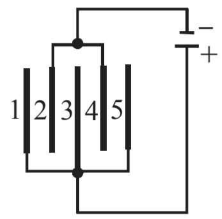
CHAPTER 12

Electrostatics

Section-A JEE Advanced/ IIT-JEE

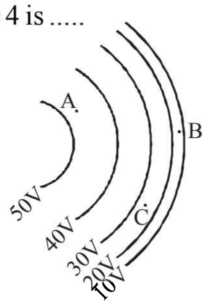
A Fill in the Blanks

1. Five identical capacitor plates, each of area A, are arranged such that adjacent plates are at a distance d apart, the plates are connected to a source of emf V as shown in the figure
(1984- 2 Marks)



The charge on plate 1 is ..... and on plate 4 is .....

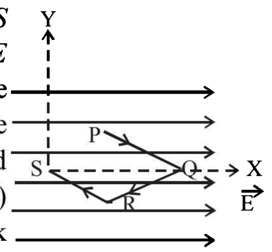
2. Figure shows line of constant potential in a region in which an electric field is present. The values of the potential are written in brackets. Of the points A, B and C, the magnitude of the electric field is greatest at the point ...
(1984- 2 Marks)



3. Two small balls having equal positive charges Q (coulomb) on each are suspended by two insulating strings of equal length L (metre) from a hook fixed to a stand. The whole set up is taken in a satellite into space where there is no gravity (state of weightlessness). The angle between the two strings is .... and the tension in each string is .... newtons.
(1986 - 2 Marks)

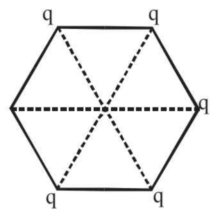
4. Two parallel plate capacitors of capacitances C and $2C$ are connected in parallel and charged to a potential difference V. The battery is then disconnected and the region between the plates of the capacitor C is completely filled with a material of dielectric constant K. The potential differences across the capacitors now becomes............. *(1988 - 2 Marks)*

5. A point charge q moves from point P to point S along the path $PQRS$ (fig.) in a uniform electric field E pointing parallel to the positive direction of the X-axis. The cooridnates of the points P, Q, R and S are (a, b, O), $(2a, O, O)$ $(a, -b, O)$ and (O, O, O) respectively. The work done by the field in the above process is given by the expression ....
(1989 - 2 Marks)



6. The electric potential V at any point x, y, z (all in metres) in space is given by $V = 4x^2$ volts. The electric field at the point (1m, 0, 2 m) is .... V/m. *(1992 - 1 Mark)*

7. Five point charges, each of value $+q$ coul, are placed on five vertices of a regular hexagon of side L metres. The magnitude of the force on the point charge of value $-q$ coul. placed at the centre of the hexagen is .... newton. *(1992 - 1 Mark)*



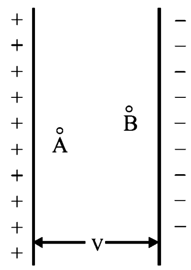
B True/False

1. The work done in carrying a point charge from one point to another in an electrostatic field depends on the path along which the point charge is carried. *(1981- 2 Marks)*

2. Two identical metallic spheres of exactly equal masses are taken. One is given a positive charge Q coulombs and the other an equal negative charge. Their masses after charging are different. *(1983 - 2 Marks)*

3. A small metal ball is suspended in a uniform electric field with the help of an insulated thread. If high energy X-ray beam falls on the ball, the ball will be deflected in the direction of the field. *(1983 - 2 Marks)*

4. Two protons A and B are placed in between the two plates of a parallel plate capacitor charged to a potential difference V as shown in the figure. The forces on the two protons are identical.
(1986 - 3 Marks)



5. A ring of radius R carries a uniformly distributed charge $+Q$. A point charge $-q$ is placed on the axis of the ring at a distance $2R$ from the centre of the ring and released from rest. The particle executes a simple harmonic motion along the axis of the ring. *(1988 - 2 Marks)*

6. An electric line of forces in the $x-y$ plane is given by the equation $x^2 + y^2 = 1$. A particle with unit positive charge, initially at rest at the point $x = 1$, $y = 0$ in the $x-y$ plane, will move along the circular line of force. *(1988 - 2 Marks)*

C MCQs with One Correct Answer

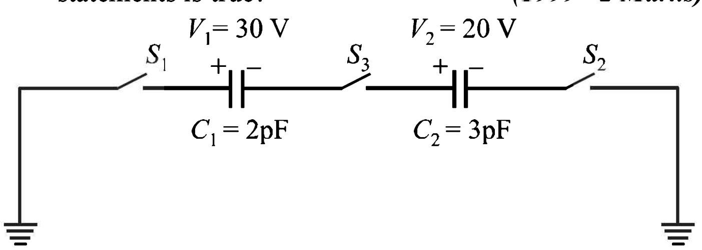
1. A hollow metal sphere of radius 5 cms is charged such that the potential on its surface is 10 volts. The potential at the centre of the sphere is *(1983 - 1 Mark)*
(a) zero
(b) 10 volts
(c) same as at a point 5 cms away from the surface
(d) same as at a point 25 cms away from the surface

2. Two point charges $+q$ and $-q$ are held fixed at $(-d, o)$ and (d, o) respectively of a x-y coordinate system. Then *(1995S)*
(a) The electric field E at all points on the x-axis has the same direction
(b) Electric field at all points on y-axis is along x-axis
(c) Work has to be done in bringing a test charge from ∞ to the origin
(d) The dipole moment is $2qd$ along the x-axis

3. A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance $2C$ is similarly charged to a potential difference $2V$. The charging battery is now disconnected and the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of the other. The final energy of the configuration is *(1995S)*
(a) zero (b) $\frac{3}{2}CV^2$ (c) $\frac{25}{6}CV^2$ (d) $\frac{9}{2}CV^2$

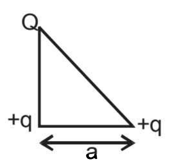
4. Two identical metal plates are given positive charges Q_1 and Q_2 $(<Q_1)$ respectively. If they are now brought close together to form a parallel plate capacitor with capacitance C, the potential difference between them is *(1999 - 2 Marks)*
(a) $(Q_1+Q_2)/(2C)$ (b) $(Q_1+Q_2)/C$
(c) $(Q_1-Q_2)/C$ (d) $(Q_1-Q_2)/(2C)$

5. For the circuit shown in Figure, which of the following statements is true? *(1999 - 2 Marks)*

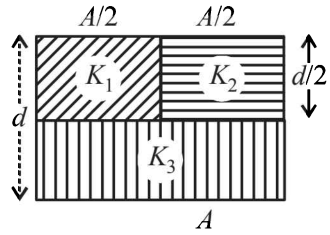


(a) With S_1 closed $V_1 = 15$ V, $V_2 = 20$ V
(b) With S_3 closed, $V_1 = V_2 = 25$ V
(c) With S_1 and S_2 closed, $V_1 = V_2 = 0$
(d) With S_1 and S_3 closed, $V_1 = 30V$, $V_2 = 20V$

6. Three charges Q, $+q$ and $+q$ are placed at the vertices of a right-angled isosceles triangle as shown. The net electrostatic energy of the configuration is zero if Q is equal to *(2000S)*
(a) $\frac{-q}{1+\sqrt{2}}$
(b) $\frac{-2q}{2+\sqrt{2}}$
(c) $-2q$
(d) $+q$

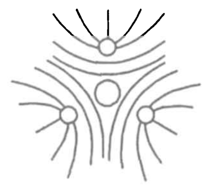


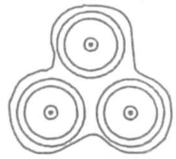
7. A parallel plate capacitor of area A, plate separation d and capacitance C is filled with three different dielectric materials having dielectric constants k_1, k_2 and k_3 as shown. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant k is given by *(2000S)*



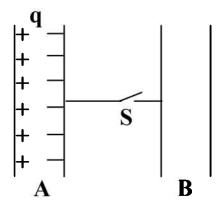
(a) $\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{2K_3}$ (b) $\frac{1}{K} = \frac{1}{K_1+K_2} + \frac{1}{2K_3}$
(c) $K = \frac{K_1K_2}{K_1+K_2} + 2K_3$ (d) $K = K_1 + K_2 + 2K_3$

8. 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 *(2001S)*

(a)  (b) 

(c)  (d) 

9. Consider the situation shown in the figure. The capacitor A has a charge q on it whereas B is uncharged. The charge appearing on the capacitor B a long time after the switch is closed is *(2001S)*



(a) zero (b) $q/2$
(c) q (d) $2q$

10. A uniform electric field pointing in positive x-direction exists in a region. Let A be the origin, B be the point on the x-axis at $x = +1$ cm and C be the point on the y-axis at $y = +1$ cm. Then the potentials at the points A, B and C satisfy: *(2001S)*
(a) $V_A < V_B$ (b) $V_A > V_B$
(c) $V_A < V_C$ (d) $V_A > V_C$

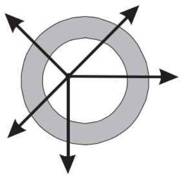
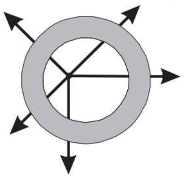
11. Two equal point charges are fixed at $x = -a$ and $x = +a$ on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to *(2002S)*
(a) x (b) x^2
(c) x^3 (d) $1/x$

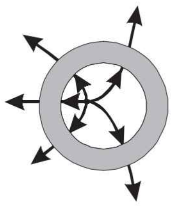
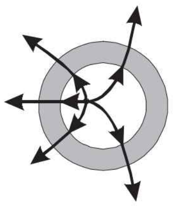
12. Two identical capacitors, have the same capacitance C. One of them is charged to potential V_1 and the other V_2. The negative ends of the capacitors are connected together. When the positive ends are also connected, the decrease in energy of the combined system is *(2002S)*

(a) $\frac{1}{4}C\left(V_1^2 - V_2^2\right)$ (b) $\frac{1}{4}C\left(V_1^2 + V_2^2\right)$

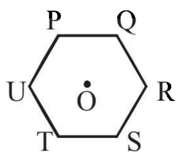
(c) $\frac{1}{4}C\left(V_1 - V_2\right)^2$ (d) $\frac{1}{4}C\left(V_1 + V_2\right)^2$

13. A metallic shell has a point charge 'q' kept inside its cavity. Which one of the following diagrams correctly represents the electric lines of forces? *(2003S)*

(a)  (b) 

(c)  (d) 

14. Six charges of equal magnitude, 3 positive and 3 negative are to be placed on *PQRSTU* corners of a regular hexagon, such that field at the centre is double that of what it would have been if only one +ve charge is placed at *R*. Which of the following arrangement of charge is possible for P, Q, R, S, T and U respectively. *(2004S)*



(a) +, +, +, –, –, – (b) –, +, +, +, –, –

(c) –, +, +, –, +, – (d) +, –, +, –, +, –

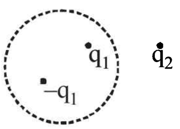
15. A Gaussian surface in the figure is shown by dotted line. The electric field on the surface will be *(2004S)*

(a) due to q_1 and q_2 only

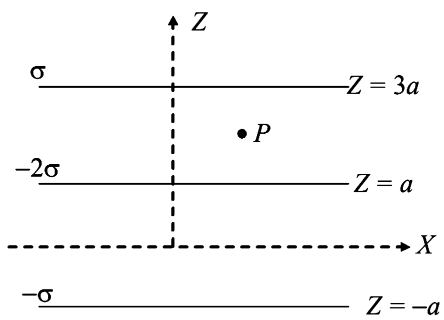
(b) due to q_2 only

(c) zero

(d) due to all



16. Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is *(2005S)*



(a) $\frac{2\sigma}{\varepsilon_0}\hat{k}$ (b) $\frac{4\sigma}{\varepsilon_0}\hat{k}$ (c) $-\frac{2\sigma}{\varepsilon_0}\hat{k}$ (d) $-\frac{4\sigma}{\varepsilon_0}\hat{k}$

17. A long, hollow conducting cylinder is kept coaxially inside another long, hollow conducting cylinder of larger radius. Both the cylinders are initially electrically neutral. *(2007)*

(a) A potential difference appears between the two cylinders when a charge density is given to the inner cylinder.

(b) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder.

(c) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinders

(d) No potential difference appears between the two cylinders when same charge density is given to both the cylinders.

18. Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then *(2007)*

(a) negative and distributed uniformly over the surface of the sphere

(b) negative and appears only at the point on the sphere closest to the point charge

(c) negative and distributed non-uniformly over the entire surface of the sphere

(d) zero

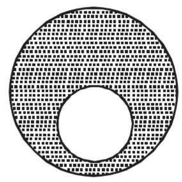
19. A spherical portion has been removed from a solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is *(2007)*

(a) zero everywhere

(b) non-zero and uniform

(c) non-uniform

(d) zero only at its center



20. Positive and negative point charges of equal magnitude are kept at $\left(0,0,\frac{a}{2}\right)$ and $\left(0,0,\frac{-a}{2}\right)$ respectively. The work done by the electric field when another positive point charge is moved from $(-a, 0, 0)$ to $(0, a, 0)$ is *(2007)*

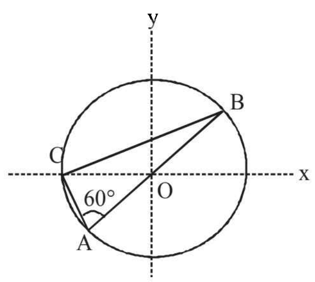
(a) positive

(b) negative

(c) zero

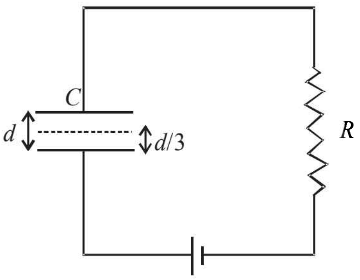
(d) depends on the path connecting the initial and final positions

21. Consider a system of three charges $q/3$, $q/3$ and $-2q/3$ placed at points A, B and C, respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle $CAB = 60°$ *(2008)*



(a) The electric field at point O is $\dfrac{q}{8\pi\varepsilon_0 R^2}$ 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 $\dfrac{q^2}{54\pi\varepsilon_0 R^2}$
(d) The potential at point O is $\dfrac{q}{12\pi\varepsilon_0 R}$

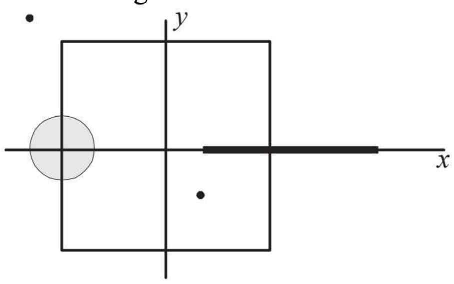
22. A parallel plate capacitor C with plates of unit area and separation d is filled with a liquid of dielectric constant $K = 2$. The level of liquid is $d/3$ initially. Suppose the liquid level decreases at a constant speed v, the time constant as a function of time t is – *(2008)*



(a) $\dfrac{6\varepsilon_0 R}{5d+3vt}$
(b) $\dfrac{(15d+9vt)\,\varepsilon_0 R}{2d^2-3dvt-9v^2t^2}$
(c) $\dfrac{6\varepsilon_0 R}{5d-3vt}$
(d) $\dfrac{(15d-9vt)\,\varepsilon_0 R}{2d^2-3dvt-9v^2t^2}$

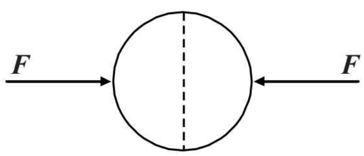
23. Three concentric metallic spherical shells of radii R, $2R$, $3R$, are given charges Q_1, Q_2, Q_3, respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells, $Q_1 : Q_2 : Q_3$, is *(2009)*
(a) $1:2:3$ (b) $1:3:5$
(c) $1:4:9$ (d) $1:8:18$

24. A disc 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 – 7 C and 3 C are placed at $(a/4, -a/4, 0)$ and $(-3a/4, 3a/4, 0)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm a/2, y = \pm a/2, z = \pm a/2$. The electric flux through this cubical surface is *(2009)*



(a) $\dfrac{-2C}{\varepsilon_0}$ (b) $\dfrac{2C}{\varepsilon_0}$ (c) $\dfrac{10C}{\varepsilon_0}$ (d) $\dfrac{12C}{\varepsilon_0}$

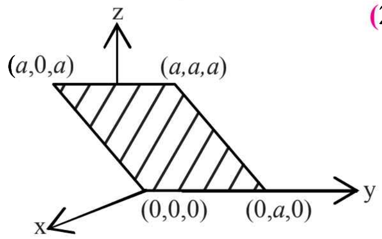
25. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to *(2010)*



(a) $\dfrac{1}{\varepsilon_0}\sigma^2 R^2$ (b) $\dfrac{1}{\varepsilon_0}\sigma^2 R$ (c) $\dfrac{1}{\varepsilon_0}\dfrac{\sigma^2}{R}$ (d) $\dfrac{1}{\varepsilon_0}\dfrac{\sigma^2}{R^2}$

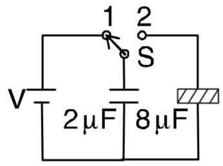
26. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\dfrac{81\pi}{7}\times 10^5\ \text{Vm}^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity $2\times 10^{-3}\,\text{ms}^{-1}$. Given $g = 9.8\ \text{m s}^{-2}$, viscosity of the air $= 1.8\times 10^{-5}$ Ns m^{-2} and the density of oil $= 900$ kg m^{-3}, the magnitude of q is *(2010)*
(a) 1.6×10^{-19}C (b) 3.2×10^{-19}C
(c) 4.8×10^{-19}C (d) 8.0×10^{-19}C

27. 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 **(2011)**



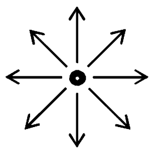
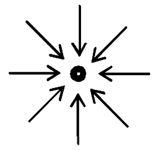
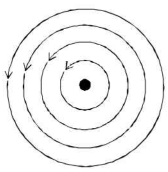
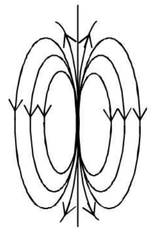
(a) $2E_0a_2$
(b) $\sqrt{2}E_0a^2$
(c) $E_0\,a^2$
(d) $\dfrac{E_0a^2}{\sqrt{2}}$

28. A 2 μF capacitor is charged as shown in the figure. The percentage of its stored energy dissipated after the switch S is turned to position 2 is *(2011)*

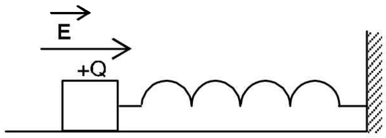


(a) 0%
(b) 20%
(c) 75%
(d) 80%

29. Which of the field patterns given below is valid for electric field as well as for magnetic field? *(2011)*

(a) 
(b) 
(c) 
(d) 

30. A wooden block performs SHM on a frictionless surface with frequency, ν_0. The block carries a charge +Q on its surface. If now a uniform electric field $\vec{E}$ is switched-on as shown, then the SHM of the block will be *(2011)*

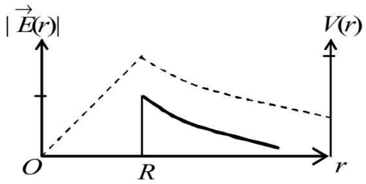


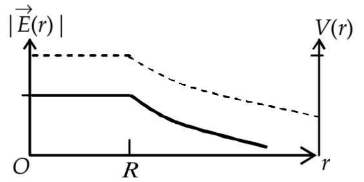
(a) of the same frequency and with shifted mean position.
(b) of the same frequency and with the same mean position
(c) of changed frequency and with shifted mean position.
(d) of changed frequency and with the same mean position.

31. Two large vertical and parallel metal plates having a separation of 1 cm are connected to a DC voltage source of potential difference X. A proton is released at rest midway between the two plates. It is found to move at 45° to the vertical JUST after release. Then X is nearly

(a) $1 \times 10^{-5}\ V$ (b) $1 \times 10^{-7}\ V$ ***(2012)***
(c) $1 \times 10^{-9}\ V$ (d) $1 \times 10^{-10}\ V$

32. Consider a thin spherical shell of radius R with 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? ***(2012)***

(a)


(b)


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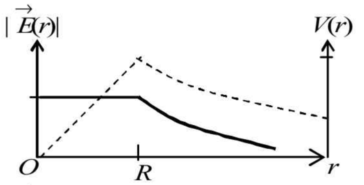
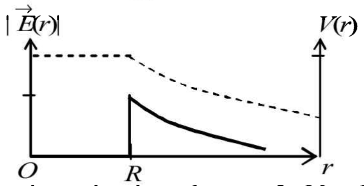
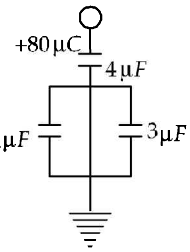


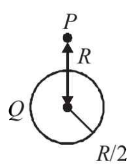
(d)


33. In the given circuit, a charge of +80 μC is given to the upper plate of the 4 μF capacitor. Then in the steady state, the charge on the upper plate of the 3 μF capacitor is ***(2012)***

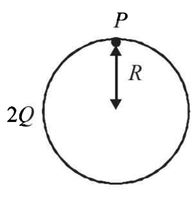


(a) +32 μC
(b) +40 μC
(c) +48 μC
(d) +80 μC

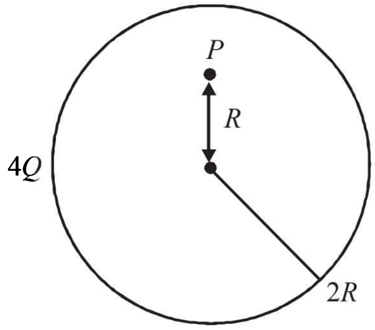
34. Charges Q, $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $R/2$, R and $2R$ respectively, as shown in figure. If magnitude of the electric fields at point P at a distance R from the centre of sphere 1, 2 and 3 are E_1, E_2 and E_3 respectively, then ***(JEE Adv. 2014)***



Sphere 1



Sphere 2



Sphere 3

(a) $E_1 > E_2 > E_3$ (b) $E_3 > E_1 > E_2$
(c) $E_2 > E_1 > E_3$ (d) $E_3 > E_2 > E_1$

D MCQs with One or More than One Correct

1. Two equal negative charges $-q$ are fixed at points $(0, -a)$ and $(0, a)$ on y – axis. A positive charge Q is released from rest at the point $(2a, 0)$ on the x - axis. The charge Q will ***(1984- 2 Marks)***

(a) execute simple harmonic motion about the origin
(b) move to the origin remain at rest
(c) move to infinity
(d) execute oscillatory but not simple harmonic motion

2. A parallel plate air capacitor is connected to a battery. The quantities charge, voltage, electric field and energy associated with this capacitor are given by Q_0, V_0, E_0 and U_0 respectively. A dielectric slab is now introduced to fill the space between the plates with battery still in connection. The corresponding quantities now given by Q, V, E and U are related to the previous one as ***(1985 - 2 Marks)***

(a) $Q > Q_0$ (b) $V > V_0$
(c) $E > E_0$ (d) $U > U_0$

3. A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to : ***(1987 - 2 Marks)***

(a) $-\dfrac{Q}{2}$ (b) $-\dfrac{Q}{4}$ (c) $+\dfrac{Q}{4}$ (d) $+\dfrac{Q}{2}$

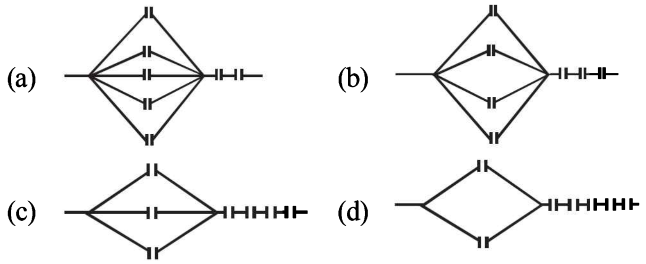
4. A parallel plate capacitor is charged and the charging battery is then disconnected. If the plates of the capacitor are moved farther apart by means of insulating handles : ***(1987 - 2 Marks)***

(a) the charge on the capacitor increases.
(b) the voltage across the plates increases.
(c) the capacitance increases.
(d) the electrostatic energy stored in the capacitor increases

5. A solid conducting sphere having a charge Q is surrounded by an uncharged concentric conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of $-3Q$, the new potential difference between the same two surfaces is : ***(1989 - 2 Marks)***

(a) V (b) $2V$
(c) $4V$ (d) $-2V$

6. Seven capacitors each of capacitance $2\mu F$ are to be connected in a configuration to obtain an effective capacitance of $\left(\frac{10}{11}\right)\mu F$. Which of the combination (s) shown in figure will achieve the desired result? ***(1990 - 2 Marks)***



7. A parallel plate capacitor of plate area A and plate separation d is charged to potential difference V and then the battery is disconnected. A slab of dielectric constant K is then inserted between the plates of the capacitor so as to fill the space between the plates. If Q, E and W denote respectively, the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted), and work done on the system, in question, in the process of inserting the slab, then ***(1991 - 2 Marks)***

(a) $Q = \dfrac{\varepsilon_0 AV}{d}$ (b) $Q = \dfrac{\varepsilon_0 KAV}{d}$

(c) $E = \dfrac{V}{Kd}$ (d) $W = \dfrac{\varepsilon_0 AV^2}{2d}\left[1 - \dfrac{1}{K}\right]$

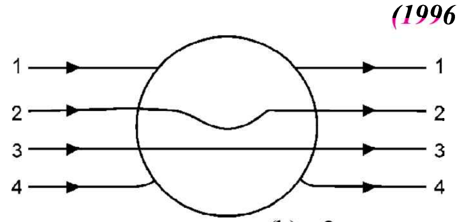
8. Two identical thin rings, each of radius R metres, are coaxially placed a distance R metres apart. If Q_1 coulomb, and Q_2 coulomb, are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is ***(1992 - 2 Marks)***

(a) zero (b) $\dfrac{q(Q_1 - Q_2)(\sqrt{2} - 1)}{(4\sqrt{2}\pi\varepsilon_0 R)}$

(c) $\dfrac{q\sqrt{2}(Q_1 + Q_2)}{(4\pi\varepsilon_0 R)}$ (d) $\dfrac{q(Q_1 + Q_2)(\sqrt{2} + 1)}{(4\sqrt{2}\pi\varepsilon_0 R)}$

9. The magnitude of electric field $\vec{E}$ in the annular region of a charged cylindrical capacitor. ***(1996 - 2 Marks)***
(a) is same throughout
(b) is higher near the outer cylinder than near the inner cylinder
(c) varies as $1/r$, where r is the distance from axis
(d) varies as $1/r^2$ where r is the distance from the axis.

10. A metallic solid sphere is placed in a uniform electric fied. The lines of force follow the path(s) shown in Figure as ***(1996 - 2 Marks)***



(a) 1 (b) 2
(c) 3 (d) 4

11. A dielectric slab of thickness d is inserted in a parallel plate capacitor whose negative plate is at $x = 0$ and positive plate is at $x = 3d$. The slab is equidistant from the plates. The capacitor is given some charge. As one goes from 0 to $3d$,
(a) the magnitude of the electric field remains the same.
(b) the direction of the electric field remains the same.
(c) the electric potential increases continuously.
(d) the electric potential increases at first, then decreases and again increases. ***(1998S - 2 Marks)***

12. A charge $+q$ is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$,..... $x = \infty$ on the x axis, and a charge $-q$ is fixed at each of the points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$,.... $x = \infty$. Here x_0 is a positive constant. Take the electric potential at a point due to a charge Q at a distance r from it to be $Q/(4\pi\varepsilon_0 r)$. Then, the potential at the origin due to the above system of charges is ***(1998S - 2 Marks)***

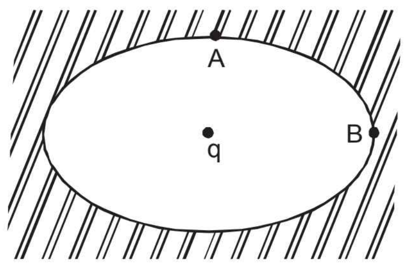
(a) 0 (b) $\dfrac{q}{8\pi\varepsilon_0 x_0 \ln 2}$

(c) ∞ (d) $\dfrac{q \ln 2}{4\pi\varepsilon_0 x_0}$

13. A positively charged thin metal ring of radius R is fixed in the xy plane with its centre at the origin O. A negatively charged particle P is released from rest at the point $(0, 0, z_0)$ where $z_0 > 0$. Then the motion of P is ***(1998S - 2 Marks)***
(a) periodic, for all values of z_0 satisfying $0 < z_0 < \infty$
(b) simple harmonic, for all values of z_0 satisfying $0 < z_0 \le R$
(c) approximately simple harmonic, provided $z_0 << R$
(d) such that P crosses O and continues to move along the negative z axis towards $z = -\infty$

14. 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 ***(1998S - 2 Marks)***
(a) increases as r increases, for $r < R$.
(b) decreases as r increases, for $0 < r < \infty$.
(c) decreases as r increases, for $R < r < \infty$.
(d) is discontinuous at $r = R$.

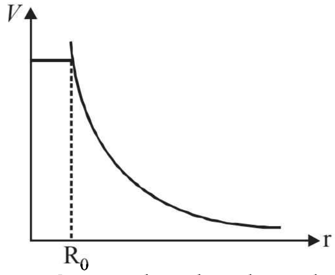
15. An ellipsoidal cavity is carved within a perfect conductor. A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in the figure. Then ***(1999S - 3 Marks)***



(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

16. A spherical symmetric charge system is centered at origin. Given, Electric potential ***(2006S - 5 Marks)***

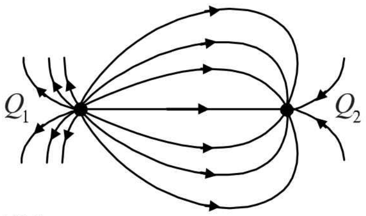
$$V = \frac{Q}{4\pi\varepsilon_0 R_0} \ (r \le R_0), \ V = \frac{Q}{4\pi\varepsilon_0 r} \ (r > R_0)$$



(a) Within $r = 2R_0$ total enclosed net charge is Q
(b) Electric field is discontinued at $r = R_0$
(c) Charge is only present at $r = R_0$
(d) Electrostatic energy is zero for $r < R_0$

17. 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). ***(2009)***
(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

18. 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 ***(2010)***



(a) $|Q_1| > |Q_2|$
(b) $|Q_1| < |Q_2|$
(c) at a finite distance to the left of Q_1 the electric field is zero
(d) at a finite distance to the right of Q_2 the electric field is zero

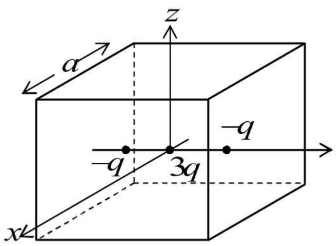
19. A spherical metal shell A of radius R_A and a solid metal sphere B of radius $R_B (< R_A)$ are kept far apart and each is given charge '+Q'. Now they are connected by a thin metal wire. Then ***(2011)***

(a) $E_A^{inside} = 0$ (b) $Q_A > Q_B$

(c) $\frac{\sigma_A}{\sigma_B} = \frac{R_B}{R_A}$ (d) $E_A^{on\,surface} < E_B^{on\,surface}$

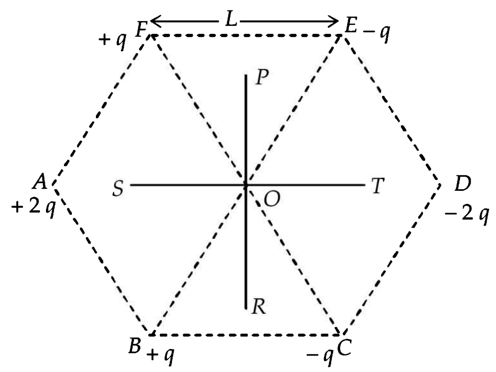
20. Which of the following statement(s) is/are correct? ***(2011)***
(a) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss law will still be valid.
(b) The Gauss law can be used to calculate the field distribution around an electric dipole.
(c) If the 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 $(V_B - V_A)$.

21. A cubical region of side a has its centre at the origin. It encloses three fixed point charges, $-q$ at $(0, -a/4, 0)$, $+3q$ at $(0, 0, 0)$ and $-q$ at $(0, +a/4, 0)$. Choose the correct options(s) ***(2012)***



(a) The net electric flux crossing the plane $x = +a/2$ is equal to the net electric flux crossing the plane $x = -a/2$
(b) The net electric flux crossing the plane $y = +a/2$ is more than the net electric flux crossing the plane $y = -a/2$.
(c) The net electric flux crossing the entire region is $\frac{q}{\varepsilon_0}$
(d) The net electric flux crossing the plane $z = +a/2$ is equal to the net electric flux crossing the plane $x = +a/2$.

22. 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? ***(2012)***



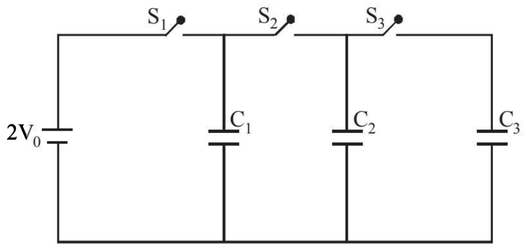
(a) The electric field at O is 6K along OD
(b) The potential at O is zero
(c) The potential at all points on the line PR is same
(d) The potential at all points on the line ST is same

23. 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 $\frac{\rho_1}{\rho_2}$ can be ***(JEE Adv. 2013)***

(a) -4 (b) $-\frac{32}{25}$

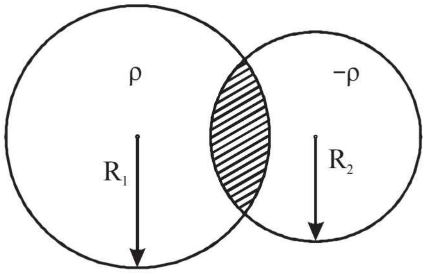
(c) $\frac{32}{25}$ (d) 4

24. In the circuit shown in the figure, there are two parallel plate capacitors each of capacitance C. The switch S_1 is pressed first to fully charge the capacitor C_1 and then released. The switch S_2 is then pressed to charge the capacitor C_2. After some time, S_2 is released and then S_3 is pressed. After some time *(JEE Adv. 2013)*



(a) The charge on the upper plate of C_1 is $2CV_0$
(b) The charge on the upper plate of C_1 is CV_0
(c) The charge on the upper plate of C_2 is 0
(d) The charge on the upper plate of C_2 is $-CV_0$

25. 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 Adv. 2013)

(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

26. Let $E_1(r)$, $E_2(r)$ and $E_3(r)$ be the respective electric field 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 Adv. 2014)*

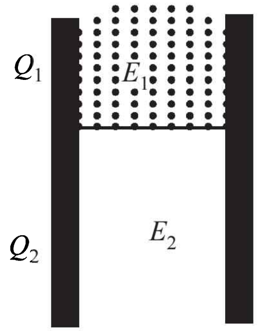
(a) $Q = 4\sigma\pi r_0^2$

(b) $r_0 = \dfrac{\lambda}{2\pi\sigma}$

(c) $E_1(r_0/2) = 2E_2(r_0/2)$

(d) $E_2(r_0/2) = 4E_3(r_0/2)$

27. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers 1/3 of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1. When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2. The electric field in the dielectric is E_1 and that in the other portion is E_2. Choose the correct option/options, ignoring edge effects. *(JEE Adv. 2014)*



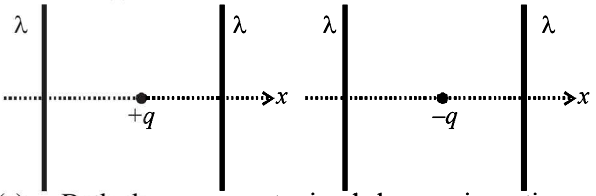
(a) $\dfrac{E_1}{E_2} = 1$

(b) $\dfrac{E_1}{E_2} = \dfrac{1}{K}$

(c) $\dfrac{Q_1}{Q_2} = \dfrac{3}{K}$

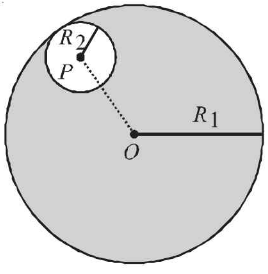
(d) $\dfrac{C}{C_1} = \dfrac{2+K}{K}$

28. 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 displacement about their equilibrium positions, then the correct statement(s) is(are) *(JEE Adv. 2015)*



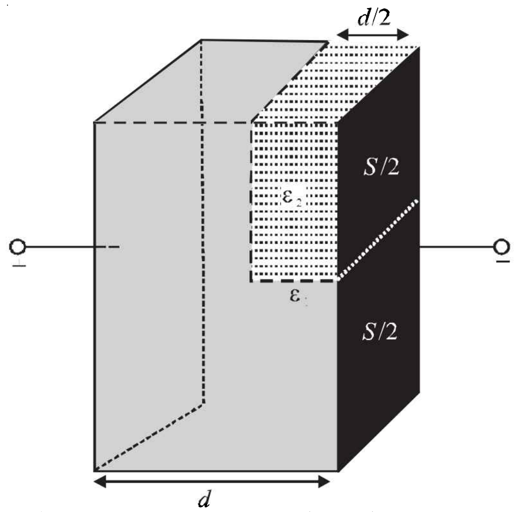
(a) Both charges execute simple harmonic motion
(b) Both charges will continue moving in the direction of their displacement
(c) Charge +q executes simple harmonic motion while charge –q continues moving in the direction of its displacement
(d) Charge –q executes simple harmonic motion while charge +q continues moving in the direction of its displacement

29. Consider a uniform spherical 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 Adv. 2015)*



(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 depend on $\vec{a}$

30. A parallel plate capacitor having plates of area S and plate separation d, has capacitance C_1 in air. When two dielectrics of different relative primitivities ($\varepsilon_1 = 2$ and $\varepsilon_2 = 4$) are introduced between the two plates as shown in the figure, the capacitance becomes C_2. The ratio $\frac{C_2}{C_1}$ is *(JEE Adv. 2015)*

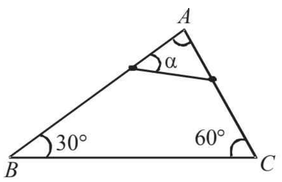


(a) 6/5 (b) 5/3
(c) 7/5 (d) 7/3

E Subjective Problems

1. Three charges each of value q, are placed at the corners of an equilateral triangle. A fourth charge Q is placed at the centre of the triangle. *(1978)*
(i) If $Q = -q$, will the charges at the corners move towards centre or fly away from it.
(ii) For what value of Q will the charges remain stationary? In this situation how much work is done in removing the charges to infinity?

2. A rigid insulated wire frame, in the form of right triangle ABC is set in a vertical plane. Two beads of equal masses m each carrying charges q_1 and q_2 are connected by a chord of length l and can slide without friction on the wires. Considering the case when the beads are stationary, determine : *(1978)*

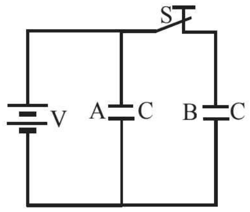


(i) the angle α,
(ii) the tension in the chord, and
(iii) the normal reactions on the beads.
If the chord is now cut, what are the values of the charges for which the beads continue to remain stationary?

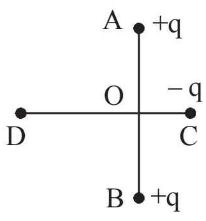
3. A charge 'Q' is distributed over two concentric hollow spheres of radii 'r' and 'R' (>r) such that the surface densities are equal. Find the potential at the common centre. *(1981- 3 Marks)*

4. A thin fixed ring of radius 1 metre has a positive charge 1×10^{-5} coulomb uniformly distributed over it. A particle of mass 0. 9 gm and having a negative charge of 1×10^{-6} coulomb is placed on the axis at a distance of 1 cm from the centre of the ring. show that the motion of the negatively charged particle is approaximately simple harmonic. Calculate the time period of oscillations. *(1982 - 5marks)*

5. The figure shows two identical parallel plate capacitors connected to a battery with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant (or relative permittivity) 3. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric. *(1983 - 6 Marks)*



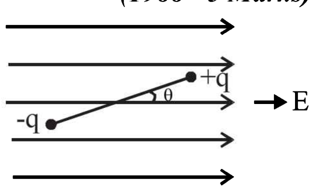
6. Two fixed, equal, positive charges, each of magnitude 5×10^{-5} coul are located at points A and B separated by a distance of 6 m. An equal and opposite charge moves towards them along the line COD, the perpendicular bisector of the line AB. *(1985 - 6 Marks)*



The moving charge, when it reaches the point C at a distance of 4 m from O, has a kinetic energy of 4 joules. Calculate the distance of the farthest point D which the negative charge will reach before returning towards C.

7. Three particles, each of mass 1 gm and carrying a charge q, are suspended from a common point by insulated massless strings, each 100 cm long. If the particles are in equilibrium and are located at the corners of an equilateral triangle of side length 3 cm, calculate the charge q on each particle. (Take $g = 10\ m/s^2$). *(1988 - 5 Marks)*

8. A point particle of mass M is attached to one end of a massless rigid non-conducting rod of length L. Another point particle of the same mass is attached to the other end of the rod. The two particles carry charges $+q$ and $-$ q respectively. This arrangement is held in a region of a uniform electric field E such that the rod makes a small angle θ (say of about 5 degree) with the field direction, fig. Find an expression for the minimum time needed for the rod to become parallel to the field after it is set free. *(1989 - 8mark)*

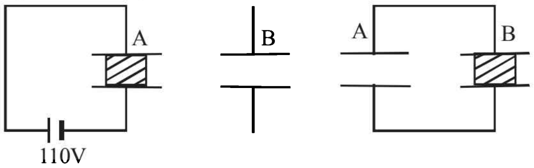


9. Three concentric spherical metallic shells A, B and C of radii a, b and c ($a < b < c$) have surface charge densities σ, $-\sigma$ and σ respectively. *(1990 -7 Marks)*
(i) Find the potential of the three shells A, B and C.
(ii) If the shells A and C are at the same potential, obtain the relation between the radii a, b and c.

10. Two fixed charges $-2Q$ and Q are located at the points with coordinates ($-3a$, 0) and (+ $3a$, 0) respectively in the x-y plane. *(1991 - 4 + 2 + 2 Marks)*
(a) Show that all points in the x-y plane where the electric potential due to the two charges is zero, lie on a circle. Find its radius and the location of its centre.
(b) Give the expression $V(x)$ at a general point on the x - axis and sketch the function $V(x)$ on the whole x-axis.
(c) If a particle of charge $+q$ starts form rest at the centre of the circle, show by a short quantative argument that the particle eventually crosses the circle. Find its speed when it does so.

11. (a) A charge of Q coulomb is uniformly distributed over a spherical volume of radius R metres. Obtain an expression for the energy of the system.
(b) What will be the corresponding expression for the energy needed to completely disassemble the planet earth against the gravitational pull amongst its constituent particles ?
Assume the earth to be a sphere of uniform mass density. Calculate this energy, given the product of the mass and the radius of the earth to be 2.5×10^{31} kg. m.
(c) If the same charge of Q coulomb as in part (a) above is given to a spherical conductor of the same radius R, what will be energy of the system ? *(1992 - 10 Marks)*

12. Two parallel plate capacitors A and B have the same separation $d = 8.85 \times 10^{-4}$ m between the plates. The plate area of A and B are $0.04\ m^2$ and $0.02 m^2$ respectively. A slab of dielectric constant (relative permittivity) $K = 9$ has dimensions such that it can exactly fill the space between the plates of capacitor B. *(1993 - 2 + 3 + 2 Marks)*



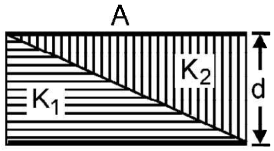
(a) (b) (c)

(i) The dielectric slab is placed inside A as shown in figure (a). A is then charged to a potential difference of 110V. Calculate the capacitance of A and the energy stored in it.
(ii) The battery is disconnected and then the dielectric slab is moved from A. Find the work done by the external agency in removing the slab from A.
(iii) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected as shown in figure (c). Calculate the energy stored in the system.

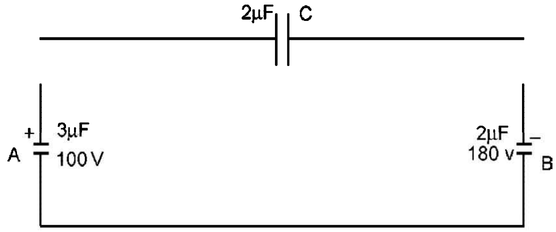
13. A circular ring of radius R with uniform positive charge density λ per unit length is located in the y-z plane with its centre at the origin O. A particle of mass m and positive charge q is projected from the point P $(R\sqrt{3}, 0, 0)$ on the positive x-axis directly towards O, with an initial speed v. Find the smallest (non-zero) value of the speed v such that the particle does not return to P. *(1993-4 Marks)*

14. Two square metal plates of side 1 m are kept 0.01 m apart like a parallel plate capacitor in air in such a way that one of their edges is perpendicular to an oil surface in a tank filled with an insulating oil. The plates are connected to a battery of emf 500 V. The plates are then lowered vertically into the oil at a speed of 0.001 ms^{-1}. Calculate the current drawn from the battery during the process. (Dielectric constant of oil = 11, $\varepsilon_0 = 8.85 \times 10^{-12} C^2N^{-1}m^{-1}$) *(1994 - 6 Marks)*

15. The capacitance of a parallel plate capacitor with plate area A and separation d is C. The space between the plates is filled with two wedges of dielectric constants K_1 and K_2, respectively. Find the capacitance of the resulting capacitor. *(1996 - 2 Marks)*



16. Two capacitors A and B with capacities 3 μF and 2 μF are charged to a potential difference of 100 V and 180 V respectively. The plates of the capacitors are connected as shown in the figure with one wire from each capacitor free. The upper plate of A is positive and that of B is negative. An uncharged 2 μF capacitor C with lead wires falls on the free ends to complete the circuit. Calculate *(1997 - 5 Marks)*



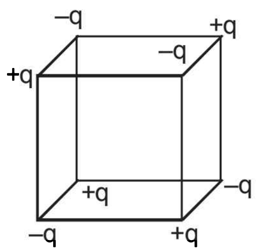
(i) the final charge on the three capacitors. and
(ii) the amount of electrostatic energy stored in the system before and after the completion of the circuit.

17. A conducting sphere S_1 of radius r is attached to an insulating handle. Another conducting sphere S_2 of radius R is mounted on an insulating stand. S_2 is initially uncharged. S_1 is given a charge Q, brought into contact with S_2, and removed. S_1 is recharged such that the charge on it is again Q; and it is again brought into contact with S_2 and removed. This procedure is repeated n times. *(1998 - 8 Marks)*
(a) Find the electrostatic energy of S_2 after n such contacts with S_1.
(b) What is the limiting value of this energy as $n \to \infty$?

18. A non-conducting disc of radius a and uniform positive surface charge density σ is placed on the ground, with its axis vertical. A particle of mass m and positive charge q is dropped, along the axis of the disc, from a height H with zero initial velocity. The particle has $q/m = 4 \epsilon_0\, g/\sigma$ *(1999 - 10 Marks)*
(a) Find the value of H if the particle just reaches the disc.
(b) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.

19. Four point charges $+8mC, -1mC, -1mC$, and $+8mC$ are fixed at the points $-\sqrt{\frac{27}{2}}$m, $-\sqrt{\frac{3}{2}}$m, $+\sqrt{\frac{3}{2}}$m and $+\sqrt{\frac{27}{2}}$m respectively on the y-axis. A particle of mass 6×10^{-4} kg and charge +0.1 μC moves along the -x direction. Its speed at $x = +\infty$ is V_0. Find the least value of V_0 for which the particle will cross the origin. Find also the kinetic energy of the particle at the origin. Assume that space is gravity free.
Given $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 Nm^2/C^2$. *(2000 - 10 Marks)*

20. Charges $+q$ and $-q$ are located at the corners of a cube of side as show in the figure. Find the work done to separate the charges to infinite distance. *(2003 - 2 Marks)*



21. A charge $+Q$ is fixed at the origin of the co-ordinate system while a small electric dipole of dipole moment $\vec{p}$ pointing away from the charge along the x-axis is set free from a point far away from the origin. ***(2003 - 4 Marks)***

(a) Calculate the K.E. of the dipole when it reaches to a point $(d, 0)$.

(b) Calculate the force on the charge $+Q$ at this moment.

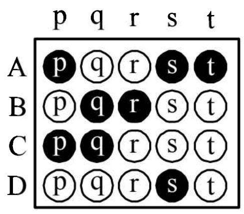
22. Two uniformly charged large plane sheets S_1 and S_2 having charge densities σ_1 and σ_2 $(\sigma_1 > \sigma_2)$ are placed at a distance d parallel to each other. A charge q_0 is moved along a line of length $a(a < d)$ at an angle 45° with the normal to S_1. Calculate the work done by the electric field ***(2004)***

23. A conducting liquid bubble of radius a and thickness t $(t << a)$ is charged to potential V. If the bubble collapses to a droplet, find the potential on the droplet. ***(2005 - 2 Marks)***

F Match the Following

DIRECTIONS (Q. No. 1) : *Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r and s. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example :*

If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s then the correct darkening of bubbles will look like the given.



1. Six point charges, each of the same magnitude q, are arranged in different manners as shown in **Column-II**. In each case, a point M and line PQ passing through M are shown. Let E be the electric field and V be the electric potential at M (potential at infinity is zero) due to the given charge distribution when it is at rest. Now, the whole system is set into rotation with a constant angular velocity about the line PQ. Let B be the magnetic field at M and μ be the magnetic moment of the system in this condition. Assume each rotating charge to the equivalent to a steady current. ***(2009)***

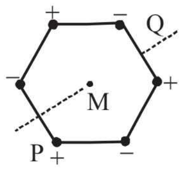
Column-I | **Column-II**

A) $E = 0$

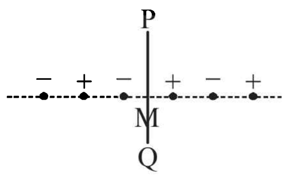
(B) $V \neq 0$

(C) $B = 0$

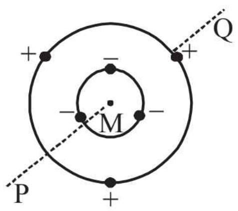
(D) $\mu \neq 0$

(p) 

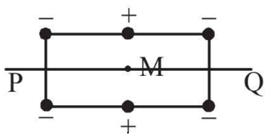
Charges are at the corners of a regular hexagon. M is at the centre of the hexagon. PQ is perpendicular to the plane of the hexagon .

(q) 

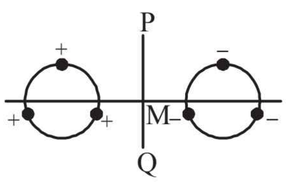
Charges are on a line perpendicular to PQ at equal intervals. M is the mid-point between the two innermost charges.

(r) 

Charges are placed on two coplanar insulating rings at equal intervals. M is the common centre of the rings. PQ is perpendicular to the plane of the rings.

(s) 

Charges are placed at the corners of a rectangle of sides a and $2a$ and at the mid points of the longer sides. M is at the centre of the rectangle. PQ is parallel to the longer sides.

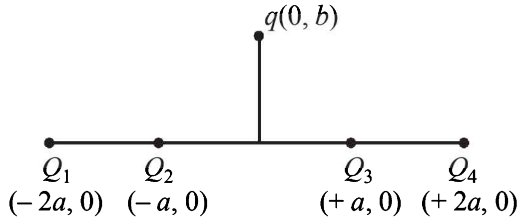
(t) 

Charges are placed on two coplanar, identical insulating rings at equal intervals. M is the mid-point between the centres of the rings. PQ is perpendicular to the line joining the centres and coplanar to the rings.

DIRECTIONS (Q. No. 2) : *Following question has matching lists. The codes for the lists have choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

2. Four charges 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-I with List-II and select the correct answer using the code given below the lists. *(JEE Adv. 2014)*

	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.**	$-y$



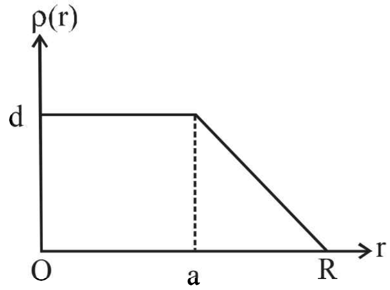
Codes:

(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

G Comprehension Based Questions

PASSAGE-I

The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density ρ (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. *(2008)*



1. 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

2. For a = 0, the value of d (maximum value of ρ as shown in the figure) is –

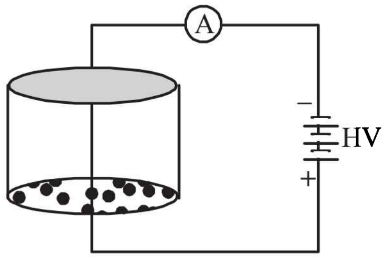
(a) $\dfrac{3Ze}{4\pi R^3}$ (b) $\dfrac{3Ze}{\pi R^3}$

(c) $\dfrac{4Ze}{3\pi R^3}$ (d) $\dfrac{Ze}{3\pi R^3}$

3. 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

PASSAGE-II

Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius r <<h. Now a high voltage source (HV) is connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$. Due to their conducting surface, the balls will get charged, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collisions between the balls and the interaction between them is negligible. (Ignore gravity)



4. Which one of the following statements is correct? *(JEE Adv. 2016)*
(a) The balls will stick to the top plate and remain there
(b) The balls will bounce back to the bottom plate carrying the same charge they went up with
(c) The balls will bounce back to the bottom plate carrying the opposite charge they went up with
(d) The balls will execute simple harmonic motion between the two plates

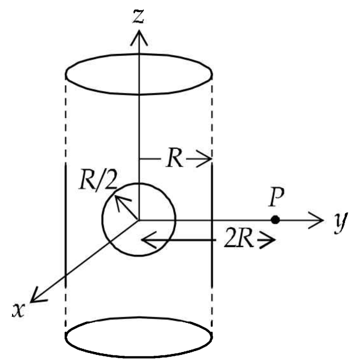
5. The average current in the steady state registered by the ammeter in the circuit will be *(JEE Adv. 2016)*
(a) zero
(b) proportional to the potential V_0
(c) proportional to $V_0^{1/2}$
(d) proportional to V_0^2

H Assertion & Reason Type Questions

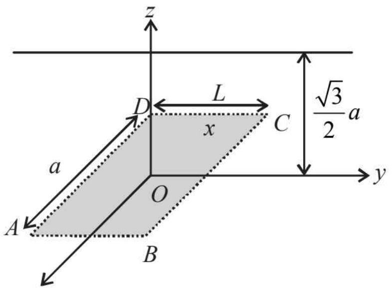
1. **STATEMENT-1 :** For practical purposes, the earth is used as a reference at zero potential in electrical circuits.
and
STATEMENT-2 : The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$. ***(2008)***
(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(b) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(c) Statement -1 is True, Statement-2 is False
(d) Statement -1 is False, Statement-2 is True

I Integer Value Correct Type

1. 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 $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at $r = R$, find the value of a. ***(2009)***
2. Four point charges, each of +q, are rigidly fixed at the four corners of a square planar soap film of side 'a'. The surface tension of the soap film is γ. The system of charges and planar film are in equilibrium, and $a = k\left[\frac{q^2}{\gamma}\right]^{1/N}$, where 'k' is a constant. Then N is ***(2011)***
3. An infinitely long solid cylinder of radius R has a uniform volume charge density ρ. It has a spherical cavity of radius $R/2$ with its centre on the axis of the cylinder, as shown in the figure. The magnitude of the electric field at the point P, which is at a distance $2R$ from the axis of the cylinder, is given by the expression $\frac{23\rho R}{16K\varepsilon_0}$. The value of k is ***(2012)***



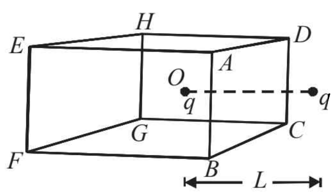
4. An infinitely long uniform line charge distribution of charge per unit length λ lies parallel to the y-axis in the $y-z$ plane at $z = \frac{\sqrt{3}}{2}$ a (see figure). If the magnitude of the flux of the electric field through the rectangular surface $ABCD$ lying in the $x-y$ plane with its centre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



(JEE Adv. 2015)

Section-B JEE Main / AIEEE

1. On moving a charge of 20 coulomb by 2 cm, 2 J of work is done, then the potential difference between the points is **[2002]**
(a) 0.1 V (b) 8V
(c) 2V (d) 0.5V.
2. If there are n capacitors in parallel connected to V volt source, then the energy stored is equal to **[2002]**
(a) CV (b) $\frac{1}{2}nCV^2$
(c) CV^2 (d) $\frac{1}{2n}CV^2$
3. A charged particle q is placed at the centre O of cube of length L ($A\,B\,C\,D\,E\,F\,G\,H$). Another same charge q is placed at a distance L from O. Then the electric flux through $ABCD$ is **[2002]**



(a) $q/4\pi\epsilon_0 L$
(b) zero
(c) $q/2\pi\epsilon_0 L$
(d) $q/3\pi\epsilon_0 L$
4. If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium then the value of q is **[2002]**
(a) $Q/2$ (b) $-Q/2$
(c) $Q/4$ (d) $-Q/4$
5. Capacitance (in F) of a spherical conductor with radius 1 m is **[2002]**
(a) 1.1×10^{-10} (b) 10^{-6}
(c) 9×10^{-9} (d) 10^{-3}

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

(a) $(\phi_2 - \phi_1)\varepsilon_o$ (b) $(\phi_1 + \phi_2)/\varepsilon_o$

(c) $(\phi_2 - \phi_1)/\varepsilon_o$ (d) $(\phi_1 + \phi_2)\varepsilon_o$

7. A sheet of aluminium foil of negligible thickness is introduced between the plates of a capacitor. The capacitance of the capacitor **[2003]**

(a) decreases (b) remains unchanged

(c) becomes infinite (d) increases

8. A thin spherical conducting shell of radius R has a charge q. Another charge Q is placed at the centre of the shell. The electrostatic potential at a point P a distance $\frac{R}{2}$ from the centre of the shell is **[2003]**

(a) $\frac{2Q}{4\pi\varepsilon_o R}$ (b) $\frac{2Q}{4\pi\varepsilon_o R} - \frac{2q}{4\pi\varepsilon_o R}$

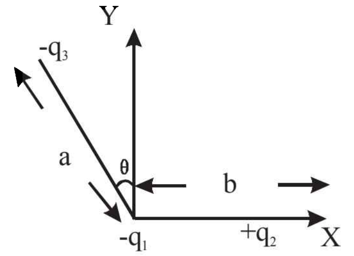
(c) $\frac{2Q}{4\pi\varepsilon_o R} + \frac{q}{4\pi\varepsilon_o R}$ (d) $\frac{(q+Q)2}{4\pi\varepsilon_o R}$

9. The work done in placing a charge of 8×10^{-18} coulomb on a condenser of capacity 100 micro-farad is **[2003]**

(a) 16×10^{-32} joule (b) 3.1×10^{-26} joule

(c) 4×10^{-10} joule (d) 32×10^{-32} joule

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



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

(c) $\frac{q_2}{b^2} + \frac{q_3}{a^2}\cos\theta$ (d) $\frac{q_2}{b^2} - \frac{q_3}{a^2}\sin\theta$

11. The length of a given cylindrical wire is increased by 100%. Due to the consequent decrease in diameter the change in the resistance of the wire will be **[2003]**

(a) 200% (b) 100%

(c) 50% (d) 300%

12. Two spherical conductors B and C having equal radii and carrying equal charges on them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that B but **uncharged** is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is **[2004]**

(a) $F/8$ (b) $3F/4$

(c) $F/4$ (d) $3F/8$

13. A charge particle 'q' is shot towards another charged particle 'Q' which is fixed, with a speed 'v'. It approaches 'Q' upto a closest distance r and then returns. If q were given a speed of '$2v$' the closest distances of approach would be **[2004]**

(a) $r/2$ (b) $2r$

(c) r (d) $r/4$

14. Four charges equal to $-Q$ are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium the value of q is **[2004]**

(a) $-\frac{Q}{2}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

(c) $-\frac{Q}{4}(1+2\sqrt{2})$ (d) $\frac{Q}{2}(1+2\sqrt{2})$

15. A charged oil drop is suspended in a uniform field of 3×10^4 v/m so that it neither falls nor rises. The charge on the drop will be (Take the mass of the charge = 9.9×10^{-15} kg and $g = 10$ m/s^2) **[2004]**

(a) 1.6×10^{-18} C (b) 3.2×10^{-18} C

(c) 3.3×10^{-18} C (d) 4.8×10^{-18} C

16. Two point charges + $8q$ and – $2q$ are located at $x = 0$ and $x = L$ respectively. The location of a point on the x axis at which the net electric field due to these two point charges is zero is **[2005]**

(a) $\frac{L}{4}$ (b) $2L$

(c) $4L$ (d) $8L$

17. Two thin wire rings each having a radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are $+q$ and $-q$. The potential difference between the centres of the two rings is **[2005]**

(a) $\frac{q}{2\pi\epsilon_0}\left[\frac{1}{R} - \frac{1}{\sqrt{R^2+d^2}}\right]$

(b) $\frac{qR}{4\pi\epsilon_0 d^2}$

(c) $\frac{q}{4\pi\epsilon_0}\left[\frac{1}{R} - \frac{1}{\sqrt{R^2+d^2}}\right]$

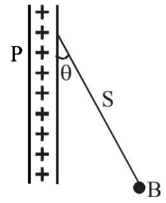
(d) zero

18. A parallel plate capacitor is made by stacking n equally spaced plates connected alternatively. If the capacitance between any two adjacent plates is 'C' then the resultant capacitance is **[2005]**

(a) $(n+1)C$ (b) $(n-1)C$

(c) nC (d) C

19. A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to **[2005]**



(a) cot θ
(b) cos θ
(c) tan θ
(d) sin θ

20. A fully charged capacitor has a capacitance 'C'. It is discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat capacity 's' and mass 'm'. If the temperature of the block is raised by 'ΔT', the potential difference 'V' across the capacitance is

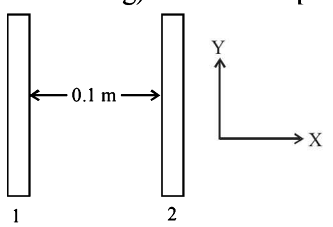
(a) $\dfrac{mC\Delta T}{s}$ (b) $\sqrt{\dfrac{2mC\Delta T}{s}}$ **[2005]**

(c) $\sqrt{\dfrac{2ms\Delta T}{C}}$ (d) $\dfrac{ms\Delta T}{C}$

21. An electric dipole is placed at an angle of 30° to a non-uniform electric field. The dipole will experience **[2006]**

(a) a translational force only in the direction of the field
(b) a translational force only in a direction normal to the direction of the field
(c) a torque as well as a translational force
(d) a torque only

22. Two insulating plates are both uniformly charged in such a way that the potential difference between them is $V_2 - V_1 = 20$ V. (i.e., plate 2 is at a higher potential). The plates are separated by $d = 0.1$ m and can be treated as infinitely large. An electron is released from rest on the inner surface of plate 1. What is its speed when it hits plate 2? ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg) **[2006]**



(a) 2.65×10^6 m/s
(b) 7.02×10^{12} m/s
(c) 1.87×10^6 m/s
(d) 32×10^{-19} m/s

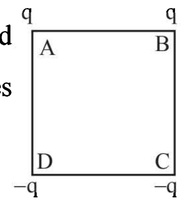
23. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of spheres A and B is

(a) 4 : 1 (b) 1 : 2 **[2006]**
(c) 2 : 1 (d) 1 : 4

24. An electric charge $10^{-3}\ \mu$C is placed at the origin (0, 0) of $X-Y$ co-ordinate system. Two points A and B are situated at $\left(\sqrt{2}, \sqrt{2}\right)$ and (2, 0) respectively. The potential difference between the points A and B will be **[2007]**

(a) 4.5 volts (b) 9 volts
(c) Zero (d) 2 volt

25. Charges are placed on the vertices of a square as shown. Let $\vec{E}$ be the electric field and V the potential at the centre. If the charges on A and B are interchanged with those on D and C respectively, then **[2007]**



(a) $\vec{E}$ changes, V remains unchanged
(b) $\vec{E}$ remains unchanged, V changes
(c) both $\vec{E}$ and V change
(d) $\vec{E}$ and V remain unchanged

26. The potential at a point x (measured in μm) due to some charges situated on the x-axis is given by
$V(x) = 20/(x^2 - 4)$ volt
The electric field E at $x = 4\ \mu$m is given by **[2007]**

(a) (10/9) volt/μm and in the +ve x direction
(b) (5/3) volt/μm and in the –ve x direction
(c) (5/3) volt/μm and in the +ve x direction
(d) (10/9) volt/μm and in the –ve x direction

27. A parallel plate condenser with a dielectric of dielectric constant K between the plates has a capacity C and is charged to a potential V volt. The dielectric slab is slowly removed from between the plates and then reinserted. The net work done by the system in this process is **[2007]**

(a) zero (b) $\dfrac{1}{2}(K-1)\,CV^2$

(c) $\dfrac{CV^2(K-1)}{K}$ (d) $(K-1)\,CV^2$

28. If g_E and g_M are the accelerations due to gravity on the surfaces of the earth and the moon respectively and if Millikan's oil drop experiment could be performed on the two surfaces, one will find the ratio **[2007]**

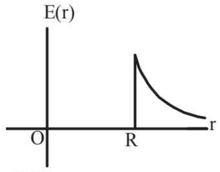
$\dfrac{\text{electronic charge on the moon}}{\text{electronic charge on the earth}}$ to be

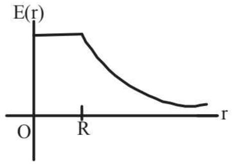
(a) g_M / g_E (b) 1
(c) 0 (d) g_E / g_M

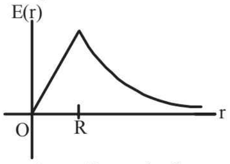
29. A parallel plate capacitor with air between the plates has capacitance of 9 pF. The separation between its plates is 'd'. The space between the plates is now filled with two dielectrics. One of the dielectrics has dielectric constant k_1 = 3 and thickness $\dfrac{d}{3}$ while the other one has dielectric constant k_2 = 6 and thickness $\dfrac{2d}{3}$. Capacitance of the capacitor is now **[2008]**

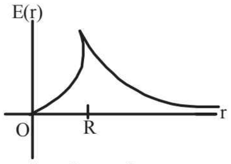
(a) 1.8 pF (b) 45 pF
(c) 40.5 pF (d) 20.25 pF

30. A thin spherical shell of radus 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? **[2008]**

(a) 

(b) 

(c) 

(d) 

31. 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 : **[2009]**

(a) 9.60×10^{-17}J (b) -2.24×10^{-16} J
(c) 2.24×10^{-16} J (d) -9.60×10^{-17} J

32. 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: **[2009]**

(a) -1 (b) 1 (c) $-\dfrac{1}{\sqrt{2}}$ (d) $-2\sqrt{2}$

33. *This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.* **[2009]**

Statement-1 : For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

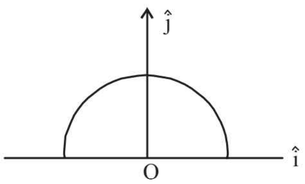
Statement-2 : The net work done by a conservative force on an object moving along a closed loop is zero.

(a) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(b) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is false, Statement-2 is true.
(d) Statement-1 is true, Statement-2 is false.

34. Let $P(r) = \dfrac{Q}{\pi R^4} r$ 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 the sphere, the magnitude of electric field is : **[2009]**

(a) $\dfrac{Q}{4\pi \in_0 r_1^2}$ (b) $\dfrac{Qr_1^2}{4\pi \in_0 R^4}$
(c) $\dfrac{Qr_1^2}{3\pi \in_0 R^4}$ (d) 0

35. 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 **[2010]**



(a) $\dfrac{q}{4\pi^2 \varepsilon_0 r^2}\hat{j}$
(b) $-\dfrac{q}{4\pi^2 \varepsilon_0 r^2}\hat{j}$
(c) $-\dfrac{q}{2\pi^2 \varepsilon_0 r^2}\hat{j}$
(d) $\dfrac{q}{2\pi^2 \varepsilon_0 r^2}\hat{j}$

36. Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0\left(\dfrac{5}{4} - \dfrac{r}{R}\right)$ 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 **[2010]**

(a) $\dfrac{\rho_0 r}{4\varepsilon_0}\left(\dfrac{5}{3} - \dfrac{r}{R}\right)$ (b) $\dfrac{4\pi\rho_0 r}{3\varepsilon_0}\left(\dfrac{5}{3} - \dfrac{r}{R}\right)$
(c) $\dfrac{4\rho_0 r}{4\varepsilon_0}\left(\dfrac{5}{4} - \dfrac{r}{R}\right)$ (d) $\dfrac{\rho_0 r}{3\varepsilon_0}\left(\dfrac{5}{4} - \dfrac{r}{R}\right)$

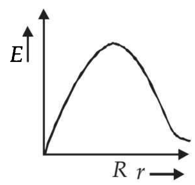
37. Two identical charged spheres suspended from a common point by two massless strings of length l are initially a distance $d(d << l)$ apart because of their mutual repulsion. The charge begins to leak from both the spheres at a constant rate. As a result charges approach each other with a velocity v. Then as a function of distance x between them, **[2011]**

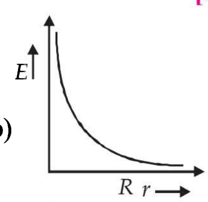
(a) $v \propto x^{-1}$ (b) $v \propto x^{1/2}$
(c) $v \propto x$ (d) $v \propto x^{-1/2}$

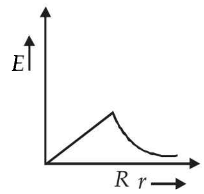
38. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre and a, b are constants. Then the charge density inside the ball is : **[2011]**

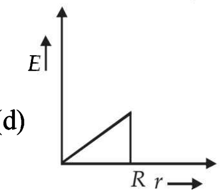
(a) $-6a\varepsilon_0 r$ (b) $-24\pi a\varepsilon_0$
(c) $-6a\varepsilon_0$ (d) $-24\pi a\varepsilon_0 r$

39. 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: **[2012]**

(a) 

(b) 

(c) 

(d) 

40. This questions has statement-1 and statement-2. Of the four choices given after the statements, choose the one that best describe the two statements. **[2012]**

An insulating solid sphere of radius R has a uniformly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point out side the sphere. The electric potential at infinite is zero.

Statement -1 : When a charge q is take from the centre of the surface of the sphere its potential energy changes by $\dfrac{q\rho}{3\varepsilon_0}$.

Statement -2 : The electric field at a distance r ($r<R$) from the centre of the sphere is $\frac{\rho r}{3\varepsilon_0}$.

(a) Statement 1 is true, Statement 2 is true; Statement 2 is not the correct explanation of statement 1.

(b) Statement 1 is true Statement 2 is false.

(c) Statement 1 is false Statement 2 is true.

(d) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1

41. Two capacitors C_1 and C_2 are charged to 120 V and 200 V respectively. It is found that connecting them together the potential on each one can be made zero. Then **[JEE Main 2013]**

(a) $5C_1 = 3C_2$ (b) $3C_1 = 5C_2$

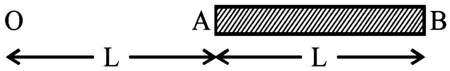
(c) $3C_1 + 5C_2 = 0$ (d) $9C_1 = 4C_2$

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

(a) y (b) –y

(c) $\frac{1}{y}$ (d) $-\frac{1}{y}$

43. 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]**



(a) $\frac{Q}{8\pi\varepsilon_0 L}$ (b) $\frac{3Q}{4\pi\varepsilon_0 L}$

(c) $\frac{Q}{4\pi\varepsilon_0 L \ln 2}$ (d) $\frac{Q\ln 2}{4\pi\varepsilon_0 L}$ s

44. 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]**

(a) 120 J/C (b) -120 J/C

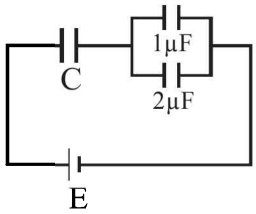
(c) -80 J/C (d) 80 J/C

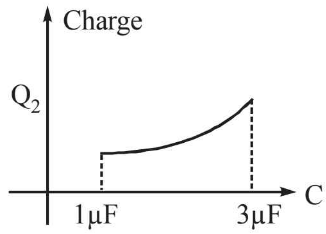
45. A parallel plate capacitor is made of two circular plates separated by a distance 5 mm and with a dielectric of dielectric constant 2.2 between them. When the electric field in the dielectric is 3×10^4 V/m the charge density of the positive plate will be close to: **[JEE Main 2014]**

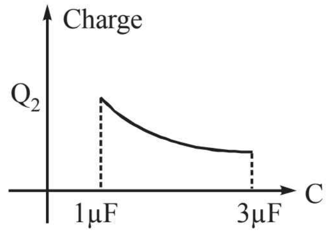
(a) 6×10^{-7} C/m² (b) 3×10^{-7} C/m²

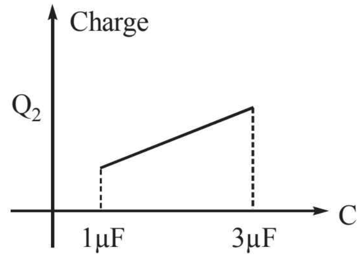
(c) 3×10^{4} C/m² (d) 6×10^{4} C/m²

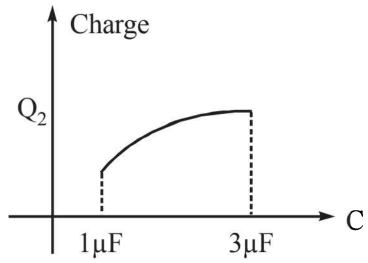
46. In the given circuit, charge Q_2 on the 2μF capacitor changes as C is varied from 1μF to 3μF. Q_2 as a function of 'C' is given properly by: (*figures are drawn schematically and are not to scale*) **[JEE Main 2015]**



(a)


(b)


(c)


(d)


47. 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

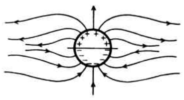
(a) $R_1 = 0$ and $R_2 < (R_4 - R_3)$ **[JEE Main 2015]**

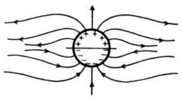
(b) $2R < R_4$

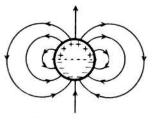
(c) $R_1 = 0$ and $R_2 > (R_4 - R_3)$

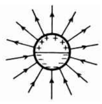
(d) $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$

48. A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge - σ in the lower half. The electric field lines around the cylinder will look like figure given in : (*figures are schematic and not drawn to scale*) **[JEE Main 2015]**

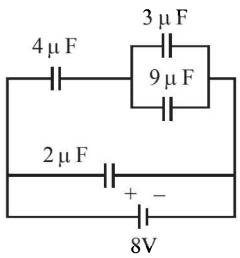
(a) 

(b) 

(c) 

(d) 

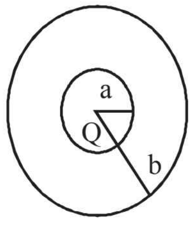
49. A combination of capacitors is set up as shown in the figure. The magnitude of the electric field, due to a point charge Q (having a charge equal to the sum of the charges on the 4 μ F and 9 μ F capacitors), at a point distance 30 m from it, would equal : **[JEE Main 2016]**



(a) 420 N/C (b) 480 N/C

(c) 240 N/C (d) 360 N/C

50. The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), have volume charge density $\rho = \frac{A}{r}$, where A is a constant and r is the distance from the centre. At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is : **[JEE Main 2016[**



(a) $\frac{2Q}{\pi\left(a^2-b^2\right)}$ (b) $\frac{2Q}{\pi a^2}$

(c) $\frac{Q}{2\pi a^2}$ (d) $\frac{Q}{2\pi\left(b^2-a^2\right)}$