The following questions given below consist of an "Assertion" (A) and "Reason" (R) Type questions. Use the following Key to choose the appropriate answer.

(A) If both (A) and (R) are true, and (R) is the correct explanation of (A).

(B) If both (A) and (R) are true but (R) is not the correct explanation of (A).

(C) If (A) is true but (R) is false.

(D) If (A) is false but (R) is true.

Q.1 **Assertion :** For a non-uniformly charged thin circular ring with net charge zero, the electric field at any point on axis of the ring is zero.

Reason : For a non-uniformly charged thin circular ring with net charge zero, the electric potential at each point on axis of the ring is zero. **[D]**

Sol. For a non-uniformly charged thin circular ring with net zero charge, electric potential at each point on its axis is zero. Hence electric field at each point on it's axis must be perpendicular to the axis. Therefore Assertion is false and Reason is true.

Q.2 **Assertion :** If the electric field strength equals zero at a given point, must the electric potential be equal to zero for that point.

Reason : Electric field is gradient of voltage or electric potential. **[D]**

Sol. **A :** False **R :** True

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

$E = 0$ when $\frac{dV}{dr} = 0$

$\therefore$ V = constant

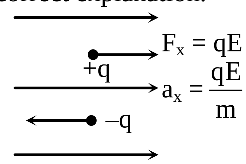
V can have any value

i.e. v = 0 or constant

Q. 3 **Assertion :** If a proton and an electron are placed in same uniform electric field. They experience different acceleration.

Reason : Electric force on test charge is independent of mass. **[B]**

Sol. Both assertion and reason are correct but reason is not the correct explanation.



$F_{-x} = qE$

$$a_{-x} = \frac{qE}{m}$$

The direction of acceleration are opposite hence assertion is correct.

$$F_e = \frac{kq_1q_2}{r^2}$$

Electric force depends on charge and not on mass. Hence reason is also correct but it is not the correct explanation of assertion.

Q.4 **Assertion :** Across the surface of a charged conductor potential is discontinuous.

Reason : Electrostatic force is a conservative force. **[D]**

Q.5 **Assertion :** Four electric charges of equal magnitude are placed at four corners of a square. Out of these four charges two are positive and two are negative. Then the electrostatic potential energy of system of these four charges must be positive.

Reason : Electrostatic force may be attractive or repulsive. **[D]**

Q.6 **Assertion :** The change in potential energy of a two charge system is independent of the choice of zero potential energy reference.

Reason : Potential energy of a charge may decreases when it moves opposite to electric field **[B]**

Q.7 **Assertion :** In any condition when a conducting sphere is charged then the charge on it must be distributed uniformly over it surface because it is a sphere

Reason : The surface of a conducting body is a equipotential surface **[D]**

Q. 8 **Assertion :** When charges are shared between two bodies, there occurs no loss of charge, but there does occur a loss of energy.

Reason : In case of sharing of charges conservation of energy fails. **[C]**

Q. 9 **Assertion :** A solid sphere and a hollow sphere of same radius are charged to same potential, then they will carry the same charge.

Reason : The charge on a sphere having given potential is independent of the radius. **[C]**

Sol. **[C]** Capacitance $C = \frac{q}{V}$. So both solid as well as hollow sphere have same amount of charge

Q.10 **Assertion** : Electrons move away from a region of lower potential to a region of higher potential

Reason : Since an electron has a negative charge

[A]

Q.11 **Assertion** : Insulators do not allow flow of current through themselves.

Reason : They have no free charge carriers.

[A]

Q.12 **Assertion** : If a point charge q is placed in front of an infinite grounded conducting plane surface, the point charge will experience a force.

Reason : This force is due to the induced charge on the conducting surface which is at zero potential

[A]

Q.13 **Assertion** : A metallic shield in the form of a hollow shell, can be built to block an electric field.

Reason : In a hollow spherical shell, the electric field inside is zero at every point.

[A]

Q.14 **Assertion** : Work done in moving any charge through any distance on an equipotential surface is zero.

Reason : Potential difference between any two points on an equipotential surface is zero. **[A]**

Q.15 **Assertion :** When charged balloon is put against on insulating wall, it get stick to the wall.

Reason : Wall acquire a net negative charge & thus attract balloon. **[C]**

Sol. Wall become electrically polarized & attract balloon.

Q.16 **Assertion :** A charged metal plate has the same potential at all points on its surface & different distribution of charge.

Reason : As conductors have uniform distribution of charge, so potential & charge distribution is same at every point. **[C]**

Sol. At sharp point metal has more charge density at the edges & corner charge density will be more.

Statements based Question :17

This section contains Statement-1 and Statement-2. Of the four choices given here, choose the one that best describes the two Statement.

(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.17 **Statement – 1** The electric field inside a charged conductor is zero.

and

Statement – 2 The charge resides on the outer surface in a conductor. **[A]**

Q.18 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.

[AIEEE-2009]

Statement 2 : The net work done by a conservative force on an object moving along a closed loop is zero.

(A) Statement-1 is true, Statement-2 is false

(B) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explaination of Statement-1

(C) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explaination of Statement-1

(D) Statement-1 is false, Statement-2 is true.

[B]

Sol. Both the statements are the definations of conservative forces.

Q.19 **Assertion :** Charge on body can have value 2×10^{-19}C.

Reason : Charge is quantized. **[D]**

Sol. q = ne

$$n = \frac{q}{e} = \frac{2\times10^{-19}}{1.6\times10^{-19}}$$

$$= \frac{5}{4} \text{ (Not possible)}$$

$\therefore$ Assertion is wrong

& Reason is correct.

Q.20 **Assertion :** Two adjacent conductor carrying the same positive charge have a potential difference between them.

Reason : The potential of a conductor depend upon the charge given to it. **[C]**

Sol. Potential of conductor depends upon size as well as charge.

$\therefore$ Reason is false

Thus potential of both conductor of different size can have potential difference.

$\therefore$ Assertion is true

PHYSICS

Q.1 Two short dipoles of dipole moment $p_1 = p_2 = 40$ μCm are oriented in two ways as shown in figure A and B. If distance between dipoles is 2m then match the physical quantities given in column-I with their magnitudes given in column-II.

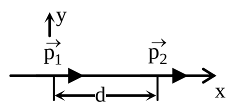


fig. A

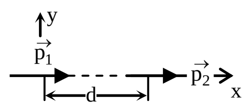


fig. B

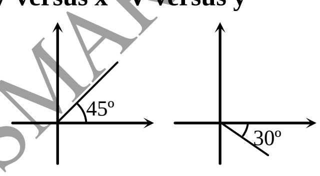
Column -I Physical quantities	Column -II Magnitudes (in SI unit)
(A) Torque experienced by $\vec{p}_1$ in Fig. A	(P) 3.6
(B) Torque experienced by $\vec{p}_1$ in Fig. B	(Q) 5.4
(C) Force experienced by $\vec{p}_1$ in Fig. A	(R) 0
(D) Torque experienced by $\vec{p}_2$ in Fig. B	(R) 1.8

A → R **B → S**
C → Q **D → P**

Q.2 Column-I shows graphs of electric potential V versus x and y in a certain region for four situations. Column-II shows the range of angle which the electric field vector makes with positive x-direction.

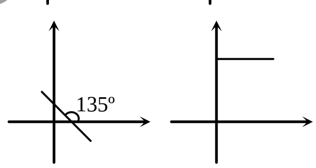
Column -I (**V versus x**, **V versus y**) — **Column -II** (**Range of angle**)

(A)



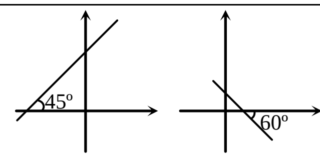
(P) 0º ≤ θ < 45º

(B)



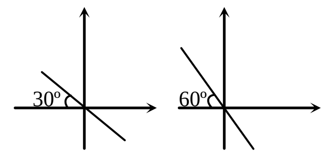
(Q) 45º ≤ θ < 90º

(C)



(R) 90º ≤ θ < 135º

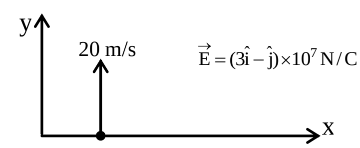
(D)



(S) 135º ≤ θ ≤ 180º

A → S **B → P**
C → R **D → Q**

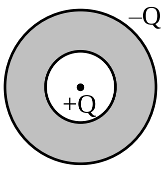
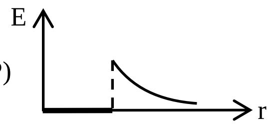
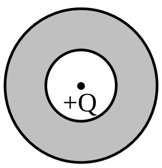
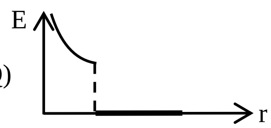
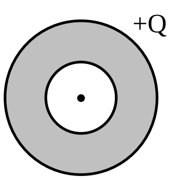
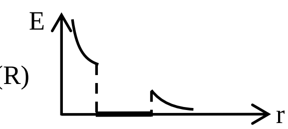
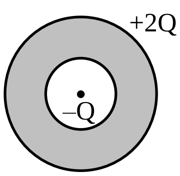
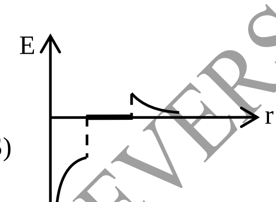
Q.3 A charged particle (charge 1μC, mass 1 kg) is fired from a point on ground in vertically upward direction with velocity 20 m/s in a region where an electric field $\vec{E} = (3\hat{i} - \hat{j}) \times 10^7$ N/C also exists as shown. Match different characteristics of its motion given in column-I with their magnitudes in S.I. units in column-II. (Take g = 10 m/s^2)



Column -I	Column -II
(A) Velocity of particle at its highest point	(P) 10
(B) Distance from point of projection where it lands on ground	(Q) 30
(C) Maximum height reached by particle above ground	(R) 45
(D) Angle in degrees which its velocity vector makes with horizontal at t = $\frac{2}{5}$ sec.	(S) 60

A → Q **B → S** **C → P** **D → R**

Q.4 Entries in column-I shows four hollow metal spheres each with internal radius a and external radius b. Match each charge distribution in column-I with the corresponding graph of electric field versus radial distance r from centre as shown in column-II.

Column-I		**Column-II**	
(A)		(P)	
(B)		(Q)	
(C)		(R)	
(D)		(S)	

A $\rightarrow$ Q B $\rightarrow$ R C $\rightarrow$ P D $\rightarrow$ S

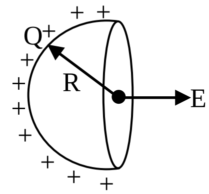
Q.5 Column-I contains some physical quantities and column-II contains their corresponding units. Match the physical quantities of column-I with their possible units in column-II.

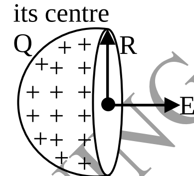
Column-I	**Column-II**
(A) Electric flux	(P) Coulomb/meter^2
(B) Electric dipole moment	(Q) $\dfrac{\text{Coulomb}}{\text{volt} - \text{meter}}$
(C) Permittivity	(R) volt-meter
(D) Surface charge density	(S) Coulomb-meter

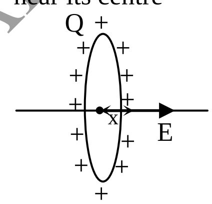
A $\rightarrow$ R B $\rightarrow$ S C $\rightarrow$ Q D $\rightarrow$ P

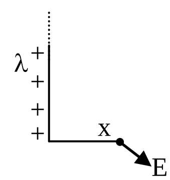
Q.6 Match the column for electric field given in column II for the uniformly charged bodies in column I.

Column-I	**Column-II**
(A) hollow hemisphere at its centre	(P) $\dfrac{\lambda}{2\sqrt{2}\pi\varepsilon_0 x}$
(B) solid hemisphere at its centre	(Q) $\dfrac{Q}{8\pi\varepsilon_0 R^2}$
(C) on the axis of ring near its centre	(R) $\dfrac{3Q}{8\pi\varepsilon_0 R^2}$
(D) semi- infinite wire	(S) $\dfrac{\lambda}{2\varepsilon_0 R^2}\left[x - \dfrac{3x^3}{2R^2}\right]$









A $\rightarrow$ Q B $\rightarrow$ R C $\rightarrow$ S D $\rightarrow$ P

Q.7 Two spherical shells shown in figure have uniformly distributed charge q_1 and q_2 r is distance from common centre consider the following.

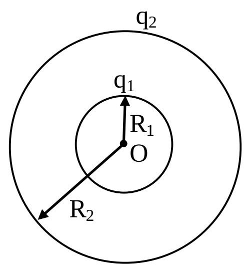
E_1 = Electric field for $r < R_1$

E_2 = Electric field for $R_1 < r < R_2$

V_1 = Electric potential for $r < R_1$

V_2 = Electric potential for $R_1 < r < R_2$

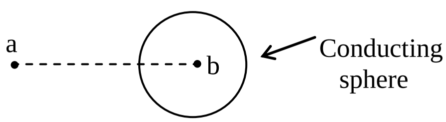
the match the following columns.



Column-I	Column-II
(A) E_1	(P) is constant for q_2 and vary for q_1
(B) V_1	(Q) is zero for q_2 and vary for q_1
(C) V_2	(R) its constant
(D) E_2	(S) is zero

A $\rightarrow$ S B $\rightarrow$ R C $\rightarrow$ P D $\rightarrow$ Q

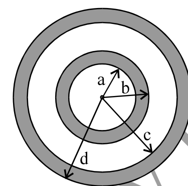
Q.8 For the situation shown in the figure below. match the entries of column I with the entries of column II. (point charge is placed at a & b)



Column-I	Column-II
(A) If we displace the inside charge	(P) distribution of charge on inner surface of conductor is uniform
(B) If we displace the out side charge while keeping inside charge at b	(Q) distribution of charge on inner surface of conductor is non-uniform
(C) In the situation shown i.e. charge are placed at a & b	(R) distribution of charge on the outer surface of conductor is uniform
(D) If outside charge is not present and inside charge is displaced	(S) distribution of charge on the outer surface of conductor is non-uniform

A $\rightarrow$ QS ; B $\rightarrow$ PS ; C $\rightarrow$ PS ; D $\rightarrow$ QR

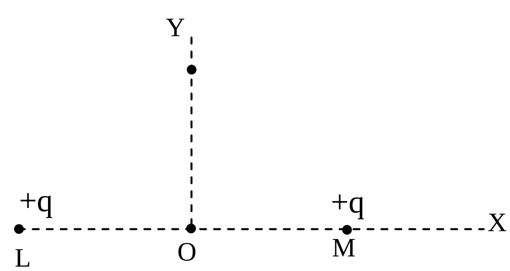
Q.9 A small conducting spherical shell with inner radius a and outer radius b is concentric with a larger conducting spherical shell with inner radius c and outer radius d. as shown in figure. The inner shell has total charge +2q and the outer shell has charge –4q. Match the column for the electric field (magnitude and direction) in term of q and distance r from the common centre of two shells.



Column I	Column II
(A) $r < a$	(P) $\lvert E \rvert = 0$
(B) $b < r < c$	(Q) $\lvert E \rvert = \dfrac{Q}{2\pi\varepsilon_0 r^2}$
(C) $c < r < d$	(R) radially inward
(D) $r > d$	(S) radially outward.

Ans. A $\rightarrow$P, B $\rightarrow$ Q,S C $\rightarrow$ P D $\rightarrow$ Q,R

Q.10 In figure, charges, each + q, are fixed at L and M. O is the mid-point of distance LM. X and Y axes are as shown. Consider the situations given in column-I and match them with the information in column-II.

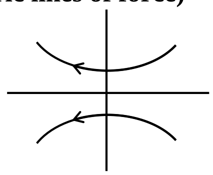
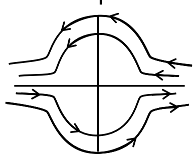
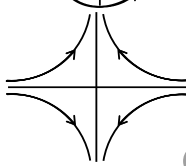
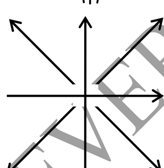


Column-I	Column-II
(A) Let us place a charge + q at O, displace it slightly along Z-axis and release. Assume that it is allowed to move only along X-axis. At position O,	(P) Force on the charge is zero
(B) Place a charge – q at O. Displace it slightly along X-axis and release. Assume that it is allowed to move only along X-axis. At position O,	(Q)Potential energy of the system is maximum
(C) Place a charge + q at O.	(R)Potential energy

Displace it slightly along Y-axis and release. Assume that it is allowed to move only along Y-axis. At position O,	of the system is maximum
(D) Place a charge – q at O. Displace it slightly along Y-axis and release. Assume that it is allowed to move only along Y-axis. At position O,	(S) The charge is in equilibrium

Ans. **A →P,R,S; B →P,Q,S; C**

Q.11

Column I (Potential function)	**Column II (Electric lines of force)**
(A) $V = \frac{x}{y}$	(P) 
(B) $V = x^2 – y^2$	(Q) 
(C) $V = x^2 + y^2$	(R) 
(D) V = xy	(S) 

Ans. **A → Q, B → R, C → S, D → P**

Q.12 Match the force or set of forces in the left hand column to a characteristic of force or set of forces in the right-hand column.

Column I (Force)	**Column II (Characteristic)**
(A) Electric (Electrostatic)	(P) Proportional to $\frac{1}{(\text{distance})^2}$
(B) Gravity	(Q) Always attracts
(C) Both Electric and Gravity	(R) Always repels
(D) Neither electric nor gravity	(S) Attracts or repels

Ans. **A→ P,S ; B→ P,Q; C→ P; D→ R**

Q.13 Two spherical shells shown in figure have uniformly distributed charge q_1 and q_2, r is distance from common centre consider the following.

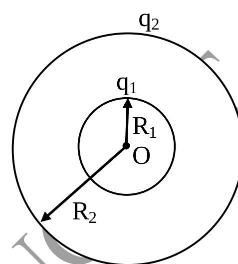
E_1 = Electric field for $r < R_1$

E_2 = Electric field for $R_1 < r < R_2$

V_1 = Electric potential for $r < R_1$

V_2 = Electric potential for $R_1 < r < R_2$

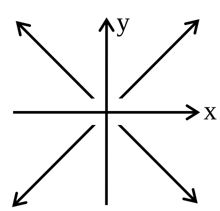
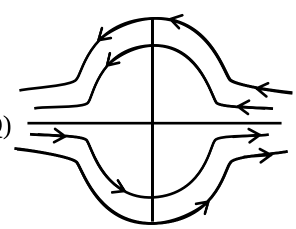
the match the following columns.



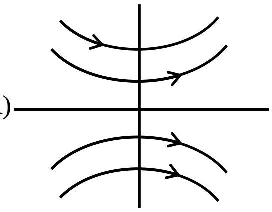
Column-I	**Column-II**
(A) E_1	(P) is constant for q_2 and vary for q_1
(B) V_1	(Q) is zero for q_2 and vary for q_1
(C) V_2	(R) its constant
(D) E_2	(S) is zero

Ans. **A→ S ; B→ R; C→ P; D → Q**

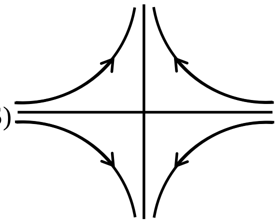
Q.14 In a certain region of x-y plane potential function is given & corresponding electric lines of force given.

Potential function	**Electric lines of force**
(A) $V = x^2 – y^2$	(P) 
(B) V = xy	(Q) 

(C) $V = x^2 + y^2$ (R)



(D) $V = \frac{x}{y}$ (S)



Sol. (A) $\rightarrow$ S, **(B)** $\rightarrow$ R, **(C)** $\rightarrow$ P, **(D)** $\rightarrow$ Q

Tangent to electric lines of force will give direction of electric field.

(C) $V = x^2 + y^2$

$E = -\nabla V$

$E = -2x\hat{i} - 2y\hat{j}$

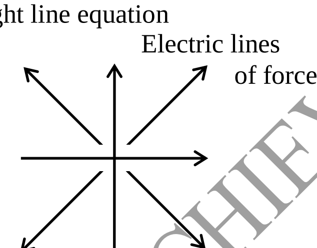
Tangent to electric line of force will give direction of electric field.

$\therefore \frac{dy}{dx} = \frac{Ey}{Ex} = \frac{y}{x}, \quad \frac{dy}{y} = \frac{dx}{x}$

Log y = log x + c

$\frac{y}{x} = c \quad \Rightarrow y = cx$

Straight line equation



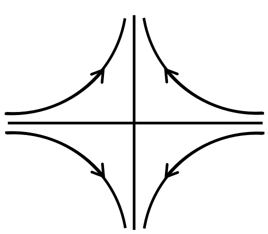
(A) $V = x^2 - y^2$

$E = -2x\hat{i} + 2y\hat{j}$

$\frac{dy}{dx} = \frac{-y}{x}$

$\log y = -\log x + c$

$xy = c$



Corresponding curve is drawn as electric lines of force.

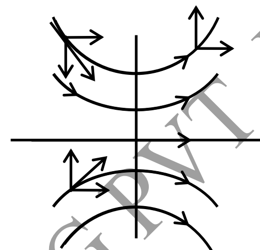
(B) $V = xy$

$E = -y\hat{i} - x\hat{j}$

$\frac{dy}{dx} = \frac{x}{y}$

$\boxed{y^2 = x^2 + c}$

Corresponding curve is shown.



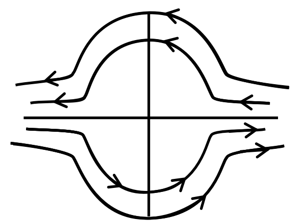
(D) $V = \frac{x}{y}$

$E = -\frac{1}{y}\hat{i} + \frac{x}{y^2}\hat{j}$

$\frac{dy}{dx} = \frac{x}{y} - \frac{y}{y}$

Ydy = xdx

$x^2 + y^2 = c$



Corresponding curve is given.

Q.15 Identical drops of a liquid each having charge q and radius coalesce:

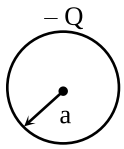
Column-I	**Column-II**
(A) $E_{big} = \ldots E_{small}$	(P) $n^{1/3}$
(B) $V_{big} = \ldots V_{small}$	(Q) n^3
(C) $C_{big} = \ldots C_{small}$	(R) $n^{2/3}$
(D) $\sigma_{big} = \ldots \sigma_{small}$	(S) $n^{-1/3}$

Sol. **(A) $\rightarrow$ (P), (B) $\rightarrow$ (R), (C) $\rightarrow$ (P), (D) $\rightarrow$ (P)**

Q.16 In each situation of column-I, some charge distributions are given with all details explained. The electrostatic potential energy and its nature is given situation in column-II. Then match situation in column-I with the corresponding results in column-II -

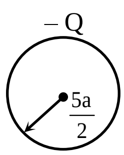
Column-I | **Column-II**

(A) A thin shell of radius a and having a charge –Q uniformly distributed over its surface as shown



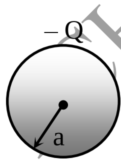
(P) $\frac{1}{8\pi\varepsilon_0}\frac{Q^2}{a}$ in magnitude

(B) A thin shell of radius $\frac{5a}{2}$ and having a charge –Q uniformly distributed over its surface and a point charge –Q placed at its centre as shown



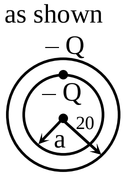
(Q) $\frac{3}{20\pi\varepsilon_0}\frac{Q^2}{a}$ in magnitude

(C) A solid sphere of radius a and having a charge –Q uniformly distributed throughout its volume as shown



(R) $\frac{2}{5\pi\varepsilon_0}\frac{Q^2}{a}$ in magnitude

(D) A solid sphere of radius a and having a charge –Q uniformly distributed throughout its volume. The solid sphere is surrounded by a concentric thin uniformly charged spherical shell of radius 20 and carrying charge –Q as shown



(S) positive in sign

(T) negative in sign

Sol. **A → PS ; B → Q,S ; C → Q,S ; D → S**

(A) Electrostatic potential energy

$$= \frac{1}{4\pi\varepsilon_0}\frac{(-Q)^2}{2a} = \frac{Q^2}{8\pi\in_0 a}$$

(B) Electrostatic potential energy

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{(-Q)\times(-Q)}{5a/2} + \frac{(-Q)^2}{2(5a/2)}\right] = \frac{3}{20}\frac{Q^2}{\pi\varepsilon_0 a}$$

(C) Electrostatic potential energy

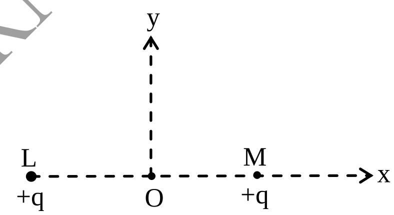
$$= \frac{1}{4\pi\varepsilon_0}\frac{3Q^2}{5a} = \frac{3}{20}\frac{Q^2}{\pi\varepsilon_0 a}$$

(D) Electrostatic potential energy

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{3Q^2}{5a} + \frac{(-Q^2)}{2(2a)} + \frac{(-Q)\times(-Q)}{2a}\right]$$

$$= \frac{27Q^2}{80\pi\varepsilon_0 a}$$

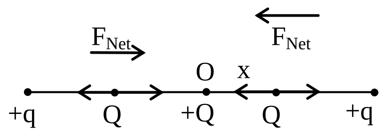
Q.17 In figure, charges, each +q, are fixed at L and M. O is the mid point of distance LM. x and y axes are as shown. Consider the situations given in Column-I and match them with the information given in column-II -



Column-I		***Column-II***
(A)	Let us place a charge Q at O, displace it slightly along x-axis and release. Assume that it is allowed to move only along x-axis. At position O	*(P) Force on the charge of magnitude Q is zero*
(B)	Place a charge – Q at O. It is displaced slightly along x-axis and release. Assume that it is allowed to move only on x-axis. At position O	*(Q) Charge of magnitude Q i.e. |Q| is in stable equilibrium*
(C)	Place a charge +Q at O, displace it slightly along y-axis and release. Assume that it is allowed to move only along y-axis. At position O	*(R) Charge of magnitude Q i.e. |Q| is in unstable equilibrium*
(D)	*Place a charge –Q at O, displace it slightly along y-axis and release. Assume that it is allowed to move only along y-axis. At position O*	*(S) Kinetic energy of charge is maximum*
		(T) Potential energy of charge is minimum

Sol. **A → P, Q, S, T** **B → P, R**

C → P, R **D → P, Q, S, T**

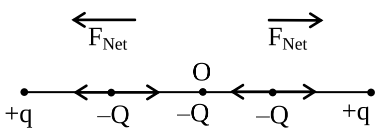


Q will come back to O

∴ It is in stable equilibrium

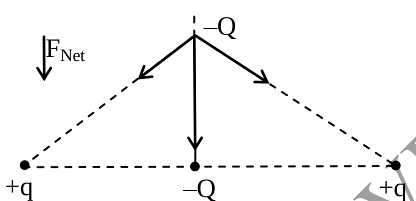
kinetic energy of charge Q is maximum at O. Potential energy of system is minimum

When charge Q is at O



– Q will not come back to O after displacing from O.

∴ It is in unstable equilibrium Potential energy of system is maximum at O. Kinetic energy of – Q is minimum at O.

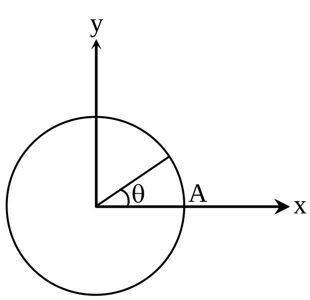


– Q will come back to O

∴ – Q is in stable equilibrium

Now we can say about Potential energy and kinetic energy

Q.18 A non conducting ring has linear charge density λ. Match the following column regarding this ring. θ is the angle measured from A

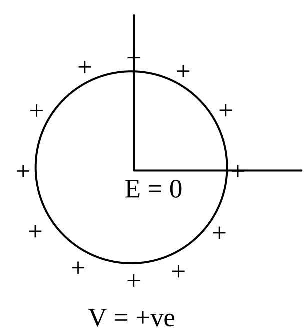


Column-I	Column-II
(A) $\lambda = \lambda_0$ cb/m	(P) Electric field at centre of the ring is in the direction to $(-\hat{j})$
(B) $\lambda = \lambda_0 \cos\theta$ cb/m where $0 \le \theta \le 2\pi$	(Q) Electric field at center of the ring is zero
(C) $\lambda = \lambda_0 \sin\theta$ cb/m where $0 \le \theta \le 2\pi$	(R) Electric potential at centre of ring is zero
(D) $\lambda = \lambda_0(1 - \cos 2\theta)$ cb/m where $0 \le \theta \le 2\pi$	(S) Electric field intensity at centre of the ring is direction $(-\hat{i})$
	(T) Electrostatics potential at centre of ring is positive

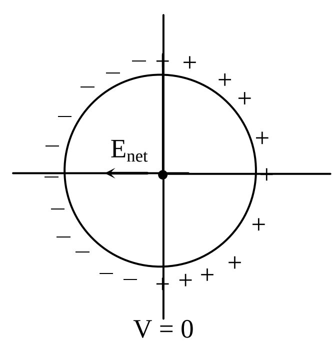
Sol. **A → Q, T** **B → S, R**

C → P, R **D → Q, T**

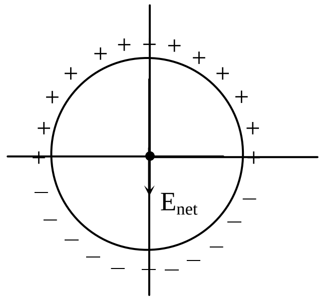
(A)



(B)



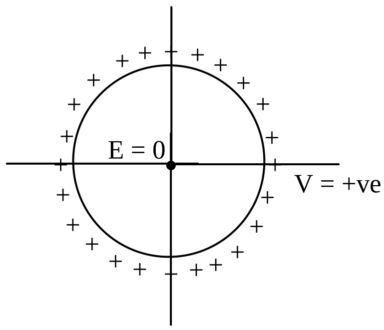
(C)



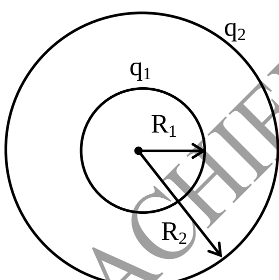
V = 0

$\lambda = \lambda_0 \times 2\sin^2\theta$

(D)



Q.19 Two spherical shells are as shown in figure. Suppose r is the distance of a point from their common centre. Then, match the entries of column I with the entries of column II.



Column - I		**Column - II**	
(a)	Electric field for $r < R_1$	(p)	is constant for q_2 and varying for q_1
(b)	Electric potential for $r < R_1$	(q)	is zero for q_2 and varying for q_1
(c)	Electric potential for $R_1 < r < R_2$	(r)	is constant
(d)	Electric field for $R_1 < r < R_2$	(s)	is zero

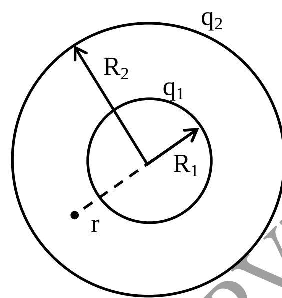
(A) $a \to s,\ b \to r,\ c \to p,\ d \to q$

(B) $a \to r,\ b \to s,\ c \to q,\ d \to p$

(C) $a \to p,\ b \to q,\ c \to r,\ d \to s$

(D) $a \to q,\ b \to p,\ c \to s,\ d \to r$ **[A]**

Sol.



$r < R_1$

$E = 0 + 0 = 0$

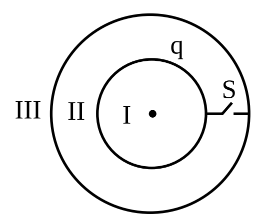
$V = \frac{kq_1}{R_1} + \frac{kq_2}{R_2} = \text{constant}$

$R_1 < r < R_2$

$E = \frac{kq_1}{r^2} + 0$

$V = \frac{kq_1}{r} + \frac{kq_2}{R_2}$

Q.20 A charged sphere is enclosed by a concentric neutral conducting sphere as shown. The three region are marked as I, II and III. Region I is inside hollow charged sphere, region II is outside charged sphere and inside uncharged (outer) sphere, while region III is outside to both. Match the entries of column I with the entries of column II. All answers has to be given in steady state.



Column-I		**Column-II**	
(A)	When S is open, then in region II	(P)	Electric field intensity is zero
(B)	When S is open, then in region III	(Q)	Electric potential is zero
(C)	When S is closed, then	(R)	Electric field

	in region I		intensity is nonzero
(D)	When S is closed, then in region II	(S)	Electrical potential is non zero

Sol. A $\rightarrow$ R,S; B $\rightarrow$ R,S; C $\rightarrow$ P,S; D $\rightarrow$ P,S

When S is open then in region II E = $\frac{kq}{r^2}$

$\therefore$ E $\neq$ 0

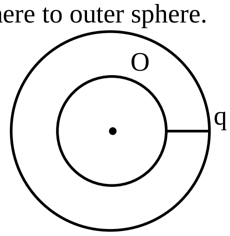
in region III E = $\frac{kq}{r^2}$

$\therefore$ E $\neq$ 0

Potential is $\frac{kq}{r}$ in both region

$\therefore$ V $\neq$ 0

When S is closed then in region all change has gone from inner sphere to outer sphere.

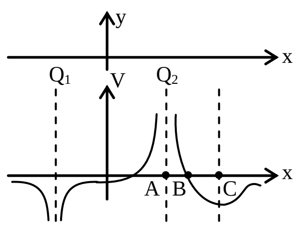


in region I and II

E = 0

in region I and II V $\neq$ 0

***Q.1** The figure shows the potential variation along x-axis due to two point charges Q_1 and Q_2 placed on x-axis. Examining this plot we can deduce that -



(A) $|Q_1| > |Q_2|$

(B) C is a point of stable equilibrium for positive charge for displacement along x-axis

(C) B is stable equilibrium point for positive charge for displacement along x-axis

(D) work done by electric forces in bringing an electron from point A to C through a circular path is negative **[A,B,D]**

Q.2 Two particles of same mass and charge are thrown simultaneously in the same direction along the horizontal with same velocity v from two different heights h_1 and h_2 ($h_1 < h_2$). Initially they were located on the same vertical line above ground. Choose the wrong alternative(s) -

(A) Both the particle will always lie on a vertical line

(B) Both will take same time to reach ground

(C) Horizontal displacement of the particle lying at h_1 is less and the particle lying at h_2 is more than the value which would had been in the absence of charges on them

(D) At any moment acceleration of the centre of mass of two particles will be g downwards

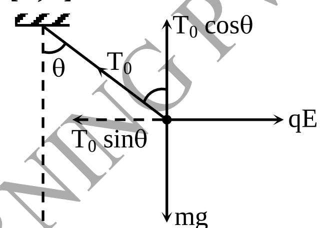
[A,B,D]

Q.3 A simple pendulum of length ℓ has a bob of mass m, with a charge q on it. A vertical sheet of charge, with charge σ per unit area, passes through the point of suspension of the pendulum. At equilibrium, the string makes an angle θ with vertical. Its time period of oscillation is T in this position. Then -

(A) $\tan\theta = \frac{\sigma q}{2\epsilon_0 mg}$ (B) $\tan\theta = \frac{\sigma q}{\epsilon_0 mg}$

(C) $T < 2\pi\sqrt{\ell/g}$ (D) $T > 2\pi\sqrt{\ell/g}$

Sol. **[A,D]**



$E = \sigma/2\epsilon_0$

$T_0 \cos\theta = mg$

$T_0 \sin\theta = qE$

$\tan\theta = \frac{q}{mg}\ (\sigma/2\epsilon_0)$

As $T_0 = \sqrt{(mg)^2 + (qE)^2}$

i.e. $T_0 > mg$

i.e. the effective value of g is increased, hence time period of oscillation decreases.

Q.4 Two equal positive charges are fixed at the points (0, a) and (0, –a) on the y-axis. An electron is released from rest from point (–2a, 0) on the x-axis. The electron will -

(A) execute simple harmonic motion about the origin

(B) move to the origin and remain at rest

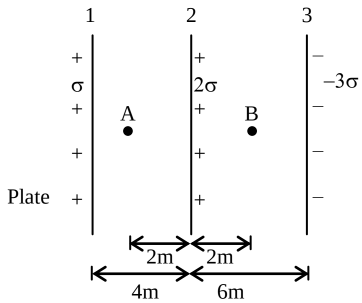
(C) move to infinity

(D) be at a point of highest potential on x-axis at the moment when the system of the two fixed charges and electron is having minimum electric potential energy

[D]

Q.5 The figure shows three infinite thin non-conducting charged plates perpendicular to the plane of the paper with charge per unit area +σ, +2σ and –3σ. As we move from plate 1 to plate

2 magnitude of potential change occured is V_{12}, that from plate 2 to 3 is V_{23} and that from plate 1 to 3 is V_{13}. Then-



(A) Ratio of net electric field at ponit A to that at point B is 1/3

(B) $9V_{12} = 2\ V_{23}$

(C) $2V_{13} = 7\ V_{12}$

(D) $3V_{13} = 5V_{23}$ **[A,B]**

Q. 6 In a uniform electric field, equipotential surfaces must –

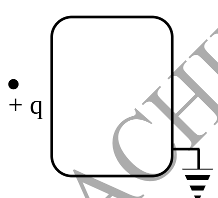
(A) be plane surface

(B) be normal to the direction of the field

(C) be spaced such that surfaces having equal differences in potential are separated by equal distance

(D) have increasing potentials in the direction of the field **[A,B,C]**

Q. 7 In front of an earthed conductor a point charge +q is placed as shown in figure -



(A) On the surface of conductor the net charge is always negative

(B) On the surface of conductor at the same points charges are negative and at some points charges may be positive distributed non uniformly

(C) Inside the conductor electric field due to point charge is non-zero

(D) None of these **[A,B,C]**

Sol. Charge is distributed over the surface of conductor in such a way that net field due to the charge and outside charge q is zero inside. Field due to only q is non-zero.

Q. 8 A dipole is placed in the electric field created by a uniformly charged long wire. It is possible that the dipole experiences –

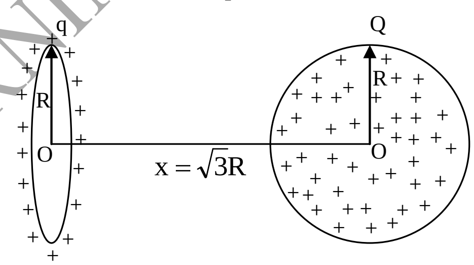
(A) No net force but a net torque

(B) No net force and no net torque

(C) A net force but no net torque

(D) A net force and a net torque **[A,C,D]**

Q.9 A uniformly charged ring charge +q has radius R. A uniformly charged solid sphere (over its total volume) has charge Q is placed on the axis of ring at a distance $x = \sqrt{3}R$ from centre of ring as shown. Radius of sphere is also R, then –



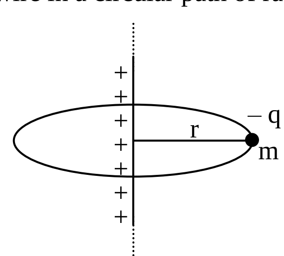
(A) Electric force on ring is $\frac{\sqrt{3}kQq}{8R^2}$

(B) Electric force on ring is $\frac{kQq}{2R^2}$

(C) The increase in tension in ring due to sphere is $\frac{kQq}{16\pi R^2}$

(D) The increase in tension in ring due to sphere is $\frac{kQq}{8\pi R^2}$ **[A, C]**

Q.10 A uniformly charged (linear charge density λ) very long wire in placed fixed. A negative charge particle –q of mass m revolves around this wire in a circular path of radius r then –



(A) Time period of mass m is $2\pi r\sqrt{\frac{m}{2k\lambda q}}$

(B) Time period of mass m is $2\pi r\sqrt{\frac{m}{k\lambda q}}$

(C) Minimum work required to change the orbit radius form r to 2r is $k\lambda\, q\log_e 2$

(D) Minimum work required to change the orbit radius from r to 2r is $2k\lambda\, q\log_e 2$

[A,D]

Q.11 A conductor A is given a charge +Q and then placed inside a deep metal Can B, without touching it. Then -

(A) potential of A does not change when it is placed inside B

(B) if B is earthed, +Q amount of charge flows from it into the earth

(C) if B is earthed, the potential of A is reduced

(D) if B is earthed, the potential of A is increased **[A,B.C]**

Q.12 A point charge q is placed at origin. Let $\vec{E}_A$, $\vec{E}_B$ and $\vec{E}_C$ be the electric fields at three points A(1, 2, 3), B(1, 1, –1) and C(2, 2, 2) due to charge q. Then

(A) $\vec{E}_A$ is perpendicular to $\vec{E}_B$

(B) $\vec{E}_A$ is parallel to $\vec{E}_B$

(C) $\frac{|\vec{E}_B|}{|\vec{E}_C|} = 8$

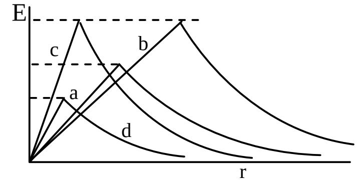
(D) None of these **[A]**

Q. 13 A particle A of mass m and charge q moves directly towards a fixed point charge q. The speed of A is v when it is far away from the fixed point charge. Then the minimum separation between the particles is proportional to :

(A) q^2 (B) $\frac{1}{v^2}$

(C) $\frac{1}{m}$ (D) All the above **[D]**

Q.14 Four sphere each of different radius named 'a', 'b', 'c', 'd' are given, each are solid insulating uniformly charged and carrying equal total charge. Variation of electric field with distance r from the centre is given. Then



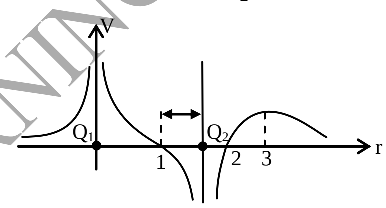
(A) Radius of sphere a > Radius of sphere b

(B) Radius of sphere a < Radius of sphere b

(C) Volume charged density of c > volume charged density of b

(D) Volume charged density of c < volume charged density of b **[B,C]**

Q. 15 Two point charges Q_1 and Q_2 lie along a line at a distance from each other. Figure show the potential variation along the line of charges-



(A) Q_1 is positive & Q_2 is negative

(B) Q_1 is negative & Q_2 is positive

(C) Magnitude of Q_1 is more than magnitude of Q_2

(D) Magnitude of Q_1 is less than magnitude of Q_2

[A,C]

Sol. Near positive charge net potential is positive and near negative charge potential is negative. Q_1 is positive & Q_2 is negative, at 1 potential is zero and this point is near to Q_2

Magnitude of Q_1 is more than magnitude of Q_2.

Q. 16 Two identical conducting balls have positive charges q_1 & q_2 respectively. The balls are brought together so that they touch and then put back in their original positions. The force between the balls may be -

(A) remain same as it was before the balls touched.

(B) greater than before the balls touched

(C) less than before the balls touched

(D) zero

Sol. **[A, B]**

If $q_1 = q_2 = Q$

$F_i \propto q_1q_2$ $\therefore F_i \propto Q^2$

After touching new charges on each

ball is $\frac{Q_1+Q_2}{2} = \frac{2Q}{2} = Q$

$F_{new} \propto Q^2$

$\therefore F_i = F_{new}$

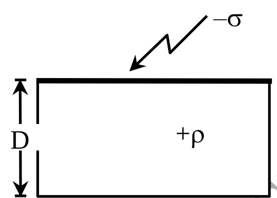
if $q_1 \neq q_2$

$$F_{new} = \left(\frac{q_1+q_2}{2}\right)^2$$

$$= \frac{q_1^2}{4}+\frac{q_2^2}{4} + \frac{2q_1q_2}{4}$$

$F_{new} > F_i$

Q.17 We have an infinite non-conducting sheet of negligible thickness carrying a uniform surface charge density – σ and next to it, an infinite parallel slab of thickness D with uniform volume charge density +ρ. All charges are fixed.



(A) Magnitude of electric field at a distance h above the negatively charged sheet is $\frac{\rho D-\sigma}{2\varepsilon_0}$

(B) Magnitude of electric field inside the slab at a distance h below the negatively charged sheet (h < D) is $\frac{\sigma+\rho(D-2h)}{2\varepsilon_0}$

(C) Magnitude of electric field at a distance h below the bottom of the slab is– $\frac{\rho D-\sigma}{4\varepsilon_0}$

(D) Magnitude of electric field at a distance h below the bottom of the slab is $\frac{\rho D-\sigma}{2\varepsilon_0}$

Sol. **[A,B,D]**

At a distance h above the sheet

$$E = E_{sheet} + E_{slab}$$

$$= \frac{-\sigma}{2\varepsilon_0}+\frac{\rho D}{2\varepsilon_0}=\frac{\rho D-\sigma}{2\varepsilon_0}$$

At a distance h below the top surface of slab

$$E_{slab} = \frac{\rho(D-2h)}{2\varepsilon_0}$$

$$E = E_{sheet} + E_{slab} = \frac{\sigma}{2\varepsilon_0}+\frac{\rho(D-2h)}{2\varepsilon_0}$$

$$= \frac{\sigma+\rho(D-2h)}{2\varepsilon_0}$$

At a distance h below the bottom surface of the slab $= \frac{-\sigma}{2\varepsilon_0}+\frac{\rho D}{2\varepsilon_0}=\frac{\rho D-\sigma}{2\varepsilon_0}$

Q.18 At distance of 5 cm and 10 cm outwards from the surface of a uniformly charged solid sphere, the potentials are 100V and 75V respectively. Then -

(A) potential at its surface is 150V

(B) the charge on the sphere is (5/3) × 10^{-10} C

(C) the electric field on the surface is 1500 V/m

(D) the electric potential at its centre is 225 V

[A,C,D]

Sol. The potential at surface, 5 cm from surface and 10 cm from surface outwards is

$$V_s = \frac{KQ}{R} \qquad \ldots\ldots(1)$$

$$\frac{KQ}{R+5} = 100 \qquad \ldots\ldots (2)$$

$$\frac{KQ}{R+10} = 75 \qquad \ldots\ldots(3)$$

From equation (2) and (3) ⇒ R = 10 cm

∴ from equation (2)

$$Q = \frac{100\times15\times10^{-2}}{9\times10^{9}} = \frac{5}{3} \times 10^{-9}\ C$$

⇒ B is false

$V_{surface} = \dfrac{KQ}{R} = \dfrac{100 \times (R+5)}{R} = \dfrac{100 \times 15}{10} = 150$

$V \Rightarrow$ A is true

$V_{centre} = \dfrac{3}{2}\dfrac{KQ}{R} = 225$ volts

$\Rightarrow$ D is true

$E_{surface} = \dfrac{KQ}{R^2} = \dfrac{150}{10 \times 10^{-2}} = 1500$ V/m

$\Rightarrow$ C is true

Q.19 Three concentric conducting spherical shells have radii **r**, **2r** and **3r** and charges $\mathbf{q_1}$, $\mathbf{q_2}$ and $\mathbf{q_3}$ respectively. Innermost and outermost shells are earthed as shown in the figure. Select the correct alternatives:

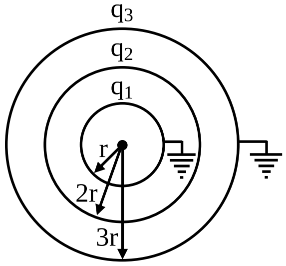


Fig.

(A) $q_1 + q_3 = -q_2$ (B) $q_1 = -\dfrac{q_2}{4}$

(C) $\dfrac{q_3}{q_1} = 3$ (D) $\dfrac{q_3}{q_2} = -\dfrac{1}{3}$

[A,B,C]

Sol. Potential of innermost shell is zero.

$\therefore \dfrac{q_1}{r} + \dfrac{q_2}{2r} + \dfrac{q_3}{3r} = 0$

or, $6q_1 + 3q_2 + 2q_3 = 0$ …(1)

Similarly, potential on outermost shell is also zero.

$\therefore \dfrac{q_1}{3r} + \dfrac{q_2}{3r} + \dfrac{q_3}{3r} = 0$

or, $q_1 + q_3 = -q_2$ …(2)

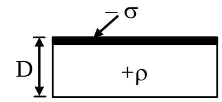
Solving equations (1) and (2), we get

$q_1 = -\dfrac{q_2}{4}$, $\dfrac{q_3}{q_1} = 3$

and, $\dfrac{q_3}{q_2} = -\dfrac{3}{4}$

$\therefore$ The options (A), (B) and (C) are correct.

Q.20 We have an infinite non-conducting sheet of negligible thickness carrying a uniform surface charge density $-\sigma$ and next to it , an infinite parallel slab of thickness D with uniform volume charge density $+\rho$. All charges are fixed.



(A) Magnitude of electric field at a distance h above the negatively charged sheet is $\dfrac{\rho D - \sigma}{2\varepsilon_0}$

(B) Magnitude of electric field inside the slab at a distance h below the negatively charged sheet (h < D) is $\dfrac{\sigma + \rho(D-2h)}{2\varepsilon_0}$

(C) Magnitude of electric field at a distance h below the bottom of the slab is $\dfrac{\rho D - \sigma}{4\varepsilon_0}$

(D) Magnitude of electric field at a distance h below the bottom of the slab is $\dfrac{\rho D - \sigma}{2\varepsilon_0}$

[A,B,D]

Sol. At a distance h above the sheet

$E = E_{sheet} + E_{slab}$

$= \dfrac{-\sigma}{2\varepsilon_0} + \dfrac{\rho D}{2\varepsilon_0} = \dfrac{\rho D - \sigma}{2\varepsilon_0}$

At a distance h below the top surface of slab

$E_{slab} = \dfrac{\rho(D-2h)}{2\varepsilon_0}$

$E = E_{sheet} + E_{slab} = \dfrac{\sigma}{2\varepsilon_0} + \dfrac{\rho(D-2h)}{2\varepsilon_0}$

$= \dfrac{\sigma + \rho(D-2h)}{2\varepsilon_0}$

At a distance h below the bottom surface of the slab $= \dfrac{-\sigma}{2\varepsilon_0} + \dfrac{\rho D}{2\varepsilon_0} = \dfrac{\rho D - \sigma}{2\varepsilon_0}$

PHYSICS

Q.1 A particle that carries a negative charge '–q' is placed at rest in a uniform electric field. 10 N/C. It experiences a force and moves. In a certain time't', it is observed to acquire a velocity $10\hat{i} - 10\hat{j}$ m/s. The given electric field intersects a surface of area A m^2 in the x-z plane. Electric flux through the surface is –

Sol. **[7]**

Force on a charge –q in an electric field

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

This force acts in a direction opposite to $\vec{E}$. Therefore the particle, initially placed at rest, will move opposite to $\vec{E}$ under the action of force. Obviously, direction of $\vec{V}$ will be opposite to $\vec{E}$.

Now $\vec{V} = 10\hat{i} - 10\hat{j}$ m/s (given)

unit vector in the direction of $\vec{V}$,

$$\vec{V} = \frac{10\hat{i} - 10\hat{j}}{\sqrt{(10)^2 + (-10)^2}}$$

$$= \frac{10\hat{i} - 10\hat{j}}{10\sqrt{2}}$$

$$\therefore \ \vec{V} = \frac{i}{\sqrt{2}} - \frac{j}{\sqrt{2}}$$

So unit vector opposite to $\vec{V}$, i.e. in the direction of

$$\vec{E} = -\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}$$

Magnitude of $\vec{E}$ is 10 N/C (given)

Therefore $\vec{E} = 10\left(-\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}\right)$ ….(1)

The surface of area Am^2 has been placed in the x-z plane so that its area vector can be expressed as,

$\vec{A} = A\hat{j}$($\vec{A}$ being normal to x-z plane, will be along y-axis)

Electric flux, in case of a uniform electric field,

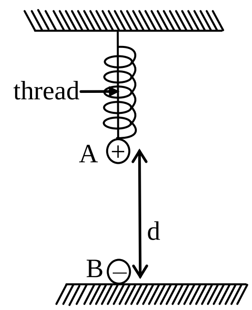
$$\phi = \vec{E}.\vec{A} = 10\left[-\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}\right].A\hat{j}$$

$$= \frac{10A}{\sqrt{2}} = 5\sqrt{2} \ \text{A Nm}^2/\text{C}$$

Q.2 Point charges $q_1 = -4$ nC and $q_2 = +4$ nC are separated by 3 mm, forming an electric dipole. The dipole is placed in uniform electric field whose direction makes an angle of 30º with line connecting the charges. What is the magnitude of this field in N/C if the torque exerted on the dipole has magnitude 7.2×10^{-9} N-m.

[1200]

Q.3 As shown in figure sphere A of mass 5 kg and charge 100 μC is tied with a thread so that spring of spring constant 10^4 N/m is in its natural length while sphere B of same mass and charge – 100 μC is fixed just below A at seperation d = 50 cm then the maximum elongnation in spring in centimeters when the thread is burnt is (g = 10 m/s^2)........................



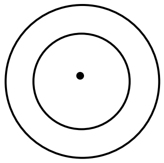
[0010]

Q.4 A non coducting sphere of radius R = 5 cm has its centre at origin O. It has a spherecial cavity of radius r = 1 cm whose centre is at (0, 3 cm). Solid meterial of sphere has uniform positive charge density $\rho = \frac{10^{-6}}{\pi}$ C/m^3. Then potential at point P(4 cm, 0) in volts is ………….. .

[0035]

Q.5 In the figure two conducting concentric spherical shells are shown. If the electric potential at the centre is 2000 V and the electric potential of the other shell is 1500 V. then the potential of the inner shell is......... **[2000 V]**

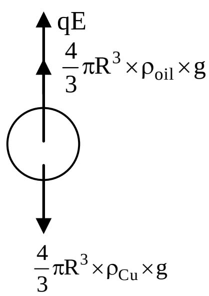
Sol.



Potential to centre is same as potential at the inner surface of the spherical shell.

Q.6 A copper ball of density 8.6 g/cm^3, 1 cm in diameter is immersed in oil of density 0.8 g/cm^3. What is the charge in μC on the ball, if it remains just suspended in an electric field of intensity 3600 V/m acting in upward direction. **[0034]**

Sol.



For equilibrium

$$qE + \frac{4}{3}\pi R^3 \times \rho_{oil} \times g = \frac{4}{3}\pi R^3 \times \rho_{Cu} \times g$$

$$q = \frac{\frac{4}{3}\pi R^3(\rho_{Cu} - \rho_{oil})g}{E}$$

$$q = \frac{\frac{4}{3} \times 3.14 \times (0.5\times10^{-2})^3(7.8)\times10^3\times10}{3600}$$

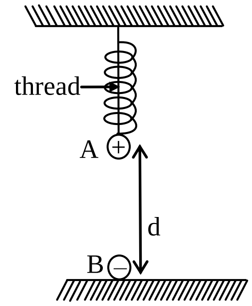
$$q = \frac{\frac{4}{3} \times 3.14 \times 7.8 \times 0.125 \times 10^{-2}}{3600}$$

$q = 3.4 \times 10^{-5}$ C

$= 34 \times 10^{-6}$ C

$= 34$ μC

Q.7 As shown in figure sphere A of mass 5 kg and charge 100 μC is tied with a thread so that spring of spring constant 10^4 N/m is in its natural length while sphere B of same mass and charge – 100 μC is fixed just below A at separation d = 50 cm then the maximum elongation in spring in centimeters when the thread is burnt is (g = 10 m/s^2)........................

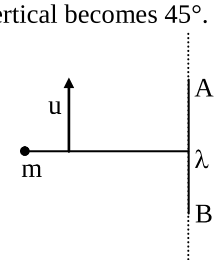


[0010]

Q.8 A non conducting sphere of radius R = 5 cm has its centre at origin O. It has a spherical cavity of radius r = 1 cm whose centre is at (0, 3 cm). Solid material of sphere has uniform positive charge density $\rho = \frac{10^{-6}}{\pi}$ C/m^3. Then potential at point P(4 cm, 0) in volts is ……………. **[0035]**

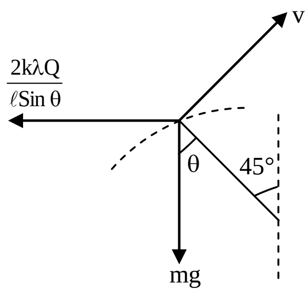
Q.9 Three charges – q, + 2q and – q are placed at the vertices of an isosceles right angled triangle ABC, angle B being 90º and AB = BC = a. If q = 1.6 × 10^{-19} C and a = 1.5 × 10^{-10}m then energy required to dissociate the system of charges is x × 10^{-18} J, then the value of x is - **[0005]**

Q.10 AB is a vertical rigid infinite wire carrying a linear of density λ = 10 μC/m. A particle having mass
m = 2 gm and charge Q = 1μC is fixed to the wire by means of a light, insulating and inextensible string having length = $2\sqrt{2}$ m. Find the vertical velocity u in with which it should be projected under gravity from the shown position so that the string slacks when its angle with vertical becomes 45°.



[0006]

Sol.



Equation of circular motion

$$mg\cos\theta - \frac{2k\lambda Q\sin\theta}{\ell\sin\theta} = \frac{mv^2}{\ell} \quad ...(1)$$

Using work energy principle

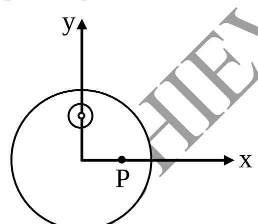
$$-mg\ell\cos\theta + \int_{\ell}^{\ell\sin\theta}\frac{2k\lambda Q dx}{x} = \frac{1}{2}m(v^2 - u^2) \quad ..(2)$$

By using (1) & (2)

$u = 5.7$ m/s

$\approx$ 6 m/s

Q.11 A non-conducting sphere of radius R = 5 cm has its centre at origin O of co-ordinate system. It has a spherical cavity of radius r = 1 cm having its centre at (0, 3 cm). Solid material of sphere has uniform positive charge density $\rho = \frac{10^{-6}}{\pi}$ coulomb m^{-3}. Calculate potential at point P (4 cm, 0). [in volt] **[0035]**



Sol. Assume given sphere is solid, potential V_1 at P is to be calculated. But in cavity there is no charge therefore potential V_2 due to charge assumed in cavity must be subtracted from V_1.

Charge on solid sphere = $\frac{4}{3}\pi R^3 \times \rho$

$= \frac{5}{3} \times 10^{-10}$ cb

Potential at P can be calculated say V_1

V_2 = Potential due to cavity sphere

$$= \frac{\frac{4}{3}\pi r^3\rho}{4\pi\varepsilon_0 a} = 0.24\text{V}$$

Potential at P $= V_1 - V_2 = 35.16$ volt

Q.12 In a certain region of space, electric potential V is given by $V = ax^2 + ay^2 + 2az^2$ (where a is a constant of proper dimensions). Work done by electric field in bringing a 2μC charge from origin to (0,0,0.1m) is (-5×10^{-8})joule. Find the approximate value of a in V/m^2.

Sol. **[1]**

W by electric field = -5×10^{-8} J

W against electric field = $+ 5 \times 10^{-8}$ joule

$2 \times 10^{-6}\,[2 \times a \times (0.1)^2 - 0\,]$

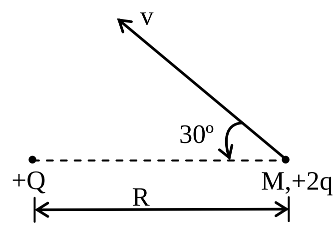
$= + 5 \times 10^{-5}$ joule

$4 \times 10^{-6} \times a \times \frac{1}{100} = 5 \times 10^{-8}$

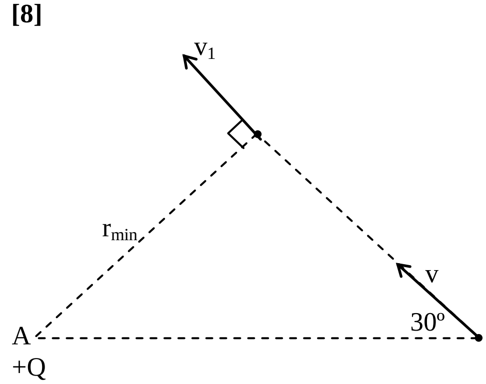
$4 \times 10^{-8} \times a = 5 \times 10^{-8}$

$a = \frac{5}{4} = 1.2$ V/m^2

Q.13 In the diagram shown, the charge + Q is fixed. Another charge +2q, is projected from a distance R from the fixed charge. Minimum separation between two charges if the velocity becomes $\frac{1}{\sqrt{3}}$ times of the projected velocity at this moment is (assume gravity to be present) in cm (R = 10cm given)-



Sol. **[8]**



Angular momentum about A is conserved as $\tau_{external} = 0$

$mv\sin 30^\circ \times R = v_1 \times m \times r_{min}$

$\frac{Rv}{2} = \frac{1}{\sqrt{3}} \times r_{min}$

$r_{min} = \frac{\sqrt{3}R}{2} = \frac{1.713 \times 10}{2} = 8.665 = 8$ cm

Q.14 A beam of charged particles accelerated using a potential difference of 5000 V falls to rest on a metal plate normally constituting a current of 500 μA. Find the force exerted by the beam on the plate ? (specific charge = 4×10^6 C kg^{-1} for each particle). (in μN). **[0025]**

Sol. Let m, q = mass and charge of each particle

V = accelerating voltage

v, p = velocity and momentum acquired by each particle

$\therefore \quad \frac{1}{2} mv^2 = qV$

or $\quad v = (2qV/m)^{1/2}$

$\therefore \quad p = mv = (2mqV)^{1/2}$

Number of particles reaching the plate per second

= N = i/q, where i = current

Momentum delivered to plate per second = force on plate

$= Np = \frac{1}{q}(2mqV)^{1/2} = i\left(\frac{2V}{q/m}\right)^{1/2}$

$= 500 \times 10^{-6}\left[\frac{2 \times 5000}{4 \times 10^6}\right]^{\frac{1}{2}}$ N

$= 25 \times 10^{-6}$ N

0	0	2	5

Q.15 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.

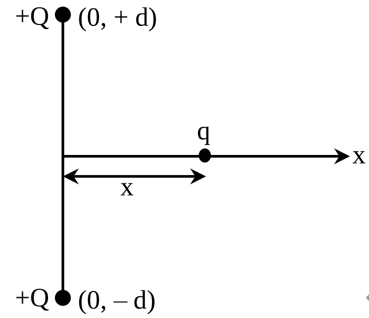
[IIT-2009]

Ans. 2

Q.16 Two equal point charges of same sign are fixed on y-axis, on the either sides of the origin equidistant from it, distance between them d. A third charge moves along x axis. Find the distance of third charge from either of the two fixed charges when force on third charge is maximum. [d = 10 cm] give answer in cm.

[0012]

Sol.



$F_{net} = \frac{2KQq}{(d^2+x^2)}\left[\frac{x}{[d^2+x^2]^{1/2}}\right]$

$\frac{dF_{Net}}{dx} = 0$

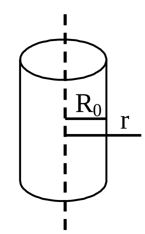
$x = \frac{d}{\sqrt{2}}$

Required distance $\sqrt{d^2 + \frac{d^2}{2}} = d\frac{\sqrt{3}}{2}$ = 10 × 1.2

= 12.2 cm

Q.17 A straight infinitely long cylinder of radius R_0 = 10 cm is uniformly charged with a surface charge density $\sigma = +10^{-12}$ C/m^2. The cylinder serves as a source of electrons, with the velocity of the emitted electrons perpendicular to its surface. Electron velocity must be … × 10^5 m/s to ensure that electrons can move away, from the axis of the cylinder to a distance greater than $r = 10^3$ m.

Ans. [4] $\frac{1}{2} mv^2 = \frac{\lambda e}{2\pi \in_0} \log_n \frac{r}{R_0}$



$v = \sqrt{\frac{\lambda e}{\pi \in_0 m} \log \frac{r}{R_0}}$

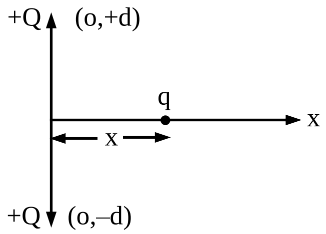
$\sigma = \frac{Q}{2\pi R_0 \times L}$

$\lambda = \frac{Q}{L} = \sigma \times 2\pi R_0 \quad \therefore v = \sqrt{\frac{2\sigma e R_0}{\in_0 m} \log \frac{r}{R_0}}$

3.7×10^5m/s or 4×10^5 m/s

Q.18 Two equal point charges of same sign fixed are on y axis, to the two sides of the origin equidistant from it, distance being d. A third charge moves along x axis. Find the distance from either of the two fixed charges, when force is maximum. [d = $\frac{10}{\sqrt{3}}$ cm] Give answer in cm.

Sol. [5]



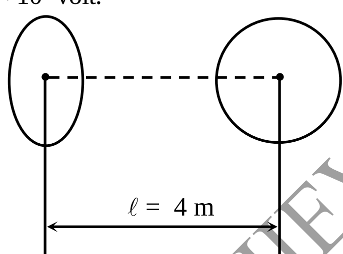
$$F_{Net} = \frac{2kQq}{(d^2 + x^2)}\left[\frac{x}{[d^2 + x^2]^{1/2}}\right]$$

$$\frac{d\,F_{Net}}{dx} = 0$$

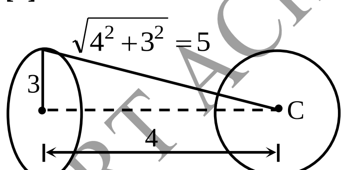
$$x = \frac{d}{\sqrt{2}}$$

Required distance $\sqrt{d^2 + \frac{d^2}{2}} = \frac{d\sqrt{3}}{2}$

Q.19 A thin ring of radius R = 3m has been uniformly charged with an amount of 20 µC and placed in relation to a conducting sphere in such a way that the centre of the sphere O, lies on the rings axis at a distance of ℓ = 4m from the plane of the ring. The potential of the sphere is……….× 18 × 10^3 volt.



Sol. **[2]**



potential at C = $\frac{kQ}{\sqrt{4^2+3^2}} = \frac{kQ}{5}$

$$= \frac{9\times10^9 \times 20\times10^{-6}}{5}$$

$$= \frac{18\times10^4}{5} = 3.6\times10^4 \text{ volt}$$

Q.20 A charged dust particle of radius 5 × 10^{-7} m is located in a horizontal electric field having an intensity of 6.28 × 10^5 V/m. The surrounding medium is air with coefficient of viscosity η = 1.6 × 10^{-5} N-s/m^2. If the particle moves with a uniform horizontal speed 0.02 m/s, the number of electrons on it is……….× 10.

Sol. **[3]**

As dust particle is moving with uniform velocity along horizontal, the dust particle is in dynamic-equilibrium and as the forces acting on dust particle along horizontal are electric force (qE) and viscous force (6πηrν).

So, qE = 6πηrν or

neE = 6πηrν [as q = ηe]

and hence n = $\frac{6\pi\eta r\nu}{eE}$

$$= \frac{6\times3.14\times1.6\times10^{-5}\times5\times10^{-7}\times0.02}{(1.6\times10^{-19})(6.28\times10^5)}$$

$\simeq$ 30

PHYSICS

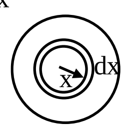
Q.1 The electric field inside a sphere which carries a charge density proportional to the distance from the origin $\rho = \propto r$ ($\propto$ is a constant) is:

(A) $\frac{\propto r^3}{4\varepsilon_0}$ (B) $\frac{\propto r^2}{4\varepsilon_0}$

(C) $\frac{\propto r^2}{3\varepsilon_0}$ (D) None of these

[B]

Sol. We can consider all the charge inside the sphere to be concentrated at the centre of sphere, consider an elementary shell of radius x and thickness dx



$$E = \frac{k\int dq}{r^2} = \frac{k\int_0^r 4\pi x^2 dx(\propto x)}{r^2} = \frac{\propto r^2}{4\varepsilon_0}$$

Q.2 At a point in space, the electric field points towards north. In the region surrounding this point, the rate of change of potential will be zero along –

(A) North

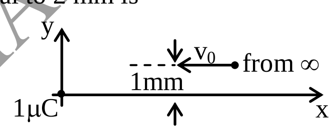
(B) South

(C) North-South

(D) East-West **[D]**

Sol. $E_{east-west = 0} \Rightarrow \left(\frac{dv}{dr}\right)_{east-west} = 0$

Q.3 A particle of mass 1 kg and charge 1 μC is projected towards another point charge 1 μC fixed at origin as shown in figure. The minimum initial velocity of projection required for the particle to move along a trajectory having minimum distance from fixed charge equal to 2 mm is -



(A) $\sqrt{\frac{2}{3}}$ m/s (B) $3\sqrt{2}$ m/s

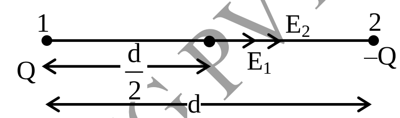
(C) $\sqrt{\frac{3}{2}}$ m/s (D) $2\sqrt{3}$ m/s **[D]**

Q.4 Two unlike charges of the same magnitude Q are placed at a distance d. The intensity of the electric field at the middle point in the line joining the two charge is -

(A) zero (B) $\frac{8Q}{4\pi\varepsilon_0 d^2}$

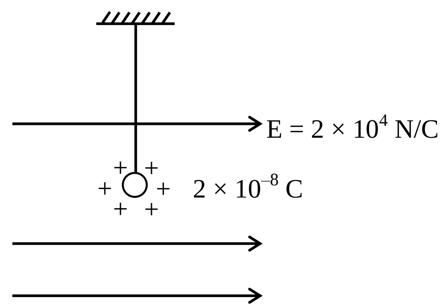
(C) $\frac{6Q}{4\pi\varepsilon_0 d^2}$ (D) $\frac{4Q}{4\pi\varepsilon_0 d^2}$ **[B]**

Sol.



$$E_{Net} = E_1 + E_2 = \frac{kQ}{\left(\frac{d}{2}\right)^2} + \frac{kQ}{\left(\frac{d}{2}\right)^2} = \frac{8Q}{4\pi\varepsilon_0 d^2}$$

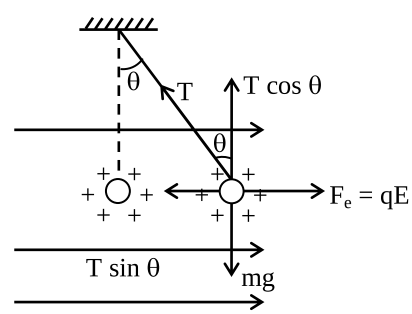
Q.5 Calculate the tension in the thread during equilibrium condition -



(A) 8.8 N (B) 8.8×10^2 N

(C) 8.8×10^{-4} N (D) 8.8×10^{-3} N **[C]**

Sol.



during equilibrium

$T \cos\theta = mg$

$T \sin\theta = qE$

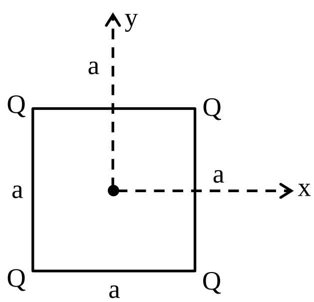
$T = \sqrt{(mg)^2 + (qE)^2}$

$T = \sqrt{(80 \times 10 \times 10^{-6})^2 + (2 \times 10^{-8} \times 2 \times 10^4)^2}$

$T = \sqrt{64 \times 10^{-8} + 16 \times 10^{-8}}$

$T = \sqrt{80 \times 10^{-8}} = 8.8 \times 10^{-4}$ N

Q.6 A charge –q is placed at (0, 0, – z) where z << a. On releasing –q from this position -



(A) –q will move towards z = – ∞

(B) –q will move towards z = ∞

(C) –q will move to and fro about the origin

(D) –q will remain stationary at (0, 0, – z) **[C]**

Sol. –q will experience a restoring force and will perform SHM

Q.7 Two small identical spheres having charges + 10μC and –90μC attract each other with a force of F newton. If they are kept in contact and then separated by the same distance, the new force between them is -

(A) F/6 (B) 16F

(C) 16F/9 (D) 9F **[C]**

Sol. $F = \frac{k(10)(90)}{r^2}$ ....(i)

charge on each when contact is made

$q_1' = q_2' = \frac{10 + (-90)}{2} = -40\mu C$

$\therefore$ New force $F' = \frac{k(40)(40)}{r^2}$

$\therefore \frac{F'}{F} = \frac{40 \times 40}{10 \times 90} = \frac{16}{9}$

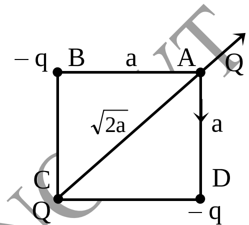
$\therefore \boxed{F' = \frac{16}{9}F}$

Q.8 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) $-\frac{1}{\sqrt{2}}$ **[A]**

Sol.



Since net force on charge Q is zero (Placed at corner A).

$\frac{KQ^2}{(\sqrt{2}a)^2} + \left[\sqrt{2}\ \frac{kQq}{a^2}\right] = 0$

$\Rightarrow \frac{kQ^2}{2a^2} = \frac{-\sqrt{2}kQq}{a^2}$

$\Rightarrow \frac{Q}{q} = -2\sqrt{2}$

So option (1) is correct.

Q.9 Two points P and Q are maintained at the potentials of 10V and –4V, respectively. The work done in moving 100 electrons from P to Q is . **[AIEEE-2009]**

(A) $- 9.60 \times 10^{-17}$ J

(B) 9.60×10^{-17} J

(C) $- 2.24 \times 10^{-16}$ J

(D) 2.24×10^{-16} J **[D]**

Sol. $W = q(\Delta V)$

$= q(V_f - V_i)$

$= - 100 \times 1.6 \times 10^{-19} (- 4 - 10)$

$= 1.6 \times 14 \times 10^{-17}$

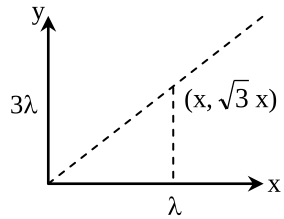
$= 2.24 \times 10^{-4}$ J

Q.10 Two uniformly long charged wires with linear densities λ and 3λ are placed along X and Y axis respectively. Determined the slope of electric field at any point on the line $y = \sqrt{3}\,x$.

(A) $3\sqrt{3}$ (B) $\frac{\sqrt{3}}{3\sqrt{2}}$

(C) $\frac{1}{3\sqrt{3}}$ (D) $\sqrt{3}$ **[C]**

Sol.



$$\vec{E} = \frac{3\lambda}{2\pi \in_0 x}\,\hat{i} + \frac{\lambda}{2\pi \in_0 x\sqrt{3}}\,\hat{j}$$

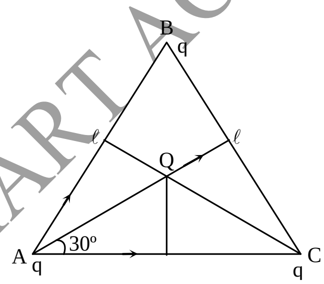
$$\text{Slope} = \frac{E_y}{E_x} = \frac{1}{\sqrt{3}} \div 3 = \frac{1}{3\sqrt{3}}$$

Q.11 Three charges each of +q, are placed at the vertices of an equilateral triangle. The charge needed at the centre of the triangle for the charges to be in equilibrium is –

(A) $\frac{-q}{\sqrt{3}}$ (B) $-\sqrt{3}q$

(C) $\sqrt{3}q$ (D) $-\sqrt{3}q$ **[A]**

Sol.



$$F = \sqrt{F_{AB}^2 + F_{AC}^2 + (2F_{AB}, F_{AC})\cos 30^o}$$

$$= \frac{q^2}{\ell^2}\sqrt{1+1+1} = \frac{\sqrt{3}q^2}{\ell^2}$$

$$F_{center} = \frac{q.Q.e}{\ell^2}$$

$$F + F_{center} = 0$$

$$= \frac{\sqrt{3}q^2}{\ell^2} + \frac{3qQ}{\ell^2} = 0$$

$$= \frac{3qQ}{\ell^2} = -\frac{\sqrt{3}q^2}{\ell^2}$$

$$\therefore \quad Q = -\frac{q}{\sqrt{3}} = -\frac{\sqrt{3}q^2}{\ell^2}$$

Q.12 The electric field and electric potential at a point are E and V respectively, then –

(A) If E = 0, V must be zero

(B) If V = 0, E must be zero

(C) If $E \neq 0$, V may be zero

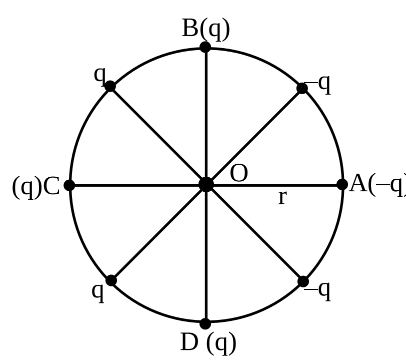
(D) If $V \neq 0$, E cannot be zero **[C]**

Q. 13 Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 20 cm surrounding the total charge is 50 V-m. The flux over a concentric sphere of radius 40 cm will be –

(A) 25 V-m (B) 50 V-m

(C) 100 V-m (D) 200 V-m **[B]**

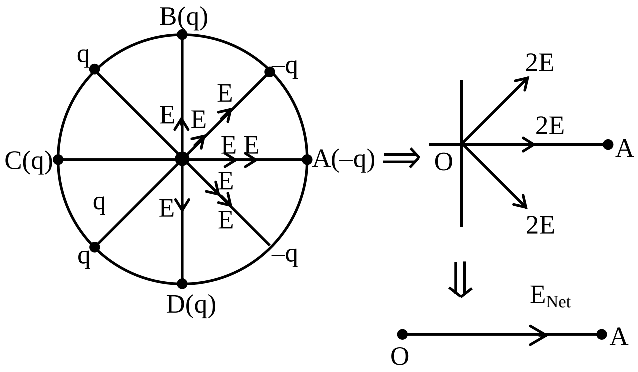
Q. 14 Some point charges are placed on the circumference of circle at equal distance. (See fig.) The direction of electric field at centre O will be along -



(A) OA (B) OB

(C) OC (D) OD **[A]**

Sol. Since magnitude of each charges are same and situated at equal distance from centre O so all charge will produce same magnitude of electric field at centre.



Q. 15 20 J of work has to be done against an existing electric field to take a charge of – 0.1 C from A to B, then potential difference $V_B – V_A$ is –

(A) 20 V (B) 120 V

(C) – 80 V (D) – 200 V **[D]**

Q. 16 A non-conducting sheet of large surface area and thickness d = 10 cm contains uniform charge distribution of density 17.7×10^{-9} C/m^3. Electric field intensity at a point inside the plate, at a distance x = 2 cm from one of the outer surfaces is

(A) 30 V/m (B) 60 V/m

(C) 120 V/m (D) 180 V/m **[B]**

Q. 17 A uniform electric field $\vec{E} = a\hat{i} + b\hat{j}$, intersects a surface of area A. What is the flux through this area if the surface lies in the yz plane –

(A) aA (B) 0

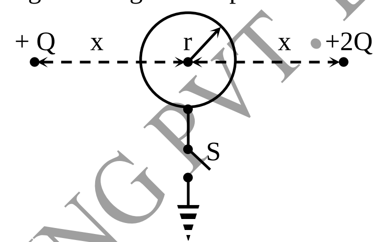
(C) bA (D) $A\sqrt{a^2+b^2}$ **[A]**

Q. 18 A solid sphere of radius R is charged uniformly. At what distance from its surface is the electrostatic potential half of the potential at the centre ?

(A) R (B) $\frac{R}{2}$

(C) $\frac{R}{3}$ (D) 2R **[C]**

Q. 19 Two particles having positive charges + Q and + 2Q are fixed at equal distance x from centre of an conducting sphere having zero net charge and radius r as shown. Initially the switch S is open. After the switch S is closed, the net charge flowing out of sphere is -



(A) $\frac{Qr}{x}$ (B) $\frac{2Qr}{x}$

(C) $\frac{3Qr}{x}$ (D) $\frac{6Qr}{x}$ **[C]**

Sol. Initially the potential at centre of sphere is

$$V_C = \frac{1}{4\pi\varepsilon_0}\frac{Q}{x} + \frac{1}{4\pi\varepsilon_0}\frac{2Q}{x} = \frac{1}{4\pi\varepsilon_0}\frac{3Q}{x}$$

After the sphere grounded, potential at centre becomes zero. Let the net charge on sphere finally be q.

$$\therefore \frac{1}{4\pi\varepsilon_0}\frac{q}{r} + \frac{1}{4\pi\varepsilon_0}\frac{3Q}{x} = 0 \text{ or } q = \frac{3Qr}{x}$$

$\therefore$ The charge flowing out of sphere is $\frac{3Qr}{x}$

Q.20 Four equal positive charges each +Q are placed at corners of a square of side length L. A charge particle having negative charge $–q_1$ is placed at centre of square and the system of these five charges becomes in equilibrium –

(A) The presence of $–q_1$ charge makes the electric potential energy of system negative

(B) The presence of $– q_1$ charge cannot makes the electric potential energy negative

(C) The presence of – q_1 charge makes the electric potential energy zero

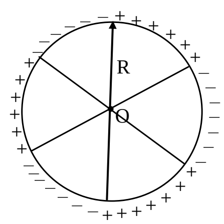
(D) All of the above can possible **[C]**

Q.21 A charged soap bubble having surface charge density σ and radius r. If pressure inside soap bubble and pressure outside it is same then the surface tension for soap bubble is-

(A) $T = \frac{\sigma^2 R}{8\varepsilon_0}$ (B) $T = \frac{\sigma^2 R}{4\varepsilon_0}$

(C) $T = \frac{\sigma^2 R}{2\varepsilon_0}$ (D) $T = \frac{\sigma^2 R}{\varepsilon_0}$ **[A]**

Q.22 A ring of radius R is marked in six equal parts and these parts are charged uniformly with a charge of magnitude Q but positive and negative alternately as shown. Then the electric field at centre of ring will be –



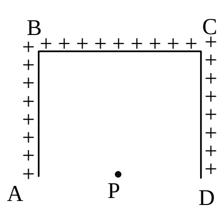
(A) $\frac{k\lambda}{r}$ where $\lambda = \frac{3Q}{\pi R}$

(B) $\frac{2k\lambda}{r}$ where $\lambda = \frac{3Q}{\pi R}$

(C) $\frac{3k\lambda}{r}$ where $\lambda = \frac{3Q}{\pi R}$

(D) None of these **[D]**

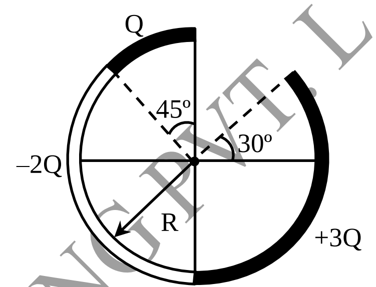
Q.23 Three wires AB, BC, CD of equal length ℓ are charged uniformly with linear charge density λ and are placed as shown. P is a point which lies at a distance ℓ from the wire BC on its perpendicular bisector. Then the electric field at P is –



(A) $\frac{2k\lambda}{\sqrt{5}\ell}(2\sqrt{5}-1)$ (B) $\frac{2k\lambda}{\sqrt{5}\ell}(\sqrt{5}-1)$

(C) $\frac{k\lambda}{\sqrt{5}\ell}(2\sqrt{5}-3)$ (D) None of these **[A]**

Q. 24 Figure shows three circular arcs, each of radius R and total charge as indicated. The net electric potential at the centre of curvature is -



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

(C) $\frac{2Q}{\pi\varepsilon_0 R}$ (D) $\frac{Q}{\pi\varepsilon_0 R}$ **[A]**

Sol. $V = V_1 + V_2 + V_3$

$$= \frac{1}{4\pi\varepsilon_0}.\frac{Q}{R} + \frac{1}{4\pi\varepsilon_0}\left[\frac{-2Q}{R}\right] + \frac{1}{4\pi\varepsilon_0}\left[\frac{3Q}{R}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}.\left[\frac{2Q}{R}\right]$$

Q. 25 The electric potential decreases uniformly from 120 V to 80 V as one moves on the x-axis from x = – 1 cm to x = +1 cm. Then the electric field at origin -

(A) may be equal to 20 V/cm

(B) may be equal to 30 V/cm

(C) may be equal to 100 V/cm

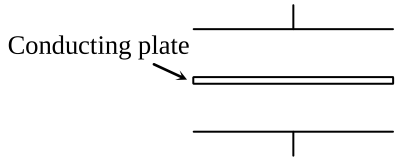
(D) All of the above are possible **[D]**

Q.26 Consider a solid cube of uniform charge density of insulating material. What is the ratio of the electrostatic potential at a corner to that at the centre. (Take the potential to be zero at infinity, as usual)

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

(C) $\frac{1}{4}$ (D) $\frac{1}{9}$ **[B]**

Q.27 A thin conducting plate is inserted in half way between the plates of a parallel plates capacitor of capacitance C.

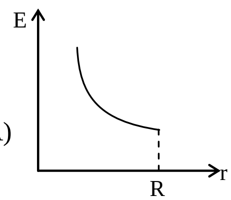


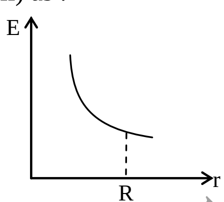
What does the value of capacitance, if both the plate of capacitor is connected by conducting wire ?

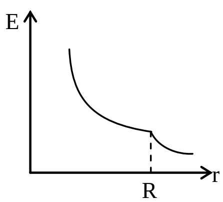
(A) C (B) 2C

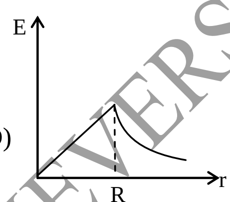
(C) 3C (D) 4C **[D]**

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

(A) 

(B) 

(C) 

(D) 

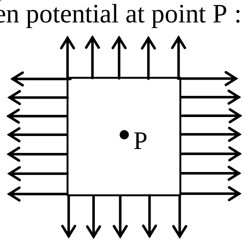
Sol. **[A]**

Using gauss theorem,

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2}$ for $r \le R$ and $E = 0$ for $r \ge R$

$\therefore$ correct graph is (A)

***Q.29** Electric lines of force are as shown in the figure . Then potential at point P :



(A) is zero (B) is not zero

(C) may be zero also (D) is not defined

Sol. **[C]**

The dotted lines may be surface boundary of a conductor. Electric lines of force do not enter a conductor. Potential of a conductor is constant but not necessarily zero.

It may be zero also. So, Point P may be inside a conductor (solid or hollow).

Q. 30 An insulating solid sphere of radius 'R' is charged in a non-uniform manner such that volume charge density $\rho = \frac{A}{r}$, where A is a positive constant and r the distance from centre. Electric field strength at any inside point at distance r_1 is -

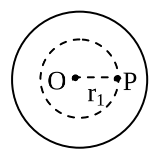
(A) $\frac{1}{4\pi\varepsilon_0}\frac{4\pi A}{r_1}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{A}{r_1}$

(C) $\frac{A}{\pi\varepsilon_0}$ (D) $\frac{A}{2\varepsilon_0}$

Sol. **[D]**

P is any inside point at distance r_1 from O. we take a spherical surface of radius r_1 as Gaussian –surface of radius r_1 as Gaussian-surface.

$$\oint_s \vec{E}.\vec{ds} = \frac{q_{in}}{\varepsilon_0}$$



By symmetry, E at all points on the surface is same and angle between $\vec{E}$ and $\vec{ds}$ is zero everywhere.

$$\therefore \oint_s \vec{E}.\vec{ds} = Es = \frac{q_{in}}{\varepsilon_0} \text{ or } E\,4\pi r^2{}_1 = \frac{q_{in}}{\varepsilon_0} \quad .....(i)$$

q_{in} : The sphere can be regarded as consisting of a large number of spherical shells.Consider a shell of inner and outer radii r and r +dr. Its volume will be $dV = 4\pi r^2$ dr. Charge in the shell,

$$dq = \rho dV = \frac{A}{r}4\pi r^2 dr$$

Total charge enclosed by Gaussian-surface,

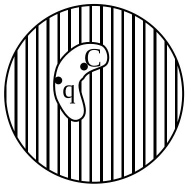
$$q_{in} = \int dq = \int_0^{r_1} rdr = 4\pi A = \frac{r_1^2}{2}$$

$$q_{in} = 4pA\int_0^{r_1} rdr = 4\pi A\ \frac{r_1^2}{2}$$

From Eq. (1) $E4\pi r_1^2 = 4\pi A\frac{r_1^2}{2} / \varepsilon_0$

$\therefore$ E = $\dfrac{A}{2\varepsilon_0}$

Q.31 The figure shows a charge q placed inside a cavity in an uncharged conductor. Now if an external electric field is switched on then :



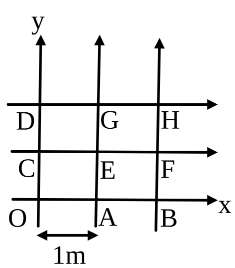
(A) only induced charge on outer surface will redistribute.
(B) only induced charge on inner surface will redistribute
(C) Both induced charge on outer and inner surface will redistribute.
(D) force on charge q placed inside the cavity will change

Sol. **[A]**

The distribution of charge on the outer surface, depends only on the charges outside, and it distributes itself such that the net electric field inside the outer surface due to the charge on outer surface and all the outer charges is zero. Similarly the distribution of charge on the inner surface, depends only on the charges inside the inner surface, and it distributes itself such that the net, electric field outside the inner surface due to the charge on inner surface and all the inner charges is zero.

Also the force on charge inside the cavity is due to the charge on the inner surface. Hence answer is option (A).

Q.32 The grid (each square of 1m × 1m), represents a region in space containing a uniform electric field. If potentials at point O, A, B, C, D, E, F, G, H are respectively 0, –1, –2, 1, 2, 0, –1, 1 and 0 volts. find the electric field intensity.

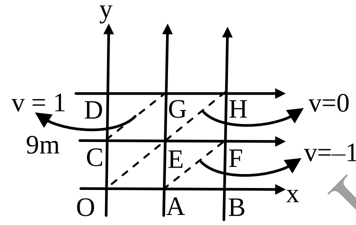


(A) $(\hat{i} + \hat{j})$V/m (B) $(\hat{i} - \hat{j})$V/m

(C) $(-\hat{i} + \hat{j})$V/m (D) $(-\hat{i} - \hat{j})$V/m

Sol. **[B]**

OEH is an equipotential surface, the uniform E.F. must be perpendicular to it pointing from higher to lower potential as shown.



Hence E = $\left(\dfrac{\hat{i}-\hat{j}}{\sqrt{2}}\right)$

E = $\dfrac{(v_E - v_B)}{EB} = \dfrac{0-(-2)}{\sqrt{2}} = \sqrt{2}$

$\therefore \vec{E} = E.\,\vec{E} = \sqrt{2}\,\dfrac{(\hat{i}-\hat{j})}{\sqrt{2}} = \hat{i}-\hat{j}$

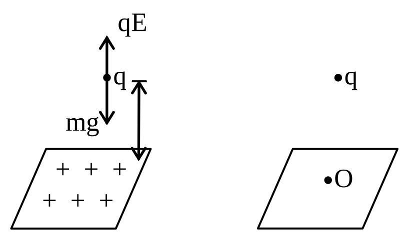
Q. 33 A small charged ball is hovering in the state of equilibrium at a height h over a large horizontal. uniformly charged dielectric plate. What would be the acceleration of the ball if a disc of radius r = 0.00lh is removed from the plate directly underneath the ball ?

(A) $\dfrac{g}{2}\left(\dfrac{r}{h}\right)^2$ (B) $\dfrac{g}{2}\left(\dfrac{h}{r}\right)^2$

(C) $\dfrac{g}{4}\left(\dfrac{r}{h}\right)^2$ (D) $\dfrac{g}{4}\left(\dfrac{h}{r}\right)^2$

Sol. **[A]**

Equilibrium mg = qE



Now 6 × πr^2 charged disc is removed as r is very less we can treat disc as a point charge

$\therefore$ unbalanced acceleration = $\dfrac{Q}{4\pi \epsilon h^2} \times \dfrac{q}{m}$

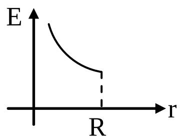
Q = 6 × πr^2

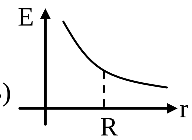
$q = \frac{mg}{E}$

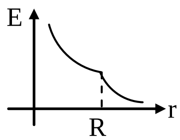
putting in acceleration expression

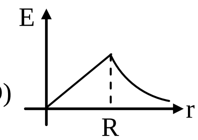
$a = \frac{g}{2}\left(\frac{r}{h}\right)^2$

Q.34 A conducting shell of radius R carries charge – Q. A point charge +Q is placed at the centre. The electric field E varies with distance r (from the center of the shell) as-

(A) 

(B) 

(C) 

(D) 

Sol. **[A]**

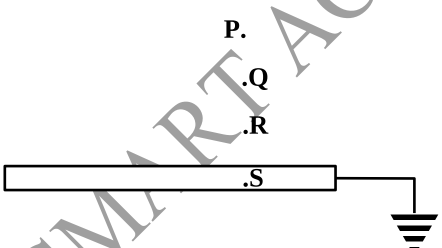
Using Gauss theorem

$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}$ for $r \le R$

and E = 0 for $r \ge R$

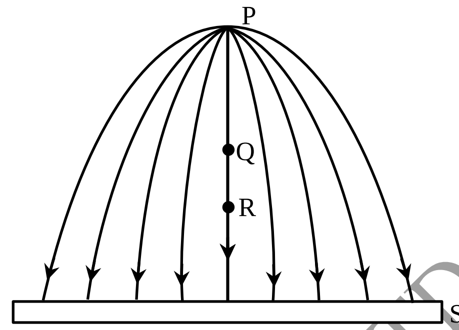
$\therefore$ The correct graph is (a).

Q.35 A positive point charge is placed at P in front of an earthed metal sheet S. Q & R are two points between P & S as shown in figure. If the electric field strength at Q & R are respectively E_Q & E_R and potential at Q & R are respectively V_Q & V_R . Then-



(A) $E_Q > E_R$ (B) $E_Q < E_R$
(C) $V_Q > V_R$ (D) $V_Q < V_R$

Sol. **[C]**



As we are are moving away from P toward sheet S spacing between electric lines of force is increasing. $\therefore$ $E_R < E_Q$ In direction of electric field potential decreases. $\therefore$ $V_R < V_Q$

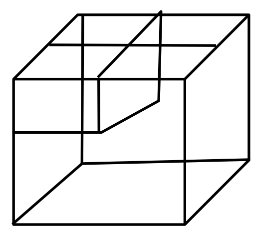
Q.36 Consider a solid cube of uniform charge density of insulating material. What is the ratio of the electrostatic potential at a corner to that at the centre. (Take the potential to be zero at infinity, as usual)

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

(C) $\frac{1}{4}$ (D) $\frac{1}{9}$

Sol. **[B]**

ρ- charge density of the cube



V_ℓ^{corner} = potential at the corner of a cube of side ℓ.

V_ℓ^{centre} = potential at the centre of a cube of side ℓ.

$V_{\ell/2}^{centre}$ = potential at the centre of a cube of side $\frac{\ell}{2}$.

$V_{\ell/2}^{corner}$ = potential at the corner of a cube of side $\frac{\ell}{2}$.

By dimensional analysis $V_\ell^{corner} \propto \frac{Q}{\ell} = \rho\ell^2$

$V_\ell^{corner} = 4\ V_{\ell/2}^{corner}$

But by super position $V_\ell^{centre} = 8\ V_{\ell/2}^{corner}$ because the centre of the larger cube lies at a corner of the eight smaller cubes of which it is made

Therefore $\frac{V_\ell^{corner}}{V_\ell^{centre}} = \frac{4V_{\ell/2}^{coner}}{8V_{\ell/2}^{centre}} = \frac{1}{2}$

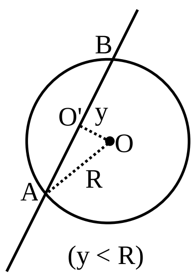
Q.37 A uniformly charged and infinitely long line having a linear charge density 'λ' is placed at a normal distance y from a point O. Consider a sphere of radius R with O as centre and R > y. Electric flux through the surface of the sphere is-

(A) zero (B) $\frac{2\lambda R}{\varepsilon_0}$

(C) $\frac{2\lambda\sqrt{R^2 - y^2}}{\varepsilon_0}$ (D) $\frac{\lambda\sqrt{R^2 + y^2}}{\varepsilon_0}$

Sol. **[C]**

Electric flux $\oint_S \vec{E}.\vec{dS} = \frac{q_{in}}{\varepsilon_0}$ q_{in} is the charge enclosed by the Gaussian-surface which, in the present case, is the surface of given sphere. As shown, length AB of the line lies inside the sphere.



(y < R)

In ΔOO'A $R^2 = y^2 + (O'A)^2$

$\therefore$ $O'A = \sqrt{R^2 - y^2}$

and $AB = 2\sqrt{R^2 - y^2}$

Charge on length AB = $2\sqrt{R^2 - y^2} \times \lambda$

$\therefore$ electric flux = $\oint_S \vec{E}.\vec{dS} = \frac{2\lambda\sqrt{R^2 - y^2}}{\varepsilon_0}$

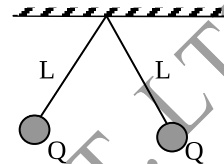
Q.38 Two identical small balls, each of mass m and having charge q are suspended by two light inelastic insulating threads each of length ℓ from the same fixed point support. If the distance (d) between two balls is very less than ℓ, then d is equal to-

(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

[A]

Q.39 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, $\frac{kq^2}{L^2}$ (B) π, $\frac{kq^2}{2L^2}$

(C) π, $\frac{kq^2}{4L^2}$ (D) $\frac{\pi}{2}$, $\frac{kq^2}{2L^2}$ **[C]**

Q.40 Two balls A and B having equal charges are placed at a fixed distance experience a force F. A similar uncharged ball after touching one of them is placed at the middle point between the two balls. The force experienced by this ball is –

(A) F/2 (B) F

(C) 2F (D) 4F **[B]**

Q.41 Two point charges placed at a distance r in air exert a force F on each other. The value of distance R at which they experience force 4F when placed in a medium of dielectric constant K = 16 is -

(A) r (B) r/8

(C) r/4 (D) r/2 **[B]**

Q.42 Three charge +4q, Q and q are placed in a straight line of length ℓ at point distance 0, $\ell/2$ and ℓ respectively. 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 **[A]**

Q.43 A proton and an electron are placed in a uniform electric field.

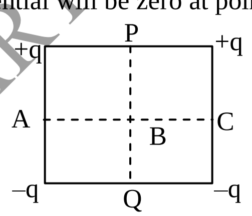
(A) The electric forces acting on them will be equal
(B) The magnitudes of the forces will be equal
(C) Their accelerations will be equal
(D) The magnitudes of acceleration will be equal **[B]**

Q.44 A charged water drop of radius 0.1 µm is in equilibrium in an electric field. If charge on it is equal to charge on an electron, then intensity of electric field will be : ($g = 10\ m/s^2$ and density of water = $1000\ kg/m^3$)
(A) 1.61 N/C (B) 26.2 N/C
(C) 262 N/C (C) 1610 N/C **[C]**

Q.45 Four charges q, 2q, – 4q and 2q are placed in order at the four corners of a square of side b. The net field at the centre of the square is –
(A) $\frac{q}{2\pi\varepsilon_0 b^2}$ from + q to – 4q
(B) $\frac{5q}{2\pi\varepsilon_0 b^2}$ from + q to – 4q
(C) $\frac{10q}{2\pi\varepsilon_0 b^2}$ from + q to – 4q
(D) $\frac{20q}{2\pi\varepsilon_0 b^2}$ from – 4q to + q **[B]**

Q.46 Point charges q, – q, 2Q and Q are placed in order at the corners A, B, C, D, of a square of side 2b. If the field at the midpoint CD is zero, then $\frac{q}{Q}$ is -
(A) 1 (B) 2
(C) $\frac{2\sqrt{2}}{5}$ (D) $\frac{5\sqrt{5}}{2}$ **[D]**

Q.47 Figure represents a square carrying charges +q, +q, –q, – q at its four corners as shown. Then the potential will be zero at points -



(A) A, B, C, P and Q
(B) A, B and C
(C) A, P, C and Q
(D) P, B and Q **[B]**

Q.48 At a certain distance from a point charge the electric field is 500 V/m and the potential is 3000 V. What is the distance ?
(A) 6 m (B) 12 m
(C) 36 m (D) 144 m **[A]**

Q.49 A charge of 5 C is given a displacement of 0.5 m, the work done in the process is 10 J. The potential difference between the two points will be -
(A) 2 V (B) 0.25 V
(C) 1 V (D) 25 V **[A]**

Q.50 A hollow charged metal sphere has radius r. If the potential difference between its surface and a point at a distance 3r from the centre is V, then electric field intensity at distance 3 r from the centre is -
(A) $\frac{V}{3r}$ (B) $\frac{V}{4r}$
(C) $\frac{V}{6r}$ (D) $\frac{V}{2r}$

Sol. **[C]** $V_A - V_B = \frac{KQ}{r} - \frac{KQ}{3r}$

$= \frac{KQ2}{3r}, V = \frac{2}{3}\frac{KQ}{r}$

Q.1(a) An infinite number of charges of equal magnitude ***q***, but of opposite sign consecutively are placed along the *x*-axis at x = $\sqrt{1}$ m, x = $\sqrt{2}$ m, x = $\sqrt{3}$ m and x = $\sqrt{4}$ m and so on upto + m. What is the value of net electrostatic force at the point, x = 0 where positive charge q_0 is present?

(b) Two conducting spheres carry equal charges. The distance between the spheres can not be considered large in comparison with the diameters of the spheres. In which case will the force of interaction between the spheres be greater (in absolute value) : when they carry like charges [fig .(a)] or when they carry unlike charges [fig. (b)]

Fig (a)

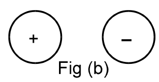


Fig (b)

Ans. **(a)** $\frac{qq_0 \log_e 2}{4\pi \in_0}$ N

(b) When they carry unlike charges

Q.2 Two identical conducting spheres, having charges of opposite sign, attract each other with a force of 0.108 N when separated by 0.5 m. The spheres are connected by a conducting wire, which is then removed, and there after repel each other with a force of 0.036 N. What were the initial charges on the spheres ?

Ans. ± 3 μC, ∓ 1μC

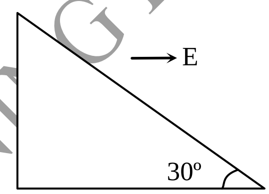
Q.3 Ten identical charges of 500 μC each are spaced equally around a circle of radius 2 m. Evaluate the electrostatic force on a charge of –20 μC located on the positive z- axis, 2 m from the *x* – *y* plane of the circle.

Ans $\vec{F} = 79.56\ (-\vec{k})$N

Q.4 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 $\in_r$ and density ρ_o. Find the density ρ of the bob for which the angle of divergence of the strings to be the same in the air and in the liquid ?

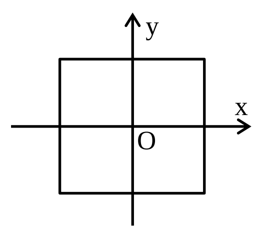
Ans. $\rho = \frac{e_r r_0}{e_r - 1}$

Q.5 An inclined plane makes an angle of 30^0 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.



Ans. t = 1.34 s

Q.6 (a) A square of side 'a' centred on the origin and with its sides parallel to the axes of *x* and *y* carries a surface charge density σ_0 within its boundaries : $\sigma(x, y) = \sigma_0\, xy$. Calculate the value of total charge on the square.



(b) A clock face has –ve point charges –q, –2q, 3q, ..., –12q fixed at the positions of the corresponding numerals. The clock hands do not disturb the net field due to the point charges. At what time does the hour hand point in the same direction as the electric field vector at the centre of the dial ?

Ans. (a) zero, (b) 9.30

Q.7 Inside a ball charged uniformly with volume density ρ there is a spherical cavity. The centre of the cavity is displaced with respect to the centre of the ball by a distance a. Find the field strength $\vec{E}$

inside the cavity, assuming the permittivity in the cavity equal to unity.

Ans. E = **a** $\rho/3\varepsilon_0$

Q.8 A particle of mass m with a charge +q is thrown upward at an angle α to the horizontal with an initial velocity v_0. All along its path a uniform electric field E exists and it is directed vertically downward. Find the time of flight, range and the maximum height reached by it. Consider gravitational field also.

Ans. $H = \dfrac{V_0^2 \sin^2\alpha}{2\left(g + \dfrac{Eq}{m}\right)}$, $R = \dfrac{V_0^2 \sin 2\alpha}{\left(g + \dfrac{Eq}{m}\right)}$

Q.9 A thin straight rod of length 2a carrying a uniformly distributed charge q is located in vacuum. Find the magnitude of the electric field strength as a function of the distance r from the rod's centre along the straight line:

(a) perpendicular to the rod and passing through its centre;

(b) coinciding with rod's direction (at the points lying outside the rod). Investigate the obtained expressions at r >> a.

Ans. (a) $E = \dfrac{q}{4\pi\varepsilon_0 r\sqrt{(a^2 + r^2)}}$

Q.10 Two positive charges q_1 and q_2 are located at the points with radius vectors $\vec{r}_1$ and $\vec{r}_2$. Find a negative charge q_3 and a radius vector $\vec{r}_3$ of the point at which it has to be placed for the force acting on each of the three charges to be equal to zero.

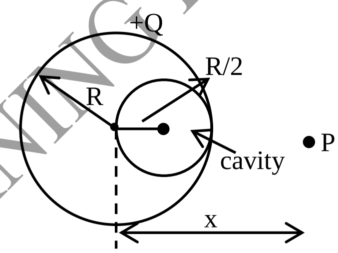
Ans. $q_3 = \dfrac{q_1 q_2}{\left(\sqrt{q_1} + \sqrt{q_2}\right)^2}$

Q.11(a) A thin wire ring of radius r has an electric charge q. What will be the increment of the force stretching the wire if a point charge q_0 is placed at the ring's centre ?

(b) A thin wire ring with a radius R and mass m carries an electric charge q. The centre of the ring contains a charge Q of the same sign as q and Q >>q. If the ring rotates with an angular velocity ω about its centre. Find the tension developed in the ring.

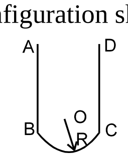
Ans. (a) $T = \dfrac{qq_0}{8\pi^2\varepsilon_0 r^2}$ (b) $\left[T = \dfrac{4\pi \in_0 m\omega^2 R^3 + Qq}{8\pi^2 \in_0 R^2}\right]$

Q.12 A solid spherical region having a spherical cavity whose diameter R is equal to the radius of the spherical region, has total charge Q. Find the electric field and potential at a point P as shown in figure.



Ans.
$E = \dfrac{\rho R^3}{3\in_0}\left[\dfrac{1}{x^2} - \dfrac{1}{R(2x-R)^2}\right]$, $V = \dfrac{\rho R^3}{3\in_0}\left[\dfrac{7x - 4R}{4x(2x-R)}\right]$

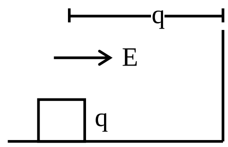
Q.13 A thread carrying a charge (uniform) λ per unit length has configuration shown in figure.



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

Ans. Zero

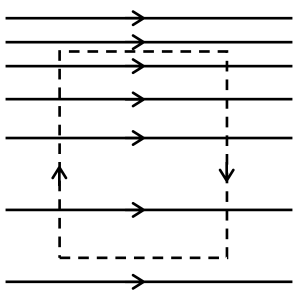
Q.14 A block of mass m containing a net positive charge q is placed on a smooth horizontal table which terminates in a vertical wall as shown in figure. The distance of the block from the wall is d. A horizontal electric field E towards right is switched on. Assuming elastic collisions (if any) find the time period of the resulting oscillatory motion. Is it a simple harmonic motion ?



Ans. $\sqrt{\dfrac{8md}{qE}}$

Q.15(A) Let us consider the configuration of an electrostatic field as shown in the fig. Is this configuration of the field possible ? Explain clearly.

(B) If field potential has the form, V (*x*, *y*) = – *axy*, where 'a' is a constant then find electric field intensity vector.



Ans. $\vec{E} = a(y\vec{i} + x\vec{j})$

Q.16 Two point charges of unknown sign but equal magnitude are fixed at positions A and B. In the figs. below, (a) to (d), potential variation between A and B is shown as we move from A to B. What can we conclude about the signs of charges at A and B for each case

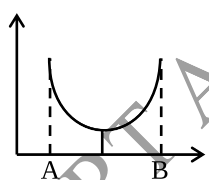


Fig (a)

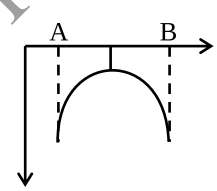


Fig (b)

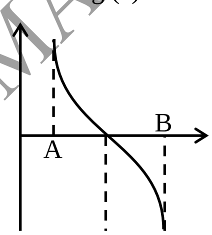


Fig (c)

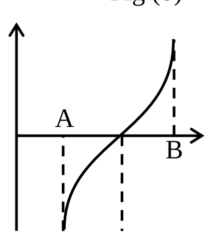


Fig (d)

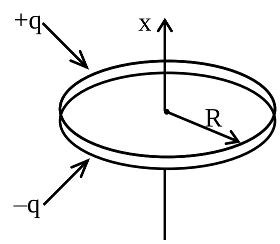
Ans. +, + ; –, –; +, – ; –, +

Q.17(a) In a typical lightning flash, the potential difference between discharge points is about 10^9 V and the quantity of charge transferred is about 30 C. How much ice would it melt at 0ºC if all the energy released could be used for this purpose ?

(b) Three concentric hollow spheres of radii 4, 6 and 8 cm have charges of +8, – 6 and 4 μC respectively. What are the potentials and field strengths at points 2, 5, 7 and 10 cm from the centre?

Ans. (a) 9 × 10^4 kg, (b) 1.35 V, 0.99 V, 0.77 V, 0.54 V; 0 V/m, 28.8 V/m, 3.67 V/m, 5.4 V/m

Q.18 Two co-axial rings, each of radius R, made of thin wire are separated by a small distance $\ell(\ell << R)$ and carry the charges q and –q. Find the electric field potential and strength on the axis of the system as a function of x- co-ordinate. Draw V versus *x* and E versus *x* diagrams. Investigate these functions at |x|>>R.



Ans. $V = \dfrac{q\ell x}{4\pi\in_0 (R^2 + x^2)^{3/2}}$, $E = \dfrac{-q\ell(R^2 - 2x^2)}{4\pi\in_0 (R^2+x^2)^{5/2}}$,

$V (x >> R) = q\ell / 4\pi\in_0 x^2$, E (X > > R)

$= q\ell / 2\pi\in_0 x^3$

Q.19 Two plane parallel conducting plates 1.5 × 10^{-2} m apart are held horizontally one above the other in air. The upper plate is maintained at positive potential of 1.5 kV while the other plate is earthed. Calculate the number of electrons which must be attached to a small oil drop of mass 4.9 × 10^{-15} kg between the plates to maintain it at rest. If the potential of upper plate is suddenly changed to – 1.5 kV, what is the initial acceleration of the charged drop ? Also obtain the terminal velocity of the drop if its radius is 5 × 10^{-6} m and coefficient of viscosity of air is 1.8 × 10^{-5} N-s/m^2. Assuming that the density of air is negligible in comparison with that of oil.

Ans. [3, 19.6 ms^{-2} downward, 5.7 × 10^{-5} ms^{-1}.]

Q.20 Two small equally charged identical conducting balls are suspended from long threads secured at one point. The charges and masses of the balls are such that they are in equilibrium when the distance between them is 10 cm (the length of the threads >> 10 cm.) One of the balls is then discharged. How will the balls behave after this ? What will be the distance between the balls when equilibrium is restored?

Ans. [10(1/4)$^{1/3}$ cm]