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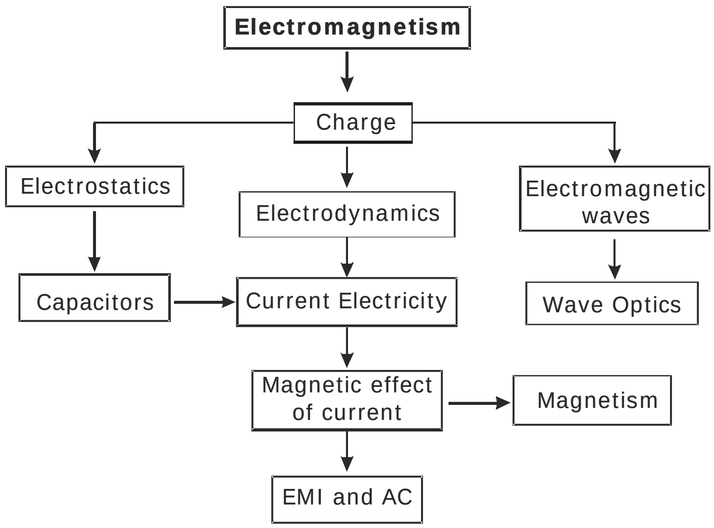
1. CHARGE

1.1 INTRODUCTION

Electromagnetism is basically the study of the charge. It can be categorized into three parts

1. Electrostatics : Study of charges at rest
2. Electrodynamics : Study of charges in Uniform motion
3. Electromagnetic waves : Study of charges accelerated.



1.2 ELECTROSTATICS

The branch of physics that deals with the electric effects of static charge is called Electrostatics.

1.3 ELECTRIC CHARGE

(1) **Definition:** Charge is the property associated with matter due to which it produces and experiences electrical and magnetic effects.

(2) **Origin of electric charge** : A neutral atom contains as many electrons as the number of protons in the nucleus. Any imbalance in this constitution results in charge on an atom.

(3) **Types:** Two types of charges exist in nature (i) Positive charge (ii) Negative charge

a. Excess electrons results in negative charge
b. Deficiency of electrons results in positive charge.
c. Benjamin Franklin was the first to assign positive and negative sign of charge.
d. The existence of two type of charges was discovered by Dufog.

(4) **Unit and dimensional formula:**

a. S.I. unit of charge is - Ampere sec = coulomb (C),
b. Smaller S.I. units are mC, C, nC $(1mC = 10^{-3}C, 1m\,C = 10^{-6}C, 1nC = 10^{-9}C)$
c. C.G.S. unit of charge is - Stat coulomb or e.s.u.
d. Electromagnetic unit of charge is - ab coulomb .
e. Dimensional formula [Q] = [AT]
f. Franklin (i.e., e.s.u. of charge) -- smallest unit of charge
Faraday is largest (1 Faraday = 96500 C)
g. The e.s.u. of charge is also called stat coulomb or Franklin (Fr) and is related to e.m.u. of charge through the relation $\dfrac{\text{emu of charge}}{\text{esu of charge}} = 3 \times 10^{10}$

(5) **Properties of charge**

(i) Charge is transferable

(ii) Charge is always associated with mass

(iii) Total charge of an isolated system remains constant (Charge is conserved)

(iv) Charge is invariable at relativistic speeds.

(v) Charge produces electric field and magnetic field

(vi) Charge resides on the surface of conductor

(vii) Charge leaks from sharp points

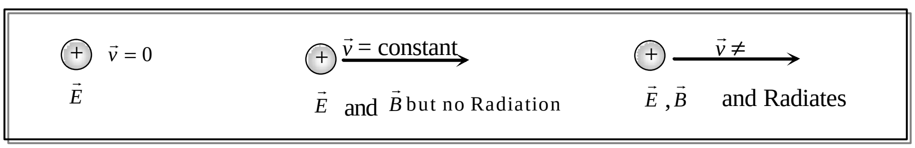
(viii) Quantization of charge: If the charge of an electron (= 1.6×10^{-19} C) is taken as elementary unit i.e. quanta of charge the charge on any body will be some integral multiple of e i.e.,

$$Q = \pm ne \text{ With } n = 1, 2, 3 \ldots.$$

Charge on a body can never be $\pm\frac{2}{3}e$, $\pm 17.2e$ or $\pm 10^{-5}e$ etc.

Also **Q = it**, where 'i' is the current and 't' is the time.

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



(6) **Comparison of Charge and Mass (Table).**

Charge	Mass
(1) Electric charge can be positive, negative or zero.	(1) Mass of a body is a positive quantity.
(2) Charge carried by a body does not depend upon velocity of the body.	(2) Mass of a body increases with its velocity as $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$ where c is velocity of light in vacuum, m is the mass of the body moving with velocity v and m_0 is rest mass of the body.
(3) Charge is quantized.	(3) The quantization of mass is yet to be established.
(4) Electric charge is always conserved.	(4) Mass is not conserved as it can be changed into energy and vice-versa.
(5) Force between charges can be attractive or repulsive, according as charges are unlike or like charges.	(5) The gravitational force between two masses is always attractive.

(7) **Types of Materials:**

The materials available in nature can be broadly categorized as -

a. Conductors

b. Insulators

The more conducting the material is the more will be value of K.

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

Where k is conductivity of the material

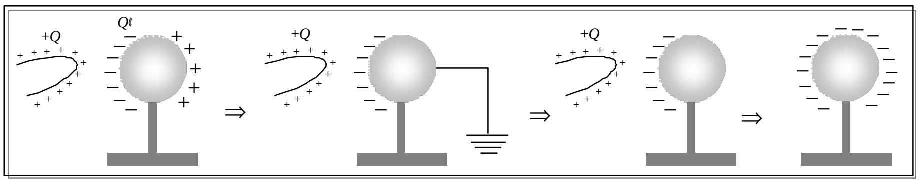
1.4 METHODS OF CHARGING

A body can be charged by following methods:

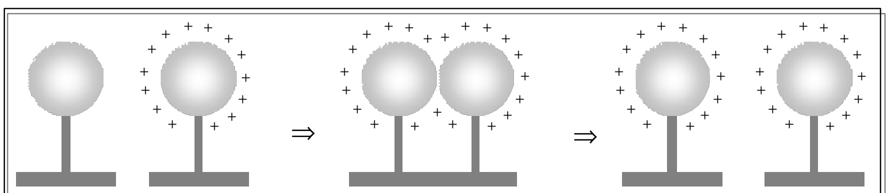
(1) By friction

e.g. Combing of hair

(2) By electrostatic induction : Inducting body neither gains nor loses charge.

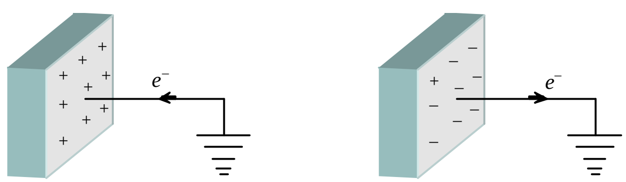


(3) Charging by conduction :

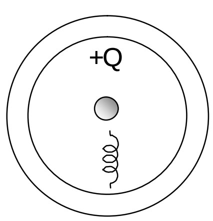


MEMORY POINTS :

a. After earthing a positively charged conductor electrons flow from earth to conductor and if a negatively charged conductor is earthed then electrons flows from conductor to earth.



b. When a charged spherical conductor placed inside a hollow insulated conductor and connected it through a fine conducting wire the charge will be completely transferred from the inner conductor to the outer conductor.



c. Lightening-rods arrestors are made up of conductors with one of their ends earthed while the other sharp end protects a building from lightening either by neutralising or conducting the charge of the cloud to the ground.

d. With rise in temperature dielectric constant of liquid decreases.

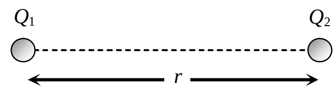
e. Induction takes place only in bodies (either conducting or non-conducting) and not in particles.

f. Induced body neither gains nor loses charge.

2. COULOMB'S LAW

2.1 Definition

If two stationary and point charges Q_1 and Q_2 are kept at a distance r, then it is found that force of attraction or repulsion between them is $F \propto \frac{Q_1Q_2}{r^2}$ i.e., $F = \frac{kQ_1Q_2}{r^2}$; (k = Proportionality constant)



(1) **Dependence of K :** Constant K depends upon system of units and medium between the two charges.

(i) **Effect of units**

(a) In C.G.S. for air K = 1 $F = \frac{Q_1Q_2}{r^2}$ Dyne

(b) In S.I. for air $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \frac{N-m^2}{C^2}$, $F = \frac{1}{4\pi\varepsilon_0}.\frac{Q_1Q_2}{r^2}$ Newton

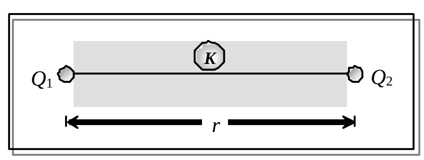
(1 Newton = 10^5 Dyne)

(c) ε_0 = Absolute permittivity of air or free space = $8.85 \times 10^{-12} \frac{C^2}{N-m^2} \left(= \frac{Farad}{m}\right)$

It's Dimension is $[ML^{-3}T^4A^2]$

2.2 Effect of medium

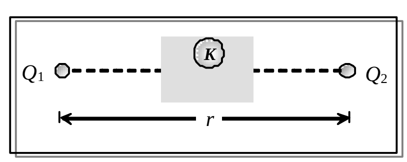
(a) When a dielectric medium is completely filled the charges inside the dielectric medium takes place and the force between the same two charges decreases by a factor of K known as dielectric constant or specific inductive capacity (SIC) of the medium, K is also called relative permittivity r of the medium (relative means with respect to free space).



Hence in the presence of medium $F_m = \frac{F_{air}}{K} = \frac{1}{4\pi\varepsilon_0 K}.\frac{Q_1Q_2}{r^2}$

Here $\varepsilon_0 K = \varepsilon_0\,\varepsilon_r = \varepsilon$ (permittivity of medium)

(b) If a dielectric medium (dielectric constant K, thickness t) is partially filled between the charges then effective air separation between the charges becomes $(r - t + t\sqrt{K})$



Hence force $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{(r - t + t\sqrt{K})^2}$

2.3 Vector form of coulomb's law :

Vector form of Coulomb's law is $\vec{F}_{12} = K.\frac{q_1q_2}{r^3}\vec{r}_{12} = K.\frac{q_1q_2}{r^2}\hat{r}_{12}$,

where $\hat{r}_{12}$ is the unit vector from first charge to second charge along the line joining the two charges.

2.4 A comparative study of fundamental forces of nature

S. No.	Force	Nature and formula	Range	Relative strength
(i)	Force of gravitation between two masses	Attractive $F = Gm_1m_2/r^2$, obey's Newton's third law of motion, it's a conservative force	Long range (between planets and between electron and proton)	1
(ii)	Electromagnetic force (for stationary and moving charges)	Attractive as well as repulsive, obey's Newton's third law of motion, it's a conservative force	Long (upto few *kelometers*)	10^{37}
(iii)	Nuclear force (between nucleons)	Exact expression is not known till date. However in some cases empirical formula U_0e^{r/r_0} can be utilized for nuclear potential energy v_0 and r_0 are constant.	Short (of the order of nuclear size 10^{-15} *m*)	10^{39} (strongest)
(iv)	Weak force (for processes like *b* decay)	Formula not known	Short (upto 10^{-15} *m*)	10^{24}

2.5 MEMORY POINTS :

a. Coulombs law is not valid for moving charges because moving charges produces magnetic field also.

b. Coulombs law is valid at a distance greater than 10^{-15} m.

c. A charge Q_1 exert some force on a second charge Q_2. If third charge Q_3 is brought near, the force of Q_1 exerted on Q_2 remains unchanged.

d. Ratio of gravitational force and electrostatic force between (i) Two electrons is $10^{-43}/1$. (ii) Two protons is $10^{-36}/1$ (iii) One proton and one electron $10^{-39}/1$.

e. Decreasing order to fundamental forces $F_{Nuclear} > F_{Electromagnetic} > F_{Weak} > F_{Gravitational}$

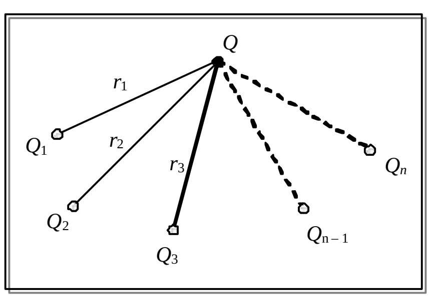
f Coulomb found that force between two point charges at rest

(i) Depends on the nature of the medium between the charges.

(ii) It is always along the line joining the charges.

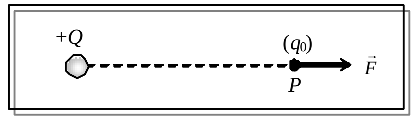
2.6 Principle of superposition : According to the principle of super position, total force acting on a given charge due to number of charges is the vector sum of the individual forces acting on that charge due to all the charges.Consider number of charge Q_1, Q_2, Q_3 ...are applying force on a charge Q

Net force on Q will be $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + ... + \vec{F}_{n-1} + \vec{F}_n$



3. ELECTRIC FIELD, POTENTIAL & POTENTIAL ENERGY

3.1 Electric field intensity $(\vec{E})$ **:** The electric field intensity at any point is defined as the force experienced by a unit positive charge placed at that point. $\vec{E} = \dfrac{\vec{F}}{q_0}$



Unit and Dimensional formula :

It's S.I. unit - $\dfrac{\text{Newton}}{\text{coulomb}} = \dfrac{\text{volt}}{\text{meter}} = \dfrac{\text{Joule}}{\text{coulomb} \times \text{meter}}$ and

C.G.S. unit - Dyne/stat coulomb.

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

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

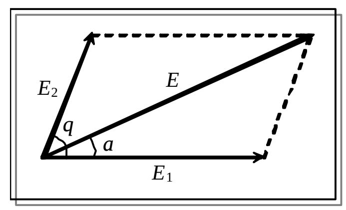
3.2 Super position of electric field (electric field at a point due to various charges) : The resultant electric field at any point is equal to the vector sum of electric fields at that point due to various charges.

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

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

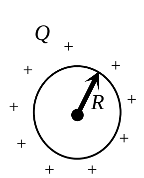
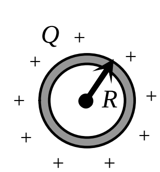
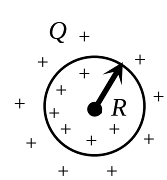
$E = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$ and the direction is given by

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



3.3 Electric field due to continuous distribution of charge : A system of closely spaced electric charges forms a continuous charge distribution

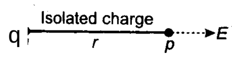
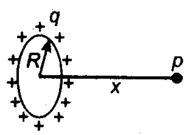
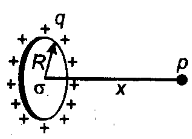
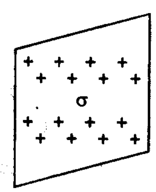
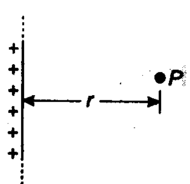
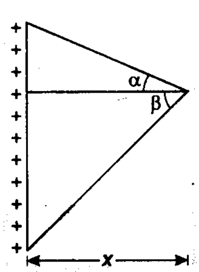
Continuous charge distribution (Table)

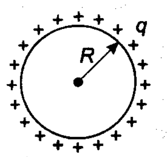
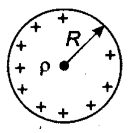
Linear charge distribution	Surface charge distribution	Volume charge distribution
In this distribution charge is distributed on a line	In this distribution charge is distributed on the surface	In this distribution charge is distributed in the whole volume of the body.
For example : - Charge on a wire, Charge on a ring etc	For example : Charge on a conducting sphere charge on a sheet etc	For example:Non conducting charged sphere.
$\lambda - \dfrac{\text{charge}}{\text{length}}$	$\sigma - \dfrac{\text{charge}}{\text{area}}$	$\rho - \dfrac{\text{charge}}{\text{volume}}$
$\lambda = \dfrac{Q}{2\pi R}$	$\sigma = \dfrac{Q}{4\pi R^2}$	$\rho = \dfrac{Q}{\frac{4}{3}\pi R^3}$
		
Circular charged ring	Spherical shall	Non conducting sphere

To find the field of a continuous charge distribution, we divide the charge into infinitesimal charge elements. The Net field at the given point is the summation of fields of all the elements. i.e., $\vec{E} = \int \vec{dE}$

(MEMORY POINT)

ELECTRIC FIELD INTENSITY OF VARIOUS SYSTEM.

S.N.	System	Electric Potential
1.	Isolated charge 	$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$
2.	A ring of charge 	$E = \frac{1}{4\pi\varepsilon_0} \frac{qx}{\left(R^2 + x^2\right)^{3/2}}$
3.	A disc of charge 	$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2 + R^2}}\right]$
4.	Infinite sheet of charge 	$E = \frac{\sigma}{2\varepsilon_0}$
5.	Infinitely long line of charge 	$E = \frac{\lambda}{2\pi\varepsilon_0 r}$
6.	Finite line of charge 	$E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 x}(\sin\alpha + \sin\beta)$ $E_{\parallel} = \frac{\lambda}{4\pi\varepsilon_0 x}(\cos\alpha - \cos\beta)$

7.	Charged spherical shell 	(a) Inside $0 \le r \le R$ $E = 0$ (b) Outside $r \ge R$ $E = \frac{q}{4\pi\varepsilon_0 r^2}$
8.	Solid sphere of charge 	(a) Inside $0 \le r \le R$ $V = \frac{\rho r}{3\varepsilon_0}$ (b) Outside $r \ge R$ $V = \frac{\rho R}{3\varepsilon_0}\left(\frac{R}{r}\right)^2$

3.4 ELECTRIC POTENTIAL

(1) **Definition :** Potential at a point in a field is defined as the amount of work done in bringing a unit positive test charge, from infinity to that point along any arbitrary path (infinity is point of zero potential). Electric potential is a scalar quantity, it is denoted by V; $V = \frac{W}{q_0}$

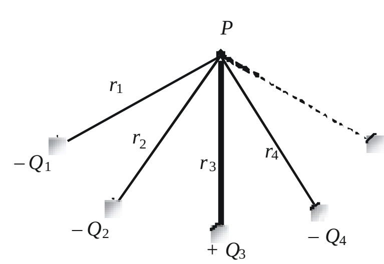
(2) **Unit and dimensional formula :** S. I. unit - $\frac{\text{Joule}}{\text{Coulomb}}$ = volt ; C.G.S. unit - Stat volt (e.s.u.); 1 volt = $\frac{1}{300}$ Stat volt ; Dimension - $[V] = [ML^2T^{-3}A^{-1}]$

(3) **Types of electric potential :** According to the nature of charge potential is of two types

(i) Positive potential : Due to positive charge.

(ii) Negative potential : Due to negative charge.

(4) **Potential of a system of point charges :** Consider P is a point at which net electric potential is to be determined due to several charges. So net potential at P



$$V = k\frac{Q_1}{r_1} + k\frac{Q_2}{r_2} + k\frac{Q_3}{r_3} + k\frac{(-Q_4)}{r_4} + \ldots$$

In general $V = \sum_{i=1}^{x} \frac{kQ_i}{r_i}$

Note:

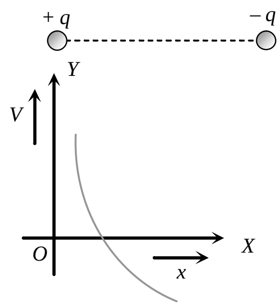
a. At the centre of two equal and opposite charge V = 0 but $E \ne 0$

b. At the centre of the line joining two equal and similar charge $V \ne 0, E = 0$

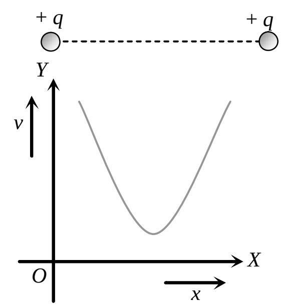
(5) **Electric potential due to a continuous charge distribution** : The potential due to a continuous charge distribution is the sum of potentials of all the infinitesimal charge elements in which the distribution may be divided i.e.,

$$V = \int dV, \quad = \int \frac{dQ}{4\,\mathrm{pe}_0 r}$$

(6) **Graphical representation of potential :** When we move from a positive charge towards an equal negative charge along the line joining the two then initially potential decreases in magnitude and at centre become zero. When we move from centre towards the negative charge then though potential remain always negative but increases in magnitude [fig. (A)]. As one move from one charge to other when both charges are like, the potential first decreases, at centre become minimum and then increases [Fig. (B)].



(A)



(B)

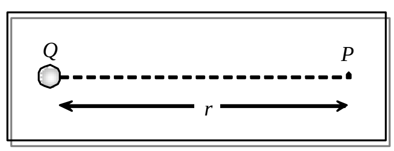
(7) **Potential difference :** In an electric field potential difference between two points A and B is defined as equal to the amount of work done (by external agent) in moving a unit positive charge from point A to point B.

i.e., $V_B - V_A = \dfrac{W}{q_0}$

In general $W = Q.\Delta V$; $\Delta V =$ Potential difference through which charge Q moves.

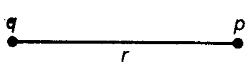
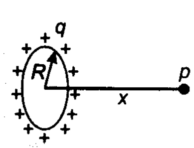
Electric potential due to various charge distribution.

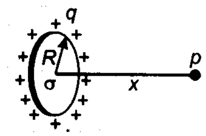
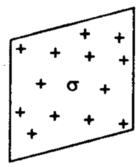
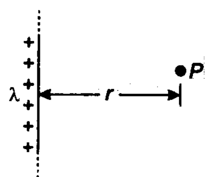
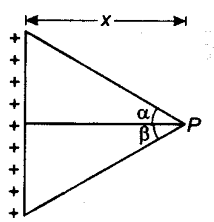
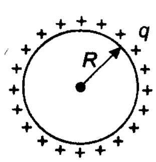
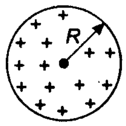
Point charge : $\boldsymbol{E} = \boldsymbol{k}\dfrac{\boldsymbol{Q}}{\boldsymbol{r}^2}$ or $\vec{E} = k\dfrac{Q}{r^2}\hat{r}$ $\left(k = \dfrac{1}{4\pi\varepsilon_0}\right)$; $V = k\dfrac{Q}{r}$



(MEMORY POINTS)

ELECTRIC POTENTIAL OF VARIOUS SYSTEM

S.N.	**System**	**Electric Potential**
1.	Isolated charge 	$V = \dfrac{q}{4\pi\varepsilon_0 r}$
2.	A ring of charge 	$V = \dfrac{q}{4\pi\varepsilon_0}\ \dfrac{q}{\sqrt{R^2 + x^2}}$

3.	A disc of charge 	$V = \frac{\sigma}{2\varepsilon_0}\left[\sqrt{R^2+x^2}-x\right]$
4.	Infinite sheet of charge 	Not defined
5.	Infinitely long line of charge 	Not defined
6.	Finite line of charge 	$V = \frac{\lambda}{4\pi\varepsilon_0}\ \ln\left\lvert\frac{\sec\beta+\tan\beta}{\sec\alpha-\tan\alpha}\right\rvert$
7.	Charged spherical shell 	(a) Inside $0 \le r \le R$ $V = \frac{q}{4\pi\varepsilon_0 R}$ (b) Outside $r > R$ $V = \frac{q}{4\pi\varepsilon_0 r}$
8.	Solid sphere of charge 	(a) Inside $0 \le r \le R$ $V = \frac{\rho R^2}{6\varepsilon_0}\left[3-\frac{r^2}{R^2}\right]$ (b) Outside $r \ge R$ $V = \frac{\rho R^3}{3\varepsilon_0}\left[\frac{1}{r}\right]$

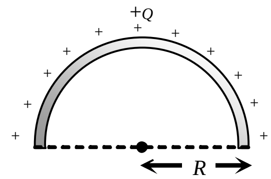
Electric field and potential in some other cases (Memory points)

(i) Uniformly charged semicircular ring : $\lambda = \frac{\text{charge}}{\text{length}}$

At centre :

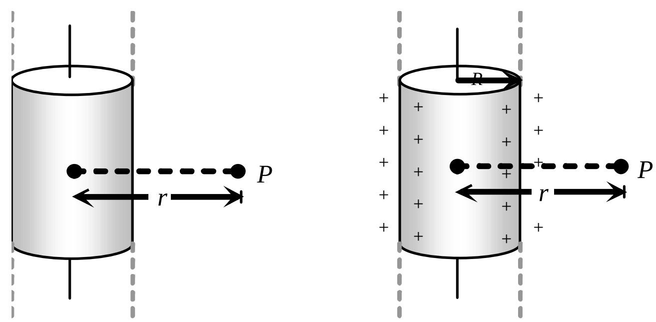
$$E = \frac{2K\lambda}{R} = \frac{Q}{2\pi^2\varepsilon_0 R^2}$$

$$V = \frac{KQ}{R} = \frac{Q}{4\pi\varepsilon_0 R}$$



(ii) Charged cylinder of infinite length

(a) Conducting (b) Non-conducting

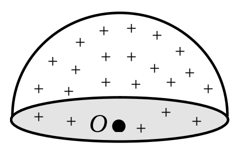


For both type of cylindrical charge distribution $E_{out} = \frac{\lambda}{2\pi\varepsilon_0 r}$, and $E_{surface} = \frac{\lambda}{2\pi\varepsilon_0 R}$ but for conducting $E_{in} = 0$ and for non-conducting $E_{in} = \frac{\lambda r}{2\pi\varepsilon_0 R^2}$. (we can also write formulae in form of ρ i.e., $E_{out} = \frac{\rho R^2}{2\varepsilon_0 r}$ etc.)

(iii) Hemispherical charged body :

At centre O, $E = \frac{\sigma}{4\varepsilon_0}$

$$V = \frac{\sigma R}{2\varepsilon_0}$$

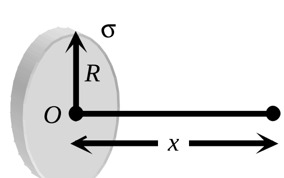


(iv) Uniformly charged disc

At a distance x from centre O on it's axis

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2 + R^2}}\right]$$

$$V = \frac{\sigma}{2\varepsilon_0}\left[\sqrt{x^2 + R^2} - x\right]$$

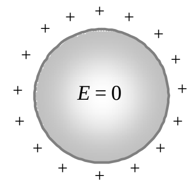


Note : Total charge on disc $Q = \sigma\pi R^2$

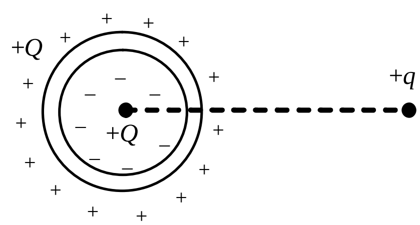
If $x \to 0$, $E \simeq \frac{\sigma}{2\varepsilon_0}$ i.e. for points situated near the disc, it behaves as an infinite sheet of charge.

3.6 MEMORY POINTS

- No point charge produces electric field at it's own position.
- Since charge given to a conductor resides on it's surface hence electric field inside it is zero.



- The electric field on the surface of a conductor is directly proportional to the surface charge density at that point i.e, $E \propto \sigma$
- Two charged spheres having radii r_1 and r_2 charge densities σ_1 and σ_2 respectively, then the ratio of electric field on their surfaces will be $\frac{E_1}{E_2} = \frac{\sigma_1}{\sigma_2} = \frac{r_2^2}{r_1^2}$
- In air if intensity of electric field exceeds the value 3×10^6 N/C air ionizes.
- Electric field is always directed from higher potential to lower potential.
- A positive charge if left free in electric field always moves from higher potential to lower potential while a negative charge moves from lower potential to higher potential.
- The practical zero of electric potential is taken as the potential of earth and theoretical zero is taken at infinity.
- An electric potential exists at a point in a region where the electric field is zero and it's vice versa.
- A point charge +Q lying inside a closed conducting shell does not exert force another point charge q placed outside the shell



- The charge q however experiences a force not because of charge +Q but due to charge induced on the outer surface of the shell.

3.6 POTENTIAL DUE TO CONCENTRIC SPHERES

Case (i) : If two concentric conducting shells of radii r_1 and r_2 ($r_2 > r_1$) carrying uniformly distributed charges Q_1 and Q_2 respectively. What will be the potential of each shell

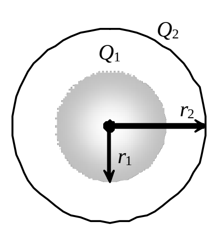
To find the solution following guidelines are to be taken.

Here after following the above guidelines potential at the surface of inner shell is

$$V_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1}{r_1} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_2}{r_2}$$

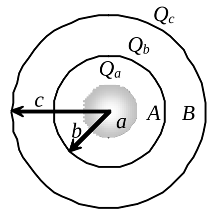
and potential at the surface of outer shell

$$V_2 = \frac{1}{4\pi\varepsilon_0} \frac{Q_1}{r_2} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_2}{r_2}$$



Case (ii) : The figure shows three conducting concentric shell of radii a, b and c (a < b < c) having charges Q_a, Q_b and Q_c respectively what will be the potential of each shell

After following the guidelines discussed above



Potential at A : $= V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_a}{a} + \frac{Q_b}{b} + \frac{Q_c}{c}\right]$

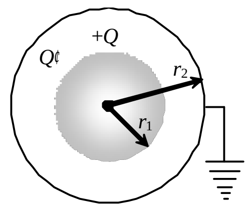
Potential at B : $V_B = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_a}{b} + \frac{Q_b}{b} + \frac{Q_c}{c}\right]$

Potential at C : $V_C = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_a}{c} + \frac{Q_b}{c} + \frac{Q_c}{c}\right]$

Case (iii) : The figure shows two concentric spheres having radii r_1 and r_2 respectively ($r_2 > r_1$). If charge on inner sphere is + Q and outer sphere is earthed then determine.

(a) The charge on the outer sphere

(b) Potential of the inner sphere



(i) Potential at the surface of outer sphere $V_2 = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r_2} + \frac{1}{4\pi\varepsilon_0}.\frac{Q'}{r_2} = 0$

$\Rightarrow Q' = -Q$

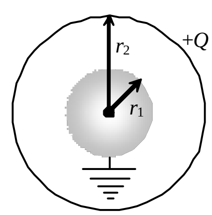
(ii) Potential of the inner sphere $V_1 = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{(-Q)}{r_2} = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

Case (iv) : In the case III if outer sphere is given a charge + Q and inner sphere is earthed then

(a) What will be the charge on the inner sphere

(b) What will be the potential of the outer sphere

(i) In this case potential at the surface of inner sphere is zero, so if Q' is the charge induced on inner sphere then



$V_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q'}{r_1} + \frac{Q}{r_2}\right] = 0$ i.e., $Q' = -\frac{r_1}{r_2}Q$

(Charge on inner sphere is less than that of the outer sphere)

(ii) Potential at the surface of outer sphere

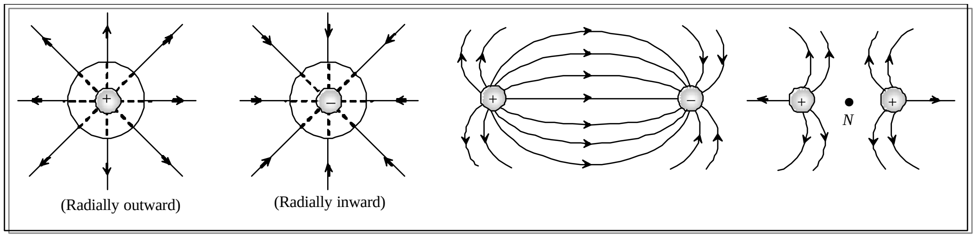
$$V_2 = \frac{1}{4\pi\varepsilon_0}.\frac{Q'}{r_2} + \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r_2}$$

$$V_2 = \frac{1}{4\pi\varepsilon_0 r_2}\left[-Q\frac{r_1}{r_2} + Q\right] = \frac{Q}{4\pi\varepsilon_0 r_2}\left[1 - \frac{r_1}{r_2}\right]$$

3.6 ELECTRIC LINES OF FORCE

(1) Definition : The electric field in a region is represented by continuous lines (also called lines of force). Field line is an imaginary line along which a positive test charge will move if left free.

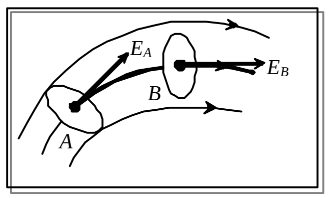
Electric lines of force due to an isolated positive charge, isolated negative charge and due to a pair of charge are shown below



(2) Properties of electric lines of force

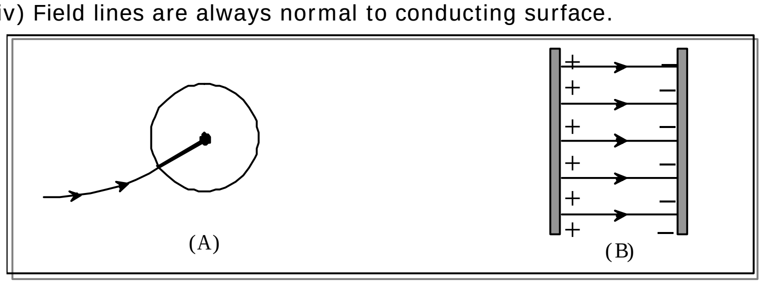
(i) Electric field lines come out of positive charge and go into the negative charge.

(ii) Tangent to the field line at any point gives the direction of the field at that point.



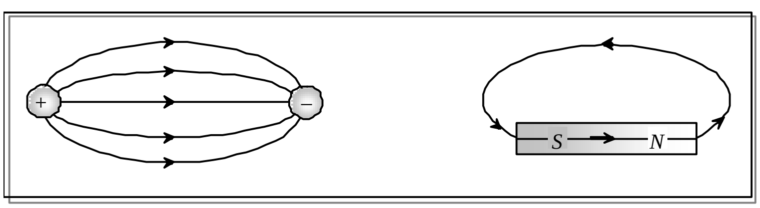
(iii) Field lines never cross each other.

(iv) Field lines are always normal to conducting surface.



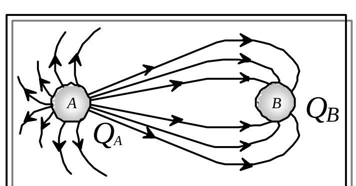
(v) Field lines do not exist inside a conductor.

(vi) The electric field lines never form closed loops. (While magnetic lines of forces form closed loop)



(vii) The number of lines originating or terminating on a charge is proportional to the magnitude of charge.

Ex. $|Q_A| > |Q_B|$



(viii) Number of lines of force per unit area normal to the area at a point represents magnitude of intensity

(ix) If the lines of forces are equidistant and parallel straight lines the field is uniform and if either lines of force are not equidistant or straight line or both the field will be non uniform, also the density of field lines is proportional to the strength of the electric field.

(3) Electrostatic shielding : Electrostatic shielding/screening is the phenomenon of protecting a certain region of space from external electric field. Sensitive instruments and appliances are affected seriously with strong external electrostatic fields. Their working suffers and they may start misbehaving under the effect of unwanted fields.

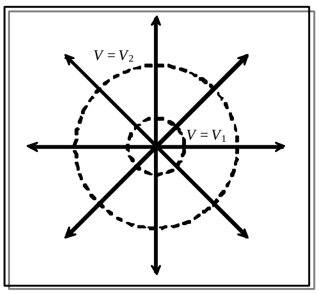
EQUIPOTENTIAL SURFACE OR LINES

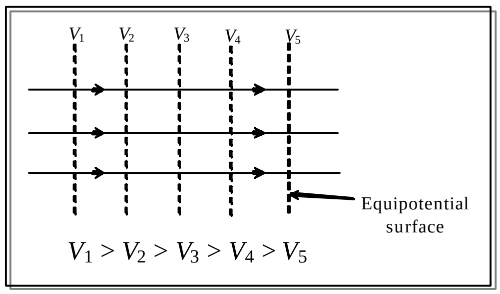
If every point of a surface is at same potential, then it is said to be an equipotential surface Physical significance of Equipotential points.

(1) The density of the equipotential lines gives an idea about the magnitude of electric field. Higher the density, larger is the field strength.

(2) The direction of electric field is perpendicular to the equipotential surfaces or lines.

(3) The equipotential surfaces produced by a point charge or a spherically charge distribution are a family of concentric spheres.



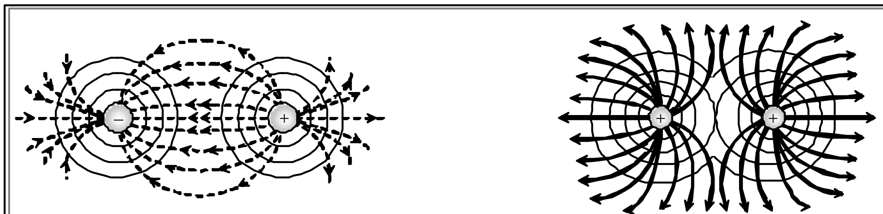


(4) For a uniform electric field, the equipotential surfaces are a family of plane perpendicular to the field lines.

(5) A metallic surface of any shape is an equipotential surface

(6) Equipotential surfaces can never cross each other

(7) Equipotential surface for pair of charges



Pair of two equal and opposite charges

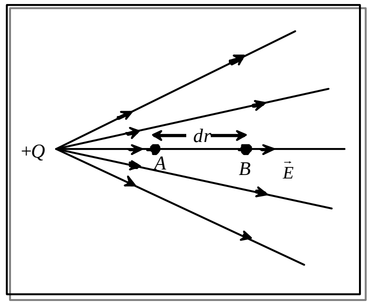
Pair of two equal and similar charges

MEMORY POINTS

- Unit field i.e. 1 N/C is defined arbitrarily as corresponding to unit density of lines of force
- Number of lines originating from a unit charge is $\frac{1}{\varepsilon_0}$
- It is a common misconception that the path traced by a positive test charge is a field line but actually the path traced by a unit positive test charge represents a field full line only when it moves along a straight line.
- Both the equipotential surface and the lines of force can be used to depict electric field in a certain region of space. The advantage of using equipotential surfaces over the lines of force is that they give a visual picture of both the magnitude and direction of the electric field.

3.7 RELATION BETWEEN ELECTRIC FIELD AND POTENTIAL

In an electric field rate of change of potential with distance is known as Potential gradient. It is a vector quantity and it's direction is opposite to that of electric field. Potential gradient relates with electric field according to the following relation $E = -\frac{dV}{dr}$; This relation gives another unit of electric field is $\frac{\text{volt}}{\text{meter}}$



In the above relation negative sign indicates that in the direction of electric field potential decreases. In space around a charge distribution we can also write

$\vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k}$.

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

With the help of formula $E = -\frac{dV}{dr}$, Potential difference between any two points in an electric field can be determined by knowing the boundary conditions

$dV = -\int_{r_1}^{r_2} \vec{E}.\vec{dr} = -\int_{r_1}^{r_2} \vec{E}.\vec{dr}\cos\theta$

MEMORY POINTS

- Negative of the slope of the V-r graph denotes intensity of electric field i.e.

  $\tan\theta = \frac{V}{r} = -E$

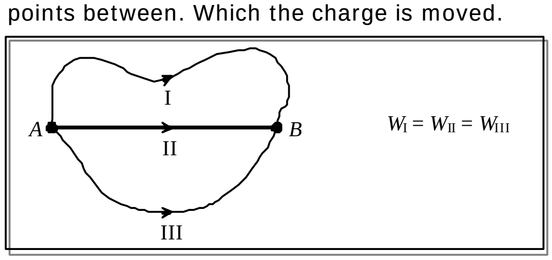
3.8 WORK DONE IN DISPLACING A CHARGE

1. **Definition :** If a charge Q displaced from one point to another point in electric field then work done in this process is W = Q x ΔV where ΔV = Potential difference between the two position of charge Q. ($\Delta V = \vec{E}\,\Delta\vec{r} = E\,\Delta r\cos\theta$ where θ is the angle between direction of electric field and direction of motion of charge.

2. **Work done in terms of rectangular component of $\vec{E}$ and $\vec{r}$:** If charge Q is given a displacement $\vec{r} = (r_1\hat{i} + r_2\hat{j} + r_3\hat{k})$ in an electric field $\vec{E} = (E_1\hat{i} + E_2\hat{j} + E_3\hat{k})$. The work done is $W = Q(\vec{E}.\vec{r}) = Q(E_1r_1 + E_2r_2 + E_3r_3)$

CONSERVATION OF ELECTRIC FIELD

As electric field is conservation, work done and hence potential difference between two point is path independent and depends only on the position of points between. Which the charge is moved.



IMPORTANT POINT

- No work is done in moving a charge on an equipotential surface.

3.9 EQUILIBRIUM OF CHARGE

(1) Definition : A charge is said to be in equilibrium, if net force acting on it is zero. A system of charges is said to be in equilibrium if each charge is separately in equilibrium.

(2) Type of equilibrium : Equilibrium can be divided in following type:

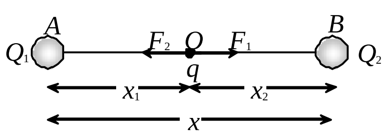
(i) Stable equilibrium : After displacing a charged particle from it's equilibrium position, if it returns back then it is said to be in stable equilibrium. If U is the potential energy then in case of stable equilibrium $\frac{d^2U}{dx^2}$ is positive i.e., U is minimum.

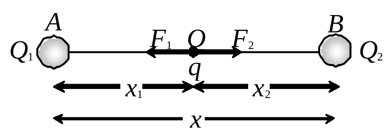
(ii) Unstable equilibrium : After displacing a charged particle from it's equilibrium position, if it never returns back then it is said to be in unstable equilibrium and in unstable equilibrium $\frac{d^2U}{dx^2}$ is negative i.e., U is maximum.

(iii) Neutral equilibrium : After displacing a charged particle from it's equilibrium position if it neither comes back, nor moves away but remains in the position in which it was kept it is said to be in neutral equilibrium and in neutral equilibrium $\frac{d^2U}{dx^2}$ is zero i.e., U is constant

(4) Different cases of equilibrium of charge

Case – 1 : Suppose three similar charge Q_1, q and Q_2 are placed along a straight line as shown below





Charge q will be in equilibrium if $|F_1| = |F_2|$

i.e. $\frac{Q_1}{Q_2} = \left(\frac{x_1}{x_2}\right)^2$; $x_1 = \frac{x}{1+\sqrt{Q_2/Q_1}}$ and $x_2 = \frac{x}{1+\sqrt{Q_2/Q_1}}$

Ex: If two charges + 4μC and + 16μC are separated by a distance of 30 cm from each other then for equilibrium a third charge should be placed between them at a distance $x_1 = \frac{30}{1+\sqrt{16/4}} = 10$ cm or $x_2 = 20$ cm

Case–2 : Two similar charge Q_1 and Q_2 are placed along a straight line at a distance x from each other and a third dissimilar charge q is placed in between them as shown below

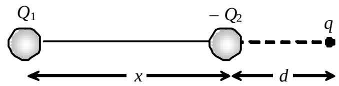
Charge q will be in equilibrium if $|F_1| = |F_2|$

i.e., $$\frac{Q_1}{Q_2} = \left(\frac{x_1}{x_2}\right)^2$$

Here also $$x_1 = \frac{x}{1+\sqrt{Q_2/Q_1}} \text{ and } x_2 = \frac{x}{1+\sqrt{Q_1/Q_2}}$$

It is very important to know that magnitude of charge q can be determined if one of the extreme charge (either Q_1 or Q_2) is in equilibrium i.e. if Q_2 is in equilibrium then $|q| = Q_1\left(\frac{x_2}{x}\right)^2$ and if Q_1 is in equilibrium then $|q| = Q_2\left(\frac{x_1}{x}\right)^2$ (It should be remember that sign of q is opposite to that of Q_1 (or Q_2)

Case – 3 : Two dissimilar charge Q_1 and Q_2 are placed along a straight line at a distance x from each other, a third charge q should be placed out side the line joining Q_1 and Q_2 for it to experience zero net force.

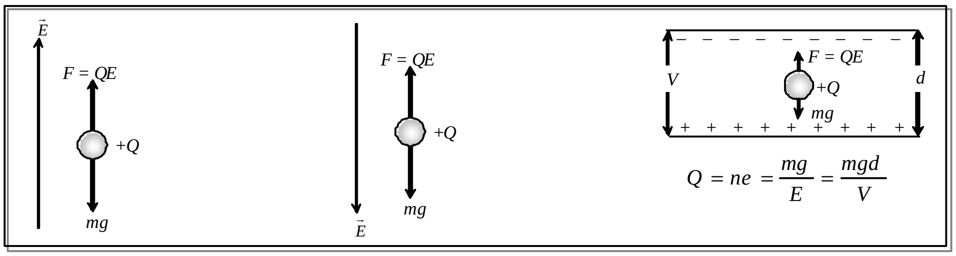


Short Trick :

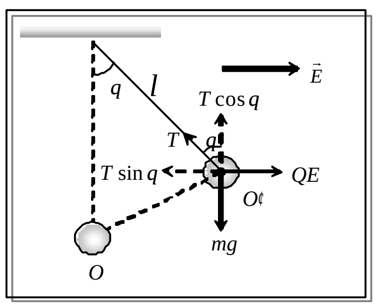
For it's equilibrium. Charge q lies on the side of chare which is smallest in magnitude and d = $\frac{x}{\sqrt{Q_1/Q_2}-1}$

Determine the Equilibrium states of suspended charge in an electric field

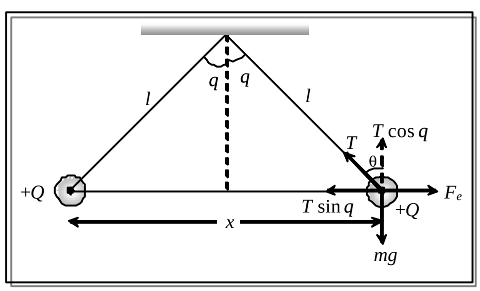
(i) **freely suspended charged particle :**



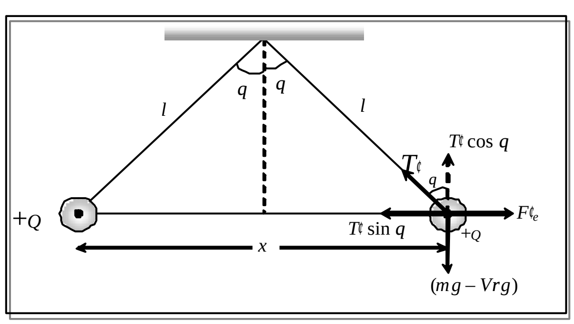
(ii) **Charged particle suspended by a massless insulated string (like simple pendulum)**



(iii) **Equilibrium of suspended two point charge system**



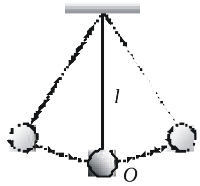
(iv) **Equilibrium of suspended point charge system in a liquid**



3.10 TIME PERIOD OF OSCILLATION OF A CHARGED BODY.

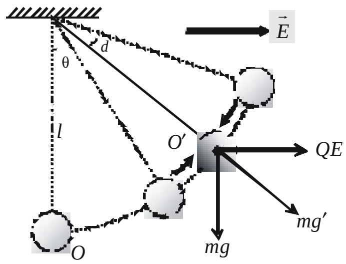
(1) Simple pendulum based :

If a simple pendulum having length l and mass of bob m oscillates about it's mean position than it's time period of oscillation $T = 2\pi\sqrt{\frac{l}{g}}$



Case - 1 :

If some charge say +Q is given to bob and an electric field E is applied in the direction as shown in figure then equilibrium position of charged bob (point charge) changes from O to O .



On displacing the bob from it's equilibrium position 0 . It will oscillate under the effective acceleration g , where

$$mg' = \sqrt{(mg)^2 + (QE)^2}$$

$$\Rightarrow g' = \sqrt{g^2 + (QE/m)^2}$$

Hence the new time period is $T_1 = 2\pi\sqrt{\frac{l}{g'}}$

$$T_1 = 2\pi\sqrt{\frac{l}{\left(g^2 + (QE/m)^2\right)^{\frac{1}{2}}}}$$

Since g' > g, hence $T_1 < T$

i.e. time period of pendulum will decrease.

Case –2 :

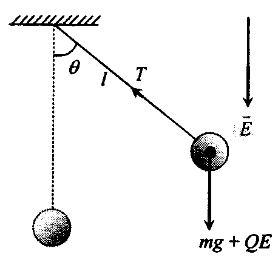
If electric field is applied in the downward direction then effective acceleration

$g' = g + QE/m$

So new time period

$$T_2 = 2\pi\sqrt{\frac{l}{g + (QE/m)}}$$

$T_2 < T$



Case–3 :

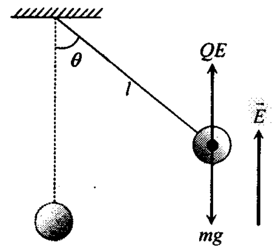
In case 2 if electric field is applied in upward direction then, effective acceleration.

$g' = g - QE/m$

So new time period

$$T_3 = 2\pi\sqrt{\frac{l}{g-(QE/m)}}$$

$T_3 > T$

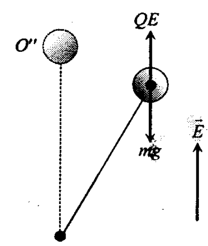


Case–4 : In the case 3,

if $T_3 = \frac{T}{2}$ i.e., $2\pi\sqrt{\frac{l}{g-QE/m}}$

$= \frac{1}{2}2\pi\sqrt{\frac{l}{g}} \Rightarrow QE = 3mg$

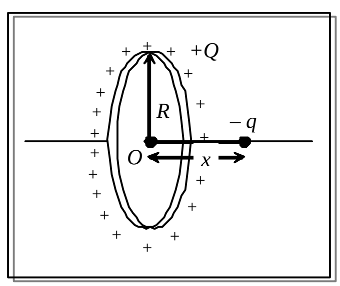
i.e., effective vertical force (gravity + electric) on the bob= mg–3 mg = –2 mg. hence the equilibrium position O'' of the bob will be above the point of suspension and bob will oscillate under on effective acceleration 2g directed upward.



Hence new time period $T_4 = 2\pi\sqrt{\frac{l}{2g}}$, $T_4 < T$

(2) Charged circular ring :

A thin stationary ring of radius R has a positive charge + Q unit. If a negative charge – q (mass m) is placed at a small distance x from the centre. Then motion of the particle will be simple harmonic motion.



Electric field at the location of – q charge $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qx}{(x^2+R^2)^{\frac{3}{2}}}$

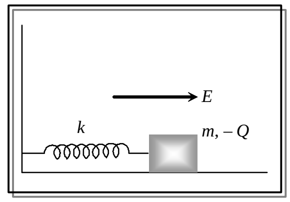
Since x << R, So x^2 neglected hence $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qx}{R^3}$

Force experienced by charged – q is $F = -q\frac{1}{4\pi\varepsilon_0}\cdot\frac{Qx}{R^3}$

$\Rightarrow F \propto -x$ hence motion is simple harmonic

Having time period $T = 2\pi\sqrt{\frac{4\pi\varepsilon_0 mR^3}{Qq}}$

(3) Spring mass system : A block of mass m containing a negative charge - Q is placed on a frictionless horizontal table and is connected to a wall through an unstretched spring of spring constant k as shown. If electric field E applied as shown in figure the block experiences an electric force, hence spring compress and block comes in new position. This is called the equilibrium position of block under the influence of electric field. If block compressed further or stretched, it execute oscillation having time period $T = 2\pi\sqrt{\frac{m}{k}}$. Maximum compression in the spring due to electric field = $\frac{QE}{k}$

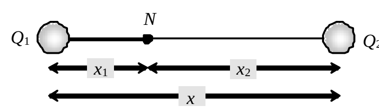


Neutral point

A neutral point is a point where resultant electrical field is zero. It is obtained where two electrical field are equal and opposite. Thus neutral points can be obtained only at those points where the resultant field is subtractive. Thus it can be obtained.

(1) At an internal point along the line joining two like charges (Due to a system of two like point charge) :

Suppose two like charges Q_1 and Q_2 are separated by a distance x from each other along a line as shown in following figure.



If N is the neutral point at a distance x_1 from Q_1 and at a distance $x_2(x - x_1)$ from Q_2 then –

At N |E.F. due to Q_1| = E.F. due to Q_2 |

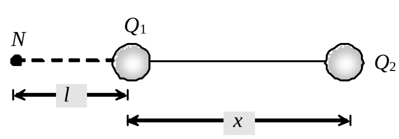
i.e. $$\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1}{x_1^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_2}{x_2^2} \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{x_1}{x_2}\right)^2$$

Short trick : $x_1 = \frac{x}{1+\sqrt{Q_2/Q_1}}$ and $x_2 = \frac{x}{1+\sqrt{Q_1/Q_2}}$

Note : In the above formula if $Q_1 = Q_2$, neutral point lies at the centre so remember that resultant field at the midpoint of two equal and like charges is zero.

(2) At an external point along the line joining two like charges (Due to a system of two unlike point charge)

Suppose two unlike charge Q_1 and Q_2 separated by a distance x from each other.



Here neutral point lies outside the line joining two unlike charges and also it lies nearer to charge which is smaller in magnitude.

If $|Q_1| < |Q_2|$ then neutral point will be obtained on the side of Q_1, suppose it is at a distance l from Q_1

Hence at neutral point ; $$\frac{kQ_1}{l^2} = \frac{kQ_2}{(x+l)^2} \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{l}{x+l}\right)^2$$

Short trick : $l = \frac{x}{\left(\sqrt{Q_2/Q_1 - 1}\right)}$

Note : In the above discussion if $|Q_1| = |Q_2|$ neutral point will be at infinity.

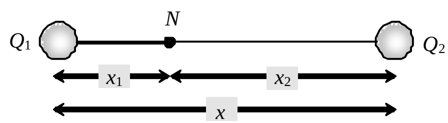
ZERO POTENTIAL DUE TO A SYSTEM OF TWO POINT CHARGE

If both charges are like then resultant potential is not zero at any finite point because potentials due to like charges will have same sign and can therefore never add up to zero. Such a point can be therefore obtained only at infinity.

If the charges are unequal and unlike then all such points where resultant potential is zero lies on a closed curve, but we are interested only in those points where potential is zero along the line joining the two charges.

Two such points exist, one lies inside and one lies outside the charges on the line joining the charges. Both the above lie nearer the smaller charge, as potential created by the charge larger in magnitude will become equal to the potential created by smaller charge at the desired point at larger distance from it.

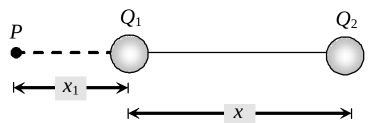
I. For internal point



(It is assumed that $|Q_1| < |Q_2|$).

$$\frac{Q_1}{x_1} = \frac{Q_2}{(x - x_1)} \Rightarrow x_1 = \frac{x}{(Q_2 / Q_1 + 1)}$$

II. For External point



$$\frac{Q_1}{x_1} = \frac{Q_2}{(x + x_1)} \Rightarrow x_1 = \frac{x}{(Q_2 / Q_1 - 1)}$$

3.11 ELECTRIC POTENTIAL ENERGY

(1) Potential energy of a charge : Work done in bringing the given charge from infinity to a point in the electric field is known as potential energy of the charge. Potential can also be written as potential energy per unit charge i.e. $V = \frac{W}{Q} = \frac{U}{Q}$.

(2) Potential energy of a system of two charges : Since work done in bringing charge Q_2 from ∞ to point B is $W = Q_2V_B$, where V_B is potential of point B due to charge Q_1 i.e. $V_B = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r}$

So, $$W = U_2 = \frac{1}{4\pi\varepsilon_0}.\frac{Q_1Q_2}{r}$$

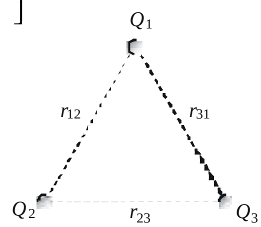
This is the potential energy of charge Q_2, Similarly potential energy of charge Q_1 will be $U_1 = \frac{1}{4\pi\varepsilon_0}.\frac{Q_1Q_2}{r}$

Hence potential energy of Q_1 = Potential energy of Q_2 = Potential energy of system $U = k\frac{Q_1Q_2}{r}$ (in C.G.S. $U = \frac{Q_1Q_2}{r}$)

(3) Potential energy of a system of n charges : In a system of n charges electric potential energy is calculated for each pair and then all energies so obtained are added algebraically. i.e. $U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1Q_2}{r_{12}} + \frac{Q_2Q_3}{r_{23}} + \ldots\ldots\right]$ and in case of continuous distribution of charge. As dU = dQ. V $\Rightarrow U = \int V\,dQ$

e.g. Electric potential energy for a system of three charges

Potential energy $= \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1Q_2}{r_{12}} + \frac{Q_2Q_3}{r_{23}} + \frac{Q_3Q_1}{r_{31}}\right]$



While potential energy of any of the charge say Q_1 is $\frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1Q_2}{r_{12}} + \frac{Q_3Q_1}{r_{31}}\right]$

Note : For the expression of total potential energy of a system of n charges consider $\frac{n(n-1)}{2}$ number of pair of charges.

(4) Electron volt (eV) : It is the smallest practical unit of energy used in atomic and nuclear physics. As electron volt is defined as " The energy acquired by a particle having one quantum of charge 1e when accelerated by 1 volt "

i.e. $1eV = 1.6 \times 10^{-19} C \times \frac{1J}{C}$ = 1.6 x 10^{-19} J = 1.6 x 10^{-12} erg

Energy acquired by a charged particle in eV when it is accelerated by V volt is E = (charge in quanta) x (p.d. in volt)

Commonly asked examples :

S.No.	Charge	Accelerated by p.d.	Gain in K.E.
(i)	Proton	5x 10^4V	K = e x 5 x 10^4 V = 5 x 10^4eV = 8 x 10^{-15} J **(JIPMER 1999)**
(ii)	Electron	100 V	K = e x 100 V = 100 eV = 1.6 x 10^{-17} J **(MP PMT 2000 ; AFMC 1999)**
(iii)	Proton	1V	K = e x 1V = 1 eV = 1.6 x 10^{-19} J (CBSE 1999)
(iv)	0.5 C	2000V	K = 0.5 x 2000 = 1000 J **(JIPMER 2002)**
(v)	α-particle	10^6 V	K = (2e) x 10^6 V = 2 MeV **(MP PET / PMT 1998)**

(5) Electric potential energy of a uniformly charged sphere :

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

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

(6) Electric potential energy of a uniformly charged thin spherical shell :

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

(7) Energy density : The energy stored per unit volume around a point in an electric field is given by

$U_e = \frac{U}{\text{Volume}} = \frac{1}{2}\varepsilon_0 E^2$. If in place of vacuum some medium is present then $U_e = \frac{1}{2}\varepsilon_0\varepsilon_r E^2$

MEMORY POINTS

- Electric potential energy is not localised but is distributed all over the field
- If a charge moves from one position to another position in an electric field so it's potential energy change and work done in this changing is $W = U_f - U_i$
- If two similar charge comes closer potential energy of system increases while if two dissimilar charge comes closer potential energy of system decreases.

3.12 MOTION OF CHARGED PARTICLE IN AN ELECTRIC FIELD

(1) When charged particle initially at rest is placed in the uniform field :

Let a charge particle of mass ma and charge Q be initially at rest in an electric field of strength E

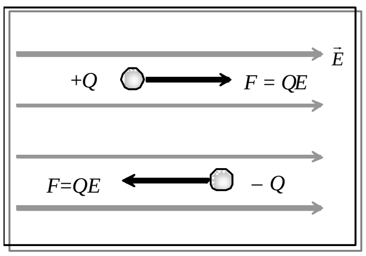


Fig. (A)

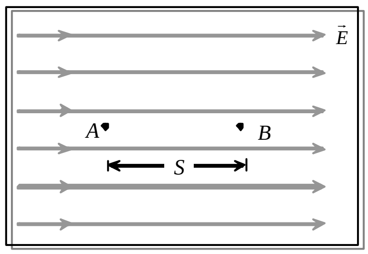


Fig. (B)

(i) Force and acceleration : The force experienced by the charged particle is F = QE. Positive charge experiences force in the direction of electric field while negative charge experiences force in the direction opposite to the field (Fig. A)

Acceleration produced by this force is $a = \frac{F}{m} = \frac{QE}{m}$

Since the field E in constant the acceleration is constant, thus motion of the particle is uniformly accelerated.

(ii) Velocity : Suppose at point A particle is at rest and in time t, it reaches the point B [fig. (B)]

V = Potential difference between A and B ; S = separation between A and B

(a) By using v = u + at, $v = 0 + Q\frac{E}{m}t$, $\Rightarrow v = \frac{QEt}{m}$

(b) By using $v^2 = u^2 + 2as$, $v^2 = 0 + 2 \times \frac{QE}{m} \times s$ $\quad v^2 = \frac{2QV}{m}$ $\left\{\because E = \frac{V}{s}\right\}$

$$\Rightarrow v = \sqrt{\frac{2QV}{m}}$$

(iii) Momentum : Momentum p = mv, $p = m \times \frac{QEt}{m} = QEt$

$$\text{or } p = m \times \sqrt{\frac{2Qv}{m}} = \sqrt{2mQv}$$

(iv) Kinetic energy : Kinetic energy gained by the particle in time t is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\frac{(QEt)^2}{m} = \frac{Q^2E^2t^2}{2m}$$

$$\text{or} \qquad K = \frac{1}{2}m \times \frac{2QV}{m} = QV$$

(2) When a charged particle enters with an initial velocity at right angle to the uniform field :

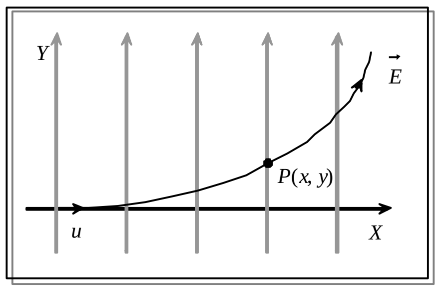
When charged particle enters perpendicularly in an electric field, it describe a parabolic path as shown

(i) Equation of trajectory : Throughout the motion particle has uniform velocity along x-axis and horizontal displacement (x) is given by the equation x = ut

Since the motion of the particle is accelerated along y-axis, we will use equation of motion for uniform acceleration to determine displacement y. From $S = ut + \frac{1}{2}at^2$ We have u = 0 (along y-axis) so $y = \frac{1}{2}at^2$

i.e. displacement along y-axis will increase rapidly with time (since $y \propto t^2$)

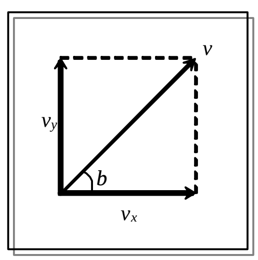
From displacement along x-axis $t = \frac{x}{u}$



So $y = \frac{1}{2}\left(\frac{QE}{m}\right)\left(\frac{x}{u}\right)^2$; This is the equation of parabola which shows $y \propto x^2$

(ii) Velocity at any instant : At any instant t, $v_x = u$ and $v_y = \frac{QEt}{m}$

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



If β is the angle made by v with x- axis than $\tan\beta = \frac{v_y}{v_x} = \frac{QEt}{mu}$

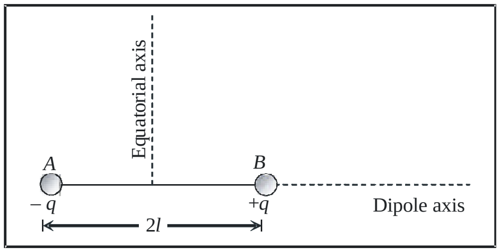
IMPORTANT POINTS

- An electric field is completely characterized by two physical quantities potential and intensity. Force characteristic of the field is intensity and work characteristic of the field is potential.
- If a charge particle (say positive) is left free in an electric field, it experiences a force (F = QE) in the direction of electric field and moves in the direction of electric field (which is desired by electric field), so its kinetic energy increases, potential energy decreases, then work is done by the electric field and it is negative.

4. ELECTRIC DIPOLE, ELECTRIC FLUX & GAUSS LAW

4.1 Electric dipole :-

(1) Definition : System of two equal and opposite charges separated by a small fixed distance is called a dipole.



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

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

(iii) Dipole length : The distance between two charges is known as dipole length (L = 2l)

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

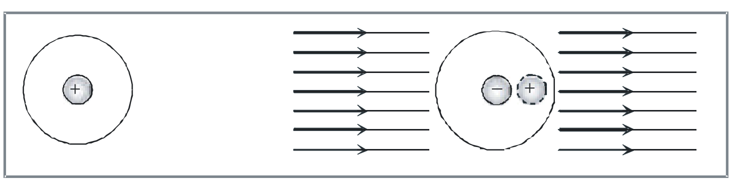
i.e. $\vec{p} = q(2\vec{l})$

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

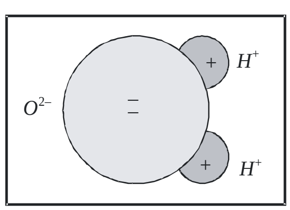
MEMORY POINTS:

A region surrounding a stationary electric dipole has electric field only.

- When a dielectric is placed in an electric field, its atoms or molecules are considered as tiny dipoles.



- Whater (H_2O), Chloroform ($CHCl_3$), ammonia (NH_3), HCl, CO molecules are some example of permanent electric dipole.

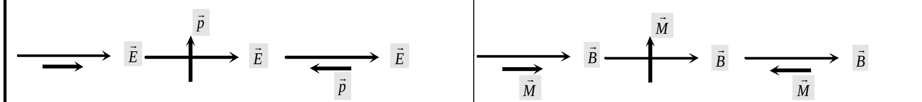


(iv) Equilibrium of dipole : We know that, for any equilibrium net torque and net force on a particle (or system) should be zero.

We already discussed when a dipole is placed in an uniform electric/magnetic field net force on dipole is always zero. But net torque will be zero only when $\theta = 0^o$ or 180^o

When $\theta = 0^o$ i.e. dipole is placed along the electric field it is said to be in stable equilibrium, because after turning it through a small angle, dipole tries to align itself again in the direction of electric field.

When $\theta = 180^o$ i.e. dipole is placed opposite to electric field, it is said to be in unstable equilibrium.



$q = 0^o$	$q = 90^O$	$q = 180^o$	$q = 0^o$	$q = 90^O$	$q = 180^o$
Stable equilibrium		Unstable equilibrium	Stable equilibrium		Unstable quilibrium
$t = 0$	$t_{max} = pE$	$t = 0$	$t = 0$	$t_{max} = MB$	$t = 0$
$W = 0$	$W = pE$	$W_{max} = 2pE$	$W = 0$	$W = MB$	$W_{max} = 2MB$
$U_{min} = -pE$	$U = 0$	$U_{max} = pE$	$U_{min} = -MB$	$U = 0$	$U_{max} = MB$

(vi) Dipole-point charge interaction : If a point charge/isolated magnetic pole is placed in dipole field at a distance r from the mid point of dipole then force experienced by point charge/pole varies according to the relation $F \propto \frac{1}{r^3}$

(vii) Dipole-dipole interaction : When two dipoles placed closed to each other, they experiences a force due to each other. If suppose two dipoles (1) and (2) are placed as shown in figure then

Both the dipoles are placed in the field of one another hence potential energy dipole (2) is

$$U_2 = -p_2E_1 \cos 0 = -p_2E_1 = -p_2 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p_1}{r^3}$$

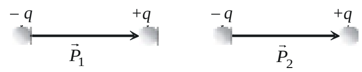
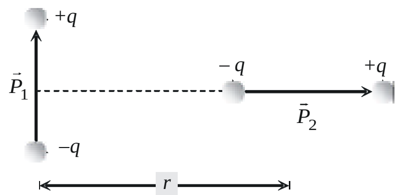
then by using $F = -\frac{dU}{dr}$, Force on dipole (2) is $F_2 = -\frac{dU_2}{dr}$

$$\Rightarrow F_2 = -\frac{d}{dr}\left\{\frac{1}{4\pi\varepsilon_0} \cdot \frac{2p_1p_2}{r^3}\right\} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{6p_1p_2}{r^4}$$

Similarly force experienced by dipole (1) $F_1 = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{6p_1p_2}{r^4}$ so $F_1 = F_2$

$$= -\frac{1}{4\pi\varepsilon_0} \cdot \frac{6p_1p_2}{r^4}$$

Negatie sign indicates that force is attractive. $|F| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{6p_1p_2}{r^4}$ and $F \propto \frac{1}{r^4}$

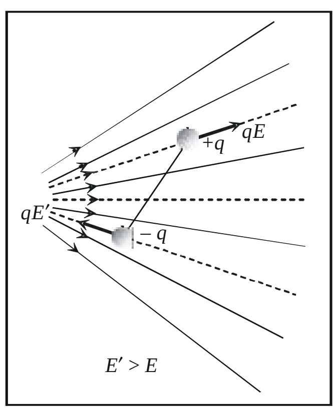
S.NO.	Relative position of dipole	Force	Potential energy
1.		$\frac{1}{4\pi\varepsilon_0}\cdot\frac{6p_1p_2}{r^4}$ (attractive)	$\frac{1}{4\pi\varepsilon_0}\cdot\frac{2p_1p_2}{r^3}$
2.		$\frac{1}{4\pi\varepsilon_0}\cdot\frac{3p_1p_2}{r^4}$ (repulsive)	$\frac{1}{4\pi\varepsilon_0}\cdot\frac{p_1p_2}{r^3}$
3.		$\frac{1}{4\pi\varepsilon_0}\cdot\frac{3p_1p_2}{r^4}$ (Perpendicular to r)	0

Note :

Same result can also be obtained for magnetic dipole.

(4) Electric dipole in non-uniform electric field : When an electric dipole is placed in a non-uniform field, the two charges of dipole experience unequal forces, therefore the net force on the dipole is not equal to zero. The magnitude of the force is given by the negative derivative of the potential energy w.r.t. distance along the axis. of the dipole i.e.

$$\vec{F} = -\frac{dU}{dr} = -\vec{p}\cdot\frac{d\vec{E}}{dr}.$$



Due to two unequal forces, a torque is produced which rotate the dipole so as to align it in the direction of field. When the dipole gets aligned with the field, the torque becomes zero and then the unbalanced force acts on the dipole and the dipole then moves linearly along the direction of field from weaker portion of the field to the stronger portion of the field. So in non-uniform electric field

(i) Motion of the dipole is translatory and rotatory

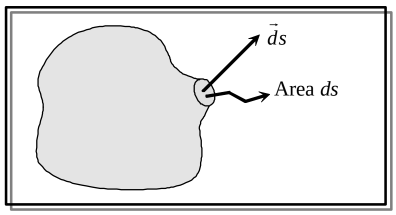
(i) Torque on it may be zero.

MEMORY POINTS:

- For a short diple, electric field intensity at a point on the axial line is double than at a point on the equatorial line on electric dipole i.e. $E_{axial} = 2_{Eequatrial}$
- It is intresting to not that dipole field $E \propto \frac{1}{r^3}$ decreases much rapidly as compared to the field of a point charge $\left(E \propto \frac{1}{r^2}\right)$

4.2 ELECTRIC FLUX

(1) Area vector : In many cases, it is convenient to treat area of a surface as a vector. The length of the vector represents the magnitude of the area and its direction is along the outward drawn normal to the area.

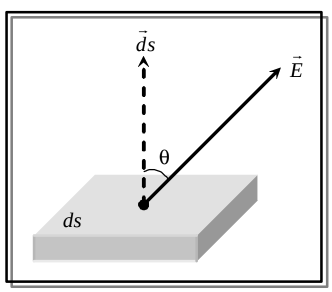


(2) Electric flux : The total number of lines of force through a given area is called the electric flux. Electric flux through an elementary area $\overrightarrow{ds}$ is defined as the scalar product of area of field i.e. $d\varphi = \vec{E} \cdot \overrightarrow{ds} = E\,ds\,\cos\theta$

Hence flux from complete area (S) $\varphi = \int E\,ds\cos\theta$ = ES cos θ

If θ = 0⁰, i.e. surface area is perpendicular to the electric field, so flux linked with it will be max.

i.e. θ_{max} = E ds and if q = 90⁰, θ_{min} = 0



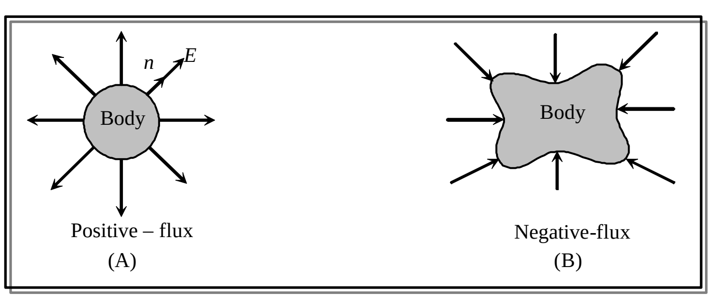
(3) Unit and Dimensional Formula

It is a scalar quantity

S.I. unit – (volt x m) or $\frac{N-C}{m^2}$

It's Dimensional formula – $(ML^3T^{-3}A^{-1})$

(4) Types : For a closed body outward flux is taken to be positive, while inward flux is to be negative



4.3 GAUSS'S LAW

(1) Definition :

This law states that electric flux ϕ_E through any closed surface is equal to $1/\varepsilon_0$ times the net charge 'q' enclosed by the surface i.e.

$$\phi_E = \oint \vec{E} \cdot \vec{ds} = \frac{q_{enclosed}}{\varepsilon_0}$$

(2) Gaussian Surface :

(a) Is imaginary surface

(b) Is spherical for a point charge, conducting and non-conducting spheres.

(c) Is cylindrical for infinite sheet of charge, infinite line of charge, charged cylindrical conductors etc.

Gauss Theorem →

- $\xrightarrow{\text{Charge distribution}}$ (E)
  - Finite charge distribution (Coulomb's Law)
  - Infinite charge (Gauss theorem)

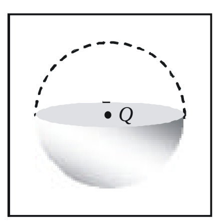
    $\oint \vec{E}.\vec{ds} = \frac{q_{net}}{\varepsilon_0}$ (Closed surface)
- $\xrightarrow{\text{Current distribution}}$ (B)
  - Finite (Biot-Savart's Law)
  - Infinite (Ampere's Law)

    $\oint \vec{B}.\vec{d\ell} = \mu_0 \Sigma I$ (closed path)

e.g If suppose a charge Q is placed at the centre of a hemisphere, then to calculate the flux through this body, to encloses the first charge we will have to imagine a Gaussian surface. This imaginary Gaussian surface will be a hemisphere as shown.

Net flux through this closed body $\phi = \frac{Q}{\varepsilon_0}$

Hence flux coming out from given hemisphere is $\phi = \frac{Q}{2\varepsilon_0}$.



AIEEE module page 61 Example

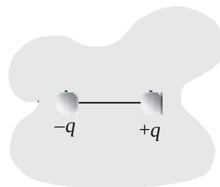
AIEEE module page 61 Q.

MEMORY PONT

- Gauss's law is valid for symmetrical charge distribution and for all vector fields obeying inverse square law.
- Gauss's and Coulomb's law are comparable.

(3) Zero Fllux : The value of flux is zero in the following circumstances

(i) If a dipole is enclosed by a surface

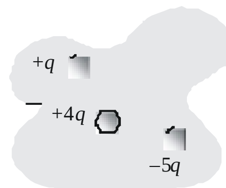


f = 0; Q_{enc} = 0

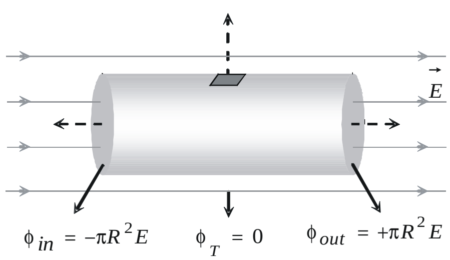
(ii) If the magnitude of positive and negative charges are equal inside a closed surface

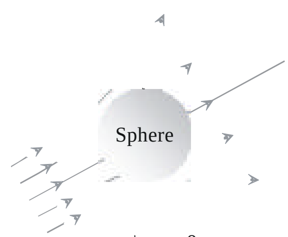
Q_{enc} = 0,

so, ϕ = 0

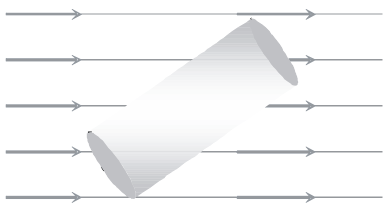


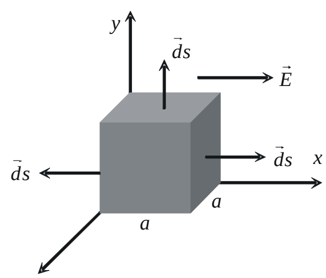
(iii) If a closed body (not enclosing any charge) is placed in an electric field (either uniform or non-uniform total flux linked with it will be zero)





$\phi_T = 0$

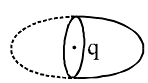




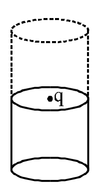
$\phi_T = 0$ $\quad$ $\phi_{in} = \phi_{out} = Ea^2$

(5) Electric flux through various surfaces :

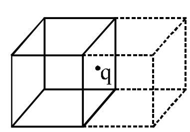
(i) $\phi_t = \frac{q}{\varepsilon_0}$, $\phi_{hemisphere} = \frac{q}{2\varepsilon_0}$



(ii) $\phi_T = \frac{q}{\varepsilon_0}$, $\phi_{cyl.} = \frac{q}{2\varepsilon_0}$.



(iii) $\phi_T = \frac{q}{\varepsilon_0}$



$\phi_{cube} = \frac{q}{2\varepsilon_0}$

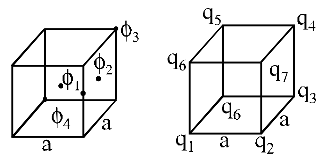
(iv) **Charge position** — f_T

Cube centre — $\phi_1 = q/\varepsilon_0$.

Face centre — $\phi_2 = q/2\varepsilon_0$.

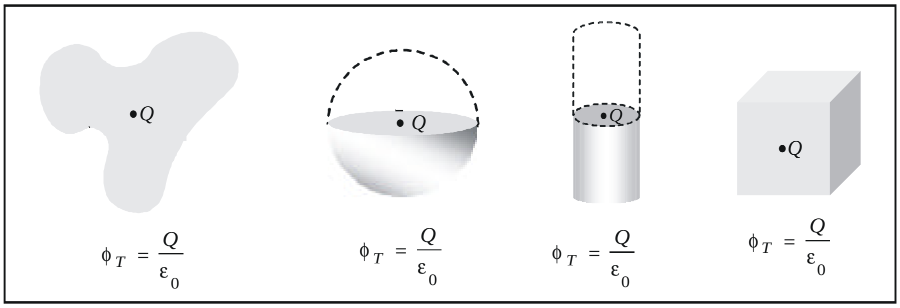
At corner — $\phi_3 = q/8\varepsilon_0$.

At centre of edge — $\phi_4 = q/4\varepsilon_0$.



$$\phi_T = \frac{1}{8\varepsilon_0} \sum_i q_i$$

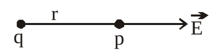
i = 1, 2, ... 8.



5. APPLICATIONS OF GAUSS'S LAW

5.1 (a) (i) Point charge :

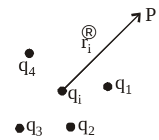
$\vec{E} = \frac{kq}{r^2}\hat{r}$; $V = \frac{kq}{r}$



(ii) Group of point charges :

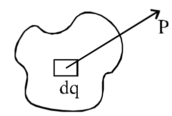
$$\vec{E} = \sum_{i=1}^{n} \frac{kq_i}{r_i^2}$$

$$V = \sum_{i=1}^{n} \frac{kq_i}{r_i}$$



(b) Uniform distribution of charges :

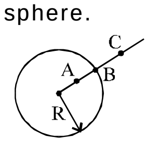
$$E = K\int \frac{dq}{r^2} = k\int_s \frac{\sigma ds}{r^2} = k\int_v \frac{\rho dv}{r^2}$$



(c) Charged spherical shell or charged conducting sphere :

(i) Electric field and potential at a point outside the conducting sphere.

$E_C = \frac{kq}{r^2}\hat{r}$, $V_C = \frac{kq}{r}$; $r > R$



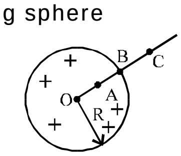
(d) Uniformly charged sphere (Non - conducting) :

(i) Electric field and potential outside the non-conducting sphere

$E_C = \frac{kq}{r^2}\hat{r}$, $V_C = \frac{kq}{r}$; $(r > R)$

(ii) Electric field and potential on the surface of non-conducting sphere

$E_B = \frac{kq}{R^2}\hat{r}$, $V_B = \frac{kq}{R}$; $(r = R)$



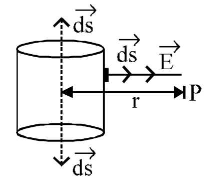
(e) Infinite line of charge :

$E_P = \frac{2k\lambda}{r}\hat{r}$; $\left\{\lambda = \frac{q}{\ell}\right\}$

$V_P = \frac{-\lambda}{2\pi\varepsilon_0}\ell n(r) + C = -\int \vec{E}\cdot d\vec{r}$

(f) Charged cylindrical conductor of finite length :

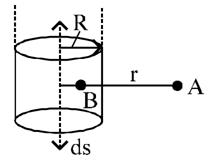
(i) Electric field and potential at a point outside the charged cylindrical conductor.



$E_A = \frac{K.2\lambda}{r}\hat{r}$; $V_A = \frac{-\lambda}{2\pi\varepsilon_0}\ell n(r) + c$

(ii) Electric field and potential at a point inside the charged cylindrical conductor.

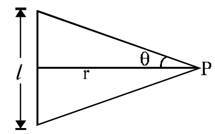
$$E_B = \frac{\lambda \vec{r}}{2\pi\varepsilon_0 R^2} \;;\; V_B = \frac{-\lambda r^2}{2\pi\varepsilon_0 R^2} + C$$



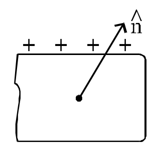
(g) Linear charge distribution of length 'ℓ' :

$$E_P = \frac{\lambda \sin\theta}{2\pi\varepsilon_0 r}\ \hat{r}$$

$$V_P = \frac{\lambda}{2\pi\varepsilon_0}\ \ell n\left(\frac{\sqrt{r^2+\ell^2}-1}{\sqrt{r^2+\ell^2}+1}\right)$$



(h) Charged conducting plane :



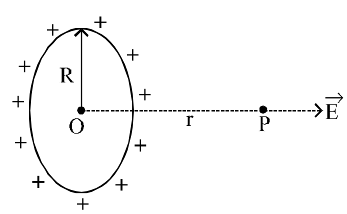
$$E = \frac{\sigma}{\varepsilon_0}\ \hat{n}\ ,\ V = \frac{-\sigma r}{\varepsilon_0} + C$$

(i) Infinite sheet of charge :

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\ \hat{n}\ ,\ V = \frac{-\sigma r}{2\varepsilon_0} + C$$

(j) Charged circular ring :

Electric field and potential (on the axis) at a distance r from the centre.



$E_P = \dfrac{\alpha R \hat{r}}{2\varepsilon_0 [R^2 + r^2]^{3/2}}$, $E_0 = 0$, (where $\alpha = \dfrac{Q}{2\pi R}$)

$E_{max} = \dfrac{2}{3\sqrt{3}} \cdot \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{Q}{R^2}$ (at $r = \dfrac{R}{\sqrt{2}}$ from the centre 'O')

$V_p = \dfrac{\alpha R}{2\pi\varepsilon_0 \sqrt{(R^2 + r^2)}}$, V_0 = const.

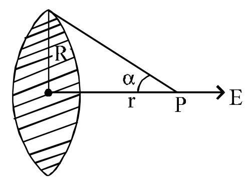
$V_{max} = \dfrac{1}{4\pi\varepsilon_0}\ \dfrac{Q}{R}$

(*k*) Charged Disc :

Electric field and potential at a point (on the axis) at a distance r from the centre.

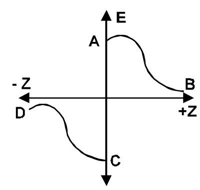
$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{r}{\sqrt{R^2 + r^2}}\right]\hat{r} = \frac{\sigma}{2\varepsilon_0}\int_0^{\alpha} \sin\theta \, d\theta.$$

(Direction of E will be along the axis of disc)



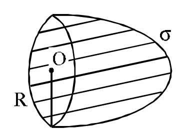
$$V = \frac{\sigma}{2\varepsilon_0}\left[\sqrt{(R^2 + r^2)} - r\right]$$

(where σ = surface charge density = $\frac{Q}{\pi R^2}$)



$$V_{centre}\ (r = 0) = \frac{\sigma R}{2\varepsilon_0}$$

(ℓ) Hemisphere :



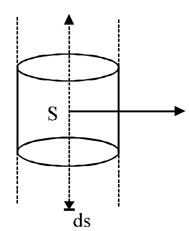
$$E_0 = \frac{\sigma}{4\varepsilon_0},\ V = \frac{\sigma R}{2\varepsilon_0}$$

(m) Uniformly charged cylinder of infinite length :

$\rho \rightarrow$ volume - charge density

(i) Electric field outside the cylinder

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



$$V = -\int_{\infty}^{r} \vec{E}\cdot d\vec{r}$$

(ii) Electric field on the surface of the cylinder

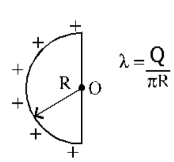
$$E_s = \frac{\rho R}{2\varepsilon_0}\ ;\ r = R$$

(iii) Electric field inside the cylinder.

$$E_{in} = \frac{\rho R}{2\varepsilon_0}\ ;\ r < R$$

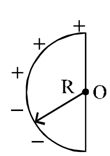
(n) Uniformly charged semicircular ring :

(i) $E_0 = \frac{k.2\lambda}{R} = \frac{Q}{2\pi^2\varepsilon_0 R^2}$



$V_0 = \frac{kQ}{R}$

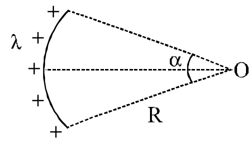
(ii) $E_0 = \frac{Q}{\pi^2\varepsilon_0 R^2}$



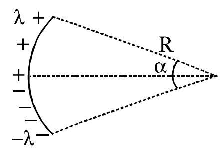
V_0 = zero.

For segment of ring :

(i) $E_0 = \dfrac{2k\lambda}{R}\sin\left(\dfrac{\alpha}{2}\right)$



$V_0 = K\lambda.\alpha$

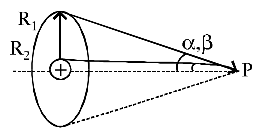


(ii) $E_0 = \dfrac{2k\lambda}{R}\,[1-\cos\alpha/2]$

V_0 = zero.

(o) Hollow disc :

$E_p = \dfrac{\sigma}{2\varepsilon_0}\int_{\alpha}^{\beta}\sin\theta\, d\theta.$



5.2 Explain the following statements on the basis of electric Field Concept

(i) The charge resides only on the outer surface of the conductor.

(ii) The electric field at any point just outside the surface of the conductor is normal to its surface and is equal to $\dfrac{\sigma}{\varepsilon_0}$.

(iii) The electric field in the cavity of a charged hollow conductor is zero.

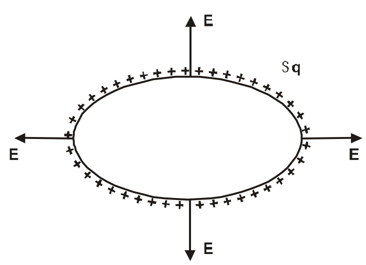
(iv) If q charges are placed in the cavity of a hollow conductor, then – q charges are induced on the inner surface and + q on the outer surface of the hollow conductor.

5.3 Explanation of the above points :

(i) Using Gauss's Theorem, we can show that any excess charge placed on an insulated conductor resides only on its outer surface. Consider a conductor having an excess charge under static conditions. Imagine a Gaussian surface inside the conductor just near its outer surface.

Since, the electric field vanishes at all points inside the conductor, the flux through the Gaussian surface must be zero. From Gauss's theorem, the total charge enclosed by the Gaussian surface must be zero i.e.,

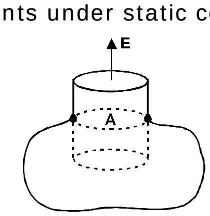
$$\phi_E = \oint \vec{E}.d\vec{S} = \frac{1}{\varepsilon_0}\Sigma q$$



As $E = 0$, so $\Sigma q = 0$.

This means that the excess charge must lie outside the Gaussian surface i.e. on the outer surface of the conductor. Thus, there can be no charges inside a conductor and entire charge resides on its outer surface.

(ii) The electric field at any point just outside the surface of the conductor is normal to its surface. If it is not so, the electric field will have a tangential component which will set the charges in motion, producing surface currents. But there can be no such currents under static conditions. Electric field E must be normal at every point on the surface of the conductor.



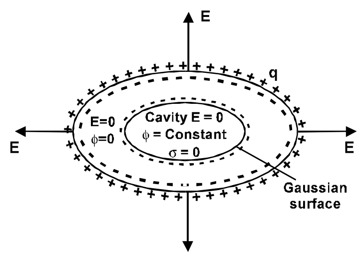
Consider a conductor having a surface charge density σ at any point on its surface. To determine E at this point, we choose a small flat pill box of cross-section A as the Gaussian surface. Since electric field E is zero at all points inside the conductor, the only contribution to the flux is through the plane cap of area A that lies outside the conductor, therefore

$$\phi_E = E.A.$$

Using Gauss's theorem :

$$\phi_E = \frac{q}{\varepsilon_0}; \qquad EA = \frac{\sigma A}{\varepsilon_0} \qquad \text{or} \qquad E = \frac{\sigma}{\varepsilon_0}$$

(iii) Electric field vanishes in the cavity of a charged hollow conductor. Consider a charged conductor with a cavity inside it. We choose the Gaussian surface inside the conductor quite close to the cavity as shown by dotted line in fig. Since, electric field vanishes everywhere inside a conductor, so by Gauss's theorem, the charge enclosed by the Gaussian surface must be zero. Hence, the electric field vanishes inside the cavity. This vanishing of the electric field inside a cavity in a conductor is called electrostatic shielding. All the charges supplied to the conductor reside on its outer surface.

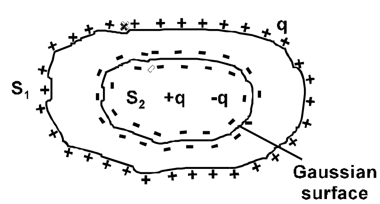


An important application of electrostatic shielding is that in a thunder storm accompanied by lightening, it is safer to sit inside a car, rather than near a tree or on the open ground.

5.4 A HOLLOW CONDUCTOR WITH A CHARGE PLACED INSIDE THE CAVITY : Consider a hollow conductor with S_1 as its outer surface and S_2 as its inner surface. Let a positive charge q be placed inside the cavity. Consider a Gaussian surface inside the conductor but quite close to the cavity. Since, electric field at every point inside the conductor is zero, therefore, according to Gauss's theorem,

$$\phi_E = \oint \vec{E}.d\vec{S} = \frac{\text{total charge}}{\varepsilon_0}$$

The total charge enclosed by the Gaussian surface must be zero. This requires a charge – q units to be induced on the inner surface S_1 of the hollow conductor. But an equal and opposite charge of + q units must appear on the outer surface S_2 of the conductor because no charges are supplied to the hollow conductor and so, the total charge on the conductor must be zero.



Thus, a charge placed on a hollow conductor does not produce any electric field inside the cavity, but a charge placed inside the cavity of a hollow conductor produces an electric field in the conductor itself.

6. CHARGE & FIELD

6.1 Motion of charged particle in uniform electric field

1. Charged particles experience a force in an electric field.

2. Magnitude of force on a charge q in an electric field E is F = qE

3. Direction of force on a positive charge is same as direction of electric field, while it is opposite to direction of electric field in case of negative charge.

4. **Motion in Uniform Electric Field -**

Case : I. Initial velocity is zero or in the direction of electric field, the force

$$F = qE$$

$\Rightarrow$ Acceleration, $a = \frac{qE}{m} \Rightarrow V = u + at$

Distance travelled in time 't', $s = ut + \frac{1}{2}at^2$

5. Accelerating a charge q through a potential difference V results in

(a) Decrease in PE = qV (b) Increase in KE = qV

6. In a non-uniform electric field, electron accelerates and translates also.

7. **Special Results :**

(i) Time taken by the particle to cover length of electric field. (In other words, time for which particle moves under the influence of electric field) :

$$T = \frac{\ell}{v}$$

(ii) Total displacement in the trajectory of electron

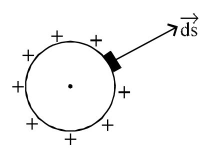
$$y = \frac{1}{2} \cdot \frac{qE}{m} \left(\frac{\ell}{v}\right)^2$$

6.2 ELECTROSTATIC PRESSURE

1. If surface charge density on a surface is σ, the electric field intensity at a point near this surface is $\frac{\sigma}{\varepsilon_0}$.

2. When a conductor is charged, then its entire surface experiences an outward force perpendicular to the surface.

3. Force on small element $d\vec{s}$ of charged conductor.



dF = (charge on ds) x Electric field = $(\sigma\, ds) \times \frac{\sigma}{2\varepsilon_0}$

$\Rightarrow \vec{F} = \oint d\vec{F} = \oint \frac{\sigma^2}{2\varepsilon_0} ds$

4. The electric force acting per unit area of charged surface is defined as electrostatic pressure.

$$P = \frac{dF}{dS} = \frac{\sigma^2}{2\varepsilon_0}$$

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

6. A soap bubble or rubber balloon expands on giving charge to it (charge of any kind +ve or - ve.)

+ve charge $\Rightarrow$ M $\downarrow$; - ve charge $\Rightarrow$ M$\uparrow$.

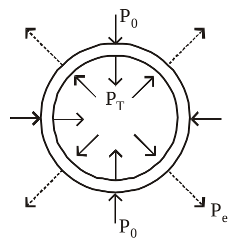
7. Energy associated per unit volume of electric field of intensity E is defined as energy density.

$$u = \frac{dW}{dV} = \frac{\varepsilon_0 E^2}{2} = \frac{\sigma^2}{2\varepsilon_0}\ \text{J/m}^3$$

$u = \int u \,.\, dV = \frac{\varepsilon_0}{2}\int_v E^2\, dV$; Where, V is the volume of electric field.

8. **Equilibrium of charged liquid surfaces :**

Soap Bubble :



Pressures (forces) act on a charged soap bubble due to :

(i) Surface tension of a soap bubble, P_T (inward)

(ii) Air outside the bubble, P_0 (inward)

(iii) Electric charges (electrostatic pressure), P_e (outward)

(iv) Air inside the soap bubble, P_i (outward)

(v) Hence, in state of equilibrium

Inward pressure = Outward pressure

$P_T + P_0 = P_i + P_e$

Excessive pressure ($P_{ex.}$) = $P_i - P_0 = P_T - P_e$

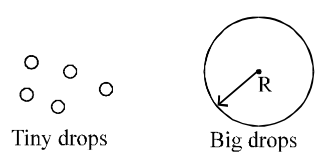
But $P_T = \frac{4T}{r}$, $P_e = \frac{\sigma^2}{2\varepsilon_0} \Rightarrow P_{ex.} = \frac{4T}{r} - \frac{\sigma^2}{2\varepsilon_0}$

(vi) If $P_i = P_0$, then $\frac{4T}{r} = \frac{\sigma^2}{2\varepsilon_0}$

7. DROP OF CHARGED LIQUID

(Mixing of identical charged tiny drops)

Let, no. of tiny drops = N



for each tiny drop, various parameters are $\leftrightarrow$ r, q, C', σ, E, V

for big drop, various parameters are $\leftrightarrow$ R, Q, C, σ_B, E_B, V_B

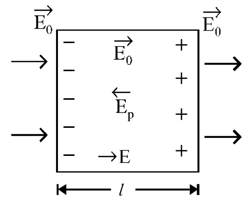
Basic concept :

Charge conservation Q = Nq

$C = N^{1/3} C'$, $\sigma_B = N^{1/3}\sigma$, $E_B = N^{1/3} E$, $V_B = N^{2/3} V$.

8. ELECTRIC FIELD IN DIELECTRIC

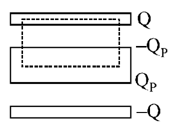
Let $\vec{E}_0$ be the applied field and $\vec{E}_p$ be the field due to polarisation. The resultant field is $\vec{E} = \vec{E}_0 + \vec{E}_P$. For homogeneous and isotropic dielectric, the direction of $\vec{E}_p$ is opposite to the direction of $\vec{E}_0$. So, resultant field is $E = E_0 - E_P$.



(i) AN ALTERNATIVE FORM OF GAUSS'S LAW : Consider a parallel plate capacitor with a charge Q, the space between the plates is filled with a dielectric slab of dielectric constant K.

$$\oint \vec{E} \cdot d\vec{s} = \frac{Q - Q_P}{\varepsilon_0} = \frac{1}{\varepsilon_0}\,[Q - (1 - 1/K)Q] = \frac{Q}{\varepsilon_0 K}$$

or $$\oint \vec{E} \cdot d\vec{s} = \frac{Q_{free}}{\varepsilon_0}$$



(ii) **Displacement vector** : -

Field due to polarisation is

$$\vec{E}_P = \frac{\sigma_P}{\varepsilon_0} = \frac{-P}{\varepsilon_0}$$

Now, $\vec{E} = \vec{E}_0 + \vec{E}_P = \vec{E}_0 - \dfrac{\vec{P}}{\varepsilon_0} \Rightarrow \varepsilon_0 \vec{E}_0 = \varepsilon_0 \vec{E} + \vec{P}$

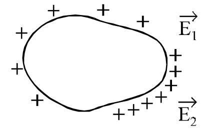
so, $\oint (\varepsilon_0 \vec{E} + \vec{P})\,.ds = \oint \varepsilon_0 \vec{E}_0 . d\vec{s} = Q_{free}$

or $\oint \vec{D}\,.\,d\vec{s} = Q_{free}$, Where $\vec{D}$ is displacement vector $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$

(iii) **Corona Discharge : -**

If a conductor has a pointed shape like a needle and a charge is given to it, the charge density at the pointed end will be very high. Correspondingly, the electric field heating these pointed ends will be very high which may cause dielectric break down in air. The charge may jump from the conductor to the air because of increased conductivity in the air. Often, this discharge of air is accompanied by a visible glow surrounding the pointed end. This phenomenon is called corona discharge.

(iv) $\dfrac{\sigma_1}{\sigma_2} = \dfrac{r_2}{r_1}$. The sphere with smaller radius has larger surface charge density to maintain the same potential.



9. MEMORY POINTS

1. The 'total' charge of a charged conductor lies at the outer surface of the conductor.

2. A dipole placed in uniform electric field experiences a torque only. The net force acting on it is zero. Thus, the dipole placed in a uniform electric field has rotatory motion alone and not translatory motion.

3. If the dipole is placed in a non-uniform field, then both net force as well as a torque act on it and it has translatory as well as rotatory motion.

4. Intensity of electric field at a point in end-side on position of a small dipole = 2 (Intensity of field in the broad side on position).

5. Potential of earth is considered to be zero.

6. The work done in moving a charge from one point to another in an electric field does not depend upon the path followed by it.

7. Best conductor of electricity is Ag (silver).

8. A soap bubble always inflates whether it is charged with positive or negative electricity.

9. When a soap bubble is charged, then during the charging process, the volume of the air inside the bubble remains constant.

10. If a charged particle having a charge q and mass m is moving in an electric field between two points having a potential difference of V volts, then the increase in kinetic energy of the body is

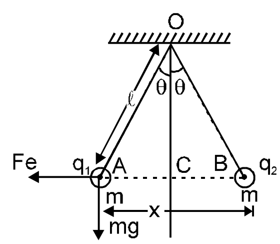
$K = Vq$ or $1/2\ mv^2 = Vq$ or $v = \sqrt{(2Vq/m)}$

11. **Polar dielectrics** are those dielectrics in which the centre of positive charge of a molecule does not coincide with the centre of negative charge and so they have a permanent dipole moment, whether they are kept in electric field or not. But even a polar dielectric does not show any dipole moment due to random orientations of dipoles.

12. **Non-polar** dielectrics are those dielectrics in which the centre of positive charge of a molecule coincides with the centre of negative charge and hence they do not show a dipole moment in the absence of electric field. However, they show a net dipole moment when they are placed in external field.

13. When two charged pith balls having charges q_1 and q_2 are suspended from same point with the help of silk threads then considering the equilibrium of any one ball (as shown in fig.)

Moment of F_e about O = Moment of mg about O.



$F_e \times OC = mg \times AC$

or $\frac{F_e}{mg} = \tan\theta$ or $\frac{q_1 q_2}{4\pi \epsilon_0 x^2 . mg} = \tan\theta$

14. If in the above problem ($x << \ell$) and the charges on the pith balls are equal (i.e. $q_1 = q_2 = q$), then it can be easily proved that

$$x = \left[\frac{q\ell}{2\pi \epsilon_0\ mg}\right]^{1/3}$$

15. The work done in moving a charge in electric field is independent of the path followed by the charge. The work done in a cyclic process is zero.

16. If n small drops, each of surface density of charge σ coalesce to form a big drop then the surface density of charge on the big drop is $\sigma' = \sigma n^{1/3}$

17. Equal amounts of charges can be given to solid or hollow conducting spheres of equal radii.

18. The work done in moving a charge in circular orbit in an electric field is zero.

19. A sphere of 1 cm. radius cannot be given charge of 1 C because the electric field intensity at the surface of air will be 9×10^{11}. In air, the electric field intensity greater than 3×10^{6} V/m ionizes the air and the charge of sphere starts leaking.

20. If a charged conductor is connected to earth, then the charge of conductor will move to earth and thereby the potential of conductor will be zero.

21. Charge density and intensity of electric field at pointed ends is more, while electric potential is same as that of other points.

22. The electric potential due to a unipolar charge is $V \propto \frac{1}{x}$, due to dipolar charge is $V \propto \frac{1}{x^2}$, due to tripolar charge is $V \propto \frac{1}{x^3}$.

23. If from any point O, equal charges q are placed on a line at distances r, 2r, 4r, 8r.......etc. then electric potential at point O will be, $V = 2kq/r$.

24. If an electron and proton are moving in a uniform electric field, then the electric force acting on them will be same, but the acceleration of proton will be 1/1836 times that of electron. (The mass of proton is 1836 times that of electron).

25. The closed imaginary surface drawn around a charge is called Gaussian surface.

26. For point charge or spherical distribution of charge, the gaussian surface will be spherical and the electric field will be perpendicular to the surface at all points.

27. If the flux emerging out of a Gaussian surface is zero, then it is not necessary that the intensity of electric field is zero.

28. Equal amounts of charges can be given to the solid or hollow conducting spheres of equal radii.

29. With increase in temperature, the dielectric constant of liquid increases.

EXERCISE#1

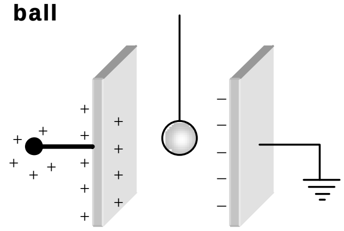
Q. 1 **Five balls numbered 1 to 5 balls suspended using separate threads. Pair (1,2), (2,4) and (4,1) show electrostatic attraction, while pair (2,3) and (4,5) show repulsion. Therefore ball 1 must be**

(A) Positively charged (B) Negatively charged

(C) Neutral (D) Made of metal

TOPIC SKILLS **: Properties of conductors**

Q. 2 **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**



(A) Is attracted to the high voltage plate and stays there

(B) Hangs without moving

(C) Swings backward and forward hitting each plate in turn

(D) None of these

TOPIC SKILLS **: Properties of charge**

Q.3 **$\sqrt{3}$ x 10^{-19} C and -10^{-6} C are placed at (0, 0, 0) and (1, 1, 1) respectively. Find the force on second in vector form**

(A) -3×10^{-16} ($\hat{i} + \hat{j} + \hat{k}$) newton (B) -5×10^{-16} ($\hat{i} + \hat{j} + \hat{k}$) newton

(C) 8×10^{6} ($\hat{i} + \hat{j} + \hat{k}$) newton (D) None

TOPIC SKILLS **: Coulomb's law in vector form.**

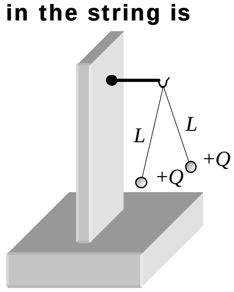
Q.4 **Force F is acting between two charges. If a sheet of glass ($\varepsilon_r = 6$) is placed between the two charges, what will be the force ?**

(A) F/4 (B) F/6

(C) F/2 (D) F/8

TOPIC SKILLS **: coulomb's law in a medium other than vacuum.**

Q. 5 **Two small balls having equal positive charge Q (coulomb) on each are suspended by two insulated string of equal length L meter, from a hook fixed to a stand. The whole set up is taken in satellite into space where there is no gravity (state of weight less ness). Then the angle between the string and tension in the string is**



(A) $180^{\circ}, \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{(2L)^2}$ (B) $90^{\circ}, \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{L^2}$

(C) $180^{\circ}, \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{2L^2}$ (D) $180^{\circ}, \frac{1}{4\pi\varepsilon_0} \cdot \frac{QL}{4L^2}$

TOPIC SKILLS **: Coulomb's law in zero gravity region.**

Q. 6 **A total charge Q is broken in two parts Q_1 and Q_2 and they are placed at a distance R from each other. The maximum force of repulsion between them will occur, when**

***TOPIC SKILLS* : Coulomb's law**

(A) $Q_2 = \frac{Q}{R}, Q_1 = Q - \frac{Q}{R}$

(B) $Q_2 = \frac{Q}{4}, Q_1 = Q - \frac{2Q}{3}$

(C) $Q_2 = \frac{Q}{4}, Q_1 = \frac{3Q}{4}$

(D) $Q_1 = \frac{Q}{2}, Q_2 = \frac{Q}{2}$

Q. 7 **Equal charges Q are placed at the four corners A, B, C, D of a square of length a. The magnitude of the force on the charge at B will be**

***TOPIC SKILLS* : Coulomb's law in vector form.**

(A) $\frac{3Q^2}{4\pi\varepsilon_0 a^2}$

(B) $\frac{4Q^2}{4\pi\varepsilon_0 a^2}$

(C) $\left(\frac{1+2\sqrt{2}}{2}\right)\frac{Q^2}{4\pi\varepsilon_0 a^2}$

(D) $\left(2+\frac{1}{\sqrt{2}}\right)\frac{Q^2}{4\pi\varepsilon_0 a^2}$

Q. 8 **Two equal charges are separated by a distance d. A third charge placed on a perpendicular bisector at x distance, will experience maximum coulomb force when**

***TOPIC SKILLS* : Coulomb's law**

(A) $x = \frac{d}{\sqrt{2}}$

(B) $x = \frac{d}{2}$

(C) $x = \frac{d}{2\sqrt{2}}$

(D) $x = \frac{d}{2\sqrt{3}}$

Q. 9 **Two point charges Q_1 and Q_2 are 3 m apart and their combined charge is 20 μC. If one repels the other with a force of 0.075 N, what are the two charges ?**

***TOPIC SKILLS* : Coulomb's law**

(A) $Q_1 = 10\mu C$, $Q_2 = 6\,\mu C$

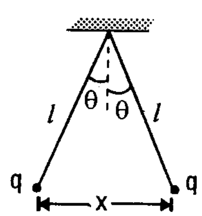
(B) $Q_1 = 13\mu C$, $Q_2 = 2\mu C$

(C) $Q_1 = 15\mu C$, $Q_2 = 5\,\mu C$

(D) None.

Q.10 **Two similar tiny balls of mass m, each carrying charge q are hung from silk threads of length ℓ as shown in Fig. These are separated by a distance x and angle between them is $2\theta \approx 10°$. Then for equilibrium**

***TOPIC SKILLS* : Coulomb's law and condition of equilibrium**



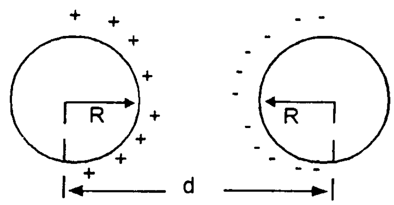
(A) $x = 2\ell$

(B) $x = \frac{\ell q^2}{4\pi\varepsilon_0 mg}$

(C) $x = \left[\frac{q^2 \ell mg}{4\pi\varepsilon_0}\right]^{1/2}$

(D) $x = \left[\frac{q^2 \ell}{2\pi\varepsilon_0 mg}\right]^{1/3}$

Q.11 **Two charged spheres of radius 'R' each are kept at a distance 'd' (d>2R). One has a charge +q and the other - q. The force between them will be**



(A) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}$

(B) $> \frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}$

(C) $< \frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}$

(D) None of these

TOPIC SKILLS :
Coulomb's law

Q.12 **A particle of mass m and charge q is lying at the mid point of two stationary particles distant 2ℓ and each carrying a charge q. If the free charged particle is displaced from its equilibrium position through distance $x(x << \ell)$, then the particle will**

(A) move in the direction of displacement
(B) stop at its equilibrium position
(C) oscillate about its equilibrium position
(D) Execute S.H.M. about its equilibrium position

TOPIC SKILLS :
Coulomb's law position of equilibrium.

Q.13 **Four charges, each of magnitude q are lying at the four corners of a square of side a. How much charge should be placed at the centre of the square, so that the whole system remains in equilibrium?**

(A) $-\frac{q}{4}(2\sqrt{2}+1)$

(B) $-\frac{q}{\sqrt{2}}$

(C) $-2\sqrt{2}\,q$

(D) $-\frac{q}{\sqrt{2}}(2\sqrt{2}+1)$

TOPIC SKILLS :
Coulomb's law and condition for equilibrium.

Q.14 **Two small identical balls A and B lying on a horizontal smooth plane are connected by a massless spring. Ball A is fixed but ball B is free to move. When both balls are charged identically, then :**

(A) At the time of maximum separation between balls, magnitude of acceleration will be maximum.
(B) At the equilibrium position of B, velocity of ball B will be maximum.
(C) The ball B executes simple harmonic motion
(D) All of the above

TOPIC SKILLS :
Coulomb's law and and motion of charge.

Q.15 **Two identical pendulums A and B are suspended from the same point. The bobs are given positive charges, with A having more charge than B. They diverge and reach at equilibrium, with A and B making angles q_1 and q_2 with the vertical respectively :**

(A) $\theta_1 > \theta_2$
(B) $\theta_1 < \theta_2$
(C) $\theta_1 = \theta_2$
(D) The tension in A is greater than that in B

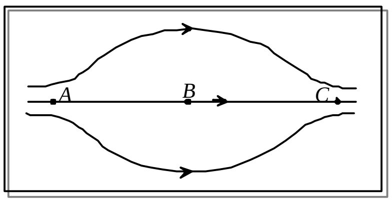
TOPIC SKILLS :
Coulomb's law and condition for equilibrium.

Q. 16 **A half ring of radius R has a charge of l per unit length. The electric field at the centre is** $\left(k = \dfrac{1}{4\pi\varepsilon_0}\right)$

(A) Zero
(B) $\dfrac{k\lambda}{R}$
(C) $\dfrac{2k\lambda}{R}$
(D) $\dfrac{k\pi\lambda}{R}$

***TOPIC SKILLS* : Electric field due to charged bodies.**

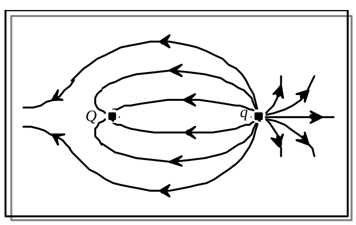
Q. 17 **The figure shows some of the electric field lines corresponding to an electric field. The figure suggests**



(A) $E_A > E_B > E_C$
(B) $E_A = E_B = E_C$
(C) $E_A = E_C > E_B$
(D) $E_A = E_C < E_B$

***TOPIC SKILLS* : Dependence of E on density of field lines.**

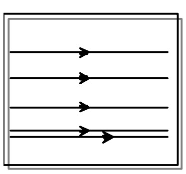
Q. 18 **The lines of force of the electric field due to two charges q and Q are sketched in the figure. State if**

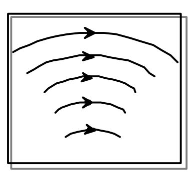


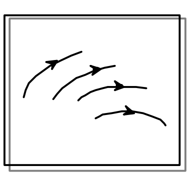
(A) Q is positive and $|Q| > |q|$
(B) Q is negative and $|Q| > |q|$
(C) q is positive and $|Q| < |q|$
(D) q is negative and $|Q| < |q|$

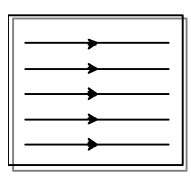
***TOPIC SKILLS* : Dependence of no. of field lines on magnitude of charge**

Q. 19 **Which of the following maps cannot represent an electric field**

(A) 

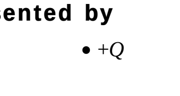
(B) 

(C) 

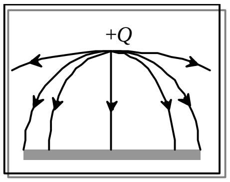
(D) 

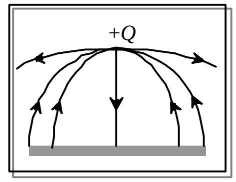
***TOPIC SKILLS* : Properties of electric field lines.**

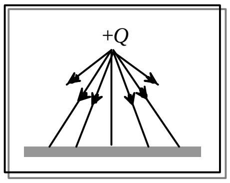
Q. 20 **A charge Q is fixed at a distance d in front of an infinite metal plate . The lines of force are represented by**

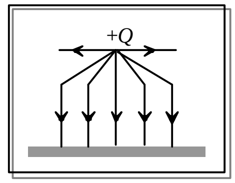


***TOPIC SKILLS* : Properties of electric field lines.**

(A) 

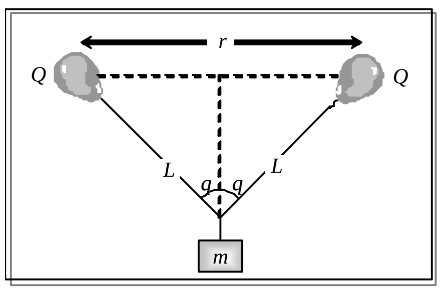
(B) 

(C) 

(D) 

Q. 21 Two similar balloons filled with helium gas are tied to L m long strings. A body of mass m is tied to another ends of the strings. The balloons float on air at distance r. If the amount of charge on the balloons is same then the magnitude of charge on each balloon will be

***TOPIC SKILLS* : Equilibrium of charged bodies.**



(A) $\left[\dfrac{mgr^2}{2k}\tan\theta\right]^{1/2}$ (B) $\left[\dfrac{2k}{mgr^2}\tan\theta\right]^{1/2}$

(C) $\left[\dfrac{mgr}{2k}\cot\theta\right]^{1/2}$ (D) $\left[\dfrac{2k}{mgr}\tan\theta\right]^{1/2}$

Q. 22 Two point charges - Q and 2Q are separated by a distance R, neutral point will be obtained at

***TOPIC SKILLS* : Neutral point i.e. Zero $\vec{E}$**

(A) A distance of $\dfrac{R}{(\sqrt{2}-1)}$ from – Q charge and lies between the charges.

(B) A distance of $\dfrac{R}{(\sqrt{2}-1)}$ from – Q charge on the left side of it

(C) A distance of $\dfrac{R}{(\sqrt{2}-1)}$ from 2Q charge on the right side of it.

(D) A point on the line which passes perpendicularly through the centre of the line joining – Q and 2Q charge.

Q. 23 A charge Q is distributed over two concentric hollow spheres of radii r and (R > r) such that the surface densities are equal. The potential at the common centre is

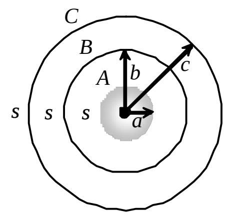
***TOPIC SKILLS* : Potential due to hollow sphere.**

(A) $\dfrac{Q(R^2+r^2)}{4\pi\varepsilon_0(R+r)}$ (B) $\dfrac{Q}{R+r}$

(C) Zero (D) $\dfrac{Q(R+r)}{4\pi\varepsilon_0(R^2+r^2)}$

Q. 24 **Three concentric metallic sphere A, B and C have radii a, b and c (a < b < c) and surface charge densities on them are s, – s and s respectively. The valves of V_A and V_B will be**

TOPIC SKILLS: **Potential due to spherical conductors.**



(A) $\frac{\sigma}{\varepsilon_0}(a-b-c), \frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{b}-b+c\right)$

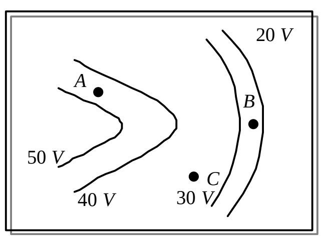
(B) $(a-b-c), \frac{a^2}{c}$

(C) $\frac{\varepsilon_0}{\sigma}(a-b-c), \frac{\varepsilon_0}{\sigma}\left(\frac{a^2}{c}-b+c\right)$

(D) $\frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{c}-\frac{b^2}{c}+c\right)$ and $\frac{\sigma}{\varepsilon_0}(a-b+c)$

Q. 25 **The figure shows the lines of constant potential in a region in which an electric field is present. The magnitude of electric field is maximum at**

TOPIC SKILLS: **Relation between field and potential.**



(A) A

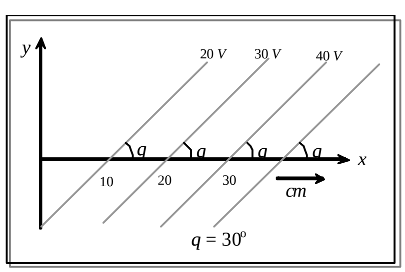
(B) B

(C) C

(D) Equal at A, B and C

Q. 26 **Some equipotential surface are shown in the figure. The magnitude and direction of the electric field is**

TOPIC SKILLS: **Electric field for equipotential surface.**



(A) 100 V/m making angle 120^0 with the x-axis

(B) 100 V/m making angle 60^0 with the x-axis

(C) 200 V/m making angle 120^0 with the x-axis

(D) None of the above

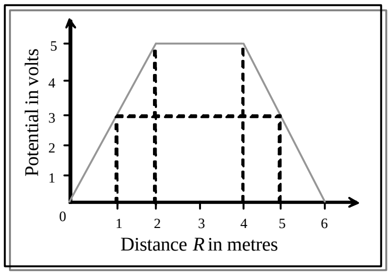
Q. 27 **The electric potential V is given as a function of distance x (metre) by V = $(5x^2 + 10x - 9)$ volt. Value of electric field at x = 1m is**

TOPIC SKILLS **: Relation between field and potential.**

(A) - 20 V/m (B) 6 V/m
(C) 11 V/m (D) - 23 V/m

Q. 28 **The variation of potential with distance R from a fixed point is as shown below. The electric field at R = 5m is**

TOPIC SKILLS **: Relation between field and potential.**



(A) 2.5 volt/m (B) –2.5 volt/m
(C) $\frac{2}{5}$ volt/m (D) $-\frac{2}{5}$ volt/m

Q. 29 **A charge (–q) and another charge (+Q) are kept at two points A and B respectively. Keeping the charge (+Q) fixed at B, the charge (–q) at A is moved to another point C such that ABC forms an equilateral triangle of side l. The network done in moving the charge (–q) is**

TOPIC SKILLS **: Electrostatic potential energy and work energy theorem.**

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{l}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{l^2}$
(C) $\frac{1}{4\pi\varepsilon_0}Qql$ (D) Zero

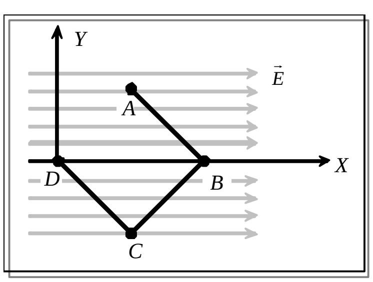
Q. 30 **Two identical thin rings each of radius R, are coaxially placed a distance R apart. If Q_1 and Q_2 are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is**

TOPIC SKILLS **: Electrostatic potential energy and work energy theorem.**

(A) Zero (B) $\frac{q(Q1-Q2)(\sqrt{2}-1)}{4\pi\varepsilon_0 R\sqrt{2}}$
(C) $\frac{q(Q_1+Q_2)\sqrt{2}}{4\pi\varepsilon_0 R}$ (D) $\frac{q\left(\frac{Q_1}{Q_2}\right)(\sqrt{2}-1)}{4\pi\varepsilon_0 R\sqrt{2}}$

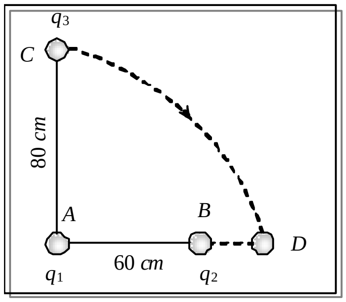
Q. 31 **A point charge q moves from point A to point D along the path ABCD in a uniform electric field. If the co-ordinates of the points A, B, C and D are (a, b, 0), (2a, 0, 0), (a, – b, 0) and (0, 0, 0) then the work done by the electric field in this process will be**

TOPIC SKILLS **: Work done by electric field.**



(A) – qEa (B) Zero
(C) 2E(a + b) q (D) $\frac{qEa}{2b}$

Q. 32 **In figure are shown charges $q_1 = +2 \times 10^{-8}$ C and $q_2 = -0.4 \times 10^{-8}$ C. A charge $q_3 = 0.2 \times 10^{-8}$ C in moved along the arc of a circle from C to D. The potential energy of q_3**



(A) Will increase approximately by 76%
(B) Will decreases approximately by 76%
(C) Will remain same
(D) Will increases approximately by 12%

TOPIC SKILLS **:** **Electrostatic potential energy due to system of charges**

Q.33 **The radius of a soap bubble is r and its surface tension is T. If the surface charge density on the bubble is s and the Qcess pressure inside it is p, then the value of s will be**

(A) $\left[2\varepsilon_0\left(\frac{4T}{r}+p\right)\right]^{1/2}$ (B) $\left[\frac{\varepsilon_0}{2}\left(\frac{4T}{r}-p\right)\right]^{1/2}$

(C) $\left[2\varepsilon_0\left(\frac{4T}{r}-p\right)\right]^{1/2}$ (D) $\left[\varepsilon_0\left(\frac{4T}{r}+p\right)\right]^{1/2}$

TOPIC SKILLS **:** **Charged drop in equilibrium.**

Q.34 **For the equilibrium of a charged bubble of surface tension T and radius r, the charge on the bubble should be-**

(A) $(128\ \pi^2 r^3\ \varepsilon_0 T)^{1/2}$ (B) $(64\pi^2 r^3\ \varepsilon_0 T)^{1/2}$
(C) $(32\pi r \varepsilon_0 T)^{1/2}$ (D) $(32\pi^2 r^3\ \varepsilon_0 T)^{1/2}$.

TOPIC SKILLS **:** **Charged drop in equilibrium.**

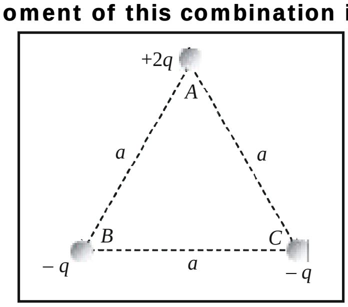
Q. 35 **A point charge Q is placed outside a hollow sperical conductor of radius R, at a distance (r > R) from its centre C. The field at C due to the induced charges on the conductor is** $\left[K = \frac{1}{4\pi\varepsilon_0}\right]$

(A) Zero (B) $K\frac{Q}{(r-R)^2}$

(C) $K\frac{Q}{r^2}$ directed towards Q (D) $K\frac{Q}{r^2}$ directed away from Q

TOPIC SKILLS **:** **Field due to spherical conductors.**

Q.36 **Three charges of (+2q), (–q) and (–q) are placed at the corners A, B and C of an equilateral triangle of side a as shown in the adjoining figure. Then the dipole moment of this combination is**



TOPIC SKILLS **:** **Dipole moment.**

(A) qa | (B) Zero

(C) $qa\sqrt{3}$ | (D) $\frac{2}{\sqrt{3}}qa$

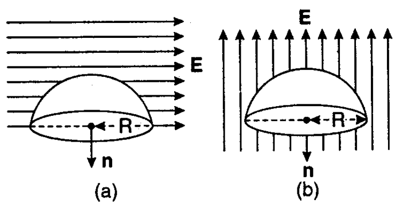
Q.37 **If the electric field is given by $6\hat{i} + 3\hat{j} + 4\hat{k}$, calculate the electric flux through a surface of area 10 units lying in Y-Z plane.**

***TOPIC SKILLS*: Electric flux.**

(A) 20 Units
(B) 30 Units
(C) 60 Units
(D) 80 Units

Q.38 **A hemispherical body is placed in a uniform electric field E. What is the flux linked with the curved surface, if field is (a) parallel to the base (Fig (a)) and (b) perpendicular to base (fig (b)).**

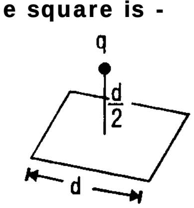
***TOPIC SKILLS*: Electric flux.**



(A) (a) 0, (b) πR^2E
(B) (a) $2\pi R^2E$, (b) $2\pi R^2E$
(C) (a) πR^2E, (b) 0
(D) None.

Q.39 **A point charge +q is at a distance d/2 from a square surface of side d and is directly above the centre of the square as shown in Fig. The electric flux through the square is -**

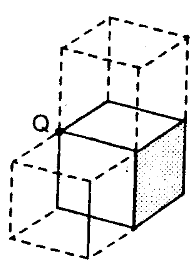
***TOPIC SKILLS*: Electric flux.**



(A) $q/\pi\varepsilon_0$
(B) $q/6\varepsilon_0$
(C) q/ε_0
(D) zero

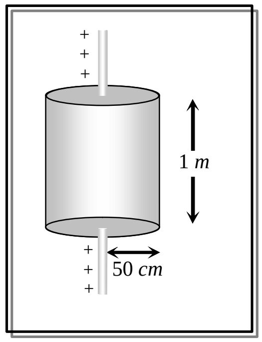
Q.40 **A charge Q is situated at the corner of a cube, the electric flux through all the six faces of the cube is**

***TOPIC SKILLS*: Electric flux using gauss law.**



(A) $\frac{Q}{6\epsilon_o}$
(B) $\frac{Q}{8\epsilon_o}$
(C) $\frac{Q}{\epsilon_o}$
(D) $\frac{Q}{2\epsilon_o}$

Q.41 **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 1 m symmetrically enclose the wire as shown in the figure. The total electric flux passing through the cylindrical surface is**



(A) $\frac{Q}{\varepsilon_0}$ (B) $\frac{100Q}{\varepsilon_0}$

(C) $\frac{10Q}{(\pi\varepsilon_0)}$ (D) $\frac{100Q}{(\pi\varepsilon_0)}$

***TOPIC SKILLS* : gauss law.**

ANSWER-KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	C	B	A	B	A	D	C	C	C	D	B	D	A	D	C
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	C	C	C	A	C	A	B	B	A	B	A	A	A	D	B
Que.	31	32	33	34	35	36	37	38	39	40	41				
Ans.	A	B	C	A	C	C	C	A	B	B	B				

EXERCISE#2

Q.1 **Two identical spheres (same mass and same charge) are suspended by silk threads and the angle between threads is 2 θ. If the entire system is immersed in water, then the value of angle -**

(A) Decreases
(B) Increases
(C) Remains same
(D) Either increases or decreases

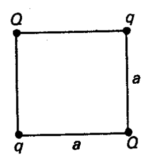
Q.2 **A non conducting ring of radius 0.5 m carries a total charge of 1.11 x 10^{-10} coulomb distributed non uniformly on its circumference producing an electric field E everywhere in space. The value of line integral. $\int_{\ell=\infty}^{\ell=0} -E\,d\ell$ [ℓ = 0 being the centre of the ring] in volt is-**

(A) + 2
(B) - 1
(C) - 2
(D) 0

Q.3 **A conducting spherical shell has inner radius R_1 and outer radius R_2 with uniform charge densities σ and – σ, respectively. The charge inside the cavity is-**

(A) Zero
(B) + 4 $\pi\sigma R_1^2$
(C) – 4 $\pi\sigma R_1^2$
(D) 4 $\pi\sigma(R_2^2 - R_1^2)$

Q.4 **In the arrangement of charges at the four corners of a square, if the net force experienced by Q is zero, then Q and q are related as-**



(A) Q = $\sqrt{2}$ q
(B) Q = 2 $\sqrt{2}$ q
(C) Q = – 2 $\sqrt{2}$ q
(D) Q = – $\sqrt{2}$ q

Q.5 **Five point charges, each of value + q coulomb, are placed on five vertices of a regular hexagon of side L metre. The magnitude of the force on a point charge of value – q coulomb placed at the centre of the hexagon is-**

(A) $\frac{kq^2}{L^2}$

(B) $\sqrt{5}\,\frac{kq^2}{L^2}$

(C) $\sqrt{3}\,\frac{kq^2}{L^2}$

(D) Zero

Q.6 **The electrostatic pressure on a charged surface having a surface charge density σ Coulomb / m² is-**

(A) $\frac{\sigma^2}{2\epsilon_0}$

(B) $\frac{\sigma}{2\epsilon_0}$

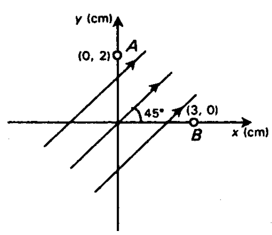
(C) $\frac{\sigma}{\epsilon_0}$

(D) $\frac{\sigma^2}{\epsilon_0}$

Q.7 **A uniform electric field pointing in positive x-direction exists in a region. Let A be the origin, B be the point on the x-axis at x = + 1 cm and C be the point on the y-axis at y = + 1 cm. Then, the potentials at the points A, B and C satisfy-**

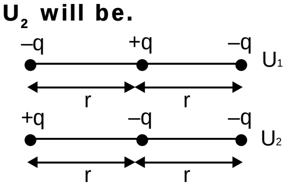
(A) $V_A < V_B$
(B) $V_A > V_B$
(C) $V_A < V_C$
(D) $V_A > V_C$

Q.8 **A uniform electric field of 400 V/m is directed at 45° above the x-axis as shown in the figure. The potential difference $V_A - V_B$ is given by-**



(A) 0
(B) 4 V
(C) 6.4 V
(D) 2.8 V

Q.9 **Two equal negative charges, each of magnitude q are kept at a distance 2r from each other. A positive charge q is placed at the mid point of the line joining the negative charges. The potential energy of this system is U_1. If any two charges close to each other are interchanged, the potential energy of the new system becomes U_2. The ratio of U_1 and U_2 will be.**



(A) 1 : 1
(B) 3 : 1
(C) 1 : 3
(D) 9 : 1

Q.10 **Two identical particles of mass m carry equal charge Q each. Initially, one is at rest on a smooth, horizontal plane and the other is projected along the plane directly towards the first particle from a large distance with a speed v. The distance of closest approach is $\frac{1}{4\pi\varepsilon_0}$ times-**

(A) $\frac{Q^2}{mv^2}$

(B) $\frac{2Q^2}{mv^2}$

(C) $\frac{Q^2}{2mv^2}$

(D) $\frac{4Q^2}{mv^2}$

Q.11 **The electric field in a region is radially outward with magnitude E = $A\gamma_0$. The charge contained in a sphere of radius γ_0 centered at the origin is-**

(A) $\frac{1}{4\pi\varepsilon_0} A\gamma_0^3$

(B) $4\pi\varepsilon_0 A\gamma_0^3$

(C) $\frac{4\pi\varepsilon_0 A}{\gamma_0}$

(D) $\frac{1}{4\pi\varepsilon_0}\frac{A}{\gamma_0^3}$

Q.12 **A charge q is placed at the centre of the line joining two equal charges Q. The system of three charges will be in equilibrium if q is equal to**

(A) $-\frac{Q}{2}$

(B) $-\frac{Q}{4}$

(C) – 4Q

(D) $+\frac{Q}{2}$

Q.13 **Calculate the number of lines of force from one coulomb of charge**

(A) 0
(B) 1
(C) $\frac{1}{\epsilon_0}$
(D) ∞

Q.14 **Two equal and opposite charges (+q and –q) are situated at a distance x from each other. The value of potential at every point will depend :**

(A) Only on q
(B) Only on x
(C) on qx
(D) on $\frac{q}{x}$

Q.15 Consider the points lying on a straight line joining two fixed opposite charges. Between the charges there is-

(A) No point where potential is zero

(B) Only one point where electric field is zero

(C) No point where electric field is zero

(D) Two points where potential is zero.

Q.16 If 1000 droplets, each of charge q and radius r are combined to form a big drop, then the potential of big drop, as compared to small droplet, will be

(A) 10 V

(B) 100 V

(C) 500 V

(D) 1000 V

Q.17 Eight dipoles of charges of magnitude e are placed inside a cube. The total electric flux coming out of the cube will be -

(A) $\frac{8e}{\varepsilon_0}$

(B) $\frac{16e}{\varepsilon_0}$

(C) $\frac{e}{\varepsilon_0}$

(D) zero

Q.18 Two infinitely long parallel wires having linear charge densities l_1 and l_2 respectively are placed at a distance of R metres. The force per unit length on either wire will be $\left(K = \frac{1}{4pe_0}\right)$

(A) $K\frac{2\lambda_1\lambda_2}{R^2}$

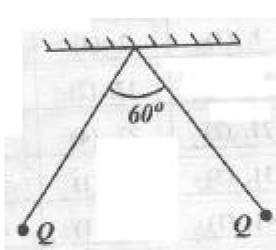
(B) $K\frac{2\lambda_1\lambda_2}{R}$

(C) $K\frac{\lambda_1\lambda_2}{R^2}$

(D) $K\frac{\lambda_1\lambda_2}{R}$

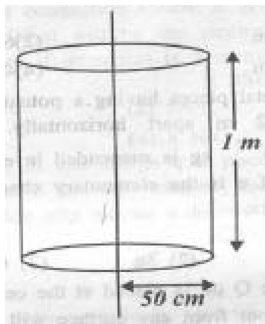
(D) Zero

Q.19 Two small spherical balls, each carrying a charge Q = 10 μC (10 micro-coulomb) are suspended by two insulating threads of equal lengths 1 m each, from a point fixed in the ceiling. It is found that in equilibrium, threads are separated by an angle 60° between them, as shown in the fig. What is the tension in the threads ? (Given, $\frac{1}{(4pe_0)} = 9 \times 10^9$ Nm/C^2)



(A) 18 N
(B) 1.8 N
(C) 0.18 N
(D) None of these

Q.20 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 symmetrically encloses the wire as shown in the fig. The total electric flux passing through the cylindrical surface is



(A) $\frac{Q}{\varepsilon_0}$

(B) $\frac{100Q}{\varepsilon_0}$

(C) $\frac{10Q}{(\pi\varepsilon_0)}$

(D) $\frac{100Q}{(\pi\varepsilon_0)}$

Q.21 There is an electric field E in X-direction. If work done in moving charge 0.2 C through a distance of 2m along a line making an angle of 60 degree with X-axis is 4.0 joule, what is the value of E ?

(A) $\sqrt{3}$ newton per coulomb
(B) 4 newton per coulomb
(C) 5 newton per coulomb
(D) none of these

Q.22 When air is replaced by dielectric medium of constant K, the maximum force of attraction between two charges separated by a distance

(A) increases K^{-1} times
(B) increases K times
(C) remains unchanged
(D) decreases K times

Q.23 An α-particle and a proton are accelerated through same potential difference from rest. The ratio of their final velocities is-

(A) $\sqrt{2}$: 1
(B) 1 : 1
(C) 1 : $\sqrt{2}$
(D) 1 : 2

Q.24 A thin spherical conducting shell of radius R has a charge q. Another charge Q is placed at the centre of the shell. The electrostatic potential at a point P a distance R/2 from the centre of the shell is-

(A) $\frac{2Q}{4\pi\varepsilon_0 R} - \frac{2q}{4\pi\varepsilon_0 R}$

(B) $\frac{2Q}{4\pi\varepsilon_0 R} + \frac{q}{4\pi\varepsilon_0 R}$

(C) $\frac{(q+Q)}{4\pi\varepsilon_0}\frac{2}{R}$

(D) $\frac{2Q}{4\pi\varepsilon_0 R}$

Q.25 Out of gravitational, electromagnetic, Vander Waals, electrostatic and nuclear forces; which two are able to provide an attractive force between two neutrons-

(A) Electrostatic and gravitational
(B) Electrostatic and nuclear
(C) Gravitational and nuclear
(D) Some other forces like Vander Waals

Q.26 Two spherical conductors B and C having equal radii and carrying equal charges in them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is-

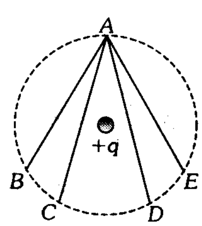
(A) $\frac{F}{4}$

(B) $\frac{3F}{4}$

(C) $\frac{F}{8}$

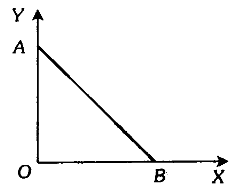
(D) $\frac{3F}{8}$

Q.27 In the electric field of a point charge q, a certain charge is carried from point A to B, C, D and E. Then the work done-



(A) Is least along the path AB
(B) Is least along the path AD
(C) Is zero along the paths AB, AC, AD and AE
(D) Is least along AE

Q.28 **As per this diagram, a point charge +q is placed at the origin O. Work done in taking another point charge – Q from the point A [co-ordinates (0, a)] to another point B [co-ordinates (a, 0] along the straight path AB is-**



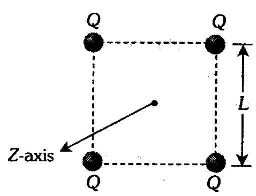
(A) Zero

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

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

(D) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right)\sqrt{2}\,a$

Q.29 **Four +ve point charges of same magnitude (Q) are placed at four corners of a rigid square frame as shown in figure. The plane of the frame is perpendicular to Z-axis. If a –ve point charge is placed at a distance z away from the above frame (z < < L) then-**



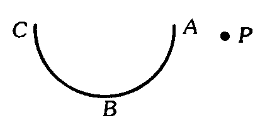
(A) – ve charge oscillates along the z-axis

(B) It moves away from the frame

(C) It moves slowly towards the frame and stays in the plane of the frame.

(D) It passes through the frame only once.

Q.30 **In the following diagram the work done in moving a point charge from point P to point A, B and C respectively is W_A, W_B and W_C, then-**



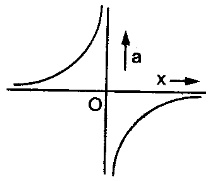
(A) $W_A = W_B = W_C$

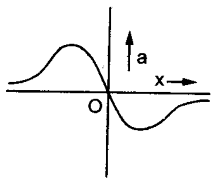
(B) $W_A = W_B = W_C = 0$

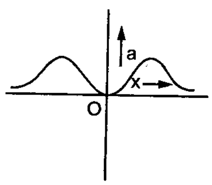
(C) $W_A > W_B > W_C$

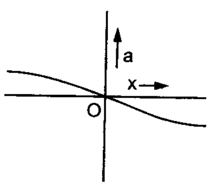
(D) $W_A < W_B < W_C$

Q.31 Two identical positive charges are fixed on the y-axis, at equal distances from the origin O. A particle with a negative charge starts on the x-axis at a large distance from O, moves along the x-axis, passes 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 ?

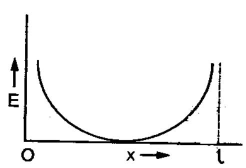
(A)


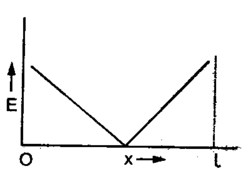
(B)


(C)


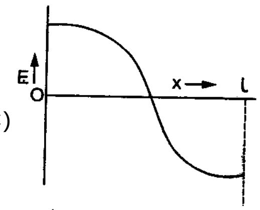
(D)


Q.32 Two identical point charges are placed at a separation of ℓ. P is a point on the line joining the charges at a distance x from any one charge. The field at P is E. E is plotted against x for values of x from close to zero to slightly less than ℓ. Which of the following best represents the resultant curve ?

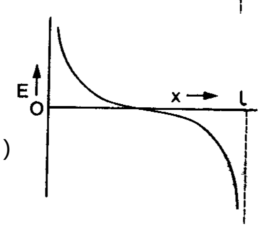
(A)


(B)


(C)



(D)



Q.33 A simple pendulum of time period T is suspended above a large horizontal metal sheet with uniformly distributed positive charge. If the bob is given some negative charge, its time period of oscillation will be-

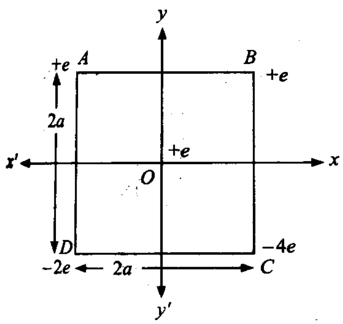
(A) > T
(B) < T
(C) T
(D) Proportional to its amplitude

ANSWER-KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	A	A	C	C	A	A	B	D	B	D	B	B	C	C	C
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	B	D	B	B	B	D	D	A	B	C	D	C	A	A	B
Que.	31	32	33												
Ans.	B	D	B												

EXERCISE#3

Q.1 **For a system of four charges shown in the fig. (Arranged at the four corners of a square of side 2a), the resulting electrostatic force on the charge at the origin O will make an angle q with Oy' axis where tanq is**



(A) 1/4

(B) 1/3

(C) 1/2

(D) 1

Q.2 **A large disc (centered at origin) of uniform surface charge density s is lying in x–y plane. What is electric field at a point (0, 0, 5)–**

(A) $\frac{\sigma}{2\varepsilon_0}\,\hat{k}$

(B) $\frac{\sigma}{2\varepsilon_0}\,(-\,\hat{k}\,)$

(C) $\frac{\sigma}{2\varepsilon_0}\,\hat{i}$

(D) $\frac{\sigma}{2\varepsilon_0}\,\hat{j}$

Q.3 **A long string with charge per unit length l on it passes through a cube of side a. The minimum flux through the cube is–**

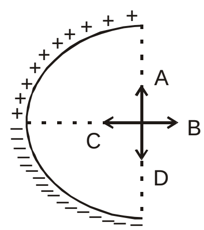
(A) $\frac{\lambda a}{\varepsilon_0}$

(B) $\frac{\sqrt{2}\lambda a}{\varepsilon_0}$

(C) $\frac{\sqrt{3}\lambda a}{\varepsilon_0}$

(D) $\frac{2\lambda a}{\varepsilon_0}$

Q.4 **Charge density on upper half is l and in lower half charge density is – l. Direction of electric field at O is–**



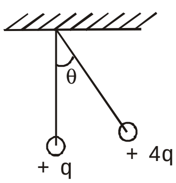
(A) Along OA

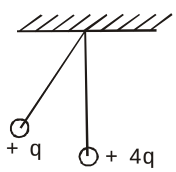
(B) Along OB

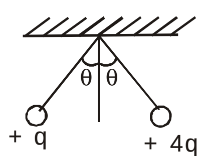
(C) Along OC

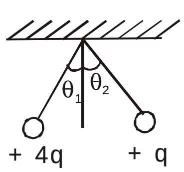
(D) Along OD

Q.5 **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 diagrams best shows the resulting positions of spheres**

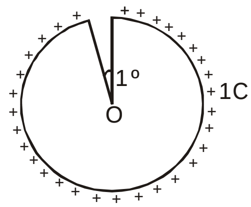
(A) 

(B) 

(C) 

(D) 

Q.6 **A small arc subtending angle 1° is cut from a uniformly charged ring of radius 1m and charge 1C. The electric field at 6the centre due to the remaining part will be –**



R = 1m

(A) 25×10^6 N/C
(B) Zero
(C) 25×10^7 N/C
(D) 25×10^8 N/C

Q.7 **A large nonconducting charged surface of charge density s covers the yz plane with charge density +s. C/m² . What is force acting on a q_2 charge situated at (–4, 2, 4) :**

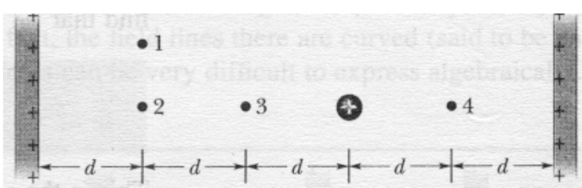
(A) $\frac{\sigma}{2\varepsilon_0} q_0 \hat{i}$

(B) $\frac{-\sigma}{2\varepsilon_0} q_0 (\hat{i})$

(C) $\frac{\sigma}{2\varepsilon_0} q_0 \hat{j}$

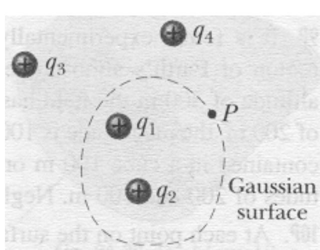
(D) $\frac{-\sigma}{2\varepsilon_0} q_0 (\hat{j})$

Q.8 **The figure shows two large, parallel, nonconducting sheets with identical (positive) uniform surface charge densities, and a point charge with a (positive) charge. The correct order of magnitude of electric field at 1, 2, 3, 4 is**



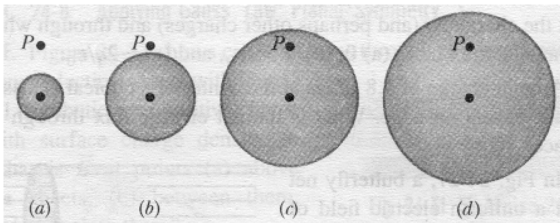
(A) $E_3 = E_4 < E_2 < E_1$
(B) $E_3 = E_4 > E_2 > E_1$
(C) $E_1 = E_2 > E_3 > E_4$
(D) None of these

Q.9 **In Fig. a full Gaussion surface encloses two of the four positively charged particles. Which of the particles contribute to the electric field at point P on the surface ?**



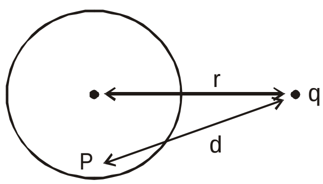
(A) q_1 only
(B) q_2 only
(C) q_1 and q_2 only
(D) q_1, q_2, q_3 and q_4

Q.10 Figure shows four spheres, each with charge Q uniformly distributed through its volume. The figure also shows a point P for each sphere, all at the same distance from the centre of the sphere. In Which case electric field at p is greatest –



(A) case a
(B) case c
(C) case d
(D) In all cases electric field will be same

Q.11 A charge q is placed is placed at r distance from the centre of a hollow conducting sphere. The electric field at a point P, (inside the conductor) which is d distance apart from q is –



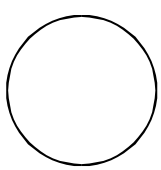
(A) Zero

(B) $\frac{kq}{d^2}$

(C) kq $\left(\frac{1}{d^2} - \frac{1}{r^2}\right)$

(D) kq $\left(\frac{1}{r^2} - \frac{1}{d^2}\right)$

Q.12 1 mC charge is uniformly distributed on a spherical shell given by $x^2 + y^2 + z^2 = 25$. What will be intensity of electric field at a point (1, 1, 2) –

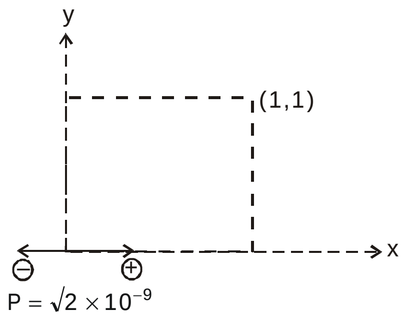


(A) 5 N/C
(B) 45 N/C

(C) $\frac{5\sqrt{3}}{2}$ N/C

(D) Zero

Q.13 **A small dipole of dipole moment $\sqrt{2} \times 10^{-9}$ c–m is placed at origin as shown. What is the magnitude of the electric field at a point (1, 1) in the plane –**



(A) $\frac{9\sqrt{3}}{2\sqrt{2}}$ N

(B) $\frac{9\sqrt{2}}{2\sqrt{3}}$ N

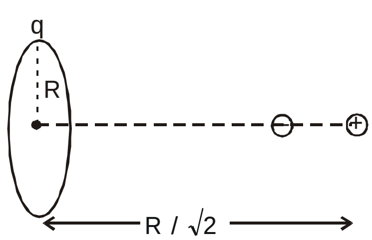
(C) $\frac{9}{2}$ N

(D) Zero

Q.14 **A dipole is fixed along x–axis, and is centered at origin. What is work done to move a point charge of 1 μC from (0, –3) to (0, 4)**

(A) 20 J
(B) 10 J
(C) Zero
(D) None of these

Q.15 **A small dipole of dipole moment P is placed along the axis of a ring of charge q and Radius R. What is force of interaction between the dipole and the ring if the dipole is placed at $\frac{R}{\sqrt{2}}$ away from the center of the ring. (Hint. : Electric field of the ring is maximum at x = $\frac{R}{\sqrt{2}}$)**



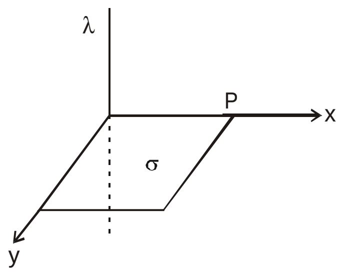
(A) $\frac{kqP}{R^2}$

(B) $\frac{kqP}{3R^2}$

(C) $\frac{kqP}{5R^2}$

(D) Zero

Q.16 **Surface charge density s is spread uniformly in xy plane. A line charge of charge density l is lying along z–axis. A point charge q is placed at a point (5,3,5). What is electric field intensity at a point (0,3,5).**



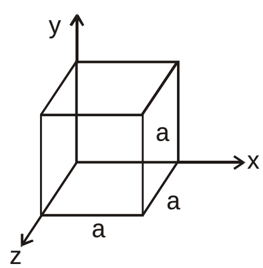
(A) $\frac{\sigma}{2\varepsilon_0}\hat{k} + \frac{\lambda}{6\pi\varepsilon_0}\hat{j} - \frac{q}{100\pi\varepsilon_0}\hat{i}$

(B) $\frac{\sigma}{2\varepsilon_0}\hat{k} - \frac{\lambda}{6\pi\varepsilon_0}\hat{j} + \frac{q}{100\pi\varepsilon_0}\hat{i}$

(C) $\frac{\sigma}{2\varepsilon_0}\hat{k} + \frac{\lambda}{6\pi\varepsilon_0}\hat{j} + \frac{q}{100\pi\varepsilon_0}\hat{i}$

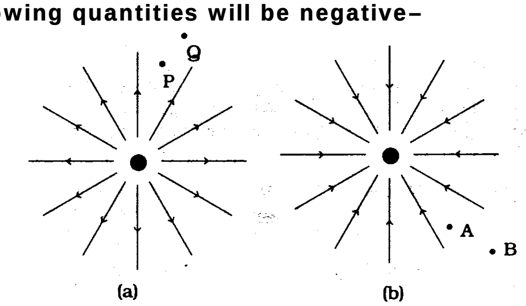
(D) $\frac{\sigma}{2\varepsilon_0}\hat{k} - \frac{\lambda}{6\pi\varepsilon_0}\hat{j} - \frac{q}{100\pi\varepsilon_0}\hat{i}$

Q.17 **A cube of size (a × a × a) is placed such that one of its corner is at origin. There exists an electric field, which various according to x and y as E = $a(3x\hat{i} + 4y\hat{j})$. Find charge enclosed by the cubic surface.**



(A) $7 \propto a^2 \varepsilon_0$
(B) $7 \propto a^3 \varepsilon_0$
(C) $7 \propto a^5 \varepsilon_0$
(D) None

Q.18 **Figure shows field lines due to single positive and negative charge which of the following quantities will be negative–**



(A) $V_B - V_A$
(B) (PE of an electron at Q) – (PE of an electron at P)

(C) Work done by external forces to move a +ve charge from A to B.

(D) Work done by electric forces to move a –ve charge from B to A.

Q.19 **A infinitely large linear charge of charge density $\lambda = 10\ \mu C/m$ is placed along Z–axis. What is work done required to take an α–particle from (2, 5, 4) to (5, – 2, 10) :**

(Hint : Think about equipotential surface)

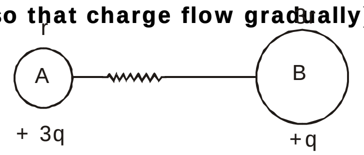
(A) 10 μJ

(B) 20 μJ

(C) 30 μJ

(D) Zero

Q.20 **Two conducting sphere A and B of radius r and 3r, having initial charges 3q and q respectively are placed far apart. If they are joined by a high resistance wire (so that charge flow gradually), the charge will flow–**



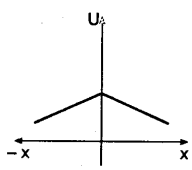
(A) From A to B

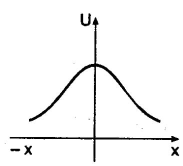
(B) From B to A

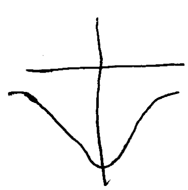
(C) Initially from A to B, then from D to A

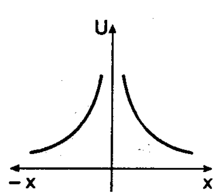
(D) Charge will not flow at all.

Q.21 **Four equal charges +q are placed at four corners of a square with its centre at origin are lying in y–z plane. The electrostatic potential energy (U) of a fifth charge –Q varies on x–axis as.**

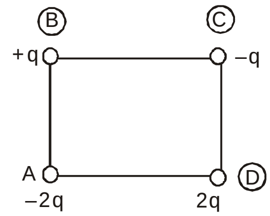
(A) 

(B) 

(C) 

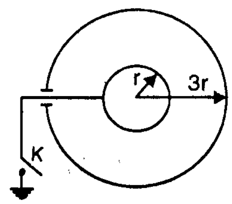
(D) 

Q.22 Four charges are placed at corners of a square. The electric field at centre of square is –



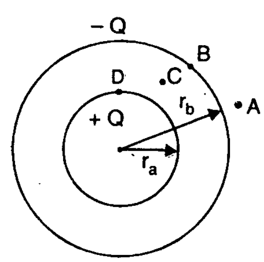
(A) Zero
(B) Along AC
(C) Along BD
(D) Perpendicular to AB

Q.23 Figure shows two conducting thin concentric shells of radii r and 3r. The outer shell carries charge q and inner shell is neutral. The amount of charge which flows from inner shell to the earth after the key K is closed, is equal to



(A) –q/3
(B) q/3
(C) 3q
(D) –3q

Q.24 A small conducting sphere of radius r_a is placed inside an equal and oppositely charged conducting shell of r_b. Four points A, B, C and D are shown in figure. Choose the wrong statement.

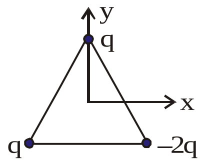


(A) $V_A = 0$
(B) $V_B = 0$
(C) $V_C = 0$
(D) $V_0 = \frac{1}{4\pi\varepsilon_0}.Q(1/r_a - 1/r_b)$

Q.25 A point charge +q is at a distance r from the centre at an uncharged conducting hollow sphere of inner radius R_1 and outer radius R_2. The electric potential at centre of sphere will be –

(A) $\frac{kq}{r}$ if $r > R_2$
(B) $kq\left(\frac{1}{r} - \frac{1}{R_1} + \frac{1}{R_2}\right)$ if $r < R_1$
(C) Both A and B
(D) Zero

Q.26 **An equilateral triangle wire frame of side L having three point charge at its vertices, is kept in xy plane as shown. Component of electric field due to the configuration in z–direction at (0, 0, 2) is (origin is the centroid of the triangle)**



(A) $\frac{9\sqrt{3}\,Kq}{8L^2}$

(B) Zero

(C) $\frac{9Kq}{8L^2}$

(D) None

Q.27 **A charge of uniform density s = 0.3 nC/m² covers the plane 2x – 3y + z = 6m. What is E (electric field) at origin.**

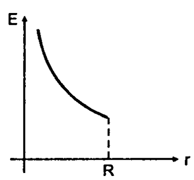
(A) $\frac{17}{\sqrt{14}}(-2\hat{i}+3\hat{j}+\hat{k})$

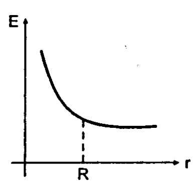
(B) $\frac{17}{\sqrt{14}}(-2\hat{i}+3\hat{j}+\hat{k})$

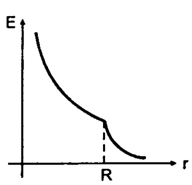
(C) $\sqrt{112}\,(\hat{i}+2\hat{j}-\hat{k})$

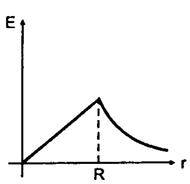
(D) None of these

Q.28 **A conducting shell of radius R carries charge –Q. A point charge +Q is placed at the centres. The electric field E varies with distance r (from the centre of the shell) as**

(A) 

(B) 

(C) 

(D) 

Q.29 **A dipole is placed at the centre of nonconducting spherical shell of radius r. If the shell is uniformly charged by a surface charge density σ, then the interaction energy between the shell and dipole will be–**

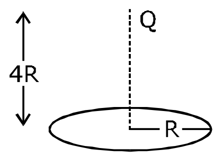
(A) $\frac{6p}{4\varepsilon_0}$

(B) $\frac{6}{\varepsilon_0}\ \frac{p}{r}$

(c) Zero

(D) $\frac{6p}{\varepsilon_0 r^2}$

Q.30 **A charge Q is fixed at a distance 4R above the centre of a disc of radius R. The magnitude of flux through the disc is ϕ. Now a hemispherical shell is placed on the disc to form a closed surface. What will be the flux through the curved surface taking direction of area vector along outward direction positive**



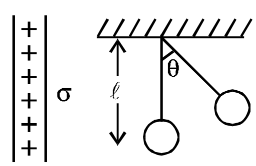
(A) Zero

(B) – ϕ

(C) ϕ

(D) 2 ϕ

Q.31 **Simple pendulum of length ℓ and bob mass m is hanging in front of a large charged nonconducting sheet having surface charge density σ. If suddenly charge q is given to the bobs and it is released from rest vertically, what will be maximum angle through which the string will deflect from vertical :**



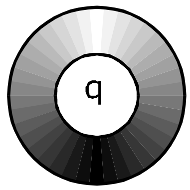
(A) $\tan^{-1}\left(\frac{\sigma q}{2\varepsilon_0 mg}\right)$

(B) $\tan^{-1}\left(\frac{\sigma q}{4\varepsilon_0 mg}\right)$

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

(D) $2\tan^{-1}\left(\frac{\sigma q}{4\varepsilon_0 mg}\right)$

Q.32 **A point charge q is located at the centre of a hollow spherical conductor having inner radius R_1 and outer radius R_2. The conductor being uncharged initially. The potential at inner surface is–**



(A) $\frac{Kq}{R_2}$

(B) KQ $\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$

(C) KQ $\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

(D) None of these

Q.33 **The electric potential at points A and B, distant r apart are + V & –V respectively. The average electric fields between them will be**

(A) V/r
(B) 2V/r
(C) V/2r
(D) 3V/2r

Q.34 **Three charges –q, + q & +q are situated in x–y plane at points (0,–a), (0, 0) & (0, a) respectively. The potential at a point distant r (r > a) in a direction making an angle q from y axis will be**

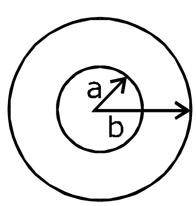
(A) $\frac{Kq}{r}\left(1+\frac{2a\cos\theta}{r}\right)$

(B) $\frac{Kq}{r}\left(1-\frac{2a\cos\theta}{r}\right)$

(C) $Kq\frac{2\cos\theta}{r^2}$

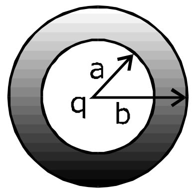
(D) None of these

Q.35 **If the electric potential at outer sphere is 5V and inner sphere is 10V, then the potential at the centre is–**



(A) Zero
(B) 10 volt
(C) 5 volt
(D) 15 volt

Q.36 **As shown in the figure, a point charge q is placed at a centre of a hollow neutral conducting spheral shell of inner radius a and outer radius b. The electric potential energy of the system will be–**



(A) 0

(B) $\frac{kq^2}{2a}$

(C) $\frac{kq^2}{2b} - \frac{kq^2}{2a}$

(D) $\frac{kq^2}{a} - \frac{kq^2}{b}$

Q.37 In the previous question, the interaction energy between the sphere and the charge will be–

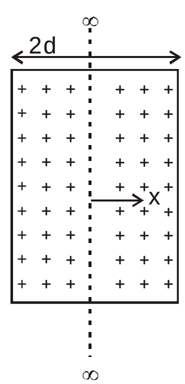
(A) 0

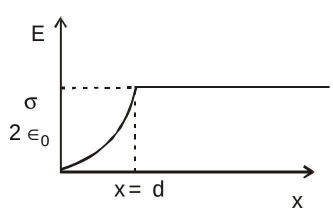
(B) $-\frac{kq^2}{a}$

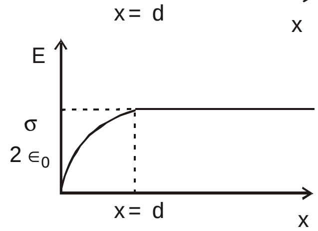
(C) $\frac{kq^2}{2a} - \frac{kq^2}{2b}$

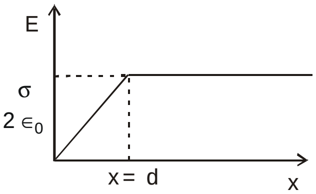
(D) None of these

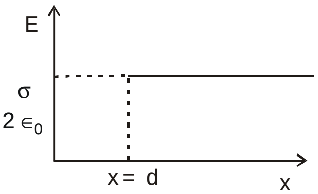
Q.38 Figure shows a cross section of a uniformly charged nonconducting plate of the thickness 2d and which is spread on yz plane. The electric field at a distance x from the central axis v/s x will be–



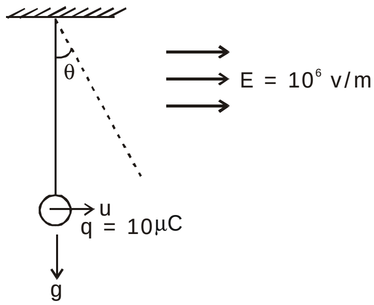
(A) 

(B) 

(C) 

(D) 

Q.39 **A ball of mass 1 kg and charge 10 μC is hanging vertically from a support O. A horizontal electric field E = 10^6 v/m is switched on. If the ball is given sufficient velocity to complete a full circle, at what q, the velocity of ball will be minimum–**



(A) 45º

(B) 90º

(C) 180º

(D) 225º

Q.40 **In the previous question, tension will be maximum for q =**

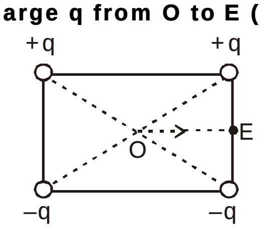
(A) 45º

(B) 90º

(C) 180º

(D) 225º

Q.41 **Four charges are placed on the corners of a square of side a, work-done in carrying a charge q from O to E (the middle of BC) will be–**



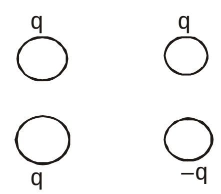
(A) $\frac{4eq}{4\pi\varepsilon_0 a}\left(1-\frac{1}{\sqrt{5}}\right)$

(B) $\frac{4eq}{4\pi\varepsilon_0 a}\ (1 + \sqrt{5}\,)$

(C) $\frac{4eq}{4\pi\varepsilon_0 a}\ (\sqrt{5}\ - 1)$

(D) 0

Q.42 **Charges q and q are given to the conducting shells in fig. (i) and q, – q are given in fig. (ii)**



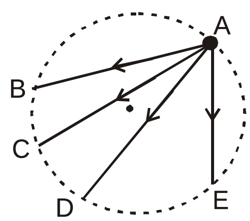
(A) Force of interaction in fig (i) > force of interaction in fig. (ii)

(B) Force of interaction in fig. (i) < force of interaction in fig. (ii)

(C) Force will be same.

(D) Nothing can be said.

Q.43 **In an electric field produced by a charge q placed at centre of a circle, the work done in carrying another charge A to B, C, D, E will be–**



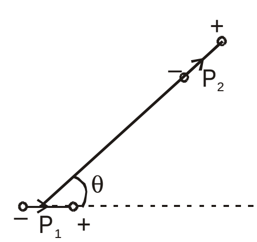
(A) Minimum along path AB

(B) Minimum along AC

(C) Minimum along AE

(D) Same along all the paths

Q.44 **Two small dipoles with dipole moments P_1 and P_2 are placed at large distance r such that angle between P_1 and P_2 is θ. The energy of interaction between there dipoles is (Hint : Potential due to dipole = $\frac{p\cos\theta}{4\pi e_0 r^2}$**



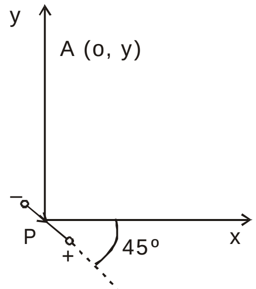
(A) $-\frac{2P_1P_2\cos\theta}{4\pi\varepsilon_0 r^3}$

(B) $-\frac{P_1P_2\cos\theta}{4\pi\varepsilon_0 r^3}$

(C) $-\frac{2P_1P_2\sin\theta}{4\pi\varepsilon_0 r^3}$

(D) $\frac{2P_1P_2\cos\theta}{4\pi\varepsilon_0 r^3}$

Q.45 **A small dipole is placed at origin such that its dipole moment $\vec{p}$ makes 45° with x–axis as shown. The electric field at a point A(0, y) will be–**



(A) $\frac{P}{4\pi\varepsilon_0(\sqrt{3}y^3)}(-\hat{i}-\hat{j})$

(B) $\frac{P}{4\pi\varepsilon_0(\sqrt{3}y^3)}(-\hat{i}+\sqrt{2}\,\hat{j})$

(C) $\frac{P}{4\pi\varepsilon_0 y^3}(-\hat{i}-2\hat{j})$

(D) $\frac{P}{4\pi\varepsilon_0(2y^3)}(-\hat{i}-2\hat{j})$

Q.46 **A charge q is uniformly distributed in a hollow sphere of radius r_1 & r_2 ($r_2 > r_1$) The electric field at a point P distance x from the centre for $r_1 < x < r_2$ is**

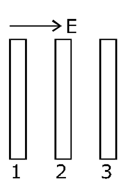
(A) $\frac{Q(x)}{4\pi\varepsilon_0\left(r_2^3-r_1^3\right)}$

(B) $\frac{Q\left(x^3-r_1^3\right)}{4\pi\varepsilon_0\left(r_2^3-r_1^3\right)}$

(C) $\frac{Q\left(x^3-r_1^3\right)}{4\pi\varepsilon_0\,x^2\left(r_2^3-r_1^3\right)}$

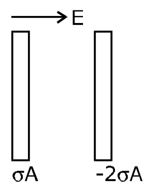
(D) $\frac{Q\left(r_1^3\right)}{4\pi\varepsilon_0\,x^2\left(r_2^3-r_1^3\right)}$

Q.47 **Three uncharged large conducting plates are placed parallel to each other. If an external uniform electric field E is applied perpendicular to plate surfaces, what will be induced surface charge density at left free surface of plate.**



(A) $-\varepsilon_0 E$
(B) $-2\varepsilon_0 E$
(C) $2\varepsilon_0 E$
(D) $-\frac{\varepsilon_0 E}{2}$

Q.48 **Two conducting plates (large) are placed parallel to each other, one placed in a uniform external electric $\vec{E}$ field as shown. Surface charge density on the right surface of second plate will be –**



(A) $\varepsilon_0 E - \frac{\sigma}{2}$

(B) $\varepsilon_0 E + \frac{\sigma}{2}$

(C) $-\sigma$

(D) None of these

Q.49 **In a region of, charged space, the electric field is in the x direction and is given by $\vec{E} = E_0 x\hat{i}$ consider an imaginary cubical volume of edge a, with all edges parallel to coordinate–axes. The charge inside the imaginary cubical volume will be.**

(A) Zero

(B) $\varepsilon_0 E_0 a^2$

(C) $\frac{1}{\varepsilon_0} E_0 a^2$

(D) $\frac{1}{6} \varepsilon_0 E_0 a^2$

Q.50 **A solid metallic sphere has a charge + 3Q. Concentric with this sphere is a conducting thin spherical shell having charge – Q. The radius of the sphere is a and that of the spherical shell is b (> a). What is the electric field at a distance r (a < r < b) from the centre ?**

(A) $\frac{Q}{2\pi\varepsilon_0 r^2}$

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

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

(D) None

Q.51 **In a certain region of space, the potential is given by : $V = k[2x^2 - y^2 + z^2]$. The electric field at the point (1, 1, 1) has magnitude equals to–**

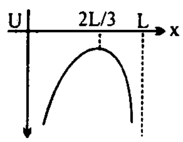
(A) $k\sqrt{6}$

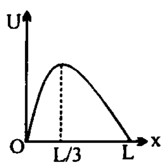
(B) $2k\sqrt{6}$

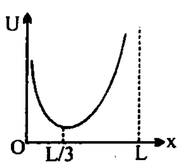
(C) $2k\sqrt{3}$

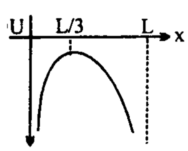
(D) $4k\sqrt{3}$

Q.52 **Two positive charge +Q and +4Q are placed at the ends of a straight line of length L. A negative charge –Q is placed between the first two charges on the straight line at a distance 'x' (0 < x < L) from the charge +Q. Then, the graph of)electrostatic potential energy) of the system of three charges versus x is**

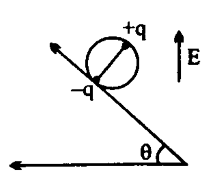
(A) 

(B) 

(C) 

(D) 

Q.53 **A wheel having mass m has charges +q and –q on diametrically opposite points. It remains in equilibrium on a rough inclined place in the presence of uniform vertical electric field E equal to**



(A) $\frac{mg}{q}$

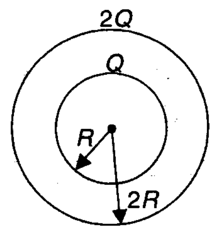
(B) $\frac{mg}{2q}$

(C) $\frac{mg\tan\theta}{2q}$

(D) None

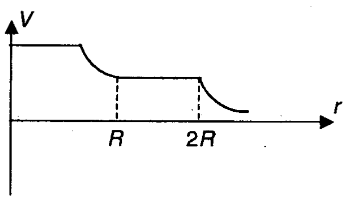
Read the following write - up and answer question no. 54 to 57 based on that

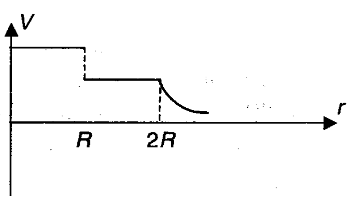
Inside a charged conducting spherical shell electric potential at any point is $\frac{Kq}{R}$ and at a point outside the shell the potential $\frac{Kq}{r}$. Electric field inside the shell at any point is zero and outside it, field is $\frac{Kq}{r^2}$. Here K is $\frac{1}{4\pi \epsilon_0}$. R is the radius of shell and r the distance from center of shell.

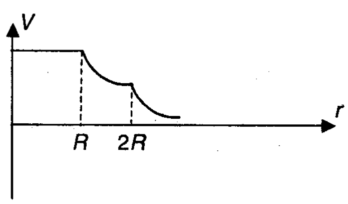


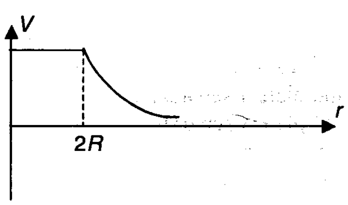
Two concentric spherical shell of radii R and 2R have charges Q and 2Q.

Q.54 If we draw a graph between electric potential V and distance r from the center, the graph will be like:

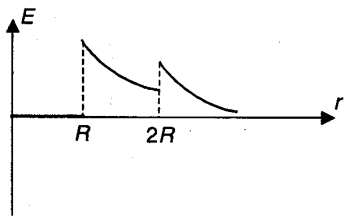
(A)


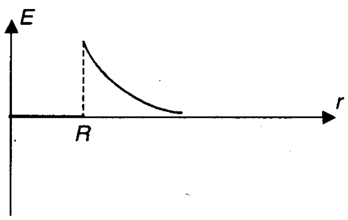
(B)


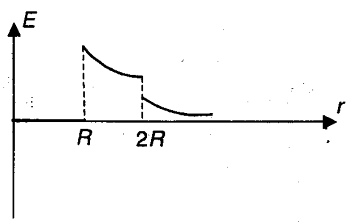
(C)


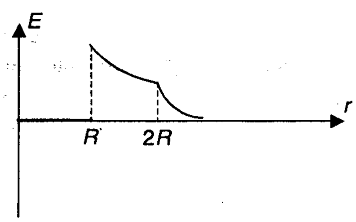
(D)


Q.55 **If we draw a graph between electric field E and distance r from the center, it will be like.**

(A)


(B)


(C)


(D)


Q.56 **Choose the correct option.**

(A) At a distance r (R < r < 2R) from the centre electric potential is $\frac{KQ}{R}$.

(B) At the same distance electric field is $\frac{KQ}{r^2}$

(C) Both (A) and (B) are correct.

(D) Both (A) and (B) are wrong.

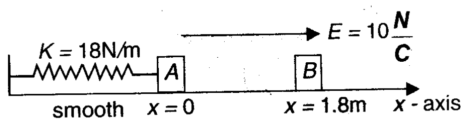
Q.57 **Match the followings :**

List I	**List II**
(p) σ^2/ϵ_0	(i) $C^2/J-m$
(q) ϵ_0	(ii) Farad
(r) $\frac{\text{ampere}-\text{second}}{\text{Volt}}$	(iii) J/m^3
(s) $\frac{V}{E}$	(iv) Meter

(A) (p) - (ii); (q) - (i); (r) - (iv); (s) - (iii)
(B) (p) - (iii); (q) - (i); (r) - (ii); (s) - (iv)
(C) (p) - (ii); (q) - (iii); (r) - (i); (s) - (iv)
(D) (p) - (iii); (q) - (ii); (r) - (i); (s) - (iv)

Read the following write - up and answer question no. 58 to 60 based on that

In the figure shown $m_A = m_B = 1$ kg. Block A is neutral while $q_B = -1$ C. Sizes of A and B are negligible. B is released from rest at a distance 1.8 m from A. Initially spring is neither compressed nor elongated.



Q.58 If collision between A and B is perfectly inelastic, what is velocity of combined mass just after collision.

(A) 6 m/s

(B) 3 m/s

(C) 9 m/s

(D) 12 m/s

Q.59 Equilibrium position of the combined mass is at x = ... m.

(A) $-\frac{2}{9}$

(B) $-\frac{1}{3}$

(C) $-\frac{5}{9}$

(D) $-\frac{7}{9}$

Q.60 The amplitude of oscillation of the combined mass will be :

(A) $\frac{2}{3}$ m

(B) $\frac{\sqrt{124}}{3}$ m

(C) $\frac{\sqrt{72}}{9}$ m

(D) $\frac{\sqrt{106}}{9}$ m

Assertion - Reason Type Questions

The following questions consist of two statements one labelled Assertion (A) and the another labelled Reason (R). Select the correct answers to these questions from the codes given below :

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

(B) Both A and R are true but R is not correct explanation of A

(C) A is true but R is false

(D) A is false but R is true.

(E) A and R both are false

Q.61 **Assertion :** When initial velocity of an electron is at right angles to the electric field, then the path of electron in this field, will be parabola.

Reason : Acceleration of electron will be in a direction opposite to electric field. The electron acst like a projection whose path is a parabola.

Q.62 **Assertion :** Electric potential at a point on equatorial line of an electric dipoe is half the potential at a point at the same distance on axial line of dipole.

Reason : The Assertions true for electric intensity due to the dipole.

Q.63 **Assertion :** Due to an infinite uniform line of charge, potential at a point distant r from the line is proportional to log r.

Reason : $E \propto \frac{1}{r}$ and $E = -\frac{dV}{dr}$

Q.64 **Assertion :** The smallest charge that can exist in nature is the charge of an electron.

Reason : It has been discovered that the elementary particles such as proton or neutron are composed of quarks having charges $\left(\pm\frac{1}{3}e\right)$ and $\left(\pm\frac{2}{3}e\right)$.

Q.65 **Assertion :** Two similarly charged bodies may attract each other.

Reason : When charge on one body (Q) is much greater than that on another (q) and they are closed enough to each other then force of attraction between Q and induced charges exceeds the force of repulsion between Q and q.

Q.66 **Assertion :** If the electric field intensity $\vec{E}$ is zero at a point, then electric potential is not necessary zero at that point.

Reason : Electric field is zero at a point exactly midway between two equal and similar charge.

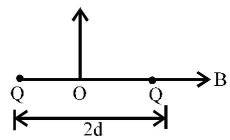
Q.67 **Assertion :** Electric potential is constant on the surface of charged conductor.

Reason : Inside the charged conductor electric field intensity is zero.

Q.68 **Assertion :** A positive point charge is brought in an electric field, the electric field at nearby point will increase.

Reason : Electric field produce by charge may favour the existing electric field.

Q.69 **Assertion :** Consider two identical charges placed distance 2d apart, along x-axis. The equilibrium of a positive test charge placed at the point O midway between them is stable for displacements along the x-axis.



Reason : Force on test charge is zero.

Q.70 **Assertion :** An ellipsoidal cavity is carved within 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. Potential at A = potential at B.

Reason : Surface of charge conductor is always equipotential.

Q.71 **Assertion :** Charges Q_1 and Q_2 are placed inside and outside respectively of an uncharged conducting shell, their separation is r. Then the force on Q_1 is zero.

Reason : Lines of force cannot enter conducting shell.

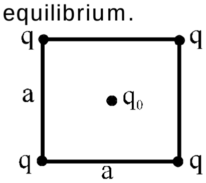
Q.72 **Assertion :** If electric field is zero at same point, potential must be zero.

Reason : $E = -\frac{dv}{dr}$

Q.73 **Assertion :** A small metal ball is suspended in a uniform electric field with an insulated thread. If high energy X-ray beam falls on the ball, the ball will be deflected in the electric field.

Reason : X-rays beam falls on the ball, the ball will be deflected in the magnetic field.

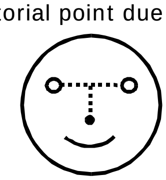
Q.74 **Assertion :** q_0 is in stable equilibrium.



Reason : No particle can be in stable equilibrium under the action of electrostatic forces alone.

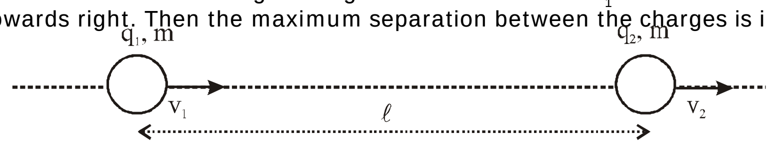
Q.75 **Assertion :** The smiling face consists of three items a thin rod of charge 3μc that forms a full circle of radius 8 cm, a second thin rod of charge 2 μc that forms a circular arc of radius 4 cm. subtending an angle of 90° about the centre of the full circle, an electric dipole with a dipole moment that is perpendicular to a radial line and that has magnitude 1.28×10^{-21} C-m, electric potential at centre is zero.

Reason : Potential on equatorial point due to dipole is zero



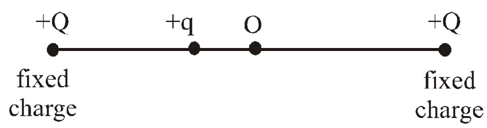
Q.76 **Assertion :** An isolated system consists of two particles of equal masses m = 10 gm and charges

$q_1 = +1\mu C$ and $q_2 = -1\mu C$ as shown in figure. The initial separation of both charges is ℓ = 1m. Both the charges are given initial velocities v_1 = 1 m/s and v_2 = 2 m/s towards right. Then the maximum separation between the charges is infinite.



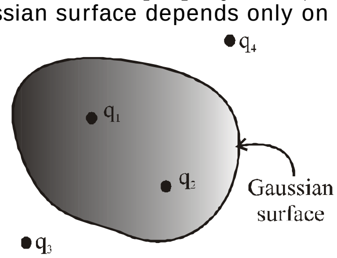
Reason : The total energy (Kinetic energy + electrostatic potential energy) of given two particle system is positive and initial velocity of separation is positive.

Q.77 **Assertion :** Two point charges +Q are fixed some distance apart. O is a point exactly in middle of both fixed charges. A charge +q is released from rest at a certain distance left of O as shown in figure. The speed of charge +q is maximum at O.



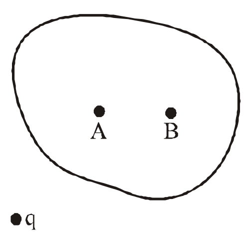
Reason : The speed of moving particle is maximum at stable equilibrium position.

Q.78 **Assertion :** Four point charges q_1, q_2, q_3 and q_4 are as shown in figure. The flux over the shown Gaussian surface depends only on charges q_1 and q_2.



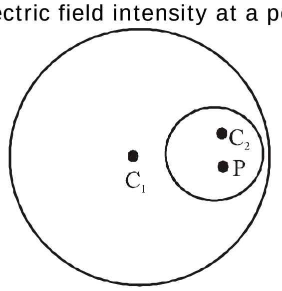
Reason : Electric field at all points on Gaussian surface depends only on charges q_1 and q_2.

Q.79 **Assertion :** A point charge q is placed near an arbitrary shaped solid conductor as shown in figure. The potential difference between the points A and B within the conductor remain same irrespective of the magnitude of charge q.



Reason : The electric field inside a solid conductor is zero.

Q.80 **Assertion :** Inside a uniformly charged non-conducting solid sphere, there is a spherical cavity. The electric field intensity at a point inside the cavity is zero.



Reason : For a Gaussian surface completely inside the cavity, the net flux is zero.

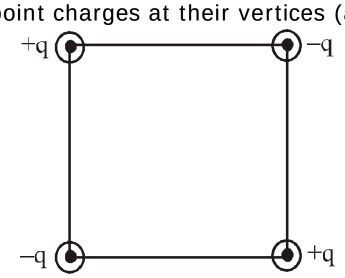
Q.81 **Assertion :** When a negative charge –q is released at a distance R from the centre and along the axis of a uniformly and positively charged fixed ring of radius R, the negative charge does oscillation but not SHM.

Reason : The acceleration on negative charge is always towards the centre of the ring but it is not proportional to the displacement from the centre of the ring.

Q.82 **Assertion :** An insulator does not conduct electricity usually.

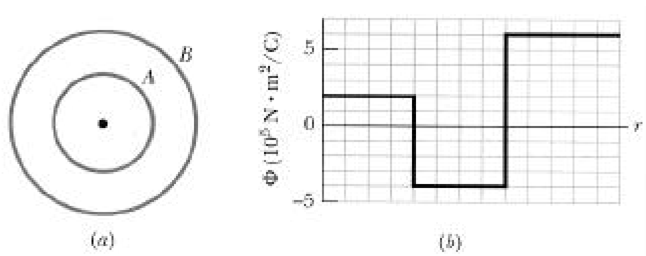
Reason : The number of electrons in an insulator is very small in comparison to that in a conductor.

Q.83 **Assertion :** The electric potential and the electric field intensity at the centre of a square having four point charges at their vertices (as shown) are zero.



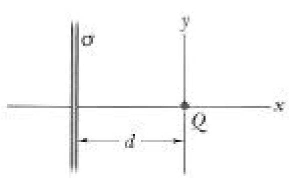
Reason : Electric field is negative derivative of the potential.

Q.84 **Assertion :** A charged particle is suspended at the centre of two concentric spherical shells that are very thin and made of monoconducting material. Figure (a) shows a cross section. Figure (b) gives the net flux through a Gaussian sphere centred on the particle, as a function of the radius r of the sphere. Charge on shell A is negative.



Reason : –ve flux means net charge inside gaussian surface is negative.

Q.85 **Assertion :** Figure shows a very large nonconducting sheet that has a uniform surface charge density of $\sigma = -2.00\ \mu C/m^2$. it also shows a particle of charge $Q = 6.00\ \mu C$, at distance d from the sheet. Both are fixed in place. Other than at infinite distances there are two points on x-axis where electric field will be zero whatever may be the value of d.



Reason : Net electric field will be zero where value due to both charge system is same and in opposite direction.

Q.86 **Assertion :** A man inside an insulated metallic cage does not receive a shock when the cage is highly charged.

Reason : No potential difference exists between the man and the charged cage.

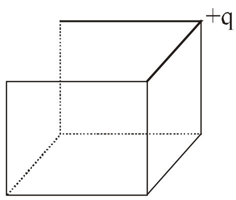
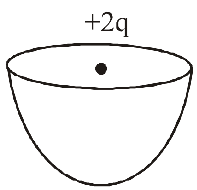
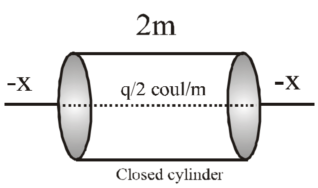
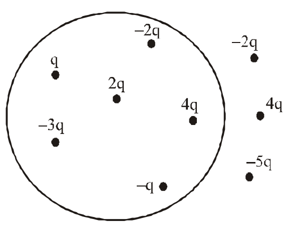
Q.87 **Assertion :** Bits of dry cork dust always stick to an electrically charged rod.

Reason : When an electrically charged rod is brought near bits of dry cork dust, they become charged.

Q.88 **Assertion :** Electric field can be non-conservative.

Reason : Electric field produced due to variation in magnetic field with respect to time is nonconservative.

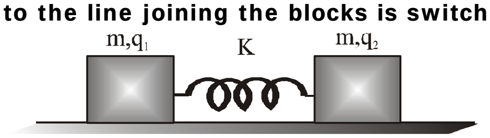
Q.89 Match the column :

Arrangement	Flux through the entire surface of the body.
(A)  (Cube)	(p) $\frac{q}{e_0}$
(B)  (hemisphere)	(q) $\frac{q}{8e_0}$
(C) 	(r) $\frac{q}{4e_0}$
(D)  (sphere)	(s) $\frac{3q}{e_0}$

Q.90 An electric dipole is placed in an electric field. The column I gives the description of electric field and the angle between the dipole moment $\vec{p}$ and the electric field intensity $\vec{E}$ and the column II gives the effect of the electric field on the dipole. Match the description in Column I with the statements in column II.

Column I	Column II
(A) Uniform electric field, $\theta = 0^o$	(p) force = 0
(B) Electric field due to a point charge, $\theta = 0^o$	(q) Torque = 0
(C) Electric field between the two oppositely charged large plates, $\theta = 90^o$	(r) $\vec{p}.\vec{E} = 0$
(D) Dipole moment parallel to uniformly charged long wire.	(s) Force $\neq 0$

Q.91 **Two blocks having equal masses have charges q_1 and q_2 and are connected by a massless spring of spring constant K. A uniform electric field parallel to the line joining the blocks is switched on.**

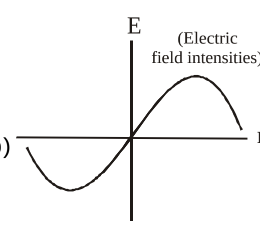
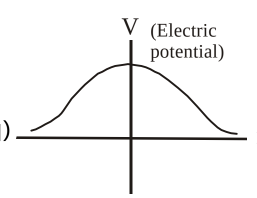
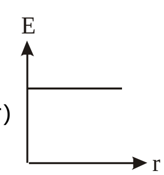
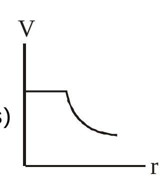


Column I	Column II
(A) $q_1 = q_2$	(p) The blocks will be at rest in centre of mass frame.
(B) $q_1 = -q_2$	(q) The blocks will perform SHM in centre of mass frame.
(C) $q_1 = 2q_2$	(r) The centre of mass of the two blocks will move with non-zero constant acceleration.
(D) $q_1 = -2q_2$	(s) The blocks will perform SHM in ground frame.

Q.92 **Column I describe some phenomenon related to charge match reasoning with column II.**

Column I	Column II
(A) Pair production	(p) Conservation of charge
(B) Annhilation	(q) Conservation of energy
(C) Charge redistribution	(r) Quantisation of charge
(D) Photoelectric effect	(s) Particle nature of light

Q.93 **Column II describe graph for charge distribution given in column I match the description.**

Column I	Column II
(A) Uniformly charged ring	(p) 
(B) Infinitely large charge conducting sheet	(q) 
(C) Infinite non conducting thin sheet.	(r) 
(D) Hollow non conducting sphere.	(s) 

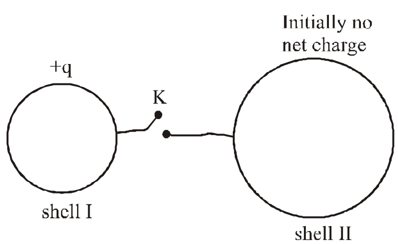
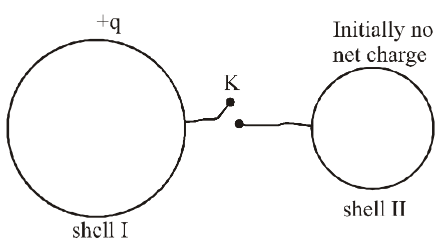
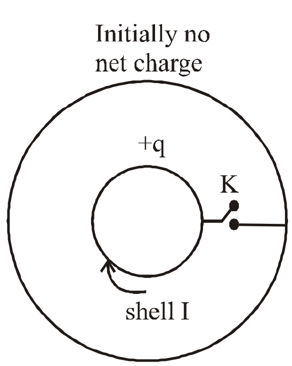
Q.94 Column II give units & dimension related to quantities given in column I match.

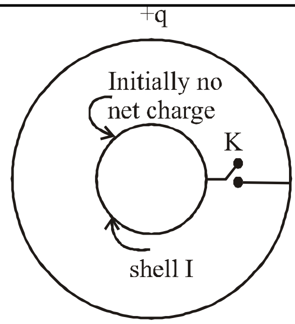
Column I	Column II
(A) Relative Permittivity	(p) Joule/Coulomb
(B) Potential	(q) $ML^2T^{-3}A^{-1}$ (A = current)
(C) Electric field intensity	(r) Unitless
(D) Dielectric constant	(s) $MLT^{-3}A^{-1}$

Q.95 Match the column

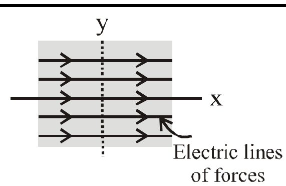
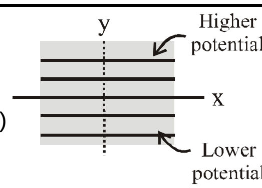
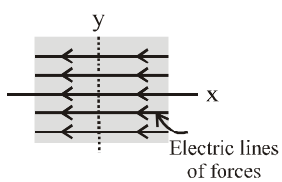
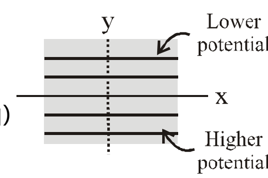
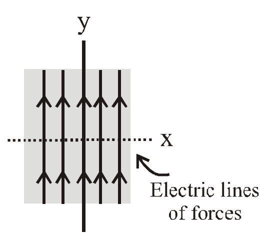
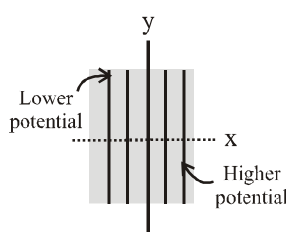
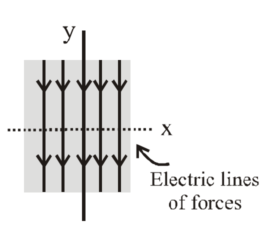
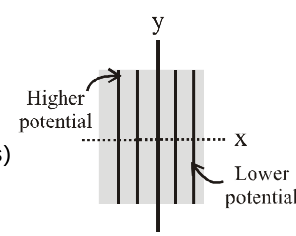
Column I	Column II
(A) Charging of a body	(p) Induction
(B) Charge	(q) Thermionic emission
(C) Due to dipoles of material	(r) Independent on frame of reference
(D) Accelerated charge particle	(s) Radiation

Q.96 Column I gives certain situation involving two thin conducting shells connected by a conducting wire via a key K. In all situations one sphere has net charge +q and other sphere has no net charge. After the key K is pressed, column II gives some resulting effect. Match the figures in Column I with the statements in Column II.

Column I	Column II
(A) 	(p) charge flows through connecting wire
(B) 	(q) Potential energy of system of spheres decreases.
(C) 	(r) No heat is produced

(D) 	(s) The sphere I has no charge after equilibrium is reached

Q.97 Column I gives certain situations in which electric field is represented by electric lines of forces in x-y plane. Column II gives corresponding representation of equipotential lines in xy-plane. Match the figure in Column I with the figures in Column II.

Column I	Column II
(A) 	(p) 
(B) 	(q) 
(C) 	(r) 
(D) 	(s) 

Q.98 Match the column

Column I	Column II
(A) Solid non conducting sphere	(p) Potential at centre = $\frac{3}{2}$ at surface
(B) Infinite non conducting sheet	(q) Absolute potential not defined
(C) Inside hollow non conducting sphere	(r) $\vec{E} = \frac{r\vec{r}}{3e_0}$ r < R
(D) Inside solid conductor	(s) E = 0

Q.99 Match the following :

Column I	Column II
(A) Experimental laws of electrolysis by Faraday.	(p) Conservation of charge.
(B) Charge on electron	(q) Lowest common factor of charge on oil drop.
(C) Pair production when high energy photons enter a thin walled box in vacuum.	(r) Conservation of mass and energy.
(D) Charge of a body is independent of its speed.	(s) Charge is invariant.

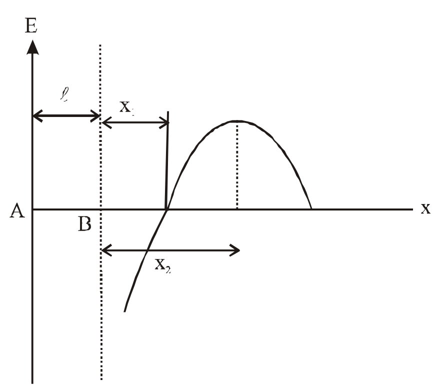
Q.100 Three concentric spherical metallic shells A, B and C of radii a, b and c (a < b < c) have charge densities of s, –s and s respectively, then

Column I	Column II
(A) The potential of A	(p) $\frac{1}{\epsilon_0}\left(\frac{a^2}{c}-\frac{b^2}{c}+c\right)s$
(B) The potential of B	(q) $\frac{1}{\epsilon_0}\left(\frac{a^2}{b}-b+c\right)s$
(C) The potential of C.	(r) $\frac{s}{\epsilon_0}$
(D) The electric field at surface of A.	(s) $\frac{1}{\epsilon_0}(a-b+c)\,s$

Q.101 Match the column –

Column I	Column II
(A) Electric field intensity	(p) Volt/m
(B) Electric potential	(q) debye
(C) Electric flux	(r) Joule/Coulomb
(D) Dipole moment	(s) Volt-m

Q.102 Two points, like charges Q_A and Q_B are positioned at points A and B. The electric field strength to the right of charge Q_B on the line that passes through the two charges varies according to a law that is represented shematically in the figure accompanying the problem without employing a definite scale. Assume electric field to be positive if its direction coincides with the positive direction on the x-axis. Distance between the charges is ℓ.



Column I	Column II
(A) Charge Q_A	(p) –ve
(B) Charge Q_B	(q) +ve
(C) $\|Q_A/Q_B\|$	(r) $\left(\frac{\ell+x_1}{x_1}\right)^2$
(D) x_2	(s) $\frac{\ell}{(Q_A/Q_B)^{1/3}-1}$

Q.103 Two point charges Q and –Q/4 are separated by L

Column I	Column II
(A) Zero potential	(p) L/3 on right side of charge –Q/4
(B) Zero electric field	(q) L/5 on left side of charge –Q/5
(C) Infinite potential	(r) L on right side of charge –Q/4
(D) Infinite electric field	(s) Near charge Q.

Q.104 Match the column

Column I	Column II
(A) Origin of friction electricity	(p) In 600 B.C. (Thales)
(B) The word charge was given by	(q) Dr. William Gillbert
(C) Two kinds of charges	(r) Du Fay
(D) Algebraic sign to charge	(s) Benjamin Frankline

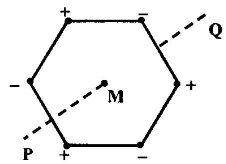
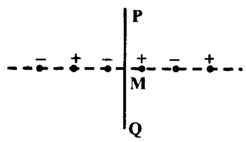
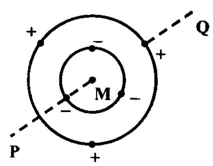
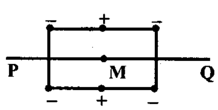
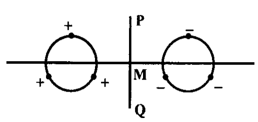
Q.105 Match the column

Column I	Column II
(A) Like charges repels and unlike attracts	(p) Dr. William Gilbert
(B) Numerical value of force between two charges	(q) Thomos Brown
(C) Methods of charging	(r) Coulomb by (torsion balance)
(D) Amount of induced charge	(s) Faraday ice pail exp.

Q.106 Match the column

Column I	Column II
(A) e/m of electron	(p) J.J. Thomson
(B) Charge and mass (indirectly) of electron and quanta of charge.	(q) R.A. millikan (by oil drop exp.)
(C) Concept of line of force	(r) M. Faraday
(D) Highest common factor method	(s) Max Plank

Q.107 Six point charges, each of the same magnitude q, are arranged in different manners as shown in Column II. In each case, a point M and a line PQ passing through M are shown. Let E be the electric field and V be the electric potential at M (potential at infinity is zero) due to the given charge distribution when it is at rest. Now, the whole system is set into rotation with a constant angular velocity about the line PQ. Let B the magnetic field at M and μ be the magnetic moment of the system in this condition. Assume each rotating charge to be equivalent to a steady current.

Column I	Column II	
(A) E = 0	(p) 	Charges are at the corners of a regular hexagon. M is at the centre of the hexagon. PQ is perpendicular to the plane of the hexagon.
(B) $V \neq 0$	(q) 	Charges are on a line perpendicular to PQ at equal intervals. M is the mid-point between the two innermost charges.
(C) B = 0	(r) 	Charges are placed on two coplanar insulating rings at equal intervals. M is the common centre of the rings. PQ is perpendicular to the plane of the rings.
(D) $\mu \neq 0$	(s) 	Charges are placed at the corners of a rectangle of sides a and 2a and at the mid points of the longer sides. M is at the centre of the rectangle. PQ is parallel to the longer sides.
	(t) 	Charges are placed on two coplanar, identical insulating rings at equal intervals. M is the mid points between the centres of the rings PQ is perpendicular to the line joining the centers and coplanar to the rings.

ANSWER-KEY

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

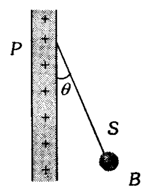
Que.	89				90				91				92			
Ans.	A-p	B-p	C-p	D-s	A-p,q	B-p,s	C-p,r	D-p,r	A-p	B-q,s	C-s	D-p,r,s	A-p	B-p	C-p	D-s
Que.	93				94				95				96			
Ans.	A-p,q	B-r	C-r	D-s	A-r	B-p,q	C-s	D-r	A-p,q	B-p,q	C-p	D-s	A-p,q	B-p,q	C-p,q,s	D-r,s
Que.	97				98				99				100			
Ans.	A-s	B-r	C-q	D-p	A-p,r	B-q	C-s	D-s	A-q	B-q	C-p,r	D-s	A-s	B-q	C-p	D-r
Que.	101				102				103				104			
Ans.	A-p	B-r	C-s	D-p	A-q	B-p	C-r	D-s	A-p,q	B-r	C-s	D-s	A-p	B-q	C-r	D-s
Que.	105				106				107							
Ans.	A-p	B-r	C-q	D-s	A-p	B-q	C-r	D-s	A-p,r,s	B-r,s	C-p,q,t	D-r,s				

EXERCISE#4

Q.1 **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 aways from both. The new force of repulsion between B and C is [AIEEE 2004]**

(A) F/4
(B) 3F/4
(C) F/8
(D) 3F/8

Q.2 **A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged coducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to [AIEEE 2005]**



(A) $\sin\theta$
(B) $\tan\theta$
(C) $\cos\theta$
(D) $\cot\theta$

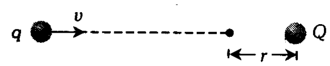
Q.3 **Two point charges +8q and –2q are located at x = 0 and x = L respectively. The location of a point on the x-axis at which the net electric field due to these two point charges is zero is [AIEEE 2005]**

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

Q.4 **Two thin wire rings each having a radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are +Q and –Q. The potential difference between the centres of the two rings is [AIEEE 2005]**

(A) Zero
(B) $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$
(C) $QR/4\pi\varepsilon_0 d^2$
(D) $\frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

Q.5 **A charged particle q is shot towards another charged particle Q which is fixed, with a speed v. It approaches Q upto a closest distance r and then returns. If q were given a speed 2v, the closest distances of approach would be [AIEEE 2004]**



(A) r
(B) 2r
(C) r/2
(D) r/4

Q.6 **Four charges equal to –Q are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium the value of q is [AIEEE 2004]**

(A) $-\frac{Q}{4}\left(1+2\sqrt{2}\right)$

(B) $\frac{Q}{4}\left(1+2\sqrt{2}\right)$

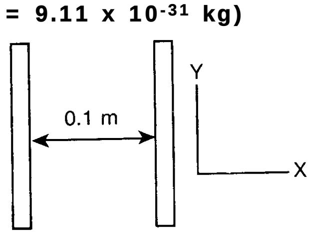
(C) $-\frac{Q}{2}\left(1+2\sqrt{2}\right)$

(D) $\frac{Q}{2}\left(1+2\sqrt{2}\right)$

Q.7 **An electric dipole is placed at an angle of 30^0 to a non- uniform electric field. The dipole will experience. [AIEEE 2006]**
(A) A translational force only in a direction normal to the direction of the field
(B) A torque as well as a translational force
(C) A torque only
(D) A translational force only in the direction of the field

Q.8 **An alpha nucleus for energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to [AIEEE 2006]**
(A) 1/m
(B) $1/v^4$
(C) $1/Z^3$
(D) V^2

Q.9 **Two insulating plates are both uniformly charged in such a way that the potential difference between them is $V_2—V_1$ = 20 V. (i.e. plate 2 is at a higher potential). The plates are separated by d = 0.1m and can be treated as infinitely large. An electron is released from rest on the inner surface of plate 1. What is its speed when it hits plate 2 ?**
(e = 1.6 x 10^{-19} C, m_e = 9.11 x 10^{-31} kg) [AIEEE 2006]



(A) 7.02×10^{12} m/s
(B) 1.87×10^{6} m/s
(C) 32×10^{-19} m/s
(D) 2.65×10^{6} m/s

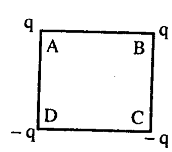
Q.10 **Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of spheres A and B is [AIEEE 2006]**
(A) 1:2
(B) 2 : 1
(C) 1 : 4
(D) 4 : 1

Q.11 **The potential energy of 1 kg particle free to move along the X- axis is given by V (x) = $\left(\frac{X^4}{4} - \frac{X^2}{2}\right)$ J .The total mechanical energy of the particle is 2J. Then, the maximum speed (in m/s) is [AIEEE 2006]**
(A) $\sqrt{2}$
(B) $1/\sqrt{2}$
(C) 2
(D) $3/\sqrt{2}$

Q.12 **An electric charge 10^{-3} μC is placed at the origin (0,0) of X–Y Co-ordinate system.**

Two points A and B are situated at ($\sqrt{2}, \sqrt{2}$) and (2,0) respectively. The potential difference between the points A and B will be
[AIEEE 2007]
(A) 2Volt
(B) 4.5 Volt
(C) 9 Volt
(D) Zero

Q.13 **Charges are placed on the vertices of a square as shown . Let $\vec{E}$ be the electric field and V the potential at the centre. If the charges on A and B are interchanged with those on D and C respectively, then**
[AIEEE 2007]



(A) $\vec{E}$ and V remain unchanged
(B) $\vec{E}$ changes, V remains unchanged
(C) $\vec{E}$ remains unchanged, V changes
(D) Both $\vec{E}$ and V change

Q.14 **The potential at a point X (measured in μm) due to some charges situated on the x axis is given by V (x) = 20/ (x^2 – 4) Volts. The electric field E at x = 4μm is given by [AIEEE 2007]**

(A) 10/9 Volt/μm and in the –ve x direction

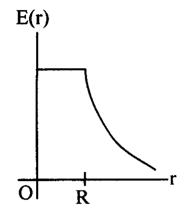
(B) 10/9 volt/μm and in the +ve x direction

(C) 5/3 Volt/μm and in the – ve x direction

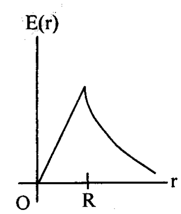
(D) 5/3 volt/μm and in the +ve x direction

Q.15 **A thin sperical shell of radius R has charge Q spread uniformly over its surface. Which of the following graphs most closely represents the electric field E (r) produced by the shell in the range 0 $\leq$ r < ∞ , where r is the distance from the centre of the sell ? [AIEEE 2008]**

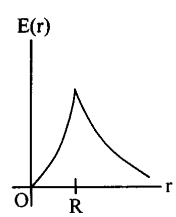
(A)



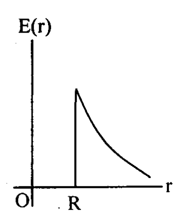
(B)



(C)



(D)



Q.16 **Let P(r) = $\frac{Q}{pR^2}$ r be the charge density distribution for a solid sphere of radius R and total charge Q. For a point 'P' inside the sphere at distance r_1 from the centre of the sphere, the magnitude of electric field is [AIEEE 2009]**

(A) 0

(B) $\frac{Q}{4\pi\varepsilon_0 r_1^2}$

(C) $\frac{Qr_1^2}{4\pi\varepsilon_0 R^4}$

(D) $\frac{Qr_1^2}{3\pi\varepsilon_0 R^4}$

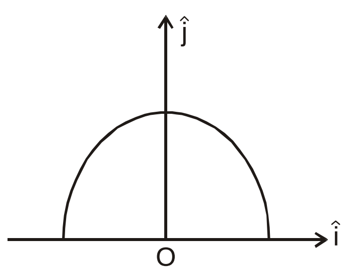
Q.17 **Two points P and Q are maintained at the potentials of 10 V and –4V, respectively. The work done in moving 100 electrons from P to Q is [AIEEE 2009]**

(A) -9.60×10^{-17} J
(B) 9.60×10^{-17} J
(C) -2.24×10^{-16} J
(D) 2.24×10^{-16} J

Q.18 **A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on Q is zero, then Q/q equals [AIEEE 2009]**

(A) $-2\sqrt{2}$
(B) –1
(C) 1
(D) $-\frac{1}{\sqrt{2}}$

Q.19 **A thin semi-circular ring of radius r has a positive charge q distributed uniformly over it. The net field $\vec{E}$ at the centre O is : [AIEEE 2010]**



(A) $\frac{q}{4p^2 e_0 r^2}\hat{j}$

(B) $-\frac{q}{4p^2 e_0 r^2}\hat{j}$

(C) $-\frac{q}{2p^2 e_0 r^2}\hat{j}$

(D) $\frac{q}{2p^2 e_0 r^2}\hat{j}$

Q.20 **Let there be a spherically symmetric charge distribution with charge density verying as r (r) = $r_0\left(\frac{5}{4}-\frac{r}{R}\right)$ upto r = R, and r (r) = 0 for r > R, where r is the distance from the origin. The electric field at a distance r(r<R) from the origin is given by : [AIEEE 2010]**

(A) $\frac{4pr_0 r}{3e_0}\left(\frac{5}{4}-\frac{r}{R}\right)$

(B) $\frac{r_0 r}{4e_0}\left(\frac{5}{3}-\frac{r}{R}\right)$

(C) $\frac{4r_0 r}{3e_0}\left(\frac{5}{4}-\frac{r}{R}\right)$

(D) $\frac{r_0 r}{3e_0}\left(\frac{5}{4}-\frac{r}{R}\right)$

Q.21 **Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30^0 with each other. When suspended in a liquid of density 0.8 g cm^{-3}, the angle remains the same. If density of the material of the sphere is 16 g cm^{-3}, the dielectric constant of the liquid is : [AIEEE 2010]**

(A) 4

(B) 3

(C) 2

(D) 1

Q.22 **The electrostatic potential inside a charged spherical ball is given by $f = ar^2 + b$ where r is the distance from the centre; a, b are constants. Then the charge density inside ball is : [AIEEE 2011]**

(A) $-6a\,e_0 r$

(B) $-24\,p\,a e_0 r$

(C) $-6a\,e_0$

(D) $-24\,p\,a e_0$

Q.23 **Two identical charged spheres suspended from a common point by two massless strings of length are initially a distance d(d<<1) apart because of their mutual repulsion. The charge begins to leak from both the spheres at a constnat rate. As a result the charges approach each other with a velocity v. Then as funciton of distance x between them,**

[AIEEE 2011]

(A) $v \propto x^{-1}$

(B) $v \propto x^{1/2}$

(C) $v \propto x$

(D) $v \propto x^{-1/2}$

Q.24 A positively charged thin metal ring of radius R is fixed in the X – Y plane with its centre at the origin O. A negatively charged particle P is released from rest at the point (0, 0, Z_0) where (Z_0 > 0). Then the motion of P is [IIT 1990]

(A) Periodic for all values of Z_0 satisfying $0 < Z_0 < \infty$

(B) Simple harmonic for all values of Z_0 satisfying $0 < Z_0 \leq R$

(C) Approximately simple harmonic provided $Z_0 << R$

(D) Such that P crosses O and continues to move along the negative Z–axis towards $Z = -\infty$

Q.25 Two point charges +q and –q are held fixed at (–d, 0) and (d, 0) respectively of a (x–y) coordinate system. Then– [IIT–95]

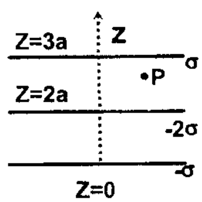
(A) The electric field E at all points on the X–axis has the same direction.

(B) Electric field at all points on Y–axis is along X–axis.

(C) Work has to be done in bringing a test charge from ∞ to the origin.

(D) The dipole moment is 2 qd along X–axis.

Q.26 There infinitely charged sheets are kept parallel to x – y plane having charge densities as shown. Then the value of electric field at 'P' is [IIT Scr. 2005]



(A) $-\frac{4\sigma}{\epsilon_0}\hat{k}$

(B) $\frac{4\sigma}{\epsilon_0}\hat{k}$

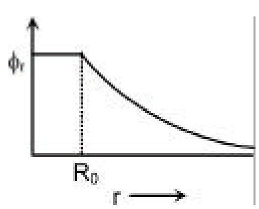
(C) $-\frac{2\sigma}{\epsilon_0}\hat{k}$

(D) $\frac{2\sigma}{\epsilon_0}\hat{k}$

Q.27 The electrostatic potential (f_r) of a spherical symmetric system, kept at origin, is shown in the adjacent figure, and given as [IIT 2006]

$$f_r = \frac{q}{4\pi\epsilon_0 r} \quad (r \ ^3\ 0)$$

$$f_r = \frac{q}{4\pi\epsilon_0 R_0} \quad (r\ £\ 0)$$



Which of the following option(s) is/are correct?

(A) For spherical region $r \leq R_0$, total electrostatic energy stored is zero.

(B) Within $r = 2R_0$, total charge is q.

(C) There will be no charge anywhere except at $r = R_0$.

(D) Electric field is discontinuous at $r = R_0$.

Q.28 A long hollow conducting cylinder is kept coaxially inside another long, hollow conducting cylinder of larger radius. Both the cylinders are initially electrically neutral. [IIT 2007]

(A) A potential difference appears between the two cylinders when a charge density is given to the inner cylinder.

(B) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder.

(C) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinders.

(D) No potential difference appears between the two cylinders when same charge density is given to both the cylinders.

Q.29 Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then- [IIT 2007]

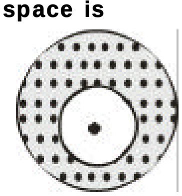
(A) Negative and distributed uniformly over the surface of the sphere

(B) Negative and appears only at the point on the sphere closest to the point charge

(C) Negative and distributed non-uniformly over the entire surface of the sphere

(D) Zero

Q.30 A spherical portion has been removed from solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is [IIT 2007]



(A) Zero every where

(B) non-zero and uniform

(C) non-uniform

(D) Zero only at its center

Q.31 Positive and negative point charge of equal magnitude are kept at $\left(0, 0, \frac{a}{2}\right)$ and $\left(0, 0, \frac{-a}{2}\right)$. respectively. The work done by the electric field when another positive point charge is moved from (–a, 0, 0) to (0, a, 0) is [IIT 2007]

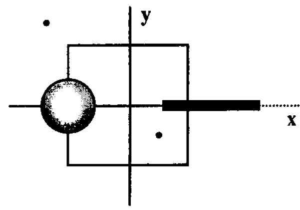
(A) Positive

(B) Negative

(C) Zero

(D) Depends on the path connecting the initaial final positions

Q.32 A disk of radius $a/4$ having a uniformly distributed charge 6C is placed in the x-y plane with its centre at $(-a/2, 0, 0)$. A rod of length a carrying a uniformly distributed charge 8C is placed on the x-axis from $x = a/4$ to $x = 5a/4$. Two point charges $-7C$ and $3C$ are placed at $(a/4, -a/4, 0)$ and $(-3a/4, 3a/4, 0)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm a/2$, $y = \pm a/2$, $z = \pm a/2$. The electric flux through this cubical surface is **[IIT 2009]**



(A) $\frac{-2C}{\varepsilon_0}$

(B) $\frac{2C}{\varepsilon_0}$

(C) $\frac{10C}{\varepsilon_0}$

(D) $\frac{12C}{\varepsilon_0}$

Q.33 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 **[IIT 2009]**

(A) 1: 2 : 3

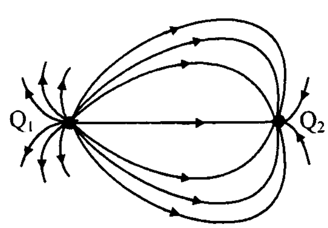
(B) 1 : 3 : 5

(C) 1 : 4 : 9

(D) 1 : 8 : 18

Q.34 A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants are r is the distance from its centre. If the electric field at $r = R/2$ is 1/8 times that at $r = R$, find the value of a. **[IIT 2009]**

Q.35 A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. These lines suggest that **[IIT 2010]**



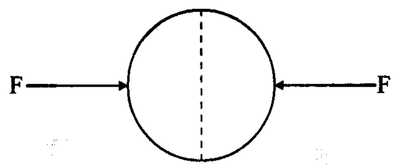
(A) $|Q_1| > |Q_2|$

(B) $|Q_1| < |Q_2|$

(C) At a finite distance to the left of Q_1 the electric field is zero

(D) At a finite distance to the right to Q_2 the electric field is zero

Q.36 A uniformly charged thin spherical shell of radius R carries uniform surface charge density of s per unit area . It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to [IIT 2010]



(A) $\frac{1}{\varepsilon_0}\sigma^2 R^2$

(B) $\frac{1}{\varepsilon_0}\sigma^2 R$

(C) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$

(D) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$

Q.37 A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7} \times 10^5 \, Vm^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} ms^{-1}. Given g = 9.8 ms^{-2}, viscosity of the air = 1.8×10^{-5} Nsm^{-2} and the density of oil = 900 kg m^{-3}, the magnitude of q is –

[IIT 2010]

(A) 1.6×10^{-19} C

(B) 3.2×10^{-19} C

(C) 4.8×10^{-19} C

(D) 8.0×10^{-19} C

Q.38 A spherical metal shell A of radius R_A and a solid metal sphere B of radius R_B ($<R_A$) are kept far apart and each is given charge '+Q'. Now they are connected by a thin metal wire. Then [IIT 2011]

(A) $E_A^{inside} = 0$

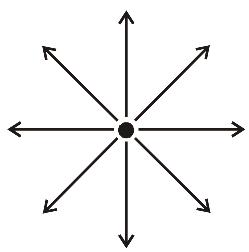
(B) $Q_A > Q_B$

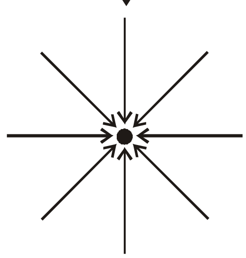
(C) $\frac{s_A}{s_B} = \frac{R_B}{R_A}$

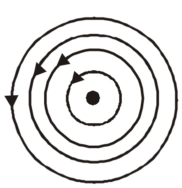
(D) $E_A^{on\ surface} < E_B^{on\ surface}$

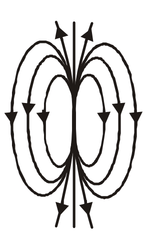
Q.39 **Four point charges, each of +q, are rigidly fixed at the four corners of a square planar soap film of side 'a'. The surface tension of the soap film is g. The systme of charges and planar film are in equilibrium, and a = k $\left[\frac{q^2}{g}\right]^{1/N}$, where 'k' is a constant. Then N is** **[IIT 2011]**

Q.40 **Which of the field patterns given below is valid for electric field as well as for magnetic field ?** **[IIT 2011]**

(A) 

(B) 

(C) 

(D) 

Q.41 Which of the following statement (S) is/are correct ? **[IIT 2011]**

(A) If the electric field due to a point charge varies as γ^{-25} instead of γ^{-2}, then the Gauss law will still be valid.

(B) The gauss law can be used to calculated the field distribution around an electric dipole.

(C) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same.

(D) The work done by the external force in movig a unit positive charge from point A at potential V_A to point B at Potential V_B is $(V_B - V_A)$

ANSWER-KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	D	B	C	D	D	B	B	A	D	B	D	D	B	B	D
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	C	D	A	C	B	C	C	D	A,C	B	C	All	A	D	B
Que.	31	32	33	34	35	36	37	38	39	40	41				
Ans.	C	A	B	2	A,D	A	D	A,B,C,D	3	C	C,D				