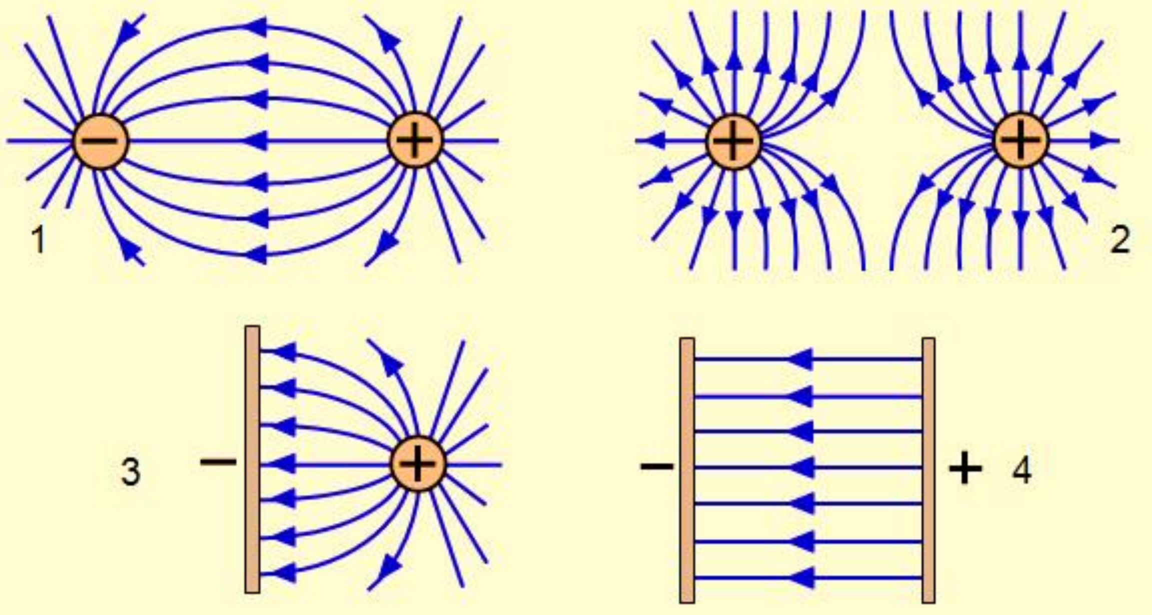
1.ELECTRIC CHARGES AND FIELDS



Physics Smart Booklet

Theory + NCERT MCQs + Topic Wise Practice MCQs + NEET PYQs

ELECTROSTATICS

QUANTIZATION OF CHARGES

All charges must be integral multiple of e i.e.
Q = ne (e = 1.6 × 10^{-19}C)
where — n = integer

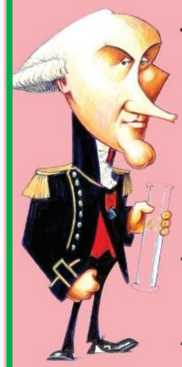
CONSERVATION OF CHARGES

It is not possible to create or destroy net charge of an isolated system

ELECTRIC CHARGES

- Charge is an intrinsic property of matter by virtue of which it experience Electric & Magnetic Effect
- Two kinds of charges +ve and -ve
- S.I. Unit Coulomb(C)

COULOMB'S LAW



- Force between two charged particles

$\vec{F} = \frac{Kq_1q_2\vec{r}}{r^3} = \frac{Kq_1q_2\hat{r}}{r^2}$

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

ε_0 = Permitivity of free space $= 8.854\times10^{-12}\, C^2 / Nm^2$

- Forces in Vector Form

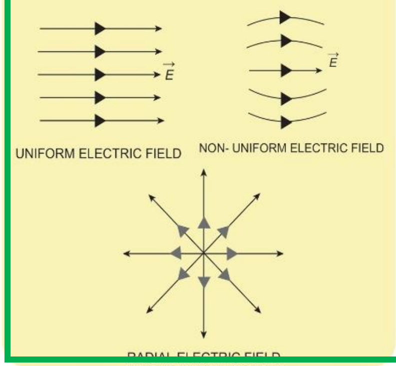
$\vec{F_{12}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{|\vec{r_1}-\vec{r_2}|^3}(\vec{r_1}-\vec{r_2})$

- Forces between Multiple Charges

$\vec{F_{net}} = \frac{q_0}{4\pi\varepsilon_0}\sum_{i=1}^{k}\frac{q_i}{r_{oi}^2}\hat{r}_{oi}$

ELECTRIC FIELD LINES

- Always normal to conducting surface.
- Lines originating from +ve charge
- Terminating at -ve charge
- Never intersect each other.
- Never form closed loop.
- Electric field lines are imaginary.
  (i) Uniform Electric Field
  (ii) Non-Uniform E.F.
  (iii) Radial Electric Field



ELECTRIC FIELD

- Electric field intensity (E) $\Rightarrow \vec{E} = \lim_{q_0 \to 0}\frac{\vec{F}}{q_0}$

In vector form— $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}$

S.I Unit — $\frac{N}{C} = \frac{V}{m}$

- Electric Field Intensity due to Point charge Q

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

- Net Electric Field with respect toorigi

$E_{net} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i}{r_{oi}^2}\hat{r}_{oi}$

- Electric field due to finite length line charge at distance r from conductor

$E_{\parallel} = \frac{\lambda}{4\pi\varepsilon_0 r}\left[\cos 0 - \cos\frac{\pi}{2}\right]$

$E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 r}\left[\sin\phi_2 + \sin\phi_1\right]$

(Here. λ is linear charge density)
Case(I): E.F due to infinite line charge

$\phi_1 = \phi_2 = \frac{\pi}{2} \to F_{\perp} = \frac{\lambda}{2\pi\varepsilon_0 r}; E_{\parallel} = 0$

Case(II): E.F due to semi-infinite line charge

$\phi_1 = \frac{\pi}{2}, \phi_2 = 0 \to E_{\parallel} = F_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 r}$

- Electric field due to a charged circular ring at a point on its axis.

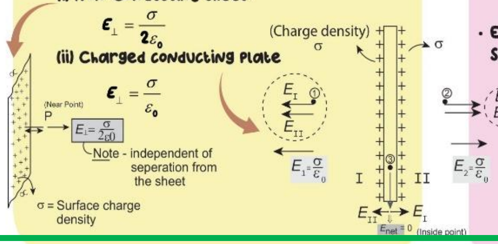
$E_p = \frac{kQx}{(R^2+x^2)^{\frac{3}{2}}}$

- Electric field due to a plane infinite sheet
(i) Non-Conducting Sheet:

$E_{\perp} = \frac{\sigma}{2\varepsilon_0}$

(ii) Charged conducting plate

$E_{\perp} = \frac{\sigma}{\varepsilon_0}$

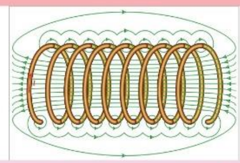


THEORY OF CONDUCTOR

A material having free electrons in its valence shell is called conductor.
- Inside a conductor, the net electrostatic field is zero
- At the surface of a charged conductor, the electrostatic field must be normal to the surface at every point
- The interior of a conductor can have no excess charge in the static situation i.e. excess charge reside only on the outer surface of conductor.
- Electric field at the ssurface of a charged conductor

$\left[E = \frac{\sigma}{\varepsilon_0}\right]$ where, σ is surface charge density.

$\left(\sigma = \frac{1}{\text{radius of curvature}}\right)$



- Electric field due to charged spherical shell or conducting sphere

$e = (r < R) = 0$

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

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

- Electric field due to a solid non-conducting sphere - (ƒ = volume charge density)

$E = (r < R) = \frac{kQr}{R^3} = \frac{\rho r}{3\varepsilon_0}$

$E = (r > R) = \frac{kQ}{r^2} = \frac{1Q}{4\pi\varepsilon_0 r^2}$

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

ELECTRIC DIPOLE

A pair of equal and opposite point charges repeated by fix distance

Electric Dipole Moment
$\vec{P} = q(2a)$ cm

- Electric field due to Electric Dipole
(i) Electric Field (E.F.) on the axis of dipole at a distance r from center of dipole:

$E = \frac{-kq}{(\gamma - a)^2} + \frac{kq}{(r+a)^2} = \frac{k2qa^2}{(r^2-a^2)^2}$

(ii) Electric field at a distance r from centre of dipole on its equatorial line:

$E_{net} = \frac{-k\vec{P}}{(r^2+a^2)^{\frac{3}{2}}}$

- Electrical potential due to Electric Dipole:

(i) Axial $\to V_p = \frac{KP}{(r^2-a^2)}$

(ii) Equatorial $\to V_p = 0$

- Force and Torque on dipole in uniform external (E.F.)

Force $\to \vec{F}_{Net} = qE - qE = 0$

Torque $\to \vec{\iota} = PESIN\theta = \vec{P}\times\vec{E}$

Work Done in Rotating Dipole
$\to W = PE(\cos\theta_1 - \cos\theta_2)$

- Potential Energy $\to U = -PE\cos\theta = \vec{P}.\vec{E}$

ELECTRIC FLUX

Total number of electric field lines passing normally throng an area

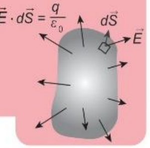
$-\phi = \oint\vec{E}.\vec{ds}$

Electric flux $(\phi) = |\vec{E}||\vec{ds}|\cos\theta$

GAUSS LAW

It states, total flux of an E.F. through a closed surface is equal to times of total charge enclosed by the surface.
Total flux through surface

$(\phi) = \frac{q_{enclosed}}{\varepsilon_0} \quad \oint\vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0}$



ELECTRIC POTENTIAL & ELECTRIC POTENTIAL ENERGY

- Work done by external charge to move from position 1 to 2 in static electric field E.

$W_{ext} = \int\vec{F}.\vec{dl} = -q\int_1^2\vec{E}.\vec{dl}$

- Electric Potential

$\to V_p = \frac{W_{ext}(\infty \to P)}{q} = -\int_{\infty}^{P}\vec{E}.\vec{dl}$

- Electric Potential due to a point charge in its surrounding: $\to V_p = \frac{Kq}{r}$

- Electric Potential due to a point charged ring at its center:

$V = \int dv = \int\frac{Kdq}{R} = \frac{K\theta}{R}$

- Electric Potential due to conducting and Non-Conducting sphere:
(i) Inside (r < R)
(ii) Outside (r > R)
(iii) At surface (r = R)
Hollow conducting

$V_p = \frac{Kq}{R}$

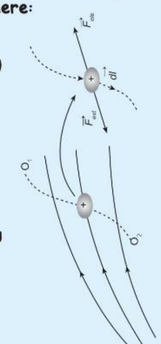
$V_p = \frac{Kq}{r}$

$V_p = \frac{Kq}{R}$

Solid Non-Conducting

$V_p = \frac{Kq}{2R^3}[3R - r^2]$

$V_p = \frac{Kq}{r} \quad V_p = \frac{Kq}{R}$



- Electric Potential Energy: Amount of work done(W) required to be done to move a charge from infinity to any given point inside the field.

$U_A = W_{\infty\to A} = -q\int_{-\infty}^{A}\vec{E}.\vec{dl} = qV_A$

- Work done in moving charge from A to B will be:

$W_{ext} = \Delta U = (U_B - U_A) = q(V_B - V_A)$

- Electric Potential Energy due to two point charges:

$U = \frac{Kq_1q_2}{r}$

- Electric Potential Energy of a system of charges:

$U_{(Total)} = kq_1q_2\frac{1}{r_{12}} + Kq_2q_3\frac{1}{r_{23}} + \frac{Kq_3q_4}{r_{34}} + \ldots$

- Relation Between Electric Field and Potential:
Electric field at a point is negative of potential gradient

Potential gradient $\to \left[E = \frac{-dV}{dr}\right]$

Electric Charges and Fields

Charge and its properties

- Charge, like mass is a basic property of matter.
- Charges are of two types – the one on proton, by convention is named positive and the other an electron, by convention is named negative. A neutron has no net charge and is electrically neutral.

Fundamental properties of charges

(a) Charge is conserved – quantity the net of charge in an isolated system remains constant.

(b) Charge is quantized – the charge on any particle is an integral multiple of a fundamental unit of charge e, namely the charge on an electron or proton. $Q = \pm ne$: n = 1, 2, 3 … where $e = 1.6\times10^{-19}\,C$. Protons and neutrons are made up of quarks with fractional values of e. However, quarks do not occur in free state.

(c) Charge is invariant – unlike mass, length and time, charge on a body is independent of its state of motion (reference frames).

(d) Charge is a scalar and is additive.

(e) Like charges repel and unlike charges attract.

Auxillary properties of electric charge

(i) An electric charge in motion produces a magnetic field in addition to the electric field.

(ii) An accelerated charge radiates energy in the form of electromagnetic waves.

Methods of charging a body

Bodies can be charged by

- **Friction** (E.g. rubbing of glass with wool etc.)
  The two bodies acquire opposite kind of charge, due to one body losing electrons to other body.
- **Conduction** (E.g. bringing an uncharged body in contact with a charged body)
  During conduction, the body getting charged acquires part of the charge from the source (charging body).
- **Induction** (E.g. bringing a uncharged body near a charged body)
  During induction, the body getting charged acquires opposite kind of charge on its surface close to the charging body. The net charge on the charged body is still zero. However, by earthing, the charged body can be made to retain one type of charge. The charge on the source body remains intact. This method is applicable to only conductors.
- irradiating a conducting body by suitable electromagnetic radiation
- heating a body to a high temperature
- by applying a large electric field
- In all the above methods the body regains electrical neutrality over a period of time.
- Whether a body is charged or not and if charged, the type and extent of charge can be detected by a device called electroscope. The amount of charge on a body can be measured by a device called electrometer.

Coulomb's law: The force (F) of attraction or repulsion between two point charges is directly proportional to the product of the charges (Q_1 and Q_2) and inversely proportional to the square of the distance (r) between them.

$$F \propto \frac{Q_1Q_2}{r^2} \quad \therefore \quad F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$$

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

ε_0 is called the permittivity of free space and $\varepsilon_0 = 8.854\times10^{-12}\ C^2\,N^{-1}\,m^{-2}$

Dimensional formula of permittivity is $M^{-1}L^{-3}T^{4}A^{2}$.

ε_r is greater than one for a medium other than vacuum. For air $\varepsilon_r \approx 1$. ε_r is called dielectric constant and is denoted by *K*.

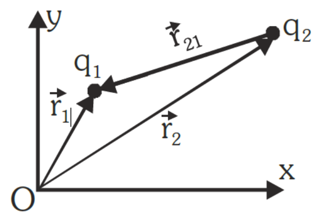
Coulomb's law is strictly valid for point charges in vacuum. The presence of a medium modifies the force which is approximately given by $F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q_1Q_2}{r^2}$

where ε_r is called the permittivity of the medium.

Coulomb's law in vector form

Coulomb's law of force between two point charges q_1 and q_2 located at $\vec{r}_1$ and $\vec{r}_2$ is written as

$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{21}^2}\hat{r}_{21}$ where F_{21} is the force exerted on q_2 by q_1 and $\hat{r}_{21}$ is the unit vector towards q_2 from q_1 and $\vec{r}_{21} = \vec{r}_2 - \vec{r}_1$



Coulomb's law in vector form

Similarly force exerted on q_1 by q_2 is

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}$$

$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2$ and $\hat{r}_{12}$ is the unit vector towards q_1 from q_2.

Since, the above equations are in vector form, q_1 and q_2 should be used with appropriate signs.

☞

- Coulomb's law is strictly applicable to point charges. However, in practice, charges are always associated with matter, which occupy finite volume. To simplify the situation, usually a charge is replaced by a charge of equal magnitude imagined to be concentrated at a single point. Such a charge is called a point charge.
- The gravitational force is usually neglected while studying the force between electric charges because gravitational force is negligible compared to electrostatic force. The ratio of electrostatic force of repulsion to the gravitational force of attraction between two electrons separated by 1 m is about 1.7×10^{43}.
- The relative permittivity ε_r of a medium is nearly constant. ε_r depends both on the property of the medium and the magnitude of the charges.
- ε_r is only a number and has no units. ε_r is also called dielectric constant.
- The unit of charge is coulomb (C).
- The charge on an electron is equal to -1.6×10^{-19} C.
- One coulomb charge has 6.25×10^{18} electrons.
- A test charge is a hypothetical infinitesimally small charge, kept at a point to evaluate the electric field at that point without disturbing the field.

Electric Field

The electric field at a point is defined as the force experienced per unit positive test charge (q_0) placed at that point. i.e.,

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

Electric field is measured in newton per coulomb (NC^{-1}). Its direction is always from a positive charge and towards a negative charge.

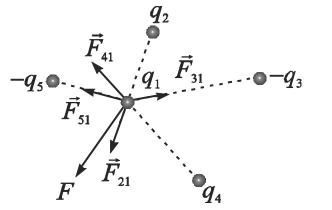
Electric field (E) at distance r from a point charge Q is $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

E is a vector and the resultant electric field at a point due to several charges is equal to the vector sum of the fields due to the individual charges.

Principle of superposition of electric forces

The resultant electric force at a point is the vector sum of the forces due to various charges. That is, $\vec{F}_{res} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots$

This is known as the principle of superposition of electric forces.



Superposition of electric forces

Electric dipole

Two equal and opposite charges separated by a small distance are said to form an electric dipole.
Every dipole is associated with a dipole moment $\vec{p}$ whose magnitude is equal to the product of the magnitude of any one charge (q) and the distance $(2a)$ between them. $\vec{p} = q \times 2\vec{a}$.

The direction of $\vec{p}$ is from negative charge to positive charge. Its unit is coulomb metre.

Field at a point on the axial line of electric dipole

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

For a point on the axis far away from the centre of the dipole (meaning a short dipole).

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$$

The direction of $\vec{E}$ is along the direction of dipole moment.

Field at a point on the equatorial line of dipole

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

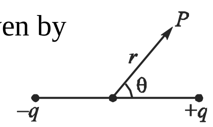
For a point on the equatorial line of a short dipole, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\left(-\frac{\vec{p}}{r^3}\right)$

The direction of $\vec{E}$ is antiparallel to the direction of electric dipole moment.

Field at any point due to a dipole

At an arbitrary point P, electric field due to a short dipole is given by

$$E = \frac{p}{4\pi\varepsilon_0 r^3}\sqrt{3\cos^2\theta + 1}$$



Torque on dipole in an electric field

When an electric dipole of moment $\vec{p}$ is held at an angle θ with the direction of *a* uniform electric field $\vec{E}$, a torque acts on the dipole, which is given by $\vec{\tau} = \vec{p} \times \vec{E} = pE\sin\theta$ in magnitude.

The torque tries to align the dipole in the direction of the field.

Electric field due to a continuous distribution of charge

If a charge Q is distributed uniformly over a body, then the electric field at a point P distant r from an element with charge dQ in the body is given by $dE = \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r^2}$.

The field due to the entire body is given by $E = \frac{1}{4\pi\varepsilon_0}\int\frac{dQ}{r^2}$

(a) For linear distribution of charge, dQ = λd*l*, where λ is called the linear charge density.
(b) For surface distribution of charge, dQ = σds, where σ is called surface charge density
(c) For volume distribution of charge dQ = ρdV where ρ is called volume charge density.

The electric field at any point on the axis of a uniformly charged ring of radius R at a distance d from its centre is given by $E = \frac{1}{4\pi\varepsilon_0}\frac{Qd}{(d^2 + R^2)^{3/2}}$.

Dielectric polarisation

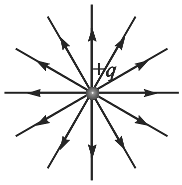
When a non polar dielectric slab is held in an electric field E_0 (in vacuum), the dielectric slab acquires a net dipole moment. The induced dipole moment $P = \alpha E_0$ where α is a constant of proportionality called atomic or molecular polarisability.

Therefore, the effective field in a polarized dielectric slab decreases to $E = E_0 - E_p$ where E_p is the induced electric field. Also $E_p = \frac{\sigma_p}{\varepsilon_0}$; σ_p = surface density of polarization charge.

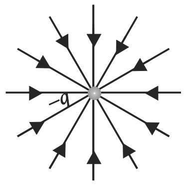
The ratio of $\left(\frac{E_0}{E}\right)$ = K, is a constant called the *dielectric constant*.

Electric field lines

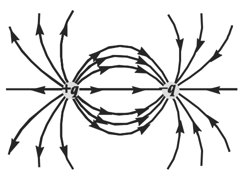
An electric field line is a line such that the direction of electric field is tangential to the line at every point on it.



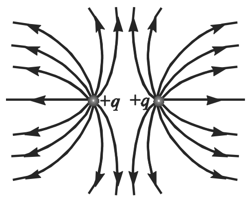
(a) Positive charge



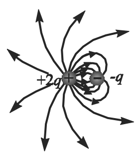
(b) Negative charge



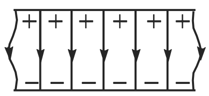
(c) A pair of equal positive and negative charges



(d) A pair of equal positive charges



(e) A combination of charge +2*q* and –*q*



(f) Field between oppositely charged parallel plates

Characteristics of field lines

1. A field line is purely a geometric representation and has no physical existence.
2. If a field line is a curve, the direction of the tangent at any point indicates the direction of the field at that point.
3. The field lines due to positive charge diverge from the charge and the field lines due to a negative charge converge to the charge.
4. A uniform electric field is represented by a set of parallel uniformly spaced lines. Non-uniformly spaced lines and curved lines represent a non uniform field.
5. Field lines can never intersect.

   If two field lines are shown to be intersecting, it means that a positive test charge placed at that point can move in two different directions. This is not possible. Thus, field lines cannot intersect each other.
6. Electric field lines are always normal at every point on the surface of a charged conductor.

Electric flux

It is defined as the total number of field lines normal drawn to a surface. Flux per unit area is equal to the field, $E = \frac{\phi}{A}$, where ϕ is the flux through an area A.

If the field lines are inclined at an angle θ to the normal to the surface of area ds, then

$$E = \frac{\phi}{ds \cos\theta} \text{ or } \phi = E\, ds \cos\theta$$

Gauss' law

The total flux across a closed surface is equal to (1/ε_0) times the algebraic sum of the enclosed charges i.e. $\phi = \frac{1}{\varepsilon_0}\Sigma Q$.

SI unit of electric flux: $NC^{-1}\ m^2$

Coulomb's law can be derived from Gauss' law.

Gauss' law is applicable for both point charges and charged bodies.

According to Gauss' law, $\phi = \oint \vec{E}.\, d\vec{S} = \frac{Q}{\varepsilon_0}$, where, ε_0 is the permittivity of free space.

- Gauss' law is applicable to continuous and closed surfaces only.
- If there are no charges within the surface or when the net charge inside the surface is zero, the net flux across the surface is zero.
- Net zero flux across a closed surface does not imply zero field at points on the surface. The field may be same or may not be same at different points on the surface, but the total flux across the surface is as given by Gauss' law.
- The net electric flux over a closed surface is independent of

(a) the nature, shape or size of the Gaussian surface

(b) the pattern of charge distribution

(c) the state of rest or motion of the charges.

(d) the presence of charges outside the surface.

- No net flux due to outside charges

  Charges outside the surface do not contribute to the total flux across the closed surface. Due to a point charge outside the surface, the flux into the surface around some point/s will be equal to flux out of the surface at some other point/s. The orientations of the surface elements will be such that the net outward flux over the entire surface, due to the outside charge will always be zero.

Electric field due to some simple charged conductors

(a) *Charged spherical shell: At a distance r from a shell of radius R and charge Q,* $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$.

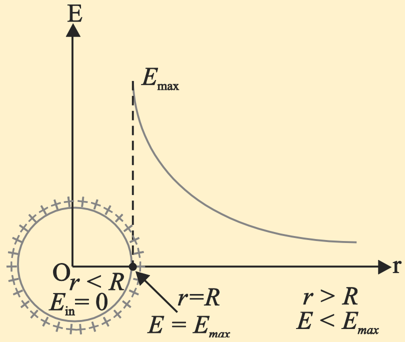
(b) *This results is valid for*

(i) charged solid conducting sphere

(ii) charged hollow conducting sphere and

(iii) uniformly charged insulating spherical shell

- For a point outside a charged spherical shell $r > R$, $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$
- For a point outside a charged spherical shell, the charged spherical shell is equivalent to a point charge, placed at its centre.
- For a point just outside a charged spherical shell r = R i.e., a point on the surface of the shell $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$



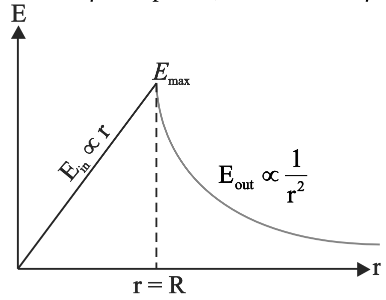
- For a point inside a charged spherical shell, r < R. The Gaussian surface does not enclose any charge. Thus, Q = 0. Therefore, E = 0.

(c) *Uniformly charged non-conducting sphere: (R = radius of the sphere, r = distance from the centre)*

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

(ii) $E_{surface} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

(iii) $E_{inside} = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}$

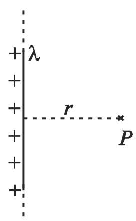


(d) *Near a charged conductor: If σ is the surface density of charge (charge/area), then* $E = \frac{\sigma}{\varepsilon_0}$

- E does not depend on the distance.
- If there is a medium other than air or vacuum around the conductor, $E = \frac{\sigma}{\varepsilon_0\varepsilon_r}$.

(e) *Infinite line of charge,* $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{r}\hat{r}$

λ = linear charge density



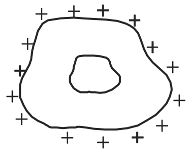
(f) *Infinite plane sheet of charge*

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

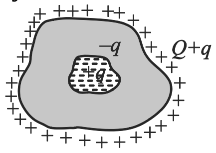
σ = surface charge density.

Electric field in a cavity inside a charged conductor

- If conductor with charge Q has a cavity, the electric field inside the cavity is zero. The entire charge Q lies on the outer surface.



- If the cavity contains a charge q, a charge –q, will be induced on the surface of the cavity and +q on the outer surface of the body. The electric field inside the cavity is not zero. The net charge on the outer surface of the body is Q + q.



If charge Q is situated at the centre of a cube, the electric flux through each surface of the cube is $\frac{1}{6}(Q/\varepsilon_0)$

- If a charge Q is situated at any corner of a cube, the electric flux through the cube is $Q/8\varepsilon_0$
- If a charge Q is situated at the centre of the face of a cube, the electric flux through the cube is $Q/2\varepsilon_0$
- If a charge Q is situated at the centre of the edge of a cube the electric flux through the cube is $Q/4\varepsilon_0$

Illustrations

1. The incorrect statement out of the following is

(A) electron + positron $\rightarrow \gamma$-ray (B) γ-ray $\rightarrow$ electron + positron

(C) Na $\xrightarrow{\text{dissociation}} Na^+ + Cl^-$ (D) electron + proton $\rightarrow \gamma$-ray

Ans (D)

During particle interactions, charge must be conserved in addition to fulfilling other conservation laws. One such conservation law is the conservation of particle number. + 1 is associated with a particle and –1 is associated with an antiparticle.

When a particle and an antiparticle come together, they annihilate each other producing a γ-ray photon. An electron and proton have equal and opposite charges. However, they are not a particle and antiparticle pair. Similarly a γ-ray photon of sufficient energy can materialize into a particle-antiparticle pair.

2. A polythene piece rubbed with wool is found to have a charge of -3.2×10^{-7} C. Then

(A) the number of electrons transferred from polythene to wool is 2×10^{12}

(B) the number of protons transferred from polythene to wool is 2×10^{12}

(C) the number of electrons transferred from wool to polythene is 2×10^{12}

(D) the number of protons transferred from wool to polythene is 2×10^{12}

Ans (C)

During the process of rubbing, only electrons which are loosely bound to atoms are dislodged and transferred from one body to another. If n electrons are transferred from wool to polythene, the charge on polythene is given by Q = ne, where e is the charge on an electron.

$$\therefore Q = ne \therefore n = \frac{Q}{e} = \frac{-3.2 \times 10^{-7}}{-1.6 \times 10^{-19}} = 2 \times 10^{12}$$

3. A, B, C and D are four similar conducting spheres suspended from an insulating string. A is found to repel C but found to attract both B and D. B is found to attract A, C and D. Then

(A) charge on D must be positive

(B) charge on D must be negative

(C) charge on D must be zero

(D) A and B must have the same kind of charge

Ans (C)

Bodies with like charges repel and unlike charges attract. A charged body also attracts a neutral body, due to the phenomenon of induction.

4. Two identical conducting balls A and B have positive charges q_1 and q_2 respectively and are separated by a distance. 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

(A) same as that before the balls touched

(B) zero

(C) less than that before the balls touched each other

(D) greater than that before the balls touched each other

Ans (D)

This problem is based on the concept that when two identical conductors with unequal charge are brought in contact, they share the net charge equally.

$$F \propto q_1 q_2 \ ; \quad F' \propto \left(\frac{q_1+q_2}{2}\right)^2 \Rightarrow F' > F$$

Alternately, if a given amount of charge is distributed into two equal parts, the force is highest compared to any other distribution. Thus, the force is higher than before.

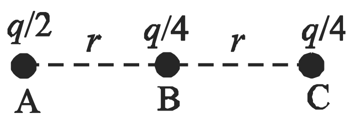
5. A, B and C are identical conducting spheres, placed at uniform spacing along a straight line. Sphere A has a certain charge. B is brought in contact with A and placed in its position. Then, C is brought in contact with B and moved back to its original position. Then

(A) $F_{AB} = F_{BC} = F_{AC}$ (B) $F_{AB} = F_{AC} = 2F_{AB}$ (C) $F_{AB} < F_{AC} < F_{BC}$ (D) $F_{AB} > F_{BC} > F_{AC}$

Ans (D)

This problem is based on the concept that when two identical charged conductors are brought into contact, they share their net charges equally. Let the charge on A be q and B be uncharged. When A and B are brought in contact, the charge on them will q/2 each. When C is brought in contact with B, q/2 is shared equally among them i.e., q/4 and q/4.

Hence, now we have the situation as shown in the figure.



Then $F_{AB} = k\dfrac{\left(\frac{q}{2}\right)\left(\frac{q}{4}\right)}{r^2} = \dfrac{1}{8}\left(\dfrac{kq^2}{r^2}\right)$

$F_{BC} = k\dfrac{\left(\frac{q}{4}\right)\left(\frac{q}{4}\right)}{r^2} = \dfrac{1}{16}\left(\dfrac{kq^2}{r^2}\right)$

$F_{AC} = k\dfrac{\left(\frac{q}{2}\right)\left(\frac{q}{4}\right)}{(2r)^2} = \dfrac{1}{32}\left(\dfrac{kq^2}{r^2}\right)$ where $k = \dfrac{1}{4\pi\varepsilon_0}$ $\therefore F_{AB} > F_{BC} > F_{AC}$

6. Two charges, q_1 and q_2 repel each other with a force of 100 N. On increasing the separation between them by 5 m, the force reduces to 64 N. The initial separation is

(A) $\dfrac{80}{9}$ m (B) $\dfrac{9}{80}$ m (C) 20 m (D) 10 m

Ans (C)

The problem is based on the application of Coulomb's law. Since both charge and separation are not known, by applying Coulomb's law for the initial and final separations, q_1q_2 can be eliminated and r can be calculated.

$F = k\dfrac{q_1q_2}{r^2}$; $100 = k\dfrac{q_1q_2}{r^2}$ ...(1)

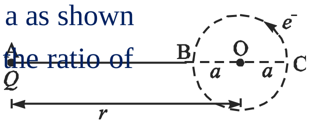
$64 = k\dfrac{q_1q_2}{(r+5)^2}$ ...(2)

From Eqs. (1) and (2) we get

$\left(\dfrac{r+5}{r}\right)^2 = \dfrac{100}{64}$; $\dfrac{r+5}{r} = \dfrac{10}{8}$

2r = 40 ∴ r = 20 m

7. A charge Q is at point A. An electron is in uniform circular motion of radius a as shown in figure. (Uniform circular motion of electron is not caused by Q). What is the ratio of magnitude of minimum force to maximum force on electron due to Q?



(A) $\dfrac{r-a}{r+a}$ (B) $\left(\dfrac{r-a}{r+a}\right)^2$ (C) $\left(\dfrac{r+a}{r-a}\right)^2$ (D) $\dfrac{r-a}{r}$

Ans (B)

This problem is based on the concept that the coulomb force between two charges is a function of the distance separating the two charges and that the force is minimum at maximum separation and force is maximum at minimum separation.

Electron experiences minimum force (due to Q), when it is at C.

$$F_{min} = \frac{kQe}{(r+a)^2}$$

Electron experiences maximum force (due to Q) when it is at B.

$$F_{max} = \frac{kQe}{(r-a)^2}$$

$$\frac{F_{min}}{F_{max}} = \frac{(r-a)^2}{(r+a)^2}$$

8. Two point charges q_1 and q_2 (both positive) are separated by a distance r which varies with time t as $r = 6 + 2t^2$. What is the ratio of force on q_1 at t = 0 to force on q_1 at t = 3 s? [Assume that the variation of r is not due to electrostatic force between them]

(A) 4 (B) 8 (C) 12 (D) 16

Ans (D)

This problem is based on the concept that the force between two charges varies as the separation keeps changing.

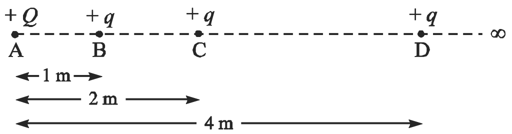
At t = 0, r = 6 and $F_0 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{6^2}$

At t = 3s, r = 24 and $F_3 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{24^2}$

Now $\dfrac{F_0}{F_3} = \dfrac{24^2}{6^2} = 16$

9. A Charge Q is placed at a point A. A number of identical charges each of magnitude q are placed at B, C, D, E and F etc at distances of 1 m, 2 m, 4 m, 8 m etc. The net force on the charge at A is

(A) $\dfrac{1}{2}\left(\dfrac{qQ}{4\pi\varepsilon_0}\right)$ (B) $\dfrac{qQ}{4\pi\varepsilon_0}$



(C) $\dfrac{qQ}{3\pi\varepsilon_0}$ (D) $\dfrac{qQ}{5\pi\varepsilon_0}$

Ans (C)

This concept is based on the principle of superposition of electrostatic forces.

$$F_{net}(\text{on } Q) = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+\frac{1}{16^2}+\ldots\ldots\right]$$

$$\left[S_\infty = \frac{a}{1-r} = \frac{1}{1-(1/4)} = \frac{4}{3}\right]$$

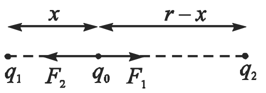
$$F_{net} = \frac{1}{3}\frac{Qq}{\pi\varepsilon_0}$$

10. Two point charges q_1 and q_2 ($q_2 > q_1$) of same nature are separated by a distance r. A small test charge (of the nature of q_1 and q_2) is placed on the line joining q_1 and q_2. Its distance from q_2 such that net force on q_0 is zero is

(A) $r\dfrac{\sqrt{q_1}}{\sqrt{q_1}-\sqrt{q_2}}$ (B) $\dfrac{r\sqrt{q_1}}{\sqrt{q_1}+\sqrt{q_2}}$ (C) $\dfrac{r\sqrt{q_2}}{\sqrt{q_1}-\sqrt{q_2}}$ (D) $\dfrac{r\sqrt{q_2}}{\sqrt{q_1}+\sqrt{q_2}}$

Ans (D)

This problem is based on the equilibrium of a test charge under the influence of other charges.



q_0 will be in equilibrium if the force on q_0 due to q_1 equals the force on q_0 due to q_2

As q_1 is weaker, for the net force to be zero on q_0, q_0 should be nearer to q_1. Let its distance from q_1 is x.

Now, force on q_0 due to q_1 is $F_1 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_0}{x^2}$ and force on q_0 due to q_2 is $F_2 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_2q_0}{(r-x)^2}$

For $F_{net} = 0,\ F_1 = F_2$.

$$\therefore\ \frac{q_1}{x^2} = \frac{q_2}{(r-x)^2}$$

$$(r-x)\sqrt{q_1} = x\sqrt{q_2} \Rightarrow r\sqrt{q_1} - x\sqrt{q_1} = x\sqrt{q_2}$$

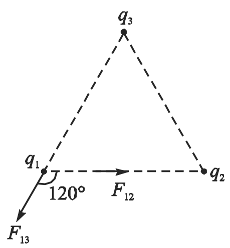
$$x(\sqrt{q_1}+\sqrt{q_2}) = r\sqrt{q_1} \Rightarrow x = \frac{r\sqrt{q_1}}{\sqrt{q_1}+\sqrt{q_2}}$$

Required distance $= r - x = r - \dfrac{r\sqrt{q_1}}{\sqrt{q_1}+\sqrt{q_2}} = r\left[\dfrac{\sqrt{q_2}}{\sqrt{q_1}+\sqrt{q_2}}\right]$

11. Three charges $q_1 = 1\ \mu C$, $q_2 = -2\ \mu C$, $q_3 = 2\ \mu C$ are placed at the vertices of an equilateral triangle of side 1 m. The magnitude of net electric force in newton on charge q_1 is

(A) 13.92×10^{-3} N (B) 18.0×10^{-3} N (C) 12.93×10^{-3} N (D) 11.23×10^{-3} N

Ans (B)



This problem is based on the principle of superposition of electric forces.

$$F_{13} = 9\times10^9\frac{(1\times10^{-6})(2\times10^{-6})}{1^2} = 18 \times 10^{-3}$$

$$F_{12} = 9\times10^4\frac{(1\times10^{-6})(2\times10^{-6})}{1^2} = 18 \times 10^{-3}$$

F_{net} on q_1 is $F = \sqrt{(18\times10^{-3})^2+(18\times10^{-3})^2+2(18\times10^{-3})(18\times10^{-3})\cos120^\circ}$

$= 18 \times 10^{-3}$ N

☞	The magnitude of two equal forces acting at 120° is equal in magnitude to either of the forces (i.e., F) The magnitude of two equal forces acting at 90° is $\sqrt{2}$ F. The magnitude of two equal forces acting at 60° is $\sqrt{3}$ F.

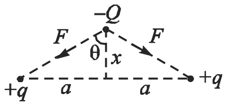
12. Two charges + q and + q are separated by a distance 2a. On the perpendicular bisector of the line joining them a charge – Q is released at a distance x from the midpoint of line joining them. Given x << a and $\left[k=\frac{1}{4\pi\varepsilon_0}\right]$ the time period of oscillation of charge – Q is

(A) $2\pi\sqrt{\frac{ma^3}{2kQq}}$ (B) $\pi\sqrt{\frac{ma^3}{2kQq}}$ (C) $2\pi\sqrt{\frac{kma^3}{2Qq}}$ (D) $\pi\sqrt{\frac{kma^3}{2Qq}}$

Ans (A)

This problem is based on the concept that a charge in stable equilibrium in between two charges can oscillate, when slightly displaced from its equilibrium position.

$$F_{net}=2F\cos\theta=2k\frac{qQ}{(x^2+a^2)}\frac{x}{(x^2+a^2)^{1/2}}$$



This is of restoring nature $\therefore$ $F_{net}=-\frac{2kQq}{(x^2+a^2)^{3/2}}x$

Given $x<<a$. $\therefore$ $F_{net}=-\left(\frac{2kQq}{a^3}\right)x$

Comparing this with $F=-m\omega^2x$, we have, $m\omega^2=\frac{2kQq}{a^3}\Rightarrow\omega=\sqrt{\frac{2kQq}{ma^3}}$

Time period is $T=\frac{2\pi}{\omega}=2\pi\sqrt{\frac{ma^3}{2kQq}}$

13. The position vectors of two point charges q_1 = (2 μC) and q_2 = (3 μC) are $(\hat{i}-2\hat{j}+k)m$ and $(2\hat{i}+3\hat{j}-k)m$ respectively. The force in newton on charge q_1 due to charge q_2 is

(A) $-\frac{1}{\sqrt{3}}\hat{i}-\frac{1}{\sqrt{2}}\hat{j}+0.1\,k$

(B) $-\sqrt{2}\,\hat{i}-\sqrt{2}\hat{j}+0.4\,k$

(C) $-0.1\hat{i}-0.5\,\hat{j}+0.2\,k$

(D) $-0.2\,\hat{i}-0.4\,\hat{j}+0.3\,k$

Ans (C)

This problem is based on the vector form of Coulomb's law.

$\vec{r}_1=\hat{i}-2\hat{j}+k,\quad q_1=2\mu C$

$\vec{r}_2=2\hat{i}+3\hat{j}-k,\quad q_2=3\mu C$

Force on charge q_1 is given by

$$\vec{F}_1=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2\hat{r}}{|\vec{r}_1-\vec{r}_2|^2} \qquad \ldots\text{(i)}$$

where $\hat{r}$ is a unit vector from q_1 to q_2

Given by $r=\frac{-i-5j+2k}{\sqrt{30}}$

$\vec{r}_1-\vec{r}_2=-\hat{i}-5\hat{j}+2k$

$|\vec{r}_1-\vec{r}_2|^2=(\sqrt{1^2+5^2+2^2})^2=(\sqrt{30})^2=30$

Using these in Equation (i)

$$\vec{F}_1=9\times10^9\frac{[2\times10^{-6}][3\times10^{-6}]}{30}\frac{(-\hat{i}-5\hat{j}+2k)}{\sqrt{30}}$$

$$=(-3.29\,\hat{i}-16.45\,\hat{j}+6.58\,\hat{k})\times 10^{-4}\ \text{N}$$

14. An isolated electron experiences a force of 8×10^{-14} N towards east in an electric field. Then, the electric field acting on the electron is

(A) 5×10^{5} NC^{-1} towards east
(B) 5×10^{5} NC^{-1} towards west
(C) 5×10^{5} NC^{-1} towards north
(D) 5×10^{5} NC^{-1} towards south

Ans (B)

This problem is based on the concept that a charge experiences a force in an electric field.

If a charge q experiences a force F in an electric field, the field is given by $E=\frac{F}{q}$.

Here, $F = 8 \times 10^{-14}$ N and q = electronic charge

$= 1.6 \times 10^{-19}$ C

$$\therefore\ E=\frac{F}{q}=\frac{8\times 10^{-14}}{1.6\times 10^{-19}}=5\times 10^{5}\ \text{NC}^{-1}$$

Since the charge of the electron is negative, the direction of the force is opposite to the direction of the field. Hence, the electric field must be of magnitude 5×10^{5} NC^{-1} and must act towards west.

15. A charge 7.5 μC is located in an electric field whose X-component is $E_X=6\times 10^{3}$ NC^{-1} and y-component is $E_Y=8\times 10^{3}$ NC^{-1}. The magnitude of the force on the charge is

(A) 7.5 N
(B) 7.5×10^{-3} N
(C) 7.5×10^{-4} N
(D) 7.5×10^{-2} N

Ans (D)

This problem is based on the concept that a charge q experiences a force $\vec{F}$ in an electric field $\vec{E}$, given by $\vec{F}=q\vec{E}$.

This vector equation can be written as three scalar equation equivalent,

$F_X=qE_X,\ F_Y=qF_Y,\ F_Z=qE_Z$

$F_x=qE_x=(7.5\times 10^{-6})(6\times 10^{3}) = 7.5 \times 6 \times 10^{-3}$ N

$F_y=qE_y=(7.5\times 10^{-6})(8\times 10^{3}) = 7.5 \times 8 \times 10^{-3}$ N

$$F=\sqrt{F_x^2+F_y^2}=(7.5)\times 10^{-3}\sqrt{6^2+8^2}$$

$= (7.5)\ (10) \times 10^{-3} = 7.5 \times 10^{-2}$ N

Aliter

Resultant electric field,

$$E=\sqrt{E_x^2+E_y^2}=10\times 10^{3}\ \text{NC}^{-1}$$

Resultant force on the charge,

$$F=qE=7.5\times 10^{-6}\times 10\times 10^{3}=7.5\times 10^{-2}\ \text{N}$$

16. A negatively charged oil drop is falling with a constant speed in a vertical electric field 2.5×10^{4} NC^{-1}. If the mass of the oil drop is 1.6×10^{-15} kg, the number of excess electrons it carries is [Assume g = 10 ms^{-2}]

(A) 2
(B) 20
(C) 4
(D) 40

Ans (C)

This problem is based on the concept that the motion of a charged particle q is determined by various forces like electric force, weight, the viscous force etc.

If the drop carries n excess electrons, the charge on the drop is q = ne. The electric force on the drop qE must be balanced by the weight of the drop, mg.

Hence, qE = mg $\Rightarrow$ (ne)E = mg

$$\Rightarrow n = \frac{mg}{eE} = \frac{1.6\times10^{-15}\times10}{1.6\times10^{-19}\times2.5\times10^{4}} = 4$$

17. A proton and an α-particle are subjected to the same electric field. The ratio of their acceleration is

(A) 1 : 2 (B) 2 : 1 (C) 1 : 4 (D) 4 : 1

Ans (B)

This problem is based on the concept that a particle of mass m and charge q experiences a force F = qE in an electric field E. Hence, it will have an acceleration $a = \frac{F}{m} = \frac{qE}{m}$.

The acceleration of the particle is given by

$a = \frac{F}{m} = \frac{qE}{m} \propto \frac{q}{m}$ for a given field.

$$\therefore \frac{a_p}{a_\alpha} = \left(\frac{q_p}{q_\alpha}\right)\left(\frac{m_\alpha}{m_p}\right) = \left(\frac{e}{2e}\right)\left(\frac{4m}{m}\right) = \frac{4}{2} = \frac{2}{1}$$

18. A particle of mass m and charge q is projected horizontally with a velocity v into an electric field E directed vertically downward. The trajectory of the particle is a

(A) straight line (B) circle (C) hyperbola (D) parabola

Ans (D)

This problem is based on the concept that the motion of a charged particle in an electric field can be analysed in a manner similar to the motion of a mass particle in a gravitational field.

In a time t the horizontal distance traveled,

$$x = vt \quad \ldots (1)$$

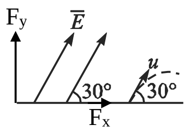
The vertical distance traveled,

$$y = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{qE}{m}\right)t^2 \quad \ldots (2)$$

Substituting for t from equation (1) into equation (2), we get $y = \frac{1}{2}\left(\frac{qE}{m}\right)t^2 = \frac{1}{2}\left(\frac{qE}{m}\right)\frac{x^2}{v^2} = \left(\frac{qE}{2mv^2}\right)x^2$

$y = kx^2$. Hence, the trajectory is a parabola.

19. In a region an electric field E = 15 NC^{-1} making an angle 30° with the horizontal plane is present. A ball having charge 2 C and mass 3 kg is projected with speed 20 ms^{-1} at an angle 30° with the horizontal. (Assume g = 10 ms^{-2}) The horizontal range of the projectile in metre is



(A) 40 (B) $20\sqrt{3}$ (C) $40\sqrt{3}$ (D) 80

Ans (D)

This problem is based on the motion of a charged particle in a region which combines both electric field and gravitational field. The electric force on the charge is, F = qE = (3 × 15) = 30 N

Vertical component of electric force = 30 sin 30° = 15 N,

and horizontal component of electric force = 30 cos 30° $= 15\sqrt{3}$ N

$$\therefore a_y = \frac{mg-15}{m} = \frac{30-15}{3} = 5\ ms^{-2} \text{ (downwards) and } a_x = \frac{30-15\sqrt{3}}{3} = 10-5\sqrt{3}\,N$$

$$u_x = 20\cos30° = 10\sqrt{3}\ ms^{-1};\quad u_y = 20\sin30° = 10\ ms^{-1}$$

Time of flight is $t_1 = \frac{2u_y}{a_y} = \frac{2(10)}{5} = 4s$

$\therefore$ Range $= u_x t_1 + \frac{1}{2}a_x t_1^2 = (10\sqrt{3})4 + \frac{1}{2}(10 - 5\sqrt{3})4^2$ = 80 m

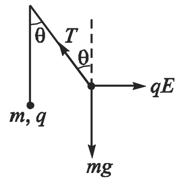
20. A bob of mass m and charge q is suspended from an insulating string of length l. The string deflects by an angle θ in a horizontal electric field E. Then

(A) $E = \frac{mg\cos\theta}{q}$ (B) $E = \frac{mg\sin\theta}{q}$ (C) $E = \frac{mg\tan\theta}{q}$ (D) $E = \frac{mg}{q}$

Ans (C)

This problem is based on the equilibrium of a charged body under the action of various forces, one among them being the electrostatic force.

Referring to the figure, the bob is in equilibrium under the action of the following three forces



(a) The electrical force qE acting along the direction of electric field.

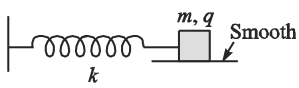
(b) The weight mg acting vertically downward.

(c) The tension T along the string.

Resolving the tension along horizontal and vertical directions, we find $T\cos\theta = mg$ and $T\sin\theta = qE$

$\therefore \frac{qE}{mg} = \frac{T\sin\theta}{T\cos\theta} = \tan\theta \;\therefore\; E = \frac{mg\tan\theta}{q}$

21. A block of mass m and charge q is attached to an unstretched spring of spring constant k. When a horizontal electric field E is switched on, the block performs simple harmonic motion, whose amplitude of oscillation is



(A) $\frac{qE}{k}$ (B) $\frac{2qE}{k}$ (C) $\frac{qE}{m}$ (D) $\frac{2qE}{m}$

Ans (A)

This problem is based on the oscillations of a charged mass and spring system in an external electric field.

In an electric field E, the block of charge q experiences a force qE. Due to this force, if the spring stretches by a distance x, the work done by the electric force is qEx. This is stored in the spring as potential energy, given by $\frac{1}{2}kx^2$

.

$\therefore \frac{1}{2}kx^2 = qEx \Rightarrow x = \frac{2qE}{k}$. Hence, the amplitude of oscillation, $A = \frac{x}{2} = \frac{qE}{k}$

Aliter

For SHM, $F = -kx;\ F_{max} = -kx_{max} \;\therefore\; F_{max} = kA \;\therefore A = \frac{F_{max}}{k} = \frac{qE}{k}$

22. The number of electrons that must be removed from a point object so that it will produce an electric field of 1600 NC^{-1} at a distance of 10 cm from it is

(A) 1.1×10^8 (B) 1.1×10^9 (C) 1.1×10^{10} (D) 1.1×10^{11}

Ans (C)

This problem is based on the concept of electric field produced by a point charge.

The electric field at a distance r from a point charge q is given by $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$. If the point object has n electrons removed from it, the charge on it is given by q = ne; where e = 1.6×10^{-19} C.

$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{ne}{r^2} \Rightarrow 1600 = 9\times10^9 \frac{n(1.6\times10^{-19})}{(10\times10^{-2})^2}$

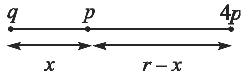
n = 1.1×10^{10}

23. Two point charges q and 4 q are held at a separation r. The resultant electric field is zero at a point P. The point P lies on the line joining q and 4 q.

(A) inside, at a distance (r/3) from charge q.
(B) outside, at a distance (r/3) from charge q.
(C) inside, at a distance (r/3) from charge 4 q.
(D) outside, at a distance (2r/3) from charge 4 q.

Ans (A)

This problem is based on the concept of null point in a region containing two or more electric fields.



Let P be a point on the line joining the two charges, at a distance x from the charge q. The electric field at P due to the two charges are in opposite directions. If the magnitude of the field due to the two charges at P are equal, then the resultant field will be zero at P. Then its distance from the charge 4 q is (r – x). The magnitude of the fields due to the charges q and 4 q will be equal at P if $\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}=\frac{1}{4\pi\varepsilon_0}\frac{4q}{(r-x)^2}$

$$\Rightarrow \frac{1}{x^2}=\frac{4}{(r-x)^2}\Rightarrow\frac{1}{x}=\frac{2}{r-x}$$

$$\therefore\ r-x=2x\Rightarrow x=\left(r/3\right).$$

The point P is called a neutral point P cannot lie outside the two charges since the force due to both q and 4q act in the same direction and hence, cannot neutral.

24. Three charges of equal magnitude q are placed at the vertices of an equilateral triangle of side r. The magnitude of the electric field at any one vertex is

(A) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{r^2}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{3}q}{r^2}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{3q}{r^2}$ (D) zero

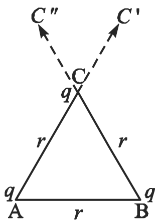
Ans (B)

This problem is based on the principle of superposition of electric fields.

From the principle of superposition, the electric field at a point due to several charges is the vector sum of the electric fields at the point due to individual charges.

Let E_A, E_B and E_C represent the magnitude of the electric field at C produced by charges at A, B and C

Then, $E_A=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ along CC′



$E_B=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ along CC″

$E_C=0$ (∵ A charge does not produce any field in its own location).

$E_A=E_B$ and the angle between $\vec{E}_A$ and $\vec{E}_B$ is 60°

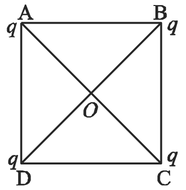
$$\therefore \text{ Net field at C, } E=\sqrt{E_A^2+E_B^2+2(E_A)(E_B)\cos\theta}=\sqrt{E_A^2+E_A^2+2E_A^2\cos60^\circ}$$

$$=\sqrt{3E_A^2}=\sqrt{3}E_A=\frac{\sqrt{3}}{4\pi\varepsilon_0}\frac{q}{r^2}$$

25. Four charges each of magnitude q are placed at the four corners of a square of side d. The electric field at the centre of the square is

(A) $\frac{1}{4\pi\varepsilon_0}\frac{4q}{d^2}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{8q}{d^2}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{16q}{d^2}$ (D) Zero

Ans (D)



This problem is based on the principle of superposition of electric fields.

The resultant field at O due to the charges at A and C is zero. The resultant field at a O due to the charges at B and D is also zero. Hence, the field at the centre of the square is zero.

26. The magnitude of the electric field at a point on the axis of a uniformly charged ring of radius R, carrying a total charge Q, at a distance d from its axis is given by

(A) $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}$ (B) $E = \frac{1}{4\pi\varepsilon_0}\frac{Qd}{R^2}$

(C) $E = \frac{1}{4\pi\varepsilon_0}\frac{Qd}{(R^2+d^2)^{3/2}}$ (D) $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

Ans (C)

This problem is based on the electric field produced due to a continuous distribution of charge.

The expression for the field must satisfy the following three conditions.

(a) As the field must be zero at the centre of the ring, $E \to 0$ as $d \to 0$.

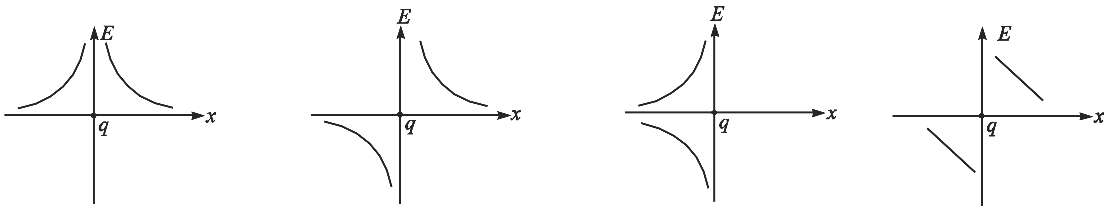
(b) As the field must be zero at infinite distance from the ring, $E \to 0$ as $d \to \infty$.

(c) At distances large when compared to the radius of the ring the field should vary as $1/d^2$ and the ring should look like a point charge i.e., as $R \to 0$;

$$E \to \frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}$$

All these qualifications are satisfied only by the choice (C).

27. Which of the following graphs best represents the variation of electric field E due to a point charge q?



(A) (B) (C) (D)

Ans (B)

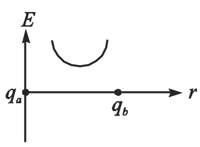
This problem is based on the graphical representation of electric field due to one or more electric charges.

The field due to a point charge should satisfy the following conditions

(a) As $x \to \infty$; $E \to 0$ and (b) $x \to 0$; $E \to \infty$

(c) E is +ve on one side and negative on another side of the charge. These conditions are satisfied only by the graph (B).

28. Two point charges q_a and q_b whose strengths are equal in magnitude are positioned at a certain distance from each other. Assuming the field strength is positive in the direction coinciding with the positive direction of x-axis, determine the signs of charges for the distribution of the field strength between the charges shown in figure.



(A) $q_a \to$ + ve, $q_b \to$ – ve (B) $q_a \to$ – ve, $q_b \to$ + ve

(C) $q_a \to$ + ve, $q_b \to$ + ve (D) $q_a \to$ – ve, $q_b \to$ – ve

Ans (A)

$q_a \bullet\xrightarrow{E\ +ve}$. This problem is related to the graphical representation of electric field due to a system of charge.

To the right of q_a field is + ve

So q_a is + ve.

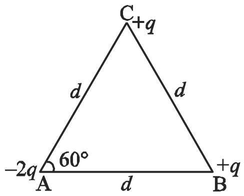
To the left of q_b field is + ve $\longrightarrow\bullet\ q_b$, so q_b is –ve

29. Three charges – 2q, + q, + q occupy the three corners of an equilateral triangle of side d. the dipole moment of the system of charges is

(A) 3 (qd) (B) $\sqrt{3}$ (qd) (C) 2 (qd) (D) $\sqrt{2}$ (qd)

Ans (B)

This question is based on the concept that the dipole moment of a dipole is a vector directed from negative charge to positive charge and has a magnitude equal to the product of charge and separation between them. p = q (2l)



The three charges may be regarded as constituting two dipole each of dipole moment qd but directed along AB and AC. Hence, the resultant dipole moment is given by

$$p=\sqrt{p_1^2+p_2^2+2p_1p_2\cos\theta}$$

$$=\sqrt{(qd)^2+(qd)^2+2(qd)(qd)\cos 60^\circ}$$

$$=\sqrt{3}\ (qd)$$

$\vec{p}$ makes an angle 30° with AB.

30. The electric field at a distance d from an electric dipole of dipole moment p along the axis is E. At a distance 2d from the dipole, the field is

(A) $\frac{E}{2}$ (B) $\frac{E}{4}$ (C) $\frac{E}{8}$ (D) $\frac{E}{16}$

Ans (C)

This question is based on the concept that the electric field at an axial distance d from an electric dipole of dipole moment p is given $\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{d^3}$. The field due to a dipole varies inversely as the cube of the distance.

$$E\propto\frac{1}{d^3}\quad\text{and}\quad E'\propto\frac{1}{(2d)^3}\quad\therefore\ E'=\frac{E}{8}$$

31. Suppose a dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$, with the vector $\vec{p}$ making an angle θ with $\vec{E}$. Let $\vec{\tau}$ be the torque and $\vec{F}$ be the net force experience by a dipole. Then

(A) $\tau=0\,;\ F\neq 0$ (B) $\tau\neq 0;\ F=0$ (C) $\tau\neq 0;\ F\neq 0$ (D) $\tau=0;\ F=0$

Ans (B)

This problem is based on the torque and the force experienced by a dipole in an electric field.

In a uniform field a dipole experiences a torque but not a net force.

32. A charge q is placed at the centre of the flat surface of a hemisphere of radius R. What is the flux through the curved surface of the hemisphere?

(A) $\frac{1}{2}\left(\frac{q}{\varepsilon_0}\right)$ (B) $\frac{q}{\varepsilon_0}$ (C) zero (D) $2\left(\frac{q}{\varepsilon_0}\right)$

Ans (A)

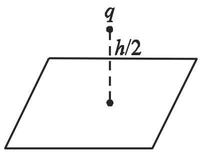
This problem is based on the concept of electric flux due to a point charge.

Flux coming out of a point charge is $\frac{q}{\varepsilon_0}$. Half of this flux passes through the curved surface of the hemisphere.

Hence, the flux through the curved surface of the hemisphere is $\frac{1}{2}\left(\frac{q}{\varepsilon_0}\right)$.

33. A charge q is placed at a height $\frac{h}{2}$ above the centre of a square of side a. The flux through the square is

(A) $\frac{q}{\varepsilon_0}$ (B) $\frac{q}{4\varepsilon_0}$



(C) $\frac{q}{6\varepsilon_0}$ (D) zero

Ans (C)

This problem is based on the concept of electric flux due to a point charge.

The charge can be regarded as being at the centre of a cube whose one face is the given square. The flux through all the six faces of the cube $\frac{q}{\varepsilon_0}$. Hence, the flux through one face is $\frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$.

34. A dielectric sphere of radius R is uniformly charged with a volume charge density ρ. At a distance r from the centre of the sphere, the electric field E varies as

(A) $\frac{1}{r}$ for $r < R$ and $\frac{1}{r^2}$ for $r \geq R$

(B) r for $r < R$ and $\frac{1}{r^2}$ for $r \geq R$

(C) $\frac{1}{r}$ for $r < R$ and $r > R$

(D) $\frac{1}{r^2}$ for $r < R$ and $r \geq R$

Ans (B)

This problem is based on the application of Gauss' law to determine the electric field due to a charged sphere.

For a dielectric sphere with a uniform volume density of charge, the electric field for $r < R$ is given by $E = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}$

and for $r \geq R$, is given by $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

35. A charged metallic conductor of arbitrary shape is positively charged. The conductor contains a cavity of arbitrary shape. Then

(A) negative charges are induced on the surface of the cavity.

(B) electric field exists inside the cavity.

(C) the electric field in the cavity is zero.

(D) the electric field in the cavity depends on its position in the conductor.

Ans (C)

This problem is based on the concept that the electric field inside a charged metallic conductor is zero. Even if there is a cavity, the electric field in the cavity is zero.

36. The number of electrons in one coulomb of charge is

Solution

$$Q = ne \Rightarrow n = \frac{Q}{e} = \frac{1}{1.6\times10^{-19}} = 6.25\times10^{18}$$

37. Charges +1 μC, +2.4 μC, – 8μC, –4 μC, + 6.2 μC are distributed over a body. The net charge on the body is

Solution

$Q = \Sigma q = 10^{-6}\,[1 + 2.4 + 6.2 - 12] = -2.4\ \mu C$

38. Two charges 8 μC and –2 μC are distributed over two identical spheres. These spheres are put in contact and then separated. The final charges on the spheres will be

Solution

Since spheres are identical, they share equal amount of charges.

$$q'_1 = q'_2 = \frac{q_1 + q_2}{2} = \frac{(8-2)}{2}\times10^{-6} = 3\ \mu C\ \text{ each}$$

39. In the above problem, what will be the final charge on the spheres if radii of spheres are 3 cm and 6 cm?

Solution

$$q'_1 = \frac{(q_1+q_2)}{r_1+r_2} r_1 = \frac{6\times10^{-6}}{9}\times3 = 2\ \mu C$$

$$q'_2 = \left(\frac{q_1+q_2}{r_1+r_2}\right) r_2 = \frac{6\times10^{-6}}{9}\times6 = 4\ \mu C$$

40. A sphere of radius 2R carrying a charge Q is put in contact with another uncharged sphere of radius R. The charge transferred by the first sphere is

Solution

$q'_1 = \left(\frac{q_1+q_2}{r_1+r_2}\right) r_1 \Rightarrow q'_1 = \frac{Q+O}{3R}\cdot 2R = \frac{2Q}{3}$ charge transferred by the first sphere is $Q - \frac{2Q}{3} = \frac{Q}{3}$

41. What is the charge of an α particle?

Solution

$Q = 2e = 2 \times 1.6 \times 10^{-19}\,C = 3.2 \times 10^{-19}\,C$

42. What type of force exists between two charges q_1 and q_2 if $q_1q_2 > 0$ and $q_1q_2 < 0$.

Solution

If $q_1q_2 > 0$, repulsive force exists

If $q_1q_2 < 0$, attractive force exists

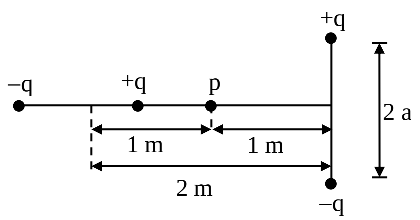
43. A body has a charge of -14.4×10^{-19} C. It has

Solution

$$n = \frac{Q}{e} = \frac{-14.4\times10^{-19}}{-1.6\times10^{-9}} = 9.$$

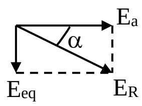
It has 9 electrons excess.

44. Two identical short electric dipoles each of dipole moment P are arranged as shown in figure. The net electric field at point 'P' is



Solution

At P, the directions of electric fields are as shown



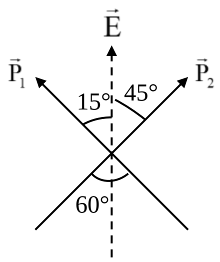
$$E_R = \sqrt{E_a^2 + E_{eq}^2} = \sqrt{4E_{eq}^2 + E_{eq}^2} = \sqrt{5}E_{eq}$$

$$E_R = \sqrt{5}\cdot\frac{1}{4\pi\varepsilon_0}\times\frac{p}{r^3}\ ; \qquad E_R = \sqrt{5}\times9\times10^9\,NC^{-1}$$

$$\tan\alpha = \frac{E_{eq}}{E_a} = \frac{1}{2} \Rightarrow \alpha = \tan^{-1}\left[\frac{1}{2}\right]$$

45. Two dipoles of moments P_1 and P_2 are inclined by 60°. This combination is pivoted in an electric field of intensity E such that dipole of moment P_1 makes an angle of 15° with this field. If magnitude of P_2 is 22×10^{-30} coulomb metre then find P_1

Solution



$P_1E \sin 15° = P_2 E \sin 45°$

$$\frac{P_1\left(\sqrt{3}-1\right)}{2\sqrt{2}} = \frac{P_2}{\sqrt{2}}$$

$$\Rightarrow P_1 = \frac{2P_2}{\sqrt{3}-1} = \frac{2\times P_2}{0.732} = \frac{2\times 22\times 10^{-30}}{0.732} = 60\times 10^{-30}\ \text{Cm}$$

46. A short electric dipole consists of two charges ± 10 μC separated by 5 mm. Calculate electric field at 10 cm from centre of dipole on its axial line, equatorial line and at an angle 60° with axis of dipole

Solution

$$E_a = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3} = \frac{9\times 10^9\times 2\times 10\times 10^{-6}\times 5\times 10^{-3}}{10^{-3}} = 9\times 10^5\,\text{NC}^{-1}$$

$$E_{eq} = \frac{E_a}{2} = 4.5\times 10^5\ \text{NC}^{-1}$$

$$E_\theta = E_{eq}\left[\sqrt{1+3\cos^2\theta}\right] = E_{eq}\frac{\sqrt{7}}{2} = \sqrt{7}\times 2.25\times 10^5\ \text{NC}^{-1}$$

47. Two charges ± 150 μC are separated by 10 cm. Calculate E at 15 cm from each charge.

Solution

Given a = 5 cm $\sqrt{r^2+a^2} = 15$ cm

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{P}{[r^2+a^2]^{3/2}} = \frac{9\times 10^9\times 150\times 10^{-6}\times 10^{-1}}{(15\times 10^{-2})^3}$$

$$E = \frac{9\times 10^3\times 15}{15\times 225\times 10^{-6}} = \frac{900}{225}\times 10^7 = 4\times 10^7\ \text{NC}^{-1}$$

Assertion and Reasoning

Each of the following questions consists of a Statement-I and a Statement-II. Examine both of them and select one of the options using the following codes:

(A) Statement-I and Statement-II are true and Statement-II is the correct explanation of Statement-I.

(B) Statement-I and Statement-II are true, but Statement-II is not the correct explanation of Statement -I

(C) Statement-I is true, but Statement -II is false

(D) Statement-I is false, but Statement -II is true

48. **Statement I**: The principle of superposition holds good for electric fields.

Statement II: Electric field is a vector.

Ans (B)

Principle of superposition does not just say that the electric fields can be vectorially added. It says that the electric field due to one charge is unaffected by the presence of another charge.

49. **Statement I:** Two point charges q_1 and q_2 separated by a distance r repel with a force F. The force would remain the same if q_1 and q_2 are distributed over two spheres, but with the separation of centres of two spheres remaining r.

Statement II: For all points external to it, a charged sphere behaves as though its charge is concentrated at its centre.

Ans (D)

50. **Statement I:** The net electric flux through an arbitrary closed surface depends on the charges enclosed by the surface and not on the charges outside the surface.

Statement II: The electric field at any point on the arbitrary closed surface depends only on the charges enclosed by the surface and not on the charges outside the closed surface.

Ans (C)

51. **Statement I:** Electric charge of an isolated system is always conserved.

Statement II: Electric charge is a scalar quantity.

Ans (B)

All scalar quantities are not conserved quantities. For example kinetic energy is a scalar but not conserved in inelastic collisions.

52. **Statement I:** The electric field at different points of a Gaussian surface is non-zero.

Statement II: The net charge enclosed by the Gaussian surface may be zero.

Ans (B)

53. **Statement I:** The electric field in a region of space is in the same direction but decreases in strength in the same direction.

Statement II: Electric field lines are closer where the field is stronger.

Ans (D)

54. **Statement I:** According to Gauss' law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$.

Statement II: The electric field $\vec{E}$ can only be attributed to the charge q.

Ans (C)

The electric field is not necessarily due to the charges enclosed by the Gaussian surface.

55. **Statement I:** Coulomb's law can be derived from Gauss' law.

Statement II: Gauss's law can be derived from Coulomb's law.

Ans (C)

Gauss' law is more general than Coulomb's law. Hence, Gauss' law cannot be derived from Coulomb's law. But Coulomb's law can be derived from Gauss' law.

56. **Statement I:** When a free neutron decays into a proton and an electron, a third particle called neutrino is also emitted which has no mass and no charge.

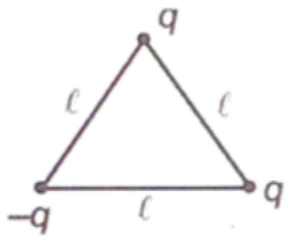
Statement II: In any nuclear interaction charge must be conserved.

Ans (A)

Since charge is already conserved when a neutron decays into a proton and an electron, the third particle neutrino must be chargeless.

NCERT LINE BY LINE QUESTIONS

1. The electrostatic force between two small charged spheres having charges of 2 x 10^{-6} C and 3 x 10^{-6} C placed 30 cm apart in air is [NCERT Pg. 46]
(a) 0,9 N (b) 0.6 N (c) 1.2 N (d) 1.8 N
2. 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 of side 20 cm (In cyclic order). What is electric force on a charge of $1\mu C$ placed at the centre of square? [NCERT Pg. 46]
(a)0.9N (b) Zero (c) 0.6 N (d) 2.4 N
3. A system of two charges $q_A = 2.5\times10^{-7}C$ and $q_B = -2.5\times10^{-7}C$ are located at points A: (0. 0,-15 cm) and B: (0. 0, 15 cm) respectively. The electric dipole moment of system is [NCERT Pg. 46]
(a) $2.5\times10^{-7}C\,m$ (b) $5\times10^{-7}C\,m$
(c) $7.5\times10^{-8}C\,m$ (d) Zero
4. A polythene piece rubbed with wool is found to have negative charge of $3.2\times10^{-6}C$. The number of excess electrons on polythene is [NCERT Pg. 46]
(a) 2×10^{13} (b) 4×10^{12} (c) 5.5×10^{9} (d) 6×10^{20}
5. An electron falls through distance of m in uniform electric field from state of rest. The time of fall if $E = 6\times10^4\ NC^{-1}$ is [NCERT Pg. 21]
(a) $1.5\times10^{-6}s$ (b) $1.94\times10^{-9}s$
(c) $3.3\times10^{-5}s$ (d) $2.3\times10^{-6}s$
6. Consider charges q,-*q* and *q* placed at vertices of an equilateral triangle as shown in figure. Calculate force on -*q* charge due toother [NCERT Pg, **17]**



1) $\dfrac{q^2}{2\pi\varepsilon_0\ell^2}$ 2) $\dfrac{q^2}{4\pi\varepsilon_0\ell^2}$ 3) $\dfrac{\sqrt{2}q^2}{\pi\varepsilon_0\ell^2}$ 4) $\dfrac{\sqrt{3}q^2}{4\pi\varepsilon_0\ell^2}$
7. Which among the given statements is incorrect statement? [NCERT Pg. 19]
(a) For every positive point charge, electric field lines will be directed radially outwards from charge.
(b) Magnitude of electric field *E* will depend on distance form point charge
(c) The electric field due to a point charge has spherical symmetry
(d) A test charge *q* experiences electric force $\vec{F}$ at a point then electric field intensity is defined as $\vec{E} = \dfrac{\vec{F}}{q^2}$
8. A proton and an electron are released form rest in uniform electric field then the correct Statement among the following is [NCERT Pg. 46]
(a) Time required to fall through certain distance is more for an electron
(b) The force experiences by proton will be more

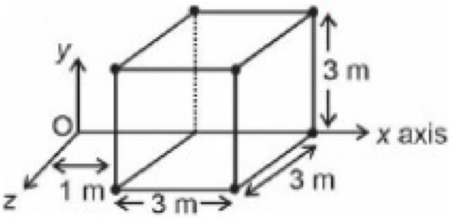
(c) Magnitude of acceleration experienced by proton is more
(d) KE gained by both charges in moving through same distance are equal

9. Regarding electric lines of force, the correct statement is/are [NCERT Pg. 24]
(a) Field lines carry information about direction of electric field
(b) Relative density of field lines at different points indicates relative strength of electric field at these points
(c) The field lines crowd where field is weak and spaced apart where field in strong
(d) Beth (a) and (b) are correct

10. The incorrect statement among the following statements is [NCERT Pg. 25]
(a) Electric field lines can never cross each other
(b) Electrostatic field lines do not form any closed loop
(c) In charge free region, electric field lines can be taken to be continuous curve
(d) Field lines around a system of two positive charges is straight and parallel lines pictorially

11. A dipole consist of two charges *q* and -*q* separated by a distance 2a. The electric field of this dipole at distance r from centre of dipole at a point *A* on axis is [NCERT Pg.28]
1) $\frac{2p}{4\pi\varepsilon_0 r^2}$ 2) $\frac{2p}{4\pi\varepsilon_0 (r^2+a^2)^{\frac{3}{2}}}$ 3) $\frac{p}{4\pi\varepsilon_0 r^3}$ 4) $\frac{2pr}{4\pi\varepsilon_0 (r^2-a^2)^2}$

12. Electric field components are $E_x = 100x^{\frac{1}{2}}, E_y = E_z = 0$. Calculate net electric flux though the cube placed in electric field at shown position. [NCERT Pg. 35]



(a) 900Nm²C⁻¹ (b) 1800Nm²C⁻¹ (c) 600 Nm²C⁻¹ (d) 3600 Nm²C⁻¹

13. An infinite long straight wire has linear charge density $\lambda = 4\times10^5 Cm^{-1}$. The electric force experienced by a proton at perpendicular distance of 10 mm from axis of wire is [NCERT Pg. 37J
(a) 1.25×10^{-4} N (b) 1.68×10^{-3}N
(c) 2.8×10^{-6} N (d) 1.15×10^{-1} N

14. Coulomb's law of electrostatic for the force between two point charges most closely resembles [NCERT Pg. 12]
(a) Law of conservation of charges
(b) Law of conservation of energy
(c) Newton's second law of motion
(d) Newton's law of gravitation

15. A point charge *q* of mass *m* is placed in front of a uniformly charged infinite sheet and released. The surface charge density of sheet is C m⁻². The kinetic energy of charge after *t* second is [NCERT Pg. 39]
1) $\frac{q^2\sigma^2t^2}{4\varepsilon_0^2 m}$ 2) $\frac{q^2\sigma^2t^2}{\varepsilon_0^2 m}$ 3) $\frac{q^2\sigma^2t^2}{8\varepsilon_0^2 m}$ 4) $\frac{q^2\sigma^2t^2}{4\varepsilon_0^2 m}$

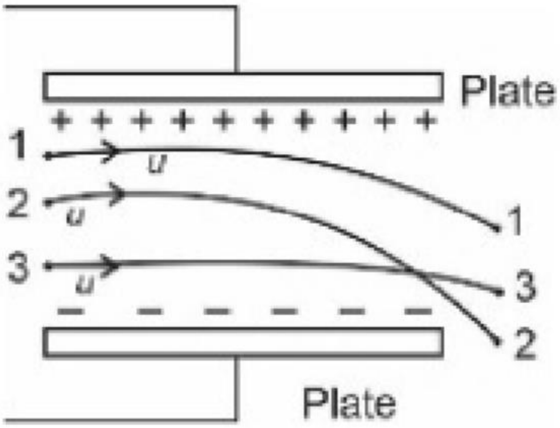
16. An electric dipole consists of two equal and opposite charges 002 μC separated by 2 mm. The dipole is placed is uniform electric field of 10^7 N C⁻¹. Maximum torque exerted by field on dipole is [NCERT Pg. 31]
(a) 2×10^{-4} Nm (b) 4×10^{-4} Nm

(c) 8×10^{-4} Nm (d) 2×10^{-6} Nm

17. A thin spherical shell is given a charge $q = 4\ \mu C$, uniformly distributed over its surface. Consider a point P outside the shell at distance of 2 m from surface. If the radius of shell is 1 m, what is electric field at point P? [NCERT Pg. 39]

(a) $4kNC^{-1}$ (b) $2kNC^{-1}$ (c) $9\ kN\ C^{-1}$ (d) $36\ kN\ C^{-1}$

18. Figure shows track of three positive charged particles through uniform electric field E. All charges are equal in value. Which charge particle has more initial kinetic energy on entering horizontally between the plate? [NCERT Pg. 47]



(a) Particle 1 (b) Particle 2

(c) Particle 3 (d) Both 1 and 2 have equal initial KE

19. A uniformly charged conducting sphere of 3 m diameter has a Surface charge density of 90 μ C/m². What is total electric flux leaving the surface of sphere? [NCERT Pg.48]

(a) $1.76\times10^{8}\ N\ m^{2}C^{-1}$ (b) $2.87\times10^{8}\ N\ m^{2}C^{-1}$

(c) $5.2\times10^{8}\ N\ m^{2}C^{-1}$ (d) $4.52\times10^{6}\ N\ m^{2}C^{-1}$

20. Incorrect statement among the following is (NCERT Pg.48)

(a) Gauss's law is useful in calculating electric field when system has some symmetry

(b) Gaussian surface can pass through a continuous charge distribution

(c) Gauss's law is based on inverse square dependence of electric field on distance

(d) In situation when surface is so chosen that some charges are outside and some inside, electric field (whose flux appears on left side of Gauss's equation) is only due to the charges inside the closed surface

NCERT BASED PRACTICE QUESTIONS

21. The electric intensity at any point between two oppositely charged plain sheets is

(a) s/3Îo (b) s/Îo

(c) s/2Îo, (d) 2s/Îo

22. The electric potential is zero

(a) Inside a conductor

(b) Midway between any two charges of the opposite signs

(c) Midway between two equal charges of the sme sign)

(d) none

23. The magnitude of an electric field does not depend upon

(a) The distance from the charged particle

(b) nature of the charges causing the field,

(c) the magnitude of the charges causing the field

(d) none

24. A free electron in an electric field
    (a) remains stationary,
    (b) moves from the higher potential to the lower potential,
    (c) moves from the lower potential to the higher potential
    (d) none
25. Electric intensity of a given charge at any point is distance from charge.
    (a) Directly proportional to,
    (b) Inversely proportional to square of,
    (c) Directly proportional to square of,
    (d) Inversely proportional to square of
26. A slab of certain dielectric is placed between two oppositely charge plates. The intensity between plates
    (a) Decreases, (b) Increases,
    (c) Remains constant (d) none
27. Matter is composed of three fundamental particles. They are
    (a) Electrons, Protons, Neutrons
    (b) Electrons, Cathode rays, masons
    (c) Electrons, neutrons, masons
    (d) none
28. is a negatively charged particle and is found around the nucleus of an atom.
    (a) Electron, (b) Proton,
    (c) Neutron, (d) None of these
29. When one or more than one electrons are removed from an atom it becomes .
    (a) Neutral particle, (b) Negatively charged particle,
    (c) positively charged particle, (d) none of these

30. If the quantity of charge on each of the two bodies is doubled, the force between them becomes
    (a) Twice, (b) Four times,
    (c) Nine times, (d) Sixteen times
31. A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to...
    (a) -(Q/2) (b) -(Q/4)
    (c) +(Q/4) (d) +(Q/2)
32. The total electric flux is...
    (a) always positive (b) always negative
    (c) always zero (d) none of the above
33. Electric charge is quantized. This means that the electric charge...
    (a) is not continuous (b) is continuous
    (c) is constant (d) has mass
34. Two equal negative charges(-q) are fixed at two points (0,a) and (0,-a) on the Y-axis. A positive charge q is released from rest at the point (2a,0) on the X-axis. The charge q will...
    (a) execute SHM about the origin

(b) move to the origin and remain at rest

(c) move to infinity

(d) execute oscillatory motion but not SHM.

35. Electric field at x =10 cm is 100i V/m and at x = -10 cm is -100 iV/m. The magnitude of charge enclosed by the cube of side 20 m is

(a) 8 c (c) 2 c (b) 3 c (d) 5 c

36. A thin metal plate p is inserted between the plates of a parallel plate capacitor of capacitance C in such a way that its edge touch the two plates forming Z shape . The capacitance now becomes:

(a) C/2 (b) 2C (c) zero (d) infinite

37. Three point charges are located on the x-axis. The first charge, q_1 = 10 μC, is at x = -1.0 m. The second charge, q_2 = 20 μC, is at the origin. The third charge, q_3 = - 30 μC, is located at x = 2.0 m. What is the force on q_2?

(a)1.65 N in the negative x- direction (b)3.15 N in the positive x- direction

(c)1.50 N in the negative x- direction (d)4.80 N in the positive x- direction

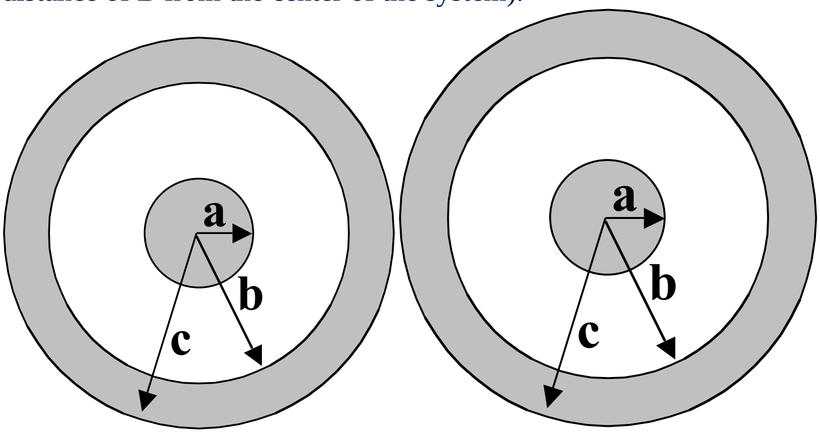
38. The electric field has a magnitude of 3.0 N/m at a distance of 60 cm from a point charge. What is the charge?

(a)1.4 nC (b)120 Pc (c)36 mC (d)12 μC

39. An electron traveling horizontally from North to South enters a region where a uniform electric field is directed downward. What is the direction of the electric force exerted on the electron once it has entered the field?

(a)downward (b)upward (c)to the east (d)to the west

40. A solid conducting sphere or radius A carries an excess charge of +6 μC. This sphere is located at the center of a hollow conducting sphere with an inner radius of B and an outer radius of C as shown. The hollow sphere also carries a total excess charge of +6 μC. Determine the excess charge on the inner surface of the outer sphere (a distance of B from the center of the system).



(a) zero (b) - 6 μC (c) + 6 μC (d) + 12 μC

41. A 1.65 nC charge with a mass of 1.5×10^{-15} kg experiences an acceleration of 6.33×10^{7} m/s^2 in an electric field. What is the magnitude of the electric field?

(a) 57.6 N/C (b) 1.65×10^{-9} N/C (c) 14.9 N/C (d) 2.67×10^{-19} N/C

42. An electric dipole is surrounded by a closed surface with the surface nearer to the negative end of the dipole than the positive end. The flux through the surface is.

(a) positive. (b) negative.

(c) proportional to the negative charge. (d) inversely proportional to the positive charge.

43. What is the potential at a distance of 0.0529 nm from a proton?

(a) 13.6 nV (b) -13.6 nV (c) 27.2 V (d) -27.2 nV

44. A parallel plate capacitor with an air dielectric is attached to a voltage source and charged. The voltage source is removed, and then the plates are separated to double their previous distance. What happens to the energy stored by the capacitor when the plates are separated?

(a) it doubles (b) it quadruples

(c) it halves (d) it is diminished by a factor of 4

45. An electron is accelerated from rest through a potential difference *V*. If the electron reaches a speed of 9.11 x 10^6 m/s, what is the potential difference?

(a) 236 V (b) 83.7 V (c) 24.9 V (d) 0.626 V

46. A parallel plate capacitor with plates of area A and plate separation d is charged so that the potential difference between the plates is V. If the capacitor is then isolated and its plate separation is decreased to d/2, what happens to its capacitance?

(a) The capacitance is twice its original value. (b) The capacitance is four times its original value.

(c) The capacitance is eight times its original value.

(d) The capacitance is one half of its original value.

47. A parallel plate capacitor has plates each of area 0.01 m^2 and with separation 0.25 mm. What is its capacitance?

(a) 40 nF (b) 0.35 nF (c) 4.4 μF (d) 88 pF

48. A parallel plate capacitor is attached to a voltage source providing 12 V. When an insulator of dielectric constant 6.0 is then used to fill the air space between the capacitor plates, what happens to the surface charge density on the plates if the voltage source is still attached?

(a) It increases by a factor of 6.0 (b) It increases by a factor of 2.0

(c) It decreases by a factor of 6.0 (d) It decreases by a factor of 2.0

49. If there is a force of 5.0 x 10-12 N acting to the left on an electron, the electric field intensity at the location of this electron will be:

(a) zero. (b) 8.0 x 10^{-31} N/C to the left

(c) 3.1 x 10^7 N/C to the left (d) 3.1 x 10^7 N/C to the right

50. In one mole or 18 grams of water, the total negative charge of all the electrons is:

(a) zero because its electrically neutral. (b) less than one C

(c) almost 100,000 C. (d) almost one million C.

51. Consider three identical metal spheres that are mounted on insulating stands. Sphere X is neutral, sphere Y has a charge -1q, and sphere Z has a charge +4q. Y and Z are touched together and then separated.

(a) Each is now charged, with a charge +1.5 q

(b) Each is now charged, with a charge +2.5 q

(c) Each is now charged, with a charge +3 q

(d) Sphere Y has charge +4 q, sphere Z now has charge -1 q

52. Consider a small, conducting sphere of 0.0010 kg mass. Extra electrons are added to this sphere and an identical sphere below it so that the excess charge on the top sphere is three times that on the lower one. How much extra charge would have to be placed upon the top sphere so that the electrical repulsion between the extra charge on these spheres would provide a force equal to the weight of the sphere when the spheres are 4.0 m apart?

(a) 5.8 x 10-12C (b) 2.4 x 10-6 C

(c) 3.6 x 10-6 C (d) 7.2 x 10-6 C

53. Consider a small, conducting sphere of 0.0010 kg mass. Extra electrons are placed on this sphere and on an identical sphere 3.0 m below it so the repulsion between these extra electrons provides a force equal to the weight of the top sphere. How many electrons must be added to each sphere?

(a) 5.0×10^{-25} (b) 3.1×10^{-6} (c) 2.0 x 1013 (d) 3.9×10^{13}

54. Electrical charge interaction can be summarized by:

(a) - charge repels other - charge. (b) + charge repels other + charge.

(c) - charge and + charge attract each other. (d) All of these.

55. Consider two point charges that are separated by a distance, 2r. If this distance between them is increased to 5 r, the force between the charges is:

(a) 1/25 as great as it had been (b) 4/25 as great as it had been

(c) 1/9 as great as it had been (d) 25 times as great as it had been

56. The electric field is zero:

(a) inside any conductor.

(b) inside any conductor with a static charge.

(c) inside any material, conductor or insulator, with a static charge.

(d) Never.

57. If the symbols] and [are used to represent a pair of charged plates, in the sketch below, +] [- the field between the two plates would be directed:

(a) upward. (b) to the left.

(c) to the right. (d) zero, so its direction would be without meaning.

58. Consider three identical metal spheres that are mounted on insulating stands. Sphere X is neutral, sphere Y has a charge -1q, and sphere Z has a charge +4q. X and Y are touched together and then separated.

(a) Each is now charged, with a charge -0.5 q.

(b) Each is now charged, with a charge -1 q

(c) Sphere X is neutral, sphere Y has a charge -1q

(d) Sphere X has charge -1 q, sphere Y is now neutral

59. A capacitor and resistor are connected in a series with a batter and a switch. The instant after the switch is closed

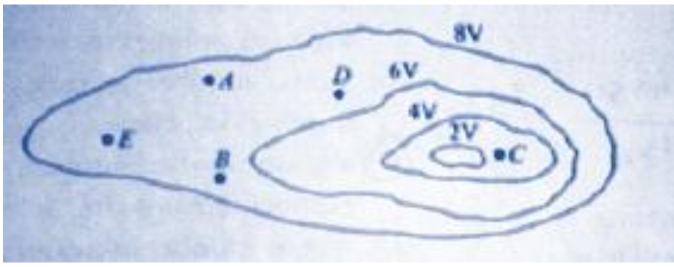
(a) the voltage across the resistor is equal to the emf of the battery

(b) the voltage across the capacitor is equal to the emf of the battery

(c) the voltage across the resistor is equal to zero

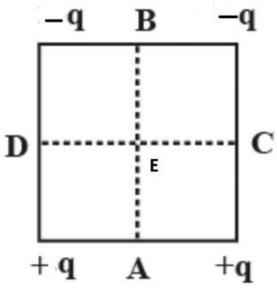
(d) the current is equal to zero

60. The figure below shows a set of equipotential lines. The electric field has the greatest magnitude at point



(a) A (b) B (c) C (d) D

61. Four charges are arranged on the corners of a square as shown below:



At which point (or points) is the electric field equal to zero?

(a) B and E (b) D and A

(c) A and C (d) A and B

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Electric Charges and Coulomb's Law

1. If a body is charged by rubbing, its weight

(a) remains precisely constant (b) increases slightly

(c) decreases slightly (d) may increase slightly or may decrease slightly

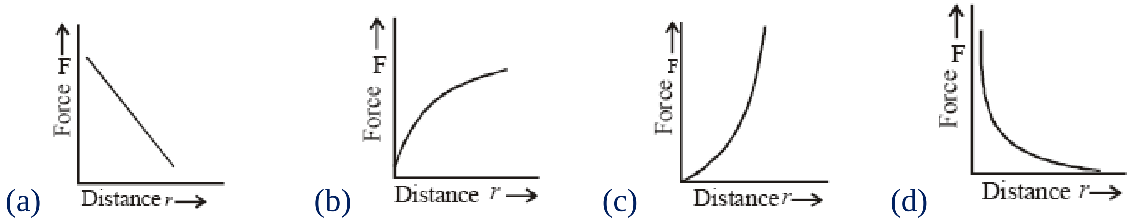
2. 1 μC contains how much units of basic charge e ?

(a) 6×10^{12} (b) 8×10^{14} (c) 7×10^{15} (d) 11×10^{11}

3. If $q_1 + q_2 = q$, then the value of the ratio q_1/q, for which the force between q_1 and q_2 is maximum is

(a) 0.25 (b) 0.75 (c) 1 (d) 0.5

4. Which of the following graphs shows the correct variation of force when the distance r between two charges varies?



5. Four charges 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) $-\frac{Q}{2}\left(1+2\sqrt{2}\right)$ (b) $\frac{Q}{4}\left(1+2\sqrt{2}\right)$ (c) $-\frac{Q}{4}\left(1+2\sqrt{2}\right)$ (d) $\frac{Q}{2}\left(1+2\sqrt{2}\right)$

6. Two small spheres each having the charge +*Q* are suspended by insulating threads of length *L* from a hook. This arrangement is taken in space where there is no gravitational effect, then the angle between the two suspensions and the tension in each will be

(a) $180^0, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(2L)^2}$ (b) $90^0, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$ (c) $180^0, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{2L^2}$ (d) $180^0, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$

7. A positively charged rod is brought near an uncharged conductor. If the rod is then suddenly withdrawn, the charge left on the conductor will be

(a) positive (b) negative (c) zero (d) cannot say

8. Quantisation of charge implies

(a) charge cannot be destroyed (b) charge exists on particles
(c) there is a minimum permissible charge on a particle
(d) charge, which is a fraction of a coulomb is not possible.

9. Two identical metal spheres A and B are supported on insulating stands and placed in contact. What kind of charges will A and B develop when a negatively charged ebonite rod is brought near A?

(a) A will have a positive charge and B will have a negative charge
(b) A will have a negative charge and B will have a positive charge
(c) Both A and B will have positive charges (d) Both A and B will have negative charges

10. The force between two charges 0.06 m apart is 5 N. If each charge is moved towards the other by 0.01 m, then the force between them will become

(a) 7.20 N (b) 11.25 N (c) 22.50 N (d) 45.00 N

11. Two equal point charges each of 3 μC are separated by a certain distance in metres. If they are located at $(\hat{i}+\hat{j}+\hat{k})$ and $(2\hat{i}+3\hat{j}-\hat{k})$, then the electrostatic force between them is

(a) 9×10^3 N (b) 16×10^{-3} N (c) 10^{-3} N (d) 9×10^{-2} N

12. A total charge Q is broken in two parts Q_1 and Q_2 and they are placed at a distance R from each other. The maximum force of repulsion between them will occur. when

(a) $Q_2 = \frac{Q}{R}, Q_1 = Q - \frac{Q}{R}$ (b) $Q_2 = \frac{Q}{4}, Q_1 = Q - \frac{2Q}{3}$
(c) $Q_2 = \frac{Q}{4}, Q_1 = \frac{3Q}{4}$ (d) $Q_1 = \frac{Q}{2}, Q_2 = \frac{Q}{2}$

13. Two particles *A* and *B* having equal charges are placed at a distance *d* apart. A third charged particle placed on the perpendicular bisection of *AB* at distance *x*. The third particle experiences maximum force when

(a) $x = \frac{d}{\sqrt{2}}$ (b) $x = \frac{d}{2}$ (c) $x = \frac{d}{2\sqrt{2}}$ (d) $x = \frac{d}{3\sqrt{2}}$

14. Two charges are at a distance d apart. If a copper plate of thickness d/2 is kept between them, the effective force will be

(a) F/2 (b) zero (c) 2F (d) 2 F

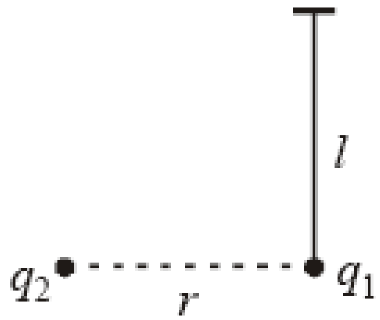
15. The ratio of electric force between two electrons to two protons separated by the same distance in air is

(a) 10^0 (b) 10^6 (c) 10^4 (d) None of these

16. A thin insulating rod is placed between two unlike point charges $+q_1$ and $-q_2$ (figure). How will the forces acting on the charges change?

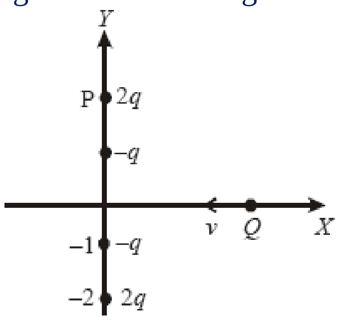
(a) The total force acting on the charge $+q_1$ will increase
(b) The total force acting on the charge $+q_1$ will decrease
(c) The total force acting on the charge $+q_1$ remain unchanged
(d) None of these

17. An isolated charge $q_1$of mass m is suspended freely by a thread of length *l*. Another charge q_2 is brought near it (r >> *l*). When q_1 is in equilibrium, tension in thread will be



(a) *mg* (b) > *mg* (c) < *mg* (d) None of these

18. Four charges are rigidly fixed along the Y-axis as shown. A positive charge approaches the system along the X-axis with initial speed just enough to cross the origin. Then its total energy at the origin is



(a) zero (b) positive (c) negative (d) data insufficient

19. What happens when some charge is placed on a soap bubble?
(a) Its radius decreases (b) Its radius increases
(c) The bubble collapses (d) None of these

20. Force between two identical charges placed at a distance of r in vacuum is F. Now a slab of dielectric of dielectric contract 4 is inserted between these two charges. If the thickness of the slab is r/2, then the force between the charges will become

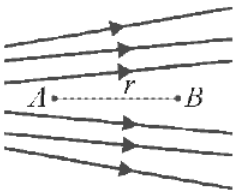
(a) F (b) $\frac{3}{5}$F (c) $\frac{4}{9}$F (d) $\frac{F}{2}$

Topic 2: Electric Field, Electric Field Lines and Dipole

21. If an electron has an initial velocity in a direction different from that of an electric field, the path of the electron is
(a) a straight line (b) a circle (c) an ellipse (d) a parabola

22. A charged oil drop is suspended in a uniform field of 3×10^4 V/m so that it neither falls nor rises. The charge on the drop will be (Take the mass of the charge = 9.9×10^{-15} kg and g = 10 m/s^2)
(a) 1.6×10^{-18} C (b) 3.2×10^{-18} C (c) 3.3×10^{-18} C (d) 4.8×10^{-18} C

23. Figure shows the electric lines of force emerging from a charged body. If the electric field at *A* and *B* are E_A and E_B respectively and if the displacement between *A* and *B* is *r* then

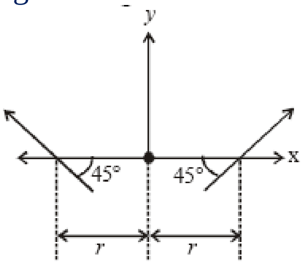


(a) $E_A > E_B$ (b) $E_A < E_B$ (c) $E_A = \frac{E_B}{r}$ (d) $E_A = \frac{E_B}{r^2}$

24. Two thin infinite parallel sheets have uniform surface densities of charge $+\sigma$ and $-\sigma$. Electric field in the space between the two sheets is

(a) σ/ε_0 (b) $\sigma/2\varepsilon_0$ (c) $2\sigma/\varepsilon_0$ (d) zero

25. Two identical electric dipoles are arranged on x-axis as shown in figure. Electric field at the origin will be



(a) Zero (b) $\frac{kp\sqrt{2}}{r^3}\hat{j}$ (c) $\frac{-kp\sqrt{2}}{r^3}\hat{j}$ (d) $\frac{-kp}{r^3}\hat{i}-\frac{kp}{r^3}\hat{j}$

26. In a region with a uniform electric field, the number of lines of force per unit area is E. If a spherical metallic conductor is placed in the area, the field inside the conductor will be

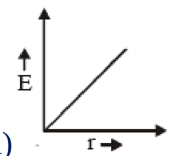
(a) zero (b) E (c) more than E (d) less than E

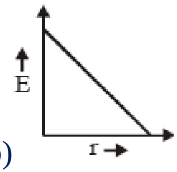
27. If a charge is moving along the direction of coulomb's force of an electric field,

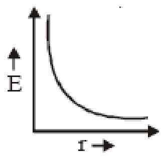
(a) work is done by the electric field (b) energy is used from some outside source

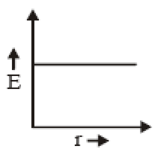
(c) strength of field decreases (d) energy of the system is decreased

28. The E-r curve for an infinite linear charge distribution will be

(a) 

(b) 

(c) 

(d) 

29. The electric field strength at a distance r from a charge q is E. What will be electric field strength if the distance of the observation point is increased to 2 r?

(a) E/2 (b) E/4 (c) E/6 (d) None of the above

30. If one penetrates a uniformly charged spherical cloud, electric field strength

(a) decreases directly as the distance from the centre

(b) increases directly as the distance from the centre

(c) remains constant (d) None of these

31. A liquid drop having 6 excess electrons is kept stationary under a uniform electric field of 25.5 kVm^{-1}. The density of liquid is 1.26×10^3 kg m^{-3}. The radius of the drop is (neglect buoyancy).

(a) 4.3×10^{-7} m (b) 7.8×10^{-7} m (c) 0.078×10^{-7} m (d) 3.4×10^{-7} m

32. An electric dipole is kept in a uniform electric field. It experiences

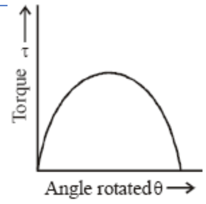
(a) a force and a torque (b) a force, but no torque

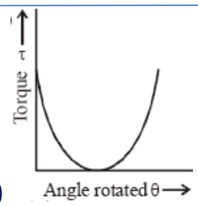
(c) a torque but no force (d) neither a force nor a torque

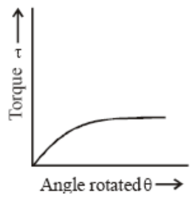
33. Two point dipoles of dipole moment $\vec{p}_1$ and $\vec{p}_2$ are at a distance x from each other and $\vec{p}_1 \| \vec{p}_2$. The force between the dipoles is :

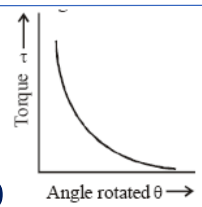
(a) $\frac{1}{4\pi\varepsilon_0}\frac{4p_1p_2}{x^4}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{3p_1p_2}{x^3}$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{6p_1p_2}{x^4}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{8p_1p_2}{x^4}$

34. Which of the following graphs shows the correct variation in magnitude of torque on an electric dipole rotated in a uniform electric field from stable equilibrium to unstable equilibrium?

(a) 

(b) 

(c) 

(d) 

35. Let $\rho(r)=\dfrac{Q}{\pi R^4}r$ be the charge density distribution for a solid sphere of radius R and total charge Q. For a point 'P' inside the sphere at distance $r1$ from the centre of the sphere, the magnitude of electric field is :

(a) $\dfrac{Q}{4\pi\in_0 r_1^2}$ (b) $\dfrac{Qr_1^2}{4\pi\in_0 R^4}$ (c) $\dfrac{Qr_1^2}{3\pi\in_0 R^4}$ (d) 0

36. An electric line of force in the xy plane is given by equation $x^2+y^2=1$. A particle with unit positive charge, initially at rest at the point $x=1$, $y=0$ in the xy plane

(a) not move at all (b) will move along straight line
(c) will move along the circular line of force (d) information is insufficient to draw any conclusion

37. A point charge q is rotated along a circle in the electric field generated by another point charge Q. The work done by the electric field on the rotating charge in one complete revolution is

(a) zero (b) positive (c) negative
(d) zero if the charge Q is at the centre and nonzero otherwise.

38. 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

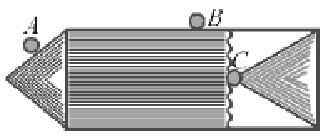
39. An electric dipole, consisting of two opposite charges of 2×10^{-6} C each separated by a distance 3 cm is placed in an electric field of 2×10^5 N/C. Torque acting on the dipole is

(a) $12\times10^{-1}N\text{-}m$ (b) $12\times10^{-2}N\text{-}m$ (c) $12\times10^{-3}N\text{-}m$ (d) $12\times10^{-4}N\text{-}m$

40. Two parallel large thin metal sheets have equal surface charge densities ($\sigma=26.4\times10^{-12}$ C/m^2) of opposite signs. The electric field between these sheets is

(a) 1.5 N/C (b) 1.5×10^{-10} N/C (c) 3 N/C (d) 3×10^{-10} N/C

41. A small metal ball is brought into contact alternatively with points A, B and C of the charged body shown in figure. After each contact the charge of the ball is determined approximately by touching it against an electroscope. If q_A, q_B and q_C are the charges, then



(a) $q_A>q_B>q_C$ (b) $q_A<q_B<q_C$ (c) $q_A=q_B$, $q_C=0$ (d) $q_A=0$, $q_B=q_C$

42. An electron and a proton are situated in a uniform electric field. The ratio of their acceleration will be

(a) zero (b) unity (c) ratio of masses of proton and electron
(d) ratio of masses of electron and proton

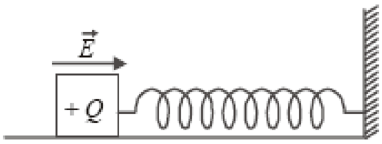
43. An electric dipole is placed at an angle of 30° with an electric field of intensity 2×10^5 NC^{-1}, It experiences a torque of 4 Nm. Calculate the charge on the dipole if the dipole length is 2 cm.

(a) 8 μC (b) 4 μC (c) 8 μC (d) 2 μC

44. If the dipole of moment 2.57×10^{-17} cm is placed into an electric field of magnitude 3.0×10^4 N/C such that the fields lines are aligned at 30° with the line joining P to the dipole, what torque acts on the dipole?

(a) 7.7×10^{-13} Nm (b) 3.855×10^{-13} Nm (c) 3.855×10^{-15} Nm (d) 7.7×10^{-15} Nm

45. A wooden block performs SHM on a frictionless surface with frequency ν_0. The block carries a charge $+Q$ on its surface. If now a uniform electric field $\vec{E}$ is switched-on as shown, then the SHM of the block will be



(a) of the same frequency and with shifted mean position.
(b) of the same frequency and with the same mean position
(c) of changed frequency and with shifted mean position.
(d) of changed frequency and with the same mean position.

46. Two point dipoles $p\hat{k}$ and $\frac{p}{2}\hat{k}$ are located at (0, 0, 0) and (1m, 0, 2m) respectively. The resultant electric field due to the two dipoles at the point (1m, 0, 0) is

(a) $\frac{9p}{32\pi \in_0}\hat{k}$ (b) $\frac{-7p}{32\pi \in_0}\hat{k}$ (c) $\frac{7p}{32\pi \in_0}\hat{k}$ (d) None of these

47. The surface density on the copper sphere is σ. The electric field strength on the surface of the sphere is

(a) σ (b) $\sigma/2$ (c) $\sigma/2\varepsilon_0$ (d) σ/ε_0

48. Two conducting spheres of radii r_1 and r_2 are charged to the same surface charge density. The ratio of electric fields near their surface is

(a) r_1^2/r_2^2 (b) r_2^2/r_1^2 (c) r_1/r_2 (d) 1 : 1

49. 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) $q E y^2$ (b) $q E^2 y$ (c) $q E y$ (d) $q^2 E y$

50. An electric dipole is placed at the centre of a sphere. Select the correct option.
(a) The flux of the electric field through the sphere is zero.
(b) The electric field is zero at every point of the sphere.
(c) The electric field is not zero anywhere on the sphere.
(d) The electric field is zero on a circle on the sphere.

51. Three equal. Charges +q are placed at each corner of an equilateral triangle. The electric field at geometric centre will be [Where l = length of each corner from geometric centre of equilateral triangle]

(a) $\frac{1}{4\pi \in_0}\frac{q}{l}$ (b) $\frac{1}{4\pi \in_0}\frac{q}{l^2}$ (c) $\frac{1}{4\pi \in_0}\frac{3q}{l^2}$ (d) zero

52. 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 min (d) zero and min.

Topic 3: Electric Flux and Gauss's Law

53. A surface has the area vector $\vec{A}=\left(2\hat{i}+3\hat{j}\right)m^2$ .The flux of an electric field through it if the field is $\vec{E}=4\hat{i}\frac{V}{m}$

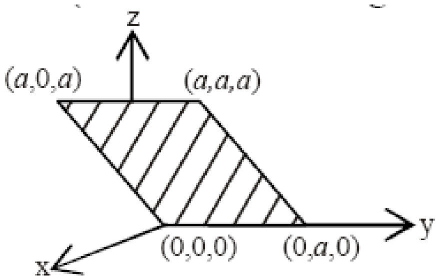
(a) 8 V-m (b) 12 V-m (c) 20 V-m (d) zero

54. A cylinder of radius R and length L is placed in a uniform electric field parallel to the cylinder axis. The total flux for the surface of the cylinder is given by
(a) $2\pi R^2 E$ (b) $\pi R^2/E$ (c) $(\pi R^2/\pi R)/E$ (d) Zero

55. The inward and outward electric flux for a closed surface in units of N-m^2/C are respectively 8×10^3 and 4×10^3. Then the total charge inside the surface is [where e0 = permittivity constant]

(a) $4\times10^3 C$ (b) $-4\times10^3 C$ (c) $\frac{\left(-4\times10^3\right)}{e}C$ (d) $-4\times10^3\varepsilon_0 C$

56. Consider an electric field $\vec{E} = E_0\hat{x}$ where E_0 is a constant. The flux through the shaded area (as shown in the figure) due to this field is

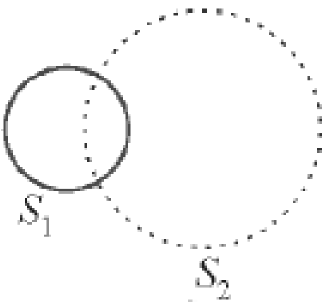


(a) $2E_0a^2$ (b) $\sqrt{2}\,E_0a^2$ (c) $E^0\,a^2$ (d) $\frac{E_0a^2}{\sqrt{2}}$

57. Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 1 m surrounding the total charge is 100 V-m. The flux over the concentric sphere of radius 2 m will be

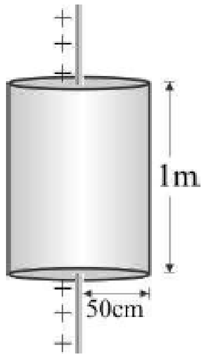
(a) 25 V-m (b) 50 V-m (c) 100 V-m (d) 200 V-m

58. A conducting sphere S_1 intersects a closed surface S_2 as shown in the figure. A positive charge q is placed at a point P. What is the value of electric flux through the surface S_2?



(a) 0 (b) $\frac{q}{\epsilon_0}$ (c) $< \frac{q}{\epsilon_0}$ (d) $> \frac{q}{\epsilon_0}$

59. Electric charge is uniformly distributed along a long straight wire of radius 1mm. The charge per cm length of the wire is Q coulomb. Another cylindrical surface of radius 50 cm and length 1m symmetrically encloses the wire as shown in the figure. The total electric flux passing through the cylindrical surface is



(a) $\frac{Q}{\varepsilon_0}$ (b) $\frac{100Q}{\varepsilon_0}$ (c) $\frac{10Q}{(\pi\varepsilon_0)}$ (d) $\frac{100Q}{(\pi\varepsilon_0)}$

60. A loop of diameter d is rotated in a uniform electric field until the position of maximum electric flux is found. The flux in this position is measured to be ϕ. What is the electric field strength?

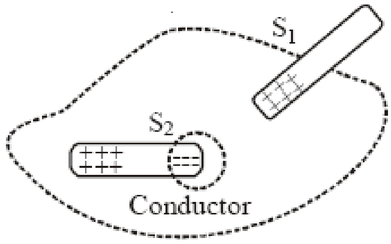
(a) $\frac{4\phi}{\pi d^2}$ (b) $\frac{2\phi}{\pi d^2}$ (c) $\frac{\phi}{\pi d^2}$ (d) $\frac{\pi\phi d^2}{4}$

61. Which of the following statement is correct?

(a) Gauss's law is valid only for symmetrical charge distributions.

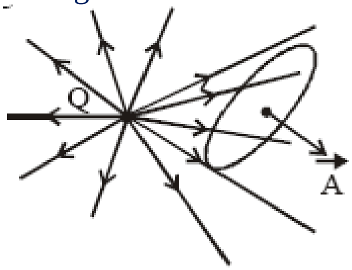
(b) Gauss's law is valid only for charge placed in vacuum.
(c) The electric field calculated by Gauss's law is the field due to the charges inside the Gaussian surface.
(d) The flux of the electric field through a closed surface due to all the charges is equal to the flux due to the charges enclosed by the surface.

62. Charge on an originally uncharged conductor is separated by holding a positively charged rod very closely nearby, as shown in Fig. Assume that the induced negative charge on the conductor is equal to the positive charge q on the rod. Then the flux through surface S_1 is



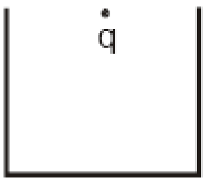
(a) zero (b) q/ε_0 (c) $-q/\varepsilon_0$ (d) None of these

63. In the figure the net electric flux through the area A is $\phi = \vec{E}.\vec{A}$ when the system is in air. On immersing the system in water the net electric flux through the area



(a) becomes zero (b) remains same Q (c) increases (d) decreases

64. A charge q is placed at the centre of the open end of a cylindrical vessel. The flux of the electric field through the surface of the vessel is



(a) zero (b) q/ε_0 (c) $q/2\varepsilon_0$ (d) $2q/\varepsilon_0$

65. If the electric flux entering and leaving a closed surface are 6×10^6 and 9×10^6 S.I. units respectively, then the charge inside the surface of permittivity of free space ε_0 is

(a) $\varepsilon_0 \times 10^6$ (b) $-\varepsilon_0 \times 10^6$ (c) $-2\varepsilon_0 \times 10^6$ (d) $3\varepsilon_0 \times 10^6$

NEET PREVIOUS YEARS QUESTIONS

1. 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 **[2018]**

(a) smaller (b) 5 times greater (c) equal (d) 10 times greater

2. Suppose the charge of a proton and an electron differ slightly. One of them is – e, the other is (e + Δe). 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 of [Given mass of hydrogen m_h = 1.67×10^{-27} kg] **[2017]**

(a) 10^{-23}C (b) 10^{-37} C (c) 10^{-47} C (d) 10^{-20} C

3. Two identical charged spheres suspended from a common point by two massless strings of lengths l, are initially at a distance d (d << l) apart because of their mutual repulsion. The charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity v. Then v varies as a function of the distance x between the spheres, as : **[2016]**

(a) $v \propto x^{\frac{1}{2}}$ (b) $v \propto x$ (c) $v \propto x^{-\frac{1}{2}}$ (d) $v \propto x^{-1}$

4. The electric field in a certain region is acting radially outward and is given by E = Aa. A charge contained in a sphere of radius 'a' centred at the origin of the field, will be given by **[2015]**

(a) $A\varepsilon_0 a^2$ (b) $4\pi\varepsilon_0 Aa^3$ (c) $\varepsilon_0 Aa^3$ (d) $4\pi\varepsilon_0 Aa^2$

5. A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre : **[NEET–2019]**

(1) increases as r increases for r < R and for r > R

(2) zero as r increases for r < R, decreases as r increases for r > R

(3) zero as r increases for r < R, increases as r increases for r > R

(4) decreases as r increases for r < R and for r > R

6. 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]**

(1) zero (2) $\frac{2\lambda}{\pi\varepsilon_0 R} N/C$ (3) $\frac{\lambda}{\pi\varepsilon_0 R} N/C$ (4) $\frac{\lambda}{2\pi\varepsilon_0 R} N/C$

7. 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]**

(1) F (2) $\frac{9F}{16}$ (3) $\frac{16F}{9}$ (4) $\frac{4F}{3}$

8. 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 ? **[NEET – 2019 (ODISSA)]**

1) $\sigma_1 = \frac{5}{6}\sigma, \sigma_2 = \frac{5}{2}\sigma$ 2) $\sigma_1 = \frac{5}{2}\sigma, \sigma_2 = \frac{5}{6}\sigma$ 3) $\sigma_1 = \frac{5}{2}\sigma, \sigma_2 = \frac{5}{3}\sigma$ 4) $\sigma_1 = \frac{5}{3}\sigma, \sigma_2 = \frac{5}{6}\sigma$

9. A sphere encloses an electric dipole with charge ±3 × 10–6 C. What is the total electric flux across the sphere ? **[NEET – 2019 (ODISSA)]**

(1) -3×10^{-6} Nm^2 /C (2) zero (3) 3×10^{-6} Nm^2 /C (4) 6×10^{-6} Nm^2 /C

10. The electric field at a point on the equatorial plane at a distance r from the centre of a dipole having dipole moment $\vec{p}$ is given by (r >> separation of two charges forming the dipole, $\in_0$ − permittivity of free space) **[NEET – 2020 (Covid-19)]**

(1) $\vec{E} = \frac{\vec{p}}{4\pi \in_0 r^3}$ (2) $\vec{E} = \frac{2\vec{p}}{4\pi \in_0 r^3}$ (3) $\vec{E} = -\frac{\vec{p}}{4\pi \in_0 r^2}$ (4) $\vec{E} = -\frac{\vec{p}}{4\pi \in_0 r^3}$

11. The acceleration of an electron due to the mutual attraction between the electron and a proton when they are 1.6 $\overset{0}{A}$ apart is, $\left(m_e \simeq 9\times10^{-31} kg, e = 1.6\times10^{-19} C\right)$ $\left(\text{Take } \frac{1}{4\pi\varepsilon_0} = 9\times10^9 Nm^2C^{-2}\right)$ **[NEET–2020 Covid]**

(1) 10^{24} m/s^2 (2) 10^{23} m/s^2 (3) 10^{22} m/s^2 (4) 10^{25} m/s^2

12. A spherical conductor of radius 10cm 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? $\left(\frac{1}{4\pi\varepsilon_0} = 9\times10^9 Nm^2/C^2\right)$

[NEET – 2020]

1) 1.28×10^7 N/C 2) 1.28×10^4 N/C 3) 1.28×10^5 N/C 4) 1.28×10^6 N/C

NCERT LINE BY LINE QUESTIONS – ANSWERS

1)	b	2)	b	3)	c	4)	a	5)	b
6)	d	7)	d	8)	d	9)	d	10)	d
11)	d	12)	a	13)	d	14)	d	15)	c
16)	b	17)	c	18)	c	19)	b	20)	d
21)	B	22)	B	23)	B	24)	C	25)	B
26)	A	27)	A	28)	A	29)	C	30)	B
31)	B	32)	C	33)	A	34)	D	35)	B
36)	D	37)	B	38)	B	39)	D	40)	B
41)	A	42)	E	43)	B	44)	A	45)	A
46)	A	47)	B	48)	C	49)	B	50)	C
51)	A	52)	D	53)	D	54)	D	55)	B
56)	A	57)	C	58)	A	59)	A	60)	C
61)	C								

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1) 4	**2)** 1	**3)** 4	**4)** 4	**5)** 2	**6)** 1	**7)** 3	**8)** 4	**9)** 1	**10)** 2
11) 2	**12)** 4	**13)** 3	**14)** 2	**15)** 1	**16)** 1	**17)** 2	**18)** 2	**19)** 2	**20)** 3
21) 4	**22)** 3	**23)** 1	**24)** 1	**25)** 3	**26)** 1	**27)** 1	**28)** 3	**29)** 2	**30)** 1
31) 2	**32)** 3	**33)** 2	**34)** 1	**35)** 2	**36)** 3	**37)** 1	**38)** 1	**39)** 3	**40)** 3
41) 1	**42)** 3	**43)** 4	**44)** 2	**45)** 3	**46)** 2	**47)** 2	**48)** 4	**49)** 3	**50)** 3
51) 4	**52)** 4	**53)** 1	**54)** 4	**55)** 4	**56)** 3	**57)** 3	**58)** 2	**59)** 2	**60)** 1
61) 4	**62)** 2	**63)** 4	**64)** 1	**65)** 4	**66)**	**67)**	**68)**	**69)**	**70)**

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1) 1	**2)** 2	**3)** 3	**4)** 2	**5)** 2	**6)** 3	**7)** 2	**8)** 4	**9)** 2	**10)** 4
11) 3	**12)** 3								

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(d)** The weight can be increased slightly, if it acquire negative charge & weight can be decreased slightly, if it acquires positive charge.

2. **(a)** $n = 1\mu c / 1.6\times10^{-19} \approx 6\times10^{12}$

3. **(d)** Let r be the distance between q_1 and q_2.
According to Coulomb's law the force between q_1 and q_2 is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1(q-q_1)}{r^2}\left(\because q_1 + q_2 = q\right)$$

For F to be maximum $\frac{dF}{dq_1} = 0,$ as q and r are constants $\quad \therefore \frac{d}{dq_1}\left[\frac{1}{4\pi\varepsilon_0 r^2}\left(q_1q - q_1^2\right)\right] = 0$

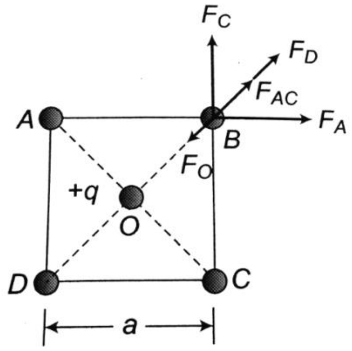
4. **(d)** From Coulomb's law $F = \frac{Kq_1q_2}{r^2}$ i.e., $F \propto \frac{1}{r^2}$ which is correctly shown by graph (d).

5. **(b)** If all charges in equilibrium, system is also in equilibrium.
Charge at centre: charge q is in equilibrium because no net force acting on it corner charge:
If we consider the charge at corner BB. This charge will experience following forces

$$F_A = k\frac{Q^2}{a^2}, F_C = \frac{KQ^2}{a^2} F_D = \frac{kQ^2}{\left(a\sqrt{2}\right)^2} \quad F_o = \frac{kQq}{\left(a\sqrt{2}\right)^2}$$

Force at B away from the centre $= F_{AC} + F_D$

$$= \sqrt{F_A^2 + F_C^2} + F_D = \sqrt{2}\frac{kQ^2}{a^2} + \frac{kQ^2}{2a^2} = \frac{kQ^2}{a^2}\left(\sqrt{2} + \frac{1}{2}\right)$$



Force at B towards the centre $= F_o = \frac{2kQq}{a^2}$

For equilibrium of charges at B, $F_{AC} + F_D = F_o$

$$\Rightarrow \frac{KQ^2}{a^2}\left(\sqrt{2} + \frac{1}{2}\right) = \frac{2KQq}{a^2} = q = \frac{Q}{4}\left(1 + 2\sqrt{2}\right)$$

6. **(a)** In the absence of gravitational force, the only force acts on the spheres is electrostatic repulsion and so the angle between two suspension becomes 180°. So force between the sphere

$$F = \frac{1}{4\pi\in_0}\frac{Q^2}{(2L)^2}$$

7. **(c)** Positively charged rod induces negative charge on the side of the sphere closer to the rod and an equal positive charge on the side away from the rod. When the rod is withdrawn, the negative charges move to neutralise the equal positive charge. The charge left is zero

8. **(d)** $q = \pm n e$ shows that minimum value of $q = \pm 1e$. where $e = 1.6\times10^{-19}$ Coulomb = Charge of one electron

9. **(a)** In contact, A and B behave as one body. Therefore, by induction, positive charge developers on A and negative charge developers on farther side of B.

10. (b) Step 1: Initial Force between two charges

Using Coulomb's law, $F = \frac{Kq_1q_2}{r^2} \Rightarrow 5 = \frac{Kq_1q_2}{(0.06)^2}$ -------(i)

Step 2: New Force between the charges

When each charge is moved towards the other by 0.01m, the new distance between them is r′=0.06m−2×0.01m=0.04m

$$F^{|} = \frac{Kq_1q_2}{(0.04)^2} \text{ ------------(ii)}$$

Step 3: Solving Equations

Dividing (2) by (1) $\Rightarrow \frac{F}{5} = \frac{(0.06)^2}{(0.04)^2} \Rightarrow F^{|} = 11.25\text{N}$

The new force would be 11.25 N

11. **(b)** Here, $r_1 = \hat{i} + \hat{j} + \hat{k} \Rightarrow r_2 = 2\hat{i} + 3\hat{j} + \hat{k}$

$$\therefore \vec{r} = \vec{r}_2 - \vec{r}_1 = \left(2\hat{i} + 3\hat{j} + \hat{k}\right) - \left(\hat{i} + \hat{j} + \hat{k}\right) = \hat{i} + 2\hat{j}$$

$|\vec{r}| = \sqrt{(1)^2 + (2)^2} = \sqrt{5}$

By Coulomb's law

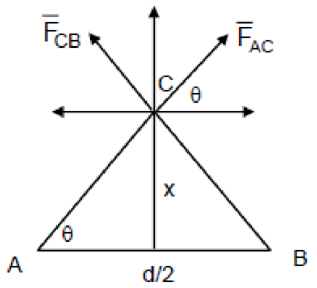
$F = \frac{1}{4\pi\varepsilon_0} = \frac{q_1 q_2}{r} = \frac{9\times10^9 \times 3\times10^{-6} \times 3\times10^{-6}}{\left(\sqrt{5}\right)^2} = \frac{81}{5}\times10^{-3}\,N =$ Nearest answer is $16\times10^{-3}\,N$

12. **(d)** $Q_1 + Q_2 = Q$--------(i) and $F = k\frac{Q_1Q_2}{r^2}$ --------(ii)

From (i) and (ii) $F = \frac{kQ_1\left(Q - Q_1\right)}{r^2}$

For F to be maximum $\frac{dF}{dQ_1} = 0 \Rightarrow Q_1 = Q_2 = \frac{Q}{2}$

13. **(c)** Force on the charge particle 'q' at 'c' is only the x component of 2



So, $F_{on\ c} = F_{CB}\,\text{Sin}\,\theta + F_{AC}\,\text{Sin}\,\theta$ But $|\bar{F}_{CB}| = |\bar{F}_{AC}|$

$= 2\,F_{CB}\,\text{Sin}\,\theta = 2\frac{KQq}{x^2 + (d/2)^2} \times \frac{x}{\left[x^2 + d^2/4\right]^{1/2}}$

$= \frac{2k\theta qx}{(x^2 + d^2/4)^{3/2}} = \frac{16kQq}{(4x^2 + d^2)^{3/2}}\,x$

For maximum force $\frac{dF}{dx} = 0$

$\frac{d}{dx}\left(\frac{16kQqx}{(4x^2 + d^2)^{3/2}}\right) = 0 \Rightarrow K\left[\frac{(4x^2 + d^2) - x\left[3/2\left[4x^2 + d^2\right]^{1/2} 8x\right]}{[4x^2 + d^2]^3}\right] = 0$

$\Rightarrow \frac{K(4x^2 + d^2)^{1/2}\left[(4x^2 + d^2)^3 - 12x^2\right]}{(4x^2 + d^2)^3} = 0 \Rightarrow (4x^2 + d^2)^3 = 12\,x^2$

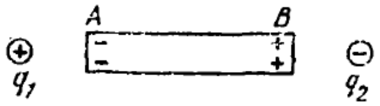
$\Rightarrow 16\,x^4 + d^4 + 8x^2d^2 = 12\,x^2$ $\qquad d^4 + 8\,x^2\,d^2 = 0$

$\Rightarrow d^2 = 0$ $\qquad d^2 + 8\,x^2 = 0$ $\qquad \Rightarrow d^2 = 8\,x^2 \Rightarrow d = \frac{d}{2\sqrt{2}}$

14. **(b)** The dielectric constant for metal is infinity, the force between the two charges would be reduced to zero.

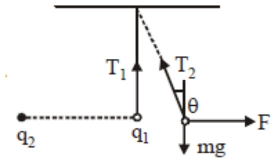
15. (a) $\frac{F_e}{F_p} = 10^0 = 1$, because force depends only on charges, distance and nature of medium and not type of charge. As all other quantities are same , the ratio will be 1.

16. **(a)** Due to polarization of the insulator rod AB, the point charge $+q_1$ will be acted upon, in addition to the point charge - q_2, by the polarization charges formed at the ends of the rod



The attractive force exerted by the negative charge induced at the end A will be stronger than the repulsive force exerted by the positive charge induced at the end B. Thus, the total force acting on the charge $+q_1$ will increase.

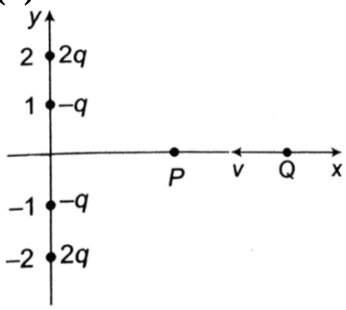
17. **(b)** Initial tension : $T_1 = mg$



Final tension : $T_2 \cos\theta = mg$ or $T_2 = \frac{mg}{\cos\theta}$; Obviously, $T_2 > mg$.

Here we have assumed q to be small so that F is almost horizontal.

18. **(b)**



There exists a point P on the x-axis (other than the origin), where not electric field is zero. Once the charge Q reaches point P, attractive forces of the two −ve charge will dominate and automatically cause the charge Q to cross the origin.
Now if Q is projected with just enough velocity to reach P, its K.E. at P is zero, But while being attracted towards origin it acquires K.E. and hence its net energy at the origin is positive. (P.E. at origin = zero).

19. **(b)** The radius of soap bubble increases because of outward force acting on the bubble due to charging.

20. **(c)** In vacuum, $F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$ --------(i)

Suppose, force between the charges is same when charges are r' distance apart in dielectric.

$\therefore F' = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{kr'^2}$ --------------(ii)

From (i) and (ii), $kr'^2 = r^2$ or $r = \sqrt{k}r'$

In the given situation, force between the charges would be $F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{\left(\frac{r}{2}+\sqrt{4}\frac{r}{2}\right)} = \frac{4}{9}\frac{q^2}{4\pi\varepsilon_0 r^2} = \frac{4F}{9}$

21. **(d)** The path is a parabola, because initial velocity can be resolved into two rectangular components, one along $\vec{E}$ and other $\perp$ to $\vec{E}$. The former decreases at a constant rate and latter is unaffected. The resultant path is therefore a parabola.

22. (c) Given : Electric field, $E=3\times10^4$ V/m
Mass of the drop, $M=9.9\times10^{-15}$kg
Let q be the amount of the charge that the drop carries.
The coulomb force balances the gravitational force acting on the drop at equilibrium.

$$\therefore\ qE = Mg \implies q = \frac{Mg}{E}$$

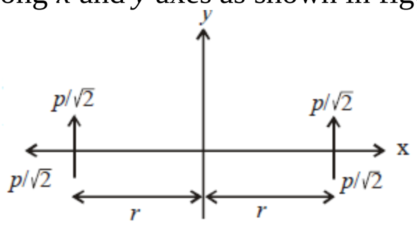
$$\therefore\ q = \frac{9.9\times10^{-15}\times10}{3\times10^4} = 3.3\times10^{-18}\ C$$

23. **(a)** Figure indicates the presence of some positive charge to the left of A. $\therefore E_A > E_B\ (\because r_A < r_B)$

24. **(a)** $E = E_1 - E_2 = \frac{\sigma}{2\varepsilon_0} - \left(\frac{-\sigma}{2\varepsilon_0}\right) = \frac{\sigma}{2\varepsilon_0} = \sigma/\varepsilon_0$

The field intensity in between sheets having equal and opposite uniform surface densities of charge becomes constant. ie, an uniform electric field is produced and it is independent of the distance between the sheets.

25. **(c)** The dipoles can be resolved along *x* and *y* axes as shown in figure.



The formulae for electric field at axial and equatorial points of a dipole are

E (axial) = $\frac{2Kp}{r^3}$ along the dipole

E (equatorial) = $\frac{Kp}{r^3}$ opposite to the direction of dipole.

Electric field at centre due to horizontal components of dipoles will cancel out.

Total electric field at centre due to vertical components will be $E = \frac{Kp/\sqrt{2}}{r^3}\times 2$ in vertically downward direction. $\therefore E = \frac{-Kp\times\sqrt{2}}{r^3}\hat{j}$

26. **(a)** Electric field inside a conductor is zero.

27. **(a)** Work is done by the electric field because q = 0°, $W = F\ s\cos\theta \rightarrow$ positive.

28. **(c)** The field due to infinite linear charge distribution

$$E = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r} \Rightarrow E \propto \frac{1}{r}.\ \text{So hyperbola}$$

29. (b) As new distance **=2r** and electric field due to single charge, $E \propto \frac{1}{r^2}$, therefore, new intensity**=**E/4.

30. **(a)** A spherical cloud behaves as a solid sphere. Therefore, E decreases directly with the decreasing distance from the centre.

31. **(b)** $F = qE = mg\ (q = 6e = 6\times 1.6\times10^{-19})$; Density (d) = $\frac{\text{mass}}{\text{volume}} = \frac{m}{\frac{4}{3}\pi r^3}$ or $r^3 = \frac{m}{\frac{4}{3}\pi d}$

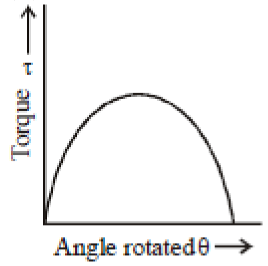
Putting the value of d and $m = \left(\frac{qE}{g}\right)$ and solving we get $r = 7.8\times10^{-7}$m

32. **(c)** In a uniform electric field, net force = 0, but torque ¹ 0.

33. **(b)** The electric field due to $\vec{P}_1$ at the position of $\vec{P}_2$ is $E_1 = \frac{KP_1}{r^3}$

$\therefore$ force of interaction between the dipoles is $F = P_2\left|\frac{dE_1}{dr}\right|$, $F = \frac{3kP_1P_2}{r^4}$

34. **(a)**



35. **(b)** Consider a differential thickness dr at a radius r.
We get the area for this differential thickness as $dA = 4\pi r^2 dr$

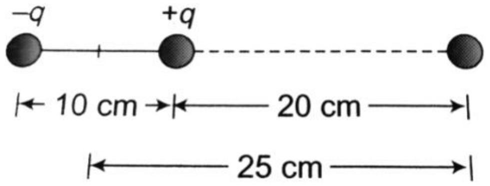
Thus we get the electric field at this point as $\frac{kdQ}{r_1^2}$ or

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{Qr4\pi r^2 dr}{\pi R^4 r_1^2} \; ; \; E = \frac{Q}{4\pi\varepsilon_0 r_1^2 \pi R^4}\int_{r=0}^{r_1} 4\pi r^3 dr$$

36. **(c)** The equation $x^2 + y^2 = 1$, represents a circle, and so particle will move along circular line of force.

37. **(a)** Because it is moving in a equipotential surface, hence the work done in complete rotation is zero.

38. **(a)** By using $E = 9\times10^9 \frac{2pr}{\left(r^2 - l^2\right)^2}$ where



$p = \left(500 \times 10^{-6}\right) \times \left(10 \times 10^{-2}\right) = 5 \times 10^{-5} c \times m,$
$r = 25cm = 0.25m, l = 5cm = 0.05m$

$$E = \frac{9 \times 10^9 \times 2 \times 5 \times 10^{-5} \times 0.25}{\left\{(0.25)^2 - (0.05)^2\right\}^2} = 6.25 \times 10^7 N/C$$

39. **(c)** Charges (q) = 2×10^{-6} C, Distance (d) = 3 cm = 3×10^{-2} m and electric field (E) = 2×10^5 N/C. Torque (τ) = q.d.
E =$(2 \times 10^{-6}) \times (3 \times 10^{-2}) \times (2 \times 10^5) = 12 \times 10^{-3}$ N–m .

40. (c) The electric field between two parallel large plates is

$$E = \frac{\sigma}{\varepsilon_0} = \frac{26.4\times10^{-12}}{8.85\times10^{-12}} = 2.98 \sim 3N/C$$

41. **(a)** The charge density nearby *A* is greatest and at *C*, it is least.

42. **(c)** $\frac{a_e}{a_m} = \frac{F_e/m_e}{F_p/m_p} = \frac{m_p(eE)}{m_e(eE)} = \frac{m_p}{m_e}$

43. **(d)** Torque, $\vec{\tau} = \vec{p} \times \vec{E} = pE\sin\theta$
$4 = p \times 2 \times 10^5 \times \sin 30°$

or, $p = \frac{4}{2\times10^5 \times \sin 30^0} = 4\times10^{-5}$Cm

Dipole moment, p = q × *l*

44. **(b)** $q = \frac{p}{l} = \frac{4\times10^{-5}}{0.02} = 2\times10^{-3} C = 2mC$

$= 3.855 \times 10^{-13}$ Nm.

45. **(c)** Due to the electric field spring compresses and so the mean portion of the block will shift by *QE*/ *K*.

46. (b) The given point is on axis of $\frac{\overline{p}}{2}$ dipole and at equatorial line of $\overline{p}$ dipole so that field at given point is

$$\left(\vec{E}_1 + \vec{E}_2\right)$$

$$\vec{E}_1 = \frac{2K(p/2)}{2^3} = \frac{Kp}{8}(+\hat{k})$$

$$\vec{E}_2 = \frac{Kp}{1}(-\hat{k})$$

$$\vec{E}_1 + \vec{E}_2 = \frac{7}{8}Kp(-\hat{k}) = -\frac{7p}{32\pi\varepsilon_0}\hat{k}$$

47. **(b)** Since $\tau = pE\sin\theta$ on decreasing the distance between the two charges, and on decreasing angle θ between the dipole and electric field, sin q decreases therefore torque decreases.

48. **(d)** As $\sigma_1 = \sigma_2$

$\therefore E_1 = E_2$ or $E_1 / E_2 = 1 \Rightarrow E_1 : E_2 = 1:1$

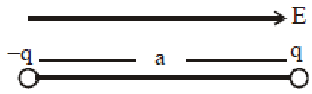
49. **(c)** K.E. acquired = work done

= force × distance = q E × y = q E y

50. **(c)** The electric field is not zero anywhere on the sphere.

51. **(d)** zero

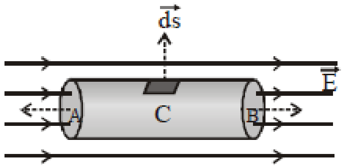
52. **(d)** When the dipole is in the direction of field then net force is qE + (–qE) = 0 and its potential energy is minimum = – p.E. = – qaE



53. **(a)**

54. **(d)** Flux through surface $A\phi_A = E \times \pi R^2$ and $\phi_B = -E \times \pi R^2$

Flux through curved surface C



$$= \int \vec{E}.\vec{ds} = \int Eds\, co90^0 = 0$$

$\therefore$ Total flux through cylinder $= \phi_A + \phi_B + \phi_C = 0$

55. **(d)** By Gauss's law $\phi = \frac{1}{\varepsilon_0}\left(Q_{enclosed}\right)$

$$\Rightarrow Q_{enclosed} = \phi\varepsilon_0 = \left(-8 \times 10^3 + 4 \times 10^3\right)\varepsilon_0$$

$= -4 \times 10^3 \varepsilon_0$ coulomb

57. **(c)** Flux does not depend on the size and shape of the close surface, and so, it remains same.

58. **(b)** The positive charge of magnitude *q* will appear of the part of the sphere which is inside close surface.

59. **(b)** The change inside cylinder is, $q_{in} = Q \times 100$.

Now $\phi = \frac{q_{in}}{\epsilon_0} = \frac{100Q}{\epsilon_0}$

60. **(a)** $\phi = EA\cos 0^0 = E \times \frac{\pi d^2}{4}$, $\quad \therefore E = \frac{4\phi}{\pi d^2}$

62. **(b)** Net charge on the conductor will be zero. So, net charge inside S, will be the charge on the rod. Hence flux through S_1 is q/ε_0.

63. **(d)** Since electric field $\vec{E}$ decreases inside water, therefore flux $\phi = \vec{E}.\vec{A}$ also decreases.

64. **(a)** The flux is zero according to Gauss' Law because it is a open surface which enclosed a charge q.

65. **(d)** By Gauss law, we know that

$\phi = \dfrac{q}{\varepsilon_0}$ Here, Net electric flux, $\phi = \phi_2 - \phi_1$

$$= 9\times10^6 - 6\times10^6 = \frac{q}{\varepsilon_0} \Rightarrow q = 3\times10^6\varepsilon_0$$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(a)** As we know, F = qE = ma $\Rightarrow a = \dfrac{qE}{m}; h = \dfrac{1qE}{2m}t^2 \quad \therefore t = \sqrt{\dfrac{2hm}{qE}}$

i.e., time $t \propto \sqrt{m}$ as 'q' is same for electron and proton.

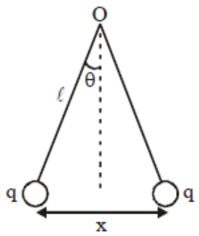
Since, electron has smaller mass so it will take smaller time.

2. **(b)** According to question, the net electrostatic force (F_E) = gravitational force (F_G)

$F_E = F_G$ or $\dfrac{1}{4\pi\varepsilon_0}\dfrac{\Delta e^2}{d^2} = \dfrac{Gm^2}{d^2} \Rightarrow \Delta e = m\sqrt{\dfrac{G}{K}} \quad \left(\dfrac{1}{4\pi\varepsilon_0} = k = 9\times10^9\right) = 1.67\times10^{-27}\sqrt{\dfrac{6.67\times10^{-11}}{9\times10^9}}$

$\Delta e \approx 1.436\times10^{-37}C$

3. **(c)** From figure $\tan\theta = \dfrac{F_e}{mg} \simeq \theta$



$\dfrac{kq^2}{x^2mg} = \dfrac{x}{2\ell}$ or $x^3 \propto q^2$ ...(1) or $x^{3/2} \propto q$ ...(2)

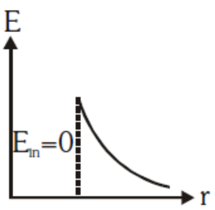
Differentiating eq. (1) w.r.t. time $\quad 3x^2\dfrac{dx}{dt} \propto 2q\dfrac{dp}{dt}$ but $\dfrac{dp}{dt}$ is constant

so $x^2(v) \propto q$ Replace q from eq. (2) $\quad x^2(v) \propto x^{3/2}$ or $v \propto x^{-1/2}$

4. **(2)** Net flux emitted from a spherical surface of radius a according to Gauss's theorem

$\phi_{net} = \dfrac{q_{in}}{\varepsilon_0}$ or, $(Aa)(4\pi a^2) = \dfrac{q_{in}}{\varepsilon_0}$ So, $q_{in} = 4\pi\varepsilon_0 Aa^3$

1. For a metal sphere $E_{in} = 0$ and $\vec{E}_{out} = \dfrac{Kq}{r^2}\hat{r}$



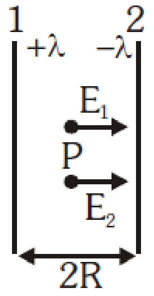
6.

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

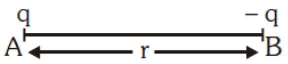
$$E = E_1 + E_2$$

$$E = \frac{\lambda}{2\pi \epsilon_0 R} + \frac{\lambda}{2\pi \epsilon_0 R}$$

$$E = \frac{\lambda}{\pi \epsilon_0 R} \text{ N/C}$$

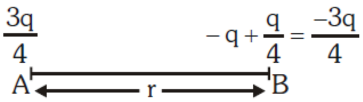


7.



$$F = \frac{-Kq^2}{r^2}$$

25% charge from A is transferred to B



$$\text{New force (F')} = \frac{K\left(\frac{3q}{4}\right)\left(\frac{-3q}{4}\right)}{r^2} = \frac{-9}{16}\frac{kq^2}{r^2} = \frac{9F}{16}$$

8. Before contact

$$Q_1 = \sigma.4\pi R^2$$

$$Q_2 = \sigma.4\pi(2R^2) = 4\left(\sigma.4\pi R^2\right) = 4Q_1$$

After contact :

$$Q_1' + Q_2' = Q_1 + Q_2 = 5Q_1,$$

$$= 5(\sigma.4\pi R^2)$$

They will be at equal potentials:

$$\frac{Q_1'}{R} = \frac{Q_2'}{2R}$$

$$\therefore Q_2' = 2Q'.$$

$$\therefore 3Q_1' = 5\left(\sigma.4\pi R^2\right)$$

$$\therefore Q_1' = \frac{5}{3}\left(\sigma.4\pi R^2\right) \text{ and } Q_2' = \frac{10}{3}\left(\sigma.4\pi R^2\right)$$

$$\therefore \ \sigma_1 = 5/3\sigma \quad \text{and} \quad \therefore \ \sigma_2 = \frac{5}{6}\sigma.$$

9. $\phi = \frac{q_{in}}{\varepsilon_0} = 0$

10. Electric field in equatorial plane $\vec{E} = -\frac{k\vec{p}}{r^3}$; $\vec{E} = -\frac{\vec{p}}{4\pi\varepsilon_0 r^3}$

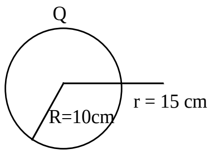
11.

$$F = K\frac{e^2}{r^2} \Rightarrow a = K\frac{e^2}{mr^2}$$

$$\Rightarrow a = 9 \times 10^9 \frac{(1.6\times10^{-19})^2}{(1.6\times10^{-10})^2(9\times10^{-31})}$$

$$\Rightarrow a = 10^{-29} \times 10^{51} = 10^{22}\ m/s^2$$

12.



$E = \frac{KQ}{r^2}$; $E = \frac{9\times10^9\times3.2\times10^{-7}}{225\times10^{-4}}$; $E = 0.128\times10^6$; $E = 1.28\times10^5\ N/C$