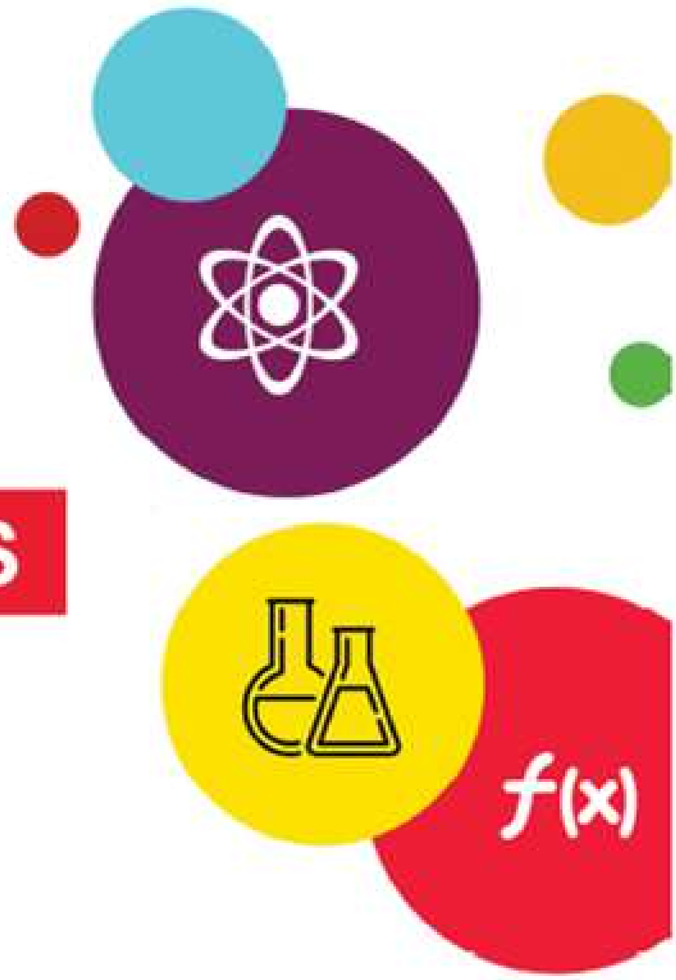
STUDY MATERIAL FOR

JEE Main

PHYSICS

CHEMISTRY

MATHEMATICS



CP PUBLICATION

CAREER POINT

Study Material for JEE Main preparation

Prepared by Career Point Kota Experts

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Electrostatics

This chapter covers the following syllabus

- Electric charge : Conservation of charge
- Coulomb's law-forces between two charges, forces between multiple charges
- Superposition principle and continuous charge distribution
- Electric field : Electric field due to a point charge
- Electric field lines
- Electric dipole, Electric field due to a dipole
- Torque on a dipole in a uniform electric field
- Electric flux
- Gauss's law and its applications to find field due to infinitely long uniformly charged straight wire
- Uniformly charged infinite plane sheet and uniformly charged thin spherical shell
- Electric potential and its calculation for a point charge
- Electric dipole and system of charges, Equipotential surfaces
- Electrical potential energy of system of two point charges in an electrostatics field

Revision Plan

Prepare Your Revision plan today!

After attempting Exercise Sheet, please fill below table as per the instruction given.

- Write Question Number (QN) which you are unable to solve at your own in **column A**.
- After discussing the Questions written in **column A** with faculty, strike off them in the manner so that you can see at the time question number during Revision, to solve such questions again.
- Write down the Question Number you feel are important or good in the **column B**.

EXERCISE	**COLUMN A** **Questions unable to solve in first attempt**	**COLUMN B** **Good or Important questions**
Exercise-1		
Exercise-2		
Exercise-3		
Exercise-4		
Exercise-5		

Revision Strategy:

Whenever you wish to revision this chapter, follow the following steps -

- **Step-1:** Review your theory notes.
- **Step-2:** Solve Questions of column A
- **Step-3:** Solve Questions of Column B
- **Step-4:** Solve questions from other Question Bank, Problem book etc.

Electrostatics

KEY CONCEPT

1. Charge

Property of a substance by virtue of which it can repel or attract another charged substance.

Charges are of two types.

(a) Positive charge : Lesser number of electrons than number of protons.

(b) Negative charge : More number of electrons than number of protons

Important Points : Only electron is responsible for a substance to be charged and not the proton.

Properties of Charge :

(i) Like charges repel while unlike charges attract each other.

(ii) Charge is quantized in nature i.e. The magnitude of charge possessed by different objects is always an integral multiple of charge of electron (or proton) i.e. $q = \pm ne$ where $n = 1, 2, 3$ ....

(iii) The minimum possible charge that can exist in nature is the charge of electron which has a magnitude of $e = 1.60207 \times 10^{-19}$ coulomb. This is also known as quantum of charge or fundamental charge.

(iv) In an isolated system the algebraic sum of total charge remains constant. This is the law of 'Conservation of charge'.

Note : The fact that electric charge is an integral multiple of electronic charge was experimentally proved by Milliken.

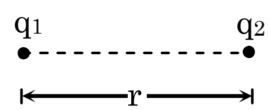
S.I. unit of charge $\rightarrow$ coulomb

1 coloumb = 3×10^9 e.s.u. = $\frac{1}{10}$ e.m.u.

(e.s.u. and emu are CGS units)

2. Coulomb's law

If q_1 & q_2 are point charges in consideration, r the distance between them and F the force acting between them



$\Rightarrow \; F = k\,\frac{q_1 q_2}{r^2}$, where k = constant.

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

where,

ε_0 = Electric permittivity of vacuum or air

= 8.85×10^{-12} coul^2 N^{-1} m^{-2} and

K = Relative permittivity

= Dielectric constant

= Specific inductive capacity

Note:

(i) Coulomb's law is applicable to point charges only. But it can be applied for distributed charges also (by considering them to be combination of large no. of point charges.)

(ii) K = 1 for air or vacuum,

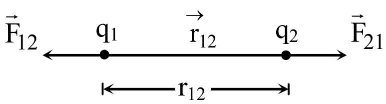
= ∞ for conductors

> 1 for any other medium.

Medium	K
Vacuum/air	1
Water	80
Mica	8
Glass	5-10
Metal	¥

Vector form of Coulombs Law :

Direction of the force acting between two charges depends upon their nature and it is along the line joining two charges.



$\vec{F}_{12}$ = force on q_1 due to q_2

$\vec{F}_{21}$ = force on q_2 due to q_1

$\hat{r}_{12}$ $\rightarrow$ unit vector from q_1 to q_2

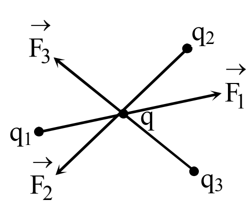
$\hat{r}_{21}$ $\rightarrow$ unit vector from q_2 to q_1

$$\vec{F}_{12} = \frac{q_1 q_2 \hat{r}_{21}}{4\pi\varepsilon_0 K r_{12}^2} \qquad \text{...(A)}$$

$$\vec{F}_{12} = \frac{q_1 q_2}{4\pi\varepsilon_0 K r_{12}^2}\hat{r}_{21} \qquad \text{...(B)}$$

3. Principle of superposition

The resultant force acting on a charge due to a group of charges is equal to the vector sum of individual forces. $\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$



4. Electric field

A charge produces an electric field in the space around it and this electric field exerts a force on any charge placed in it.

4.1 Electric field intensity -

Let q_0 be the positive test charge placed in an electric field and $\vec{F}$ is the force experienced by this charge, then

$$\vec{E} = \text{Electric field intensity} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$$

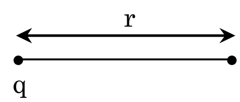
(i) Unit : Newton / coulomb or volt/metre

(ii) Since $\vec{E}$ is the force on unit charge, force on charge q is -

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

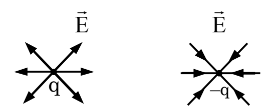
(iii) Dimension is $[M^1 L^1 T^{-3} A^{-1}]$

(iv) Electric field due to a point charge is



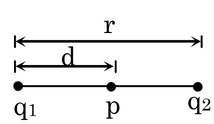
$$\vec{E} = \frac{kq}{r^2}.\hat{r}$$

(v) Direction of electric field due to positive charge is away from charge while direction of electric field due to negative charge is towards the charge.



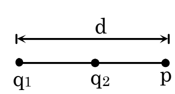
Special point :

➢ If q_1 and q_2 are at a distance r and both have the same type of charge, then the distance 'd' of the point from q_1 where electric field is zero is given by $d = \frac{\sqrt{q_1}\, r}{\left(\sqrt{q_1} + \sqrt{q_2}\right)}$. This point will lie between line joining q_1 & q_2.



➢ If q_1 and q_2 have opposite charges then distance 'd' of the point 'p' from q_1 where electric field is zero is given by

$$d = \frac{\sqrt{q_1}\, r}{\sqrt{q_1} - \sqrt{q_2}}, \quad [|q_1| > |q_2|]$$



4.2 Principle of superposition for electric field intensity :

Resultant electric field intensity at a point p due to a number of charges is vector sum of individual electric field intensities

$\therefore \ \vec{E}_p = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$

Electric field is represented by electric lines of forces.

The resultant of two electric fields E_1 and E_2 is given by $E = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$. If the resultant field E, makes an angle β with E_1 then $\tan\beta = \dfrac{E_2\sin\theta}{E_1 + E_2\cos\theta}$

4.3 Properties of electric lines of forces :

(i) Electric lines of force start from a positive charge and end on a negative charge .

(ii) No two lines of force can intersect each other. If they does so then at the point of intersection two tangents could be drawn, which gives two directions of electric at the same point, which is impossible.

(iii) The tangent drawn at any point on line of force gives the direction of force acting on a positive charge placed at that point.

(iv) These lines have a tendency to contract in length like a stretched elastic string. This actually explains attraction between opposite charges.

(v) These lines have a tendency to separate from each other in the direction perpendicular to their length. This explains repulsion between like charges.

(vi) Intensity of electric field is given by the number of electric lines of force in a unit area at that point.

(vii) Lines of force of a uniform field are parallel and at equal distance.

(viii) 1 esu charge gives $\dfrac{4\pi}{K}$ lines in a medium of dielectric constant K.

(ix) **Important :** Electric lines of force can never enter the conductor, because inside the conductor the intensity of electric filed is zero.

(x) **Important :** Lines of force leaves the surface of conductor normally.

5. Electric potential

W = work done in bringing a positive charge q_0 from infinity to that point, then, $V = \dfrac{W}{q_0}$

(a) Electric potential at infinity is taken to be zero.

(b) It is not path dependent quantity it simply depends upon the starting and end points.

(c) It is a scalar quantity.

(d) Unit : Volt or Joule/Coulomb

(e) Dimension : $[M^1 L^2 T^{-3} A^{-1}]$

(f) Potential due to a positive charge is positive and potential due to a negative charge is negative, here potential being positive and negative implies whether work is done on the charge or done by the charge respectively.

(g) Potential due to a point charge q at a distance r is $V = \dfrac{1}{4\pi\epsilon_0}\dfrac{q}{r}$

$\Rightarrow \ V \propto \dfrac{1}{r}$

(h) Total potential at a point due to a group of charges is algebraic sum of individual potentials

$V_p = V_1 + V_2 + \ldots . V_n$

(i) Electric field is gradient of electric potential at that point. $E = -\dfrac{dv}{dr}$

(j) Work done in bringing a charge Q from infinity to that point is

W = QV where V is potential at that point.

(k) Potential of earth is taken to be zero.

5.1 Potential difference :

If W be work done in moving a charge q_0 form B to A then the potential difference is given by-

$$V_A - V_B = \frac{W}{q_0}$$

(i) Unit of potential difference is volt.

(ii) This is a scalar quantity

(iii) Potential difference does not depend upon the path followed. This is because electric field is a conservative force field and work done is conservative force field does not depend upon path followed.

5.2 Relationship between electric potential and intensity of electric field

(i) $V_A = -\int_{\infty}^{A} \vec{E}\cdot\vec{dr}$, V_A = electric potential at point A .

(ii) Potential difference between two points in an electric field is given by negative value of line integral of electric field i.e.

$$V_B - V_A = -\int_{A}^{B} \vec{E}\cdot\vec{dr}$$

(iii) $\vec{E} = -\nabla V = -\text{grad } V$

$$\nabla = \text{(gradient)} = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right)$$

$$E_x = -\frac{\partial V}{\partial x},\ E_y = -\frac{\partial V}{\partial y},\ E_z = -\frac{\partial V}{\partial z}$$

(iv) If V is a function of r only, then $E = -\dfrac{dV}{dr}$

(v) For a uniform electric field, $E = -\dfrac{\Delta V}{\Delta r}$ and its direction is along the decrease in the value of V.

5.3 Equipotential surface -

(i) These are the imaginary surface (drawn in an electric field) where the potential at any point on the surface has the same value.

(ii) No two equipotential surfaces ever intersects

(iii) Equipotential surfaces are perpendicular to the electric field lines

(iv) Work done in moving a charge from a one point to the other on an equipotential surface is zero irrespective of the path followed and hence there is no change in kinetic energy of the charge.

(v) Component of electric field parallel to equipotential surface is zero.

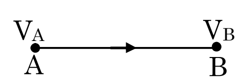
(vi) Nearer the equipotential surfaces, stronger the electric field intensity

6. Potential energy of charged particle in electric field

(a) Work done in bringing a charge from infinity to a point against the electric field is equal to the potential energy of that charge.

(b) Potential energy of a charge of a point is equal to the product of magnitude of charge and electric potential at that point i.e. P.E. = qV

(c) Work done in moving a charge from one point to other in an electric field is equal to change in its potential energy i.e. work done in moving Q from A to $B = qV_B - qV_A = U_B - U_A$

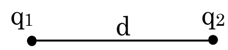


6.1 Potential Energy of System :

(i) The electric potential energy of a system of charges is the work that has been done in bringing those charges from infinity to near each other to form the system.

(ii) Energy of a system of two charges

$$PE = \frac{1}{4\pi \epsilon_0}\frac{q_1q_2}{d}$$



(iii) Energy of a system of three charges

$$PE = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_3q_1}{r_{31}}\right]$$

(iv) Energy of a system of n charges.

$$PE = \frac{1}{2}\cdot\frac{1}{4\pi\varepsilon_0}\left(\sum_{i=1}^{n} q_i\left(\sum_{\substack{j=1\\ i\neq j}}^{n}\frac{q_j}{r_{ij}}\right)\right)$$

6.2 Work done in an electric field -

(i) If electric potential at a point is V then potential energy (PE) of a charge placed at that point will be qV.

(ii) Total energy remains constant in an electric field i.e. $KE_A + PE_A = KE_B + PE_B$

KE = Kinetic energy

PE = Potential energy

(iii) A free charge moves from higher PE to lower PE state in an electric field. Hence

(a) a +ve charge will move form higher potential to lower potential while,

(b) a –ve charge will move form lower potential to higher potential

7. Motion of a charged particle in an electric field

(a) Magnitude of force on a charge q in an electric field E is $F = qE$

(b) 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.

Uniform electric field

Case : 1

Initial velocity is zero or in the direction of electric field -

$$F = qE$$

$\Rightarrow$ acceleration $a = \frac{qE}{m}$

$\Rightarrow v = u + at$

Distance travelled in time 't',

$$S = ut + \frac{1}{2}at^2$$

Case : 2

Initial velocity is perpendicular to electric field -

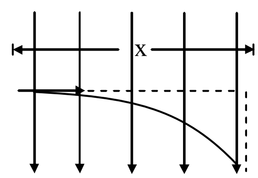
Distance travelled in X direction = ut

Distance travelled in Y direction = $\frac{1}{2}\ at^2$

where $a = \frac{qE}{m}$

Locus of the path followed -

$$Y = \frac{1}{2}\frac{ax^2}{u^2} \quad \text{(a parabola)}$$



(iii) Accelerating a charge q through a potential difference V results in

(a) decrease in PE = qV,

(b) increase in KE = qV

8. Electric flux

(a) It is defined as the total number of electric force lines passing normally through a surface placed in the field.

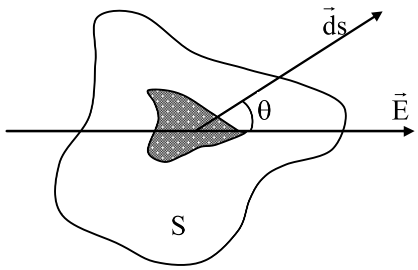
(b) It is given by the dot product of $\vec{E}$ and area vector $\vec{ds}$

$$d\phi = \vec{E}\cdot\vec{ds}$$

$\therefore$ total flux from the surface is

$$\phi = \int \vec{E}\cdot\vec{ds} = \int E\,ds\cos\theta$$

where θ = angle between electric field and normal to the area



(c) (a) if $\theta = 0$, $d\phi = Eds$ (maximum)

(b) if $\theta = 90^0$, ϕ = zero

(d) Unit : (a) Newton - metre^2 / coulomb.

(b) Volt - meter

(e) Dimension : $[M L^3 T^{-3} A^{-1}]$

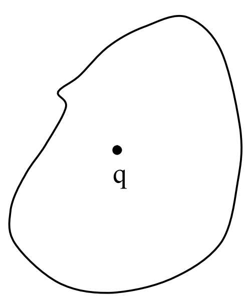
(f) Flux due to a positive charge goes out of the surface while that due to negative change comes into the surface.

(g) In case of close surface flux entering is taken as positive while flux leaving is taken as negative

9. Gauss's law

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

$$\phi_E = \oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$$

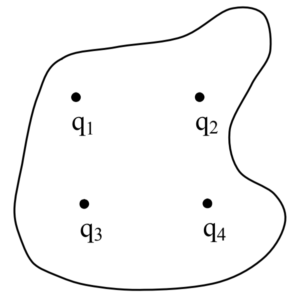


Note :

The closed surface can be hypothetical and then it is called a Gaussian surface.

If the closed surface enclosed a number of charges q_1, q_2 .... q_n etc. then

$$\phi = \oint \vec{E}.\vec{ds} = \frac{\Sigma q}{\varepsilon_0} = \frac{(q_1 + q_2 + ...q_n)}{\varepsilon_0}$$



Flux from a closed surface are :

(i) Independent of distances between charges inside the surface and their distribution.

(ii) Independent of shape, size and nature of surface.

(iii) Gauss law is valid only for the vector fields which obey inverse square law

(iv) Gauss's and coulomb's law are comparable.

Note :

(i) A charge q is placed at the centre of a cube, then .....

(a) Total flux through cube = $\frac{q}{\varepsilon_0}$

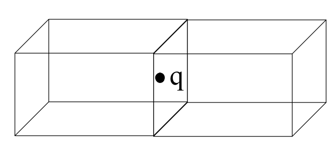
(b) Flux through each surface = $\frac{q}{6\varepsilon_0}$

(ii) A charge q is placed at the centre of a face of a cube, then total flux through cube = $\frac{q}{2\varepsilon_0}$

Explanation :

A second cube can be assumed adjacent to the first cube total flux through both cubes = $\frac{q}{\varepsilon_0}$,

So flux through each cube = $\frac{q}{2\varepsilon_0}$

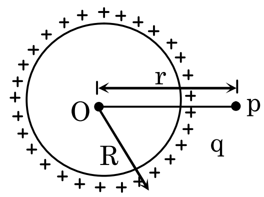


(iii) Now q is placed at a corner then the total flux will be $\frac{q}{8\varepsilon_0}$

10. Application of Gauss's law

10.1 Electric field due to a charged solid conducting sphere / Hollow conducting sphere :

(i) In both spheres, charge resides only on the outer surface of the sphere in order to remain in minimum potential energy state.



Case 1 : OP = $r \geq R$

$$\vec{E} = \frac{1}{4\pi\pi_0}\frac{q}{r^2}\hat{r} = \frac{1}{\varepsilon_0}\frac{\sigma R^2}{r^2}\hat{r}$$

(σ = surface charge density)

Case 2 : $r = R$ $\quad \vec{E} = \frac{\sigma}{\varepsilon_0}\hat{r}$

Case 3 : $r < R$ $\quad \vec{E} = 0$

i.e. At point interior to a conducting or a hollow sphere, electric field intensity is zero.

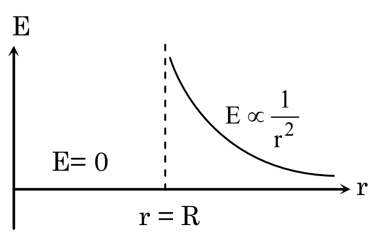
(ii) For points outside the sphere, it behaves like all the charge is present at the centre.

(iii) Intensity of electric field is maximum at the surface

(iv) Electric field at the surface is always perpendicular to the surface.

(v) For points, near the surface of the conductor, E is perpendicular to the surface

(vi) Graphically,



Electric potential :

Case 1 : $r < R$

$$V_{in} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} = \frac{\sigma R}{\varepsilon_0}$$

Case 2 : $r = R$

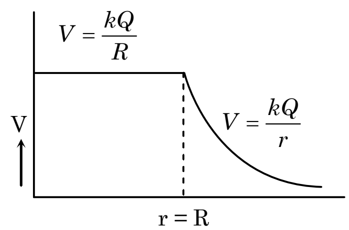
$$V_{surface} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} = \frac{\sigma R}{\varepsilon_0}$$

Case 3 : $r > R$

$$V_{out} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} = \frac{\sigma R^2}{r}$$

(i) For points interior to a conducting or a hollow sphere, potential is same everywhere and equal to the potential at the surface.

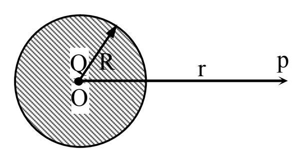
(ii) Graph :



10.2 Electric field due to solid insulating sphere

A charge given to a solid insulating sphere is distributed equally throughout its volume

Electric Field



Case 1 : $r > R$ (point is outside the sphere)

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

Case 2 : $r = R$ (point is at the surface)

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

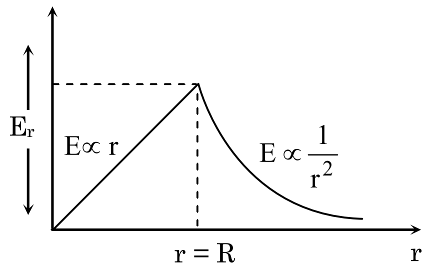
Case 3 : $r < R$ (point is inside the sphere)

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^3}r\,\hat{r} = \frac{\rho r}{3\varepsilon_0}$$

$E_{in} \propto r$

at $r = 0$, $E = 0$

(i) Graphically



(ii) Again for points outside the sphere, it behaves as all the charge is present at the centre

(iii) For points outside, it obeys inverse square law

Electric Potential

Case 1 : $r > R$

$$V_{out} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

Case 2 : $r = R$

$$V_{surface} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

Case 3 : $r < R$

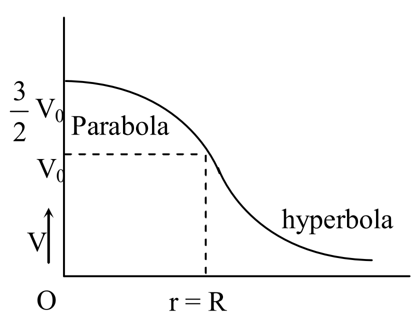
$$V_{in} = \frac{1}{4\pi\varepsilon_0}\frac{Q(3R^2 - r^2)}{2R^3}$$

At centre $r = 0$

$$V_{centre} = \frac{3}{2}\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

$V_{centre} = 3/2\ V_{surface}$

Graphically



10.3 Electric field due to infinitely long charge distribution :

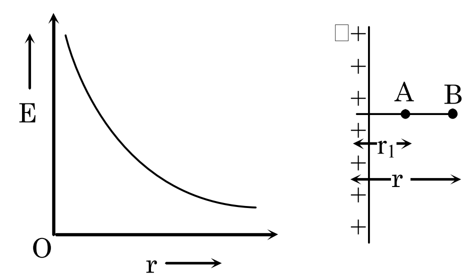
(i) A long wire is given a line charge density λ.

(ii) If wire is positively charged, direction of E will be away from the wire while for a negatively charged wire, direction of $\vec{E}$ will be towards the wire .

(iii) E at point p

$$\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{r} \text{ or } E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

(iv)



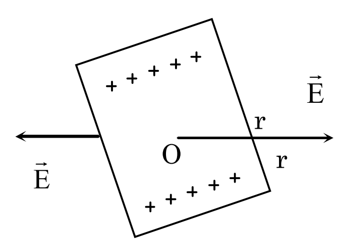
(v) Potential difference between points $A(r_1)$ & $B(r_2) = V_A - V_B = \frac{\lambda}{2\pi\varepsilon_0}\ell n\left(\frac{r_2}{r_1}\right)$

(vi) If two charged wires (λ_1) & (λ_2) are kept parallel to each other at a distance 'd', then the force on unit length of any of the wire is:

$$\frac{\lambda_1\lambda_2}{2\pi\varepsilon_0 d}$$

10.4 Electric field at a point due to an infinite sheet of charge

(i) If σ = surface charge density. Intensity at points near to the sheet = $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{r}$



(ii) Direction of electric field is perpendicular to the sheet of charge.

(iii) Intensity of electric field does not depend upon the distance of points from the sheet for the points in front of sheet.

(iv) Potential difference between two points A & B at distances r_1 & r_2 respectively is

$$V_A - V_B = \frac{\sigma}{2\varepsilon_0}(r_2 - r_1)$$

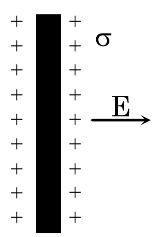
10.5 Electric field due to infinite charged metal sheet

(i) Intensity at points near the sheet

$$\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{r}$$

where

σ = surface charge density



(ii) $\vec{E}$ is independent of distance of the point from the sheet and also of the area of sheet.

(iii) Direction of electric field is perpendicular to the sheet.

(iv) Potential difference between two point A (r_1) and B (r_2) ($r_1 < r_2$) near the sheet is

$$\Delta V = V_A - V_B = \frac{\sigma}{\varepsilon_0}(r_2 - r_1)$$

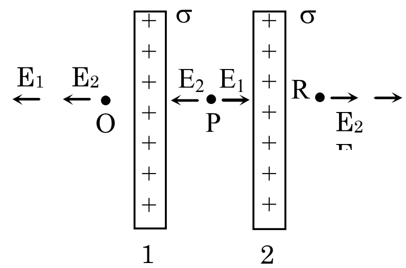
10.6 Electric field due to two infinite parallel plane sheet of charge :

(i) Both sheet have same type of charge

$$E_O = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

$$E_P = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

$$E_R = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

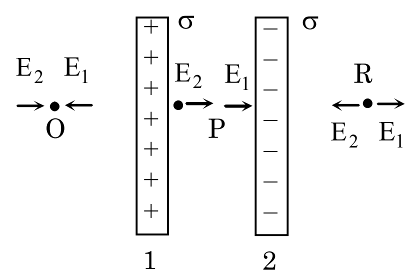


(ii) Two plates have opposite type of charge

$$E_O = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

$$E_P = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

$$E_R = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$



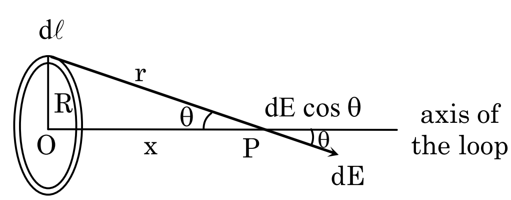
Note : In this case, we will have an uniform electric field between the two plates directed from positive to negative charged plate. Electric field intensity is zero elsewhere.

10.7 Electric field due to charged ring : Q charge is distributed over a ring of radius R.

(i) Intensity of electric field at a distance x from the centre of ring along it's axis is

$$E = \int dE \cos\theta$$

or $$E = \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(R^2 + x^2)^{3/2}}$$

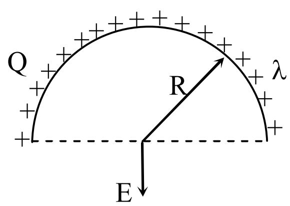


(ii) Intensity will be zero at the centre of the ring.

(iii) Intensity will be maximum at a distance $\frac{R}{\sqrt{2}}$ from the centre and $E_{max} = \frac{2}{3\sqrt{3}} \cdot \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R^2}$

(iv) Electric potential at a distance x from centre, $V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{\sqrt{(x^2+R^2)}}$

10.8 Uniformly charged semi - circular arc



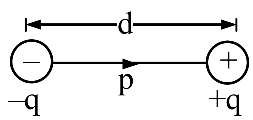
$$E_{centre} = \frac{\lambda}{2\pi\varepsilon_0 R}$$

where ℓ = linear charge density = $\frac{Q}{\pi R}$

$$V_{centre} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{R}$$

11. Electric dipole

(a) A system consisting of two equal and opposite charges separated by a small distance is termed an electric dipole.



Example : Na^+Cl^-, $H^+ Cl^-$ etc.

(b) Dipole moment: The product of the magnitude of charges and distance between them is called the dipole moment.

- This is a vector quantity which is directed from negative to positive charge.
- Unit : Coulomb - metre (C-m)
- Dimension : $[M^0 L^1 T^1 A^1]$
- Dipole moment $\vec{p} = q\,\vec{d}$

11.1 Electric field due to a dipole

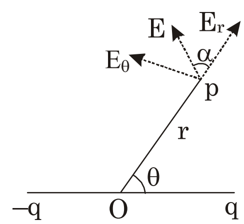
(i) There are two components of electric field at any point

(a) $E_r \rightarrow$ in the direction of $\vec{r}$

(b) $E_\theta \rightarrow$ in the direction perpendicular to $\vec{r}$

$$E_r = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2P\cos\theta}{r^3}$$

$$E_\theta = \frac{1}{4\pi\varepsilon_0} \cdot \left(\frac{P\sin\theta}{r^3}\right)$$



(ii) Resultant

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

(iii) Angle between the resultant $\vec{E}$ and $\vec{E}_r$, α is given by $\alpha = \tan^{-1}\left(\frac{E_\theta}{E_r}\right) = \tan^{-1}\left(\frac{1}{2}\tan\theta\right)$

(iv) If θ = 0, i.e point is on the axis -

$$E_{axis} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2P}{r^3}$$

θ = 0, i.e. along the axis.

(v) If θ = 90º, i.e. point is on the line bisecting the dipole perpendicularly

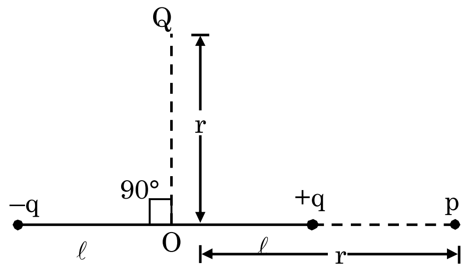
$$E_{equator} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P}{r^3}$$

(vi) So, $E_{axis} = 2E_{equator}$ (for same r)

(vii) $E_{axis} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2Pr}{(r^2-\ell^2)^2}$

$$E_{equator} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P}{(r^2+\ell^2)^{3/2}}$$

where $P = q \cdot (2\ell)$



(viii) $V = \frac{1}{4\pi\varepsilon_0} . \frac{q(2\ell)\cos\theta}{r^2}$

$= \frac{1}{4\pi\varepsilon_0} . \frac{P\cos\theta}{r^2} = \frac{1}{4\pi\varepsilon_0} . \frac{\vec{P} . \vec{r}}{r^2}$

$= \frac{1}{4\pi\varepsilon_0} . \frac{\vec{P} . \hat{r}}{r^3}$

where θ is the angle between $\vec{P}$ and $\vec{r}$.

(ix) If θ = 0, $V_{axis} = \frac{P}{4\pi\varepsilon_0 . r^2}$

(x) If θ = 90°, $V_{equator} = 0$

(xi) Here we see that $V = 0$ but $E \neq 0$ for points at equator

(xii) Again, if $r >> 2\ell$ is not true and d = 2ℓ,

$$V_{axis} = \frac{1}{4\pi\varepsilon_0} . \frac{P}{(r^2 - \ell^2)}$$

$$V_{equator} = 0$$

Note :

(i) This is not essential that at a point, where $E = 0$, V will also be zero there eg. inside a uniformly charged sphere, $E = 0$ but $V \neq 0$

(ii) Also if $V = 0$, it is not essential for E to be zero eg. in equatorial position of dipole $V = 0$, but $E \neq 0$

11.2 Electric dipole in an electric field - uniform electric field

(i) When an electric dipole is placed in an uniform electric dipole, A torque acts on it which subjects the dipole to rotatory motion. This τ is given by τ = PE sinθ or

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

(ii) Potential energy of the dipole

$$U = -\text{PE}\cos\theta = -\vec{P} . \vec{E}$$

Cases :

(a) If θ = 0°, i.e. $\vec{P} || \vec{E}$, τ = 0 and $U = -$ PE, dipole is in the minimum potential energy state and no torque acting on it and hence it is in the stable equilibrium state.

(b) For θ = 180°, i.e. $\vec{P}$ and $\vec{E}$ are in opposite direction, then τ = 0 but U = PE which is maximum potential energy state. Although it is in equilibrium but it is not a stable state and a slight perturbation can disturb it.

(c) θ = 90°, i.e. $\vec{P} \perp \vec{E}$, then

τ = PE (maximum) and $U = 0$

Note :

(a) There is no net force acting on the dipole in a uniform electric field.

(b) If dipole is placed in a nonuniform electric field, it performs rotatory as well as translator motion because now a net force also acts on the dipole along with the torque.

11.3 Work done in rotating on electric dipole in an electric field

(i) Work done in rotating the dipole from position θ_1 to θ_2 with field direction in an uniform electric field is.

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

12. Force on the surface of a charged conductor

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

(b) When a conductor is charged then it's entire surface experiences an outward force perpendicular to the surface.

(c) The force per unit area of the charged surface is called as the electrical pressure,

$$P_{electrical.} = \frac{\sigma^2}{2\varepsilon_0} \text{ N/m}^2.$$

(d) The direction of this force is perpendicular to the surface.

12.1 Energy associated with the electric field:

(i) The energy stored per unit volume in an electric field E is given by

$$U = \frac{1}{2}\ \varepsilon_0\ E^2$$

This is also called energy density

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

12.2 Drop of a charged liquid :

If n identical drops each having a charge q and radius r coalesce to form a single large drop of radius R and charge Q, then

(i) Charge will be conserved i.e. $nq = Q$

(ii) Volume will be conserved i.e.

$$n\ .\ \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \text{ or } R = n^{1/3}\, r$$

(iii) Potential of each small drops

$$V = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r}$$

(iv) Potential of large drop is given as

$$V' = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} = n^{2/3}\, V$$

(v) Electric field at surface of small drop is

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

(vi) Electric field at surface of large drop = E'

$$E' = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{R^2}$$

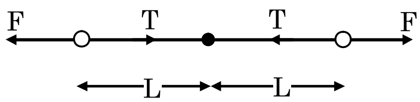
$$E' = n^{1/3}\, E.$$

SOLVED EXAMPLES

Ex.1 Two small balls having equal charges Q, are suspended from a hook with two insulating threads each of length L. This arrangement is carried in the space, where there is no gravitation. The tension in each string will be -

(A) $\frac{kQ^2}{4L^2}$ (B) 0 (C) $\frac{kQ}{4L^2}$ (D) $\frac{kQ^2}{L^2}$

Sol. (A)



(electrostatic force acting between two charged balls) $F = \frac{kQ^2}{(2L)^2} = \frac{kQ^2}{4L^2}$

$\because \quad T = F = \frac{kQ^2}{4L^2}$

Note : In the above problem, the angle between the 'threads will be 180^0.' Because in the absence of gravity, the tension in the threads will be only due to columb-repulsion. Therefore the angle between the threads will be 180^0.

Ex.2 A copper atom consists of copper nucleus surrounded by 29 electrons. The atomic weight of copper is 63.5 g/mole. Let us now take two pieces of copper each wieghing 10g. Let us transfer one electron from one piece to another for every 1000 atoms in that piece. What will be the coulomb force between the two pieces after the transfer of electron if they are 1cm. apart.

[Avogadro number $N = 6 \times 10^{23}$/g. mole, charge on an electron = -1.6×10^{-19} coulomb]

Sol. 63.5 g copper contains 6×10^{23} copper atoms.

Therefore number of copper atoms in 10g copper = $\frac{6\times10^{23}}{63.5} \times 10$

As only one electron is transferred for every 1000 atoms, therefore the number of electron transferred

$n = \frac{6\times10^{23}\times10}{63.5\times1000}$

Magnitude of charge

$q = ne = \frac{6\times10^{23}\times10}{63.5\times1000} \times 1.6 \times 10^{-19}$

Coul. = $\frac{1920}{127}$ Coul.

Separation between pieces = 1 cm = 10^{-2} m

One piece of copper has positive charge and the other negative charge, therefore force of attraction between the pieces

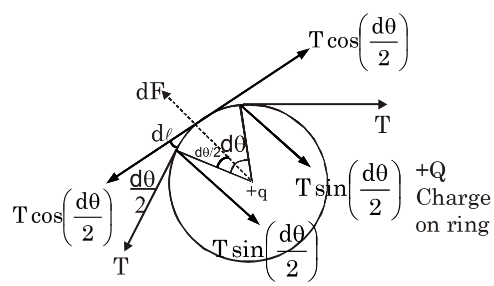
$= \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

$= \frac{9\times10^9\times\left(\frac{1920}{127}\right)\times\left(\frac{1920}{127}\right)}{(10^{-2})^2}$

$= 2.057 \times 10^{16}$N

Ex.3 A thin conducting ring of radius r has an electric charge $+Q$. What would be the increase in the tension of wire, if a point charge $+q$ is placed at the centre of the ring?

Sol.



Charge on a small element $d\ell$ of the ring

$dQ = \frac{Q}{2\pi r}d\ell$

Outward electric force on this element

$dF = \frac{1}{4\pi\varepsilon_0}\left(\frac{Qd\ell}{2\pi r}\right)\left(\frac{q}{r^2}\right)$

Let the tension be increased by T, to balance this force dF.

Net force towards centre on element $d\ell$ is

$= 2T \sin(d\theta/2) = 2T\, d\theta/2 \cong T\, d\ell/r$

$(\therefore d\ell = r d\theta, \text{Angle} = \frac{Arc}{radius})$

Hence for balance $T\dfrac{d\ell}{r} = dF$

$$\therefore T\frac{d\ell}{r} = \frac{1}{4\pi\varepsilon_0}\left(\frac{Qd\ell}{2\pi r}\right)\left(\frac{q}{r^2}\right)$$

$$\therefore T = \frac{Qq}{8\pi^2\varepsilon_0 r^2}$$

Ex.4 (a) Two similar point charges q_1 and q_2 are placed at a distance 'r' apart in air. If a dielectric slab of thickness 't' (< r) and dielectric constant 'K' is placed between the charges, calculate the coulomb force of repulsion (b). If the thickness of slab covers half the distance, between the charges, the coulomb repulsive force is reduced in the ratio 9 : 4, calculate the dielectric constant of slab.

Sol. (a) The repulsive force between the charges in air is $F_0 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{r^2}$ ....(A)

If the space is completely filled with medium of dielectric constant K, the repulsive force becomes

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{Kr^2} \quad ....(B)$$

Now let us suppose that the repulsive force is F in air if separation between charges becomes r' so

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_1^2} \quad ...(C)$$

Equating (B) & (C) $r_1' = r\sqrt{k}$

This gives equivalent air separation due to presence of dielectric of dielectric constant 'K' and thickness r. If there exists a slab of thickness t and dielectric constant K, the effective air separation between the charges will be $(r - t) + t\sqrt{k}$. Hence required repulsive force between charges

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{(r - t + t\sqrt{k})^2}$$

(b) Substituting t = r/2

$$\text{Then } F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{\left(r - \frac{r}{2} + \frac{r}{2}\sqrt{k}\right)^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{(1+\sqrt{k})^2 r^2}$$

Force in air will be $F_{air} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{r^2}$

$$\therefore \frac{F}{F_{air}} = \frac{4}{(1+\sqrt{k})^2}$$

Given $\dfrac{F}{F_{air}} = \dfrac{4}{9}$

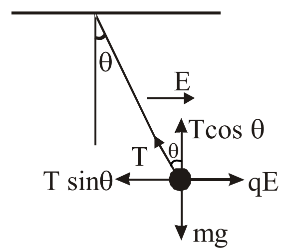
$\therefore K = 4$

Ex.5 The bob of a pendulum carries an electric charge of 39.2×10^{-10} coulomb in a horizontal electric field of 20×10^3 V/m and it is at rest. The angle made by the pendulum with the vertical will be, if the mass of pendulum is 8×10^{-6} kg and $g = 9.8$ m/s^2 -

(A) 27° (B) 45°

(C) 87° (D) 127°

Sol.



$T\sin\theta = qE$

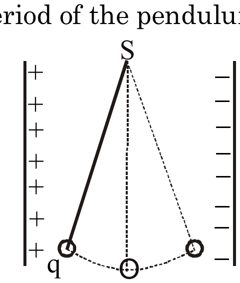
$T\cos\theta = mg$

$$\tan\theta = \frac{qE}{mg} = \frac{39.2\times10^{-10}\times20\times10^3}{8\times10^{-6}\times9.8}$$

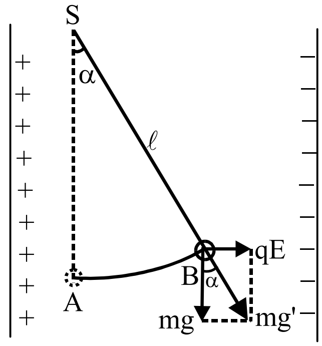
$\tan\theta = 1$

$\Rightarrow \theta = 45^0$

Ex.6 A simple pendulum is oscillating between the plates of a capacitor as shown in the fig. If the bob and the capacitor both are charged, what will be the effect on the time-period of the pendulum?



Sol.



Suppose the mass of the bob is m and the length of its thread is ℓ. When the bob and the capacitor both are uncharged, then time period is given by $T = 2\pi\sqrt{\frac{\ell}{g}}$. Suppose a charge +q is given to the bob. On charging the capacitor, the equilibrium position of the bob will change from A to B and thread of the pendulum will now make an angle α with the vertical, tan α = $\frac{qE}{mg}$

where qE is the electric force and mg is the gravitational force. On displacing the bob from the position B, it will oscillate under the effective acceleration

g', where mg' = $\sqrt{(mg)^2 + (qE)^2}$

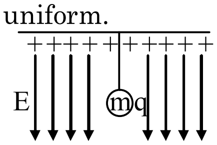
$\therefore$ g' = $\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}$

Hence the new time period of the pendulum is

$T' = 2\pi\sqrt{\frac{\ell}{g'}} . = 2\pi \frac{\sqrt{\ell}}{[g^2 + (qE/m)^2]^{1/4}}$

since $g' > g$ hence $T' < T$. i.e. time period of the pendulum will decrease

Ex.7 A simple pendulum (length ℓ, mass of the bob m) is suspended between the parallel plates of a capacitor as shown in the fig. What will be the effect on its time period if it is (i) positively charged, (ii) negatively-charged? Assuming that the electric force on the bob is less than the gravitational force and the electric field E between the plates is uniform.



Sol. When both the bob and the capacitor are uncharged, then $T = 2\pi\sqrt{\frac{\ell}{g}}$. Time-period in case (i) is

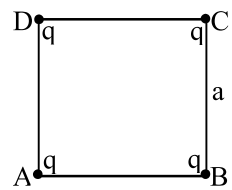
$$T_1 = 2\pi\sqrt{\frac{\ell}{\left\{g + \left(\frac{qE}{m}\right)\right\}}}$$

and in cae (ii) it is

$$T_2 = 2\pi\sqrt{\frac{\ell}{\left\{g - \left(\frac{qE}{m}\right)\right\}}}$$

Clearly, in case (i) the time period decreases ($T_1 < T$) and in case (ii) it increases ($T_2 > T$)

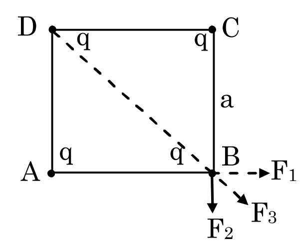
Ex.8 A square of side 'a' has equal charge 'q' at its corners. The magnitude of force at B will be-



(A) $\frac{1}{2}\frac{kq^2}{a^2}$ $(1 + 2\sqrt{2})$ (B) $\frac{1}{2}\frac{k^2q^2}{a^2}$

(C) $\frac{4kq^2}{a^2}$ (D) None of these

Sol. (A)



Force on the charge placed at B, due to charges at A, C, & D are $F_1 = \frac{kq^2}{a^2}$,

$F_2 = \frac{kq^2}{a^2}$ & $F_3 = \frac{kq^2}{(a\sqrt{2})^2} = \frac{kq^2}{2a^2}$

respectively. [Note BD = $\sqrt{2}\,a$]

Resultant of F_1 & F_2,

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

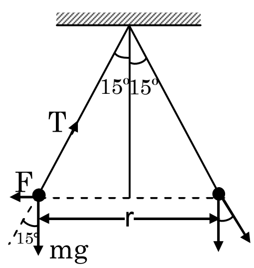
F_{12} | | F_3

$$\because F = \sqrt{F_{12}^2 + F_3^2 + 2F_{12}.F_3\cos 0} = F_{12} + F_3$$

$$= \frac{\sqrt{2}\,kq^2}{a^2} + \frac{kq^2}{2a^2}$$

Ex.9 Two identical charged spheres are suspended in air by strings of equal lengths and string make an angle of 30^0 with each other. When suspended in a liquid of density 0.8 gm cm^{-3}, the angle remains the same. What is the dielectric constant of the liquid? (Density of the material of the spheres is 1.6 gm cm^{-3})

Sol.



Suppose the mass of each sphere is m kg, the distance between them is r meter. Each sphere is in equilibrium under the action of three forces (i) weight of the sphere = mg
(ii) electrical force of repulsion

$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$ and (iii) tension T of the string. Resolving these forces in vertical and horizontal components, we have

$T\cos 15 = mg$ and

$$T\sin 15^\circ = F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$$

$$\therefore \tan 15^\circ = \frac{1}{4\pi\varepsilon_0 K}\frac{2q^2}{mgr^2} \quad ....(1)$$

On immersing in the liquid the (effective) weight of each sphere and the force of repulsion both decrease and hence the tension also decreases. The angle is still 30°. In the liquid, we have

(i) weight of the sphere = $mg - U$

$= V\sigma g - V\rho g$

$= V\sigma g\,(1 - \rho/\sigma) = mg\,(1 - 0.8/1.6)$

$= mg/2$ (V volume of sphere)

(ii) electrical force of repulsion

$$F = \frac{1}{4\pi\varepsilon_0 K}\frac{q^2}{r^2},$$

where K is dielectric constant of the liquid, and

(iii) tension T (say). Now $T\cos 15^0 = mg/2$

$$\text{and } T\sin 15^0 = \frac{1}{4\pi\varepsilon_0 K}\frac{q^2}{r^2}$$

$$\therefore \tan 15^0 = \frac{1}{4\pi\varepsilon_0 K}\frac{2q^2}{mgr^2} \quad ....(2)$$

From eq. (1) and (2) we have

$$\frac{1}{4\pi\varepsilon_0}\frac{q^2}{mgr^2} = \frac{1}{4\pi\varepsilon_0 K}\frac{2q^2}{mgr^2} \Rightarrow K = 2$$

Ex.10 An electron falls a distance of 4 cm in a uniform electric field of magnitude 5×10^4 N/C. The time taken by electron in falling will be-

(A) 2.99×10^{-7} s (B) 2.99×10^{-8} s

(C) 2.99×10^{-9} s (D) 2.99×10^{-10} s

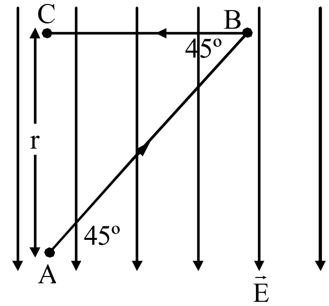
Sol. (C)

$$y = \frac{1}{2}at^2 = \frac{1}{2}\frac{eE}{m}t^2 \Rightarrow t = \sqrt{\frac{2ym}{e.E}}$$

[Putting $y = 4 \times 10^{-2}$ m, $m = 9.1 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$C, $E = 5 \times 10^4$ N/C]

$$t = \sqrt{\frac{2ym}{e.E}} = 3 \times 10^{-9} \text{ s}$$

Ex.11 In the adjacent fig. a unit positive charge moves along the path ABC in an electric field E. The potential difference between A & C will be



(A) 0 (B) Er (C) Er/2 (D) Er/4

Sol.(B) $\int_{V_A}^{V_C} dV = -\int_{r_A}^{r_C} \vec{E} \cdot \vec{dr}$

$V_C - V_A = -\vec{E}\,(\vec{r}_C - \vec{r}_A)$

$= \vec{E} \cdot \vec{r}_{CA} = Er_{CA} \cos\theta$

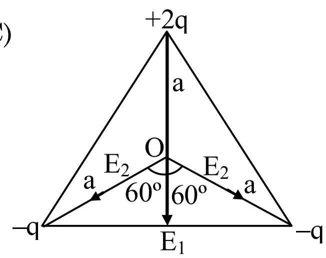
$= Er \cos 0° = Er$

Ex.12 Charge $2q$, $-q$ & $-q$ lies at the vertices of a equilateral triangle. The value of E and V at the centroid of the triangle will be-

(A) $E \neq 0$ and $V \neq 0$ (B) $E = 0$ and $V = 0$

(C) $E \neq 0$ and $V = 0$ (D) $E = 0$ and $V \neq 0$

Sol. (C)



$V = V_1 + V_2 + V_3$

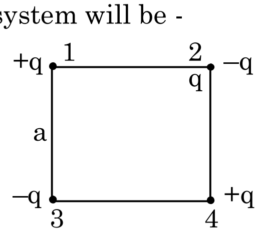
$= k\left[\frac{2q}{a} - \frac{q}{a} - \frac{q}{a}\right] = 0$

$E = E_1 + (E_2 \cos 60^0 + E_2 \cos 60^0]$

$= E_1 + E_2$

$E \neq 0$

Ex.13 In the fig. given below, the potential energy of the system will be -



(A) $\frac{kq^2}{a}\left(\sqrt{2} - 4\right)$ (B) $\frac{kq^2}{a}$

(C) 0 (D) $\frac{kq}{a}\left(\sqrt{2} - 4\right)$

Sol. (A) $U = U_{12} + U_{24} + U_{34} + U_{13} + U_{14} + U_{24}$

$$= k\left[\frac{q(-q)}{a} + \frac{(-q)(q)}{a} + \frac{(q)(-q)}{a} + \frac{(-q)(q)}{a} + \frac{(q)(q)}{a\sqrt{2}} + \frac{(-q)(-q)}{a\sqrt{2}}\right]$$

Ex.14 Two particles A and B having masses equal and charges q and $4q$. If these are accelerated from rest through same potential difference, then what will be the ratio in their speeds?

(A) 4 : 1 (B) 1 : 4

(C) 2 : 1 (D) 1 : 2

Sol. (D) $\Delta K = \Delta U \Rightarrow \frac{1}{2}mv^2 = q \times V$

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

$\Rightarrow v \propto \sqrt{q}\ ,\quad \therefore \frac{v_A}{v_B} = \sqrt{\frac{q}{4q}} = \frac{1}{2}$

Ex.15 Two identical particles of mass m carry a 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 the speed v. Find the closest distance of approach-

Sol. The masses are identical, each of mass m. Therefore we cannot treat any particle too heavier and hence at rest throughout. Since external force on the system is zero. So according to principle of conservation of linear momentum.

Initial momentum = Final momentum

$\Rightarrow mv + 0 = mv_1 + mv_2$

$\Rightarrow v = v_1 + v_2$

Where v_1 and v_2 are velocities of first and second particles. As the particles are identical, so by symmetry at nearest approach $v_1 = v_2 = \frac{v}{2}$

If d is the distance of nearest approach, then initial energy of system = Final energy at nearest approach

$$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{v}{2}\right)^2 + \frac{1}{2}m\left(\frac{v}{2}\right)^2 + \frac{1}{4\pi\varepsilon_0}\frac{(Q)(Q)}{d}$$

$$\Rightarrow \frac{1}{4}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{d}$$

$\therefore$ Distance of nearest approach,

$$d = \frac{1}{4\pi\varepsilon_0}\frac{4Q^2}{mv^2} = \frac{kq^2}{a}(\sqrt{2} - 4)$$

Ex.16 Sphere of radius 4 cm is suspended inside a hollow spherical conductor of radius 6 cm concentrically. The small sphere is charged upto 3 e.s.u and the outer surface is connected to earth. The potential difference between the spheres will be-

(A) 36 e.s.u. (B) 54 e.s.u.

(C) 30 e.s.u. (D) 0.25 e.s.u.

Sol. (D) $\therefore\ V = V_{small} - V_{large} = \frac{kq}{r} - \frac{kq}{R}$

$$= kq\left[\frac{1}{r} - \frac{1}{R}\right] \qquad .....(1)$$

$q = 3$ e.s.u., $r = 4$ cm, $R = 6$ cm and

In C.G.S. $k = 1$ dyne cm^2/stat. coulomb^2

$\therefore$ From (1) $V = 3\left[\frac{1}{4} - \frac{1}{6}\right] = 0.25$ e.s.u.

Ex.17 A sphere of radius 5 cm has electric field 5×10^6 V/m on its surface. What will be the force acting on a charge of 5×10^{-8}C placed at distance of 20cm from the centre of sphere-

(A) 1.5×10^{-2} N (B) 40 N

(C) 4 N (D) 0 N

Sol. (A) At surface, $E_s = \frac{kq}{R^2} \Rightarrow kq = E_s R^2$

At distance r =20 cm from the centre

$E = \frac{kq}{r^2}$

So force on charge $Q = 5 \times 10^{-8}$ C

$F = QE = \frac{QE_s R^2}{r^2}$

Puting $Q = 5 \times 10^{-8}$ C, $Es = 5 \times 10^6$ V/m,

$R = 0.05$ m, $r = 0.20$ cm

$F = 1.5 \times 10^{-2}$ N

Ex.18 A thin stationary ring of radius 1m has a positive charge of 1×10^{-5} coulomb uniformly distributed over it. A particle of mass 0.9 gram and having a negative charge of 1×10^{-6} coulomb is placed on the axis at a distance of 1 cm from the centre of the ring. Show that the motion of the negatively-charged particle is approximately simple harmonic. Calculate the time-period of oscillation.

Sol. The electric field on the axis of a charged ring of radius R meter at a distance x from its centre is given by

$E = \frac{1}{4\pi\varepsilon_0}\frac{qx}{(R^2 + x^2)^{3/2}}$ where q is the charge on the ring. If the distance x is very small compared to radius R, then x^2 can be neglected in $R^2 + x^2$. In this position, we have

$$E = \frac{1}{4\pi\varepsilon_0}\frac{qx}{R^3}$$

If the particle of negative charge q' is situated at a distance x, then the electric force on the particle is

$$F = -q'E = -\frac{1}{4\pi\varepsilon_0}\frac{qq'}{R^3}x.$$

Since the ring has positive charge and the particle has negative charge, hence the force F will be of attraction (towards the ring). Under the action of this force the particle will perform periodic motion in line on with side of the centre of the ring. The acceleration of the particle is given by

$a = \frac{F}{m}$

$a = -\frac{1}{4\pi\varepsilon_0}\frac{qq'}{mR^3}x = -\omega^2 x.$ ....(i)

$\therefore\ a \propto x$

In equation (i) $\omega = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{qq'}{mR^3}}$

$= \sqrt{(9\times10^9)\frac{(1\times10^{-5})(1\times10^{-6})}{(0.9\times10^{-3})(1)^3}} = 10$

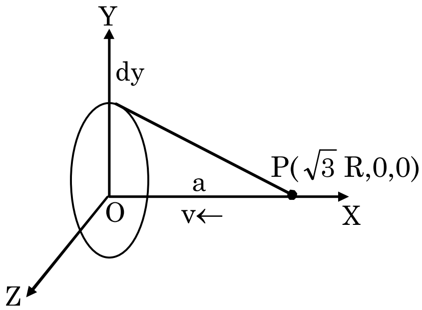
$\therefore\ a \propto x$

Since the acceleration a is directly proportional to the displacement x and is directed towards the centre of the ring, hence the motion of the particle is simple harmonic. The time period of the particle is

$T = \frac{2\pi}{\omega} = T = \frac{2\pi}{10} = \frac{\pi}{5}$ sec

Ex.19 A circular ring of radius R with uniform positive charge density 'λ' per unit length is located in the y-z plane with its centre at the origin O. A particle of mass m and positive charge q is projected from the point $P(\sqrt{3}R,\ 0,\ 0)$ on the positive x-axis directly towards O, with an initial speed v. Find the smallest (non-zero) value of speed v such that the particle does not return P

Sol.



The electric field at the centre of ring is zero. Therefore the force on charged particle at the centre of ring is zero. Hence if the particle reaches at the centre O of the ring, then it will not return to P. For minimum value of velocity v, the speed of particle at the centre must be zero. By the principle of conservation of energy.

(K.E. + P.E.) at P = (K.E. + P.E.) at O

$$\frac{1}{2}mv^2 + qV_p = 0 + qV_0$$

$$\Rightarrow \frac{1}{2}mv^2 + \frac{1}{4\pi\varepsilon_0}\frac{(2\pi R\lambda)q}{\sqrt{(\sqrt{3}R)^2 + R^2}}$$

$$= 0 + \frac{1}{4\pi\varepsilon_0}\frac{(2\pi R\lambda)q}{R}$$

$$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{(2\pi R\lambda)q}{R} - \frac{(2\pi R\lambda)q}{2R}\right]$$

$$v = \sqrt{\frac{\lambda q}{2\varepsilon_0 m}}$$

Ex.20 The radii of internal and external spheres of concentric spherical air capacitor are 1 cm and 4 cm respectively. A potential difference of 3000 volts is applied between the spheres. What velocity will be imparted to an electron. When it approaches from a distance of r_1 = 3 cm to r_2 = 2cm as measured from the centre of spheres.

Sol. The potential differences between spherical conductors $V_{ab} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{a} - \frac{q}{b}\right)$

Here a = 1cm = 10^{-2} m,

b = 4 cm = 4×10^{-2} m

$$\therefore\ 3000 = 9 \times 10^9\, q\left[\frac{1}{10^{-2}} - \frac{1}{4\times10^{-2}}\right]$$

$$\Rightarrow q = \frac{4}{9} \times 10^{-8} \text{ coul.}$$

The potential at, a point distant 3 cm from centre, $V_1 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_1} - \frac{q}{b}\right)$

The potential at a point distant 2 cm from centre, $V_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_2} - \frac{q}{b}\right)$

The gain in K.E. of electron $K = \Delta U$

$= e(V_2 - V_1)$

$$K = e\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r_2} - \frac{q}{b} - \frac{q}{r_1} + \frac{q}{b}\right]$$

$$K = \frac{1}{4\pi\varepsilon_0}eq\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$$

$$K = 9 \times 10^9 \times 1.6 \times 10^{-19} \times \frac{4}{9} \times 10^{-8}\left[\frac{1}{2\times10^{-2}} - \frac{1}{3\times10^{-2}}\right]$$

$$K = \frac{32}{3} \times 10^{-19} \text{ Joule}$$

$$\Rightarrow \frac{1}{2}mv^2 = \frac{32}{3} \times 10^{-19} \text{ joule}$$

$\Rightarrow v = 1.54 \times 10^7$ m/s [$\because\ m = 9 \times 10^{-31}$ kg]

Ex.21 A charge Q is distributed over two concentric hollow spheres of radii r and R (> r) such that their surface charge densities are equal. Find the potential at the common centre.

Sol. Suppose the charges on the spheres of radii r and R are Q_r, and Q_R respectively, Then $Q = Q_r + Q_R$

Let the surface charge density be σ. Then

$$\sigma = \frac{Q_r}{4\pi r^2} = \frac{Q_R}{4\pi R^2} \Rightarrow \frac{Q_r}{Q_R} = \frac{r^2}{R^2}$$

or $\frac{Q_r}{Q_R} + 1 = \frac{r^2}{R^2} + 1$

or $\frac{Q_r + Q_R}{Q_R} = \frac{r^2 + R^2}{R^2}$

or $\frac{Q}{Q_R} = \frac{r^2 + R^2}{R^2}$

$\therefore\ Q_R = Q\left(\frac{R^2}{r^2 + R^2}\right)$,

Similarly, $Q_r = Q\left(\frac{r^2}{r^2 + R^2}\right)$

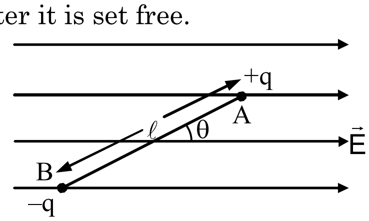
Suppose the potentials at the common centre due to Q_R and Q_r be V_R and V_r respectively. Then

$$V_R = \frac{Q_R}{4\pi\varepsilon_0 R} = \frac{QR^2}{4\pi\varepsilon_0 R(r^2 + R^2)}$$

$$Vr = \frac{Q_r}{4\pi\varepsilon_0 r} = \frac{Qr^2}{4\pi\varepsilon_0 r(r^2 + R^2)}$$

$$\therefore\ V = V_R + V_r = \frac{Q}{4\pi\varepsilon_0}\left(\frac{R + r}{r^2 + R^2}\right)$$

Ex.22 A point particle of mass M is attached to one end of a massless rigid non-conducting rod of length ℓ. Another point particle of the same mass is attached to the other end of the rod. The two particles carry charges $+q$ and $-q$ respectively. This arrangement is held in a region of a uniform electric field E such that the rod makes angle θ (say of 5^0) with the field direction. Find an expression for the minimum time needed for the rod to become parallel to the field after it is set free.



Sol. The rod comes to equilibrium position due to a torque applied by electric field. The moment of inertia of system about O,

$$I = M\left(\frac{\ell}{2}\right)^2 + M\left(\frac{\ell}{2}\right)^2 = \frac{M\ell^2}{2}$$

The electric force qE and $-qE$ act on A and B, along and opposite to the direction of electric $\vec{E}$ field respectively.

Therefore net electric force on system

$$= qE - qE = 0$$

These two force form a couple of moment which is given as

$$\tau = (qE)\ \ell \sin\theta$$

$\therefore$ Restoring couple $\tau = -\,qE\ \ell \sin\theta$

If α is angular acceleration, then from relation $\tau = I\alpha$, we have

$$I\ \alpha = -qE\ell\sin\theta = -qE\ell\theta$$

[$\because$ $\sin\theta \approx \theta$, for small value of θ]

$\therefore$ Angular acceleration $\alpha = \dfrac{-qE\ell\theta}{I}$

$\Rightarrow\ \alpha \propto -\theta$

i.e. motion is angular S.H.M. for which standard equation is $\alpha = -\omega^2\theta$

$$\therefore\ \omega^2 = \frac{qE\ell}{I} = \frac{qE\ell}{\frac{M}{2}\ell^2} = \frac{2qE}{M\ell}$$

$$\omega = \sqrt{\frac{2qE}{M\ell}}$$

$\therefore$ Time period

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{2qE}{M\ell}}$$

$\therefore$Time needed for the rod to become parallel is

$$t = \frac{T}{4} = \frac{\pi}{2}\sqrt{\frac{M\ell}{2qE}}$$

EXERCISE -1

Questions based on Charge & its properties

Q.1 Charges reside on the -
(A) Outer surface of the charged conductor
(B) Inner surface of the charged conductor
(C) Inner as well as outer surface of the charged conductor
(D) None of the above

Q.2 An isolated solid metallic sphere is charged with +Q charge .The distribution of their +Q charge on the sphere will be-
(A) uniform but on the surface alone
(B) non uniform but on the surface alone
(C) uniform inside the volume
(D) non uniform inside the volume

Q.3 One quantum of charge should be at least be equal to the charge in coulomb-

(A) 1.6×10^{-17} C (B) 1.6×10^{-19} C
(C) 1.6×10^{-10} C (D) 4.8×10^{-10} C

Q.4 The unit of charge is coulomb in SI system and esu of charge (or stat coul) in C.G.S. system 1 coulomb equals -
(A) 3×10^9 esu (B) $(1/3 \times 10^9)$esu
(C) $(1/3 \times 10^8)$ esu (D) (9×10^9) esu

Q.5 If a body is charged by rubbing it, its weight-
(A) always decreases slightly
(B) always increases slightly
(C) may increase slightly or may decrease slightly
(D) remains precisely the same

Q.6 An electron at rest has a charge of 1.6×10^{-19} C. It starts moving with a velocity v = c/2, where c is the speed of light, then the new charge on it is -
(A) 1.6×10^{-19} Coulomb
(B) $1.6 \times 10^{-19}\sqrt{1-\left(\frac{1}{2}\right)^2}$ Coulomb
(C) $1.6 \times 10^{-19}\sqrt{\left(\frac{2}{1}\right)^2-1}$ Coulomb
(D) $\frac{1.6\times10^{-19}}{\sqrt{1-\left(\frac{1}{2}\right)^2}}$ Coulomb

Q.7 If a glass rod is rubbed with silk, it acquires a positive charge because -
(A) Protons are added to it.
(B) Protons are removed from it.
(C) Electrons are added to it.
(D) Electrons are removed from it.

Q.8 Which one of the following is the unit of electric charge ?
(A) Coulomb (B) Newton
(C) Volt (D) Coulomb/Volt

Q.9 An accelerated or retarded charge produces-
(A) Electric field only
(B) Magnetic field only
(C) Localised electric and magnetic fields
(D) Electric and magnetic fields that are radiated

Q.10 Which one of the following statement regarding electrostatics is wrong ?
(A) Charge is quantized
(B) Charge is conserved
(C) There is an electric field near an isolated charge at rest
(D) A stationary charge produces both electric and magnetic fields

Q.11 A stationary electric charge produces-
(A) Only electric fields
(B) Only magnetic field
(C) Both electric as magnetic field
(D) Neither electric Nor magnetic field

Q.12 In M.K.S. System, $\frac{1}{4\pi \in_0}$ equals -
(A) 9×10^9 N-m^2/C^2
(B) 1 N-m^2/C^2
(C) 1 dyne - cm^2 / stat C^2
(D) 9×10^9 dyne $\times$ cm^2 / stat C^2

Q.13 The dimensional formula of $\in_0$ is -
(A) $[M^{-1} L^{-3} T^4 A^2]$ (B) $[M^{-1}L^{-3}T^2A^2]$
(C) $[M^1L^3T^{-4}A^{-2}]$ (D) None of these

Q.14 The ratio of electric force (F_e) to gravitational force (F_g) acting between two electrons situated in vacuum will be-
(A) 1×10^{36} (B) 2×10^{39}
(C) 6×10^{45} (D) 4×10^{42}

Q.15 F_g and F_e represent the gravitational and electrostatic force respectively between two protons situated at some distance in vacuum. The ratio of F_g to F_e is of the order of -

(A) 10^{-43} (B) 10^{1} (C) 10^{0} (D) 10^{-36}

Question based on Coulomb's Law

Q.16 There are two charges +1 micro-coulomb and +5 micro-coulomb, the ratio of force on them will be –

(A) 10^{43} (B) 1 : 1 (C) 10^{o} (D) 10^{-43}

Q.17 When the distance between two charged particle is halved, the force between them becomes -

(A) One fourth (B) One half
(C) Double (D) Four times

Q.18 The force between two point charges in vacuum is 15N, if a metal plate is introduced between the two charges, then force between them will -

(A) Becomes zero
(B) Remains the same
(C) Becomes 30 N
(D) Becomes 60 N

Q.19 The force between an α-particle and an electron separated by a distance of 1 Å in vacuum is -

(A) 2.3×10^{-8} N attractive
(B) 2.3×10^{-8} N Repulsive
(C) 4.6×10^{-8} N attractive
(D) 4.6×10^{-8} repulsive

Q.20 Two charges are at distance (d) apart in air. Coulomb force between them is F. If a dielectric material of dielectric constant (K) is placed between them, the coulomb force now becomes-

(A) F/K (B) FK (C) F/K^2 (D) K^2F

Q.21 Two point charges in air at a distance of 20 cm. from each other interact with a certain force. At what distance from each other should these charges be placed in oil of relative permittivity 5 to obtain the same force of interaction –

(A) 8.94×10^{-2} m (B) 0.894×10^{-2} m
(C) 89.4×10^{-2} m (D) 8.94×10^{2} m

Q.22 A certain charge Q is divided at first into two parts, (q) and (Q–q). Later on the charges are placed at a certain distance. If the force of interaction between the two charges is maximum then -

(A) (Q/q) = (4/1) (B) (Q/q) = (2/1)
(C)(Q/q) = (3/1) (D) (Q/q) = (5/1)

Q.23 1 esu charge is placed in vacuum at 1 cm from an equal charge of the same kind. Force between them is -

(A) 1 Newton (B) 1 dyne
(C) 2 dyne (D) 4 dyne

Q.24 The permittivity of vacuum is 8.86×10^{-12} $C^2/N\text{-}m^2$ and the dielectric constant of water is 81. The permittivity of water in $C^2/N\text{-}m^2$ is -

(A) $81 \times 8.86 \times 10^{-12}$ (B) 8.86×10^{-12}
(C) $(8.86 \times 10^{-12})/ 81$ (D) $81/(8.86 \times 10^{-12})$

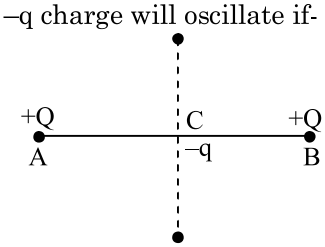
Q.25 The force between two point charges placed in vacuum at distance 1 mm is 18 N. If a glass plate of thickness 1 mm and dielectric constant 6, be kept between the charges then new force between them would be-

(A) 18 N (B) 108 N
(C) 3 N (D) 3×10^{-6} N

Q.26 Two similar and equal charges repel each other with force of 1.6 N, when placed 3m apart. Strength of each charge is-

(A) 40 μC (B) 20μC
(C) 4μC (D) 2μC

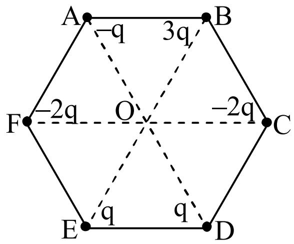
Q.27 Two similar charge of +Q , as shown in figure are placed at A and B. –q charge is placed at point C midway between A and B. –q charge will oscillate if-



(A) It is moved towards A
(B) It is moved towards B
(C) It is moved perpendicular to AB
(D) Distance between A and B is reduced

Question based on **Superposition principle**

Q.28 Six charges are placed at the corner of a regular hexagon of side a as shown. If an electron is placed at its centre O, force on it will be -

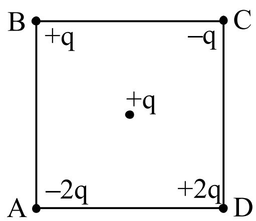


(A) zero (B) $\frac{1}{4\pi \epsilon_0} \frac{qe}{a^2}$

(C) $\frac{\sqrt{3}\, qe}{4\pi \epsilon_0\, a^2}$ (D) $\frac{qe}{2\pi \epsilon_0\, a^2}$

Q.29 The three charges each of 5×10^{-6} coulomb are placed at vertex of an equilateral triangle of side 10 cm. The force exerted on the charge of 1 μ C placed at centre of triangle in Newton will be-
(A) 13.5 (B) zero (C) 4.5 (D) 6.75

Q.30 Four charges are arranged at the corners of a square ABCD, as shown. The force on a +ve charge kept at the centre of the square is -



(A) zero
(B) along diagonal AC
(C) along diagonal BD
(D) perpendicular to the side AB

Q.31 A mass particle (mass = m and charge = q) is placed between two fixed point charges of charge q separation by 2L. The frequency of oscillation of mass particle, if it is displaced for a small distance along the line joining the charges–

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

(C) $\frac{q}{2\pi}\sqrt{\frac{1}{4m\pi\varepsilon_0 L^3}}$ (D) $\frac{q}{2\pi}\sqrt{\frac{1}{16\pi\varepsilon_0 m L^3}}$

Q.32 Two small balls having equal positive charge Q (Coulomb) on each are suspended by two insulating strings of equal length 'L' metre, from a hook fixed to a stand. The whole set up is taken in a satellite in to space where there is no gravity (state of weightlessness) Then the angle (θ) between the two strings is -
(A) 0º (B) 90º
(C) 180º (D) $0^\circ < \theta < 180^\circ$

Q.33 ABC is a right angle triangle AB = 3 cm, BC = 4 cm charges + 15, +12, –12 esu are placed at A, B and C respectively. The magnitude of the force experienced by the charge at B in dyne is-
(A) 125 (B) 35 (C) 22 (D) 0

Q.34 Equal charges of each 2μC are placed at a point x = 0, 2, 4, and 8 cm on the x-axis. The force experienced by the charge at x = 2 cm is equal to-
(A) 5 Newton (B) 10 Newton
(C) 0 Newton (D) 15 Newton

Q.35 Three equal charges (q) are placed at corners of a equilateral triangle. The force on any charge is- $\left(K = \frac{1}{4\pi\varepsilon_0}\right)$

(A) Zero (B) $\sqrt{3}\frac{Kq^2}{a^2}$

(C) $\frac{Kq^2}{\sqrt{3}a^2}$ (D) $3\sqrt{3}\frac{Kq^2}{a^2}$

Q.36 Two identical charges of charge (q) are placed at (–a,0) and (a, 0). Same nature charge particle is placed at origin. It executes S.H.M, if it is displaced -
(A) In x-direction
(B) In y-direction
(C) at an angle of 45º from the x-axis
(D) along perpendicular to the plane.

Q.37 Two equal negative charge (–q) are fixed at the points (0, a) and (0, –a) on the y-axis. A positive charge (Q) is released from rest at the point (2a, 0) on the x-axis. The charge Q will –
(A) execute simple harmonic motion about the origin.
(B) move to the origin and remains at rest
(C) move to infinity
(D) execute oscillatory but not simple harmonic motion

Q.38 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

Question based on

Electric field

Q.39 A pendulum bob of mass 80 mg and carrying a charge of 2×10^{-8} coul. is at rest in a horizontal uniform electric field of 20,000 V m^{-1}. Find the tension in the thread of pendulum -

(A) 8.8×10^{-2} N (B) 8.8×10^{-3} N
(C) 8.8×10^{-4}N (D) 8.8×10^{-5} N

Q.40 Two charges 4q and q are placed 30 cm. apart. At what point the value of electric field will be zero-

(A) 10 cm. away from q and between the charge
(B) 20 cm. away from q and between the charge
(C) 10 cm. away from q and out side the line joining the charge.
(D) 10 cm. away from 4q and out side the line joining them.

Q.41 Unit of electric field intensity is Newton/Coulomb. The other unit of this can be-

(A) Vm (B) Vm^2 (C) V/m (D) V/m^2

Q.42 If Q = 2 coulomb and force on it is F=100 Newton, then the value of field intensity will be -

(A) 100 N/C (B) 50 N/C
(C) 200 N/C (D) 10 N/C

Q.43 Four equal but like charge are placed at four corners of a square. The electric field intensity at the centre of the square due to any one charge is E, then the resultant electric field intensity at centre of square will be :

(A) Zero (B) 4E (C) E (D) 1/2E

Q.44 Two charges 9e and 3e are placed at a distance r. The distance of the point where the electric field intensity will be zero is-

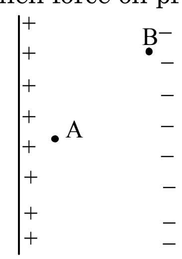
(A) $\left(\frac{r}{1+\sqrt{3}}\right)$ from 9e charge

(B) $\left(\frac{r}{1+\sqrt{1/3}}\right)$ from 9e charge

(C) $\left(\frac{r}{1-\sqrt{3}}\right)$ from 3e charge

(D) $\left(\frac{r}{1+\sqrt{1/3}}\right)$ from 3e charge.

Q.45 A proton is first placed at A and then at B between the two plates of a parallel plate capacitor charged to a P.D. of V volt as shown. Then force on proton at A is -



(A) more than at B
(B) less than at B
(C) equal to that at B
(D) nothing can be said

Q.46 An electric field can deflect -

(A) X-rays (B) Neutrons
(C) α-particles (D) γ- rays

Q.47 Dimensional formula of electric field intensity is -

(A) $MLT^{-3}A^{-1}$ (B) $MLT^{-3}A$
(C) $MLT^{3}A^{-1}$ (D) None of these

Q.48 If mass of the electron = 9.1×10^{-31} Kg. Charge on the electron = 1.6×10^{-19} coulomb and g = 9.8 m/s^2. Then the intensity of the electric field required to balance the weight of an electron is -

(A) 5.6×10^{-9} N/C (B) 5.6×10^{-11} N/C
(C) 5.6×10^{-8} N/C (D) 5.6×10^{-7} N/C

Q.49 Five charges +Q each are placed at the corners of a regular pentagon of side a, the electric field at the centre of pentagon is -

(A) Zero (B) $\frac{1}{4\pi\epsilon_0}.\frac{6Q^2}{a^2}$

(C) $\frac{1}{4\pi\epsilon_0}.\frac{Q^2}{a^2}$ (D) $\frac{1}{4\pi\epsilon_0}.\frac{6Q^2}{a\sqrt{2}}$

Q.50 The surface charge density of a thin uniformly charged disc of radius R is σ. The ratio of electric field at centre and on the axis at distance R from centre is-

(A) $\frac{1}{\sqrt{2}}$ (B) $\sqrt{2}+2$

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

Q.51 Four point charges +q, +q, –q and –q are placed respectively at the corners A, B, C and D of a square of side a, arranged in the given order. Calculate the electric field intensity at the centre of the square -

(A) $\frac{4\pi\varepsilon_0.a^2}{4\sqrt{2}q}$ (B) $\frac{4\sqrt{2}q}{4\pi\varepsilon_0.a^2}$

(C) $\frac{\pi\varepsilon_0.a^2}{4\sqrt{2}q}$ (D) $\frac{4\sqrt{2}q}{\pi\varepsilon_0.a^2}$

Q.52 In electric field, a 6.75μC charge experiences 2.5 N force, when placed at distance of 5m from the origin. Then potential gradient at this point will be- (in M.K.S.) -

(A) 5.71×10^5 (B) 3.71×10^5

(C) 18.81×10^5 (D) 1.881×10^5

Q.53 A ring of radius (R) carries a uniformly distributed charge + Q. A point charge –q is placed on the axis of the ring at a distance 2R from the centre of the ring and released from rest . The particle

(A) Becomes in rest condition immediately.

(B) Executes simple harmonic motion

(C) Motion is oscillatory but not SHM

(D) Come at the centre of ring immediately.

Q.54 A small circular ring has a uniform charge distribution. On a far-off axial point distance x from the centre of the ring, the electric field is proportional to -

(A) x^{-1} (B) $x^{-3/2}$ (C) x^{-2} (D) $x^{5/4}$

Question based on **Potential & Potential difference**

Q.55 When charge of 3 coulomb is placed in a Uniform electric field , it experiences a force of 3000 Newton, within this field, potential difference between two points separated by a distance of 1 cm along electric field is-

(A) 10 Volt (B) 90 Volt

(C) 1000 Volt (D) 3000 Volt.

Q.56 A uniform electric field having a magnitude E_0 and direction along positive x-axis exists. If the electric potential(V) is zero at x = 0 then its value at x = + x will be-

(A) $V_x = x\ E_0$ (B) $V_x = -x.E_0$

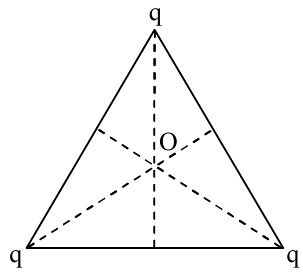
(C) $V_x = x^2\ E_0$ (D) $V_x = x^2\ E_0$

Q.57 The dimensions of potential difference in MKSQ system -

(A) $[ML^2T^{-2}Q^{-1}]$ (B) $[MLT^{-2}Q^{-1}]$

(C) $[MT^{-2}Q^{-2}]$ (D) $[ML^2\ T^{-1}\ Q^{-1}]$

Q.58 Three equal charges are placed at the three corners of an equilateral triangle as shown in the figure. The statement which is true for electric potential V and the field intensity E at the centre of the triangle is-



(A) V = 0, E = 0 (B) V = 0, E ≠ 0

(C) V ≠ 0, E = 0 (D) V ≠ 0, E ≠ 0

Q.59 Electric potential at centre of ring of radius R and uniform linear charge density λ is -

(A) $\frac{\lambda}{2\in_0}$ (B) $\frac{\lambda}{4\in_0}$

(C) $\frac{\lambda}{\in_0}$ (D) $\frac{2\lambda}{\in_0}$

Q.60 Electric potential is a -

(A) Vector quantity

(B) Scalar quantity

(C) Neither vector Nor scalar

(D) Fictious quantity

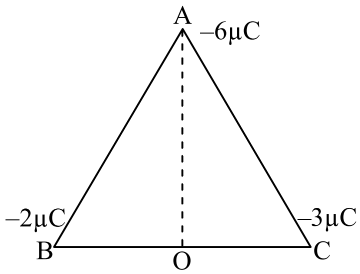
Q.61 At a point situated at certain distance from a point charge the electric field is 500 V/m and the potential is 3000 V. What is the distance of the point from point charge ?

(A) 6 m (B) 12 m

(C) 36 m (D) 144 m

Q.62 The electric potential V at any point (x, y, z) in space is given by $V = 4x^2$ volt. The electric field E (in V/m) at the point (1, 0, 2) is -
(A) +8 in x direction
(B) 8 in –x direction
(C) 16 in + x direction
(D) 16 in –x direction

Q.63 ABC is equilateral triangle of side 1m. Charges are placed at its corners as shown in fig. O is the mid-point of side BC. The potential at point (O) is-



(A) 2.7×10^3 V (B) 1.52×10^5 V
(C) 1.3×10^3 V (D) -1.52×10^5 V

Q.64 In a region where E = 0, the potential (V) varies with distance r as -
(A) $V \propto 1/r$
(B) $V \propto r$
(C) $V \propto 1/r^2$
(D) V = const. (independent of r)

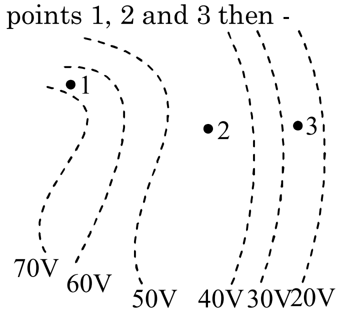
Q.65 Charges of $+\left(\frac{10}{3}\right) \times 10^{-9}$ are placed at each of the four corners of a square of side 8 cm. The potential at the intersection of the diagonals is
(A) $150\sqrt{2}$ Volt (B) $1500\sqrt{2}$ Volt
(C) $900\sqrt{2}$ Volt (D) 900 Volt

Q.66 An equipotential surface is that surface -
(A) On which each and every point has the same potential
(B) Which has negative potential
(C) Which has positive potential
(D) Which has zero potential

Q.67 The surface of a conductor -
(A) is a non-equipotential surface
(B) has all the points at the same potential
(C) has different points at different potential
(D) has at least two points at the same potential

Q.68 The electron potential (V) as a function of distance (x) [in meters] is given by $V = (5x^2 + 10x - 9)$Volt.
The value of electric field at x =1m would be -
(A) 20 Volt/m (B) 6 Volt/m
(C) 11 Volt/m (D) –23 Volt/m

Q.69 Some equipotential lines are as shown is fig. E_1, E_2 and E_3 are the electric fields at points 1, 2 and 3 then -



(A) $E_1 = E_2 = E_3$ (B) $E_1 > E_2 > E_3$
(C) $E_1 > E_2$, $E_2 < E_3$ (D) $E_1 < E_2 < E_3$

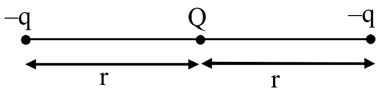
Q.70 Three charges 2q, –q, –q are located at the vertices of an equilateral triangle. At the circumcentre of the triangle.
(A) The field is zero but potential is not zero.
(B) The field is non-zero but the potential is zero.
(C) Both, field and potential are zero.
(D) Both, field and potential are non- zero

Question based on **Electric potential energy & work done**

Q.71 A point positive charge of Q' units is moved round another point positive charge of Q units in circular path. If the radius of the circle is r. The work done on the charge Q' in making one complete revolution is -
(A) $\frac{Q}{4\pi \epsilon_0 r}$ (B) $\frac{QQ'}{4\pi \epsilon_0 r}$
(C) $\frac{Q'}{4\pi \epsilon_0 r}$ (D) 0

Q.72 A particle has a mass 400 times than that of the electron and charge is double than that of a electron. It is accelerated by 5 V of potential difference. Initially the particle was at rest. Then its final kinetic energy will be -
(A) 5 eV (B) 10 eV
(C) 100 eV (D) 2000 eV

Q.73 Three charges are placed as shown in fig. If the electric potential energy of system is zero, then Q : q is -



(A) $\frac{Q}{q}=\frac{-2}{1}$ (B) $\frac{Q}{q}=\frac{2}{1}$

(C) $\frac{Q}{q}=\frac{-1}{2}$ (D) $\frac{Q}{q}=\frac{1}{4}$

Q.74 If a unit charge is taken from one point to another over an equipotential surface then-

(A) Work is done on the charge
(B) Work is done by the charge
(C) Work on the charge is constant
(D) No work is done

Q.75 In an electric field the work done in moving a unit positive charge between two points is the measures of-

(A) Resistance
(B) Potential difference
(C) Intensity of electric field
(D) Capacitance

Q.76 State which one of the following is correct ?

(A) Joule = Coulomb × Volt
(B) Joule = Coulomb / Volt
(C) Joule = Volt / Ampere
(D) Joule = Volt × Ampere

Q.77 One electron volt (eV) of energy is equal to -

(A) 1.6×10^{-12} ergs (B) 4.8×10^{-10} ergs
(C) 9×10^{11} ergs (D) 3×10^{9} ergs

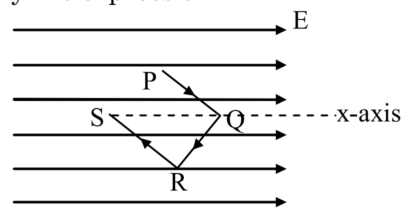
Q.78 The K.E. in electron Volt gained by an α-particle when it moves from rest at point where its potential is 70 to a point where potential is 50 volts, is -

(A) 20 eV (B) 20 MeV.
(C) 40 eV (D) 40 MeV.

Q.79 A α-particle moves towards a rest nucleus, if kinetic energy of α-particle is 10 MeV and atomic number of nucleus is 50. The closest distance of approach will be -

(A) 1.44×10^{-14} m (B) 2.88×10^{-14} m
(C) 1.44×10^{-10} m (D) 2.88×10^{-10} m

Q.80 Point charge (q) moves from point (P) to point (S) along the path PQRS as shown in fig. in a uniform electric field E. Pointing along to the positive direction of the x-axis. The co-ordinates of the points P,Q,R and S are (a, b, 0), (2a, 0, 0), (a, –b, 0) and (0, 0, 0) respectively. The work done by the field in the above process is given by the expression -



(A) q E a (B) –q E a

(C) $qEa\sqrt{2}$ (D) $qE\sqrt{(2a)^2+b^2}$

Q.81 Two identical thin rings, each of radius R metres, are coaxially placed at a distance (R) metres apart. If Q_1 coul and Q_2 coul are respectively the charges uniformly distributed on the two rings. The work done in moving a charge (q) from the centre of one ring to that of other is -

(A) zero (B) $\frac{q(Q_1-Q_2)(\sqrt{2}-1)}{\sqrt{2}\,(4\varepsilon_0\pi R)}$

(C) $\frac{q\sqrt{2}(Q_1+Q_2)}{(4\varepsilon_0\pi R)}$ (D) $\frac{q(Q_1+Q_2)(\sqrt{2}+1)}{\sqrt{2}\,(4\varepsilon_0\pi R)}$

Question based on Electric Flux and Gauss Law

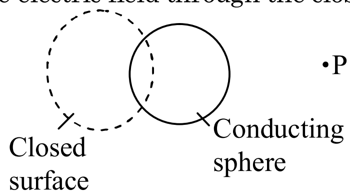
Q.82 The tangent drawn at a point on a line of electric force shows the-

(A) intensity of gravity field
(B) intensity of magnetic field
(C) intensity of electric field
(D) direction of electric field

Q.83 Which of the following statements concerning the electrostatics field line is correct-

(A) electric line of force never intersect each other
(B) electric lines of force start from positive charge and end at the negative charge
(C) electric lines of force start or ends perpendicular to the surface of a charged metal.
(D) all of the above

Q.84 Figure shows a closed surface which intersects a conducting sphere. If a positive charge is placed at the point P, the flux of the electric field through the closed surface -



(A) will remain zero
(B) will become positive
(C) will become negative
(D) will become undefined

Q.85 If electric field flux coming out of a closed surface is zero, the electric field at the surface will be -
(A) zero
(B) same at all places
(C) dependent upon the location of points
(D) infinite

Q.86 If three electric dipoles are placed in a closed surface, then the electric flux emitting from the surface will be -
(A) zero (B) positive
(C) negative (D) None

Q.87 For which of the following fields, Gauss's law is valid for-
(A) fields of point charge with distance following inverse square law
(B) uniform field
(C) all types of field
(D) this law has no concern with the field

Q.88 The electric flux coming out of the equi-potential surface is-
(A) perpendicular to the surface
(B) parallel to the surface
(C) in all directions
(D) zero

Q.89 A charge of Q coulomb is located at the centre of a cube. If the corner of the cube is taken as the origin, then the flux coming out from the faces of the cube in the direction of X- axis will be-
(A) $4\pi Q$ (B) $Q/6\in_0$
(C) $Q/3\in_0$ (D) $Q/4\in_0$

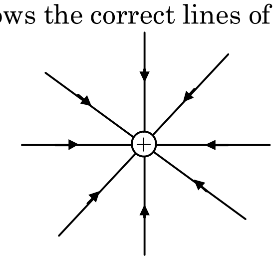
Q.90 A rectangular surface of 2 metre width and 4 metre length, is placed in an electric field of intensity 20 Newton/C, there is an angle of 60° between the perpendicular to surface and electrical field intensity. Then total flux emitted from the surface will be - (In Volt- metre)
(A) 80 (B) 40 (C) 20 (D) 160

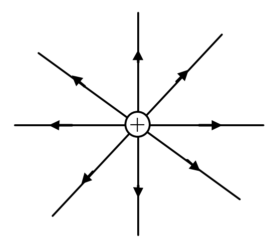
Q.91 A charge q is inside a closed surface and charge – q is outside. The out going electric flux is-
(A) $-q/\in_0$ (B) zero
(C) $q/\in_0$ (D) $2q/\in_0$

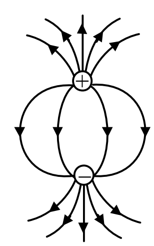
Q.92 If the electric field is uniform, then the electric lines of forces are-
(A) Divergent (B) Convergent
(C) Circular (D) Parallel

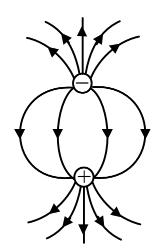
Q.93 Electric lines of forces -
(A) Exist everywhere
(B) Are imaginary
(C) Exist only in the immediate vicinity of electric charges
(D) None of the above

Q.94 Which one of the following diagrams shows the correct lines of force ?

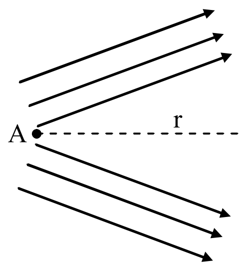
(A)


(B)


(C)


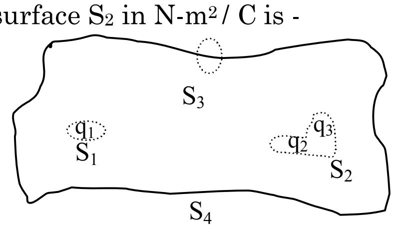
(D)


Q.95 In given figure the electric lines of force emerging from a charged body. If the electric fields at A and B are E_A and E_B are respectively and the distance between A and B is r then -



(A) $E_A > E_B$ (B) $E_A < E_B$
(C) $E_A = E_B$ (D) $E_A = (E_B)/r^2$

Q.96 Three charges $q_1 = 1\mu C$, $q_2 = 2\ \mu C$ and $q_3 = -3\ \mu C$ and four surfaces S_1, S_2, S_3 and S_4 are shown. The flux emerging through surface S_2 in N-m²/ C is -



(A) $36\pi \times 10^3$ (B) $-36\pi \times 10^3$
(C) $36\pi \times 10^9$ (D) $-36\pi \times 10^9$

Q.97 A surface enclosed an electric dipole, the flux through the surface is-
(A) Infinite (B) Positive
(C) Negative (D) Zero

Q.98 Total flux coming out of some closed surface in vacuum which encloses a point charge 8.85 μC is-
(A) 10^6 V-m (B) 2×10^6 V-m
(C) 10^{12} V-m (D) 2×10^{12} V-m

Q.99 A square of side 20 cm is enclosed by a surface of sphere of radius 80 cm. Square and sphere have the same centre. Four charges $+2 \times 10^{-6}$ C, -5×10^{-6} C, -3×10^{-6} C, $+6 \times 10^{-6}$C are located at the four corners of a square, Then out going total flux from spherical surface in N-m²/C will be-
(A) zero (B) $(16\pi) \times 10^{-6}$
(C) $(8\pi) \times 10^{-6}$ (D) $(36\ \pi) \times 10^{-6}$

Q.100 The flux emerging out from any one face of the cube when a point charge q is placed at its centre-

(A) $\frac{q}{6\varepsilon_0}$ (B) $\frac{q}{3\varepsilon_0}$ (C) $\frac{q}{\varepsilon_0}$ (D) $\frac{q}{4\varepsilon_0}$

Q.101 A charge (q) is located at one corner of a cube. The total electric flux through the cube is-

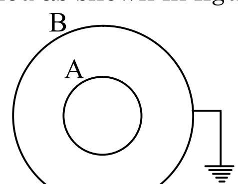
(A) $\frac{q}{\epsilon_o}$ (B) $\frac{q}{24\epsilon_o}$

(C) $\frac{q}{6\epsilon_o}$ (D) $\frac{q}{8\epsilon_o}$

Question based on **Application of Gauss Law**

Q.102 The electric field inside a spherical shell of uniform surface charge density is -
(A) Zero
(B) Constant, different from zero
(C) Proportional to the distance from the centre
(D) None of the above

Q.103 A and B are two concentric hollow spheres. If A is given a charge Q while B is earthed as shown in figure.



(A) The charge density of A and B are same
(B) The field inside and outside A is zero
(C) The field between A and B is non zero
(D) The field inside and outside B is zero

Q.104 The electric potential at the surface of an atomic nucleus (Z = 50) of radius 9×10^{-15} m is -
(A) 80V (B) 8×10^6 V
(C) 8×10^4 V (D) 8×10^2 V

Q.105 A cubical box of side 1m is immersed in a uniform electric field of strength 10^4 N/C. The flux through the cube is -
(A) 10^4 (B) 6×10^4
(C) 2×10^4 (D) Zero

Q.106 A charge Q is distributed over two concentric hollow spheres of radii r and R (> r) such that their surface charge densities are equal. Find the potential at the common centre-

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

(C) $\frac{Q(r+R)}{4\pi\varepsilon_0(R^2+r^2)}$ (D) none of these

Q.107 A hollow charged metal sphere has radius r. If the potential difference between its surface and a point at distance 3r from the centre is V, then the electric field intensity at a distance (3r) from the centre is -
(A) V/6r (B) V/4r (C) V/3r (D) V/2r

Q.108 A ball of radius R carries a positive charge whose volume charge density depends only on separation r from the ball's centre as $\rho = \rho_0 \left(1-\frac{r}{R}\right)$ where ρ_0 is a constant. Assuming the permitivity of the ball and the environment to be equal to unity. The electric field at distance r_1 from centre (For $r_1 < R$) is -
(A) $\frac{\rho_0 r_1}{3\varepsilon_0}\left(1-\frac{3r_1}{4R}\right)$ (B) $\frac{\rho_0 r_1}{3\varepsilon_0}\left(1-\frac{r_1}{R}\right)$
(C) $\frac{\rho_0 r_1}{2\varepsilon_0}\left(1-\frac{r_1}{2R}\right)$ (D) None

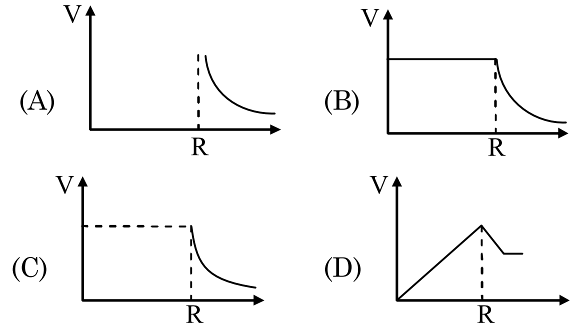
Q.109 A spherical conductor of radius 50 cm has a surface charge density of 8.85×10^{-6} C/m^2. The electric field near the surface in N/C is-
(A) 8.85×10^{-6} (B) 8.85×10^{6}
(C) 1×10^{6} (D) Zero

Q.110 A hollow metal sphere of radius 5cm is charged such that the potential on its surface is 10V. The potential at the centre of the sphere is –
(A) 0V
(B) 10V
(C) Same as at point 5cm away from the surface
(D) Same as at point 25cm away from the surface

Q.111 A solid conducting sphere having a charge Q is surrounded by an uncharged concentric conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of 3Q, the new potential difference between the same two surfaces is
(A) V (B) 2V (C) 4V (D) –2V

Q.112 The electric field intensity at a point located at distance r (r < R) from the centre of a spherical insulator (radius R) having uniform volume charge density ρ is -
(A) $\frac{\rho r}{2\in_0}$ (B) $\frac{\rho r}{\in_0}$ (C) $\frac{\rho}{2\in_0}$ (D) $\frac{\rho r}{3\in_0}$

Q.113 The dependence of electric potential V on the distance 'r' from the centre of a charged spherical shell of radius R is shown by.



Question based on Electric dipole

Q.114 If an electric dipole is kept in a uniform electric field. Then it will experience-
(A) a force
(B) a couple and moves
(C) a couple and rotates
(D) a force and moves.

Q.115 An electric dipole consists of two opposite charges each of magnitude 1×10^{-6} C separated by a distance 2 cm. The dipole is placed in an external field of 10×10^{5}N/C. The maximum torque on the dipole is -
(A) 0.2×10^{-3} N-m (B) 1.0×10^{-3} N-m
(C) 2×10^{-2} N-m (D) 4×10^{-3} N-m

Q.116 The ratio of the electric field due to a short electric dipole on its axis and on the perpendicular bisector of the dipole is-
(A) 1 : 2 (B) 2 : 1 (C) 1 : 4 (D) 4 : 1

Q.117 The region surrounding a stationary electric dipole has -
(A) electric field only
(B) magnetic field only
(C) both electric and magnetic fields
(D) neither electric nor magnetic field

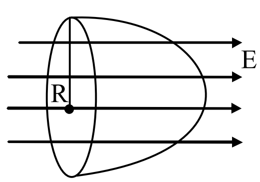
Q.118 The electric potential at distance r due to an electric dipole of moment $\vec{p}$ will be-
(A) $\frac{1}{4\pi\in_0}\frac{\vec{p}\cdot\vec{r}}{r^3}$ (B) $\frac{1}{4\pi\in_0}\frac{\vec{p}\cdot\vec{r}}{r^2}$
(C) $\frac{1}{4\pi\in_0}\frac{(\vec{p}\times\vec{r})}{r}$ (D) $\frac{1}{4\pi\in_0}\frac{(\vec{p}\times\vec{r})}{r^2}$

EXERCISE - 2

Q.1 5×10^5 lines of electric force are entering in a closed surface and 4×10^5 lines come out of the surface. The charge enclosed by the surface is -
(A) 0.885×10^{-6}C (B) 8.85×10^{-6}C
(C) -8.85×10^{-7}C (D) 8.85×10^{-8}C

Q.2 A cylinder of radius (R) and length (L) is placed in a uniform electrical field (E) parallel to the axis of the cylinder. The total flux from the surface of the cylinder is given by -
(A) $2\pi R^2 E$ (B) $\pi R^2 E$
(C) $\dfrac{\pi R^2 + \pi R^2}{E}$ (D) zero

Q.3 A hemisphere (radius R) is placed in electric field as shown in fig. Total outgoing flux is –



(A) $\pi R^2 E$ (B) $2\pi R^2 E$
(C) $4\pi R^2 E$ (D) $(\pi R^2 E)/2$

Q.4 Three identical charges each of 1 μC are kept on the circumference of a circle of radius 1 metre forming equilateral triangle. The electric field intensity at the centre of the circle in N/C is -
(A) 9×10^3 (B) 13.5×10^3
(C) 27×10^3 (D) Zero

Q.5 The number of electrons, falling on spherical conductor (radius = 0.1 m) to produce 0.036 N/C electric field at the surface of conductor, is-
(A) 2.7×10^5 (B) 2.5×10^5
(C) 2.6×10^5 (D) 2.4×10^5

Q.6 A particle of mass 6 μg carrying a charge of 10^{-9} C, is placed in the electric field of strength $E = 6 \times 10^5$ V/m, the acceleration acquired by the particle is -
(A) 10^2 m/sec^2 (B) 10^5 m/sec^2
(C) 10^3 m/sec^2 (D) 10^{20} m/sec^2

Q.7 Two small balls having equal positive charge Q on each are suspended by two insulating strings at equal length L metre, from a hook fixed to a stand. The whole set up is taken in a satellite into space where there is no gravity. Then the angle θ between two strings and tension in each string is-
(A) $0, \dfrac{kq^2}{L^2}$ (B) $\pi, \dfrac{kq^2}{2L^2}$
(C) $\pi, \dfrac{kq^2}{4L^2}$ (D) $\dfrac{\pi}{2}, \dfrac{kq^2}{2L^2}$

Q.8 The magnitude of the electric field strength (E) such that an electron placed in the field would experience an electrical force equal to its weight is [assume g = 10 m/see^2]
(A) 5.68×10^{-11} N/ Coul. Vertically up
(B) 5.68×10^{-11} N/ Coul. Vertically down
(C) 5.68×10^{-10} N/ Coul. Vertically up.
(D) 5.68×10^{-10} N/ Coul. Vertically down

Q.9 Electric potential in an electric field is given as V= K/r, (K being constant, r is distance from origin). At position vector $\vec{r} = 2\hat{i} + 3\hat{j} + 6\hat{k}$ the electric field will be -
(A) $\dfrac{(2\hat{i}+3\hat{j}+6\hat{k})K}{243}$ (B) $\dfrac{(2\hat{i}+3\hat{j}+6\hat{k})K}{343}$
(C) $\dfrac{(3\hat{i}+2\hat{j}+6\hat{k})K}{243}$ (D) $\dfrac{(6\hat{i}+2\hat{j}+3\hat{k})K}{343}$

Q.10 At any point (x, 0, 0) the electric potential V is $\left(\dfrac{1000}{x} + \dfrac{1500}{x^2} + \dfrac{500}{x^3}\right)$ volt, then electric field at x = 1 m -
(A) $5500(\hat{j}+\hat{k})$ V/m
(B) $5500\,\hat{i}$ V/m
(C) $\dfrac{5500}{\sqrt{2}}(\hat{j}+\hat{k})$ V/m
(D) $\dfrac{5500}{\sqrt{2}}(\hat{i}+\hat{k})$ V/m

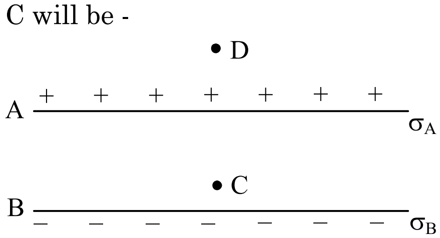
Q.11 The electric field at the surface of a charged spherical conductor is 10 KV/m. The electric field at a distance equal to the diameter from its centre will be -
(A) 2.5 V/m (B) 2.5 KV/m
(C) 5.0 KV/m (D) 5.0 V/m

Q.12 Potential difference between centre and the surface of a sphere of radius R with uniform charge density σ will be
(A) $\frac{\sigma R^2}{6\epsilon_0}$ (B) $\frac{\sigma R^2}{4\epsilon_0}$
(C) zero (D) $\frac{\sigma R^2}{2\epsilon_0}$

Q.13 Three charge +4q, Q and q are placed in a straight line of length ℓ such that +q & +4q are on the ends of line & Q is at the mid point of line. What should be the value of Q in order to make the net force on q to be zero ?
(A) – q (B) –2 q (C) –q/2 (D) 4q

Q.14 Two large metal plates each of area (A) carry charges +q and -q and facing each other. The plates are separated by a small distance (d) the electric field between the plates would be -
(A) $\frac{2q}{\epsilon_0 A}$ (B) $\frac{q}{2\epsilon_0 A}$
(C) $\frac{q}{\epsilon_0 A}$ (D) $\frac{A}{q\epsilon_0}$

Q.15 Two parallel thin sheets of infinite dimensions are uniformly charged. The surface charge density on one is σ_A and on the other is σ_B, field intensity at point C will be -



(A) Proportional to($\sigma_A - \sigma_B$)
(B) Proportional to($\sigma_A + \sigma_B$)
(C) Zero
(D) $2\sigma_A$

Q.16 A charged particle of mass (m) is kept in equilibrium in the electric field between the plates of Millikan oil drop experiment. If the direction of the electric field between the plate is reversed, then acceleration of the charged particle will be-
(A) Zero (B) g /2 (C) g (D) 2g

Q.17 Two conducting spheres of radii r_1 and r_2 are equally charged. The ratio of their potential is-
(A) r_1^2 / r_2^2 (B) r_2^2 / r_1^2
(C) r_1 / r_2 (D) r_2 / r_1

Q.18 Two identical small balls, each of mass m and charge q, are suspended in vacuum by two light inelastic non conducting threads each of length ℓ from the same fixed point support. If the distance (d) between two balls is very small in equilibrium, then d is equal to- $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$
(A) $\left(\frac{2k\ell q^2}{mg}\right)^{1/3}$ (B) $\left(\frac{2k\ell q^2}{mg}\right)^{2/3}$
(C) $\left(\frac{k\ell q^2}{2mg}\right)^{2/3}$ (D) none of these

Q.19 A small metal sphere A has a charge Q on it. The field at a point B outside the sphere is E. Now another sphere of same radius having a charge –3Q is placed at point B. The total field at a point mid-way between A and B due to both sphere is-
(A) 4E (B) 8E
(C) 12E (D) 16E

Q.20 Two similar rings P and Q (radius = 0.1 m) are placed co-axially at a distance 0.5 m apart. The charge on P and Q is 2μC and 4μC respectively. Work done to move a 5μC charge from centre of P to the center of Q is-
(A) 1.28 J (B) 0.72 J
(C) 0.144 J (D) 1.44 J

Q.21 A uniformly charged rod with charge per unit length λ is bent in to the shape of a semicircle of radius R. The electric field at the centre is - $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(A) $\frac{2k\lambda}{R}$ (B) $\frac{k\lambda}{2R}$ (C) Zero (D) None

Q.22 A thin stationary ring of radius 1 m has a positive charge 10 μC uniformly distributed over it. A particle of mass 0.9 gm and having a negative charge of 1 μC is placed on the axis at a distance of 1 cm from the centre of the ring and released then time period of oscillation of particle will be–

(A) 0.6 sec (B) 0.2 sec
(C) 0.3 sec (D) 0.4 sec

Q.23 Three point charge -q, +q and -q are placed along a straight line at equal distances(say r metre) Electric potential energy of this system of charges will be (if +q charge is in the middle)-

(A) $\frac{-3q^2}{4\pi\epsilon_0 r}$ (B) $\frac{-8q^2}{3\pi\epsilon_0 r}$

(C) $\frac{-3q^2}{8\pi\epsilon_0 r}$ (D) $\frac{-q^2}{8\pi\epsilon_0 r}$

Q.24 Four equal charges each of charge q are placed at corner of a square of side a. Potential energy of the whole system is- $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(A) $\frac{4kq^2}{a}$ (B) $\frac{4kq^2}{a}\left(1+\frac{1}{2\sqrt{2}}\right)$

(C) $\frac{1}{2\sqrt{2}}\frac{kq^2}{a}$ (D) $\frac{kq^2}{a}\left(4+\frac{1}{2\sqrt{2}}\right)$

Q.25 The potential of a charged spherical drop is V. This is divided into n similar spherical drops, then each drop will have the potential as ;

(A) $n^{-1}V$ (B) $n^{2/3}V$
(C) $n^{3/2}V$ (D) $n^{-2/3}$ V

Q.26 8 small droplets of water of same size and same charge form a large spherical drop. The potential of the large drop in comparison to potential of a small drop will be -

(A) 2 times (B) 4 times
(C) 8 times (D) same

Q.27 Three charges +3q, +q and Q are placed on a straight line with equal separation. In order to make the net force on q to be zero, the value of Q will be

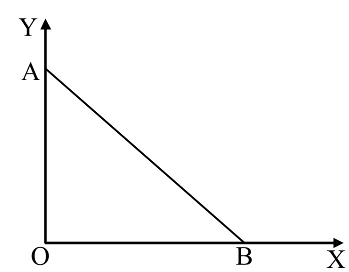
(A) +3q (B) +2q
(C) –3q (D) –4q

Q.28 In Millikan's oil drop experiment an oil drop carrying a charge Q is held stationary by a potential difference 2400V between the plates. To keep a drop of half the radius stationary the potential difference had to be made 600 V. What is the charge on the second drop -

(A) $\frac{Q}{4}$ (B) $\frac{Q}{2}$

(C) Q (D) $\frac{3Q}{2}$

Q.29 In given figure, 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.30 The electric field due to an electric dipole at a distance r from its centre in axial position is E. If the dipole is rotated through an angle of 90° about its perpendicular axis, the electric field at the same point will be-

(A) E (B) E/4
(C) E/2 (D) 2E

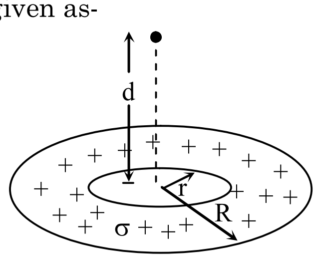
Q.31 Two electric dipoles of moment P and 64 P are placed in opposite direction on a line at a distance of 25 cm. The electric field will be zero at point between the dipoles whose distance from the dipole of moment P is-

(A) 5 cm (B) $\frac{25}{9}$ cm
(C) 10 cm (D) $\frac{4}{13}$ cm

Q.32 When an electric dipole $\vec{P}$ is placed in a uniform electric field $\vec{E}$ then at what angle between $\vec{P}$ and $\vec{E}$ the value of torque will be maximum-

(A) 90° (B) 0°
(C) 180° (D) 45°

Q.33 A thin disc of radius R has a concentric hole of radius r in it as shown in figure. Its surface charge density is σ. The electric potential on its axis at distance d is given as-



(A) $\frac{\sigma}{2\epsilon_0}\left[\sqrt{R^2+d^2}-\sqrt{r^2+d^2}\right]$

(B) $\frac{\sigma}{2\epsilon_0}\left[\sqrt{R^2+r^2}-\sqrt{R^2+d^2}\right]$

(C) $\frac{\sigma}{2\epsilon_0}\left[\sqrt{R^2+d^2}-d\right]$

(D) $\frac{\sigma}{2\epsilon_0}\left[\sqrt{r^2+d^2}-d\right]$

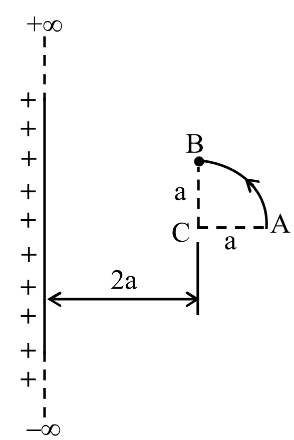
Q.34 An electric dipole has the magnitude of its charge as q and its dipole moment is p. It is placed in a uniform electric field E. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively-

(A) 2qE and minimum
(B) qE and pE
(C) Zero and minimum
(D) qE and maximum

Q.35 Two opposite and equal charges 4×10^{-8} coulomb when placed 2×10^{-2} cm away, form a dipole. If this dipole is placed in an external electric field 4×10^{8} Newton/coulomb, the value of maximum torque and the work done in rotating it through 180° from field direction will be -

(A) 64×10^{-4} Nm and 64×10^{-4} J
(B) 32×10^{-4} Nm and 32×10^{-4} J
(C) 64×10^{-4} Nm and 32×10^{-4} J
(D) 32×10^{-4} Nm and 64×10^{-4} J

Q.36 The arc AB with the centre C and the infinitely long wire having linear charge density λ are lying in the same plane. The minimum amount of work to be done to move a point charge q_0 from point A to B through a circular path AB of radius a is equal to -



(A) $\frac{q_0^2}{2\pi\varepsilon_0}\log_e\left(\frac{2}{3}\right)$ (B) $\frac{q_0\lambda}{2\pi\varepsilon_0}\log_e\left(\frac{3}{2}\right)$

(C) $\frac{q_0\lambda}{2\pi\varepsilon_0}\log_e\left(\frac{2}{3}\right)$ (D) $q_0\lambda/\sqrt{2}\,\pi\varepsilon_0$

Q.37 A ball of mass 1 g and charge 10^{-8}C moves from a point A, where potential is 600 volt to the point B where potential is zero. Velocity of the ball at the point B is 20 cm/s. The velocity of the ball at the point A will be -

(A) 22.8 cm/s (B) 228 cm/s
(C) 16.8 cm/s (D) 168 m/s

Q.38 An electric dipole is placed along the x-axis at the origin O. A point P is at a distance of 20cm from this origin such that OP makes an angle $\frac{\pi}{3}$ with the x-axis. If the electric field at P makes an angle θ with the x-axis, the value of θ would be –

(A) $\frac{\pi}{3}$ (B) $\frac{\pi}{3}+\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$
(C) $\frac{2\pi}{3}$ (D) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Q.39 An electric dipole of moment $\vec{p}$ is placed normal to the lines of force of electric intensity $\vec{E}$, then the work done in deflecting it through an angle of 180º is -

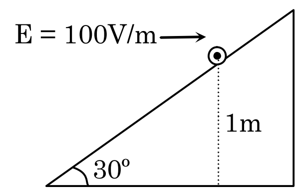
(A) pE (B) + 2pE
(C) – 2pE (D) Zero

NUMERIC RESPONSE TYPE QUESTIONS

Q.40 The electric field strength depends only on the x, y and z coordinates according to the law $E = \frac{a(x\hat{i}+y\hat{j}+z\hat{k})}{(x^2+y^2+z^2)^{3/2}}$, where a = 122.5 SI unit and is a constant. Find the potential difference (in volt) between (3, 2, 6) and (0, 3, 4).

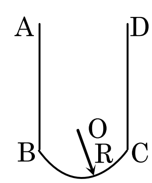
Q.41 Two spherical bobs of same mass and radius having equal charges are suspended from the same point by strings of same length. The bobs are immersed in a liquid of relative permittivity ϵ_r and density ρ_0. Find the density ρ of the bob in g/cm³ for which the angle of divergence of the strings to be the same in the air and in the liquid ($\varepsilon_r = 3$, $\rho_0 = 2$g/cm³) ?

Q.42 An inclined plane makes an angle of 30° with the horizontal electric field E of 100 V/m. A particle of mass 1 kg and charge 0.01 C slides down from a height of 1 m. If the coefficient of friction is 0.2, find the time taken for the particle to reach the bottom. (in sec)



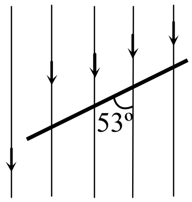
Q.43 A particle of mass m carrying charge 'q' is projected with velocity (v) from point P towards an infinite line charge from a distance 'a'. Its speed reduces to zero momentarily at point Q which is at a distance a/2 from the line charge. If another particle with mass m and charge –q is projected with the same velocity v from point P towards the line charge. Its speed is found to be $\frac{Nv}{\sqrt{2}}$ at point 'Q'. Find the value of N.

Q.44 A thread carrying a charge (uniform) λ per unit length has configuration shown in figure.



Assuming a curvature radius R to be considerably less than the length of thread. Find the magnitude of electric field strength at point O.

Q.45 A flat plate with dimensions 4 cm × 6 cm is set with its plane at 37° to a uniform electric field $\vec{E} = 600\hat{j}$ N/C, as shown below. What is the flux (in Nm²/C) through the plate ?

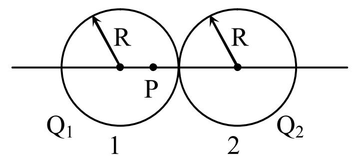


Q.46 A charge Q is uniformly distributed over a large plastic plate. The electric field at a point P close to the centre of the plate is 10 V/m. If the plastic plate is replaced by a copper plate of the same geometrical dimensions and carrying the same charge Q, the electric field (in V/m) at the point P will become -

Q.47 Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 10 cm surrounding the total charge is 25 V-m. The flux (in V-m) over a concentric sphere of radius 20 cm will be -

Q.48 Electric flux through a surface of area 100 m² lying in the xy plane is (in V-m) if $\vec{E} = \hat{i} + \sqrt{2}\,\hat{j} + \sqrt{3}\,\hat{k}$.

Q.49 Figure shows, in cross section, two solid spheres with uniformly distributed charge throughout their volumes. Each has radius R. Point P lies on a line connecting the centres of the spheres, at radial distance R/2 from the center of sphere 1. If the net electric field at point P is zero and Q_1 is 64 μC, what is Q_2 (in μC)



EXERCISE - 3

Q.1 If an electron enters into a space between the plates of a parallel plate capacitor at an angle α with the plates and leaves at an angle β to the plates. The ratio of its kinetic energy while entering the capacitor to that while leaving will be -

(A) $\left(\frac{\sin\beta}{\sin\alpha}\right)^2$ (B) $\left(\frac{\cos\beta}{\cos\alpha}\right)^2$

(C) $\left(\frac{\cos\alpha}{\cos\beta}\right)^2$ (D) $\left(\frac{\sin\alpha}{\sin\beta}\right)^2$

Q.2 Force between two identical charges placed at a distance of r in vacuum is F. Now a slab of dielectric constant K = 4 is inserted between these two charges. The thickness of the slab is r/2. The force between the charges will now become -

(A) F/4 (B) F/2

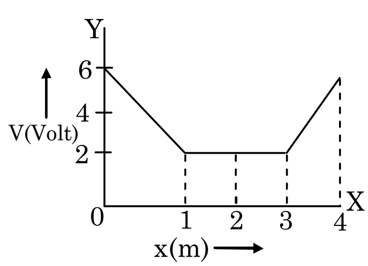
(C) $\frac{3}{5}$ F (D) $\frac{4}{9}$ F

Q.3 A conducting sphere of radius R is charged to a potential of V volt. Then the electric field at a distance r (>R) from the centre of the sphere would be -

(A) $\frac{RV}{r^2}$ (B) $\frac{V}{r}$

(C) $\frac{rV}{R^2}$ (D) $\frac{R^2V}{r^3}$

Q.4 The variation of electric potential with distance from a fixed point is shown in figure. What is the value of electric field at x = 2m -



(A) Zero (B) 6/2 (C) 6/1 (D) 6/3

Q.5 In a certain region of surface there exists a uniform electric field of $2 \times 10^3\ \hat{k}$ V/m. A rectangular coil of dimensions 10 cm × 20 cm is placed in x-y plane. The electric flux through the coil is -

(A) Zero (B) 30 V-m

(C) 40 V-m (D) 50 V-m

Q.6 The electric flux from a cube of edge ℓ is ϕ. What will be its value if edge of cube is made 2ℓ and charge enclosed is halved -

(A) $\phi/2$ (B) 2ϕ (C) 4ϕ (D) ϕ

Q.7 Each of the two point charges are doubled and their distance is halved. Force of interaction becomes n times, where n is -

(A) 4 (B) 1 (C) 1/16 (D) 16

Q.8 Two point charges repel each other with a force of 100 N. One of the charges is increased by 10% and other is reduced by 10%. The new force of repulsion at the same distance would be-

(A) 100 N (B) 121 N

(C) 99 N (D) None of these

Q.9 A positive point charge q is carried from a point B to a point A in the electric field of a point charge +Q at O. If the permittivity of free space is ε_0, the work done in the process is given by (where a = OA and b = OB) -

(A) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{1}{a}+\frac{1}{b}\right)$

(B) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{1}{a}-\frac{1}{b}\right)$

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

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

Q.10 A spherical charged conductor has σ surface charge density. The electric field on its surface is E. If the radius of the sphere is doubled keeping the surface charge density unchanged, what will be the electric field on the surface of the new sphere -

(A) $\frac{E}{4}$ (B) $\frac{E}{2}$

(C) E (D) 2 E

Q.11 Three equal and similar charges are placed at (–a, 0, 0), (0, 0, 0) and (+a, 0, 0). What is the nature of equilibrium of the charge at the origin-

(A) Stable when moved along the Y-axis

(B) Stable when moved along Z-axis

(C) Stable when moved along X-axis

(D) Unstable in all of the above cases

Q.12 Two conducting spheres each of radius R carry charge q. They are placed at a distance r from each other, where r > 2 R. The neutral point lies at a distance r/2 from either sphere. If the electric field at the neutral point due to either sphere be E, then the total electric potential at that point will be -

(A) r E/2 (B) r E

(C) RE/2 (D) RE

Q.13 A ring of radius R carries a charge +q. A test charge $-q_0$ is released on its axis at a distance $\sqrt{3}$ R from its centre. How much kinetic energy will be acquired by the test charge when it reaches the centre of the ring -

(A) $\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{R}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{2R}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{\sqrt{3}R}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{3R}$

Q.14 Two spheres of radii r_1 and r_2 are at the same potentials. If their surface densities of charges be σ_1 and σ_2 respectively, then σ_1/σ_2 -

(A) r_1/r_2 (B) r_2/r_1

(C) $(r_1/r_2)^2$ (D) $(r_2/r_1)^2$

Q.15 A proton and an electron are released infinite distance apart and they attracted towards each other. Which of the following statement about their kinetic energy is true -

(A) Kinetic energy of electron is more than that of proton

(B) Kinetic energy of electron is less than that of proton

(C) Kinetic energy of electron = kinetic energy of proton

(D) None of the above is true as it depending on the distance between the particles

Q.16 The electric field strength due to a ring of radius R at a distance x from its centre on the axis of ring carrying charge Q is given by

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(R^2+x^2)^{3/2}}$$

At what distance from the centre will the electric field be maximum -

(A) x = R (B) x = R/2

(C) $x = R/\sqrt{2}$ (D) $x = \sqrt{2}\,R$

Q.17 Two conducting spheres of radii r_1 and r_2 are charged such that they have the same electric field on their surfaces. The ratio of the electric potential at their centres is -

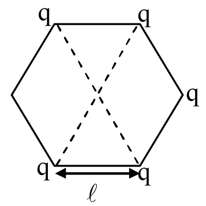
(A) $\sqrt{r_1/r_2}$

(B) r_1/r_2

(C) r_1^2/r_2^2

(D) None of the above

Q.18 Five equal and similar charges are placed at the corners of a regular hexagon as shown in the figure. What is the electric field and potential at the centre of the hexagon -



(A) $\frac{5}{4\pi\varepsilon_0}\frac{q}{\ell}, \frac{5}{4\pi\varepsilon_0}\frac{q}{\ell^2}$

(B) $\frac{1}{4\pi\varepsilon_0}\frac{q}{\ell}, \frac{5}{4\pi\varepsilon_0}\frac{q}{\ell^2}$

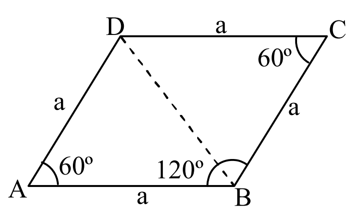
(C) $\frac{1}{4\pi\varepsilon_0}\frac{q}{\ell^2}, \frac{5}{4\pi\varepsilon_0}\frac{q}{\ell}$

(D) $\frac{1}{4\pi\varepsilon_0}\frac{q}{\ell}, \frac{1}{4\pi\varepsilon_0}\frac{q}{\ell^2}$

Q.19 A half ring of radius R has a charge of λ per unit length. The potential at the centre of the half ring is $\left(k = \frac{1}{4\pi\epsilon_0}\right)$

(A) $k\frac{\lambda}{R}$ (B) $k\frac{\lambda}{\pi R}$ (C) $k\frac{\lambda}{R}$ (D) $k\pi\lambda$

Q.20 A charge +Q at A (See figure) produces electric field E and electric potential V at D. If we now put charges –2Q and +Q at B and C respectively, then the electric field and potential at D will be –



(A) E and 0

(B) 0 and V

(C) $\sqrt{2}$ E and $\frac{V}{\sqrt{2}}$

(D) $\frac{E}{\sqrt{2}}$ and $\frac{V}{\sqrt{2}}$

Q.21 A and B are two points on the axis and the perpendicular bisector respectively of an electric dipole. A and B are far away from the dipole and at equal distances from it. The fields at A and B are $\vec{E}_A$ and $\vec{E}_B$ are respectively such that -

(A) $\vec{E}_A = \vec{E}_B$ (B) $\vec{E}_A = 2\vec{E}_B$

(C) $\vec{E}_A = -2\vec{E}_B$ (D) $\vec{E}_A = \frac{1}{2}\vec{E}_B$

Q.22 A long string with a charge of λ per unit length passes through an imaginary cube of edge ℓ. The maximum possible flux of the electric field through the cube will be -

(A) $\lambda\ell / \varepsilon_0$ (B) $\sqrt{2}\ \lambda\ell / \varepsilon_0$

(C) $6\ \lambda\ell^2 / \varepsilon_0$ (D) $\sqrt{3}\ \lambda\ell / \varepsilon_0$

Q.23 If a positive charge is shifted from a low-potential region to a high-potential region, the electric potential energy -

(A) increases

(B) decreases

(C) remains the same

(D) May increase or decrease

Q.24 A particle of mass 0.002 kg and a charge 1μC is held at rest on a frictionless horizontal surface at a distance of 1m from a fixed charge of 1mC. If the particle is released, it will be repelled. The speed of the particle when it is at a distance of 10m from the fixed charge is -

(A) 60 ms^{-1} (B) 75 ms^{-1}

(C) 90 ms^{-1} (D) 100 ms^{-1}

Q.25 A charge Q is placed at each of two opposite corners of a square. A charge q is placed at each of the two opposite corners of the square. If the resultant electric field on Q is zero, then -

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

(C) $Q = -2q$ (D) $Q = 2\sqrt{2}\ q$

Q.26 Electric potential is given by :

$$V = 6x - 8xy^2 - 8y + 6yz - 4z^2$$

Electric field at the origin is -

(A) $-6\hat{i} + 8\hat{j}$ (B) $6\hat{i} - 8\hat{j}$

(C) $\hat{i} + \hat{j}$ (D) Zero

Q.27 A hollow conducting sphere of radius R has charge (+Q) on its surface. The electric potential within the sphere at a distance $r = \frac{R}{3}$ from the centre is -

(A) Zero (B) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

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

Q.28 The electric field outside a charged long straight wire is given by $E = -\frac{5000}{r}\ V\,m^{-1}$. It is radially inward. The value of $V_B - V_A$ is - [Given r_B = 60 cm and r_A = 30 cm]

(A) 5000 $\log_e 2$ volt (B) 0 V

(C) 2 V (D) 2500 V

Q.29 A proton is projected with velocity 7.45×10^5 m/s towards an another proton which is at rest from very large distance. The minimum distance of approach is-

(A) 10^{-12} m (B) 10^{-14} m

(C) 10^{-10}m (D) 10^{-8}m

Q.30 Two equal positive charges are kept at points A and B. The electric potential at the points between A and B (excluding these points) is studied while moving from A to B. The potential-

(A) Continuously increases

(B) Continuously decreases

(C) Increases then decreases

(D) Decreases then increases

Q.31 An electron moves with velocity $\vec{v}$ in x-direction. An electric field acts on it in y-direction. The force on the electron acts in -

(A) +ve direction of Y-axis

(B) –ve direction of Y-axis

(C) +ve direction of Z-axis

(D) –ve direction of Z-axis

Q.32 Two identical simple 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 equilibrium, with A and B making angles θ_1 and θ_2 with the vertical respectively. Which of the following is correct -

(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

EXERCISE - 4

Old Examination Questions [AIEEE/JEE Main]

Q.1 When two charges are placed at distance a apart. Find the magnitude of third charge which is placed at mid point the line joining the charge, so that system is in equilibrium - **[AIEEE-2002]**

(A) $-\frac{Q}{4}$ (B) $-\frac{Q}{2}$

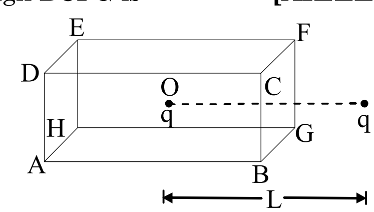
(C) $-\frac{Q}{3}$ (D) – Q

Q.2 On moving a charge of 20 coulombs by 2 cm, along electric field 2J of work is done, then the potential difference between the points is - **[AIEEE-2002]**

(A) 0.1 V (B) 8 V

(C) 2 V (D) 0.5 V

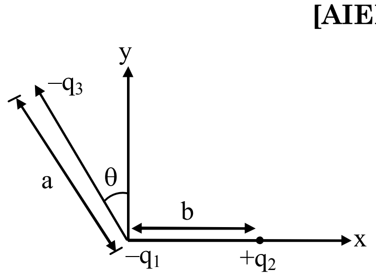
Q.3 A charged particle q is placed at the centre O of cube of length L (ABCDEFGH). Another same charge q is placed at a distance L from O. Then the electric flux through BCFG is - **[AIEEE-2002]**



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

(C) $\frac{q}{2\pi\varepsilon_0}L$ (D) $\frac{q}{3\pi\varepsilon_0 L}$

Q.4 Three charges $-q_1$, $+q_2$ and $-q_3$ are placed as shown in figure. The x-component of the force on $-q_1$ is proportional to - **[AIEEE-2003]**



(A) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\sin\theta$

(B) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\cos\theta$

(C) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\sin\theta$

(D) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\cos\theta$

Q.5 If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be - **[AIEEE-2003]**

(A) $(\phi_1+\phi_2)/\varepsilon_0$ (B) $(\phi_2-\phi_1)/\varepsilon_0$

(C) $(\phi_1+\phi_2)\varepsilon_0$ (D) $(\phi_2-\phi_1)\varepsilon_0$

Q.6 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 - **[AIEEE-2003]**

(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.7 Two spherical conductors B and C having equal radii and carrying equal charges on 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 - **[AIEEE-2004]**

(A) F/4 (B) 3F/4

(C) F/8 (D) 3F/8

Q.8 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 of '2v', the closest distances of approach would be - **[AIEEE-2004]**

(A) r (B) 2 r
(C) r/2 (D) r/4

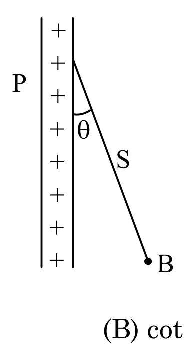
Q.9 Four charges equal to – Q are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium the value of q is – **[AIEEE-2004]**

(A) $-\frac{Q}{4}(1+2\sqrt{2})$ (B) $\frac{Q}{4}(1+2\sqrt{2})$
(C) $-\frac{Q}{2}(1+2\sqrt{2})$ (D) $\frac{Q}{2}(1+2\sqrt{2})$

Q.10 A charged oil drop is suspended in a uniform field of 3×10^4 v/m so that it neither falls nor rises. The charge on the drop will be (Take the mass of the charge $= 9.9 \times 10^{-15}$ kg and $g = 10$ m/s^2) - **[AIEEE-2004]**

(A) 3.3×10^{-18} C (B) 3.2×10^{-18} C
(C) 1.6×10^{-18} C (D) 4.8×10^{-18} C

Q.11 A charged ball B hangs from a silk thread S which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to - **[AIEEE-2005]**



(A) cos θ (B) cot θ
(C) sin θ (D) tan θ

Q.12 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) 2 L (B) L/4
(C) 8 L (D) 4 L

Q.13 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) $QR/4\pi\epsilon_0 d^2$

(B) $\frac{Q}{2\pi\epsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

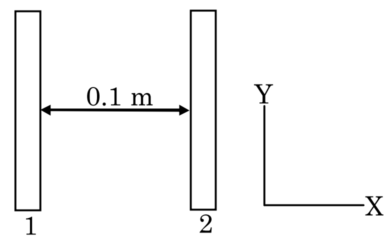
(C) zero

(D) $\frac{Q}{4\pi\epsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

Q.14 An electric dipole is placed at an angle of 30º to a non-uniform electric field. The dipole will experience - **[AIEEE 2006]**

(A) a torque as well as a translational force
(B) a torque only
(C) a translational force only in the direction of the field
(D) a translational force only in a direction normal to the direction of the field

Q.15 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 = 0.1 m 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 ? ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg) - **[AIEEE 2006]**

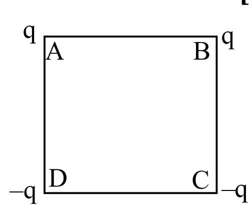


(A) 1.87×10^6 m/s
(B) 32×10^{-19} m/s
(C) 2.65×10^6 m/s
(D) 7.02×10^{12} m/s

Q.16 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 sphere 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) 2 : 1 (B) 1 : 4
(C) 4 : 1 (D) 1 : 2

Q.17 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) 9 volt (B) zero
(C) 2 volt (D) 4.5 volt

Q.18 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]**

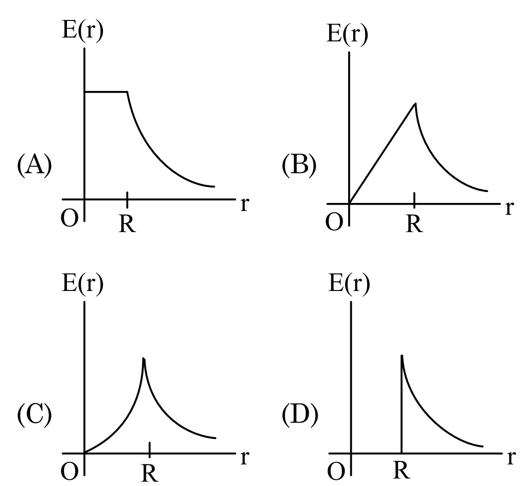


(A) $\vec{E}$ remains unchanged, V changes
(B) Both $\vec{E}$ and V change
(C) $\vec{E}$ and V remain unchanged
(D) $\vec{E}$ changes, V remains unchanged

Q.19 The potential at a point x (measured in μm) due to some changes situated on the x-axis is given by V (x) = 20 /(x^2 – 4) volts. The electric field E at x = 4 μm is given by **[AIEEE 2007]**
(A) 5/3 Volt/μm and in the –ve x direction
(B) 5/3 Volt/μm and in the +ve x direction
(C) 10/9 Volt/μm and in the –ve x direction
(D) 10/9 Volt/μm and in the +ve x direction

Q.20 If g_E and g_m are the accelerations due to gravity on the surfaces of the earth and the moon respectively and if Millikan's oil drop experiment could be performed on the two surfaces, one will find the ratio (electronic charge on the moon/electronic charge on the earth) to be - **[AIEEE 2007]**
(A) 1 (B) 0
(C) g_E/g_M (D) g_M/g_E

Q.21 A thin spherical 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 $0 \le r < \infty$, where r is the distance from the centre of the shell? **[AIEEE 2008]**



Q.22 This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.

Statement-1 :

For a mass M kept at the centre of a cube of side 'a', the flux of gravitational field passing through its sides is $4\pi GM$.

and

Statement-2 :

If the direction of a field due to a point source is radial and its dependence on the distance 'r' from the source is given as $\frac{1}{r^2}$, its flux through a closed surface depends only on the strength of the source enclosed by the surface and not on the size or shape of the surface.

[AIEEE-2008]

(A) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is true. Statement-2 is true; Statement-2 is not a correct explanation for Statement-1

(C) Statement-1 is true, Statement-2 is false.

(D) Statement-1 is false, Statement-2 is true.

Q.23 **Statement-1 :** For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

Statement-2 : The net work done by a conservative force on an object moving along a closed loop is zero. **[AIEEE-2009]**

(A) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is true. Statement-2 is true; Statement-2 is not a correct explanation for Statement-1

(C) Statement-1 is true, Statement-2 is false.

(D) Statement-1 is false, Statement-2 is true.

Q.24 Let $\rho(r) = \frac{Q}{\pi R^4} r$ be the volume charge density distribution for a solid sphere of radius R and total charge Q. For 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) $\frac{Q}{4\pi \in_0 r_1^2}$

(C) $\frac{Qr_1^2}{4\pi \in_0 R^4}$ (D) $\frac{Qr_1^2}{3\pi \in_0 R^4}$

Q.25 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

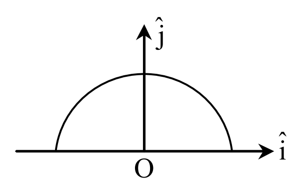
(C) -2.24×10^{-16} J (D) 2.24×10^{-16} J

Q.26 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.27 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) $\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$ (B) $\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$

(C) $-\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$ (D) $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

Q.28 Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0\left(\frac{5}{4} - \frac{r}{R}\right)$ upto r = R, and $\rho(r) = 0$ 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) $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$ (B) $\frac{4\pi\rho_0 r}{3\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$

(C) $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ (D) $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

Q.29 Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30° 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 1.6 g cm^{-3}, the dielectric constant of the liquid is - **[AIEEE-2010]**

(A) 1 (B) 4 (C) 3 (D) 2

Q.30 The electrostatic potential inside a charged spherical ball is given by $\phi = a r^2 + b$ where r is the distance from the centre; a, b are constants. Then the charge density inside the ball is : **[AIEEE-2011]**

(A) $-24\pi a\varepsilon_0 r$ (B) $-6 a\varepsilon_0 r$

(C) $-24\pi a\varepsilon_0$ (D) $-6 a\varepsilon_0$

Q.31 Two identical charged spheres suspended from a common point by two massless strings of length l are initially a distance $d(d<<l)$ apart because of their mutual repulsion. The charge begins to leak from both the spheres at a constant rate. As a result the charges approach each other with a velocity v. Then as a function of distance x between them, **[AIEEE-2011]**

(A) $v \propto x^{-1/2}$ (B) $v \propto x^{-1}$

(C) $v \propto x^{1/2}$ (D) $v \propto x$

Q.32 Two positive charges of magnitude 'q' are placed at the ends of a side (side 1) of a square of side '2a'. Two negative charges of the same magnitude are kept at the other corners. Starting from rest, if a charges Q moves from the middle of side 1 to the centre of square, its kinetic energy at the centre of square is - **[AIEEE-2011]**

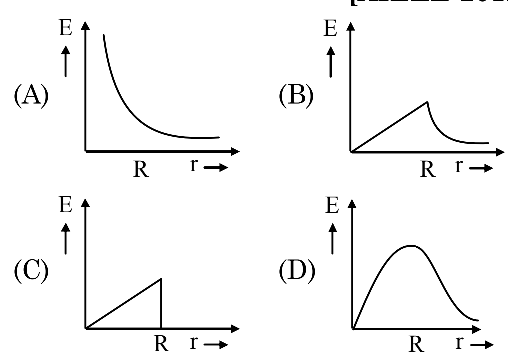
(A) zero

(B) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1 + \frac{1}{\sqrt{5}}\right)$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1 - \frac{2}{\sqrt{5}}\right)$

(D) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1 - \frac{1}{\sqrt{5}}\right)$

Q.33 In a uniformly charged sphere of total charge Q and radius R, the electric field E is plotted as a function of distance from the centre. The graph which would correspond to the above will be- **[AIEEE-2012]**



Q.34 This question has Statement-1 and Statement-2. Of the four choices given after the Statements, choose the one that best describes the two Statements. An insulating solid sphere of radius R has a uniformly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point out side the sphere. The electric potential at infinity is zero. **[AIEEE-2012]**

Statement 1 : When a charge 'q' is taken from the centre to the surface of the sphere, its potential energy changes by $\frac{q\rho}{3 \in_0}$.

Statement 2 : The electric field at a distance r (r < R) from the centre of the sphere is $\frac{\rho r}{3 \in_0}$.

(A) Statement 1 is true, Statement 2 is false

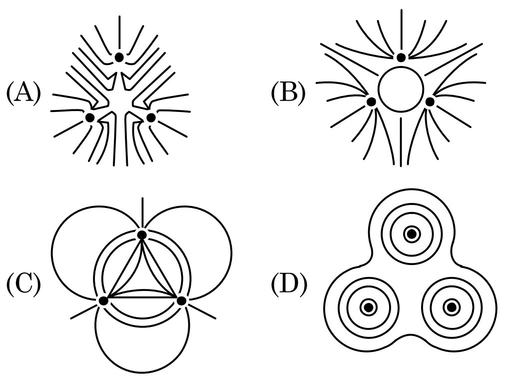
(B) Statement 1 is false, Statement 2 is true.

(C) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation for Statement 1

(D) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1

Q.35 Three positive charges of equal value q are placed at vertices of an equilateral triangle. The resulting lines of force should be sketched as in

[AIEEE Online-2012]



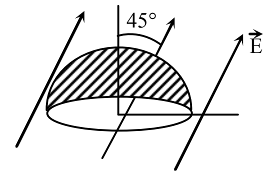
Q.36 The electric potential V(x) in a region around the origin is given by $V(x) = 4x^2$ volts. The electric charge enclosed in a cube of 1 m side with its centre at the origin is (in colomb) :

[AIEEE Online-2012]

(A) $8\in_0$ (B) 0

(C) $-8\in_0$ (D) $-4\in_0$

Q.37 The flat base of a hemisphere of radius a with no charge inside it lies in a horizontal plane. A uniform electric field $\vec{E}$ is applied at an angle $\frac{\pi}{4}$ with the verticals direction. The electric flux through the curved surface of the hemisphere is : **[AIEEE Online-2012]**



(A) $\frac{\pi a^2 E}{(2\sqrt{2})}$ (B) $\frac{\pi a^2 E}{\sqrt{2}}$

(C) $\frac{(\pi+2)\pi a^2 E}{(2\sqrt{2})}$ (D) $\pi a^2 E$

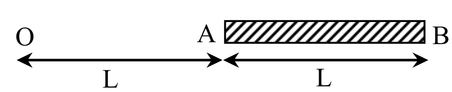
Q.38 A charge of total amount Q is distributed over two concentric hollow spheres of radii r and R(R > r) such that the surface charge densities on the two spheres are equal. The electric potential at the common centre is :

[AIEEE Online-2012]

(A) $\frac{1}{4\pi\varepsilon_0}\frac{(R-r)Q}{2(R^2+r^2)}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)Q}{(R^2+r^2)}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)Q}{2(R^2+r^2)}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{(R-r)Q}{(R^2+r^2)}$

Q.39 A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at a distance L from the end A is – **[JEE Main-2013]**



(A) $\frac{Q}{4\pi \in_0 L \ln 2}$ (B) $\frac{Q \ln 2}{4\pi \in_0 L}$

(C) $\frac{Q}{8\pi \in_0 L}$ (D) $\frac{3Q}{4\pi \in_0 L}$

Q.40 Two charges, each equal to q, are kept at x = – a and x = a on the x-axis. A particle of mass m and charge $q_0 = \frac{q}{2}$ is placed at the origin. If charge q_0 is given a small displacement (y << a) along the y-axis, the net force acting on the particle is proportional to - **[JEE Main-2013]**

(A) $\frac{1}{y}$ (B) $-\frac{1}{y}$ (C) y (D) – y

Q.41 A uniform electric field $\vec{E}$ exists between the plates of a charged condenser. A charged particle enters the space between the plates and perpendicular to $\vec{E}$. The path of the particle between the plates is a - **[JEE Main Online-2013]**

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

Q.42 Two point dipoles of dipole moment $\vec{p}_1$ and $\vec{p}_2$ are at a distance x from each other and $\vec{p}_1 || \vec{p}_2$. The force between the dipoles is- **[JEE Main Online-2013]**

(A) $\frac{1}{4\pi\varepsilon_0}\frac{4p_1p_2}{x^4}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{3p_1p_2}{x^3}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{6p_1p_2}{x^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{6p_1p_2}{x^4}$

Q.43 Two balls of same mass and carrying equal charge are hung from a fixed support of length ℓ. At electrostatic equilibrium, assuming that angles made by each thread is small, the separation x between the balls is proportional to : **[JEE Main Online-2013]**

(A) ℓ (B) ℓ^2 (C) $\ell^{2/3}$ (D) $\ell^{1/3}$

Q.44 A point charge of magnitude + 1μC is fixed at (0, 0, 0). An isolated uncharged spherical conductor, is fixed with its centre at (4cm, 0, 0). The potential and the induced electric field at the centre of the sphere is- **[JEE Main Online-2013]**

(A) 1.8×10^5 V and -5.625×10^6 V/m
(B) 0 V and 0V/m
(C) 2.25×10^5 V and -5.625×10^6 V/m
(D) 2.25×10^5V and 0V/m

Q.45 Two small equal point charges of magnitude q are suspended from a common point on the ceiling by insulating massless strings of equal lengths. They come to equilibrium with each string making angle θ from the vertical. If the mass of each charge is m, then the electrostatic potential at the centre of line joining them will be $\left(\frac{1}{4\pi\in_0} = k\right)$.

[JEE Main Online-2013]

(A) $\sqrt[2]{kmg\tan\theta}$ (B) $\sqrt{kmg\tan\theta}$
(C) $4\sqrt{kmg/\tan\theta}$ (D) $4\sqrt{kmg\tan\theta}$

Q.46 Consider a finite insulated, uncharged conductor placed near a finite positively charged conductor. The uncharged body must have a potential – **[JEE Main Online-2013]**

(A) less than the charged conductor and more than at infinity
(B) more than the charged conductor and les than at infinity
(C) more than the charged conductor and more than at infinity
(D) less than the charged conductor and less than at infinity

Q.47 A liquid drop having 6 excess electrons is kept stationary under a uniform electric field of 25.5 kV m^{-1}. the density of liquid is 1.26×10^3 kg m^{-3}. The radius of the drop is (neglect buoyancy) – **[JEE Main Online-2013]**

(A) 4.3×10^{-7} m (B) 7.8×10^{-7} m
(C) 0.078×10^{-7} m (D) 3.4×10^{-7} m

Q.48 This question has statement-1 and statement-2. of the four choices given after the statements, choose the one that best describes the two statements.

Statement-1 : No work is required to be done to move a test charge between any two points on an equipotential surface.

Statement-2 : Electric lines of force at the equipotential surfaces are mutually perpendicular to each other

[JEE Main Online-2013]

(A) Statement-1 is true, Statement 2 is true, Statement-2 is the correct explanation of Statement-1
(B) Statement-1 is true, Statement 2 is true, Statement-2 is **not** correct explanation of Statement-1
(C) Statement-1 is true, Statement-2 is false
(D) Statement-1 is false, Statement-2 is true

Q.49 The surface charge density of a thin charged disc of radius R is σ. The value of the electric field at the centre of the disc is $\frac{\sigma}{2\in_0}$. With respect to the field at the centre, the electric field along the axis at a distance R from the centre of the disc.
[JEE Main Online-2013]
(A) reduces by 70.7%
(B) reduces by 29.3%
(C) reduces by 9.7 %
(D) reduces by 14.6%

Q.50 Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_O$, where V_O is the potential at the original and V_A the potential at x = 2 m is -
[JEE Main-2014]
(A) –120 V (B) – 80 V (C) 80 V (D) 120 V

Q.51 The magnitude of the average electric field normally present in the atmosphere just above the surface of the Earth is about 150 N/C, directed inward towards the centre of Earth. This gives the total net surface charge carried by the Earth to be : **[JEE Main Online-2014]**
[Given ε_0 = 8 .85× 10^{-12} $C^2/N\text{–}m^2$, $R_E = 6.37\times10^6$ m]
(A) + 670 kC (B) –670 kC
(C) – 680 kC (D) + 680 kC

Q.52 A cone of base radius R and height h is located in a uniform electric field $\vec{E}$ parallel to its base. The electric flux entering the cone is :
[JEE Main Online-2014]
(A) $\frac{1}{2}EhR$ (B) E h R
(C) 2 E h R (D) 4E h R

Q.53 A spherically symmetric charge distribution is characterized by a charge density having the following variation :

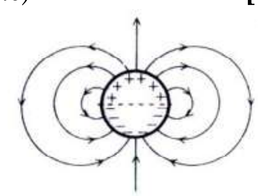
$$\rho(r) = \rho_0\left(1-\frac{r}{R}\right) \text{ for } r < R$$

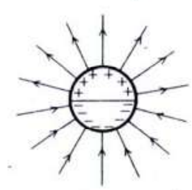
$$\rho(r) = 0 \qquad \text{for } r \geq R$$

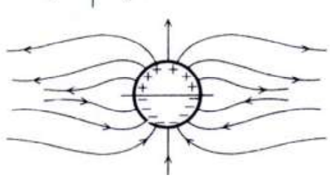
Where r is the distance from the centre of the charge distribution and ρ_o is a constant. The electric field at an internal point (r < R) is : **[JEE Main Online-2014]**
(A) $\frac{\rho_o}{4\in_o}\left(\frac{r}{3}-\frac{r^2}{4R}\right)$ (B) $\frac{\rho_o}{\in_o}\left(\frac{r}{3}-\frac{r^2}{4R}\right)$
(C) $\frac{\rho_o}{3\in_o}\left(\frac{r}{3}-\frac{r^2}{4R}\right)$ (D) $\frac{\rho_o}{12\in_o}\left(\frac{r}{3}-\frac{r^2}{4R}\right)$

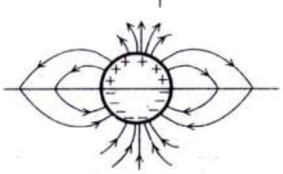
Q.54 The electric field in a region of space is given by, $\vec{E} = E_o\hat{i} + 2E_o\hat{j}$ where E_0 = 100 N/C. The flux of this field through a circular surface of radius 0.02 m parallel to the Y-Z plane is nearly:
[JEE Main Online-2014]
(A) 0.125 Nm^2/C (B) 0.02 Nm^2/C
(C) 0.005 Nm^2/C (D) 3.14 Nm^2/C

Q.55 A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge –σ in the lower half. The electric field lines around the cylinder will look like figure given in -
(*Figure are schematic and not drawn to scale*) **[JEE Main -2015]**

(A) 

(B) 

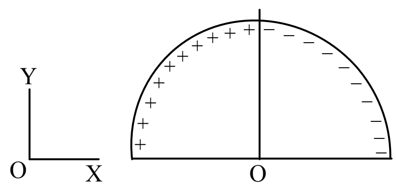
(C) 

(D) 

Q.56 A uniformly charged solid sphere of radius R has potential V_0 (measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}$, $\frac{5V_0}{4}$, $\frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then - **[JEE Main -2015]**

(A) $R_1 = 0$ and $R_2 > (R_4 - R_3)$
(B) $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$
(C) $R_1 = 0$ and $R_2 < (R_4 - R_3)$
(D) $2R < R_4$

Q.57 A wire, of length L(= 20 cm), is bent into a semi-circular arc. If the two equal halves, of the arc, were each to be uniformly charged with charges $\pm$ Q, [$|Q| = 10^3\ \varepsilon_0$ Coulomb where ε_0 is the permittivity (in SI units) of free space] the net electric field at the centre O of the semi-circular arc would be : **[JEE Main Online-2015]**

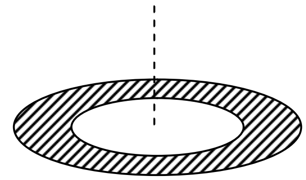


(A) $(25 \times 10^3\ \text{N/C})\,\hat{i}$ (B) $(50 \times 10^3\ \text{N/C})\,\hat{j}$
(C) $(25 \times 10^3\ \text{N/C})\,\hat{j}$ (D) $(50 \times 10^3\ \text{N/C})\,\hat{i}$

Q.58 An electric field $\vec{E} = (25\hat{i} + 30\hat{j})\text{NC}^{-1}$ exists in a region of space. If the potential at the origin is taken to be zero then the potential at x = 2 m, y = 2 m is : **[JEE Main Online-2015]**

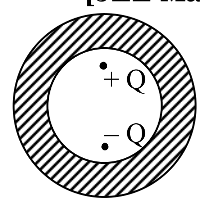
(A) – 140 V (B) – 120 V
(C) – 130 V (D) – 110 V

Q.59 A thin disc of radius b = 2a has a concentric hole of radius 'a' in it (see figure). It carries uniform surface charge 'σ' on it. If the electric field on its axis at height 'h' (h << a) from its centre is given as 'Ch' then value of 'C' is : **[JEE Main Online-2015]**



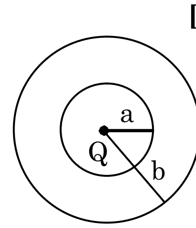
(A) $\frac{\sigma}{4a\varepsilon_0}$ (B) $\frac{\sigma}{8a\varepsilon_0}$ (C) $\frac{\sigma}{2a\varepsilon_0}$ (D) $\frac{\sigma}{a\varepsilon_0}$

Q.60 Shown in the figure are two point charges +Q and –Q inside the cavity of a spherical shell. The charges are kept near the surface of the cavity on opposite sides of the centre of the shell. If σ_1 is the surface charge on the inner surface and Q_1 net charge on it and σ_2 the surface charge on the outer surface and Q_2 net charge on it then : **[JEE Main Online-2015]**



(A) $\sigma_1 \neq 0$, $Q \neq 0$; $\sigma_2 \neq 0$, $Q_2 \neq 0$
(B) $\sigma_1 \neq 0$, $Q_1 = 0$; $\sigma_2 = 0$, $Q_2 = 0$
(C) $\sigma_1 = 0$, $Q_1 = 0$; $\sigma_2 = 0$, $Q_2 = 0$
(D) $\sigma_1 \neq 0$, $Q_1 = 0$; $\sigma_2 \neq 0$, $Q_2 = 0$

Q.61 The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), has volume charge density $\rho = \frac{A}{r}$, where A is a constant and r is the distance from the centre. At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is **[JEE-Main 2016]**



(A) $\frac{Q}{2\pi a^2}$ (B) $\frac{Q}{2\pi(b^2 - a^2)}$
(C) $\frac{2Q}{\pi(a^2 - b^2)}$ (D) $\frac{2Q}{\pi a^2}$

Q.62 The potential (in volts) of a charge distribution is given by

$V(z) = 30 - 5z^2$ for $|z| \le 1$ m

$V(z) = 35 - 10\,|z|$ for $|z| \ge 1$ m

V(z) does not depend on x and y. If this potential is generated by a constant charge per unit volume ρ_0 (in units of $\in_0$) which is spread over a certain region, then choose the correct statement.

[JEE-Main Online - 2016]

(A) $\rho_0 = 10\in_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere

(B) $\rho_0 = 20\in_0$ in the entire region

(C) $\rho_0 = 40\in_0$ in the entire region

(D) $\rho_0 = 20\in_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere

Q.63 Within a spherical charge distribution of charge density $\rho(r)$, N equipotential surfaces of potential V_0, $V_0 + \Delta V$, $V_0 + 2\Delta V$, ...$V_0 + N\Delta V$ $(\Delta V > 0)$, are drawn and have increasing radii r_0, r_1, r_2, ... r_N, respectively. If the difference in the radii of the surfaces is constant for all values of V_0 and ΔV then :

[JEE-Main Online - 2016]

(A) $\rho(r) \propto \frac{1}{r^2}$

(B) $\rho(r) \propto r$

(C) $\rho(r) \propto \frac{1}{r}$

(D) $\rho(r) = \text{constant}$

Q.64 An electric dipole has fixed dipole moment $\vec{p}$, which makes angle θ with respect to x-axis. When subjected to an electric field $\vec{E}_1 = E\hat{i}$, it experience a torque $\vec{T}_1 = \tau\hat{k}$. When subjected to another electric field $\vec{E}_2 = \sqrt{3}\ E_1\hat{j}$ it experiences a torque $\vec{T}_2 = -\vec{T}_1$. The angle θ is.

[JEE-Main 2017]

(A) 30°   (B) 45°

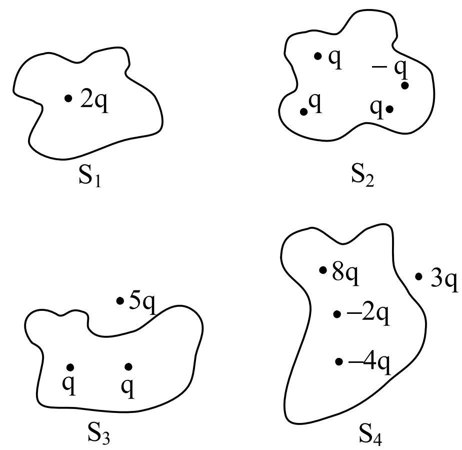
(C) 60°   (D) 90°

Q.65 There is a uniform electrostatic field in a region. The potential at various points on a small sphere centred at P, in the region, is found to vary between in limits 589.0 V to 589.8 V. What is the potential at a point on the sphere whose radius vector makes an angle of 60° with the direction of the field ? **[JEE-Main Online - 2017]**

(A) 589.4 V   (B) 589.5 V

(C) 589.2 V   (D) 589.6 V

Q.66 Four closed surfaces and corresponding charge distributions are shown below



Let the respective electric fluxes through the surfaces be ϕ_1, ϕ_2, ϕ_3 and ϕ_4. Then –

[JEE-Main Online - 2017]

(A) $\phi_1 > \phi_2 > \phi_3 > \phi_4$

(B) $\phi_1 < \phi_2 = \phi_3 > \phi_4$

(C) $\phi_1 > \phi_3$; $\phi_2 > \phi_4$

(D) $\phi_1 = \phi_2 = \phi_3 = \phi_4$

Q.67 Three concentric metal shells A, B and C of respective radii a, b and c $(a < b < c)$ have surface charge densities $+\sigma$, $-\sigma$ and $+\sigma$ respectively. The potential of shell B is : **[JEE Main - 2018]**

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

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

Q.68 A body of mass M and charge q is connected to a spring of spring constant k. It is oscillating along x-direction about its equilibrium position, taken to be at x = 0, with an amplitude A. An electric field E is applied along the x-direction. Which of the following statements is correct ? **[JEE-Main Online-2018]**

(A) The total energy of the system is $\frac{1}{2}m\omega^2A^2 + \frac{1}{2}\frac{q^2E^2}{k}$

(B) The new equilibrium position is at a distance : $\frac{2qE}{k}$ from x = 0

(C) The new equilibrium position is at a distance: $\frac{qE}{2k}$ from x = 0

(D) The total energy of the system is $\frac{1}{2}m\omega^2A^2 - \frac{1}{2}\frac{q^2E^2}{k}$

Q.69 A solid ball of radius R has a change density ρ given by $\rho = \rho_0\left(1-\frac{r}{R}\right)$ for $0 \le r \le R$. The electric field outside the ball is - **[JEE-Main Online-2018]**

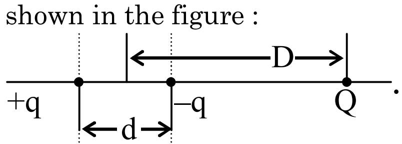
(A) $\frac{\rho_0 R^3}{\varepsilon_0 r^2}$ (B) $\frac{4\rho_0 R^3}{3\varepsilon_0 r^2}$

(C) $\frac{3\rho_0 R^3}{4\varepsilon_0 r^2}$ (D) $\frac{\rho_0 R^3}{12\varepsilon_0 r^2}$

Q.70 Two identical conducting spheres, A and B, carry equal charge. They are separated by a distance much larger than their diameter, and the force between them is F. A third identical conducting sphere, C, is uncharged. Sphere C is first touched to A, then to B, and then removed. As a result, the force between A and B would be equal to - **[JEE-Main Online-2018]**

(A) $\frac{3F}{4}$ (B) $\frac{F}{2}$ (C) F (D) $\frac{3F}{8}$

Q.71 A system of three charges are placed as shown in the figure :



If D >> d, the potential energy of the system is best given by : **[Main-2019]**

(A) $\frac{1}{4\pi\epsilon_0}\left[+\frac{q^2}{d}+\frac{qQd}{D^2}\right]$

(B) $\frac{1}{4\pi\epsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{D^2}\right]$

(C) $\frac{1}{4\pi\epsilon_0}\left[-\frac{q^2}{d}+\frac{2qQd}{D^2}\right]$

(D) $\frac{1}{4\pi\epsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{2D^2}\right]$

Q.72 Four point charges –q, +q, +q and –q are placed on y-axis at y = –2d, y = –d, y = +d, y = +2d, respectively. The magnitude of the electric field E at a point a the x-axis at x = D, with D >> d, will behave as : **[Main-2019]**

(A) $E \propto \frac{1}{D}$ (B) $E \propto \frac{1}{D^3}$

(C) $E \propto \frac{1}{D^4}$ (D) $E \propto \frac{1}{D^2}$

Q.73 In free space, a particle A of charge 1μC is held fixed at a point P. Another particle B of the same charge and mass 4μg is kept at a distance of 1 mm from P. If B is released, then its velocity at a distance of 9 mm from P is -

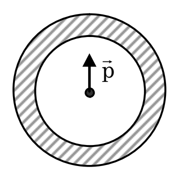
$$\left[\text{Take}\ \frac{1}{4\pi\epsilon_0} = 9\times10^9\,\text{Nm}^2\text{C}^{-2}\right]$$

[Main-2019]

(A) 1.0 m/s (B) 3.0×10^4 m/s

(C) 2.0×10^3 m/s (D) 1.5×10^2 m/s

Q.74 Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{P}$ as shown. In this case; **[Main-2019]**



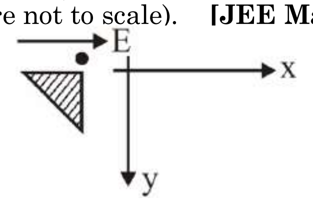
(A) surface charge density on the inner surface is uniform and equal to $\frac{(Q/2)}{4\pi a^2}$

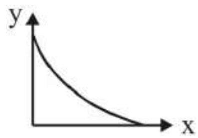
(B) surface charge density on the outer surface depends on $|\vec{p}|$

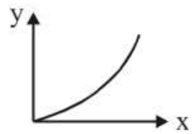
(C) surface charge density on the inner surface of the shell is zero everywhere

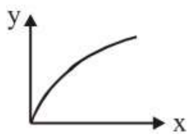
(D) electric field outside the shell is the same as that of a point charge at the centre of the shell

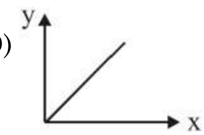
Q.75 A small point mass carrying some positive charge on it, is released from the edge of a table. There is a uniform electric field in this region in the horizontal direction. Which of the following options then correctly describe the trajectory of the mass ? (Curves are drawn schematically and are not to scale). **[JEE Main 2020]**



(A) 

(B) 

(C) 

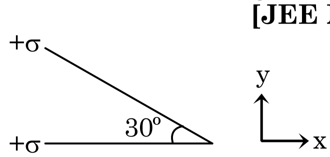
(D) 

Q.76 Concentric metallic hollow spheres radii R and 4R hold charges Q_1 and Q_2 respectively. Given that surface charge densities of the concentric spheres are equal, the potential difference V(R) – V(4R) is : **[JEE Main 2020]**

(A) $\frac{3Q_1}{16\pi\varepsilon_0 R}$ (B) $\frac{3Q_1}{4\pi\varepsilon_0 R}$

(C) $\frac{Q_2}{4\pi\varepsilon_0 R}$ (D) $\frac{3Q_2}{4\pi\varepsilon_0 R}$

Q.77 Two infinite planes each with uniform surface charge density + σ are kept in such a way that the angle between them is 30º. The electric field in the region shown between them is given by – **[JEE Main 2020]**



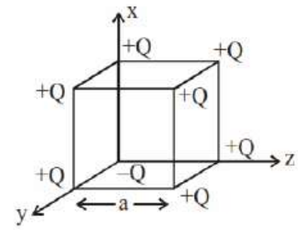
(A) $\frac{\sigma}{2\epsilon_0}\left[(1+\sqrt{3})\hat{y}+\frac{\hat{x}}{2}\right]$

(B) $\frac{\sigma}{\epsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y}+\frac{\hat{x}}{2}\right]$

(C) $\frac{\sigma}{2\epsilon_0}\left[(1+\sqrt{3})\hat{y}-\frac{\hat{x}}{2}\right]$

(D) $\frac{\sigma}{2\epsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

Q.78 A cube of side 'a' has point charges +Q located at each of its vertices except at the origin where the charge is –Q. The electric field at the centre of cube is : **[JEE Main 2021]**



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

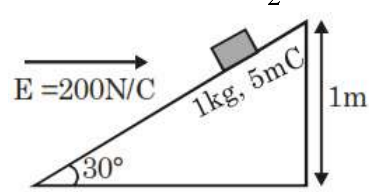
(B) $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

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

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

Q.79 An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field $200\frac{N}{C}$ as shown in the figure. A body of mass 1kg and charge 5 mC is allowed to slide down from rest at a height of 1m. If the coefficient of friction is 0.2, find the time taken by the body to reach the bottom. **[JEE Main 2021]**

[$g = 9.8\ m/s^2$, $\sin 30° = \frac{1}{2}$; $\cos 30° = \frac{\sqrt{3}}{2}$]



(A) 0.92 s (B) 0.46 s (C) 2.3 s (D) 1.3 s

Q.80 The electric field in a region is given $\vec{E}=\left(\frac{3}{5}E_0\hat{i}+\frac{4}{5}E_0\hat{j}\right)\frac{N}{C}$. The ratio of flux of reported field through the rectangular surface of area 0.2 m^2 (parallel to y – z plane) to that of the surface of area 0.3 m^2 (parallel to x – z plane) is a : b, where a = _____. **[JEE Main 2021]**

[Here $\hat{i}$, $\hat{j}$ and $\hat{k}$ are unit vectors along x, y and z-axes respectively]

Q.81 Given below are two statements : **[JEE Main 2021]**

Statement I : An electric dipole is placed at the centre of a hollow sphere. The flux of electric field through the sphere is zero but the electric field is not zero anywhere in the sphere.

Statement II : If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at any point on the spherical surface of radius r (< R) is zero but the electric flux passing through this closed spherical surface of radius r is not zero.

In the light of the above statements, choose the correct answer from the options given below :

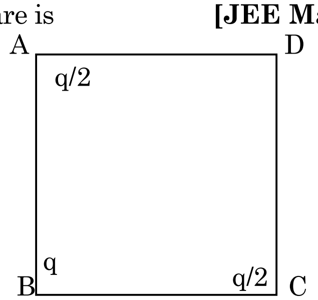
(A) Both Statement I and Statement II are true

(B) Statement I is true but Statement II is false

(C) Both Statement I and Statement II are false

(D) Statement I is false but Statement II is true.

Q.82 The three charges $\frac{q}{2}$, q and $\frac{q}{2}$ are placed at the corners *A*, *B* and *C* of a square of side '*a*' as shown in figure. The magnitude of electric field (*E*) at the corner *D* of the square is **[JEE Main 2022]**



(A) $\frac{q}{4\pi \epsilon_0 a^2}\left(\frac{1}{\sqrt{2}}+\frac{1}{2}\right)$

(B) $\frac{q}{4\pi \epsilon_0 a^2}\left(1+\frac{1}{\sqrt{2}}\right)$

(C) $\frac{q}{4\pi \epsilon_0 a^2}\left(1-\frac{1}{\sqrt{2}}\right)$

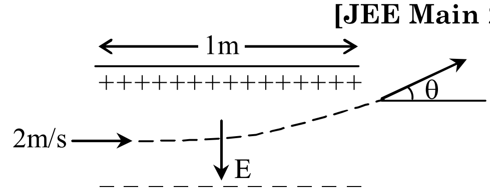
(D) $\frac{q}{4\pi \epsilon_0 a^2}\left(\frac{1}{\sqrt{2}}-\frac{1}{2}\right)$

Q.83 Two identical positive charges Q each are fixed at a distance of '2a' apart from each other. Another point charge q_0 with mass 'm' is placed at midpoint between two fixed charges. For a small displacement along the line joining the fixed charges, the charge q_0 executes SHM. The time period of oscillation of charge q_0 will be **[JEE Main 2022]**

(A) $\sqrt{\frac{4\pi^3\varepsilon_0 ma^3}{q_0 Q}}$ (B) $\sqrt{\frac{q_0 Q}{4\pi^3\varepsilon_0 ma^3}}$

(C) $\sqrt{\frac{2\pi^2\varepsilon_0 ma^3}{q_0 Q}}$ (D) $\sqrt{\frac{8\pi^3\varepsilon_0 ma^3}{q_0 Q}}$

Q.84 A uniform electric field E = (8m/e) V/m is created between two parallel plates of length 1 m as shown in figure, (where m = mass of electron and e = charge of electron). An electron enters the field symmetrically between the plates with a speed of 2 m/s. The angle of the deviation (θ) of the path of the electron as it comes out of the field will be_______. **[JEE Main 2022]**



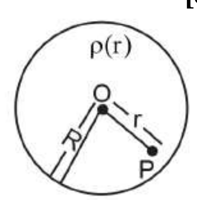
(A) $\tan^{-1}(4)$ (B) $\tan^{-1}(2)$

(C) $\tan^{-1}\left(\frac{1}{3}\right)$ (D) $\tan^{-1}(3)$

Q.85 A spherically symmetric charge distribution is considered with charge density varying as

$$\rho(r) = \begin{cases} \rho_0\left(\frac{3}{4}-\frac{r}{R}\right) & \text{for } r \le R \\ \text{Zero} & \text{for } r > R \end{cases}$$

Where, r(r < R) is the distance from the centre O (as shown in figure). The electric field at point P will be : **[JEE Main 2022]**



(A) $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{3}{4}-\frac{r}{R}\right)$ (B) $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{3}{4}-\frac{r}{R}\right)$

(C) $\frac{\rho_0 r}{4\varepsilon_0}\left(1-\frac{r}{R}\right)$ (D) $\frac{\rho_0 r}{5\varepsilon_0}\left(1-\frac{r}{R}\right)$

Q.86 Two identical metallic spheres A and B when placed at certain distance in air repel each other with a force of F. Another identical uncharged sphere C is first placed in contact with A and then in contact with B and finally placed at midpoint between spheres A and B. The force experienced by sphere C will be :

[JEE Main 2022]

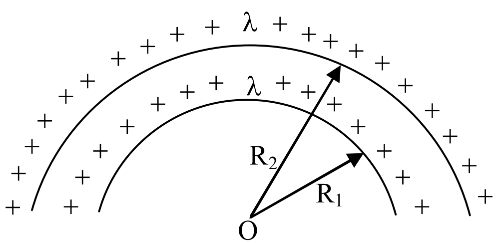
(A) 3F/2 (B) 3F/4 (C) F (D) 2F

Q.87 The volume charge density of a sphere of radius 6 m is 2 $\mu C\ cm^{-3}$. The number of lines of force per unit surface area coming out from the surface of the sphere is _______ $\times 10^{10}\ NC^{-1}$. [Given : Permittivity of vacuum $\in_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1} - m^{-2}$]

[JEE Main 2022]

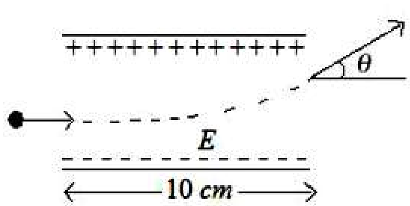
Q.88 The electric potential at the centre of two concentric half rings of radii R_1 and R_2, having same linear charge density λ is:

[JEE Main 2023]

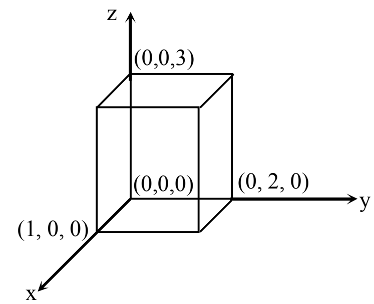


(A) $\frac{\lambda}{4\varepsilon_0}$ (B) $\frac{\lambda}{2\varepsilon_0}$ (C) $\frac{2\lambda}{\varepsilon_0}$ (D) $\frac{\lambda}{\varepsilon_0}$

Q.89 A uniform electric field of 10 N/C is created between two parallel charged plates (as shown in figure). An electron enters the field symmetrically between the plates with a kinetic energy 0.5 eV. The length of each plate is 10 cm. The angle (θ) of deviation of the path of electron as it comes out of the field is ____ (in degree). **[JEE Main 2023]**

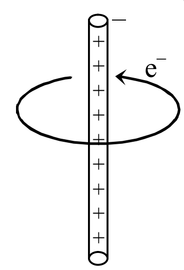


Q.90 As shown in figure, a cuboid lies in a region with electric field $E = 2x^2\hat{i} - 4y\hat{j} + 6\hat{k}\ \frac{N}{C}$. The magnitude of charge within the cuboid is $n\in_0 C$. The value of n is ______ (if dimension of cuboid is $1 \times 2 \times 3\ m^3$). **[JEE Main 2023]**



Q.91 An electron revolves around an infinite cylindrical wire having uniform linear charge density $2 \times 10^{-8}\ C\ m^{-1}$ in circular path under the influence of attractive electrostatic field as shown in the figure. The velocity of electron with which it is revolving is ________ $\times 10^6\ m\ s^{-1}$. Given mass of electron $= 9 \times 10^{-31}$ kg

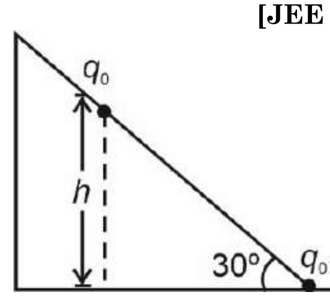
[JEE Main 2023]



Q.92 As shown in the figure, a configuration of two equal point charges ($q_0 = +2\mu$ C) is placed on an inclined plane. Mass of each point charge is 20 g. Assume that there is no friction between charge and plane. For the system of two point charges to be in equilibrium (at rest) the height $h = x \times 10^{-3}$ m. The value of x is ________.

(Take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ N\ m^2C^{-2}$, $g = 10\ ms^{-2}$)

[JEE Main 2023]



Q.93 Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle θ with each other. When suspended in water the angle remains the same. If density of the material of the sphere is 1.5 g/cc, the dielectric constant of water will be ________
(Take density of water = 1 g/cc)
[JEE Main 2024]

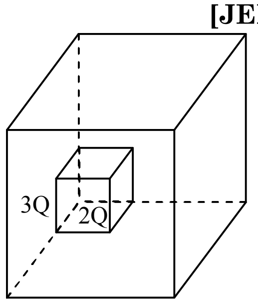
Q.94 A electron is moving under the influence of the electric field of a uniformly charged infinite plane sheet S having surface charge density +σ. The electron at t = 0 is at a distance of 1 m from S and has a speed of 1 m/s. The maximum value of σ if the electron strikes S at t = 1 s is $\alpha\left[\frac{m \in_0}{e}\right]\frac{C}{m^2}$, the value of α is ________.
[JEE Main 2024]

Q.95 A particle of charge '–q' and mass 'm' moves in a circle of radius 'r' around an infinitely long line charge of linear charge density '+λ'. Then time period will be given as :
(Consider k as Coulomb's constant)
[JEE Main 2024]

(A) $T = \frac{1}{2\pi r}\sqrt{\frac{m}{2k\lambda q}}$ (B) $T^2 = \frac{4\pi^2 m}{2k\lambda q} r^3$

(C) $T = 2\pi r\sqrt{\frac{m}{2k\lambda q}}$ (D) $T = \frac{1}{2\pi}\sqrt{\frac{2k\lambda q}{m}}$

Q.96 C_1 and C_2 are two hollow concentric cubes enclosing charges 2Q and 3Q respectively as shown in figure. The ratio of electric flux passing through C_1 and C_2 is :
[JEE Main 2024]



(A) 2 : 3 (B) 5 : 2
(C) 2 : 5 (D) 3 : 2

Q.97 Two charges of 5Q and –2Q are situated at the points (3a, 0) and (–5a, 0) respectively. The electric flux through a sphere of radius '4a' having center at origin is- **[JEE Main 2024]**

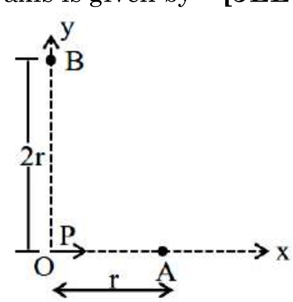
(A) $\frac{2Q}{\varepsilon_0}$ (B) $\frac{3Q}{\varepsilon_0}$

(C) $\frac{7Q}{\varepsilon_0}$ (D) $\frac{5Q}{\varepsilon_0}$

Q.98 An electron is made to enters symmetrically between two parallel and equally but oppositely charged metal plates, each of 10 cm length. The electron emerges out of the field region with a horizontal component of velocity 10^6 m/s. If the magnitude of the electric field between the plates is 9.1 V/cm, then the vertical component of velocity of electron is (mass of electron = 9.1×10^{-31} kg and charge of electron = 1.6×10^{-19} C)
[JEE Main 2025]

(A) 1×10^6 m/s (B) 0
(C) 16×10^6 m/s (D) 16×10^4 m/s

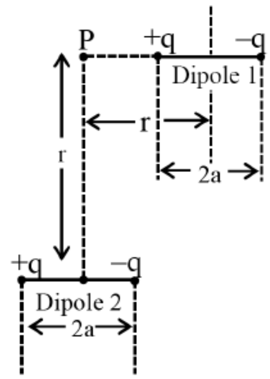
Q.99 For a short dipole placed at origin O, the dipole moment P is along x-axis, as shown in the figure. If the electric potential and electric field at A are V_0 and E_0, respectively, then the correct combination of the electric potential and electric field, respectively, at point B on the y-axis is given by **[JEE Main 2025]**



(A) $\frac{V_0}{2}$ and $\frac{E_0}{16}$ (B) zero and $\frac{E_0}{8}$

(C) zero and $\frac{E_0}{16}$ (D) V_0 and $\frac{E_0}{4}$

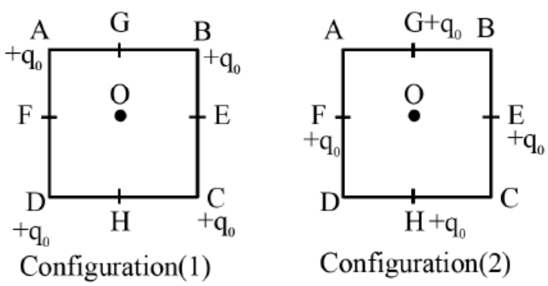
Q.100 A point particle of charge Q is located at P along the axis of an electric dipole 1 at a distance r as shown in the figure. The point P is also on the equatorial plane of a second electric dipole 2 at a distance r. The dipoles are made of opposite charge q separated by a distance 2a. For the charge particle at P not to experience any net force, which of the following correctly describes the situation? **[JEE Main 2025]**



(A) $\frac{a}{r} - 20$ (B) $\frac{a}{r} \sim 10$

(C) $\frac{a}{r} \sim 0.5$ (D) $\frac{a}{r} \sim 3$

Q.101

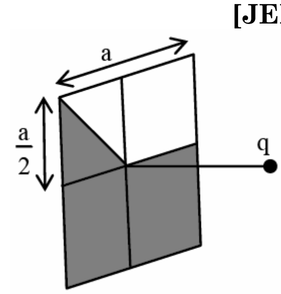


In the first configuration (1) as shown in the figure, four identical charges (q_0) are kept at the corners A, B, C and D of square of side length 'a'. In the second configuration (2), the same charges are shifted to mid points G, E, H and F, of the square, If $K = \frac{1}{4\pi\varepsilon_0}$, the difference between the potential energies of configuration (2) and (1) is given by : **[JEE Main 2025]**

(A) $\frac{Kq_0^2}{a}(4\sqrt{2} - 2)$ (B) $\frac{Kq_0^2}{a}(3 - \sqrt{2})$

(C) $\frac{Kq_0^2}{a}(4 - 2\sqrt{2})$ (D) $\frac{Kq_0^2}{a}(3\sqrt{2} - 2)$

Q.102 A square loop of sides a = 1 m is held normally in front of a point charge q = 1C. The flux of the electric field through the shaded region is $\frac{5}{p} \times \frac{1}{\varepsilon_0} \frac{Nm^2}{C}$, where the value of p is ____. **[JEE Main 2025]**



EXERCISE - 5

Old Examination Questions [IIT JEE Advanced]

Q.1 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- **[IIT - 92]**

(A) zero

(B) $\frac{q(Q_1 - Q_2)(\sqrt{2}-1)}{4\sqrt{2}\pi\varepsilon_0 R}$

(C) $\frac{q\sqrt{2}(Q_1 + Q_2)}{4\pi\varepsilon_0 R}$

(D) $\frac{q(Q_1 + Q_2)(\sqrt{2}+1)}{4\sqrt{2}\pi\varepsilon_0 R}$

Q.2 The electric potential V at any point x, y, z in space is given by $V = 4x^2$ volt/ meter^2. The electric field at the point (1m, 0, 2m) is – **[IIT - 92]**

(A) 8 V/m (B) 4 V/m
(C) 16 V/m (D) 4/3 V/m

Q.3 Five point charges, each of value + q, are placed on five vertices of a regular hexagon of side L. The magnitude of the force on a point charge of value – q placed at the centre of the hexagon is - **[IIT - 92]**

(A) $\frac{Kq^2}{L^2}$ (B) $\frac{Kq^2}{4L^2}$

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

Q.4 Two point charges +q and –q are held fixed at (–d, 0) and (d, 0) respectively of a (x, y) coordinate system, then – **[IIT-1995]**

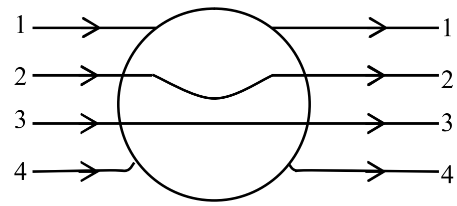
(A) The electric field $\vec{E}$ at all points on the x-axis has the same direction

(B) $\vec{E}$ at all points on the Y-axis is along $\hat{i}$

(C) Work has to be done in bringing a test charge from infinity to the origin

(D) The dipole moment is 2qd directed along $\hat{i}$

Q.5 A metallic solid sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in figure as **[IIT-1996]**



(A) 1 (B) 2 (C) 3 (D) 4

Q.6 An electron of mass m_e, initially at rest, moves through a certain distance in a uniform electric field in time t_1 A proton of mass m_p, also initially at rest, takes time t_2 to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio t_2/t_1 is nearly equal to – **[IIT-1997]**

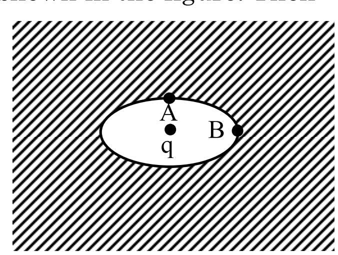
(A) 1 (B) $(m_p/m_e)^{1/2}$
(C) $(m_e / m_p)^{1/2}$ (D) 1836

Q.7 A charge + q is fixed at each of the point $x = x_0$, $x = 3x_0$, $x = 5x_0$, ...∞ on the x-axis , and charges –q is fixed at each of the point $x = 2x_0$, $x = 4x_0$, $x = 6x_0$,........ad inf. Here x_0 is a positive constant. Take the electric potential at a point due to a charge Q at a distance r from it to be $Q / (4\pi\varepsilon_0 r)$. Then the potential at the origin due to the above system of charges is- **[IIT-1998]**

(A) 0 (B) $\frac{q}{8\pi\varepsilon_0 x_0 \ln 2}$

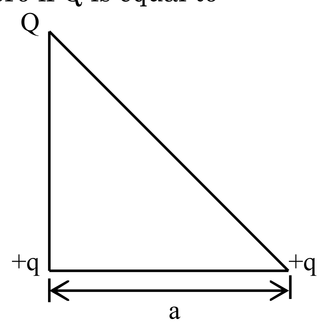
(C) ∞ (D) $\frac{q \ln 2}{4\pi\varepsilon_0 x_0}$

Q.8 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 as shown in the figure. Then - **[IIT-1999]**



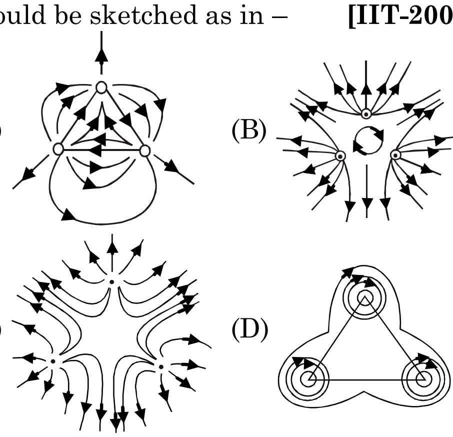
(A) Electric field near A in the cavity = electric field near B in the cavity
(B) Charge density at A = charge density at B
(C) Potential at A ≠ potential at B
(D) Total electric field flux through the surface of the cavity is q/ε_0.

Q.9 Three charges Q, +q and +q are placed at the vertices of a right angled isosceles triangle as shown in figure. The net electrostatics energy of the configuration is zero if Q is equal to - **[IIT-2000]**



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

Q.10 Three positive charges of equal value q are placed at the vertices of an equilateral triangle. The resulting lines of force should be sketched as in – **[IIT-2001]**



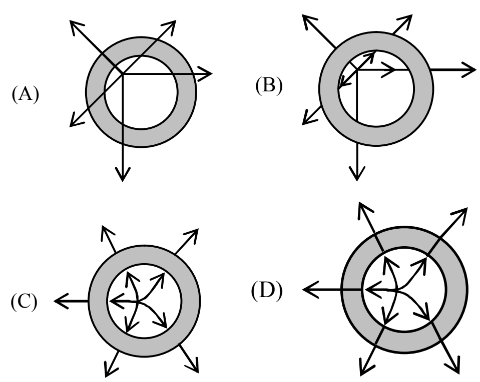
Q.11 A uniform electric field pointing in positive x-direction exists in a region. Let A be the origin, B be the point on the x-axis at x = + 1 cm and C be the point on the y axis at y = + 1 cm. Then the potentials at the points A, B, and C satisfy. **[IIT-2001]**

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

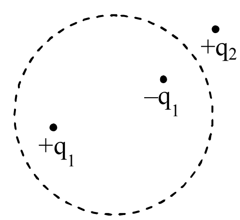
Q.12 Two equal point charges are fixed at x = – a and x = + a on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to – **[IIT-2002]**

(A) x (B) x^2
(C) x^3 (D) $1 / x$

Q.13 A point charge 'q' is placed at a point inside a hollow conducting sphere which of the following electric lines of force pattern is correct ? **[IIT-2003]**

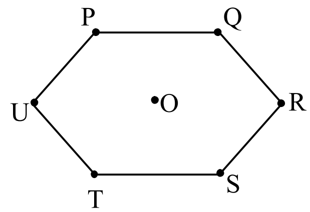


Q.14 In the given figure, charges q_1 and $-q_1$ are inside a Gaussian surface, where as charge q_2 is outside the surface. Electric field on the Gaussian surface will be **[IIT-2004]**



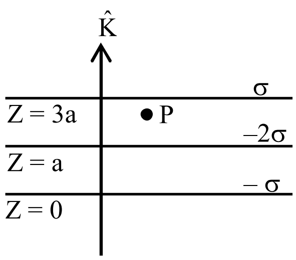
(A) only due to q_2
(B) zero on the Gaussian surface
(C) uniform on the Gaussian surface
(D) due to all

Q.15 Six charges of equal magnitude are placed at six corners of a regular hexagon. Find arrangement the charges in order PQRSTU which produce double electric field at centre as compared to electric filed produce by single charges +q at R - **[IIT-2004]**



(A) +++ – – – (B) + – + – + –
(C) – + + – + – (D) – + + + – –

Q.16 Three large charged sheets having surface charge density as shown in the figure. The sheets are placed parallel to XY plane. Then electric field at point P – **[IIT-2005]**



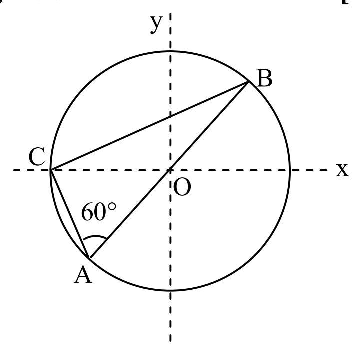
(A) $\frac{-4\sigma}{\epsilon_0}\hat{k}$ (B) $\frac{4\sigma}{\epsilon_0}\hat{k}$

(C) $\frac{2\sigma}{\epsilon_0}\hat{k}$ (D) $-\frac{2\sigma}{\epsilon_0}\hat{k}$

Q.17 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.18 Positive and negative point charges 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 initial and final positions

Q.19 Consider a system of three charges $\frac{q}{3}$, $\frac{q}{3}$ and $-\frac{2q}{3}$ placed at points A, B and C respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle CAB = 60°.
Figure : **[IIT-2008]**



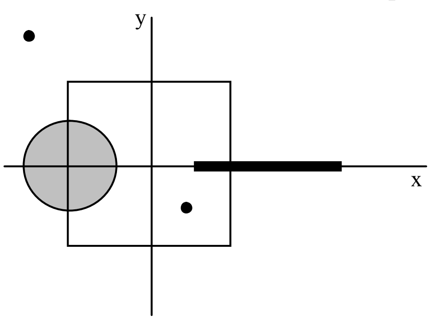
(A)The electric field at point O is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative x-axis
(B) The potential energy of the system is zero
(C) The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\varepsilon_0 R^2}$
(D) The potential at point O is $\frac{q}{12\pi\varepsilon_0 R}$

Q.20 **STATEMENT-1** **[IIT-2008]**
For practical purposes the earth is used as a reference at zero potential in electrical circuits.
and
STATEMENT-2
The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$
(A) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1
(B) Statement-1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1
(C) Statement-1 is true, Statement-2 is false
(D) Statement-1 is false, Statement-2 is true

Q.21 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

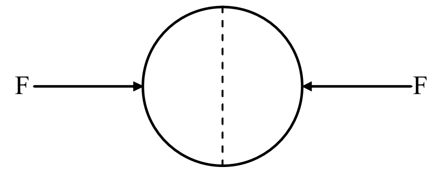
Q.22 A disk of radius a/4 having a uniformly distributed charge 6C is placed in the x-y plane with its centre at (–a/2, 0, 0). A rod of length 'a' carrying a uniformly distributed charge 8C is placed on the x-axis from x = a/4 to x = 5a/4. Two point charges –7C and 3C are placed at (a/4, –a/4, 0) and (–3a/4, 3a/4, 0) respectively. Consider a cubical surface formed by six surfaces x = ± a/2, y = ±a/2, z = ±a/2. The electric flux 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.23 A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = \kappa r^a$, where κ and a are constants and r is the distance from its centre. If the electric field at $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at r = R, find the value of a. **[IIT-2009]**

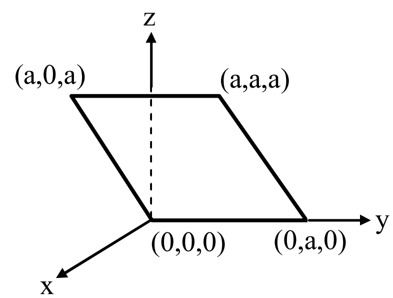
Q.24 A uniformly charged thin spherical shell of radius R carries uniform surface charge density of per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to – **[IIT-2010]**



(A) $\frac{1}{\varepsilon_0}\sigma^2R^2$ (B) $\frac{1}{\varepsilon_0}\sigma^2R$

(C) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$ (D) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$

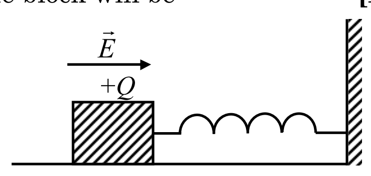
Q.25 Consider and electric field $\vec{E} = E_0\hat{x}$, where E_0 is a constant. The flux through the shaded area (as shown in the figure) due to this field is – **[IIT-2011]**



(A) $2E_0a^2$ (B) $\sqrt{2}E_0a^2$

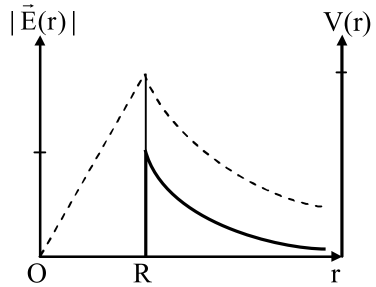
(C) E_0a^2 (D) $\frac{E_0a^2}{\sqrt{2}}$

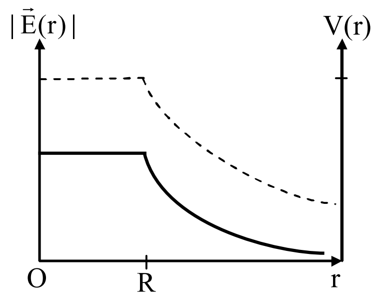
Q.26 A wooden block performs SHM on a frictionless surface with frequency, ν_0. The block carries a charge + Q on its surface. If now a uniform electric field $\vec{E}$ is switched-on as shown, then SHM of the block will be – **[IIT-2011]**

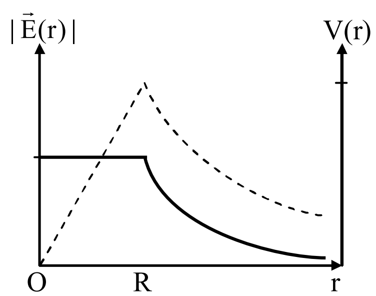


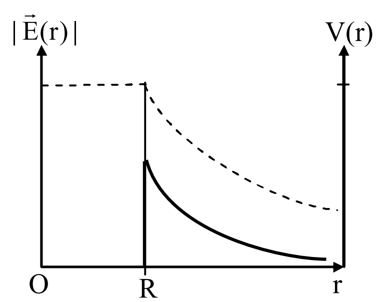
(A) of the same frequency and with shifted mean position
(B) of the same frequency and with the same mean position
(C) of changed frequency and with shifted mean position.
(D) of changed frequency and with the same mean position

Q.27 Consider a thin spherical shell of radius R with its centre at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field $|\vec{E}(r)|$ and the electric potential V(r) with the distance r from the centre, is best represented by which graph ? **[IIT-2012]**

(A)


(B)


(C)


(D)


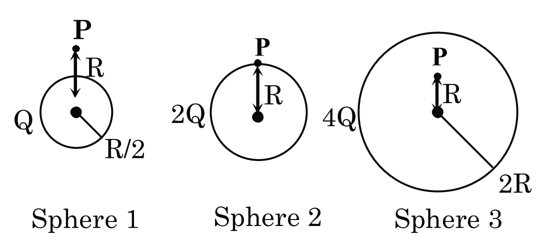
Q.28 Two large vertical and parallel metal plates having a separation of 1 cm are connected to a DC voltage source of potential difference X. A proton is released at rest midway between the two plates. It is found to move at 45° to the vertical just after release. Then X is nearly. **[IIT-2012]**

(A) 1×10^{-5} V (B) 1×10^{-7} V
(C) 1×10^{-9} V (D) 1×10^{-10} V

Q.29 Let $E_1(R)$ and E_2 (r) and E_3 (r) be the respective electric fields at a distance r from a point charge Q, an infinitely long wire with constant linear charge density λ, and an infinite plane with uniform surface charge density σ. If E_1 (r_0) = E_2 (r_0) = E_3 (r_0) at a given distance r_0, then **[JEE-Advanced 2014]**

(A) $Q = 4\sigma\pi r_0^2$
(B) $r_0 = \dfrac{\lambda}{2\pi\sigma}$
(C) $E_1 (r_0 / 2) = 2E_2 (r_0 /2)$
(D) $E_2 (r_0 /2) = 4E_3 (r_0 /2)$

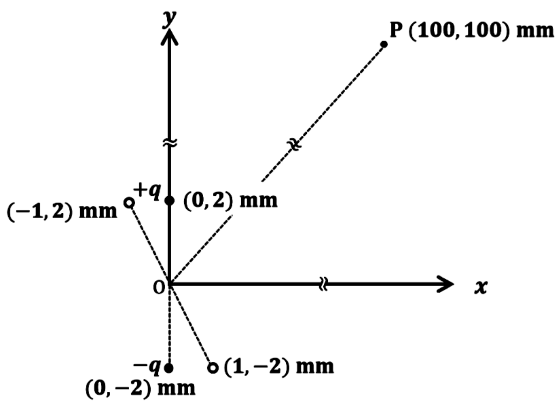
Q.30 Charges Q, 2Q and 4Q are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii R/2, R and 2R respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2 and E_3 respectively, then – **[JEE-Advanced 2014]**



(A) $E_1 > E_2 > E_3$
(B) $E_3 > E_1 > E_2$
(C) $E_2 > E_1 > E_3$
(D) $E_3 > E_2 > E_1$

Q.31 An electric dipole is formed by two charges +q and –q located in xy-plane at (0,2) mm and (0, –2) mm, respectively, as shown in the figure. The electric potential at point P (100, 100) mm due to the dipole is V_0. The charges +q and –q are then moved to the points (–1, 2) mm and (1, –2) mm, respectively. What is the value of electric potential at P due to the new dipole?

[JEE Advanced 2023]



(A) $V_0/4$ (B) $V_0/2$

(C) $V_0/\sqrt{2}$ (D) $3V_0/4$

Q.32 Two beads, each with charge q and mass m, are on a horizontal, frictionless, non-conducting, circular hoop of radius R. One of the beads is glued to the hoop at some point, while the other one performs small oscillations about its equilibrium position along the hoop. The square of the angular frequency of the small oscillations is given by [ε_0 is the permittivity of free space.] **[JEE Advanced 2024]**

(A) $q^2/(4\pi\varepsilon_0 R^3 m)$ (B) $q^2/(32\pi\varepsilon_0 R^3 m)$

(C) $q^2/(8\pi\varepsilon_0 R^3 m)$ (D) $q^2/(16\pi\varepsilon_0 R^3 m)$

Q.33 Two co-axial conducting cylinders of same length ℓ with radii $\sqrt{2}$ R and 2R are kept, as shown in Fig. 1. The charge on the inner cylinder is Q and the outer cylinder is grounded. The annular region between the cylinders is filled with a material of dielectric constant k = 5. Consider an imaginary plane of the same length ℓ at a distance R from the common axis of the cylinders. This plane is parallel to the axis of the cylinders. The cross-sectional view of this arrangement is shown in Fig. 2. Ignoring edge effects, the flux of the electric field through the plane is (ϵ_0 is the permittivity of free space):

[JEE-Advanced-2025]

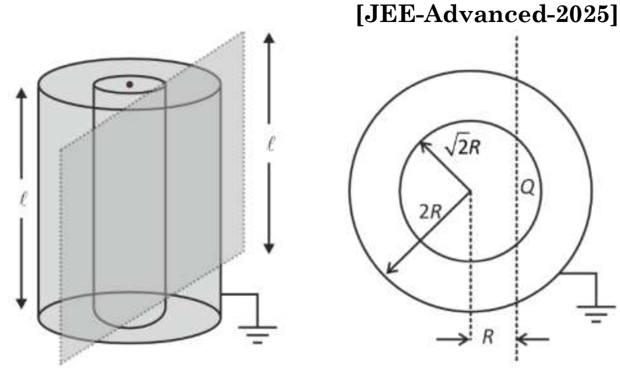


Fig. 1 Fig. 2

(A) $\dfrac{Q}{30\in_0}$ (B) $\dfrac{Q}{15\in_0}$

(C) $\dfrac{Q}{60\in_0}$ (D) $\dfrac{Q}{120\in_0}$

ANSWER KEY

EXERCISE - 1

1. (A)	**2.** (A)	**3.** (B)	**4.** (A)	**5.** (C)	**6.** (A)	**7.** (D)
8. (A)	**9.** (D)	**10.** (D)	**11.** (A)	**12.** (A)	**13.** (A)	**14.** (D)
15. (D)	**16.** (B)	**17.** (D)	**18.** (A)	**19.** (C)	**20.** (A)	**21.** (A)
22. (B)	**23.** (B)	**24.** (A)	**25.** (C)	**26.** (A)	**27.** (C)	**28.** (D)
29. (B)	**30.** (D)	**31.** (A)	**32.** (C)	**33.** (C)	**34.** (B)	**35.** (B)
36. (A)	**37.** (D)	**38.** (A)	**39.** (C)	**40.** (A)	**41.** (C)	**42.** (B)
43. (A)	**44.** (B)	**45.** (C)	**46.** (C)	**47.** (A)	**48.** (B)	**49.** (A)
50. (B)	**51.** (B)	**52.** (B)	**53.** (C)	**54.** (C)	**55.** (A)	**56.** (B)
57. (A)	**58.** (C)	**59.** (A)	**60.** (B)	**61.** (A)	**62.** (B)	**63.** (D)
64. (D)	**65.** (B)	**66.** (A)	**67.** (B)	**68.** (A)	**69.** (C)	**70.** (B)
71. (D)	**72.** (B)	**73.** (D)	**74.** (D)	**75.** (B)	**76.** (A)	**77.** (A)
78. (C)	**79.** (A)	**80.** (B)	**81.** (B)	**82.** (D)	**83.** (D)	**84.** (B)
85. (C)	**86.** (A)	**87.** (A)	**88.** (A)	**89.** (C)	**90.** (A)	**91.** (C)
92. (D)	**93.** (B)	**94.** (B)	**95.** (A)	**96.** (B)	**97.** (D)	**98.** (A)
99. (A)	**100.** (A)	**101.** (D)	**102.** (A)	**103.** (C)	**104.** (B)	**105.** (D)
106. (C)	**107.** (A)	**108.** (A)	**109.** (C)	**110.** (B)	**111.** (A)	**112.** (D)
113. (B)	**114.** (C)	**115.** (C)	**116.** (B)	**117.** (A)	**118.** (A)	

EXERCISE - 2

1. (C)	**2.** (D)	**3.** (A)	**4.** (D)	**5.** (B)	**6.** (B)	**7.** (C)
8. (B)	**9.** (B)	**10.** (B)	**11.** (B)	**12.** (C)	**13.** (A)	**14.** (C)
15. (B)	**16.** (D)	**17.** (D)	**18.** (A)	**19.** (D)	**20.** (B)	**21.** (A)
22. (A)	**23.** (C)	**24.** (B)	**25.** (D)	**26.** (B)	**27.** (A)	**28.** (B)
29. (A)	**30.** (C)	**31.** (A)	**32.** (A)	**33.** (A)	**34.** (C)	**35.** (D)
36. (B)	**37.** (C)	**38.** (B)	**39.** (D)	**40.** 7.00	**41.** 3.00	**42.** 1.34
43. 2.00	**44.** 0.00	**45.** 1.15	**46.** 10.00	**47.** 25.00	**48.** 173.20	**49.** 72.00

EXERCISE - 3

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

EXERCISE - 4

1. (A)	**2.** (A)	**3.** (B)	**4.** (A)	**5.** (D)	**6.** (B)	**7.** (D)
8. (D)	**9.** (B)	**10.** (A)	**11.** (D)	**12.** (A)	**13.** (B)	**14.** (A)
15. (C)	**16.** (A)	**17.** (B)	**18.** (D)	**19.** (D)	**20.** (A)	**21.** (D)
22. (A)	**23.** (A)	**24.** (C)	**25.** (D)	**26.** (A)	**27.** (D)	**28.** (C)
29. (D)	**30.** (D)	**31.** (A)	**32.** (D)	**33.** (B)	**34.** (B)	**35.** (A)
36. (C)	**37.** (B)	**38.** (B)	**39.** (B)	**40.** (C)	**41.** (C)	**42.** (D)
43. (D)	**44.** (C)	**45.** (D)	**46.** (A)	**47.** (B)	**48.** (C)	**49.** (A)
50. (B)	**51.** (C)	**52.** (B)	**53.** (B)	**54.** (A)	**55.** (A)	**56.** (C,D)
57. (A)	**58.** (D)	**59.** (A)	**60.** (C)	**61.** (A)	**62.** (A)	**63.** (C)
64. (C)	**65.** (A)	**66.** (D)	**67.** (B)	**68.** (A)	**69.** (D)	**70.** (D)
71. (B)	**72.** (C)	**73.** (C)	**74.** (D)	**75.** (D)	**76.** (A)	**77.** (D)
78. (B)	**79.** (D)	**80.** 1	**81.** (B)	**82.** (A)	**83.** (A)	**84.** (B)
85. (C)	**86.** (B)	**87.** 45.00	**88.** (B)	**89.** 45	**90.** 12	**91.** 8
92. 300	**93.** 3	**94.** 8	**95.** (C)	**96.** (C)	**97.** (D)	**98.** (C)
99. (C)	**100.** (D)	**101.** (D)	**102.** 48.00			

EXERCISE - 5

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