CHAPTER - 12
ELECTROSTATICS

SYNOPSIS

Electrostatics is the branch of physics which deals with electric charges at rest. There are two types of charges +ve and –ve. Like charges repell and unlike charges attract. Unit of charge is coulomb (C) in SI. In C.G.S the unit is stat coulomb or electrostatic unit of charge (esu of charge)

Electrification by friction

When two substances are rubbed together, electrons are transferred from one body to the other. The transfer of electrons takes place from the material in which electrons are held less tightly to the nucleus to the materials where electrons are held more tightly. The substance which loses electrons become +ve and the one which gains electrons become –vely charged

Properties of charges

1. Quantization
2. Additive property
3. Charge conservation
4. Speed independence

Difference between mass and charge

1. Charge can be +ve, –ve or zero, but mass is always +ve
2. Charge is quantized. Mass is not strictly quantized
3. Charge is independent of speed. Mass increases with speed as

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

m_0 – rest mass

m – mass when moving with a velocity v

c – velocity of light

Similarities between gravitational and electrostatic field

Both are

1. Central forces
2. Conservative
3. Inverse square law forces
4. Long range forces

5. Two body interaction

Difference

Electrostatic force	Gravitational force
1. May be attractive or repulsive	Always attractive
2. Affected by the medium	Not affected by the medium
3. Of strong magnitude	Of weak magnitude

Note that the electrostatic force between the electron and proton is 10^{38} times as large as the gravitational force between them for equal distance of separation

Coulomb's law

The force of attraction or repulsion between two charges q_1 and q_2 is directly proportional to the product of the charges and inversely proportional to the square of the distance between them

$$F \propto \frac{q_1 q_2}{r^2} \quad F = \frac{1}{4\pi \epsilon_0} \frac{q_1 q_2}{r^2}$$

ϵ_0 is the absolute permittivity of free space (air or vacuum) $\frac{1}{4\pi \epsilon_0} = 9 \times 10^9 \, Nm^2C^{-2}$

When the charges are kept in a medium other than air or vacuum, $F = \frac{1}{4\pi \epsilon_0 \epsilon_r} \frac{q_1 q_2}{r^2}$

ϵ_r is the relative permittivity or dielectric constant of the medium. $\epsilon_0 \epsilon_r = \epsilon$ is the absolute permittivity of the medium

$$\frac{F_{air}}{F_{medium}} = \epsilon_r$$

The force between two charges will be reduced to zero if a metal plate is introduced between them. For metals $\epsilon_r = \infty$

$$\epsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$$

Principle of superposition

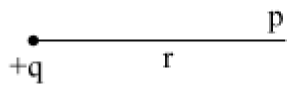
When a number of charges are interacting, the total force on a given charge is the vector sum of the individual forces exerted on the given charge by all the other charges.

Electricfield

The space surrounding a charge where another charge experiences a force is known as an electric field.

The intensity of the electric field $(\vec{E})$ at a point is the force experienced by a unit +ve charge (+1C) placed at that point. The magnitude of the intensity of the electric field at a point P due to a point charge is given by

$$E = \frac{1}{4\pi \epsilon_0} \frac{q}{r^2}$$



where r is the distance of the point from the point charge. The force experienced by a charge of q coulomb placed in an electric field strength $\vec{E}$ is given by

$$\vec{F} = q\vec{E}$$

Acceleration of a charged particle in an electricfield $\vec{a} = \frac{q\vec{E}}{m}$

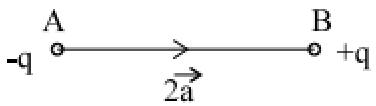
Unit of $\vec{E}$ is NC^{-1} or Vm^{-1}

$[E] = [I^{-1} MLT^{-3}]$

Properties of electric lines of force

1. Electric lines start from a +ve charge and ends on a –ve charge
2. Electric lines do not intersect each other
3. The tangent at any point on the electric line gives the direction of the electric field at that point
4. The number of lines of force passing normally through unit area taken around a point gives the intensity of the electricfield at that point. It is also known as the electric flux density.
5. In a uniform electric field electric lines are parallel and equidistant from each other
6. Lines of force always start normal to a surface and end normal to a surface

Electric dipole



Two equal and opposite charges separated by a small vector distance form an electric dipole. The length of the dipole is a vector quantity. Its direction is from the –ve to the +ve charge. The length AB of the dipole is represented by $2\vec{a}$.

Electric dipole moment $\vec{P}$

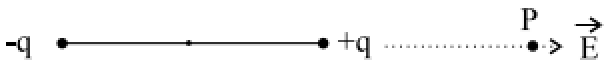
It is the product of one of the charges and the distance between the charges.

(length of the dipole is $2\vec{a}$)

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

It is a vector quantity. Its direction is from –ve to +ve charge

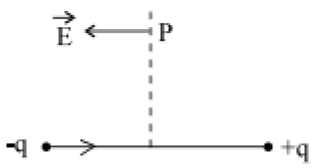
Intensity of the electric field at a point on the axial line



$$E = \frac{1}{4\pi \epsilon_0} \frac{2Pr}{\left(r^2 - a^2\right)^2}.$$ If a<< r(ie short dipole)

$$E = \frac{1}{4\pi \epsilon_0} \frac{2P}{r^3}$$

Intensity of the electric field at a point on the equational line



$E = \frac{1}{4\pi\epsilon_0}\frac{P}{\left(r^2+a^2\right)^{3/2}}$; If a<<r, $E = \frac{1}{4\pi\epsilon_0}\frac{P}{r^3}$

For a short dipole $E_{axial} = 2E_{equatorial}$

The direction of the electric field is antiparallel to the direction of the length of the dipole

Null point

A null point in an electric field is the point where the resultant field is zero

a) when two like charge are separated by a distance the null point will be:

(1) on the line joining the charges

(2) in between the charges

(3) nearer to the smaller charge

Also, $\frac{q_1}{r_1^{\,2}} = \frac{q_2}{r_2^{\,2}}$ where r_1 and r_2 are the distance of the null point from q_1 and q_2

If $q_1 = q_2$ null point will be at the centre

(b) When two unlike charge are separated by a distance the null point will be

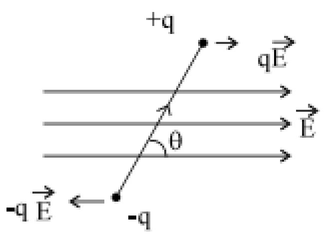
(1) on the line joining the charges

(2) outside the charges

(3) nearer to the smaller charge

Also, $\frac{q_1}{r_1^{\,2}} = \frac{q_2}{r_2^{\,2}}$ where r_1 and r_2 are the distance of the null point from the charges. If $q_1 = q_2$ there will be no null point.

Torque acting on an electric dipole placed in a uniform electric field



Torque $\tau = PE\sin\theta$ ie $\vec{\tau} = \vec{P}\times\vec{E}$

(i) When the dipole is in stable equilibrium, θ = 180°, τ = PE sin 180° = 0

(ii) When the dipole is perpendicular to the field, τ = PE sin90 = PE

This is the maximum torque.

(iii) When the dipole is in unstable equillibrium

θ = 180°, τ = PE sin 180° = 0

In stable equilibrium, $\vec{E}$ is parallel to $\vec{P}$

In unstable equilibrium, $\vec{E}$ is antiparallel to $\vec{P}$

Work done in rotating a dipole from θ_1 to θ_2 in a uniform electric field. (Potential energy of an electric dipole placed in a uniform electric field)

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

θ_1 - initial

θ_2 - final

If θ_1 = 90^0 and $\theta_2 = \theta$, W = –pE cos θ

Electric potential : V at a point in an electricfield is the amount of work done in bringing a unit +ve charge (+1C) from infinity to that point against the direction of the field

$V = -\int_{\infty}^{r} \vec{E} \cdot d\vec{r}$ V is a scalar quantity $V = \frac{W}{q}$. Unit of V is JC^{-1} (volt)

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

Potential difference between two points in an electric field is the amount of work done to bring a unit +ve charge from one point to the other against the direction of the field

dV = $V_B - V_A$

Equipotential surface is the surface over which the electric potential remains the same

On an equipotential surface the p.d between any two points is zero. Hence no work is done in moving a test charge on an equipotential surface

The electric field (ie, electric lines) are perpendicular to an equipotential surface

Potential gradient is the rate of change of potential w.r.t distance, ie $\frac{dv}{dr}$. It is a vector quantity

Electric field $E = \frac{-dV}{dr}$

In a constant electric field E $\times$ r = V

Unit of electric field is Vm^{-1}

Unit of potential gradient also is Vm^{-1}

Potential at a point due to a point charge is

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

Potential due to a large number of charges q_1, q_2, ... is,

$$V = \frac{1}{4\pi\epsilon_0}\frac{q_1}{r_1} + \frac{1}{4\pi\epsilon_0}\frac{q_2}{r} + ------$$

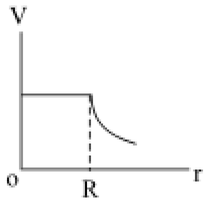
Potential due to a uniformly charged conducting spherical shell (or a conducting solid sphere) of radius R:

1. Potential at any point outside the shell at a distance r from the centre

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

2. On the surface of the shell, $V = \frac{1}{4\pi\epsilon_0}\frac{q}{R}$

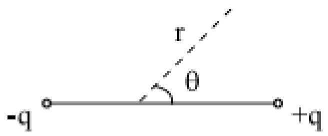
3. Inside the shell, $V = \frac{1}{4\pi\epsilon_0}\frac{q}{R}$



Electric potential due to an electric dipole (short dipole)

1. At any point,

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

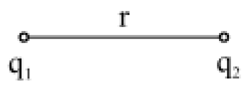


2. $V_{axial} = \frac{1}{4\pi\epsilon_0}\frac{p}{r^2}$

3. $V_{equitorial} = 0$

   Potential energy of a system of two charges

$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

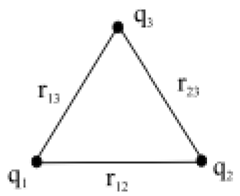


   Potential energy = Potential $\times$ charge

   Potential energy of system of three charges

   $U = U_{12} + U_{23} + U_{13}$

$$= \frac{1}{4\pi\epsilon_0}\left[\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_1 q_3}{r_{13}}\right]$$



Electric flux (ϕ) through an area (surface) in an electric field is the number of lines of force passing normally through the area. Flux through an area $d\vec{s}$ is given by $d\phi = \vec{E}.d\vec{s}$ ie, $d\phi = Eds\ \cos\theta$

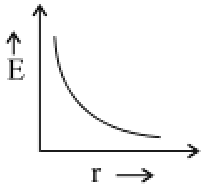
Flux is a scalar quantity. Note that the direction of area is normal to the area taken

Gauss's theorem : The total electric flux through any closed surface enclosing a charge is equal to $\frac{1}{\epsilon_0}$ times the total charge enclosed by the surface

$$\phi = \oint \vec{E}.d\vec{s} = \frac{1}{\epsilon_0}.q$$

Applications

1. Electric field due to a point charge = $\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$



2. Electric field due to an infinitely long line charge,

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

3. Electric field due to an infinite thin plane sheet of charge

$$E = \frac{\sigma}{2\epsilon_0}$$

4. Electric field due to two infinite parallel sheets of charge with equal but opposite charge densities,
   (i) outside the sheets = 0

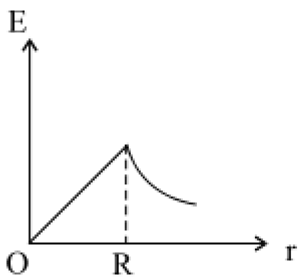
   (ii) in between the sheets = $\frac{\sigma}{\epsilon_0}$

5. Electric field due to a charged nonconducting solid sphere of radius R:

   (i) outside the sphere (r > R) $\quad E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$

   (ii) on the sphere (r = R) $\quad E = \frac{1}{4\pi\epsilon_0}\frac{q}{R^2}$

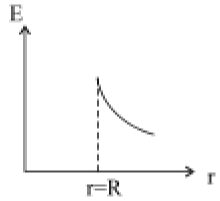
   (iii) inside the sphere (r < R) $\quad E = \frac{1}{4\pi\epsilon_0}\frac{q}{R^3}r$



6. Electricfield due to a charged conducting shell (or conducting sphere) of radius R

   (i) outside the shell (r > r), $E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$

(ii) on the sphere (r = R), $E = \frac{1}{4\pi \epsilon_0} \frac{q}{R^2}$



(iii) inside the sphere (r < R) E = 0

Electrostatic shielding is the vanishing of the electric field inside a conducting cavity

PART I - (JEEMAIN)

SECTION - I - Straight objective type questions

1. Three charges 4 q, Q and q are in a straight line in the positions $0, \ell/2$ and ℓ respectively. Resultant force at q will be zero if Q is equal to

1) -q　　2) -2q　　3) -q/2　　4) 4q

2. A charge q is placed at the centroid of an equilateral triangle. Three charges equal to Q are placed at the vertices of the triangle. The system of four charges will be in equilibrium if q is equal to

1) $-Q\sqrt{3}$　　2) $-Q/3$　　3) $-Q/\sqrt{3}$　　4) $Q/\sqrt{3}$

3. The charges 9e and 3e are placed at a distance r. The distance of the point where the electric field intensity will be zero is

1) $\frac{r}{\sqrt{3}+1}$ from 3e charge　　2) $\frac{r}{\sqrt{3}+1}$ from 9e charge

3) $\frac{r}{\sqrt{3}-1}$ from 3e charge　　4) $\frac{r}{\sqrt{3}-1}$ from 9e charge

4. A non-conducting ring of radius R has uniformly distributed positive charge Q. A small part of the length d, is removed (d<<R). The electric field at the centre of the ring will now be

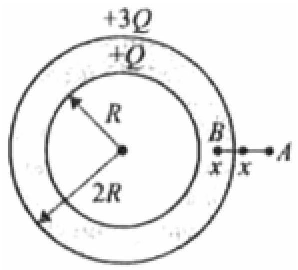
1) directed towards the gap inversely proportional to R^3

2) directed towards the gap, inversely proportional to R^2

3) directed away from the gap, inversely proportional to R^3

4) directed away from the gap, inversely proportional to R^2

5. Two concentric conducting thin shells of radius R and 2R carry charges +Q and +3Q respectively. The magnitude of electric field at points A and B at a distance x outside and inside from the surface of outer sphere is same. Then the value of x is



1) $\frac{R}{3}$ 2) $\frac{2R}{3}$ 3) $\frac{R}{4}$ 4) $\frac{R}{2}$

6. Two identical small bodies each of mass m and charge q are suspended from two strings each of length l from a fixed point. This whole system is taken into an artificial satellite. Then the tension in strings is

1) $\frac{kq^2}{l^2}+2mg$ 2) $\frac{kq^2}{4l^2}+2mg$ 3) $\frac{kq^2}{l^2}$ 4) $\frac{kq^2}{4l^2}$

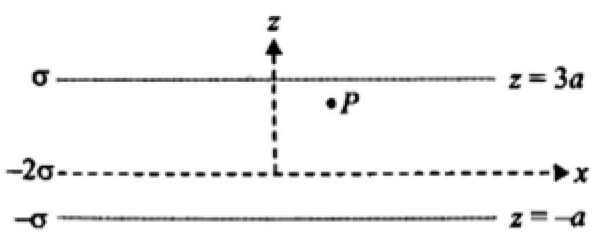
7. Five identical charges +q are placed at five corner of a regular hexagon of side a. Find the magnitude of electric field at centre

1) $\frac{q}{4\pi\varepsilon_0 a^2}$ 2) $\frac{q}{2\pi\varepsilon_0 a^2}$ 3) $\frac{5q}{4\pi\varepsilon_0 a^2}$ 4) $\frac{5q}{2\pi\varepsilon_0 a^2}$

8. A uniform horizontal electric field E is established in the space between two large vertical parallel plates. A small conducting sphere of mass m is suspended in the field from a string of length L. If the sphere is given charge +q, then the period of oscillation of the pendulum is

1) $2\pi\sqrt{L/g}$ 2) $2\pi\sqrt{\frac{L}{g+qE/m}}$ 3) $2\pi\sqrt{\frac{L}{g-qE/m}}$ 4) $2\sqrt{\frac{L}{\sqrt{g^2+(qE/m)^2}}}$

9. Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is

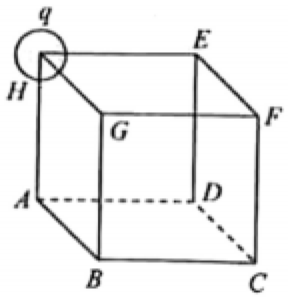


1) $\frac{2\sigma}{\varepsilon_0}\hat{k}$ 2) $-\frac{2\sigma}{\varepsilon_0}\hat{k}$ 3) $\frac{4\sigma}{\varepsilon_0}\hat{k}$ 4) $-\frac{4\sigma}{\varepsilon_0}\hat{k}$

10. A point charge of $+6\,\mu C$ is placed at a distance 20 cm directly above the centre of a square of side 40 cm. The magnitude of the flux through the square is

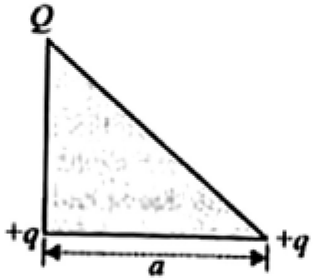
1) ε_0 2) $\frac{1}{\varepsilon_0}$ 3) $\varepsilon_0 \times 10^{-6}$ 4) $\frac{1}{\varepsilon_0} \times 10^{-6}$

11. A small spherically symmetric charge q is placed at one vertex of a cube as shown. The flux through the faces ABCD and HGFE are, respectively



1) $\frac{q}{24\varepsilon_0}, \frac{q}{24\varepsilon_0}$ 2) $0, \frac{q}{8\varepsilon_0}$ 3) $\frac{q}{8\varepsilon_0}, 0$ 4) $\frac{q}{24\varepsilon_0}, 0$

12. Three charges Q, +q and +q are placed at the vertices of a right angled isosceles triangle as shown in figure. The net electrostatic energy of the configuration is zero if Q is equal to



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

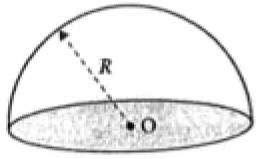
13. An external agency carries -5C of charge from infinity to a point in an electrostatic field and performs 100 Joules of work. The potential at the given point is

1) +10V 2) -10V 3) +20 V 4) -20 V

14. A point charge q is placed at a distance of r from the centre of an uncharged conducting sphere of radius R (<r). The potential at any point on the sphere is

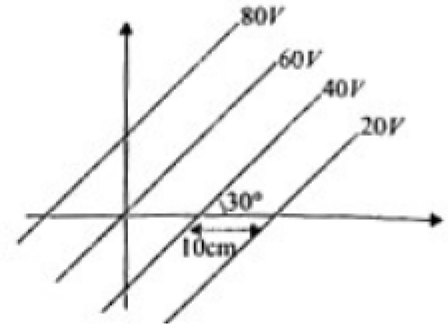
1) zero 2) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$ 3) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{qR}{r^2}$ 4) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{qr^2}{R}$

15. Charge Q coulombs is uniformly distributed throughout the volume of solid hemisphere of radius R metres. Then the potential at centre O of the hemisphere in volts is



1) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{2R}$ 2) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{4R}$ 3) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{4R}$ 4) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{8R}$

16. If the given figure shows equipotential surfaces, then the magnitude of electric field is

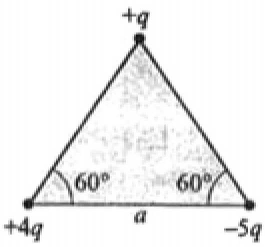


1) 50 N/C 2) 100 N/C 3) 200 N/C 4) 400 N/C

17. Two short dipoles, each of dipole moment p, are placed at origin. The dipole moment of one dipole is along x-axis, while that of other is along y-axis. The magnitude of electric field at a point (a,0) is given by

1) $\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{2p}{a^3}$ 2) $\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{p}{a^3}$ 3) $\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\sqrt{5}P}{a^3}$ 4) zero

18. Find the magnitude of dipole moment of the following system



1) $\sqrt{21}\,aq$ 2) zero 3) 4 aq 4) 10 aq

19. In a region, if electric field is defined as $\vec{E} = \left(\hat{i} + 2\hat{j} + \hat{k}\right) v/m$ then the potential difference between two pontes A(0,0,0) and B (2,3,4) in that region, is

1) 6V 2) 12 V 3) 8V 4) 9V

SECTION - II
Numerical Type Questions

20. Three point charges q, 2q and 8q are arranged on positive x-axis within a distance of 24 cm so that system's potential energy is minimum. The distance of charge q from charge 2q in cm is

21. A thin rod of length $l = \sqrt{0.44}\ \mathrm{m}$ is placed along positive x-axis with one end at origin. The linear charge density λ of the rod depends on x as $\lambda = ax$ where $a = (20/9)\mu C/m$. The work done by an external agent to bring a point charge q = 1.5 mC from infinity to the point (0,1,0) in Joules is

22. A solid sphere of radius R has a charge Q distributed in its volume with charge density $\rho = kr^a$, where k and a are positive constants and r is the distance from its centre. If the electric field at r = R/2 is 1/8 times that at r = R, the value of a is

23. Two identically charged spheres are suspended by strings of equal length. The strings make an angle of 2θ with each other. When suspended in a liquid of density 900 kg/m³, the angle remains the same. What is the dielectric constant of the liquid if the density of the material of the spere is 1200 kg/m³?

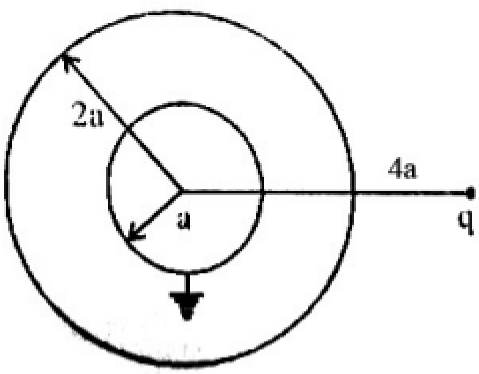
24. Three concentric spherical metallic shells A, B and C of radii a,b and c (a<b<c) have surface charge densities $\sigma, -\sigma$ and σ respectively. A and C are at the same potential. If a = 7cm and b = 17 cm, then the value of c-(a+b) in cm is

PART - II (JEE ADVANCED)

SECTION - III (One correct answer type including passage)

Paragraph Questions(25,26 & 27)

A solid uncharged conducting sphere of radius a is concentric with an uncharged conducting shell of radius 2a. A point charge q is palced at a distance 4a from common centre of sphere and shell. The sphere is then grounded.



25. The charge that will appear on solid sphere is

1) $-\frac{q}{2}$ 2) $-\frac{q}{4}$ 3) $-\frac{q}{8}$ 4) $-\frac{q}{16}$

26. Select the correct statement

    1) Charge on surface of inner sphere is non-uniform

    2) Charge on inner surface of outer shell is non-uniform

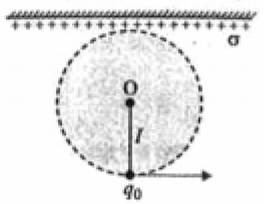
    3) Charge on surface of outer shell is non-uniform

    4) All of the above

27. The potential of outer shell is

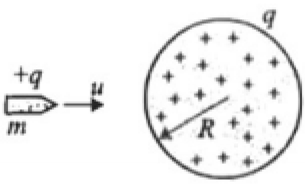
    1) $\frac{q}{32\pi\varepsilon_0 a}$ 2) $\frac{q}{16\pi\varepsilon_0 a}$ 3) $\frac{q}{8\pi\varepsilon_0 a}$ 4) $\frac{q}{4\pi\varepsilon_0 a}$

28. In the figure shown a large conducting ceiling have uniform charge density σ, below which a charged particle of charge q_0 and mass m is hung from point O through small string of length l. The minimum horizontal velocity required for the particle so that it can move in complete circle is



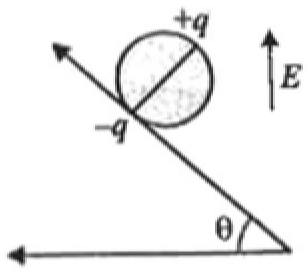
    1) $\sqrt{5gl}$ 2) $\sqrt{5gl+\frac{\sigma q_0}{\varepsilon_0 m}}$ 3) $\sqrt{5l\left(g+\frac{\sigma q_0}{\varepsilon_0 m}\right)}$ 4) $\sqrt{gl+\frac{\sigma q_0}{\varepsilon_0 m}}$

29. A bullet of mass m and charge q is fired towards a fixed solid uniformly charged sphere of radius R and total charge +q. If it strikes the surface of sphere with speed u, find the minimum speed u so that it can penetrate through the sphere. (Neglect all resistance forces or friction acting on bullet except electrostatic forces)



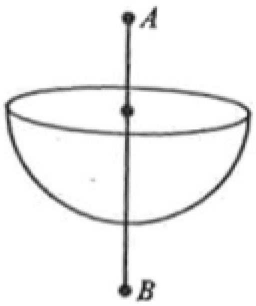
    1) $\frac{q}{\sqrt{2\pi\varepsilon_0 mR}}$ 2) $\frac{q}{\sqrt{4\pi\varepsilon_0 mR}}$ 3) $\frac{\sqrt{3}q}{\sqrt{2\pi\varepsilon_0 mR}}$ 4) $\frac{\sqrt{3}q}{\sqrt{4\pi\varepsilon_0 mR}}$

30. A wheel having mass m has charges +q and -q on diametrically opposite points. It remains in equilibrium on a rough inclined plane in the presence of uniform vertical electric field E equal to



1) $\frac{mg}{q}$ 2) $\frac{mg}{2q}$ 3) $\frac{mg\tan\theta}{2q}$ 4) none

31. The diagram show a uniformly charged hemisphere of radius R. it has volume charge denisty ρ. If the electric field at a point at a distance of 2R above its centre is E, then what is the electric field at the point which is 2R below its centre?



1) $\rho R/6\varepsilon_0 + E$ 2) $\rho R/12\varepsilon_0 - E$ 3) $-\rho R/6\varepsilon_0 + E$ 4) $\rho R/24\varepsilon_0 + E$

SECTION - IV (More than one correct answer)

32. The electric potential in a region along the x-axis varies with x-according to the relation $V(x) = 4+5x^2$. Then,

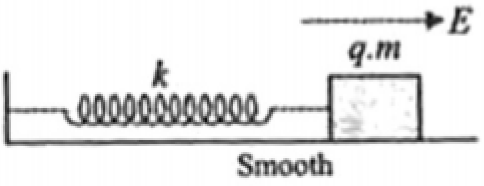
1) potential difference between the points x = 1 and x = -2 is 15V

2) force experienced by a one coulomb charge at x = -1 m will be 10N

3) the force experienced by the above charge will be towards +x - axis

4) a uniform electric field exists in the region along the +x-axis

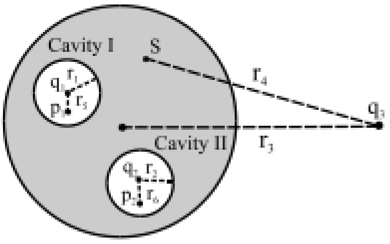
33. A block of mass m is attached to a spring of force constant k. Charge on the block is q. A horizontal electric field E is acting in the direction as shown. Block is released with the spring in unstretched position. Then,



1) block will execute SHM
2) time period of oscillation is $2\pi\sqrt{\frac{m}{k}}$
3) amplitude of oscillation is $\frac{qE}{k}$
4) block will oscillate but not simple harmonically

34. Two fixed charges -2Q and +Q are located at points (-3a, 0) and +3a, 0). Then,
1) Point where the electric potential due to the two charges is zero, lie on a circle of radius 4a and having centre at (5a,0)
2) potential is zero at x = 0
3) If a particle of charge +q is released from the point (5a,0), it will eventually move to infinity
4) electric field at origin is along +ve x-axis

35. Figure shows a spherical conductor of radius R with two spherical cavities of radii r_1 and r_2 inside it. The spherical conductor is given charge Q and two charges q_1 and q_2 are placed at the centre of the cavities. A point charge q_3 is placed outside the conductor distance r_3 from the centre of the conductor



Choose the correct option/ options

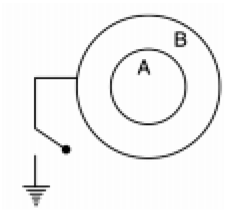
A) Potential of the spherical conductor is $\frac{1}{4\pi\varepsilon_0}\left[\frac{Q+q_1+q_2}{R}+\frac{q_3}{r_3}\right]$

B) Potential at point P_1 inside cavity 1 at distance r_5 from centre inside the cavity is $\frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_5}-\frac{q_1}{r_1}+\frac{q_3}{r_3}+\frac{(Q+q_1+q_2)}{R}\right]$

C) Electric field at P_2 at distance r_6 from centre of cavity II inside cavity is $\frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_6^2}$ directed away from centre

D) Electric field at point S inside the conducting medium due to charges on the outer surface of the spherical conductor is $\frac{1}{4\pi\varepsilon_0}\frac{q_3}{r_4^2}$ to wards q_3..

36. Two concentric shells have radii R and 2R, charges q_A and q_B and potentials 2V and $\left(\frac{3}{2}\right)V$, respectively. Now, shell B is earthed and let charges on them become q'_A and q'_B. Then



A) $\frac{q_A}{q_B} = \frac{1}{2}$

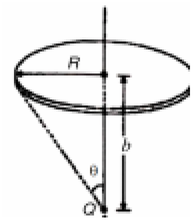
B) $\left|\frac{q'_A}{q'_B}\right| = 1$

C) Potential of A after earthing becomes $\left(\frac{3}{2}\right)V$.

D) Potential difference between A and B after earthing becomes $\frac{V}{3}$

SECTION - V (Numerical Type - Upto two decimal place)

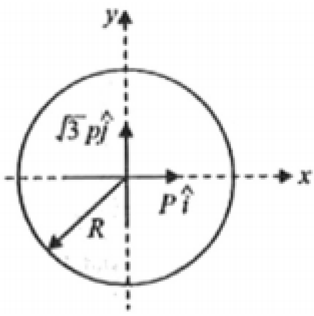
37. A point charge Q is located on the axis of a disc of radius R at a distance b from the plane of the disc as shown in the figure. The radius of the disc if one-fourth of the total electric flux from the charge passes through the disc is (Given b = 1m)



38. The energy stored in an imaginary cubical volume of side *a* placed in front of an infinitely large nonconducting sheet of uniform charge density σ, is $\frac{\sigma^2 a^3}{n\varepsilon_0}$. Then find n

SECTION - VI (Matrix Matching)

39. Two short dipole moments $p\hat{i}$ and $\sqrt{3}p\hat{j}$ are placed at origin. A circle of radius R with centre at origin is drawn in figure. Column I shows certain positions on this circle and Column II gives coordinates of these positions. Match the entries of column I with entries of column II



Column I	Column II
A) A point on circle where potential is maximum	p) $\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$
B) A point on circle where potentials is zero	q) $\left(-\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$
C) A point on circle where magnitude of electric field is maximum	r) $\left(-\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$
D) A point on circle where magnitude of electric field is minimum	s) $\left(\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$