01

ELECTROSTATICS

Chapter 01

Electrostatics

1. Electric Charge

1.1 Definition

Charge is the property associated with matter due to which it produces and experiences electrical and magnetic effects.

1.2 Type

There exists two types of charges in nature
(i) Positive charge
(ii) Negative charge

Charges with the same electrical sign repel each other, and charges with opposite electrical sign attract each other.

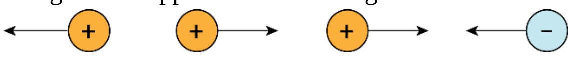


Fig 1.1: Types of Charges

1.3 Unit and dimensional formula

S.I. unit of charge is *coulomb* (*C*),

$$\left(1\text{mC} = 10^{-3}\text{C},\ 1\mu\text{C} = 10^{-6}\text{C},\ 1\text{nC} = 10^{-9}\text{C}\right)$$

C.G.S. unit of charge is *e.s.u*. 1C = 3 × 10^9 e.s.u.
Dimensional formula [Q] = [AT].

1.4 Point Charge

Whose spatial size is negligible as compared to other distances.

1.5 Properties of charge

(i) Charge is a Scalar Quantity: Charges can be added or subtracted algebraically.

(ii) Charge is transferable: If a charged body is put in contact with an uncharged body, uncharged body becomes charged due to transfer of electrons from one body to the other.

(iii) Charge is always associated with mass, *i.e.*, charge can not exist without mass though mass can exist without charge.

(iv) Charge is conserved: Charge can neither be created nor be destroyed.

(v) Invariance of charge: The numerical value of an elementary charge is independent of velocity.

(vi) Charge produces electric field and magnetic field: A charged particle at rest produces only electric field in the space surrounding it. However, if the charged particle is in non accelerated motion it produces both electric and magnetic fields. And if the motion of charged particle is accelerated it not only produces electric and magnetic fields but also radiates energy in the space surrounding the charge in the form of electromagnetic waves.

(vii) Charge resides on the surface of conductor: Charge resides on the outer surface of a conductor because like charges repel and try to get as far away as possible from one another and stay at the farthest distance from each other which is outer surface of the conductor. This is why a solid and hollow conducting sphere of same outer radius will hold maximum equal charge and a **soap bubble expands on charging.**

(viii) Quantization of charge: When a physical quantity can have only discrete values rather than any value, the quantity is said to be quantized. The smallest charge that can exist in nature is the charge of an electron. If the charge of an electron $"e" = \left(-1.6\times10^{-19}\text{C}\right)$ is taken as elementary unit *i.e.* quanta of charge the charge on any body will be some integral multiple of *e i.e.*, Q = ± ne with n = 0, 1, 2, 3 ...... Charge on a body can never be 0.5 e, ±17.2 e or $\pm10^{-5}$ e *etc*.

1.6 Comparison of Charge and Mass

We are familiar with role of mass in gravitation, and we have just studied some features of electric charge. We can compare the two as shown below:

Charge		Mass	
1.	Electric charge can be positive, negative or zero.	**1.**	Mass of a body is a positive quantity.
2.	Charge carried by a body does not	**2.**	Mass of a body increases with its velocity as

	depend upon velocity of the body		$m = \dfrac{m_0}{\sqrt{1-v^2/c^2}}$ where c is velocity of light in vacuum, m is the mass of the velocity v and m_0 is rest mass of the body.
3.	Charge is quantized.	**3.**	The quantization of mass is yet to be established.
4.	Electric charge is always conserved.	**4.**	Mass is not conserved as mass can be converted into energy
5.	Force between charges can be attractive or repulsive	**5.**	The gravitational force between two masses is always attractive.

1.7 Methods of Charging

A body can be charged by following methods:

(i) **By friction:** In friction when two bodies are rubbed together, electrons are transferred from one body to the other. As a result of this one body becomes positively charged while the other negatively charged, e.g., when a glass rod is rubbed with silk, the rod becomes positively charged while the silk becomes negatively charged. However, ebonite on rubbing with wool becomes negatively charged making the wool positively charged. Clouds also become charged by friction. In charging by friction in accordance with conservation of charge, **both positive and negative charges in equal amounts appear simultaneously due to transfer of electrons from one body to the other.**

(ii) **By electrostatic induction:** If a charged body is brought near an uncharged body, the charged body will attract opposite charge and repel similar charge present in the uncharged body. As a result of this one side of neutral body (closer to charged body) becomes oppositely charged while the other is similarly charged. This process is called electrostatic induction.

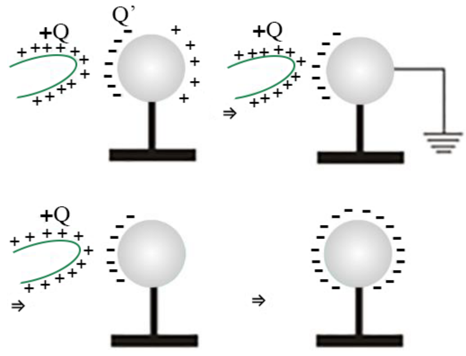


Fig 1.2

NOTE:

Inducting body neither gains nor loses charge.

(iii) **Charging by conduction:** Charging by conduction involves the contact of a charged object to a neutral object. Hence when an uncharged conductor is brought in contact with a charged conductor, charge is shared between the two conductors and hence the uncharged conductor gets charged.

NOTE:

Inducting body neither gains nor loses charge.

A truck carrying explosives has a metal chain touching the ground, to conduct away the charge produced by friction.

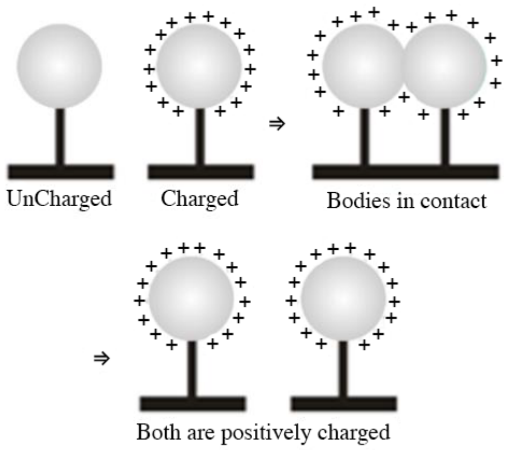


Fig 1.3

1.8 Electroscope

It is a simple apparatus with which the presence of electric charge on a body is detected. When metal knob is touched with a charged body, some charge is transferred to the gold leaves, which then diverges due to repulsion. The separation gives a rough idea of the amount of charge on the body. If a charged body is brought near a charged electroscope the leaves will also diverge as the charge on body is similar to that on electroscope and will usually converge if opposite. If the induction effect is strong enough, leaves after converging may again diverge.

In case of uncharged electroscope, if the charged body is brought is contact, the electroscope gets charged and the leaves diverge. when a charged body is brought near electroscope (but not is contact), different charges appear on different parts of electroscope resulting in divergence of leaves.

(1) **Uncharged electroscope**

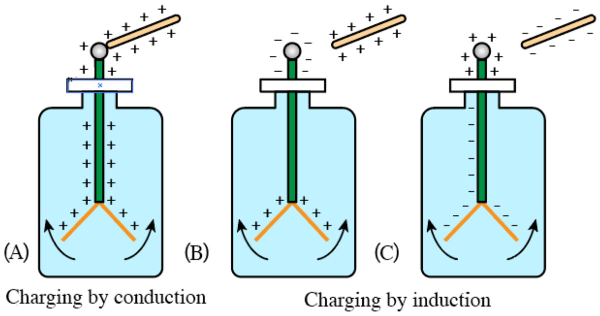


Fig 1.4

(2) **Charged electroscope**

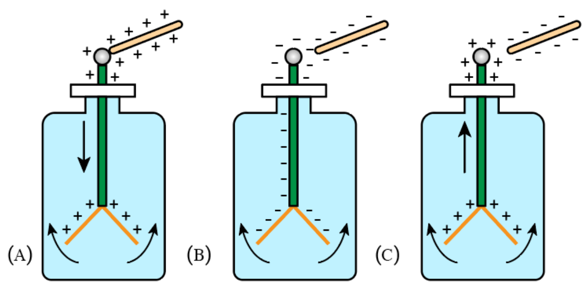


Fig 1.5

2. Coulomb's Law

If two stationary and point charges q_1 and q_2 are kept at a distance *r*, then it is found that force of attraction or repulsion between them is proportional to the product of the two charges and inversely proportional to the square of the distance between them. Mathematically, Coulomb's law can be written as

$$F = k\frac{q_1q_2}{r^2}$$

where k is a proportionality constant.

In SI units k has the value, $k = 8.988 \times 10^9 \text{ N m}^2/\text{C}^2$

$9.0 \times 10^9 \text{ N m}^2/\text{C}^2$

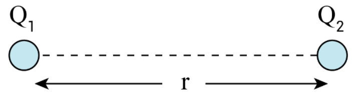


Fig 1.6

(a) The direction of force is always along the line joining the two charges.

(b) The force is repulsive if the charges have the same sign and attractive if their signs are opposite.

(c) This force is conservative in nature.

(d) This is also called inverse square law.

2.1 Variation of *k*

Constant *k* depends upon system of units and medium between the two charges.

2.1.1 Effect of units

(a) In C.G.S. for air k = 1, $F = \frac{kQ_1Q_2}{r^2}$ *Dyne*

(b) In S.I. for air

$$k = \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \frac{N-m^2}{C^2}, \quad F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1Q_2}{r^2}$$

Newton (1 Newton = 10^5 Dyne)

NOTE:

- Absolute permittivity of air or free space

  $= 8.85\times10^{-12}\frac{C^2}{N-m^2}\left(=\frac{\text{Farad}}{m}\right).$

  Dimension is $\left[M^{-1}L^{-3}T^4A^2\right]$

- ε_0 relates with absolute magnetic permeability (μ_0) and velocity of light (*c*) according to the following relation $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

2.1.2 Effect of medium

(a) When a dielectric medium is completely filled in between charges rearrangement of the charges inside the dielectric medium takes place and the net force between the same two charges, decreases by a factor of K known as **dielectric constant**. K is also called relative permittivity ε_r of the medium (relative means with respect to free space).

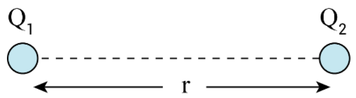


Fig 1.7

Hence in the presence of medium

$$F_m = \frac{F_{air}}{K} = \frac{1}{4\pi\varepsilon_0 K}\cdot\frac{Q_1 Q_2}{r^2}$$

$$\varepsilon_0 K = \varepsilon_0 \varepsilon_r = \varepsilon$$

Here (permittivity of medium)

Medium	K
Vacuum/air	1
Water	80
Mica	6
Glass	5-10
Metal	∞

2.2 Vector form of Coulomb's law

It is helpful to adopt a convention for subscript notation.

F_{12} = force on 1 due to 2, F_{21} = force on 2 due to 1

Suppose the position vectors of two charges q_1 and q_2 are $\vec{r}_1$ and $\vec{r}_2$, then electric force on charge q_1 due to charge q_2 is,

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{|\vec{r}_1 - \vec{r}_2|^3}(\vec{r}_1 - \vec{r}_2)$$

Similarly, electric force on q_2 due to charge q_1 is

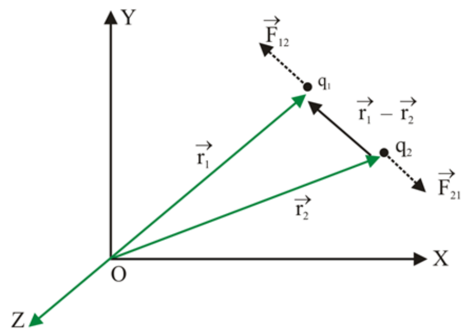


Fig 1.8

Force is a vector, so in vector form the Coulomb's law is written as

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{|\vec{r}_2 - \vec{r}_1|^3}(\vec{r}_2 - \vec{r}_1)$$

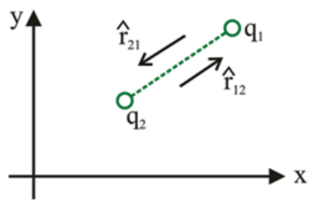


Fig 1.9

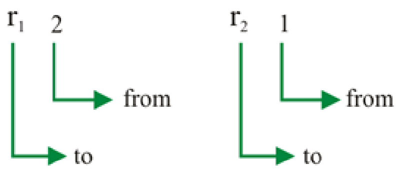
where $\hat{r}_{12}$ is a unit vector directed toward q_1 from q_2.

$$\hat{r}_{12} = -\hat{r}_{21}$$

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

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_1}{r^2}(-\hat{r}_{21})$$

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



Remember convention for $\hat{r}$.

Here q_1 and q_2 are to be substituted with sign.

Position vector of charges q_1 and q_2 are $\vec{r}_1 = x_1\hat{i} + y_1\hat{j} + z_1\hat{k}$ and $\vec{r}_2 = x_2\hat{i} + y_2\hat{j} + z_2\hat{k}$ respectively, where (x_1, y_1, z_1) and (x_2, y_2, z_2) are the co-ordinates of charges q_1 and q_2.

2.3 Principle of superposition

According to the principle of superposition, total force acting on a given charge due to number of charges is the vector sum of the individual forces acting on that charge due to all the charges.

Consider number of charge Q_1, Q_2, Q_3…are applying force on a charge Q

Net force on Q will be

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \dots\dots\dots + \vec{F}_{n-1} + \vec{F}_n$$

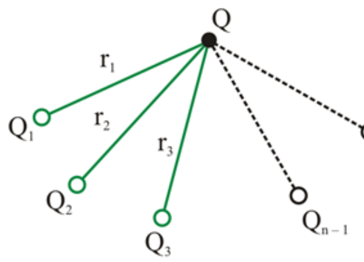


Fig 1.10

The magnitude of the resultant of two electric forces is given by $F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$ and the force direction is given by $\tan\alpha = \dfrac{F_2\sin\theta}{F_1 + F_2\cos\theta}$

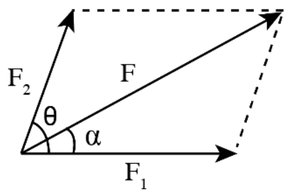


Fig 1.11

3. Electric Field

A positive charge or a negative charge is said to create its field around itself. Thus space around a charge in which another charged particle experiences a force is said to have electric field in it.

3.1 Electric Field Intensity ($\vec{E}$)

The electric field intensity at any point is defined as the force experienced by a unit positive charge placed at that point.

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Fig 1.12

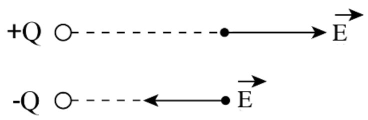
Where $q_0 \to 0$ so that presence of this charge may not affect the source charge Q and its electric field is not changed, therefore expression for electric field intensity can be better written as $\vec{E} = \lim_{q_0 \to 0} \dfrac{\vec{F}}{q_0}$

- **Unit and Dimensional formula:** Its S.I. unit – $\dfrac{\text{Newton}}{\text{coulomb}} = \dfrac{\text{volt}}{\text{meter}} = \dfrac{\text{Joule}}{\text{coulomb} \times \text{meter}}$ and

  C.G.S. unit = *Dyne/stat coulomb*.

  Dimension: $[E] = [MLT^{-3}A^{-1}]$

- **Direction of electric field:** Electric field (intensity) $\vec{E}$ is a vector quantity. Electric field due to a positive charge is always directed away from the charge and that due to a negative charge is always directed towards the charge



3.2 Relation between Electric Force and Electric field

In an electric field $\vec{E}$ a charge (Q) experiences a force $\vec{F} = Q\vec{E}$. If charge is positive then force is directed in the direction of field while if charge is negative force acts on it in the opposite direction of field

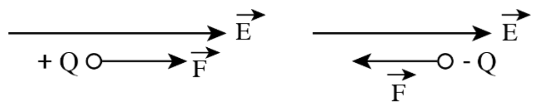


Fig 1.13

3.3 Superposition of Electric Field

The resultant electric field at any point is equal to the vector sum of electric fields at that point due to various charges.

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \dots$$

The magnitude of the resultant of two electric fields are given by

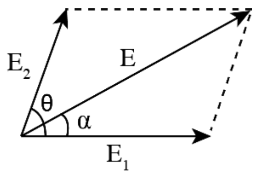


Fig 1.14

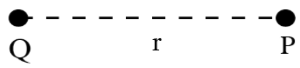
$E = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$ and the direction is given by

$$\tan\alpha = \frac{E_2\sin\theta}{E_1 + E_2\cos\theta}$$

3.4 Point Charge

Point charge produces its electric field at a point P which is distance r from it given by

$$E_P = \frac{Q}{4\pi\varepsilon_0 r^2} \text{ (Magnitude)}$$



- For + ve point charge, E is directed away from it.
- For – ve point charge, E is directed towards it.

3.5 Continuous Charge Distributions

There are infinite number of ways in which we can spread a continuous charge distribution over a region of space. Mainly three types of charge distributions will be used. We define three different charge densities.

Symbol	Definition	SI units
(lambda) λ =	Charge per unit length	C/m
(sigma) σ =	Charge per unit area	C/m^2
(rho) ρ =	Charge per unit volume	C/m^3

of

If a total charge q is distributed along a line of length ℓ, over a surface area A or throughout a volume V, we can calculate charge densities from.

$$\lambda = \frac{q}{\ell},\quad \sigma = \frac{q}{A},\quad \rho = \frac{q}{V}$$

3.6 Properties of Electric Field Lines

- Electric field lines originate from a **positive charge** & terminate on a **negative charge**.

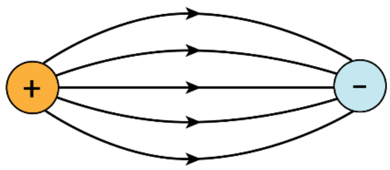


Fig 1.15

- The number of field lines originating/terminating on a charge is **proportional** to the magnitude of the charge.

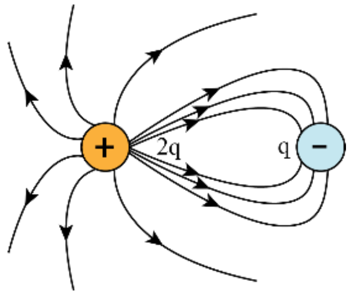


Fig 1.16

- The number of field lines passing through perpendicular unit area will be **proportional** to the **magnitude** of electric field there.
- Tangent to a Field line at any point gives the **direction** of electric field at that point. This will be **instantaneous** path charge will take if kept there.

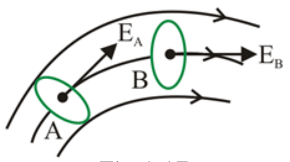


Fig 1.17

- Two or more field lines can never intersect each other. [they cannot have multiple directions].
- **Uniform field lines** are straight, parallel & uniformly placed
- Field lines cannot form a **loop**.

4. Electric Flux

4.1 Definition

Electric flux is measure of the field lines crossing a surface.

It is scalar quantity with SI unit $\frac{N}{C}$ -m^2 or V-m

"The number of field lines passing through perpendicular unit area will be proportional to the magnitude of Electric Field there" (Theory of Field Lines)

$$\frac{N}{A} \propto E \Rightarrow N \propto EA_{\perp}$$

$\therefore$ Electric Flux, $\Phi_{A_\perp} = EA_\perp$

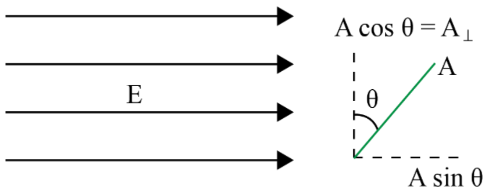


Fig 1.18

As θ increases, flux through area A decreases. If we draw a vector of magnitude A along the positive normal, it is called the **area vector,** $\vec{A}$ corresponding to the area A.

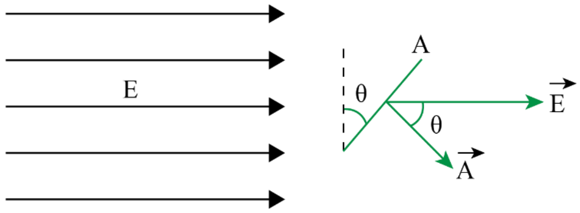


Fig 1.19

$\therefore$ Electric Flux, $\Phi_A = EA\cos\theta = \vec{E}\cdot\vec{A}$

(Assuming Electric Field is uniform over whole area)

NOTE:

If Electric field is not constant over the area of cross section, then $\Phi = \int \vec{E}.d\vec{A}$

4.2 Unit and Dimension

Flux is a scalar quantity.

S.I. unit: (volt × m) or $\dfrac{N.m^2}{C}$

it's dimensional formula: $(ML^3T^{-3}A^{-1})$

4.3 Types of Flux

For a closed body outward flux is taken to be **positive**, while inward flux is taken to be **negative.**

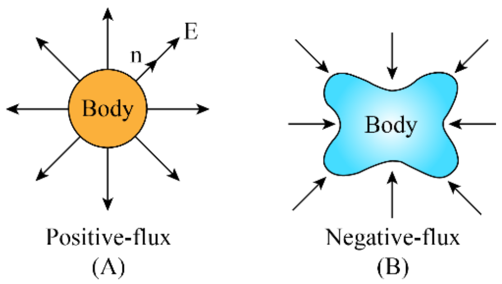


Fig 1.20

5. Gauss's Law

5.1 Definition

According to Gauss's law, total electric flux through a closed surface enclosing a charge is $\dfrac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.

i.e. $\phi_{net} = \dfrac{1}{\varepsilon_0}(Q_{enc.})$

i.e. . $\oint \vec{E}.d\vec{A} = \dfrac{Q_{en}}{\varepsilon_0}$

NOTE:

Gauss's law is only applicable for a closed surface.

5.2 Gaussian Surface

The closed surface on which Gauss law is applicable is defined as a Gaussian surface.

NOTE:

- Gaussian surface can be of any shape & size, only condition is that it should be closed.
- Gaussian surface is hypothetical in nature. It does not have a physical existence.

5.3 Deriving Gauss's law from Coulomb's law

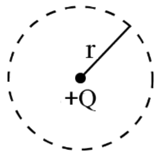


Fig 1.21

Lets take a spherical gaussian surface with charge '+Q' kept at the centre.

We know field lines for a +ve charge are always radially outward.

Angle between $d\vec{A}$ & $\vec{E}$ is zero.

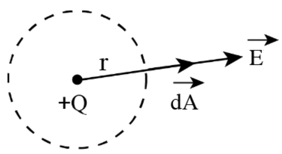


Fig 1.22

$$E = \frac{kQ}{r^2} = \frac{Q}{4\pi \epsilon_0 r^2}$$

$$\text{Net flux} = \oint \vec{E}.\vec{dA} = \oint \frac{Q}{4\pi \epsilon_0 r^2} dA$$

$$= \frac{Q}{4\pi \epsilon_0 r^2} \oint dA = \frac{Q}{4\pi \epsilon_0 r^2} . 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

Hence **Net flux = Q/ε_0.**

NOTE:

Although we derived gauss's law for a spherical surface it is valid for any shape of gaussian surface and for any charge kept anywhere inside the surface

5.4 Coulomb's law from Gauss's law

We choose an imaginary sphere (Gaussian surface) of radius r centred on the charge +q. Due to symmetry, E must have the same magnitude at any point on the surface, and $\vec{E}$ points radially outward, parallel to $\vec{dA}$.Hence we write the integral in Gauss's law as

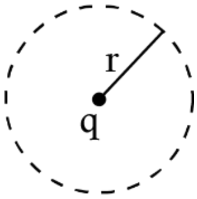


Fig 1.23

$$\phi_{net} = \oint \vec{E}.\vec{dA} = \oint E\,dA = E\oint dA = E\left(4\pi r^2\right)$$

$Q_{enclosed} = q$

$$\text{Thus, } E\left(4\pi r^2\right) = \frac{q}{\varepsilon_0} \quad \text{or} \quad E = \frac{q}{4\pi\varepsilon_0 r^2}$$

From the definition of the electric field, the force on a point charge q_0 located at a distance r from the charge q is $F = q_0E$. This is Coulomb's law.

6. Applications of Gauss's Law

Using Gauss's law to derive 'E' due to various charge distributions.

6.1 Electric Field due to a Line Charge

Consider an infinite line which has a linear charge density λ. Using Gauss's law, let us find the electric field at a distance 'r' from the line charge.

The **cylindrical symmetry** tells us that the field strength will be the same at all points at a fixed distance r from the line. Thus, if the charges are positive. The field lines are directed radially outwards, perpendicular to the line charge.

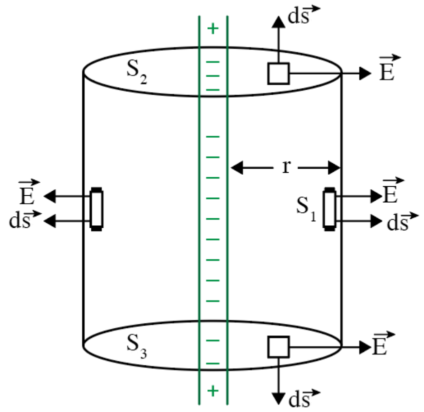


Fig 1.24

The appropriate choice of Gaussian surface is a cylinder of **radius r** and **length L**. On the flat end faces, S_2 and S_3, $\vec{E}$ is perpendicular $\vec{dS}$, which means flux is zero through them. On the curved surface S_1, $\vec{E}$ is parallel to $\vec{dS}$, so that $\vec{E}.\vec{dS}$ = EdS. The charge enclosed by the cylinder is $Q = \lambda L$. Applying Gauss's law to the curved surface, we have

$$E\oint dS = E\left(2\pi rL\right) = \frac{\lambda L}{\varepsilon_0} \quad \text{or} \quad \boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}} = \frac{2k\lambda}{r}$$

NOTE:

This is the field at a distance r from the line. It is directed away from the line if the charge is positive and towards the line if the charge is negative.

6.2 Electric Field due to a Plane Sheet of Charge

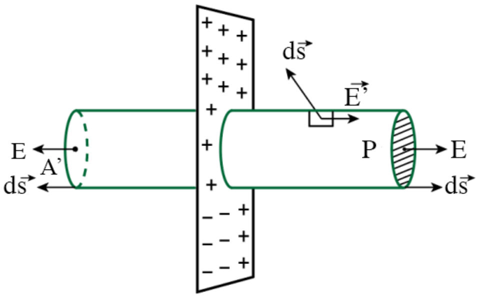


Fig 1.25

Consider a large plane sheet of charge with surface charge density (charge per unit area) **σ**. We have to find the electric field E at a point P in front of the sheet.

NOTE:

If the charge is positive, the field is away from the plane.

To calculate the field E at P. Choose a cylinder of area of cross-section A through the point P as the Gaussian surface. The flux due to the electric field of the plane sheet of charge passes only through the two circular caps of the cylinder.

According to Gauss law $\oint \vec{E}.d\vec{S} = q_{in} / \varepsilon_0$

$$\underbrace{\int \vec{E}.\vec{dS}}_{\text{I circular surface}} + \underbrace{\int \vec{E}.\vec{dS}}_{\text{II circular surface}} + \underbrace{\int \vec{E}.\vec{dS}}_{\text{cylindrical surface}} = \frac{\sigma A}{\varepsilon_0}$$

or $\quad EA + EA + 0 = \dfrac{\sigma A}{\varepsilon_0}$

or $\quad \boxed{E = \dfrac{\sigma}{2\varepsilon_0}}$

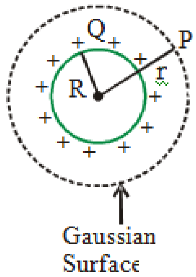
NOTE:

We see that the field is uniform and does not depend on the distance from the charge sheet. This is true as long as the sheet is large as compared to its distance from P.

6.3 Uniformly Charged Charge Hollow Sphere

6.3.1 Outside the Sphere

P is a point outside the sphere at a distance r from the centre.



According to Gauss's law,

$$\oint \vec{E}.d\vec{s} = \frac{Q}{\varepsilon_0} \text{ or } E\left(4\pi r^2\right) = \frac{Q}{\varepsilon_0}$$

Electric field at P (Outside sphere)

$$E_{out} = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2} = \frac{\sigma R^2}{\varepsilon_0 r^2}$$

$$\left\{\begin{aligned} Q &= \sigma \times A \\ &= \sigma \times 4\pi R^2 \end{aligned}\right\}$$

6.3.2 At the surface of sphere

At surface r = R

So, $E_s = \dfrac{1}{4\pi\varepsilon_0}.\dfrac{Q}{R^2} = \dfrac{\sigma}{\varepsilon_0}$

6.3.3 Inside the sphere

Inside the sphere electric field is zero.

$q_{enclosed} = 0$

$\therefore \quad E_{in} = 0$

Graphical variation of electric field with distance

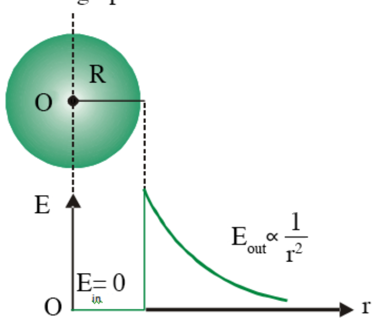


Fig 1.26

6.4 Uniform Spherical Volume Charge Distribution

We consider a spherical uniformly charge distribution of radius R in which total charge Q is uniformly distributed throughout the volume.

The charge density

$$\rho = \frac{\text{total charge}}{\text{total volume}} = \frac{Q}{\frac{4}{3}\pi R^3} = \frac{3Q}{4\pi R^3}$$

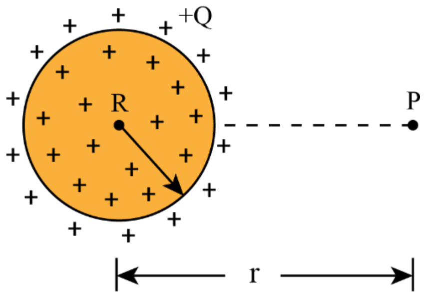


Fig 1.27

6.4.1 Outside the sphere at P (r > R)

According to Gauss's law

$$\oint \vec{E}\,.\vec{ds} = \frac{Q}{\varepsilon_0} \text{ or } E\left(4\pi r^2\right) = \frac{Q}{\varepsilon_0}$$

$$E_{out} = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2}$$

$$\textit{using } \rho = \frac{Q}{\frac{4}{3}\pi R^3}$$

$$E_{out} = \frac{\rho R^3}{3\varepsilon_0 r^2}$$

6.4.2 At the surface of sphere

At surface r = R

$$E_s = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{R^2} = \frac{\rho R}{3\varepsilon_0}$$

6.4.3 Inside the sphere

At a distance r from the centre. ($r \le R$)

$$\oint \vec{E}_{in}.\vec{ds} = \frac{q_{in}}{\varepsilon_0} = \frac{Qr^3}{\varepsilon_0 R^3}$$

$$E_{in}\left(4\pi r^2\right) = \frac{Qr^3}{\varepsilon_0 R^3}$$

$$E_{in} = \frac{1}{4\pi\varepsilon_0}.\frac{Qr}{R^3} = \frac{\rho r}{3\varepsilon_0} \left\{E_{in} \propto r\right\}$$

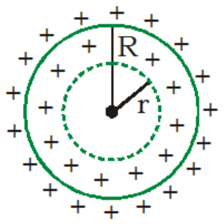


Fig 1.28

Graphical variation of electric field with distance

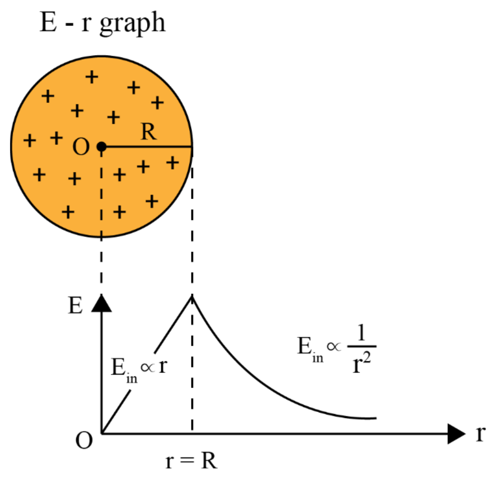
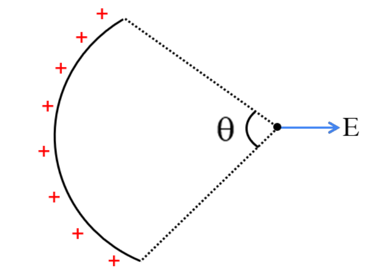
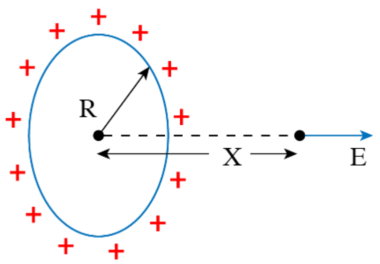
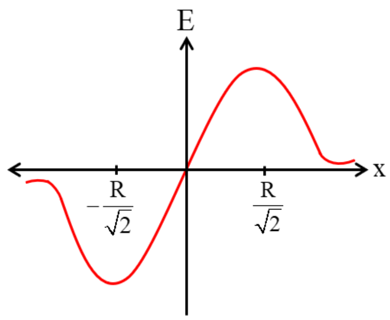
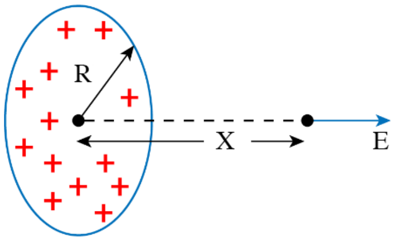
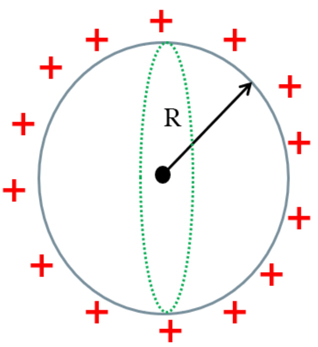
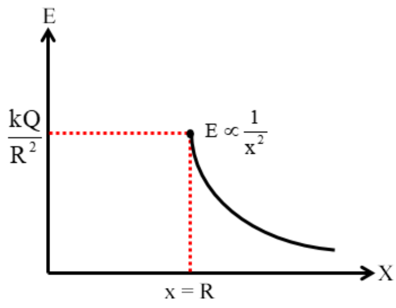
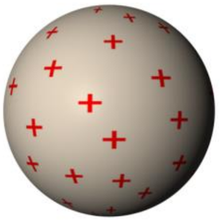
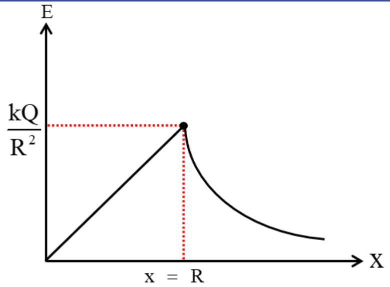
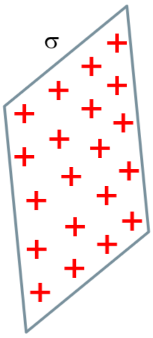
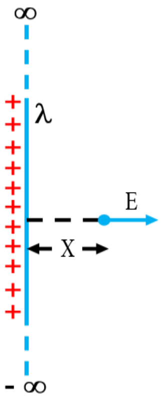


Fig 1.29

Electric Field Due to Various Uniform Charge Distribution

(i) At the centre of circular arc 	$E=\frac{kQ}{R^2}\frac{\sin(\theta/2)}{\theta/2}$	
(ii) At a point on the axis of ring 	$E=\frac{kQx}{(R^2+x^2)^{3/2}}$	
(iii) At a point on the axis of disc 	$E=\frac{2kQ}{R^2}\left(1-\frac{x}{(R^2+x^2)^{3/2}}\right)$	
(iv) Hollow sphere 	For $x<R$ $E=0$ For $x \geq R$ $E=\frac{kQ}{x^2}$	
(v) Non conducting solid sphere 	For $x<R$ $E=\frac{kQx}{R^3}$ For $x\geq R$ $E=\frac{kQ}{x^2}$	

Continued...

(vi) Infinite thin sheet 	$E = \frac{\sigma}{2\varepsilon_0}$	
(vii) Infinite wire 	$E = \frac{2k\lambda}{x}$	

7. Electric Potential Energy

7.1 Potential energy of 2 charges system

It is always change in potential energy that is defined as

$\Delta U = -W_{\text{conservative force}} = -W_{\text{Coulomb force}}$

Potential energy is defined for a system of charges in a particular configuration.

Consider a system of two charges q_1 and q_2. Suppose, the charge q_1 is fixed and the charge q_2 is taken from a point A to B.

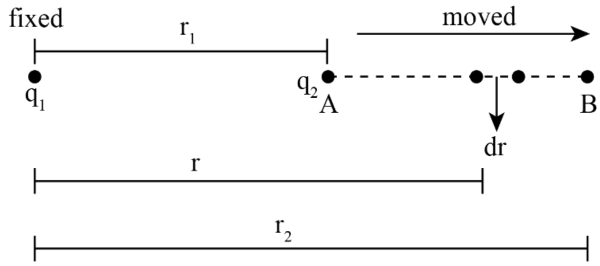


Fig 1.30

The electric force on the charge q_2 is $\vec{F} = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}\hat{r}$

The total work done as the charge q_2 moves from A to B is

$$W = \int_{r_1}^{r_2} \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} dr = \frac{q_1 q_2}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

The change in potential energy $U(r_2) - U(r_1)$ is, therefore,

$$U(r_2) - U(r_1) = -W = \frac{q_1 q_2}{4\pi\varepsilon_0}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

As the potential energy of the two-charge system is assumed to be zero when they have infinite separation.

The potential energy when the separation is r is

$$U(r) = U(r) - U(\infty) = \frac{q_1 q_2}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{\infty}\right) = \frac{q_1 q_2}{4\pi\varepsilon_0 r}$$

The potential energy depends essentially on the separation between the charges and is independent of the spatial location of the charged particles.

Above equation gives the electric potential energy of a pair of charges.

NOTE:

> Electric potential energy is a scalar quantity so in the above formula take sign of Q_1 and Q_2.

7.2 Electron volt (*eV*)

It is the practical unit of energy used in atomic and nuclear physics. As electron volt is defined as "the energy acquired by a particle having one quantum of charge, when accelerated by 1*volt*" *i.e.*

$$1\text{eV} = 1.6\times10^{-19}\,\text{C}\times\frac{1\text{J}}{\text{C}}$$
$$= 1.6\times10^{-19}\,\text{J}$$
$$= 1.6\times10^{-12}\ \text{erg}$$

7.3 Potential energy of a system of *n* charges

In a system of *n* charges electric potential energy is calculated for each pair and then all energies so obtained are added algebraically. *i.e.* $U = \dfrac{1}{4\pi\varepsilon_0}\left[\dfrac{Q_1Q_2}{r_{12}} + \dfrac{Q_2Q_3}{r_{23}} + \ldots\ldots\ldots\right]$

8. Electric Potential

Suppose, a test charge q is moved in an electric field from a point A to a point B while all the other charges in question remain fixed. If the electric potential energy changes by $U_B - U_A$ due to this displacement, we define the potential difference between the point A and the point B as

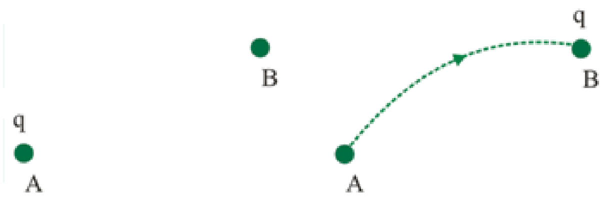


Fig 1.31

$$\Delta V = \frac{\Delta U}{q} \quad \text{i.e.} \quad V_B - V_A$$
$$= \frac{U_B - U_A}{q} = \frac{W_{ext}}{q} \quad [\Delta KE = 0]$$

Conversely, if a charge q is taken through a potential difference $V_B - V_A$, the electric potential energy is increased by $U_B - U_A = q(V_B - V_A)$.

Also $W_{ext} = q(V_B - V_A)[\Delta KE = 0]$

Potential difference between two points gives us an idea about work which has to be done in very slowly moving a charge between those points.

8.1 Electric Potential due to a point charge

Consider a point charge Q placed at a point A.

The potential at P is, $V = \frac{kQ}{r}$

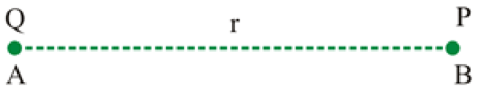


Fig 1.32

($\because V_\infty$ is taken as 0)

The electric potential due to a system of charges may be obtained by finding potentials due to the individual charges using equation and then adding them. Thus,

$$V = \frac{1}{4\pi\varepsilon_0}\sum\frac{Q_i}{r_i}$$

Electric potential is a scalar quantity, hence sign of charges is to be used in expression.

Electric potential is denoted by *V*.

8.2 Unit and dimensional formula

S. I. unit = $\frac{\text{Joule}}{\text{Coulomb}}$ = volt

$[V] = [ML^2T^{-3}A^{-1}]$

8.3 Types of electric potential

According to the nature of charge, potential is of two types

(i) Positive potential : Due to positive charge.

(ii) Negative potential : Due to negative charge.

NOTE:

At the centre of two equal and opposite charge

$V = 0$ but $E \neq 0$.

- At the centre of the line joining two equal and similar charge $V \neq 0$, $E = 0$.
- **If left free to move,**

Positive charge will always move from higher to lower potential points.

Negative charge will always move from lower to higher potential points.

(Because this motion will decrease potential energy of a system)

9. Relation between Electric Field & Potential

In an electric field rate of change of potential with distance is known as potential gradient. It is a vector quantity and its direction is opposite to that of electric field. Potential gradient relates with electric field according to the following relation

$E = -\frac{dV}{dr}$; This relation gives another unit of electric field which is $\frac{\text{volt}}{\text{meter}}$. In the above relation negative sign indicates that potential decreases in the direction of electric field.

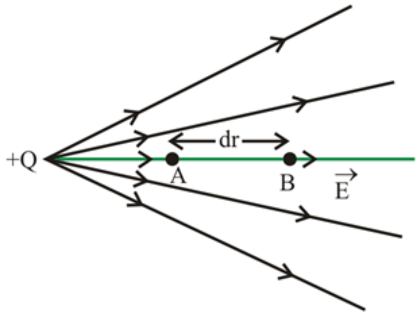


Fig 1.33

In the space around a charge distribution we can also write $\vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k}$

where $E_x = -\frac{dV}{dx}$, $E_y = -\frac{dV}{dy}$ and $E_z = -\frac{dV}{dz}$

Suppose *A*, *B* and *C* are three points in an uniform electric field as shown in below figure.

(i) Potential difference between point *A* and *B* is

$$V_B - V_A = -\int_A^B \vec{E} \cdot \vec{dr}$$

Since displacement is in the direction of electric field, hence

$\theta = 0^o$

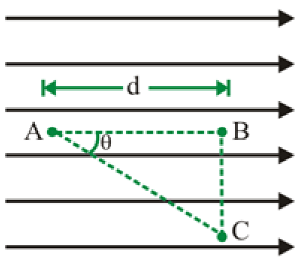


Fig 1.34

So,

$$V_B - V_A = -\int_A^B E\,.\,dr\,\cos 0 = -\int_A^B E\,.\,dr = -Ed$$

9.1 Equipotential Surface or Lines

1. If every point of a surface is at same potential, then it is said to be an equipotential surface. Regarding equipotential surface following points should be kept in mind :
2. The direction of electric field is perpendicular to the equipotential surfaces or lines.
3. The equipotential surfaces produced by a point charge or a spherical charge distribution are a family of concentric spheres.

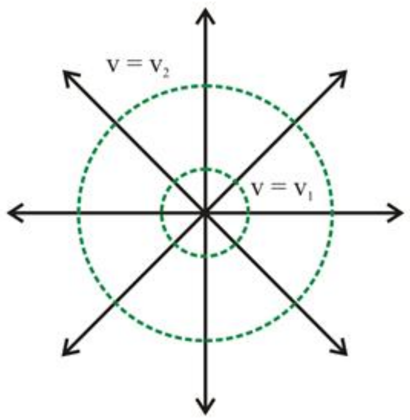


Fig 1.35

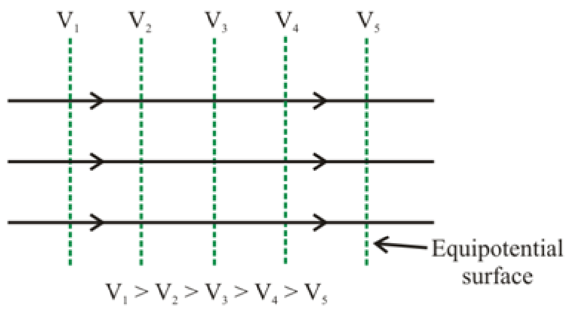


Fig 1.36

4. For a uniform electric field, the equipotential surfaces are a family of plane perpendicular to the field lines.
5. A metallic surface of any shape is an equipotential surface *e.g.* When a charge is given to a metallic surface, it distributes itself in a manner such that its every point comes at same potential even if the object is of irregular shape and has sharp points on it.

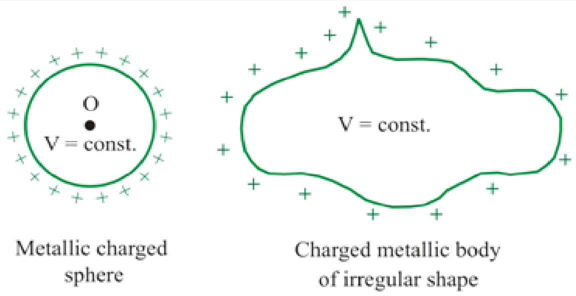
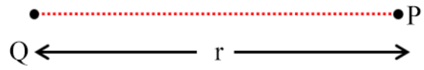
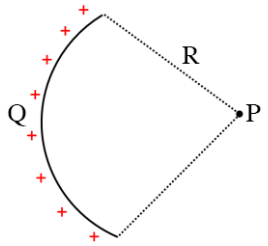
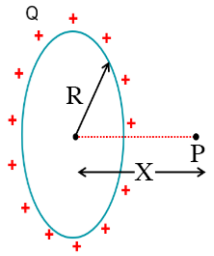
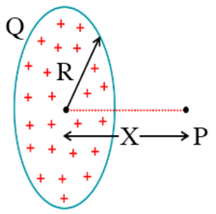
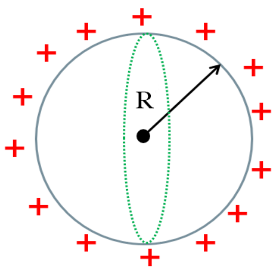
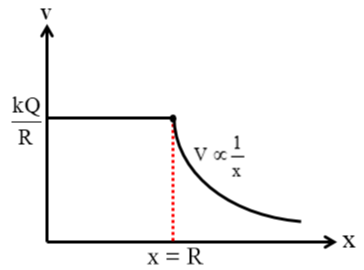
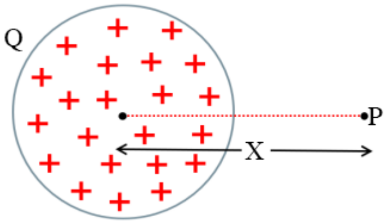
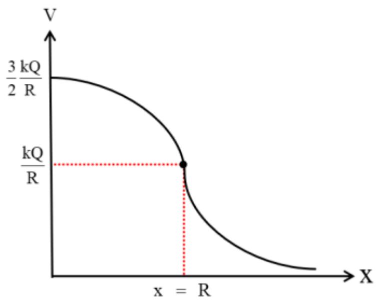


Fig 1.37

6. Equipotential surfaces can never cross each other.

   It is a common misconception that the path traced by a positive test charge is a field line but actually the path traced by a unit positive test charge represents a field line only when it moves along a straight line.

Electric Potential due to Various Charge Configurations

(i) Point charge 	$V_P = \dfrac{kQ}{r}$	
(ii) At a centre of circular arc 	$V_P = \dfrac{kQ}{R}$	
(iii) At a point on the axis of the ring 	$V_P = \dfrac{kQ}{\sqrt{R^2 + x^2}}$	
(iv) At a point on the axis of Disc 	$V_P = \dfrac{2kQ}{R^2}\left(\sqrt{R^2 + x^2} - x\right)$	
(v) Hollow sphere or conducting solid sphere 	(i) For $x \le R$ $V_P = \dfrac{kQ}{R}$ (ii) For $x = R$ $V_P = \dfrac{kQ}{R}$ (ii) For $x \ge R$ $V_P = \dfrac{kQ}{x}$	
(vi) Uniformly charged non-conducting solid sphere 	(i) For $x < R$ $V_P = \dfrac{kQ}{2R^3}\left(3R^2 - x^2\right)$ (ii) For $x = R$ $V_P = \dfrac{kQ}{R}$ (iii) For $x > R$ $V_P = \dfrac{kQ}{x}$	

10. Electric Dipole

10.1 General information

System of two equal and opposite charges separated by a small fixed distance is called a dipole.

(i) Dipole axis: Line joining negative charge to positive charge of a dipole is called its axis. It may also be termed as its longitudinal axis.

(ii) Equatorial axis: Perpendicular bisector of the dipole is called its equatorial or transverse axis as it is perpendicular to length.

(iii) Dipole length: The distance between two charges is known as dipole length (d)

(iv) Dipole moment: It is a quantity which gives information about the strength of dipole. It is a vector quantity and is directed from negative charge to positive charge along the axis. It is denoted as $\vec{p}$ and is defined as the product of the magnitude of either of the charge and the dipole length (d).

i.e. $\vec{p} = q\left(\vec{d}\right)$, where $\vec{d}$ is the displacement vector from -q to +q.

Its S.I. unit is ***coulomb-metre*** another units is ***Debye*** (1 *Debye* = 3.3 × 10^{-30} *C* × *m*) and its dimensions are $M^0L^1T^1A^1$.

NOTE:

- A region surrounding a stationary electric dipole has electric field only.
- When a dielectric is placed in an electric field, its atoms or molecules are considered as tiny dipoles and potential due to an electric dipole

(a) Electric Potential due to a dipole

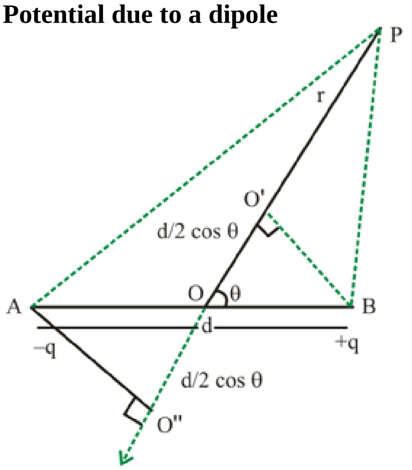


Fig 1.38

$$V_P = \frac{k(-q)}{AP} + \frac{k(+q)}{BP}$$

r >> d (distance 'r' is large as compared to d);

$AP \approx O''P \quad BP \approx O'P$

$$E = \frac{2kp}{r^3} \quad O'P = \frac{r-d}{2\cos\theta}$$

$$V_p = \frac{k(-q)}{r + \frac{d\cos\theta}{2}} + \frac{k(+q)}{r - \frac{d\cos\theta}{2}}$$

$$= k(+q)\left[\frac{1}{r - \frac{d\cos\theta}{2}} - \frac{1}{r + \frac{d\cos\theta}{2}}\right].$$

$$= \frac{kq\, d\cos\theta}{r^2 - \frac{d^2}{4}\cos^2\theta}$$

$$V_p = \frac{k(qd)\cos\theta}{r^2 - \frac{d^2}{4}\cos^2\theta} = \frac{kp\cos\theta}{r^2 - \frac{d^2}{4}\cos^2\theta} \left[\because p = qd\right].$$

since r >> d

$$V_p = \frac{kp\cos\theta}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2}.$$

θ is angle with the axis of dipole ; r is distance from centre of dipole.

(b) Electric Field due to dipole

Let the point P be at distance r from the centre of the dipole on the side of the charge q, as shown in fig (a). Then

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

where $\hat{p}$ is the unit vector along the dipole axis (from –q to q). Also

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

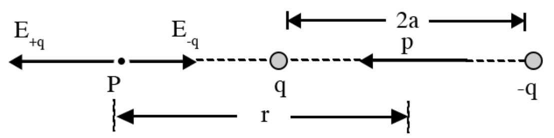


Fig 1.39

(a) For points on the axis.

The total field at P is

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

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

For r > > a

$$E = \frac{2kp}{r^3} \;(r >> a) \;...(i)$$

(ii) For points on the equatorial plane

The magnitudes of the electric fields due to the two charges + q and –q are given by

$$E_{+q} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r^2+a^2}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r^2+a^2} \text{ and are equal.}$$

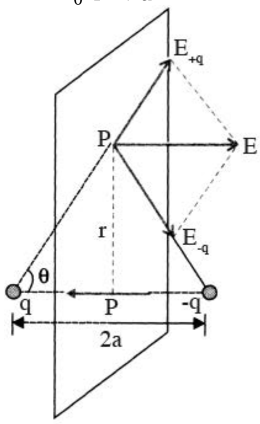


Fig 1.40

(p is the dipole moment vector of magnitude p = q × 2a and directed from –q to q).

The directions of E_{+q} and E_{-q} are as shown in fig. (b). Clearly, the components normal to the dipole axis cancel away. The components along the dipole axis add up. The total electric field is opposite to $\hat{p}$. We have

$$\vec{E} = -(E_{+q} + E_{-q})\cos\theta \quad = -\frac{2qa}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}\hat{p}$$

At large distances (r >> a), this reduces to

$$\vec{E} = -\frac{2qa}{4\pi\varepsilon_0 r^3}\hat{p} \;(r >> a)...(ii)$$

From Eqs. (i) and (ii), it is clear that the dipole field at large distances does not involve q and a separately ; it depends on the product qa. In terms of p, the electric field of a dipole at large distances takes simple forms :

At a point on the dipole axis

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

At a point on the equatorial plane

$$\vec{E} = \frac{-\vec{p}}{4\pi\varepsilon_0 r^3} = \frac{-k\vec{p}}{r^3}\;(r >> a)$$

10.2 Electric Dipole in uniform electric field

(i) **Force and Torque:** If a dipole is placed in a uniform field such that dipole (*i.e.* $\vec{p}$) makes an angle θ with direction of field, then two equal and opposite force act on dipole and constitute a couple whose tendency is to rotate the dipole. Hence a torque is developed in it and dipole tries to align it self in the direction of field. Consider an electric dipole in placed in a uniform electric field such that dipole (i.e. $\vec{p}$) makes an angle θ with the direction of electric field as shown

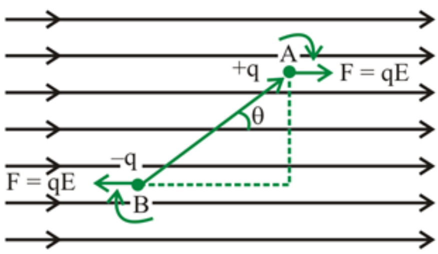


Fig 1.41

(a) Net force on electric dipole $F_{net} = 0$

(b) Torque $\tau = pE\sin\theta \left(\vec{\tau} = \vec{p}\times\vec{E}\right)$

(ii) **Work:** From the above discussion it is clear that in an uniform electric field dipole tries to align itself in the direction of electric field (i.e. equilibrium position). To change it's angular position some work has to be done.

Suppose an electric dipole is kept in an uniform electric field by making an angle θ_1 with the field, if it is again turn so that it makes an angle θ_2 with the field, work done in this process is given by the formula

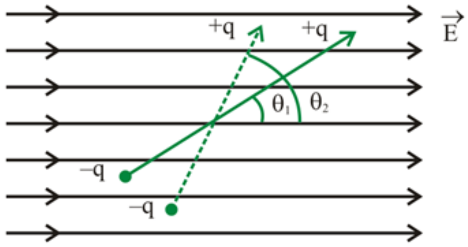


Fig 1.42

$$W = pE(\cos\theta_1 - \cos\theta_2)$$

Potential energy: In case of a dipole (in a uniform field), potential energy of dipole is defined as work done in rotating a dipole from a direction perpendicular to the field to the given direction i.e. if $\theta_1 = 90^o$ and $\theta_2 = \theta$ then

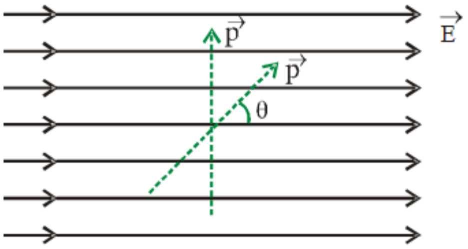


Fig 1.43

$W = \Delta U = U_\theta - U_{90^\circ} = -pE\cos\theta$

$\Rightarrow U_\theta = -pE\cos\theta$

[U (90°) = 0] or $\boxed{U = -\vec{p}.\vec{E}}$

11. Electrostatics of Conductors

11.1 Properties of Conductors

- **Inside a conductor, electrostatic field is zero**

  Consider a conductor, neutral or charged. There may also be an external electrostatic field. In the static situation the electric field is zero everywhere inside the conductor. As long as electric field is not zero, the free charge carriers would experience force and drift. In the static situation, the free charges have so distributed themselves that the electric field is zero everywhere inside. Electrostatic field is zero inside a conductor.

- **At the surface of a charged conductor, electrostatic field must be normal to the surface at every point**

  If E were not normal to the surface, it would have some non-zero component along the surface. Free charges on the surface of the conductor would then experience force and move. In the static situation, therefore, E should have no tangential component. Thus electrostatic field at the surface of a charged conductor must be normal to the surface at every point. (For a conductor without any surface charge density, field is zero even at the surface).

- **The charge kept in the material of a conductor will come to its outermost surface.**

  We know electric field at all points inside the material of a conductor is zero. This means 'E' at all points on the Gaussian surface is zero.

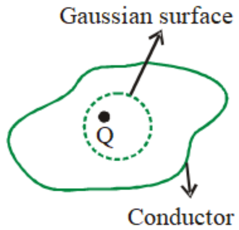


Fig 1.44

$$\int \vec{E}.\vec{dA} = \frac{Q_{en}}{\varepsilon_0} \Rightarrow E = 0 \Rightarrow \boxed{Q_{en} = 0}$$

Charge cannot remain inside so it comes outside dotted surface.

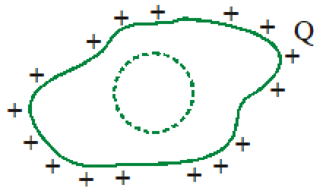


Fig 1.45

- **Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface**

  This follows from results 1 and 2 above. Since E = 0 inside the conductor and has no tangential component on the surface, no work is done in moving a small test charge within the conductor and on its surface. That is, there is no potential difference between any two points inside or on the surface of the conductor. Hence, the result. If the conductor is charged, electric field normal to the surface exists; this means potential will be different for the surface and a point just outside the surface.

  In a system of conductors of arbitrary size, shape and charge configuration, each conductor is characterized by a constant value of potential, but this constant may differ from one conductor to the other.

- **Electric field just outside the surface of a charged conductor**

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

where σ is the surface charge density and $\hat{n}$ is a unit vector normal to the surface in the outward direction.

For $\sigma > 0$, electric field is normal to the surface outward ; for $\sigma < 0$, electric field is normal to the surface inward.

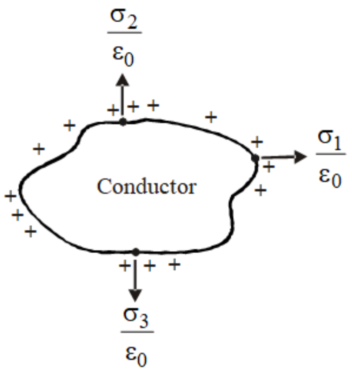


Fig 1.46

11.2 Cases of Concentric Shells Initially

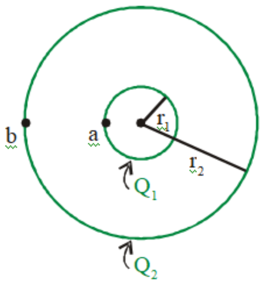


Fig 1.47

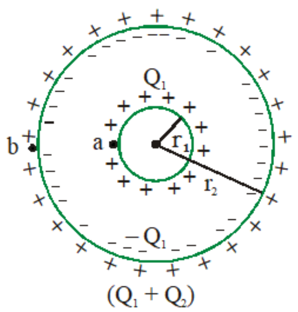


Fig 1.48

$$V_a = \frac{kQ_1}{r_1} + \frac{k(-Q_1)}{r_2} + \frac{k(Q_1+Q_2)}{r_2}$$

$$V_b = \frac{kQ_1}{r_2} + \frac{k(-Q_1)}{r_2} + \frac{k(Q_1+Q_2)}{r_2}$$

11.3 Cases of Earthing a Conductor

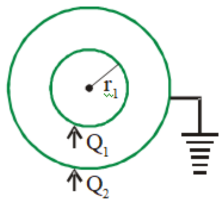


Fig 1.49

- Firstly do charge distribution before earthing.
- After charge distribution, assume some 'x' charge flown to ground (after earthing).
- Do re-distribution of charge.
- Take a point on the conductor (which is earthed) & do net potential of it equals 0. Calculate x.

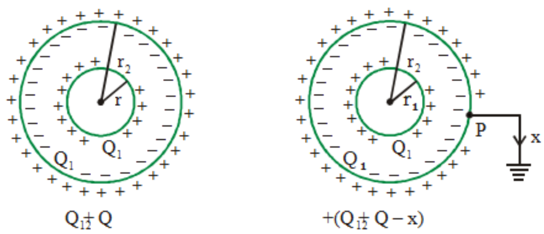


Fig 1.50

$$V_P = 0 = \frac{kQ_1}{r_2} + \frac{k(-Q_1)}{r_2} + \frac{k(Q_1+Q_2-x)}{r_2} \Rightarrow x = Q_1 + Q_2$$

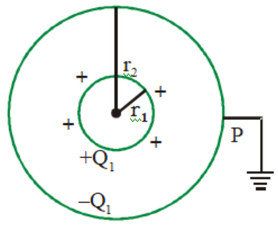


Fig 1.51

Charge is flown from outer surface because as long as Q_1 remains on inner shell, '– Q_1' will be induced on inner shell.

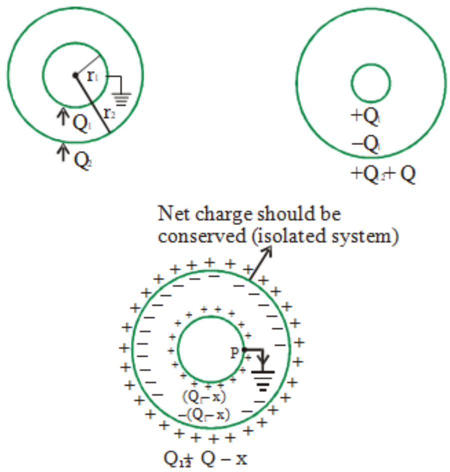


Fig 1.52

$$V_P = 0 = \frac{k(Q_1 - x)}{r_1} + \frac{k(-(Q_1 - x))}{r_2} + \frac{k(Q_1 + Q_2 - x)}{r_2}$$

$$\Rightarrow \frac{Q_1 - x}{r_1} - \frac{(Q_1 - x)}{r_2} + \frac{Q_1 + Q_2 - x}{r_2} = 0$$

$$\Rightarrow \frac{Q_1}{r_1} + \frac{Q_2}{r_2} = \frac{x}{r_1} = \boxed{x = Q_1 + Q_2 \frac{r_1}{r_2}}$$

NOTE:

As it can be seen not all charge on the surface flows to ground. When the outermost conductor is earthed then the charge residing on the outermost surface of outer conductor will flow to ground.

11.4 Connection of Charged conductors

Steps

- Do charge distribution before connection.
- Assume 'x' charge flows from one conductor to another.
- Do redistribution of charges.
- Equate net potential of conductor (1) equal to net potential of conductor (2).

Fig 1.53

Assumption: Distance between them is very large.

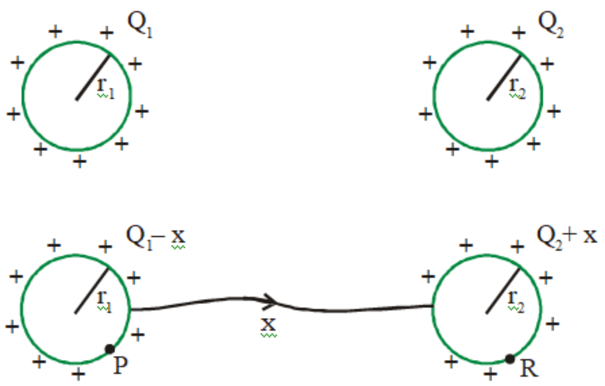


Fig 1.54

Final charges

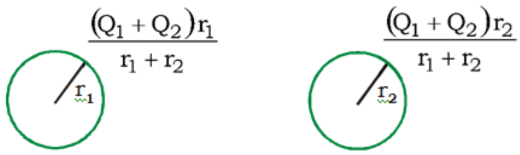


Fig 1.55

Final common potential = $k \cdot \left(\frac{Q_1 + Q_2}{r_1 + r_2}\right)$

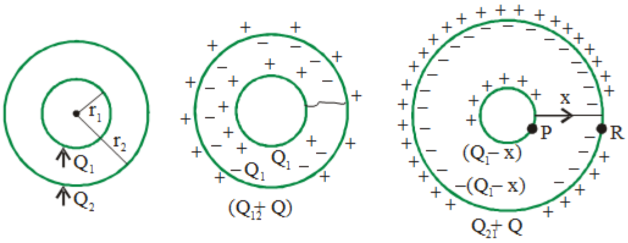


Fig 1.56

$V_P = V_R$

$$V_P = \frac{k(Q_1 - x)}{r_1} + \frac{k - (Q_1 - x)}{r_2} + \frac{k(Q_1 + Q_2)}{r_2}$$

$$\Rightarrow \quad V_R = \frac{k(Q_1 - x)}{r_2} + \frac{k - (Q_1 - x)}{r_2} + \frac{k(Q_1 + Q_2)}{r_2}$$

$V_P = V_R$

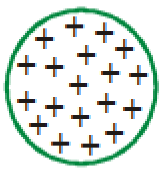
$$\Rightarrow \quad \frac{k(Q_1 - x)}{r_1} = \frac{k(Q_1 - x)}{r_2} \Rightarrow (Q_1 - x)\left[\frac{1}{r_1} - \frac{1}{r_2}\right] = 0$$

$\Rightarrow \quad x = Q_1$

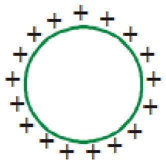
This indicates that all the charge on shell (1) will flow to shell (2).

12. Self Energy of Charged Sphere

Consider a uniformly charged sphere of radius R having a total charge Q. The electric potential energy of this sphere is equal to the work done in bringing the charges from infinity to assemble the sphere.



$$U = \frac{3Q^2}{20\pi\varepsilon_0 R}$$



$$U = \frac{Q^2}{8\pi\varepsilon_0 R}$$

The energy stored per unit volume around a point in an electric field is given by $u_e = \frac{U}{\text{Volume}} = \frac{1}{2}\varepsilon_0 E^2$. If in place of vacuum some medium of dielectric constant K is present then $u_e = \frac{1}{2}K\varepsilon_0 E^2$.

13. Plate Theory

13.1 Charged Conducting Plate

$$\text{Net Flux} = \frac{Q_{en}}{\varepsilon_0} = \frac{\sigma\pi r^2}{\varepsilon_0}$$

(cylindrical Gaussian surface)

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

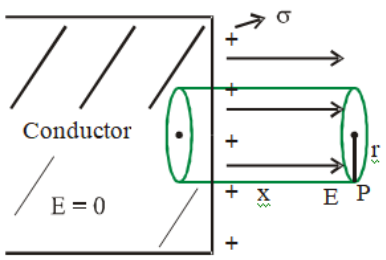


Fig 1.57

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

Net electric field at point P, near a conducting surface, having surface charge distribution 'σ' is given by [σ/ε_0].

13.2 Parallel Plate Theory

To find charge distribution on each surface of plates

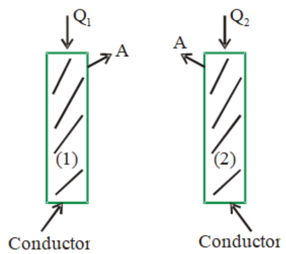


Fig 1.58

Two conducting plates having area 'A' (area is large as compared to distance, so that field is uniform) and the thickness of plates is small so that charge only appears on parallel faces.

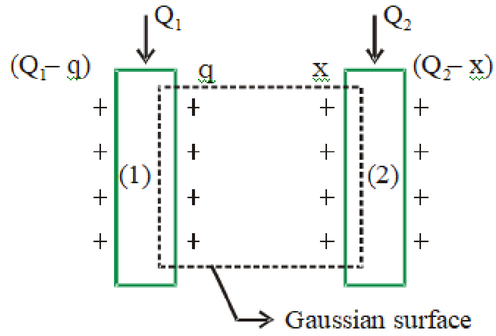


Fig 1.59

Since the field lines are parallel, the net flux through the gaussian surface will be zero, surface (1) & (2) be inside the material of the conductor.

Hence it can be said that net charge enclosed will be zero which implies the charges appearing on the facing surfaces are equal & opposite to each other.

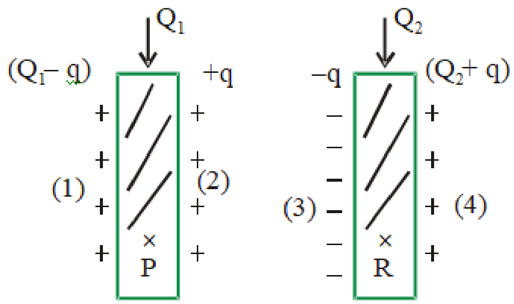


Fig 1.60

Net electric field at any point 'P' or 'R' has to be zero.

$(E_{net})_P = 0$

There are 4 distributions, the net field at P should be zero.

$$(E_P)_1 = \frac{\sigma}{2\varepsilon_0}(\rightarrow) = \frac{(Q_1 - q)}{2A\varepsilon_0}(\rightarrow)$$

$$(E_P)_2 = \frac{q}{2A\varepsilon_0}(\leftarrow)$$

$$(E_P)_3 = \frac{q}{2A\varepsilon_0}(\rightarrow)$$

$$(E_P)_4 = \frac{Q_2 + q}{2A\varepsilon_0}(\leftarrow)$$

$$\Rightarrow |(E_P)_1| + |(E_P)_3| = |(E_P)_2| + |(E_P)_4|$$

This shows $\frac{Q_1 - q}{2A\varepsilon_0} + \frac{q}{2A\varepsilon_0} = \frac{q}{2A\varepsilon_0} + \frac{Q_2 + q}{2A\varepsilon_0}$

$\boxed{q = \dfrac{Q_1 - Q_2}{2}}$ so final distributions would be

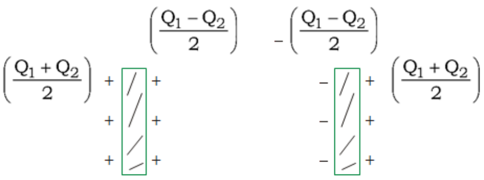


Fig 1.61

NOTE:

> When charged conducting plates are placed parallel to each other, the two outermost surfaces get equal charges and the facing surfaces get equal and opposite charges.

14. Force on a charged conductor

To find force on a charged conductor (due to repulsion of like charges) imagine a small part XY to be cut and just separated from the rest of the conductor MLN. The field in the cavity due to the rest of the conductor is E_2, while field due to small part is E_1. Then

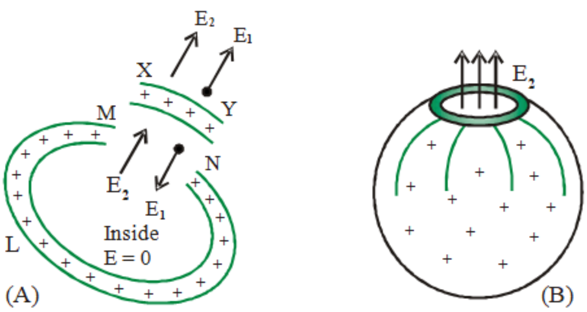


Fig 1.62

Inside the conductor

$E = E_1 - E_2 = 0$ or $E_1 = E_2$

Outside the conductor $E = E_1 + E_2 = \dfrac{\sigma}{\varepsilon_0}$.

Thus, $E_1 = E_2 = \dfrac{\sigma}{2\varepsilon_0}$

To find force, imagine charged part XY (having charge σ dA placed in the cavity MN having field E_2). Thus force dF = $(\sigma dA)E_2$ or $dF = \dfrac{\sigma^2}{2\varepsilon_0} dA$. The force per unit area or electric pressure is $P = \dfrac{dF}{dA} = \dfrac{\sigma^2}{2\varepsilon_0}$ (Electrostatic pressure)

The force is always outwards as $(\pm \sigma)^2$ is positive i.e., whether charged positively or negatively, this force will try to expand the charged body.

NCERT Corner

Important Points to Remember

1. From simple experiments on frictional electricity, one can infer that there are two types of charges in nature; and that like charges repel and unlike charges attract. By convention, the charge on a glass rod rubbed with silk is positive; that on a plastic rod rubbed with fur is then negative.
2. Charge is not only a scalar (or invariant) under rotation; it is also invariant for frames of reference in relative motion. This is not always true for every scalar. For example, kinetic energy is a scalar under rotation, but is not invariant for frames of reference in relative motion.
3. Conductors allow movement of electric charge through them, insulators do not. In metals, the mobile charges are electrons; in electrolytes both positive and negative ions are mobile.
4. 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.

   F_{21} = force on q_2 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 constant of proportionality.

   In SI units, the unit of charge is coulomb. The experimental value of the constant ε_0 is

   $\varepsilon_0 = 8.854\times10^{-12}\,C^2N^{-}m^{-2}$

   The approximate value of k is

   $k = 9 \times 10^9\ N\ m^2\ C^{-2}$
5. The ratio of electric force and gravitational force between a proton and an electron is

   $\frac{ke^2}{G\ m_em_p} \cong 2.4\times10^{39}$
6. Superposition Principle: The principle is based on the property that the forces with which two charges attract or repel each other are not affected by the presence of a third (or more) additional charge(s). For an assembly of charges q_1, q_2, q_3, ..., the force on any charge, say q_1, is the vector sum of the force on q_1 due to q_2, the force on q_1 due to q_3, and so on. For each pair, the force is given by the Coulomb's law for two charges stated earlier.
7. An electric field line 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. The relative closeness of field lines indicates the relative strength of electric field at different points; they crowd near each other in regions of strong electric field and are far apart where the electric field is weak. In regions of constant electric field, the field lines are uniformly spaced parallel straight lines.
8. Some of the important properties of field lines 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 (iv) They cannot form closed loops.
9. The flux $\Delta\varphi$ of electric field E through a small area element ΔS is given by

   $\Delta\phi = E.\,\Delta S$

   The vector area element $\Delta S = \Delta S\ n$

   Where ΔS is the magnitude of the aera element and n is normal to the area element, which can be considered planar for sufficiently small ΔS.

   For an area element of a closed surface, n is taken to be the direction of outward normal, by convention.
10. Gauss's law: The flux of electric field through any closed surface S is $1/\varepsilon_0$ times the total charge enclosed by S. The law is especially useful in determining electric field E, when the source distribution has simple symmetry.
11. The electric field due to a discrete charge configuration is not defined at the locations of the discrete charges. For continuous volume charge distribution, it is defined at any point in the distribution.
12. An electric dipole is a pair of equal and opposite charges q and –q separated by some distance 2a. Its dipole moment vector p has magnitude 2qa and is in the direction of the dipole axis from –q to q.
13. Field of an electric dipole in its equatorial plane (i.e., the plane perpendicular to its axis and passing through its centre) at a distance r from the centre:

$$E = \frac{-P}{4\pi\varepsilon_0}\frac{1}{(\alpha^2 + r^2)^{3/2}}$$

$$\cong \frac{-P}{4\pi\varepsilon_o r^3}. \quad \text{for } r >> \alpha$$

Dipole electric field on the axis at a distance r from the centre:

$$E = \frac{2pr}{4\pi\varepsilon_0 (r^2 - \alpha^2)^3}$$

$$\cong \frac{2}{4\pi\varepsilon_0 r^3} \qquad \text{for } \ r >> \alpha$$

The $1/r^3$ dependence of dipole electric fields should be noted in contrast to the $1/r^2$ dependence of electric field due to a point charge.

14. In a uniform electric field E, a dipole experiences a torque τ given by

$\tau = p \times E$

but experiences no net force.

15. Electrostatics field **E** is zero in the interior of a conductor; just outside the surface of a charged conductor, **E** is normal to the surface given by **E** = $\frac{\sigma}{\varepsilon_0} n$ where n is the unit vector along the outward normal to the surface 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.

Solved Example

Example 1

The electrostatic force on a small sphere of charge 0.4 μC due to another small sphere of charge –0.8 μC 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 **[NCERT]**

Sol. Charge of the first sphere is, $q_1 = 0.4\ \mu C = 0.4 \times 10^{-6} C$

Charge of the second sphere is, $q_2 = -0.8 \mu C$

$= -0.8 \times 10^{-6} C$

We have the electrostatic force given by Coulomb's law as,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

$$\Rightarrow r = \sqrt{\frac{q_1q_2}{4\pi\varepsilon_0 F}}$$

Substituting the given values in the above equation, we get,

$$\Rightarrow r = \sqrt{\frac{0.4\times10^{-6}\times8\times10^{-6}\times9\times10^{9}}{0.2}}$$

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

$\therefore\quad r = 0.12$ m

Therefore, we found the distance between charged sphere to be r = 0.12 m.

(b) What is the force on the second sphere due to the first?

Ans. From Newton's third law of motion, we know that every action has an equal and opposite reaction.
Thus, we could say that the given two spheres would attract each other with the same force.

So, the force on the second sphere due to the first sphere will be 0.2N

Example 2

(a) Explain the meaning of the statement 'electric charge of a body is quantised'.

(b) Why can one ignore quantisation of electric charge when dealing with macroscopic i.e., large scale charges? **[NCERT]**

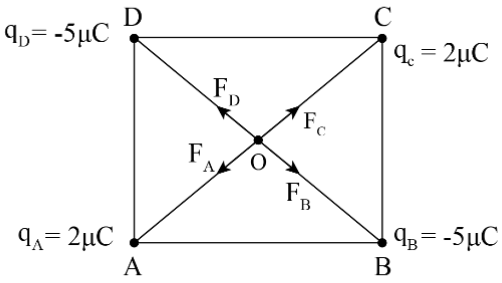
Sol. The given statement 'Electric charge of a body is quantized' means that only integral number (1, 2,3,..., n) of electrons can be transferred from one body to another. That is, charges cannot be transferred from one body to another in fraction.

(b) On a macroscopic scale or large-scale, the number of charges is as large asthe magnitude of an electric charge.
So, quantization is considered insignificant at a macroscopic scale for an electric charge and electric charges are considered continuous.

Example 3

Four point charges $q_A = 2\ \mu C$, $q_B = -5\ \mu C$, $q_C = 2\ \mu C$, and $q_D = -5\ \mu C$ are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of 1 μC placed at the centre of the square? **[NCERT]**

Sol. Consider the square of side length 10cm given below with four charges at its corners and let O be its centre.



From the figure we find the diagonals to be,

AC = BD = $10\sqrt{2}$ cm

$\Rightarrow$ AO = OC = DO = OB = $5\sqrt{2}$ cm

Now the repulsive force at O due to charge at A.

$$F_{AO} = k\frac{q_Aq_0}{OA^2} = k\frac{(+2\mu C)(1\mu C)}{\left(5\sqrt{2}\right)^2} \quad ...(1)$$

And the repulsive force at O due to charge at D,

$$F_{BO} = k\frac{q_Bq_0}{OB^2} = k\frac{(-5\mu C)(1\mu C)}{\left(5\sqrt{2}\right)^2} \quad ...(3)$$

And the attractive force of O due to charge at C,

$$F_{CO} = k\frac{q_C q_0}{OC^2} = k\frac{(-5\mu C)(1\mu C)}{\left(5\sqrt{2}\right)^2} \quad ...(4)$$

We find that (1) and (2) are of same magnitude but they act in the opposite direction and hence they cancel out each other. Similarly, (3) and (4) are of the same magnitude but in the opposite direction and hence they cancel out each other too. Hence, the net force on charge at centre O is found to be zero.

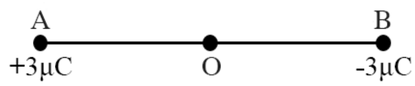
Example 4

Two point charges $q_A = 3\ \mu C$ and $q_B = -3\ \mu C$ are located 20 cm apart in vacuum.

(a) What is the electric field at the midpoint O of the line AB joining the two charges ?

(b) If a negative test charge of magnitude 1.5×10^{-9} C is placed at this point, what is the force experienced by the test charge? **[NCERT]**

Sol. The situation could be represented in the following figure. Let O be the midpoint of line AB.



We are given :

AB = 20 cm

AO = OB = 10 cm

Take E to be the electric field at point O, then,

The electric field at point O due to charge +3μC would be,

$$E_1 = \frac{3\times10^{-6}}{4\pi\varepsilon_0(AO)^2} = \frac{3\times10^{-6}}{4\pi\varepsilon_0(10\times10^{-2})^2}\ NC^{-1} \text{ along OB}$$

The electric field at point O due to charge – 3 μC would be,

$$E_2 = \left|\frac{3\times10^{-6}}{4\pi\varepsilon_0(OB)^2}\right| = \frac{3\times10^{-6}}{4\pi\varepsilon_0(10\times10^{-2})^2}\ NC^{-1} \text{ along OB}$$

The net electric field,

$\Rightarrow E = E_1 + E_2$

$$\Rightarrow E = 2 \times \frac{9\times10^9 \times 3\times10^{-6}}{(10\times10^{-2})^2}$$

$\Rightarrow E = 5.4 \times 10^6\ NC^{-1}$

Therefore, the electric field at mid-point O is $E = 5.4\times10^6\ NC^{-1}$ along OB.

(b) We have a test charge of magnitude 1.5×10^{-9} C placed at midpoint O and we found the electric field at this point to be $E = 5.4 \times 10^6\ NC^{-1}$. So, the force experienced by the test charge would be F,

$\Rightarrow F = qE$

$\Rightarrow F = 1.5 \times 10^{-9} \times 5.4 \times 10^6$

$\Rightarrow F = 8.1 \times 10^{-3}$ N

This force will be directed along OA since like charges repel and unlike charges attract.

Example 5

An electric dipole with dipole moment 4×10^{-9} C m is aligned at 30° with the direction of a uniform electric field of magnitude $5 \times 10^4\ NC^{-1}$. Calculate the magnitude of the torque acting on the dipole.

[NCERT]

Sol. We are given the following:

Electric dipole moment, $\vec{p} = 4 \times 10^{-9}$ Cm

Angle made by $\vec{p}$ with uniform electric fields, $\theta = 30°$

Electric field, $\vec{E} = 5 \times 10^4\ NC^{-1}$

Torque acting on the dipole is given by

$\tau = pE \sin\theta$

Substituting the given values we get,

$\Rightarrow \tau = 4 \times 10^{-9} \times 5 \times 10^4 \times \sin 30°$

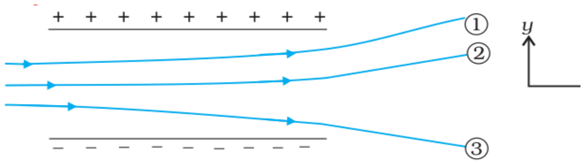
$$\Rightarrow \tau = 20 \times 10^{-5} \times \frac{1}{2}$$

$\therefore\ \tau = 10^{-4}$ Nm

Thus, the magnitude of the torque acting on the dipole is found to be 10^{-4} Nm.

Example 6

Figure 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? **[NCERT]**



Sol. From the known properties of charges, we know that the unlike charges attract and like charges repel each other.

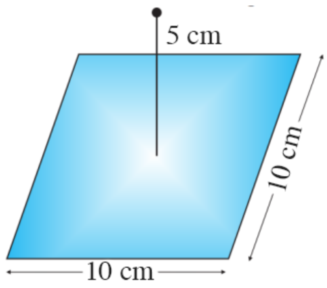
So, the particles 1 and 2 that move towards the positively charged plate while repelling away from the negatively charged plate would be negatively charged and the particle 3 that moves towards the negatively charged plate while repellingaway from the positively charged plate would be positively charged.

Now, we know that the charge to mass ratio (which is generally known as emf) is directly proportional to the displacement or the amount of deflection for a givenvelocity.

Since the deflection of particle 3 is found to be maximum among the three, it would have the highest charge to mass ratio.

Example 7

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. 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.) **[NCERT]**



Sol. Consider the square as one face of a cube of edge length 10cm with a charge q at its centre, according to Gauss's theorem for a cube, total electric flux is through all its six faces.

$$\phi_{total} = \frac{q}{\varepsilon_0}$$

The electric flux through one face of the cube could be now given by, $\phi = \frac{\phi_{total}}{6}$.

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

$\varepsilon_0 = 8.854 \times 10^{-12} N^{-1}C^2m^{-2}$ = Permittivity of free space

The net charge enclosed would be, q = 10μC = 10 × 10^{-6} C

Substituting the values given in the question, we get,

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

$\therefore \phi = 1.88 \times 10^5 \ Nm^2C^{-1}$

Example 8

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 centred 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? **[NCERT]**

Sol. We are given:

Electric flux due to the given point charge, $\phi = -1.0 \times 10^3 \ Nm^2/C$

Radius of the Gaussian surface enclosing the point charge, r =10.0cm

Electric flux piercing out through a surface depends on the net charge enclosed by the surface according to Gauss's law and is independent of the dimensions of the arbitrary surface assumed to enclose this charge.

Hence, 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 could be given by the relation,

$$\phi_{total} = \frac{q}{\varepsilon_0}$$

Where, q = net charge enclosed by the spherical surface

$\varepsilon_0 = 8.854 \times 10^{-12} N^{-1}C^2m^{-2}$ = Permittivity of free space

$\Rightarrow q = \phi\varepsilon_0$

Substituting the given values,

$\Rightarrow q = -1.0 \times 10^3 \times 8.854 \times 10^{-12} = -8.854 \times 10^{-9}$ C

$\Rightarrow q = -8.854$ nC

Example 9

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? **[NCERT]**

Sol. We have the relation for electric field intensity E at a distance (d) from the centre of a sphere containing net charge q is given by,

$$E = \frac{q}{4\pi\varepsilon_0 d^2} \quad ....(1)$$

Where,

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

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

$\varepsilon_0 = 8.884 \times 10^{-12}\ N^{-1} C^2 m^{-2}$ = Permittivity of free space

$$\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2C^{-2}$$

From (1), the unknown charge would be,

$q = E(4\pi\varepsilon_0)d^2$

Substituting the given values we get,

$$\Rightarrow q = \frac{1.5\times10^3\times(0.2)^2}{9\times10^9} = 6.67\times10^{-9}C$$

$\Rightarrow q = 6.67$ nC

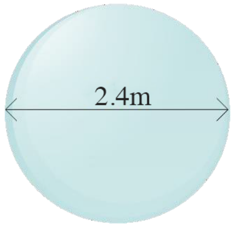
Therefore, the net charge on the sphere is found to be 6.67 nC.

Example 10

A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 μC/m^2. (a) Find the charge on the sphere. (b) What is the total electric flux leaving the surface of the sphere?

[NCERT]

Sol.



(a) Given that,

Diameter of the sphere, d = 2.4 m.

Radius of the sphere, r = 1.2 m.

Surface charge density,

$\sigma = 80.0\mu C/m^2 = 80 \times 10^{-6}/m^2$

Total charge on the surface of the sphere,

$\Rightarrow Q = \sigma \times 4\pi r^2 = 80 \times 10^{-6} \times 4 \times 3.14 \times (1.2)^2$

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

Therefore, the charge on the sphere is found to be 1.447×10^{-3}C.

(b) Total electric flux (ϕtotal) leaving out the surface containing net charge is given by Gauss's law as,

$$\phi_{total} = \frac{Q}{\varepsilon_0}............(1)$$

Where, permittivity of free space,

$\varepsilon_0 = 8.854 \times 10^{-12}\ N^{-1}C^2m^{-2}$.

We found the charge on the sphere to be,

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

Substituting these in (1), we get,

$$\phi_{total} = \frac{1.447\times10^{-3}}{8.8854\times10^{-12}}$$

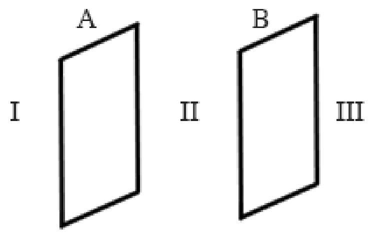
$\Rightarrow \phi_{total} = 1.63 \times 10^{-8}\ NC^{-1}m^2$

Therefore, the total electric flux leaving the surface of the sphere is found to be $1.63 \times 10^{-8}\ NC^{-1}\ m^2$

Example 11

Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 17.0×10^{-22} C/m^2. What is E: (a) in the outer region of the first plate, (b) in the outer region of the second plate, and (c) between the plates? **[NCERT]**

Sol. The given nature of metal plates is represented in the figure below:



Here, A and B are two parallel plates kept close to each other. The outer regionof plate A is denoted as I , outer region of plate B is denoted as III , and the region between the plates, A and B, is denoted as II.

It is given that:

Charge density of plate A, $\sigma = 17.0 \times 10^{-22} C/m^2$

Charge density of plate B, $\sigma = -17.0 \times 10^{-22} C/m^2$

In the regions I and III, electric field E is zero. This is because the charge is not enclosed within the respective plates.

Now, the electric field E in the region II is given by

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

Where,

Permittivity of free space $\varepsilon_0 = 8.854 \times 10^{-12}\ N^{-1}C^2m^{-2}$

Clearly,

$$E = \frac{17.0 \times 10^{-22}}{8.854 \times 10^{-12}} \Rightarrow E = 1.92 \times 10^{-10} N/C$$

Thus, the electric field between the plates is 1.92×10^{-10} N/C.

Example 12

In a certain region of space, electric field is along the z-direction throughout. The magnitude of electric field is, however, not constant but increases uniformly along the positive z-direction, at the rate of 10^5 NC^{-1} per metre. What are the force and torque experienced by a system having a total dipole moment equal to 10^{-7} Cm in the negative z-direction? **[NCERT]**

Sol. We know that the dipole moment of the system, P = q × dl = -10^{-7} Cm. Also, the rate of increase of electric field per unit length is given as

$$\frac{dE}{dl} = 10^5 NC^{-1}$$

Now, the force (F) experienced by the system is given by F = qE

$$F = q\frac{dE}{dl} \times dl$$

$$\Rightarrow F = P\frac{dE}{dl}$$

$\Rightarrow F = -10^{-7} \times 10^5$

$\Rightarrow F = -10^{-2}$ N

Clearly, the force is equal to -10^{-2} N in the negative z – direction i.e., it is opposite to the direction of electric field.

Thus, the angle between electric field and dipole moment is equal to 180º. Now, the torque is given by $\tau = PE \sin\theta$

$\tau = PE \sin 180^\circ = 0$

Therefore, it can be concluded that the torque experienced by the system is zero.

Example 13

Two charges 5×10^{-8} C and -3×10^{-8} C are located 16 cm apart. At what point(s) on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero. **[NCERT]**

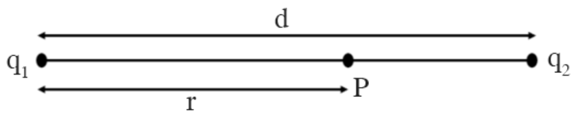
Sol. It is provided that, First charge, $q = 5 \times 10^{-8} C$

Second charge, $q_2 = -3 \times 10^{-8} C$

Distance between the two given charges,

$d = 16 cm = 0.16$ m

Case 1. When point P is inside the system of two charges.
Consider a point named P on the line connecting the two charges.



r is the distance of point P from q_1.

Potential at point P will be,

$$V = \frac{q_1}{4\pi\varepsilon_o r} + \frac{q_2}{4\pi\varepsilon_0 (d-r)}$$

Where, ε_o is the Permittivity of free space

But V = 0 so,

$$0 = \frac{q_1}{4\pi\varepsilon_o r} + \frac{q_2}{4\pi\varepsilon_o (d-r)}$$

$$\Rightarrow \frac{q_1}{4\pi\varepsilon_o r} = -\frac{q_2}{4\pi\varepsilon_o (d-r)}$$

$$\Rightarrow \frac{q_1}{r} = -\frac{q_2}{(d-r)}$$

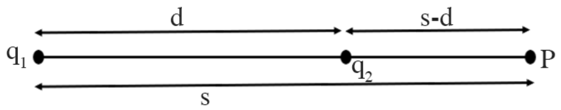
$$\Rightarrow \frac{5\times10^{-8}}{r} = -\frac{-3\times10^{-8}}{(0.16-r)}$$

$$\Rightarrow \frac{0.16}{r} = \frac{8}{5}$$

We get,

r = 0.1m =10cm

Therefore, the potential is zero at 10 cm distance from the positive charge. Case 2. When point P is outside the system of two charges.



Potential at point P will be,

$$V = \frac{q_1}{4\pi\varepsilon_o s} + \frac{q_2}{4\pi\varepsilon_0 (s-d)}$$

Where, ε_o is the Permittivity of free space

But V = 0 so,

$$0 = \frac{q_1}{4\pi\varepsilon_o s} + \frac{q_2}{4\pi\varepsilon_o (s-d)}$$

$$\Rightarrow \frac{q_1}{4\pi\varepsilon_o s} = -\frac{q_2}{4\pi\varepsilon_o (s-d)}$$

$$\Rightarrow \frac{q_1}{s} = -\frac{q_2}{(s-d)}$$

$$\Rightarrow \frac{5\times10^{-8}}{s} = -\frac{-3\times10^{-8}}{(s-0.16)}$$

$$\Rightarrow \frac{0.16}{s} = \frac{8}{5}$$

We get,

s = 0.4 m = 40 cm

Therefore, the potential is zero at 40 cm distance from the positive charge.

Example 14

A spherical conductor of radius 12 cm has a charge of 1.6×10^{-7}C distributed uniformly on its surface. What is the Electric field **[NCERT]**

(a) inside the sphere

(b) just outside the sphere

(c) at a point 18 cm from the centre of the sphere?

Sol. (a) It is provided that,
Spherical conductor's radius, $r = 12\text{cm} = 0.12\text{m}$
The charge is evenly distributed across the conductor. The electric field within a spherical conductor is zero because the total net charge within a conductor is zero.

(b) Just outside the conductor, Electric field E is given by

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

Where, ε_o is the Permittivity of free space

Value of $\frac{1}{4\pi\varepsilon_o} = 9\times10^9\ NC^{-2}m^{-2}$

$$\Rightarrow E = \frac{1.6\times10^{-7}\times9\times10^9}{(0.12)^2}$$

$$\Rightarrow E = 10^5\,NC^{-1}$$

Clearly, the electric field just outside the sphere is 10^5 NC^{-1}.

(c) Let electric field at a given point which is 18 cm from the sphere centre = E_1

The formula for electric field is given by,

$$E_1 = \frac{q}{4\pi\varepsilon_o d^2}$$

Where, ε_o is the Permittivity of free space

Value of $\frac{1}{4\pi\varepsilon_o} = 9\times10^9\, NC^{-2}m^{-2}$

$$\Rightarrow E = \frac{1.6\times10^{-7}\times9\times10^9}{(0.18)^2}$$

$$\Rightarrow E = 4.4\times10^4\, NC^{-1}$$

Therefore, the electric field at a given point 18 cm from the sphere centre is 4.4×10^4 NC^{-1}.

Example 15

A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q.

(a) A charge q is placed at the centre of the shell. What is the surface charge density on the inner and outer surfaces of the shell?

(b) Is the electric field inside a cavity (with no charge) zero, even if the shell is not spherical, but has any irregular shape? Explain. **[NCERT]**

Sol. Provided that,

Charge located at the centre of shell is +q. Hence, a charge of magnitude -q will be induced to the inner surface of the shell. Therefore, net charge on the shell's inner surface is -q.

Surface charge density at the shell's inner surface is given by the relation,

$$\sigma_1 = \frac{-q}{4\pi r_1^2}$$

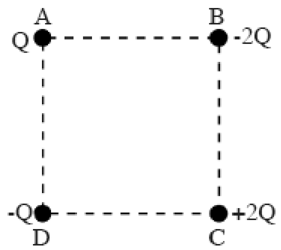
A charge of +q is induced on the outer surface of the shell. A charge of magnitude Q is placed on the outer surface of the shell. Therefore, total charge on the outer surface of the shell is Q + q. Surface charge density at the shell's outer surface is,

$$\sigma_2 = \frac{-q}{4\pi r_2^2}$$

(b) Yes, the electric field intensity is zero inside a cavity, even if the shell is notspherical and has any random shape. Take a closed circle such that a part of it is inside the hole along a field line while the rest is within the conductor. The network performed by the field in taking a test charge over a closed circuit is zero because the field is zero inside the conductor. Hence, the electric field is zero, whatever theframe is.

Example 16

Four charges are placed on corners of a square as shown in figure having side of 5 cm. If Q is one micro coulomb, then electric field intensity at centre will be



(a) 1.02×10^7 N/C upwards

(b) 2.04×10^7 N/C downwards

(c) 2.04×10^7 N/C upwards

(d) 1.02×10^7 N/C downwards

Sol. **(a)**

$|E_C| > |E_A|$ so resultant of E_C & E_A is $E_{CA} = E_C - E_A$ directed toward Q

Also $|E_B| > |E_D|$ so resultant of E_B and E_D i.e.

$E_{BD} = E_B - E_D$ directed toward $-2Q$ charge

hence Net electric field at centre is

$$E = \sqrt{(E_{CA})^2 + (E_{BD})^2} \quad ...(i)$$

By proper calculations

$$|E_A| = 9\times10^9 \times \frac{10^{-6}}{\left(\frac{5}{\sqrt{2}}\times10^{-2}\right)^2} = 0.72 \times 10^7 \text{ N/C}$$

$$|E_B| = 9\times10^9 \times \frac{2\times10^{-6}}{\left(\frac{5}{\sqrt{2}}\times10^{-2}\right)^2} = 1.44\times10^7 \text{ N/C};$$

$$|E_C| = 9\times10^9\times\frac{2\times10^{-6}}{\left(\frac{5}{\sqrt{2}}\times10^{-2}\right)^2} = 1.44\times10^7\ \text{N/C}$$

$$|E_D| = 9\times10^9\times\frac{10^{-6}}{\left(\frac{5}{\sqrt{2}}\times10^{-2}\right)^2} = 0.72\times10^7\ \text{N/C};$$

So, $|E_{CA}| = |E_C| - |E_A| = 0.72\times10^7$ N/C and $|E_{BD}| = |E_B| - |E_D|$

$= 0.72\times10^7$ N/C.

Hence from equation – (i)

$E = 1.02\times10^7$ N/C upwards.

Example 17

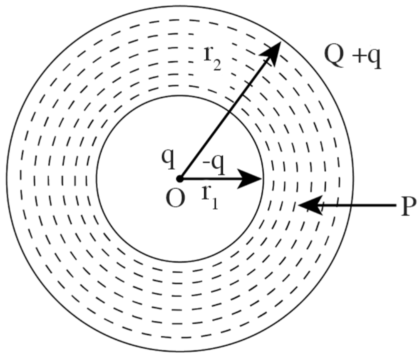
A spherical conducting shell of inner radius r_1, and outer radius r_2 has a charge 'Q'. A charge 'q' is placed at the centre of the shell.

(a) What is the surface charge density on the

(i) inner surface (ii) outer surface of the shell?

(b) Write expression for the electric field at a point $x > r_2$ from the centre of the shell.

Sol. (a) Charge Q resides on outer surface of spherical conducting shell. Due to charge q placed at centre, charge induced on inner surface is –q and on outer surface it is +q. So, total charge on inner surface –q and on outer surface it is Q + q.



Surface charge density on inner surface $= -\frac{q}{4\pi r_1^2}$

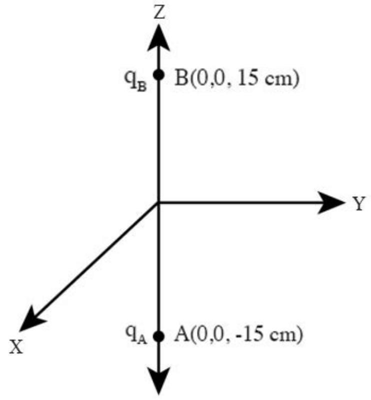
Surface charge density on outer surface $= \frac{Q+q}{4\pi r_2^2}$

(b) For external points, whole charge acts at centre, so electric field at distance $x > r_2$.

$$\vec{E}(x) = \frac{1}{4\pi\varepsilon_0}\frac{Q+q}{x^2}\hat{r}$$

Example 18

A system has two charges $q_A = 2.5\times10^{-7}$ C and $q_B = -2.5\times10^{-7}$ C located at points A = (0, 0, – 15 cm) and B = (0, 0, + 15 cm) respectively. What are the total charge and electric dipole moment of the system?



Sol. Given $q_A = 2.5\times10^{-7}$ C, $q_B = -2.5\times10^{-7}$ C

$2l$ = AB = 30 cm = 0.30 m

Total charge of the system q = qA + qB

$q = 2.5\times10^{-7}$ C $- 2.5\times10^{-7}$ C

q = 0

Electric dipole moment, $\vec{p} = q.2\vec{l}$

$\vec{p} = 7.5\times10^{-8}$ cm directed along negative z-axis

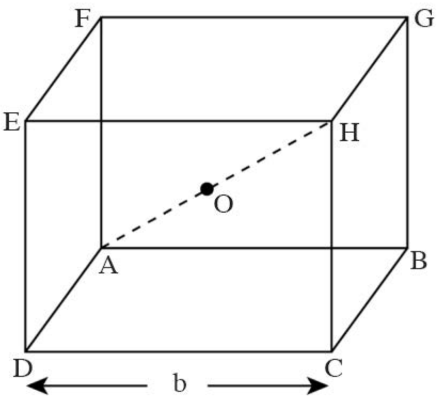
$\vec{p} = 7.5\times10^{-8}\ \text{cm}\left(-\hat{k}\right)$

Example 19

A cube of side b has a charge q at each of its vertices. Determine the potential and electric field due to this charge-array at the centre of the cube.

Sol. O is the centre of cube ABCDEFGH. Charge q is placed at each of eight corners of the cube.

Electric Potential:



Side of cube = b

Length of each diagonal

$= \sqrt{b^2 + b^2 + b^2} = \sqrt{3}b$

Distance of each corner from centre O.

= half the diagonal

$= . \dfrac{\sqrt{3}b}{2}$

Potential at O due to charge at each corner

$= \dfrac{1}{4\pi\varepsilon_0} \dfrac{q}{(\sqrt{3}\,b/2)}$

$= \dfrac{1}{4\pi\varepsilon_0} \dfrac{2q}{\sqrt{3}\,b}$

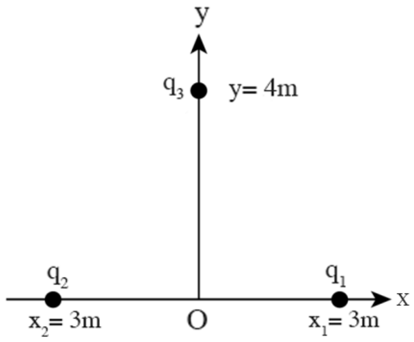
∴ Net potential at O due to all 8 charges at corners of the cube

$$V = 8 \times \frac{1}{4\pi\varepsilon_0} \frac{2q}{\sqrt{3}\,b} = \frac{1}{4\pi\varepsilon_0} . \frac{16q}{\sqrt{3}\,b}$$

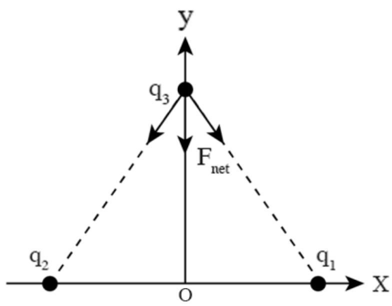
Electric Field : The electric field at O due to charges at all corners of the cube is zero, since, electric fields due to charges at opposite corners such as A and H,G and D, B and E, F and C are equal and opposite.

Example 20

Two point charges $q_1 = q_2 = 2mC$ are fixed at $x_1 = +3m$ and $x_2 = -3m$ as shown in figure. A third particle of mass 1 g and charge $q_3 = -4mC$ is released from rest at y = 4.0 m. All these charges are on a frictionless plane. Find the speed of the particle as it reaches the origin.



Sol. How to proceed: Here, the charge q_3 is attracted towards q_1 and q_2 both. So, the net force on q_3 is towards origin.



By this force charge is accelerated towards origin, but this acceleration is not constant. So, to obtain the speed of particle at origin by kinematics we will have to first find the acceleration at same intermediate position and then will have to integrate with proper limits. On the other hand, it is easy to use energy conservation principle as the only forces are conservative.

Let v be the speed of particle at origin. From conservation of mechanical energy, $U_i + K_i = U_f + K_f$

or

$$\frac{1}{4\pi\varepsilon_0}\left[\frac{q_3q_2}{(r_{32})_i} + \frac{q_3q_1}{(r_{31})_i} + \frac{q_2q_1}{(r_{21})_i}\right] + 0$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_3q_2}{(r_{32})_f} + \frac{q_3q_1}{(r_{31})_f} + \frac{q_2q_1}{(r_{21})_f}\right] + \frac{1}{2}mv^2$$

Here, $(r_{21})_i = (r_{21})_f$. Substituting the proper values, we have

$$(9.0 \times 10^9)\left[\frac{(-4)(2)}{(5.0)} + \frac{(-4)(2)}{(5.0)}\right] \times 10^{-12} = (9.0 \times 10^9)$$

$$\left[\frac{(-4)\,(2)}{(3.0)} + \frac{(-4)\,(2)}{(3.0)}\right] \times 10^{-12} + \frac{1}{2} \times 10^{-3} \times v^2$$

$$(9\times10^{-3})\left(-\frac{16}{5}\right)=(9\times10^{-3})\left(-\frac{16}{3}\right)+\frac{1}{2}\times10^{-3}\times v^2$$

\

$$(9\times10^{-3})\,(16)\left(\frac{2}{15}\right)=\frac{1}{2}\times10^{-3}\times v^2$$

\ v = 6.2 m/s

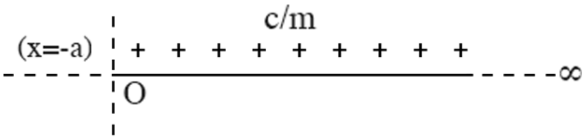
Example 21

A long thin rod lies along the x-axis with one end at the origin. It has a uniform charge density l C/m. Assuming it to infinite in length, the electric field at point x = – a on the x-axis will

(a) $\frac{\lambda}{\pi\varepsilon_0 a}$ (b) $\frac{\lambda}{2\pi\varepsilon_0 a}$

(c) $\frac{\lambda}{4\pi\varepsilon_0 a}$ (d) $\frac{2\lambda}{\pi\varepsilon_0 a}$

Sol. **(c)**



For infinite length

Electric field at a point along axis $=\frac{\lambda}{4\pi\epsilon_0 r}$

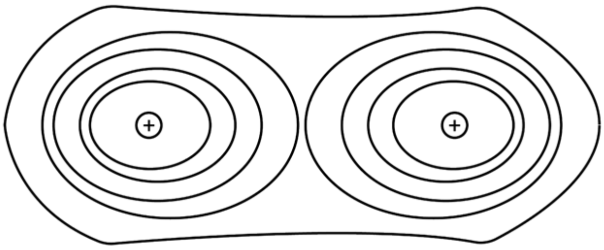
r = a

$$E=\frac{\lambda}{4\pi\epsilon_0 a}$$

Example 22

Depict the equipotential surfaces for a system of two identical positive point charges placed a distance 'd' apart.

Sol. Equipotential surfaces due to two identical charges is shown in fig.



Example 23

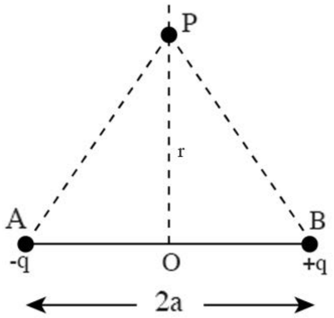
Find the electrostatic potential at equatorial point of an electric dipole.

Sol. Let P be a point on the equator of an electric dipole formed of charges –q and +q at separation 2a.

The distance of point P from centre of dipole = r

AP = BP = $\sqrt{r^2+a^2}$

Electrostatics potential at P, $V_P=\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{BP}-\frac{q}{AP}\right)$



$$V_P=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{\sqrt{r^2+a^2}}-\frac{q}{\sqrt{r^2+a^2}}\right]=0$$

Thus, electrostatic potential at each equatorial point of an electric dipole is zero.

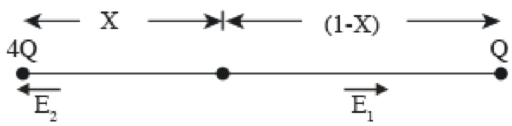
Example 24

(i) Two point charges 4Q and Q are separated by a distance 1 m in air. At what point on the line joining the charges is the electric field intensity zero?

(ii) Also calculate the electrostatic potential energy of the charges if Q = 2 × 10^{-7} C.

Sol. (i) Let x be the distance of point P from charge 4Q where electric field intensity is zero, then

$$\vec{E}=\vec{E}_1+\vec{E}_2=0$$



As E_1 and E_2 are oppositely directed.

In magnitude,

$$\Rightarrow\frac{1}{4\pi\varepsilon_0}\frac{4Q}{x^2}=\frac{1}{4\pi\varepsilon_0}\frac{Q}{(1-x)^2}\Rightarrow\frac{4}{x^2}=\frac{1}{(1-x)^2}$$

$\Rightarrow x^2 = 4(1-x)^2 \Rightarrow x = \pm\ 2\,(1-x)$

If we take (+) sign x = 2 (1 – x).

This gives m $x = \frac{2}{3}$ = **66.7 cm**

If we take (–) sign, $x = -2(1-x) \Rightarrow x = 2$ m, Which is not possible since the charges are having same sign, the point must lie between the two charges. Hence the answer will be only 66.7cm.

(ii) Electrostatic potential energy,

$$U = \frac{1}{4\pi\varepsilon_0}\frac{(4Q)(Q)}{r} = \frac{1}{4\pi\varepsilon_0}\frac{4Q^2}{r}$$

$$= 9 \times 10^9 \times \frac{4\times(2\times10^{-7})^2}{(1)} = 1.44 \times 10^{-3} \text{ J}$$

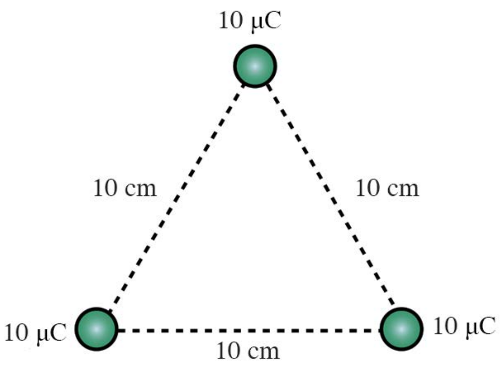
Example 25

Three particles, each having a charge of 10micro coulomb are placed at the corners of an equilateral triangle of side 10cm. The electrostatic potential energy of the system is (Given $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ N-m^2/C^2$)

(a) Zero (b) Infinite

(c) 27 J (d) 100 J

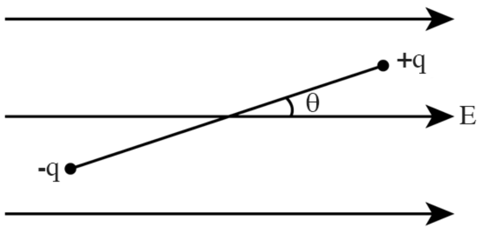
Sol. **(c)** Potential energy of the system,



$$U = 9\times10^9\left[\frac{(10\times10^{-6})^2}{0.1}\times3\right] = 27 \text{ J}$$

Example 26

A point particle of mass M is attached to one end of a massless rigid non-conducting rod of length L. Another point particle of the same mass is attached to other end of the rod. The two particles carry charges +q and – q respectively. This arrangement is held in a region of a uniform electric field E such that the rod makes a small angle q (say of about 5 degrees) with the field direction (see figure). What will be the minimum time, needed for the rod to become parallel to the field after it is set free



(a) $t = 2\pi\sqrt{\frac{mL}{2pE}}$ **(b)** $t = \frac{\pi}{2}\sqrt{\frac{mL}{2qE}}$

(c) $t = \frac{3\pi}{2}\sqrt{\frac{mL}{2pE}}$ **(d)** $t = \pi\sqrt{\frac{2mL}{pE}}$

Sol. **(b)**

In the given situation system oscillate in electric field with maximum angular displacement q. It's time period of oscillation (similar to dipole)

$T = 2\pi\sqrt{\frac{I}{pE}}$ where I = moment of inertia of the system and p = qL

Hence the minimum time needed for the rod becomes parallel to the field is $t = \frac{T}{4} = \frac{\pi}{2}\sqrt{\frac{I}{pE}}$

Here $I = M\left(\frac{L}{2}\right)^2 + M\left(\frac{L}{2}\right)^2 = \frac{ML^2}{2}$

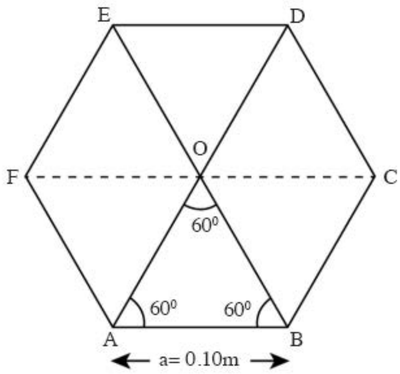
Þ $t = \frac{\pi}{2}\sqrt{\frac{ML^2}{2\times qL\times E}} = \frac{\pi}{2}\sqrt{\frac{ML}{2qE}}$

Example 27

A regular hexagon of side 0.10 m has a charge 5 mC at each of its vertices. Calculate the potential at the centre of the hexagon.

Sol. The potential due to similar charges is additive.

Let O be the centre of the hexagon.



In triangle OAB, all angles are 60º, so

$$OA = OB = AB = a$$

So, in a regular hexagon distance of each corner from centre is equal to the side of the cube

r = OA = OB = OC = OD = OE = OF = a = 0.10 m

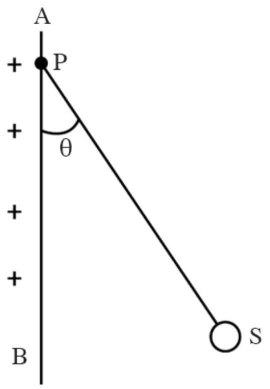
The net potential at O, $V = 6\times\frac{1}{4\pi\varepsilon_0}\frac{q}{a}$.

Here q = 5mC = 5×10^{-6} C, a = 0.10 m

$\therefore$ **$V = 6 \times 9 \times 10^9 \times 5 \times \frac{10^{-6}}{0.10} = 2.7 \times 10^6$ volt**

Example 28

An infinite plane with uniformly distributed positive charge has surface charge density s. A small metallic sphere S of mass m and charge +Q is attached to a thread and tied to a point P on the sheet AB. The angle which PS makes with the plane AB is given by



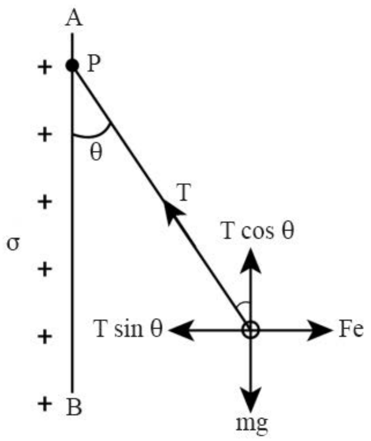
(a) $\tan^{-1}\left(\frac{Q\sigma}{\varepsilon_0 mg}\right)$

(b) $\cot^{-1}\left(\frac{Q\sigma}{2\varepsilon_0 mg}\right)$

(c) $\tan^{-1}\left(\frac{Q\sigma}{2\varepsilon_0 mg}\right)$

(d) $\cot^{-1}\left(\frac{Q\sigma}{\varepsilon_0 mg}\right)$

Sol.



At equilibrium of Pendulum

T sin q = F_e

T cos q = mg

$$\tan\theta = \frac{F_e}{mg} = \frac{QE}{mg}$$

$$\tan\theta = \frac{Q\sigma}{2\varepsilon_0 mg}$$

$$\theta = \tan^{-1}\left[\frac{Q\sigma}{2\varepsilon_0 mg}\right]$$

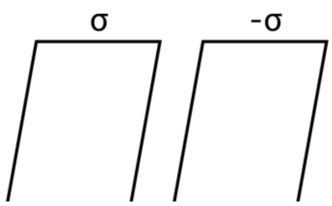
Example 29

Two infinite plane parallel sheets separated by a distance d have equal and opposite uniform charge densities s. Electric field at a point between the sheets is

(a) Zero (b) $\frac{\sigma}{\varepsilon_0}$

(c) $\frac{\sigma}{2\varepsilon_0}$ (d) $\frac{2\sigma}{\varepsilon_0}$

Sol. **(b)**



Electric field at point between the sheets

= E_I - E_{II}

$$E_1 = \frac{\sigma}{2\in_0}\ E_{II} = \frac{-\sigma}{2\in_0} = \frac{\sigma}{2\in_0} + \frac{\sigma}{2\in_0} = \frac{\sigma}{\in_0}$$

Example 30

A point charge Q is placed outside a hollow spherical conductor of radius R, at a distance (r > R) from its centre C. The field at C due to the induced charges on the conductor is $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(a) Zero (b) $k\frac{Q}{(r-R)^2}$

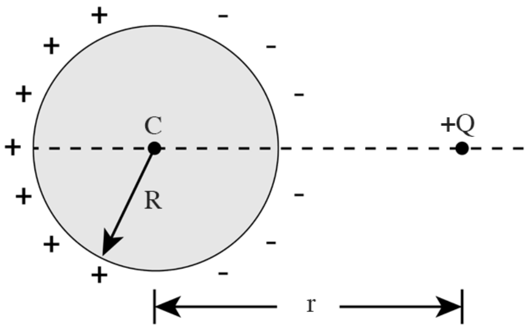
(c) $k\frac{Q}{r^2}$ directed towards Q

(d) $k\frac{Q}{r^2}$ directed away from Q

Ans. (c)

Sol. According to the figure show below. The total field at C must be zero. The field at C due to the point charge is E =

towards left $k\frac{Q}{r^2}$. The field at C due to the induced charges must be $\frac{kQ}{r^2}$ towards right i.e. directed towards Q



EXERCISE – 1: Basic Objective Questions

Electric Charge and its Properties

1. A glass rod when rubbed with silk cloth acquires

(a) +ve charge and silk cloth acquires equal –ve charge

(b) No charge

(c) –ve charge and silk cloth acquires equal +ve charge

(d) +ve charge and silk cloth acquires more –ve charge

2. Frictional electricity is produced on the two objects due to:

(a) Loss of electrons by one object

(b) Loss of protons by one object

(c) Loss of electrons by one object and equal number of electrons gained by the other object

(d) Loss of protons by one object and equal number of protons gained by the other object

3. How many electrons will have a charge of one coulomb?

(a) 6.25×10^{19} (b) 6.25×10^{18}

(c) 6.25×10^{15} (d) 1.6×10^{-19}

4. A spherical conducting ball is suspended by a conducting thread. A positive point charge is moved near the ball. The ball will

(a) be attracted to the point charge and swing towards it

(b) be repelled from the point charge and swing away from it

(c) not be affected by the point charge

(d) either (a) or (b)

5. When 10^{19}electrons are removed from a neutral metal plate, the electric charge on it is

(a) – 1.6 C (b) + 1.6 C

(c) 10^{+19} C (d) 10^{-19} C

6. For the phenomenon of electrostatic induction, mark out the correct statement.

(a) The magnitude of the net induced charge is zero

(b) The magnitude of net induced charge is equal and opposite to the inducing charge

(c) The mass of the body changes slightly

(d) Electrostatic induction is a permanent phenomenon

7. The specific charge of a proton is 9.6×10^7 C kg^{-1}. The specific charge of an alpha particle will be

(a) 9.6 × 107 C kg^{-1}

(b) 19.2 × 107 C kg^{-1}

(c) 4.8 × 107 C kg^{-1}

(d) 2.4 × 107 C kg^{-1}

8. A comb rubbed through one's dry hair attracts small bits of paper. This is because

(a) comb is a good conductor

(b) paper is a good conductor

(c) the atoms in the paper get polarized by the charged comb

(d) the comb possesses magnetic properties

9. **Assertion:** When charges are shared between any two bodies, no charge is really lost, but some loss of energy does occur.

Reason: Some energy disappears in the form of heat, sparking etc.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

10. **Assertion:** Charge is invariant.

Reason: Charge does not depend on speed of frame of reference.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

11. **Assertion:** There is a spark or crackle when we take off our synthetic clothes or sweater in dry weather.

Reason: Discharge of electric charges occurs through our body, which accumulated due to rubbing of insulating surface.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

12. **Assertion:** It is observed that if two glass rods rubbed with silk cloth are brought close to each other, they repel.

Reason: Electrification causes repulsion of same polarity.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

13. **Assertion:** The mass of positively charged body is slightly less than the mass of negatively charged body.

Reason: Loosely bound electrons in a material are transferred on rubbing.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

Force between charges

14. The law that governs the force between electric charges is called

(a) Ampere's law (b) Coulomb's law
(c) Faraday's law (d) Ohm's law

15. If charge and distance between two charges are reduced to half, then force between them will be

(a) remain same (b) increases four times
(c) reduce four times (d) None of the above

16. Two point charges +2C and +6C repel each other with a force of 12 N. If a charge of – 2C is given to each of these charges, the force will be

(a) zero (b) 8 N (attractive)
(c) 8 N (repulsive) (d) None of these

17. Charges 4Q, q and Q are placed along x-axis at position $x = 0, x = l/2$ and $x = l$, respectively. Find the value of q, so that force on charge Q is zero.

(a) Q (b) Q/2
(c) – Q/2 (d) – Q

18. Two charges of 10μC and 20μC are separated by 20 cm. The ratio of force acting on them will be:

(a) 1 : 1 (b) 2 : 1
(b) 1 : 2 (d) 1 : 4

19. A charge q_1 exerts some force on a second charge q_2. If a third charge q_3 is brought near, the force of q_1 exerted on q_2 will:

(a) increase (b) decrease
(c) remain unchanged (d) none of these

20. An electron is moving around the nucleus of a hydrogen atom in a circular orbit of radius r. The Coulomb force between the two is

(a) $K\frac{e^2}{r^3}\vec{r}$ (b) $K\frac{e^2}{r^2}\hat{r}$
(c) $-K\frac{e^2}{r^3}\hat{r}$ (d) $-K\frac{e^2}{r^3}\vec{r}$

21. The distance between charges 5×10^{-11}C and -2.7×10^{-11}C is 0.2 m. The distance, at which third charge should be placed from second charge in order that it will not experience any force along the line joining the two charges, is

(a) 0.44 m (b) 0.65 m
(c) 0.556 m (d) 0.350 m

22. Three equal charges each +Q, placed at the corners of an equilateral triangle of side a. What will be the force on any charge $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(a) $\frac{kQ^2}{a^2}$ (b) $\frac{2kQ^2}{a^2}$
(c) $\frac{\sqrt{2}kQ^2}{a^2}$ (d) $\frac{\sqrt{3}kQ^2}{a^2}$

23. Three identical charges are placed at the corners of an equilateral triangle. If the force between any two charges is F, then the net force on each will be

(a) $\sqrt{2}$ F (b) 2 F
(c) $\sqrt{3}$ F (d) 3 F

24. A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on q is zero, then the q/Q equals

(a) $-2\sqrt{2}$ (b) –1

(c) 1 (d) $-\frac{1}{\sqrt{2}}$

25. A charge q is placed at the centre of the line joining two exactly equal positive charges Q. The system of three charges will be in equilibrium, if q is equal to

(a) –Q/4 (b) +Q

(c) –Q (d) Q/2

26. Point charges +4q, –q and +4q are kept on the X-axis at points x = 0, x = a and x = 2a respectively.

(a) Only –q is in stable equilibrium

(b) None of the charges is in equilibrium

(c)All the charges are in unstable equilibrium

(d) All the charges are in stable equilibrium

27. Electrical force between two point charges is 200 N. If we increase 10% charge on one of the charges and decrease 10% charge on the other, then electrical force between them for the same distance becomes

(a) 198 N (b) 100 N

(c) 200 N (d) 99 N

28. **Assertion:** Due to Coulomb's force charges cannot apply torque on each other.

Reason: Coulomb's force is central force.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

29. **Assertion:** The Coulomb force is strongest force in the universe.

Reason: The Coulomb force is stronger than the nuclear force inside nucleus.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

30. **Assertion:** If there is Coulomb attraction between two bodies, both of them may not be charged.

Reason: They will be oppositely charged.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Electric Field

31. Electric lines of force about a negative point charge are

(a) Circular, anticlockwise (b) Circular, clockwise

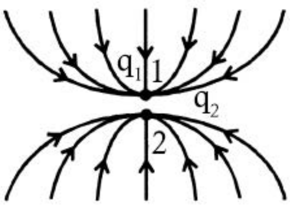
(c) Radial, inwards (d) Radial outwards

32. A force of 2.25 N acts on a charge of 15×10^{-4} C placed at point in field. Calculate the intensity of electric field at that point

(a) 1500 NC^{-1} (b) 150 NC^{-1}

(c) 15000 NC^{-1} (d) none of the above

33. Figure given here is plot of lines of force due to two charges $q_1$and q_2. The signs of the two charges are:



(a) both positive

(b) both negative

(c) upper positive, lower negative

(d) upper negative, lower positive

34. Electric lines of force

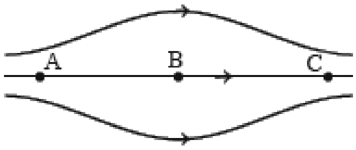
(a) exist every where

(b) exist only in the immediate vicinity of electric charge

(c) exist only when both positive and negative charges are near each other

(d) are imaginary

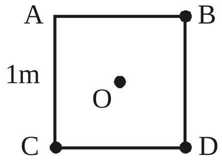
35. The figure shows some of the electric field lines corresponding to an electric field. The figure suggests



(a) $E_A > E_B > E_C$. (b) $E_A = E_B = E_C$

(c) $E_A = E_C > E_B$ (d) $E_A > E_C > E_B$

36. Three charges, each of +4μC, are placed at the corners B, C, D of a square ABCD of side 1 m. The electric field at the centre O of the square is



(a) 7.2×10^4 N towards A

(b) 7.2×10^4 N towards C

(c) 3.6×10^4 N towards A

(d) 3.6×10^4 N towards C

As clear from the diagram, this field acts towards A.

37. The point charges Q and –2Q are placed at some distance apart. If the electric field at the location of Q is E, the electric field at the location of –2Q will be:

(a) $-\frac{3E}{2}$ (b) –E

(c) $-\frac{E}{2}$ (d) –2E

38. **Assertion:** Electric lines of force never cross each other.

Reason: Electric fields at a point superimpose to give one resultant electric field.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

39. **Assertion:** Three equal charges are situated on a circle of radius r such that they form an equilateral triangle, then the electric field intensity at the centre is zero.

Reason: The forces on unit positive charge at the centre, due to three equal charges are represented by the three sides of a triangle taken in the same order. Therefore, electric field intensity at centre is zero.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

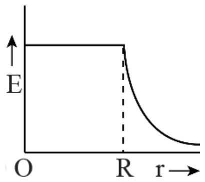
Electric field due to continuous charge distribution

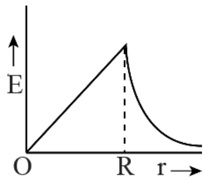
40. The electric field strength due to a uniformly charged ring of radius R at a distance x from its centre on its axis carrying charge Q has somewhere maximum value on the axis. This is at distance

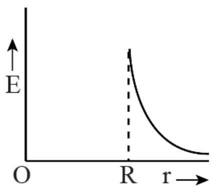
(a) x = R (b) x = 2R

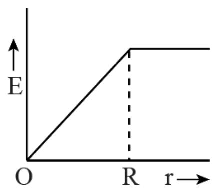
(c) x = 0 (d) $x = \frac{R}{\sqrt{2}}$

41. The electric field due to a uniformly charged non-conducting sphere of radius R as a function of the distance from its centre is represented graphically by

(a)


(b)


(c)


(d)


42. The charge density on the surface of a conducting sphere is 64×10^{-7} C/m^2 and the electric intensity at a distance of 2 m from the centre of the sphere is $4\pi\times 10^4$ N/C. The radius of the sphere is

(a) 0.83 m (b) 0.4 m

(c) 0.6 m (d) 0.38 m

43. The number of electrons to be put on spherical conductor of radius 0.1 m, to produce an electric field of 0.036 N/C just above its surface, is:

(a) 3.4×10^5 (b) 2.5×10^5

(c) 3.7 × 105 (d) 4.7×10^5

44. The electric intensity outside a charged sphere of radius R at a distance r(r > R) is

(a) $\frac{\sigma R^2}{\varepsilon_0 r^2}$ (b) $\frac{\sigma r^2}{\varepsilon_0 R^2}$

(c) $\frac{\sigma r}{\varepsilon_0 R}$ (d) $\frac{\sigma R}{\varepsilon_0 r}$

45. A charged particle is free to move in an electric field. It will travel

(a) always along a line of force

(b) along a line of force, if its initial velocity is zero

(c) along a line of force, if it has same initial velocity in the direction of an active angle with the line of force

(d) None of the above

46. Forces exerted by a uniform electric field on an electron having mass m_e and proton of mass m_p are represented as F_e and F_p respectively are related as

(a) $F_p = F_e$ (b) $\frac{F_e}{F_p} = \frac{m_e}{m_p}$

(c) $\frac{F_e}{F_p} = \frac{m_p}{m_e}$ (d) $\frac{F_e}{F_p} = \frac{m_e^2}{m_p^2}$

47. A particle of mass 2×10^{-3} kg, charge 4×10^{-3} C enters in an electric field of 5 V/m, then its kinetic energy after 10 s is

(a) 0.1 J (b) 1 J

(c) 10 J (d) 100 J

48. An electron moves through a small distance in a uniform electric field. The magnitude of electric field is 2×10^4 NC^{-1}. Now, if the direction of field is reversed keeping the magnitude same and a proton moves through the same distance, then which of the following options is correct?

(a) The time of fall will be more in case of electron

(b) The time of fall will be more in case of proton

(c) The time of fall will be same in both cases

(d) The time of fall will be independent of charge

49. A pendulum bob of mass m carrying a charge q is at rest with its string making an angle θ with the vertical in a uniform horizontal electric field E. The tension in the string is

(a) $\frac{mg}{\sin\theta}$ or $\frac{qE}{\cos\theta}$ (b) $\frac{mg}{\cos\theta}$ or $\frac{qE}{\sin\theta}$

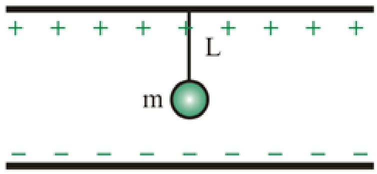
(c) $\frac{qE}{mg}$ (d) $\frac{mg}{qE}$

50. Charge q is uniformly distributed over a thin half ring of radius R. The electric field at the centre of the ring is

(a) $\frac{q}{2\pi^2\varepsilon_0 R^2}$ (b) $\frac{q}{4\pi^2\varepsilon_0 R^2}$

(c) $\frac{q}{4\pi\varepsilon_0 R^2}$ (d) $\frac{q}{2\pi\varepsilon_0 R^2}$

51. A small sphere carrying a charge 'q' is hanging in between two parallel uncharged plates by a string of length L. Time period of the pendulum is T_0. When the parallel plates are charged, creates electric field E between the plates, the time period changes to T. The ratio T/T_0 is equal to



(a) $\left(\frac{g+\frac{qE}{m}}{g}\right)^{1/2}$ (b) $\left(\frac{g}{g+\frac{qE}{m}}\right)^{3/2}$

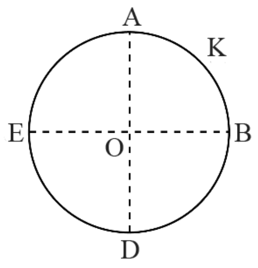
(c) $\left(\frac{g}{g+\frac{qE}{m}}\right)^{1/2}$ (d) None of these

52. A semi-circular arc of radius 'a' is charged uniformly and the charge per unit length is λ. The electric field at the centre of this arc is

(a) $\frac{\lambda}{2\pi\varepsilon_0 a}$ (b) $\frac{\lambda}{2\pi\varepsilon_0 a^2}$

(c) $\frac{\lambda}{4\pi^2\varepsilon_0 a}$ (d) $\frac{\lambda^2}{2\pi\varepsilon_0 a}$

53. A thin conducting ring of radius R is given a charge +Q. The electric field at the centre O of the ring due to the charge on the part AKB of the ring is E. The electric field at the centre due to the charge on the part ACDB of the ring is



(a) 3 E along KO (b) E along OK

(c) E along KO (d) 3 E along OK

54. An oil drop having a mass 4.8×10^{-10} g and charge 2.4×10^{-18}C stands still between two charged horizontal plates separated by a distance of 1 cm. If now the polarity of the plates is changed, instantaneous acceleration of the drop is (g =10 ms-2)

(a) 5 ms^{-2} (b) 10 ms^{-2}

(c) 15 ms^{-2} (d) 20 ms^{-2}

55. **Assertion:** If a proton and an electron are placed in the same uniform electric field. They experience different acceleration.

Reason: Electric force on a test charge is independent of its mass.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

56. **Assertion:** A point charge is brought in an electric field. The field at a nearby point will increase, whatever be the nature of the charge.

Reason: The electric field is independent of the nature of charge.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

57. **Assertion:** The graph of the intensity of electric field (E) inside a uniformly charged non-conducting sphere with the distance r from the centre of the sphere is a straight line passing through the origin.

Reason: Inside a uniformly charged non-conducting sphere, the electric field at a distance r is from the centre is given by $E = \frac{KQ}{R^3}r$.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Gauss's law

58. A plane area of 100 cm^2 is placed in uniform electric field of 100 N/C such that the angle between area vector and electric field is 60°. The electric flux through the surface is

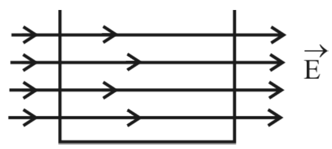
(a) 0.5 Wb (b) 5 Wb

(c) 1 Wb (d) 0

59. Electric flux through a surface element $dS = 5\hat{i}$ placed in an electric field $E = 4\hat{i} + 4\hat{j} + 4\hat{k}$ is

(a) 10 units (b) 20 units
(c) 4 units (d) 16 units

60. A square surface of side L meters is in the plane of the paper. A uniform electric field $\vec{E}$ (volt/m), also in the plane of the paper, is limited only to the lower half of the square surface, (see figure). The electric flux in SI units associated with the surface is



(a) $EL^2/2$ (b) zero

(c) EL^2 (d) $EL^2/(2\varepsilon_0)$

61. The number of lines of force passing normally through unit area of a surface situated in an electric field is called as:

(a) surface charge density

(b) electric flux density through that surface which is equal to E

(c) linear density

(d) molecular density

62. The electric flux through a closed surface area S enclosing charge Q is ϕ. If the surface area is doubled, then the flux is

(a) 2ϕ (b) $\phi/2$

(c) $\phi/4$ (d) ϕ

63. A point charge of value 10^{-7} C is situated at the centre of cube of 1 m side. The electric flux through its total surface area is

(a) 113×10^4 Nm^2/C (b) 11.3×10^4 Nm^2/C

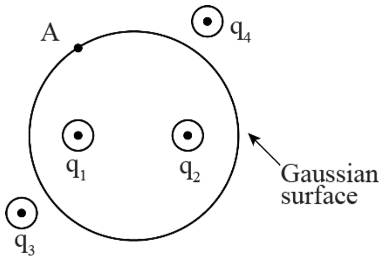
(c) 1.13×10^4 Nm^2/C (d) none of these

64. A charge q is located at the centre of a cube. The electric flux through any face is

(a) $\frac{q}{6(4\pi\varepsilon_0)}$ (b) $\frac{2\pi q}{6(4\pi\varepsilon_0)}$

(c) $\frac{4\pi q}{6(4\pi\varepsilon_0)}$ (d) $\frac{\pi q}{6(4\pi\varepsilon_0)}$

65. Consider the Gaussian surface that surrounds part of charge distributions. Then contribution of the electric field at a point A arises from charges



(a) $q_1$and q_2 only (b) $q_1$and q_4 only

(c) q_1, $q_2$and q_1 only (d) all of these

66. Gauss's law is valid for

(a) any closed surface

(b) only regular closed surfaces

(c) any open surface

(d) only irregular open surfaces

67. If the flux of the electric field through a closed surface is zero then

(a) Electric field must be zero everywhere on the surface

(b) Total charge inside the surface must be zero

(c) Electric field must be uniform throughout the closed surface

(d) Charge outside the surface must be zero

68. A hollow insulated conduction sphere is given a positive charge of $10\mu C$. What will be the electric field at the centre of the sphere if its radius is 2 metres?

(a) zero (b) $5\mu Cm^{-2}$

(c) $20\mu Cm^{-2}$ (d) $8\mu Cm^{-2}$

69. A solid sphere of radius R has a uniform distribution of electric charge in its volume. At a distance x from its centre for x < R, the electric field is directly proportional to

(a) $1/x^2$ (b) $1/x$

(c) x (d) x^2

70. **Assertion:** The electric flux emanating out and entering a closed surface are 8×10^3 V m and 2×10^3 V m, respectively. The charge enclosed by the surface is 0.053 μC.

Reason: According to Gauss's theorem in electrostatics, net flux enclosed $\phi = q/\varepsilon_o$.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

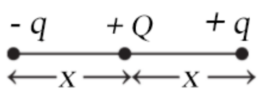
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Electric Potential Energy

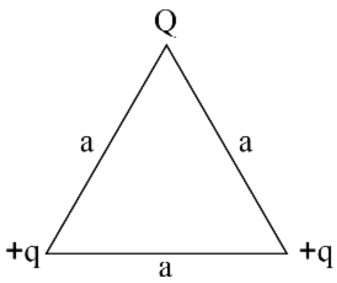
71. Three charges $-q, +Q$ and $+q$ are placed in a straight line as shown. If the total potential energy of the system is zero, then the ratio q/Q is



(a) 2 (b) 5.5

(c) 4 (d) 1.5

72. Three charges are placed at the vertex of an equilateral triangle as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) – q (b) q/2

(c) – 2q (d) – q/2

73. In bringing an electron towards another electron, the electrostatic potential energy of the system

(a) decreases (b) increases

(c) remains same (d) becomes zero

74. If a positive charge is shifted from a low potential region to a high potential region, then electric potential energy

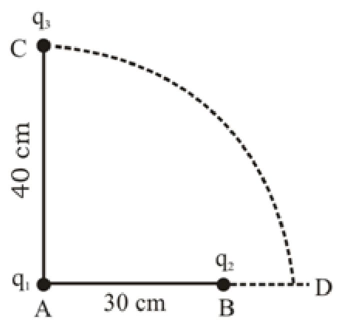
(a) decreases

(b) increases

(c) remains same

(d) may increase or decrease

75. Two charges q_1 and q_2 are placed 30 cm apart, as shown in the figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D. The change in the potential energy of the system is $\frac{q_3}{4\pi\epsilon_0}k$, where k is



(a) $8q_1$ (b) $6q_1$

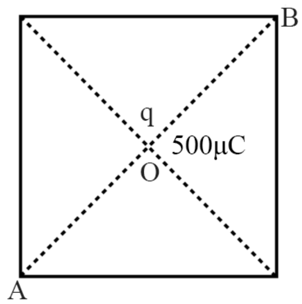
(c) $8q_2$ (d) $6q_2$

76. Three point charges $q, -2q$ and $-2q$ are placed at the vertices of an equilateral triangle of side a. The work done by some external force to increase their separation to 2a will be

(a) $\frac{1}{4\pi\varepsilon_0}\frac{2q^2}{a}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{2a}$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{8q}{a^2}$ (d) zero

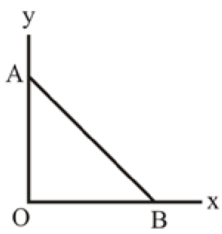
77. A 500 mC charge is at the centre of a square of side 10 cm. Find the work done in moving the charge of 10 μC between two diagonally opposite points on the square.



(a) 2 J (b) 0 J

(c) 4 J (d) 25 J

78. As per the diagram, a point charge +q is placed at the origin O. Work done in taking another point charge –Q from the point A [coordinates (0, a)] to another point B [coordinates (a; 0)] along the straight path AB is:



(a) Zero (b) $\left(\frac{-qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\sqrt{2}a$

(c) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\cdot\frac{a}{\sqrt{2}}$ (d) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\cdot\sqrt{2}a$

79. A charge of 8 mC is located at the origin. Calculate the work done in taking a small charge of -2×10^{-9} C from a point P (0, 0, 3 cm) to a point Q (0, 4 cm, 0), via a point R (0, 6 cm, 9 cm).

(a) 1.2J (b) 2J

(c) 4J (d) 1J

80. Positive and negative point charges of equal magnitude are kept at $\left(0,0,\frac{a}{2}\right)$ and $\left(0,0,\frac{-a}{2}\right)$ respectively. The work done by the electric field when another positive point charge is moved from (–a, 0, 0) to (0, a, 0) is

(a) positive

(b) negative

(c) zero

(d) depends on the path connecting the initial and final positions

81. A bullet of mass 2 g is having a charge of $2\mu C$. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s?

(a) 50 V (b) 5 KV

(c) 50 KV (d) 5 V

82. An electron of mass m and charge e is accelerated from rest through a potential difference V in vacuum. The final speed will be:

(a) $\frac{2eV}{m}$ (b) $v\sqrt{\frac{e}{m}}$

(c) $\sqrt{\frac{3eV}{m}}$ (d) $\sqrt{\frac{2eV}{m}}$

83. A proton is about 1840 times heavier than an electron. When it is accelerated by a potential difference of 1 kV, its kinetic energy will be:

(a) 1840 keV (b) 1/1840 keV

(c) 1 keV (d) 920 keV

84. A particle of mass 2g and charge $1\mu C$ is held at a distance of 1m from a fixed charge 1mC. If the particle is released it will be repelled. The speed of particle when it is at a distance of 10m from the fixed charge is:

(a) 90 m/s (b) 100 m/s

(c) 45 m/s (d) 55 m/s

85. Two charged particles having charges 1μC and –1μC and of mass 50 gm each are held at rest while their separation is 2 meters. Find the speed of the particles when their separation is 1 meter.

(a) 0.20 m/s (b) 0.6 m/s

(c) 0.3 m/s (d) 0.4 m/s

86. **Assertion:** Work done in carrying + q charge from one surface A to another surface B at the same potential is zero.

Reason: Work done in moving a charge is product of charge and potential difference.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

reason is the correct explanation of the assertion.

Electric Potential

87. Electric Potential is a:

(a) Scalar quantity (b) Vector quantity

(c) Both of the above (d) None of the above

88. The work done on a unit positive charge in bringing it from infinity to any point in the field is called

(a) Electric potential at that point

(b) Electric intensity at that point

(c) Capacity

(d) Electric potential energy at that point

89. The electrostatic potential of a uniformly charged thin spherical shell of charge Q and radius R at a distance r from the centre is

(a) $\frac{Q}{4\pi\varepsilon_0 r}$ for points outside and $\frac{Q}{4\pi\varepsilon_0 R}$ for points on surface of the sphere

(b) $\frac{Q}{4\pi\varepsilon_0 r}$ for both points inside and outside the shell

(c) zero for points outside and $\frac{Q}{4\pi\varepsilon_0 r}$ for points inside the shell

(d) zero for both points inside and outside the shell

90. Two electric charges $12\mu C$ and $-6\mu C$ are placed 20 cm apart in air. There will be a point P on the line joining these charges and outside the region between them, at which the electric potential is zero. The distance of P from $-6\mu C$ charge is

(a) 0.10 m (b) 0.15 m

(c) 0.20 m (d) 0.25 m

91. A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is

(a) zero (b) 10 V

(c) same as at a point 5 cm away from the surface

(d) same as at a point 25 cm away from the surface

92. A solid spherical conductor is given a charge. The electrostatic potential of the conductor is

(a) Constant throughout the conductor

(b) Largest at the centre

(c) Largest on the surface

(d) Largest somewhere between the centre and the surface

93. Two charged spheres of radii R_1 and R_2 have equal surface charge density. The ratio of their potential is

(a) R_1/R_2 (b) R_2/R_1

(c) $(R_1/R_2)^2$ (d) $(R_2/R_1)^2$

94. An arc of radius r carries charge. The linear density of charge is λ and the arc subtends an angle $\pi/3$ at the centre. What is electric potential at the centre

(a) $\frac{\lambda}{4\varepsilon_0}$ (b) $\frac{\lambda}{8\varepsilon_0}$

(c) $\frac{\lambda}{12\varepsilon_0}$ (d) $\frac{\lambda}{16\varepsilon_0}$

95. The potential of a large liquid drop when eight liquid drops are combined is 20 V. Then, the potential of each single drop was

(a) 10 V (b) 7.5 V

(c) 5 V (d) 2.5 V

96. **Assertion:** Electrons move away from a low potential region to high potential region.

Reason: Because electrons have negative charge.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Electric Field and Potential

97. The electric potential at a point in free space due to a charge Q coulomb is $Q \times 10^{11}$ V. The electric field at that point is

(a) $4\pi\varepsilon 0\ Q \times 10^{22}$ V/m

(b) $12\pi\varepsilon 0\ Q \times 10^{22}$ V/m

(c) $4\pi\varepsilon 0\ Q \times 10^{22}$ V/m

(d) $12\pi\varepsilon 0\ Q \times 10^{22}$ V/m

98. In a uniform electric field

(a) All points are at same potential

(b) no two points can have same potential

(c) pair of points separated by same distance must have same difference of potential

(d) none of these

99. A conducting sphere of radius R is charged to a potential of V volt. Then the electric field at a distance r (> R) from the centre of the sphere would be

(a) $\frac{RV}{r^2}$ (b) $\frac{V}{r}$

(c) $\frac{rV}{R^2}$ (d) $\frac{R^2V}{r^3}$

100. Which of the following is proportional to the inverse square of distance r.

(a) The potential at a distance r from an isolated point charge

(b) Electric field at distance r from an isolated point charge

(c) The force per unit length between two thin straight charged conductors separated by distance r

(d) Electrostatic force between two large charged bodies kept at small separation apart.

101. Which of the following is not the property of equipotential surfaces?

(a) They do not cross each other

(b) They are concentric spheres for uniform electric field

(c) Rate of change of potential with distance on them is zero

(d) They can be imaginary spheres

102. What is not true for equipotential surface for uniform electric field?

(a) Equipotential surface is flat

(b) Equipotential surface is spherical

(c) Electric field lines are perpendicular to equipotential

surface

(d) Work done is zero

103. An electric field is spread uniformly in Y-axis. Consider a point A as origin point. The coordinates of point B are equal to (0, 2) m. The coordinates of point C are (2, 0) m. At points A B, and C, electric potentials are V_A, V_B and V_C, respectively. From the following options, which is correct?

(a) $V_A = V_C < V_B$ (b) $V_A = V_B = V_C$

(c) $V_A = V_B > V_C$ (d) $V_A = V_C > V_B$

104. The work done in moving a positive charge on an equipotential surface is

(a) finite and positive (b) infinite

(c) finite and negative (d) zero

105. The electric field lines are closer together near an object A than they are near an object B, we can conclude

(a) The potential near A is greater than near B

(b) The potential near A is less than near B

(c) The potential near A is equal to potential near B

(d) nothing about relative potential be predicted

106. Given a metallic uniformly charged sphere. The radius of the sphere is increased keeping its potential same. What is the effect on the value of the electric field intensity at its surface?

(a) increases (b) decreases

(c) remains constant (d) nothing can be said

107. From a point charge, there is a fixed-point A. At A, there is an electric field of 500V/m and potential difference of 3000 V. Distance between point charge and A will be:

(a) 6 m (b) 12 m

(c) 16 m (d) 24 m

108. A particle of mass m and charge q is placed at rest in a uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is:

(a) qEy^2 (b) qE^2y

(c) qEy (d) q^2Ey

109. There is an electric field E in x-direction. If the work done on moving a charge of 0.2 C through a distance of 2 m along a line making an angle 60° with x-axis is 4J, then what is the value of E?

(a) 3 N/C (b) 4 N/C

(c) 5 N/C (d) 20 N/C

110: n identical mercury droplets charged to the same potential V coalesce to form a single bigger drop. The potential of new drop will be

(a) V/n (b) nV

(c) nV^2 (d) $n^{2/3}V$

111. The electric potential at any point x, y, z in metres is given by $V = 3x^2$. The electric field at a point (2, 0, 1) is

(a) 12 Vm^{-1} (b) – 6 Vm^{-1}

(c) 6 Vm^{-1} (d) – 12 Vm^{-1}

112. The potential at a point x (measured in μm) due to some charges situated on the x-axis is given by:

$V(x) = 20/(x^2 - 4)$ volt

The electric field E at x = 4μm is given by

(a) $\frac{5}{3} V/\mu m$ and in the –ve x direction

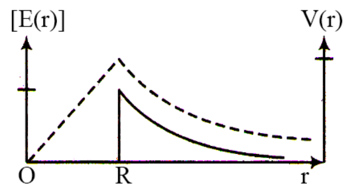
(b) $\frac{5}{3} V/\mu m$ and in the +ve x direction

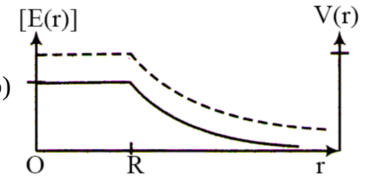
(c) $\frac{10}{9} V/\mu m$ and the –ve x direction

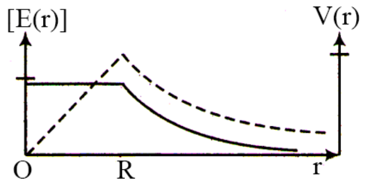
(d) $\frac{10}{9} V/\mu m$ and in the +ve x direction

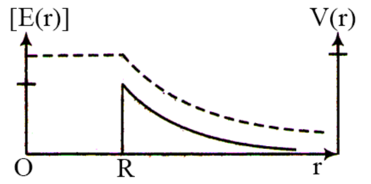
The value of the electric field E is positive, hence the electric field is in the positive x-direction.

113. Consider a thin spherical shell of radius R with its centre at the origin carrying uniform positive surface charge density. The variation of the magnitude of the electric field |E (r)| and the electric potential V (r) with the distance r from the centre, is best represented by which graph?

(a) 

(b) 

(c) 

(d) 

114. The potential of the electric field produced by point charge at any point (x,y,z) is given by $V = 3x^2 + 5$, where x, y are in metre and V is in volt. The intensity of the electric field at $(-2,1,0)$ is

(a) $+17\,Vm^{-1}$ (b) $-17\,Vm^{-1}$

(c) $+12\,Vm^{-1}$ (d) $-12\,Vm^{-1}$

115. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field at that point is:

(a) $\vec{E} = \hat{i}\left(2xy + z^3\right) + \hat{j}x^2 + \hat{k}3xz^2$

(b) $\vec{E} = \hat{i}\,2xy + \hat{j}\left(x^2 + y^2\right) + \hat{k}\left(3xz - y^2\right)$

(c) $\vec{E} = \hat{i}z^3 + \hat{j}xyz + \hat{k}z^2$

(d) $\vec{E} = \hat{i}\left(2xy - z^3\right) + \hat{j}xy^2 + \hat{k}3z^2x$

116. **Assertion:** The value of V and E at the middle point of the line joining an electron and a proton is zero.

Reason: V is a vector and E is a scalar.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

117. **Assertion:** At a point in space, the electric field points toward north. In the region, surrounding this point the rate of change of potential will be zero along the east and west.

Reason: Electric field due to a charge is the space around the charge.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Electric Dipole

118. The electric dipole moment of an electron and a proton 4.3 nm apart is

(a) $6.88 \times 10^{-28}\,C - m$

(b) $2.56 \times 10^{-29}\,C^2 - m^{-1}$

(c) $3.72 \times 10^{-14}\,C - m^{-1}$

(d) $1.1 \times 10^{-46}\,C^2 - m$

119. What is the angle between the electric dipole moment and the electric field strength due to it on the equatorial line?

(a) 0° (b) 90°

(c) 180° (d) none of these

120. Let E_a be the electric field due to a dipole in its axial plane distant l and let E_q be the field in the equatorial plane distant l, then the relation between E_a and E_q will be:

(a) $E_a = 4\,E_q$ (b) $E_q = 2\,E_a$

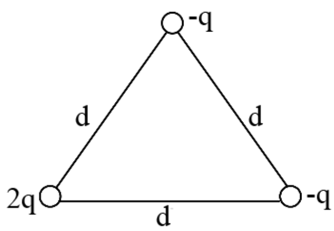
(c) $E_a = 2\,E_q$ (d) $E_q = 3\,E_a$

121. A charge situated at a certain distance along the axis of an electric dipole experience a force F. If the distance of the charge from the dipole is doubled, then the force acting on it will become

(a) 2F (b) $\frac{F}{2}$

(c) $\frac{F}{4}$ (d) $\frac{F}{8}$

122. Three charges are arranged on the vertices of an equilateral triangle as shown. The dipole moment of the combination is



(a) zero (b) 2qd

(c) $\sqrt{3}qd$ (d) 3qd

123. A point Q lies on the perpendicular bisector of an electrical dipole of dipole moment p. If the distance of a point from the dipole is r (much larger than the size of the dipole), then the electric field at that point is proportional to

(a) p^{-1} and r^{-2} (b) p and r^{-2}

(c) p^{2} and r^{-3} (d) p and r^{-3}

124. Three point charges $+q, -2q$ and $+q$ are placed at points $(x = 0, y = a, z = 0)$, $(x = 0, y = 0, z = 0)$ and $(x = a, y = 0, z = 0)$, respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are

(a) $\sqrt{2}qa$ along $+ y -$direction

(b) $\sqrt{2}qa$ along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$

(c) qa along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$

(d) $\sqrt{2}qa$ along $+ x -$direction

125. The electric field due to an electric dipole at a distance r from its centre at axial position is E. If the dipole is rotated through an angle of 90° about its perpendicular axis, the electric field at the same point will be

(a) E (b) $\frac{E}{4}$

(c) $\frac{E}{2}$ (d) 2E

126. The electric intensity due to a dipole of length 10 cm and having a charge of 500 μC, at a point on the axis at a distance 20 cm from one of the charges in air, is

(a) 6.25×10^{7} N/C (b) 9.28×10^{7} N/C

(c) 13.1×10^{11} N/C (d) 20.5×10^{7} N/C

127. **Assertion:** A point charge placed at any point on the axis of an electric dipole at some large distance experiences a force F. The force acting on the point charge when its distance from the dipole is doubled is $\frac{F}{8}$.

Reason: Coulomb's law obeys $F \propto \frac{1}{r^{3}}$.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

128. **Assertion:** On going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.

Reason: Electric field is inversely proportional to square of distance from the charge or an electric dipole.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Dipole In Electric Field

129. If a dipole of dipole moment $\vec{p}$ is placed in a uniform electric field then torque acting on it is given by

(a) $\vec{\tau} = \vec{p}.\vec{E}$ (b) $\vec{\tau} = \vec{p} \times \vec{E}$

(c) $\vec{\tau} = \vec{p} + \vec{E}$ (d) $\vec{\tau} = \vec{p} - \vec{E}$

130. A positive charge is fixed at the origin. An electric dipole, which is free to move and rotate, is placed on the positive x–axis. Its dipole moment is directed towards the positive x-axis. The dipole will :

(a) Move towards the origin

(b) Move away from the origin

(c) Rotate by p/2

(d) Rotate by p

131. An electric dipole with a dipole moment 4×10^{-9} Cm is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^{4} NC^{-1}. Calculate the magnitude of the torque acting on the dipole.

(a) 10^{-4} Nm (b) 10^{-2} Nm

(c) 2×10^{-4} Nm (d) 5×10^{-3} Nm

132. An electric dipole of moment 'p' is lying along a uniform electric field 'E'. The work done in rotating the dipole by 90° is

(a) pE/2 (b) 2 p E

(c) p E (d) $\sqrt{2}$ p E

133. An electric dipole has the magnitude of its charge as q and its dipole moment is p. It is placed in uniform electric field E. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively

(a) q. E and max. (b) 2 q. E and min.

(c) q. E and p.E (d) zero and min.

134. An electric dipole of dipole moment $\vec{p}$ is placed in uniform electric field $\vec{E}$. It is then rotated by an angle of θ. The work done is

(a) pE sinθ (b) pE cosθ

(c) pE (1-cosθ) (d) pE (1-sinθ)

135. A charge q is placed at (1, 2, 1) and other charge –q is placed at (0,1, 0) such that they form an electric dipole. There exists a uniform electric field $\vec{E} = 2\hat{i} + 3\hat{j}$. What is torque experienced by the dipole.

(a) $q\left(3\hat{i} + 2\hat{j} + k\right)$N.m (b) $q\left(-3\hat{i} + 2\hat{j} + k\right)$N.m

(c) $q\left(-3\hat{i} + 2\hat{j} - k\right)$N.m (d) $q\left(\hat{i} - 2\hat{j} + k\right)$N.m

136. An electric dipole consists of two opposite charges each 0.05μC separated by 30 mm. The dipole is placed in a uniform external electric field of $10^6\,NC^{-1}$. The maximum torque exerted by the field on the dipole is

(a) 6×10^{-3} Nm (b) 3×10^{-3} Nm

(c) 15×10^{-3} Nm (d) 1.5×10^{-3} Nm

137. An electric dipole placed in a non-uniform electric field experience:

(a) both, a torque and a net force

(b) only a force but no torque

(c) only a torque but no net force

(d) no torque and no net force

138. **Assertion:** Electric dipole in non-uniform electric field may have translatory and rotational motion both.

Reason: Net force is always zero on dipole in non-uniform electric field.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

139. **Assertion:** When a dipole is placed along the uniform electric field it is said to be in stable equilibrium.

Reason: If dipole is along the direction of field its potential energy is maximum.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Dielectrics

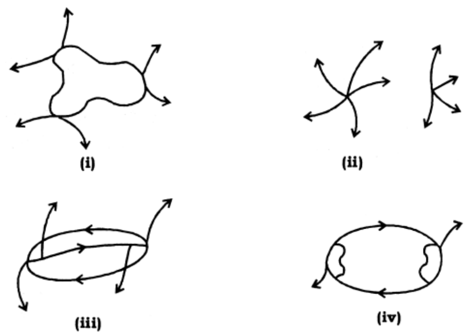
140. When air medium in which two charges kept apart at a distance r is replaced by a dielectric medium of dielectric constant K, the force between the charges is

(a) remain unchanged (b) 1/K times

(c) $\frac{1}{K^2}$ times (d) K^2 times

Conductors And Its Properties

141. Which of the following figures cannot possibly represent electrostatics field lines



(a) i, ii, iii, iv (b) i, ii, iii only

(c) i, iii, iv only (d) ii, iii, iv only

142. Two concentric metallic spherical shells are given unequal positive charges. Then,

(a) the outer sphere is always at a higher potential

(b) the inner sphere is always at a higher potential

(c) both the spheres are at the same potential

(d) no prediction can be made about their potentials unless the actual values of charges and radii are known

143. The concentric spheres of radii R and r have similar charges with equal surface densities (σ). What is the electric potential at their common centre?

(a) $\frac{\sigma}{\varepsilon_0}(R-r)$ (b) $\frac{\sigma}{\varepsilon_0}(R+r)$

(c) $\frac{R\sigma}{\varepsilon_0}$ (d) $\frac{\sigma}{\varepsilon_0}$

144. Identify the false statement.

(a) Inside a charged or neutral conductor, electrostatic field is zero.

(b) The electrostatic field at the surface of the charged conductor must be tangential to the surface at any point.

(c) There is no net charge at any point inside the conductor.

(d) Electrostatic potential is constant throughout the volume of the conductor.

(e) Electric field at the surface of a charged conductor is proportional to the surface charge density.

145. The charge given to any conductor resides on its outer surface, because

(a) the free charge tends to be in its minimum potential energy state

(b) the free charge tends to be in its minimum kinetic energy state

(c) the free charge tends to be in its maximum potential energy state

(d) the free charge tends to be in its maximum kinetic energy state

146. Surface charge density on uniformly charged sphere is

(a) Directly proportional to the radius of the sphere

(b) Inversely proportional to the radius of the sphere

(c) Directly proportional to the square of the radius of the sphere

(d) Inversely proportional to the square of the radius of the sphere

147. A circular metal plate of radius 10 cm is given a charge of 20 μC on its surface. The charge density of the plate is

(a) 6.36×10^{-4} C/m^2 (b) 2×10^{-6} C/m^2

(c) 3×10^{-9} C/m^2 (d) 3.184×10^{-4} C/m^2

148. The surface density of charge on a conductor situated in air is 2×10^4 C/m^2. The electric field intensity at a point very near to its surface is

(a) 2.2×10^{15} N/C (b) 2.2×10^9 N/C

(c) 3.3×10^7 N/C (d) 3.3×10^{15} N/C

149. If a conductor is electrically neutral, then

(a) Net charge on it should be zero

(b) Potential on it should be zero

(c) Both charge and potential should be zero

(d) None of these may not be zero

150. Which of the following may be discontinuous across a charged conducting surface?

(a) Electric potential

(b) Electric intensity

(c) Both electric intensity and potential

(d) None of these

151. **Assertion:** Electrostatic potential is constant throughout the volume of the conductor and has the same value as on its surface.

Reason: Electric field inside the conductor is zero.

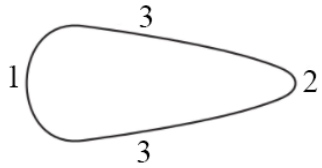
(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

152. Consider a non-spherical conductor shown in the figure which is given a certain amount of positive charge. The charge distributes itself on the surface such that the charge densities are σ_1, σ_2 and $\sigma_3$at the region 1, 2 and 3 respectively. Then



(a) $\sigma_1 > \sigma_2 > \sigma_3$ (b) $\sigma_2 > \sigma_3 > \sigma_1$

(c) $\sigma_3 > \sigma_1 > \sigma_2$ (d) $\sigma_2 > \sigma_1 > \sigma_3$

153. Two charged metallic spheres of radii r_1 and r_2 are touched and separated. What is the ratio of their surface charge density?

(a) $\frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1}$ (b) $\frac{\sigma_1}{\sigma_2} = \frac{r_1}{r_2}$

(c) $\frac{\sigma_1}{\sigma_2} = 1$ (d) $\frac{\sigma_1}{\sigma_2} = \frac{r_2 r_1}{r_1 + r_2}$

154. A conducting sphere of radius R and carrying charge Q is joined to an uncharged conducting sphere of radius 2R. The charge flowing between them would be

(a)2Q (b) $\frac{4Q}{3}$

(c) $\frac{2Q}{3}$ (d) Q

155. Two spherical conductors B and C having equal radii and carrying equal charges in them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is

(a) $\frac{F}{4}$ (b) $\frac{3F}{4}$

(c) $\frac{F}{8}$ (d) $\frac{3F}{8}$

156. A ball with charge – 50e is placed at the centre of a hollow spherical shell has a net charge of – 50e. What is the charge on the shell's outer surface?

(a) – 50 e (b) Zero

(c) – 100 e (d) + 100 e

157. **Assertion:** The lightning conductor at the top of high building has sharp pointed ends.

Reason: The surface charge density of charge at sharp points is very high resulting in setting up of electric wind.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

158. **Assertion:** The tyres of aircrafts are slightly conducting.

Reason: If a conductor is connected to the ground, the extra charge induced on the conductor will flow to the ground.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

159. **Assertion:** Electric field intensity within a conductor is always zero.

Reason: Electric field lines of force can pass through the conductor.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

160. **Assertion:** During lightning, it is safe to sit inside the car.

Reason: The hollow structure of car provides electrostatic shielding.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.
(c) Assertion is true, but Reason is false.
(d) Both Assertion and Reason are false.

EXERCISE – 2: Previous Year Questions

1. An electric dipole is placed in an uniform electric field with the dipole axis making an angle θ with the direction of the electric field. The orientation of the dipole for stable equilibrium is **[J&K CET 2011]**

(a) $\pi/6$ (b) $\pi/3$

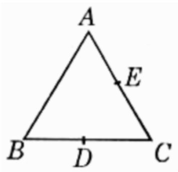
(c) 0 (d) $\pi/2$

2. The electric field at a point due to an electric dipole, on an axis inclined at an angle $\theta\left(<90^{o}\right)$ to the dipole axis, is perpendicular to the dipole axis, if the angle θ is **[KCET 2011]**

(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(1/2)$

(c) $\tan^{-1}\left(\sqrt{2}\right)$ (d) $\tan^{-1}\left(1/\sqrt{2}\right)$

3. Three charges, each +q, are placed at the corners of an isosceles triangle ABC of sides BC, AC and AB. D and E are the mid points of BC and CA. The work done in taking a charge Q from D to E is: (Given BC = AC): **[CBSE-AIPMT 2011]**



(a) zero (b) $\frac{3qQ}{4\pi\varepsilon_0 a}$

(c) $\frac{3qQ}{8\pi\varepsilon_0 a}$ (d) $\frac{qQ}{4\pi\varepsilon_0 a}$

4. The electric potential V at any, point (x, y, z), in meters in space is given by V = $4x^2$ volt. The electric field at the point (1, 0, 2) in volt/meter, is **[AIPMT 2011]**

(a) 16 along positive X-axis

(b) 8 along negative X-axis

(c) 8 along positive X-axis

(d) 16 along negative X-axis

5. A charged oil drop is suspended in uniform field of $3\times10^4\,Vm^{-1}$, so that it neither falls nor rise. The charge on the drop will be (take, the mass of the charge 9.9×10^{-15}kg and $g=10\ ms^{-2}$) **[UP CPMT 2011]**

(a) $3.3\times10^{-18}C$ (b) $3.2\times10^{-18}C$

(c) $1.6\times10^{-18}C$ (d) $4.8\times10^{-18}C$

6. Charge $q_2$of mass m revolves around a stationary charge q_1 in a circular orbit of radius r. The orbital periodic time of $q_2$would be **[J&K CET 2011]**

(a) $\left[\frac{4\pi^2 mr^3}{kq_1q_2}\right]^{1/2}$ (b) $\left[\frac{kq_1q_2}{4\pi^2 mr^3}\right]^{1/2}$

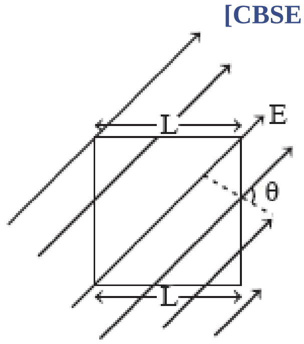
(c) $\left[\frac{4\pi^2 mr^4}{kq_1q_2}\right]^{1/2}$ (d) $\left[\frac{4\pi^2 mr^2}{kq_1q_2}\right]^{1/2}$

7. Two identical charged spheres of material density ρ, suspended from the same point by inextensible strings of equal length make an angle θ between the strings. When suspended in a liquid of density σ and the angle θremains the same. The dielectric constant K of the liquid is **[KCET 2011]**

(a) $\frac{\rho}{\rho-\sigma}$ (b) $\frac{\rho-\sigma}{\rho}$

(c) $\frac{\rho}{\rho+\sigma}$ c (d) $\frac{\rho+\sigma}{\rho}$

8. A square surface of side L metre in the plane of the paper is placed in a uniform electric field E (volt/metre) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure. The electric flux linked to the surface in unit of $Nm^2\,C^{-1}$ is **[CBSE AIPMT 2011]**



(a) EL^2 (b) $EL^2\cos\theta$

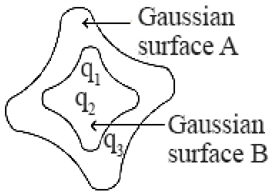
(c) $EL^2\sin\theta$ (d) zero

9. A point charge Q is placed at one of the vertices of a cubical block. The electric flux flowing through this cube is **[2011 Manipal]**

(a) $\frac{Q}{6\varepsilon_0}$ (b) $\frac{Q}{4\varepsilon_0}$

(c) $\frac{Q}{8\varepsilon_0}$ (d) $\frac{Q}{\varepsilon_0}$

10. The electric flux for Gaussian surface A that encloses the charged particles in free is (given $q_1 = -14\,nC$, $q_2 = 78.85\,nC$, $q_3 = -56\,nC$) **[MP PMT 2011]**



(a) $10^3\ Nm^2C^{-1}$ (b) $10^3\ CN^{-1}\ m^{-2}$

(c) $6.32\times10^3\ Nm^2\ C^{-1}$ (d) $6.32\times10^3\ CN^{-1}\ m^{-2}$

11. Which of the following is not true? **[EAMCET 2011]**

(a) For a point charge, the electrostatic potential varies as 1/r

(b) For a dipole, the potential depends on the position vector and dipole moment vector

(c) The electric dipole potential varies as 1/ r at large distance

(d) For a point charge, the electrostatic field varies as $1/r^2$

12. Three charges each of magnitude q are placed at the corners of an equilateral triangle, the electrostatic force on the charge placed at the centre is (each side of triangle is L) **[AFMC 2012]**

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{L^2}$

(c) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{3q^2}{L^2}$ (d) $\frac{1}{12\pi\varepsilon_0}\cdot\frac{q^2}{L^2}$

13. When a piece of polythene is rubbed with wool, a charge of $-2\times10^{-7}\,C$ is developed on polythene. What is the amount of mass which is transferred to polythene? **[UP CPMT 2012]**

(a) $5.69\times10^{-19}\,kg$ (b) $6.25\times10^{-19}\,kg$

(c) $9.63\times10^{-19}\,kg$ (d) $11.38\times10^{-19}\,kg$

14. Two metallic spheres of radii 1 cm and 3 cm are given charges of -1×10^{-2}C and 5×10^{-2}C, respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is: **[CBSE-AIPMT 2012]**

(a) 1×10^{-2}C (b) 2×10^{-2}C

(c) 3×10^{-2}C (d) 4×10^{-2}C

15. What is the flux through a cube of side 'a' if a point charge of q is at one of its corners? **[CBSE-AIPMT 2012]**

(a) $\frac{q}{2\epsilon_0}6a^2$ (b) $\frac{2q}{\epsilon_0}$

(c) $\frac{q}{8\epsilon_0}$ (d) $\frac{q}{\epsilon_0}$

16. An electric dipole of moment 'p' is placed in an electric field of intensity 'E'. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when θ = 90°, the torque and the potential energy of the dipole will respectively be: **[CBSE-AIPMT 2012]**

(a) pE cosθ, –pE sinθ (b) pE sinθ, –pE cosθ

(c) pE sinθ, –2pE cosθ (d) pE sinθ, 2pE cosθ

17. The unit of physical quantity obtained by the line integral of electric field is **[J&K CET 2012]**

(a) NC^{-1} (b) Vm^{-1}

(c) JC^{-1} (d) $C^2N^{-1}m^{-2}$

18. Four point charges -Q, – q, 2q and 2Q are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero, is **[CBSE AIPMT 2012]**

(a) Q = - q (b) $Q = -\frac{1}{q}$

(c) Q = q (d) $Q = \frac{1}{q}$

19. Two equal point charges Q are fixed at $x = -a$ and $x = +a$ on X-axis. Another point charge is placed at the origin. The change in electrical potential energy of Q, when it is displaced by a small amount x along X-axis, is approximately proportional to **[Manipal 2012]**

(a) x (b) x^2

(c) x^3 (d) $\frac{1}{x}$

20. Each of the two point charges are doubled and their distance is halved. Force of interaction becomes n times, where n is **[UP CPMT 2013]**

(a) 4 (b) 1

(c) 1/16 (d) 16

21. A cylindrical conductor is placed near another positively charged conductor. The net charge acquired by the cylindrical conductor will be

[UP CPMT, KCET 2013]

(a) positive only (b) negative only

(c) zero

(d) either positive or negative

22. An electron enters uniform electric field maintained by parallel plates and of value E Vm^{-1} with a velocity $v\,ms^{-1}$, the plates are separated by a distance d metre, then acceleration of the electron in the field is

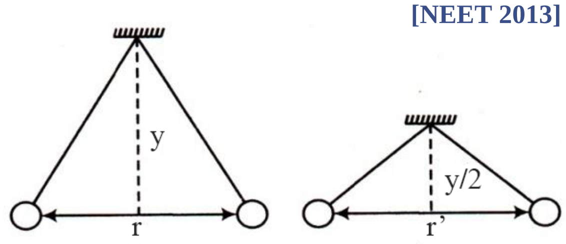
[Manipal 2013]

(a) $\frac{Ee}{m}$ (b) $\frac{-Ee}{m}$

(c) $\frac{Ee}{md}$ (d) $Ee\frac{d}{m}$

23. Two pitch balls carrying equal charges are suspended from a common point by strings of equal length, the equilibrium separation between them is r. Now, the strings are rigidly clamped at half the height. The equilibrium separation between the balls now become

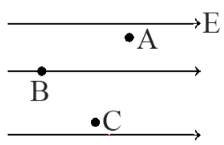
[NEET 2013]



(a) $\left(\frac{1}{\sqrt{2}}\right)^2$ (b) $\left(\frac{r}{\sqrt[3]{2}}\right)$

(c) $\left(\frac{2r}{\sqrt{2}}\right)$ (d) $\left(\frac{2r}{3}\right)$

24. A B, and C are three points in a uniform electric field. The electric potential is **[NEET 2013]**



(a) maximum at A

(b) maximum at B

(c) maximum at C

(d) same at all the three points A B, and C

25. Two charged spheres separated at a distance d exert a force F on each other. If they are immersed in a liquid of dielectric constant K = 2, then the force is (if all conditions are same) **[UK PMT 2014]**

(a) F/2 (b) F

(c) 2F (d) 4F

26. If a charge on the body is 1 nC, then how many electrons are present on the body? **[KCET 2014]**

(a) 1.6×10^{19} (b) 6.25×10^{9}

(c) 6.25×10^{27} (d) 6.25×10^{28}

27. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are:

[CBSE AIPMT 2014]

(a) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (b) Both are zero

(c) Zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (d) $\frac{Q}{4\pi\varepsilon_0 R}$ and Zero

28. In a region, the potential is represented by V (x, y, z) = 6x – 8xy – 8y + 6yz, where V is in volts and x, y, z are in meters. The electric force experienced by a charge of 2 coulomb situated at point (1,1,1) is: **[CBSE AIPMT 2014]**

(a) 24 N (b) $4\sqrt{35}$N

(c) $6\sqrt{5}$N (d) 30 N

29. Electric field at a point of distance r from a uniformly charged wire of infinite length having linear charge density λ is directly proportional to

[Kerala CEE 2014]

(a) r^{-1} (b) r

(c) r^2 (d) r^{-2}

(e) None of these

30. Two equal and opposite charges of masses m_1 and m_2 are accelerated in a uniform electric field through the same distance. What is the ratio of their accelerations, if their ratio of masses is $m_1/m_2 = 0.5$? **[KCET 2014]**

(a) $\frac{a_1}{a_2} = 0.5$ (b) $\frac{a_1}{a_2} = 1$

(c) $\frac{a_1}{a_2} = 2$ (d) $\frac{a_1}{a_2} = 3$

31. An electric dipole of dipole moment **p** is placed in a uniform external electric field **E**. Then, the **[Kerala CEE 2014]**

(a) torque experienced by the dipole is $E \times p$

(b) torque is zero, if p is perpendicular to E

(c) torque is maximum, if p is perpendicular to E

(d) potential energy is maximum, if p is parallel to E

(e) potential energy is maximum, if p is perpendicular to E

32. An electric dipole placed in a non-uniform electric field experiences **[UK PMT 2014]**

(a) both a torque and a net force

(b) only a force but no torque

(c) only a torque but no net force

(d) no torque and no net force

33. What is the nature of Gaussian surface involved in Gauss' law of electrostatics? **[KCET 2014]**

(a) Scalar (b) Electrical

(c) Magnetic (d) Vector

34. Two concentric spheres kept in air have radii R and r. They have similar charge and equal surface charge density σ. The electrical potential at their common centre is (ε_0 =permittivity of free space) **[MHT CET 2014]**

(a) $\frac{\sigma(R+r)}{\varepsilon_0}$ (b) $\frac{\sigma(R-r)}{\varepsilon_0}$

(c) $\frac{\sigma(R+r)}{2\varepsilon_0}$ (d) $\frac{\sigma(R+r)}{4\varepsilon_0}$

35. Two charges of equal magnitude q are placed in air at a distance 2a apart and third charge – 2q is placed at mid – point. The potential energy of the system is (ε_0 = permittivity of free space) **[MHT CET 2014]**

(a) $-\frac{q^2}{8\pi\varepsilon_0 a}$ (b) $-\frac{3q^2}{8\pi\varepsilon_0 a}$

(c) $-\frac{5q^2}{8\pi\varepsilon_0 a}$ (d) $-\frac{7q^2}{8\pi\varepsilon_0 a}$

36. What is the electric potential at a distance of 9 cm from 3 nC? **[KCET 2014]**

(a) 270 V (b) 3 V

(c) 300 V (d) 30 V

37. Work done in carrying an electric charge Q_1 once round a circle of radius R with a charge Q_2 at the centre of the circle is **[EAMCET 2014]**

(a) $\frac{Q_1Q_2}{4\pi\varepsilon_0 R}$ (b) ∞

(c) $\frac{Q_1Q_2}{4\pi\varepsilon_0 R^2}$ (d) 0

38. The electric field in a certain region is acting radially outward and is given by E = Ar. A charge contained in a sphere of radius 'a' centered at the origin of the field, will be given by: **[CBSE AIPMT 2015]**

(a) $\epsilon_0 Aa^3$ (b) $4\pi\epsilon_0 Aa^2$

(c) $A\epsilon_0 a^2$ (d) $4\pi\epsilon_0 Aa^3$

39. When an α-particle of mass 'm' moving with velocity '*v*' bombards on a heavy nucleus of charge 'Ze', its distance of closest approach from the nucleus depends on m as: **[NEET 2016]**

(a) $\frac{1}{m}$ (b) $\frac{1}{\sqrt{m}}$

(c) $\frac{1}{m^2}$ (d) m

40. An electric dipole is placed at an angle of 30° with an electric field intensity 2×10^5 N/C. It experiences a torque equal to 4 Nm. The charge on the dipole, if the dipole length is 2 cm is **[NEET 2016]**

(a) 2 mC (b) 5 mC

(c) 7 μC (d) 8 mC

41. The electric field strength due to a point charge of $5\mu C$ at a distance of 80 cm from the charge is **[UP CPMT 2016]**

(a) $5\times10^4\ N/C$ (b) $7\times10^4\ N/C$

(c) $3.5\times10^4\ N/C$ (d) $7\times10^2\ N/C$

42. An electric dipole is placed at an angle of 30° with an electric field intensity $2\times10^5\ N/C$. It experiences a torque equal to 4 N – m. The charge on the dipole, if the dipole length is 2 cm, is **[NEET 2016]**

(a) 8 mC (b) 2 mC

(c) 5 mC (d) 7 μC

43. A certain charge Q is divided into two parts q and Q – q. How the charge Q and q must be related, so that when q and (Q – q) is placed at a certain distance apart experience maximum electrostatic repulsion? **[JIPMER 2017]**

(a) Q = 2q (b) Q = 3q

(c) Q = 4q (d) Q = 4q + c

44. Suppose the charge of a proton and an electron differ slightly. One of them is -e and the other is $(e+\Delta e)$.

If the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance d (much greater than atomic size) apart is zero, then Δe is of the order (Take, mass of hydrogen, $m_h = 1.67\times10^{-27}$ kg)

[NEET 2017]

(a) 10^{-20} C (b) 10^{-23} C

(c) 10^{-37} C (d) 10^{-47} C

45. Two identical conducting balls A and B have positive charges q_1 and q_2 respectively but $q_1 \neq q_2$. The balls are brought together so that they touch each other and then kept in their original positions. The force between them is **[JIPMER 2017]**

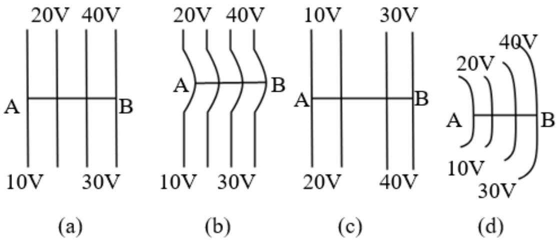
(a) less than that before the balls touched

(b) greater than that before the balls touched

(c) same as that before the balls touched

(d) zero

46. The diagrams below show regions of equipotential. **[NEET 2017]**



A positive charge is moved from A to B in each diagram.

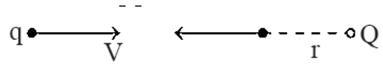
(a) Minimum work is required to move q in figure (a).

(b) Maximum work is required to move q in figure (b).

(c) Maximum work is required to move q in figure (c).

(d) In all the four cases the work done is the same.

47. A charged particle q is shot with speed towards another fixed charged particle Q. It approaches Q upto a closest distance r and then returns. If q were given a speed $2v$, the closest distance of approach would be **[JIPMER 2017]**



(a) r (b) 2r

(c) r/2 (d) r/4

48. An electron falls from rest through a vertical distance h in a uniform and vertically upward directed electric field E. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance h. The time of fall of the electron, in comparison to the time of fall of the proton is **[NEET 2018]**

(a) 10 times greater (b) 5 times greater

(c) smaller (d) equal

49. Two-point charges A and B, having charges +Q and –Q respectively; are placed at certain distance apart and force acting between them is F. If 25% charge of A is transferred to B, then force between the charges becomes **[NEET 2019]**

(a) $\dfrac{9F}{16}$ (b) $\dfrac{16F}{9}$

(c) $\dfrac{4F}{3}$ (d) F

50. A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre is: **[NEET 2019]**

(a) zero as r increases for r < R, decreases as r increases for r > R

(b) zero as r increases for r < R, increases as r increases for r > R

(c) decreases as r increases for r < R and for r > R

(d) increases as r increases for r < R and for r > R

51. Two parallel infinite line charges with linear charge densities $+\lambda$ C/m and $-\lambda$ C/m are placed at a distance of 2R in free space. What is the electric field mid-way between the two ine charges? **[NEET 2019]**

(a) $\dfrac{2\lambda}{\pi\varepsilon_0 R}$ N / C (b) $\dfrac{\lambda}{\pi\varepsilon_0 R}$ N / C

(c) $\dfrac{\lambda}{2\pi\varepsilon_0 R}$ N / C (d) Zero

52. Two metal spheres, one of radius R and the other of radius 2R respectively have the same surface charge density σ. They are brought in contact and separated. What will be the new surface charge densities on them? **[2019 NEET Odisha]**

(a) $\sigma_P = \frac{5}{6}\sigma,\ \sigma_Q = \frac{5}{2}\sigma$ (b) $\sigma_P = \frac{5}{2}\sigma,\ \sigma_Q = \frac{5}{6}\sigma$

(c) $\sigma_P = \frac{5}{2}\sigma,\ \sigma_Q = \frac{5}{3}\sigma$ (d) $\sigma_P = \frac{5}{3}\sigma,\ \sigma_Q = \frac{5}{6}\sigma$

53. A sphere encloses an electric dipole with charge $\pm 3\times10^{-6}\,C$. What is the total electric flux across the sphere? **[2019 NEET Odisha]**

(a) $-3\times10^{-6}\ N-m^2/C$

(b) Zero

(c) $3\times10^{6}\ N-m^2/C$

(d) $6\times10^{-6}\ N-m^2/C$

54. Potential difference is given as V(x) = $-x^2y$ volt. Find electric field at a point (1, 2) **[JIPMER 2019]**

(a) $\hat{i}+4\hat{j}\,Vm^{-1}$ (b) $-4\hat{i}-\hat{j}\,Vm^{-1}$

(c) $4\hat{i}+\hat{j}\,Vm^{-1}$ (d) $4\hat{i}-\hat{j}\,Vm^{-1}$

55. A spherical conductor of radius 10 cm has a charge of 3.2×10^{-7} C distributed uniformly, what is the magnitude of electric field at a point 15 cm from the centre of the sphere? **[NEET 2020]**

$\left(\frac{1}{4\pi\epsilon_0} = 9\times10^9\ Nm^2/C^2\right)$

(a) $1.28\times10^4\ N/C$ (b) $1.28\times10^5\ N/C$

(c) $1.28\times10^6\ N/C$ (d) $1.28\times10^7\ N/C$

56. In a certain region of space with volume $0.2\,m^3$, the electric potential is found to be 5 V throughout. The magnitude of electric field in this region is: **[NEET 2020]**

(a) 1 N/C (b) 5 N/C

(c) Zero (d) 0.5 N/C

57. A short electric dipole has a dipole moment of 16×10^{-9} Cm. The electric potential due to the dipole at a point at a distance of 0.6 m from the centre of the dipole, situated on a line making an angle of 60º with the dipole axis is: **[NEET 2020]**

$\left(\frac{1}{4\pi\epsilon_0} = 9\times10^9\ Nm^2/C^2\right)$

(a) 400 V (b) zero

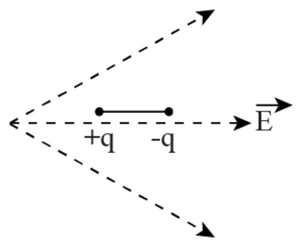
(c) 50 V (d) 200 V

58. Two charged spherical conductors of radius R_1 and R_2 are connected by a wire. Then the ratio of surface charge densities of the spheres (σ_1/σ_2) is: **[NEET 2021]**

(a) $\frac{R_1}{R_2}$ (b) $\frac{R_2}{R_1}$

(c) $\sqrt{\left(\frac{R_1}{R_2}\right)}$ (d) $\frac{R_1^2}{R_2^2}$

59. A dipole is placed in an electric field as shown. In Which direction will it move?



[NEET 2021]

(a) Towards the left as its potential energy will increase.

(b) Towards the right as its potential energy will decrease.

(c) Towards the left as its potential energy will decrease.

(d) Towards the right as its potential energy will increase.

60. Twenty even drops of same size are charged at 220 V each. They combine to form a bigger drop. Calculate the potential of the bigger drop **[NEET 2021]**

(a) 660 V (b) 1320 V

(c) 1520 V (d) 1980 V

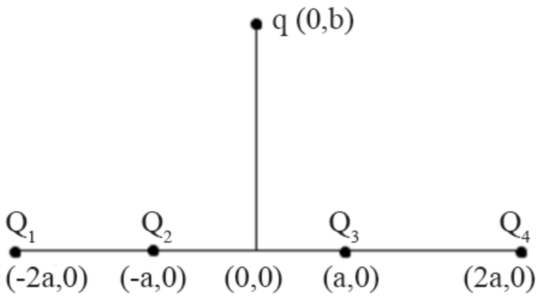
EXERCISE – 3: Achiever's Section

1. Four charges each equal to – Q are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium, the value of q is

(a) $-\frac{Q}{4}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

(c) $-\frac{Q}{2}(1+2\sqrt{2})$ (d) $\frac{Q}{2}(1+2\sqrt{2})$

2. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x axis at x = – 2a, –a, +a and +2a, respectively. A positive charge q is placed on the positive y axis at a distance b> 0. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match List I with List II and select the correct answer using the code given below the lists.



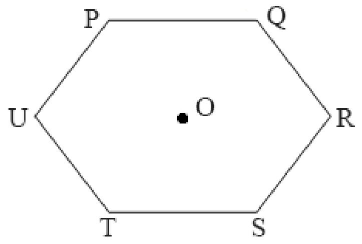
List I	**List II**
P. Q_1, Q_2, Q_3, Q_4 all positive	1. +x
Q. Q_1, Q_2 positive; Q_3, Q_4 negative	2. –x
R. Q_1, Q_4 positive; Q_2, Q_3 negative	3. +y
S. Q_1, Q_3 positive; Q_2, Q_4 negative	4. –y

Codes :

(a) P -3, Q-1, R-4, S-2 (b) P-4, Q-2, R-3, S-1

(c) P-3, Q-1, R-2, S-4 (d) P-4, Q-2, R-1, S-3

3. Six charges of equal magnitudes, 3 positives and 3 negatives are to be placed on PQRSTU corners of a regular hexagon, such that field at the centre is double that of what it would have been if only one +ve charge is placed at R.



(a) +, +, +, –, –, – (b) –, +, +, +, –, –

(c) –, +, +, –, +, – (d) +, –, +, –, +, –

4. A ring of charge with radius of 50 cm has gap of 0.002 C_3=1μF m. If the ring carries a charge of 1 C, what is the electric field at the centre?

(a) 8.5 × C_1=1μF N/C (b) 7.2 × C_4=1μF N/C

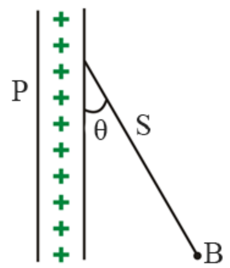
(c) 3.2 × C_2=1.5μF N/C (d) 4.5 × C_4=3μF N/C

5. An electron is rotating around an infinite positive linear charge in a circle of radius 0.1 m, if the linear charge density is 1 μC/m then the velocity of electron in m/s will be

(a) 0.562×10^7 (b) 5.62×10^7

(c) 562×10^7 (d) 0.0562×10^7

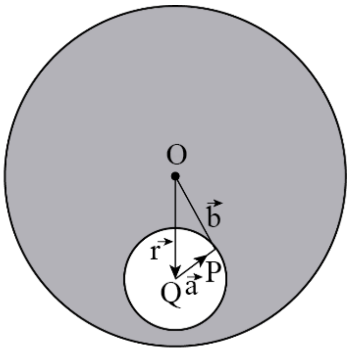
6. A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to



(a) $\cos\theta$ (b) $\cot\theta$

(c) $\sin\theta$ (d) $\tan\theta$

7. A spherical portion has been removed from a solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is



(a) zero everywhere

(b) non-zero and uniform

(c) non-uniform

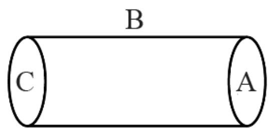
(d) zero only at its centre

8. Positive charge Q is distributed uniformly over a circular ring of radius R. A point particle having a mass (m) and a negative charge − q is placed on its axis at a distance x from the centre. Assuming x < R, find the time period of oscillation of the particle, if it is released from there [neglect gravity].

(a) $\left[\dfrac{16\pi^3\varepsilon_0 R^3 m}{Qq}\right]^{1/2}$ (b) $\left[\dfrac{8\pi^3\varepsilon_0 R^3}{q}\right]^{1/2}$

(c) $\left[\dfrac{2\pi^3\varepsilon_0 R^3}{3q}\right]^{1/2}$ (d) None of these

9. A hollow cylinder has a charge q C within it. If ϕ is the electric flux in unit of voltmeter associated with the curved surface B, the flux linked with the plane surface A in unit of voltmeter will be



(a) $\dfrac{1}{2}\left(\dfrac{q}{\varepsilon_0}-\phi\right)$ (b) $\dfrac{q}{2\varepsilon_0}$

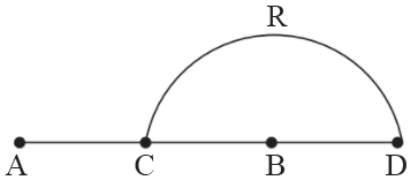
(c) $\dfrac{\phi}{3}$ (d) $\dfrac{q}{\varepsilon_0}-\phi$

10. Consider an atom with atomic number Z as consisting of a positive point charge at the centre and surrounded by a distribution of negative electricity uniformly distributedwithin a sphere of radius R. The electric field at a point inside the atom at a distance r from the centre is

(a) $\dfrac{Ze}{4\pi\varepsilon_0}\left[\dfrac{1}{r^2}-\dfrac{r}{R^3}\right]$ (b) $\dfrac{Ze}{4\pi\varepsilon_0}\left[\dfrac{1}{r^2}+\dfrac{r}{R^3}\right]$

(c) $\dfrac{2Ze}{4\pi\varepsilon_0 r^2}$ (d) Zero

11. Charges + q and – q are placed at points A and B respectively, which are a distance 2L apart, C is the mid – point between A and B. The work done in moving a charge + Q along the semi – circle CRD is



(a) $\dfrac{qQ}{4\pi\varepsilon_0 L}$ (b) $\dfrac{qQ}{2\pi\varepsilon_0 L}$

(c) $\dfrac{qQ}{6\pi\varepsilon_0 L}$ (d) $\dfrac{-qQ}{6\pi\varepsilon_0 L}$

12. Two identical thin rings, each of radius R meters, are coaxially placed a distance R meters apart. If Q_1 coulomb, and Q_2coulomb, are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is

(a) zero (b) $\dfrac{q(Q_1-Q_2)(\sqrt{2}-1)}{(4\sqrt{2}\pi\varepsilon_0 R)}$

(c) $\dfrac{q\sqrt{2}(Q_1-Q_2)}{(4\pi\varepsilon_0 R)}$ (d) $\dfrac{q(Q_1+Q_2)(\sqrt{2}+1)}{(4\sqrt{2}\pi\varepsilon_0 R)}$

13. Two equal point charges are fixed at x = –a and x = + a on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to

(a) x (b) x^2

(c) x^3 (d) 1/x

14. It is possible to have a positively charged body at

(a) zero potential

(b) negative potential

(c) positive potential

(d) All of these

15. **Assertion:** A and B are two conducting spheres of same radius. A being solid and B hollow. Both are charged to the same potential. Then, charge on A = charge on B.

Reason: Potentials on both are same.

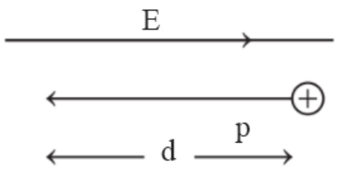
(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

(c) Assertion is correct but Reason is incorrect.

(d) Both Assertion and Reason are incorrect.

16. In the figure, a proton moves a distance d in a uniform electric field E as shown in the figure. Does the electric field do a positive or negative work on the proton? Does the electric potential energy of the proton increase or decrease?



(a) Negative, increase (b) Positive, decrease

(c) Negative, decrease (d) Positive, increase

17. An electron of 100 eV is fired directly towards a metal plate having surface charge density of -2×10^7 What is the distance from where the electron be projected so that it just fails to strike the plate?

(a) 0.22 mm (b) 0.33 mm

(c) 0.44 mm (d) 0.66 mm

18. A ball of mass 1 g and charge 10^{-8}C moves from a point A, where potential is 600 V to the point B, where potential is zero. Velocity of the ball at the point B, is 20 cms^{-1} The velocity of the ball at the point A will be

(a) 22.8 cms^{-1} (b) 228 cms^{-1}

(c) 16.8 ms^{-1} (d) 168 ms^{-1}

19. The ionization potential of mercury is 10.39 V. How far an electron must travel in an electric field of $1.5 \times 10^6 \, V/m$ to gain sufficient energy to ionize mercury?

(a) $\frac{10.39}{1.6 \times 10^{-19}} m$ (b) $\frac{10.39}{2 \times 1.6 \times 10^{-19}} m$

(c) $10.39 \times 1.6 \times 10^{-19} m$ (d) $\frac{10.39}{1.5 \times 10^6} m$

20. This question has statement 1 and statement 2. Of the four choices given after the statements, choose the one that best describes the two statements.

An insulating solid sphere of radius R has a uniform positive charge density ρ. As a result of this uniform charge distribution, there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point outside the sphere. The electric potential at infinity is zero.

Statement 1: When a charge q is taken from the centre to the surface of the sphere its potential energy changes by $\frac{q\rho}{3\varepsilon_0}$.

Statement 2: The electric field at a distancer (r <R) from the center of the sphere is $\frac{\rho r}{3\varepsilon_0}$

(a) Statement 1 is false, Statement 2 is true.

(b) Statement 1 is true, Statement 2 is false.

(c) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation for Statement 1.

(d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation for Statement 1.

21. An electric dipole has a fixed dipole moment $\vec{P}$, which makes angle θ with respect to *x*-axis. When subjected to an electric field $\vec{E}_1 = E\hat{i}$, it experiences a torque $\vec{T}_1 = \tau\hat{k}$. When subjected to another electric field $\vec{E}_2 = \sqrt{3}E_1\hat{j}$ it experiences a torque $\vec{T}_2 = -\vec{T}_1$ The angle θ is :

(a) 30° (b) 45°

(c) 60° (d) 90°

22. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of spheres A and B is

(a) 4 : 1 (b) 1 : 2

(c) 2 : 1 (d) 1 : 4

23. Consider two concentric spherical metal shells of radii r_1 and r_2(r_2> r_1). If the outer shell has a charge q and the inner one is grounded, the charge on the inner shell is

(a) $\frac{-r_2}{r_1}q$ (b) zero

(c) $\frac{-r_1}{r_2}q$ (d) – q

24. Two conducting spheres of radii R_1 and R_2 are charged with charges Q_1 and Q_2 , respectively. On bringing them in contact, there is

(a) no increase in the energy of the system

(b) an increase in the energy of the system, if $Q_1R_2 \neq Q_2R_1$

(c) always a decrease in the energy of the system

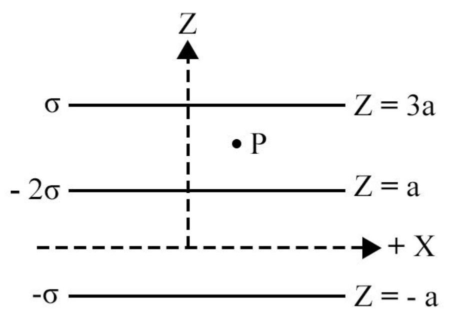
(d) a decrease in the energy of the system, if $Q_1R_2 = Q_2R_1$

25. Two infinitely long parallel conducting plates having surface charge densities $+\sigma$ and $-\sigma$ respectively, are separated by a small distance. The medium between the plates is vacuum. If ε_0 is the dielectric permittivity of vacuum, then the electric field in the region between the plates is

(a) 0 (b) $\frac{\sigma}{2\varepsilon_0}Vm^{-1}$

(c) $\frac{\sigma}{\varepsilon_0}Vm^{-1}$ (d) $\frac{2\sigma}{\varepsilon_0}Vm^{-1}$

26. Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is



(a) $\frac{2\sigma}{\varepsilon_0}k$ (b) $-\frac{2\sigma}{\varepsilon_0}k$

(c) $\frac{4\sigma}{\varepsilon_0}k$ (d) $-\frac{4\sigma}{\varepsilon_0}k$

27. **Assertion:** All the charge in a conductor gets distributed on whole of its outer surface.

Reason: In a dynamic system, charges try to keep their potential energy minimum.

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If both assertion and reason are false.

28. **Assertion:** Net electric field inside conductor is zero.

Reason: Total positive charge equals to total negative charge in a conductor.

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If both assertion and reason are false.

29. **Assertion:** The surface charge densities of two spherical conductors of different radii are equal. Then the electric field intensities near their surfaces are also equal.

Reason: Surface charge density is equal to charge per unit area.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

30. **Assertion:** Vehicle carrying inflammable materials usually have metallic ropes touching the ground during motion.

Reason: The charge accumulated in the body may cause fire.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Answer Key

CHAPTER 1: ELECTROSTATICS

EXERCISE – 1: Basic Objective Questions

1. (a)	**17.** (d)	**33.** (b)	**49.** (b)	**65.** (d)	**81.** (c)	**97.** (a)	**113.** (d)	**129.** (b)	**145.** (a)
2. (c)	**18.** (a)	**34.** (d)	**50.** (a)	**66.** (a)	**82.** (d)	**98.** (d)	**114.** (d)	**130.** (a)	**146.** (d)
3. (b)	**19.** (c)	**35.** (c)	**51.** (c)	**67.** (b)	**83.** (c)	**99.** (a)	**115.** (a)	**131.** (a)	**147.** (d)
4. (a)	**20.** (d)	**36.** (a)	**52.** (a)	**68.** (a)	**84.** (a)	**100.** (b)	**116.** (d)	**132.** (c)	**148.** (a)
5. (b)	**21.** (c)	**37.** (c)	**53.** (b)	**69.** (c)	**85.** (c)	**101.** (b)	**117.** (b)	**133.** (d)	**149.** (a)
6. (a)	**22.** (d)	**38.** (b)	**54.** (d)	**70.** (a)	**86.** (a)	**102.** (b)	**118.** (a)	**134.** (c)	**150.** (b)
7. (c)	**23.** (c)	**39.** (a)	**55.** (b)	**71.** (c)	**87.** (a)	**103.** (d)	**119.** (c)	**135.** (b)	**151.** (a)
8. (c)	**24.** (a)	**40.** (d)	**56.** (d)	**72.** (d)	**88.** (a)	**104.** (d)	**120.** (c)	**136.** (d)	**152.** (d)
9. (b)	**25.** (a)	**41.** (b)	**57.** (a)	**73.** (b)	**89.** (a)	**105.** (d)	**121.** (d)	**137.** (a)	**153.** (a)
10. (a)	**26.** (c)	**42.** (a)	**58.** (a)	**74.** (b)	**90.** (c)	**106.** (b)	**122.** (c)	**138.** (c)	**154.** (c)
11. (a)	**27.** (a)	**43.** (b)	**59.** (b)	**75.** (c)	**91.** (b)	**107.** (a)	**123.** (d)	**139.** (c)	**155.** (d)
12. (a)	**28.** (a)	**44.** (a)	**60.** (b)	**76.** (d)	**92.** (a)	**108.** (c)	**124.** (b)	**140.** (b)	**156.** (c)
13. (b)	**29.** (d)	**45.** (b)	**61.** (b)	**77.** (b)	**93.** (a)	**109.** (d)	**125.** (c)	**141.** (c)	**157.** (a)
14. (b)	**30.** (c)	**46.** (a)	**62.** (d)	**78.** (a)	**94.** (c)	**110.** (d)	**126.** (a)	**142.** (b)	**158.** (a)
15. (a)	**31.** (c)	**47.** (c)	**63.** (c)	**79.** (a)	**95.** (c)	**111.** (d)	**127.** (c)	**143.** (b)	**159.** (c)
16. (a)	**32.** (a)	**48.** (b)	**64.** (c)	**80.** (c)	**96.** (a)	**112.** (d)	**128.** (d)	**144.** (b)	**160.** (a)

EXERCISE – 2: Previous Year Questions

1. (c)	**2.** (c)	**3.** (a)	**4.** (b)
5. (a)	**6.** (a)	**7.** (a)	**8.** (d)
9. (c)	**10.** (a)	**11.** (c)	**12.** (a)
13. (d)	**14.** (c)	**15.** (c)	**16.** (b)
17.(c)	**18.** (a)	**19.** (b)	**20.** (d)
21.(c)	**22.** (a)	**23.** (b)	**24.** (b)
25.(a)	**26.** (b)	**27.** (d)	**28.** (b)
29.(a)	**30.** (c)	**31.** (c)	**32.** (a)
33.(d)	**34.** (a)	**35.** (d)	**36.** (c)
37.(d)	**38.** (d)	**39.** (a)	**40.** (a)
41.(b)	**42.** (b)	**43.** (a)	**44.** (c)
45.(b)	**46.** (d)	**47.** (d)	**48.** (c)
49.(a)	**50.** (a)	**51.** (b)	**52.** (d)
53.(b)	**54.** (c)	**55.** (d)	**56.** (c)
57.(d)	**58.** (b)	**59.** (b)	**60.** (d)

EXERCISE – 3: Achiever's Section

1. (b)	**2.** (a)	**3.** (c)	**4. (b)**
5. (b)	**6.** (d)	**7.** (b)	**8. (a)**
9. (a)	**10.** (a)	**11.** (d)	**12. (b)**
13.(b)	**14.** (d)	**15.** (a)	**16. (a)**
17.(c)	**18.** (a)	**19.** (d)	**20. (a)**
21.(c)	**22.** (c)	**23.** (c)	**24. (d)**
25.(c)	**26.** (b)	**27.** (a)	**28. (c)**
29.(b)	**30.** (a)		

Exercise–1: Basic Objective Questions

Electric Charge and its Properties

1. A glass rod when rubbed with silk cloth acquires

(a) +ve charge and silk cloth acquires equal –ve charge

(b) No charge

(c) –ve charge and silk cloth acquires equal +ve charge

(d) +ve charge and silk cloth acquires more –ve charge

Ans. (a)

Sol. When a glass rod is rubbed with a silk cloth, electrons from the glass rod move to the silk cloth. During this process, the glass rod becomes positively charged and the silk cloth becomes negatively charged. Also, the magnitude of the charge on the silk cloth is the same as that on the glass rod.

2. Frictional electricity is produced on the two objects due to:

(a) Loss of electrons by one object

(b) Loss of protons by one object

(c) Loss of electrons by one object and equal number of electrons gained by the other object

(d) Loss of protons by one object and equal number of protons gained by the other object

Ans. (c)

Sol. Frictional electricity is also called as static electricity, which gets developed on objects when they are rubbed with each other. When rubbed with each other, both the objects get electrically charged where in one object acquires a positive charge due to loss of electrons from it whereas the other object acquires an equal negative charge due to gain of electrons by it. A glass rod rubbed with a silk cloth is an example of frictional electricity.

3. How many electrons will have a charge of one coulomb?

(a) 6.25×10^{19} (b) 6.25×10^{18}

(c) 6.25×10^{15} (d) 1.6×10^{-19}

Ans. (b)

Sol.

$$Q_e = 1.6\times10^{-19} = 1e^-$$

$$\therefore 1C = \frac{1}{1.6\times10^{-19}}e^-$$

$$1C = 0.625\times10^{19}e^- = 6.25\times10^{18}e^-$$

4. A spherical conducting ball is suspended by a conducting thread. A positive point charge is moved near the ball. The ball will

(a) be attracted to the point charge and swing towards it

(b) be repelled from the point charge and swing away from it

(c) not be affected by the point charge

(d) either (a) or (b)

Ans. (a)

Sol. When a positive point charge comes closer to conducting ball, negative charges will be induced on the side of ball facing positive point charge. This process is also known as induction. Due to this induced opposite charge, there will be an attractive force between positive and negative charge.

5. When 10^{19} electrons are removed from a neutral metal plate, the electric charge on it is

(a) – 1.6 C (b) + 1.6 C

(c) 10^{+19} C (d) 10^{-19} C

Ans. (b)

Sol.

$$\text{Charge, } q = ne$$

$$\Rightarrow q = 10^{19}\times1.6\times10^{-19} = 1.6C$$

6. For the phenomenon of electrostatic induction, mark out the correct statement.

(a) The magnitude of the net induced charge is zero

(b) The magnitude of net induced charge is equal and opposite to the inducing charge

(c) The mass of the body changes slightly

(d) Electrostatic induction is a permanent phenomenon

Ans. (a)

Sol. In the phenomenon of electrostatic induction, the magnitude of the net induced charge turns out to be zero because both the objects involved in the process develop opposite charges of equal magnitudes.

7. The specific charge of a proton is 9.6×10^7 C kg^{-1}. The specific charge of an alpha particle will be

(a) 9.6×107 C kg^{-1}

(b) 19.2×107 C kg^{-1}

(c) 4.8×107 C kg^{-1}

(d) 2.4×107 C kg^{-1}

Ans. (c)

Sol. Alpha particle is doubly ionized He atom. It carries a +ve charge, two times the charge of proton and mass of alpha particle is (2 Neutron + 2 Proton) almost 4 times the mass of proton.

So, if specific charge of proton is $= \frac{+e}{m_p}$

Then, specific charge of alpha particle $= \frac{+2e}{4m_p}$

$= \text{Specific charge of proton} \times \frac{1}{2}$

So, Specific charge of Alpha particle $= \frac{9.6 \times 10^7}{2} = 4.8 \times 10^7 \, C\,kg^{-1}$

8. A comb rubbed through one's dry hair attracts small bits of paper. This is because

(a) comb is a good conductor

(b) paper is a good conductor

(c) the atoms in the paper get polarized by the charged comb

(d) the comb possesses magnetic properties

Ans. (c)

Sol. When the comb passes through dry hair it gets electrically charged by friction. Hence, attracts small bits of paper. This is because paper gets polarized in the presence of charged comb resulting in a net force of attraction.

9. **Assertion:** When charges are shared between any two bodies, no charge is really lost, but some loss of energy does occur.

Reason: Some energy disappears in the form of heat, sparking etc.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (b)

Sol. Charge is always conserved but energy is lost in the terms of heat etc.

10. **Assertion:** Charge is invariant.

Reason: Charge does not depend on speed of frame of reference.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Any physical quantity which is independent of reference frame is known as invariant. Since charge is intrinsic property so it remains invariant.

11. **Assertion:** There is a spark or crackle when we take off our synthetic clothes or sweater in dry weather.

Reason: Discharge of electric charges occurs through our body, which accumulated due to rubbing of insulating surface.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Due to rubbing between synthetic clothes and our body electrons are transferred so clothes become charged.

12. **Assertion:** It is observed that if two glass rods rubbed with silk cloth are brought close to each other, they repel.

Reason: Electrification causes repulsion of same polarity.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. When a glass rod is rubbed with silk, the rod becomes positively charged while the silk becomes negatively charged. So both glass rods become positively charged and repel with each other.

13. **Assertion:** The mass of positively charged body is slightly less than the mass of negatively charged body.

Reason: Loosely bound electrons in a material are transferred on rubbing.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (b)

Sol. A positively charged body loses electrons and a negatively charged body has excess electrons. Therefore, both assertion and reason are true but reason is not the correct explanation of the assertion.

Force between charges

14. The law that governs the force between electric charges is called

(a) Ampere's law (b) Coulomb's law

(c) Faraday's law (d) Ohm's law

Ans. (b)

Sol. If two stationary point charges are kept at a particular distance, then the force of attraction or repulsion between them is inversely proportional to the square of the distance and directly proportional to the product of magnitudes of charges. This law is nothing but Coulomb's law.

15. If charge and distance between two charges are reduced to half, then force between them will be

(a) remain same (b) increases four times

(c) reduce four times (d) None of the above

Ans. (a)

Sol. As per Coulomb's law, $F = k\frac{q_1 q_2}{r^2}$ According to ,

$$F' = k\frac{\left(\frac{q_1}{2}\right)\left(\frac{q_2}{2}\right)}{\left(\frac{r}{2}\right)^2} = k\frac{q_1 q_2}{r^2} = F$$

Thus, force between them will remains same.

16. Two point charges +2C and +6C repel each other with a force of 12 N. If a charge of – 2C is given to each of these charges, the force will be

(a) zero (b) 8 N (attractive)

(c) 8 N (repulsive) (d) None of these

Ans. (a)

Sol. On adding – 2C to both, one charge becomes neutral and hence Coulomb's force get equal to zero.

17. Charges 4Q, q and Q are placed along x-axis at position $x = 0, x = 1/2$ and $x = 1,$ respectively. Find the value of q, so that force on charge Q is zero.

(a) Q (b) Q/2

(c) – Q/2 (d) – Q

Ans. (d)

Sol. From Coulomb's law, the force acting between two charges (q_1, q_2) separated at a distance r is given by

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

Total force acting on charge Q is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(1/2)^2} + \frac{1}{4\pi\varepsilon_0}\frac{4Q \cdot Q}{(1)^2}$$

According to question, F = 0

$$\therefore \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(1/2)^2}+\frac{1}{4\pi\varepsilon_0}\cdot\frac{4Q^2}{(1)^2}=0$$

$$\Rightarrow \quad q=-Q$$

18. Two charges of 10μC and 20μC are separated by 20 cm. The ratio of force acting on them will be:

(a) 1 : 1 (b) 2 : 1

(b) 1 : 2 (d) 1 : 4

Ans. (a)

Sol. $$\left|\vec{F}_{12}\right|=\left|\vec{F}_{21}\right|\Rightarrow\frac{\left|\vec{F}_{12}\right|}{\left|\vec{F}_{21}\right|}=\frac{kQ_1Q_2}{R^2}\times\frac{R^2}{kQ_1Q_2}=1$$

Therefore, the ratio of forces is 1 : 1

19. A charge q_1 exerts some force on a second charge q_2. If a third charge q_3 is brought near, the force of q_1 exerted on q_2 will:

(a) increase (b) decrease

(c) remain unchanged (d) none of these

Ans. (c)

Sol. Force due to q_1 exerted on q_2 will remain the same, but the net force exerted on q_2 will change.

20. An electron is moving around the nucleus of a hydrogen atom in a circular orbit of radius r. The Coulomb force between the two is

(a) $K\frac{e^2}{r^3}\vec{r}$ (b) $K\frac{e^2}{r^2}\hat{r}$

(c) $-K\frac{e^2}{r^3}\hat{r}$ (d) $-K\frac{e^2}{r^3}\vec{r}$

Ans. (d)

Sol. $$F=K\frac{(-e)(+e)}{r^2}=K\frac{e^2}{r^2}$$

Now, $\vec{F}$ is acting along $(-\vec{r})$:

$$\vec{F}=K\frac{e^2}{r^3}(-\vec{r})=\frac{-Ke^2}{r^3}\vec{r}$$

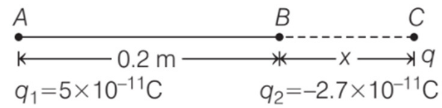
21. The distance between charges 5×10^{-11}C and -2.7×10^{-11}C is 0.2 m. The distance, at which third charge should be placed from second charge in order that it will not experience any force along the line joining the two charges, is

(a) 0.44 m (b) 0.65 m

(c) 0.556 m (d) 0.350 m

Ans. (c)

Sol.



Let a charge q is placed at a point C such that force at C is zero.

F_{q_2} = force on q due to charge q_2 and

F_{q_1} = force on q due to charge q_1.

As, $F_{q_1}+F_{q_2}=0\Rightarrow F_{q_1}=-F_{q_2}$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{(x+0.2)^2}=\frac{1}{4\pi\varepsilon_0}\cdot\frac{qq_2}{x^2}$$

$$\Rightarrow \frac{5\times10^{-11}}{(x+0.2)^2}=\frac{2.7\times10^{-11}}{x^2}$$

$$\Rightarrow \quad x=0.556\text{ m}$$

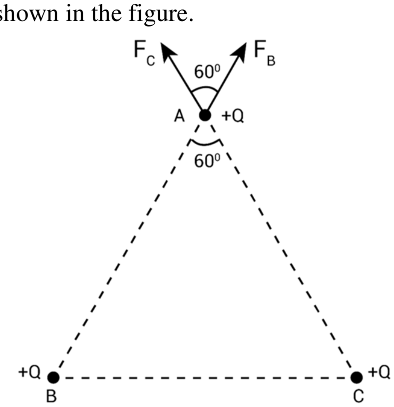
22. Three equal charges each +Q, placed at the corners of an equilateral triangle of side a. What will be the force on any charge $\left(k=\frac{1}{4\pi\varepsilon_0}\right)$

(a) $\frac{kQ^2}{a^2}$ **(b)** $\frac{2kQ^2}{a^2}$

(c) $\frac{\sqrt{2}kQ^2}{a^2}$ **(d)** $\frac{\sqrt{3}kQ^2}{a^2}$

Sol. **(d)**

Suppose net force is to be calculated on the charge which is kept at A. Two charges kept at B and C are applying force on that particular charge, with direction as shown in the figure.



Since $F_B = F_C = F = k\dfrac{Q^2}{a^2}$

So, $F_{net} = \sqrt{F_B^2 + F_C^2 + 2F_BF_C\cos 60}$

$F_{net} = \sqrt{3}F = \dfrac{\sqrt{3}kQ^2}{a^2}$

23. Three identical charges are placed at the corners of an equilateral triangle. If the force between any two charges is F, then the net force on each will be

(a) $\sqrt{2}$ F (b) 2 F

(c) $\sqrt{3}$ F (d) 3 F

Ans. (c)

Sol.

Net force on each charge will be

$$F_{net} = \sqrt{F^2 + F^2 + 2F^2 \cos 60^o}$$

$$\Rightarrow F_{net} = \sqrt{2F^2 + 2F^2 \times \frac{1}{2}}$$

$$= \sqrt{2F^2 + F^2}$$

$$\Rightarrow F_{net} = \sqrt{3F^2} = \sqrt{3}F$$

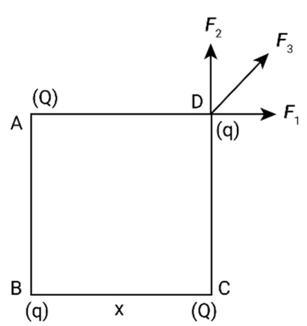
24. A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on q is zero, then the q/Q equals

(a) $-2\sqrt{2}$ (b) –1

(c) 1 (d) $-\dfrac{1}{\sqrt{2}}$

Ans. (a)

Sol.



Let, the side of square be x , and its diagonal be $x\sqrt{2}$.

Now, the horizontal force = vertical force

$F_1 = F_2 = \dfrac{kQq}{x^2}$, and $F_3 = \dfrac{kq^2}{2x^2}$

Now, the resultant force $F = \sqrt{F_1^2 + F_2^2} = F_1\sqrt{2}$ where, F_1 and F_2 are perpendicular to each other.

Now equating the resultant force and F_3 ;

$$\frac{kq^2}{2x^2} = F_1\sqrt{2}$$

$$\Rightarrow \frac{-kq^2}{2x^2} = \frac{kQq\sqrt{2}}{x^2}$$

$$\therefore q = -2\sqrt{2}Q$$

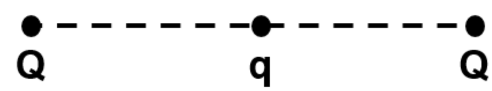
25. A charge q is placed at the centre of the line joining two exactly equal positive charges Q. The system of three charges will be in equilibrium, if q is equal to

(a) –Q/4 (b) +Q

(c) –Q (d) Q/2

Ans.(a)

Sol.



For equilibrium $F_{net} = 0$ on each charge

F on one of $Q = 0$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0} \times \frac{Qq}{(r/2)^2} + \frac{1}{4\pi\varepsilon_0} \times \frac{Q^2}{r^2} = 0$$

$$q = -\frac{Q}{4}$$

26. Point charges +4q, –q and +4q are kept on the X-axis at points x = 0, x = a and x = 2a respectively.

(a) Only –q is in stable equilibrium

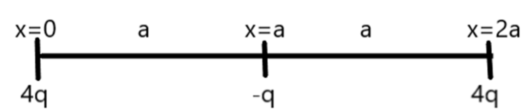
(b) None of the charges is in equilibrium

(c) All the charges are in unstable equilibrium

(d) All the charges are in stable equilibrium

Ans. (c)

Sol.



At the present position all three charges are in equilibrium.

Force acting on -q = $-\frac{4kq^2}{a^2}$ due to both charges 4q in opposite directions. Clearly, -q is in equilibrium. Force on each 4q charge is given by:

$$+k\frac{16q^2}{(2a)^2}-k\frac{4q^2}{a^2}=k\frac{4q^2}{a^2}-k\frac{4q^2}{a^2}=0$$

However, as $F\propto\frac{1}{r^2}$, when they are displaced slightly from this position, they will not return to this position again. Hence, they are in unstable equilibrium position.

27. Electrical force between two point charges is 200 N. If we increase 10% charge on one of the charges and decrease 10% charge on the other, then electrical force between them for the same distance becomes

(a) 198 N (b) 100 N

(c) 200 N (d) 99 N

Ans. (a)

Sol. Let two charges be q_1 and q_2 and r be the distance between them, then electrical force,

$$F=\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r^2}=200\text{ N} \quad ...(i)$$

If q_1 is increased by 10%, then

$$q_1^{'}=\frac{110}{100}q_1$$

and q_2 is decreased by 10%, then

$$q_2^{'}=\frac{90}{100}q_2$$

Then, electrical force between them is

$$F'=\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_2^{'}q_2^{'}}{r^2}$$

$$\Rightarrow \quad F'=\frac{1}{4\pi\varepsilon_0}\frac{\frac{110}{100}q_1\times\frac{90}{100}q_2}{r^2}$$

$$\Rightarrow \quad F'=\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r^2}\times\frac{99}{100} \quad ...(ii)$$

From Eqs. (i) and (ii), we get

$$F'=200\times\frac{99}{100}$$

$$\Rightarrow \quad F'=198\text{ N}$$

28. **Assertion:** Due to Coulomb's force charges cannot apply torque on each other.

Reason: Coulomb's force is central force.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Since Coulomb's force is central force. It acts along line of joining two charges so net torque of this force becomes zero.

29. **Assertion:** The Coulomb force is strongest force in the universe.

Reason: The Coulomb force is stronger than the nuclear force inside nucleus.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (d)

Sol. Among all four basic forces of nature (Gravitational, Electromagnetic, Strong Nuclear and Weak Nuclear), strong nuclear force is much stronger than electrostatic force (Coulomb's force). Moreover, it is the strongest of all the four fundamental forces in nature.

30. **Assertion:** If there is Coulomb attraction between two bodies, both of them may not be charged.

Reason: They will be oppositely charged.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (c)

Sol. Coulomb attraction exists even when one body is charged, and the other is uncharged. If both are charged then they must be oppositely charged otherwise any charge can attract any uncharged body. So the reason is false.

Electric Field

31. Electric lines of force about a negative point charge are

(a) Circular, anticlockwise (b) Circular, clockwise

(c) Radial, inwards (d) Radial outwards

Ans. (c)

Sol. The electric lines of force will be radial and inwards about a negative point charge. In point charge, its direction is radial and will have negative charge. So, its direction is inwards, pointing towards the charge.

32. A force of 2.25 N acts on a charge of 15×10^{-4} C placed at point in field. Calculate the intensity of electric field at that point

(a) 1500 NC^{-1} (b) 150 NC^{-1}

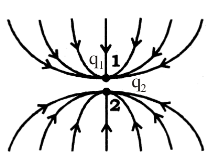
(c) 15000 NC^{-1} (d) none of the above

Ans. (a)

Sol. $F = qE$

$$\Rightarrow E = \frac{F}{q} = \frac{2.25}{15\times10^{-4}} = 15\times10^{2} = 1500 NC^{-1}$$

33. Figure given here is plot of lines of force due to two charges q_1 and q_2. The signs of the two charges are:



(a) both positive

(b) both negative

(c) upper positive, lower negative

(d) upper negative, lower positive

Ans. (b)

Sol. Electric lines of force start from the positive charge and end at the negative charge. Since the electric lines for both the charges are ending, therefore both q_1 and q_2 are negative charges

34. Electric lines of force

(a) exist every where

(b) exist only in the immediate vicinity of electric charge

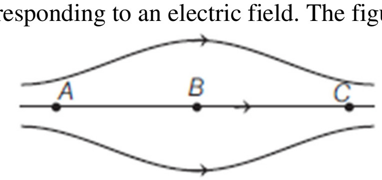
(c) exist only when both positive and negative charges are near each other

(d) are imaginary

Ans. (d)

Sol. Electric lines of force are imaginary, which are thought to be so for better understanding purposes.

35. The figure shows some of the electric field lines corresponding to an electric field. The figure suggests



(a) $E_A > E_B > E_C$. (b) $E_A = E_B = E_C$

(c) $E_A = E_C > E_B$ (d) $E_A > E_C > E_B$

Ans. (c)

Sol. Electric field intensity at a particular point is directly proportional to the number of electric lines of forces crossing per unit area.

$E_A = E_B$ ...(i)

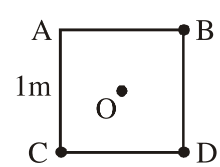
As, density of electric line of force in region A and C are more as compare to B.

Hence, $E_A > E_B$ ...(ii)

From Eqs. (i) and (ii), we get

$E_A = E_C > E_B$

36. Three charges, each of +4μC, are placed at the corners B, C, D of a square ABCD of side 1 m. The electric field at the centre O of the square is



(a) 7.2×10^4 N towards A

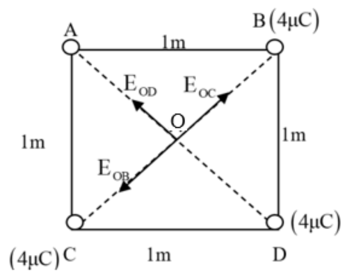
(b) 7.2×10^4 N towards C

(c) 3.6×10^4 N towards A

(d) 3.6×10^4 N towards C

Ans. (a)

Sol.



$$OA = OB = OC = OD = \frac{1}{\sqrt{2}} \text{ m}$$

E_{OB} and E_{OC} will cancel each other because of equal magnitudes and opposite directions.

$$\left|\vec{E}_{Net}\right| = \left|\vec{E}_{OD}\right| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(OD)^2}$$

$$\Rightarrow \left|\vec{E}_{Net}\right| = \frac{9\times10^9\times4\times10^{-6}}{\left(\frac{1}{\sqrt{2}}\right)^2} = 72\times10^3 \text{ N/C}$$

As clear from the diagram, this field acts towards A.

37. The point charges Q and –2Q are placed at some distance apart. If the electric field at the location of Q is E, the electric field at the location of –2Q will be:

(a) $-\frac{3E}{2}$ (b) $-E$

(c) $-\frac{E}{2}$ (d) $-2E$

Ans. (c)

Sol. As field on Q is E, force on Q is $F = QE$

Let field on –2Q be E'. So, force on –2Q will be $F' = -2QE'$

Using Coulomb's law, the forces on both will be equal, i.e., $F' = F$ or $QE = -2QE'$.

So, $E' = -\frac{E}{2}$

38. **Assertion:** Electric lines of force never cross each other.

Reason: Electric fields at a point superimpose to give one resultant electric field.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (b)

Sol. If electric lines of forces cross each other, then the electric field at the point of intersection will have two directions simultaneously; this is not possible physically. Since electric field is vector quantity so for resultant field principle of superposition is applied.

39. **Assertion:** Three equal charges are situated on a circle of radius r such that they form an equilateral triangle, then the electric field intensity at the centre is zero.

Reason: The forces on unit positive charge at the centre, due to three equal charges are represented by the three sides of a triangle taken in the same order. Therefore, electric field intensity at centre is zero.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

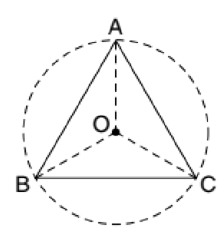
(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol.



Resultant of electric field intensity at O due to Band C is equal and opposite of that due to A.

Electric field due to continuous charge distribution

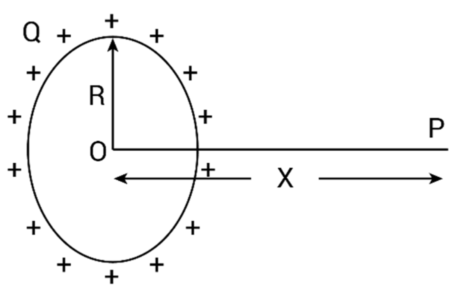
40. The electric field strength due to a uniformly charged ring of radius R at a distance x from its centre on its axis carrying charge Q has somewhere maximum value on the axis. This is at distance

(a) $x = R$ (b) $x = 2R$

(c) $x = 0$ (d) $x = \frac{R}{\sqrt{2}}$

Ans. (d)

Sol.



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

$$\frac{dE}{dx}=\frac{1}{4\pi\varepsilon_0}Q\left[\frac{1}{(R^2+x^2)^{\frac{3}{2}}}+x\left(\frac{-3}{2}\right)(R^2+x^2)^{\frac{-5}{2}}2x\right]$$

$$\frac{dE}{dx}=\frac{Q}{4\pi\varepsilon_0}\frac{1}{(R^2+x^2)^{\frac{3}{2}}}\left[1-\frac{3x^2}{R^2+x^2}\right]$$

For maximum E;

$$\frac{dE}{dx}=0$$

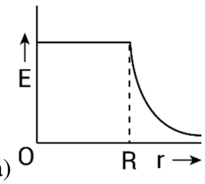
$$\frac{Q}{4\pi\varepsilon_0}\frac{1}{(R^2+x^2)^{\frac{3}{2}}}\left[1-\frac{3x^2}{R^2+x^2}\right]=0$$

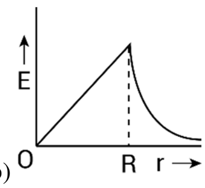
$$1-\frac{3x^2}{R^2+x^2}=0$$

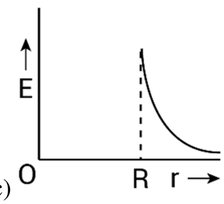
$$R^2+x^2=3x^2$$

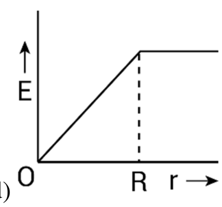
$$x=\pm\frac{R}{\sqrt{2}}$$

41. The electric field due to a uniformly charged non-conducting sphere of radius R as a function of the distance from its centre is represented graphically by

(a)


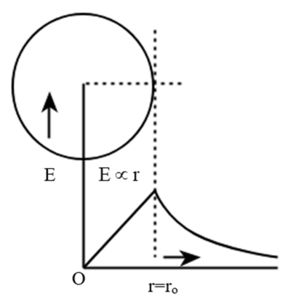
(b)


(c)


(d)


Ans. (b)

Sol.



Inside a uniformly charged non-conducting sphere, charge is uniformly distributed. So, the field is there. In such cases, the electric field is directly proportional to the distance from the centre. Outside the sphere, field is inversely proportional to the square of the distance. So, the graph flows as shown.

42. The charge density on the surface of a conducting sphere is 64×10^{-7} C/m^2 and the electric intensity at a distance of 2 m from the centre of the sphere is $4\pi\times 10^4$ N/C. The radius of the sphere is

(a) 0.83 m (b) 0.4 m

(c) 0.6 m (d) 0.38 m

Ans. (a)

Sol. $\sigma = 64 \times 10^{-7}$ C/m^2 ; $E = 4\pi \times 10^4$ N/C

$$\sigma = \frac{q}{4\pi R^2}; E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$$

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

$$\Rightarrow R^2 = \frac{E}{\sigma}\times\varepsilon_0 r^2 = \frac{4\pi\times10^4}{64\times10^{-7}}\times8.85\times10^{-12}\times4$$

$$\Rightarrow R = \sqrt{0.694} = 0.83\,\text{m}$$

43. The number of electrons to be put on spherical conductor of radius 0.1 m, to produce an electric field of 0.036 N/C just above its surface, is:

(a) 3.4×10^5 (b) 2.5×10^5

(c) 3.7×10^5 (d) 4.7×10^5

Ans. (b)

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

$$n = \frac{Er^2}{e}4\pi\varepsilon_0 = \frac{0.036\times0.1\times0.1}{9\times10^9\times1.6\times10^{-19}} = 2.5\times10^5$$

44. The electric intensity outside a charged sphere of radius R at a distance r(r > R) is

(a) $\frac{\sigma R^2}{\varepsilon_0 r^2}$ (b) $\frac{\sigma r^2}{\varepsilon_0 R^2}$

(c) $\frac{\sigma r}{\varepsilon_0 R}$ (d) $\frac{\sigma R}{\varepsilon_0 r}$

Ans. (a)

Sol. The electric intensity outside a charged sphere,

$$E = \frac{kq}{r^2} = \frac{k(\sigma A)}{r^2}$$

$$= \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\sigma 4\pi R^2}{r^2} = \frac{\sigma R^2}{\varepsilon_0 r^2}$$

45. A charged particle is free to move in an electric field. It will travel

(a) always along a line of force

(b) along a line of force, if its initial velocity is zero

(c) along a line of force, if it has same initial velocity in the direction of an active angle with the line of force

(d) None of the above

Ans. (b)

Sol. Because E points is along the tangent to the lines of force. If initial velocity is zero, then due to the force, it moves in the direction of E.

46. Forces exerted by a uniform electric field on an electron having mass m_e and proton of mass m_p are represented as F_e and F_p respectively are related as

(a) $F_p = F_e$ (b) $\frac{F_e}{F_p} = \frac{m_e}{m_p}$

(c) $\frac{F_e}{F_p} = \frac{m_p}{m_e}$ (d) $\frac{F_e}{F_p} = \frac{m_e^2}{m_p^2}$

Ans. (a)

Sol. The force (F) on charge q due to electric field strength E is

$F = qE$

Here, E is uniform, hence $F_p = F_e$.

47. A particle of mass 2×10^{-3} kg, charge 4×10^{-3} C enters in an electric field of 5 V/m, then its kinetic energy after 10 s is

(a) 0.1 J (b) 1 J

(c) 10 J (d) 100 J

Ans. (c)

Sol. Force on a charge placed inside an electric field given as

$$F = qE$$

$$\Rightarrow ma = qE \Rightarrow a = qE/m$$

$$\Rightarrow \frac{dv}{dt} = \frac{qE}{m} \Rightarrow dv = \frac{qE}{m}$$

Integrating with proper limits,

$$\int_0^v dv = \int_0^t \frac{qE}{m}dt$$

Now, $v = \frac{1}{m}qE(t)$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\frac{q^2E^2t^2}{m^2}$$

$$= \frac{1}{2}\frac{q^2E^2t^2}{m} = \frac{(4\times10^{-3})^2\times5^2\times10^2}{2\times2\times10^{-3}}$$

$$= 10\text{ J}$$

48. An electron moves through a small distance in a uniform electric field. The magnitude of electric field is 2×10^4 NC^{-1}. Now, if the direction of field is reversed keeping the magnitude same and a proton moves through the same distance, then which of the following options is correct?

(a) The time of fall will be more in case of electron

(b) The time of fall will be more in case of proton

(c) The time of fall will be same in both cases

(d) The time of fall will be independent of charge

Ans. (b)

Sol. The time required to fall through distance d can be derived as:

$$d=\frac{1}{2}\left(\frac{qE}{m}\right)t^2 \Rightarrow t=\sqrt{\frac{2dm}{qE}}$$

Since $t^2 \propto m$, a proton takes more time.

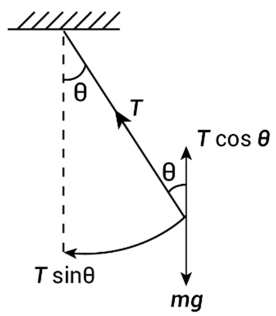
49. A pendulum bob of mass m carrying a charge q is at rest with its string making an angle θ with the vertical in a uniform horizontal electric field E. The tension in the string is

(a) $\frac{mg}{\sin\theta}$ or $\frac{qE}{\cos\theta}$ (b) $\frac{mg}{\cos\theta}$ or $\frac{qE}{\sin\theta}$

(c) $\frac{qE}{mg}$ (d) $\frac{mg}{qE}$

Ans. (b)

Sol. For the equilibrium of the bob,



$T\sin\theta = qE$ and $T\cos\theta = mg$

Therefore, $T=\frac{qE}{\sin\theta}$ or $T=\frac{mg}{\cos\theta}$

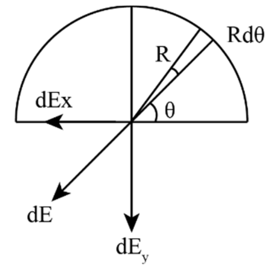
50. Charge q is uniformly distributed over a thin half ring of radius R. The electric field at the centre of the ring is

(a) $\frac{q}{2\pi^2\varepsilon_0R^2}$ (b) $\frac{q}{4\pi^2\varepsilon_0R^2}$

(c) $\frac{q}{4\pi\varepsilon_0R^2}$ (d) $\frac{q}{2\pi\varepsilon_0R^2}$

Ans. (a)

Sol.



Consider element of charge $dq=\lambda R d\theta$, where

$\lambda=\frac{q}{\pi R}$ [line charge density]

For symmetry, X component of field at O cancels.

Thus, the field at O due to element is

$$dE_0 = 2dE_y$$

$$\Rightarrow dE_0 = 2dE\sin\theta$$

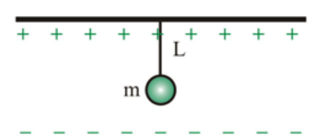
$$\Rightarrow dE_0 = \frac{2dq}{4\pi\varepsilon_0R^2}\sin\theta$$

$$\Rightarrow dE_0 = \frac{2\lambda R d\theta}{4\pi\varepsilon_0R^2}\sin\theta$$

$$\Rightarrow \int dE_0 = \frac{2\lambda}{4\pi\varepsilon_0R}\int_0^{\pi/2}\sin\theta d\theta$$

$$\Rightarrow E_0 = \frac{q}{2\pi^2\varepsilon_0R^2}$$

51. A small sphere carrying a charge 'q' is hanging in between two parallel uncharged plates by a string of length L. Time period of the pendulum is T_0. When the parallel plates are charged, creates electric field E between the plates, the time period changes to T. The ratio T/T_0 is equal to

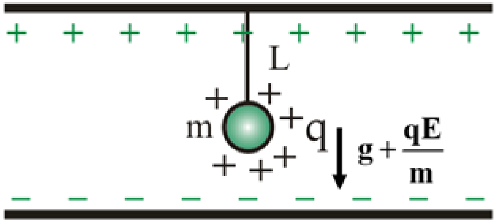


(a) $\left(\frac{g+\frac{qE}{m}}{g}\right)^{1/2}$ (b) $\left(\frac{g}{g+\frac{qE}{m}}\right)^{3/2}$

(c) $\left(\frac{g}{g+\frac{qE}{m}}\right)^{1/2}$ (d) None of these

Ans. (c)

Sol.



$$T_0 = 2\pi\sqrt{\frac{l}{g}}$$

$$g' = g + \frac{qE}{m}$$

$$T = 2\pi\sqrt{\frac{l}{g'}} \quad \Rightarrow \quad T = 2\pi\sqrt{\frac{l}{\left(g+\frac{qE}{m}\right)}}$$

$$\frac{T}{T_0} = \sqrt{\frac{g}{g+\frac{qE}{m}}} \quad \Rightarrow \quad \frac{T}{T_0} = \left[\frac{g}{g+\frac{qE}{m}}\right]^{\frac{1}{2}}$$

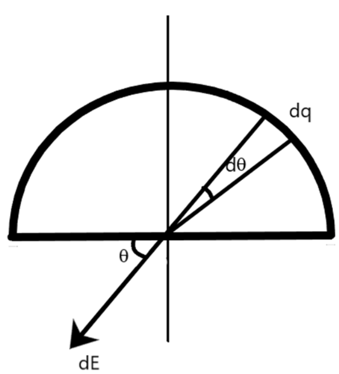
52. A semi-circular arc of radius 'a' is charged uniformly and the charge per unit length is λ. The electric field at the centre of this arc is

(a) $\frac{\lambda}{2\pi\varepsilon_0 a}$ (b) $\frac{\lambda}{2\pi\varepsilon_0 a^2}$

(c) $\frac{\lambda}{4\pi^2\varepsilon_0 a}$ (d) $\frac{\lambda^2}{2\pi\varepsilon_0 a}$

Ans. (a)

Sol.



$$dE = \frac{kdq}{R^2}$$

Due to symmetry $E_x = 0$

$$dE_y = -dE\sin\theta$$

$$dE_y = \frac{-kdq\sin\theta}{R^2}$$

$$dE_y = \frac{-kR\lambda d\theta\sin\theta}{R^2}$$

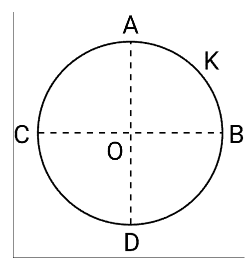
$$E_y = \frac{-k\lambda}{R}\int_0^{\pi}\sin\theta d\theta$$

$$E_y = \frac{-k\lambda}{R}[-\cos]_0^{\pi} = \frac{-2k\lambda}{R}$$

$$|E_y| = \left|\frac{2k\lambda}{R}\right| = \frac{2\lambda}{4\pi\varepsilon_0 R}$$

$$\therefore E_y = \frac{\lambda}{2\pi\varepsilon_0 a}[\because R = a]$$

53. A thin conducting ring of radius R is given a charge +Q. The electric field at the centre O of the ring due to the charge on the part AKB of the ring is E. The electric field at the centre due to the charge on the part ACDB of the ring is



(a) 3 E along KO (b) E along OK

(c) E along KO (d) 3 E along OK

Ans. (b)

Sol. Electric field due to the given charge on the ring is zero at centre 'O'. So, the electric field due to AKB is equal and opposite to electric field due to ACDB, from the principle of superposition.

Since E is field strength of AKB along KO, so electric field due to ACDB acts along OK and is equal to E.

54. An oil drop having a mass 4.8×10^{-10} g and charge 2.4×10^{-18}C stands still between two charged horizontal plates separated by a distance of 1 cm. If now the polarity of the plates is changed, instantaneous acceleration of the drop is ($g = 10ms^{-2}$)

(a) 5 ms^{-2} (b) 10 $ms^{-2}{}_2$

(c) 15 ms^{-2} (d) 20 ms^{-2}

Ans. (d)

Sol. As drop is in equilibrium, $mg = qE$

$$\Rightarrow E = \frac{mg}{q}$$

$$E = \frac{4.8\times10^{-10}\times10^{-3}\times10}{2.4\times10^{-18}} = 2\times10^{6}\ \text{V/m}$$

Now, when polarity is changed, force from electric field also comes in the direction of mg.

So, $F_{net} = mg + qE = ma$

$$\Rightarrow a = g + \frac{q}{m}E$$

$$a = 10 + \frac{2.4\times10^{-18}\times2\times10^{6}}{4.8\times10^{-10}\times10^{-3}} = 20\,\text{ms}^{-2}$$

55. **Assertion:** If a proton and an electron are placed in the same uniform electric field. They experience different acceleration.

Reason: Electric force on a test charge is independent of its mass.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (b)

Sol. $F = qE$

Electron and proton have same amount of charge so they have same magnitude of Coulomb's force. They have different accelerations because they have different masses $\left(a = \frac{F}{m}\right)$.

Therefore, both assertion and reason are true but reason is not the correct explanation of the assertion.

56. **Assertion:** A point charge is brought in an electric field. The field at a nearby point will increase, whatever be the nature of the charge.

Reason: The electric field is independent of the nature of charge.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (d)

Sol. Electric field at the nearby point will be resultant of existing field and field due to the charge brought. It may increase or decrease if the charge is positive or negative as electric field depends on nature of charge and depending on the position of the point with respect to the charge brought.

57. **Assertion:** The graph of the intensity of electric field (E) inside a uniformly charged non-conducting sphere with the distance r from the centre of the sphere is a straight line passing through the origin.

Reason: Inside a uniformly charged non-conducting sphere, the electric field at a distance r is from the centre is given by $E = \frac{KQ}{R^3}r$.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Rea son is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Electric field inside solid non-conducting sphere is $E_{in} = \frac{1}{4\pi\varepsilon_0}.\frac{Qr}{R^3} = \frac{\rho r}{3\varepsilon_0}\{E_{in} \propto r\}$. So graph is a straight line.

Gauss's law

58. A plane area of 100 cm² is placed in uniform electric field of 100 N/C such that the angle between area vector and electric field is 60º. The electric flux through the surface is

(a) 0.5 Wb (b) 5 Wb

(c) 1 Wb (d) 0

Ans. (a)

Sol.

$$\text{Electic Flux } (\phi) = \vec{E}.\vec{A} = EA\cos\theta$$
$$\Rightarrow \phi = 0.01m^2 \times 100 N/C \times \cos 60^o$$
$$\Rightarrow \phi = 0.5 Wb$$

59. Electric flux through a surface element $dS = 5\hat{i}$ placed in an electric field $E = 4\hat{i} + 4\hat{j} + 4\hat{k}$ is

(a) 10 units (b) 20 units

(c) 4 units (d) 16 units

Ans. (b)

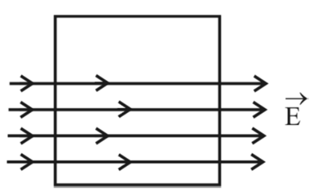
Sol. $\phi = E \cdot dS,\ E = 4\hat{i} + 4\hat{j} + 4\hat{k}$

and $dS = 5\hat{i}$

$$\Rightarrow \phi = \left(4\hat{i} + 4\hat{j} + 4\hat{k}\right)\cdot\left(5\hat{i}\right)$$

$\phi = 20$ units

60. A square surface of side L meters is in the plane of the paper. A uniform electric field $\vec{E}$ (volt/m), also in the plane of the paper, is limited only to the lower half of the square surface, (see figure). The electric flux in SI units associated with the surface is



(a) $EL^2/2$ (b) zero

(c) EL^2 (d) $EL^2/(2\varepsilon_0)$

Ans. (b)

Sol. Electric flux,

For upper half, $E = 0, \phi_1 = 0$

For lower half,

$$\phi_2 = \int \vec{E}.d\vec{S} = \int EdS\cos\theta = \int EdS\cos 90^o = 0$$

61. The number of lines of force passing normally through unit area of a surface situated in an electric field is called as:

(a) surface charge density

(b) electric flux density through that surface which is equal to E

(c) linear density

(d) molecular density

Ans. (b)

Sol. The number of lines of force passing normally through the unit area of a surface situated in an electric field is called flux density or electric flux density through that surface, which is equal to E.

62. The electric flux through a closed surface area S enclosing charge Q is ϕ. If the surface area is doubled, then the flux is

(a) 2ϕ (b) $\phi/2$

(c) $\phi/4$ (d) ϕ

Ans. (d)

Sol. By Gauss' law, $\phi_E = \dfrac{q}{\varepsilon_0}$

$\therefore$ Flux will remain same, i.e. ϕ.

[$\because$ flux through a closed surface due to enclosed charge does not depend upon surface area]

63. A point charge of value 10^{-7} C is situated at the centre of cube of 1 m side. The electric flux through its total surface area is

(a) $113 \times 10^4\ Nm^2/C$ (b) $11.3 \times 10^4\ Nm^2/C$

(c) $1.13 \times 10^4\ Nm^2/C$ (d) none of these

Ans. (c)

Sol. $$\phi = \frac{q_{enclosed}}{\varepsilon_0} = \frac{10^{-7}}{8.854\times 10^{-12}} = 1.13\times 10^4\ Nm^2/C$$

64. A charge q is located at the centre of a cube. The electric flux through any face is

(a) $\dfrac{q}{6(4\pi\varepsilon_0)}$ (b) $\dfrac{2\pi q}{6(4\pi\varepsilon_0)}$

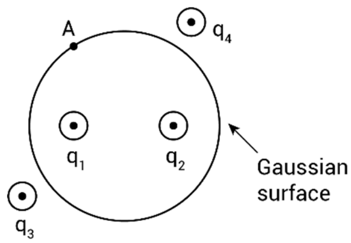
(c) $\dfrac{4\pi q}{6(4\pi\varepsilon_0)}$ (d) $\dfrac{\pi q}{6(4\pi\varepsilon_0)}$

Ans. (c)

Sol. According to Gauss's Law, electric flux passing through any closed surface around a charge q is $\dfrac{q}{\varepsilon_0}$.

Due to symmetry of electric field around the charge, and all the six faces of the cube being equivalent, the electric flux through any face is $\frac{1}{6}$ times the flux $\frac{q}{\varepsilon_0}$, which is equal to $\frac{4\pi q}{6(4\pi\varepsilon_0)}$.

65. Consider the Gaussian surface that surrounds part of charge distributions. Then contribution of the electric field at a point A arises from charges



(a) q_1 and q_2 only (b) q_1 and q_4 only

(c) q_1, $q_2$and q_1 only(d) all of these

Ans. (d)

Sol. Net electric field at a point A is due to all charges in its surroundings

66. Gauss's law is valid for

(a) any closed surface

(b) only regular closed surfaces

(c) any open surface

(d) only irregular open surfaces

Ans. (a)

Sol. Gauss's law is valid for any closed surface not necessary to be a regular closed surface.

67. If the flux of the electric field through a closed surface is zero then

(a) Electric field must be zero everywhere on the surface

(b) Total charge inside the surface must be zero

(c) Electric field must be uniform throughout the closed surface

(d) Charge outside the surface must be zero

Ans. (b)

Sol. According to Gauss's law, if total electric flux through a closed surface is zero, then, the total charge inside the surface must be zero and also, the electric field due to charge inside the surface must be zero.

Also, $\int \vec{E}\cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_0} = 0 \Rightarrow \vec{E} = 0$

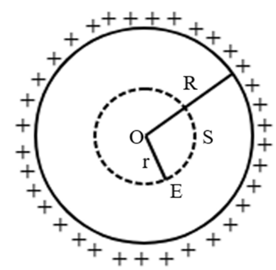
68. A hollow insulated conduction sphere is given a positive charge of $10\mu C$. What will be the electric field at the centre of the sphere if its radius is 2 metres?

(a) zero (b) $5\mu Cm^{-2}$

(c) $20\mu Cm^{-2}$ (d) $8\mu Cm^{-2}$

Ans. (a)

Sol.



$q_{inside} = 0$

$\int \vec{E}.d\vec{s} = \frac{q}{\varepsilon_0} = 0$

$\Rightarrow E = 0$

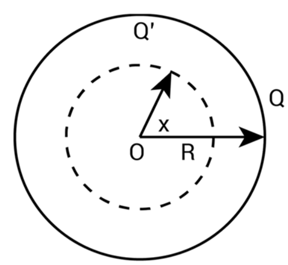
69. A solid sphere of radius R has a uniform distribution of electric charge in its volume. At a distance x from its centre for x < R, the electric field is directly proportional to

(a) $1/x^2$ (b) $1/x$

(c) x (d) x^2

Ans. (c)

Sol.



Consider a small sphere of radius x the charge carried by this sphere is given by

$$Q' = \frac{Q}{\frac{4}{3}\pi R^3} \times \frac{4}{3}\pi x^3$$

$$Q' = \frac{Q}{R^3}.x^3$$

Electric field due to this charge on the surface of the small sphere of radius x

$$E = k.\frac{Q'}{x^2} = k.\frac{Q}{R^3}x$$

70. **Assertion:** The electric flux emanating out and entering a closed surface are 8×10^3 V m and 2×10^3 V m, respectively. The charge enclosed by the surface is $0.053\ \mu C$.

Reason: According to Gauss's theorem in electrostatics, net flux enclosed $\phi = q/\varepsilon_o$.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

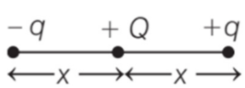
Sol. According to Gauss's theorem in electrostatics, net flux enclosed $\phi = q/\varepsilon_o$. We have

$$q = \varepsilon_o \phi = 8.85 \times 10^{-12}\left(8 \times 10^3 - 2 \times 10^3\right)$$

$$= 53.10 \times 10^{-9} C = 0.053 \mu C.$$

Electric Potential Energy

71. Three charges $-q, +Q$ and $+q$ are placed in a straight line as shown. If the total potential energy of the system is zero, then the ratio q/Q is



(a) 2 (b) 5.5

(c) 4 (d) 1.5

Ans. (c)

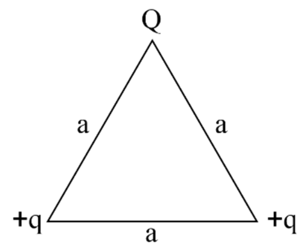
Sol. Potential energy of the system,

$$\frac{-kqQ}{x} - \frac{kQq}{x} - \frac{kq^2}{2x} = 0$$

$$\Rightarrow \frac{-4kqQ + kq^2}{2x} = 0$$

$$\Rightarrow kq^2 = 4\ kQq \Rightarrow q/Q = 4$$

72. Three charges are placed at the vertex of an equilateral triangle as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) – q (b) q/2

(c) – 2q (d) – q/2

Ans. (d)

Sol. Electrostatic potential energy of the given system is given as

$$U = \frac{1}{4\pi\varepsilon_0} \times \frac{1}{a}\left(Qq + Qq + q^2\right)$$

Given, $U = 0$

$$\Rightarrow \quad 2Qq = -q^2 \quad \Rightarrow \quad Q = -\frac{q}{2}$$

73. In bringing an electron towards another electron, the electrostatic potential energy of the system

(a) decreases (b) increases

(c) remains same (d) becomes zero

Ans. (b)

Sol. Electrostatic potential energy of system of two electrons,

$$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-e)(-e)}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}$$

Thus, as r decreases, potential energy U increases.

74. If a positive charge is shifted from a low potential region to a high potential region, then electric potential energy

(a) decreases

(b) increases

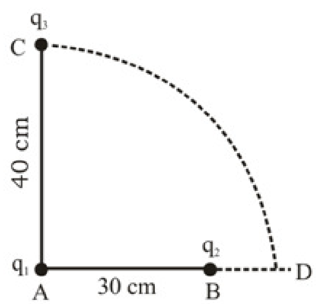
(c) remains same

(d) may increase or decrease

Ans. (b)

Sol. When positive charge is shifted from a low potential to a high potential region, the electric potential energy increases.

75. Two charges q_1 and q_2 are placed 30 cm apart, as shown in the figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D. The change in the potential energy of the system is $\frac{q_3}{4\pi\epsilon_0}k$, where k is



(a) $8q_1$ (b) $6q_1$

(c) $8q_2$ (d) $6q_2$

Ans.(c)

Sol. $AB = 0.3m$

$AC = AD = 0.4m$

$BC = \sqrt{0.3^2 + 0.4^2} = 0.5m$

$BD = AD - AB = 0.1m$

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_1q_3}{r_{13}}\right]$$

$$U_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{AB} + \frac{q_2q_3}{BC} + \frac{q_1q_3}{AC}\right]$$

$$U_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{0.3} + \frac{q_2q_3}{0.5} + \frac{q_1q_3}{0.4}\right]$$

$$U_f = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{AB} + \frac{q_2q_3}{BD} + \frac{q_1q_3}{AD}\right]$$

$$U_f = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{0.3} + \frac{q_2q_3}{0.1} + \frac{q_1q_3}{0.4}\right]$$

$$\Delta U = U_f - U_i = \frac{1}{4\pi\varepsilon_0}[8q_2q_3] = \frac{q_3}{4\pi\varepsilon_0}[8q_2]$$

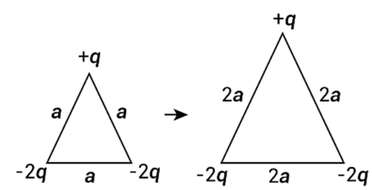
76. Three point charges $q, -2q$ and $-2q$ are placed at the vertices of an equilateral triangle of side a. The work done by some external force to increase their separation to 2a will be

(a) $\frac{1}{4\pi\varepsilon_0}\frac{2q^2}{a}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{2a}$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{8q}{a^2}$ (d) zero

Ans. (d)

Sol. According to the work energy theorem, work done in increasing the separation from a to 2a is $W = U_f - U_i$



Here, $U_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{q(-2q)}{a} + \frac{q(-2q)}{a} + \frac{(-2q)(-2q)}{a}\right]$

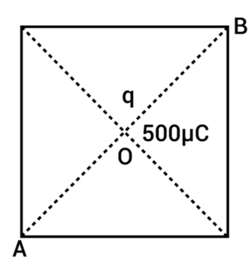
$= \frac{1}{4\pi\varepsilon_0 a}[-2q^2 - 2q^2 + 4q^2] = 0$

Similarly, U_f is also zero.

$\Rightarrow \quad U_f - U_i = 0$

Hence, $\quad W = 0$

77. A 500 mC charge is at the centre of a square of side 10 cm. Find the work done in moving the charge of 10 µC between two diagonally opposite points on the square.



(a) 2 J (b) 0 J

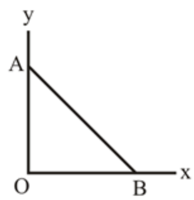
(c) 4 J (d) 25 J

Ans. (b)

Sol. The points A and B are equidistant from the centre of square where charge q = 500 µC is located ; therefore, points A and B are at the same potential i.e.,

$V_A = V_B$. Work done in moving charge q_0 = 10mC from A to B is W = q_0 (V_B - V_A) = 0

78. As per the diagram, a point charge +q is placed at the origin O. Work done in taking another point charge –Q from the point A [coordinates (0, a)] to another point B [coordinates (a; 0)] along the straight path AB is:



(a) Zero (b) $\left(\frac{-qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\sqrt{2}a$

(c) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right).\frac{a}{\sqrt{2}}$ (d) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right).\sqrt{2}a$

Ans. (a)

Sol. $U = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$

$$U_A = \frac{(-Q)q}{4\pi\varepsilon_0(OA)} = -\frac{Qq}{4\pi\varepsilon_0 a}$$

$$U_B = \frac{(-Q)q}{4\pi\varepsilon_0(OB)} = -\frac{Qq}{4\pi\varepsilon_0 a}$$

$$W_{AB} = U_A - U_B = -\frac{Qq}{4\pi\varepsilon_0 a} - \left(-\frac{Qq}{4\pi\varepsilon_0 a}\right) = 0$$

79. A charge of 8 mC is located at the origin. Calculate the work done in taking a small charge of -2×10^{-9} C from a point P (0, 0, 3 cm) to a point Q (0, 4 cm, 0), via a point R (0, 6 cm, 9 cm).

(a) 1.2J (b) 2J

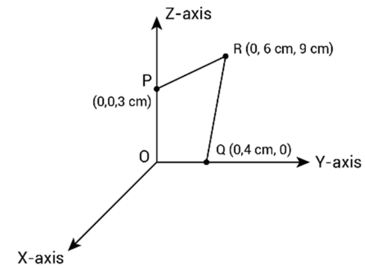
(c) 4J (d) 1J

Ans. (a)

Sol. Charge located at the origin, q = 8 mC = 8×10^{-3} C

A small charge is moved from a point P to point R to point Q, $q_1 = -2 \times 10^{-9}$C

The figure given below represents all points.



Potential at point P, $V_1 = \frac{q}{4\pi\varepsilon_o d_1}$

Where d_1 = 3cm = 0.03 m

Potential at point Q, $V_2 = \frac{q}{4\pi\varepsilon_o d_2}$

Where d_2 = 4cm = 0.04 m

Work done by the electrostatic force does not depend on the path.

$W = q_1 [V_2 - V_1]$

$$\Rightarrow W = q_1\left[\frac{q}{4\pi\varepsilon_o d_2} - \frac{q}{4\pi\varepsilon_o d_1}\right]$$

$$\Rightarrow W = \frac{q_1 q}{4\pi\varepsilon_o}\left[\frac{1}{d_2} - \frac{1}{d_1}\right]$$

Value of $\frac{1}{4\pi\varepsilon_o} = 9\times10^9\,NC^{-2}m^{-2}$

$$\Rightarrow W = 9\times10^9 \times 8\times10^{-3} \times (-2\times10^{-9})\left[\frac{1}{0.04} - \frac{1}{0.03}\right]$$

$\Rightarrow W = 1.2$ J

Clearly, work done during the process is 1.27 J.

80. Positive and negative point charges of equal magnitude are kept at $\left(0,0,\frac{a}{2}\right)$ and $\left(0,0,\frac{-a}{2}\right)$ respectively. The work done by the electric field when another positive point charge is moved from (–a, 0, 0) to (0, a, 0) is

(a) positive

(b) negative

(c) zero

(d) depends on the path connecting the initial and final positions

Ans. (c)

Sol. A (- a, 0, 0), B (0, a, 0)

Point charge is moved from A to B

$V_A = V_B = 0$ [$\because$ A and B are at same distance]

$\therefore$ $W = 0$

81. A bullet of mass 2 g is having a charge of $2\mu C$. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s?

(a) 50 V (b) 5 KV

(c) 50 KV (d) 5 V

Ans. (c)

Sol. Velocity $v = \sqrt{\frac{2qV}{m}}$

$$V = \frac{mv^2}{2q} = \frac{2\times10^{-3}(10^2)}{2(2\times10^{-6})} = 50,000V = 50\,kV$$

82. An electron of mass m and charge e is accelerated from rest through a potential difference V in vacuum. The final speed will be:

(a) $\frac{2\,eV}{m}$ (b) $v\sqrt{\frac{e}{m}}$

(c) $\sqrt{\frac{3\,eV}{m}}$ (d) $\sqrt{\frac{2\,eV}{m}}$

Ans. (d)

Sol. $\frac{1}{2}mv^2 = eV \Rightarrow v = \sqrt{\frac{2eV}{m}}$

83. A proton is about 1840 times heavier than an electron. When it is accelerated by a potential difference of 1 kV, its kinetic energy will be:

(a) 1840 keV (b) 1/1840 keV

(c) 1 keV (d) 920 keV

Ans. (c)

Sol. KE = Relative charge $\times$ accelerating potential $= 1e\times1kV = 1keV$

84. A particle of mass 2g and charge $1\mu C$ is held at a distance of 1m from a fixed charge 1mC. If the particle is released it will be repelled. The speed of particle when it is at a distance of 10m from the fixed charge is:

(a) 90 m/s (b) 100 m/s

(c) 45 m/s (d) 55 m/s

Ans. (a)

Sol. Potential at 1m from the charge

$$V_A = \frac{K\times10^{-3}}{1} = K\times10^{-3}$$

Potential at 10m from the charge

$$V_B = \frac{K\times10^{-3}}{10} = K\times10^{-4}$$

Potential difference

$$V_A - V_B = K(10^{-3} - 10^{-4})$$

Velocity at 10 m is v :

$$\frac{1}{2}mv^2 = (V_A - V_B)q$$

$$\frac{1}{2}(2\times10^{-3})v^2 = K\times10^{-6}\left(1-\frac{1}{10}\right)\times10^{-3}$$

$$v^2 = K\times\frac{9}{10}\times10^{-6} = 9\times10^9\times\frac{9}{10}\times10^{-6} = 8100$$

Thus, $v = 90\,ms^{-1}$

85. Two charged particles having charges $1\mu C$ and $-1\mu C$ and of mass 50 gm each are held at rest while their separation is 2 meters. Find the speed of the particles when their separation is 1 meter.

(a) 0.20 m/s (b) 0.6 m/s

(c) 0.3 m/s (d) 0.4 m/s

Ans. (c)

Sol. Change in electrostatic P.E $= 2\left[\frac{1}{2}mv^2\right]$

$$\frac{1}{4\pi\varepsilon_0}.\frac{1\times10^{-12}}{1} - \frac{1}{4\pi\varepsilon_0}.\frac{1\times10^{-12}}{2} = 50\times10^{-3}v^2$$

$$\Rightarrow \frac{9\times10^9\times10^{-12}}{2} = 50\times10^{-3}v^2$$

$$\Rightarrow v^2 = \frac{9\times10^{-3}}{100\times10^{-3}}$$

$$\Rightarrow v^2 = \frac{9}{100} \Rightarrow v = 0.3m/s$$

86. **Assertion:** Work done in carrying + q charge from one surface A to another surface B at the same potential is zero.

Reason: Work done in moving a charge is product of charge and potential difference.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Work done by electric force is given by $q(V_2 - V_1)$ Thus, both the assertion and reason are true and reason is the correct explanation of the assertion.

Electric Potential

87. Electric Potential is a:

(a) Scalar quantity (b) Vector quantity

(c) Both of the above (d) None of the above

Ans. (a)

Sol. Electric potential is a scalar quantity. It has a magnitude but it does not have direction. The electric potential is defined as the amount of work done per unit positive charge to bring it from infinity to that point, under the influence of electric field.

88. The work done on a unit positive charge in bringing it from infinity to any point in the field is called

(a) Electric potential at that point

(b) Electric intensity at that point

(c) Capacity

(d) Electric potential energy at that point

Ans. (a)

Sol. The work done on a unit positive charge in bringing it from infinity to any point in the field is called electric potential at that point. The potential at infinity is assumed to be zero.

89. The electrostatic potential of a uniformly charged thin spherical shell of charge Q and radius R at a distance r from the centre is

(a) $\frac{Q}{4\pi\varepsilon_0 r}$ for points outside and $\frac{Q}{4\pi\varepsilon_0 R}$ for points on surface of the sphere

(b) $\frac{Q}{4\pi\varepsilon_0 r}$ for both points inside and outside the shell

(c) zero for points outside and $\frac{Q}{4\pi\varepsilon_0 r}$ for points inside the shell

(d) zero for both points inside and outside the shell

Ans. (a)

Sol. If charge on a conducting sphere of radius R is Q, then potential outside the sphere,

$$V_{out} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

At the surface of sphere, $V_s = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

90. Two electric charges $12\mu C$ and $-6\mu C$ are placed 20 cm apart in air. There will be a point P on the line joining these charges and outside the region between them, at which the electric potential is zero. The distance of P from $-6\mu C$ charge is

(a) 0.10 m (b) 0.15 m

(c) 0.20 m (d) 0.25 m

Ans. (c)

Sol. Let charges are placed at A $12\mu C$ and $-6\mu C$ be placed at B.

Potential at point P is zero

Let it is at x unit from B, i.e. $-6\ \mu C$.

$$\Rightarrow \quad V_P = V_A + V_B = 0$$

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_A}{(20+x)} = -\frac{1}{4\pi\varepsilon_0}\frac{q_B}{x}$$

$$\frac{12\times10^{-6}}{20+x} = \frac{-(-6\times10^{-6})}{x}$$

$$\Rightarrow \quad 2x = 20 + x$$

$$= 20\ \text{cm} = 0.20\ \text{m}$$

91. A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is

(a) zero (b) 10 V

(c) same as at a point 5 cm away from the surface

(d) same as at a point 25 cm away from the surface

Ans. (b)

Sol. A hollow metal sphere has equipotential surface from its center to outer surface, which suggests that all the points on this surface (whether it be outer surface or the exact center of the sphere) have the same potential.

92. A solid spherical conductor is given a charge. The electrostatic potential of the conductor is

(a) Constant throughout the conductor

(b) Largest at the centre

(c) Largest on the surface

(d) Largest somewhere between the centre and the surface

Ans. (a)

Sol. Electrostatic potential is given by $V = \frac{kq}{r}$ [where, $k = \frac{1}{4\pi\varepsilon_0}$]

The electric field is equal to the potential gradient with a negative sign and there is no electric field inside the conductor.

Hence, electrostatic potential of the conductor is constant throughout the conductor.

93. Two charged spheres of radii R_1 and R_2 have equal surface charge density. The ratio of their potential is

(a) R_1/R_2 (b) R_2/R_1

(c) $(R_1/R_2)^2$ (d) $(R_2/R_1)^2$

Ans. (a)

Sol. Surface charge density is given as

$$\sigma = \frac{Q}{A} = \frac{Q}{4\pi R^2}$$

As, $\sigma_1 = \sigma_2$

$$\Rightarrow \frac{Q_1}{4\pi R_1^2} = \frac{Q_2}{4\pi R_2^2}$$

$$\Rightarrow \frac{Q_1}{4\pi\varepsilon_0 R_1^2} = \frac{Q_2}{4\pi\varepsilon_0 R_2^2} \Rightarrow \frac{V_1}{V_2} = \frac{R_1}{R_2}$$

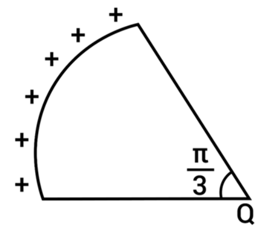
94. An arc of radius r carries charge. The linear density of charge is λ and the arc subtends an angle $\pi/3$ at the centre. What is electric potential at the centre

(a) $\frac{\lambda}{4\varepsilon_0}$ (b) $\frac{\lambda}{8\varepsilon_0}$

(c) $\frac{\lambda}{12\varepsilon_0}$ (d) $\frac{\lambda}{16\varepsilon_0}$

Ans. (c)

Sol.



Length of the arc = $\pi r/3$

Charge of the arc $q = \lambda \pi r/3$

$$V = \frac{kq}{r} = \frac{K\pi r\lambda}{3r}$$

$$V = K\lambda\frac{\pi}{3} \qquad V = \frac{1}{4\pi\epsilon_0}\cdot\frac{\lambda\pi}{3}$$

$$V = \frac{\lambda}{12\epsilon_0}$$

95. The potential of a large liquid drop when eight liquid drops are combined is 20 V. Then, the potential of each single drop was

(a) 10 V (b) 7.5 V

(c) 5 V (d) 2.5 V

Ans. (c)

Sol. Volume of 8 drops = Volume of a big drop

$$\therefore \left(\frac{4}{3}\pi r^3\right)\times 8 = \frac{4}{3}\pi R^3$$

$$\Rightarrow \quad 8r^3 = R^3$$

$$\Rightarrow \quad 2r = R \qquad ...(i)$$

According to charge conservation,

$$8q = Q \qquad ...(ii)$$

Potential of one small drop, $V' = \frac{q}{4\pi\varepsilon_0 r}$

Similarly, potential of big drop, $V = \frac{Q}{4\pi\varepsilon_0 R}$

$$\text{Now, } \frac{V'}{V} = \frac{q}{Q}\times\frac{R}{r} \Rightarrow \frac{V'}{20} = \frac{q}{8q}\times\frac{2r}{r}$$

[from Eqs. (i) and (ii)]

$$\therefore \quad V' = 5\text{ V}$$

96. **Assertion:** Electrons move away from a low potential region to high potential region.

Reason: Because electrons have negative charge.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Electrons have negative charge and in an electric field negative charge moves from lower potential to higher potential.

Electric Field and Potential

97. The electric potential at a point in free space due to a charge Q coulomb is $Q \times 10^{11}$ V. The electric field at that point is

(a) $4\pi\varepsilon 0\ Q \times 10^{22}$ V/m

(b) $12\pi\varepsilon 0\ Q \times 10^{22}$ V/m

(c) $4\pi\varepsilon 0\ Q \times 10^{22}$ V/m

(d) $12\pi\varepsilon 0\ Q \times 10^{22}$ V/m

Ans. (a)

Sol. $V = \dfrac{Q}{4\pi\varepsilon_0 r} = Q \times 10^{11}$

Thus, $4\pi\varepsilon_0 r = 10^{-11}$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} = \frac{Q(4\pi\varepsilon_0)}{(4\pi\varepsilon_0 r)^2} = \frac{Q(4\pi\varepsilon_0)}{(10^{-11})^2} = 4\pi\varepsilon_0 Q \times 10^{22}\ \text{Vm}^{-1}$$

98. In a uniform electric field

(a) All points are at same potential

(b) no two points can have same potential

(c) pair of points separated by same distance must have same difference of potential

(d) none of these

Ans. (d)

Sol. Let $\vec{E} = E\hat{i}$

(a) Then for two points (0,0) & (x,0) $V_{(x,0)} - V_{(0,0)} = Ex$

Hence, all the points are not at same potential.

(b) For 2 points B (0,0) and A (0,y)

$$V_A - V_B = \int_A^B \vec{E}.\vec{dl}$$

$$V_{0,y} - V_{0,0} = \int_0^0 E dx = 0$$

$$V_{0,y} = V_{0,0}$$

So, they have the same potential

(c) As seen above, if x=y, then (0,y) and (x,0) have same distance from the origin but their potential difference is different. Hence, the correct answer is (d)

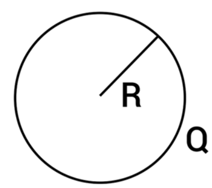
99. A conducting sphere of radius R is charged to a potential of V volt. Then the electric field at a distance r (> R) from the centre of the sphere would be

(a) $\dfrac{RV}{r^2}$ (b) $\dfrac{V}{r}$

(c) $\dfrac{rV}{R^2}$ (d) $\dfrac{R^2V}{r^3}$

Ans. (a)

Sol. Conducting sphere



If r > R

$$V = \frac{1}{4\pi\epsilon_0}.\frac{Q}{R} = k.\frac{Q}{R}$$

$$Q = \frac{V.R}{k} \qquad E = k.\frac{Q}{r^2}$$

$$E = k.\frac{VR}{kr^2} \Rightarrow E = \frac{VR}{r^2}$$

100. Which of the following is proportional to the inverse square of distance r.

(a) The potential at a distance r from an isolated point charge

(b) Electric field at distance r from an isolated point charge

(c) The force per unit length between two thin straight charged conductors separated by distance r

(d) Electrostatic force between two large charged bodies kept at small separation apart.

Ans. (b)

Sol. The electric field is proportional to the inverse square of the distance r from an isolated point charge. Suppose a point charge (Q) produces an electric field at a point P, that is at a distance r from it, then,

electric field of the point charge is given by $E = \frac{kQ}{r^2}$

101. Which of the following is not the property of equipotential surfaces?

(a) They do not cross each other

(b) They are concentric spheres for uniform electric field

(c) Rate of change of potential with distance on them is zero

(d) They can be imaginary spheres

Ans. (b)

Sol. Equipotential surfaces are plane surfaces as the uniform field is directed in a fixed direction for all points.

The electric field is always perpendicular to equipotential surface as $E = -\frac{dV}{dr}$.

Now as the surfaces are equipotential, so it must be spaced such that the surfaces have equal differences in potential and are separated by equal distances.

We have $E = -\frac{dV}{dr}$, so it must have decreasing potentials in the direction of the field.

102. What is not true for equipotential surface for uniform electric field?

(a) Equipotential surface is flat

(b) Equipotential surface is spherical

(c) Electric field lines are perpendicular to equipotential surface

(d) Work done is zero

Ans. (b)

Sol. A surface with constant value of potential at all the points is known as equipotential surface. Along x-axis, for a uniform electric field, the equipotential surfaces are planes normal to the x-axis, i.e., parallel to the yz-plane. This cannot be accomplished from a spherical surface.

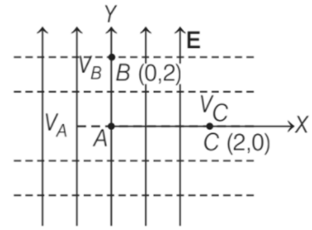
103. An electric field is spread uniformly in Y-axis. Consider a point A as origin point. The coordinates of point B are equal to (0, 2) m. The coordinates of point C are (2, 0) m. At points A B, and C, electric potentials are V_A, V_B and V_C, respectively. From the following options, which is correct?

(a) $V_A = V_C < V_B$ (b) $V_A = V_B = V_C$

(c) $V_A = V_B > V_C$ (d) $V_A = V_C > V_B$

Ans. (d)

Sol. Potential decreases in the direction of electric field. Dotted lines are equipotential lines.



$\therefore \quad V_A = V_C$ and $V_C > V_B$

104. The work done in moving a positive charge on an equipotential surface is

(a) finite and positive (b) infinite

(c) finite and negative (d) zero

Ans. (d)

Sol. W = Potential difference × charge

In an equipotential surface, potential at every point is the same and therefore, potential difference between two points on the surface = 0. Hence, work done (W) = 0.

105. The electric field lines are closer together near an object A than they are near an object B, we can conclude

(a) The potential near A is greater than near B

(b) The potential near A is less than near B

(c) The potential near A is equal to potential near B

(d) nothing about relative potential be predicted

Ans. (d)

Sol. In this case, we cannot come to a proper conclusion as nothing can be predicted about relative potential.

106. Given a metallic uniformly charged sphere. The radius of the sphere is increased keeping its potential same. What is the effect on the value of the electric field intensity at its surface?

(a) increases (b) decreases

(c) remains constant (d) nothing can be said

Ans. (b)

Sol. Electric potential $V = \frac{kQ}{R}$

V = constant

Electric Field (E) = $\frac{kQ}{R^2} = \frac{kQ}{R} \times \frac{1}{R}$

$E = \frac{kV}{R}$

Since radius is increased therefore

Electric field decreases.

107. From a point charge, there is a fixed-point A. At A, there is an electric field of 500V/m and potential difference of 3000 V. Distance between point charge and A will be:

(a) 6 m (b) 12 m

(c) 16 m (d) 24 m

Ans. (a)

Sol. $E = \frac{kq}{d^2}$; $V = \frac{kq}{d}$

Thus, $d = \frac{V}{E} = \frac{3000}{500} = 6\text{m}$

108. A particle of mass m and charge q is placed at rest in a uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is:

(a) qEy^2 (b) qE^2y

(c) qEy (d) q^2Ey

Ans. (c)

Sol. K.E. acquired = Work Done = Force × Distance

$\Rightarrow = qE \times y = qEy$

109. There is an electric field E in x-direction. If the work done on moving a charge of 0.2 C through a distance of 2 m along a line making an angle 60° with x-axis is 4J, then what is the value of E?

(a) 3 N/C (b) 4 N/C

(c) 5 N/C (d) 20 N/C

Ans. (d)

Sol. $W = \vec{F}.\vec{r} = Fr\cos\theta = qEr\cos\theta$

$4 = (0.2)(E)(2)\cos 60^o$

$E = \frac{4}{(0.2)(2\cos 60^0)} = 20\,\text{NC}^{-1}$

110. n identical mercury droplets charged to the same potential V coalesce to form a single bigger drop. The potential of new drop will be

(a) V/n (b) nV

(c) nV^2 (d) $n^{2/3}V$

Ans. (d)

Sol. As, volume of n identical droplets = volume of bigger droplet

$\frac{4}{3}\pi r^3(n) = \frac{4}{3}\pi R^3$

$\frac{R^3}{r^3} = n \Rightarrow \frac{R}{r} = n^{1/3}$

$\Rightarrow R = rn^{1/3}$

Let Q be the final charge on the bigger droplet.

By conservation of charge, nq = Q

Potential of smaller droplets is $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Potential of bigger droplet is

$V' = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} = \frac{1}{4\pi\varepsilon_0}\frac{nq}{r(n)^{1/3}}$

$V' = n^{1-1/3}V = Vn^{2/3}$

111. The electric potential at any point x, y, z in metres is given by $V = 3x^2$. The electric field at a point (2, 0, 1) is

(a) 12 Vm^{-1} (b) – 6 Vm^{-1}

(c) 6 Vm^{-1} (d) – 12 Vm^{-1}

Ans. (d)

Sol. Electric potential is given in ,

$V = 3x^2$

As, $E = -(\partial V/\partial x)$

$\Rightarrow E = -\left[\frac{\partial}{\partial x}(3x^2)\right] = -6x$

$E_{(2,0,1)} = -6(2) = -12\ Vm^{-1}$

112. The potential at a point x (measured in μ m) due to some charges situated on the x-axis is given by:

$V(x) = 20/(x^2 - 4)$ volt

The electric field E at x = 4 μ m is given by

(a) $\frac{5}{3}V/\mu m$ and in the –ve x direction

(b) $\frac{5}{3}V/\mu m$ and in the +ve x direction

(c) $\frac{10}{9}V/\mu m$ and the –ve x direction

(d) $\frac{10}{9}V/\mu m$ and in the +ve x direction

Ans. (d)

Sol. $V(x)=\frac{20}{(x^2-4)}$ volt

Now, the electric field $E=-\frac{dV}{dx}=-\frac{d}{dx}\left(\frac{20}{x^2-4}\right)$

Differentiating on both sides, we get;

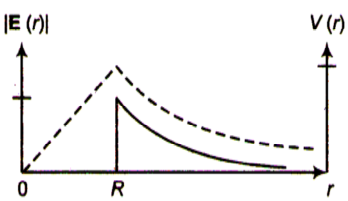
$$E=-\left(\frac{-20(2x)}{(x^2-4)^2}\right)=\frac{40x}{(x^2-4)^2}$$

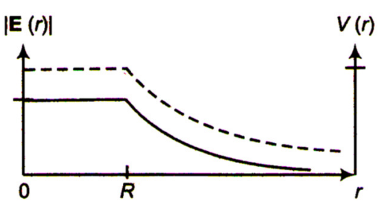
Now, at $x=4\mu m$ (given)

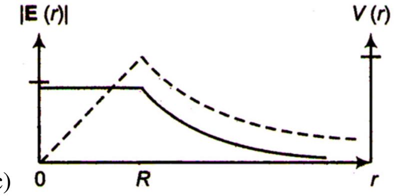
$$E=\frac{40\times4}{(4^2-4)^2}=\frac{10}{9}\text{ volt/}\mu m$$

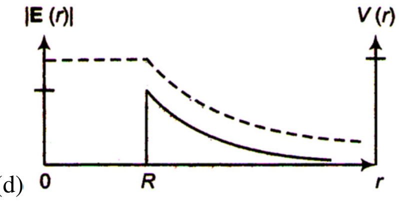
The value of the electric field E is positive, hence the electric field is in the positive x-direction.

113. Consider a thin spherical shell of radius R with its centre at the origin carrying uniform positive surface charge density. The variation of the magnitude of the electric field |E (r)| and the electric potential V (r) with the distance r from the centre, is best represented by which graph?

(a)


(b)


(c)


(d)


Ans. (d)

Sol. For a spherical shell;

Electric field;

For $r<R$, $E=0$

For $r>R$, $E=\frac{kQ}{r^2}$

Electric potential;

For $r<R, V=\frac{kQ}{R}=\text{constant}$

For $r>R, V=\frac{kQ}{r}$

Thus, correct option would be (d).

114. The potential of the electric field produced by point charge at any point (x,y,z) is given by $V=3x^2+5$, where x, y are in metre and V is in volt. The intensity of the electric field at $(-2,1,0)$ is

(a) $+17\,Vm^{-1}$ (b) $-17\,Vm^{-1}$

(c) $+12\,Vm^{-1}$ (d) $-12\,Vm^{-1}$

Ans. (d)

Potential, $(V)=3x^2+5$

Intensity of the electric field

$=\frac{dV}{dx}=6x$

$=6(-2)(E\text{ at }x=-2)=-12\,Vm^{-1}$

115. The electric potential at a point (x, y, z) is given by V = – x^2y – xz^3 + 4. The electric field at that point is:

(a) $\vec{E}=\hat{i}(2xy+z^3)+\hat{j}x^2+\hat{k}3xz^2$

(b) $\vec{E}=\hat{i}\,2xy+\hat{j}(x^2+y^2)+\hat{k}(3xz-y^2)$

(c) $\vec{E}=\hat{i}z^3+\hat{j}xyz+\hat{k}z^2$

(d) $\vec{E} = \hat{i}(2xy - z^3) + \hat{j}xy^2 + \hat{k}3z^2x$

Ans. (a)

Sol.

$$\vec{E} = -\left[\frac{\partial V}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial V}{\partial z}\right]$$

$$\vec{E} = -\left[(-2xy - z^3)\hat{i} + (-x^2)\hat{j} + (-3xz^2)\hat{k}\right]$$

$$\vec{E} = \hat{i}(2xy + z^3) + \hat{j}x^2 + \hat{k}3xz^2$$

116. **Assertion:** The value of V and E at the middle point of the line joining an electron and a proton is zero.

Reason: V is a vector and E is a scalar.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (d)

Sol. $V = \frac{k\sum q}{r} = 0$, as $\sum q = -e + e = 0$.

Unit positive charge held at the centre will be repelled by proton and attracted by electron with same force. Therefore, E cannot be zero. The assertion is wrong. Now V is scalar and E is a vector so reason is also wrong.

117. **Assertion:** At a point in space, the electric field points toward north. In the region, surrounding this point the rate of change of potential will be zero along the east and west.

Reason: Electric field due to a charge is the space around the charge.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (b)

Sol. Since the electric field is directed from south to north hence rate of change of potential will be along this direction, but it is zero along east and west. Reason is also true but does not explain the assertion.

Electric Dipole

118.

The electric dipole moment of an electron and a proton 4.3 nm apart is

(a) $6.88\times10^{-28}\,C-m$

(b) $2.56\times10^{-29}\,C^2-m^{-1}$

(c) $3.72\times10^{-14}\,C-m^{-1}$

(d) $1.1\times10^{-46}\,C^2-m$

Ans. (a)

Sol. The electric dipole moment is equal to

$p = 1.6\times10^{-19}\times4.3\times10^{-9}$

$[\because p = q\times 2l]$

$= 6.88\times10^{-28}\,C-m$

119. What is the angle between the electric dipole moment and the electric field strength due to it on the equatorial line?

(a) 0° (b) 90°

(c) 180° (d) none of these

Ans. (c)

Sol. As electric dipole moment and electric field are in opposite direction so, the angle between electric dipole moment and electric field on the equatorial line is 180°.

120. Let E_a be the electric field due to a dipole in its axial plane distant l and let E_q be the field in the equatorial plane distant l, then the relation between E_a and E_q will be:

(a) $E_a = 4\,E_q$ (b) $E_q = 2\,E_a$

(c) $E_a = 2\,E_q$ (d) $E_q = 3\,E_a$

Ans. (c)

Sol. $E_a = \frac{2p}{4\pi\varepsilon_0 d^3}$ $\quad E_e = \frac{p}{4\pi\varepsilon_0 d^3}$

$E_a = 2E_q$

121. A charge situated at a certain distance along the axis of an electric dipole experience a force F. If the distance of the charge from the dipole is doubled, then the force acting on it will become

(a) 2F (b) $\frac{F}{2}$

(c) $\frac{F}{4}$ (d) $\frac{F}{8}$

Ans. (d)

Sol. The electric field at a point distance r from electric dipole is

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{2p}{r^3} \text{ (axial line)}$$

where, p is dipole moment and r is the distance of charge from centre of dipole.

or $E \propto \frac{1}{r^3}$

Force on charge,

$F = QE$

or $F \propto \frac{1}{r^3}$

$\therefore \frac{F_2}{F_1} = \left(\frac{r_1}{r_2}\right)^3$

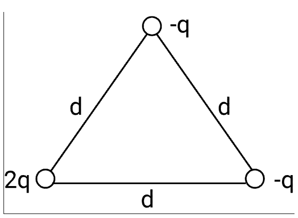
Given, $r_1 = r, r_2 = 2r$

and $F_1 = F$

$\therefore \frac{F_2}{F} = \left(\frac{r}{2r}\right)^3 = \frac{1}{8}$

$\Rightarrow F_2 = \frac{F}{8}$

122. Three charges are arranged on the vertices of an equilateral triangle as shown. The dipole moment of the combination is

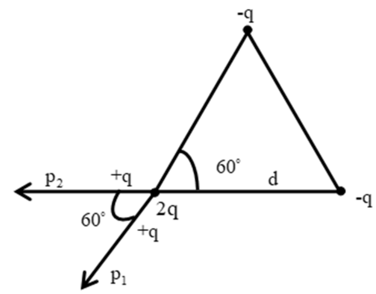


(a) zero (b) 2qd

(c) $\sqrt{3}$qd (d) 3qd

Ans. (c)

Sol.



$$|\vec{P}_{net}| = \sqrt{p^2 + p^2 + 2p^2 \cos 60^o}$$

$= \sqrt{3}p$

$= \sqrt{3}qd$

123. A point Q lies on the perpendicular bisector of an electrical dipole of dipole moment p. If the distance of a point from the dipole is r (much larger than the size of the dipole), then the electric field at that point is proportional to

(a) p^{-1} and r^{-2} (b) p and r^{-2}

(c) p^2 and r^{-3} (d) p and r^{-3}

Ans. (d)

Sol. $E = \frac{p}{4\pi\varepsilon_0}.\frac{1}{\left(r^2 + a^2\right)^{3/2}}$

Now for, r >> a, we have

$$E = \frac{p}{4\pi\varepsilon_0}.\frac{1}{\left(r^3\right)}$$

Now, angle between p_{axi} and p is zero.

$$E_{equitorial} = \frac{kp}{r^3}$$

$E \propto p \Rightarrow E \propto r^{-3}$

124. Three point charges $+q, -2q$ and $+q$ are placed at points $(x = 0, y = a, z = 0)$, $(x = 0, y = 0, z = 0)$ and $(x = a, y = 0, z = 0)$, respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are

(a) $\sqrt{2}$qa along + y − direction

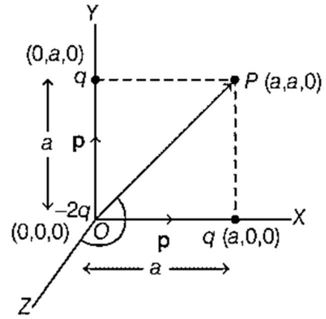
(b) $\sqrt{2}$qa along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$

(c) qa along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$

(d) $\sqrt{2}$qa along + x − direction

Ans. (b)

Sol. Choose the three coordinate axes as x y, and z and plot the charges with the given coordinates as shown



O is the origin at which −2q charge is placed. The system is equivalent to two dipoles along x and y-directions, respectively. The dipole moments of two dipoles are shown in figure. The resultant dipole moment will be directed along OP, where $P \equiv (a, a, 0)$. The magnitude of resultant dipole moment is

$$p' = \sqrt{p^2 + p^2} = \sqrt{(qa)^2 + (qa)^2}$$
$$= \sqrt{2}qa$$

125. The electric field due to an electric dipole at a distance r from its centre at axial position is E. If the dipole is rotated through an angle of 90° about its perpendicular axis, the electric field at the same point will be

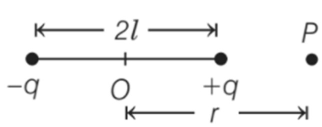
(a) E (b) $\frac{E}{4}$

(c) $\frac{E}{2}$ (d) 2E

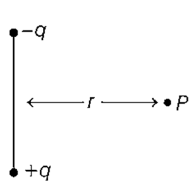
Ans. (c)

Sol. When a dipole AB of very small length is taken, then for a point P located at a distance r from the axis the electric field is given by

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3} \quad ...(i)$$



where, p is dipole moment. When dipole is rotated by 90°, then electric field is given by



From Eqs. (i) and (ii), we get

$$E' = \frac{E}{2}$$

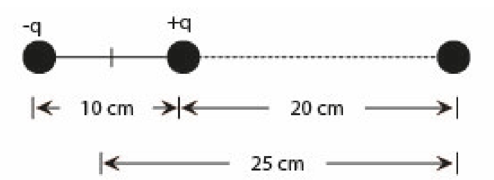
126. The electric intensity due to a dipole of length 10 cm and having a charge of 500 μC, at a point on the axis at a distance 20 cm from one of the charges in air, is

(a) 6.25×10^7 N/C (b) 9.28×10^7 N/C

(c) 13.1×10^{11} N/C (d) 20.5×10^7 N/C

Ans. (a)

Sol.



$$p = (500 \times 10^{-6})(10 \times 10^{-2}) = 5 \times 10^{-5} \text{Cm}$$

$$r = 25\text{cm} = 0.25\text{m}$$

$$l = 5\text{cm} = 0.05\text{m}$$

$$E = 9 \times 10^9 \left(\frac{2pr}{(r^2 - l^2)^2} \right)$$

$$E = \frac{(9 \times 10^9)(2)(5 \times 10^{-5})(0.25)}{((0.25)^2 - (0.05)^2)^2}$$

$$E = 6.25 \times 10^7 \ \text{N/C}$$

127. **Assertion:** A point charge placed at any point on the axis of an electric dipole at some large distance experiences a force F. The force acting on the point charge when its distance from the dipole is doubled is $\frac{F}{8}$.

Reason: Coulomb's law obeys $F \propto \frac{1}{r^3}$.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (c)

Sol. Force acting on a point charge in dipole field varies

$F = qE$

as and $E = \frac{kp}{r^3}$

$F \propto \frac{1}{r^3}$.

128. **Assertion:** On going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.

Reason: Electric field is inversely proportional to square of distance from the charge or an electric dipole.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (d)

Sol. The rate of decrease of electric field is different in the two cases. In case of a point charge, it decreases as $1/r^2$ but in the case of electric dipole it decreases more rapidly, as $E \propto 1/r^3$.

Dipole In Electric Field

129. If a dipole of dipole moment $\vec{p}$ is placed in a uniform electric field then torque acting on it is given by

(a) $\vec{\tau} = \vec{p}.\vec{E}$ (b) $\vec{\tau} = \vec{p} \times \vec{E}$

(c) $\vec{\tau} = \vec{p} + \vec{E}$ (d) $\vec{\tau} = \vec{p} - \vec{E}$

Ans.(b)

Sol. Dipole moment $\vec{p} = q\vec{a}$ (where q is magnitude of charge and a is distance between charges). When a dipole of dipole moment $\vec{p}$ is placed in a uniform electric field E, the torque is given by the product of either force and the perpendicular distance between the two forces.

That is,

$\tau = qEa \sin\theta$

This can also be shown as the cross product of dipole moment and electric field, $\vec{\tau} = \vec{p} \times \vec{E}$

130. A positive charge is fixed at the origin. An electric dipole, which is free to move and rotate, is placed on the positive x–axis. Its dipole moment is directed towards the positive x-axis. The dipole will :

(a) Move towards the origin

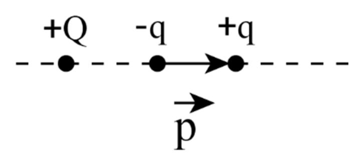
(b) Move away from the origin

(c) Rotate by p/2

(d) Rotate by p

Ans. (a)

Sol.



-q charge is near the +Q as compare to +q, so attractive force will be greater than repulsive force. Therefore, dipole moves towards the origin.

131. An electric dipole with a dipole moment 4×10^{-9} Cm is aligned at 30º with the direction of a uniform electric field of magnitude 5×10^4 NC^{-1}. Calculate the magnitude of the torque acting on the dipole.

(a) 10^{-4} Nm (b) 10^{-2} Nm

(c) 2×10^{-4} Nm (d) 5×10^{-3} Nm

Ans. (a)

Sol. A dipole placed in a uniform electric field, experiences a torque t = pE sin q which tends to align the dipole parallel to the direction of field.

Torque t = pE sin q

Here p = 4×10^{-9} C-m, E = 5×10^4 NC^{-1}, q = 30º

Torque t = $4 \times 10^{-9} \times 5 \times 10^4$ sin 30º

$4 \times 10^{-9} \times 5 \times 10^4 \times 1/2 = 10^{-4}$ Nm

132. An electric dipole of moment 'p' is lying along a uniform electric field 'E'. The work done in rotating the dipole by 90° is

(a) pE/2 (b) 2 p E

(c) p E (d) $\sqrt{2}$ p E

Ans. (c)

Sol. $W = \Delta pE = pE_{final} - pE_{initial} = 0 - (-pE) = pE$

133. An electric dipole has the magnitude of its charge as q and its dipole moment is p. It is placed in uniform electric field E. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively

(a) q. E and max. (b) 2 q. E and min.

(c) q. E and p.E (d) zero and min.

Ans. (d)

Sol. $U = -\vec{p}.\vec{E} = -pE \Rightarrow$ Minimum

$F = \frac{-dU}{dr} = P\frac{dE}{dr} = 0$ (Since E is constant)

134. An electric dipole of dipole moment $\vec{p}$ is placed in uniform electric field $\vec{E}$. It is then rotated by an angle of θ. The work done is

(a) pE sinθ (b) pE cosθ

(c) pE (1-cosθ) (d) pE (1-sinθ)

Ans. (c)

Sol.

U_i = - PE cos0° = - PE

U_f = - PE cosθ

ΔU = - PE cosθ + PE

= PE (1 - cosθ)

∴ W = PE (1 - cosθ)

135. A charge q is placed at (1, 2, 1) and other charge –q is placed at (0,1, 0) such that they form an electric dipole. There exists a uniform electric field $\vec{E} = 2\hat{i} + 3\hat{j}$. What is torque experienced by the dipole.

(a) $q(3\hat{i} + 2\hat{j} + \hat{k})$ N.m (b) $q(-3\hat{i} + 2\hat{j} + \hat{k})$ N.m

(c) $q(-3\hat{i} + 2\hat{j} - \hat{k})$ N.m (d) $q(\hat{i} - 2\hat{j} + \hat{k})$ N.m

Ans. (b)

Sol.

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

$\vec{E} = 2\hat{i} + 3\hat{j}$

$\vec{p} = q(\hat{i} + \hat{j} + \hat{k}) = q\hat{i} + q\hat{j} + q\hat{k}$

$\vec{\tau} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ q & q & q \\ 2 & 3 & 0 \end{vmatrix} = q(-3\hat{i} + 2\hat{j} + \hat{k})$ N.m

136. An electric dipole consists of two opposite charges each 0.05μC separated by 30 mm. The dipole is placed in a uniform external electric field of $10^6\,NC^{-1}$. The maximum torque exerted by the field on the dipole is

(a) 6×10^{-3} Nm (b) 3×10^{-3} Nm

(c) 15×10^{-3} Nm (d) 1.5×10^{-3} Nm

Ans. (d)

Sol.

Given, $q = 0.05\mu C = 5\times10^{-8}\,C$,

$2a = 30$ mm $= 0.03$ and $E = 10^6\,NC^{-1}$

Torque acting on an electric dipole placed in an uniform electric field,

$\tau = pE\sin\theta$

For maximum torque, $\theta = 90^o$

$\therefore \quad \tau_{max} = pE = E(q\times 2a)$

$= 10^6 \times 5\times10^{-8} \times 0.03$

$= 1.5\times10^{-3}$ N – m

137. An electric dipole placed in a non-uniform electric field experience:

(a) both, a torque and a net force

(b) only a force but no torque

(c) only a torque but no net force

(d) no torque and no net force

Ans. (a)

Sol. If an electric dipole is placed in a non-uniform electric field, then the positive and negative charges of the dipole will experience a net force. And as one end of the dipole experiences a force in one direction and the other end in the opposite direction, so the dipole will have a net torque also.

138. **Assertion:** Electric dipole in non-uniform electric field may have translatory and rotational motion both.

Reason: Net force is always zero on dipole in non-uniform electric field.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (c)

Sol. When an electric dipole is placed in a non-uniform electric field, the two charges of dipole experiences unequal forces, therefore, the net force on the dipole is not equal to zero. Due to two unequal forces, a torque is produced which rotate the dipole so as to align it in the direction of the field. When the dipole gets aligned with the field, the torque becomes zero and then the unbalanced force acts on the dipole and the dipole then moves linearly along the direction of field from weaker portion of the field to the stronger portion of the field. So in non-uniform electric field, motion of the dipole is translatory and rotatory both.

139. **Assertion:** When a dipole is placed along the uniform electric field it is said to be in stable equilibrium.

Reason: If dipole is along the direction of field its potential energy is maximum.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (c)

Sol. When $\theta = 0^o$ that is, dipole is placed along the electric field it is said to be in stable equilibrium, because after turning it through a small angle, dipole tries to align itself again in the direction of electric field. Potential energy is minimum as $U_{min} = -pE\cos\theta$.

Dielectrics

140. When air medium in which two charges kept apart at a distance r is replaced by a dielectric medium of dielectric constant K, the force between the charges is

(a) remain unchanged (b) 1/K times

(c) $\frac{1}{K^2}$ times (d) K^2 times

Ans. (b)

Sol. Force between two charged particles, when air is the medium between them is given as

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r^2}$$

where, q_1 and q_2 are charge on the particles and r is the distance between them.

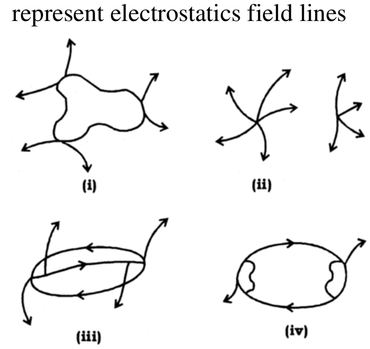
Now, if a dielectric is inserted between them, the force is given as

$$F' = \frac{1}{4\pi\varepsilon}\cdot\frac{q_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_0 K}\cdot\frac{q_1q_2}{r^2}$$

$$= \frac{1}{K}F \qquad (\text{As, } \varepsilon = K\,\varepsilon_0)$$

Conductors And Its Properties

141. Which of the following figures cannot possibly represent electrostatics field lines



(a) i, ii, iii, iv (b) i, ii, iii only

(c) i, iii, iv only (d) ii, iii, iv only

Ans. (c)

Sol. In figure (1), the field lines are not normal to the surface, so it cannot represent electrostatic field lines.

In figure (3), the field lines intersect each other, so it cannot represent electrostatic field lines.

In figure (4), closed loops are not formed in the area between the field lines.

142. Two concentric metallic spherical shells are given unequal positive charges. Then,

(a) the outer sphere is always at a higher potential

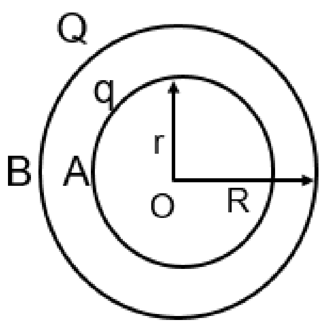
(b) the inner sphere is always at a higher potential

(c) both the spheres are at the same potential

(d) no prediction can be made about their potentials unless the actual values of charges and radii are known

Ans. (b)

Sol. Two concentric metallic spherical shells are given a positive charge. The potential difference depends on the radius of the spherical shells. As the inner sphere has less radius, so the potential will be high. The radius of outer-sphere has a large radius in comparison to the inner sphere, then the potential is less when compared to the inner sphere. Therefore, the inner sphere has more potential than the outer sphere.



143. The concentric spheres of radii R and r have similar charges with equal surface densities (σ). What is the electric potential at their common centre?

(a) $\frac{\sigma}{\varepsilon_0}(R-r)$ (b) $\frac{\sigma}{\varepsilon_0}(R+r)$

(c) $\frac{R\sigma}{\varepsilon_0}$ (d) $\frac{\sigma}{\varepsilon_0}$

Ans. (b)

Sol. Charge on outer sphere $q_1 = 4\pi R^2\sigma$

Charge on inner sphere $q_2 = 4\pi r^2\sigma$

$$v = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{R} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r}$$

$$\Rightarrow v = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{R} + \frac{q_2}{r}\right]$$

$$\Rightarrow v = \frac{1}{4\pi\varepsilon_0}\left[\frac{4\pi R^2\sigma}{R} + \frac{4\pi r^2\sigma}{r}\right]$$

$$\therefore v = \frac{\sigma}{\varepsilon_0}(R+r)$$

144. Identify the false statement.

(a) Inside a charged or neutral conductor, electrostatic field is zero.

(b) The electrostatic field at the surface of the charged conductor must be tangential to the surface at any point.

(c) There is no net charge at any point inside the conductor.

(d) Electrostatic potential is constant throughout the volume of the conductor.

(e) Electric field at the surface of a charged conductor is proportional to the surface charge density.

Ans. (b)

Sol. Electrostatic field at the surface of a conductor is perpendicular to the surface.

145. The charge given to any conductor resides on its outer surface, because

(a) the free charge tends to be in its minimum potential energy state

(b) the free charge tends to be in its minimum kinetic energy state

(c) the free charge tends to be in its maximum potential energy state

(d) the free charge tends to be in its maximum kinetic energy state

Ans. (a)

Sol. Charge given to a conductor is uniformly distributed at its outer surface to acquire its minimum potential energy state.

146. Surface charge density on uniformly charged sphere is

(a) Directly proportional to the radius of the sphere

(b) Inversely proportional to the radius of the sphere

(c) Directly proportional to the square of the radius of the sphere

(d) Inversely proportional to the square of the radius of the sphere

Ans. (d)

Sol. Surface charge density $= \frac{Q}{4\pi R^2}$

147. A circular metal plate of radius 10 cm is given a charge of 20 μC on its surface. The charge density of the plate is

(a) 6.36×10^{-4} C/m^2 (b) 2×10^{-6} C/m^2

(c) 3×10^{-9} C/m^2 (d) 3.184×10^{-4} C/m^2

Ans. (d)

Sol. $$\sigma = \frac{Q}{2\pi R^2} = \frac{20\times10^{-6}}{2\times3.14\times10^{-2}} = 3.184\times10^{-4}\ C/m^2$$

148. The surface density of charge on a conductor situated in air is 2×10^4 C/m^2. The electric field intensity at a point very near to its surface is

(a) 2.2×10^{15} N/C (b) 2.2×10^9 N/C

(c) 3.3×10^7 N/C (d) 3.3×10^{15} N/C

Ans. (a)

Sol. $\sigma = 2 \times 10^{-4}$ C/m^2

$$E = \frac{\sigma}{\epsilon_0} = 2.2\times10^{15}\,N/C$$

149. If a conductor is electrically neutral, then

(a) Net charge on it should be zero

(b) Potential on it should be zero

(c) Both charge and potential should be zero

(d) None of these may not be zero

Ans. (a)

Sol. The net charge on the conductor should be zero, as conductor is electrically neutral. So, the potential of a neutral conductor may not be zero and it depends on the other charges available in the surrounding.

150. Which of the following may be discontinuous across a charged conducting surface?

(a) Electric potential

(b) Electric intensity

(c) Both electric intensity and potential

(d) None of these

Ans. (b)

Sol. For a conducting sphere

$E_{inside} = 0$

$E_{outside} = \frac{KQ}{r^2}$

Hence at the boundary, electric intensity $\vec{E}$ is discontinuous, while $V_A - V_B = \int \vec{E}.\vec{dr}$,potential difference between two points on the surface, is an integral of a non-infinite quantity, which cannot be discontinuous.

151. Assertion: Electrostatic potential is constant throughout the volume of the conductor and has the same value as on its surface.

Reason: Electric field inside the conductor is zero.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

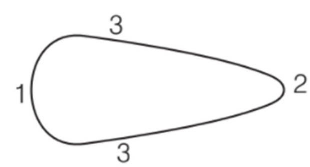
(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Inside the conductor, net electric field is zero; therefore, the potential difference is also zero. Due to zero potential difference, potential remains constant throughout inside total volume.

152. Consider a non-spherical conductor shown in the figure which is given a certain amount of positive charge. The charge distributes itself on the surface such that the charge densities are σ_1, σ_2 and $\sigma_3$at the region 1, 2 and 3 respectively. Then



(a) $\sigma_1 > \sigma_2 > \sigma_3$ (b) $\sigma_2 > \sigma_3 > \sigma_1$

(c) $\sigma_3 > \sigma_1 > \sigma_2$ (d) $\sigma_2 > \sigma_1 > \sigma_3$

Ans. (d)

Sol.

Charge density is inversely proportional to radius of curvature, i.e.

Charge density $\propto \frac{1}{\text{Radius of curvature}}$

$R_3 > R_1 > R_2$

Therefore, as shown in figure,

$\sigma_2 > \sigma_1 > \sigma_3$

153. Two charged metallic spheres of radii $r_1$and r_2 are touched and separated. What is the ratio of their surface charge density?

(a) $\frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1}$ (b) $\frac{\sigma_1}{\sigma_2} = \frac{r_1}{r_2}$

(c) $\frac{\sigma_1}{\sigma_2} = 1$ (d) $\frac{\sigma_1}{\sigma_2} = \frac{r_2 r_1}{r_1 + r_2}$

Ans. (a)

Sol. Common potential:

$$V = \frac{k(Q_1 - x)}{r_1} = \frac{k(Q_2 + x)}{r_2}$$

$$\Rightarrow \frac{Q_1 - x}{Q_2 + x} = \frac{r_1}{r_2}$$

Ratio of charge densities:

$$\frac{\sigma_1}{\sigma_2} = \frac{\frac{Q_1 - x}{4\pi r_1^2}}{\frac{Q_2 + x}{4\pi r_2^2}} = \frac{Q_1 - x}{Q_2 + x} \times \frac{r_2^2}{r_1^2} = \frac{r_1}{r_2} \times \frac{r_2^2}{r_1^2}$$

$$\Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1}$$

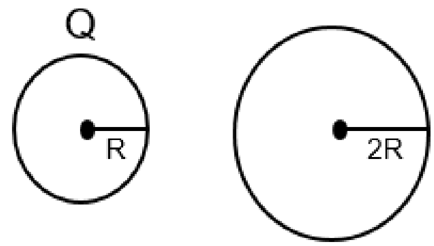
154. A conducting sphere of radius R and carrying charge Q is joined to an uncharged conducting sphere of radius 2R. The charge flowing between them would be

(a)2Q (b) $\frac{4Q}{3}$

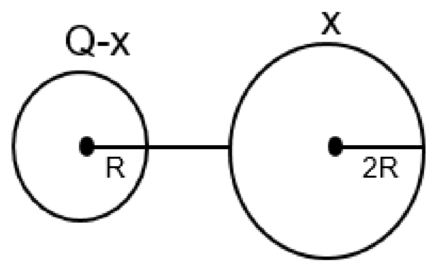
(c) $\frac{2Q}{3}$ (d) Q

Ans. (c)

Sol.



When joined together



When joined together, let charge flown from first sphere to the next sphere be x. Also, potentials at both spheres can be equated and hence, we have:

$$\frac{k(Q - x)}{R} = \frac{kx}{2R}$$

$$k(Q - x) = x$$

$$x = \frac{2Q}{3}$$

155. Two spherical conductors B and C having equal radii and carrying equal charges in them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is

(a) $\frac{F}{4}$ (b) $\frac{3F}{4}$

(c) $\frac{F}{8}$ (d) $\frac{3F}{8}$

Ans. (d)

Sol. Let the spherical conductors B and C have same charge as q. The electric force between them is

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

where, r being the distance between them. When third uncharged conductor A is brought in contact with B, then charge on each conductor

$$q_A = q_B = \frac{q_A + q_B}{2}$$
$$= \frac{0+q}{2} = \frac{q}{2}$$

When this conductor A is now brought in contact with C, then charge on each conductor

$$q_A = q_C = \frac{q_A + q_C}{2}$$
$$= \frac{(q/2)+q}{2} = \frac{3q}{4}$$

Hence, electric force acting between B and C is

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{q_B q_C}{r^2}$$
$$= \frac{1}{4\pi\varepsilon_0}\frac{(q/2)(3q/4)}{r^2}$$
$$= \frac{3}{8}\left[\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}\right] = \frac{3F}{8}$$

156. A ball with charge – 50e is placed at the centre of a hollow spherical shell has a net charge of – 50e. What is the charge on the shell's outer surface?

(a) – 50 e (b) Zero

(c) – 100 e (d) + 100 e

Ans. (c)

Sol. The net charge on the outer surface is $(-50e - 50e) = -100e$.

157. **Assertion:** The lightning conductor at the top of high building has sharp pointed ends.

Reason: The surface charge density of charge at sharp points is very high resulting in setting up of electric wind.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. A charged cloud induces opposite charge on pointed conductors. At sharp points of the conductor surface density of charge is very high and charge begins to leak from the pointed ends by setting up oppositely charged electric wind. This wind, when comes in contact with the charged cloud, neutralizes some of its charge lowering the potential difference between the cloud and the building. This reduces the chances of lightning striking the building (if the lightning strikes the building, the charge is conducted to the Earth and the building remains safe).

158. **Assertion:** The tyres of aircrafts are slightly conducting.

Reason: If a conductor is connected to the ground, the extra charge induced on the conductor will flow to the ground.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. During take-off and landing, the friction between tyres and the runway may cause electrification of tyres. Due to conducting nature of tyre, the charge so collected is conducted to the ground and electrical sparking is avoided.

159. **Assertion:** Electric field intensity within a conductor is always zero.

Reason: Electric field lines of force can pass through the conductor.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (c)

Sol. Since conductor cannot hold net charge inside it, so electric field intensity within a conductor is always zero. Therefore, electric field lines of force cannot pass through the conductor.

160. **Assertion:** During lightning, it is safe to sit inside the car.

Reason: The hollow structure of car provides electrostatic shielding.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Since cars are made of metal, the net electric field inside is always zero. So charge produced due to lightning is distributed on the outer surface of the car and finally transferred to Earth.

EXERCISE – 2: Previous Year Questions

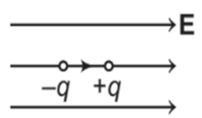
1. An electric dipole is placed in an uniform electric field with the dipole axis making an angle θ with the direction of the electric field. The orientation of the dipole for stable equilibrium is **[J&K CET 2011]**

(a) $\pi/6$ (b) $\pi/3$

(c) 0 (d) $\pi/2$

Ans. (c)

Sol. For stable equilibrium, the angle θ should be zero.



$\tau = pE\sin\theta$

$= 0$

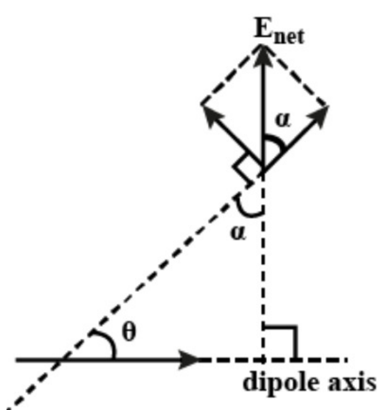
2. The electric field at a point due to an electric dipole, on an axis inclined at an angle $\theta\left(<90^{\circ}\right)$ to the dipole axis, is perpendicular to the dipole axis, if the angle θ is **[KCET 2011]**

(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(1/2)$

(c) $\tan^{-1}\left(\sqrt{2}\right)$ (d) $\tan^{-1}\left(1/\sqrt{2}\right)$

Ans. (c)

Sol. Here, $\alpha+\theta=90^{\circ}$



$\Rightarrow \quad \tan\alpha = \frac{1}{2}\tan\theta$

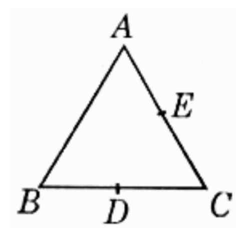
$\Rightarrow \quad \tan\theta = 2\tan\alpha = 2\tan\left(90^{\circ}-\theta\right)$

$\Rightarrow \quad \tan^2\theta = 2$

$\Rightarrow \quad \tan\theta = \sqrt{2}$

$\Rightarrow \quad \theta = \tan^{-1}\left(\sqrt{2}\right)$

3. Three charges, each +q, are placed at the corners of an isosceles triangle ABC of sides BC, AC and AB. D and E are the mid points of BC and CA. The work done in taking a charge Q from D to E is: (Given BC = AC): **[CBSE-AIPMT 2011]**



(a) zero (b) $\frac{3qQ}{4\pi\varepsilon_0 a}$

(c) $\frac{3qQ}{8\pi\varepsilon_0 a}$ (d) $\frac{qQ}{4\pi\varepsilon_0 a}$

Ans. (a)

Sol. AC = BC

DC = DB = EC = EA $\Rightarrow$ BE = DA

As all charges at A, B, and C are equal and distances of D and E from A, B, and C are also equal, so it can be concluded from symmetry that the potentials at D and E are also equal.

$\Rightarrow \; V_D = V_E \Rightarrow \; W = q\Delta V = 0$

4. The electric potential V at any, point (x, y, z), in meters in space is given by V = $4x^2$ volt. The electric field at the point (1, 0, 2) in volt/meter, is **[CBSE-AIPMT 2011]**

(a) 16 along positive X-axis

(b) 8 along negative X-axis

(c) 8 along positive X-axis

(d) 16 along negative X-axis

Ans. (b)

Sol. $\vec{E} = -\left[\frac{\partial V}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial V}{\partial z}\right] = -8x\hat{i}$

$\vec{E}_{(1,0,2)} = -8(1)\hat{i} = -8\hat{i}$

5. A charged oil drop is suspended in uniform field of $3\times10^4\,Vm^{-1}$, so that it neither falls nor rise. The charge on the drop will be (take, the mass of the charge 9.9×10^{-15} kg and $g = 10\ ms^{-2}$) **[UP CPMT 2011]**

(a) $3.3\times10^{-18}C$ (b) $3.2\times10^{-18}C$

(c) $1.6\times10^{-18}C$ (d) $4.8\times10^{-18}C$

Ans. (a)

Sol. For stationary oil drop,

Force due to electric field = Weight of the oil drop

$$qE = mg \Rightarrow q = \frac{mg}{E}$$

$$q = \frac{9.9\times10^{-15}\times10}{3\times10^4}$$

$$= 3.3\times10^{-18}C$$

6. Charge q_2 of mass m revolves around a stationary charge q_1 in a circular orbit of radius r. The orbital periodic time of q_2 would be **[J&K CET 2011]**

(a) $\left[\frac{4\pi^2 mr^3}{kq_1q_2}\right]^{1/2}$ (b) $\left[\frac{kq_1q_2}{4\pi^2 mr^3}\right]^{1/2}$

(c) $\left[\frac{4\pi^2 mr^4}{kq_1q_2}\right]^{1/2}$ (d) $\left[\frac{4\pi^2 mr^2}{kq_1q_2}\right]^{1/2}$

Ans. (a)

Sol. We have,

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} = mr\omega^2 = \frac{4\pi^2 mr}{T^2}$$

$$T^2 = \frac{(4\pi\varepsilon_0)r^2(4\pi^2 mr)}{q_1q_2}$$

$$\Rightarrow \quad T = \left[\frac{4\pi^2 mr^3}{kq_1q_2}\right]^{1/2}$$

7. Two identical charged spheres of material density ρ, suspended from the same point by inextensible strings of equal length make an angle θ between the strings. When suspended in a liquid of density σ and the angle θ remains the same. The dielectric constant K of the liquid is **[KCET 2011]**

(a) $\frac{\rho}{\rho-\sigma}$ (b) $\frac{\rho-\sigma}{\rho}$

(c) $\frac{\rho}{\rho+\sigma}c$ (d) $\frac{\rho+\sigma}{\rho}$

Ans. (a)

Sol.

$$E_r = \frac{F_a}{F_m} = \frac{mg}{(m-m_l)g}$$

$$= \frac{\rho V}{(\rho-\sigma)V} = \frac{\rho}{(\rho-\sigma)}$$

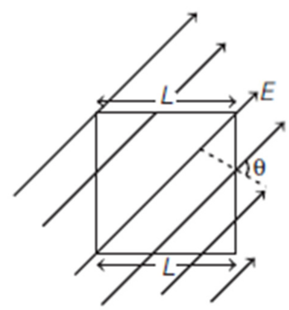
where, ρ = density of sphere,

σ = density of liquid

and V = volume of the liquid.

8. A square surface of side L metre in the plane of the paper is placed in a uniform electric field E (volt/metre) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure.

The electric flux linked to the surface in unit of Nm^2C^{-1} is **[CBSE AIPMT 2011]**



(a) EL^2 (b) $EL^2\cos\theta$

(c) $EL^2\sin\theta$ (d) zero

Ans. (d)

Sol. Flux of electric field E through any area A is defined as $\phi = EA\cos\theta$. The lines are parallel to the surface.

$\Rightarrow$ Angle between E and $A = 90^o$, hence $\phi = 0$.

9. A point charge Q is placed at one of the vertices of a cubical block. The electric flux flowing through this cube is **[2011 Manipal]**

(a) $\frac{Q}{6\varepsilon_0}$ (b) $\frac{Q}{4\varepsilon_0}$

(c) $\frac{Q}{8\varepsilon_0}$ (d) $\frac{Q}{\varepsilon_0}$

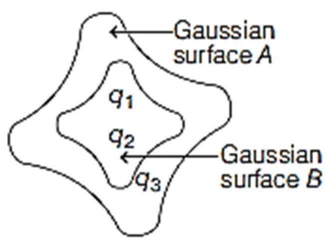
Ans. (c)

Sol. Let ϕ_{total} be the total electric flux and ϕ_{cube} be that of flowing through cube. So, when a point charge Q is placed at one of the vertices of a cubical block, then only (1/8)th part of total flux will pass through this cube, therefore

$$\phi_{cube} = \frac{\phi_{total}}{8} = \frac{Q}{8\varepsilon_0} \quad \left[\because \phi_{total} = \frac{Q}{\varepsilon_0}\right]$$

10. The electric flux for Gaussian surface A that encloses the charged particles in free is(given, $q_1 = -14\,nC, q_2 = 78.85\,nC, q_3 = -56\,nC$)

[MP PMT 2011]



(a) $10^3\ Nm^2C^{-1}$ (b) $10^3\ CN^{-1}\ m^{-2}$

(c) $6.32\times10^3\ Nm^2\ C^{-1}$ (d) $6.32\times10^3\ CN^{-1}\ m^{-2}$

Ans. (a)

Sol. Flux is due to charges enclosed per ε_0.

$\therefore$ Total flux $= (-14 + 78.85 - 56)\,nC/\varepsilon_0$

$$= 8.85\times10^{-9}\,C\times\frac{4\pi}{4\pi\varepsilon_0}$$

$$= 8.85\times10^{-9}\times9\times10^9\times4\pi$$

$$= 1000.4\,Nm^2/C \simeq 1000\,Nm^2\,C^{-1}$$

11. Which of the following is not true?

[EAMCET 2011]

(a) For a point charge, the electrostatic potential varies as 1/r

(b) For a dipole, the potential depends on the position vector and dipole moment vector

(c) The electric dipole potential varies as 1/ r at large distance

(d) For a point charge, the electrostatic field varies as $1/r^2$

Ans. (c)

Sol. For a point charge, $V \propto \frac{1}{r}$

For a dipole, $V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{r^2}$ [on axial position]

i.e. $V \propto \frac{1}{r^2}$

The electric dipole potential varies as 1/r at large distance is not true.

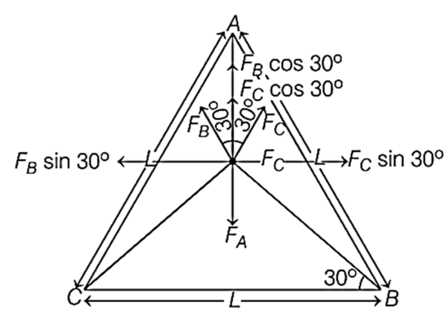
12. Three charges each of magnitude q are placed at the corners of an equilateral triangle, the electrostatic force on the charge placed at the centre is (each side of triangle is L) **[AFMC 2012]**

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{L^2}$

(c) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{3q^2}{L^2}$ (d) $\frac{1}{12\pi\varepsilon_0}\cdot\frac{q^2}{L^2}$

Ans. (a)

Sol. In the following figure, since $|F_A| = |F_B| = |F_C|$ and they are equally inclined with each other, so their resultant will be zero.



$$F_A = F_B\cos30^\circ + F_C\cos30^\circ \text{ and } F_B\sin30^\circ = F_C\sin30^\circ$$

13. When a piece of polythene is rubbed with wool, a charge of $-2\times10^{-7}\,C$ is developed on polythene. What is the amount of mass which is transferred to polythene? **[UP CPMT 2012]**

(a) $5.69\times10^{-19}\,kg$ (b) $6.25\times10^{-19}\,kg$

(c) $9.63\times10^{-19}\,kg$ (d) $11.38\times10^{-19}\,kg$

Ans. (d)

Sol. Number of electrons transferred, n = q /e

Mass transferred to polythene $= m_e \times n$

$= m_e \times \left(\frac{q}{e}\right)$

$= 9.1\times10^{-31} \times \left(\frac{2\times10^{-7}}{1.6\times10^{-19}}\right)$

$= 11.38\times10^{-19}\,\text{kg}$

14. Two metallic spheres of radii 1 cm and 3 cm are given charges of -1×10^{-2}C and 5×10^{-2}C, respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is: **[CBSE-AIPMT 2012]**

(a) 1×10^{-2}C (b) 2×10^{-2}C

(c) 3×10^{-2}C (d) 4×10^{-2}C

Ans. (c)

Sol.

$Q_{total} = Q_{Big} + Q_{Small}$

$Q_{total} = 5\times10^{-2} - 1\times10^{-2} = 4\times10^{-2}$

Now, since potentials are equal, we have

$\frac{kQ_{small}}{r_{small}} = \frac{kQ_{big}}{r_{big}} \Rightarrow \frac{Q_{small}}{Q_{big}} = \frac{r_{small}}{r_{big}}$

$\Rightarrow Q_{Small} : Q_{Big} = 1:3$

$\Rightarrow Q_{Big} = \frac{3}{4}\left(4\times10^{-2}\right) = 3\times10^{-2}\,C$

15. What is the flux through a cube of side 'a' if a point charge of q is at one of its corners?

[CBSE-AIPMT 2012]

(a) $\frac{q}{2\epsilon_0}6a^2$ (b) $\frac{2q}{\epsilon_0}$

(c) $\frac{q}{8\epsilon_0}$ (d) $\frac{q}{\epsilon_0}$

Ans. (c)

Sol. According to Gauss's Law, the electric flux through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed on the surface. Since, q is the charge enclosed by the surface, then the flux is $\phi = \frac{q}{\varepsilon_0}$. If charge q is placed at a corner of cube, it will be divided into 8 such cubes, hence electric flux through a single cube will be $\phi' = \frac{1}{8}\left(\frac{q}{\varepsilon_0}\right)$.

16. An electric dipole of moment 'p' is placed in an electric field of intensity 'E'. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when θ = 90°, the torque and the potential energy of the dipole will respectively be: **[CBSE-AIPMT 2012]**

(a) pE cosθ, –pE sinθ (b) pE sinθ, –pE cosθ

(c) pE sinθ, –2pE cosθ (d) pE sinθ, 2pE cosθ

Ans. (b)

Sol. $U = -\int \tau\, d\theta = -\int_{\pi/2}^{\theta} pE\sin\theta\, d\theta = -pE\cos\theta$

$\tau = pE\sin\theta$

17. The unit of physical quantity obtained by the line integral of electric field is **[J&K CET 2012]**

(a) NC^{-1} (b) Vm^{-1}

(c) JC^{-1} (d) $C^2N^{-1}m^{-2}$

Ans. (c)

Sol. The unit of physical quantity obtained by the line integral of electric field is JC^{-1}.

$\because \quad E = -\frac{dV}{dl}$

$\Rightarrow \quad -\int E\,dl = V = \frac{W}{q}$

18. Four point charges -Q, – q, 2q and 2Q are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero, is

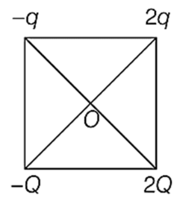
[CBSE AIPMT 2012]

(a) Q = - q (b) $Q = -\frac{1}{q}$

(c) Q = q (d) $Q = \frac{1}{q}$

Ans. (a)

Sol. If potential at centre is zero, then



$V_1 + V_2 + V_3 + V_4 = 0$

$-\frac{kQ}{r} - \frac{kq}{r} + \frac{k2Q}{r} + \frac{k2q}{r} = 0$

or $\quad -Q - q + 2q + 2Q = 0$

or $\quad Q = -q$

19. Two equal point charges Q are fixed at $x = -a$ and $x = +a$ on X-axis. Another point charge is placed at the origin. The change in electrical potential energy of Q, when it is displaced by a small amount x along X-axis, is approximately proportional to **[Manipal 2012]**

(a) x (b) x^2

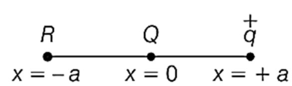
(c) x^3 (d) $\frac{1}{x}$

Ans. (b)

Sol.

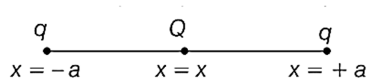
Case I Electric potential energy,

$$U_1 = \frac{1}{4\pi\varepsilon_0}\frac{2Qq}{a}$$



Case II Electric potential energy,

$$U_2 = \frac{1}{4\pi\varepsilon_0}Qq\left(\frac{1}{a+x} + \frac{1}{a-x}\right)$$



Change in potential energy

$= U_2 - U_1$

$$= \frac{1}{4\pi\varepsilon_0}Qq\left[\frac{1}{a+x} + \frac{1}{a-x} - \frac{2}{a}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}Qq\left[\frac{a(a-x+a+x) - 2(a^2 - x^2)}{(a^2 - x^2)a}\right]$$

For $x << a$, $\Delta U = \frac{1}{4\pi\varepsilon_0}Qq\frac{2x^2}{a^3}$

$\Rightarrow \quad \Delta U = x^2$

20. Each of the two point charges are doubled and their distance is halved. Force of interaction becomes n times, where n is **[UP CPMT 2013]**

(a) 4 (b) 1

(c) 1/16 (d) 16

Ans. (d)

Sol.

From the formula, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{2q_1 \times 2q_2}{(r/2)^2} = \frac{4}{1/4}F = 16F$$

$nF = 16F \Rightarrow n = 16$

21. A cylindrical conductor is placed near another positively charged conductor. The net charge acquired by the cylindrical conductor will be **[UP CPMT, KCET 2013]**

(a) positive only (b) negative only

(c) zero

(d) either positive or negative

Ans. (c)

Sol. Net charge acquired by induction is zero, as there is only transfer of electrons from one part of the body to the other.

22. An electron enters uniform electric field maintained by parallel plates and of value E Vm^{-1} with a velocity $v\,ms^{-1}$, the plates are separated by a distance d metre, then acceleration of the electron in the field is **[Manipal 2013]**

(a) $\frac{Ee}{m}$ (b) $\frac{-Ee}{m}$

(c) $\frac{Ee}{md}$ (d) $Ee\frac{d}{m}$

Ans. (a)

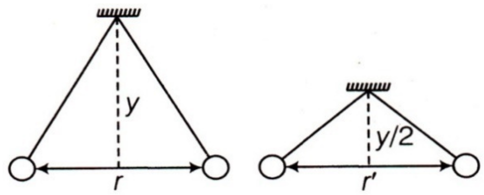
Sol. We know that, $F = eE$

Therefore, acceleration in electron due to force F

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

23. Two pitch balls carrying equal charges are suspended from a common point by strings of equal length, the equilibrium separation between them is r. Now, the strings are rigidly clamped at half the height. The equilibrium separation between the balls now become

[NEET 2013]

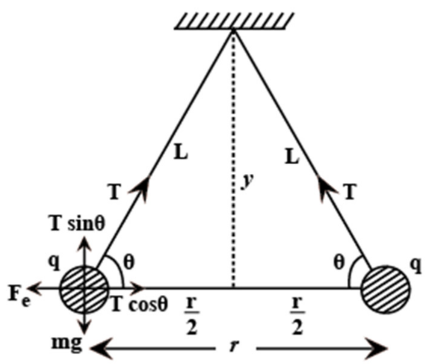


(a) $\left(\frac{1}{\sqrt{2}}\right)^2$ (b) $\left(\frac{r}{\sqrt[3]{2}}\right)$

(c) $\left(\frac{2r}{\sqrt{2}}\right)$ (d) $\left(\frac{2r}{3}\right)$

Ans. (b)

Sol.



At equilibrium, $\sum F_x = 0; \sum F_y = 0$

$T\sin\theta = mg$

$\Rightarrow T\cos\theta = F_e = \frac{Kq^2}{r^2}$ [Dividing the two]

$r^2 = \frac{mg}{Kq^2}\tan\theta$

$\Rightarrow \tan\theta = \frac{y}{\frac{r}{2}}$ [As $\frac{mg}{Kq^2}$ is a constant]

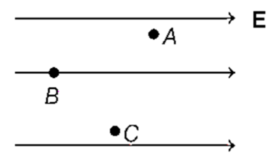
$r^2 = C \times \frac{2y}{r}$

$\Rightarrow r \propto y^{1/3}$

$\therefore \frac{r'}{r} = \left(\frac{y'}{y}\right)^{1/3}$

$\Rightarrow r' = \frac{r}{\sqrt[3]{2}}$

24. A B, and C are three points in a uniform electric field. The electric potential is **[NEET 2013]**



(a) maximum at A

(b) maximum at B

(c) maximum at C

(d) same at all the three points A B, and C

Ans. (b)

Sol. The electric field is maximum at B, because electric field is directed along decreasing potential $V_B > V_C > V_A$. Therefore, electric potential is maximum at point B.

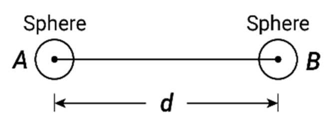
25. Two charged spheres separated at a distance d exert a force F on each other. If they are immersed in a liquid of dielectric constant K = 2, then the force is (if all conditions are same) **[UK PMT 2014]**

(a) F/2 (b) F

(c) 2F (d) 4F

Ans. (a)

Sol. Consider the situation shown in the diagram.

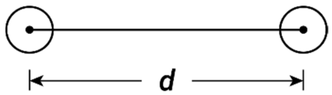


Let charges on sphere A and B be q_1 and q_2, respectively.

Force between the charges placed in air by Coulomb's law (spheres can be assumed as point charges placed at their centres)

$$F_{AB} = k_1 \frac{q_1 q_2}{d^2} \quad \ldots(i)$$

where, $k_1 = 1/4\pi\varepsilon_0$.



When the spheres are immersed in a liquid, then force between the charges is

$$F'_{AB} = k_1 \cdot \frac{q_1 \cdot q_2}{K \cdot d^2} = k_1 \frac{q_1 \cdot q_2}{2d^2} \quad \ldots(ii)$$

where, k is dielectric constant of the liquid =2.

On dividing Eqs. (i) and (ii), we get

$$\frac{F_{AB}}{F'_{AB}} = \frac{k_1}{k_1/2} = 2$$

According to question, $F_{AB} = F$

$$\Rightarrow \frac{F}{F'_{AB}} = 2 \Rightarrow F'_{AB} = \frac{F}{2}$$

26. If a charge on the body is 1 nC, then how many electrons are present on the body? **[KCET 2014]**

(a) 1.6×10^{19} (b) 6.25×10^{9}

(c) 6.25×10^{27} (d) 6.25×10^{28}

Ans. (b)

Sol.

Given, $q = 1\text{ nC} = 1\times1\times10^{-9}\,C$

$(\because 1\text{ nC} = 1\times10^{-9}\,C)$

$e = 1.6\times10^{-19} \Rightarrow n = ?$

From the property of quantisation charge,

$$q = ne \Rightarrow n = \frac{q}{e} = \frac{1\times10^{-9}}{1.6\times10^{-19}}$$

$$= 0.625\times10^{-9}\times10^{19} = 6.25\times10^{9}$$

27. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are: **[CBSE AIPMT 2014]**

(a) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (b) Both are zero

(c) Zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (d) $\frac{Q}{4\pi\varepsilon_0 R}$ and Zero

Ans. (d)

Sol. For conducting sphere, the potential at centre will be equal to the potential on the sphere, i.e.,

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

Electric field at centre is zero.

28. In a region, the potential is represented by V (x, y, z) = 6x – 8xy – 8y + 6yz, where V is in volts and x, y, z are in meters. The electric force experienced by a charge of 2 coulomb situated at point (1,1,1) is: **[CBSE AIPMT 2014]**

(a) 24 N (b) $4\sqrt{35}$N

(c) $6\sqrt{5}$N (d) 30 N

Ans. (b)

Sol. $V_{(x,y,z)} = 6x - 8xy - 8y + 6yz$

$$E = \frac{\partial V}{\partial(x,y,z)}$$

$$\Rightarrow E = \frac{\partial}{\partial x}(6x-8xy-8y+6yz) + \frac{\partial}{\partial y}(6x-8xy-8y+6yz)$$

$$+\frac{\partial}{\partial z}(6x-8xy-8y+6yz)$$

$$E = (-6+8y)\hat{i} + (8x+8-6z)\hat{j} - 6y\hat{k}$$

$$E_{(1,1,1)} = 2\hat{i} + 10\hat{j} - 6\hat{k}$$

$$\left|E_{(1,1,1)}\right| = 2\sqrt{35}$$

$$F = qE = 2\left(2\sqrt{35}\right) = 4\sqrt{35}$$

29. Electric field at a point of distance r from a uniformly charged wire of infinite length having linear charge density λ is directly proportional to **[Kerala CEE 2014]**

(a) r^{-1} (b) r

(c) r^2 (d) r^{-2}

(e) None of these

Ans. (a)

Sol. We know that, electric field at distance r from an infinitely long line charge is given by

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

$$\Rightarrow \lambda = 2\pi\varepsilon_0 \cdot rE$$

$$E \propto r^{-1}$$

30. Two equal and opposite charges of masses m_1 and m_2 are accelerated in a uniform electric field through the same distance. What is the ratio of their accelerations, if their ratio of masses is $m_1 / m_2 = 0.5$? **[KCET 2014]**

(a) $\frac{a_1}{a_2} = 0.5$ (b) $\frac{a_1}{a_2} = 1$

(c) $\frac{a_1}{a_2} = 2$ (d) $\frac{a_1}{a_2} = 3$

Ans. (c)

Sol. We know that,

$F_1 = q_1E = m_1a_1$ ...(i)

$F_2 = q_2E = m_2a_2$ ...(ii)

From Eqs. (i) and (ii), we get

$$\frac{a_1}{a_2} = \frac{F_1/m_1}{F_2/m_2} = \frac{F \cdot m_2}{F \cdot m_1} \quad [\because F_1 = F_2]$$

$$\Rightarrow \frac{a_1}{a_2} = \frac{m_2}{m_1} = \frac{1}{0.5} = \frac{10}{5} = 2$$

$$\Rightarrow \frac{a_1}{a_2} = 2 \quad [\because m_1/m_2 = 0.5]$$

31. An electric dipole of dipole moment **p** is placed in a uniform external electric field **E**. Then, the **[Kerala CEE 2014]**

(a) torque experienced by the dipole is $E \times p$

(b) torque is zero, if p is perpendicular to E

(c) torque is maximum, if p is perpendicular to E

(d) potential energy is maximum, if p is parallel to E

(e) potential energy is maximum, if p is perpendicular to E

Ans. (c)

Sol. Torque on dipole, $\tau = pE \sin\theta$ The direction of torque is perpendicular to the plane of paper inwards, i.e. when the dipole is parallel or anti-parallel to E and maximum at $\theta = 90^o$. So, torque is maximum, if **p** is perpendicular to **E**.

32. An electric dipole placed in a non-uniform electric field experiences **[UK PMT 2014]**

(a) both a torque and a net force

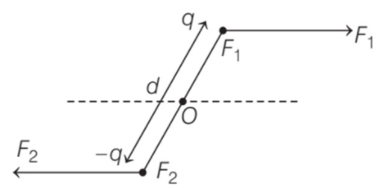
(b) only a force but no torque

(c) only a torque but no net force

(d) no torque and no net force

Ans. (a)

Sol. Consider the diagram, where an electric dipole is placed in non-uniform electric field.



Electric field at the sight of q is E_1 and electric field at the sight of $-q$ is E_2.

F_1 = force on the charge $q = qE_1$

F_2 = force on the charge $-q = -qE_2$

Net force on the dipole,

$$F = F_1 + F_2 = q(E_1 - E_2)$$

$\therefore$ $|E_1| \neq |E_2|$

$\Rightarrow$ $|F| \neq 0$

τ_1 = torque on the dipole due to E_1

$= p \times E_1$ (clockwise)

τ_2 = torque on the dipole due to E_2

$= p \times E_2$ (clockwise)

where, $p = \frac{1}{2}qd$ is dipole moment of the dipole.

$$\tau_{net} = \tau_1 + \tau_2 = p \times E_1 + p \times E_2 \neq 0$$

Hence, both torque (τ_{net}) and force (F) act on the dipole.

33. What is the nature of Gaussian surface involved in Gauss' law of electrostatics? **[KCET 2014]**

(a) Scalar (b) Electrical

(c) Magnetic (d) Vector

Ans. (d)

Sol. The Gauss' law in electrostatic given a relation between electric flux through any closed hypothetical surface (called a Gaussian surface) and the charge enclosed by the surface. So, the nature of Gaussian surface is vector.

34. Two concentric spheres kept in air have radii R and r. They have similar charge and equal surface charge density σ. The electrical potential at their common centre is (ε_0=permittivity of free space)

[MHT CET 2014]

(a) $\frac{\sigma(R+r)}{\varepsilon_0}$ (b) $\frac{\sigma(R-r)}{\varepsilon_0}$

(c) $\frac{\sigma(R+r)}{2\varepsilon_0}$ (d) $\frac{\sigma(R+r)}{4\varepsilon_0}$

Ans. (a)

Sol. Potential due to a uniformly charged sphere is

$$V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{R} \quad ...(i)$$

Also, $$\sigma=\frac{Q}{4\pi R^2}=\frac{Q\varepsilon_0}{4\pi\varepsilon_0 R^2}$$

$$\frac{\sigma R^2}{\varepsilon_0}=\frac{1\times Q}{4\pi\varepsilon_0}$$

$$\Rightarrow \quad \frac{\sigma R}{\varepsilon_0}=\frac{Q}{4\pi\varepsilon_0}\times\frac{1}{R} \quad ...(ii)$$

From Eqs. (i) and (ii), we get $V=\frac{\sigma R}{\varepsilon_0}$

Potential due to sphere (1), $V_1=\frac{\sigma R}{\varepsilon_0}$

Potential due to sphere (2), $V_2=\frac{\sigma r}{\varepsilon_0}$

Net potential at centre,

$$V=V_1+V_2=\frac{\sigma}{\varepsilon_0}(R+r)$$

35. Two charges of equal magnitude q are placed in air at a distance 2a apart and third charge – 2q is placed at mid – point. The potential energy of the system is (ε_0 = permittivity of free space)

[MHT CET 2014]

(a) $-\frac{q^2}{8\pi\varepsilon_0 a}$ (b) $-\frac{3q^2}{8\pi\varepsilon_0 a}$

(c) $-\frac{5q^2}{8\pi\varepsilon_0 a}$ (d) $-\frac{7q^2}{8\pi\varepsilon_0 a}$

Ans. (d)

Sol. Potential energy of the system,

$$U=\frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}}+\frac{q_1q_3}{r_{13}}+\frac{q_2q_3}{r_{23}}\right]$$

$$=\frac{1}{4\pi\varepsilon_0}\left[\frac{q(-2q)}{a}+\frac{q(-2q)}{a}+\frac{qq}{2a}\right]$$

$$=\frac{1}{4\pi\varepsilon_0}\left[\frac{-2q^2}{a}-\frac{2q^2}{a}+\frac{q^2}{2a}\right]$$

$$=\frac{1}{4\pi\varepsilon_0}\left[\frac{-4q^2}{a}+\frac{q^2}{2a}\right]=\frac{-7q^2}{8\pi\varepsilon_0 a}$$

36. What is the electric potential at a distance of 9 cm from 3 nC? **[KCET 2014]**

(a) 270 V (b) 3 V

(c) 300 V (d) 30 V

Ans. (c)

Sol.

Given, $q=3\text{ nC}=3\times10^{-9}\text{ C}$,

$r=9\text{ cm}=9\times10^{-2}\text{ m}$

We know that, potential due to point charge is given by

$$V=\frac{1}{4\pi\varepsilon_0}\frac{q}{r}=\frac{9\times10^9\times3\times10^{-9}}{9\times10^{-2}}$$

$$=3\times10^2$$

$$\Rightarrow V=300\text{ V}$$

37. Work done in carrying an electric charge Q_1 once round a circle of radius R with a charge Q_2 at the centre of the circle is **[EAMCET 2014]**

(a) $\frac{Q_1Q_2}{4\pi\varepsilon_0 R}$ (b) ∞

(c) $\frac{Q_1Q_2}{4\pi\varepsilon_0 R^2}$ (d) 0

Ans. (d)

Sol. Electrostatic force is a conservative force, so work done in carrying an electric charge Q_1 once round a circle of radius R with a charge Q_2 at the centre of the circle is zero.

38. The electric field in a certain region is acting radially outward and is given by E = Ar. A charge contained in a sphere of radius 'a' centered at the origin of the field, will be given by: **[CBSE AIPMT 2015]**

(a) $\epsilon_0 Aa^3$ (b) $4\pi\epsilon_0 Aa^2$

(c) $A\epsilon_0 a^2$ (d) $4\pi\epsilon_0 Aa^3$

Ans. (d)

Sol. From Gauss's law: $\oint E_{in} dS = \frac{q_{en}}{\varepsilon_0}$

At r = a, E = Aa,

$$\oint E_{in} dS = (Aa)4\pi a^2 = \frac{q_{en}}{\varepsilon_0}$$

$$\Rightarrow q_{en} = 4\pi\varepsilon_0 Aa^3$$

39. When an α-particle of mass 'm' moving with velocity '*v*' bombards on a heavy nucleus of charge 'Ze', its distance of closest approach from the nucleus depends on m as: **[NEET 2016]**

(a) $\frac{1}{m}$ (b) $\frac{1}{\sqrt{m}}$

(c) $\frac{1}{m^2}$ (d) m

Ans. (a)

Sol. At closest distance of approach, kinetic energy will be equal to potential energy

$$\frac{1}{2}mv^2 = \frac{KQq}{d} \Rightarrow d \propto \frac{1}{m}$$

40. An electric dipole is placed at an angle of 30° with an electric field intensity 2 × 10^5 N/C. It experiences a torque equal to 4 Nm. The charge on the dipole, if the dipole length is 2 cm is **[NEET 2016]**

(a) 2 mC (b) 5 mC

(c) 7 μC (d) 8 mC

Ans. (a)

Sol. $p = lq = \left(\frac{2}{100}\right)q = 0.02q$

$$\tau = pE\sin\theta$$

$$4 = (0.02q)(2\times10^5)\sin 30^o$$

$$q = 200\times10^{-5}C = 2\,mC$$

41. The electric field strength due to a point charge of $5\mu C$ at a distance of 80 cm from the charge is **[UP CPMT 2016]**

(a) $5\times10^4\ N/C$ (b) $7\times10^4\ N/C$

(c) $3.5\times10^4\ N/C$ (d) $7\times10^2\ N/C$

Ans. (b)

Sol. Given, $q = 5\mu C = 5\times10^{-6}C$

$r = 80\text{ cm} = 80\times10^{-2}\,m$

Electric field strength,

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

$$\Rightarrow E = 9\times10^9\times\frac{5\times10^{-6}}{(80\times10^{-2})^2}$$

$$\Rightarrow E = 7.0\times10^4\ N/C$$

42. An electric dipole is placed at an angle of 30^o with an electric field intensity $2\times10^5\ N/C$. It experiences a torque equal to 4 N – m. The charge on the dipole, if the dipole length is 2 cm, is **[NEET 2016]**

(a) 8 mC (b) 2 mC

(c) 5 mC (d) $7\mu C$

Ans. (b)

Sol. $\because$ Torque on an electric dipole in an electric field,

$$\tau = p\times E$$

$$\Rightarrow |\tau| = pE\sin\theta$$

where, θ is angle between E and p.

$$\Rightarrow 4 = p\times2\times10^5\times\sin 30$$

$$\Rightarrow p = 4\times10^{-5}\text{ cm}$$

$$\Rightarrow p = q2l$$

$$\therefore q2l = 4\times10^{-5}$$

where, $2l = 2\text{cm} = 2\times10^{-2}\,m$

$$\therefore q = \frac{4\times10^{-5}}{2\times10^{-2}}$$

$$\Rightarrow 2\times10^{-3}C = 2\text{ mC}$$

43. A certain charge Q is divided into two parts q and Q – q. How the charge Q and q must be related, so that when q and (Q – q) is placed at a certain distance apart experience maximum electrostatic repulsion? **[JIPMER 2017]**

(a) Q = 2q (b) Q = 3q

(c) Q = 4q (d) Q = 4q + c

Ans. (a)

Sol. The electrostatic force of repulsion between the charge q and (Q – q) at separation r is given by

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q(Q-q)}{r^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ-q^2}{r^2}$$

If F is maximum, then $\frac{\partial F}{\partial q} = 0$

i.e. $\frac{1}{4\pi\varepsilon_0} \cdot \frac{(Q-2q)}{r^2} = 0$

As, $1/4\,\pi\varepsilon_0 r^2$ is constant, therefore

$Q - 2q = 0$ or $Q = 2q$

44. Suppose the charge of a proton and an electron differ slightly. One of them is -e and the other is $(e + \Delta e)$. If the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance d (much greater than atomic size) apart is zero, then Δe is of the order (Take, mass of hydrogen, $m_h = 1.67 \times 10^{-27}$ kg)

[NEET 2017]

(a) 10^{-20}C (b) 10^{-23}C

(c) 10^{-37}C (d) 10^{-47}C

Ans. (c)

Sol. Net charge on one H-atom,

$q = -e + e + \Delta e = \Delta e$

Net electrostatic repulsive force between two H-atoms,

$$F_r = \frac{kq^2}{d^2} = \frac{k(\Delta e)^2}{d^2}$$

Similarly, net gravitational attractive force between two H-atoms,

$$F_G = \frac{Gm^2}{d^2}$$

It is given that,

$$F_r - F_G = 0$$

$$\Rightarrow \frac{K(\Delta e)^2}{d^2} - \frac{Gm^2}{d^2} = 0$$

$$\Rightarrow (\Delta e)^2 = \frac{Gm_r^2}{K}$$

$$(\Delta e)^2 = \frac{(6.67\times10^{-11})(1.67\times10^{-27})^2}{9\times10^9}$$

$$\Rightarrow \Delta\varepsilon = 1.437\times10^{-37}\ \text{C}$$

45. Two identical conducting balls A and B have positive charges q_1 and q_2 respectively but $q_1 \neq q_2$. The balls are brought together so that they touch each other and then kept in their original positions. The force between them is **[JIPMER 2017]**

(a) less than that before the balls touched

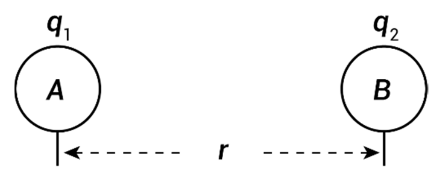
(b) greater than that before the balls touched

(c) same as that before the balls touched

(d) zero

Ans. (b)

Sol. According to Coulomb's law, the force of repulsion between them is given by $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$



When the charged spheres A and B are brought in contact, each sphere will attain equal charge q'

$$q' = \frac{q_1 + q_2}{2}$$

Now, the force of repulsion between them at the same distance r is

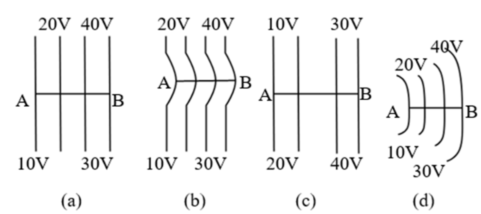
$$F' = \frac{q' \times q'}{4\pi\varepsilon_0 r^2} = \frac{1}{4\pi\varepsilon_0}$$

$$\frac{\left(\frac{q_1+q_2}{2}\right)\left(\frac{q_1+q_2}{2}\right)}{r^2} = \frac{\left(\frac{q_1+q_2}{2}\right)^2}{4\pi\varepsilon_0 r^2}$$

As, $\left(\frac{q_1+q_2}{2}\right)^2 > q_1 q_2$

$\therefore$ $F' > F$

46. The diagrams below show regions of equipotential. **[NEET 2017]**



A positive charge is moved from A to B in each diagram.

(a)Minimum work is required to move q in figure(a).

(b)Maximum work is required to move q in figure(b).

(c)Maximum work is required to move q in figure(c).

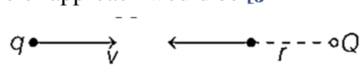
(d)In all the four cases the work done is the same.

Ans. (d)

Sol. Work done = Change in potential energy $= q(V_A - V_B)$

Since change in potential energy is same in all cases, work done in all the four cases is the same

47. A charged particle q is shot with speed v towards another fixed charged particle Q. It approaches Q upto a closest distance r and then returns. If q were given a speed $2v$, the closest distance of approach would be **[JIPMER 2017]**



(a) r (b) 2r

(c) r/2 (d) r/4

Ans. (d)

Sol. At closest distance r, the whole kinetic energy of charge q is converted into potential energy.

$$\therefore \quad \frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Q\cdot q}{r}$$

$$\Rightarrow \quad r = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2Q\cdot q}{mv^2}$$

In next case, $r' = \frac{1}{4\pi\varepsilon_0}\frac{2Qq}{m(2v)^2}$

$$\Rightarrow \quad r' = \frac{1}{4}\left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{2Qq}{mv^2}\right)$$

$$\Rightarrow \quad r' = \frac{r}{4}$$

48. An electron falls from rest through a vertical distance h in a uniform and vertically upward directed electric field E. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance h. The time of fall of the electron, in comparison to the time of fall of the proton is **[NEET 2018]**

(a) 10 times greater (b) 5 times greater

(c) smaller (d) equal

Ans. (c)

Sol. Force on a charged particle in the presence of an electric field is given as

$$F = qE \qquad \ldots(i)$$

where, q is the charge on the charged particle and E is the electric field.

From Newton's second law of motion, force on a particle with mass m is given as

$$F = ma \qquad \ldots(ii)$$

where, a is the acceleration.

From Eqs. (i) and (ii), we get

$$F = ma = qE$$

$$\Rightarrow a = \frac{qE}{m} \qquad \ldots(iii)$$

Now, consider that a particle falls from rest through a vertical distance h. Therefore, $u = 0$ and the second equation of motion becomes

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

or $h = 0\times t + \frac{1}{2}at^2 = \frac{1}{2}\times\frac{qE}{m}t^2$

[from Eq. (iii)]

$$\Rightarrow \quad t^2 = \frac{2hm}{qE} \text{ or } t = \sqrt{\frac{2hm}{qE}}$$

Since, the particles given in the question is electron and proton and the quantity $\sqrt{2h/qE}$ (here, $q_p = q_e = e$) for both of them is constant. Thus, we can write

$$t = k\sqrt{m}$$

where, $k = \sqrt{\frac{2h}{qE}}$

or $t \propto \sqrt{m}$

As, mass of proton $(m_p) >>$ mass of electron (m_e).

Thus, the time of fall of an electron would be smaller than the time of fall of a proton.

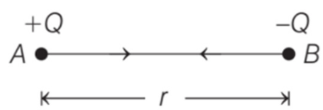
49. Two point charges A and B, having charges +Q and –Q respectively; are placed at certain distance apart and force acting between them is F. If 25% charge of A is transferred to B, then force between the charges becomes **[NEET 2019]**

(a) $\frac{9F}{16}$ (b) $\frac{16F}{9}$

(c) $\frac{4F}{3}$ (d) F

Ans. (a)

Sol. The force between two point charges A and B, having charges + Q and – Q respectively is given by



$$F = \frac{kQ_AQ_B}{r^2} = \frac{kQ(-Q)}{r^2} = -\frac{kQ^2}{r^2} ...(i)$$

where, k = constant $= \frac{1}{4\pi\varepsilon_0}$

and r = distance between two charges A and B. When 25% charge of A is transferred to B, then new amount of charge on A and B respectively become

$$Q'_A = \frac{75}{100}(Q_A) = \frac{3}{4}Q$$

$$Q'_B = \left(\frac{25}{100}Q_A + Q_B\right)$$

$$= \left(\frac{1}{4}Q - Q\right) = \frac{-3}{4}Q$$

So, the force between the two charges now becomes

$$F' = \frac{kQ'_A Q'_B}{r^2} = \frac{k\left(\frac{3Q}{4}\right)\left(-\frac{3}{4}Q\right)}{r^2}$$

$$= \frac{-9kQ^2}{16r^2} = \frac{9}{16}F \text{ [from Eq.(i)]}$$

Thus, the new force between the charges is 9/16 times the initial force between the charges.

50. A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre is: **[NEET 2019]**

(a) zero as r increases for r < R, decreases as r increases for r > R

(b) zero as r increases for r < R, increases as r increases for r > R

(c) decreases as r increases for r < R and for r > R

(d) increases as r increases for r < R and for r > R

Ans. (a)

Sol. By Gauss law:

r < R

$$\Rightarrow \oint E_{in} dS = \frac{q_{en}}{\varepsilon_0} = 0$$

So, for r < R, the electric field is zero.

r > R

$$E_0 dS = \frac{q_{en}}{\varepsilon_0}$$

$$\Rightarrow E_0 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$\Rightarrow E_0 \propto \frac{1}{r^2}$$

As electric field is inversely proportional to 'r'. So, for r > R, the electric field is decreases for increase in 'r'.

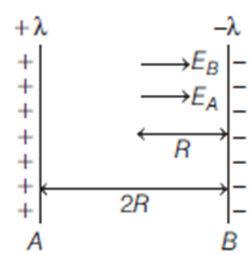
51. Two parallel infinite line charges with linear charge densities $+\lambda$ C/m and $-\lambda$ C/m are placed at a distance of 2R in free space. What is the electric field mid-way between the two line charges? **[NEET 2019]**

(a) $\frac{2\lambda}{\pi\varepsilon_0 R}$ N/C (b) $\frac{\lambda}{\pi\varepsilon_0 R}$ N/C

(c) $\frac{\lambda}{2\pi\varepsilon_0 R}$ N/C (d) Zero

Ans. (b)

Sol. Consider two infinite line charges with linear charge densities $+\lambda$ C/m and $-\lambda$ C/m respectively, which are lying in y-direction as shown in the figure below



Then, the electric field due to line A at the mid-way between the two line charges, i.e. at R is

$$|E_A| = \frac{\lambda}{2\pi\varepsilon_0 R} \text{ N/C} \qquad ...(i)$$

which lies along +ve x-axis (outward), i.e. from A to B.

Similarly, the electric field due to line B at the mid-way between the two line charges, i.e. at R is

$$|E_B| = \frac{\lambda}{2\pi\varepsilon_0 R} N/C \qquad \ldots(ii)$$

Due to negative charge on B, E_B also lies along +ve x-axis (inward), i.e. from A to B.

So, the resultant electric field at R is given as

$$|E_R| = |E_A| + |E_B|$$

Substituting the values from Eqs. (i) and (ii), we get

$$|E_R| = \frac{\lambda}{2\pi\varepsilon_0 R} + \frac{\lambda}{2\pi\varepsilon_0 R} = \frac{\lambda}{\pi\varepsilon_0 R} N/C$$

which also lies along the +ve x-axis, i.e. from A to B.

52. Two metal spheres, one of radius R and the other of radius 2R respectively have the same surface charge density σ. They are brought in contact and separated. What will be the new surface charge densities on them? **[2019 NEET Odisha]**

(a) $\sigma_P = \frac{5}{6}\sigma,\ \sigma_Q = \frac{5}{2}\sigma$ (b) $\sigma_P = \frac{5}{2}\sigma,\ \sigma_Q = \frac{5}{6}\sigma$

(c) $\sigma_P = \frac{5}{2}\sigma,\ \sigma_Q = \frac{5}{3}\sigma$ (d) $\sigma_P = \frac{5}{3}\sigma,\ \sigma_Q = \frac{5}{6}\sigma$

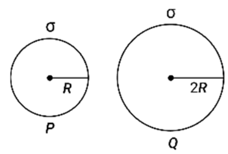
Ans. (d)

Sol.

The surface charge density of a closed surface area having charge Q is given by

$$\sigma = \frac{\text{Charge}}{\text{Area}} = \frac{Q}{A} \quad \text{or} \quad Q = \sigma A$$

Thus, the charges on sphere P and Q having same charge density as shown in the figure below is given by



$$Q_P = \sigma \times 4\pi R^2 = 4\pi\sigma R^2 \qquad \ldots(i)$$

$$\text{and } Q_Q = \sigma \times 4\pi(2R)^2 = 16\pi\sigma R^2 \qquad \ldots(ii)$$

When they are brought in contact with each other, the total charge will be

$$Q_t = Q_P + Q_Q$$
$$= 4\pi\sigma R^2 + 16\pi\sigma R^2$$

[from Eqs. (i) and (ii)]

$$= 20\pi\sigma R^2 \qquad \ldots(iii)$$

In connection of two charged conducting bodies, the potential will become same on both, i.e.

$$\frac{Q_P}{4\pi\varepsilon_0 R} = \frac{Q_Q}{4\pi\varepsilon_0 2R}$$

$$\Rightarrow \frac{Q_P}{R} = \frac{Q_Q}{2R} \Rightarrow \frac{Q_P}{Q_Q} = \frac{1}{2}$$

So, the charges on the sphere P and Q after separation will be distributed as

$$\Rightarrow Q'_P = \frac{1}{3}Q_t \text{ and } Q'_Q = \frac{2}{3}Q_t$$

After separation, the new surface charge densities on P and Q will be

$$\sigma_P = \frac{Q'_P}{\text{Area}} = \frac{1}{3}\frac{Q_t}{\text{Area}}$$
$$= \frac{1}{3}\frac{20\pi\sigma R^2}{4\pi R^2} = \frac{5}{3}\sigma$$

$$\text{and } \sigma_Q = \frac{Q'_Q}{\text{Area}} = \frac{2}{3}\frac{Q_t}{\text{Area}}$$
$$= \frac{2}{3} \times \frac{20\pi\sigma R^2}{4\pi(2R)^2}$$
$$= \frac{2}{3} \times \frac{5}{4}\sigma = \frac{5}{6}\sigma$$

53. A sphere encloses an electric dipole with charge $\pm 3 \times 10^{-6}$ C. What is the total electric flux across the sphere? **[2019 NEET Odisha]**

(a) -3×10^{-6} N – m^2/C

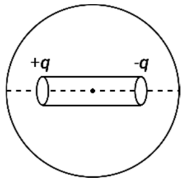
(b) Zero

(c) 3×10^{6} N – m^2/C

(d) 6×10^{-6} N – m^2/C

Ans. (b)

Sol. When a sphere encloses a charged dipole,



Here, $q = \pm 3\times 10^{-6}$ C

Thus, according to Gauss's law, the net electric flux across the closed surface is equal to the net charge enclosed by it divided by ε_0, i.e.

$$\phi_E = \frac{q_{in}}{\varepsilon_0} = \frac{+3\times10^{-6} - 3\times10^{-6}}{\varepsilon_0} = 0$$

Hence, electric flux across the sphere is zero.

54. Potential difference is given as $V(x) = -x^2y$ volt. Find electric field at a point (1, 2). **[JIPMER 2019]**

(a) $\hat{i} + 4\hat{j}\,Vm^{-1}$ (b) $-4\hat{i} - \hat{j}\,Vm^{-1}$

(c) $4\hat{i} + \hat{j}\,Vm^{-1}$ (d) $4\hat{i} - \hat{j}\,Vm^{-1}$

Ans. (c)

Sol. Given, potential difference,

$$V(x) = -x^2y \text{ volt}$$

$$\therefore\; E = -\Delta V$$

$$= -\left[\hat{i}\frac{\partial}{\partial x}(-x^2y) + \hat{j}\frac{\partial}{\partial y}(-x^2y)\right]$$

$$= -[-2xy\hat{i} - x^2\hat{j}] = 2xy\hat{i} + x^2\hat{j}$$

$$E \text{ at } (1,2) = 2\times1\times2\hat{i} + 1^2\hat{j}$$

$$= 4\hat{i} + \hat{j}\,Vm^{-1}$$

55. A spherical conductor of radius 10 cm has a charge of 3.2×10^{-7} C distributed uniformly, what is the magnitude of electric field at a point 15 cm from the centre of the sphere ? **[NEET 2020]**

$$\left(\frac{1}{4\pi\epsilon_0} = 9\times10^9\,Nm^2/C^2\right)$$

(a) 1.28×10^4 N/C (b) 1.28×10^5 N/C

(c) 1.28×10^6 N/C (d) 1.28×10^7 N/C

Ans. (d)

Sol. $E = \frac{kQ}{r^2} = \frac{9\times10^9\times3.2\times10^{-7}}{15\times15\times10^{-4}}$

$$E = \frac{3.2}{25}\times10^6 = 0.128\times10^6$$

$$E = 1.28\times10^5\ N/C$$

56. In a certain region of space with volume $0.2\,m^3$, the electric potential is found to be 5 V throughout. The magnitude of electric field in this region is : **[NEET 2020]**

(a) 1 N/C (b) 5 N/C

(c) Zero (d) 0.5 N/C

Ans: (c)

Sol. given v = const. (5 volt)

$$\therefore\; E = -\frac{dv}{dr}$$

$E = 0$

57. A short electric dipole has a dipole moment of 16×10^{-9} Cm. The electric potential due to the dipole at a point at a distance of 0.6 m from the centre of the dipole, situated on a line making an angle of 60º with the dipole axis is: **[NEET 2020]**

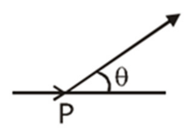
$$\left(\frac{1}{4\pi\epsilon_0} = 9\times10^9\,Nm^2/C^2\right)$$

(a) 400 V (b) zero

(c) 50 V (d) 200 V

Ans. (d)

Sol :



$$V = \frac{kP\cos\theta}{r^2} = \frac{9\times10^9\times16\times10^{-9}\times1}{(0.6)^2\times2} = \frac{400}{2} = 200$$

58. Two charged spherical conductors of radius R_1 and R_2 are connected by a wire. Then the ratio of surface charge densities of the spheres (σ_1/σ_2) is: **[NEET 2021]**

(a) $\frac{R_1}{R_2}$ (b) $\frac{R_2}{R_1}$

(c) $\sqrt{\left(\frac{R_1}{R_2}\right)}$ (d) $\frac{R_1^2}{R_2^2}$

Ans. (b)

Sol. For a conducting sphere,

$$E = \frac{\sigma}{\epsilon_0}$$

$$V = \frac{\sigma R}{\epsilon_0}$$

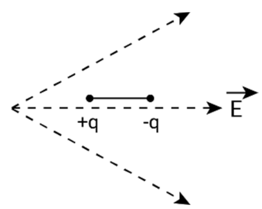
As both spheres have same potential after connecting with wire,

$$V_1 = V_2$$

$$\sigma_1 R_1 = \sigma_2 R_2$$

$$\Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

59. A dipole is placed in an electric field as shown. In Which direction will it move?



[NEET 2021]

(a) Towards the left as its potential energy will increase.

(b) Towards the right as its potential energy will decrease.

(c) Towards the left as its potential energy will decrease.

(d) Towards the right as its potential energy will increase.

Ans. (b)

Sol. Towards the right as its potential energy will decrease as field lines are close at charge +q,

So net on the dipole acts towards right side.

A system always moves to decreases it's potential energy.

60. Twenty-seven drops of same size are charged at 220 V each. They combine to form a bigger drop. Calculate the potential of the bigger drop. **[NEET 2021]**

(a) 660 V (b) 1320 V

(c) 1520 V (d) 1980 V

Ans. (d)

Sol. $\frac{4}{3}\pi R^3 = 27\left(\frac{4}{3}\pi r^3\right)$

$$\Rightarrow R = 3r \qquad ...(1)$$

$$V = \frac{Kq}{r}$$

$$\Rightarrow \frac{V_1}{V_2} = \left(\frac{q_1}{q_2}\right)\left(\frac{r_2}{r_1}\right)$$

$$\Rightarrow \frac{220}{V_2} = \left(\frac{q}{27q}\right)\left(\frac{3r}{r}\right)$$

$$\Rightarrow \frac{220}{V_2} = \frac{1}{9}$$

$$\Rightarrow V_2 = 220 \times 9$$

$$= 1980\,\text{Volt}$$

EXERCISE – 3: Achievers Section

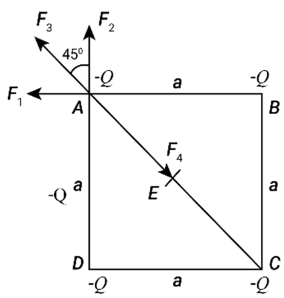
1. Four charges each equal to – Q are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium, the value of q is

(a) $-\frac{Q}{4}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

(c) $-\frac{Q}{2}(1+2\sqrt{2})$ (d) $\frac{Q}{2}(1+2\sqrt{2})$

Ans. (b)

Sol.



Net force at center will be zero.

Taking force at one point (bottom right vertex)

There will be two forces acting on it as shown in figure,

$$F_1 = k\frac{Q^2}{a^2}$$

$$F_2 = k\frac{Q^2}{2a^2}$$

Third force is between centre charge q and corner charge –Q but it will be positive,

$$F_3 = k\frac{Qq}{\left(\frac{a}{\sqrt{2}}\right)^2}$$

$$F_3 = 2k\frac{Qq}{a^2}$$

Total force at corner charge –Q,

$$\sqrt{2}F_1 + F_2 = F_3$$

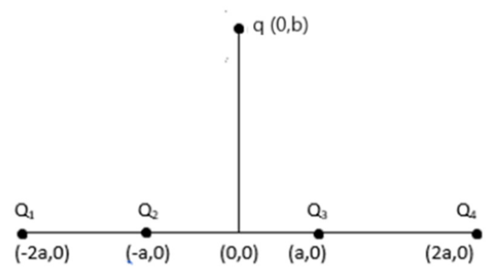
$$\sqrt{2}\left(k\frac{Q^2}{a^2}\right) + k\frac{Q^2}{2a^2} = 2k\frac{Qq}{a^2}$$

$$\sqrt{2}Q + \frac{Q}{2} = 2q$$

$$2q = \frac{Q}{2}\left(2\sqrt{2}+1\right)$$

$$q = \frac{Q}{4}\left(2\sqrt{2}+1\right)$$

2. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x axis at x = – 2a, –a, +a and +2a, respectively. A positive charge q is placed on the positive y axis at a distance b> 0. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match List I with List II and select the correct answer using the code given below the lists.



List I	**List II**
P. Q_1, Q_2, Q_3, Q_4 all positive	1. +x
Q. Q_1, Q_2 positive; Q_3, Q_4 negative	2. –x
R. Q_1, Q_4 positive; Q_2, Q_3 negative	3. +y
S. Q_1, Q_3 positive; Q_2, Q_4 negative	4. –y

Codes :

(a) P -3, Q-1, R-4, S-2 (b) P-4, Q-2, R-3, S-1

(c) P-3, Q-1, R-2, S-4 (d) P-4, Q-2, R-1, S-3

Ans. (a)

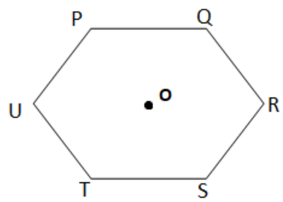
Sol. (1)If all charges are positive, then net field is in +y axis, (P-3)

(2) If Q_1, Q_2 positive and Q_3, Q_4 negative, then net field is in +x axis, (Q-1)

(3) If Q_1, Q_4 positive, and Q_2, Q_3 negative, then net field is in –y axis, (R-4)

(4) If Q_1, Q_3 positive, and Q_2, Q_4 negative, then net field is in –x axis, (S-2)

3. Six charges of equal magnitudes, 3 positives and 3 negatives are to be placed on PQRSTU corners of a regular hexagon, such that field at the centre is double that of what it would have been if only one +ve charge is placed at R.



(a) +, +, +, –, –, – (b) –, +, +, +, –, –

(c) –, +, +, –, +, – (d) +, –, +, –, +, –

Ans. (c)

Sol. To get double the electric field (when only positive charge is placed at R), we need to place a negative charge just opposite to it, which is U.

Now we need to place the remaining charges such that they cancel each other.

So, both the negative charges need to be placed at P and S while positive charges need to be placed at Q and T. Thus, option (c) will be correct.

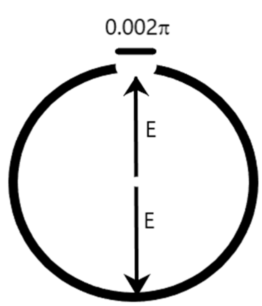
4. A ring of charge with radius of 50 cm has gap of 0.002 $C_3 = 1\mu F$ m. If the ring carries a charge of 1 C, what is the electric field at the centre?

(a) 8.5 × $C_1 = 1\mu F$ N/C (b) 7.2 × $C_4 = 1\mu F$ N/C

(c) 3.2 × $C_2 = 1.5\mu F$ N/C (d) 4.5 × $C_4 = 3\mu F$ N/C

Ans. (b)

Sol.



Charge on gap of ring (dq): $\frac{q}{2\pi R} \times (0.002\pi) = 2\times10^{-3}$ C

If charge is present on the gap, electric field at the center of the ring will be equal to zero. On the other hand, if charge is not present in the gap, electric field at the center of the ring would be due to the rest of the ring, which is nothing but equal and opposite to the electric field produced due to the charge in the gap. This field is given by:

$$\text{Electric field, } E = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2} = \frac{9\times10^9 \times 2\times10^{-3}}{2500\times10^{-4}} = 0.072\times10^9$$

$\Rightarrow E = 7.2\times10^7$ N/C

5. An electron is rotating around an infinite positive linear charge in a circle of radius 0.1 m, if the linear charge density is 1 μC/m then the velocity of electron in m/s will be

(a) 0.562×10^7 (b) 5.62×10^7

(c) 562×10^7 (d) 0.0562×10^7

Ans. (b)

Sol. Radius, $r = 0.1$ m, and linear charge density,

$\rho = 1\ \mu C/m = 10^{-6}$ C/m

Now, the electric field at a distance r is, $E = \frac{\rho}{2\pi\varepsilon_0 r}$

Therefore, due to the electric field, electrons revolve in orbit in a circular motion, hence electric force = centrifugal force.

$$eE = \frac{mv^2}{r}$$

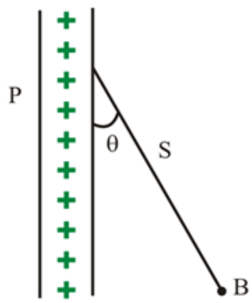
Therefore, the velocity of electrons, $v = \sqrt{\frac{eEr}{m}}$

$$\Rightarrow v = \sqrt{\frac{e\rho}{2\pi\varepsilon_0 m}}$$

$$\Rightarrow v = \sqrt{\frac{1.6\times10^{-19}\times10^{-6}}{2\pi\times8.85\times10^{-12}\times9\times10^{-31}}}$$

$\Rightarrow v = 5.6\times10^7$ m/s

6. A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to

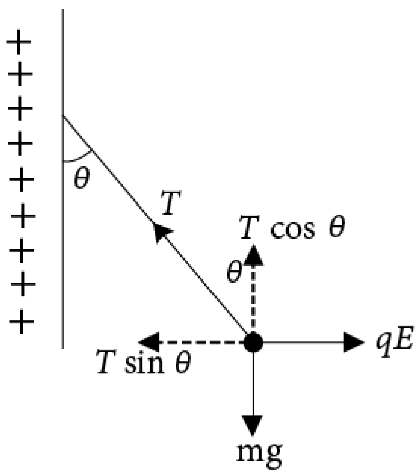


(a) $\cos\theta$ (b) $\cot\theta$

(c) $\sin\theta$ (d) $\tan\theta$

Ans. (d)

Sol.



Vertical tension in the string, $T\cos\theta = mg$ ... (1)

Horizontal tension in the string caused due to the swinging

motion of the ball, $T\sin\theta = qE$ .... (2)

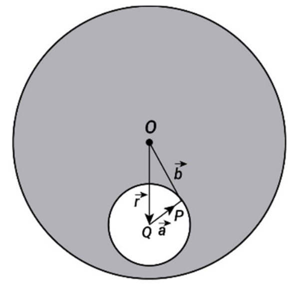
Where, E is the electric field, $E = \dfrac{\sigma}{\varepsilon_0}$

Now, dividing equation (2) by (1); we get

$$\frac{T\sin\theta}{T\cos\theta} = \frac{qE}{mg} \Rightarrow \tan\theta = \frac{q\sigma}{\varepsilon_0 mg}$$

Therefore, $\tan\theta \propto \sigma$

7. A spherical portion has been removed from a solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is



(a) zero everywhere

(b) non-zero and uniform

(c) non-uniform

(d) zero only at its centre

Ans. (b)

Sol. Using Gauss's law, electric field for an internal point is given by;

$$\Rightarrow \vec{E}(r) = \frac{\rho\vec{r}}{3\varepsilon_r}$$

This problem can be solved by superposition of electric fields due to the larger sphere without cavity and smaller sphere with opposite charge density.

Electric field due to larger sphere (internal point $\overrightarrow{OR}$), $\vec{E}_1 = \dfrac{\rho\vec{r}_1}{3\varepsilon_r}$

Electric field due to smaller sphere (internal point $\overrightarrow{O'R}$), $\vec{E}_2 = \dfrac{-\rho\vec{r}_2}{3\varepsilon_r}$

Superposition of electric fields;

$$\Rightarrow \vec{E} = \vec{E}_1 + \vec{E}_2 = \frac{\rho(\vec{r}_1 - \vec{r}_2)}{3\varepsilon_r} = \frac{\rho\overrightarrow{OO'}}{3\varepsilon_r} = \frac{\rho\vec{a}}{3\varepsilon_r}$$

Where $\vec{a}$ is the position vector of center of smaller sphere with respect to larger sphere, which remains constant.

Thus, electric field is uniform both in magnitude and direction.

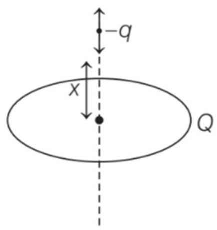
8. Positive charge Q is distributed uniformly over a circular ring of radius R. A point particle having a mass (m) and a negative charge $-q$ is placed on its axis at a distance x from the centre. Assuming $x < R$, find the time period of oscillation of the particle, if it is released from there [neglect gravity].

(a) $\left[\dfrac{16\pi^3\varepsilon_0 R^3 m}{Qq}\right]^{1/2}$ (b) $\left[\dfrac{8\pi^3\varepsilon_0 R^3}{q}\right]^{1/2}$

(c) $\left[\frac{2\pi^3\varepsilon_0 R^3}{3q}\right]^{1/2}$ (d) None of these

Ans: (a)

Sol. When the negative charge is shifted at a distance x from the centre of the ringalong its axis, then force acting on the point charge due to the ring is



$$F = qE \qquad (\text{towards centre})$$

$$= q \cdot \frac{kQx}{(R^2+x^2)^{3/2}}$$

If $R >> x$, then $R^2 + x^2 \simeq R^2$

and $F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qqx}{R^3}$ (towards centre)

Since force on charged particle is acting in opposite direction of electric field, hence acceleration on charged particle towards centre of ring is given by

$$\Rightarrow a = -\frac{F}{m} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{Qqx}{mR^3}$$

Since, restoring force $F_E \propto -x$,

therefore, motion of charged particle will be SHM.

Time period of SHM,

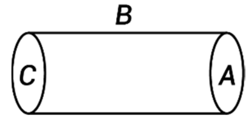
$$T = \frac{2\pi}{\omega} = \left[\frac{16\pi^3\varepsilon_0 R^3 m}{Qq}\right]^{1/2}$$

But, acceleration, $a = -\omega^2 x$

$$-\frac{1}{4\pi\varepsilon_0} \cdot \frac{Qqx}{mR^3} = -\omega^2 x$$

$$\Rightarrow \quad \omega = \sqrt{\frac{Qq}{4\pi\varepsilon_0 m R^3}}$$

9. A hollow cylinder has a charge q C within it. If ϕ is the electric flux associated with the curved surface B, the flux linked with the plane surface A in unit of voltmeter will be



(a) $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$ (b) $\frac{q}{2\varepsilon_0}$

(c) $\frac{\phi}{3}$ (d) $\frac{q}{\varepsilon_0} - \phi$

Ans: (a)

Sol. Gauss' law states that, the net electric flux through any closed surface is equal to the net charge inside the surface divided by ε_0.

i.e. $\phi_{total} = \frac{q}{\varepsilon_0}$

Let electric flux linked with surfaces A, B and C are ϕ_A, ϕ_B and ϕ_C, respectively.

i.e. $\phi_{total} = \phi_A + \phi_B + \phi_C$

Since, $\phi_C = \phi_A$

$\therefore \quad 2\phi_A + \phi_B = \phi_{total} = \frac{q}{\varepsilon_0}$

or $\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi_B\right)$

Hence, $\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$ (given, $\phi_B = \phi$)

10. Consider an atom with atomic number Z as consisting of a positive point charge at the centre and surrounded by a distribution of negative electricity uniformly distributed within a sphere of radius R. The electric field at a point inside the atom at a distance r from the centre is

(a) $\frac{Ze}{4\pi\varepsilon_0}\left[\frac{1}{r^2} - \frac{r}{R^3}\right]$ (b) $\frac{Ze}{4\pi\varepsilon_0}\left[\frac{1}{r^2} + \frac{r}{R^3}\right]$

(c) $\frac{2Ze}{4\pi\varepsilon_0 r^2}$ (d) Zero

Ans. (a)

Sol. The electric field, $E = \frac{Q_{enclosed}}{4\pi\varepsilon_0 r^2}$

Where, the charge enclosed by the atom,

$Q_{enclosed}$ = charge on nucleus + volume $= Ze + \frac{4}{3}\pi r^3 \rho$

Where, ρ is the charge density of the atom,

$$\rho = \frac{\text{total charge on an atom}}{\text{volume}} = \frac{-Ze}{\frac{4}{3}\pi R^3} = -\frac{3}{4}\frac{Ze}{\pi R^3}$$

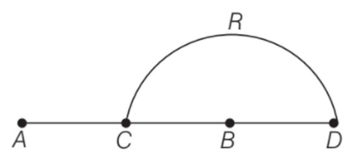
After putting the value of density, then

$$Q_{\text{enclosed}} = Ze - Ze\frac{r^3}{R^3}$$

Therefore, the electric field at a point inside theatom at a distance r from the centre is,

$$E = \frac{Ze - Ze\frac{r^3}{R^3}}{4\pi\varepsilon_0 r^2} = \frac{Ze}{4\pi\varepsilon_0}\left(\frac{1}{r^2} - \frac{r}{R^3}\right)$$

11. Charges + q and – q are placed at points A and B respectively, which are a distance 2L apart, C is the mid – point between A and B. The work done in moving a charge + Q along the semi – circle CRD is

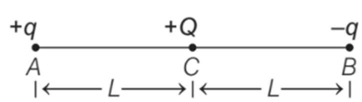


(a) $\frac{qQ}{4\pi\varepsilon_0 L}$ (b) $\frac{qQ}{2\pi\varepsilon_0 L}$

(c) $\frac{qQ}{6\pi\varepsilon_0 L}$ (d) $\frac{-qQ}{6\pi\varepsilon_0 L}$

Ans. (d)

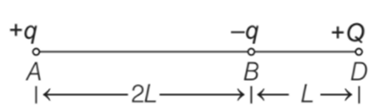
Sol. In first case, when charge + Q is situated at C.



Electric potential energy of system,

$$U_1 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q(-q)}{2L} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{(-q)Q}{L} + \frac{1}{4\pi\varepsilon_0}\frac{qQ}{L}$$

In second case, when charge + Q is moved from C to D



Electric potential energy of system in this case,

$$U_2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q(-q)}{2L} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ}{3L} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{(-q)(Q)}{L}$$

$$\text{Work done}(\Delta U) = U_2 - U_1$$

$$= \left(-\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{2L} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ}{3L} - \frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ}{L}\right) - \left(-\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{2L} - \frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ}{3L} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ}{L}\right)$$

$$= \frac{qQ}{4\pi\varepsilon_0}\left[\frac{1}{3L} - \frac{1}{L}\right] = \frac{qQ}{4\pi\varepsilon_0}\frac{(1-3)}{3L}$$

$$= -\frac{2qQ}{12\pi\varepsilon_0 L} = -\frac{qQ}{6\pi\varepsilon_0 L}$$

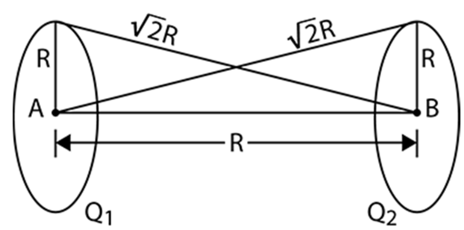
12. Two identical thin rings, each of radius R meters, are coaxially placed a distance R meters apart. If Q_1 coulomb, and Q_2coulomb, are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is

(a) zero (b) $\frac{q(Q_1 - Q_2)(\sqrt{2}-1)}{(4\sqrt{2}\pi\varepsilon_0 R)}$

(c) $\frac{q\sqrt{2}(Q_1 - Q_2)}{(4\pi\varepsilon_0 R)}$ (d) $\frac{q(Q_1 + Q_2)(\sqrt{2}+1)}{(4\sqrt{2}\pi\varepsilon_0 R)}$

Ans. (b)

Sol.



Potential at A;

$$\Rightarrow V_1 = k\left(\frac{Q_1}{R} + \frac{Q_2}{\sqrt{2}R}\right)$$

Potential at B;

$$\Rightarrow V_2 = k\left(\frac{Q_2}{R} + \frac{Q_1}{\sqrt{2}R}\right)$$

So, work done to move charge (q) from A to B is;

$$\Rightarrow W = q(V_1 - V_2)$$

$$\Rightarrow W = q\left(k\left(\frac{Q_1}{R}+\frac{Q_2}{\sqrt{2}R}\right)-k\left(\frac{Q_2}{R}+\frac{Q_1}{\sqrt{2}R}\right)\right)$$

$$\Rightarrow W = \frac{kq(Q_1 - Q_2)(\sqrt{2}-1)}{\sqrt{2}R}$$

13. Two equal point charges are fixed at x = –a and x = + a on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to

(a) x (b) x^2

(c) x^3 (d) 1/x

Ans. (b)

Sol. Initial potential energy of the system,

$$U_i = 2\times\frac{kQq}{a}$$

Final potential energy of the system,

$$U_f = \left(\frac{kQq}{a+x}+\frac{kQq}{a-x}\right)$$

$$\Rightarrow U_f = \frac{kQq(a-x+a+x)}{a^2-x^2}$$

$$\Rightarrow U_f = \frac{2kQqa}{a^2\left(1-\frac{x^2}{a^2}\right)} = \frac{2kQq}{a\left(1-\frac{x^2}{a^2}\right)}$$

$$\Rightarrow dU = U_f - U_i = \frac{2kaQq}{a^2-x^2}-\frac{2kQq}{a}$$

$$= \frac{2ka^2Qq - 2kQqa^2 - 2kQqx^2}{a(a^2-x^2)} = \frac{-2kQqx^2}{a(a^2-x^2)}$$

$$\Rightarrow dU \propto x^2$$

14. It is possible to have a positively charged body at

(a) zero potential

(b) negative potential

(c) positive potential

(d) All of these

Ans. (d)

Sol. A positively charged body can have positive, negative or zero potential. When we ground the charged body, potential difference between body and ground is zero but not the charge and same for negatively charged body.

15. **Assertion:** A and B are two conducting spheres of same radius. A being solid and B hollow. Both are charged to the same potential. Then, charge on A = charge on B.

Reason: Potentials on both are same.

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

(c) Assertion is correct but Reason is incorrect.

(d) Both Assertion and Reason are incorrect.

Ans. (a)

Sol. As charge is being distributed on the outer surface of conducting sphere and for hollow sphere also, charge is distributed on outer surface. If both spheres have same potential, then charge will be same, independent of the fact that sphere is hollow or solid,

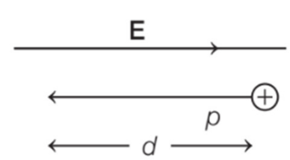
$$\frac{V_1}{V_2} = \left(\frac{R_2}{R_1}\right)\left(\frac{Q_1}{Q_2}\right)$$

As $V_1 = V_2$

$R_1 = R_2 \Rightarrow Q_1 = Q_2$

Therefore, both Assertion and reason are correct and Reason is the correct explanation of Assertion.

16. In the figure, a proton moves a distance d in a uniform electric field E as shown in the figure. Does the electric field do a positive or negative work on the proton? Does the electric potential energy of the proton increase or decrease?



(a) Negative, increase (b) Positive, decrease

(c) Negative, decrease (d) Positive, increase

Ans. (a)

Sol. Since, the proton is moving against the direction of electric field, so work is done by the proton against electric field. It implies that electric field does negative work on the proton. Again, proton is moving in electric field from a low potential region to a high potential region, hence its potential energy increases.

17. An electron of 100 eV is fired directly towards a metal plate having surface charge density of –2 × 10^7 What is the distance from where the electron be projected so that it just fails to strike the plate?

(a) 0.22 mm (b) 0.33 mm

(c) 0.44 mm (d) 0.66 mm

Ans. (c)

Sol. K.E of 10^7

10^7

$\frac{q}{2\pi R}\times dl=\frac{1}{5}\times 10^{-2}C$

18. A ball of mass 1 g and charge 10^{-8}C moves from a point A, where potential is 600 V to the point B, where potential is zero. Velocity of the ball at the point B, is 20 cms^{-1} The velocity of the ball at the point A will be

(a) 22.8 cms^{-1} (b) 228 cms^{-1}

(c) 16.8 ms^{-1} (d) 168 ms^{-1}

Ans. (a)

Sol.

By using, $\frac{1}{2}m\left(v_1^2 - v_2^2\right) = QV$

$\frac{1}{2}\times 10^{-3}[v_1^2 - (0.2)^2] = 10^{-8}(600-0)$

$\Rightarrow$ $v_1 = 22.8\ cms^{-1}$

19. The ionization potential of mercury is 10.39 V. How far an electron must travel in an electric field of $1.5\times10^6 V/m$ to gain sufficient energy to ionize mercury?

(a) $\frac{10.39}{1.6\times10^{-19}}$ m (b) $\frac{10.39}{2\times1.6\times10^{-19}}$ m

(c) $10.39\times1.6\times10^{-19}$ m (d) $\frac{10.39}{1.5\times10^{6}}$ m

Ans. (d)

Sol. Ionization potential (V) of mercury is the energy required to strip it of an electron. The electric field strength is given by, $E=\frac{V}{d}$ where, d is distance between plates creating electric field.

Given, V = 10.39 V

$E = 1.5\times10^6\ Vm^{-1}$

$\therefore \quad d = \frac{V}{E} = \frac{10.39}{1.5\times10^6}$ m

Hence, distance travelled by electron to gain ionization energy is $= \frac{10.39}{1.5\times10^6}$ m

20. This question has statement 1 and statement 2. Of the four choices given after the statements, choose the one that best describes the two statements.

An insulating solid sphere of radius R has a uniform positive charge density ρ . As a result of this uniform charge distribution, there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point outside the sphere. The electric potential at infinity is zero.

Statement 1: When a charge q is taken from the centre to the surface of the sphere its potential energy changes by $\frac{q\rho}{3\varepsilon_0}$.

Statement 2: The electric field at a distancer (r <R) from the center of the sphere is $\frac{\rho r}{3\varepsilon_0}$

(a) Statement 1 is false, Statement 2 is true.

(b) Statement 1 is true, Statement 2 is false.

(c) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation for Statement 1.

(d)Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation for Statement 1.

Ans. (a)

Sol. Applying Gauss's law

$$\int \vec{E}\,\vec{dA} = \frac{q_e}{\varepsilon_0}$$

$$\int EdA\cos(0) = \frac{\rho\frac{4}{3}\pi r^3}{\varepsilon_0}$$

$$E\int dA = \frac{\rho 4\pi r^3}{3\varepsilon_0}$$

$$E\times 4\pi r^2 = \frac{\rho 4\pi r^3}{3\varepsilon_0}$$

$$E = \frac{\rho r}{3\varepsilon_0}$$

Hence statement 2 is right,

Now, change in potential energy

$\Delta U = q\Delta V$

$\Delta U = q\left(V_s - V_c\right)$

Here

$\Delta V = -\int \vec{E}.\vec{dr}$

$\Delta V = -\int_0^R \frac{\rho r}{3\varepsilon_0} dr$

$\Delta V = -\frac{\rho}{3\varepsilon_0}\left[\frac{r^2}{2}\right]_0^R$

$\Delta V = -\frac{\rho R^2}{6\varepsilon_0}$

Now

$\Delta U = q \times -\frac{\rho R^2}{6\varepsilon_0}$

$\Delta U = -\frac{\rho q R^2}{6\varepsilon_0}$

Hence statement 1 is false

21. An electric dipole has a fixed dipole moment $\overline{P}$, which makes angle θ with respect to *x*-axis. When subjected to an electric field $\vec{E_1} = E\hat{i}$, it experiences a torque $\vec{T_1} = \tau\hat{k}$. When subjected to another electric field $\vec{E_2} = \sqrt{3}E_1\hat{j}$ it experiences a torque $\vec{T_2} = -\vec{T_1}$

The angle θ is:

(a) 30° (b) 45°

(c) 60° (d) 90°

Ans. (c)

Sol. Electric dipole moment $\vec{P}$ makes angle θ with respect to the x-axis. Electric field $\vec{E_1} = E\hat{i}$, and $\vec{E_2} = \sqrt{3}E_1\hat{j}$. Torque, $\vec{T_1} = \tau\hat{k}$ and $\vec{T_2} = -\vec{T_1}$.

Now, torque $T = PE\sin\theta$

Therefore, $T_1 = PE_1\sin\theta$, and $E_2 = \sqrt{3}E_1\hat{j}$

(given in the question)

Therefore, the angle between the dipole and electric field is $90-\theta$, then torque $T_2 = PE_2\sin(90-\theta)$

$\therefore T_2 = P\sqrt{3}E_1\cos\theta$ .....(1)

Now, from the question, it is given that $T_2 = -T_1$, therefore, $|T_2| = |-T_1|$ $PE_1\sin(90-\theta) = P\sqrt{3}E_1\cos\theta$

$\Rightarrow \tan\theta = \sqrt{3}$

$\therefore \theta = 60^\circ$

22. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of spheres A and B is

(a) 4 : 1 (b) 1 : 2

(c) 2 : 1 (d) 1 : 4

Ans. (c)

Sol. When we connect both spheres with wire then,

$V_A = V_B$

$\frac{kq_1}{R_1} = \frac{kq_2}{R_2}$

$\frac{q_1}{q_2} = \frac{R_1}{R_2}$

Electric fields on sphere A and B:

$E_A = \frac{kq_1}{R_1^2}$,

$E_B = \frac{kq_2}{R_2^2}$

Taking ratio,

$\frac{E_A}{E_B} = \frac{kq_1}{R_1^2} \times \frac{R_2^2}{kq_2}$

$\frac{E_A}{E_B} = \frac{q_1}{q_2} \times \frac{R_2^2}{R_1^2}$

$\frac{E_A}{E_B} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2}$

$\frac{E_A}{E_B} = \frac{R_2}{R_1}$

$\frac{E_A}{E_B} = \frac{2}{1}$

23. Consider two concentric spherical metal shells of radii r_1 and r_2($r_2 > r_1$). If the outer shell has a charge q and the inner one is grounded, the charge on the innershell is

(a) $\frac{-r_2}{r_1}q$ (b) zero

(c) $\frac{-r_1}{r_2}q$ (d) $-q$

Ans. (c)

Sol. Let the charge on the inner shell be q'.

The total charge will be zero.

So, $\frac{Kq'}{r_1}+\frac{Kq}{r_2}=0 \quad (\because r_2 > r_1)$

$\Rightarrow \quad q'=\frac{-Kq/r_2}{K/r_1} \Rightarrow q'=-\frac{r_1}{r_2}q$

24. Two conducting spheres of radii R_1 and R_2 are charged with charges Q_1 and Q_2, respectively. On bringing them in contact, there is

(a) no increase in the energy of the system

(b) an increase in the energy of the system, if $Q_1R_2 \neq Q_2R_1$

(c) always a decrease in the energy of the system

(d) a decrease in the energy of the system, if $Q_1R_2 = Q_2R_1$

Ans. (d)

Sol.

Potential, $V_1=\frac{1}{4\pi\varepsilon_0}\frac{Q_1}{R_1}$

and $V_2=\frac{1}{4\pi\varepsilon_0}\frac{Q_2}{R_2}$

If $V_1=V_2$, then $\frac{Q_1}{R_1}=\frac{Q_2}{R_2}$

$\Rightarrow Q_1R_2=Q_2R_1$

In this case, there will be no flow of charges.

However, if the given spheres have unequal potentials,

then the charges shall flow from higher potential to

lower potential. Flow of charges shall be accompanied

by loss of energy.

25. Two infinitely long parallel conducting plates having surface charge densities +σ and -σ respectively, are separated by a small distance. The medium between the plates is vacuum. If ε_0 is the dielectric permittivity of vacuum, then the electric field in the region between the plates is

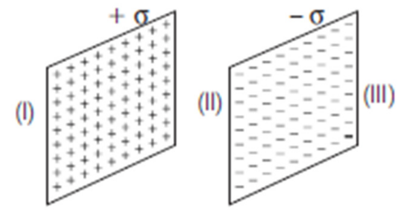
(a) 0 (b) $\frac{\sigma}{2\varepsilon_0}Vm^{-1}$

(c) $\frac{\sigma}{\varepsilon_0}Vm^{-1}$ (d) $\frac{2\sigma}{\varepsilon_0}Vm^{-1}$

Ans. (c)

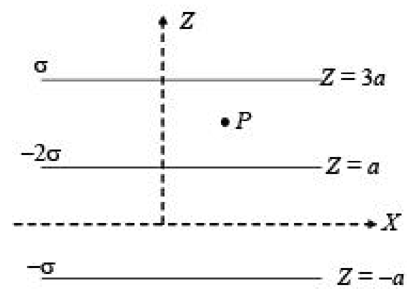
Sol.

Between the plates, i.e. in the region II as shown in figure, electric field is given by



$$E=\frac{1}{2\varepsilon_0}(\sigma_1-\sigma_2)$$
$$=\frac{1}{2\varepsilon_0}\times 2\sigma=\frac{\sigma}{\varepsilon_0}Vm^{-1}$$

26. Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is



(a) $\frac{2\sigma}{\varepsilon_0}\hat{k}$ (b) $-\frac{2\sigma}{\varepsilon_0}\hat{k}$

(c) $\frac{4\sigma}{\varepsilon_0}\hat{k}$ (d) $-\frac{4\sigma}{\varepsilon_0}\hat{k}$

Ans. (b)

Sol. Electric field due to a charge sheet is given by;

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

For positive charged sheet, electric field's direction

is away from the sheet, and for negatively charged sheet, it is towards the sheet.

$$\Rightarrow E_{net} = E_{z=a} + E_{z=3a} + E_{z=-a}$$

$$\Rightarrow E_{net} = \frac{2\sigma}{2\varepsilon_0}\left(-\hat{k}\right) + \frac{\sigma}{2\varepsilon_0}\left(-\hat{k}\right) + \frac{\sigma}{2\varepsilon_0}\left(-\hat{k}\right) = -\frac{2\sigma}{\varepsilon_0}\hat{k}$$

27. **Assertion:** All the charge in a conductor gets distributed on whole of its outer surface.

Reason: In a dynamic system, charges try to keep their potential energy minimum.

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If both assertion and reason are false.

Ans. (a)

Sol. Charge resides on the outer surface of a conductor because like charges repel and try to get as far away as possible from one another and stay at the farthest distance from each other. This to ensuring to maintain minimum potential energy to easily move around from one body to another, which is why they occupy the outer surface of the conductor.

28. **Assertion:** Net electric field inside conductor is zero.

Reason: Total positive charge equals to total negative charge in a conductor.

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If both assertion and reason are false.

Ans. (c)

Sol. Charge resides on outer surface of conductor. So, the electric field inside it is $\oint E_{in} dS = \frac{q_{en}}{\varepsilon_0} = 0$

Also, the charges are not the same, i.e., the total positive charge is not equal to the total negative charge in a conductor. This is to ensure smooth conductivity.

29. **Assertion:** The surface charge densities of two spherical conductors of different radii are equal. Then the electric field intensities near their surfaces are also equal.

Reason: Surface charge density is equal to charge per unit area.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (b)

Sol. As $\sigma_1 = \sigma_2$ (Given)

Let r_1 and r_2 be two different radii.

Therefore, $\frac{q_1}{4\pi r_1^2} = \frac{q_2}{4\pi r_2^2}$, or $\frac{q_1}{q_2} = \frac{r_1^2}{r_2^2}$

Then the ratio of electric field intensities near the surface of spherical conductor is given by

$$\frac{E_1}{E_2} = \frac{q_1}{4\pi\varepsilon_0 r_1^2} \times \frac{4\pi\varepsilon_0 r_2^2}{q_2} = \frac{q_1}{q_2} \times \frac{r_2^2}{r_1^2} = 1, \text{ i.e., } E_1 = E_2.$$

According to definition, surface charge density is equal to charge per unit area.

30. **Assertion:** Vehicle carrying inflammable materials usually have metallic ropes touching the ground during motion.

Reason: The charge accumulated in the body may cause fire.

(a) Both Assertion and Reason are true, and the Reason is the correct explanation of the Assertion.

(b) Both Assertion and Reason are true, but the Reason is not the correct explanation of the Assertion.

(c) Assertion is true, but Reason is false.

(d) Both Assertion and Reason are false.

Ans. (a)

Sol. Due to rubbing between tyre of vehicle and road, charge is produced and deposited on insulating tyres so if it is transferred to vehicle due to inflammable material it may catch fire. To avoid it, metallic chain is used which transfers excess charge into Earth.