Exercise-1

Marked Questions may have for Revision Questions.

PART - I : SUBJECTIVE QUESTIONS

SECTION (A) : PROPERTIES OF CHARGE AND COULOMB'S LAW

A-1. Two point charges $q_1 = 2 \times 10^{-3}$ C and $q_2 = -3 \times 10^{-6}$C are separated by a distance x = 10 cm. Find the magnitude and nature of the force between the two charges.

A-2. Two point charges $q_1 = 20\mu C$ and $q_2 = 25\mu C$ are placed at (–1, 1, 1) m and (3, 1, –2)m, with respect to a coordinate system. Find the magnitude and unit vector along electrostatic force on q_2?

A-3. 20 positively charged particles are kept fixed on the X-axis at points x = 1 m, 2 m, 3 m, ..., 20 m. The first particle has a charge 1.0×10^{-6} C, the second 8×10^{-6} C, the third 27×10^{-6} C and so on. Find the magnitude of the electric force acting on a 1 C charge placed at the origin.

A.4. (i) Two charged particles having charge 4.0×10^{-6} C and mass 24×10^{-3} Kg each are joined by an insulating string of length 1 m and the system is kept on a smooth horizontal table. Find the tension in the string.
(ii) If suddenly string is cut then what is the acceleration of each particle?
(iii) Are they having equal acceleration?

A-5. Two identical conducting spheres (of negligible radius), having charges of opposite sign, attract each other with a force of 0.108 N when separated by 0.5 meter. The spheres are connected by a conducting wire, which is then removed (when charge stops flowing), and thereafter repel each other with a force of 0.036 N keeping the distance same. What were the initial charges on the spheres?

A-6. Two small spheres, each of mass 0.1 gm and carrying same charge 10^{-9} C are suspended by threads of equal length from the same point. If the distance between the centres of the sphere is 3 cm, then find out the angle made by the thread with the vertical. (g = 10 m/s^2) & $\tan^{-1}\left(\frac{1}{100}\right) = 0.6^o$

A-7. The distance between two fixed positive charges 4e and e is ℓ. How should a third charge 'q' be arranged for it to be in equilibrium? Under what condition will equilibrium of the charge 'q' be stable (for displacement on the line joining 4e and e) or will it be unstable?

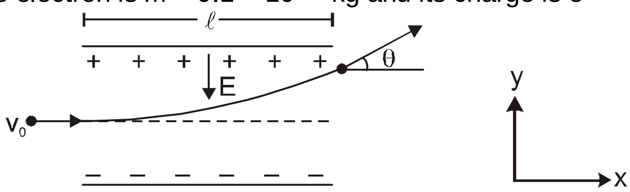
A-8. Three charges, each of value q, are placed at the corners of an equilateral triangle. A fourth charge Q is placed at the centre O of the triangle.
(a) If Q = –q, will the charges at corners start to move towards centre or away from it.
(b) For what value of Q at O will the charges remain stationary?

A-9. Two charged particles A and B, each having a charge Q are placed a distance d apart. Where should a third particle of charge q be placed on the perpendicular bisector of AB so that it experiences maximum force? Also find the magnitude of the maximum force.

SECTION (B) : ELECTRIC FIELD

B-1. The electric force experienced by a charge of 5×10^{-6} C is 25×10^{-3} N. Find the magnitude of the electric field at that position of the charge due to the source charges.

B-2. A uniform electric field $E = 91 \times 10^{-6}$ V/m is created between two parallel, charged plates as shown in figure. An electron enters the field symmetrically between the plates with a speed $v_0 = 4 \times 10^3$ m/s. The length of each plate is ℓ = 1m. Find the angle of deviation of the path of the electron as it comes out of the field. (Mass of the electron is $m = 9.1 \times 10^{-31}$ kg and its charge is $e = -1.6 \times 10^{-19}$ C).



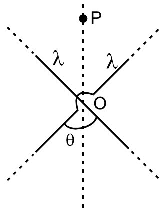
B-3. Two point particles A and B having charges of 4×10^{-6} C and -64×10^{-6} C respectively are held at a separation of 90 cm. Locate the point(s) on the line AB or on its extension where the electric field is zero.

B-4. Three point charges q_0 are placed at three corners of square of side a. Find out electric field intensity at the fourth corner.

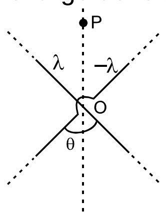
B-5. Two point charges $3\mu C$ and $2.5\ \mu C$ are placed at point A (1, 1, 2)m and B (0, 3, –1)m respectively. Find out electric field intensity at point C(3, 3, 3)m.

B-6. A hollow sphere of radius a carries a total charge Q distributed uniformly over its surface. A small area dA of the sphere is cut off. Find the electric field at the centre due to the remaining sphere.

B-7. (i) Two infinitely long line charges each of linear charge density λ are placed at an angle θ as shown in figure. Find out electric field intensity at a point P, which is at a distance x from point O along angle bisector of line charges.

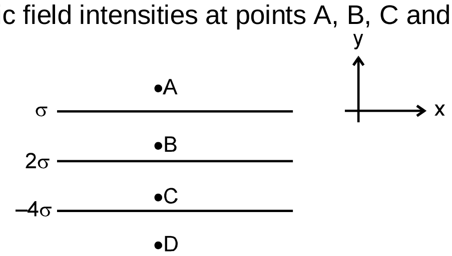


(ii) Repeat the above question if the line charge densities are λ and $-\lambda$. as shown in figure.



B-8. The bob of a simple pendulum has a mass of 60 g and a positive charge of 6×10^{-6} C. It makes 30 oscillations in 50 s above earth's surface. A vertical electric field pointing upward and of magnitude 5×10^4 N/C is switched on. How much time will it now take to complete 60 oscillations? ($g = 10\ m/s^2$)

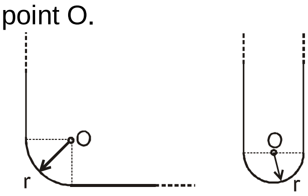
B-9. If three infinite charged sheets of uniform surface charge densities σ, 2σ and -4σ are placed as shown in figure, then find out electric field intensities at points A, B, C and D.



B-10. Find out electric field intensity due to uniformly charged solid non-conducting sphere of volume charge density ρ and radius R at following points :
(i) At a distance r from surface of sphere (inside)
(ii) At a distance r from the surface of sphere (outside)

B-11. Repeat the question if sphere is a hollow non-conducting sphere of radius R and has uniform surface charge density σ.

B-12. A thread carrying a uniform charge λ per unit length has the configuration shown in figure a and b. Assuming a curvature radius r to be considerably less than the length of the thread, find the magnitude of the electric field strength at the point O.



SECTION (C) : ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

C-1. A point charge 20 μC is shifted from infinity to a point P in an electric field with zero acceleration. If the potential of that point is 1000 volt, then
(i) Find out work done by external agent against electric field?
(ii) What is the work done by electric field?
(iii) If the kinetic energy of charge particle is found to increase by 10 mJ when it is brought from infinity to point P, then what is the total work done by external agent?
(iv) What is the work done by electric field in the part (iii)
(v) If a point charge 30 μC is released at rest at point P, then find out its kinetic energy at a large distance?

C-2. Two particles A and B having charges of 4×10^{-6} C and -8×10^{-6} C respectively, are held fixed at a separation of 60 cm. Locate the point(s) on the line AB where the electric potential is zero.

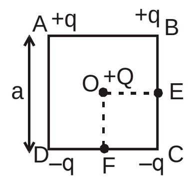
C-3. Six equal point charges q_0' each are placed at six corners of a regular hexagon of side 'a'. Find out work required to take a point charge 'q' slowly :
(i) From infinity to the centre of hexagon.
(ii) From infinity to a point on the axis which is at a distance '$\sqrt{3}$ a' from the centre of hexagon.
(iii) Does your answer to part (i) and (ii) depends on the path followed by the charge.

C-4. 20 J of work has to be done against an existing electric field to take a charge of 0.05 C from A to B. How much is the potential difference $V_B - V_A$?

C-5. A charge of 8 mC is located at the origin. Calculate the work done by external agent in taking a small charge of -2×10^{-9} C from a point A(0, 0, 0.03 m) to a point B(0, 0.04 m, 0) via a point C(0, 0.06 m, 0.09 m).

C-6. A positive charge Q = 50 μ C is located in the xy plane at a point having position vector $\vec{r}_0 = \left(2\hat{i} + 3\hat{j}\right)$ m where $\hat{i}$ and $\hat{j}$ are unit vectors in the positive directions of X and Y axis respectively. Find:
(a) The electric intensity vector and its magnitude at a point having co-ordinates (8 m, – 5 m).
(b) Work done by external agent in transporting a charge q = 10 μC from (8 m, 6 m) to the point (4 m, 3 m).

C-7. Four charges + q, + q, – q, – q are fixed respectively at the corners of A, B, C and D of a square of side 'a' arranged in the given order. Calculate the electric potential and intensity at O (Center of square). If E and F are the midpoints of sides BC, CD respectively, what will be the work done by external agent in carrying a charge Q slowly from O to E and from O to F?



C-8. A charge Q is distributed over two concentric hollow spheres of radius r and R (R > r), such that the surface densities of charge are equal. Find the potential at the common centre.

C-9. Two uniformly charged concentric hollow spheres of radii R and 2 R are charged. The inner sphere has a charge of 1 μC and the outer sphere has a charge of 2 μC of the same sign. The potential is 9000 V at a point P at a distance 3R from the common centre O. What is the value of R?

C-10. In front of a uniformly charged infinite non-conducting sheet of surface charge density σ, a point charge q_0 is shifted slowly from a distance a to b (b > a). If work done by external agent is W, then find out relation between the given parameters.

C-11. An electric field of 20 N/C exists along the negative x-axis in space. Calculate the potential difference $V_B - V_A$, where the points A and B are given by :
(a) A = (0, 0) ; B = (0, 4m) (b) A = (2m, 1m) ; B = (4m, 3m)

C-12. A uniform field of 8 N/C exists in space in positive x-direction.
(a) Taking the potential at the origin to be zero, write an expression for the potential at a general point (x, y, z). (b) At which points, the potential is 160 V? (c) If the potential at the origin is taken to be 80V, what will be the expression for the potential at a general point? (d) What will be the potential at the origin if the potential at x = infinity is taken to be zero ?

C-13. A particle of charge $+3 \times 10^{-9}$ C is in a uniform field directed to the left. It is released from rest and moves a distance of 5 cm, after which its kinetic energy is found to be 4.5×10^{-5} J.
(a) What work was done by the electrical force?
(b) What is the magnitude of the electrical field?
(c) What is the potential of the starting point with respect to the end point?

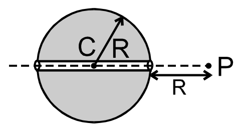
C-14. In the previous problem, suppose that another force in addition to the electrical force acts on the particle so that when it is released from rest, it moves to the right. After it has moved 5 cm, the additional force has done 9×10^{-5} J of work and the particle has 4.5×10^{-5} J of kinetic energy.
(a) What work was done by the electrical force?
(b) What is the magnitude of the electric field?
(c) What is the potential of the starting point with respect to the end point?

SECTION (D) : ELECTRIC POTENTIAL ENERGY OF A POINT CHARGE

D-1. An α particle is placed in an electric field at a point having electric potential 5V. Find its potential energy ?

D-2. Find the potential energy of a charge q_0 placed at the centre of regular hexagon of side a, if charge q is placed at each vertex of regular hexagon?

D-3. A solid uniformly charged fixed non-conducting sphere of total charge Q and radius R contains a tunnel of negligible diameter. If a point charge '–q' of mass 'm' is released at rest from point P as shown in figure then find out its velocity at following points



(i) At the surface of sphere (ii) At the centre of the sphere

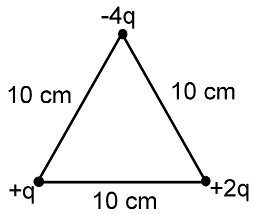
D-4. Two identical charges, 5 μC each are fixed at a distance 8 cm and a charged particle of mass 9×10^{-6} kg and charge – 10 μC is placed at a distance 5 cm from each of them and is released. Find the speed of the particle when it is nearest to the two charges.

D-5. A particle of mass m, charge q > 0 and initial kinetic energy K is projected from infinity towards a heavy nucleus of charge Q assumed to have a fixed position.
(a) If the aim is perfect, how close to the centre of the nucleus is the particle when it comes instantaneously to rest?
(b) With a particular imperfect aim, the particle's closest approach to nucleus is twice the distance determined in (a). Determine speed of particle at the closest distance of approach.

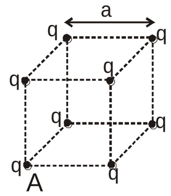
SECTION (E) : POTENTIAL ENERGY OF A SYSTEM OF POINT CHARGES

E-1. Two positive point charges 15 μC and 10 μC are 30 cm apart. Calculate the work done in bringing them closer to each other by 15 cm.

E-2. Three point charges are arranged at the three vertices of a triangle as shown in Figure. Given : $q = 10^{-7}$ C, calculate the electrostatic potential energy of the system.

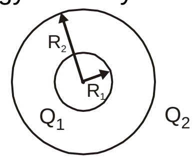


E-3. Eight equal point charges each of charge 'q' and mass 'm' are placed at eight corners of a cube of side 'a'.
(i) Find out potential energy of charge system
(ii) Find out work done by external agent against electrostatic forces and by electrostatic forces to increase all sides of cube from a to 2a.
(iii) If all the charges are released at rest, then find out their speed when they are at the corners of cube of side 2a.
(iv) If keeping all other charges fixed, charge of corner 'A' is released then find out its speed when it is at infinite distance?
(v) If all charges are released simultaneously from rest then find out their speed when they are at a very large distance from each other.



SECTION (F) : SELF ENERGY AND ENERGY DENSITY

F-1. Two concentric spherical shells of radius R_1 and R_2 ($R_2 > R_1$) are having uniformly distributed charges Q_1 and Q_2 respectively. Find out total energy of the system.



F-2 A spherical shell of radius R with a uniform charge q has point charge q_0 at its centre. Find the work performed by the electric forces during the shell expansion slowly from radius R to 2R. Also find out work done by external agent against electric forces.

F-3. Two identical non-conducting spherical shells having equal charge Q, which is uniformly distributed on it, are placed at a distance d apart. From where they are released. Find out kinetic energy of each sphere when they are at a large distance.

F-4. In a solid uniformly charged sphere of total charge Q and radius R, if energy stored out side the sphere is U_0 joules then find out self energy of sphere in term of U_0?

SECTION (G) : QUESTIONS BASED ON RELATION BETWEEN $\vec{E}$ AND V :

G-1. If $\vec{E} = 2y\hat{i} + 2x\hat{j}$, then find V(x, y, z).

G-2. If $V = x^2y + y^2z$ then find $\vec{E}$(x, y, z).

G-3. If $V = 2r^2$ then find out (i) $\vec{E}(1, 0, -2)$ (ii) $\vec{E}(r = 2)$

G-4. An electric field $\vec{E} = (10\hat{i} + 20\hat{j})$ N/C exists in the space. If the potential at the origin is taken to be zero, find the potential at (3m, 3m).

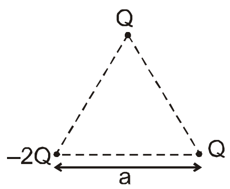
G-5. An electric field $\vec{E} = Bx\hat{i}$ exists in space, where B = 20 V/m^2. Taking the potential at (2 m, 4 m) to be zero, find the potential at the origin.

G-6. If $E = 2r^2$, then find V(r)

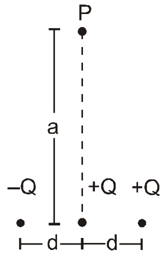
G-7. If $\vec{E} = 2x^2\hat{i} - 3y^2\hat{j}$, then find V(x, y, z)

SECTION (H) : DIPOLE

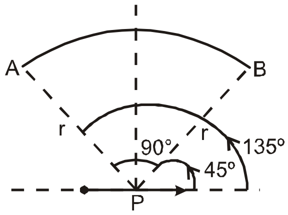
H-1. Three charges are arranged on the vertices of an equilateral triangle as shown in figure. Find the dipole moment of the combination.



H-2. Three point charges –Q, Q and Q are placed on a straight line with distance d between chargesas shown. Find the magnitude of the electric field at the point P in the configuration shown which is at a distance a from middle charge Q in the system provided that a >> d. Take 2Qd = p.



H-3. A charge ' q ' is carried slowly from a point A (r, 135º) to a point B (r, 45º) following a path which is a quadrant of circle of radius ' r '. If the dipole moment is $\vec{P}$, then find out the work done by external agent.



H-4. Find out the magnitude of electric field intensity and electric potential due to a dipole of dipole moment $\vec{P} = \hat{i} + \sqrt{3}\hat{j}$ kept at origin at following points.

(i) (2, 0, 0) (ii) (–1, $\sqrt{3}$, 0)

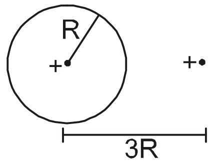
H-5. A molecule of a substance has permanent electric dipole moment equal to 10^{-29} C-m. A mole of this substance is polarised (at low temperature) by applying a strong electrostatic field of magnitude (10^6 Vm^{-1}). The direction of the field is suddenly changed by an angle of 60º. Estimate the heat released by the substance in aligning its dipoles along the new direction of the field. For simplicity, assume 100% polarisation to the sample.

SECTION (I) : ELECTRIC LINES OF FORCE, FLUX CALCULATION AND GAUSS'S LAW

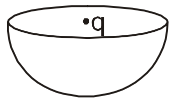
I-1. Find out the electric flux through an area 10 m^2 lying in XY plane due to an electric field $\vec{E} = 2\hat{i} - 10\hat{j} + 5\hat{k}$

I-2. In a uniform electric field E if we consider an imaginary cubical closed suface of side a, then find the net flux through the cube ?

I-3. Find the flux of the electric field through a spherical surface of radius R due to a charge of 8.85 × 10^{-8}C at the centre and another equal charge at a point 3R away from the centre
(Given : ε_0 = 8.85 × 10^{-12} units)



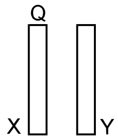
I-4. A charge q is placed at the centre of an imaginary hemispherical surface. Using symmetry arguments and the Gauss's law, find the electric flux due to this charge through the given surface.



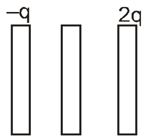
I-5. What do you predict by the given statement about the nature of charge (positive or negative) enclosed by the closed surface. "In a closed surface, lines which are leaving the surface are double than the lines which are entering it".

SECTION (J) : CONDUCTOR, IT'S PROPERTIES & ELECTRIC PRESSURE

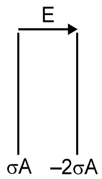
J-1. Two conducting plates X and Y, each having large surface area A (on one side), are placed parallel to each other as shown in figure. The plate X is given a charge Q whereas the other is neutral. Find:
(a) The surface charge density at the inner surface of the plate X,
(b) The electric field at a point to the left of the plates,
(c) The electric field at a point in between the plates and
(d) The electric field at a point to the right of the plates.



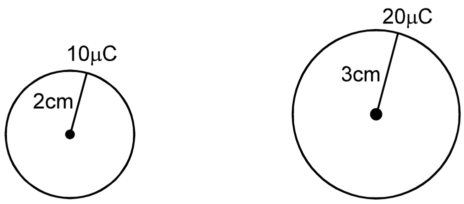
J-2. Three identical metal plates with large equal surface areas are kept parallel to each other as shown in figure. The leftmost plate is given a charge –q, the rightmost a charge 2q and the middle one remains neutral. Find the charge appearing on the outer surface of the leftmost plate.



J-3. Two thin conducting plates (very large) parallel to each other carrying total charges σA and $-2\sigma A$ respectively (where A is the area of each plate), are placed in a uniform external electric field E as shown. Find the surface charge on each surface.



J-4. Figure shows two conducting spheres separated by large distance and of radius 2cm and 3cm containing charges $10\mu C$ and $20\mu C$ respectively. When the spheres are connected by a conducting wire then find out following :

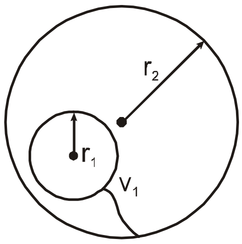


(i) Ratio of the final charge.
(ii) Final charge on each sphere.
(iii) Ratio of final charge densities.
(iv) Heat produced during the process.

J-5. Two concentric hollow conducting spheres of radius a and b (b > a) contains charges Q_a and Q_b respectively. If they are connected by a conducting wire then find out following
(i) Final charges on inner and outer spheres.
(ii) Heat produced during the process.

J-6. There are two concentric metal shells of radii r_1 and r_2 (> r_1). If initially, the outer shell has a charge q and the inner shell is having zero charge and then inner shell is grounded. Find :
(i) Charge on the inner surface of outer shell.
(ii) Final charges on each sphere.
(iii) Charge flown through wire in the ground.

J-7. A metal sphere of radius r_1 charged to a potential V_1 is then palced in a thin-walled uncharged conducting spherical shell of radius r_2. Determine the potential acquired by the spherical shell after it has been connected for a short time to the sphere by a conductor.



PART - II : ONLY ONE OPTION CORRECT TYPE

SECTION (A) : PROPERTIES OF CHARGE AND COULOMB'S LAW

A-1. A charged particle q_1 is at position (2, –1, 3). The electrostatic force on another charged particle q_2 at (0, 0, 0) is :

(A) $\frac{q_1q_2}{56\pi\in_0}(2\hat{i}-\hat{j}+3\hat{k})$ (B) $\frac{q_1q_2}{56\sqrt{14}\pi\in_0}(2\hat{i}-\hat{j}+3\hat{k})$

(C) $\frac{q_1q_2}{56\pi\in_0}(\hat{j}-2\hat{i}-3\hat{k})$ (D) $\frac{q_1q_2}{56\sqrt{14}\pi\in_0}(\hat{j}-2\hat{i}-3\hat{k})$

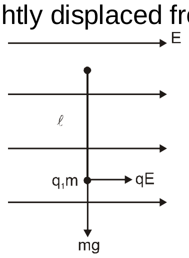
A-2. Three charges +4q, Q and q are placed in a straight line of length ℓ at points at distance 0, $\ell/2$ and ℓ respectively from one end of line. What should be the value of Q in order to make the net force on q to be zero?
(A) –q (B) –2q (C) –q/2 (D) 4q

A-3. Two similar very small conducting spheres having charges 40 μC and –20 μC are some distance apart. Now they are touched and kept at the same distance. The ratio of the initial to the final force between them is :
(A) 8 : 1 (B) 4 : 1 (C) 1 : 8 (D) 1 : 1

A-4. 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/4 (C) r/8 (D) 2r

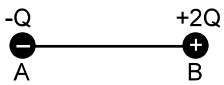
SECTION (B) : ELECTRIC FIELD

B-1. A simple pendulum has a length ℓ & mass of bob m. The bob is given a charge q coulomb. The pendulum is suspended in a uniform horizontal electric field of strength E as shown in figure, then calculate the time period of oscillation when the bob is slightly displaced from its mean position.



(A) $2\pi\sqrt{\frac{\ell}{g}}$ (B) $2\pi\sqrt{\left\{\frac{\ell}{g+\frac{qE}{m}}\right\}}$ (C) $2\pi\sqrt{\left\{\frac{\ell}{g-\frac{qE}{m}}\right\}}$ (D) $2\pi\sqrt{\frac{\ell}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

B-2. Charges 2Q and –Q are placed as shown in figure. The point at which electric field intensity is zero will be:



(A) Somewhere between –Q and 2Q (B) Somewhere on the left of –Q
(C) Somewhere on the right of 2Q
(D) Somewhere on the perpendicular bisector of line joining –Q and 2Q

B-3. The maximum electric field intensity on the axis of a uniformly charged ring of charge q and radius R will be :

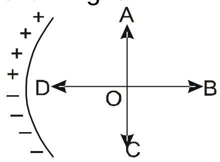
(A) $\frac{1}{4\pi\varepsilon_0}\frac{q}{3\sqrt{3}R^2}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{3R^2}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{3\sqrt{3}R^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{3q}{2\sqrt{3}R^2}$

B-4. A charged particle of charge q and mass m is released from rest in a uniform electric field E. Neglecting the effect of gravity, the kinetic energy of the charged particle after time 't' seconds is

(A) $\frac{Eqm}{t}$ (B) $\frac{E^2q^2t^2}{2m}$ (C) $\frac{2E^2t^2}{mq}$ (D) $\frac{Eq^2m}{2t^2}$

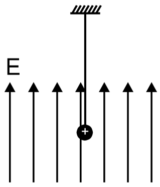
B-5. A flat circular fixed disc has a charge +Q uniformly distributed on the disc. A charge +q is thrown with kinetic energy K, towards the disc along its axis. The charge q :
(A) may hit the disc at the centre
(B) may return back along its path after touching the disc
(C) may return back along its path without touching the disc
(D) any of the above three situations is possible depending on the magnitude of K

B-6. The linear charge density on upper half of semi-circular section of ring is λ and that at lower half is $-\lambda$. The direction of electric field at centre O of ring is :



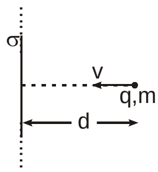
(A) along OA (B) along OB (C) along OC (D) along OD

B-7. A positively charged pendulum is oscillating in a uniform electric field as shown in Figure. Its time period of SHM as compared to that when it was uncharged. (mg > qE)



(A) Will increase (B) Will decrease
(C) Will not change (D) Will first increase then decrease

B-8. The particle of mass m and charge q will touch the infinitely large plate of uniform charge density σ if its velocity v is more than: {Given that $\sigma q > 0$}



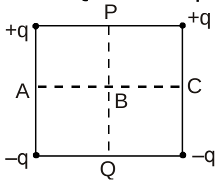
(A) 0 (B) $\sqrt{\dfrac{2\sigma q d}{m \epsilon_0}}$ (C) $\sqrt{\dfrac{\sigma q d}{m \epsilon_0}}$ (D) none of these

B-9. There is a uniform electric field in X-direction. If the work done by external agent in moving a charge of 0.2 C through a distance of 2 metre slowly along the line making an angle of 60º with X-direction is 4 joule, then the magnitude of E is :
(A) $\sqrt{3}$N/C (B) 4 N/C (C) 5 N/C (D) 20 N/C

SECTION (C) : ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

C-1. 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

C-2. 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, C, P and Q are mid points of sides)



(A) A, B, C, P and Q (B) A, B and C (C) A, P, C and Q (D) P, B and Q

C-3. Two equal positive charges are kept at points A and B. The electric potential, while moving from A to B along straight line :
(A) continuously increases (B) remains constant
(C) decreases then increases (D) increases then decreases

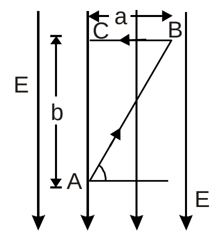
C-4. A semicircular ring of radius 0.5 m is uniformly charged with a total charge of 1.5×10^{-9} coul. The electric potential at the centre of this ring is :
(A) 27 V (B) 13.5 V (C) 54 V (D) 45.5 V

C-5. When a charge of 3 coul is placed in a uniform electric field, it experiences a force of 3000 newton. The potential difference between two points separated by a distance of 1 cm along field within this field is:
(A) 10 volt (B) 90 volt (C) 1000 volt (D) 3000 volt

C-6. A 5 coulomb charge experiences a constant force of 2000 N when moved between two points separated by a distance of 2 cm in a uniform electric field. The potential difference between these two points is:
(A) 8 V (B) 200 V (C) 800 V (D) 20,000 V

C-7. The kinetic energy which an electron acquires when accelerated (from rest) through a potential difference of 1 volt is called :
(A) 1 joule (B) 1 electron volt (C) 1 erg (D) 1 watt

C-8. The potential difference between points A and B in the given uniform electric field is :



(A) Ea (B) $E\sqrt{(a^2+b^2)}$ (C) Eb (D) $(Eb/\sqrt{2})$

C-9. An equipotential surface and an electric line of force :
(A) never intersect each other (B) intersect at 45º
(C) intersect at 60º (D) intersect at 90º

C-10. A particle of charge Q and mass m travels through a potential difference V from rest. The final momentum of the particle is :
(A) $\frac{mV}{Q}$ (B) $2Q\sqrt{mV}$ (C) $\sqrt{2mQV}$ (D) $\sqrt{\frac{2QV}{m}}$

C-11. If a uniformly charged spherical shell of radius 10 cm has a potential V at a point distant 5 cm from its centre, then the potential at a point distant 15 cm from the centre will be :
(A) $\frac{V}{3}$ (B) $\frac{2V}{3}$ (C) $\frac{3}{2}V$ (D) 3V

C-12. A hollow uniformly charged sphere has radius r. If the potential difference between its surface and a point at distance 3r from the centre is V, then the electric field intensity at a distance 3r from the centre is:
(A) V/6r (B) V/4r (C) V/3r (D) V/2r

C-13. A hollow sphere of radius 5 cm is uniformly charged such that the potential on its surface is 10 volts then potential at centre of sphere will be :
(A) Zero
(B) 10 volt
(C) Same as at a point 5 cm away from the surface
(D) Same as at a point 25 cm away from the centre

C-14. A charge +q is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$, ... upto infinity on the x-axis and a charge –q is fixed at each of the points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$, ... upto infinity. Here x_0 is a positive $\frac{Q}{4\pi\epsilon_0 r}$ constant. Take the electric potential at a point due to a charge Q at a distance r from it to be. Then the potential at the origin due to the above system of charges is: **[JEE 1998 Screening, 2/200]**
(A) 0 (B) $\frac{q}{8\pi\epsilon_0 x_0 \ell n2}$ (C) ∞ (D) $\frac{q\,\ell n2}{4\pi\epsilon_0 x_0}$

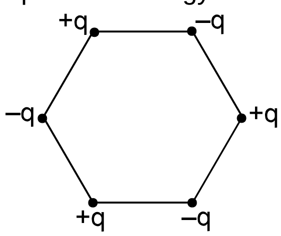
SECTION (D) : ELECTRIC POTENTIAL ENERGY OF A PARTICLE

D-1. If a charge is shifted from a high potential region to low potential region, the electrical potential energy:
(A) Increases (B) Decreases
(C) May increase or decrease. (D) Remains constant

D-2. A particle of mass 2 g and charge 1μC is held at rest on a frictionless horizontal surface at a distance of 1 m from a fixed charge of 1 mC. If the particle is released it will be repelled. The speed of the particle when it is at distance of 10 m from the fixed charge is:
(A) 100 m/s (B) 90 m/s (C) 60 m/s (D) 45 m/s

SECTION (E) : POTENTIAL ENERGY OF A SYSTEM OF POINT CHARGES

E-1. Six charges of magnitude + q and –q are fixed at the corners of a regular hexagon of edge length a as shown in the figure. The electrostatic potential energy of the system of charged particles is :



(A) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{8}-\frac{15}{4}\right]$ (B) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{2}-\frac{9}{4}\right]$ (C) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{4}-\frac{15}{2}\right]$ (D) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{2}-\frac{15}{8}\right]$

E-2. You are given an arrangement of three point charges q, 2q and xq separated by equal finite distances so that electric potential energy of the system is zero. Then the value of x is :
(A) $-\frac{2}{3}$ (B) $-\frac{1}{3}$ (C) $\frac{2}{3}$ (D) $\frac{3}{2}$

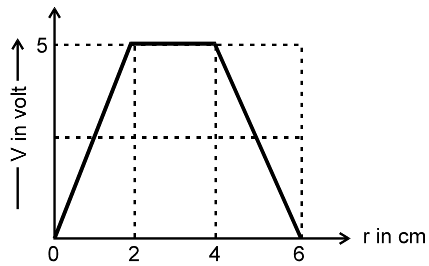
SECTION (F) : SELF ENERGY AND ENERGY DENSITY

F-1. A uniformly charged sphere of radius 1 cm has potential of 8000 V at surface. The energy density near the surface of sphere will be:
(A) 64×10^5 J/m^3 (B) 8×10^3 J/m^3 (C) 32 J/m^3 (D) 2.83 J/m^3

F-2. If ' n ' identical water drops (assumed spherical each) each charged to a potential energy U coalesce to form a single drop, the potential energy of the single drop is(Assume that drops are uniformly charged):
(A) $n^{1/3}$ U (B) $n^{2/3}$ U (C) $n^{4/3}$ U (D) $n^{5/3}$ U

SECTION (G) : QUESTIONS BASED ON RELATION BETWEEN $\vec{E}$ AND V :

G-1. The variation of potential with distance r from a fixed point is shown in Figure. The electric field at r = 5 cm, is :



(A) (2.5) V/cm (B) (–2.5) V/cm (C) (–2/5) cm (D) (2/5) V/cm

G-2. In the above question, the electric force acting on a point charge of 2 C placed at the origin will be :
(A) 2 N (B) 500 N (C) –5 N (D) –500 N

G-3. The electric potential V as a function of distance x (in metre) is given by V = $(5x^2 + 10x - 9)$ volt. The value of electric field at x = 1 m would be :
(A) – 20 volt/m (B) 6 volt/m (C) 11 volt/m (D) –23 volt/m

G-4. A uniform electric field having a magnitude E_0 and direction along positive x-axis exists. If the electric potential V is zero at x = 0, then its value at x = +x will be :
(A) $V_x = xE_0$ (B) $V_x = -xE_0$ (C) $V_x = x^2E_0$ (D) $V_x = -x^2 E_0$

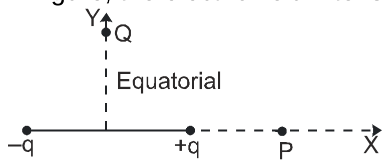
G-5. Let E be the electric field and V, the electric potential at a point.
(A) If E ≠ 0, V cannot be zero (B) If E = 0, V must be zero
(C) If V = 0, E must be zero (D) None of these

G-6. The electric field in a region is directed outward and is proportional to the distance r from the origin. Taking the electric potential at the origin to be zero, the electric potential at a distance r :
(A) increases as one goes away from the origin. (B) is proportional to r^2
(C) is proportional to r (D) is uniform in the region

G-7. A non-conducting ring of radius 0.5 m carries a total charge of 1.11×10^{-10} C distributed non-uniformly on its circumference producing an electric field $\vec{E}$ every where in space. The value of the line integral $\int_{\ell=\infty}^{\ell=0} -\vec{E}.d\vec{\ell}$ (ℓ = 0 being centre of the ring) in volts is : (Approximately) **[JEE 1997, 1]**
(A) +2 (B) –1 (C) –2 (D) zero

SECTION (H) : DIPOLE

H-1. Due to an electric dipole shown in figure, the electric field intensity is parallel to dipole axis :



(A) at P only (B) at Q only (C) both at P and at Q (D) neither at P nor at Q

H-2. An electric dipole of dipole moment $\vec{p}$ is placed at the origin along the x-axis. The angle made by electric field with x-axis at a point P, whose position vector makes an angle θ with x-axis, is :
(where, $\tan\alpha = 1/2 \tan\theta$)
(A) α (B) θ (C) θ + α (D) θ + 2α

H-3. An electric dipole consists of two opposite charges each of magnitude 1.0 μC, separated by a distance of 2.0 cm. The dipole is placed in an external electric field of 1.0×10^5 N/C. The maximum torque on the dipole is :
(A) 0.2×10^{-3} N-m (B) 1.0×10^{-3} N-m (C) 2.0×10^{-3} N-m (D) 4.0×10^{-3} N-m

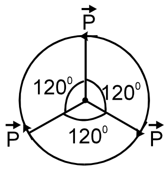
H-4. A dipole of electric dipole moment P is placed in a uniform electric field of strength E. If θ is the angle between positive directions of P and E, then the potential energy of the electric dipole is largest when θ is :
(A) zero (B) $\pi/2$ (C) π (D) $\pi/4$

H-5. Two opposite and equal charges of magnitude 4×10^{-8} coulomb each when placed 2×10^{-2} cm apart form a dipole. If this dipole is placed in an external electric field of 4×10^{8} N/C, the value of maximum torque and the work required in rotating it through 180º from its initial orientation which is along electric field will be : (Assume rotation of dipole about an axis passing through centre of the dipole):
(A) 64×10^{-4} N-m and 44×10^{-4} J
(B) 32×10^{-4} N-m and 32×10^{-4} J
(C) 64×10^{-4} N-m and 32×10^{-4} J
(D) 32×10^{-4} N-m and 64×10^{-4} J

H-6. At a point on the axis (but not inside the dipole and not at infinity) of an electric dipole
(A) The electric field is zero
(B) The electric potential is zero
(C) Neither the electric field nor the electric potential is zero
(D) The electric field is directed perpendicular to the axis of the dipole

H-7. The force between two short electric dipoles separated by a distance r is directly proportional to :
(A) r^2 (B) r^4 (C) r^{-2} (D) r^{-4}

H-8. Three dipoles each of dipole moment of magnitude p are placed tangentially on a circle of radius R in its plane positioned at equal angle from each other as shown in the figure. Then the magnitude of electric field intensity at the centre of the circle will be :



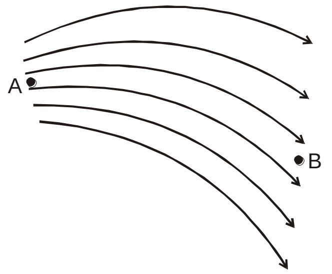
(A) $\frac{4kp}{R^3}$ (B) $\frac{2kp}{R^3}$ (C) $\frac{kp}{R^3}$ (D) 0

SECTION (I) : ELECTRIC LINES OF FORCE, FLUX CALCULATION AND GAUSS'S LAW

I-1. A square of side 'a' is lying in xy plane such that two of its sides are lying on the axis. If an electric field $\vec{E} = E_0 x\hat{k}$ is applied on the square. The flux passing through the square is :
(A) E_0a^3 (B) $\frac{E_0a^3}{2}$ (C) $\frac{E_0a^3}{3}$ (D) $\frac{E_0a^2}{2}$

I-2. If electric field is uniform, then the electric lines of forces are:
(A) Divergent (B) Convergent (C) Circular (D) Parallel

I-3. The figure shows the electric lines of force emerging from a charged body. If the electric fields at A and B are E_A and E_B respectively and if the distance between A and B is r, then



(A) $E_A < E_B$ (B) $E_A > E_B$ (C) $E_A = \frac{E_B}{r}$ (D) $E_A = \frac{E_B}{r^2}$

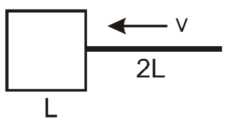
I-4. Select the correct statement :
(A) The electric lines of force are always closed curves
(B) Electric lines of force are parallel to equipotential surface
(C) Electric lines of force are perpendicular to equipotential surface
(D) Electric line of force is always the path of a positively charged particle.

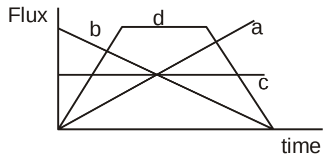
I-5. If the electric flux entering and leaving a closed surface are respectively of magnitude ϕ_1 and ϕ_2, then the electric charge inside the surface will be :

(A) $\frac{\phi_2-\phi_1}{\varepsilon_0}$ (B) $(\phi_1-\phi_2)\varepsilon_0$ (C) $\varepsilon_0(\phi_2-\phi_1)$ (D) $\varepsilon_0(\phi_2+\phi_1)$

I-6. An electric dipole is placed at the centre of a sphere. Mark the correct options.
(A) The electric field is zero at every point of the sphere.
(B) The flux of the electric field through the sphere is non-zero.
(C) The electric field is zero on a circle on the sphere.
(D) The electic field is not zero anywhere on the sphere.

I-7. Figure (i) shows an imaginary cube of edge length L. A uniformly charged rod of length 2L moves towards left at a small but constant speed v. At t = 0, the left end of the rod just touches the centre of the face of the cube opposite to it. Which of the graphs shown in figure (ii) represents the flux of the electric field through the cube as the rod goes through it ?

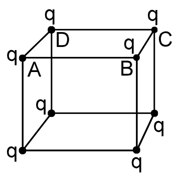
(i) 

(ii) 

(A) a (B) b (C) c (D) d

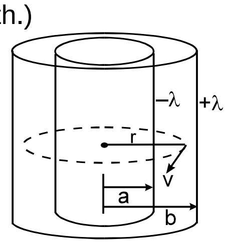
I-8. Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 20 cm surrounding the total charge is 50 V-m. The flux over a concentric sphere of radius 40 cm will be:
(A) 50 V-m (B) 75 V-m (C) 100 V-m (D) 200 V-m

I-9. Eight point charges (can be assumed as uniformly charged small spheres and their centres at the corner of the cube) having value q each are fixed at vertices of a cube. The electric flux through square surface ABCD of the cube is



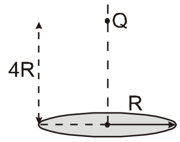
(A) $\frac{q}{24\in_0}$ (B) $\frac{q}{12\in_0}$ (C) $\frac{q}{6\in_0}$ (D) $\frac{q}{8\in_0}$

I-10. Figure shows two large cylindrical shells having uniform linear charge densities + λ and – λ. Radius of inner cylinder is 'a' and that of outer cylinder is 'b'. A charged particle of mass m, charge q revolves in a circle of radius r. Then, its speed 'v' is : (Neglect gravity and assume the radii of both the cylinders to be very small in comparison to their length.)



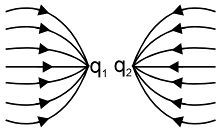
(A) $\sqrt{\frac{\lambda q}{2\pi\in_0 m}}$ (B) $\sqrt{\frac{2\lambda q}{\pi\in_0 m}}$ (C) $\sqrt{\frac{\lambda q}{\pi\in_0 m}}$ (D) $\sqrt{\frac{\lambda q}{4\pi\varepsilon_0 m}}$

I-11. A positive charge Q is placed at a distance of 4R above the centre of a disc of radius R. The magnitude of flux through the disc is ϕ. Now a hemispherical shell of radius R is placed over the disc such that it forms a closed surface. The flux through the curved surface (taking direction of area vector along outward normal as positive), is :



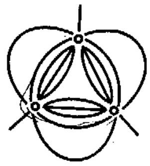
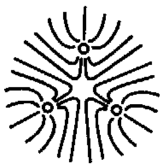
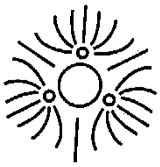
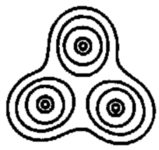
(A) zero (B) ϕ (C) $-\phi$ (D) 2ϕ

I-12. The given figure gives electric lines of force due to two charges q_1 and q_2. What are the signs of the two charges?

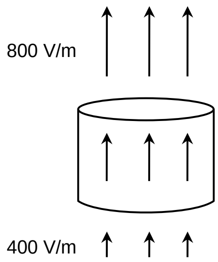


(A) Both are negative
(B) Both are positive
(C) q_1 is positive but q_2 is negative
(D) q_1 is negative but q_2 is positive

I-13. Three positive charges of equal value q are placed at the vertices of an equilateral triangle. The resulting lines of force should be sketched as in : **[JEE 2001(Scr.), 3/105]**

(A) 
(B) 
(C) 
(D) 

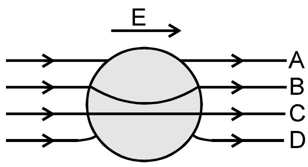
I-14. A cylinder on whose surfaces there is a vertical electric field of varying magnitude as shown. The electric field is uniform on the top surface as well as on the bottom surface therefore, this cylinder encloses **[Olympiad (stage-1) 2017]**



(A) no net charge
(B) net positive charge
(C) net negative charge
(D) There is not enough information to determine whether or not there is net charge inside the cylinder.

SECTION (J) : CONDUCTOR, IT'S PROPERTIES & ELECTRIC PRESSURE

J-1. A metallic solid sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in figure as : **[JEE 1996, 2/100]**



(A) A (B) B (C) C (D) D

J-2. A neutral spherical metallic object A is placed near a finite metal plate B carrying a positive charge. The electric force on the object will be :
(A) away from the plate B
(B) towards the plate B
(C) parallel to the plate B
(D) zero

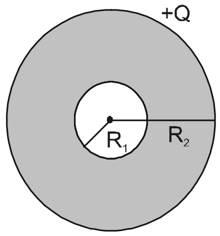
J-3. A positive point charge q is brought near a neutral metal sphere.
(A) The sphere becomes negatively charged.
(B) The sphere becomes positively charged.
(C)The interior remains neutral and the surface gets non-uniform charge distribution.
(D) The interior becomes positively charged and the surface becomes negatively charged.

J-4. Three concentric conducting spherical shells carry charges as follows : + 4Q on the inner shell, – 2Q on the middle shell and – 5 Q on the outer shell. The charge on the inner surface of the outer shell is:
(A) 0 (B) 4 Q (C) – Q (D) – 2 Q

J-5. A charge q is uniformly distributed over a large plastic plate. The electric field at a point P close to the centre and just above the surface of the plate is 50 V/m. If the plastic plate is replaced by a copper plate of the same geometrical dimensions and carrying the same uniform charge q, the electric field at the point P will become:

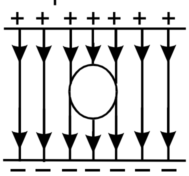
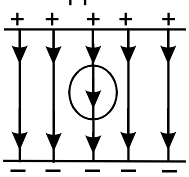
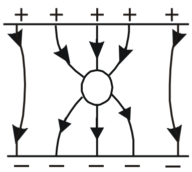
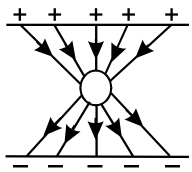
(A) zero (B) 25 V/m (C) 50 V/m (D) 100 V/m

J-6. Figure shows a thick metallic sphere. If it is given a charge +Q, then electric field will be present in the region

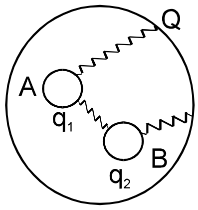


(A) $r < R_1$ only (B) $r > R_1$ and $R_1<r<R_2$ (C) $r \geq R_2$ only (D) $r \leq R_2$ only

J-7. An uncharged sphere of metal is placed in a uniform electric field produced by two large conducting parallel plates having equal and opposite charges, then lines of force look like:

(A)  (B)  (C)  (D) 

J-8. Two small conductors A and B are given charges q_1 and q_2 respectively. Now they are placed inside a hollow metallic conductor (C) carrying a charge Q. If all the three conductors A, B and C are connected by conducting wires as shown, the charges on A, B and C will be respectively:



(A) $\frac{q_1+q_2}{2}, \frac{q_1+q_2}{2}, Q$ (B) $\frac{Q+q_1+q_3}{3}, \frac{Q+q_1+q_2}{3}, \frac{Q+q_1+q_2}{3}$

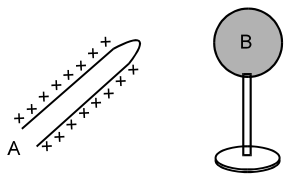
(C) $\frac{q_1+q_2+Q}{2}, \frac{q_1+q_2+Q}{2}$, 0 (D) 0, 0, $Q + q_1 + q_2$

J-9. You are travelling in a car during a thunder storm. In order to protect yourself from lightening, would you prefer to :

(A) Remain in the car (B) Take shelter under a tree

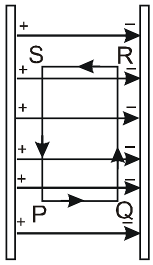
(C) Get out and be flat on the ground (D) Touch the nearest electrical pole

J-10. A positively charged body 'A' has been brought near a neutral brass sphere B mounted on a glass stand as shown in the figure. The potential of B will be:



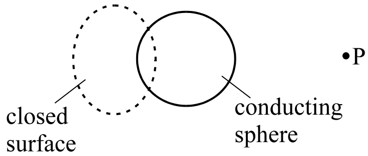
(A) Zero (B) Negative (C) Positive (D) Infinite

J-11. The amount of work done by electric field in joules in carrying a charge +q along the closed path PQRSP between the oppositely charged metal plates is: (where, E is electric field between the plates)



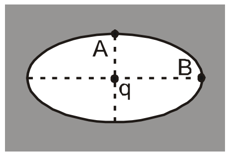
(A) zero
(B) q
(C) qE (PQ + QR + SR + SP)
(D) q/ε_0

J-12. Figure shows a closed surface which intersects a conducting sphere. If a positive charge is placed at the point P, the flux of the electric field through the closed surface:



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

J-13. An ellipsoidal cavity is carved within a perfect conductor. A positive charge q is placed at the center of the cavity. The points A and B are on the cavity surface as shown in the figure. Then : **[JEE 1999 (Scr.), 3/100]**

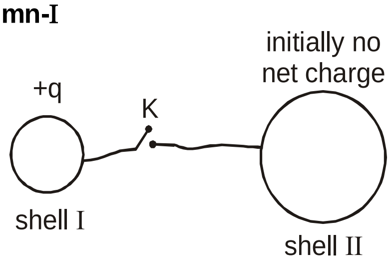


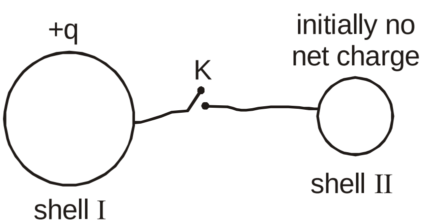
(A) Electric field near A in the cavity = electric field near B in the cavity
(B) Charge density at A = Charge density at B
(C) Potential at A = Potential at B
(D) Total electric field flux through the surface of the cavity is q/ε_0.

PART - III : MATCH THE COLUMN

1. Column I gives certain situations involving two thin conducting shells connected by a conducting wire via a key K. In all situations, one sphere has net charge +q and other sphere has no net charge. After the key K is pressed, column II gives some resulting effects. Match the figures in Column I with the statements in Column II.

Column-I

(A) 

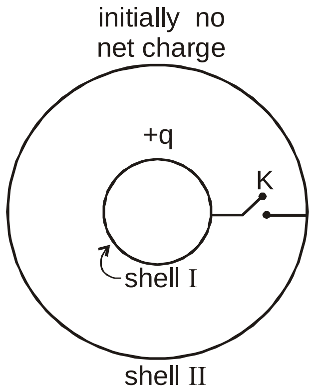
(B) 

Column-II

(p) Charge flows through connecting wire

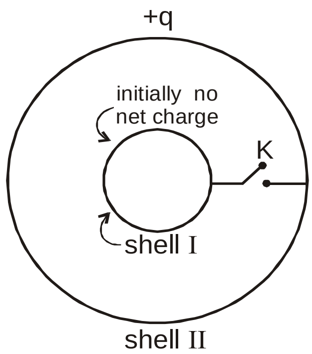
(q) Potential energy of system of spheres decreases.

(C)



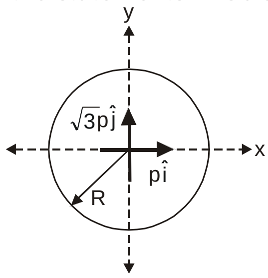
(r) No heat is produced.

(D)



(s) The shell I has no charge after equilibrium is reached.

2. Column I gives a situation in which two dipoles of dipole moment $p\hat{i}$ and $\sqrt{3}p\hat{j}$ are placed at origin. A circle of radius R with centre at origin is drawn as shown in figure. Column II gives coordinates of certain positions on the circle. Match the statements in Column I with the statements in Column II.



Column-I	Column-II
(A) The coordinate(s) of point on circle where potential is maximum	(p) $\left(\frac{R}{2}, \frac{\sqrt{3}\,R}{2}\right)$
(B) The coordinate(s) of point on circle where potential is zero	(q) $\left(-\frac{R}{2}, -\frac{\sqrt{3}\,R}{2}\right)$
(C) The coordinate(s) of point on circle where magnitude of electric field intensity is $\frac{1}{4\pi\varepsilon_0}\frac{4p}{R^3}$	(r) $\left(-\frac{\sqrt{3}\,R}{2}, \frac{R}{2}\right)$
(D) The coordinate(s) of point on circle where magnitude of electric field intensity is $\frac{1}{4\pi\varepsilon_0}\frac{2p}{R^3}$	(s) $\left(\frac{\sqrt{3}\,R}{2}, -\frac{R}{2}\right)$

Exercise-2

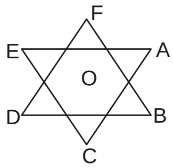
Marked Questions may have for Revision Questions.

PART - I : ONLY ONE OPTION CORRECT TYPE

1. A total charge of 20 μC is divided into two parts and placed at some distance apart. If the charges experience maximum coulombian repulsion, the charges should be :

(A) 5μC, 15 μC (B) 10 μC, 10 μC (C) 12 μC, 8 μC (D) $\frac{40}{3}\mu$C, $\frac{20}{3}\mu$C

2. The magnitude of electric force on 2 μ c charge placed at the centre O of two equilateral triangles each of side 10 cm, as shown in figure is P. If charge A, B, C, D, E & F are 2 μc, 2 μc, 2 μc, –2 μc, – 2 μc, –2 μc respectively, then P is:

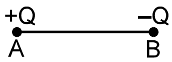


(A) 21.6 N (B) 64.8 N (C) 0 (D) 43.2 N

3. Five balls, numbered 1 to 5, are suspended using separate threads. Pairs (1, 2), (2, 4), (4, 1) show electrostatic attraction, while pairs (2, 3) and (4, 5) show repulsion. Therefore ball 1 :

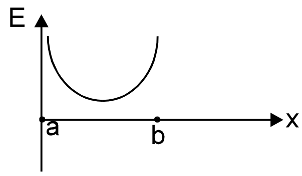
(A) Must be positively charged (B) Must be negatively charged
(C) May be neutral (D) Must be made of metal

4. Two point charges of same magnitude and opposite sign are fixed at points A and B. A third small point charge is to be balanced at point P by the electrostatic force due to these two charges. The point P :



(A) lies on the perpendicular bisector of line AB (B) is at the mid point of line AB
(C) lies to the left of A (D) none of these.

5. Two point charges a & b, whose magnitudes are same are positioned at a certain distance from each other with a at origin. Graph is drawn between electric field strength at points between a & b and distance x from a. E is taken positive if it is along the line joining from a to b. From the graph, it can be decided that

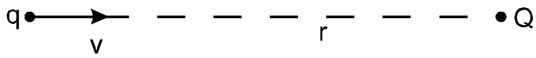


(A) a is positive, b is negative (B) a and b both are positive
(C) a and b both are negative (D) a is negative, b is positive

6. A solid sphere of radius R has a volume charge density $\rho = \rho_0 r^2$ (Where ρ_0 is a constant and r is the distance from centre). At a distance x from its centre (for x < R), the electric field is directly proportional to :

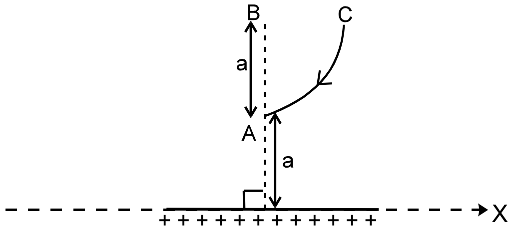
(A) $1/x^2$ (B) $1/x$ (C) x^3 (D) x^2

7. A charged particle 'q' is shot from a large distance with speed v towards a fixed charged particle Q. It approaches Q upto a closest distance r and then returns. If q were given a speed '2v', the closest distance of approach would be :



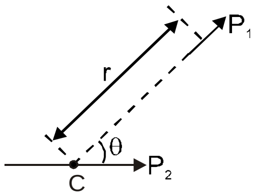
(A) r (B) 2r (C) r/2 (D) r/4

8. For an infinite line of charge having charge density λ lying along x-axis, the work required in moving charge q from C to A along arc CA is :



(A) $\frac{q\lambda}{\pi\varepsilon_0}\log_e\sqrt{2}$ (B) $\frac{q\lambda}{4\pi\varepsilon_0}\log_e\sqrt{2}$ (C) $\frac{q\lambda}{4\pi\varepsilon_0}\log_e 2$ (D) $\frac{q\lambda}{2\pi\varepsilon_0}\log_e\frac{1}{2}$

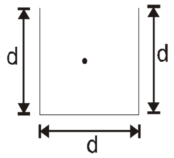
9. Two short electric dipoles are placed as shown (r is the distance between their centres). The energy of electric interaction between these dipoles will be:



(C is centre of dipole of moment P_2)

(A) $\frac{2k\,P_1P_2\cos\theta}{r^3}$ (B) $\frac{-2k\,P_1P_2\cos\theta}{r^3}$ (C) $\frac{-2k\,P_1P_2\sin\theta}{r^3}$ (D) $\frac{-4k\,P_1P_2\cos\theta}{r^3}$

10. A charge q is placed at the centre of the cubical vessel (with one face open) as shown in figure. The flux of the electric field through the surface of the vessel is :

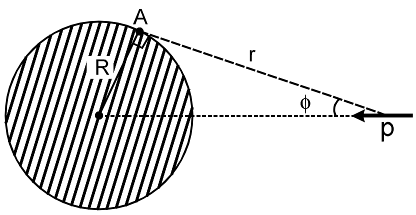


(A) zero (B) q/ε_0 (C) $\frac{q}{4\varepsilon_0}$ (D) $5q/6\varepsilon_0$

11. The electric field above a uniformly charged nonconducting sheet is E. If the nonconducting sheet is now replaced by a conducting sheet, with the charge same as before, the new electric field at the same point is :

(A) 2E (B) E (C) E/2 (D) None of these

12. A dipole having dipole moment p is placed in front of a solid uncharged conducting sphere as shown in the diagram. The net potential at point A lying on the surface of the sphere is :



(A) $\frac{kp\cos\phi}{r^2}$ (B) $\frac{k\;p\cos^2\phi}{r^2}$ (C) zero (D) $\frac{2kp\cos^2\phi}{r^2}$

13. The net charge given to an isolated conducting solid sphere:

(A) must be distributed uniformly on the surface (B) may be distributed uniformly on the surface
(C) must be distributed uniformly in the volume (D) may be distributed uniformly in the volume.

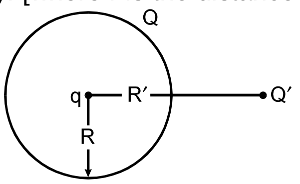
14. The net charge given to a solid insulating sphere:
(A) must be distributed uniformly in its volume
(B) may be distributed uniformly in its volume
(C) must be distributed uniformly on its surface
(D) the distribution will depend upon whether other charges are present or not.

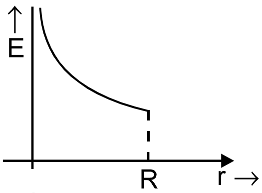
15. A charge Q is kept at the centre of a conducting sphere of inner radius R_1 and outer radius R_2. A point charge q is kept at a distance r (> R_2) from the centre. If q experiences an electrostatic force 10 N then assuming that no other charges are present, electrostatic force experienced by Q will be:
(A) – 10 N (B) 0 (C) 20 N (D) none of these

16. Two uniformly charged non-conducting hemispherical shells each having uniform charge density σ and radius R form a complete sphere (not stuck together) and surround a concentric spherical conducting shell of radius R/2. If hemispherical parts are in equilibrium then minimum surface charge density of inner conducting shell is:
(A) -2σ (B) $-\sigma/2$ (C) $-\sigma$ (D) 2σ

17. A solid metallic sphere has a charge +3Q. Concentric with this sphere is a conducting spherical shell having charge –Q. The radius of the sphere is a and that of the spherical shell is b(>a). What is the electric field at a distance r(a < r < b) from the centre?
(A) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{r}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{r^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

18. A charge ' q ' is placed at the centre of a conducting spherical shell of radius R, which is given a charge Q. An external charge Q′ is also present at distance R′ (R′ > R) from ' q '. Then the resultant field will be best represented for region r < R by: [where r is the distance of the point from q]



(A)


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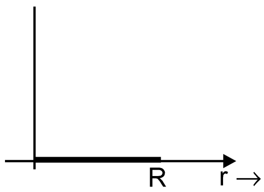

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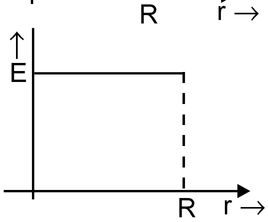

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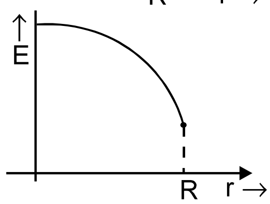
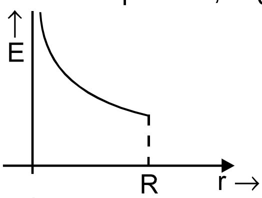


19. In the above question, if Q' is removed then which option is correct:

(A)


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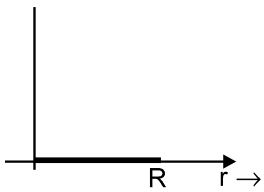
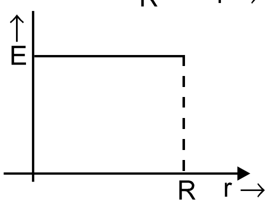


(C)


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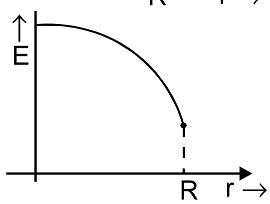


20. Two identical charged spheres suspended from a common point by two light strings of length l, are initially at a distance d(<< l) apart due to their mutual repulsion. The charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity ν. If x denotes the distance between the spheres, the ν varies as **[Olympiad (Stage-1) 2017]**

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

21. Acidified water from certain reservoir kept at a potential V falls in the form of small droplets each of radius r through a hole into a hollow conducting sphere of radius a. The sphere is insulated and is initially at zero potential. If the drops continue to fall until the sphere is half full, the potential acquired by the sphere is **[Olympiad (Stage-1) 2017]**

(A) $\frac{a^2V}{2r^2}$ (B) $\sqrt{\frac{a}{r}}\frac{V}{2}$ (C) $\frac{a^3V}{2r^3}$ (D) $\frac{aV}{r}$

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

1. Two small equally charged identical conducting balls are suspended from long threads from the same point. The charges and masses of the balls are such that they are in equilibrium. The distance between them is a = $(108)^{1/3}$ cm (the length of the threads L >> a) .One of the ball is discharged. After sometime both balls comes to rest in equilibrium. What will be the distance b (in cm) between the balls when equilibrium is restored?

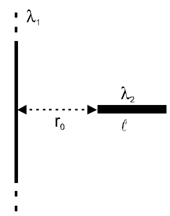
2. Two identical spheres of same mass and specific gravity (which is the ratio of density of a substance and density of water) 2.4 have different charges of Q and – 3Q. They are suspended from two strings of same length ℓ fixed to points at the same horizontal level, but distant ℓ from each other. When the entire set up is transferred inside a liquid of specific gravity 0.8, it is observed that the inclination of each string in equilibrium remains unchanged. The dielectric constant of the liquid is K. Find the value of 4K.

3. Two small balls of masses 3m and 2m and each having charges Q are connected by a string passing over a fixed pulley. Calculate the acceleration of the balls (in m/sec^2) if the whole assembly is located in a uniform electric field E = mg/2Q acting vertically downwards. Neglect any interaction between the balls. Take g = 10 m/s^2

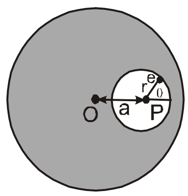
4. Two like charged, infinitely long parallel wires with the same linear charge density of 3×10^{-8} C/cm are 2 cm apart. The work done against electrostatic force per unit length to be done in bringing them closer by 1 cm is $\frac{x}{100}$ J/m: Find the integer closest to x.

5. The electric field at a point A on the perpendicular bisector of a uniformly charged wire of length ℓ = 3m and total charge q = 5 nC is x V/m. The distance of A from the centre of the wire is b = 2m. Find the value of x.

6. An infinitely long string uniformly charged with a linear charge density λ_1 and a segment of length ℓ uniformly charged with linear charge density λ_2 lie in a plane at right angles to each other and separated by a distance r_0 as shown in figure. The force with which these two interact is $\frac{\lambda_1 \lambda_2}{4\pi\varepsilon_0}\ell n(x)$. If $\ell = r_0$, then find the value of x.

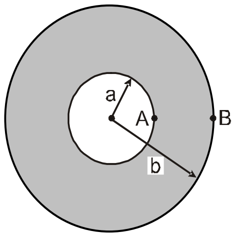


7. A cavity of radius r is present inside a solid dielectric sphere of radius R, having a volume charge density of ρ. The distance between the centres of the sphere and the cavity is a. An electron e is kept inside the cavity at an angle $\theta = 45^0$ as shown. The electron (mass m and charge –e) touches the sphere again after time $\left(\frac{P\sqrt{2}\,mr\varepsilon_0}{ea\rho}\right)^{1/2}$? Find the value of P. Neglect gravity.



8. A solid conductor sphere having a charge Q is surrounded by an uncharged concentric conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be 30V. If the shell is now given a charge –3Q, the new potential difference between the same two surfaces is x V Find the value of x :

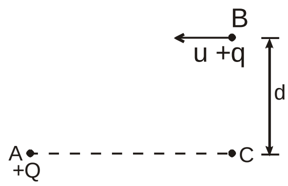
9. A hollow sphere having uniform charge density ρ (charge per unit volume) is shown in figure. If b = 2a and potential difference between A and B is $\frac{\rho a^2}{n\varepsilon_0}$. Then find the value of n :



10. Two identical particles of mass m carry a charge Q each. Initially, one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards the first particle from a large distance, with a speed V. The closest distance of approach is $\frac{xQ^2}{4\pi\varepsilon_0 mv^2}$. Find the value of x :

11. A particle having charge + q is fixed at a point O and a second particle of mass m and having charge – q_0 moves with constant speed in a circle of radius r about the charge + q. The energy required to be supplied to the moving charge to increase radius of the path to 2 r is $\frac{qq_0}{n\pi\varepsilon_0 r}$. Find the value of n.

12. A positive charge +Q is fixed at a point A. Another positively charged particle of mass m and charge +q is projected from a point B with velocity u as shown in the figure. The point B is at large distance from A and at distance 'd' from the line AC. The initial velocity is parallel to the line AC. The point C is at very large distance from A. Find the minimum distance (in meter) of +q from +Q during the motion. Take Qq = $4\pi\epsilon_0$ mu^{2}d and $d = (\sqrt{2} - 1)$ meter.

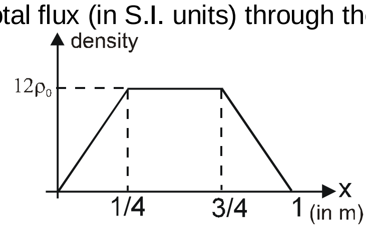


13. Small identical balls with equal charges of magnitude 'q' each are fixed at the vertices of a regular 2019-gon (a polygon of 2019 sides) with side 'a' = 4μm. At a certain instant, one of the balls is released and a sufficiently long time interval later, the ball adjacent to the first released ball is freed. The kinetic energies of the released balls are found to differ by K = 9 ×10^9 J at a sufficiently large distance from the polygon. Determine the charge q in mC.

14. The electric potential varies in space according to the relation: V = 3x + 4y. A particle of mass 10 Kg starts from rest from point (2, 3.2) under the influence of this field. Find the speed in m/s of the particle when it crosses the x-axis. The charge on the particle is +1C. Assume V and (x, y) are in S.I. units.

15. The electric field in a region is given by $\vec{E} = E_0 x\hat{i}$. The charge contained inside a cubical volume bounded by the surface x = 0, x = 2m, y = 0, y = 2m, z = 0 and z = 2m is $n\varepsilon_0E_0$. Find the value of n.

16. The volume charge density as a function of distance X from one face inside a unit cube is varying as shown in the figure. Find the total flux (in S.I. units) through the cube (If ρ_0 = 8.85 × 10^{-12} C/m^3). :



17. A very long uniformly charged thread oriented along the axis of a circle of radius R = 1m rests on its centre with one of the ends. The charge per unit length on the thread is $\lambda = 16\varepsilon_0$. Find the flux of the vector E through the circle area in (Vm).

18. The electric field in a region is radially outward with magnitude E = 2r. The charge contained in a sphere of radius a = 2m centred at the origin is $4x\pi\varepsilon_0$. Find the value of x.

19. Two isolated metallic solid spheres of radii R and 2R are charged such that both of these have same charge density 12 $\mu C/m^2$. The spheres are located far away from each other, and connected by a thin conducting wire. Find the new charge density on the bigger sphere in $\mu C/m^2$.

20. A metallic sphere of radius R is cut in two parts along a plane whose minimum distance from the sphere's centre is h = R/2 and the sphere is uniformly charged by a total electric charge Q. The minimum force necessary (to be applied on each of the two parts) to hold the two parts of the sphere together is $\frac{3kQ^2}{pR^2}$.

Then find the value of p ?

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

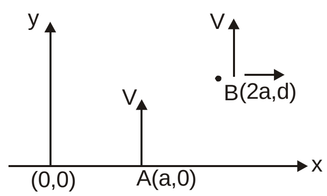
1. Select the correct alternative :
(A) The charge gained by the uncharged body from a charged body due to conduction is equal to half of the total charge initially present.
(B) The magnitude of charge increases with the increase in velocity of charge
(C) Charge cannot exist without matter although matter can exist without net charge
(D) Between two non–magnetic substances repulsion is the true test of electrification (electrification means body has net charge)

2. Two equal negative charges –q each are fixed at the points (0, a) and (0, –a) on the y-axis .A positive charge Q is released from rest at the point (2a, 0) on the x-axis. The charge Q will :
(A) Execute simple harmonic motion about the origin
(B) At origin velocity of particle is maximum.
(C) Move to infinity
(D) Execute oscillatory but not simple harmonic motion.

3. An oil drop has a charge – 9.6 × 10^{-19} C and mass 1.6 × 10^{-15} gm. When allowed to fall, due to air resistance force it attains a constant velocity. Then if a uniform electric field is to be applied vertically to make the oil drop ascend up with the same constant speed, which of the following are correct. (g = 10 ms^{-2}) (Assume that the magnitude of resistance force is same in both the cases)
(A) The electric field is directed upward
(B) The electric field is directed downward
(C) The intensity of electric field is 1/3 × 10^2 NC^{-1}
(D) The intensity of electric field is 1/6 × 10^5 NC^{-1}

4. A non-conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance r from its centre.
(A) increases as r increases, for $r \le R$
(B) decreases as r increases, for $0 < r < \infty$.
(C) decreases as r increases, for $R < r < \infty$.
(D) is discontinuous at r = R

5. A uniform electric field of strength E exists in a region. An electron (charge –e, mass m) enters a point A with velocity $V\hat{j}$. It moves through the electric field & exits at point B.Then



(A) $\vec{E} = -\frac{2amv^2}{ed^2}\hat{i}$.
(B) Rate of work done by the electric field at B is $\frac{4\,ma^2v^3}{d^3}$.
(C) Rate of work by the electric field at A is zero.
(D) Velocity at B is $\frac{2av}{d}\hat{i} + v\hat{j}$.

6. Which of the following quantites depends on the choice of zero potential or zero potential energy ?
(A) Potential at a particular point
(B) Change in potential energy of a two-charge system
(C) Potential energy of a two - charge system
(D) Potential difference between two points

7. The electric field intensity at a point in space is equal in magnitude to :
(A) Magnitude of the potential gradient there
(B) The electric charge there
(C) The magnitude of the electric force, a unit charge would experience there
(D) The force, an electron would experience there

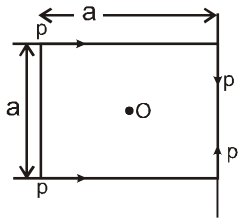
8.✍ The electric field produced by a positively charged particle, placed in an xy-plane is 7.2 (4i + 3j) N/C at the point (3 cm, 3cm) and 100 $\hat{i}$ N/C at the point (2 cm, 0).
(A) The x-coordinate of the charged particle is –2cm.
(B) The charged particle is placed on the x-axis.
(C) The charge of the particle is 10 x 10^{-12} C.
(D) The electric potential at the origin due to the charge is 9V.

9.✍ At distance of 5cm and 10cm 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^{-9}C.
(C) The electric field on the surface is 1500 V/m
(D) The electric potential at its centre is 225V.

10. The electric potential decreases uniformly from 180 V to 20 V as one moves on the X-axis from x = – 2 cm to x = + 2 cm. The electric field at the origin :
(A) must be equal to 40V/cm.
(B) may be equal to 40V/cm.
(C) may be greater than 40V/cm.
(D) may be less than 40V/cm.

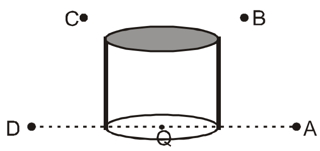
11. An electric dipole is kept in the electric field produced by a point charge.
(A) dipole will experience a force.
(B) dipole will experience a torque.
(C) it is possible to find a path (not closed) in the field on which work required to move the dipole is zero.
(D) dipole can be in stable equilibrium.

12.✍ Four short dipoles each of dipole moment ‘p’ are placed at the vertices of a square of side a. The direction of the dipole moments are shown in the figure.



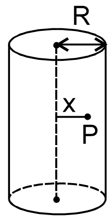
(A) Electric field at O is $\frac{\sqrt{2}\,p}{2\pi \in_0 a^3}$
(B) Electric field at O is $\frac{\sqrt{2}\,p}{\pi \in_0 a^3}$
(C) Electrostatic potential at O is zero
(D) Net dipole moment is 2p

13. Figure shows a charge Q placed at the centre of open face of a cylinder as shown in figure. A second charge q is placed at one of the positions A, B, C and D, out of which positions A and D are lying on a straight line parallel to open face of cylinder. In which position(s) of this second charge, the flux of the electric field through the cylinder remains unchanged ?



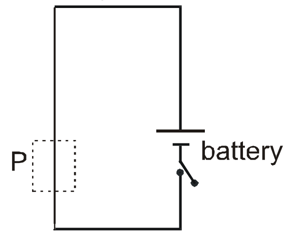
(A) A
(B) B
(C) C
(D) D

14. A long cylindrical volume (of radius R) contains a uniformly distributed charge of density ρ. Consider a point P inside the cylindrical volume at a distance x from its axis as shown in the figure. Here x can be more than or less than R.Electric field at point P is :



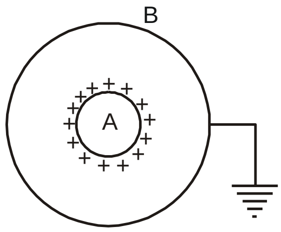
(A) $\frac{\rho x}{2\varepsilon_0}$ if x < R (B) $\frac{\rho x}{\varepsilon_0}$ if x < R (C) $\frac{\rho R^2}{4\varepsilon_0 x}$ if x > R (D) $\frac{\rho R^2}{2\varepsilon_0 x}$ if x > R

15. An imaginary closed surface P is constructed around a neutral conducting wire connected to a battery and a switch as shown in figure. As the switch is closed, the free electrons in the wire start moving along the wire. In any time interval, the number of electrons entering the closed surface P is equal to the number of electrons leaving it. On closing the switch, the flux of the electric field through the closed surface:



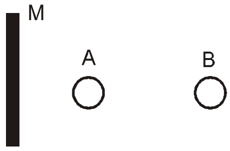
(A) remains unchanged (B) remains zero (C) is increased (D) is decreased

16. A and B are two conducting concentric spherical shells. A is given a charge Q while B is uncharged. If now B is earthed as shown in figure. Then :



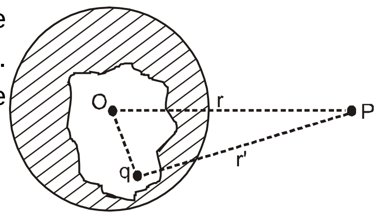
(A) The charge appearing on inner surface of B is -Q
(B) The field inside and outside A is zero.
(C) The field between A and B is not zero.
(D) The charge appearing on outer surface of B is zero.

17. A large nonconducting sheet M is given a uniform charge density. Two uncharged small metal spheres A and B are placed near the sheet as shown in figure.



(A) M attracts A (B) A attracts B (C) M attracts B (D) B attracts A

18. A point charge 'q' is within an electrically neutral conducting shell whose outer surface is a sphere of radius R. The centre of outer surface is at O. Consider a point P outside the conductor as shown in the figure. The magnitude of electric field at P

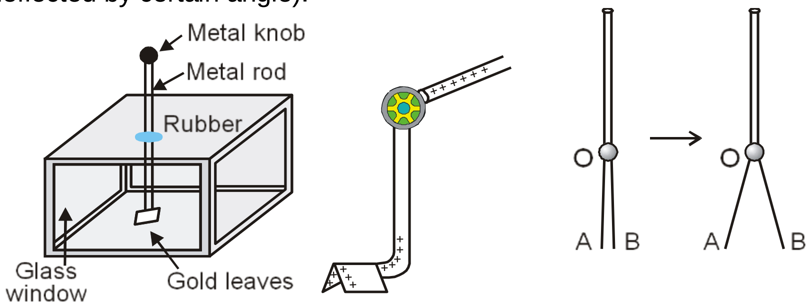


(A) due to charge induced on inner surface of the conductor is zero
(B) due to charge induced on inner surface of the conductor is $kq/(r')^2$
(C) due to charge induced on outer surface of the conductor is kq/r^2
(D) due to charge induced on surface of the conductor is kq/r^2

PART - IV : COMPREHENSION

COMPREHENSION # 1

A leaf electroscope is a simple apparatus to detect any charge on a body. It consists of two metal leaves OA and OB, free to rotate about O. Initially both are very slightly separated. When a charged object is touched to the metal knob at the top of the conducting rod, charge flows from knob to the leaves through the conducting rod. As the leaves are now charged similarly, they start repelling each other and get separated, (deflected by certain angle).



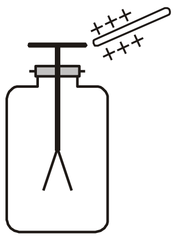
The angle of deflection in static equilibrium is an indicator of the amount of charge on the charged body.

1. When a + 20 C rod is touched to the knob, the deflection of leaves was 5°, and when an identical rod of – 40 C is touched, the deflection was found to be 9°. If an identical rod of +30 C is touched, then the deflection may be :

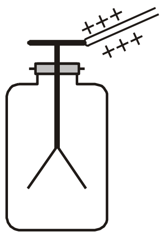
(A) 0 (B) 2° (C) 7° (D) 11°

2. If we perform these steps one by one.

(i) A positively charged rod is brought closer to initially uncharged knob (A)



(ii) Then the positively charged rod is touched to the knob (B)



(iii) Now the +vely charged rod is removed, and a negatively charged. (C)

rod of same magnitude is brought closer at same distance

In which case, the leaves will converge (come closer), as compared to the previous state ?

(A) (i) (B) (i) and (iii)

(C) only (iii) (D) In all cases, the leaves will diverge

3. In an electroscope, both leaves are hinged at the top point O. Each leaf has mass m, length ℓ and gets charge q. Assuming the charge to be concentrated at ends A and B only, the small angle of deviation (θ) between the leaves in static equilibrium, is equal to :

(A) $\left(\frac{4kq^2}{\ell^2 mg}\right)^{1/3}$ (B) $\left(\frac{kq^2}{\ell^2 mg}\right)^{1/3}$ (C) $\left(\frac{2kq^2}{\ell^2 mg}\right)^{1/2}$ (D) $\left(\frac{64kq^2}{\ell^2 mg}\right)^{1/3}$

COMPREHENSION # 2

A charged particle is suspended at the centre of two thin concentric spherical charged shells, made of non conducting material. Figure A shows cross section of the arrangement. Figure B gives the net flux ϕ through a Gaussian sphere centered on the particle, as a function of the radius r of the sphere.

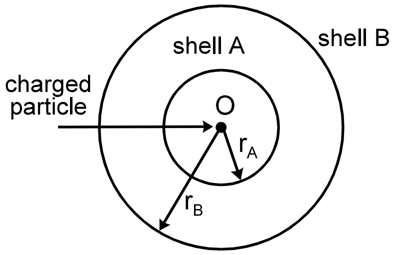


Figure A

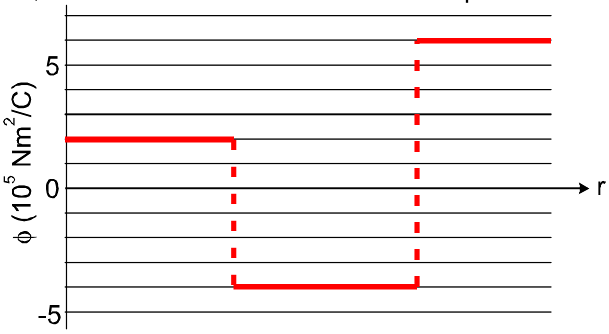


Figure B

4. What is the charge on the central particle ?

(A) 0.2 μC (B) 2 μC (C) 1.77 μC (D) 3.4 μC

5. What is the charge on shell A ?

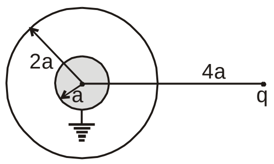
(A) 5.31×10^{-6} C (B) -5.31×10^{-6} C (C) -3.54×10^{-6} C (D) -1.77×10^{-6} C

6. In which range of the values of r is the electric field zero ?

(A) 0 to r_A (B) r_A to r_B (C) For $r > r_B$
(D) For no range of r, electric field is zero.

COMPREHENSION # 3

A solid conducting sphere of radius 'a' is surrounded by a thin uncharged concentric conducting shell of radius 2a. A point charge q is placed at a distance 4a from common centre of conducting sphere and shell. The inner sphere is then grounded.



7. The charge on solid sphere is :

(A) $-\frac{q}{2}$ (B) $-\frac{q}{4}$ (C) $-\frac{q}{8}$ (D) $-\frac{q}{16}$

8. Pick up the correct statement.
(A) Charge on surface of inner sphere is non-uniformly distributed.
(B) Charge on inner surface of outer shell is non-uniformly distributed.
(C) Charge on outer surface of outer shell is non-uniformly distributed.
(D) All the above statements are false.

9. The potential of outer shell is :

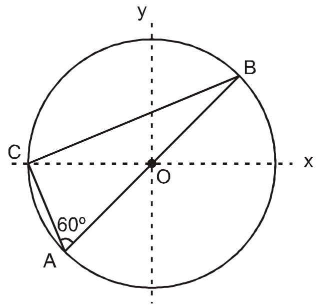
(A) $\frac{q}{32\pi\varepsilon_o a}$ (B) $\frac{q}{16\pi\varepsilon_o a}$ (C) $\frac{q}{8\pi\varepsilon_o a}$ (D) $\frac{q}{4\pi\varepsilon_o a}$

Exercise-3

✍ Marked Questions can be used as Revision Questions.
* Marked Questions may have more than one correct option.

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1.✍ Consider a system of three charges $\frac{q}{3}$, $\frac{q}{3}$ and $-\frac{2q}{3}$ placed at points A, B and C, respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle CAB = 60º. **[JEE 2008, 3/163]**



(A) The electric field at point O is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative x-axis.

(B) The potential energy of the system is zero.

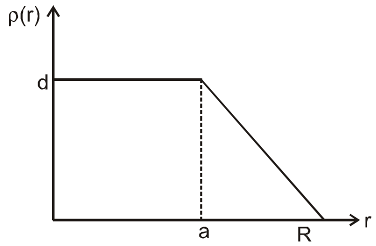
(C) The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\varepsilon_0 R^2}$

(D) The potential at point O is $\frac{q}{12\pi\varepsilon_0 R}$.

Paragraph for Question Nos. 2 to 4 ✍

The nuclear charge (Ze) is non–uniformly distributed within a nucleus of radius R. The charge density $\rho(r)$ [charge per unit volume] is dependent only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction. **[JEE 2008 ; 4 × 3 = 12/163]**

Figure :



2.✍ The electric field at r = R is :
(A) independent of a
(B) directly proportional to a
(C) directly proportional to a^2
(D) inversely proportional to a

3.✍ For a = 0, the value d (maximum value of ρ as shown in the figure) is :
(A) $\frac{3Ze^2}{4\pi R^3}$ (B) $\frac{3Ze}{\pi R^3}$ (C) $\frac{4Ze}{3\pi R^3}$ (D) $\frac{Ze}{3\pi R^3}$

4.✍ The electric field within the nucleus is generally observed to be linearly dependent on r. This implies :
(A) a = 0 (B) a = R/2 (C) a = R (D) a = 2R/3

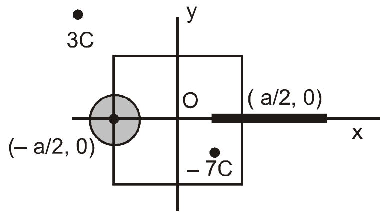
5. **STATEMENT-1 :** For practical purposes, the earth is used as a reference at zero potential in electrical circuits. **[JEE 2008, 3, –1/163]**

and

STATEMENT-2 : The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1
(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1
(C) STATEMENT-1 is True, STATEMENT-2 is False
(D) STATEMENT-1 is False, STATEMENT-2 is True.

6. A disk of radius a/4 having a uniformly distributed charge 6C is placed in the x-y plane with its centre at (–a/2, 0, 0). A rod of length a carrying a uniformly distributed charge 8C is placed on the x-axis from x = a/4 to x = 5a/4. Two point charges –7C and 3C are placed at (a/4, –a/4, 0) and (–3a/4, 3a/4, 0), respectively. Consider a cubical surface formed by six surfaces x = ± a/2, y = ± a/2, z = ±a/2. The electric flux through this cubical surface is : **[JEE 2009, 3/160, –1]**



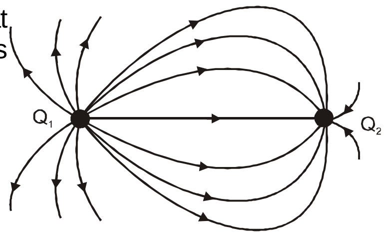
(A) $\frac{-2C}{\varepsilon_0}$ (B) $\frac{2C}{\varepsilon_0}$ (C) $\frac{10C}{\varepsilon_0}$ (D) $\frac{12C}{\varepsilon_0}$

7. Three concentric metallic spherical shells of radii R, 2R, 3R, are given charges Q_1, Q_2, Q_3, respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells, $Q_1 : Q_2 : Q_3$, is **[JEE 2009, 3/160, –1]**
(A) 1 : 2 : 3 (B) 1 : 3 : 5 (C) 1 : 4 : 9 (D) 1 : 8 : 18

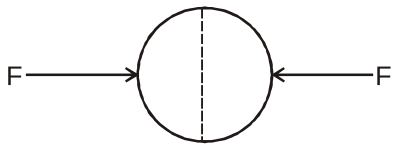
8. Under the influence of the Coulomb field of charge +Q, a charge –q is moving around it in an elliptical orbit. Find out the correct statement(s). **[JEE 2009, 4/160, –1]**
(A) The angular momentum of the charge –q is constant.
(B) The linear momentum of the charge –q is constant.
(C) The angular velocity of the charge – q is constant.
(D) The linear speed of the charge –q is constant.

9. A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at r = R/2 is 1/8 times that at r = R, find the value of a. **[JEE 2009, 4/160, –1]**

10. A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. These lines suggest that : **[JEE 2010, 3/163]**
(A) $|Q_1| > |Q_2|$
(B) $|Q_1| < |Q_2|$
(C) at a finite distance to the left of Q_1 the electric field is zero
(D) at a finite distance to the right of Q_2 the electric field is zero



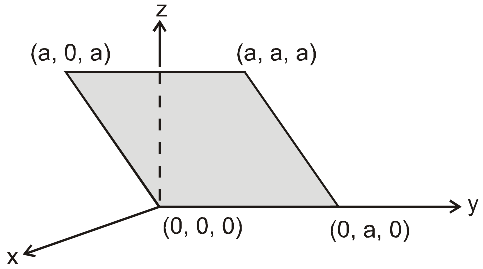
11. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to **[JEE 2010, 5/163, –2]**



(A) $\frac{1}{\varepsilon_0}\sigma^2R^2$ (B) $\frac{1}{\varepsilon_0}\sigma^2R$ (C) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$ (D) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$

12. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7}\times10^5$ Vm^{-1}. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} m s^{-1}. Given g = 9.8 m s^{-2}, viscosity of the air = 1.8×10^{-5} Ns m^{-2} and the density of oil = 900 kg m^{-3}, the magnitude of q is : **[JEE 2010, 5/163, –2]**
(A) 1.6×10^{-19} C (B) 3.2×10^{-19} C (C) 4.8×10^{-19} C (D) 8.0×10^{-19} C

13. Consider an electric field $\vec{E} = E_0\hat{x}$, where E_0 is a constant. The flux through the shaded area (as shown in the figure) due to this field is : **[JEE-2011, 3/160, –1]**

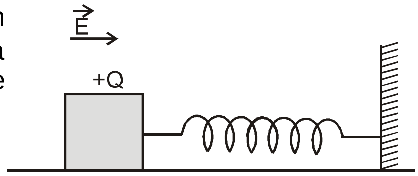


(A) $2E_0a^2$ (B) $\sqrt{2}\,E_0a^2$ (C) E_0a^2 (D) $\frac{E_0a^2}{\sqrt{2}}$

14*. A spherical metal shell A of radius R_A and a solid metal sphere B of radius R_B (< R_A) are kept far apart and each is given charge '+Q'. Now they are connected by a thin metal wire. Then **[JEE-2011, 4/160]**

(A) $E_A^{inside} = 0$ (B) $Q_A > Q_B$ (C) $\frac{\sigma_A}{\sigma_B} = \frac{R_B}{R_A}$ (D) $E_A^{on\,surface} < E_B^{on\,surface}$

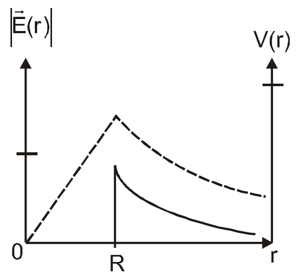
15. **A** wooden block performs SHM on a frictionless surface with frequency, ν_0. The block carries a charge +Q on its surface. If now a uniform electric field **E** is switched-on as shown, then the SHM of the block will be **[JEE 2011, 3/160, –1]**

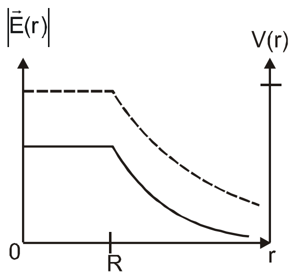


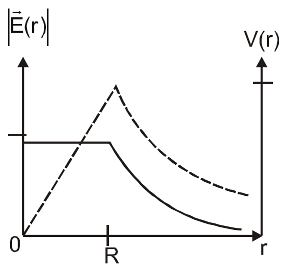
(A) of the same frequency and with shifted mean position.
(B) of the same frequency and with the same mean position.
(C) of changed frequency and with shifted mean position.
(D) of changed frequency and with the same mean position.

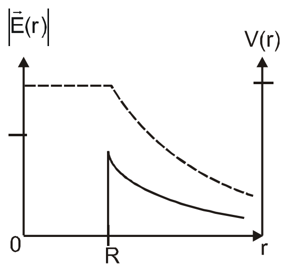
16. Which of the following statement(s) is/are correct? **[JEE 2011, 4/160]**
(A) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss law will still be valid.
(B) The Gauss law can be used to calculate the field distribution around an electric dipole.
(C) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same.
(D) The work done by the external force in moving a unit positive charge from point A at potential V_A to point B at potential V_B is $(V_B - V_A)$.

17. Consider a thin spherical shell of radius R with its centre at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field $|\vec{E}(r)|$ and the electric potential V(r) with the distance r from the centre, is best represented by which graph? **[JEE 2012, Paper-1 : 3/70, –1]**

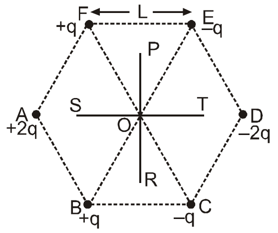
(A)


(B)


(C)


(D)


18*. Six point charges are kept at the vertices of a regular hexagon of side L and centre O, as shown in the figure. Given that K = $\frac{1}{4\pi\varepsilon_0}\frac{q}{L^2}$, which of the following statement (s) is (are) correct? **[JEE 2012, Paper-1 : 4/66]**

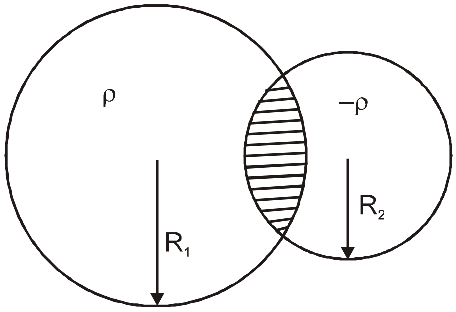


(A) the elecric field at O is 6K along OD
(B) The potential at O is zero
(C) The potential at all points on the line PR is same
(D) The potential at all points on the line ST is same.

19*. Two non-conducting solid spheres of radii R and 2R, having uniform volume charge densities ρ_1 and ρ_2 respectively, touch each other. The net electric field at a distance 2R from the centre of the smaller sphere, along the line joining the centres of the spheres, is zero. The ratio ρ_1/ρ_2 can be ;
[JEE (Advanced)-2013; 3/60, –1]

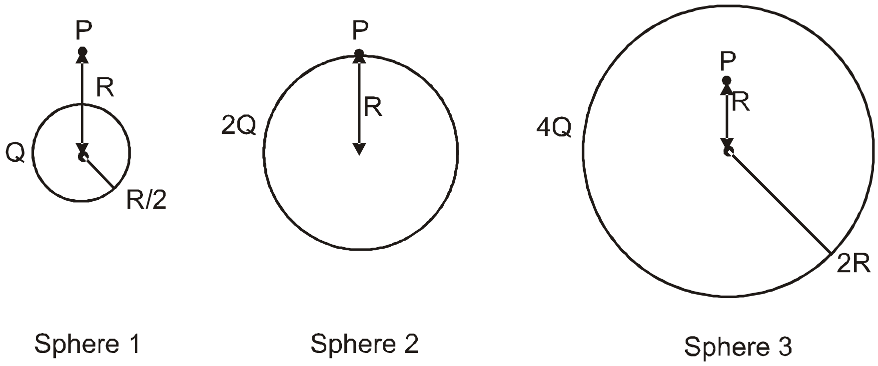
(A) –4 (B) $-\frac{32}{25}$ (C) $\frac{32}{25}$ (D) 4

20*. Two non–conducting spheres of radii R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$, respectively, are placed such that they partially overlap, as shown in the figure. At all points in the overlapping region : **[JEE (Advanced) 2013; 3/60, –1]**



(A) the electrostatic field is zero (B) the electrostatic potential is constant
(C) the electrostatic field is constant in magnitude (D) the electrostatic field has same direction

21. Charges Q, 2Q and 4Q are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii R/2, R and 2R respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1 E_2 and E_3 respectively, then
[JEE (Advanced) 2014, 3/60, –1]



(A) $E_1 > E_2 > E_3$ (B) $E_3 > E_1 > E_2$ (C) $E_2 > E_1 > E_3$ (D) $E_3 > E_2 > E_1$

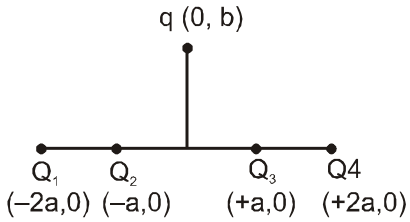
22. Let $E_1(r)$, $E_2(r)$ and $E_3(r)$ be the respective electric fields at a distance r from a point charge Q, an infinitely long wire with constant linear charge density λ, and an infinite plane with uniform surface charge density σ. if $E_1(r_0) = E_2(r_0) = E_3(r_0)$ at a given distance r_0, then **[JEE (Advanced) 2014, P-1, 3/60]**

(A) $Q = 4\sigma\pi r_0^2$ (B) $r_0 = \frac{\lambda}{2\pi\sigma}$ (C) $E_1(r_0/2) = 2E_2(r_0/2)$ (D) $E_2(r_0/2) = 4E_3(r_0/2)$

23. Four charge Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x axis at x = –2a –a, +a and +2a, respectively. A positive charge q is placed on the positive y axis at a distance b > 0. Four options of the signs of these charges are given in List-I. The direction of the forces on the charge q is given in List-II Match List-1 with List-II and select the correct answer using the code given below the lists.

[JEE (Advanced)-2014, 3/60, –1]

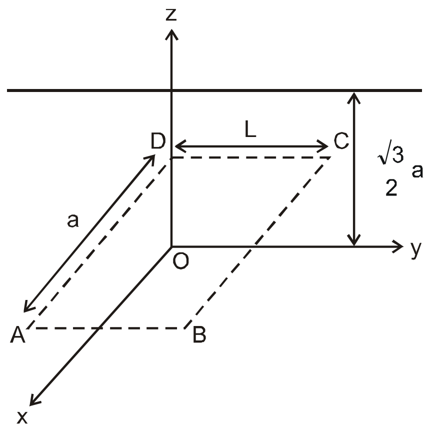
	List-I	**List-II**
P.	Q_1, Q_2, Q_3, Q_4 all positive	**1.** +x
Q.	Q_1, Q_2 positive Q_3, Q_4 negative	**2.** –x
R.	Q_1, Q_4 positive Q_2, Q_3 negative	**3.** +y
S.	Q_1, Q_3 positive Q_2, Q_4 negative	**4.** –y



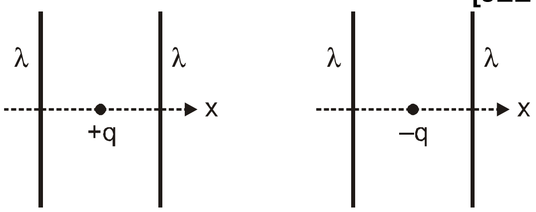
Code :

(A) P-3, Q-1, R-4, S-2 (B) P-4, Q-2, R-3, S-1 (C) P-3, Q-1, R-2, S-4 (D) P-4, Q-2, R-1, S-3

24. An infinitely long uniform line charge distribution of charge per unit length λ lies parallel to the y-axis in the y-z plane at $z = \frac{\sqrt{3}}{2}a$ (see figure). If the magnitude of the flux of the electric field through the rectangular surface ABCD lying in the x-y plane with its centre at the origin is $\frac{\lambda L}{n\varepsilon_0}$ (ε_0 = permittivity of free space), then the value of n is : **[JEE (Advanced) 2015 ; P-1, 4/88]**



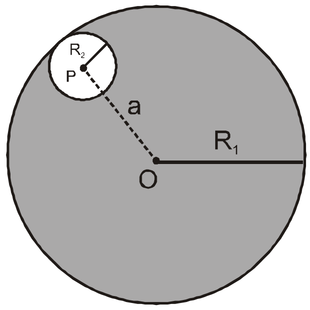
25. The figures below depict two situations in which two infinitely long static line charges of constant positive line charge density λ are kept parallel to each other. In their resulting electric field, point charges q and –q are kept in equilibrium between them. The point charges are confined to move in the x-direction only. If they are given a small dispacement about their equilibrium positions, then the correct ststement(s) is (are) : **[JEE (Advanced) 2015 ; P-1 4/88, –2]**



(A) Both charges execute simple harmonic motion.
(B) Both charges will continue moving in the direction of their displacement.
(C) Charge +q executes simple haramonic motion while charge –q continues moving in the direction of its displacement.
(D) Charge –q executes simple haramonic motion while charge +q continues moving in the direction of its displacement.

26. Consider a uniform speherical charge distribution of radius R_1 centred at the origin O. In this distribution, a spherical cavity of radius R_2, centred at P with distance OP = a = $R_1 - R_2$ (see figure) is made. If the electric field inside the cavity at position $\vec{r}$ is $\vec{E}(\vec{r})$, then the correct statement(s) is(are)

[JEE (Advanced) 2015 ; P-2,4/88, –2]



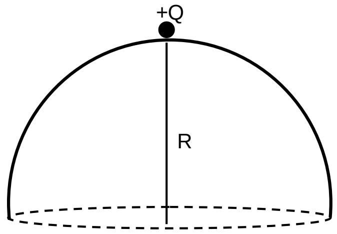
(A) $\vec{E}$ is uniform, its magnitude is independent of R_2 but its direction depends on $\vec{r}$

(B) $\vec{E}$ is uniform, its magnitude depends on R_2 and its direction depends on $\vec{r}$

(C) $\vec{E}$ is uniform, its magnitude is independent of a but its direction depends on $\vec{a}$

(D) $\vec{E}$ is uniform, and both its magnitude and direction depends on $\vec{a}$

27. A point charge +Q is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct ? **[JEE (Advanced) 2017 ; 4/61, –2]**



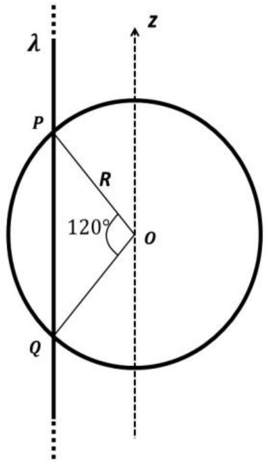
(A) Total flux through the curved and the flat surface is Q/ε_0

(B) The component of the electric field normal to the flat surface is constant over the surface

(C) The circumference of the flat surface is an equipotential

(D) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$

28*. An infinitely long thin non-conducting wire is parallel to the z-axis and carries a uniform line charge density λ. It pierces a thin non-conducting spherical shell of radius R in such a way that the arc PQ subtends an angle 120° at the centre O of the spherical shell, as shown in the figure. The permittivity of free space is ε_0. Which of the following statements is (are) true? **[JEE (Advanced) 2018 ; 4/60, –2]**



(A) The electric flux through the shell is $\sqrt{3}R\lambda / \varepsilon_0$

(B) The z-component of the electric field is zero at all the points on the surface of the shell

(C) The electric flux through the shell is $\sqrt{2}R\lambda / \varepsilon_0$

(D) The electric field is normal to the surface of the shell at all points

29. A particle, of mass 10^{-3}kg and charge 1.0 C, is initially at rest. At time t = 0, the particle comes under the influence of an electric field $\vec{E}(t) = E_0 \sin\omega t \hat{i}$ where E_0 = 1.0 NC^{-1} and ω = 10^3 rad s^{-1}. Consider the effect of only the electrical force on the particle. Then the maximum speed, in ms^{-1}, attained by the particle at subsequent times is ____________. **[JEE (Advanced) 2018 ; 3/60]**

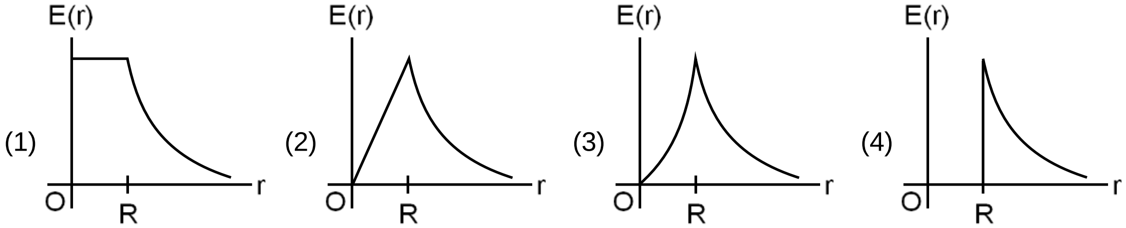
30. The electric field E is measured at a point P(0, 0, d) generated due to various charge distributions and the dependence of E on d is found to be different for different charge distributions. List-I contains different relations between E and d. List-II describes different electric charge distributions, along with their locations. Match the functions in List-I with the related charge distributions in List-II.
[JEE (Advanced) 2018 ; 3/60, –1]

List-I		**List-II**	
P.	E is independent of d	1.	A point charge Q at the origin
Q.	$E \propto 1/d$	2.	A small dipole with point charges Q at (0, 0, ℓ) and –Q at (0, 0, –ℓ) Take $2\ell << d$
R.	$E \propto 1/d^2$	3.	An infinite line charge coincident with the x-axis, with uniform linear charge density λ.
S.	$E \propto 1/d^3$	4.	Two infinite wires carrying uniform linear charge density parallel to the x-axis. The one along (y = 0, z = ℓ) has a charge density +λ and the one along (y = 0, z = –ℓ) has a charge density –λ. Take $2\ell << d$
		5.	Infinite plane charge coincident with the xy-plane with uniform surface charge density.

(A) P → 5 ; Q → 3, 4 ; R → 1 ; S → 2
(B) P → 5 ; Q → 3 ; R → 1, 4 ; S → 2
(C) P → 5 ; Q → 3 ; R → 1, 2; S → 4
(D) P → 4 ; Q → 2, 3 ; R → 1 ; S → 5

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. A thin spherical shell of radius R has charge Q spread uniformly over its surface. Which of the following graphs most closely represents the electric field E (r) produced by the shell in the range $0 \le r < \infty$, where r is the distance from the centre of the shell? **[AIEEE-2008, 3/105]**



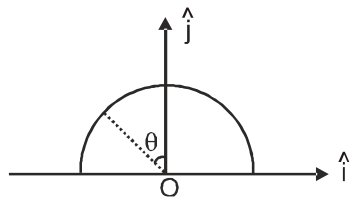
2. Two points P and Q are maintained at the potentials of 10 V and –4 V respectively. The work done in moving 100 electrons from P to Q is : **[AIEEE-2009, 4/144]**
(1) 9.60×10^{-17} J (2) -2.24×10^{-16} J (3) 2.24×10^{-16} J (4) -9.60×10^{-17} J

3. 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, 4/144]**
(1) –1 (2) 1 (3) $-\frac{1}{\sqrt{2}}$ (4) $-2\sqrt{2}$

4. **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, 6/144]**
STATEMENT 2 : The net work done by a conservative force on an object moving along a closed loop is zero.
(1) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(2) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(3) Statement-1 is false, Statement-2 is true.
(4) Statement-1 is true, Statement-2 is false.

5. Let $\rho(r) = \frac{Q}{\pi R^4} r$ be the charge density distribution for a solid sphere of radius R and total charge Q. For a point 'P' inside the sphere at distance r_1 from the centre of sphere, the magnitude of electric field is : **[AIEEE 2009, 4/144]**
(1) $\frac{Q}{4\pi\varepsilon_0 r_1^2}$ (2) $\frac{Qr_1^2}{4\pi\varepsilon_0 R^4}$ (3) $\frac{Qr_1^2}{3\pi\varepsilon_0 R^4}$ (4) 0

6. A thin semi-circular ring of radius r has a positive charge q distributed uniformly over it. The net field $\vec{E}$ at the centre O is : **[AIEEE 2010, 4/144]**



(1) $\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$ (2) $-\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$ (3) $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$ (4) $\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

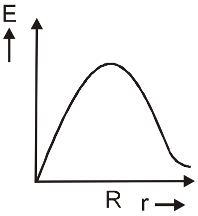
7. Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0\left(\frac{5}{4} - \frac{r}{R}\right)$ upto r = R, and $\rho(r)$ = 0 for r > R, where r is the distance from the origin. The electric field at a distance r (r < R) from the origin is given by **[AIEEE 2010, 4/144]**
(1) $\frac{4\pi\rho_0 r}{3\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ (2) $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ (3) $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$ (4) $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

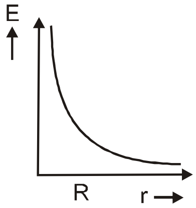
8. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30º with each other. When suspended in a liquid of density 0.8 g cm^{-3}, the angle remains the same. If density of the material of the sphere is 1.6 g cm^{-3}, the dielectric constant of the liquid is **[AIEEE 2010, 8/144]**
(1) 4 (2) 3 (3) 2 (4) 1

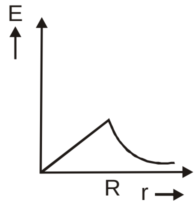
9. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre; a,b are constants. Then the charge density inside the ball is : **[AIEEE 2011, 4/120, –1]**
(1) $-24\pi a\varepsilon_0 r$ (2) $-6\pi a\varepsilon_0 r$ (3) $-24\pi a\varepsilon_0$ (4) $-6 a\varepsilon_0$

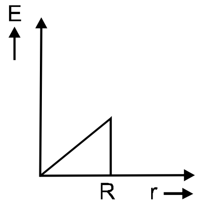
10. Two positive charges of magnitude 'q' are placed at the ends of a side (side 1) of a square of side '2a'. Two negative charges of the same magnitude are kept at the other corners. Starting from rest, if a charge Q moves from the middle of side 1 to the centre of square, its kinetic energy at the centre of square is : **[AIEEE 2011, 11 May; 4, –1]**
(1) zero (2) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1+\frac{1}{\sqrt{5}}\right)$ (3) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1-\frac{2}{\sqrt{5}}\right)$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1-\frac{1}{\sqrt{5}}\right)$

11. In a uniformly charged sphere of total charge Q and radius R, the electric field E is plotted as function of distance from the centre. The graph which would correspond to the above will be : **[AIEEE 2012 ; 4/120, –1]**

(1) 

(2) 

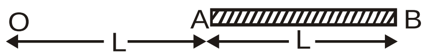
(3) 

(4) 

12. This question has statement-1 and statement-2. Of the four choices given after the statements, choose the one that best describes the two statements. **[AIEEE 2012 ; 4/120, –1]**
An insulating solid sphere of radius R has a unioformly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point out side the sphere. The electric potential at infinite is zero.
STATEMENT-1 : When a charge 'q' is taken from the centre to the surface of the sphere its potential energy changes by $q\rho/3\varepsilon_0$.
STATEMENT-2 : The electric field at a distance r (r < R) from the centre of the sphere is $\rho r/3\varepsilon_0$.
(1) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of statement-1.
(2) Statement-1 is true Statement-2 is false.
(3) Statement-1 is false Statement-2 is true.
(4) Statement-1 is true, Statement-2 is true, Statement-2 is the correct explanation of Statement-1.

13. Two charges, each equal to q, are kept at x = – a and x = a on the x-axis. A particle of mass m and charge $q_0 = q/2$ is placed at the origin. If charge q_0 is given a small displacement (y <<a) along the y-axis, the net force acting on the particle is proportional to : **[JEE (Main) 2013, 4/120, –1]**
(1) y (2) –y (3) 1/y (4) – 1/y

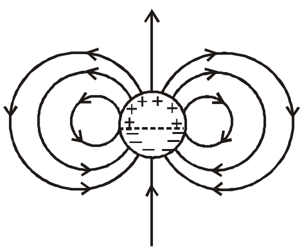
14. A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at distance L from the end A is : **[JEE (Main) 2013, 4/120, –1]**

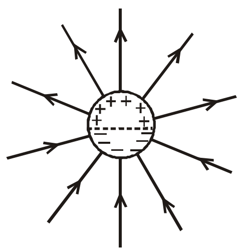


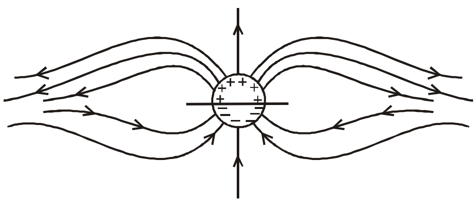
(1) $\dfrac{Q}{8\pi \epsilon_0 L}$ (2) $\dfrac{3Q}{4\pi \epsilon_0 L}$ (3) $\dfrac{Q}{4\pi \epsilon_0 L\ln 2}$ (4) $\dfrac{Q\ln 2}{4\pi \epsilon_0 L}$

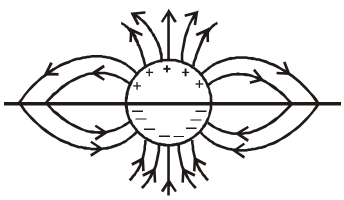
15. Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_O$, where V_O is the potential at the origin and V_A the potential at x = 2 m is : **[JEE (Main) 2014, 4/120, –1]**
(1) 120 J (2) –120 J (3) – 80 J (4) 80 J

16. A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge $-\sigma$ in the lower half. The electric field lines around the cylinder will look like figure given in : (figures are schematic and not drawn to scale) **[JEE (Main) 2015; 4/120, –1]**

(1) 

(2) 

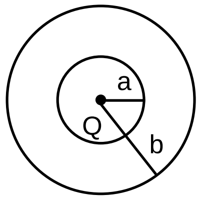
(3) 

(4) 

17.* A uniformly charged solid sphere of radius R has potential V_0 (measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}, \frac{5V_0}{4}, \frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then **[JEE (Main) 2015; 4/120, –1]**

(1) $R_1 = 0$ and $R_2 > (R_4 - R_3)$
(2) $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$
(3) $R_1 = 0$ and $R_2 < (R_4 - R_3)$
(4) $2R < R_4$

18. The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), has volume charge density $\rho = A/r$, where A is a constant and r is the distance from the centre. At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is : **[JEE (Main) 2016 ; 4/120, –1]**



(1) $\frac{Q}{2\pi(b^2 - a^2)}$ (2) $\frac{2Q}{\pi(a^2 - b^2)}$ (3) $\frac{2Q}{\pi a^2}$ (4) $\frac{Q}{2\pi a^2}$

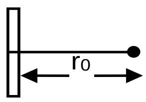
19. An electric dipole has a fixed dipole moment $\vec{p}$, which makes angle θ with respect to x-axis. When subjected to an electric field $\vec{E}_1 = E\hat{i}$, it experiences a torque $\vec{T}_1 = \tau\hat{k}$. When subjected to another electric field $\vec{E}_2 = \sqrt{3}E_1\hat{j}$ it experiences a torque $\vec{T}_2 = -\vec{T}_1$. The angle θ is : **[JEE (Main) 2017; 4/120, –1]**

(1) 90° (2) 30° (3) 45° (4) 60°

20. Three concentric metal shells A, B and C of respective radii a, b and c (a < b < c) have surface charge densities $+\sigma$, $-\sigma$ and $+\sigma$ respectively. The potential of shell B is : **[JEE (Main) 2018; 4/120, –1]**

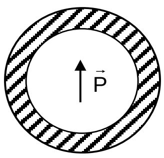
(1) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2 - c^2}{b} + a\right]$ (2) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2 - c^2}{c} + a\right]$ (3) $\frac{\sigma}{\varepsilon_0}\left[\frac{a^2 - b^2}{a} + c\right]$ (4) $\frac{\sigma}{\varepsilon_0}\left[\frac{a^2 - b^2}{b} + c\right]$

21. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (υ) of the point charge, as a function of instantaneous distance r from line charge, is proportional to : **[JEE (Main) 2019; 4/120, –1]**



(1) $\upsilon \propto \left(\frac{r}{r_0}\right)$ (2) $\upsilon \propto \ell n\left(\frac{r}{r_0}\right)$ (3) $\upsilon \propto \sqrt{\ell n\left(\frac{r}{r_0}\right)}$ (4) $\upsilon \propto e^{+r/r_0}$

22. Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{P}$ as shown. In this case : **[JEE (Main) 2019; 4/120, –1]**



(1) electric field outside the shell is the same as that of a point charges at the centre of the shell
(2) surface charge density on the inner surface of the shell is zero everywhere
(3) surface charge density on the inner surface is uniform and equal to $\frac{(Q/2)}{4\pi a^2}$
(4) surface charge density on the outer surface depends on $|\vec{P}|$

23. Let a total charge 2Q be distributed in a sphere of radius R, with the charge density given by $\rho(r) = kr$, where r is the distance from the centre. Two charges A and B, of –Q each, are placed on diametrically opposite points, at equal distance, a, from the centre. If A and B do not experience any force, then : **[JEE (Main) 2019; 4/120, –1]**

(1) $a = 3R/2^{1/4}$ (2) $a = 2^{-1/4}R$ (3) $a = 8^{-1/4}R$ (4) $a = R/\sqrt{3}$