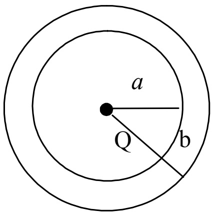
JEE Mains & Advanced Past Years Questions

JEE-MAIN PREVIOUS YEAR'S

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

[*JEE Main - 2016*]



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

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

2. 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 torque $\vec{T}_2 = -\vec{T}_1$. The angle θ is :

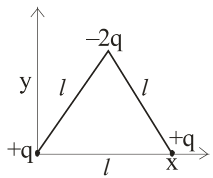
[*JEE Main - 2017*]

(*a*) 60° (*b*) 90°

(*c*) 30° (*d*) 45°

3. Determine the electric dipole moment of the system of three charges, placed on the vertices of an equilateral triangle, as shown in the figure:

[*JEE Main - 2019 (January)*]



(*a*) $\sqrt{3}q\ell\frac{\hat{j}-\hat{i}}{\sqrt{2}}$ (*b*) $(q\ell)\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

(*c*) $2q\ell\hat{j}$ (*d*) $-\sqrt{3}q\ell\hat{j}$

4. For a uniformly charged ring of radius R, the electric field on its axis has the largest magnitude at a distance h from its centre. Then value of h is:

[JEE Main - 2019 (January)]

(*a*) $\frac{R}{\sqrt{5}}$ (*b*) $\frac{R}{\sqrt{2}}$

(*c*) R (*d*) $R\sqrt{2}$

5. Three charges +Q, q, +Q are placed respectively, at distance, 0, d/2 and d from the origin, on the x-axis. If the net force experienced by +Q, placed at x = 0, is zero, then value of q is ***[JEE Main - 2019 (January)]***

(*a*) –Q/4 (*b*) +Q/2

(*c*) +Q/4 (*d*) –Q/2

6. Charge is distributed within a sphere of radius R with a volume charge density $\rho(r) = \frac{A}{r^2}e^{-2r/a}$, where A and a are constants. If Q is the total charge of this charge distribution the radius R is:

[JEE Main - 2019 (January)]

(*a*) $a\log\left(1-\frac{Q}{2\pi aA}\right)$ (*b*) $\frac{a}{2}\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$

(*c*) $\frac{a}{2}\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$ (*d*) $\frac{a}{2}\log\left(1-\frac{1}{2\pi aA}\right)$

7. Two point charge $q_1\left(\sqrt{10}\mu C\right)$ and q2 (– 25μC) are placed on the x-axis at x = 1 m and x = 4 m respectively. The electric field (in V/m) at a point y = 3 m on y-axis is, $\left[\text{take}\frac{1}{4\pi\varepsilon_0} = 9\times10^9\,\text{Nm}^2\text{C}^{-2}\right]$

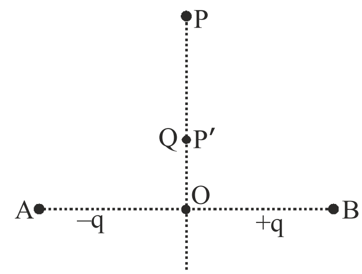
[JEE Main - 2019 (January)]

(*a*) $\left(63\hat{i}-27\hat{j}\right)\times10^2$ (*b*) $\left(-63\hat{i}+27\hat{j}\right)\times10^2$

(*c*) $\left(81\hat{i}-81\hat{j}\right)\times10^2$ (*d*) $\left(-81\hat{i}+81\hat{j}\right)\times10^2$

8. Charges – q and + q located at A and B, respectively, constitute an electric dipole. Distance AB = 2a, O is the mid point of the dipole and OP is perpendicular to AB. A charge Q is placed at P where OP = y and y >> 2a. the charge Q experiences an electrostatic force F. If Q is now moved along the equatorial line to P' such that $OP' = \left(\frac{y}{3}\right)$, the force on Q will be close to $\left(\frac{y}{2} >> 2a\right)$

[JEE Main - 2019 (January)]



(*a*) 3F (*b*) $\frac{F}{3}$

(*c*) 9F (*d*) 27F

9. Four point charges –q, +q, +q and –q are placed on y-axis at y = –2d, y = –d, y = +d and y = +2d, respectively. The magnitude of the electric field E at a point on the x-axis at x = D, with D>> d, will behave as:-

[JEE Main-2019 (April)]

(*a*) $E \propto \frac{1}{D}$ (*b*) $E \propto \frac{1}{D^3}$

(*c*) $E \propto \frac{1}{D^2}$ (*d*) $E \propto \frac{1}{D^4}$

10. The bob of a simple pendulum has mass 2g and a charge of 5.0 μC. It is at rest in a uniform horizontal electric field of intensity 2000V/m. At equilibrium, the angle that the pendulum makes with the vertical is (Take g = 10 m/s^s)

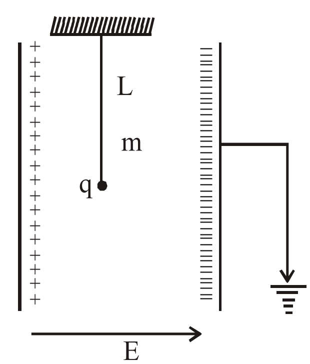
[JEE Main-2019 (April)]

(*a*) $\tan^{-1}(5.0)$ (*b*) $\tan^{-1}(2.0)$

(*c*) $\tan^{-1}(0.5)$ (*d*) $\tan^{-1}(0.2)$

11. A simple pendulum of length L is placed between the plates of a parallel plate capacitor having electric field E, as shown in figure. Its bob has mass m and charge q. The time period of the pendulum is given by :

[JEE Main-2019 (April)]



(*a*) $2\pi\sqrt{\frac{L}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$ (*b*) $2\pi\sqrt{\frac{L}{\left(g+\frac{qE}{m}\right)}}$

(*c*) $2\pi\sqrt{\frac{L}{\left(g-\frac{qE}{m}\right)}}$ (*d*) $2\pi\sqrt{\frac{L}{\sqrt{g^2-\frac{q^2E^2}{m^2}}}}$

12. An electric dipole is formed by two equal and opposite charges q with separation d. The charges have same mass m. It is kept in a uniform electric field E. If it is slightly rotated from its equilibrium orientation, then its angular frequency ω is : **[*JEE Main-2019 (April)*]**

(*a*) $\sqrt{\dfrac{qE}{2md}}$ (*b*) $2\sqrt{\dfrac{qE}{md}}$

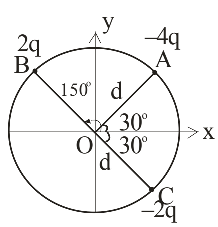
(*c*) $\sqrt{\dfrac{2qE}{md}}$ (*d*) $\sqrt{\dfrac{qE}{md}}$

13. 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 (April)*]**

(*a*) $a = \dfrac{3R}{2^{1/4}}$ (*b*) $a = R/\sqrt{3}$

(*c*) $a = 8^{-1/4}R$ (*d*) $a = 2^{-1/4}R$

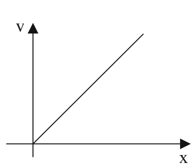
14. Three charged particles A, B and C with charges –4q, 2q and –2q are present on the circumference of a circle of radius d. The charged particles A, C and centre O of the circle formed an equilateral triangle as shown in figure. Electric field at O along x-direction is: **[*JEE Main-2020 (January)*]**

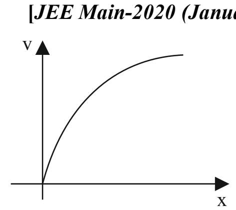


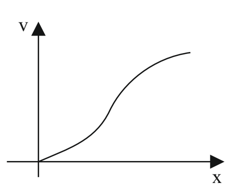
(*a*) $\dfrac{\sqrt{3}q}{\pi\varepsilon_0 d^2}$ (*b*) $\dfrac{\sqrt{3}q}{4\pi\varepsilon_0 d^2}$

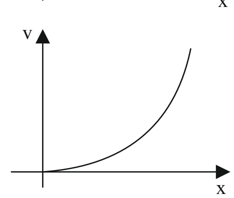
(*c*) $\dfrac{3\sqrt{3}q}{4\pi\varepsilon_0 d^2}$ (*d*) $\dfrac{2\sqrt{3}q}{\pi\varepsilon_0 d^2}$

15. A particle of mass m and charge q is released from rest in a uniform electric field. If there is no other force on the particle, the dependence of its speed v on the distance x travelled by it is correctly given by (graphs are schematic and not drawn to scale) **[*JEE Main-2020 (January)*]**

(*a*)


(*b*)


(*c*)


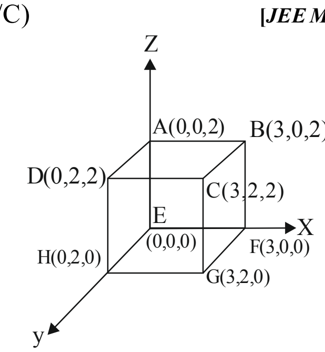
(*d*)


16. An electric dipole of moment $\vec{p} = (-\hat{i} - 3\hat{j} + 2\hat{k})\ 10^{-29}$ C.m. is at the origin (0,0,0). The electric field due to this dipole at $\vec{r} = (+\hat{i} + 3\hat{j} + 5\hat{k})$ (note that $\vec{r}.\vec{p} = 0$) is parallel to: **[*JEE Main-2020 (January)*]**

(*a*) $\left(+\hat{i} + 3\hat{j} - 2\hat{k}\right)$ (*b*) $\left(-\hat{i} + 3\hat{j} - 2\hat{k}\right)$

(*c*) $\left(+\hat{i} - 3\hat{j} - 2\hat{k}\right)$ (*d*) $\left(-\hat{i} - 3\hat{j} + 2\hat{k}\right)$

17. An electric field $\vec{E} = 4x\hat{i} - (y^2 + 1)\hat{j}$ N/C passes through the box shown in figure. The flux of the electric field through surface ABCD and BCGF and marked as ϕ_I and ϕ_{II} respectively. The difference between $(\phi_I - \phi_{II})$ is (in Nm^2/C) **[*JEE Main-2020 (January)*]**



18. In finding the electric field using gauss law the formula $|\vec{E}| = \dfrac{q_{enc}}{\varepsilon_0 |A|}$ is applicable. In the formula ε_0 is permittivity of free space, A is the area of Gaussian surface and q_{enc} is charges enclosed by the Gaussian surface. This equation can be used in which of the following situation? **[*JEE Main-2020 (January)*]**

(*a*) Only when the Gaussian surface in an equipotential surface

(*b*) Only when $|\vec{E}|$ = constant on the surface.

(*c*) Only when the Gaussian surface is an equipotential surface and $|\vec{E}|$ is constant of the surface.

(*d*) For any choice of Gaussian surface

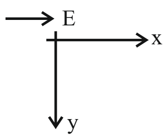
19. Consider two charged metallic spheres S_1 and S_2 of radii R_1 and R_2, respectively. The electric fields E_1 (on S_1) and E_2 (on S_2) on their surfaces are such that $E_1/E_2 = R_1/R_2$. Then the ratio V_1(on S_1)/V_2 (on S_2) of the electrostatic potentials on each sphere is **[*JEE Main-2020 (January)*]**

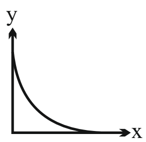
(*a*) $\left(\dfrac{R_1}{R_2}\right)^3$ (*b*) $\dfrac{R_1}{R_2}$

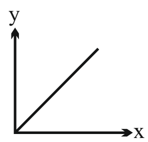
(*c*) $\left(\dfrac{R_2}{R_1}\right)$ (*d*) $\left(\dfrac{R_1}{R_2}\right)^2$

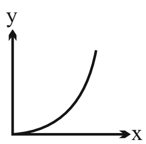
20. A small point mass carrying some positive charge on it, is released from the edge of a table. There is a uniform electric field in this region in the horizontal direction. Which of the following options then correctly describe the trajectory of the mass? (Curves are drawn schematically and are not to scale).

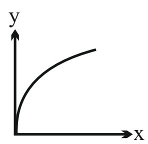
[*JEE Main-2020 (September)*]



(*a*) 

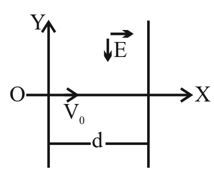
(*b*) 

(*c*) 

(*d*) 

21. A charged particle (mass m and charge q) moves along X-axis with velocity V_0. When it passes through the origin it enters a region having uniform electric field $\vec{E} = -E\hat{j}$ which extends upto x = d. Equation of path of electron in the region x > d is

[*JEE Main-2020 (September)*]



(*a*) $y = \frac{qEd}{mV_0^2}(x - d)$ (*b*) $y = \frac{qEd^2}{mV_0^2}x$

(*c*) $y = \frac{qEd}{mV_0^2}\left(\frac{d}{2} - x\right)$ (*d*) $y = \frac{qEd}{mV_0^2}x$

22. A particle of charge q and mass m is subjected to an electric field $E = E_0(1 - ax^2)$ in the x-direction, where a and E_0 are constants. Initially the particle was at rest at x = 0. Other than the initial position the kinetic energy of the particle becomes zero when the distance of the particle from the origin is

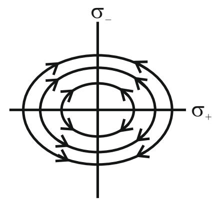
[*JEE Main-2020 (September)*]

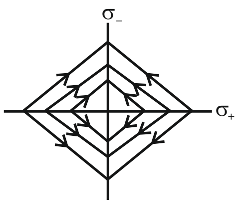
(*a*) $\sqrt{\frac{3}{a}}$ (*b*) $\sqrt{\frac{2}{a}}$

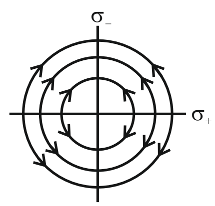
(*c*) $\sqrt{\frac{1}{a}}$ (*d*) a

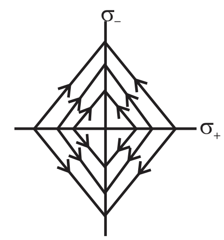
23. Two charged thin infinite plane sheets of uniform surface charge density σ_+ and σ_-, where $|\sigma_+| > |\sigma_-|$, intersect at right angle. Which of the following best represents the electric field lines for this system?

[*JEE Main-2020 (September)*]

(*a*) 

(*b*) 

(*c*) 

(*d*) 

24. Consider the force F on a charge 'q' due to a uniformly charged spherical shell of radius R carrying charge Q distributed uniformly over it. Which one of the following statements is true for F, if 'q' is placed at distance r from the centre of the shell?

[*JEE Main-2020 (September)*]

(*a*) $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for all r

(*b*) $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{R^2} > F > 0$ For r < R

(*c*) $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for r > R

(*d*) $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{R^2}$ for r < R

25. Two identical electric point dipoles have dipole moments $\vec{p_1} = p\hat{i}$ and $\vec{p_2} = p\hat{i}$ and are held on the x axis at distance 'a' from each other. When released, they move along the x-axis with the direction of their dipole moments remaining unchanged. If the mass of each dipole is 'm', their speed when they are infinitely far apart is

[*JEE Main-2020 (September)*]

(*a*) $\frac{P}{a}\sqrt{\frac{1}{2\pi\varepsilon_0 ma}}$ (*b*) $\frac{P}{a}\sqrt{\frac{2}{\pi\varepsilon_0 ma}}$

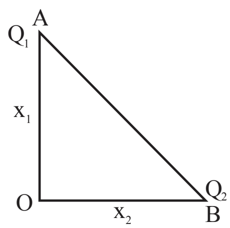
(*c*) $\frac{P}{a}\sqrt{\frac{1}{\pi\varepsilon_0 ma}}$ (*d*) $\frac{P}{a}\sqrt{\frac{3}{2\pi\varepsilon_0 ma}}$

26. Suppose that intensity of a laser is $\left(\frac{315}{\pi}\right)$ W /m The rms electric field, in units of V/m associated with this source is close to the nearest integer is ______.
($\varepsilon_0 = 8.86 \times 10^{-12}\ C^2Nm^{-2}$; $c = 3 \times 10^8\ ms^{-1}$)

[*JEE Main-2020 (September)*]

27. Charges Q_1 and Q_2 are at points A and B of a right angle triangle OAB (see figure). The resultant electric field at point O is perpendicular to the hypotenuse, then Q_1/Q_2 is proportional to

[*JEE Main-2020 (September)*]

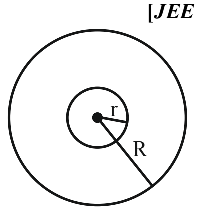


(*a*) $\frac{x_1^3}{x_2^3}$ (*b*) $\frac{x_2^2}{x_1^2}$

(*c*) $\frac{x_1}{x_2}$ (*d*) $\frac{x_2}{x_1}$

28. A charge Q is distributed over two concentric conducting thin spherical shells radii r and R (R > r). If the surface charge densities on the two shells are equal, the electric potential at the common centre is

[*JEE Main-2020 (September)*]



(*a*) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$ (*b*) $\frac{1}{4\pi\varepsilon_0}\frac{(R+2r)Q}{2(R^2+r^2)}$

(*c*) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{2(R^2+r^2)}Q$ (*d*) $\frac{1}{4\pi\varepsilon_0}\frac{(2R+r)}{(R^2+r^2)}Q$

29. Concentric metallic hollow spheres of radii R and 4R hold charges Q_1 and Q_2 respectively. Given that surface charge densities of the concentric spheres are equal, the potential difference V(R) – V(4R) is **[*JEE Main-2020 (September)*]**

(*a*) $\frac{3Q_2}{4\pi\varepsilon_0 R}$ (*b*) $\frac{3Q_1}{16\pi\varepsilon_0 R}$

(*c*) $\frac{Q_2}{4\pi\varepsilon_0 R}$ (*d*) $\frac{3Q_1}{4\pi\varepsilon_0 R}$

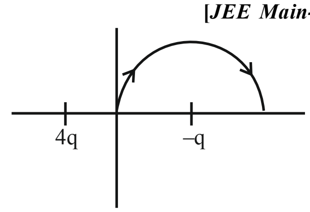
30. Hydrogen ion and singly ionized helium atom are accelerated, from rest, through the same potential difference. The ratio of final speeds of hydrogen and helium ions is close to **[*JEE Main-2020 (September)*]**

(*a*) 2 : 1 (*b*) 1 : 2

(*c*) 10 : 7 (*d*) 5 : 7

31. A two point charges 4q and –q are fixed on the x- axis at $x = -\frac{d}{2}$ and $x = \frac{d}{2}$, respectively. If a third point charge 'q' is taken from the origin to x = d along the semicircle as shown in the figure, the energy of the charge will

[*JEE Main-2020 (September)*]



(*a*) Decrease by $\frac{q^2}{4\pi\varepsilon_0 d}$ (*b*) Decrease by $\frac{4q^2}{3\pi\varepsilon_0 d}$

(*c*) Increase by $\frac{2q^2}{3\pi\varepsilon_0 d}$ (*d*) Increase by $\frac{3q^2}{4\pi\varepsilon_0 d}$

32. Ten charges are placed on the circumference of a circle of radius R with constant angular separation between successive charges. Alternate charges 1, 3, 5, 7, 9 have charge (+q) each, while 2, 4, 6, 8, 10 have charge (–q) each. The potential V and the electric field E at the centre of the circle are respectively.

(**Take** V = 0 at infinity)

[*JEE Main-2020 (September)*]

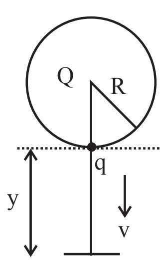
(*a*) V = 0; E = 0

(*b*) $V = \frac{10q}{4\pi\varepsilon_0 R}$; $E = \frac{10q}{4\pi\varepsilon_0 R^2}$

(*c*) $V = \frac{10q}{4\pi\varepsilon_0 R} = E = 0$

(*d*) V = 0; $E = \frac{10q}{4\pi\varepsilon_0 R^2}$

33. A solid sphere of radius R carries a charge Q + q distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q. If it acquires a speed v when it has fallen through a vertical height y (see figure), then : (assume the remaining portion to be spherical). **[*JEE Main-2020 (September)*]**



(*a*) $v^2 = y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

(*b*) $v^2 = 2y\left[\frac{qQR}{4\pi\varepsilon_0 (R+y)^3 m} + g\right]$

(*c*) $v^2 = y\left[\frac{qQ}{4\pi\varepsilon_0 R^2 ym} + g\right]$

(*d*) $v^2 = 2y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

NUMERICAL BASED QUESTIONS

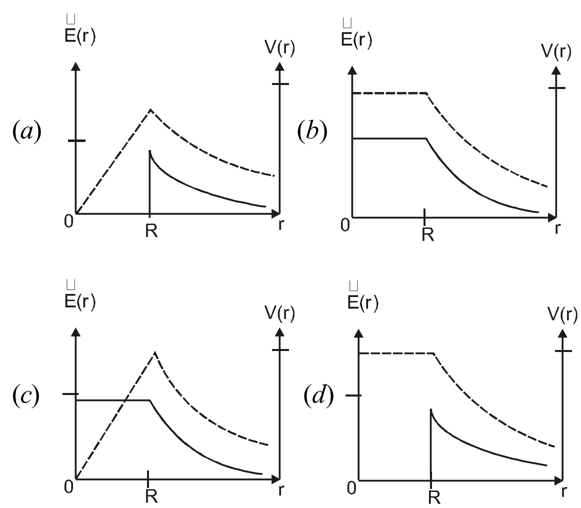
34. An infinite number of point charges, each carrying $1\mu C$ charge, are placed along the y-axis at $y = 1m, 2m$, $4m, 8m$. The total force on a 1 C point charge, placed at the origin, is $x \times 10^3$ N. The value of x_1 to the nearest integer, is. Take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ Nm^2/C^2$

[*JEE Main-2021 (March)*]

JEE-ADVANCED PREVIOUS YEAR'S

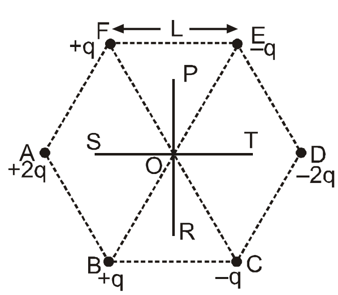
1. Consider a thin spherical shell of radius R with its centre at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field $|\vec{E}(r)|$ and the electric potential V(r) with the distance r from the centre, is best represented by which graph?

[*JEE-2012*]



2. 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*]

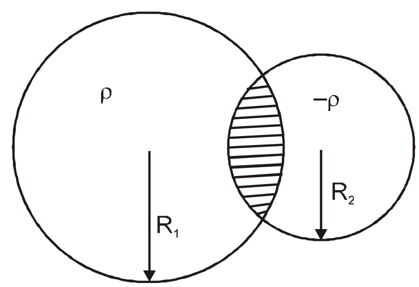


(*a*) the elecric field at O is 6K along OD
(*b*) The potential at O is zero
(*c*) The potential at all points on the line PR is same
(*d*) The potential at all points on the line ST is same.

3. 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 ;

(*a*) –4 (*b*) $-\frac{32}{25}$
(*c*) $\frac{32}{25}$ (*d*) 4

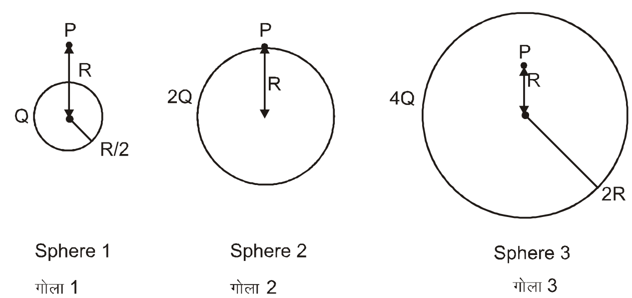
4. Two non–conducting spheres of radii R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$, respectively, are placed such that they partially overlap, as shown in the figure. At all points in the overlapping region:



(*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

5. Charges Q, 2Q and 4Q are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii R/2, R and 2R respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1 E_2 and E_3 respectively, then

[*JEE Advanced - 2014*]



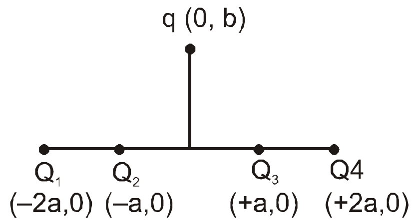
(*a*) $E_1 > E_2 > E_3$ (*b*) $E_3 > E_1 > E_2$
(*c*) $E_2 > E_1 > E_3$ (*d*) $E_3 > E_2 > E_1$

6. 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*]**

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

7. 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*]**



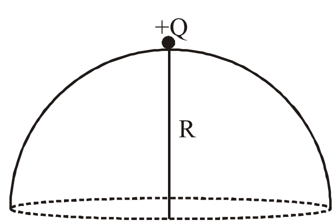
List-I	**List-II**
P. Q_1,Q_2,Q_3, Q_4, all positive	**1.** +x
Q_1,Q_2 positive Q_3,Q_4 negative	**2.** –x
R. Q_1,Q_4 positive Q_2, Q_3 negative	**3.** +y
S. Q_1,Q_3 positive Q_2, Q_4 negative	**4.** –y

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

8. A point charge +Q is placed just outside an imaginary hemispherical surfce of radius R as shown in the figure. Which of the following statements is/are correct? **[*JEE Advanced - 2017*]**



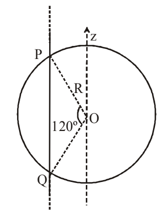
(*a*) Total flux through the curved and the flat surface is $\frac{Q}{\varepsilon_0}$

(*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 $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$

9. 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 120º 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*]**



(*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

10. 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 betweene E and d. List-II describe 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*]**

List - I	**List - II**
P. E is indpendent of d	**1.** A point charge Q at the origion
$E \propto \frac{1}{d}$	**2.** A small dipole with point charges Q at (0, 0 , ℓ) and –Q(0, 0, – ℓ). Take $2\ell << d$
R. $E \propto \frac{1}{d^2}$	**3.** An infinite line charge coincident with the x-axis, with uniform linear charge density λ.
S. $E \propto \frac{1}{d^3}$	**4.** Two infinite wires carrying iniform linear Charge density parallel to the x-axis. The one along (y = 0, z = ℓ) has a charge den sity + 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*) $P \rightarrow 5; Q \rightarrow 3, 4; R \rightarrow 1; S \rightarrow 2$

(*b*) $P \rightarrow 5; Q \rightarrow 3; R \rightarrow 1, 4; S \rightarrow 2$

(*c*) $P \rightarrow 5; Q \rightarrow 3; R \rightarrow 1,2; S \rightarrow 4$

(*d*) $P \rightarrow 4, Q \rightarrow 2, 3; R \rightarrow 1; S \rightarrow 5$

11. A thin spherical insulating shell of radius R carries a uniformly distributed charge such that the potential at its surface is V_0. A hole with a small area $\alpha 4\pi R^2 (\alpha << 1)$ is made on the shell without affecting the rest of the shell. Which one of the following statements is correct?

(*a*) The ratio of the potential at the center of the shell to that of the point at $\frac{1}{2}$R from center towards the hole will be $\frac{1-\alpha}{1-2\alpha}$ **[*JEE Advanced - 2019*]**

(*b*) The magnitude of electric field at the center of the shell is reduced by $\frac{\alpha V_0}{2R}$

(*c*) The magnitude of electric field at a point, located on a line passing through the hole and shell's center on a distance 2R from the center of the spherical shell will be reduced by $\frac{\alpha V_0}{2R}$

(*d*) The potential at the center of the shell is reduced by $2\alpha V_0$

12. A charged shell of radius R carries a total charge Given Φ as the flux of electric field through a closed cylindrical surface of height h, radius r and with its center same as that of the shell. Here, center of the cylinder is a point on the axis of the cylinder which is equidistant from its top and bottom surfaces. Whichof the following option(s) is/are correct? [$\in_0$ is the permittivity of free space]

[*JEE Advanced - 2019*]

(*a*) If $h > 2R$ and $r > R$ then $\Phi = \frac{Q}{\in_0}$

(*b*) If $h < \frac{8R}{5}$ and $r = \frac{3R}{5}$ then $\Phi = 0$

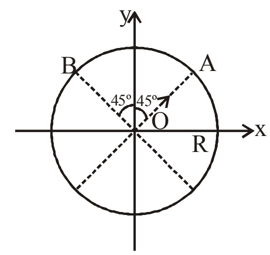
(*c*) If $h > 2R$ and $r = \frac{4R}{5}$ then $\Phi = \frac{Q}{5\in_0}$

(*d*) If $h > 2R$ and $r = \frac{3R}{5}$ then $\Phi = \frac{Q}{5\in_0}$

13. An electric dipole with dipole moment $\frac{P_0}{\sqrt{2}}(\hat{i}+\hat{j})$ is held fixed at the origin O in the presence of an uniform electric field of magnitude E_0. If the potential is constant on a circle of radius R centered at the origin as shown in figure, then the correct statement(s) is/are:

[*JEE Advanced - 2019*]

(ε_0 is permittivity of free space, R >> dipole size)



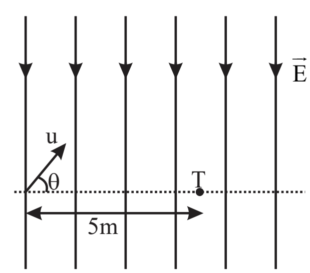
(*a*) $R = \left(\frac{P_0}{4\pi\varepsilon_0 E_0}\right)^{1/3}$

(*b*) The magnitude of total electric field on any two points of the circle will be same

(*c*) Total electric field at point A is $\vec{E}_A = \sqrt{2}E_0(\hat{i}+\hat{j})$

(*d*) Total electric field at point B is $\vec{E}_B = 0$

14. A uniform electric field, $\vec{E} = -40\sqrt{3}\hat{y}NC^{-1}$ is applied in a region. A charged particle of mass m carrying positive charge q is projected in this region with an initial speed of $2\sqrt{10}\times 10^6 ms^{-1}$. This particle is aimed to hit a target T, which is 5 m away from its entry point into the field as shown schematically in the figure. Take $\frac{q}{m} = 10^{10} Ckg^{-1}$. Then- **[*JEE Advanced - 2020*]**



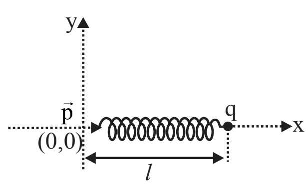
(*a*) the particle will hit T if projected at an angle 45° from the horizontal

(*b*) the particle will hit T if projected either at an angle 30° or 60° from the horizontal

(*c*) time taken by the particle to hit T could be $\sqrt{\frac{5}{6}}$ μs as well as $\sqrt{\frac{5}{2}}$ ms

(*d*) time taken by the particle to hit T $\sqrt{\frac{5}{3}}$ ms

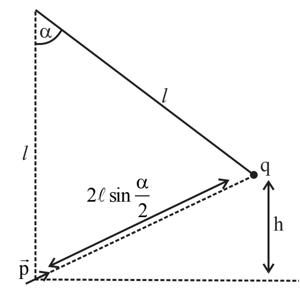
15. One end of a spring of negligible unstretched length and spring constant k is fixed at the origin (0,0). A point particle of mass m carrying a positive charge q is attached at its other end. The entire system is kept on a smooth horizontal surface. When a point dipole $\vec{p}$ pointing towards the charge q is fixed at the origin, the spring gets stretched to a length ℓ and attains a new equilibrium position (see figure below). If the point mass is now displaced slightly by $\Delta\ell << \ell$ from its equilibrium position and released, it is found to oscillate at frequency $\frac{1}{\delta}\sqrt{\frac{k}{m}}$. The value of δ is......... **[JEE Advanced - 2020]**



16. A circular disc of radius R carries surface charge density $\sigma(r) = \sigma_0\left(1-\frac{r}{R}\right)$, where σ_0 is a constant and r is the distance from the center of the disc. Electric flux through a large spherical surface that encloses the charged disc completely is ϕ_0. Electric flux through another spherical surface of radius $\frac{R}{4}$ and concentric with the disc is ϕ. Then the ratio $\frac{\phi_0}{\phi}$ is ..... **[JEE Advanced - 2020]**

17. A point charge q of mass m is suspended vertically by a string of length *l*. A point dipole of dipole moment $\vec{p}$ is now brought towards q from infinity so that the charge moves away. The final equilibrium position of the system including the direction of the dipole, the angles and distances is shown in the figure below. If the work done in bringing the dipole to this position is N×(mgh),
where g is the acceleration due to gravity, then the value of N is _________ .

(Note that for three coplanar forces keeping a point mass in equilibrium, $\frac{F}{\sin\theta}$ is the same for all forces, where F is any one of the forces and θ is the angle between the other two forces) **[JEE(Advanced) - 2020]**



18. Two identical non-conducting solid spheres of same mass and charge are suspended in air from a common point by two non-conducting, massless strings of same length. At equilibrium, the angle between the strings is α. The spheres are now immersed in a dielectric liquid of density 800 kg m^3 and dielectric constant 21. If the angle between the strings remains the same after the immersion, then **[JEE Advanced - 2020]**

(*a*) electric force between the spheres remains unchanged
(*b*) electric force between the spheres reduces
(*c*) mass density of the spheres is 840 kg m^{-3}
(*d*) the tension in the strings holding the spheres remains unchanged

19. Two large circular discs separated by a distance of 0.01 m are connected to a battery via a switch as shown in the figure. Charged oil drops of density 900 kg m^{-3} are released through a tiny hole at the center of the top disc. Once some oil drops achieve terminal velocity, the switch is closed to apply a voltage of 200 V across the discs. As a result, an oil drop of radius 8×10^{-7} m stops moving vertically and floats between the discs. The number of electrons present in this oil drop is ________. (Neglect the buoyancy force, take acceleration due to gravity =10 ms^{-2} and charge on an
electron (e) = 1.6×10^{-19} C) **[JEE Advanced - 2020]**

JEE Mains & Advanced Past Years Questions

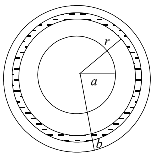
JEE-MAIN
PREVIOUS YEAR'S

1. (*a*) From Gauss's law

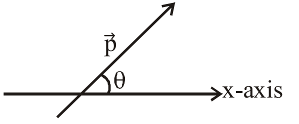
$$E \times 4\pi r^2 = \frac{Q + \int_a^r \left(4\pi x^2 dx\right)\frac{A}{x}}{\in_0}$$

$$\Rightarrow E = \frac{Q}{4\pi r^2} + \frac{A}{2} - \frac{Aa^2}{2r^2}$$

For E to be const., $\frac{Q}{4\pi r^2} = \frac{Aa^2}{2r^2} \Rightarrow A = \frac{Q}{2\pi a^2}$



2. (*a*) So from $\vec{\tau} = \vec{p} \times \vec{E}$



$$\tau\hat{k} - \tau\hat{k} = \left(p_x\hat{i} + p_y\hat{j}\right) \times \left(E\hat{i} + \sqrt{3}E\hat{j}\right)$$

$$= p_x \times \sqrt{3}E\hat{k} + p_y E\left(-\hat{k}\right)$$

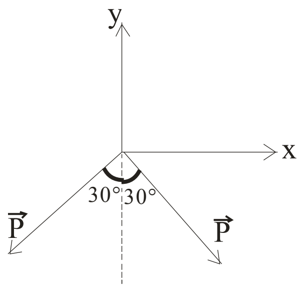
$$0 = E\hat{k}\left(\sqrt{3}p_x - p_y\right)$$

$$\frac{p_y}{p_x} = \sqrt{3}$$

$$\tan\theta = \sqrt{3}$$

$$\theta = 60^\circ$$

3. (*d*)



$\left|\vec{P}\right| = qL$

$\vec{P}_{net} = 2P\cos 30^\circ\left(-\hat{j}\right) \;= P\sqrt{3}\left(-\hat{j}\right)$

$= \sqrt{3}\; qL\left(-\hat{j}\right)$

4. (*b*) Electric field

$$E = \frac{kQx}{\left(x^2 + R^2\right)^{3/2}}$$

For maxima $\dfrac{dE}{dx} = 0$

After solving we get, $\left(x = \pm\dfrac{R}{\sqrt{2}}\right)$

5. (*a*) $\dfrac{4kQq}{d^2} + \dfrac{kQ^2}{d^2} = 0$

$\Rightarrow$ $q = -Q/4$

6. (*b*) $Q = \int \rho 4\pi r^2 dr = \int_0^R \left(\dfrac{A}{r^2} e^{-\frac{2r}{a}}\right)\left(4\pi r^2\right)dr$

$$= 4\pi A \frac{a}{2}\left(1 - e^{\frac{-2R}{a}}\right)$$

$$\Rightarrow\; R = \frac{-a}{2}\log\left(1 - \frac{Q}{2\pi Aa}\right)$$

7. (*a*) $\vec{E} = \dfrac{kq_2}{r_2^3}\vec{r}_2 = k \times 10^{-6}$

$$\left[\frac{\sqrt{10}}{10\sqrt{10}}(-\hat{i} + 3\hat{j}) + \frac{(-25)}{125})(-4\hat{i} + 3\hat{j})\right]$$

$$= (9 \times 10^3)\left[\frac{1}{10}(-\hat{i} + 3\hat{j}) - \frac{1}{5}(-4\hat{i} + 3\hat{j})\right]$$

$$= (9 \times 10^3)\left[\left(-\frac{1}{10} + \frac{4}{5}\right)\hat{i} + \left(\frac{3}{10} - \frac{3}{5}\right)\hat{i}\right]$$

$$= 9000\left(\frac{7}{10}\hat{i} - \frac{3}{10}\hat{j}\right)$$

$$= (63\,\hat{i} - 27\,\hat{j})\,(100)$$

8. (*d*) $\because\; F \propto \dfrac{1}{r^3}$

Required force = 27 C

9. (*d*) Electric field at $p = 2E_1\cos\theta_1 - 2E_2\cos\theta_2$

$$= \frac{2K_q}{\left(d^2 + D^2\right)} \times \frac{D}{\left(d^2 + D^2\right)^{1/2}} - \frac{2K_q}{\left[(2d)^2 + D^2\right]} \times \frac{D}{\left[(2d)^2 + D^2\right]^{1/2}}$$

$$= 2KqD\left[\left(d^2 + D^2\right)^{-3/2} - \left(4d^2 + D^2\right)^{-3/2}\right]$$

$$= \frac{2KqD}{D^3}\left[\left(1 + \frac{d^2}{D^2}\right)^{-3/2} - \left(1 + \frac{4d^2}{D^2}\right)^{-3/2}\right]$$

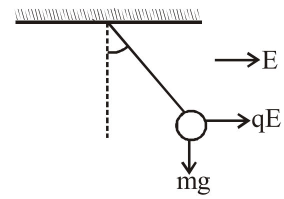
Applying binomial approximation $\because d << D$

$$= \frac{2KqD}{D^3}\left[1 - \frac{3}{2}\frac{d^2}{D^2} - \left(1 - \frac{3 \times 4d^2}{2D^2}\right)\right]$$

$$= \frac{2KqD}{D^3}\left[\frac{12}{2}\frac{d^2}{D^2} - \frac{3}{2}\frac{d^2}{D^2}\right]$$

$$= \frac{9kqd^2}{D^4}$$

10. (*c*)



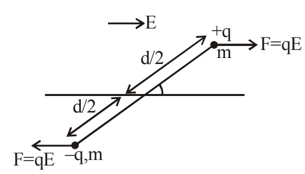
$$\tan\theta = \frac{qE}{mg} = \frac{5 \times 10^{-6} \times 2000}{2 \times 10^{-3} \times 10}$$

$$\tan\theta = \frac{1}{2} \Rightarrow \theta = \tan^{-1}(0.5)$$

11. (*a*) $g_{ff} = \sqrt{g^2 + \left(\dfrac{qE}{m}\right)^2}$

$$T = 2\pi\sqrt{\frac{\ell}{g_{eff}}} = \sqrt{\frac{\ell}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$$

12. (*c*)



moment of inertia $(I) = m\left(\dfrac{d}{2}\right)^2 \times 2 = \dfrac{md^2}{2}$

Now by $\tau = I\alpha$

$$(qE)\,(d\sin\theta) = \frac{md^2}{2}.\alpha$$

$$\alpha = \left(\frac{2qE}{md}\right)\sin\theta$$

for small θ

$$\Rightarrow\; \alpha = \left(\frac{2qE}{md}\right)\theta \Rightarrow \text{Angular frequency}\; \omega = \sqrt{\frac{2qE}{md}}$$

13. (*c*) $E\,4\pi a^2 = \dfrac{\int_0^a kr\,4\pi^2 dr}{\varepsilon_0}$

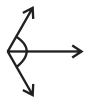
$$E = \frac{k\,4\pi a^4}{4\times 4\pi\varepsilon_0}$$

$$2Q = \int_0^R kr\,4\pi r^2 dr$$

$$k = \frac{2Q}{\pi R^4}$$

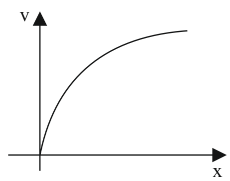
$$QE = \frac{1}{4\pi\varepsilon_0}\frac{QQ}{(2a)^2}$$

$$R = a8^{1/4}$$

14. (*a*) 

$$E_{net} = \frac{4kq}{d^2}\times 2\cos 30^o = \frac{q\sqrt{3}}{\pi\varepsilon_0 d^2}$$

15. (*b*) $V^2 = \dfrac{2qE}{m}x$



16. (*a*) Since is best $\vec{p}.\vec{r} = 0$

$\vec{E}$ must be antiparallel to $\vec{p}$

So, $\vec{E} = -\lambda(\vec{p})$

where λ is a arbitary positive constant

Now $\vec{A} = a\hat{i} + b\hat{j} + c\hat{k}$

$\vec{A} \parallel \vec{E}$

$$\frac{a}{\lambda} = \frac{b}{3\lambda} = \frac{c}{-2\lambda} = k$$

17. (48)

Flux via ABCD

$$\phi_1 = \int \vec{E}.d\vec{A} = 0$$

Flux via BCEF

$$\phi_2 = \int \vec{E}.d\vec{A}$$

$$\phi_2 = \vec{E}.\vec{A} = (4x\hat{i} - (y^2+1)\hat{j}).4i$$

$$= 16x,\ x = 3$$

$$\phi_2 = 48\frac{N-m^2}{C};\ \phi_1 - \phi_2 = -48\frac{N-m^2}{C}$$

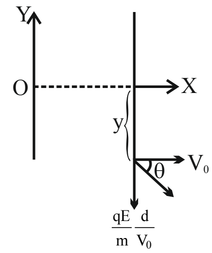
18. (*c*) Magnitude of electric field is constant & the surface is equipotential

19. (*d*) $\dfrac{E_1}{E_2} = \dfrac{r_1}{r_2}$

$$\frac{V_1}{V_2} = \frac{E_1 r_1}{E_2 r_2} = \frac{r_1}{r_2}\times\frac{r_1}{r_2} = \left(\frac{r_1}{r_2}\right)^2$$

20. (*b*) $\vec{F} = qE\hat{i} + mg\hat{j}$

Since initial velocity is zero. It will move in straight line.

21. (*c*) 

$$y = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{d}{V_0}\right)^2$$

$$y = -\frac{qEd}{mV_0^2}x + C$$

$$\text{At } x = d,\ y = -\frac{qEd^2}{2mV_0^2} \Rightarrow C = \frac{qEd^2}{2mV_0^2}$$

$$y = -\frac{qEd}{mV_0^2}x + \frac{qEd^2}{2mV_0^2}$$

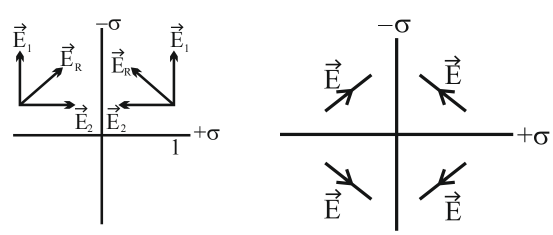
$$y = \frac{qEd^2}{mV_0^2}\left(\frac{d}{2} - x\right)$$

22. (*a*) $E = E_0(1 - ax^2)$

$$\frac{vdv}{dx} = \frac{qE_0}{m}(1 - ax^2)$$

$$\Rightarrow \frac{v^2}{2} = \frac{qE_0}{m}\left[x - \frac{ax^3}{3}\right] = 0$$

$$\Rightarrow x = \sqrt{\frac{3}{a}}$$

23. (*d*) 

24. (*c*) For spherical shell

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \qquad (r > R)$$

$$= 0 \qquad (r < R)$$

Force on charge in electric field

$F = qE$

25. (*a*) $\vec{p}$ $\overleftarrow{p}\bullet$

$U = \vec{p}\cdot\vec{E}$

$\vec{E} = \dfrac{2\vec{p}}{4\pi\varepsilon_0 \times a^3}$

$\therefore\ \Delta U_{loss} = \dfrac{2p^2}{4\pi\varepsilon_0 a^3} = 2\times\dfrac{1}{2}mv^2$

$\Rightarrow\ v = \dfrac{p}{a}\sqrt{\dfrac{1}{2\pi\varepsilon_0 ma}}$

26. (194.42)

$\because I = \dfrac{1}{2}\varepsilon_0 E_0^2 c$

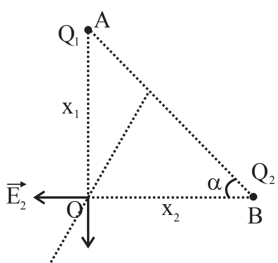
$\Rightarrow\ E_0 = \sqrt{\dfrac{2I}{\varepsilon_0 c}}$

$\therefore\ E_{rms} = \dfrac{E_0}{\sqrt{2}} = \sqrt{\dfrac{I}{\varepsilon_0 c}}$

$= \sqrt{\dfrac{315}{\pi}\times\dfrac{1}{8.86\times10^{-12}\times3\times10^8}}$

$= 194.42$

27. (*c*)



Net field along AB at O must be zero

$E_2\cos\alpha = E_1\sin\alpha$

$\dfrac{kQ}{x_2^2}\cdot\dfrac{x_2}{AB} = \dfrac{kQ_1}{x_1^2}\cdot\dfrac{x_1}{AB}$

$\dfrac{Q_1}{Q_2} = \dfrac{x_1}{x_2}$

28. (*a*) Let charges on shells be q_1 and q_2

$q_1 + q_2 = Q$ ...(i)

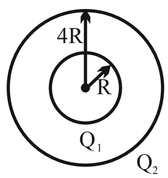
$\dfrac{q_1}{4\pi r^2} = \dfrac{q_2}{4\pi R^2}$ ...(ii)

We get $q_1 = \dfrac{r^2}{r^2+R^2}Q,\ q_2 = \dfrac{R^2}{r^2+R^2}Q$

$V = \dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{q_1}{r}+\dfrac{q_2}{R}\right)$

$= \dfrac{1}{4\pi\varepsilon_0}\dfrac{(R+r)}{(R^2+r^2)}Q$

29. (*b*)



$\because\ \dfrac{Q_1}{R^2} = \dfrac{Q_2}{16R^2}$

$\Rightarrow\ Q_2 = 16Q_1$

$\left(\dfrac{KQ_1}{R}+\dfrac{KQ_2}{4R}\right)-\left(\dfrac{KQ_1}{4R}+\dfrac{KQ_2}{4R}\right) = V_1 - V_2$

$\Rightarrow\ V_1 - V_2 = \dfrac{3}{4}\times\dfrac{Q_1}{4\pi\varepsilon_0 R} = \dfrac{3Q_1}{16\pi\varepsilon_0 R}$

30. (*a*) $k = qV$

$\dfrac{1}{2}mv^2 = qV$

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

$\dfrac{V_H}{V_{He}} = \sqrt{\dfrac{q_H m_{He}}{m_H q_{He}}} = 2:1$

31. (*b*) $\Delta u = \dfrac{4q^2}{4\pi\varepsilon_0}\left[\dfrac{1}{3d/2}-\dfrac{1}{d/2}\right]$

$\Delta u = -\dfrac{4q^2}{3\pi\varepsilon_0 d}$

32. (*a*) $\sum q = 0$

$\Rightarrow\ V = 0$

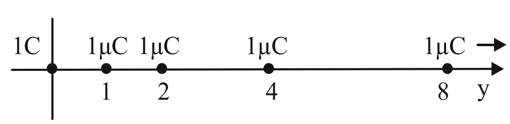
Also, field of one charge will get cancelled due to another symmetrical charge in front of it.

33. (*d*) $\dfrac{1}{2}mv^2 = mgy + \Delta U_{elec.}$

$\Delta U_{elec.} = kQq\left[\dfrac{1}{R}-\dfrac{1}{(R+y)}\right]$

$\Rightarrow\ v^2 = 2y\left[\dfrac{qQ}{4\pi\varepsilon_0 R(R+y)m}+g\right]$

34. (12)



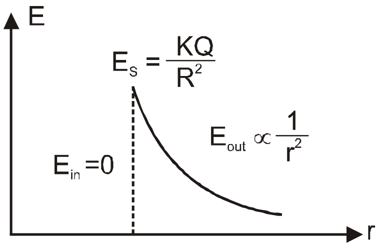
$= 9\times10^9\times10^{-6}\left[1+\left(\dfrac{1}{2}\right)^2+\left(\dfrac{1}{2^2}\right)^2+\left(\dfrac{1}{2^3}\right)^2+\left(\dfrac{1}{2^\infty}\right)^2\right]$

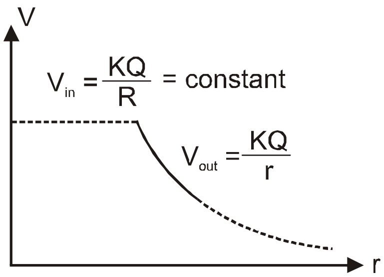
$= 9\times10^9\times10^{-6}\left[\dfrac{1}{1-\dfrac{1}{4}}\right]$

$\therefore\ \left[S_\infty = \dfrac{a}{1-r}\right]$ for G.P. $= 9\times10^3\times\dfrac{4}{3} = 12\times10^3$ N

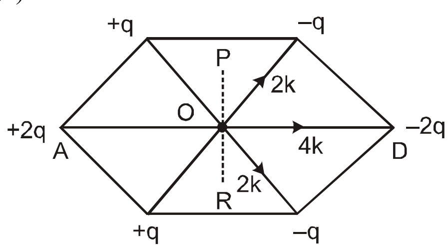
JEE-ADVANCED PREVIOUS YEAR'S

1. (*d*)





2. (*a,b,c*)



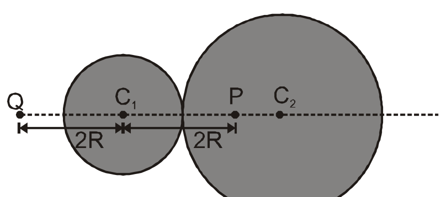
$E_0 = 6$ K (along OD)

$V_0 = 0$

Potential on line PR is zero

PR

3. (*b,d*)



At point P

If resultant electric field is zero then

$$\frac{KQ_1}{4R^2} = \frac{KQ_2}{8R^3}R$$

$$\frac{\rho_1}{\rho_2} = 4$$

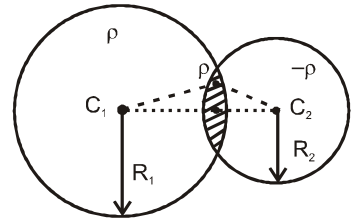
At point Q

If resultant electric field is zero then

$$\frac{KQ_1}{4R^2} + \frac{KQ_2}{25R^2} = 0$$

$$\frac{\rho_1}{\rho_2} = -\frac{32}{25} \quad (\rho_1 \text{ must be negative})$$

4. (*c,d*)



For electrostatic field,

$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$= \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1P} + \frac{(-\rho)}{3\varepsilon_0}\overrightarrow{C_2P}$$

$$= \frac{\rho}{3\varepsilon_0}(\overrightarrow{C_1P} + \overrightarrow{PC_2})$$

$$\vec{E}_P = \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1C_2}$$

For electrostatic potential, Since electric field is non zero so it is not equipotential.

5. (*c*) $E_1 = \frac{KQ}{R^2}$

$$E_2 = \frac{k(2Q)}{R^2} \Rightarrow E_2 = \frac{2kQ}{R^2}$$

$$E_3 = \frac{k(4Q)R}{(2R)^3} \Rightarrow E_3 = \frac{kQ}{2R^2}$$

$$E_3 < E_1 < E_2$$

6. (*c*) $\frac{Q}{4\pi \in_0 r_0^2} = \frac{\lambda}{2\pi \in_0 r_0} = \frac{\sigma}{2 \in_0}$

$Q = 2\pi\sigma r_0^2$ A incorrect

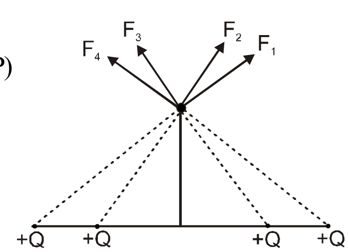
$r_0 = \frac{\lambda}{\pi\sigma}$ B incorrect

$$E_1\left(\frac{r_0}{2}\right) = \frac{4E_1(r_0)}{1}$$

$E_2\left(\frac{r_0}{2}\right) = 2E_2(r_0) \Rightarrow$ C correct

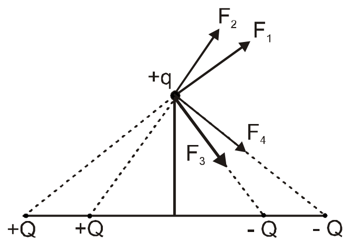
$E_3\left(\frac{r_0}{2}\right) = E_3(r_0) = E_2(r_0)$ D incorrect

7. (*a*) (P)



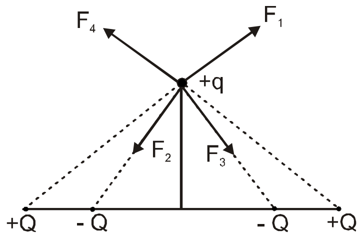
Component of forces along x-axis will vanish. Net force along +ve y-axis

(Q)



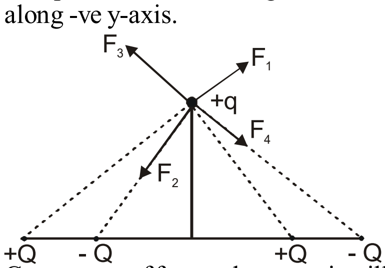
Component of forces along y-axis will vanish. Net force along +ve x-axis

(R)



Component of forces along x-axis will vanish. Net force along -ve y-axis.

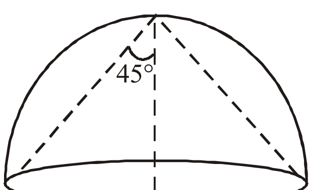
(S)



Component of forces along y-axis will vanish. Net force along -ve x-axis.

Ans.(*a*) P—3, Q—1, R—4, S—2

8. (*c,d*)



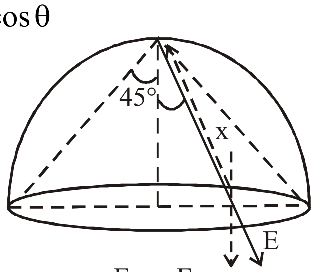
(*a*) ϕ total due to charge Q is $= \dfrac{Q}{\varepsilon_0}$

so ϕ through the curved and flat surface will be less than $\dfrac{Q}{\varepsilon_0}$

(*b*) The component of the electric field perpendicular to the flat surface will decrease so we move away from the centre as the distance increase (magnitude of electric field decreases) as well as the angle between the normal and electric field will increase.

2nd Method

$$x = \frac{R}{\cos\theta}$$



E = E cos

$$E = \frac{KQ}{x^2} = \frac{KQ\cos^2\theta}{R^2}$$

$$E\perp = \frac{KQ\cos^3\theta}{R^2}$$

As we move away from centre $\theta\uparrow$ $\cos\theta$ so$\downarrow$ $E\perp\downarrow$

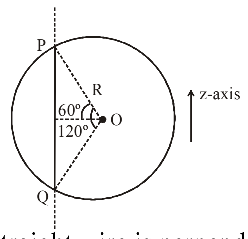
(*c*) Since the circumference is equidistant from 'Q' it will be equuipotential $V = \dfrac{KQ}{\sqrt{2}R}$

(*d*) $\Omega = 2\pi(1-\cos\theta); \theta = 45°$

$$\phi = -\frac{\Omega}{4\pi}\times\frac{Q}{\varepsilon_0} = -\frac{2\pi(1-\cos\theta)}{4\pi}\frac{Q}{\varepsilon_0}$$

$$= -\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$$

9. (*a,b*)



Field due to straight wire is perpendicular to the wire & radially outward. Hence $E_z = 0$

Length, PQ = 2R sin 60 = $\sqrt{3}R$ According to Gauss's law

total flux = $\oint \vec{E}.\vec{ds} = \dfrac{q_{in}}{\epsilon_0} = \dfrac{\lambda\sqrt{3}R}{\epsilon_0}$

10. (*b*) (*i*) $E = \dfrac{KQ}{d^2} \Rightarrow E \propto \dfrac{1}{d^2}$

(*ii*) Dipole

$$E = \frac{2kp}{d^3}\sqrt{1+3\cos^2\theta}$$

$E \propto \dfrac{1}{d^3}$ for dipole

(*iii*) For line charge

$$E = \frac{2k\lambda}{d}$$

$$E \propto \frac{1}{d}$$

(*iv*) $E = \dfrac{2K\lambda}{d-\ell} - \dfrac{2K\lambda}{d+\ell} = 2K\lambda\left[\dfrac{d+\ell-d+\ell}{d^2-\ell^2}\right]$

$$E = \frac{2K\lambda(2\ell)}{d^2\left[1-\dfrac{\ell^2}{d^2}\right]}$$

$$E \propto \frac{1}{d^2}$$

(*v*) Electric field due to sheet

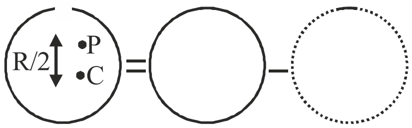
$$\in = \frac{\sigma}{2\in_0}$$

$\in$ = v is independent of r

11. (*a*) Let charge on the sphere initially be Q.

$\therefore \quad \dfrac{kQ}{R} = V_0$

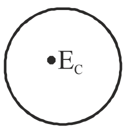
and charge removed = αQ

(*a*) 

and $V_P = \dfrac{kQ}{R} - \dfrac{2kQ\alpha}{R} = \dfrac{kQ}{R}(1-2\alpha)$

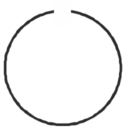
$V_C = \dfrac{kQ(1-\alpha)}{R}$

$\therefore \quad \dfrac{V_C}{V_P} = \dfrac{1-\alpha}{1-2\alpha}$



(*b*) $(E_C)_{initial} = \text{zero}$

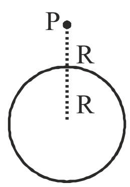
$(E_C)_{initial} = \dfrac{k\alpha Q}{R^2}$



$\Rightarrow$ Electric field increases

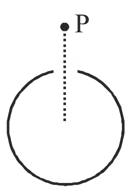
(*c*) $(E_P)_{final} = \dfrac{kQ}{4R^2} - \dfrac{k\alpha Q}{R^2}$

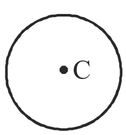
$\Delta E_P = \dfrac{kQ}{4R^2} - \dfrac{kQ}{4R^2} + \dfrac{k\alpha Q}{R^2} = \dfrac{k\alpha Q}{R^2} = \dfrac{V_0\alpha}{R}$



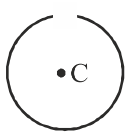
(*d*) $(V_C)_{initial} = \dfrac{kQ}{R}$

$(V_C)_{final} = \dfrac{kQ(1-\alpha)}{R}$





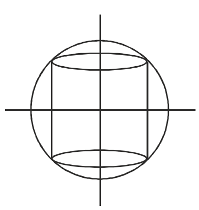
$\Delta V_C = \dfrac{kQ}{R}(\alpha) = \alpha V_0$



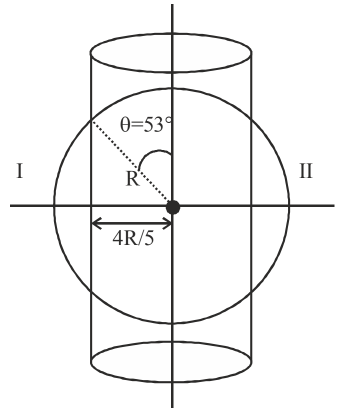
12. (*a,b,d*)

For option (1), cylinder encloses the shell, thus option is correct

For option (2),



cylinder perfectly enclosed by shell,
thus $\phi = 0$, so option is correct.
for option (3)



$\phi = \dfrac{2\times Q}{2\epsilon_0}(1-\cos 53^\circ) = \dfrac{2Q}{5\epsilon_0}$

For option (4) :

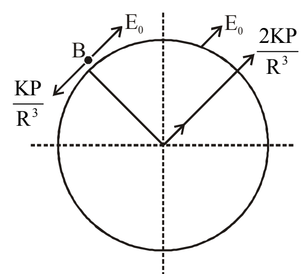
Flux enclosed by cylinder $= \phi = \dfrac{2Q}{2\epsilon_0}(1-\cos 37^\circ) = \dfrac{Q}{5\epsilon_0}$

13. (*a,d*)

(1) $\vec{P} = \dfrac{P_0}{\sqrt{2}}(\hat{i}+\hat{j})$

E.F. at B along tangent should be zero since circle is equi-potential.

So, $E_0 = \dfrac{K|\vec{P}|}{R^3}$ & $E_B = 0$



So, $R^3 = \dfrac{KP_0}{E_0} = \left(\dfrac{P_0}{4\pi\epsilon_0 E_0}\right)$

So $R = \left(\dfrac{P_0}{4\pi\epsilon_0 E_0}\right)^{1/3}$

So, (*a*) is correct

(*b*) Because E_0 is uniform & due to dipole E.F. is different at different points, so magnitude of total E.F. will also be different at different points

So, (*b*) is incorrect

(*c*) $E_A = \dfrac{2KP}{R^3} + \dfrac{KP}{R^3} = 3\dfrac{KP}{R^3}\dfrac{P}{\sqrt{2}}(\hat{i}+\hat{j})$

So, (*c*) is wrong

(*d*) $E_B = 0$

So, (*d*) is correct

14. (*b,c*)

$a_y = -400\sqrt{3}\times10^{10}$ $[qE_y = ma_y]$

$$R = 5 = \frac{40\times10^{12}\sin 2\theta}{400\sqrt{3}\times10^{10}}\left[R(\text{range}) = \frac{u^2\sin 2\theta}{a_y}\right]$$

$$\sin 2\theta = \frac{\sqrt{3}}{2}$$

$2\theta = 60^\circ, 120 \quad \Rightarrow \theta = 30^\circ, 60^\circ$

$$\text{Time of flight } T_1 = \frac{2\times2\sqrt{10}\times10^6\times\frac{1}{2}}{400\sqrt{3}\times10^{10}} = \sqrt{\frac{5}{6}}\mu s$$

(for θ=30º)

$$\text{Time of flight } T_2 = \frac{2\times2\sqrt{10}\times10^6\times\frac{\sqrt{3}}{2}}{400\sqrt{3}\times10^{10}} = \sqrt{\frac{5}{3}}\mu s$$

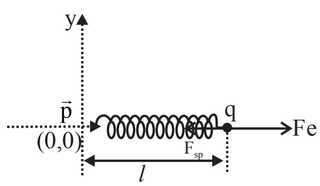
(for θ=60º)

15. (3.14)

$\Delta\ell \to x$

At $\ell : Fe = F_{SP}$

$$k\ell = \frac{2kpq}{\ell^3}$$



$$F_{net} = F_{sp} - Fe = k(\ell + x) - \frac{q(2kp)}{(\ell + x)^3}$$

$$= k(x+\ell) - \frac{q(2kp)}{\ell^3(1 + x/\ell)^3}$$

$$kx + k\ell - q\left(\frac{2kp}{\ell^3}\right)\left(1 - \frac{3x}{\ell}\right)$$

$$= kx + k\ell - q\left(\frac{2kp}{\ell^3}\right) + \frac{2kpq}{\ell^3}\cdot\frac{3x}{\ell}$$

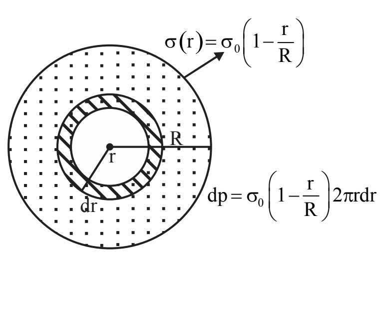
$$F_N = kx + k\ell\left(\frac{3x}{\ell}\right) = 4kx$$

$$k_{eq} = 4k \qquad T = 2\pi\sqrt{\frac{m}{4k}} = \pi\sqrt{\frac{m}{k}}$$

$$f = \frac{1}{\pi}\sqrt{\frac{k}{m}}$$

So $\delta = \pi = 3.14$

16. (6.40)



$$\phi = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^R \sigma_0\left(1 - \frac{r}{R}\right)2\pi r\,dr}{\varepsilon_0}$$

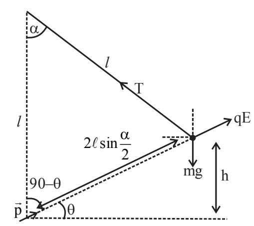
$$\phi = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^{R/4} \sigma_0\left(1 - \frac{r}{R}\right)2\pi r\,dr}{\varepsilon_0}$$

$$\therefore \frac{\phi_0}{\phi} = \frac{\sigma_0 2\pi\int_0^R\left(r - \frac{r^2}{R}\right)dr}{\sigma_0 2\pi\int_0^{R/4}\left(r - \frac{r^2}{R}\right)dr}$$

$$= \frac{\frac{R^2}{2} - \frac{R^2}{3}}{\frac{R^2}{32} - \frac{R^2}{3\times64}} = \frac{32}{5}$$

$= 6.40$

17. (*b*)



$U_i = 0$

$$U_f = \frac{kqP}{\left(2\ell\sin\frac{\alpha}{2}\right)^2} + mgh \qquad \text{...(i)}$$

Now, from ΔOAB

$\alpha + 90 - \theta + 90 - \theta = 180 \qquad \Rightarrow \alpha = 2\theta$

From ΔABC : $h = 2\ell\sin\left(\frac{\alpha}{2}\right)\sin\theta$

$$h = 2\ell\sin\left(\frac{\alpha}{2}\right)\sin\left(\frac{\alpha}{2}\right)$$

Now charge is in equilibrium at point B.

So, using sine rule

$$\Rightarrow \frac{mg}{\sin\left[90 + \frac{\alpha}{2}\right]} = \frac{qE}{\sin[180 - 2\theta]}$$

$$\Rightarrow \frac{mg}{\cos\frac{\alpha}{2}} = \frac{qE}{\sin 2\theta}$$

$$\Rightarrow \frac{mg}{\cos\frac{\alpha}{2}} = \frac{qE}{\sin\alpha} \Rightarrow \frac{mg}{\cos\frac{\alpha}{2}} = \frac{qE}{2\sin\frac{\alpha}{2}\cos\frac{\alpha}{2}}$$

$$\Rightarrow qE = mg2\sin\left(\frac{\alpha}{2}\right)$$

$$\Rightarrow \frac{q2kp}{\left[2\ell\sin\frac{\alpha}{2}\right]^3} = mg2\sin\left(\frac{\alpha}{2}\right)$$

$$\Rightarrow \frac{kpq}{\left[2\ell\sin\frac{\alpha}{2}\right]^2} = mg\sin\left(\frac{\alpha}{2}\right)\times\left(2\ell\sin\frac{\alpha}{2}\right)$$

$$\Rightarrow \frac{kpq}{\left[2\ell\sin\frac{\alpha}{2}\right]^2} = mgh \Rightarrow \text{substituting this in equation}$$

...(i)

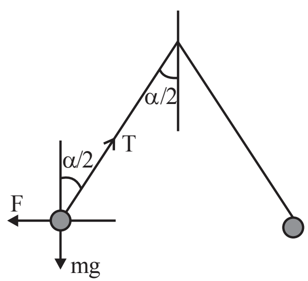
$$U_f = mgh + \frac{kpq}{\left[2\ell\sin\frac{\alpha}{2}\right]^2}$$

$\Rightarrow$ U_f=2mgh

W=ΔU=Nmgh=N=2

18. (*a,c*)

The net electric force on any sphere is lesser but by Coulomb law the force due to one sphere to another remain the same.



In equilibrium

$T\cos\frac{\alpha}{2} - mg$ and $T\sin\frac{\alpha}{2} = F$

After immersed is dielectric liquid.

As given no change in angle α.

So $T\cos\frac{\alpha}{2} = mg - V\rho g$

when ρ=800 Kg/m^3

and $T\sin\frac{\alpha}{2} = \frac{F}{e_r}$

$$\therefore \frac{mg}{F} = \frac{mg - V\rho g}{\frac{F}{e_r}}$$

$$\frac{1}{e_r} = 1 - \frac{\rho}{d}$$

d=density of sphere

$$\frac{1}{21} = 1 - \frac{800}{d}$$

d=840

19. (6)

$$E = \frac{V}{d} = \frac{200}{0.01} = 2\times10^4\,V/m$$

When terminal velocity is achieved

qE=mg

$$\Rightarrow n\times1.6\times10^{-19}\times2\times10^4 = \frac{4\pi}{3}\left(8\times10^{-7}\right)^3\times900\times10$$

$\Rightarrow n \approx 6$