\theta$$
$$= 0$$

$$\boxed{\therefore\ \vec{E} = \frac{-1}{4 \times \pi\varepsilon_0} \times \frac{\vec{p}}{d^3}}$$

Ques: what is the expression for the electric field produced by a dipole of moment **p** at a point at a distance r in the equatorial plane? Draw a E v/s r graph for the same **(PYQ 2015)**

Ans:

$$\vec{E} = \frac{1}{4 \times \pi\varepsilon_0} \times \frac{\vec{p}}{r^3}$$



Similar PYQs

(Hint: field will be 0 in b/w the charges, on the line joining them)

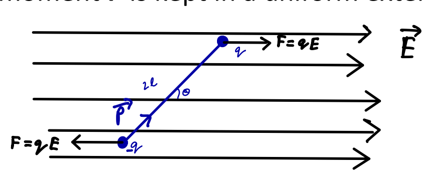
ques: a) derive an expression for the electric field at the equatorial line for a dipole

b) Two identical point charges, q each are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the lone joining the charges such that system remains in equilibrium. Find the position and nature of Q.

(PYQ 2019)

Behaviour of dipole in external electric field

Let us assume that a dipole of dipole moment **P** is kept in a uniform external field **E** at an angle θ with the field.



As we can see from the figure, the net force on the dipole will be zero. But since line of action of the two forces is not the same, the dipole will experience a torque τ which can be written as,

$$\tau = qE \times 2l\sin\theta$$
$$\tau = 2lq \times E\sin\theta.$$
$$\tau = p \times E\sin\theta$$
$$\boxed{\vec{\tau} = \vec{p} \times \vec{E}}$$

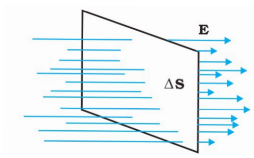
- From this we can see that net torque on the dipole is zero when it makes an angle of 0°(parallel) or 180°(anti-parallel) with the field.
- When the dipole is parallel to the field, it is known as the position of stable equilibrium and when it is anti-parallel, it is known as the position of unstable equilibrium.
- The torque on the dipole is maximum when it is perpendicular to the field.

Dipole in non-uniform electric field

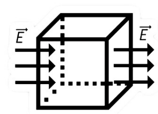
In a non-uniform field, the two charges +q, -q experience different forces therefore net force is not zero. The net torque may or may not be zero depending upon the orientation of the dipole.

Electric Flux (ϕ)

Electric flux can be defined as the number of field lines crossing per unit area, perpendicular to it.



$$\Phi = \int_S \vec{E} \bullet \hat{n} dA = o$$



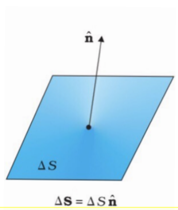
NO FLUX GIVEN

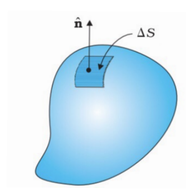
Mathematically,

$\boxed{\phi = \mathbf{E.A}}$

= EAcosθ (Where **E** is the field vector and **A** is the area vector)

Note: the direction of the area vector is along the normal to the area.





Ques: Given a uniform electric field **E** = 5 ×10^3 $\hat{i}$ N/C. Find flux of this field through a square of side 10cm whose plane is parallel to the y-z plane. What would be the flux through the same square if its plane makes an angle of 30° with the x-axis? **(PYQ 2014)**

Ans: 1) ϕ= E A cosθ

= 5 × 10^3 × 10^{-2} cos0° = 50 NC^{-1} m^2

2) Since plane makes angle of 30°, normal will make angle of 90-30= 60°

ϕ=E A cosθ = 5 × 10^3 × 10^{-2} cos60°= 25 NC^{-1} m^2

Gauss's Law (PYQ 2019,2018,2017,2016,2014)

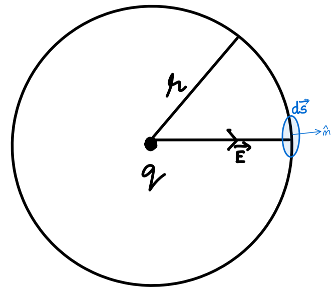
'Total electric flux through a closed surface is equal to 1/ε_0 times the total charge enclosed by the closed surface'

$$\boxed{\phi = \oint \mathbf{E.ds} = q/\varepsilon_0}$$

Derivation:

Let us assume a sphere of radius r which encloses charge q. Consider differential area ds. The flux through ds can be written as,

$$\phi = \oint \vec{E} \cdot d\vec{s}$$
$$= \oint E ds \cos 0^{\circ}$$
$$= \frac{1}{4 \times \pi\varepsilon_0} \times \frac{q}{r^2} \oint ds$$
$$= \frac{1}{4 \times \pi\varepsilon_0} \quad \frac{q}{k^2} \quad 4 \times \pi r^2 = \frac{q}{\varepsilon_0}$$
$$\phi = \oint \vec{E} \cdot d\vec{s} = \frac{q}{\varepsilon_0}$$

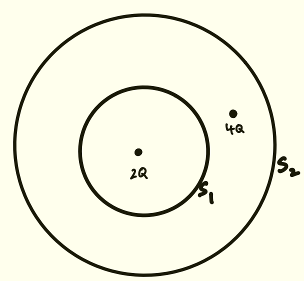


Note: if net charge enclosed by a surface is zero, then the net flux through that surface is also zero (since $\phi = q/\varepsilon_\circ$).

Important points regarding Gauss' law

- Gauss' law is true for any closed surface, irrespective of its shape
- The term q on the right side of the equation refers to all the charges inside the closed surface.
- The term E on the left side is due to all charges both inside and outside the surface.
- The closed surface is called Gaussian surface and it cannot pass through a point charge (can pass through continuous charge)
- Gauss law is based on inverse square dependence on distance as seen in coulomb's law. Any violation of gauss law will result in departure from the inverse square law.

Ques: Consider two hollow concentric spheres, S_1 and S_2 ($S_2 > S_1$) enclosing charges 2Q and 4Q resp. Find the ratio of flux through them. How will the flux through S_1 change if a medium of dielectric constant k is introduced in S_1? **(PYQ 2014)**



Ans:

According to gauss law, $\phi = q/\varepsilon_\circ$

1) $\phi_1 = 2Q/\varepsilon_\circ$; $\phi_2 = 6Q/\varepsilon_\circ$

   $\phi_1/\phi_2 = 1/3$

2) If a medium of dielectric const K is introduced in S_1

   $\varepsilon = k\varepsilon_\circ$

   $\phi_1 = 2Q/k\varepsilon_\circ$

Similar PYQs 

1. If the net electric flux through a closed surface is zero, then we can infer

   (A) no net charge is enclosed by the surface.

   (B) uniform electric field exists within the surface.

   (C) electric potential varies from point to point inside the surface.

   (D) charge is present inside the surface. PYQ 2020 (Ans A)

(According to gauss law)

Application of Gauss's Law

I) Field due to an infinitely long straight uniformly charged wire (PYQ 2017)

Consider an infinite straight wire with uniform charge density λ, draw a cylindrical Gaussian surface of radius r and length l around it.

$$\phi = \oint \vec{E} \cdot d\vec{s}$$

$$\Rightarrow \oint \vec{E} \cdot d\vec{s} = \int_{I} \cancel{\vec{E} \cdot d\vec{s}}^{\,0} + \int_{II} \cancel{\vec{E} \cdot d\vec{s}}^{\,0} + \int_{III} E \cdot d\vec{s} \qquad (\because E \perp S_I, E \perp S_{II})$$

$$\Rightarrow \phi = \int_{III} E \cdot ds \cos 0^\circ \qquad (\because E \parallel S_{III})$$

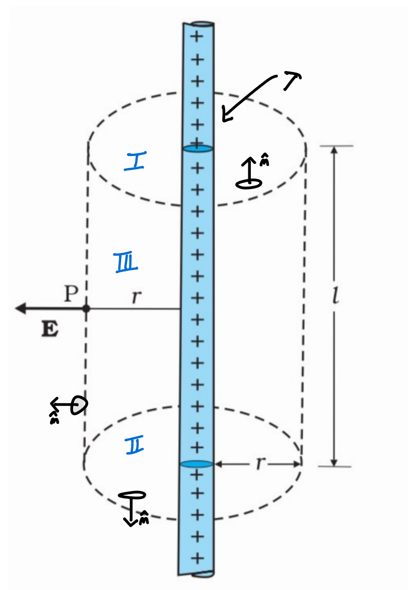
$$\Rightarrow \phi = E \int ds = E \cdot 2 \times \pi r l \quad — (1)$$

also, $\phi = \dfrac{q}{\varepsilon_0} = \dfrac{\lambda l}{\varepsilon_0} \quad — (2)$

Equating 1,2

$$\Rightarrow E \cdot 2 \times \pi r l = \frac{\lambda l}{\varepsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\lambda}{2 \times \pi \varepsilon_0 r}}$$



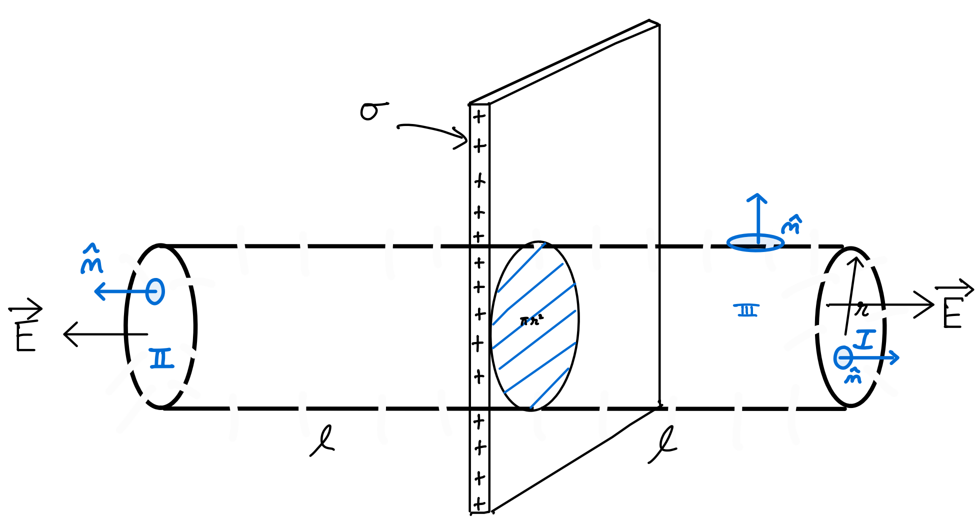
Important PYQ

How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased ?

(PYQ 2016)

II) FIELD DUE TO UNIFORMLY CHARGED PLANE SHEET (PYQ 2017)

Consider an infinite plane sheet with uniform charge density σ, draw a cylindrical Gaussian surface of radius r and length 2l as shown.



$$\phi = \oint \vec{E}\, d\vec{s}$$

$$\phi = \int \vec{E} \cdot d\vec{s}_I + \vec{E} \cdot d\vec{s}_{II} + \cancel{\vec{E} \cdot d\vec{s}_{III}}^{\,0}$$ $(\because E \perp S_{III})$

$$= \int E ds_I \cos 0^\circ + \int E \cdot ds_{II} \cos 0^\circ$$ $(\because E \parallel S_I\ ,\ E \parallel S_{II})$

$$= E \int ds + E \int ds$$

$$= 2E\pi r^2$$

also, $$\phi = \frac{q}{\varepsilon_0} = \frac{\sigma \pi r^2}{\varepsilon_0} \quad -②$$

Equating 1,2

$$\Rightarrow 2E\pi r^2 = \frac{\sigma \pi r^2}{\varepsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

Important PYQ 

(a) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

(PYQ 2017)

III) FIELD DUE TO A UNIFORMLY CHARGED THIN SPHERICAL SHELL (PYQ 2020)

Consider a uniformly charged spherical shell of radius r with uniform charge density , draw a spherical Gaussian surface of radius x

Case 1: x > r

Consider the Gaussian surface at a distance x (from centre) outside the sphere

According to Gauss's law

$$\phi = \oint \vec{E} \cdot d\vec{s} \quad (\because \vec{E} \parallel \hat{m})$$

$$\phi = \oint E ds \cos 0^\circ = E \oint ds$$

$$= E \cdot 4 \times \pi x^2 \quad -①$$

also,

$$\phi = \frac{q}{\varepsilon_0} = \frac{\sigma 4 \times \pi r^2}{\varepsilon_0} \quad -②$$

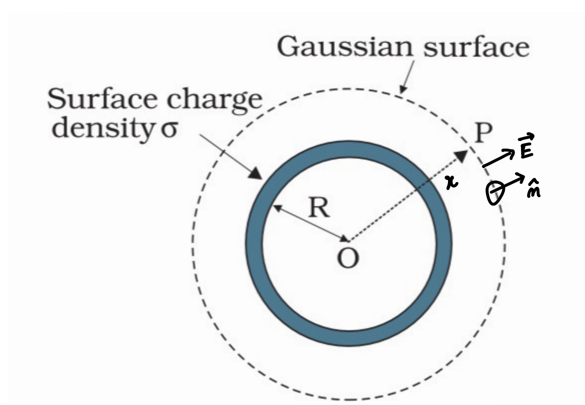
Equating 1,2

$$\Rightarrow E \cdot 4 \times \pi x^2 = \frac{\sigma 4 \times \pi r^2}{\varepsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\sigma r^2}{\varepsilon_0 x^2}}$$

For x=r

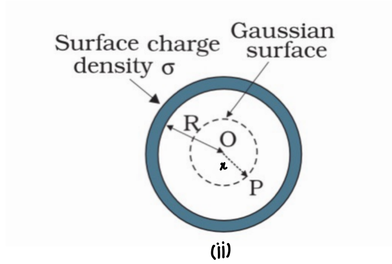
$$\boxed{E = \frac{\sigma}{\varepsilon_0}}$$



(i)

Not included in CBSE 2020-21

Case 2: x < r



(ii)

Consider the Gaussian surface inside the sphere. As shown in the previous part

$$E.4\times\pi x^2=\frac{q}{\varepsilon_0}$$

Charge enclosed in this Gaussian surface is 0 therefore,

$$E=0$$

Ques: A hollow cylindrical box of length 1m and area of cross-section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by **E** = 50x î, where E is in NC^{-1} and x is in meters. Find

i) Net flux through the cylinder

ii) Charge enclosed by the cylinder (**PYQ 2013**)

Ans:

$$\phi_2=E_2\cdot A\cos 0^\circ \quad (\because \vec{E}\parallel\hat{n})$$

$$=50\times2\times25\times10^{-4}$$

$$2\cdot5\times10^{-1}Nc^{-1}m^2$$

$$\phi_1=E_1\cdot A\cos 180^\circ \quad (\because \vec{E}\text{ opp to }\hat{n})$$

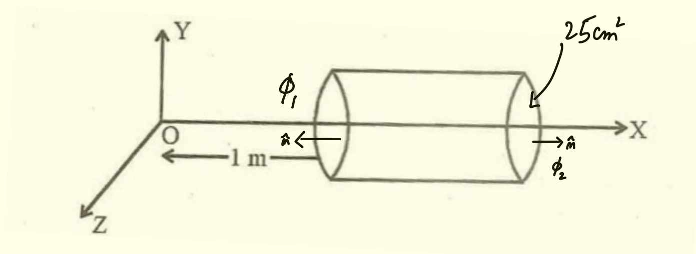
$$=-50\times1\times25\times10^{-4}$$

$$=-1.25X10^{-1}Nc^{-1}m^2$$

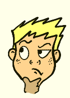
$$\phi=\phi_1+\phi_2$$

$$=(-1\cdot25+2\cdot5)\times10^{-1}$$

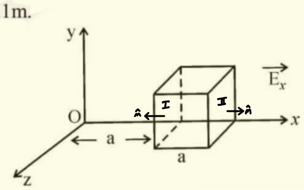
$$=1\cdot25\times10^{-1}NC^{-1}m^2$$



Important PYQ



Define electric flux and write its SI unit. The electric field components in the figure shown are : $E_x = \alpha x$, $E_y = 0$, $E_z = 0$ where $\alpha = \frac{100\ N}{Cm}$. Calculate the charge within the cube, assuming a = 0.1m.



PYQ 2018

(b) An electric field is uniform and acts along + x direction in the region of positive x. It is also uniform with the same magnitude but acts in – x direction in the region of negative x. The value of the field is E = 200 N/C for x > 0 and E = – 200 N/C for x < 0. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at x = + 10 cm and the other is at x = – 10 cm.

Find :

(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder.

PYQ 2020

SOLUTIONS FOR SIMILAR PYQS

Ans 1. PYQ 2015 soln

A. Force on Q/2

$E = 0$ (Field inside conductor is 0)

$\therefore F = E \times \frac{Q}{2} = 0$

B. Force on 2Q

$E = E_{Q/2} + E_Q$

$E = \frac{1}{4\times\pi\varepsilon_0} \times \frac{Q}{2x^2} + \frac{1}{4\times\pi\varepsilon_0} \times \frac{Q}{x^2}$

$E = \frac{3Q}{8\times\pi\varepsilon_0 x^2}$

$F = qE = \frac{3Q^2}{4\times\pi\varepsilon_0 x^2}$

Ans 2. PYQ 2018 soln

$F = eE$

$F = ma$

$a = \frac{eE}{m}$

$a = \frac{1\cdot 6\times 10^{-19}\times 2\times 10^4}{9\cdot 1\times 10^{-30}}$

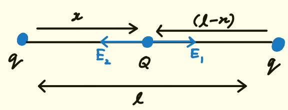
$a = 3\cdot 52\times 10^{14} \quad m/s^2$

$s = ut + \frac{1}{2}at^2$

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2\times 1.5\times 10^{-2}}{3.52\times 10^{14}}}$

$t = 2.9\times 10^{-9}s$

Ans3. PYQ 2019 soln



Nature is positive (see fig)

$E_1 = E_2$

$\frac{1}{4\times\pi\varepsilon_0} \times \frac{q}{x^2} = \frac{1}{4\times\pi\varepsilon_0} \times \frac{q}{(l-x)^2}$

$\Rightarrow x^2 = (l-x)^2$

$x^2 = l^2 + x^2 - 2lx$

$\Rightarrow x = \frac{l}{2} = \frac{2}{2} = 1m$

Ans4. PYQ 2016 soln

According to gauss law, $\phi = \frac{q}{\varepsilon_0}$

Since charge enclosed remains same, flux doesn't change.

Ans5. PYQ 2018 soln

$\phi_1 = EA_1\cos\theta = EA_1\cos 180^\circ$

$\phi_1 = -EA_1$

$= -100\times 0.1\times (0\cdot 1)^2$

$= -0.1Nm^2/c$

$\phi_2 = EA_2\cos\theta = EA_2\cos 0^\circ$

$\phi_2 = 100\times 0.2\times (0\cdot 1)^2$

$= 0.2Nm^2/c$

$\phi = \phi_1 + \phi_2$

$\phi = (0\cdot 2 - 0\cdot 1)Nm^2/c$

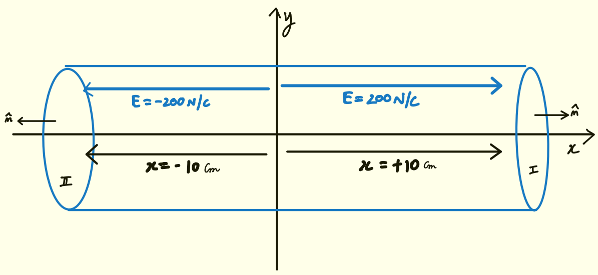
$\phi = 0.1Nm^2/c$

$\phi = \frac{q}{\varepsilon_0}$

$q = \phi\varepsilon_0 = 8\cdot 85\times 10^{-12}\times 10^{-1}$

$= 8.85\times 10^{-13}C$

Ans6. PYQ 2020 soln



$\phi_1 = E\cdot\pi r^2 = 200\times 3\cdot 14\times 5^2\times 10^{-4}$

$= 1.57Nm^2/C$

$\phi_2 = 200\times 5^2\times 3\cdot 14$

$= 1\cdot 57Nm^2/c$

$\phi = \phi_1 + \phi_2$

$= 1\cdot 57 + 1\cdot 57$

$= 3\cdot 14Nm^2/c$

$\phi = \frac{q}{\varepsilon_0}$

$q = \phi\varepsilon_0 = 3\cdot 14\times 8\cdot 85\times 10^{-12}$

$= 2.78\times 10^{-11}C$