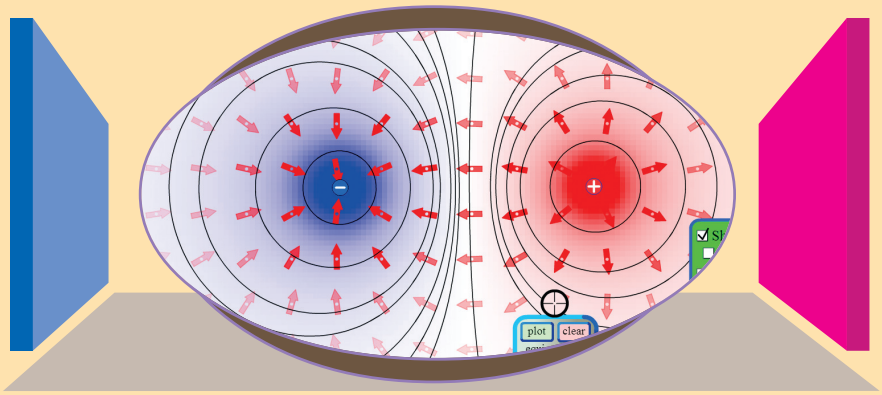
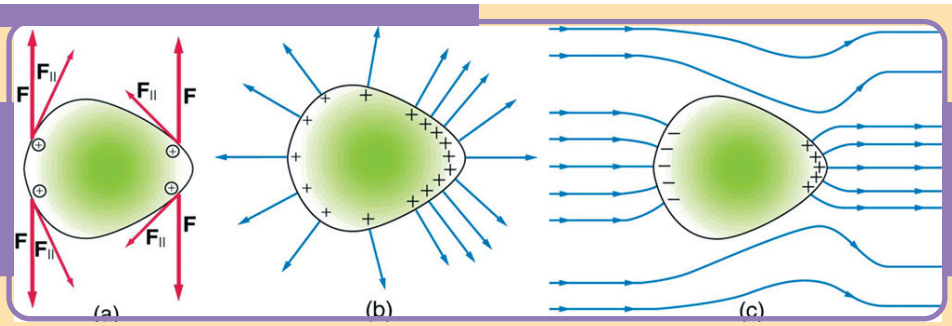


CHAPTER 1

ELECTRIC CHARGES AND FIELDS



CONTENTS

NEET Syllabus

Electric charges and their conservation. Coulomb's law-force between two point charges, forces between multiple charges; superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines; electric dipole, electric field due to a dipole; torque on a dipole in a uniform electric field.Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside)

INTRODUCTION

- Electrostatics is the branch of Physics, which deals with static electric charges or charges at rest. In this chapter, we shall study the basic phenomena about static electric charges. The charges in a electrostatic field are analogous to masses in a gravitational field. These charges have forces acting on them and hence possess potential energy. The ideas are widely used in many branches of electricity and in the theory of atom.

CHARGE

- An American Scientist Benjamin Franklin introduced a convention that charge that appears on amber (resinous) is –ve and that on wool (vitreous) is +ve.
- The gravitational force of attraction between two electrons 1 cm apart = 5.5×10^{-67} N. However an electron repels another electron at 1 cm with a force 2.3×10^{-24} N. This force is called electric force which is much larger than gravitational force $F_e/F_g \simeq 10^{42}$.
- Charge is quantized, all observable charges must be an integral multiples of electron's charge ($e = 1.6 \times 10^{-19}$ C). If an object contains n_1 protons and n_2 electron, the net charge on it is $(n_1 - n_2)e$.
- **Quarks:** These are the particles having fractional charges (e.g., e/ 3 ; –e/3) but they never exist independently. They exist in group so as to make total charge on a body as an integral multiple of e.
- In macroscopic level, quantization of charge is insignificant.
- A neutral body has equal number of protons and electrons.
- A +ve charge means loss of electrons.
- A –ve charges means gain of electrons.
- Like charges repel each other and unlike charges attract each other.
- S.I. unit of charge is coulomb (C).
- Units of charge
  SI : Coulomb, CGS : esu/Stat Coulomb/Franklin
  $1\ C = 3 \times 10^9$ Stat Coulombs, $1\ Ah = 3600\ C$
- Electric charge of an isolated system is conserved.
- Charge is relativistically invariant
  $q_{rest} = q_{relativisitc\ speeds}$.
- A charged body may attract a light uncharged body due to charging by induction.
- Static charge produces electric field only. But charge in motion can produces electric and magnetic field both.
- Oscillating or accelerating charge emits electro magnetic radiation.

METHODS OF CHARGING

1. Charging by Friction

This is the introductory electrostatics. When two bodies are rubbed with each other, due to friction electrons are transferred from one body to other. Some examples of frictional electricity are given below.

- A comb passed through dry hair becomes charged.
- An automobile is charged as it passes through air.
- A paper sheet is charged when it is passed through a printing machine.
- A gramophone record becomes charged where it is rubbed with dry cloth.
- Charge on a glass rod rubbed with silk is conventionally taken as +ve, the charge on silk being -ve. Electrons are transferred from glass to silk.
- Charge on an ebonite (or amber) rod rubbed with fur (or wool) conventionally taken as –ve, the charge on fur (or wool) being +ve. Electrons are transferred from fur (or wool) to ebonite or amber. Thus once being rubbed an ebonite rod starts attracting fur (or wool).
- Metals have free electrons (or amber outer most electrons due to their zero inertia are free to move). Thus they can conduct electricity due to their free electrons.
- Electrolysis conduct due to their +ve as well as –ve ions.
- Insulators or dielectrics have no free electron. Hence they do not conduct.
- Semiconductors behave like insulators at low temperature, but at room temperature they conduct electricity due to their free electrons and holes

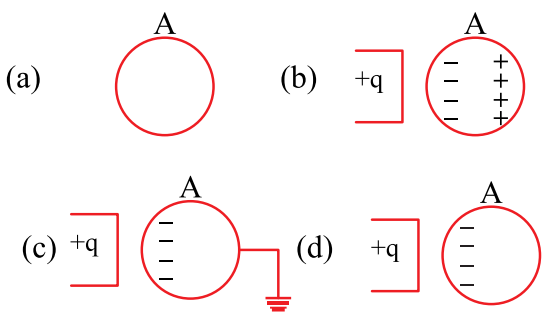
2. Charging by Conduction

- When a charged body is touched with a neutral body, some amount of charge is flown from

charged body to neutral body (actually, electrons flow from low potential body to high potential body) till electric potential of both bodies are equal. So in this case, the neutral body becomes charged and the nature of charge developed in this body is identical to that on initial charged body.

3. Charging by Induction

- In this process, a charged body (let take q) should be placed very close to neutral body without touching it.
- In neutral body, opposite charges (in this case – ve) will appear at the near end to charged body and like charges (in this case +ve) will appear at far end. This rearrangement of charges in neutral body is known as induction.
- For charging by induction, neutral body should be grounded / earthed. So charges appeared in far end is neutralized by transfer of electrons between the earth and body. Leaving only near end charges (in this case –ve) in the body.
- After removing earth and then the charged body, the excess charge (in this case –ve) in neutral body is distributed uniformly, making the body oppositely charged.



- Amount of charge induced depends on nature of initially neutral body. If K is its dielectric constant, amount of charge induced

$$\boxed{q' = -q\left(1 - \frac{1}{K}\right)}$$ (will be discussed later)

For metals $K \to \infty$, So $q' = -q$.

For other bodies ($K > 1$), So $|q'| < |q|$

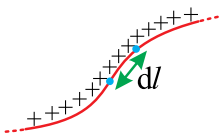
Earthing

- If any body is connected with earth then its potential becomes zero, charge may or may not be zero.
- If an isolated body is connected with earth then its potential and charge both are zero, in fact to make the potential zero, excess charge from the body is removed to earth.

DISTRIBUTION OF CHARGE

- **Linear charge distribution** : In which the charge is distributed along a line. Charge on small length dl

$$dq = \lambda dl \Rightarrow q = \int \lambda dl$$

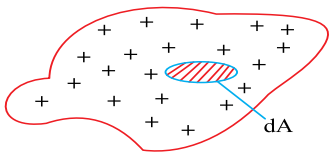


If charge is distributed uniformly $dq = \lambda dl$

where λ = linear charge density = $\frac{dq}{dl}$

- **Surface charge distribution** : In which the charge is distributed over a surface. Charge on a small area dA

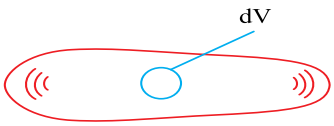
$$dq = \sigma dA \Rightarrow q = \int \sigma dA$$



where σ surface charge density = $\frac{dq}{dA}$

- **Volume charge distribution** : In which the charge is distributed in a volume charge on small volume dV

$$dq = \rho dV \Rightarrow q = \int \rho dV$$



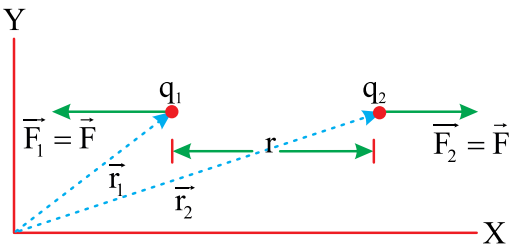
where ρ = volume charged density = $\frac{dq}{dV}$

COULOMB'S LAW

- Consider two point charges q_1 and q_2 are in vacuum at a separation r, the force between them is $F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$ where 'ϵ_0' is called permittivity of vacuum.

  In S.I. units, $\epsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$

  So, $\frac{1}{4\pi\epsilon_0} \simeq 9\times10^9\ Nm^2/C^2$



  Vectorically, $\vec{F}_1 = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2(\vec{r}_1-\vec{r}_2)}{|\vec{r}_1-\vec{r}_2|^3}$

  If the charges are located in a medium

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

  where ϵ = permittivity of the medium

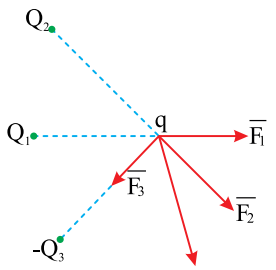
  Also, the ratio of ϵ and ϵ_0 is called = relative permittivity of the medium (ϵ_r)

  $\Rightarrow \epsilon = \epsilon_0\epsilon_r$

- 'ϵ_r' is also called dielectric constant of the medium. It is represented by 'k' also.
- Similar charges repel each other i.e. two positive charges (or two negative charges) exert force on each other that act away from the charges. Dissimilar charges attract each other.
- $\epsilon_r = 1$ for vacuum and $\epsilon_r \to \infty$ for metals
- Force between two charges in vacuum / Force between same charge in a medium of dielectric constant $k = \frac{F_0}{F} = k$.
- Coulomb's law is applicable for point charges only.
- Electrostatic force is a conservative force, which depends on intervening medium b/w charges.
- The force of interaction between two charges is independent of presence or absence of other charge(s).

SUPERPOSITION PRINCIPLE

- If more than two charges are present in space, the net force $\bar{F}$ on any charge q, is the vector sum of the electrical forces (coulomb forces) acting on it individually due to other charges.



  $\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$ where F_1 is the force on charge q due to charge Q_1 and so on.

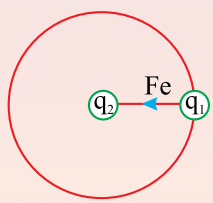
- If equal charges are symmetrically distributed around a given charge then resultant force on the given charge is zero.

Illustration 1 :

A particle of charge q_1 and mass m is revolving around a fixed negative charge of magnitude q_2 in a circular path of radius r. Find the time period of revolution.

Solution :

The force of attraction between q_1 and q_2 provides necessary centripetal force.



Hence $F_e = F_c = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2} = m\omega^2 r$

$\Rightarrow \omega = \sqrt{\frac{q_1q_2}{4\pi\epsilon_0 mr^3}}$ and Time period $T = \frac{2\pi}{\omega}$

$$T = 4\pi r\sqrt{\frac{\pi\epsilon_0 mr}{q_1 q_2}}$$

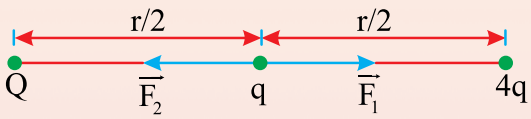
Illustration 2 :

Two point charges Q and q are placed at distance r and $\frac{r}{2}$ respectively along a straight line from a third charge 4q. If q is in equilibrium, determine $\frac{Q}{q}$.

Solution :

Net force on q = 0

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



$$\Rightarrow \frac{1}{4\pi\epsilon_0}\frac{Qq}{(r/2)^2} - \frac{1}{4\pi\epsilon_0}\frac{4q.q}{(r/2)^2} = 0$$

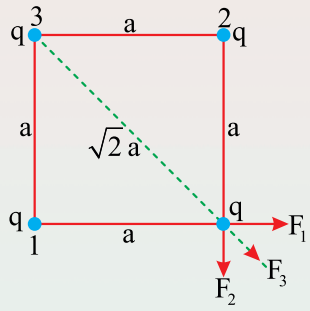
$$\Rightarrow \frac{Q}{q} = 4$$

Illustration 3 :

Consider four equal charges (q each) placed on the corners of a square with side a. Determine the magnitude and direction of the resultant force on the charge on lower right corner.

Solution:

The forces on the charge on lower right corner due to charges 1, 2, 3 are $F_1 = kq^2/a^2$, $F_2 = kq^2/a^2$, $F_3 = kq^2/2a^2$ The resultant of F_1 and F_2 is



$$F_{12} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos 90^\circ} = \sqrt{2}kq^2/a^2$$

This is in the direction parallel to F_3. Therefore the total force on the said charge is $F = F_{12} + F_3$

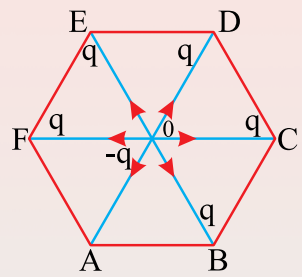
$F = \frac{1}{2}\frac{kq^2}{a^2}(1+2\sqrt{2})$ The direction of F is 45° below the horizontal line

Illustration 4 :

Five point charges, each of value +q are placed on five vertices of a regular hexagon of side L. What is the magnitude of the force on a point charge of value –q coulomb placed at the centre of the hexagon?

Solution:

If there had been a sixth charge +q at the remaining vertex of hexagon force due to all the six charges on -q at O will be zero (as the forces due to individual charges will balance each other), i.e., $\vec{F}_R = 0$.



Now If $\vec{f}$ is the force due to sixth charge and $\vec{F}$ due to remaining five charges, $\vec{F} + \vec{f} = 0$

i.e. $\vec{F} = -\vec{f}$ or,

$$F = f = \frac{1}{4\pi\varepsilon_0}\frac{q \times q}{L^2} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L}\right]^2$$

ELECTRIC FIELD

- The space around electric charge upto which its influence is felt is known as electric field.
- Electric field is a conservative field.
- **Intensity of Electric Field:** The intensity of electric field or electric field strength E at a point in space is defined as the force experienced by unit positive test charge placed at that point".
- The intensity of electric field is also often called as electric field strength.

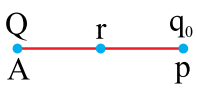
- Consider an electric field in a given region. Bring a charge q_0 to a given point in that field without disturbing any other charge that has produced the field.
- Let $\vec{F}$ be the electric force experienced by q_0 and it is found to be proportional to q_0

  $\vec{F} \propto q_0 \Rightarrow \vec{F} = \vec{E}q_0$. Here $\vec{E}$ is proportionality constant called electric field strength

  $$\vec{E} = \frac{\vec{F}}{q_0}$$
- Electric field strength is a vector quantity. Its direction is the direction along which a free positive charge experiences the force in the electric field.
- The S.I unit of electric field strength is newton per coulomb (NC^{-1}). It can also be expressed in volt per meter (Vm^{-1}).

Electric field internsity due to an isolated point charge :

- Consider a point charge 'Q' placed at point A as shown. Let us find the electric field $\vec{E}$ at a point P at a distance 'r' from charge Q. Imagine a positive test charge q_0 at P. The charge Q produces a field $\vec{E}$ at P.



The force applied by Q on q_0 is given by

$$F = \frac{1}{4\pi \in_0}\frac{Qq_0}{r^2}$$. This acts along AP.

According to definition

$$\vec{E} = \frac{\vec{F}}{q_0} \Rightarrow \vec{E} = \frac{1}{4\pi \in_0}\frac{Q}{r^2}\hat{r}$$

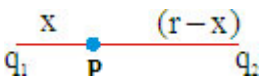
- If 'Q' is positive, E is along $\overrightarrow{AP}$ and if 'Q' is negative E will be along $\overrightarrow{PA}$.
- If the charge 'Q' is in a medium of permittivity ε, and dielectric constant K, $\left(K = \frac{\varepsilon}{\varepsilon_0}\right)$ the intensity of electric field in a medium (E_{med}) is given by

$$E_{med} = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2} \qquad \therefore E_{med} = \frac{E_{free\ space}}{K}$$

NULL POINT OR NEUTRAL POINT

- In the case of a system of charges if the net electric field is zero at a point, it is known as null point.
- **Application :** Two point (like) charge q_1 and q_2 are separated by a distance 'r' and fixed, We can locate the point on the line joining those charges where resultant or net field is zero.

Case 1: If the charges are like, the neutral point will be between the charges.



Let P be the null point where $\vec{E}_{net} = 0$

$\Rightarrow \vec{E}_1 + \vec{E}_2 = 0$ (due to those charges)

or $\vec{E}_1 = -\vec{E}_2$ and $E_1 = E_2$

$$\Rightarrow \frac{1}{4\pi \in_0}\frac{q_1}{x^2} = \frac{1}{4\pi \in_0}\frac{q_2}{(r-x)^2}$$

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

on solving we get $$x = \frac{r}{\sqrt{\frac{q_2}{q_1}} + 1}$$

Case 2 : If the charges are unlike, the neutral point will be outside the charge on the line joining them.

In this case $$\frac{q_1}{x^2} = \frac{q_2}{(r+x)^2}$$

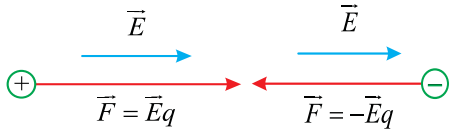
On solving we get $$x = \frac{r}{\sqrt{\frac{q_2}{q_1}} - 1}$$

- If instead of a single charge, field is produced by number of charges, by the principle of super position resultant electric field intensity $\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + ...$

MOTION OF A CHARGED PARTICLE IN A UNIFORM ELECTRIC FIELD :

A charged body of mass 'm' and charge 'q' is initially at rest in a uniform electric field of intensity E. The force acting on it, $F = Eq$.

- Here the direction of F is in the direction of field if 'q' is $+ve$ and opposite to the field if 'q' is $-ve$.



- The body travels in a straight line path with uniform acceleration $a = \frac{F}{m} = \frac{Eq}{m}$, initial velocity $u = 0$.

At an instant of time t.

Its final velocity, $v = u + at = \left(\frac{Eq}{m}\right)t$

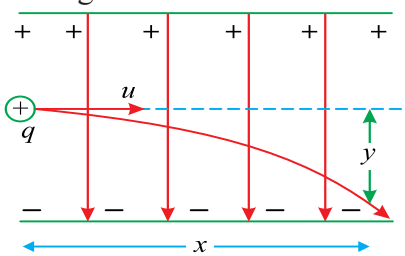
Displacement $s = ut + \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{Eq}{m}\right)t^2$

Momentum, $P = mv = (Eq)t$

Kinetic energy,

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{E^2q^2}{m}\right)t^2$$

- When a charged particle enters perpendicularly into a uniform electric field of intensity E with a velocity 'v' then it describes parabolic path as shown in figure.



- Along the horizontal direction, there is no acceleration and hence $x = ut$.

Along the vertical direction, acceleration

$a = \frac{F}{m} = \frac{Eq}{m}$ (here gravitational force is not considered)

Hence vertical displacement, $y = \frac{1}{2}\left(\frac{Eq}{m}\right)t^2$

$$y = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{x}{u}\right)^2 = \left(\frac{qE}{2mu^2}\right)x^2$$

- At any instant of time t, horizontal component of velocity, $v_x = u$
- vertical component of velocity

$$v_y = at = \left(\frac{Eq}{m}\right)t$$

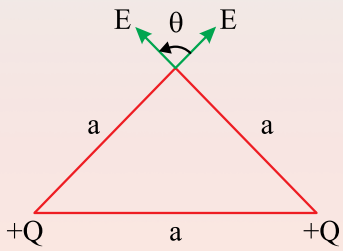
$$\therefore v = |\vec{v}| = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 + \frac{E^2q^2t^2}{m^2}}$$

- Two charges +Q each are separated by a distance 'd'. The intensity of electric field at the midpoint of the line joining the charges is zero.

Illustration 5 :

Two charges +Q each are placed at the two vertices of an equilateral triangle of side a. The intensity of electric field at the third vertex is

Solution:



$$E^1 = \sqrt{E^2 + E^2 + 2 \times E \times E \times \cos\theta}$$

$$= \sqrt{2E^2 + 2E^2\cos\theta} \quad = \sqrt{2E^2(1+\cos\theta)}$$

$$= 2E\cos\frac{\theta}{2}; \text{ Here } \theta = 60^0$$

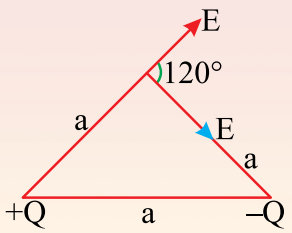
$$\therefore \quad E = \sqrt{3}\,\frac{1}{4\pi\epsilon_0}\frac{Q}{a^2}$$

Illustration6 :

Two charges +Q, -Q are placed at the two vertices of an equilateral triangle of side 'a', then the intensity of electric field at the third vertex is

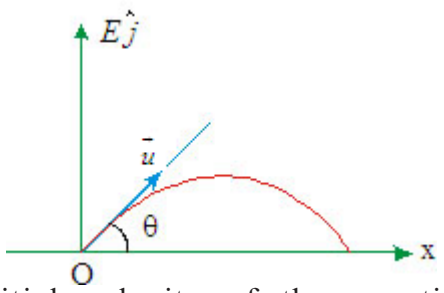
Solution:

$$E^1 = 2E\cos\frac{\theta}{2} = E\ (\theta = 120^0)$$



$$E^1 = \frac{1}{4\pi\in_0}\frac{Q}{a^2}$$

➢ **Oblique projection of charged particle in an uniform elctric field (Neglecting gravitational force) :** Consider a uniform electric field E in space along Y-axis. A negative charged particle of mass 'm' and charge 'q' be projected in the XY plane from a point 'O' with a velocity u making an angle θ with the X-axis. (Neglecting gravitational force).



➢ Initial velocity of the particle is $\vec{u} = u\cos\theta\hat{i} + u\sin\theta\hat{j}$

Force acting on the particle is $\vec{F} = q\vec{E}$ (along-ve Y axis)

$$\vec{a} = -\frac{qE}{m}\hat{j}$$

Velocity of the particle after time 't' is

$$\vec{v} = \vec{u} + \vec{a}t;\ \vec{v} = u\cos\theta\hat{i} + (u\sin\theta - at)\hat{j}$$

If the point of projection is taken as origin, its position vector after time 't' is

$\vec{r} = x\hat{i} + y\hat{j}$ where x=(ucos θ) t

$$y = (u\sin\theta)t - \frac{1}{2}at^2$$

If the charged particle is projected along the x-axis, then $\theta = 0^0$

$$\Rightarrow \bar{v} = u\hat{i} - \frac{Eq}{m}t\hat{j}$$

Here $x = ut$ and $y = \frac{1}{2}\frac{Eq}{m}t^2$

➢ Direction of motion of particle after time 't' makes an angle α with x-axis, where

$$\tan\alpha = \frac{Eqt}{mu}$$

➢ A charged particle of charge $\pm Q$ is projected with an initial velocity u in a vertically upward electric field making an angle θ to the horizontal. Then

If gravitational force is considered

Net force $= mg \mp F = mg \mp Eq$

Net acceleration $= g \mp \frac{Eq}{m}$

➢ The negative sign is used when electric field is in upward direction where as positive sign is used when electric field is in downward direction for positively charged projected particle.

a. Time of flight $= \dfrac{2u\sin\theta}{g \mp \frac{EQ}{m}}$

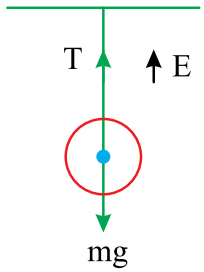
b. Maximum height $= \dfrac{u^2\sin^2\theta}{2\left(g \mp \frac{EQ}{m}\right)}$

c. Range $= \dfrac{u^2\sin 2\theta}{g \mp \frac{EQ}{m}}$

TIME PERIOD OF OSCILLATION OF A CHARGED BODY

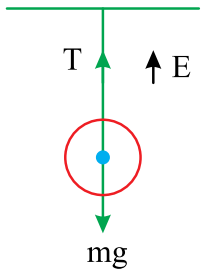
➢ The bob of a simple pendulum is given a +ve charge and it is made to oscillate in a vertically upward electric field, then the time period of oscillation is

$$T = 2\pi\sqrt{\frac{l}{g - \frac{EQ}{m}}}$$



- In the above case, if the bob is given a -ve charge then the time period is given by

$$T = 2\pi\sqrt{\frac{l}{g + \frac{EQ}{m}}}$$



- A sphere is given a charge of 'Q' and is suspended in a horizontal electric field. The angle made by the string with the vertical is,

$$\theta = \tan^{-1}\left(\frac{EQ}{mg}\right)$$

- The tension in the string is $\sqrt{(EQ)^2 + (mg)^2}$

Hence effective acceleration

$$g_{eff} = \frac{F}{m} = \sqrt{g^2 + \left(\frac{Eq}{m}\right)^2}$$

$\therefore$ Time period of oscillation is given by

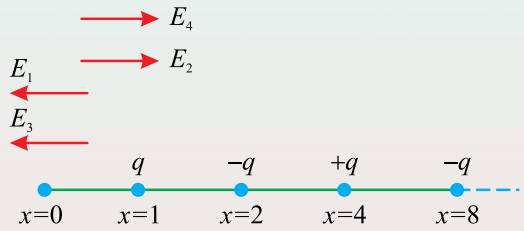
$$T = 2\pi\sqrt{\frac{l}{g_{eff}}} = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + \left(\frac{Eq}{m}\right)^2}}}$$

Illustration7 :

An infinite number of charges each 'q' are placed in the x-axis at distances of 1,2,4,8...meter from the origin. If the charges are alternately positive and negative find the intensity of electric field at origin.

Solution:

The electric field intensities due to positive charges and due to -ve charges the field intensity is towards the charges



The resultant intensity at the origin

$$E = E_1 - E_2 + E_3 - E_4 - - - - -$$

$$E = \frac{Q}{4\pi\epsilon_0}\left(1 - \frac{1}{2^2} + \frac{1}{4^2} - \frac{1}{8^2} + ...\right)$$

Since the expression in the bracket is in GP

with a common ratio $= = \frac{-1}{2^2} = \frac{-1}{4}$

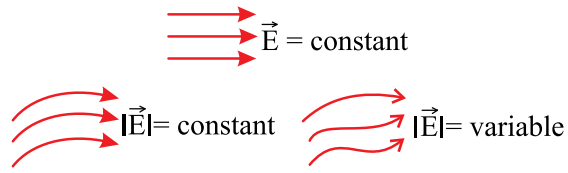
$$E = \frac{Q}{4\pi\epsilon_0}\frac{1}{\left[1 - \left(\frac{-1}{4}\right)\right]} = \frac{Q}{4\pi\epsilon_0}\frac{4}{5}$$

$$E = \frac{4}{5}\frac{Q}{4\pi\epsilon_0}$$

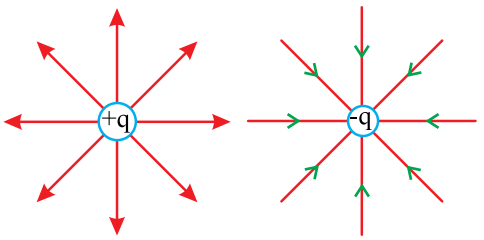
$$E = \frac{Q}{5\pi\epsilon_0}$$

ELECTRIC FIELD LINES

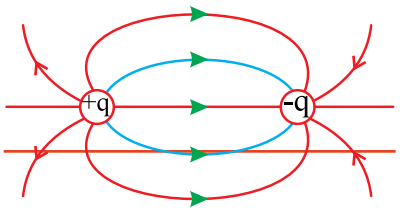
- It is a path such that the tangent to this path at any point gives the direction of electric field intensity at that point. Line of force start from a positive charge and end on a negative charge. It can be straight or curved. They do not intersect each other. At a point where magnitude of E is more, lines of force are more crowded. Lines of force do not exist inside a conductor, because E = 0 inside a conductor.
- Line of force is not the path travelled by test charge in Electric field.



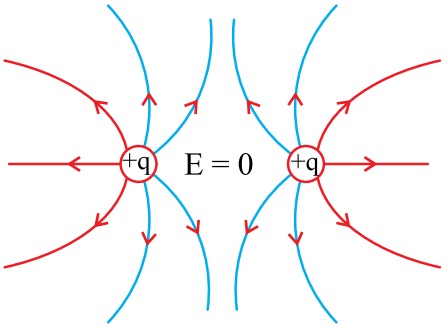
- Number of lines of force originating from a given charge is proportional to the magnitude of charge



➢ Electric lines of force should be ⊥ to equipotential surface.



➢ Electric lines of force do not form a loop.



Electric lines of force are always ⊥ to equipotential surface.

Illustration 8 :

An α particle is located at a point where electric field strength is 3 × 10⁴ N/C. Calculate (a) the force on the α -particle (b) its acceleration.

Solution :

(a) $\vec{F} = q\vec{E}$

$\vec{F} = (2\times1.6\times10^{-19})C\times3\times10^{4}(N/C)$

$= 6\times1.6\times10^{-15} = 9.6\times10^{-15}\,N$

(b) $\vec{a} = \frac{\vec{F}}{m} = \frac{q\vec{E}}{m} = \frac{9.6\times10^{-15}\ N}{4\times1.6\times10^{-27}kg}$ us

$= 1.5\times10^{12} m/s^2$

Illustration 9 :

A pendulum bob has mass 4 mg and carries a charge 2 × 10⁻⁹ coulomb. It hangs in equilibrium from a massless thread of length 50 cm whose other end is fixed to a vertical wall. A horizontal electric field of intensity 200 V/cm exists in space. Calculate

(a) Angle made by the thread with the vertical

(b) Tension in the thread

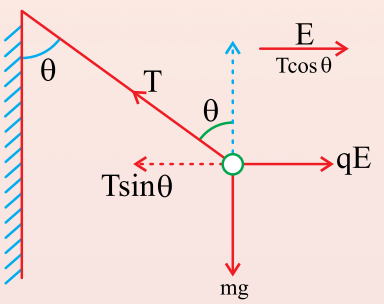
Solution :

(a) At equilibrium, $qE = T\sin\theta$

$mg = T\cos\theta$ Therefore,

$$\tan\theta = \frac{qE}{mg} = \frac{2\times10^{-9}\times2\times10^{4}}{4\times10^{-6}\times10} = 1.0$$

$\theta = 45°$



(b) Tension T, electric force F_e and gravity force mg act on the bob, as shown $\vec{T} + q\vec{E} + m\vec{g} = 0$

Also T balances the resultant of qE and mg.

Therefore $T = \sqrt{(qE)^2 + (mg)^2}$

$= \sqrt{2}\,qE$ (as $qE = mg$)

$= \sqrt{2} \times 2\times10^{-9}\times2 \times10^{4}$

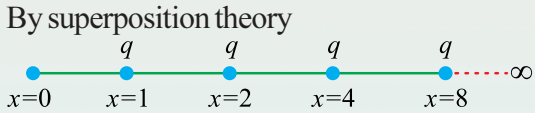
$= 5.64 \times 10^{-5}$ N

Illustration 10:

Along x-axis at positions x = 1, x = 2, x = 4 ..... ∞ charges q are placed. What will be electric field at x = 0 due to these charges. What will be the value of electric field if the charges are alternately positive and negative.

Solution:

By superposition theory



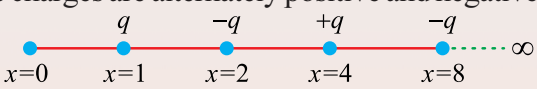
$$E = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+.....\right]$$

$$= \frac{q}{4\pi\epsilon_0}\left[\frac{1}{1}+\frac{1}{4}+\frac{1}{16}+\frac{1}{64}+.....\right]$$

Terms in the bracket are G.P. with first term a = 1 and common ratio $r = \frac{1}{4}$. Its sum $S = \frac{a}{1-r}$

$$\therefore\ E = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{1-1/4}\right] = \left[\frac{1}{4\pi\epsilon_0}\right]\frac{4}{3}q$$

If the charges are alternately positive and negative



$$E = \frac{q}{4\pi\epsilon_0}\left[1-\frac{1}{4}+\frac{1}{16}-\frac{1}{64}+....\right]$$

where a = 1, r = –1/4

$$E = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{1-(-1/4)}\right] = \left[\frac{1}{4\pi\epsilon_0}\right]\frac{4q}{5}$$

Illustration 11 :

A copper ball of density 8.6 gm/cm³, 1 cm in diameter is immersed in oil of density 0.8 g/cm³. What is the charge on the ball if it remains just suspended in oil in an electric field of intensity 36000 V cm⁻¹ acting in the upward direction?

Solution :

$E = 36000\ V\ cm^{-1} = 3.6 \times 10^6\ N/C$

$= 3.6 \times 10^{11}$ dyne/C

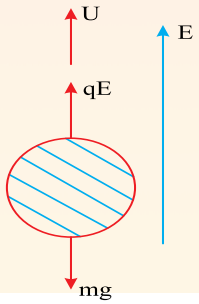
r = radius of the ball = 0.5 cm

V = volume of the ball

$$= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{1}{2}\right)^3 = \frac{\pi}{6}cm^3$$

U = upthrust = weight of the displaced oil =

$$Vdg = \frac{\pi}{6} \times 0.8 \times 980 \text{ dyne}$$



$$m = \text{mass of the ball} = Vd_1 = (8.6)\frac{\pi}{6}$$

For equilibrium; U + qE = mg

$$\frac{\pi}{6}\times 0.8\times 10^{-2}\times 9.8 + q\times 3.6\times 10^{11}$$

$$= \frac{\pi}{6}\times 8.6\times 10^{-2}\times 9.8$$

Solving $q = 1.11 \times 10^{-12}$ Coulomb.

Illustration 12:

A charge q = 1 μ C is placed at point (1m, 2m, 4m). Find the electric field at point P(0m, –4m, 3m).

Solution :

Here, $\vec{r}_q = \hat{i} + 2\hat{j} + 4\hat{k}$

and $\vec{r}_p = -4\hat{j} + 3\hat{k}$

$\therefore$ $\vec{r}_p - \vec{r}_q = -\hat{i} - 6\hat{j} - \hat{k}$

or

$$|\vec{r}_p - \vec{r}_q| = \sqrt{(-1)^2 + (-6)^2 + (-1)^2} = \sqrt{38}\ m$$

Now, $$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{|\vec{r}_p - \vec{r}_q|^3}(\vec{r}_p - \vec{r}_q)$$

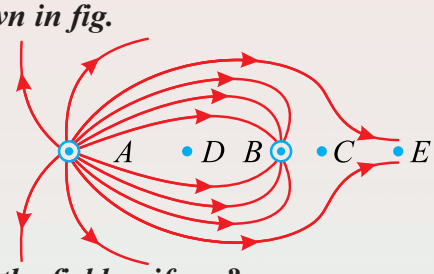
Substituting the values, we have

$$\vec{E} = \frac{(9\times 10^9)(1.0\times 10^{-6})}{(38)^{3/2}}(-\hat{i} - 6\hat{j} - \hat{k})$$

$$\vec{E} = (-38.42\hat{i} - 231.52\hat{j} - 38.42\hat{k})\ \frac{N}{C}$$

Illustration 13 :

The field lines for two point charges are shown in fig.



i. Is the field uniform?

ii. Determine the ratio q_A / q_B.

iii. What are the signs of q_A and q_B ?

iv. If q_A and q_B are separated by a distance 10 cm, find the position of neutral point.

Solution:

i. No

ii. Number of lines coming from or coming to a charge is proportional to magnitude of charge,

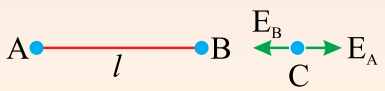
so $\frac{q_A}{q_B} = \frac{12}{6} = 2$

iii. q_A is positive and q_B is negative

iv. C is the other neutral point.

v. For neutral point $E_A = E_B$

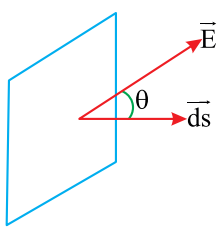
$$\frac{1}{4\pi\varepsilon_0}\frac{q_A}{(l+x)^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_B}{x^2}$$



$$\left(\frac{l+x}{x}\right)^2 = \frac{q_A}{q_B} = 2 \Rightarrow x = 24.2\,\text{cm}$$

ELECTRIC FLUX

- It is the measure of total number of electric lines of force crossing normally the given area.
- The total flux passes through the given surface is given by $\phi = \vec{E}.\vec{A}$



$\therefore \phi = EA\cos\theta$

where θ is the angle made by the normal with the electric field.

- Its unit is N m²/Coulomb or volt-meter. Its dimension is $ML^3T^{-3}A^{-1}$.

The area vector of shown surface is $d\vec{s}$.

θ acute $\Rightarrow \phi$ is + ve

$\Rightarrow$ exiting line of force

θ obtuse $\Rightarrow \phi$ is – ve

$\Rightarrow$ entering line of force

- This vector is perpendicular to the surface. Then flux linked with this surface

$$\phi_E = \int \vec{E}\cdot\vec{ds} = E(ds)\cos\theta$$

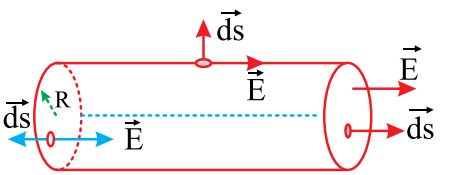
- Electric flux is also defined as the total number of lines of force passing normally through the given surface.
- The value of ϕ is zero in the following circumstances :

(a) If a dipole is (or many dipoles are) enclosed by a closed surface

(b) Magnitude of (+ve) and (-ve) charges are equal inside a closed surface

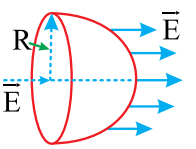
(c) If no charge is enclosed by the closed surface

(d) Incoming flux (- ve) = out going flux (+ve)



$\phi_{in} = -\pi R^2 E$ and $\phi_{out} = \pi R^2 E$

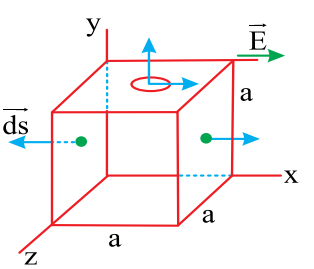
$\phi_{total} = 0$



$\phi_{in} = \phi_{circular} = -\pi R^2 E$

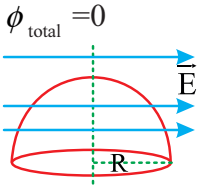
and $\phi_{out} = \phi_{curved} = \pi R^2 E$

$\phi_{total} = 0$

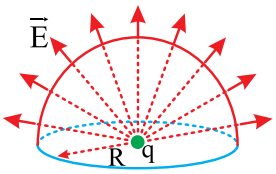


$\phi_{in} = -a^2 E$ and $\phi_{out} = a^2 E$

$\phi_{total} = 0$



$\phi_{total} = 0$



$$E = \frac{kq}{R^2} \qquad \phi = 2\pi R^2 \times \frac{q}{4\pi\epsilon_0 R^2} = \frac{q}{2\epsilon_0}$$

Note : here electric field is radial

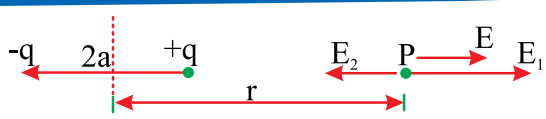
ELECTRIC DIPOLE

- A pair of equal and opposite charges separated by a small distance is called a dipole. Its dipole moment is $p = q \times d$ where d is the distance between the charges and q is magnitude of the charge. Dipole moment $\vec{p}$ is a vector and direction of $\vec{p}$ is from --q to +q.
- For convenience of calculation the distance d is written as $2a$ in which case $|\vec{p}| = 2a.q$

  $\vec{p}$ (resultant due to many dipoles)

  $= \vec{p}_1 + \vec{p}_2 + ...$

FIELD INTENSITY AT A POINT ON THE AXIS OF A DIPOLE



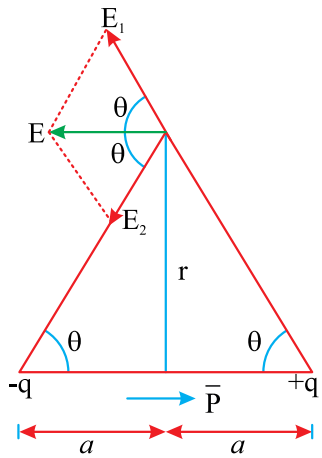
$$E_a = \frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2 - a^2)^2}$$

- Vectorially $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}r}{(r^2 - a^2)^2}$ where r is the distance of the point from the centre of the dipole. The direction of $\vec{E}$ is same as the direction of dipole moment $\vec{p}$. If r >> a,

$$\vec{E}_a = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3} = \frac{2k\vec{p}}{r^3}$$

FIELD INTENSITY AT A POINT ON THE EQUATORIAL LINE OF A DIPOLE

- $$E_e = \frac{1}{4\pi\epsilon_0}\frac{p}{\left(r^2 + a^2\right)^{3/2}}$$



$$\vec{E}_e = -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{\left(r^2 + a^2\right)^{\frac{3}{2}}} = -\frac{k\vec{p}}{(r^2 + a^2)^{3/2}}$$

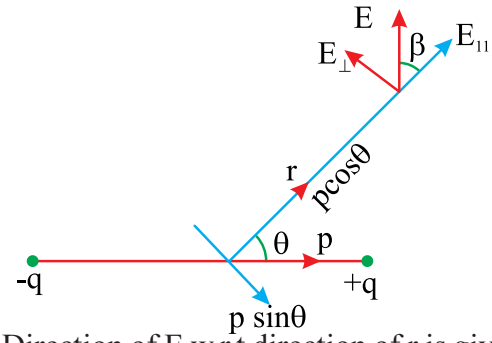
If r >> a, $\vec{E}_e = -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3} = -k\vec{p}/r^3$

For r >> a $\vec{E}_a = -2\vec{E}_e$

FIELD INTENSITY AT A POINT HAVING POLAR CO-ORDINATES (R, θ)

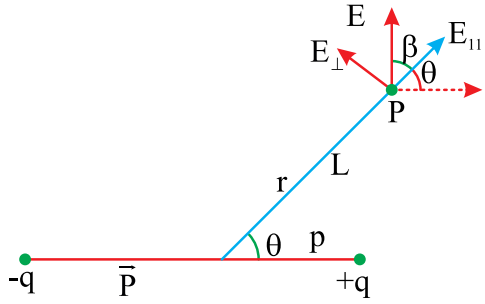
- $E_{11} = \frac{2p\cos\theta}{4\pi\epsilon_0 r^3}$ $\qquad E_{\perp} = \frac{p\sin\theta}{4\pi\epsilon_0 r^3}$

$$E = \sqrt{E_{11}^2 + E_{\perp}^2} \qquad E = \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}\sqrt{3\cos^2\theta + 1}$$



- Direction of E w.r.t direction of r is given by

$$\tan\beta = \frac{\tan\theta}{2} \text{ or } \beta = \tan^{-1}\left[\frac{\tan\theta}{2}\right]$$



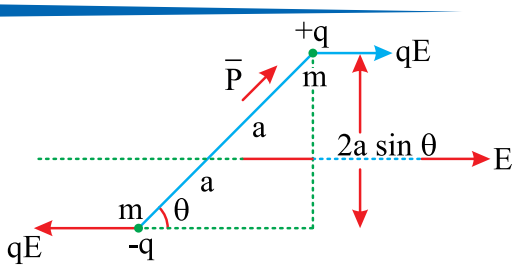
Note : For a short dipole

(a) $E \propto \frac{1}{r^3}$ on the same line

(b) $\vec{E}_a = -2\vec{E}_e$ for same `r'

TORQUE ON A DIPOLE PLACED IN AN EXTERNAL UNIFORM ELECTRIC FIELD

➢



Net Force on dipole = qE – qE = 0

Net Torque on the dipole τ

= (Either force) × (perpendicular distance between the two parallel forces)

$= qE \,.\, 2a \sin\theta = 2aq.E.\sin\theta \Rightarrow \tau = pE\sin\theta$

Vectorically, $\bar{\tau} = \bar{p} \times \bar{E}$

($\vec{\tau}$ tries to allign $\vec{p}$ along $\vec{E}$)

angular acceleration $\alpha = \frac{\tau}{I} = \frac{pE\sin\theta}{2ma^2}$

Illustration 14:

Calculate the electric field intensity due to an electric dipole of length 10 cm having charges of 100 μC at a point 20 cm from each charge on equatorial line.

Solution:

The electric intensity on the equatorial line of an electric dipole is

$$E = \frac{1}{4\pi\epsilon_0}\frac{p}{(d^2+l^2)^{3/2}}$$

$p = 2l\,q$ C-m

$= 10^{-5}$ C-m

$d^2 + l^2 = (20 \times 10^{-2})^2 = 4 \times 10^{-2}$

$$\therefore E = \frac{9\times10^9\times10^{-5}}{(4\times10^{-2})^{3/2}}$$

$$= \frac{9\times10^9\times10^{-5}}{10^{-3}\times8} = \frac{9}{8}\times10^7$$

$= 1.125 \times 10^7$ N/C

Illustration 15 :

Find out the torque on dipole in N-m given : Electric dipole moment $\vec{P} = 10^{-7}(5\hat{i}+\hat{j}-2\hat{k})$ coulomb meter and electric field $\vec{E} = 10^7(\hat{i}+\hat{j}+\hat{k})$ Vm^{-1} is -

Solution:

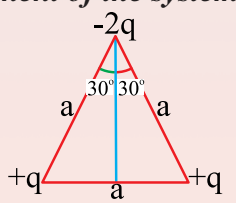
$$\vec{\tau} = \vec{P}\times\vec{E} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & 1 & -2 \\ 1 & 1 & 1 \end{vmatrix}$$

$= \hat{i}(1+2) + \hat{j}(-2-5) + \hat{k}(5-1) \;\; = 3\hat{i} - 7\hat{j} + 4\hat{k}$

$|\vec{\tau}| = 8.6$ N-m

Illustration 16 :

Three points charges +q, –2q, +q are arranged on the vertices of an equilateral triangle as shown in the figure. Find the dipole moment of the system.



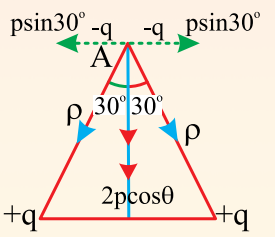
Solution:

Arrangement of the charges is equivalent to two dipoles having dipole moment p each as shown above.

Net dipole moment

$P_{net} = p\cos 30° + p\cos 30°$

$P_{net} = 2p\cos 30° = p\sqrt{3} = qa\sqrt{3}$

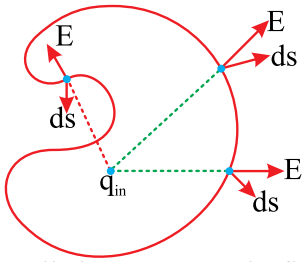


GAUSS THEOREM

➢ Gauss Theorem states that "The total electric flux linked with a real or imaginary closed surface is equal to the total electric charge enclosed by the surface divided by ϵ_0, where ϵ_0 is the permittivity of free space".

$\phi_E = \frac{q_{in}}{\epsilon_0}$ (in vacuum) whose q_{in} is the charge enclosed inside the closed surface.

In medium other than vacuum $\phi_E = \frac{q_{in}}{\epsilon} = \frac{q_{in}}{\epsilon_0 \epsilon_r}$

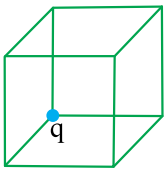


- For some small element areas ds, flux $\vec{E}.\vec{ds}$ is positive and for some ds, it may be negative or zero. But overall algebraic sum of $\vec{E}.\vec{ds}$ i.e $\int \vec{E}.\vec{ds}$ remains unchanged and it is equal to $\frac{q_{in}}{\epsilon_0}$.

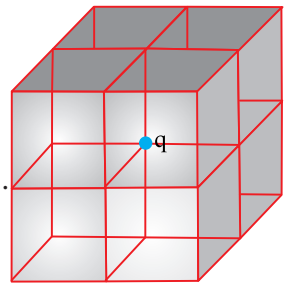
Gauss Law : A Few Points for Consideration

- Gauss Theorem is applicable for all types of surfaces, whether regular or irregular, but surface must be fully closed.
- However to calculate electric field using Gauss Theorem only symmetrical surfaces should be considered.
- In the formula $\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\epsilon_0}$, $\vec{E}$ is due to entire charge distribution while net flux is due to those charges only which are enclosed inside the closed Gaussian surface.
- If a closed body encloses no net charge, then total flux linked with that closed body will be zero, but It is not necessary that field will also be zero.
- If a point charge q is at the centre of a symmetrical closed body of 'n' symmetrically identical faces, then flux linked with each will be $\phi = \frac{q}{n\epsilon_0}$
- If a point charge is at the centre of a cube then the flux linked with the cube is
- The flux linked or emerging out of any face of the cube, in this case is $\phi = \frac{q}{6\epsilon_0}$.
- If a point charge is at one corner of the face of cube, then flux emerging out of the cube is

$\varphi_{cube} = \frac{q}{8\epsilon_0}$

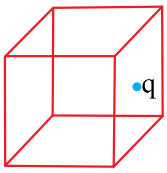


Total $\phi = \frac{q}{\epsilon_0}$



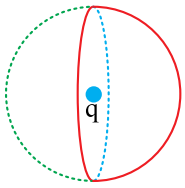
- If a point charge is placed at the centre of a face of the cube, then total flux emerging out of the cube is

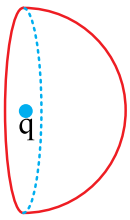
$\phi = \frac{q}{2\epsilon_0}$



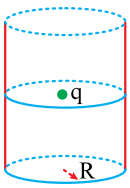
- Similarly for sphere, hemi sphere and cylinder the flux given by

$\phi_{Sphere} = \frac{q}{\epsilon_0}$

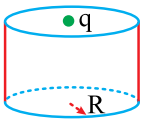




$\phi_{hemisphere} = \frac{q}{2\epsilon_0}$



$\phi_{Total} = \frac{q}{\epsilon_0}$

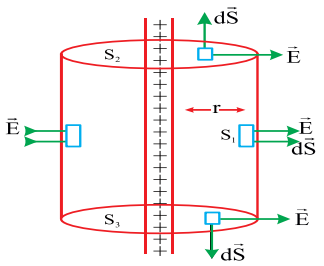


$\phi_{cylinder} = \frac{q}{2\epsilon_0}$

APPLICATIONS OF GAUSS LAW

1. Electric Field due to a Uniformly Charged Infinite Line Charge:

- Consider an infinite line which has a linear charge density λ. Using Gauss's law, let us find the electric field at a distance 'r' from the line charge.
- The cylindrical symmetry tells us that the field strength will be the same at all points at a fixed distance r from the line. Thus, the field lines are directed radially outwards, perpendicular to the line charge.

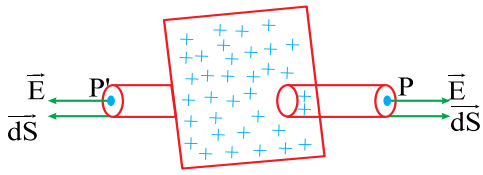


- The appropriate choice of Gaussian surface is a cylinder of radius r and length L. On the flat end faces, S_2 and S_3, $\vec{E}$ is perpendicular $d\vec{S}$, which means flux is zero on them. On the curved surface S_1, $\vec{E}$ is parallel $d\vec{S}$, so that $\vec{E}, d\vec{S} = EdS$.
- The charge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

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

2. Electric Field Due to a Uniformly Charged Infinite Non Conducting Sheet:

- Let us consider a thin non-conducting charged plane sheet, infinite in extent, and having a surface charge density (charge per unit area) $\sigma\ C/m^2$.
- Let P be a point, distance r from the sheet, at which the electric intensity is required.
- Let us choose a point P' symmetrical with P, on the other side of the sheet. Let us now draw a Gaussian cylinder cutting through the sheet, with its plane ends parallel to the sheet and passing through P and P'. Let A be the area of each end.



- By symmetry, the electric intensity at all points on either side near the sheet will be perpendicular to the sheet, directed outward (if the sheet is positively charged). Thus $\vec{E}$ is perpendicular to the plane ends of the cylinder and parallel to the curved surface. Also its magnitude will be the same at P and P'. Therefore, the flux through the two plane ends is

$$\phi_E = \int \vec{E}.d\vec{S} + \int \vec{E}.d\vec{S} \quad = \int E\,dS + \int E\,dS$$

$$= EA + EA = 2EA$$

- The flux through the curved surface of the Gaussian cylinder is zero because $\vec{E}$ and $d\vec{S}$ are at right angles everywhere on the curved surfaces.
- Hence, the total flux through the Gaussian cylinder is

$$\phi_E = 2EA$$

The charge enclosed by the Gaussian surface $q = \sigma A$

Applying Gauss's law, we have

$$2EA = \frac{\sigma A}{\varepsilon_0} \Rightarrow \qquad E = \frac{\sigma}{2\varepsilon_0}$$

3. Electric Field Due to a Uniformly Charged Infinite Conducting Sheet:

- In this case charge on sheet is uniformly distributed on its both sides.

$$Q_{enc} = s \times 2A,\ \phi_E = 2EA = \frac{\sigma \times 2A}{\varepsilon_0}$$

so $E = \dfrac{\sigma}{\varepsilon_0}$ (Electric field inside the conductor is zero)

4. Electric Fieeld Due to a Uniformly Charged Spherical Shell (Or a Solid Spherical Conductor):

- Electric field due to a uniformly charged spherical shell at a point outside the shell is

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} = \frac{\sigma R^2}{\epsilon_0 r^2} \text{ where } \sigma = \frac{q}{4\pi R^2}$$

R = radius of the spherical shell
r = distance of the point from the centre of the shell.

- If $r < R$, $\vec{E} = 0$, i.e electric field inside the shell is zero.
- If $r = R$, $\vec{E} = \frac{q}{4\pi R^2}\hat{r}$ i.e. field is maximum at the surface.
- If $r > R$, $\vec{E} = \frac{q}{4\pi r^2}\hat{r}$ i.e for points outside the shell, electric field is the same as that due to a point charge kept at the centre of the shell. The results are proved below.
- Let +q charge is uniformly distributed over the spherical shell.
- For points inside the shell, the Gaussian surface is the dotted spherical surface of radius r and charge contained = 0

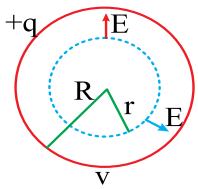
$$\oint \vec{E}.\vec{ds}. = \phi_E$$

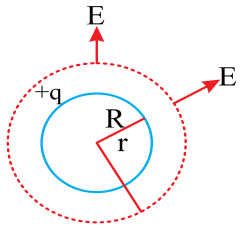
$$E.\oint ds = \frac{q_{in}}{\epsilon_0} \Rightarrow E.4\pi r^2 = 0$$

$E = 0$

- For points outside the shell, charge contained $(q_{in}) = +q$

$$E\oint ds = \frac{q_{in}}{\epsilon_0} \quad ; \qquad E.4\pi r^2 = \frac{q_{in}}{\epsilon_0}$$





$$\Rightarrow E = \frac{1}{4\pi\epsilon_0}\frac{q_{in}}{r^2}$$

at the surface $r = R$

- Same result applies to a conducting solid sphere as for a shell because all charge on a conductor resides on its outer surface.

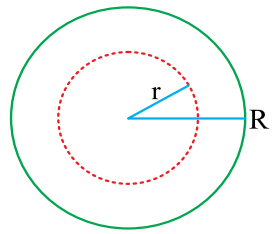
5. Electric Field due to a Uniformly Charged Non Conducting Solid Sphere:

- Let ρ = volume charge density

For points inside the sphere the gaussian surface (dotted sphere) contains charge $q_{in} = \frac{4}{3}\pi r^3\rho$

Then $\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\epsilon_0}$ becomes

$$E.4\pi r^2 = \frac{\frac{4}{3}\pi r^3\rho}{\epsilon_0} \Rightarrow E = \frac{\rho r}{3\epsilon_0} \qquad ..... (i)$$

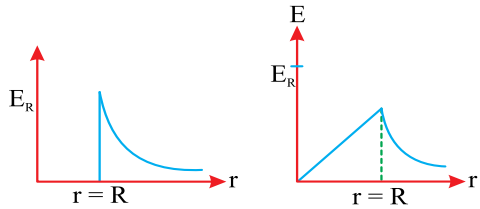


But $\rho = \frac{\text{total charge}}{\text{volume}} = \frac{q}{\frac{4}{3}\pi r^3}$ and

Therefore $E = \frac{\rho r}{3\epsilon_0} = \frac{q}{4\pi\epsilon_0 R^2}\frac{r}{R}$

$= E_R\frac{r}{R}$ where E_R is the electric field at the surface of the sphere.

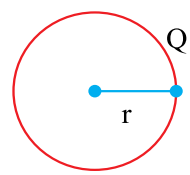
- For outside points, electric field is same for a conducting shell/solid sphere and a non conducting uniformly charged sphere.



Conducting sphere Non-conducting sphere

- Ahollow sphere of radius r is given a charge Q. Intensity of electric field inside a charged hollow conducting sphere is zero.

Intensity of electric field on the surface of the sphere is $\frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$



Intensity of electric field at any point outside the sphere is (at a distance 'x' from the centre)

$$\frac{1}{4\pi\epsilon_0}\frac{Q}{x^2}$$

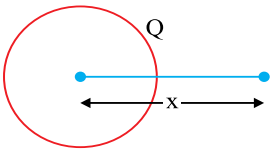


Illustration 17 :

What is the value of electric flux in SI unit in Y-Z plane of area 2m², if intensity of electric field is $\vec{E}=(5\hat{i}+2\hat{j})$ N/C.

Solution:

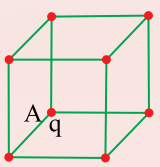
$$\phi=\vec{E}.\vec{dA}=(5\hat{i}+2\hat{j}).2\hat{i}=10\ \frac{N}{C}m^2$$

Illustration 18 :

A point charge q is placed at a corner of a cube with side L. Find flux through entire surface and flux through each face.

Solution:

A corner of a cube can be supposed to be the centre of a big cube made up of 8 such cubes, therefore flux through it is $q/8\epsilon_0$. The direction of E is parallel to the three faces that pass through this face, thus flux through these is zero.



Flux through the other three faces

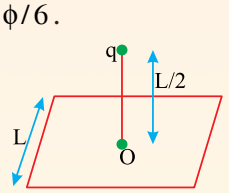
$$=\frac{1}{3}\left(\frac{q}{8\epsilon_0}\right)=\frac{q}{24\epsilon_0}$$

Illustration 19 :

A point charge +q is located L/2 above the centre of a square having side L. Find the flux through this square.

Solution:

The charge q can be supposed to be situated at the centre of a cube having side L with outward flux ϕ. In this cube the square is one of its face having flux $\phi/6$.



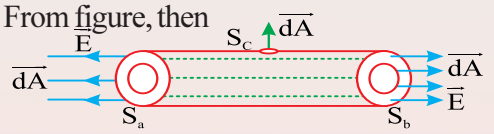
$\therefore$ Flux through the square $=\frac{q}{6\varepsilon_0}$

Illustration 20 :

A cylinder of length L and radius b has its axis coincident with the x axis. The electric field in this region $\vec{E}=200\hat{i}$. Find the flux through (a) the left end of cylinder (b) the right end of cylinder (c) the cylinder curved surface, (d) the closed surface area of the cylinder.

Solution:

From figure, then



(a) $\phi_a=\vec{E}.\vec{A}=EA\cos\theta$

$=200\times\pi b^2\times\cos\pi=-200\pi b^2$

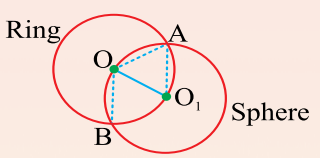
(b) $\phi_b=EA\cos 0°=200\pi b^2$

(c) $\phi_c=EA\cos 90°=0$

(d) $\phi=\phi_a+\phi_b+\phi_c=-200\pi b^2+200\pi b^2+0=0$

Illustration 21 :

A charge Q is distributed uniformly on a ring of radius r. A sphere of equal radius r is constructed. With its centre at the periphery of the ring (fig.) Find the flux of the electric field through the surface of the sphere.



Solution:

From the geometry of the fig. OA = OO_1 and O_1A= O_1O. Thus, OAO_1 is an equilateral triangle.

Hence $\angle AOO_1=60^0$ OR $\angle AOB=120^0$

The arc AO_1B of the ring subtends an angle 120^0 at the centre O. Thus, one third of the ring is inside the sphere. The charge enclosed by the sphere $=\frac{Q}{3}$. Thus flux out of sphere $\frac{Q}{3\epsilon_0}$

CLASS ROOM TEACHING QUESTIONS EXERCISE

CHARGE & CONSERVATION OF CHARGE

1. Two identical metallic spheres A and B of exactly equal masses are given equal positive and negative charges by friction respectively. Then

1) mass of A > Mass of B
2) mass of A < Mass of B
3) mass of A = Mass of B
4) mass of A $\geq$ Mass of B

2. Two spheres of equal mass A and B are given +q and -q charge respectively then

1) mass of A increases
2) mass of B increases
3) mass of A remains constant
4) mass of B decreases

3. A soap bubble is given a positive charge, then its radius.

1) Decreases 2) Increases
3) Remains unchanged
4) Nothing can be predicted as information is insufficient

4. Due to the motion of a charge, its magnitude

1) changes
2) does not change
3) increases (or) decreases depends on its speed
4) can not be predicted

5. Induction precedes attraction because

1) an uncharged body can attract an uncharged body due to induction of opposite charge on it
2) a charged body can attract an uncharged body due to induction of same charge on it.
3) a charged body can attract an uncharged body due to induction of opposite charge on it.
4) a charged body can attract another charged body due to induction of same charge on it.

6. A : Charge cannot exist without mass but mass can exist without charge.
B : Charge is invariant but mass is variant with velocity
C : Charge is conserved but mass alone may not be conserved.

1) A, B, C are true 2) A, B, C are not true
3) A, B are only true 4) A,B are false, C is true

7. The quantization of charge reveals that

1) Any charge is an integral multiple of electronic charge
2) Any charge is an half integral multiple of electronic charge
3) Charge is invariant
4) Charge does not exist with matter

8. When a soap bubble is given a negative charge, then

1) It bursts 2) It expands
3) It contracts 4) Can't predict

9. The charge induced on the surface of a dielectric, facing a charge is

1) Lesser and dissimilar
2) Lesser and similar
3) Greater and similar 4) Equal and similar

10. You are travelling in a car during a thunder storm. In order to protect yourself from lightening, would you prefer to

1) Stand under the tree
2) Remain in the car
3) Get out and run from the car
4) Get out and be flat on the ground

11. The electronic charge is 1.6×10^{-19} coulomb. If a body carries a negative charge of 9.6×10^{-10} coulombs, what is the number of excess electrons on the body ?

1) 6×10^{9} 2) $1/6 \times 10^{-29}$
3) 6×10^{-29} 4) 6×10^{29}

12. 64 small drops of mercury, each of radius 'r' and charge q are combined to form a big drop. The ratio of the surface density of the charge of each small drop to that of a big drop is

1) 4 : 1 2) 1 : 4 3) 1 : 64 4) 64 : 1

13. Five balls numbered 1 to 5 are suspended using separate threads. Pairs (1,2); (2,4) and (4,1) show electrostatic attraction, while pairs (2,3) and (4,5) show repulsion. The ball 1 may be

1) positively charged
2) negatively charged
3) either (+ve) or (–ve) 4) neutral

KEY

1) 2 2) 2 3)2 4) 2 5) 3 6) 1
7) 1 8) 2 9) 1 10) 2 11) 1 12) 2
13) 4

COULOMB'S LAW

14. The ratio of the force between two small spheres (with constant charges) F_1 in air and F_2 in a medium of dielectric constant k is respectively

1) 1 : k 2) k : 1
3) 1 : k^2 4) K^2 : 1

15. A certain charge Q is divided at first into two parts, q and Q - q. Later on the charges are placed at a certain distance. If the force of interaction between two charges is maximum, then

1) $\frac{Q}{q} = \frac{4}{1}$ 2) $\frac{Q}{q} = \frac{2}{1}$

3) $\frac{Q}{q} = \frac{3}{1}$ 4) $\frac{Q}{q} = \frac{1}{3}$

16. Two identical bodies in which charges are 40μC and –20μC. They are some distance apart. Now they are touched and kept at the same distance. The ratio of the initial to the final force between them is

1) 8 : 1 2) 4 : 1 3) 1 : 8 4) 1 : 1

17. Three charges 4 q, Q and q are placed in straight line of length *l* at points distant 0, *l*/2 and *l* respectively. What should be Q in order to make the net force on q to be zero ?

1) –q 2) –2q 3) $-\frac{q}{2}$ 4) 4q

18. The electrostatic force between two point charges q_1 and q_2 at separation r is given by $F = k\frac{q_1q_2}{r^2}$. The constant k

1) Depends upon system of units only
2) Depends upon medium between the charges
3) Depends on both '1' and '2'
4) Is independent of both '1' and '2'

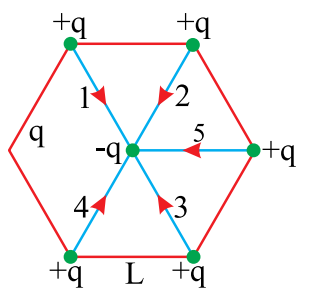
19. Two point charges placed at a certain distance r in air exert a force F on each other. Then the distance r' at which these charges will exert the same force in a medium of dielectric constant K is given by

1) r 2) $\frac{r}{K}$ 3) $\frac{r}{\sqrt{K}}$ 4) $r\sqrt{K}$

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

1) Only –q is in stable equilibrium
2) None of the charges are in equilibrium
3) All the charges are in unstable equilibrium
4) All the charges are in stable equilibrium

21. Five point charges, each of value +*q* coulomb, are placed on five vertices of a regular hexagon of side *L* meter figure. The magnitude of the force on a point charge of value – *q* coulomb placed at the centre of the hexagon is



1) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$ 2) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L^2}$

3) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{(2L^2)}$ 4) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{(2L)^2}$

22. A charge Q is to be divided on two objects. What should be value of charges on the objects so that the force between the object can be maximum?

1) $\frac{2Q}{3}, \frac{Q}{3}$ 2) $\frac{Q}{2}, \frac{Q}{2}$

3) $\frac{Q}{4}, \frac{2Q}{4}$ 4) $\frac{Q}{5}, \frac{4Q}{5}$

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

1) $\frac{4\pi\varepsilon_0 Fd^2}{q^2}$ 2) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$

3) $\sqrt{\frac{4\pi\varepsilon_0 Fe^2}{d^2}}$ 4) $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$

24. Three point charges are placed at the corners of an equilateral triangle. Assuming only electrostatics forces are acting–

1) if the charges have different magnitudes and different signs, the system will be in equilibrium
2) the system will be in equilibrium if the charges have the same magnitudes but different signs
3) the system can never be in equilibrium.
4) the system will be in equilibrium if the charges rotate about the centre of the triangle

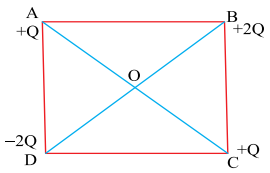
25. Two charges are placed at a distance apart. If a glass slab is placed between them, force between them will

1) be zero 2) increase
3) decrease 4) remains the same

26. A negatively charged particle is situated on a straight line joining two other stationary particles each having charge +q. The direction of motion of the negatively charged particle will depend on

1) the magnitude of charge
2) the position at which it is situated
3) both magnitude of charge and its position
4) the magnitude of +q

27. Four charges are arranged at the corners of a square ABCD as shown in the figure. The force on the positive charge kept at the centre 'O' is



1) zero
2) along the diagonal AC
3) along the diagonal BD
4) perpendicular to side AB

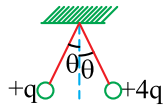
28. Two identical +ve charges are at the ends of a straight line AB. Another identical +ve charge is placed at 'C' such that AB=BC. A, B and C being on the same line. Now the force on 'A'

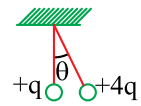
1) increases 2) decreases
3) remains same 4) we cannot say

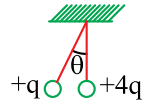
29. Two identical pendulums A and B are suspended from the same point. Both are given positive charge, with A having more charge than B. They diverge and reach equilibrium with the suspension of A and B making angles θ_1 and θ_2 with the vertical respectively.

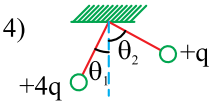
1) $\theta_1 > \theta_2$ 2) $\theta_1 < \theta_2$ 3) $\theta_1 = \theta_2$
4) The tension in A is greater than that in B

30. Two metal spheres of same mass are suspended from a common point by a light insulating string. The length of each string is same. The spheres are given electric charges +q on one end and +4q on the other. Which of the following diagram best shows the resulting positions of spheres?

1) 

2) 

3) 

4) 

31. Two point charges $-q$ and $+2q$ are placed at a certain distance apart in the same order. Where should a third point charge be placed so that it is in equilibrium?

1) at the midpoint on the line joining the two charges
2) on the line joining the two charges on the left of $-q$
3) between $-q$ and $+2q$
4) at any point on the right bisector of the line joining $-q$ and $+2q$.

32. Dimensions of ε_0 are

1) $\left[M^{-1}L^{-3}T^{4}A^{2}\right]$ 2) $\left[M^{0}L^{-3}T^{3}A^{3}\right]$

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

33. The coulomb electrostatic force is defined for

1) two spherical charges at rest only
2) two point charges in motion
3) two point charges at rest 4) both 2&3

34. Which of the following statements are correct?

a) The electrostatic force does not depend on medium in which the charges are placed
b) The electrostatic force between two charges does not exist in vacuum
c) The gravitational force between masses can be usually neglected in comparison with electrostatic force
d) Any excess charge given to a conductor, not always resides on the outer surface of the conductor.

1) both a & c 2)only 'c' 3)both c & d 4) all

35. Two identical coins be 4.5m apart on a table. They carry similar charges. If the force of repulsion is 40/9 N, then charge on each one is

1)100 μ C 2)440 μ C 3)110 μ C4) 550 μ C

36. Coulomb's law for electric charges, most closely resembles

1) The law of conservation of momentum
2) The law of conservation of energy
3) The law of conservation of charge
4) Newton's law of gravitation

37. The ratio of the force between two small conducting spheres of equal charge in (a) a medium of dielectric constant 2, and (b) air is respectively

1) 1 : 4 2) 4 : 1 3) 1 : 2 4) 2 : 1

38. Two identical metal balls with charge '+2Q' and '–Q' are some distance apart, F being the force between them. They are first joined by a conducting wire, then removed. The force between them now will be

1) F/2 2) F/6 3) F/4 4) F/8

39. Two spheres of same charge, placed at some distance, experience a force 'F' A similar uncharged sphere, after touching one of them is placed at the mid point between the two balls. The force experienced by this ball would be

1)F 2)2F 3)3F 4)4F

40. There are two charges +2 μ C and –6 μ C at certain separation. Then the ratio of forces acting on them will be

1) 1 : 1 2) 1 : 3 3) 3 : 1 4) 1 : 6

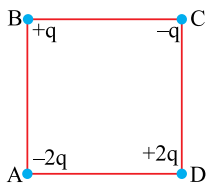
41. Two particles each of mass 'm' and carrying charge of magnitude q each are at some separation. If they are in equilibrium under mutual electrostatic and gravitational forces, of the order then q/m(in C/kg) is

1)10^{-15} 2)10^{-5} 3)10^{-10} 4)10^{-25}

42. Two particles of charges 'Q_1' and 'Q_2' placed at a some distance, the force between them is 'F'. If the distance between them is reduced to half and charge on each particle is doubled, the force between the particles would become

1) 4F 2) 16F 3) 32F
4) Remains unchanged

43. Four charges are arranged at the corners of a square ABCD, as shown. The force on a +ve charge kept at the centre of the square is



1) zero
2) along diagonal AC
3) along diagonal BD
4) perpendicular to the side AB

44. Two spheres P and Q are given charges of +10 C and + 20 C respectively, and the separation between them is 80 cm. The electric field at a point A on the line joining the centres of the two spheres is zero. Then A is at a distance from the sphere 'P'

1) 45 cm 2) 33 cm 3) 60 cm 4) 20 cm

45. Two negative charges each '–q' are placed at point $(0,\pm a)$ on y-axis , one positive charge q is placed at x = 2a, this charge will

1) oscillate but not execute S.H.M.
2) execute S.H.M. about the origin
3) execute S.H.M along x-axis
4) move towards origin and will become stationary

46. Two stationary particles each of '+q' are placed at a distance apart. Now a negatively charged particle is placed in a straight line joining two charges. The direction of motion of the negatively charged particle will depend on

1) The position at which it is situated
2) The magnitude of its charge
3) The magnitude of +q charge
4) The magnitudes of the both the charges

47. F_g and F_e represent the gravitational and electrostatic force respectively between electrons situated at some distance. The ratio of F_g to F_e is of the order of

($G = 6.67 \times 10^{-11} \frac{N-m^2}{kg^2}$)

1) 10^{43} 2) 10^{1} 3) 10^{0} 4) 10^{-43}

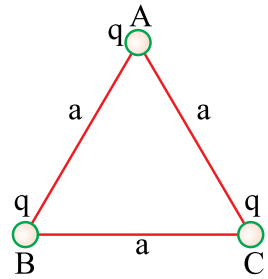
48. Two charges +4e and +e are x distance apart at what distance charge q must be placed from charge +e so that it is in equilibrium ?

1) x/2 2) 2x/3 3) x/3 4) x/6

49. An electron is moving round the nucleus of a hydrogen atom in a circular orbit of radius r. The coulomb force $\vec{F}$ between the two is

1) $K\frac{e^2}{r^2}\hat{r}$ 2) $-K\frac{e^2}{r^2}\hat{r}$ 3) $-K\frac{e^2}{r^3}\hat{r}$ 4) $K\frac{e^2}{r^3}\vec{r}$

50. In the fig. force on charge at A in the direction normal to BC will be



1) $-\frac{kq}{a^2}$ 2) $-\frac{kq^2}{2a^2}$ 3) $\frac{kq^2}{2a^2}$ 4) $\frac{\sqrt{3}kq^2}{a^2}$

51. Two particle of equal mass m and charge q are placed at a distance of 16 cm. Net force on each charge is zero then value of $\frac{q}{m}$ is

1) l 2) $\sqrt{\frac{\pi\varepsilon_0}{G}}$ 3) $\sqrt{\frac{G}{4\pi\varepsilon_0}}$ 4) $\sqrt{4\pi\varepsilon_0 G}$

52. Two point charge q_1 and q_2 are placed at a distance of $50\,cm$ from each other in air, and interact with a certain force. Now the same charges are put in an oil whose relative permittivity is 5. If the interacting force between them is still the same, their separation now is

1) $16.6\,cm$ 2) $22.3\,cm$
3) $35.0\,cm$ 4) $28.4\,cm$

53. What equal charges would to be placed on earth and moon to neutralize their gravitational attraction (Use mass of earth = 10^{25} kg, mass of moon = 10^{23} kg)

1) 8.6×10^{13} C 2) 6.8×10^{26} C
3) 8.6×10^{3} C 4) 9×10^{6} C

54. Two small identical spheres, each of mass 1 g and carrying same charge 10^{-9} C are suspended by threads of equal length. If the distance between centers of the sphere is 0.3 cm in equilibrium the inclination of the thread with the vertical will be

1) $\tan^{-1}(0.1)$ 2) $\tan^{-1}(2)$
3) $\tan^{-1}(1.5)$ 4) $\tan^{-1}(0.6)$

55. 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 :

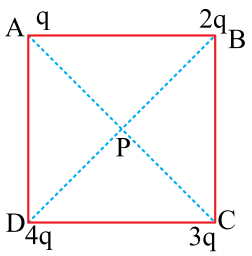
1) $-\frac{Q}{2}$ 2) $-\frac{Q}{4}$ 3) $+\frac{Q}{4}$ 4) $+\frac{Q}{2}$

KEY

14) 2	15) 2	16) 1	17) 1	18) 3	19) 3
20) 3	21) 2	22) 2	23) 4	24) 3	25) 3
26) 2	27) 3	28) 1	29) 3	30) 1	31) 2
32) 1	33) 3	34) 2	35) 1	36) 4	37) 3
38) 4	39) 1	40) 1	41) 3	42) 2	43) 4
44) 2	45) 1	46) 1	47) 4	48) 3	49) 2
50) 4	51) 4	52) 2	53) 1	54) 1	55) 2

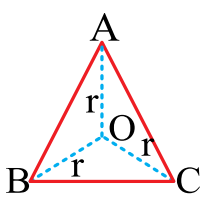
ELECTRIC FIELD

56. q, 2q , 3q and 4q charges are placed at the four corners A, B, C and D of a square. The field at the centre P of the square has the direction parallel to



1) AB 2) CB 3) AC 4) BD

57. Three charges + Q each are placed at the corners A, B and C of an equilateral triangle. At the circumcenter, O the electric field will be



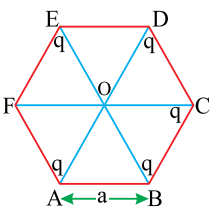
1) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{r^2}$ 2) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

3) Zero 4) $\frac{1}{4\pi\varepsilon_0}\frac{QQ}{r^2}$

58. In the diagram shown electric field intensity will be zero at a point

1) Between –q and +2 q charge
2) Towards +2q charge on the line
3) Away from line towards +2q charge
4) Away from line towards –q charge

59. Five charges each equal to q are placed at the five corners A, B, C, D, and E of a regular hexagon ABCDEF of side a. Then the electric intensity at the centre O of the hexagon is



1) $\frac{q}{4\pi\varepsilon_0 a^2}$ along $\vec{OF}$

2) $\frac{q}{4\pi\varepsilon_0 a^2}$ along $\vec{FO}$

3) $\frac{q}{4\pi\varepsilon_0 3a^2}$ along $\vec{OF}$

4) $\frac{5q}{4\pi\varepsilon_0 a^2}$ along $\vec{OF}$

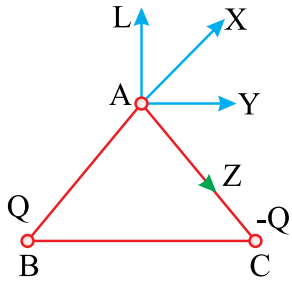
60. Two points charges 'Q' and '–3Q' are at some separation. If the electric field at the location of 'Q' is 'E', then at the location of –3Q it will be

1) –E/3 2) –3E 3) E/3 4) –E

61. "No two electric lines of force will intersect " from this which of the following statements is/are true?

1) the field is uniform at that point of intersection
2) the field is non-uniform at that point of intersection
3) the electric field is strong and may have more than one direction at the point of intersection
4) at the point of intersection the electric field will have two different directions which is not possible

62. For the given figure the direction of electric field at A will be



1) towards AL 2) towards AY
3) towards AX 4) towards AZ

63. Two positive charges of 1ìC and 2ìC are placed 1 meter apart. The value of electric field in N/C at the middle point of the line joining the charges will be

1) 10.8×10^4 2) 3.6×10^4
3) 1.8×10^4 4) 5.4×10^4

64. An electron travels a distance of 0.10 m in an electric field of intensity $3200 V/m$, enters perpendicular to the field with a velocity $4\times10^7 m/s$, what is its deviation in its path

1) $1.76 mm$ 2) $17.6 mm$
3) $176\ mm$ 4) 0. $0.176\ mm$

65. (-10^{-6}) C charge is on a drop of water having mass 10^{-6} kg. What amount of electric field is applied on the drop so that it is in the balanced condition with its weight :–

1) 10 V/m upward 2) 10 V/m downward
3) 0.1 V/m downward 4) 0.1 V/m upward

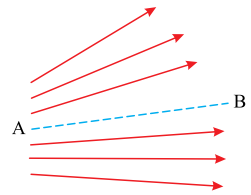
66. An electron and a proton are set free in a uniform electric field. The ratio of their acceleration is :

1) unity 2) zero 3) $\frac{m_p}{m_e}$ 4) $\frac{m_e}{m_p}$

67. An electron enters an electric field with its velocity in the direction of the electric lines of field then

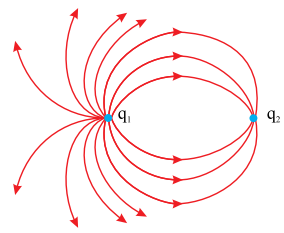
1) the path of the electron will be a circle
2) the path of the electron will be a parabola
3) the velocity of the electron will decrease just after enter
4) the velocity of the electron will increase just after enter

68. 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



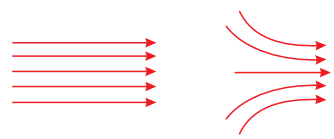
1) $E_A > E_B$ 2) $E_A < E_B$
3) $E_A = \frac{E_B}{r}$ 4) $E_A = \frac{E_B}{r^2}$

69. Figure shows lines of force for a system of two point charges. The possible choice for the charges is



1) $q_1 = 4\mu C, q_2 = -1.0\mu C$ 2) $q_1 = 1\mu C, q_2 = -4\mu C$
3) $q_1 = -2\mu C, q_2 = +4\mu C$ 4) $q_1 = 3\mu C, q_2 = 2\mu C$

70. Drawings I and II show two samples of electric field lines



1) 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
2) In both I and II the electric field is the same every where
3) In both cases the field becomes stronger on moving from left to right
4) The electric field in I is the same everywhere, but in II the electric field becomes stronger on moving from left to right

71. An electron is projected with certain velocity into an electric field in a direction opposite to the field. Then it is
1) accelerated 2) retarded
3) neither accelerated nor retarded
4) either accelerated or retarded

72. The acceleration of a charged particle in a uniform electric field is
1) proportional to its charge only
2) inversely proportional to its mass only
3) proportional to its specific charge
4) inversely proportional to specific charge

73. An electron and proton are placed in an electric field. The forces acting on them are F_1 and F_2 and their accelerations are a_1 and a_2 respectively then
1) $\bar{F}_1 = \bar{F}_2$ 2) $\bar{F}_1 + \bar{F}_2 = 0$
3) $|\bar{a}_1| = |\bar{a}_2|$ 4) $|\bar{a}_1| \geq |\bar{a}_2|$

74. The bob of a pendulum is positively charged. Another identical charge is placed at the point of suspension of the pendulum. The time period of pendulum
1) increases 2) decreases
3) becomes zero 4) remains same.

75. A positive charge q_0 placed at a point P near a charged body experiences a force of repulsion of magnitude F, the electric field E of the charged body at P is
1) $\frac{F}{q_0}$ 2) $< \frac{F}{q_0}$ 3) $> \frac{F}{q_0}$ 4) F

76. A cube of side b has charge q at each of its vertices. The electric field at the centre of the cube will be
1) zero 2) $\frac{32q}{b^2}$ 3) $\frac{q}{2b^2}$ 4) $\frac{q}{b^2}$

77. An electron and proton are sent into an electric field. The ratio of force experienced by them is
1)1 : 1 2)1 : 1840 3)1840 : 1 4)1 : 9

78. An electron enters in an electric field with its velocity in the direction of the electric lines of force. Then
1) the path of the electron will be a circle
2) the path of the electron will be a parabola
3) the velocity of the electron will decrease
4) the velocity of the electron will increase

79. A charged bead is capable of sliding freely through a string held vertically in tension. An electric field is applied parallel to the string so that the bead stays at rest of the middle of the string. If the electric field is switched off momentarily and switched on
1) the bead moves downwards and stops as soon as the field is switched on
2) the bead moved downwards when the field is switched off and moves upwards when the field is switched on
3) the bead moves downwards with constant acceleration till it reaches the bottom of the string
4) the bead moves downwards with constant velocity till it reaches the bottom of the string

80. 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
1) a straight line 2) a circle
3) a parabola 4) an ellipse

81. An electron of mass M_e, initially at rest, moves through a certain distance in a uniform electric field in time t_1. 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_2/t_1 is nearly equal to
1) 1 2) $\sqrt{M_p/M_e}$ 3) $\sqrt{M_e/M_p}$ 4) 1836

82. Two point charges q and -2q are placed some distance d apart. If the electric field at the location of q is E, then at the location of -2q is
1) $-\frac{E}{2}$ 2) –2E 3) $\frac{E}{2}$ 4) – 4E

83. The field acting on the flowing charges is
1) electrostatic both inside and outside the cell
2) non-electrostatic both inside and outside the cell
3) electrostatic inside the cell and non-electrostatic outside the cell
4) non-electrostatic inside the cell and electrostatic outside the cell

84. An electron moves with a velocity $\vec{v}$ in an electric field $\vec{E}$. If the angle between $\vec{v}$ and $\vec{E}$ is neither 0 nor π, then path followed by the electron is

1) straight line 2) circle
3) ellipse 4) parabola

85. A charged particle is free to move in an electric field

1) It will always move perpendicular to the line of force
2) It will always move along the line of force in the direction of the field.
3) It will always move along the line of force opposite to the direction of the field.
4) It will always move along the line of force in the direction of the field or opposite to the direction of the field depending on the nature of the charge

86. Two parallel plates carry opposite charges such that the electric field in the space between them is in upward direction. An electron is shot in the space and parallel to the plates. Its deflection from the original direction will be

1) Upwards 2) Downwards
3) Circular 4) does not deflect

87. The Electric field is given by $\vec{E} = \frac{\vec{F}}{q_0}$, here the test charge '$q_0$' should be

a) Infinitesimally small and positive
b) Infinitesimally small and negative
1) only a 2) only 'b'
3) a (or) b 4) neither 'a' nor 'b'

88. Statement A: If an electron travels along the direction of electric field it gets accelerated
Statement B: If a proton travels along the direction of electric field it gets retarded

1) Both A & B are true 2) A is true, B is false
3) A is false, B is true 4) Both A & B are false

89. The property of the electric line of force

a) The tangent to the line of force at any point is parallel to the direction of 'E' at the point
b) No two lines of force intersect each other
1) both a & b 2) only a 3) only b 4) a or b

90. The magnitude of electric field intensity at a point in space, is equal to

1) The product of potential difference and charge
2) The product of force and charge
3) The force, a unit charge would experience there
4) The force, an electron would experience there

91. The electric field at the surface of a charged spherical conductor is 10 kV/m. The electric field at an outward radial distance equal to the radius from its surface will be

1)1.5kV/m 2)2.5kV/m 3)4kV/m 4)5kV/m

92. Two particles having equal charges, but masses are in the ratio 1:2, are placed in an uniform electric field 'E' and allowed to move simultaneously. The ratio of their kinetic energies at any instant will be

1) 1 : 2 2) 2 : 1 3) 1 : 8 4) 8 : 1

93. The electric field between two parallel plates carrying opposite charges is in upward direction. An electron is shot inside, and parallel to the plates. Its deflection from the original direction will be along a

1) Circular 2)Parabola
3) Downwards 4) Upwards

94. The electrostatic field due to a charged conductor just outside the conductor is

1) Zero and parallel to the surface at every point inside the conductor
2) Zero and is normal to the surface at every point inside the conductor
3) Parallel to the surface at every point and zero inside the conductor
4) Normal to the surface at every point and zero inside the conductor.

95. A ring with a uniform charge Q and radius R, is placed in the yz plane with its centre at the origin

1) The field at the origin is zero
2) The potential at the origin is $\sqrt{\frac{kQ}{R}}$

3) The field at the point $(x,0,0)$ is $\frac{kQ}{x^2}$

4) The field at the point $(x,0,0)$ is $\frac{kQ}{R^2+x^2}$

96. Two metal plates having a p.d of 600 volts are 2 cm apart. It is found that a particle of mass 1.96×10^{-12} g remains suspended in the electric field. The intensity of electric field is

1) $1.96 \times 10^{-12} \times 600$ volt /m
2) 3×10^4 volt/m
3) 3×10^2 volt/m 4) 12×10^4 volt/m

97. An electron moving with a speed of 5×10^6m/s is shot parallel to the electric field of strength 1×10^3 N/C arranged so as to retard its motion. How far will the electron travel in the field before coming (momentarily) to rest ?($m_e = 9.1\times10^{-31}$ kg)

(1) 7 m (2)70 cm (3)7 cm (4)0.7 cm

98. Charge Q is given a displacement $\vec{r} = a\hat{i}+\hat{j}$ in an electric field $\vec{E} = E_1\hat{i}+E_2\hat{j}$. The work done is

1) $Q(E_1a + E_2)$ 2) $Q\sqrt{(E_1a)^2+(E_2)^2}$

3) $Q(E_1 + E_2)$ 4) $Q\left(\sqrt{E_1^2+E_2^2}\right)\sqrt{a^2+1}$

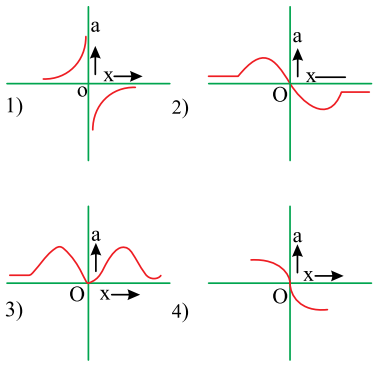
99. A point charge q = 50μC is located in the x-y plane at the point of position vector $\vec{r}_0 = 2\hat{i}+3\hat{j}$. What is the electric field at the point of position vector $\vec{r} = 8\hat{i}-5\hat{j}$?

1) 1200 V/m 2) 4×10^{-2} V/m
3) 900 V/m 4) 4500 V/m

100. The height of a tower is *h*. The acceleration due to gravity is *g*. Everywhere in the surroundings of the tower there is a uniform electric field of intensity *E* in the horizontal direction away from the tower. A particle of mass *m* and carrying a charge *q* is dropped from the top of the tower. The distance of the particle when it reaches the ground from the foot of the tower is (neglect the effect of air on the motion of the particle)

1) $\frac{qEh}{mg}$ 2) $\frac{qEhg}{m}$ 3) $\frac{mg}{qEh}$ 4) $\frac{m}{qEgh}$

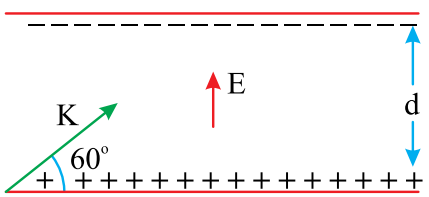
101. Two identical positive charges are fixed on the y-axis, at equal distance from the origin O, A particle with a negative charge starts on the negative x-axis at a large distance from O, moves along the x-axis passed through O and moves far away from O. Its acceleration a is taken as positive along its direction of motion. The particle's acceleration a is plotted against its x-coordinate. Which of the following best represents the plot?



102. Two conductors of the same shape and size. One of copper and the other of aluminium (less conducting) are placed in a uniform electric field. the charge induced in alumnium.

1) Will be less than in copper
2) Will be more than in copper
3) Will be equal to that in copper
4) Will not be connected with copper

103. An electron of kinetic energy K is projected between two charged plates at an angle 60°, as shown in figure. If electrons doesn't reach to the upper plate just before striking then the magnitude of electric field will be more than



1) $\frac{K}{ed}$ 2) $\frac{2K}{ed}$ 3) $\frac{K}{2ed}$ 4) $\frac{K}{4ed}$

104. The electric field, at a distance of 20 cm from the centre of a dielectric sphere of radius 10 cm is 100 V/m. Then E at 3 cm distance from the centre of sphere is

1) 100 V/m 2) 125 V/m
3) 120 V/m 4) zero

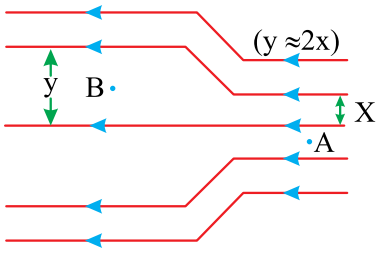
105. There is a uniform electric field of strength 10^3 V/m along y–axis. A body of mass 1 g and charge 10^{-6} C is projected into the field from origin along the positive x–axis with a velocity 10m/s. Its speed in m/s after 10s is (Neglect gravitation)

1) 10 2) $5\sqrt{2}$ 3) $10\sqrt{2}$ 4) 20

106. Choose correct statement regarding electric lines of force

1) emerges from negative charge and meet at positive charge
2) where the density of electric lines of force are more, the electric field in that region is weak.
3) it is in radial direction for a point charge
4) has a physical existence

107. Fig shows field lines of an electric field, the line spacing parallel to the page is same everywhere. If the magnitude of the field at A is 40 N/C, then the magnitude of the field at B is approximately

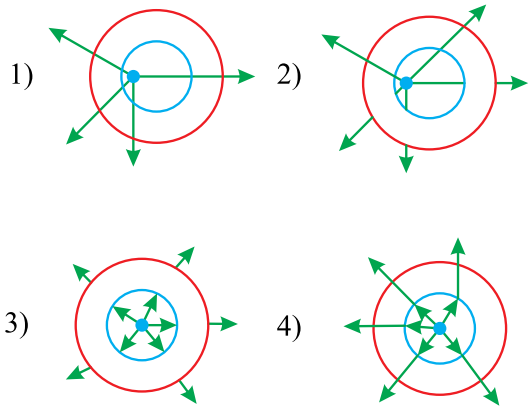


1) 40 N/C 2) 80 N/C
3) 20 N/C 4) cannot be determined

108. Semicircular ring of radius 0.5 m is uniformly charged with a total charge of 1.4×10^{-9}C. The electric field intensity at centre of this ring is

1) zero 2) 320V/m
3) 64V/m 4) 32V/m

109. A metallic shell has a point charge q kept inside its cavity. Which one of the following diagrams correctly represents the electric lines of forces ?



KEY

56) 2	57) 3	58) 4	59) 1	60) 3	61) 4
62) 2	63) 2	64) 1	65) 2	66) 3	67) 3
68) 1	69) 1	70) 4	71) 1	72) 3	73) 2
74) 4	75) 2	76) 1	77) 1	78) 3	79) 4
80) 3	81) 2	82) 3	83) 4	84) 4	85) 4
86) 2	87) 1	88) 4	89) 1	90) 3	91) 2
92) 2	93) 2	94) 4	95) 1	96) 2	
97) 3	98) 1	99) 4	100) 1	101) 2	
102) 3	103) 4	104) 3	105) 3	106) 3	
107) 3	108) 4	109) 3			

DIPOLE

110. Electric field intensity at a point varies as r^{-3} for

1) A point charge
2) An electric dipole
3) A plane infinite sheet of charge
4) A line charge of infinite length

111. An electric dipole consists of two opposite charges each of magnitude 1.0×10^{-6} coulomb separated by a distance of 2.0 cm. The dipole is placed in an external field of 1.0×10^5 N/C. The maximum torque on the dipole is

1) 0.2×10^{-3} N-m 2) 1.0×10^{-3} N-m
3) 2.0×10^{-3} N-m 4) 4.0×10^{-3} N-m

112. When an electric dipole is kept near a positive charge, it will experience

1) A force only
2) A torque only
3) Both force and torque
4) Neither force nor torque

113. An electric dipole is placed in a uniform electric field. It may experience

1) A force only
2) A torque only
3) Both force and torque
4) It depends on position of the dipole

114. P and Q are two points on the axis and the perpendicular bisector respectively of an electric dipole. Both the points are far away from the dipole, and at equal distances from it. If $\vec{E_P}$ and $\vec{E_Q}$ are fields at P and Q, then

1) $\vec{E_P} = \vec{E_Q}$
2) $\vec{E_P} = -2\vec{E_Q}$
3) $\vec{E_P} = 2\vec{E_Q}$
4) $|E_Q| = \frac{1}{2}|E_P|$, and $\vec{E_Q}$ is perpendicular to $\vec{E_P}$

115. For a given dipole at a point (away from the center of dipole) intensity of the electric field is E. Charges of the dipole are brought closer such that distance between point charges is half, and magnitude of charges are also halved. The intensity of the field now at the same point becomes

1) One fourth 2) Doubled
3) Four times 4) Halved

116. Two point charges + q and –q are held fixed at (–d,0)and (d,0) respectively of a coordinate system, then

1) The electric field $\vec{E}$ at all points on the x-axis has the same direction
2) at all points on the Y-axis is along $\vec{i}$
3) Work has to be done in bringing a test charge from infinity to the origin slowly.
4) The dipole moment is 2qd directed along $\vec{i}$

117. An electric dipole is placed in an electric field generated by a point charge

1) the net electric force on the dipole must be zero
2) the net electric force on the dipole may be zero
3) the torque on the dipole due to the field must be zero
4) the torque on the dipole due to the field may be zero

118. For a dipole, the value of each charge is 10^{-10} state coulomb and separation is 1 α, then its dipole moment is

1) one debye 2) 2 debye
3) 10^{-3}debye 4) 3×10^{-20}debye

119. For a dipole $q = 2 \times 10^{-6}$ C ; d = 0.01m find the maximum torque on the dipole if $E = 5 \times 10^5$ N/C

1) $1\times10^{-3}\,Nm^{-1}$ 2) $10\times10^{-2}\,Nm^{-1}$
3) $10\times10^{-3}\,Nm$ 4) $1\times10^{2}\,Nm^{2}$

120. An electric dipole is situated in an electric field of uniform intensity E whose dipole moment is p and moment of inertia is I. If the dipole is displaced then the angular frequency of its oscillation is

1) $\left(\frac{pE}{I}\right)^{\frac{1}{2}}$ 2) $\left(\frac{pE}{I}\right)^{\frac{3}{2}}$
3) $\left(\frac{I}{pE}\right)^{\frac{1}{2}}$ 4) $\left(\frac{p}{IE}\right)^{\frac{1}{2}}$

121. The angle between electric dipole moment p and the electric field E when the dipole is in stable equilibrium

1) 0 2) $\pi/4$ 3) $\pi/2$ 4) π

122. 'Debye' is the unit of

1) electric flux 2) electric dipole moment
3) electric potential 4) electric field intensity

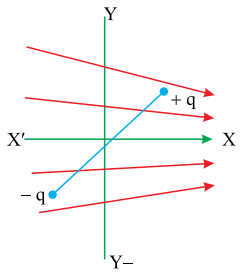
123. The electric field at a point at a distance r from an electric dipole is proportional to

1) $\frac{1}{r}$ 2) $\frac{1}{r^2}$ 3) $\frac{1}{r^3}$ 4) r^2

124. An electric dipole placed with its axis in the direction of a uniform electric field experiences

1) a force but not torque
2) a torque but no force
3) a force as well as a torque
4) neither a force nor a torque

125. An electric dipole is placed in a non uniform electric field increasing along the +ve direction of X - axis. In which direction does the dipole



1) move along + ve direction of X - axis, rotate clockwise
2) move along - ve direction of X - axis, rotate clockwise
3) move along + ve direction of X - axis, rotate anti clockwise
4) move along - ve direction of X - axis, rotate anti clockwise

126. An electric dipole placed in a non uniform electric field experiences

1) a force but no torque
2) a torque but no force
3) a force as well as a torque
4) neither a force nor a torque

127. If E_a be the electric field intensity due to a short dipole at a point on the axis and E_r be that on the perpendicular bisector at the same distance from the dipole, then

1) $E_a = E_r$ 2) $E_a = 2E_r$

3) $E_r = 2E_a$ 4) $E_a = \sqrt{2E_r}$

128. The angle between the electric dipole moment and the electric field strength due to it, on the equatorial line is

1) 0^0 2) 90^0 3) 180^0 4) 60^0

129. Two small neutral conducting spheres are taken and their centres are separated by a distance 2*a*. If '*n*' electrons are removed from one of them and deposited on the other, what is the magnitude of electric field intensity due to the system at a point on the line joining the centres of the spheres and at a distance *d* from the midpoint of the line joining the two spheres? (*e* is quantity of charge)

1) $\frac{2nea}{4\pi\varepsilon_o d^3}$ 2) $\frac{2n^2e^2a}{4\pi\varepsilon_o d^3}$ 3) $\frac{4nea}{4\pi\varepsilon_o d^3}$ 4) $\frac{4n^2e^2a}{4\pi\varepsilon_o d^3}$

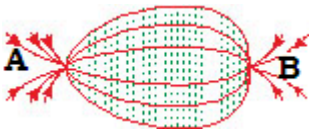
130. Electric field intensity at point varies as r^{-3} for

1) A point charge
2) An electric dipole
3) A plane infinite sheet of charge
4) A line charge of infinite length

131. An electric dipole is placed at an angle of 30° to a non-uniform electric field. the dipole will experience

1) A translational force only in a direction normal to the direction of the field
2) A torque as well as a translational force
3) A torque only
4) A translational force only in the direction of the field.

132. The spatial distribution of the electric field due to charges (*A*, *B*) is shown in figure. Which one of the following statements is correct?



1) *A* is +ve and *B* – ve and $|A| > |B|$
2) *A* is –ve and *B* + ve ; $|A| = |B|$
3) Both are +ve but $A > B$
4) Both are –ve but $A > B$

133. A charge is situated at a certain distance along the axis of an electric dipole experience a force *F*. If the distance of the charge from the dipole is doubled, the force acting on it will become

1) $2F$ 2) $\frac{F}{2}$ 3) $\frac{F}{4}$ 4) $\frac{F}{8}$

134. A point particle of mass M is attached to one end of a massless rigid non-conducting rod of length L. Another point particle of same mass is attached to the other end of the rod. The two particles carry charges +q and –q respectively. This arrangement is held in a region of uniform electric field E such that the rod makes a small angle θ (< 50) with the field direction. The minimum time needed for the rod to become parallel to the field after it is set free. (rod rotates about centre of mass)

1) $2\pi\sqrt{\frac{ML}{2qE}}$ 2) $\pi\sqrt{\frac{ML}{2qE}}$

3) $\frac{\pi}{2}\sqrt{\frac{ML}{2qE}}$ 4) $4\pi\sqrt{\frac{ML}{2qE}}$

KEY

110) 2	111) 3	112) 3	113) 2
114) 2	115) 1	116) 4	117) 4
118) 1	119) 3	120) 1	121) 1
122) 2	123) 3	124) 4	125) 1
126) 3	127) 2	128) 3	129) 3
130) 2	131) 2	132) 1	133) 4
134) 3			

ELECTRIC FLUX AND GAUSS LAW

135. The magnitude of electric field E in the annular region of a charged cylindrical capacitor

1) is same throughout
2) is higher near the outer cylinder than near the inner cylinder
3) varies as $1/r$, where r is the distance from the axis
4) varies as $1/r^2$ where r is the distance from the axis

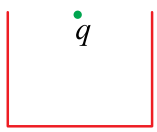
136. Electric charge is uniformly distributed along a long straight wire of radius 1 mm. The charge per cm length of the wire is Q coulomb. Another cylindrical surface of radius 50 cm and length 1m symmetrical encloses the wire as shown in the figure. The total electric flux passing through the cylindrical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

1) $\frac{Q}{\varepsilon_0}$ 2) $\frac{100Q}{\varepsilon_0}$ 3) $\frac{100Q}{(\varepsilon_0)^2}$ 4) $\frac{100Q}{(\pi\varepsilon_0)}$

137. An electric charge q is placed at the centre of a cube of side l. The electric flux through one of its faces will be

1) $\frac{q}{\varepsilon_0}$ 2) $\frac{q}{6\varepsilon_0}$ 3) $\frac{q}{\varepsilon_0 l^2}$ 4) $\frac{q}{4\pi\varepsilon_0 l^2}$

138. 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



1) zero 2) q/ε_0 3) $q/2\varepsilon_0$ 4) $2q/\varepsilon_0$

139. A point charge q is placed at one corner of a cube of edge a. The flux through each of the cube faces is

1) $\frac{q}{\varepsilon_0}$ 2) $\frac{q}{16\varepsilon_0}$

3) $\frac{q}{24\varepsilon_0}$ 4) $\frac{q}{48\varepsilon_0}$

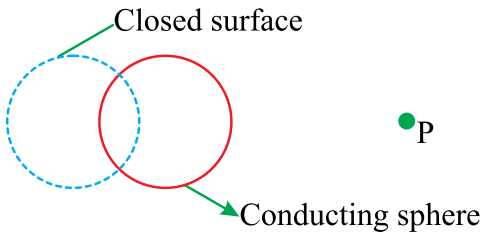
140. A hemispherical body of radius 'R' is placed in a uniform electric field 'E'. If the field E is parallel to the base of the hemisphere the flux linked with it is

1) $2\pi RE$ 2) $2\pi R^2E$ 3) πR^2E 4) zero

141. The length, and radius of a cylinder are 'L' and 'R' respectively. The total flux for the surface of the cylinder, when it is placed in a uniform electric field 'E' parallel to the axis of the cylinder is

1) zero 2) $2\pi R^2E$ 3) $\frac{2\pi R^2}{E}$ 4) πR^2E

142. Below figure shows a closed surface which intersects a conducting sphere. If a positive charge is placed at P, the flux of the electric field through the closed surface



1) will remain zero 2) will be positive
3) will be negative 4) will be undefined

143. Two infinite linear charges are placed parallel to each other at a distance 0.1 m from each other. If the linear charge density on each is 5 5μ C/m, then the force acting on a unit length of each linear charge will be

1) 2.5 N/m 2) 3.25 N/m
3) 4.5 N/m 4) 7.5 N/m

144. A sphere of radius R and charge Q is placed inside an imaginary sphere of radius 2R whose centre coincides with the given sphere. the flux related to imaginary sphere is

1) $\frac{Q}{\varepsilon_0}$ 2) $\frac{Q}{2\varepsilon_0}$ 3) $\frac{4Q}{\varepsilon_0}$ 4) $\frac{2Q}{\varepsilon_0}$

145. $20\mu C$ **charge is placed inside a closed surface then flux related to surface is** ϕ. **If** $80\mu C$ **charge is added inside the surface then change in flux is**

1) 4ϕ 2) 5ϕ 3) ϕ 4) 8ϕ

146. The electric field at a distance $\frac{3R}{2}$ **from the centre of a charged conducting spherical shell of radius R is E. The electric field at a distance** $\frac{R}{2}$ **from the centre of the sphere is**

1) E 2) $\frac{E}{2}$ 3) $\frac{E}{3}$ 4) Zero

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

1) Increase four times
2) Be reduce to half
3) Remain the same
4) Be doubled

148. A sphere of radius R, is charged uniformly with total charge Q. Then correct statement for electric field is (r = distance from centre)

1) $\frac{KQr}{R^3}$, where r < R

2) $\frac{KQ}{r^2}$, where r ≥ R

3) it is zero at all points 4) 1 and 2 both

149. 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**

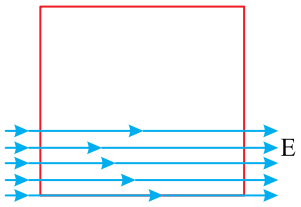
1) $1.5 N/C$ 2) $1.5\times10^{-10} N/C$

3) $3N/C$ 4) $3\times10^{-10} N/C$

150. Gauss law is given by $\varepsilon_0 \oint_s \vec{E}.\vec{ds} = q$, **if net charge enclosed in Gaussian surface is zero then**

1) E on surface must be zero
2) incoming and outgoing electric lines are equal
3) there is a net incoming electric lines
4) none

151. A square surface of side L is in the plane of the paper. A uniform electric field E ($V m^{-1}$), also in the plane of the paper, is limited only to the lower half of the square surface, (see figure). The electric flux in SI units associated withe the surface is



1) $EL^2/(2\varepsilon_0)$ 2) $EL^2/2$
3) zero 4) EL^2

152. Given : $\vec{E} = (10\hat{i} + 7\hat{j})$ Vm^{-1}. The electric flux through 1 m^2 area in XZ plane is

1)10 Vm 2)7 Vm 3)100 Vm 4) 49 Vm

153. A cubical Gaussian surface encloses electric flux of 30 C per unit permittivity of a charge. The electric flux through each face of the cube per unit permittivity is

1) 30 C 2) 15 C 3) 10 C 4) 5 C

154. As one penetrates uniformly charged conducting sphere, what happens to the electric field strength

1) decreases inversely as the square of the distance
2) decreases inversely as the distance
3) becomes zero
4) increases inversely as the square of distance

155. Mark the correct option

1) Gauss law is valid only for unsymmetrical charge distributions
2) Gauss law is valid only for charge placed in vacuum
3) The electric field calculated by Gauss law is the field due to the charges outside the Gaussian surface.
4) 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

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

1) The electric field must be zero every where on the surface
2) The electric field must not be zero everywhere on the surface
3) The charge inside the surface must be zero
4) The charge in the vicinity of the surface must be zero

157. 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

1) $E = \frac{\sigma}{\varepsilon_o K}$ 2) $E = \frac{\sigma}{2\varepsilon_o}$
3) $E = \frac{\sigma}{2\varepsilon_o K}$ 4) $E = \frac{K\sigma}{2\varepsilon_o}$

158. The electric flux from a cube of edge l is ϕ. Its value if edge of cube is made $2l$ and charge enclosed is halved is

1) $\phi/2$ 2) 2ϕ 3) 4ϕ 4) ϕ

159. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be

1) $(\phi_1 + \phi_2)/\varepsilon_o$ 2) $(\phi_1 - \phi_2)/\varepsilon_o$
3) $(\phi_1 + \phi_2)\varepsilon_o$ 4) $(\phi_2 - \phi_1)\varepsilon_o$

160. Electric flux at a point in an electric field is

1) positive 2) negative
3) zero 4) positive or negative

161. Electric flux over a surface in an electric field may be

1) positive 2) negative
3) zero 4) positive, negative, zero

162. A charge Q is placed at the mouth of a conical flask. The flux of the electric field through the flask is

1) zero 2) Q/ε_0 3) $\frac{Q}{2\varepsilon_0}$ 4) $< \frac{Q}{2\varepsilon_0}$

163. An electric dipole is placed at the centre of a sphere. Find the electric flux passing through the sphere.

1) 1 2) ∞ 3) 0 4) –2C

164. Electric field intensity at a point due to an infinite sheet of charge having surface charge density σ is E. If sheet were conducting electric intensity would be

1) E/2 2) E 3) 2 E 4) 4 E

165. Two thin infinite parallel sheets (non conducting) have uniform surface densities of charge + σ and $-\sigma$. Electric field in the space between the two sheets is

1) $\sigma/\in_0$ 2) $\sigma/2\in_0$ 3) $2\sigma/\in_0$ 4) zero

166. In the above question, if the sheets were thick and conducting, value of E in the space between the two sheets would be

1) $2\sigma/\in_0$ 2) $\sigma/\in_0$
3) zero 4) $4\sigma/\in_0$

167. In the above problem the value of E in the space outside the sheets is.

1) $\sigma/\in_0$ 2) $\sigma/2\in_0$ 3) zero 4) $2\sigma/\in_0$

168. The Gaussian surface for calculating the electric field due to a charge distribution is

1) any closed surface around the charge distribution
2) any surface near the charge distribution
3) a spherical surface
4) a closed surface at a every point of which electric field has a normal component which is zero or a fixed value

169. The electric flux over a sphere of radius 1m is ϕ. If radius of the sphere were doubled without changing the charge enclosed, electric flux would become

1) 2ϕ 2) $\phi/2$ 3) $\phi/4$ 4) ϕ

170. A uniformly charged conducting sphere of 2.4m diameter has a surface charge density of 80.0μC/m².

The charge on the sphere, the total electric flux leaving the surface of the sphere ?

1) $1.45\times10^{-6}C$, $164\times10^{8}\ Nm^2C^{-1}$
2) $1.45\times10^{-4}C$, $16.4\times10^{8}\ Nm^2C^{-1}$
3) $1.45\times10^{-3}C$, $1.64\times10^{8}\ Nm^2C^{-1}$
4) $1.45\times10^{-5}C$, $164\times10^{9}\ Nm^2C^{-1}$

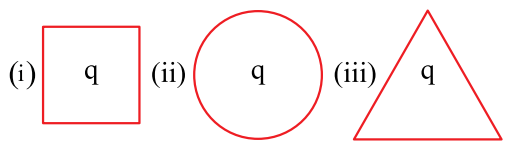
171. Charge of 2C is placed at the centre of a cube. What is the electric flux passing through one face ?

1) $\frac{1}{(3\varepsilon_0)}$ 2) $\left(\frac{1}{4}\right)\varepsilon_0$
3) $\frac{2}{\varepsilon_0}$ 4) $\frac{3}{\varepsilon_0}$

172. A point charge +q is placed at mid point of a cube of side 'L'. The electric flux emerging from the cube is

1) q/ε_0 2) $6qL^2/\varepsilon$ 3) $q/6L^2\varepsilon_0$ 4) zero

173. A charge q is enclosed as shown below, the electric flux is



1) maximum in (i)
2) maximum in (ii)
3) maximum in (iii)
4) equal in all

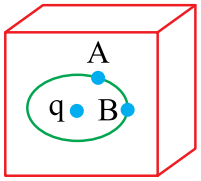
174. An ellipsoidal cavity is carved with in a perfect conductor. A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in the figure then

a) Electric field near A in the cavity = Electric field near B in the cavity

b) Charge density at A = Charge density at B

c) **Potential at A = Potential at B**

d) **Total electric flux through the surface of the cavity is q/ε_0.**



1) a,b,c,d are correct

2) a,b,c are correct

3) only a and b are correct

4) only c and d are correct

175. Two infinitely long thin straight wires having uniform linear charge densities λ and 2λ are arranged parallel to each other at a distance r apart. The intensity of the electric field at a point midway between them is

1) $\frac{2\lambda}{\pi\varepsilon_0 r}$ 2) $\frac{\lambda}{\pi\varepsilon_0 r}$ 3) $\frac{\lambda}{2\pi\varepsilon_0 r}$ 4) $\frac{3\lambda}{2\pi\varepsilon_0 r}$

176. A : A metallic shield in the form of a hollow shell may be built to block an electric field.

R : In a hollow spherical shield, the electric field inside it is zero at every point.

1) Both 'A' and 'R' are true and 'R' is the correct explanation of 'A'.

2) Both 'A' and 'R' are true and 'R' is not the correct explanation of 'A'.

3) 'A' is true and 'R' is false

4) 'A' is false and 'R' is true

177. Intensity of electric field inside a uniformly charged hollow sphere is

1) zero 2) non zero constant

3) change with r 4) inversely proportional to r

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

1) $\frac{1}{x}$ 2) x 3) $\frac{1}{x^2}$ 4) x^2

179. The electric field inside a spherical shell of uniform surface charge density is

1) constant

2) proportional to the distance form the centre

3) Zero 4) None

180. The total electric flux leaving a spherical surface of radius 1 cm and surrounding an electric dipole is

1) $\frac{q}{\varepsilon_0}$ 2)zero 3) $\frac{2q}{\varepsilon_0}$ 4) infinite

181. In the situation when the Gaussian surface is so chosen that there are some charges inside and some outside, then regarding the electric field at any point and the electric flux through the Gaussian surface, which of the following is correct?

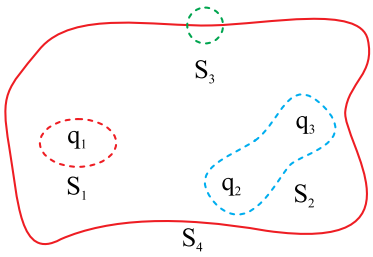
1) The field is due to the outside charges and flux depends on the inside charges

2) The field is due to all the charges and flux depends on the inside charges

3) The field is due to all the charges and flux depends on the outside charges

4) The field is due to the inside charges and flux depends on the outside charges

182. Three charges $q_1 = 1\,\mu c$, $q_2 = 2\,\mu c$ and $q_3 = -3\,\mu c$ and four surfaces S_1, S_2, S_3 and S_4 are shown in figure. The flux merging through surface S_2 in N-m²/C is



1) $36\pi \times 10^3$ 2) $-36\pi \times 10^3$

3) $36\pi \times 10^9$ 4) $-36\pi \times 10^9$

183. A charge of 4×10^{-9}C is uniformly distributed over the surface of a ring of radius 0.3 m. The intensity of the electric field at a point on the axis of the ring at a distance of 0.4 m from the plane of the ring is

1) 40.7 v/m 2) 151.2 v/m
3) 251.2 v/m 4) 115.2 v/m

184. Two infinitely long parallel conducting plates having surface charge densities $+\sigma$ and $-\sigma$ respectively are separated by a small distance. the medium between the plates is vacuum. if ϵ_0 is dielectric permittivity of vacuum, then the electric field in the region between the plates is

1) zero 2) $\sigma/2\epsilon_0$ 3) σ/ϵ_0 4) $2\sigma/\epsilon_0$

185. Let $\rho(r)=\frac{Qr}{\pi R^4}$ be the charge density distribution for a solid sphere of radius R and total charge Q. For a point P inside the sphere at a distance r_1 from the centre of the sphere, the magnitude of electric field is

1) $\frac{Q}{4\pi\epsilon_0 r_1^2}$ 2) $\frac{Qr_1^2}{4\pi\epsilon_0 R^4}$
3) $\frac{Qr_1^2}{3\pi\epsilon_0 R^4}$ 4) zero

186. A is a spherical conductor placed concentrically inside a hollow spherical conductor B. A is given +q charge and B is earthed. Then the electric intensity is not zero

1) Inside A 2) Outside B
3) On the surface of B 4) Between A and B

187. An infinite parallel plane sheet of a metal is charged to charge density σ coulomb per square meter in a medium of dielectric constant K. Intensity of electric field near the metallic surface will be

1) $E=\frac{\sigma}{\epsilon_0 K}$ 2) $E=\frac{K}{2\epsilon_0}$
3) $E=\frac{\sigma}{2\epsilon_0 K}$ 4) $E=\frac{K\sigma}{2\epsilon_0}$

188. Two infinitely long parallel conducting plates having surface charge densities + s and – s respectively, are separated by a small distance. The medium between the plates is vacuum. If ε_0 is the dielectric permittivity of vacuum, then the electric field in the region between the plates is

1) 0 volt m^{-1} 2) $\sigma/2\varepsilon_0$ volt m^{-1}
3) σ/ε_0 volt m^{-1} 4) $z\sigma/\varepsilon_0$ volt m^{-1}

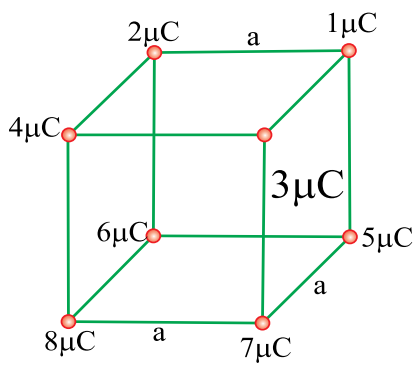
189. The Electric field at a point is

A. always continuous.
B. continuous if there is no charge at that point.
C. discontinuous only if there is a negative charge at that point.
D. discontinuous if there is a charge at that point.

1) A,C are true 2) All are true
3) B,D are true 4) B,C are true

190. The total flux associated with given cube will be - where 'a' is side of cube

$$\left(\frac{1}{\varepsilon_0}=4\pi\times9\times10^9\right)$$



1) $162\pi\times10^{-3}$ Nm²/C
2) $162\pi\times10^{3}$Nm²/C
3) $162\pi\times10^{-6}$ Nm²/C
4) $162\pi\times10^{6}$Nm²/C

KEY

135) 3	136) 2	137) 2	138) 3
139) 3	140) 4	141) 1	142) 2
143) 3	144) 1	145) 1	146) 4
147) 3	148) 4	149) 3	150) 2
151) 3	152) 2	153) 4	154) 3
155) 4	156) 3	157) 1	158) 1
159) 4	160) 3	161) 4	162) 3
163) 3	164) 3	165) 1	166) 1
167) 3	168) 4	169) 4	170) 3
171) 1	172) 1	173) 4	174) 4
175) 2	176) 1	177) 1	178) 2
179) 3	180) 2	181) 2	182) 2
183) 4	184) 4	185) 2	186) 4
187) 3	188) 3	189) 3	190) 2

HINTS SOLUTIONS

1. Body which losses electrons gets positive charge and which gain electrons gets negative charge
2. Body which losses electrons gets positive charge and which gain electrones gets negative charge
3. Due to repulsion, size of bubble increases
4. Charge is invariant;
5. Unlike charges attract
6. All are properties of charge
7. q=ne where n=1,2,3...;
8. Due to repulsion.
9. $q^1 = -q(1-1/k)$
10. Charge will remain on outer surface of the car.
11. (1) : q = ne
12. Surface density $\sigma = \frac{Q}{4\pi R^2}$ for big drop $Q = Nq$ and $R = N^{1/3} r$
13. like charges repel and unlike charges attract
14. $F_{air} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$; $F_{med} = \frac{1}{4\pi\varepsilon}\frac{q_1q_2}{r^2}$ and $K = \frac{\varepsilon}{\varepsilon_0}$
15. F is maximum when $q_1 = q_2$;
16. $F \propto q_1q_2$
    When two identical bodies touched, they will share the charges equally.
17. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$
18. K depends on system of units and medium between charges
19. $r_{med} = \frac{r_{air}}{\sqrt{k}}$
20. In equlibrium $F_{net} = 0$; $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$
21. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$
22. F is maximum when charge divided into two equal parts
23. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$; $q_1 = q_2 = Ne$
24. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ and in equilibrium $F_{net} = 0$
25. $F_{med} = \frac{F_{air}}{K}$
26. Conceptual
27. Like charges repel and unlike charges attract
28. $\overrightarrow{F_{net}} = \overrightarrow{F_1} + \overrightarrow{F_2}$ where $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$
29. $\tan\theta = \frac{F}{mg}$; Here $F_{12} = F_{21}$ and $m_1 = m_2$
30. $\tan\theta = \frac{F}{mg}$

    Here $F_{12} = F_{21}$ and $m_1 = m_2$
31. In equilibrium $\overrightarrow{F_{net}} = \overrightarrow{F_1} + \overrightarrow{F_2} = 0$
32. $F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$; $D.F$ of $\varepsilon_0 = D.F$ of $\frac{q^2}{Fr^2}$
33. Coulomb's law is applicable only for static and point charges
34. Ratio of F_G and F_e is $1:10^{36}$

35. $F = \frac{1}{4\pi\varepsilon_0 k}\frac{Q.Q_2}{r^2}$;

36. Conceptual

37. $F = \frac{1}{4\pi\varepsilon_0 k}\frac{Q.Q_2}{r^2}$

38. $F = k\frac{2Q^2}{r^2}$

New Change =

$$\frac{Q_1+Q_2}{2} = \frac{Q}{2} \Rightarrow F_2 = \frac{k\left(\frac{Q}{2}\right)^2}{r^2} = \frac{F}{8}$$

39. $F_2 = k\frac{Q\left(\frac{Q}{2}\right)}{\left(\frac{r}{2}\right)^2} - k\frac{\left(\frac{Q}{2}\right)\left(\frac{Q}{2}\right)}{\left(\frac{r}{2}\right)^2} = 2F - F = F$

40. $F_{12} = F_{21}$;

41. $F_e = F_g$;

42. $F \propto \frac{Q_1Q_2}{r^2}$

43. Resultant force is perpendicular to AB

44. $\frac{10}{4\pi\in_0 x^2} = \frac{1}{4\pi\in_0}.\frac{20\times1}{(0.8-x)^2}$.

$2x^2 = (0.8-x)^2$;

$1.414x = 0.8 - x$, $x = 33\,cm$

45. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ in S.H.M acceleration (a) α - displacement

46. Conceptual

47. (4) : Gravitational force between two electron

$$F_g = \frac{G\ m_e m_e}{r^2}$$

$$= \frac{6.67\times10^{-11}\times(9.1\times10^{-31})^2}{r^2}$$

Electrostatic force between 2 electrons

$$F_e = \frac{1}{4\pi\in_0}.\frac{q_e\cdot q_e}{r^2}$$

$$F_e = \frac{9\times10^9\times(1.6\times10^{-19})^2}{r^2};\ \frac{F_g}{F_e} = 10^{-43}$$

48. $X = \frac{d}{\sqrt{\frac{q_2}{q_1}+1}}$ from $q_1 < q_2$

49. Nucleus of hydrogen atom contains one proton of charge (+ e). The revolving electron arries a charge $(-e)$

According to Coulomb's law

$$F = \frac{K(e)(-e)}{r^2}\hat{r} = -\frac{Ke^2}{r^3}\vec{r}$$

50. $F_{res} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

51. $F_{Gravitational} = F_{Electrostatic}$

52. $r_{medium} = \frac{r_{air}}{\sqrt{K}}$

53. $F_{Gravitation} = F_{electrostatic}$;

54. $\tan\theta = \frac{F}{mg}$

55. Since, q is at the centre of two charges Q and Q, net force on it is zero, whatever the magnitude and sign of charge on it. For the equilibrium of Q, q should be negative because other charge Q will repel it, so q should attract it. Simultaneously these attractions and repulsions should be equal

56. $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ Due to positive charge $\vec{E}$ radially outwards

and Due to -ve charge $\vec{E}$ radially inwards

57. $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$ where $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

58. $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$

59. $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 + \vec{E}_5$

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

61. Properties of electric lines of force

62. $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ Due to positive charge $\vec{E}$ radially outwards and Due to -ve charge $\vec{E}$ radially inwards

63. $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$ where $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

64. Motion of electron is like horizontal projectile

$\therefore Y = \frac{1}{2}at^2$; Where $a = \frac{Eq}{m}$; $x = vt$

65. mg= Eq;

66. $a = \frac{Eq}{m}$

67. Electron experience deceleration.

68. If electric lines of force are crowded electric field strength is more if they are apart from each other E strength is less.

69. Due to positive charge electric lines of force diverge and due to negative charge electric lines of force converge

70. Properties of electric lines of force

71. $a = \frac{Eq}{m}$;

72. $a = \frac{Eq}{m}$

73. $\vec{F}_{12} = -\vec{F}_{21}$ but $a = \frac{Eq}{m}$

74. Conceptual

75. $E = \frac{F}{q_0}$ where q_0 is test charge

76. $E_{center} = 0$;

77. $F_{12} = F_{21}$

78. $a = \frac{Eq}{m}$ here electron experience retardation

79. Conceptual

80. Along Y-direction, electron experience acceleration

81. $S = \frac{1}{2}at^2$ where $a = \frac{Eq}{m}$

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

83. Conceptual

84. Electron experience acceleration opposite to $\vec{E}$

85. Charge experience acceleration due to $\vec{E}$

86. Electron experience acceleration opposite to $\vec{E}$

87. According definition of $\vec{E}$

88. $a = \frac{Eq}{m}$;

89. Conceptual

90. $E = \frac{F}{q_0}$ where q_0 is test charge

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

92. $KE = \frac{1}{2}\frac{q_0^2E^2t^2}{m}$

93. Electron experience acceleration opposite to $\vec{E}$

94. Electrostatic field due to a charged conductor is zero inside the conductor and constant at the surface of the conductor, being normal to the surface at every point.

95. Field at the origin, the centre of the ring is zero. Potential at the origin = K Q/R

96. (2) : $E = \frac{v}{d}$

97. $v^2 = 2as$; Where $a = \frac{Eq}{m}$

98. F ; $W = \vec{F}\cdot\vec{r}$

$W = q(E_1 i + E_2 j).(ai + j)$;

$W = q(E_1 a + E_2)$

99. $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ where $\vec{r} = \vec{r}_2 - \vec{r}_1$

100. $time\ of\ descent\ \sqrt{\frac{2h}{g}}, s = ut + 1/2at^2$

101. Conceptual

102. Conceptual

103. $\tan\theta = \frac{qEx}{mv^2}$; $\tan\theta = \frac{qEx}{2KE}$

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

105. $v = u + at$ where $a = \frac{Eq}{m}$

106. Conceptual

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

108. $E = \frac{2QSin\frac{\phi}{2}}{4\pi\varepsilon_0 R^2\phi}$ for semi circular ring $\phi = \pi$

109. Conceptual

110. Due to dipole $E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$; $E_{equ} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

111. $\tau_{max} = PE$ where $p = q(2a)$

112. Conceptual

113. In uniform field $F_{net} = 0$ $\tau_{net} \neq 0$

114. $E_{axal} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$ from $-q\ to\ +q$

$E_{equ} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$; from $+q$ to $-q$

115. $E_{axal} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

116. $p = q(2a)$ direction from $-q$ to $+q$

117. $\tau = PE\sin\theta$;

118. $p = q(2a)$

119. $\tau_{max} = PE$;

120. In angular S.H.M

$\alpha = -\omega^2\theta$ where $\omega^2 = \frac{PE}{I}$

121. In stable equilibrium $\tau = 0$ and potential energy $= -PE$

122. Conceptual

123. $E_{axal} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

124. In uniform field $F_{net} = 0$ $\tau_{net} \neq 0$

125. $\vec{\tau} = \vec{P}\times\vec{E}$

126. In nonuniform field $\tau_{net} \neq 0$ $F_{net} \neq 0$

127. $E_{axal} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$; $E_{equ} = \frac{1}{4\pi\varepsilon_0}\frac{P}{r^3}$

128. $\vec{E}_{equ}$ direction is from +q to - q and $\vec{P}$ direction is from -q to +q

129. $E_{axal} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$ where $p = q2a$ and $q = ne$

130. $E_{axal} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

131. As the electric field is non-uniform, the dipole will experience a translational force as well as a torque

132. Electric lines of force usually start (i.e., diverge out) from positive charge and end (i.e., converge) on negative charge or extends to infinity.

133. The electric field at a point distance r from electric dipole is

$R = \frac{1}{4\pi\varepsilon_0}.\frac{2p}{r^3}$ (axial line)

where p is dipole moment and r is the distance of charge from centre of dipole.

or $E \propto \frac{1}{r^3}$

Force on charge is

$F = QE$ or $F \propto \frac{1}{r^3}$

$\frac{F_2}{F_1} = \left(\frac{r_1}{r_2}\right)^2$

Given $r_1 = r_2 = 2r$, $F_1 = F$

$\frac{F_2}{F} = \left(\frac{r}{2r}\right)^3 = \frac{1}{8}$ or $F_2 = \frac{F}{8}$

134. At equilibrium $\tau_{Clock} = \tau_{anticlock}$ $I\alpha = -PE\theta$

135. Conceptual

136. $\phi_{total} = \frac{1}{\varepsilon_0}(q)$; 137. $\phi_{face} = \frac{\phi_{Cube}}{6}$

138. $\phi_{surface} = \frac{\phi_{total}}{2}$;

139 $\phi_{cube} = \frac{\phi_{total}}{8}$; $\phi_{face} = \frac{\phi_{Cube}}{3}$

140. Electric flux $\phi = \vec{E}.\vec{A}$;

141. $\phi = \vec{E}.\vec{A}$

142. $\phi_{leaving}$ is taken as positive and $\phi_{entering}$ is taken as negative.

143. $E = \frac{\lambda}{2\pi\varepsilon_0 r}$; 144. $\phi_{total} = \frac{1}{\varepsilon_0}(q)$

145. $\phi_{total} = \frac{1}{\varepsilon_0}(q)$; 146. $E_{inside} = 0$

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

148. Due to uniformly charged sphere $E_{out} \alpha \frac{1}{r^2}$, $E_{in} \alpha r$

149. $E = \frac{\sigma}{\varepsilon_0}$ $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$;

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

151. Electric flux (f_e) is a measure of the number of field lines crossing a surface. The number of field lines passing through unit area (N/s) will be proportional to the electric field,

$\frac{N}{S} \propto E \Rightarrow N \propto ES$

The quantity *ES* is the electric flux through surface *S*. As we have seen in the problem that, lines of force that enter the closed surface leave the surface immediately, so no electric flux is bound to the system. Hence, electric flux is zero.

152. $\phi = \vec{E}.\vec{A}$;

153. $\phi_{face} = \frac{\phi_{Cube}}{6}$;

154. $E_{inside} = 0$

155. Conceptual

156. $\phi_{total} = \frac{1}{\varepsilon_0}(q_{in})$;

157. $E = \frac{\sigma}{2\varepsilon}$ and $K = \frac{\varepsilon}{\varepsilon_0}$

158. $\phi_{total} = \frac{1}{\varepsilon_0}(q_{in})$

159. $\phi_{leaving}$ is taken as positive and $\phi_{entering}$ is taken as negative.

160. $\phi_{total} = \frac{1}{\varepsilon_0}(q_{in})$;

161. Conceptual

162. $\phi_{flask} = \frac{\phi_{total}}{2}$

163. $\phi_{flask} = \frac{\phi_{total}}{2}$;

164. E(Nonconducting) $= \frac{\sigma}{2\varepsilon_0}$; E(Conducting) $= \frac{\sigma}{\varepsilon_0}$

165. E(Nonconducting) $= \frac{\sigma}{2\varepsilon_0}$ and $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$

167. Conceptual

168. E(Nonconducting) $= \frac{\sigma}{2\varepsilon_0}$ and $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$

169. $\phi_{total} = \frac{1}{\varepsilon_0}(q_{in})$;

170. $\phi_{face} = \frac{\phi_{Cube}}{6}$

171. $\phi_{face} = \frac{\phi_{Cube}}{6}$;

172. $\phi_{total} = \frac{1}{\varepsilon_0}(q_{in})$

173. $\phi_{total} = \frac{1}{\varepsilon_0}(q_{in})$

174. Conceptual

175. $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$ and $E_{net} = \frac{\lambda}{2\pi\varepsilon_0 r}$

176. Conceptual

177. For conducting spherical shell $E_{inside} = 0$

178. For nonconducting sphere $E_{inside} \alpha\, r$

179. For conducting spherical shell $E_{inside} = 0$

180. $\Sigma Q = 0$

181. Conceptual;

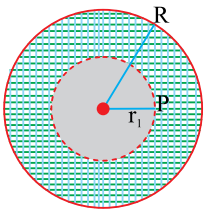
182. $\oint \vec{E}.d\vec{s} = \frac{q\,inside}{\in_0}$

183. $E = \frac{1}{4\pi\in_o}\frac{Q.x}{\left(x^2 + R^2\right)^{3/2}}$

184. From the knowledge of theory, $E = \sigma/\in_0$

185. In the figure, dotter sphere of radius r_1 is the Gaussian surface.
According to gauss's theorem

$$\oint \vec{E}.d\vec{s} = \frac{q\,inside}{\in_0}$$



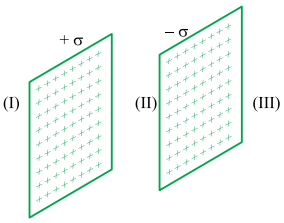
Here $\theta = 0^0$; $E\left(4\pi r_1^2\right) = \frac{q_{in}}{\varepsilon_0}$

$dq = \rho dv$; $dq = \rho 4\pi r^2 dr$

186. For conducting spherical shell $E_{inside} = 0$ and $E_{outside}\, \alpha \frac{1}{r^2}$

187. $E = \frac{\sigma}{2\in} = \frac{\sigma}{2\in_0 K}$

188. Between the plates, i.e., in the region II as shown in the figure, electric field is given by



$$E = \frac{1}{2\varepsilon_0}(\sigma_1 - \sigma_2) = \frac{1}{2\varepsilon_0} \times 2\sigma = \frac{\sigma}{\varepsilon_0} Vm^{-1}$$

189. Conceptual

190. $\phi_{total} = \frac{q_{net}}{\varepsilon_0}$ and $\phi_{cube} = \frac{\phi_{total}}{8}$

STUDENT PRACTICE QUESTIONS EXERCISE

ELECTRIC CHARGE

1. **One million electrons are added to a glass rod. The total charge on the rod is**
   1) $10^{-13}C$ 2) $-1.6\times10^{-13}C$
   3) $+1.6\times10^{-12}C$ 4) $10^{-12}C$
2. **A body has a charge of 9.6×10^{-20} coulomb. It is**
   1) possible 2) not possible
   3) may (or) may not possible
   4) Data not sufficient
3. **A charged spherical conductor has a surface charge density of 0.7 C/m^2. When its charge is increased by 0.44C, the charge density changes by 0.14 C/m^2. The radius of the sphere is**
   1) 5 cm 2) 1 0 m 3) 0.5 m 4) 5 m

KEY

1) 2 2) 2 3) 3

COULOMB'S LAW

4. **A force of 4N is acting between two charges in air. If the space between them is completely filled with glass $(\varepsilon_r = 8)$, then the new force will be**
   1) 2N 2) 5N 3) 0.2N 4) 0.5N
5. **There are two charges $+1\,\mu c$ and $+2\,\mu c$ kept at certain separation . The ratio of electro static forces acting on them will be in the ratio of**
   1) 1 : 2 2) 2 : 1 3) 1 : 1 4) 1 : 4
6. **Two identical metal spheres possess +60C and –20C of charges. They are brought in contact and then separated by 10 cm. The force between them is**
   1) $36\times10^{13}N$ 2) $36\times10^{14}N$
   3) $36\times10^{12}N$ 4) $3.6\times10^{12}N$
7. **Two charges +8q and - 2q are fixed on X-axis at origin and $x = +a$ locations. A third charge +q is to be located on X-axis (other than infinitely far away) so that it is in equilibrium. The location of the third charge is correctly represented by**
   1) $x = 2a$ 2) $x = 3a/2$
   3) $x = -a$ 4) $x = 3a$
8. **Three charges -q, +q and -q are placed at the corners of an equilateral triangle of side 'a'. The resultant electric force on a charge +q placed at the centroid O of the triangle is**
   1) $\frac{3q^2}{4\pi\varepsilon_0 a^2}$ 2) $\frac{q^2}{4\pi\varepsilon_0 a^2}$
   3) $\frac{q^2}{2\pi\varepsilon_0 a^2}$ 4) $\frac{3q^2}{2\pi\varepsilon_0 a^2}$
9. **A charge of $+2\mu C$ is placed at x=0 and a charge of $-32\mu C$ at x=60 cm. A third charge –Q be placed on the x-axis such that it experiences no force. The distance of the point from $+2\mu C$ is(in cm)**
   1) -20 2) 20 3) 15 4) 10
10. **Two charges when kept at a distance of 1m apart in vacuum have some force of repulsion. If the force of repulsion between these two charges be same, when placed in an oil of dielectric constant 4, the distance of separation is**
    1) 0.25m 2) 0.4m 3) 0.5m 4) 0.6m
11. **The excess (equal in number) number of electrons that must be placed on each of two small spheres spaced 3 cm apart with force of repulsion between the spheres to be $10^{-19}N$ is**
    1) 25 2) 225 3) 625 4) 1250
12. **Two small conducting spheres each of mass $9\times10^{-4}kg$ are suspended from the same point by non conducting strings of length 100 cm. They are given equal and similar charges until the strings are equally inclined at 45^0 each to the vertical. The**

charge on each sphere is ..... coulomb

1) 1.4×10^{-6} 2) 1.6×10^{-6}

3) 2×10^{-6} 4) 1.96×10^{-6}

13. A charge +q is fixed to each of three corners of a square. On the empty corner a charge Q is placed such that there is no net electrostatic force acting on the diagonally opposite charge. Then

1) $Q=-2q$ 2) $Q=-2\sqrt{2}q$

3) $Q=-\sqrt{2q}$ 4) $Q=-4q$

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

1) 198 N 2) 100 N 3) 200 N 4) 99 N

15. N fundamental charges each of charge 'q' are to be distributed as two point charges separated by a fixed distance, then the maximum to minimum force bears a ratio (N is even and greater than 2)

1) $\frac{(N-1)^2}{4N^2}$ 2) $\frac{4N^2}{(N-1)}$

3) $\frac{N^2}{4(N-1)}$ 4) $\frac{2N^2}{(N-1)}$

16. A particle A having a charge of $2\times10^{-6}C$ and a mass of 100g is placed at the bottom of a smooth inclined plane of inclination 30^0. The distance of another particle of same mass and charge, be placed on the incline so that it may remain in equilibrium is

1) 27 cm 2) 16 cm 3) 30 cm 4) 45 cm

17. Two identical particles of charge q each are connected by a massless spring of force constant k. They are placed over a smooth horizontal surface. They are released when unstretched. If maximum extension of the spring is r, the value of k is : (neglect gravitational effect)

1) $k=\frac{q}{r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ 2) $k=\frac{1}{4\pi\varepsilon_0}\frac{q^2}{l^2}\times\frac{1}{r}$

3) $k=\frac{2q}{r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ 4) $k=\frac{q}{r}\sqrt{\frac{2}{\pi\varepsilon_0 r}}$

18. A regular pentagon has four charges each +q at four of its vertices. At the center of the pentagon, a charge +q is kept. If the distance of a vertex from the center is a, the magnitude of the net force acting on the charge at the center is

1) $\frac{q^2}{4\pi\varepsilon_o a^2}$ 2) zero 3) $\frac{4q^2}{4\pi\varepsilon_o a^2}$ 4) $\frac{2q^2}{4\pi\varepsilon_o a^2}$

KEY

4) 4	5) 3	6) 1	7) 1	8) 4
9) 1	10) 3	11) 3	12) 1	13) 2
14) 1	15) 3	16) 1	17) 2	18) 1

ELECTRIC FIELD & ELECTRIC LINES OF FORCE

19. Two charges of $50\,\mu C$ and $100\,\mu C$ are separated by a distance of 0.6m. The intensity of electric field at a point midway between them is

1) $50\times10^6\,V/m$ 2) $5\times10^6\,V/m$

3) $10\times10^6\,V/m$ 4) $10\times10^{-6}\,V/m$

20. Two point charges Q and -3Q are placed some distance apart. If the electric field at the location of Q is $\vec{E}$, the field at the location of -3Q is

1) $\vec{E}$ 2) $-\vec{E}$

3) $+\frac{\vec{E}}{3}$ 4) $-\frac{\vec{E}}{3}$

21. A mass m carrying a charge q is suspended from a string and placed in a uniform horizontal electric field of intensity E. The angle made by the string with the vertical in the equilibrium position is

1) $\theta = \tan^{-1}\frac{mg}{Eq}$ 2) $\theta = \tan^{-1}\frac{m}{Eq}$

3) $\theta = \tan^{-1}\frac{Eq}{m}$ 4) $\theta = \tan^{-1}\frac{Eq}{mg}$

22. A proton of mass 'm' charge 'e' is released from rest in a uniform electric field of strength 'E'. The time taken by it to travel a distance 'd' in the field is

1) $\sqrt{\frac{2de}{mE}}$ 2) $\sqrt{\frac{2dm}{Ee}}$ 3) $\sqrt{\frac{2dE}{me}}$ 4) $\sqrt{\frac{2Ee}{dm}}$

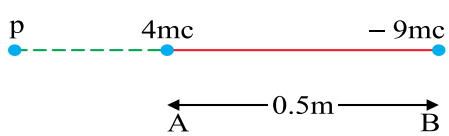
23. An infinite number of charges each of magnitude q are placed on x - axis at distances of 1,2, 4, 8, ... meter from the origin. The intensity of the electric field at origin is

1) $\frac{q}{3\pi\varepsilon_0}$ 2) $\frac{q}{6\pi\varepsilon_0}$ 3) $\frac{q}{2\pi\varepsilon_0}$ 4) $\frac{q}{4\pi\varepsilon_0}$

24. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F.F is proportional to

1) $\frac{1}{\varepsilon_o}\sigma^2R^2$ 2) $\frac{1}{\varepsilon_o}\sigma^2R$ 3) $\frac{1}{\varepsilon_o}\frac{\sigma^2}{R}$ 4) $\frac{1}{\varepsilon_o}\frac{\sigma^2}{R^2}$

25. Two point charges of magnitude 4 μ C and -9 μ C are 0.5m apart. The electric intensity is zero at a distance 'x' m from 'A' and 'y' m from 'B'. 'x' and 'y' are respectively



1) 0.5m, 1.0m 2) 1.0m, 1.5m

3) 2.0m, 1.5m 4) 1.5m, 2.0m

26. Point charges of $3\times10^{-9}C$ are situated at each of three corners of a square whose side is 15 cm. The magnitude and direction of electric field at the vacant corner of the square is

1) 2296 V/m along the diagonal

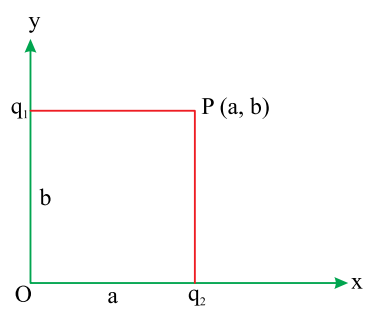
2) 9622 V/m along the diagonal

3) 22.0 V/m along the diagonal 4) zero

27. 'n' charges Q, 4Q, 9Q, 16Q ..... are placed at distances of 1, 2, 3 ..... meter from a point 'O' on the same straight line. The electric intensity at 'O' is

1) $\frac{Q}{4\pi\in_0 n^2}$ 2) $\frac{Q}{4\pi\in_0 n}$ 3) Infinity 4) $\frac{nQ}{4\pi\in_0}$

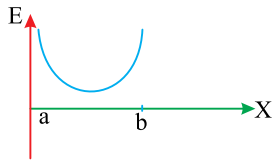
28. Two point charges $q_1 = 2\mu C$ and $q_2 = 1\mu C$ are placed at distances b=1 cm and a=2 cm from the origin on the y and x axes as shown in figure. The electric field vector at point (a, b) will subtend an angle θ with the x - axis given by



1) tan $\theta = 1$ 2) tan $\theta = 2$

3) tan $\theta = 3$ 4) tan $\theta = 4$

29. Two point charges Q_a & Q_b, whose magnitudes are same are positioned at a certain distance from each other with Q_a at origin. Graph is drawn between electric field strength at points between Q_a&Q_b and distance x from Q_a. E is taken positive if it is along the line joining from Q_a to Q_b. From the graph, it can be decided that



1) a is positive, b is negative

2) a and b both are positive

3) a and b both are negative

4) a is negative, b is positive

30. Find out electric filed intensity at point A(1,0,2)due to a point charge –20 μ C situated at point B(0, $\sqrt{2}$,1) :-

1) $-22.5 \times 10^3\left(\hat{i}-\sqrt{2}\hat{j}+\hat{k}\right)$

2) $8.5 \times 10^3\left(\hat{i}+\sqrt{2}\hat{j}+\hat{k}\right)$

3) $22.5 \times 10^3\left(\hat{i}+\sqrt{2}\hat{j}-\hat{k}\right)$

4) $8.5 \times 10^3\left(\hat{i}-\sqrt{2}\hat{j}+\hat{k}\right)$

KEY

19) 2	20) 3	21) 4	22) 2
23) 1	24) 1	25) 2	26) 1
27) 4	28) 2	29) 1	30) 1

ELECTRIC DIPOLE

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

1) $\tan^{-1}(2)$ 2) $\tan^{-1}(\sqrt{2})$

3) $\tan^{-1}(1/\sqrt{2})$ 4) Zero

32. An electric dipole consists of two opposite charges of magnitude $1\mu C$ separated by a distance of 2cm. The dipole is placed in an electric filed $10^{-5}Vm^{-1}$. The maximum torque that the field exert on the dipole is

1) $10^{-3}\,Nm$ 2) $2\times10^{-13}\,Nm$

3) $3\times10^{-3}\,Nm$ 4) $4\times10^{-3}\,Nm$

33. An electric dipole is formed two particles fixed at the ends of a light rigid rod of length l. The mass of each particle is m and charges are -q and +q The system is suspended by a torsionless thread in an electric field of intensity E such that the dipole axis is parallel to the field if it is slightly displaced, the period of angular motion is

1) $\frac{1}{2\pi}\sqrt{\frac{2qE}{ml}}$ 2) $2\pi\sqrt{\frac{ml}{qE}}$ 3) $2\pi\sqrt{\frac{ml}{2qE}}$ 4) $\frac{1}{2\pi}\sqrt{\frac{ml}{4qE}}$

34. For an electric dipole consisting of a positive and equal negative charges separated by a finite distance, the number of axial and equatorial lines respectively

1) 1,1 2) 1,2 3) 1,3 4) 1,∞

35. Two equal charges 'q' of opposite sign are separated by a small distance '2a'. The electric intensity 'E' at a point on the perpendicular bisector of the line joining the two charges at a very large distance 'r' from the line is

1) $\frac{1}{4\pi\varepsilon_0}\frac{qa}{r^2}$ 2) $\frac{1}{4\pi\varepsilon_0}\frac{2qa}{r^3}$

3) $\frac{1}{4\pi\varepsilon_0}\frac{2qa}{r^2}$ 4) $\frac{1}{4\pi\varepsilon_0}\frac{qa}{r^3}$

KEY

31) 2 32) 2 33) 3 34) 4 35) 2

ELECTRIC FLUX & GAUSS LAW

36. The electric field in a region of space is given by $\vec{E}=5\hat{i}+2\hat{j}\ NC^{-1}$. The electric flux due to this field through an area $2m^2$ lying in the YZ plane in S.I. units is

1) 10 2) 20 3) $10\sqrt{2}$ 4) $2\sqrt{29}$

37. Number of electric lines of force emerging from 1C of positive charge in vacuum is

1) 8.85×10^{-12} 2) 9×10^{9}

3) $1/4\pi\times9\times10^{9}$ 4) 1.13×10^{11}

38. A charge of 5 C is placed at the centre of a spherical Gaussian surface of radius 5 cm. The electric flux through the surface is $\frac{1}{\varepsilon_0}$ times of

1) 0.1 N-m²/C 2) 0.5 N-m²/C
3) 1 N-m²/C 4) 5 N-m²/C

39. In a region where intensity of electric field is $5\ NC^{-1}$, 40 lines of electric force are crossing, then lines of force crossing if the field is $10\ NC^{-1}$ will be

1) 20 2) 80 3) 100 4) 200

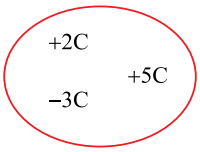
40. An electron is placed at the centre of a Conducting sphere of radius 0.2 meter having a charge 5×10^{-2} coulomb. The force on the electron is

1) zero 2) $11\times10^{9}\ N$ 3) $22.5\times10^{9}\ N$ 4) $2.5\times10^{9}\ N$

41. Eight charges, $1\mu C$, $-7\mu C$, $-4\mu C$, $10\mu C$, $2\mu C$, $-5\mu C$, $-3\mu C$ and $6\mu C$ are situated at the eight corners of a cube of side 20 cm. A spherical surface of radius 80 cm encloses this cube. The center of sphere coincides with center of the cube. Then the outgoing flux from the spherical surface(in units Vm) is

1) $36\pi\times10^{3}$ 2) $684\pi\times10^{3}$
3) zero 4) $72\pi\times10^{3}$

42. Calculate the net flux emerging from given enclosed surface - Nm² C⁻¹



1) 4.5×10^{11} 2) 45×10^{12}
3) zero 4) 1.12×10^{12}

43. A surface $E=10\hat{j}$ is kept in an electric field $E=2\hat{i}+4\hat{j}+7\hat{k}$. How much electric flux will come out through this surface ?

1) 40 unit 2) 50 unit 3) 30 unit 4) 20 unit

44. The magnitude of the electric field on the surface of a sphere of radius r having a uniform surface charge density σ is

1) σ/ε_0 2) $\sigma/2\varepsilon_0$ 3) $\sigma/\varepsilon_0 r$ 4) $\sigma/2\varepsilon_0 r$

45. A cylinder of length L and radius b has its axis coincident with the x axis. The electric field in this region $\vec{E}=200\ \hat{i}$. Find the flux through (i) the left end of cylinder (ii) the right end of cylinder (iii) the cylinder curved surface, (iv) the closed surface area of the cylinder.

1) (i) $-100\pi b^2$ (ii) $100\pi b^2$ (iii) $50\pi b^2$ (iv) $50\pi b^2$
2) (i) $-200\pi b^2$ (ii) $200\pi b^2$ (iii) 0 (iv) 0
3) (i) $-100\pi b^2$ (ii) $100\pi b^2$ (iii) $100\pi b^2$ (iv) $100\pi b^2$
4) (i) $-200\pi b^2$ (ii) $200\pi b^2$ (iii) $200\pi b^2$ (iv) $200\pi b^2$

46. A charge q is placed at the centre of the open end of cylindrical vessel. Find the flux of the electric field through the surface of the vessel.

1) $\frac{q}{2\epsilon_0}$ 2) $\frac{q}{\epsilon_0}$ 3) $\frac{q}{3\epsilon_0}$ 4) zero

47. A large flat metal surface has uniform charge density $+\sigma$. An electron of mass m and charge e leaves the surface at an angle at point A with speed v, and return to it at point B. The maximum value of AB is ____

1) $\frac{vm\epsilon_0}{\sigma e}$ 2) $\frac{v^2 m\epsilon_0}{e\sigma}$ 3) $\frac{v^2 e}{\epsilon_0\sigma m}$ 4) $\frac{v^2\sigma e}{\epsilon_0 m}$

48. The inward and outward electric flux for a closed surface in units of N-m²/C are respectively 8×10^3 and 4×10^3. Then the total charge inside the surface in S.I units is (where ε_0 =permittivity constant)

1) 4×10^3 2) -4×10^3
3) $-\frac{\pi R^2-\pi R}{E}$ 4) $-4\times10^3\varepsilon_0$

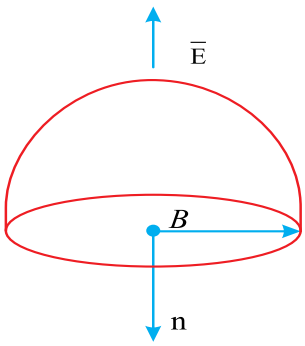
49. A cylinder of radius R and length L is placed in the uniform electric field E parallel to the cylinder axis. The total flux from the two flat surfaces of the cylinder is given by

1) $2\pi R^2 E$ 2) $\frac{\pi R^2}{E}$ 3) $\frac{\pi R^2-\pi R}{E}$ 4) zero

50. A cube is arranged such that its length , breadth , height are along X,Y and Z directions. One of its corners is situated at the origin . Length of each side of the cube is 25cm . The components of electric field are $E_x = 400\sqrt{2}\,N/C$, $E_y = 0$ and $E_z = 0$ respectively. The flux coming out of the cube at one end will be

1) $25\sqrt{2}Nm^2/C$ 2) $5\sqrt{2}Nm^2/C$
3) $250\sqrt{2}Nm^2/C$ 4) $25Nm^2/C$

51. If a hemispherical body is placed in a uniform electric field E then the flux linked with the curved surface is

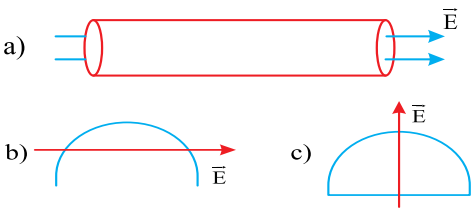


1) $2\pi R^2 E$ 2) $\pi R^2 E$
3) $4\pi R^2 E$ 4) $6\pi R^2 E$

52. A sheet of semi-circular paper (radius *R*) is turned around the center in to a cone as shown. If a point charge +*q* is kept at the vertex of the cone, the electric flux that comes out of the base of the cone is

1) $\frac{q}{4\varepsilon_o}$ 2) $\frac{q(2-\sqrt{3})}{4\varepsilon_o}$ 3) Zero 4) $\frac{q}{2\varepsilon_o}$

53. In a uniform electric field find the total flux associated with the given surfaces (R is radius)



1) $a=0, b=0, c=0$
2) $a=0, b=(\pi R^2 E), c=0$
3) $a=2\pi RE, b=(\pi R^2 E), c=0$
4) $a=\pi R^2 E, b=0, c=0$

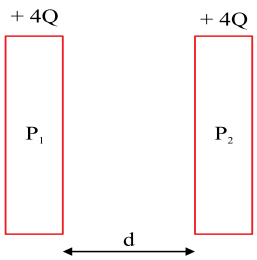
54. An infinitely long thin straight wire has uniform linear charge density of 1/3 coul.m^{-1}. Then the magnitude of the electric intensity at a point 18 cm away is

1) $0.33\times10^{11}\,NC^{-1}$ 2) $3\times10^{11}\,NC^{-1}$
3) $0.66\times10^{11}\,NC^{-1}$ 4) $1.32\times10^{11}\,NC^{-1}$

55. Consider two concentric spherical surface S_1 with radius a and S_2 with radius 2a, both centered on the origin. There is a charge +q at the origin, and no other charges. Compare the flux ϕ_1 through S_1 with the flux ϕ_2 through S_2

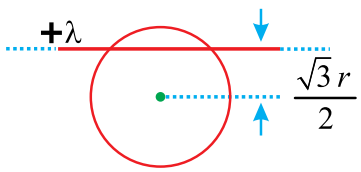
1) $\phi_1 = 4\phi_2$ 2) $\phi_1 = 2\phi_2$
3) $\phi_1 = \phi_2$ 4) $\phi_1 = \phi_2/2$

56. The electric field on two sides of a large charged plates shown in figure. The charge density on the plate in S.I. units is given by (ε_o is the permittivity of free space in S.I. units)



1) $2\varepsilon_o$ 2) $4\varepsilon_o$ 3) $10\varepsilon_o$ 4) zero

57. A Gaussian sphere of radius '*r*' intercepts a line with a uniform charge density $+\lambda$ as shown. The line is at a distance "*r*/2" from the centre of the sphere. What is the electric flux associated with the Gaussian sphere?



1) $\frac{r\lambda}{\varepsilon_o}$ 2) $\frac{\sqrt{3}\, r\lambda}{2\varepsilon_o}$ 3) $\frac{\sqrt{3}\, r\lambda}{\varepsilon_o}$ 4) $\frac{r\lambda}{2\varepsilon_o}$

58. A cube of side *l* is placed in a uniform field E, where E = E $\hat{i}$. The net electric flux through the cube is

1) Zero 2) l^2E 3) $4l^2E$ 4) $6l^2E$

59. A point charge +q is placed at the centre of a cube of side L. The electric flux emerging from the cube is

1) $\frac{q}{\varepsilon_0}$ 2) Zero 3) $\frac{6qL^2}{\varepsilon_0}$ 4) $\frac{q}{6L^2\varepsilon_0}$

60 A long thin flat sheet has a uniform surface charge density σ. The magnitude of the electric field at a distance ' r ' from it is given by

1) σ/ε_0 2) $\sigma/2\varepsilon_0$ 3) $\sigma/\varepsilon_0 r$ 4) $\sigma/2\varepsilon_0 r$

61 A charge of 8.85C is placed at the centre of a spherical Gaussian surface of radius 5 cm. The electric flux through the surface is

1) 10^{12} V/m 2) 10^{-12} V/m
3) 10^{8} V/m 4) 10^{10} V/m

62. The inward and outward electric flux for a closed surface in units of N–m²/C are respectively 8 × 10³ and 4 × 10³. Then the total charge inside the surface in S.I. units is (where $\in_o$ = permittivity in free space)

1) 4×10^3 2) -4×10^3

3) $\frac{(-4\times10^3)}{\in_0}$ 4) $-4\times10^3 \in_o$

63. The total flux linked with unit negative charge put in air is

1) $\frac{1}{\varepsilon_0}$ out wards 2) $\frac{1}{\varepsilon_0}$ inwards

3) $\frac{1}{4\pi\varepsilon_0}$ outwards 4) $\frac{1}{4\pi\varepsilon_0}$ inwards

KEY

36) 1	37) 4	38) 4	39) 2	40) 1
41) 3	42) 1	43) 1	44) 1	45) 2
46) 1	47) 2	48) 4	49) 4	50) 1
51) 2	52) 2	53) 1	54) 1	55) 3
56) 2	57) 1	58) 1	59) 1	60) 2
61) 1	62) 4	63) 2		

HINTS SOLUTIONS

1. $Q = \pm ne$ n is integer ;
2. $Q = \pm ne$ n is integer
3. $\Delta\sigma = \frac{\Delta Q}{A}$;
4. $F^{|} = \frac{F}{K}$;
5. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

6. $F = \frac{1}{4\pi\varepsilon_0}\frac{(q_1+q_2)^2}{4d^2}$; 7. $\frac{k\,8q.q}{r^2} - \frac{k\,q.q}{(r-a)^2} = 0$

8. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$; 9. $x = \frac{d}{\sqrt{\frac{q_2}{q_1}} - 1}$ From $q_1 < q_2$

10. $t^1 = \frac{t}{\sqrt{k}}$; 11. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ and q = ne

12. F = w tan θ where $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

13. $\frac{1}{4\pi\in_0}\sqrt{2}\frac{q^2}{a^2} + \frac{1}{4\pi\in_0}\frac{Qq}{(\sqrt{2}a)^2} = 0$

14. $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$; $q_1^1 = \frac{110}{100}q_1$ and $q_2^1 = \frac{90}{100}q_2$

15. $\frac{F_{max}}{F\,min} = \frac{(N/2)^2}{(N-1)1}$ 16. $mg\sin\theta = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$

17. $F_C = kx$
18. $F_{\text{due to 4 charges}} + F_{\text{due to one charge}} = 0$. Therefore, the force due to 4 charges is negative of force due to one charge

19. $E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{x_1^2} - \frac{1}{4\pi\varepsilon_0}\frac{q_2}{x_2^2}$; 20. $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^3}\vec{r}$

21. $qE = mg\tan\theta$; 22: $s = \frac{1}{2}\frac{qE}{m}t^2$

23. $E = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{4^2} + ------\right]$

24. Pressure $= \frac{\sigma^2}{2\varepsilon_o}$ and Force $= \frac{\sigma^2}{2\varepsilon_o} \times \pi R^2$

25. Distance of null point $x = \dfrac{d}{\sqrt{\dfrac{Q_2}{Q_1}} \pm 1}$

+ve for like charges -ve for unlike charges

26. $E = E\left(\sqrt{2} + 1/2\right)E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$

r = length of the side

27. $E = \dfrac{1}{4\pi \in_o}.\left[\dfrac{Q_1}{x_1^2} + \dfrac{Q_2}{x_2^2} + ... + \dfrac{Q_n}{x_n^2}\right]$

28. $Tan\theta = \dfrac{E_2}{E_1}$

30. $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r_{AB}^2}$

$r_{AB} = (1-0)\hat{i} + \left(\sqrt{2} - 0\right)\hat{j} + (1-2)\hat{k}$

31. $\alpha + \theta = 90, \tan\alpha = \dfrac{1}{2}\tan\theta$

32. $\tau_{\max} = pE = 2aqE$

33. $\tau = PE\sin\theta$; $\tau = I\alpha$; $I\alpha = PE\sin\theta$

I = moment of inertia = $\dfrac{ml^2}{2}$

$\therefore$ Time period $= 2\pi\sqrt{\dfrac{I}{pE}}$

34. 1 axial line and infinite number of equatorial lines

35. Similar to B on equatorial line of a short bar magnet

36. $\phi_E = \int \vec{E}.\vec{ds} = E \times s = 5 \times 2$; 37: $\phi_E = \dfrac{q}{\varepsilon_0}$

38. $\phi \propto q$; 39. $E = \dfrac{\phi}{A}$;

40. $E_{inside} = 0, F = Eq$

41. $\phi_E = \dfrac{q}{\varepsilon_0}$

42. $\int \overline{E}.\overline{ds} = \dfrac{q}{\varepsilon_0} = \dfrac{2+5-3}{8.85\times10^{-12}} = 4.5\times10^{11}$

43. $\phi = \overline{E}.\overline{S} = 40\,units$

44. $E \times 4\pi r^2 = \dfrac{q}{\varepsilon_0}$; $E = \dfrac{q}{4\pi\varepsilon_0 r^2} = \dfrac{\sigma}{\varepsilon_0}$

45. $\phi = E.A$; 46: $\int \overline{E}.\overline{ds} = \dfrac{q}{\varepsilon_0}$

47. Field near metal surface E= $\dfrac{\sigma}{\in_0}$

Force on electron = eE = $\dfrac{e\sigma}{\in_0}$

Acceleration of electron a = $\dfrac{e\sigma}{m\in_0}$

It will act as projectile with max range

$= \dfrac{u^2}{a} = \dfrac{u^2}{e\sigma} \times m\in_0$

48. $\phi_E = \dfrac{q}{\varepsilon_0}$; 49. $\phi = \overline{E}.\overline{A}$

50. $\overline{E}_1.\overline{A}_1 + \overline{E}_2.\overline{A}_2 + \overline{E}_3.\overline{A}_3 = \phi$; 51. $\phi = \overline{E}.\overline{A}$

52. The circumference of the base of the cone is semi circumference of the paper which is p*R*. Hence the radius of the base is *R*/2. The semi-vertical angle of the cone is 30°, since sinq = (R/2)/R = 1/2. The solid angle subtended by the base at the vertex is 2p(1 - cos θ) = $\pi(2-\sqrt{3})$. The flux is uniformly distributed so for 4p steradians it is q/e_o, for steradians it is $\dfrac{q(2-\sqrt{3})}{4\varepsilon_o}$

53. $\phi = \overline{E}.\overline{A}$; 54. $E = \lambda / 2\pi\varepsilon_0 r$

55. Flux through both will be same as net charge enclosed by both is same

56. Electric field due to plate= $\dfrac{\sigma}{2\varepsilon_o}$

57. The chord length by geometry is r. The charge enclosed is $r\lambda$

58. In ward equal to outward flux so net flux is zero

59. Total flux $= \dfrac{q}{\varepsilon_0}$; 60. $E = \dfrac{\sigma}{2\varepsilon_0}$

61. $E = \dfrac{8.85}{8.85\times10^{-12}} = 10^{12}$

62. Net flux $= -4\times10^3$

$-4\times10^3 = \dfrac{q}{\varepsilon_0}$; $q = -4\times10^3\varepsilon_0$

63. Due to -ve charge flux is inward

WORK AT HOME
PREVIOUS EXAMS QUESTIONS

1. **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

2. **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) $\frac{\lambda}{2\pi\varepsilon_0 R} N/C$

3. **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) $\frac{4F}{3}$

4. **An electron falls from rest through a vertical distance h in a uniform and vertically upward directed electric field E. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance h. The time of fall of the electron, in comparison to the time of fall of the proton is** **[NEET 2018]**
   1) 10 times greater
   2) 5 times greater
   3) Smaller
   4) Equal

5. **A toy car with charge q moves on a frictionless horizontal plane surface under the influence of a uniform electric field $\vec{E}$. Due to the force $q\vec{E}$, its velocity increases from 0 to 6 m/s in one second duration. At that instant the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 seconds are respectively** **[NEET 2018]**
   1) 1 m/s, 3.5 m/s
   2) 1 m/s, 3 m/s
   3) 2 m/s, 4 m/s
   4) 1.5 m/s, 3 m/s

6. **Suppose the charge of a proton and an electron differ slightly. one of them is -e, the other is $(e+\Delta e)$. if the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance d (much greater than atomic size) apart is zero. Then Δe is of the order of [Given mass of hydrogen $m_h = 1.67\times10^{-27}$ Kg]** **[NEET 2017]**
   1) 10^{-23} C
   2) 10^{-37} C
   3) 10^{-47} C
   4) 10^{-20} C

7. **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** **[NEET 2016]**
   1) $v \propto x^{-1/2}$
   2) $v \propto x^{1/2}$
   3) $v \propto x$
   4) $v \propto x^{-1}$

8. **The electric field in a certain region is acting radially outward and is given by E = Ar. A charge contained in a sphere of radius 'a' centered at the origin of the field, wil be given by** **[AIPMT 2015]**

1) $4\pi\epsilon_0 Aa^3$ 2) $\epsilon_0 Aa^3$ 3) $4\pi\epsilon_0 Aa^3$ 4) $A\epsilon_0 a^2$

9. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are: [AIPMT 2014]

1) Both are zero 2) Zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$

3) $\frac{Q}{4\pi\varepsilon_0 R}$ and Zero 4) $\frac{Q}{4\pi\varepsilon_0 R}$ & $\frac{Q}{4\pi\varepsilon_0 R^2}$

10. What is the flux through a cube of side 'a' if a point charge of q is at one of its corner: [CBSE AIPMT 2012]

1) $\frac{q}{8\epsilon_0}$ 2) $\frac{q}{\epsilon_0}$ 3) $\frac{q}{2\epsilon_0}6a^2$ 4) $\frac{2q}{\epsilon_0}$

11. Domestic electrical wiring has three wires [DUMET 2011]

1) positive, negative and neutral
2) positive, negative and earth
3) live, neutral and earth
4) positive, negative and live

12. A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will [CBSE AIPMT 2011]

1) be reduced to half
2) remain the same
3) be doubled
4) increase four times

13. Two positive ions, each carrying a charge q, are separated by a distance d. If F is the force of repulsion between the ions, the number of electrons emission from each ion will be (e being the charge on an electron) [CBSE AIPMT 2010]

1) $\frac{\sqrt{4\pi\varepsilon_0 Fd^2}}{e}$ 2) $\sqrt{\frac{4\pi\varepsilon_0 Fe^2}{d^2}}$

3) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$ 4) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$

14. Two copper balls, each weighing 10 g, are kept in air 10 cm apart. If one electron from every 10^6 atoms in transferred from one ball to the other, the coulomb force between them is (atomic weight of copper is 63.5) [MANIPAL 2010]

1) $2.0\times10^{10}\ N$ 2) $2.0\times10^{4}\ N$

3) $2.0\times10^{8}\ N$ 4) $2.0\times10^{6}\ N$

15. 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 [DUMET 2010]

1) $2h$ 2) 2 days 3)2 yr 4)20 yr

16. A ball with charge – 50e is placed at the centre of a hollow spherical shell has a net charge of – 50e. What is the charge on the shell's outer surface? [DUMET 2010]

1) $-50e$ 2)Zero 3)$-100\ e$ 4)$+100\ e$

17. When 10^{19} electrons are removed from a neutral metal plate, the electric charge on it is [VMMC 2010]

1) $-1.6\ C$ 2) $+1.6\ C$

3) $10^{+19}\ C$ 4) $10^{-19}\ C$

18. Among two spheres A and B, first has radius 10 cm and charge $10^{-6}\ C$ and second has radius 30 cm and charge $10^{-5}\ C$. When they are touched, charge on both are, q_A and q_B respectively, will be [MANIPAL 2010]

1) $q_A = 2.75\ \mu C,\ q_B = 3.15\ \mu C$
2) $q_A = 1.09\ \mu C,\ q_B = 1.53\ \mu C$
3) $q_A = q_B = 5.5\ \mu C$ 4) None of the above

19. Two charges are at a distance d apart. If a copper plate of thickness $\frac{d}{2}$ is kept between them, the effective force will be [MANIPAL 2010]

1) $\frac{F}{2}$ 2) zero 3) $2F$ 4) $\sqrt{2F}$

20. A charged particle is free to move in an electric field. It will travel [BHU 2010]

1) always along a line of force
2) along a line of force, if its initial velocity is zero
3) along a line of force, if it has same initial velocity in the direction of an acute angle with the line of force
4) None of the above

21. An electron moving with the speed 5×10^6 per sec is shooted parallel to the electric field of intensity 1×10^3 N/C. Field is responsible for the retardation of motion of electron. Now evaluate the distance travelled by the electron before coming to test for an instant (mass of $e = 9 \times 10^{-31}$ kg, charge= 1.6×10^{-19} C) [BHU 2010]

1) 7 *m* 2) 0.7 *mm* 3) 7 *cm* 4) 0.7 *cm*

22. 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 [BHU 2010]

1) $\frac{Eq^2m}{2t^2}$ 2) $\frac{2E^2t^2}{mq}$ 3) $\frac{E^2q^2t^2}{2m}$ 4) $\frac{Eqm}{t}$

23. At what distance along the central axis of a uniformly charged plastic disc of radius *R* the magnitude of the electric field equal to one-half the magnitude of the field at the centre of the surface of the disc? [CMC 2010]

1) $\frac{R}{\sqrt{2}}$ 2) $\frac{R}{\sqrt{3}}$ 3) $\sqrt{2}R$ 4) $\sqrt{3R}$

24. An electron of mass *m* and charge *q* is accelerated from rest in a uniform electric field of strength *E*. The velocity acquired by it as it travels a distance *l* is [MANIPAL 2010]

1) $\sqrt{\frac{2Eql}{m}}$ 2) $\sqrt{\frac{2Eq}{ml}}$ 3) $\sqrt{\frac{2Em}{ql}}$ 4) $\sqrt{\frac{2Em}{ql}}$

25. Two parallel infinite line charges + λ an – λ are placed with a separation distance *R* in free space. The net electric field exactly mid-way between the two line charges is [MANIPAL 2010]

1) zero 2) $\frac{2\lambda}{\pi\varepsilon_0 R}$ 3) $\frac{\lambda}{\pi\varepsilon_0 R}$ 4) $\frac{1}{2\pi\varepsilon_0 R}$

26. The ionization potential of mercury is 10.39 *V*. How far an electron must travel in an electric field of 1.5×10^6 *V/m* to gain sufficient energy to ionize mercury? [MANIPAL 2010]

1) $\frac{10.39}{1.6\times10^{-19}}m$ 2) $\frac{10.39}{2\times1.6\times10^{-19}}m$

3) $10.39\times1.6\times10^{-19}\ m$ 4) $\frac{10.39}{1.5\times10^{6}}m$

27. The electric field and the potential of an electric dipole vary with distance *r* as [MANIPAL 2010]

1) $\frac{1}{r}$ and $\frac{1}{r^2}$ 2) $\frac{1}{r^2}$ and $\frac{1}{r}$

3) $\frac{1}{r^2}$ and $\frac{1}{r^3}$ 4) $\frac{1}{r^3}$ and $\frac{1}{r^2}$

28. The electric dipole moment of an electron and a proton 4.3 nm apart is [DUMET 2010]

1) $6.88\times10^{-28}\ Cm$ 2) $2.56\times10^{-29}\ C^2/m$

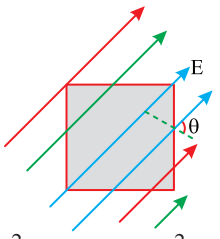
3) $3.72\times10^{-14}\ C/m$ 4) $1.1\times10^{-46}\ C^2/m$.

29. The electrostatic potential of a uniformly charged thin spherical shell of charge *Q* and radius *R* at a distance *r* from the centre is [MANIPAL 2010]

1) $\frac{Q}{4\pi\varepsilon_0 r}$ for points outside and $\frac{Q}{4\pi\varepsilon_0 R}$ for points inside the shell
2) $\frac{Q}{4\pi\varepsilon_0 r}$ for both points inside and outside the shell
3) zero for points outside and $\frac{Q}{4\pi\varepsilon_0 r}$ for points inside the shell
4) zero for both points inside and outside the shell

30. 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 place at an angle θ with the horizontal side of the square as shown in figure. The electric flux linked to the surface in unit of V-m is

[CBSE AIPMT 2010]



1) EL^2 2) EL^2 cosq 3) EL^2 sinq 4) zero

31. The charge given to any conductor resides on its outer surface, because[AFMC 2009]

1) the free charge tends to be in its minimum potential energy state
2) the free charge tends to be in its minimum kinetic energy state
3) the free charge tends to be in its maximum potential energy state
4) the free charge tends to be in its maximum kinetic energy state

32. Two spherical conductors B and C having equal radii and carrying equal charges in them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged, is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is

[JIPMER 2009]

1) $\frac{F}{4}$ 2) $\frac{3F}{4}$ 3) $\frac{F}{8}$ 4) $\frac{3F}{8}$

33. The distance between charges 5×10^{-11}C and -2.7×10^{-11} C is 0.2 m. The distance at which is third charge should be placed from second charge in order that it will not experience any force along the line joining the two charges is [MANIPAL 2009]

1)0.44m 2) 0.65m 3) 0.556m 4) 0.350 m

34. A charged oil drop is suspended in 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) [JIPMER 2009]

1) $3.3\times10^{-18}C$ 2) $3.2\times10^{-18}C$
3) $1.6\times10^{-18}C$ 4) $4.8\times10^{-18}C$

35. One of the following is not a property of field lines [DUMET 2009]

1) field lines are continuous curves without any breaks
2) two field lines cannot cross each other
3) field lines start at positive charges and end at negative charges
4) they form closed loops

36. A point charge Q is placed at one of the vertices of a cubical block. The electric flux flowing through this cube is[MANIPAL 2009]

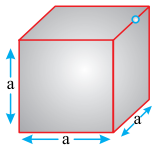
1) $\frac{Q}{6\varepsilon_0}$ 2) $\frac{Q}{4\varepsilon_0}$ 3) $\frac{Q}{8\varepsilon_0}$ 4) $\frac{Q}{\varepsilon_0}$

37. Gauss's law is valid for [DUMET 2009]

1) any closed surface
2) only regular closed surfaces
3) any open surface
4) only irregular open surfaces

38. In figure + Q charge is located at one of the edge of the cube, then electric flux through cube due to + Q charge is

[BVP, MPPMT, VMMC 2009]



1) $\frac{+Q}{\varepsilon_0}$ 2) $\frac{+Q}{2\varepsilon_0}$ 3) $\frac{+Q}{4\varepsilon_0}$ 4) $\frac{+Q}{8\varepsilon_0}$

39. A comb run through ones dry hair attracts small bits of paper. This is due to

[AFMC 2008]

1) comb is a good conductor
2) paper is a good conductor
3) the atoms is the paper get polarised by the charged comb
4) the comb possesses magnetic properties.

40. Each of the two point charges are doubled and their distance is halved. Force of interaction becomes *n* times, where *n* is **[AMU 2008]**

1) 4 2)1 3)1/16 (4)16

41. A cylindrical conductor is placed near another positively charged conductor. The net charge acquired by the cylindrical conductor will be **[AMU 2008]**

1) positive only 2) negative only
3) zero 4)either positive or negative

42. A table tennis ball which has been covered with a conducting paint is suspended by a silk thread so that it hangs between two metal plates. One plate is earthed. When the other plate is connected to a high voltage generator, the ball **[BHU 2008]**

1) is attracted to the high voltage plate and stays there
2) hangs without moving
3) swings backward and forward hitting each plate in turn
4) is repelled to the earthed plate and stays there

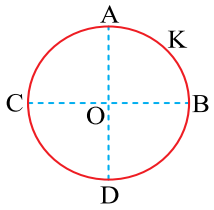
43. What is charge on 90 kg of electrons? **[DUMET 2008]**

1) 1.58×10^{13} 2) 2.3×10^{12}
3) 2.53×10^{12} 4) None of these

44. If charge and distance between two charges are reduced to half. Force between them **[DUMET 2008]**

1) remains same 2)increases four times
3) reduce four times 4)None of the above

45. A thin conducting ring of radius *R* is given a charge + *Q*. The electric field at the centre *O* of the ring due to the charge on the part *AKB* of the ring is *E*. The electric field at the centre due to the charge on the par *ACDB* of the ring is **[CBSE AIPMT 2008]**



1) 3*E* along *KO* 2) *E* along *OK*
3) *E* along *KO* 4) 3*E* along *OK*

46. Charge *q* is uniformly distributed over a thin half ring of radius *R*. The electric field at the centre of the ring is **[AIIMS 2008]**

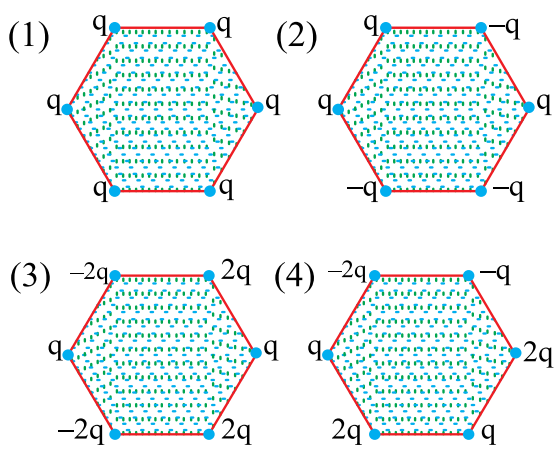
1) $\frac{q}{2\pi^2\varepsilon_0 R^2}$ 2) $\frac{q}{4\pi\,\varepsilon_0 R^2}$

3) $\frac{q}{4\pi\varepsilon R^2}$ 4) $\frac{q}{2\pi\varepsilon_0 R^2}$

47. A charge *Q* is uniformly distributed over a large square plate of copper. The electric field at a point very close to the centre of the plate is 10 Vm^{-1}. If the copper plate is replaced by a plastic plate of the same geometrical dimensions and carrying the same charge *Q* uniformly distributed, then the electric field at the point *P* will be **[BHU 2008]**

1) 5 Vm^{-1} 2) zero
3) 10 Vm^{-1} 4) 20 Vm^{-1}

48. Figure below show regular hexagons, with charges at the vertices. In which case is the electric field at the centre zero? **[BHU 2008]**



49. A hollow cylinder has a charge *q C* within it. If ϕ is the electric flux in unit of volt-meter associated with the curved surface *B*, the flux linked with the plane surface *A* in unit of volt-meter will be **[AIIMS 2008]**

1) $\frac{1}{2}\left(\frac{q}{\varepsilon_0}-\phi\right)$ 2) $\frac{q}{2\varepsilon_0}$ 3) $\frac{\phi}{3}$ 4) $\frac{q}{\varepsilon_0}-\phi$

50. When air is replaced by a dielectric medium of constant *K*. The maximum force of attraction between two charges separated by a distance **[AFMC 2007]**

1) increase K^{-1} times 2) increases K times
3) decreases K times 4) remains constant

51. Assertion: The lighting conductor at the top of high building has sharp pointed ends. Reason: The surface density of charge at sharp points is very high resulting in setting up of electric wind **[AIIMS 2007]**

1) Both assertion and reason are true and the reason is the correct explanation of the assertion
2) Both assertion and reason are true but the reason is not the correct explanation of the assertion
3) Assertion is true but reason is false
4) Both assertion and reason are false

52. Two point charges + 2*C* and + 6 *C* repel each other with a force of 12 *N*. If a charge of – 2*C* is given to each of these charges the force will now be **[AMU 2007]**

1) zero 2) 8 *N* (attractive)
3) 8 *N* (repulsive) 4) None of these

53. An electron is moving round the nucleus of a hydrogen atom in a circular orbit of radius *r*. The Coulomb force *F* between the two is **[BHU 2007]**

1) $k\frac{e^2}{r^3}r$ 2) $-k\frac{e^2}{r^3}r$ 3) $k\frac{e^2}{r}r$ 4) $-k\frac{e^2}{r}r$

54. Three point charges + *q*, – 2*q* and + *q* are placed at points ($x = 0, y = a, z = 0$), ($x = 0, y = 0, z = 0$) an ($x = a, y = 0, z = 0$), respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are **[CBSE AIPMET 2007]**

1) $\sqrt{2}\,qa$ along $+y$ direction
2) $\sqrt{2}\,qa$ along the line joining points ($x = 0, y = 0, z = 0$) and ($x = a, y = a, z = 0$)
3) qa along the line joining points ($x = 0, y = 0, z = 0$) and ($x = a, y = a, z = 0$)
4) $\sqrt{2}\,qa$ along $+x$ direction

55. A charge *q* is located at the centre of a cube. The electric flux through any face is **[BHU JIPMER 2007]**

1) $\frac{\pi q}{6(4\pi\varepsilon_0)}$ 2) $\frac{q}{6(4\pi\varepsilon_0)}$ 3) $\frac{2\pi q}{6(4\pi\varepsilon_0)}$ 4) $\frac{4\pi q}{6(4\pi\varepsilon_0)}$.

56. If the electric flux entering and leaving an enclosed surface respectively are ϕ_1 and ϕ_2, the electric charge inside the surface will be **[RPMT, AFMC 2007]**

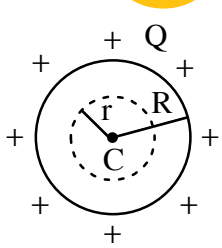
1) $\frac{\phi_2-\phi_1}{\varepsilon_0}$ 2) $\frac{\phi_2+\phi_1}{\varepsilon_0}$ 3) $\frac{\phi_1-\phi_2}{\varepsilon_0}$ 4) $\varepsilon_0(\phi_2-\phi_1)$

KEY

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

HINTS SOLUTIONS

1.



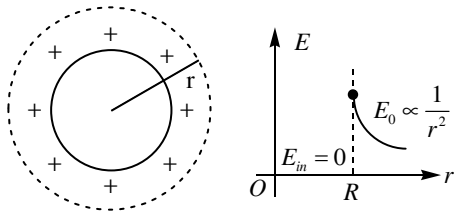
Charge Q will be distributed over the surface of hollow metal sphere.

(i) For r < R (inside)

By Gauss law, $\oint \vec{E}_{in}.\overrightarrow{dS} = \frac{q_{en}}{\varepsilon_0} = 0$

$\Rightarrow E_{in} = 0 \qquad (\because q_{en} = 0)$

(ii) For r > R (outside)



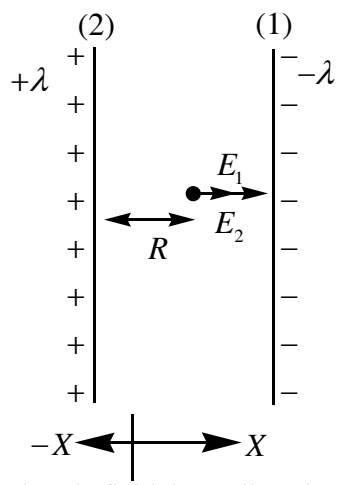
$\oint \vec{E}_0.\overrightarrow{dS} = \frac{q_{en}}{\varepsilon_0}$

Here, $q_{en} = Q (\because q_{en} = Q)$

$\therefore E_0 4\pi r^2 = \frac{Q}{\varepsilon_0}$

$\therefore E_0 \propto \frac{1}{r^2}$

2.



Electric field due to line charge (1)

$\vec{E}_1 = \frac{\lambda}{2\pi\varepsilon_0 R}\hat{i} N/C$

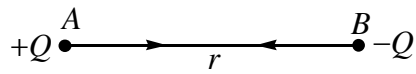
Electric field due to line charge (2)

$\vec{E}_2 = \frac{\lambda}{2\pi\varepsilon_0 R}\hat{i} N/C$

$\vec{E}_{neet} = \vec{E}_1 + \vec{E}_2 = \frac{\lambda}{2\pi\varepsilon_0 R}\hat{i} + \frac{\lambda}{2\pi\varepsilon_0 R}\hat{i}$

$= \frac{\lambda}{\pi\varepsilon_0 R}\hat{i}\, N/C$

3.

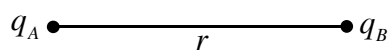


$F = \frac{kQ^2}{r^2}$

If 25% of charge of A transferred to B then

$q_A = Q - \frac{Q}{4} = \frac{3Q}{4}$ and

$q_B = -Q + \frac{Q}{4} = \frac{-3Q}{4}$



$F_1 = \frac{kq_Aq_B}{r^2}$; $F_1 = \frac{k\left(\frac{3Q}{4}\right)^2}{r^2}$; $F_1 = \frac{9}{16}\frac{kQ}{r^2}$

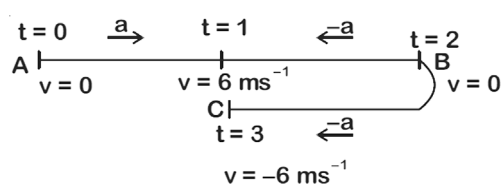
$F_1 = \frac{9F}{16}$.

4. $h = \frac{1}{2}\frac{eE}{m}t^2 \qquad \therefore t = \sqrt{\frac{2hm}{eE}}$

$\therefore t \propto \sqrt{m}$ as 'e' is same for electron and proton.

$\therefore$ Electron has smaller mass so it will take smaller time.

5.



Acceleration a $a = \frac{6-0}{1} = 6ms^{-2}$

For t = 0 to t = 1s,

$S_1 = \frac{1}{2}\times 6(1)^2 = 3m$ .....(i)

For $t = 1s$ to $t = 2s$,

$$S_2 = 6.1 - \frac{1}{2}\times 6(1)^2 = 3m \qquad .....(ii)$$

For $t = 2s$ to $t = 3s$,

$$S_3 = 0 - \frac{1}{2}\times 6(1)^2 = -3m \qquad .....(iii)$$

Total displacement $S = S_1 + S_2 + S_3 = 3m$

Average velocity $= \frac{3}{3} = 1ms^{-1}$

Total distance travelled = 9m

Average speed $= \frac{9}{3} = 3ms^{-1}$

6. $f_{electrostatic} = f_{gravitation}$

7. $F = \frac{Kq^2}{x^2} = mg\tan\theta$; $\qquad \frac{dF}{dq} = 0$

8. $ES = \frac{Q}{\varepsilon_0}$;

$(Aa)\times 4\pi a^2 = \frac{Q}{\varepsilon_0}$; $Q = 4\pi\varepsilon_0 Aa^3$

10. Since if charge q is placed at the corner of a cube then charge enclosed = q/8

Therefore, $\phi_{cube} = \frac{q_{enclosed}}{\epsilon_0} = \frac{q}{8\epsilon_0}$

11. Domestic electric wiring has there wires as live, neutral and earth.
Hence, we can say the electric flux depends only on net enclosed charge by surface.

12. Total flux $= \frac{\text{Net enclosed chargae}}{\varepsilon_0}$

13. Two positive ions each carrying a charge q are kept at a distance d, then it is found that force of repulsion between them is

$$F = \frac{kqq}{d^2} = \frac{1}{4\pi\varepsilon_0}\frac{qq}{d^2}$$

where, $q = ne$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{n^2e^2}{d^2} \quad ; \quad n = \frac{\sqrt{4\pi\varepsilon_0 Fd^2}}{e^2}$$

14. Number of electrons, n

$$= \frac{6\times 10^{23}}{63.5}\times 10\times\frac{1}{10^6} = \frac{6\times 10^{18}}{63.5}$$

$$q = \frac{6\times 10^{18}\times 1.6\times 10^{-19}}{63.5}C$$

or $\qquad q = 1.5\times 10^{-2}C$

$$F = \frac{9\times 10^9\times 1.5\times 10^{-2}\times 1.5\times 10^{-2}}{\left(\frac{10}{100}\right)}N$$

$= 2.0 \times 10^8 N.$

15. 1 electron has a charge of $1.6 \times 10^{-19} C$
10^{10} electron would have a charge of $q = ne$
$= 1.6\times 10^{-19}\times 10^{10} = 1.6\times 10^{-9} C$
Thus, in 1s, charge accumulated $= 1.6\times 10^{-9} C$
So, time taken to accumulate 1 C

$$= \frac{1}{1.6\times 10^{-9}} = 0.625\times 10^9$$

$= 6.25\times 10^8 s = 173611 h$
= 7233 days = 20 yr.

16. The net charge on the outer surface is
$(-50e - 50e) = -100e$

17. Charge $q = ne$

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

18. Let q be the charge transferred then

$$\frac{q_1 + q}{r_1} = \frac{q_2 - q}{r_2}$$

19. From Coulomb's law, electric force between two charges is directly proportional to product of charges and inversely proportional to square of distance between them. That is

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

Where, $k = \frac{1}{4\pi\varepsilon_0}$ = proportionality constant.

If a medium is placed between the charges, then

$$F' = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{d^2}$$

Since, medium placed between the charge is a metallic plate, so for it $K = \infty$
Hence, $F = 0$.

20. Because E point along the tangent to the lines of force. If initial velocity is zero, then due to the force, moves in the direction of E.

21. Electric force, qE, $= ma$

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

$$a = \frac{1.6\times10^{-19}\times1\times10^{3}}{9\times10^{-31}} = \frac{1.6\times10^{5}}{9}\ ms^{-2}$$

$$u = 5\times10^{6} \text{ and } v = 0$$

From $v^2 = u^2 - 2as \Rightarrow s = \frac{u^2}{2a}$

Distance, $s = \frac{(5\times10^{6})^2\times9}{2\times1.6\times10^{15}} = 7\,cm$

22. When charge q is released in uniform electric field E then its acceleration

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

So, its motion will be uniformly accelerated motion and its velocity after t second is given by

$$v = at = \frac{qE}{m}t$$

The KE of charged particle

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{qE}{m}t\right)^2$$

$$= \frac{q^2E^2t^2}{2m}$$

23. At a point on the axis of uniformly charged disc at a distance x above the centre of the disc, the magnitude of the electric field is

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2+R^2}}\right]$$

but $E_c = \frac{\sigma}{2\varepsilon_0}$ such that, $\frac{E}{E_c} = \frac{1}{2}$

Then, $1 - \frac{x}{\sqrt{x^2+R^2}} = \frac{1}{2}$

or, $\frac{x}{\sqrt{x^2+R^2}} = \frac{1}{2}$

Squaring both sides and multiplying by $x^2 + R^2$ to obtain

$$x^2 - \frac{x^2}{4} + \frac{R^2}{4}$$

Thus, $x^2 = \frac{R^2}{3}$; $x = \frac{R}{\sqrt{3}}$

24. Here, $u = 0$, $a = \frac{qE}{m}$

$s = l$ and $v = ?$

$$v^2 = u^2 + 2as$$

$$v^2 = 0 + 2\frac{qEl}{m} \quad ; \quad v = \sqrt{\frac{2qEl}{m}}$$

25. According to Gauss's theorem

$$\oint E.ds = \frac{q_{in}}{\varepsilon_0}\ ;\ E.2\pi R\times l = \frac{\lambda}{\varepsilon_0}$$

$$E = \frac{1}{2\pi}\frac{\lambda}{\varepsilon_0(R/2)}\times2 = \frac{2\lambda}{\pi\varepsilon_0 R}$$

26. $E = \frac{v}{d}$

27. Electric field and electric potential at a general point at a distance r from the centre of the dipole is

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

and $V_g = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$

28. The electron dipole moment is equal to

$$p = 1.6\times10^{-19}\times4.3\times10^{-9}$$

$$= 6.88\times10^{-28}\ Cm$$

29. If charge on a conducting sphere of radius R is Q then potential outside the sphere,

$$V_{out} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

At the surface of sphere $V_s = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

30. Flux of electric field E through any area A is defined as $\phi = EA\cos q$ or $\phi = E.A = 0$ the lines are parallel to the surface.

32. Let the spherical conductors B and C have same charge as q. The electric force between them is

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

r, being the distance between them. When third uncharged conductor A is brought in contact with B, then charge on each conductor.

$$q_A = q_B = \frac{q_A + q_B}{2} = \frac{0+q}{2} = \frac{q}{2}$$

When this conductor A is now brought in contact with C, then charge on each conductor

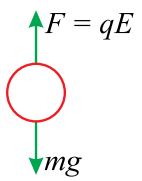
$$q_A = q_C = \frac{q_A + q_C}{2} = \frac{(q/2)+q}{2} = \frac{3q}{4}$$

Hence, electric force acting between B and C is

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{q_B\, q_C}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{(q/2)\,(3q/4)}{r^2}$$

$$= \frac{3}{8}\left[\frac{q}{4\pi\varepsilon_0}\frac{q^2}{r^2}\right] = \frac{3F}{8}$$

33. In steady state,
electric force on drop



= weight of drop
$qE = mg$

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

34. In this case by placing three at three sides of given cube and four cube above, the charge will be in the centre. So the flux linked with each case will be one eight of the flux $\frac{Q}{\varepsilon_0}$.

Flux associated with given cube $= \frac{Q}{8\varepsilon_0}$.

39. When a comb runs through one's dry hair, then comb gets charged and when it comes close to paper, it induces opposite charges in paper. The field due to the charges in comb, polarizes the atoms in the paper. Finally it attracts the paper

40. From the formula

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

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{2q_1\times2q_2}{(r/2)^2} = \frac{4}{1/4}F \Rightarrow F' = 16F$$

$nF = 16\,F$; $n = 16$

41. Net charge acquired by induction is zero.

42. When the other plate is connected to the high voltage generator, the negative charge induced on the ball cause attraction. When it strikes the +ve plate charge distribution again takes place. This causes repulsion. Hence, the ball swings backward and forward hitting each plate in turn.

43. Since e/m is the charge per kg of electrons, therefore, charge on 90 kg of electrons.

$$= \frac{e}{m}\times90 = 1.76\times10^{11}\times90 = 1.58\times10^{13}\,C$$

44. As per Coulomb's Law $F = k\frac{q_1q_2}{r^2}$

According to question,

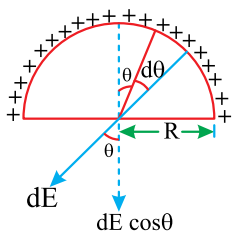
$$F' = k\frac{(q_1/2)\,(q_2/2)}{(r/2)^2} = k\frac{q_1q_2}{r^2} = F$$

Thus, force them will remain same.

45. As the ring is conducting, so electric field at its centre is zero,
i.e., $E_{\text{total}} = 0$ or $E_{AKB} + E_{ACDB} = 0$
or $E_{ACDB} = -E_{AKB}$
or $E_{ACDB} = -E$ (along KO)
Therefore, the electric field at the centre due to the charge on the part $ACDB$ of the ring is E along OK.

46. From figure $dl = Rdq$

charge on $dl = \lambda Rd\theta$ $\left\{\lambda = \frac{q}{\pi R}\right\}$



Electric field at centre due to dl is

$$dE = \frac{k.\lambda E d\theta}{R^2}$$

We need to consider only the component dE cos q, as the component dE sin q will cancel out.

Total field at centre $= 2\int_0^{\pi/2} dE\cos\theta$

$$= \frac{2k\lambda}{R}\int_0^{\pi/2}\cos\theta\, d\theta = \frac{2k\lambda}{R} = \frac{q}{2\pi^2\varepsilon_0 R^2}.$$

47. Electric field will remain same.

48. In the case (1), the fields due to charges at the opposite corners cancel each other. So, in this case net electric field at the centre will be zero.

49. Gauss's law states that the net electric flux through any closed surface is equal to the net charge inside the surface divided by e_0.

i.e., $Q_{\text{total}} = \frac{q}{\varepsilon_0}$

Let electric flux linked with surfaces A, B and C are f_A, f_B and f_C respectively. That is.

$\phi_{\text{total}} = \phi_A = \phi_B + \phi_C$

Since, $\phi_C = \phi_A$

$$2\phi_A + \phi_B = \phi_{\text{total}} = \frac{q}{\varepsilon_0}$$

or $$\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi_B\right)$$

But $\phi_B = \phi$ (given)

Hence, $\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

50. From Coulomb's law the force of attraction between two charges q_1 and q_2 separated by a distance r is given by

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

where ε_0 is the absolute permittivity of the material medium.

For air $\varepsilon = \varepsilon_0$ and for all other materials.

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

For all dielectric the value of K is greater than 1, thus, if some dielectric between the charges, then the force between them decreases K times.

51. We know that surface density of charge is very large on the sharp ends of a conductor. This charge from pointed ends sets up a charged electric wind. This charged electric wind comes in contact with the charged clouds and then source of its charge is neutralized and so potential drops between building and clouds. Hence, chances of lightning on building is reduced. Even if lightning strikes the building, charge is conducted by the lightning conductor to the earth and there is no harm to building.

52. On adding $-2C$ to both, one charge becomes neutral and hence Coulomb's force equals zero.

53. Let charges on an electron and hydrogen nucleus are q_1 and q_2. The Coulomb's force between them at a distance r is

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

Putting, $\frac{1}{4\pi\varepsilon_0} = k$ (given)

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

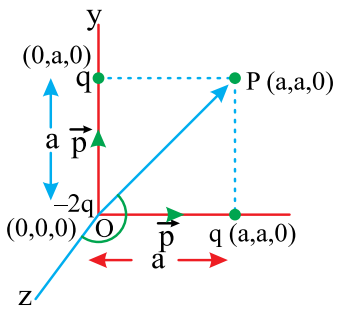
Since, the nucleus of hydrogen atom has one proton, so charge on nucleus is e i.e. $q_2 = e$ also $q_1 = e$ for electron.

So, $F = -k\frac{e.e}{r^2}r = -k\frac{e^2}{r^2}r$

but $r = \frac{r}{|r|} = \frac{r}{r}$

Hence, $F = -k\frac{e^2}{r^2}.\frac{r}{r} = -k\frac{e^2}{r^3}.r$

54. Choose the three coordinate axes as x, y and z and plot the charges with the given coordinates as shown.



O is the origin at which $-2q$ charge is placed. The system is equivalent to two dipoles along x and y-directions respectively. The dipole moments of two dipoles are shown in figure. The resultant dipole moment will be directed along OP where $P^{o}(a, a, 0)$. The magnitude of resultant dipole moment is

$$p' = \sqrt{p^2 + p^2}$$

$$= \sqrt{(qa)^2 + (qa)^2}$$

$$= \sqrt{2}\, qa$$

55. From Gauss's law; $\phi = \dfrac{q}{\varepsilon_0}$

This is the net flux coming out of the cube. Since, a cube has 6 sides so electric flux through any face is

$$\phi' = \frac{\phi}{6} = \frac{q}{6\varepsilon_0} = \frac{4\pi q}{6(4\pi\varepsilon_0)}$$

56. According to Gauss theorem, "the net electric flux through any closed surface is equal to the net charge inside the surface divided by $\in_0$".

Therefore, $\phi = \dfrac{q}{\varepsilon_0}$

Let $-q_1$ be the charge due to which flux f_1 is entering the surface

$$\phi_1 = \frac{-q_1}{\varepsilon_0} \quad \text{or} \quad -q_1 = \varepsilon_0\phi_1$$

Let $+q_2$ be the charge, due to which flux f_2 is leaving the surface

$$\phi_2 = \frac{q_2}{\varepsilon_0} \quad \text{or} \quad q_2 = \varepsilon_0\phi_2$$

So, electric charge inside the surface

$= q_2 - q_1 = \varepsilon_0\phi_2 + \varepsilon_0\phi_1 = \varepsilon_0(\phi_2 - \phi_1)$.

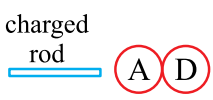
MULTI MODEL QUESTIONS

ELECTRIC CHARGE

1. An insulator (non-conductor) can be charged by (*a*) conduction (*b*) induction (*c*) friction

1) a,c 2) b,c 3) c only 4) b only

2. Two isolated metal spheres are identical. They are electrically neutral and are touching. An electrically charged rod is then brought near the spheres without touching them, as the drawing shows. After a while, with the rod held in place, the spheres are separated, and the rod is then removed. The following statements refer to the masses m_A and m_B of the spheres after they are separated and the rod is removed. Which of the following statements is true?



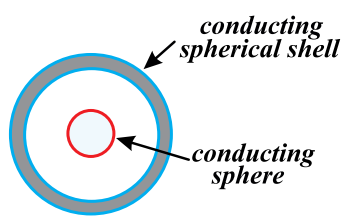
1) $m_A = m_B$

2) $m_A > m_B$ if the rod is positive

3) $m_A > m_B$ if the rod is negative

4) $m_A > m_B$ irrespective of the charge (+ve or -ve) on the rod

3. A conducting sphere that carries a total charge of -3*q* is placed at the centre of a conducting spherical shell that carries a total charge of +5*q*. The conductors are in electrostatic equilibrium. The charges on the *inner* and *outer surfaces* of the shell are respectively



1)+3*q*,+2*q* 2)+*q*,+*q* 3)+2*q*,+3*q* 4)+2*q*,+7*q*

KEY

1) 3 2) 4 3) 1

COULOMB'S LAW

4. Two small identical balls are suspended from a common point by two identical strings. When they are given identical charges, they move apart and the strings make with the vertical an angle of θ. Now the system is immersed in a liquid and as a result the angle q does not change. If ρ is the density of the material of the balls and σ is the density of the liquid, the dielectric constant of the liquid is

1) $\frac{\rho}{\rho-\sigma}$ 2) $\frac{\rho-\sigma}{\rho}$ 3) $\frac{\sigma}{\rho-\sigma}$ 4) $\frac{\rho-\sigma}{\sigma}$

5. An electron is kept on the north-eastern side of an alpha particle at a distance *r*. The force acting on the electron is

1) $\frac{2e^2}{4\pi\varepsilon_o r^2}$ SW 2) $\frac{e^2}{4\pi\varepsilon_o r^2}$ NE

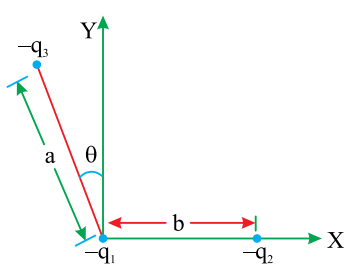
3) $\frac{2e^2}{4\pi\varepsilon_o r^2}$ NE 4) $\frac{e^2}{4\pi\varepsilon_o r^2}$ SW

6. Two point charges are fixed on the X-axis: q_1 = 12.0 mC is located at the origin and q_2 = -3.0 mC is located at point *A*, with x_2 = 8.0 cm. Where should a third charge, q_3, be placed on the X-axis so that the total electrostatic force acting on it is zero?

1) at x_3 = 16 cm 2) at x_3 = 12 cm

3) at x_3 = 24 cm 4) at x_3 = 6 cm

7. Three charges $-q_1$, $+q_2$ and $-q_3$ are placed as shown in the figure. The x-component of the force on $-q_1$ is proportional to



1) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\sin\theta$ 2) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\cos\theta$

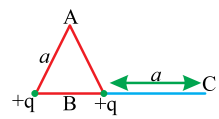
3) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\sin\theta$ 4) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\cos\theta$

KEY

4) 1 5) 1 6) 3 7) 3

ELECTRIC FIELD & ELECTRIC LINES OF FORCE

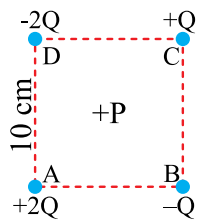
8. Two charges each +*q* are at the vertices of the equilateral triangle of side *a* as shown. A is a vertex, B is midpoint of the side and C is a point at a distance *a* from the right vertex as shown in the figure. The magnitudes of electric intensities at A, B and C are respectively . The correct ascending order of these intensities is



1) $E_B < E_A < E_C$ 2) $E_C < E_A < E_B$

3) $E_A < E_B < E_C$ 4) $E_B < E_C < E_A$

9. Four electrical charges are arranged on the corners of a 10 cm square ABCD as shown. What would be the direction of the resulting electric field at the centre point P?



1) parallel to AD 2) parallel to CB

3) parallel to AB 4) parallel to CD

10. A positive charge kept at one of the vertices of a regular hexagon produces electric intensity *E* at the centre of the hexagon. If the charge is moved to an adjacent vertex, the magnitude of change in the electric intensity will be

1) zero 2) $\sqrt{3}E$

3) E 4) $E/\sqrt{3}$

11. A conducting sphere has a radius 30 cm. If the dielectric strength of surrounding air is 3×10^6 V/m, the maximum amount of charge the sphere can hold in micro-coulombs is

1) 0.03 2) 0.3 3) 3 4) 30

12. A regular tetrahedron has four identical faces each an equilateral triangle of side *L*. A charge +*q* is kept at one of the vertices. The magnitude of electric intensity due to this charge at the centroid of the face opposite to it is ($k = 1/4\pi\varepsilon_0$)

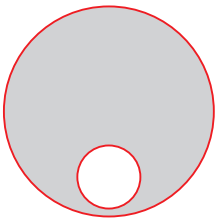
1) $\frac{2Kq}{3L^2}$ 2) $\frac{3kq}{2L^2}$ 3) $\frac{3kq}{L^2}$ 4) $\frac{4kq}{3L^2}$

13. A uniform electric field of intensity *E* is in the Y-negative direction. An electron of mass *m* and charge *e* is fired through the origin with initial velocity *u* in the X-positive direction. The displacement undergone by the electron during a time interval *t* is

1) ut 2) $eEt^2/2m$

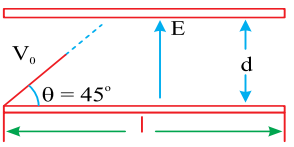
3) $\sqrt{ut+(eEt^2/2m)^2}$ 4) $\sqrt{ut-(eEt^2/2m)^2}$

14. A spherical portion has been removed from a solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is



1) zero everywhere
2) non-zero and uniform
3) non-uniform
4) zero only at its centre

15. An electron is projected as in fig at a speed of 6×10^6 ms^{-1} at an angle of 45° E = 2000 V m^{-1} directed upward, d = 3cm and l = 10cm. Will the electron strike either of the plates?



1) Upper plate 2) Lower plate
3) Upper plate at the edge 4) No where

16. Two large conducting plates are placed parallel to each other with a separation of d between them. An electron starting from rest near one of the plates reaches the other plate in time t. If e is the charge on the electron and m is its mass, then the surface charge density on the inner surface is

1) $\frac{dme}{4\pi\varepsilon_0 t^2}$ 2) $\frac{dm\varepsilon_0}{4\pi et^2}$ 3) $\frac{2dm\varepsilon_0}{et^2}$

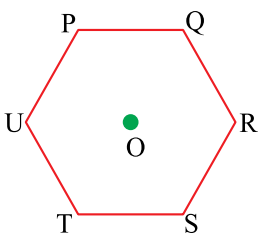
4) none of the above

17. A particle of mass 1kg and carrying positive charge 0.01 C is sliding down an inclined plane of angle of 30° with the horizontal. An electric field E is applied to stop the particle. If the coefficient of friction between the particle and the surface of the plane is $\frac{1}{2\sqrt{3}}$, E must be

1) 1260 V/m 2) 245 V/m

3) $140\sqrt{3}\ V/m$ 4) $\frac{490}{\sqrt{3}}\ V/m$

18. Six charges of equal magnitude, 3 positive and 3 negative are to be placed to PQRSTU corners of a regular hexagon, such that field at the centre is double that of what it would have been if only one +ve charge is placed at R.

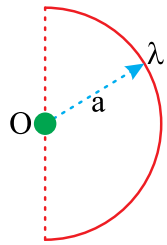


1) +, + , +, – , – , – 2) –, + , +, – , –
3) – , +, + , – , + , – 4) +, – , +, – , + , –

19. A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the centre is directed

1) perpendicular to the diameter
2) parallel to the diameter
3) at an angle tilted towards the diameter
4) at an angle tilted away from the diameter.

20. Electric field at the centre 'O' of a semicircle of radius 'a' having linear charge density λ is given as



1) $\frac{2\lambda}{\varepsilon_0 a}$ 2) $\frac{\lambda\pi}{\varepsilon_0 a}$ 3) $\frac{\lambda}{2\pi\varepsilon_0 a}$ 4) $\frac{\lambda}{\pi\varepsilon_0 a}$

21. A small bob is suspended from the roof with a string and hangs vertically. The bob is given a charge +*q* and a uniform horizontal electric field is set up in the neighbourhood of the bob. Now the bob hangs in the field such that the string makes an angle of 30° with the vertical. If the charge on the bob is made +3*q*, and the bob once again comes to equilibrium, then the angle made by the string with the vertical will be

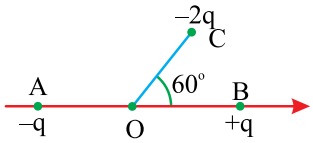
1) 30° 2) 45° 3) 60° 4) 90°

KEY

8) 3	9) 4	10) 2	11) 4	12) 2
13) 2	14) 2	15) 2	16) 3	17) 3
18) 3	19) 1	20) 3	21) 1	

ELECTRIC DIPOLE

22. Figure shows three charges - *q*, + *q* and - 2*q* kept at points A, B and C respectively. OA = OB = OC = *r*. The electric field intensity at O has a magnitude of



1) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ 2) $\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{3}q}{r^2}$

3) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{r^2}$ 4) $\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{3}q}{2r^2}$

23. An electric dipole produces electric field in its surroundings. The angle between the directions of electric field at any point on the axial line and the electric field at any point on the equatorial line is

1) 0° 2) 90° 3) 180° 4) 60°

24. Let E_a be the electric field due to a dipole in its axial plane distance *l* and let E_q be the field in the equatorial plane distance *l*, then the relation between E_a and E_q will be

1) $E_a = 4E_q$ 2) $E_q = 2E_a$
3) $E_a = 2E_q$ 4) $E_q = 3E_a$

25. A particle of mass 1Kg and carrying 0.01C is at rest on an inclined plane of angle 30⁰ with horizontal when an electric field of $\frac{490}{\sqrt{3}}NC^{-1}$ applied parallel to horizontal. The coefficient of friction is

1) 0.5 2) $\frac{1}{\sqrt{3}}$ 3) $\frac{\sqrt{3}}{2}$ 4) $\frac{\sqrt{3}}{7}$

26. A electric field of $1.5\times10^4 NC^{-1}$ exists between two parallel plates of length 2 cm. An electron enters the region between the plates at right angles to the field with a kinetic energy of $E_k = 2000eV$. The deflection that the electron experiences at the deflecting plates is

1) 0.34 mm 2) 0.57 mm
3) 7.5 mm 4) 0.75 mm

27. A bob of a simple pendulum of mass 40gm with a positive charge 4×10^{-6} C is oscillating with a time period T_1 .An electric field of intensity 3.6×10^4 N/C is applied vertically upwards. Now the time period is T_2 the value of $\frac{T_2}{T_1}$ is (g = 10m/s²)

1) 0.16 2) 0.64 3) 1.25 4) 0.8

28. A given charges situated at a certain distance from an electric dipole in the end on position, experiences a force F. If the distance of charge is doubled, the force acting on the charge will be

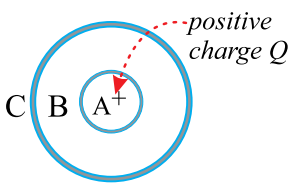
1) 2F 2) F/2 3) F/4 4) F/8

KEY

22) 3 23) 3 24) 3 25) 4 26) 4
27) 3 28) 4

ELECTRIC FLUX & GAUSS LAW

29. A point charge +Q is surrounded by two uncharged concentric conducting shells as shown. The region of space inside the inner shell is A, the region of space between the two shells is B and the region of space outside of outer shell is C. Regarding the electric field which of the following is correct?



1) it exists in A only 2) it exists in B and C only
3) it exists in C only 4) it exists in A, B and C

30. Two infinitely long straight conductors each having a charge density l are arranged parallel to each other. The separation between them is *d*. What happens to the force per unit length on each conductor, when the separation between them is doubled?

1) remains same 2) doubled
3) halved 4) becomes 1/4th

31. An equilateral triangle ABC has a side *a*. Two infinitely long thin straight wires having uniform linear charge densities λ and λ are arranged at A and B perpendicular to the plane of the triangle. The magnitude of electric intensity at the third vertex C will be

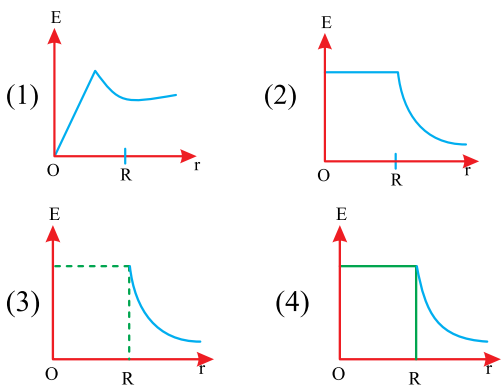
1) $\frac{\lambda}{2\pi\varepsilon_0 a}$ 2) $\frac{\lambda}{\pi\varepsilon_0 a}$ 3) *zero* 4) $\frac{\sqrt{3}\lambda}{2\pi\varepsilon_0 a}$

32. Let three be a spherically symmetric charge distribution with charge density varying as $r(r) = r_0 = \rho_0\left(\frac{5}{4}-\frac{r}{R}\right)$ upto r = R, and r(r) = 0 for r > R, distance from the origin. The electric field at a distance r(r < R) from the origin is given by

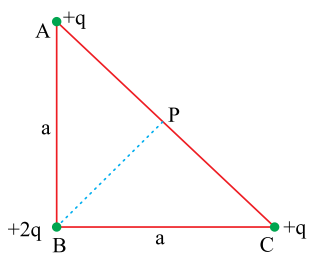
1) $\frac{4\pi\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4}-\frac{r}{R}\right)$ 2) $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3}-\frac{r}{R}\right)$

3) $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4}-\frac{r}{R}\right)$ 4) $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4}-\frac{r}{R}\right)$

33. An isolated solid metal sphere of radius *R* is given an electric charge. The variation of the intensity of the electric field with the distance *r* from the centre of the sphere is best shown by



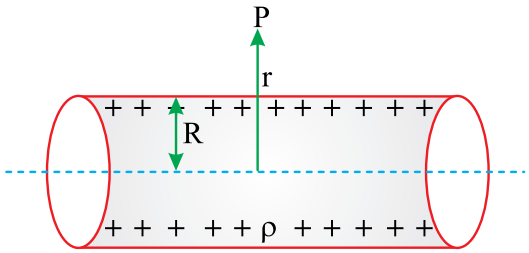
34. Three charges +q, +q, +2q are arranged as shown in figure. What is the field at point P (center of side AC)



1) $E = \frac{q}{\pi\varepsilon_0 a^2}$ 2) $E = \frac{q}{2\pi\varepsilon_0 a^2}$

3) $E = \frac{q}{3\pi\varepsilon_0 a^2}$ 4) $E = \frac{q}{4\pi\varepsilon_0 a^2}$

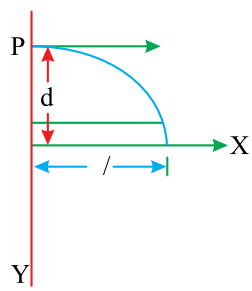
35. Point P is at a distance of *r*(> R) from the axis of the cylinder. The volume charge density and radius of this cylinder are ρ and *R* respectively



What is the electric field at point P?

1) $\frac{\rho R^2}{2\varepsilon_0 r}$ 2) $\frac{\rho R^2}{2\varepsilon_0}$ 3) $\frac{\rho R^2}{\varepsilon_0 r}$ 4) $\frac{\rho R^2}{\varepsilon_0}$

36. The electron is projected from a distance *d* and with initial velocity *u* parallel to a uniformly charged flat conducting plate as shown. It strikes the plate after traveling a distance *l* along the direction. The surface charge density of the conducting plate is equal to



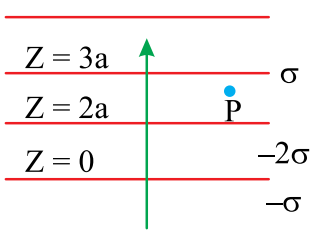
1) $\frac{2d\varepsilon_0 mu^2}{el^2}$

2) $\frac{2d\varepsilon_0 mu}{el}$

3) $\frac{d\varepsilon_0 mu^2}{el}$

4) $\frac{d\varepsilon_0 mu}{el}$

37. Three infinitely charged sheets are kept parallel to *x-y* plane having charge densities as shown in figure. Then the value of electric field at 'P' is



1) $\frac{-2\sigma}{\varepsilon_0}\hat{k}$ 2) $\frac{2\sigma}{\varepsilon_0}\hat{k}$ 3) $\frac{-4\sigma}{\varepsilon_0}\hat{k}$ 4) $\frac{4\sigma}{\varepsilon_0}\hat{k}$

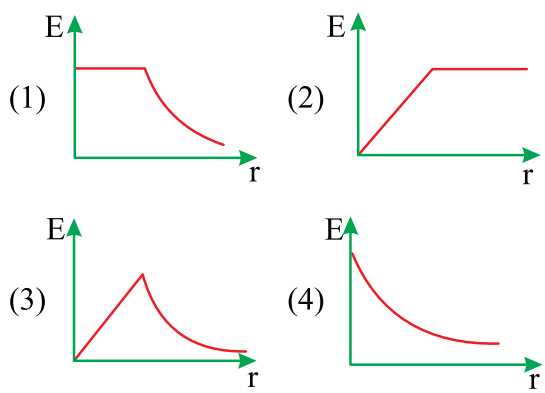
38. Three concentric metallic spherical shells of radii R, 2R, 3R are given charges Q_1, Q_2, Q_3 respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells $Q_1 : Q_2 : Q_3$ is

1) 1 : 2 : 3 2) 1 : 3 : 5
3) 1 : 4 : 9 4) 1 : 8 : 18

39. A point charge +q, is placed at a distance d from an isolated conducting plane. The field at a point P on the other side of the plane is

1) directed perpendicular to the plane and away from the plane.
2) directed perpendicular to the plane but towards the plane.
3) directed radially away from the point charge.
4) directed radially towards the point charge

40. Which graph shows variation of electric field of a uniformly charged non conducting sphere w.r.t. distance (r) from the centre :



41. A solid metallic sphere has a charge +3Q. Concentric with this sphere is a conducting spherical shell having charge –Q. The radius of the sphere is 'a' and that of the spherical shell is 'b' (b > a). What is the electric field at a distance R (a < R < b) from the centre?

1) $\frac{4Q}{2\pi\varepsilon_0 R^2}$ 2) $\frac{3Q}{4\pi\varepsilon_0 R^2}$

3) $\frac{3Q}{2\pi\varepsilon_0 R^2}$ 4) $\frac{Q}{2\pi\varepsilon_0 R}$

KEY

29) 3 30) 2 31) 1 32) 2 33) 3
34) 1 35) 1 36) 1 37) 1 38) 2
39) 1 40) 3 41) 2

HINTS SOLUTIONS

1. Induction needs separation of charges and transferring one of the charges to Earth, which is possible only in conductors
2. If the rod has +ve charge, by induction a negative charge appears on A and a positive charge on B. When A has negative charge it has more mass (surplus electrons) than B
3. Before the conducting sphere is kept inside, the conducting shell has +5*q* charge on its outer surface. Now keeping the conducting sphere at the centre with charge -3*q*, induces +3*q* on the inner surface of the shell and -3*q* on the outer surface of the shell. This -3*q* added to already existing +5*q* gives +2*q*, which is the charge on the outer surface. The charge on the inner surface is the induced charge +3*q*
4. As the orientation of the balls does not change, the electric force in each case must be proportional to the apparent weight of the ball.

$$\frac{q^2}{r^2} \infty V\rho g \ , \frac{Kq^2}{r^2} \infty V\rho g$$

5. The charge on alpha particle is 2*e*. The electron is attracted and electric forces are central forces and act along the line joining the charged particles.
6. If q_3 is at a distance *x* from the origin, for net force to be zero we must have , solving gives *x* .On each sphere, gravity force *mg*, electric force kq/L^2 and tension *T* act and keep it in equilibrium. Apply Lami's theorem or resolve
7. Use superposition principle
8. The field at A is $\sqrt{3}kq^2/a^2$, the field at B is zero and the field at C is sum of kq^2/a^2 and $kq^2/4a^2$
9. The net intensity due to charges at B and D is along PD and the net intensity due to charges at A and C is along PC. these two intensities are equal, the resultant will be along the bisector of angle DPC.
10. $\Delta E = 2E\sin(\frac{\theta}{2})$; 11. $E = \frac{Q}{4\pi\varepsilon_0 r^2}$
12. The distance between the charge and the centroid of opposite face is obtained by Pythagoras, where the hypotenuse is *L* and one of the sides containing the right angle is . The other side required is Apply intensity formula
13. Motion of electron along X-axis is without acceleration and so the displacement in a time *t* is *ut*. Motion of electron along Y-axis is with acceleration *eE/m* and is $eEt^2/2m$. The resultant of these two displacements in perpendicular direction is obtained by $S = \sqrt{S_\chi^2 + S_\gamma^2}$
14. It is non-zero and uniform
    It is obtained by using per super position method.

    Assuming no cavity $E = \frac{K.\rho.4/3\pi r^3}{r^2} = \frac{K.\rho 4\pi.r}{3}$

    Assuming only charge existing in cavity

    $\vec{E_{r_2}} = \frac{K.\rho.4/3\pi r_2^3}{r_2^2} = \frac{K.\rho 4\pi.r_2}{3}$; Net field

    $\vec{E_P} = \vec{E_1} - \vec{E_2}$

    Thus, it is uniform and non zero
15. Use range formula; 16. $S = ut + \frac{1}{2}a\ t^2$
17. $mg(\sin\alpha - \mu\cos\alpha) - \mu qE\sin\alpha = qE\cos\alpha$
18. P and S cancel field; Q and T cancel field
    R and U add on
19. E directed perpendicular to its diameter

21. Three forces on the bob, T, mg and qE produce equilibrium. Resolving T and applying the condition of equilibrium gives $qE = mg\tan q$

22. The field at 'O' due to charges at A and B are equal and their resultant is $2q/r^2$. The field due to the charge at C is also $2q/r^2$ towards C. The angle between the two vectors is 120°

23. The axial filed is from +ve charge to -ve charge and the equatorial field is from -ve charge to +ve charge. As they are anti-parallel, the angle is 180°

24. $E_a = 2E_q$

25. $N = mg\sin\theta + qE\sin\theta$; $mg\sin\theta = \mu N + qE\cos\theta$

26. $y = \dfrac{eE\alpha^2}{4k}(K = K.E)$; 27. $T = 2\pi\sqrt{\dfrac{l}{g_{eff}}}$

28. In case of an electric dipole, $F \propto \dfrac{1}{r^3}$

new force $= F/2^3 = F/8$

29. Visualize concentric Gaussian spheres of radii less that the of inner shell, more than that of inner shell but less than that of outer shell and more than that of outer shell. All these contain a net charge +Q, suggesting that field must exist in A, B and C. Remember the total induced charges on both the shells is zero as induction is only redistribution of charge but not creation of charge

30. The field due to an infinitely long straight conductor at any point in its neighbourhood is given by directed perpendicular to the wire. Consider an element of length dx of the second conductor. The charge on it is λdx. The force acting on it is $E'\lambda dx$. $F = \dfrac{\lambda^2}{2\pi\varepsilon_o d}$

31. $E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$

32. Apply shell theorem, the total charge upto distance r can be calculated as followed
$dq = 4pr^2.dr.r$

$$= 4\pi r^2.dr.\rho_0\left[\frac{5}{4} - \frac{r}{R}\right] = 4\pi\rho_0\left[\frac{5}{4}r^2dr - \frac{r^3}{R}dr\right]$$

$$\int dq = q = 4\pi\rho_0\int_0^r\left(\frac{5}{4}r^2dr - \frac{r^3}{R}dr\right)$$

$$= 4\pi\rho_0\left[\frac{5}{4}\frac{r^2}{3} - \frac{1}{R}\frac{r^4}{4}\right]; E = \frac{kq}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0}.\frac{1}{r^2}.4\pi\rho_0\left[\frac{5}{4}\left(\frac{r^2}{3}\right) - \frac{r^4}{4R}\right]$$

$$; E = \frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$$

33. $E = 0,\ r \le R$; $E = \dfrac{q}{4\pi\varepsilon_0 r^2}$ $r > R$

34. $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{2q}{(BP)^2}$; $BP = \sqrt{BC^2 - PC^2}$ $a/\sqrt{2}$

35. $\oint \vec{E}.d\vec{A} = \dfrac{q}{\varepsilon_0}$

Let l be the length of the cylinder.
Total charge on the cylinder, $q = r(pR^2 l)$

$$\Rightarrow E(2\pi r l) = \frac{\rho\pi R^2 l}{\varepsilon_0} \Rightarrow E = \frac{\rho R^2}{2\varepsilon_0 r}$$

36. $S = ut + \dfrac{1}{2}a\,t^2$; 37. $E = \sigma/\varepsilon_0$

38. The charge distribution on the shells outer surface will be
For Shell 1 $\rightarrow Q_1$; For Shell 2 $\rightarrow Q_1 + Q_2$
For Shell 3 $\rightarrow Q_1 + Q_2 + Q_3$; σ is same

40. $E \propto r$ Where r<R; $E \propto \dfrac{1}{r^2}$ Where r>R

41. For conducting sphere $E_{in} = 0$ where r<R

$E_{Out} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$ where r>R