CHAPTER : 1

# ELECTRIC CHARGES AND FIELD

## STUDY NOTES

**Electrostatics :** It is the study of electric charges at rest.

**Electric charge:** It is an intrinsic property. It is of two types i.e, positive and negative charge. SI unit of charge is coulomb (C).

**Fundamental law of electrostatics:** Like charges repel and unlike charges attract each other.

**Electrostatic induction :** It is the process of temporary electrification of a conductor in which opposite charges appear at its closer end and similar charges appear at its farther end in the presence of a nearby charged body. An insulated conductor can be positively or negatively charged by induction.

Three basic properties of electric charges. These are: (i) quantization, (ii) additivity, and (iii) conservation.

**Coulomb's law :** It states that the force of attraction or repulsion between two stationary point charges $q_1$ and $q_2$ is directly proportional to product of their magnitudes and inversely proportional to the square of the distance $r$ between them. Mathematically,

$$F = k\frac{q_1 q_2}{r^2}$$

The proportionality constant $k$ depends on the nature of the medium between the two charges. For vacuum medium value of $k$ in SI units,

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

$\varepsilon_0$ is called permittivity of free space and its value is $8.854 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$

**Permittivity ($\varepsilon$):** It is the property of a medium which determines the electric force between two charges placed in a given medium.

**Dielectric constant ($K$) or relative permittivity ($\varepsilon_r$):** It is the ratio between permittivity of a given medium to that of permittivity of free space. It is given by

$$\varepsilon_r \text{ or } K = \frac{\varepsilon}{\varepsilon_0} = \frac{F_{vac}}{F_{med}}$$

Where $\varepsilon$ is permittivity of a given medium

Coulomb's law for any medium is written as

$$F_{med} = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2} = \frac{F_{vac}}{k}$$

**Principle of superposition of electrostatic forces:** According to it when a number of charges are interacting, the total force on a given charge is the vector sum of the forces exerted on it due to all other charges. The force between two charges is not affected by the presence of other charges. The total force on charge $q_1$ due to charges $q_2, q_3....q_N$ will be

$$\vec{F_1} = \vec{F}_{12} + \vec{F}_{13} + ....., + \vec{F}_{1N}$$

$$= \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{N}\frac{q_i}{r_{1i}^2}\hat{r}_{1i}$$

$$= \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{N}\frac{q_i\left(\vec{r}_1-\vec{r}_i\right)}{\left|\vec{r}_1-\vec{r}_i\right|^3}$$

Here,

$$\hat{r}_{1i} = \frac{\vec{r}_1-\vec{r}_i}{\left|\vec{r}_1-\vec{r}_i\right|}$$ = a unit vector pointing from $q_1$ to $q_i$.

**Electric field:** It is defined as the electrostatic force per unit test charge acting on a very small positive full charge placed at the given point.It is written as:

$$\vec{E} = \lim_{q_0 \to 0}\frac{\vec{F}}{q_0}$$

It is a vector quantity whose direction is same as that of the force exerted on a positive test charge present at that point.

The SI unit of electric field is newton per coulomb ($NC^{-1}$) or volt per metre ($Vm^{-1}$).

Dimension of electric field is $[E] = [MLT^{-3}A^{-1}]$

**Electric field due to a point charge *q* at a distance *r*** is given by

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

If $q$ is positive,direction of E is radially outwards and if $q$ is negative, direction of E points is radially inwards. It is spherically symmetric.

**Electric field due to a system of point charges :**

**Superposition principle for electric fields:** According to this principle the electric field at any point due to a group of point charges is equal to the vector sum of the electric fields produced by each charge individually at that point. It is not affected by presence of other charges.

$$\vec{E}_1 = \vec{E}_1 + \vec{E}_2 + ..... + \vec{E}_N$$

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

$$= \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i}{\left|\vec{r}-\vec{r}_i\right|^3}\left(\vec{r}-\vec{r}_i\right)$$

For continuous charge distribution the charge involved is much greater than the charge on an electron, hence, we can ignore its quantum nature and assume that it is distributed in a continuous manner. This is known as a continuous charge distribution.

Volume charge density, $\rho = \frac{dq}{dV}$ $Cm^{-3}$

Surface charge density, $\sigma = \frac{dq}{dS}$ $Cm^{-2}$

Linear charge density, $\lambda = \frac{dq}{dL}$ $Cm^{-1}$

**Electrostatic force and field due to a continuous charge distribution is given by**

$$\vec{F}_{cont} = \vec{F}_V + \vec{F}_S + \vec{F}_L$$

$$\vec{F}_{cont} = \frac{q_0}{4\pi\varepsilon_0}\left[\int_V \frac{\rho}{r^2}\hat{r}\,dV + \int_S \frac{\sigma}{r^2}\hat{r}\,dS + \int_L \frac{\lambda}{r^2}\hat{r}\,dL\right]$$

Now, $\vec{E}_{cont} = \dfrac{\vec{F}_{cont}}{q_0}$

$$= \frac{1}{4\pi\varepsilon_0}\left[\int_V \frac{\rho}{r^2}\hat{r}\,dV + \int_S \frac{\sigma}{r^2}\hat{r}dS + \int_L \frac{\lambda}{r^2}\hat{r}dL\right]$$

**Electric field due to a general charge distribution is given by**

$$\vec{E}_{total} = \vec{E}_{discreat} + \vec{E}_{cont}$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\sum_{i=1}^{N}\frac{q_i\hat{r}_i}{r_i^2} + \int_V \frac{\rho\hat{r}}{r^2}\,dV + \int_S \frac{\sigma}{r^2}\hat{r}\,dS + \int_L \frac{\lambda}{r^2}\hat{r}dL\right]$$

**Electric dipole and dipole moment:** An electric dipole is made up of a pair of equal and opposite charges $+q$ and $-q$ separated by distance $2a$. Its dipole moment is given by

$\vec{p}$ = Either charge × vector drawn from $-q$ to $+q$.

$= q \times 2\vec{a}$

Magnitude of dipole moment, $p = q \times 2a$

It is a vector quantity having direction along the dipole axis from $-q$ to $+q$. Its unit is coulomb metre (Cm).

**Electric field at an axial point of a dipole is given by**

$$E_{axial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2pr}{(r^2-a^2)^2} \simeq \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3} \text{ for } r >> a$$

Here '$r$' is the distance of the point on the axis of dipole from the centre of dipole

At any axial point, the direction of electric field due to the dipole is along the direction of dipole moment $\vec{p}$.

**Electric field at an equatorial point of a dipole is given by**

$$E_{equa} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{(r^2+a^2)^{3/2}} \simeq \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{r^3} \text{ for } r >> a$$

The direction of electric field at a point on the perpendicular bisector of the dipole field (that is on the equatorial line) is antiparallel to the direction of dipole moment $\vec{p}$.

The electric field due to a short dipole at a certain distance along the axis is twice the electric field at the same distance along the equatorial line.

**Torque on a dipole in a uniform electric field**

The torque on a dipole of moment $\vec{p}$ when placed in a uniform electric field at an angle θ with it is given by

$\tau = pE \sin\theta$

It can also be written as, $\vec{\tau} = \vec{p} \times \vec{E}$

**Electric lines of force:** An electric line of force is an imaginary curve along which a small positive charge would tend to move when free to do so in an electric field and the tangent to these lines at any point gives the direction of electric field at that point.

**Properties of electric lines of force:**

(1) These are continuous curves without any breaks.

(2) Such two lines of force can never cross each other.

(3) They begin from positive charges and terminate at negative charges.They do not form closed loops.

(4) The relative closeness of these lines indicates the strength of the electric field at different points.

(5) They are always normal to the surface of a conductor.

(6) They tend to contract length wise and expand laterally.

**Electric flux:** The electric flux through a given area is the count of the total number of electric lines of force passing normally through that area.If $\vec{E}$ is the electric field that makes an angle θ with the normal to the area elements ΔS, then the electric flux is given by

$$\Delta\phi_E = E\Delta S \cos\theta = \vec{E}.\Delta\vec{S}$$

The electric flux through any surface S, open or closed, is equal to the surface integral of $\vec{E}$ over the surface S.

$$\phi_E = \int_S \vec{E}.\vec{dS}$$

It is a scalar quantity.

SI unit of electric flux = $Nm^2\ C^{-1}$

**Gauss's theorem:** It states that the total flux of electric field $\vec{E}$ through a closed surface S is equal to $1/\varepsilon_0$ times the charge $q$ enclosed by the surface S.

$$\phi_E = \oint_S \vec{E}.\vec{dS} = \frac{q}{\varepsilon_0}$$

**Electric field due to a long straight wire having linear charge density λ** is given by

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \quad i.e., \quad E \propto \frac{1}{r}$$

where $r$ is the perpendicular distance of the wire from the observation point.

**Electric field due to an infinite plane sheet having surface charge densityσ is given by**

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

It does not depend on the distance of the observation point from the planar sheet.

**Electric field of a thin spherical shell having surface charge density σ:** Let R is the radius of the shell, then

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r^2} \qquad \text{For } r > R \text{ (Outside points)}$$

$$E = 0 \qquad \text{For } r < R \text{ (Inside points)}$$

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{R^2} \qquad \text{For } r = R \text{ (At the surface)}$$

where $q = 4\pi R^2 \sigma$

**Electric field of a uniformly charged solid sphere having volume charge density ρ:** Let R radius of the sphere, then

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r^2} \qquad \text{For } r > R \text{ (Outside points)}$$

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{qr}{R^3} \qquad \text{For } r < R \text{ (Inside points)}$$

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{R^2} \qquad \text{For } r = R \text{ (At the surface)}$$

where $q = \frac{4}{3}\pi R^3 \rho$

# QUESTION BANK

## MULTIPLE CHOICE QUESTIONS

1. Shyam created an experimental setup. He took a parallel plate capacitor where parallel plates are separated by a distance of 15 mm. He placed a circular loop in between the plates (without touching the ground and plates) and rotated it . For which orientation of the loop, the number of electric field lines passing through the loop is maximum?
   (a) When the area vector of the loop is parallel to the plates
   (b) When the area vector of the loop is perpendicular to the plates
   (c) When the area vector of the loop makes an angle 30° with the vertical axis
   (d) When the area vector of the loop makes an angle 60° with the horizontal axis

2. A closed hemisphere of $r = 5$ cm is suspended vertically in an electric field $\vec{E} = 5\vec{j}$ V/cm .What is the number of field lines leaving the curved surface of the hemisphere?
   (a) $-125\pi$ V-cm (b) $125\pi$V-cm (c) $-2500\pi$ V-cm (d) $2500\ \pi$ V-cm

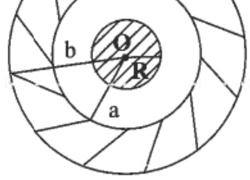
3. Mr. Samal's family went to a forest in their car. They were enjoying themselves and had set up their tents. Suddenly, it began to rain heavily accompanied by thunder and lightning. They got into the car and waited for the weather to improve.
   (a) As electric field lines won't flow through bad conductors
   (b) As it as good conductor and electric fields lines cannot exist inside conductor
   (c) They should come out and take shelter under trees
   (d) None of the above

4. A circular loop of radius R carries a uniformly distributed charge +Q. A point charge $+q$ and mass $m$ is placed on the axis of the loop at a distance $z(z << R)$ from the centre of the loop in equilibrium. The charged particle is pushed slightly downwards then the particle executes:
   (a) A SHM along the circular path (b) A SHM along the axis of loop
   (c) A motion along parabolic path (d) A motion along a hyperbolic path

5. Sanjana took an open roof cubical box . She placed a charge $q$ symmetrically with respect to the box. What is the total electric flux through the faces of the box?
   (a) $\frac{q}{\varepsilon_0}$ (b) $\frac{6q}{5\varepsilon_0}$ (c) $\frac{5q}{6\varepsilon_0}$ (d) $\frac{q}{6\varepsilon_0}$

6. Two charges, each equals to $q$, are kept at $x = -a$ and $x = a$ on the $x$-axis. A particle of mass $m$ and charge $q_0 = q/2$ is placed at the origin. If charge $q_0$ is given a small displacement ($y<<a$) along the $y$-axis, the net force acting on the particle is proportional to
   (a) $y$ (b) $-y$
   (c) $1/y$ (d) $-(1/y)$

7. A solid metal sphere of radius R having charge $q$ is enclosed inside the concentric spherical shell of inner radius $a$ and outer radius $b$ as shown in the figure. The approximate variation electric field $\vec{E}$ as a function of distance $r$ from centre O is given by

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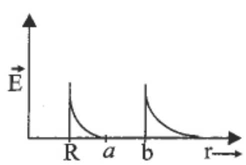


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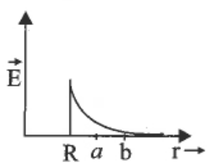


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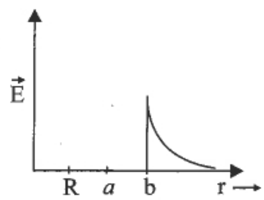


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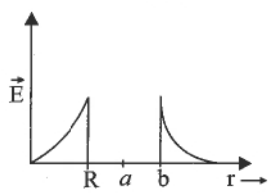


**8.** Two identical tennis balls each having mass '$m$' and charge '$q$' are suspended from a fixed point by threads of length '$l$'. What is the equilibrium separation when each thread makes a small angle '$\theta$' with the vertical?

(a) $x = \left(\dfrac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{1/2}$ (b) $x = \left(\dfrac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{1/3}$ (c) $x = \left(\dfrac{q^2 l^2}{2\pi\varepsilon_0 m^2 g}\right)^{1/3}$ (d) $x = \left(\dfrac{q^2 l^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{1/3}$

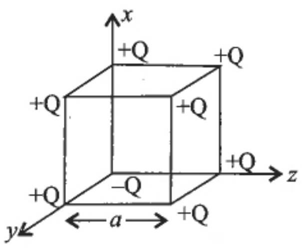
**9.** An electric dipole is placed on the x-axis in proximity to a line charge of linear charge density $3.0 \times 10^{-6}$ C/m. Line charge is placed on the $z$-axis and positive and negative charge of the dipole is at a distance of 10 mm and 12 mm from the origin respectively. If total force of 4 N is exerted on the dipole, find out the amount of positive or negative charge of the dipole.

(a) 0.485 mC (b) 815.1 nC (c) 8.8 μC (d) 4.44 μC

**10.** A certain charge Q is divided into two parts $q$ and (Q − $q$). How should the charges Q and q be divided so that $q$ and (Q − $q$) placed at a certain distance apart experience maximum electrostatic repulsion?

(a) Q = 2$q$ (b) Q = 4$q$ (c) Q = 3$q$ (d) Q = $q$/2

**11.** A cube of side '$a$' has point charges +Q located at each of its vertices except at the origin where the charge is −Q. The electric field at the centre of cube is :




(a) $\dfrac{2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x} + \hat{y} + \hat{z})$

(b) $\dfrac{Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x} + \hat{y} + \hat{z})$

(c) $\dfrac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x} + \hat{y} + \hat{z})$

(d) $\dfrac{-Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x} + \hat{y} + \hat{z})$

**12.** An electric dipole of moment $\vec{p} = (-\hat{i} - 3\hat{j} + 2\hat{k}) \times 10^{-29}$ Cm is at the origin (0, 0, 0). The electric field due to this dipole at $\vec{r} = (+\hat{i} + 3\hat{j} + 2\hat{k})$ (note that $\vec{r}.\vec{p} = 0$) is parallel to

(a) $(+\hat{i} + 3\hat{j} - 2\hat{k})$ (b) $(+\hat{i} - 3\hat{j} - 2\hat{k})$

(c) $(-\hat{i} + 3\hat{j} + 2\hat{k})$ (d) $(-\hat{i} - 3\hat{j} + 2\hat{k})$

**13.** An electron is moving with constant velocity along $x$-axis. If a uniform electric field is applied along $y$-axis, then its path in the $x$–$y$ plane will be :

(a) a straight line (b) a circle (c) a parabola (d) an ellipse

**14.** A dipole of dipole moment 'p' is placed in non-uniform electric field along x-axis. Electric field is increasing at the rate of 1 V $m^{-1}$. The force on dipole is:

(a) 0 (b) 2p (c) p/2 (d) p

**15.** In a certain region of space, electric field is along the z-direction throughout. The magnitude of electric field is however not constant, but increases uniformly along the positive $z$-direction at the rate of $10^5$N $C^{-1}$ $m^{-1}$. The force experienced by the system having a total dipole moment equal to $10^{-7}$C m in the negative z – direction is

(a) $-10^{-2}$ N (b) $10^{-2}$ N (c) $10^{-4}$ N (d) $-10^{-4}$ N

**16.** 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 point $x = 1$, $y = 0$ in the $xy$-plane

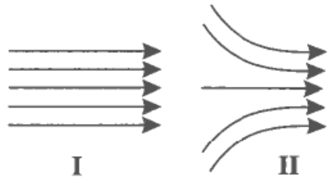
(a) not move at all (b) will move along the straight line

(c) will move along the circular line of force (d) information insufficient to draw any conclusion

**17.** A large flat metal surface has uniform charge density + σ. An electron of mass $m$ and charge $e$ leaves the surface at point A with speed $v$, and return it at point B. The maximum value of AB is:

(a) $\dfrac{vm\varepsilon_0}{\sigma e}$ (b) $\dfrac{v^2 m\varepsilon_0}{\sigma e}$ (c) $\dfrac{v^2 e}{\varepsilon_0 \sigma m}$ (d) $\dfrac{v^2 \sigma e}{m\varepsilon_0}$

**18.** Observe the two images, then:




(a) the electric fields in both I and II are produced by negative charge located somewhere on the left and positive charges located somewhere on the right

(b) in both I and II the electric field is the same everywhere

(c) in both cases the field becomes stronger on moving from left to right

(d) the electric field in I is the same everywhere, but in II the electric field becomes stronger on moving from left to right

**19.** An electric dipole is placed in a non uniform electric field increasing along the +ve direction of X-axis. The dipole moves along. _______________ and rotates ___________.

(a) +ve direction of X-axis, clockwise
(b) –ve direction of X-axis, clockwise
(c) +ve direction of X-axis, anticlockwise
(d) –ve direction of X-axis, anticlockwise

**20.** A particle of mass $5 \times 10^{-5}$ kg and charge $2 \times 10^{-3}$ C moves from rest in a uniform electric magnitude 5 V/m. Its kinetic energy after 10 seconds is

(a) $2\times10^3$J
(b) $10^3$ J
(c) $10^2$ J
(d) $10^{-3}$ J

**21.** A ring of radius R carries a charge Q uniformly distributed over its length. A charge $q$ at centre will experience a force equal to

(a) $\frac{qQ}{4\pi\epsilon_0 r^2}$
(b) $\frac{qQ}{8\pi\epsilon_0 r^2}$
(c) zero
(d) none of these

**22.** Two charges +6 nC and +15 nC are placed along the x-axis at $x = 0$ and $x = 2$ m respectively. A negative charge $q$ is placed between them such that the resultant force on it is zero. The negative charge is placed at

(a) 0.755 m
(b) 0.58 m
(c) 0.66 m
(d) 0.225 m

**23.** Which of the following statements is true?

(a) the number of times electric lines of force cross depends on the charge distribution.

(b) no two lines of force can intersect each other.

(c) two lines of force intersect each other at least once.

(d) lines of force in a dielectric medium can intersect each other.

**24.** What is the unit of physical quantity obtained by the line integral of electric field?

(a) $JC^{-1}$
(b) $NC^{-1}$
(c) $Vm^{-1}$
(d) $C^2N^{-1}m^2$

**25.** An electron of mass $M_e$ initially at rest, moves through a certain distance in a uniform electric field in time $t_1$. A proton of mass $M_p$ also initially at rest takes time $t_2$ to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio $t_1 / t_2$ is nearly equal to:

(a) 1
(b) 1836
(c) $\sqrt{\frac{M_e}{M_p}}$
(d) $M_p/M_e$

**26.** Let the force acting between two charges be F, if air is replaced by another medium having relative permittivity 2, then the force acting between them becomes

(a) F/2
(b) 4F
(c) F/4
(d) 2F

**27.** The force of interaction between two charges $q_1 = 6\ nC$ and $q_2 = 2nC$ is 12 N. If charge $q = -2nC$ is added to each of the charges then the new force of interaction is:

(a) 0 N
(b) 8 N
(c) 10 N
(d) 12 N

**28.** Electric intensity at any point on the equatorial line of a electric dipole is directed along

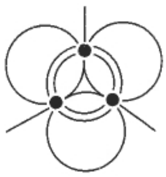
(a) in the direction of $p$

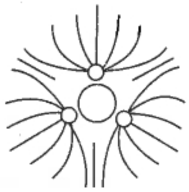
(b) in a direction opposite of that of $p$

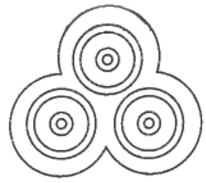
(c) in a direction perpendicular to $p$

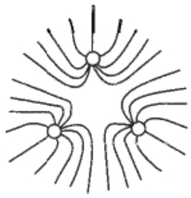
(d) in any other direction.

**29.** Which one of the following represents the lines of forces of three positive charges of equal value $q$ are placed at the vertices of an equilateral triangle?

(a) 

(b) 

(c) 

(d) 

**30.** Let a charge Q is placed at the centre of the line joining two equal charges $q$. This system of three charges will be in equilibrium if Q is equal to:

(a) $\frac{q}{4}$

(b) $\frac{q}{2}$

(c) $-\frac{q}{4}$

(d) $-\frac{q}{2}$

**31.** A point charge q is kept at the centre of a metallic insulated spherical shell. Then

(a) electric field outside the sphere is zero

(b) net induced charge on the sphere is zero

(c) electric field inside the sphere is zero

(d) electric potential inside the sphere is zero.

**32.** Let $\left|\vec{E}_{axial}\right|$ and $\left|\vec{E}_{equatorial}\right|$ and be the magnitude of electric field intensity of a dipole along its axial direction and along its equatorial line respectively then ,

(a) $\left|\vec{E}_{axial}\right| = \left|\vec{E}_{equatorial}\right|$

(b) $3\left|\vec{E}_{axial}\right| = 2\left|\vec{E}_{equatorial}\right|$

(c) $\left|\vec{E}_{axial}\right| = 2\left|\vec{E}_{equatorial}\right|$

(d) $2\left|\vec{E}_{axial}\right| = 3\left|\vec{E}_{equatorial}\right|$

**33.** A hollow metal sphere of radius 5 cm is charged, such that the potential on its surface is 20 V. The potential at the centre of the sphere is:

(a) 0 V

(b) 20 V

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

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

**34.** If one penetrates a uniformly charged sphere, the electric field strength

(a) increases

(b) remains the same as at the surface

(c) decreases

(d) is zero at all points

**35.** The number of electric field lines entering and leaving an enclosed surface respectively are $\phi_1$ and $\phi_2$. Then electric charge inside the surface is given by :

(a) $(\phi_1 - \phi_2)\varepsilon_0$

(b) $(2\phi_1 - 3\phi_2)/\varepsilon_0$

(c) $(\phi_1 + \phi_2)/\varepsilon_0$

(d) $(\phi_2 - \phi_1)/\varepsilon_0$

**36.** A soap bubble is given a positive charge. Then its radius

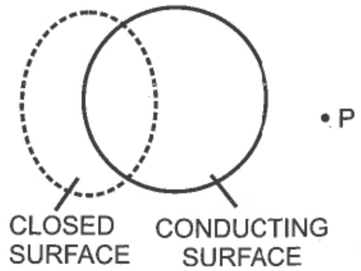
(a) decreases

(b) increases

(c) remains unchanged

(d) nothing can be predicted

**37.** Figure shows a closed surface which intersects a charged metal ball. If a positive charge is placed at the point P, the flux of the electric field through the closed surface :



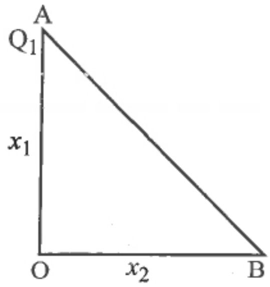

(a) will remain zero

(b) will become negative

(c) will become positive

(d) will become undefined.

**38.** Charges $Q_1$ and $Q_2$ are at points A and B of a right angle triangle OAB (see figure). The resultant electric field at point O is perpendicular to the hypotenuse, then $Q_1/Q_2$ is proportional to :




(a) $\frac{x_1^3}{x_2^3}$ (b) $\frac{x_2^3}{x_1^3}$ (c) $\frac{x_1}{x_2}$ (d) $\frac{x_2}{x_1}$

**39.** Electric potential at any point inside a charged hollow sphere:

(a) increases with distance (b) is a constant

(c) decreases with distance (d) is zero.

**40.** Electric field intensity at any point at a distance r from a infinite linear charge distribution varies

(a) directly as $r$ (b) inversely as $r$

(c) directly as $r^2$ (d) inversely as $r^2$

**41.** Debye is the unit of

(a) electric flux (b) electric dipole moment

(c) electric potential (d) electric field intensity

**42.** An infinite plane sheet of a metal is charged to charge density σ $C/m^2$ in a medium of dielectric constant K. Intensity of electric field near the metallic surface will be:

(a) $E = \frac{\sigma}{\varepsilon_0 K}$ (b) $E = \frac{\sigma}{2\varepsilon_0}$ (c) $E = \frac{\sigma}{2\varepsilon_0 K}$ (d) $E = \frac{K\sigma}{2\varepsilon_0}$

**43.** A circular disc of radius R is held parallel to a uniform field of strength E. Net electric flux associated with the disc is:

(a) zero (b) $E \times \pi r^2$ (c) $E \times 2\pi r$ (d) $E \times 4\pi r$

**44.** Solid angle subtended by a sphere at its centre is :

(a) $2\pi$ (b) $2\pi^2$ (c) $4\pi^2$ (d) $4\pi$

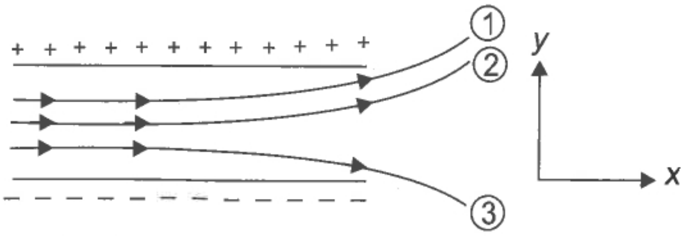
**45.** Electric flux linked with a given plane surface is maximum when the angle between the electric lines of force and the normal to the surface is :

(a) 0° (b) 45° (c) 90° (d) 135°

**46.** A rectangular sheet of dimension $a \times b$ is held perpendicular to a uniform field of strength E.The flux linked with the surface is :

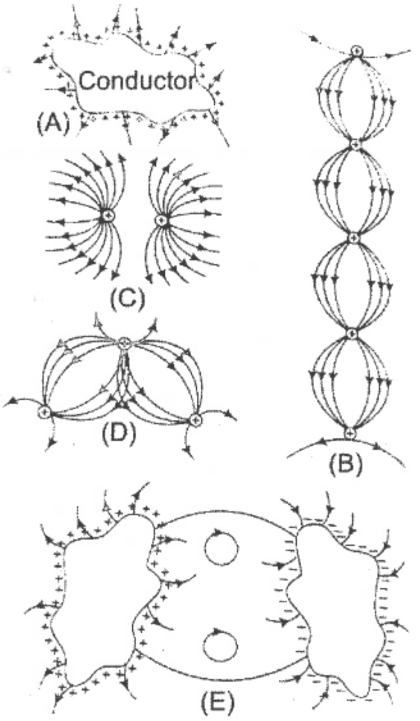
(a) zero (b) $Eab$ (c) $Ea^2$ (d) $4Ea$

**47.** Figure below shows tracks of three charged particles in a uniform electrostatic field. Which particle has the highest charge to mass ratio? (hint: particle 3 shows maximum deflection)




(a) 1 (b) 2 (c) 3 (d) Data insufficient

**48.** Which among the following represents the electric field lines?




(a) (A), (C) (b) (B) only (c) (C) only (d) (D), (E)

**49.** Charge $q_2$ of mass m revolves around a stationary charge $q_1$ in a circular orbit of radius $r$. The orbital periodic time of $q_2$ would be

(a) $\left[\dfrac{4\pi^2 mr^3}{kq_1q_2}\right]^{\frac{1}{2}}$ (b) $\left[\dfrac{4\pi^2 mr^4}{kq_1q_2}\right]^{\frac{1}{2}}$ (c) $\left[\dfrac{4\pi^2 mr^2}{kq_1q_2}\right]^{\frac{1}{2}}$ (d) $\left[\dfrac{kq_1q_2}{4\pi^2 mr^3}\right]^{1/2}$

**50.** 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) $(-Q)/4) \times (1 + 2\sqrt{2})$ (b) $(-Q)/2) \times (1 + 2\sqrt{2})$

(c) $(Q/4) \times (1 + 2\sqrt{2})$ (d) $(Q/2) \times (1 + 2\sqrt{2})$

**51.** There exists an electric field of 1 N/C along Y direction. The flux passing through the square of 1 m placed in XY plane inside the electric field is

(a) 1.0 $Nm^2C^{-1}$ (b) 10.0 $Nm^2C^{-1}$ (d) zero (c) 2.0 $Nm^2C^{-1}$

**52.** An electric dipole is placed in an uniform electric field with the dipole axis making an angle θ with the direction of the electric field. The orientation of the dipole for stable equilibrium is

(a) π/6 (b) π/3 (c) 0 (d) π/2

**53.** A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will

(a) be reduced to half (b) remain the same

(c) be doubled (d) increase four times

**54.** The Gaussian surface for calculating the electric field due to a charge distribution

(a) any surface near the charge distribution

(b) always a spherical surface

(c) a symmetrical closed surface containing the charge distribution, at every point of which electric field has a single fixed value

(d) None of the given options

**55.** The electric field at a point due to an electric dipole, on an axis inclined at an angle θ (<90°) to the dipole axis, is perpendicular to the dipole axis, if the angle is is θ

(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(\sqrt{2})$ (c) $\tan^{-1}\frac{1}{2}$ (d) $\tan^{-1}\frac{1}{\sqrt{2}}$

**56.** Two copper balls, each weighing 10 g, are kept in air 10 cm apart. If one electron from every $10^6$ atoms is transferred from one ball to the other, the Coulomb force between them is (atomic weight of copper is 63.5)

(a) $2.0 \times 10^{10}$N (b) $2.0 \times 10^4$ N (c) $2.0 \times 10^7$ N (d) $2.0 \times 10^6$ N

**57.** If the linear charge density of a cylinder is 4μ $Cm^{-1}$, then electric field intensity at point 3.6 cm from axis is

(a) $4 \times 10^5$ $NC^{-1}$ (b) $2 \times 10^6$ $NC^{-1}$ (c) $8 \times 10^7$ $NC^{-1}$ (d) $12 \times 10^7$ $NC^{-1}$

**58.** If $10^{10}$ electrons are acquired by a body every second, the time required for the body to get a total charge of C will be

(a) 2 h (b) 2 days (c) 2 yr (d) 20 yr

**59.** A ball with charge –50 e placed at the centre of a hollow spherical shell has a net charge of –50e. What is the charge on the shell's outer surface?

(a) –50e (b) Zero (c) –100e (d) +100e

**60.** Two identical conducting balls A and B have positive charge. $q_1$ and $q_2$ respectively but $q_1 \neq q_2$. The balls are brought together so that they touch each other and then kept in their original positions, the force between them is

(a) less than that before the balls touched
(b) greater than that before the balls touched
(c) same as that before the balls touched
(d) zero

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

(a) –1.6 C (b) $10^{+19}$ C (c) +1.6 C (d) $10^{-19}$ C

**62.** Mark the correct option.

(a) In electrostatics, there is no motion of charge at all in conductor's bulk
(b) In electrostatics, there is a motion of charged particle in conductor's bulk
(c) In electrostatics and current electricity them is a net motion of charged particles in the bulk of the material of the conductor
(d) In electrostatics and current electricity them is no net motion of charged particles in the bulk of the material of the conductor

**63.** Among two discs A and B, first has radius 10 cm and charge $10^{-5}$ C and second has radius 30 cm and charge $10^{-6}$C. When they are touched, charges on both are, $q_A$ and $q_B$ respectively will be

(a) $q_A$ = 2.75 μC, $q_B$ = 3.15μC
(b) $q_A$ = 1.09μC, $q_B$ = 1.53 μC
(c) $q_A = q_B$ = 5.5 μC
(d) None of the above.

**64.** Two charges are at a distance *d* apart. If a copper plate of $\frac{d}{2}$ thickness is kept between them, the effective force will be

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

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

(a) always along a line of force
(b) along a line of force, if its initial velocity is zero
(c) along a line of force, if it has same initial velocity in the direction of an active angle with the line of force
(d) None of the above

**66.** An electron moving with the speed $5 \times 10^6$ per sec is shooted parallel to the electric field of intensity $1\times10^3$ N/C. Field is responsible for the retardation of motion of electron. Now evaluate the distance travelled by the electron before coming to rest for an instant (mass of e = $9\times10^{-31}$ kg, charge = $1.6\times10^{-19}$ C)

(a) 7 m (b) 0.7 mm (c) 7 cm (d) 0.7 cm

67. A charged particle of mass $m$ and charge $q$ is released from rest in uniform electric field E. Neglecting the effect of gravity, the kinetic energy of the charged particle after $t$ second is
(a) $Eq^2M/2t^2$ (b) $E^2q^2t^2/2m$ (c) $2E^2t^2/mq$ (d) $Eqm/t$

68. Electric flux emanating through a surface element $\vec{ds} = 5\hat{i}$ placed in an electric field $\vec{E} = 4\hat{i} + 4\hat{j} + 4\hat{k}$ is
(a) 10 units (b) 4 units (c) 20 units (d) 16 units

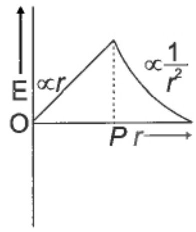
69. When air medium in which two charges kept apart at a distance $r$ is replaced by a dielectric medium of dielectric constant K, the force between the charges
(a) remains unchanged
(b) decreases K times
(c) increases K times
(d) increases $K^2$ times

70. A charged oil drop is suspended in uniform field of $3\times10^4$ V/m so that it neither falls nor rises. The charge on the drop will be (Take the mass of the charge = $9.9\times10^{-15}$ kg and g = 10 m/s$^2$)
(a) $3.3\times10^{-18}$ C (b) $1.6\times10^{-18}$ C (c) $3.2\times10^{-18}$ C (d) $4.8\times10^{-18}$ C

71. Which one of the following is not a property of field lines?
(a) Field lines are continuous curves without any breaks.
(b) Two field lines cannot cross each other.
(c) Field lines start at positive charges and end at negative charges.
(d) They form closed loops.

72. The magnitude of electric field balance an oil drop of mass $m$, carrying charge $q$ in oil drop experiment is ($g$ = acceleration due to gravity)
(a) $q/m$ (b) $(mg)/(q^2)$ (c) $mgq$ (d) $(mg)/q$

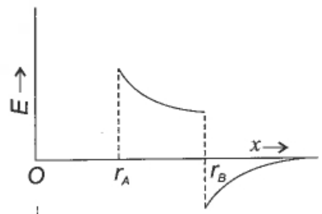
73. The figure shown below describes the variation of electric field E at a distance r in any direction from the origin O. The electric field E is due to

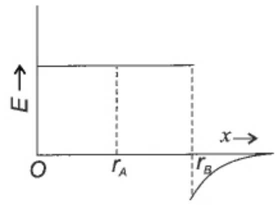


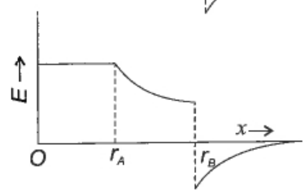

(a) a charged hollow metallic sphere of radius OP with centre at O
(b) a charged solid metallic sphere of radius OP with centre at O
(c) a uniformly charged non-conducting sphere of radius OP with centre at O
(d) a uniformly charged non-conducting hollow sphere of radius OP with centre at O

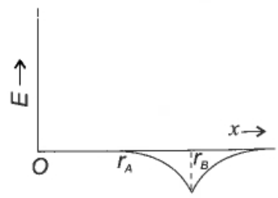
74. The point charges Q and –2 Q are placed some distance apart. If the electric field at the location of Q is E, then the electric field at the location of –2 Q will be
(a) –E/2 (b) –(3E)/2 (c) –E (d) –2E

75. Two concentric conducing thin spherical shells A and B having radii $r_A$ and $r_B$( $r_B > r_A$) are charged to $Q_A$ and $-Q_B$ ($|Q_B| > |Q_A|$). The electric field along a line passing through the centre is

(a)


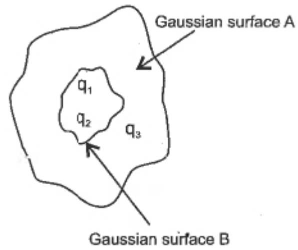

(b)



(c)



(d)



76. Two parallel large thin metal sheets have equal surface charge densities of $2.56 \times 10^{-11}$ Cm$^{-3}$ of opposite signs. The electric field between these sheets is
(a) 15NC$^{-1}$ (b) $1.5 \times 10^{-10}$NC$^{-1}$ (c) 3 NC$^{-1}$ (d) $3 \times 10^{-10}$ NC$^{-1}$

**77.** The electric flux for Gaussian surface A that encloses the charged particles in free space is (Given $q_1 = -14nC$; $q_2 = 78.85nC$ and $q_3 = -56nC$)




(a) $10^3$ Nm$^2$ C$^{-1}$
(b) $10^3$ CN$^{-1}$m$^{-2}$
(c) $6.32\times10^3$ Nm$^2$ C$^{-1}$
(d) $6.32\times10^3$ CN$^{-1}$m$^{-2}$

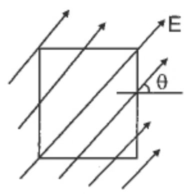
**78.** The electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 10 cm surrounding the total charge is 20 Vm. The flux over a concentric sphere of radius 20 cm will be

(a) 20 Vm (b) 25 Vm (d) 200 Vm (c) 40 Vm

**79.** A semi-circular arc of radius $a$ is charged uniformly and the charge per unit length is 2. The electric field at the centre is

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

**80.** A square surface of side L metre in the plane of the paper is placed in a uniform electric field E (volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure. The electric flux linked to the surface, in units of volt m, is




(a) E L$^2$ (b) E L$^2$ sin θ
(c) E L$^2$ cos θ (d) zero

**81.** Two positive ions, each carrying a charge q, are surface separated by a distance d. If F is the force of repulsion outward between the ions, the number of electrons missing from each ion will be (e being the charge of an electron)

(a) $\dfrac{4\pi\varepsilon_0 Fd^2}{e^2}$ (b) $\sqrt{\dfrac{4\pi\varepsilon_0 Fe^2}{d^2}}$ (c) $\sqrt{\dfrac{4\pi\varepsilon_0 Fd^2}{e^2}}$ (d) $\dfrac{4\pi\varepsilon_0 Fe^2}{d^2}$

**82.** If σ = surface charge density, ε = electric permittivity, the dimensions of $\dfrac{\sigma}{\varepsilon}$ are same as

(a) electric force (b) pressure (c) electric field intensity (d) electric charge

**83.** A point charge of q coulomb is placed at the centre of a cube of side 2 cm. The flux through one of the cube faces is

(a) $\dfrac{q}{6\varepsilon_0}$ (b) $-\dfrac{q}{6\varepsilon_0}$ (c) $\dfrac{6q}{\varepsilon_0}$ (d) $-\dfrac{6q}{\varepsilon_0}$

**84.** The frequency of oscillation of an electric dipole moment having dipole moment p and rotational inertia I, oscillating in a uniform electric field E, is given

(a) $(1/2\pi)\sqrt{\dfrac{1}{pE}}$ (b) $(1/2\pi)\sqrt{\dfrac{pE}{I}}$ (c) $2\pi\sqrt{\dfrac{I}{pE}}$ (d) $2\pi\sqrt{\dfrac{pE}{I}}$

**85.** A hollow cylinder has a charge q coulomb within it. If ϕ is the electric flux in unit of volt metre associated with the curved surface B the flux linked with the plane surface A in unit of volt metre will be

(a) $\dfrac{1}{2}(\dfrac{q}{\varepsilon_0} - \phi)$ (b) $\dfrac{q}{2\varepsilon_0}$ (c) $\dfrac{\phi}{3}$ (d) $(\dfrac{q}{\varepsilon_0} - \phi)$

**86.** A charge of magnitude 3 e and mass 2m is moving in an electric field E. The acceleration imparted to the charge is

(a) (2Ee) / (3 m) (b) (3Ee) / (2 m) (c) (2 m) / (3Ee) (d) (3 m) / (2Ee)

**87.** In the basic CsCl crystal structure, $Cs^+$ and $Cl^-$ ions are arranged in a bcc configuration as shown in the figure. The net electrostatic force exerted by the eight $Cs^+$ ions on the $Cl^-$ ion is

(a) $\dfrac{4e^2}{4\pi\varepsilon_0 3a^2}$ (b) $\dfrac{16e^2}{4\pi\varepsilon_0 3a^2}$ (c) $\dfrac{32e^2}{4\pi\varepsilon_0 3a^2}$ (d) zero

**88.** A simple pendulum has a length $l$ and the mass of the bob is $m$. The bob is given a charge of $q$ coulomb. The pendulum is suspended between the vertical plates of a charged parallel plate capacitor. If E is the electric field strength between the plates, the time period of the pendulum is given by

(a) $2\pi\sqrt{\frac{l}{g}}$ (b) $2\pi\sqrt{\frac{l}{\sqrt{g+\frac{qE}{m}}}}$ (c) $2\pi\sqrt{\frac{l}{\sqrt{g-\frac{qE}{m}}}}$ (d) $2\pi\sqrt{\frac{l}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

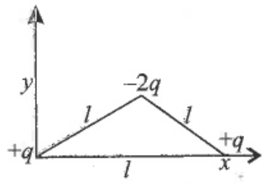
**89.** Two infinitely long parallel conducting plates having surface charge densities $+\sigma$ and $-\sigma$ respectively are separated by a small distance. The medium between the plates is vacuum. If $\varepsilon_0$ is the dielectric permittivity of vacuum, then the electric field in the region between the plates is

(a) $0\ Vm^{-1}$ (b) $\frac{\sigma}{2\varepsilon_0}$ (c) $\frac{\sigma}{\varepsilon_0}$ (d) $\frac{2\sigma}{\varepsilon_0}$

**90.** An electric dipole placed in a non-uniform electric field experiences

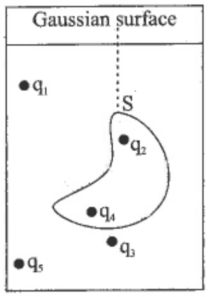
(a) both a torque and a net force (b) only a force but no torque
(c) only a torque but no net force (d) no torque and no net force.

**91.** Determine the electric dipole moment of the system of the three charges, placed on the vertices of an equilateral triangle, as shown in the figure :




(a) $(ql)\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$ (b) $\sqrt{3}ql\left(\frac{\hat{j}-\hat{i}}{\sqrt{2}}\right)$ (c) $-\sqrt{3}ql\hat{j}$ (d) $2ql\hat{j}$

**92** An arrangement of charges is done as shown in figure. Five charges $q_1$, $q_2$, $q_3$, $q_4$ and $q_5$ are fixed at their positions. Here, S is a Gaussian surface. The Gauss' law is given by $\oint E.ds = \frac{q}{\varepsilon_0}$. According to this law which of the following statements is correct?




(a) E on the LHS of the above equation will have a contribution from $q_1$, $q_5$ and $q_3$ while $q$ on the RHS will have a contribution from $q_2$ and $q_4$ only
(b) E on the LHS of the above equation will have a contribution from all charges while $q$ on the RHS will have a contribution from $q_2$ and $q_4$ only
(c) E on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from $q_1$, $q_3$, and $q_5$ only
(d) Both E on the LHS and $q$ on the RHS will have contributions from $q_2$ and $q_4$ only

## INPUT TEXT BASED MCQs

**1.** *According to Coulomb's law, the force between two point charges and found that it varied inversely as the square of the distance between the charges and was directly proportional to the product of the magnitude of the two charges and acted along the line joining the two charges. Thus, if two point charges $q_1$, $q_2$ are separated by a distance r in vacuum, the magnitude of the force (F) between them is given by*

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


*Here $\varepsilon_0$ is called the permittivity of free space and its value in SI units is $8.854 \times 10^{-12}\ C^2\ N^{-1}m^{-2}$.*

**(i)** In Coulomb's law, $F = k\frac{q_1 q_2}{r^2}$, then on which of the following factors does the proportionality constant k depends?

(a) Electrostatic force acting between the two charges
(b) Nature of the medium between the two charges
(c) Magnitude of the two charges
(d) Distance between the two charges

**(ii)** Dimenstional formula for the permittivity constant $\varepsilon_0$ of free space is

(a) $[ML^{-3}T^4A^2]$ (b) $[M^{-1}L^3T^2A^2]$ (c) $[M^{-1}L^{-3}T^4A^2]$ (d) $[ML^{-3}T^4A^{-2}]$

**(iii)** The force of repulsion between two charges of 1C each kept 1m apart in vaccum is

(a) $\frac{1}{9\times10^9}$N (b) $9\times10^9$N (c) $9\times10^7$ N (d) $\frac{1}{9\times10^{12}}$N

**(iv)** Two identical charge repel each other with a force equal to 10 mgwt when they are 0.6m apart in air ($g = 10ms^{-2}$). The value of each charge is

(a) 2mC (b) $2\times10^{-7}$ mC (c) 2nC (d) 2μC

**(v)** Coulomb's law for the force between electric charges most closely resembles with

(a) law of conservation of energy (b) Newton's law of gravitation
(c) Newton's 2nd law of motion (d) Law of conservation of charge

2. *Experimentally it is established that all free charges are integral multiples of a basic unit of charge denoted by e. Thus charge q on a body is always given by $q = \pm ne$*

*Where n= 1,2,3,4...*

*Hence no body can have a charge represented as 1.1e, 2.7e, etc.*

**(i)** Which of the following properties is not satisfies by an electric charge?

(a) Total charge conservation (b) Quantization of charge
(c) Two types of charge (d) Circular line of force

**(ii)** Which of the following charges is possible?

(a) $5.8\times10^{-18}$ C (b) $3.2\times10^{-18}$ C (c) $4.5\times10^{-19}$ C (d) $8.6\times10^{-19}$ C

**(iii)** If a charge on a body is 1nC, then how many electrons are present on the body?

(a) $6.25\times10^{27}$ (b) $1.6\times10^{19}$ (c) $6.25\times10^{28}$ (d) $6.25\times10^9$

**(iv)** If a body gives out $10^9$ electrons every second, how much time is required to get a total charge of 1C from it?

(a) 190.19 years (b) 150.12 years (c) 198.19 years (d) 188.21 years

**(v)** A polythene piece rubbed with wool is found to have a negative charge of $3.2\times10^{-7}$ C. Calculate the electrons transferred.

(a) $2\times10^{12}$ (b) $3\times10^{12}$ (c) $2\times10^{14}$ (d) $3\times10^{14}$

## ANSWERS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. (a) | 2. (b) | 3. (b) | 4. (b) | 5. (c) | 6. (a) | 7. (b) | 8. (b) | 9. (d) | 10. (a) |
| 11. (c) | 12. (a) | 13. (c) | 14. (d) | 15. (a) | 16. (c) | 17. (b) | 18. (d) | 19. (a) | 20. (c) |
| 21. (c) | 22. (a) | 23. (b) | 24. (a) | 25. (c) | 26. (a) | 27. (a) | 28. (b) | 29. (d) | 30. (a) |
| 31. (b) | 32. (c) | 33. (b) | 34. (c) | 35. (a) | 36. (b) | 37. (c) | 38. (c) | 39. (b) | 40. (b) |
| 41. (b) | 42. (a) | 43. (a) | 44. (d) | 45. (a) | 46. (b) | 47. (c) | 48. (c) | 49. (a) | 50. (c) |
| 51. (a) | 52. (c) | 53. (b) | 54. (c) | 55. (b) | 56. (c) | 57. (b) | 58. (d) | 59. (d) | 60. (b) |
| 61. (c) | 62. (a) | 63. (c) | 64. (b) | 65. (b) | 66. (c) | 67. (b) | 68. (c) | 69. (b) | 70. (a) |
| 71. (d) | 72. (d) | 73. (c) | 74. (a) | 75. (c) | 76. (c) | 77. (a) | 78. (a) | 79. (c) | 80. (d) |
| 81. (c) | 82. (c) | 83. (a) | 84. (b) | 85. (a) | 86. (b) | 87. (d) | 88. (d) | 89. (c) | 90. (a) |
| 91. (c) | 92. (b) | | | | | | | | |

**Input Text Based MCQs**

**1.** (i) (b), (ii) (c), (iii) (b), (iv) (d), (v) (b) **2.** (i) (d), (ii) (b), (iii) (d), (iv) (c), (v) (a)