

Self-Assessment

Module 1: Electric Charges, Coulomb's Law

Q.1.1.1 The following are four statements about the electric charge:

- (1) The charge, on any given object, can be increased or decreased by any small amount whatsoever.
- (2) The process of conversion of energy into matter would always take place in such a way that the total charge on the thus created matter is zero.
- (3) The net charge, on a system, equals the sum of the magnitudes of the different charges present in it.
- (4) Charge is best understood not in terms of what it is but what it does.

Out of the above, the correct statements are

- (A) (2), (3) and (4)
(B) (3) (4), (2) and (1)
(C) (2) and (4) only
(D) (1) and (3) only

Q.1.1.2 A large sphere, of radius 1m, has been uniformly charged. We can (quite reasonably) think of this sphere as a point charge if we are considering the effects of this sphere at a point distant r (in m) from its center where

- (A) $0 < r < 5$
(B) $5 < r < 10$
(C) $10 < r < 100$
(D) $100 < r < \infty$

Q.1.1.3 We often speak of terms like uniformly charged infinite wire or uniformly charged infinite plane sheet. The results obtained for such infinite objects are (quite reasonably) valid provided the distance of the point of interest from the charged objects is

- (A) Equal to or less than $(\frac{1}{100})$ of the (smallest) dimension of the object.



- (B) Between (1) to ($\frac{1}{10}$) of the smallest dimension of the object.
- (C) More than 10 times the smallest dimension of the object.
- (D) More than 100 times the smallest dimension of the object.

Q.1.1.4 We often talk of continuous charge distributions. We can do so because

- (A) The charge, on a given object, can be charged by any small (very small) amount whatsoever.
- (B) We now know about quarks whose charges have magnitudes that are a fraction of the charge on the electron; the change in the charge of an object can, therefore, be a fraction of the electronic charge.
- (C) The changes, in the charge of a macroscopic object, are only very small multiples of the electronic charge; the basic granular (or quantized) nature of charge, therefore, does not come into play.
- (D) The changes, in the charge of a macroscopic object, are (almost) always very large multiples of the electronic charge; this results in a masking of the basic granular (or quantized) nature of charge.

Q.1.1.5 A negatively charged conducting sphere A, placed on an insulating stand, is brought near an identical uncharged earthed sphere B (Fig.1.1.1). It would then be observed that

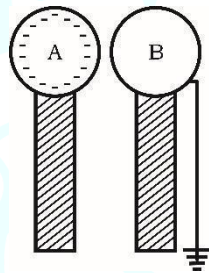


Fig.Q.1.1.1

- (A) sphere B becomes positively charged, because an equal amount of positive charge is induced on its nearer side and, an equal amount of negative charge induced on its opposite side, goes to earth.
- (B) sphere B becomes positively charged, because an equal number of protons are pulled out from earth by sphere B due to the attraction produced by the negative charge present on sphere A.
- (C) sphere B remains uncharged until it is earthed, any amount of charge, developed on it due to induction, will move to earth.
- (D) sphere B will become negatively charged, because sphere A passes on some of its negative charge on to sphere B.

Q.1.1.6 A charge q_1 is kept at the origin **O** while a charge q_2 is located at the point **P** (x, y, z). As per Coulomb's law, the force ($\mathbf{F}_{21}$) on charge 2, due to charge 1, would be given by

- (A) $\mathbf{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{(x^2 + y^2 + z^2)} (\hat{x}\mathbf{i} + \hat{y}\mathbf{j} + \hat{z}\mathbf{k})$
- (B) $\mathbf{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{(x^2 + y^2 + z^2)^{3/2}} (\hat{x}\mathbf{i} + \hat{y}\mathbf{j} + \hat{z}\mathbf{k})$
- (C) $\mathbf{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{(x^2 + y^2 + z^2)^{5/2}} (\hat{x}\mathbf{i} + \hat{y}\mathbf{j} + \hat{z}\mathbf{k})$
- (D) $\mathbf{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{(x^2 + y^2 + z^2)^3} (\hat{x}\mathbf{i} + \hat{y}\mathbf{j} + \hat{z}\mathbf{k})$

Q.1.1.7 Three different charges $(+q_1)$, $(+q_2)$ and $(-q_3)$, by themselves, exert forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, respectively, on a given charge $(+q)$. If the total force, on the charge q , due to the simultaneous presence of these three charges (at their respective positions, as before), equals $\mathbf{F}$, we would have

- (A) $|\mathbf{F}| = |\mathbf{F}_1| + |\mathbf{F}_2| + |\mathbf{F}_3|$
- (B) $\mathbf{F} = (\mathbf{F}_1 + \mathbf{F}_2) - \mathbf{F}_3$
- (C) $\mathbf{F} = \mathbf{F}_3 - (\mathbf{F}_1 + \mathbf{F}_2)$
- (D) $\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$

Q.1.1.8 Two charges $q_1 (= +10 \mu\text{C})$ and $q_2 (= -10 \mu\text{C})$ are kept at the points $(-8, 0)$ and $(+8, 0)$ in the XY plane (Fig.1.1.2) where O is the origin of coordinates and the distances have been measured in cm. The resultant force (in newton) due to these two charges, on a charge $q (= +1 \text{ mC})$, kept at the point $(0, +6)$, would be

- (A) $(-14400 \hat{\mathbf{i}})$
- (B) $(+14400 \hat{\mathbf{i}})$
- (C) $(-10800 \hat{\mathbf{i}})$
- (D) $(+10800 \hat{\mathbf{i}})$

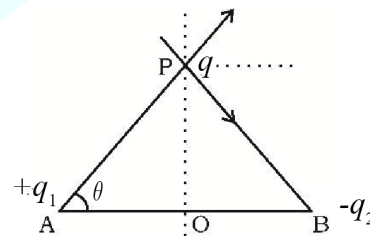


Fig.Q.1.1.2

Q.1.1.9 In the (Fig.1.1.3) shown here, ABC is an equilateral triangle of side $2a$ and G is its centroid. Four charges, as shown, are kept at the points A, B, C and G. The resultant force, on the charge $+q$, kept at G, due to the other three charges, kept at the three vertices of the triangle, equals

- (A) $\frac{q^2}{12\pi\epsilon_0 a^2} (-\hat{\mathbf{j}})$

- (B) $\frac{q^2}{4\pi\epsilon_0 a^2}(-\hat{j})$
- (C) $\frac{3q^2}{8\pi\epsilon_0 a^2}(-\hat{j})$
- (D) $\frac{3q^2}{2\pi\epsilon_0 a^2}(-\hat{j})$

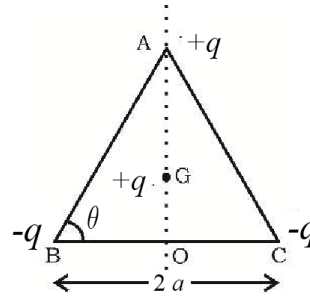


Fig.Q.1.1.3

Q.1.1.10. Five charges, as shown (Fig.1.1.4), are kept at the four vertices, and at the centre, of a square of side $2a$. The side AB lies along the x-axis, with origin at O. The resultant force, on the charge, at the centre P, due to the other four charges, would equal

- (A) $\sqrt{2} \cdot \frac{1}{4\pi\epsilon_0} \frac{q^2}{a^2}(-\hat{j})$
- (B) $\sqrt{2} \cdot \frac{1}{4\pi\epsilon_0} \frac{q^2}{a^2}(+\hat{j})$
- (C) Zero
- (D) $\frac{1}{8\sqrt{2}\pi\epsilon_0} \frac{q^2}{a^2}(-\hat{i} - \hat{j})$

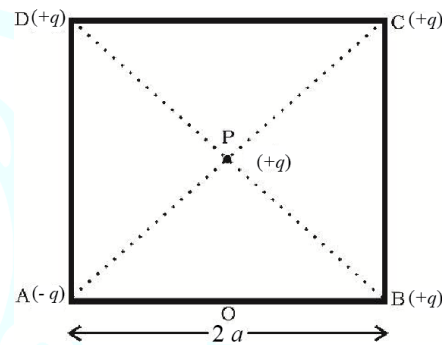


Fig.Q.1.1.4

Module 2 : Electric Field; Gauss's Law

Q.1.2.1 Let there be a point charge Q , located at some point in space. Let there be another point, in space, whose position vector, with respect to the point of location of charge Q , is $\mathbf{r}$. The electric field, $\mathbf{E}$, due to the charge Q , at this field point, (in SI units) is best obtained by

- (A) finding the force experienced by a unit charge, kept at that point
- (B) first finding the (small) force $\Delta\mathbf{F}$, experienced by a (small) charge ΔQ and then taking the ratio $= \left(\frac{\mathbf{F}}{\Delta Q} \right)$

- (C) just calculating the value of the expression $= \left(\frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \hat{\mathbf{r}} \right)$, i.e. $= \left(\frac{1}{4\pi\epsilon_0} \frac{Q}{r^3} \mathbf{r} \right)$
- (D) first finding the force experienced by a charge of $1\mu\text{C}$, kept at that point and then multiplying this force with 10^6 .

Q.1.2.2 Two charges of $(+1\mu\text{C})$ and $(+5\mu\text{C})$ are located at the points $(2,3,4)$ and $(3,4,5)$, respectively. The net electric field, due to these two charges, at the origin, would equal

- (A) $-10^3 \left[\left(\frac{18}{29\sqrt{29}} + \frac{135}{50\sqrt{50}} \right) \hat{\mathbf{i}} + \left(\frac{27}{29\sqrt{29}} + \frac{180}{50\sqrt{50}} \right) \hat{\mathbf{j}} + \left(\frac{36}{29\sqrt{29}} + \frac{225}{50\sqrt{50}} \right) \hat{\mathbf{k}} \right] \frac{\text{N}}{\text{C}}$
- (B) $-10^3 \left[\left(\frac{27}{29\sqrt{29}} + \frac{180}{50\sqrt{50}} \right) \hat{\mathbf{i}} + \left(\frac{36}{29\sqrt{29}} + \frac{225}{50\sqrt{50}} \right) \hat{\mathbf{j}} + \left(\frac{18}{29\sqrt{29}} + \frac{135}{50\sqrt{50}} \right) \hat{\mathbf{k}} \right] \frac{\text{N}}{\text{C}}$
- (C) $- \left[\left(\frac{27}{29\sqrt{29}} + \frac{180}{50\sqrt{50}} \right) \hat{\mathbf{i}} + \left(\frac{36}{29\sqrt{29}} + \frac{225}{50\sqrt{50}} \right) \hat{\mathbf{j}} + \left(\frac{18}{29\sqrt{29}} + \frac{135}{50\sqrt{50}} \right) \hat{\mathbf{k}} \right] \frac{\text{N}}{\text{C}}$
- (D) $- \left[\left(\frac{36}{29\sqrt{29}} + \frac{225}{50\sqrt{50}} \right) \hat{\mathbf{i}} + \left(\frac{18}{29\sqrt{29}} + \frac{135}{50\sqrt{50}} \right) \hat{\mathbf{j}} + \left(\frac{27}{29\sqrt{29}} + \frac{180}{50\sqrt{50}} \right) \hat{\mathbf{k}} \right] \frac{\text{N}}{\text{C}}$

Q.1.2.3. Three equal charges, Q each, are kept at the three vertices of an equilateral triangle of side a . The net electric field due to these three charges at the centroid of the triangle, has a magnitude

- (A) $\frac{3}{4\pi\epsilon_0} \left(\frac{3Q}{a^2} \right)$
- (B) $\frac{1}{4\pi\epsilon_0} \left(\frac{3Q}{a^2} \right)$
- (C) Zero
- (D) $\frac{2}{4\pi\epsilon_0} \left(\frac{3Q}{a^2} \right)$

Q.1.2.4. A non-uniformly charged wire of length $2L$ is kept symmetrically about the origin, on the X-axis. (Fig. 1.2.1) The linear charge density, on the wire, varies with x as $\lambda(x) = b|x|$ ($b = \text{a constant}$) The electric field, due to this wire, at the point $(0, a)$, would equal

- (A) $\frac{b(\sqrt{L^2+a^2}-a^2)\hat{\mathbf{j}}}{\pi\epsilon_0\sqrt{L^2+a^2}}$
- (B) $\frac{b(\sqrt{(L^2+a^2)}-a^2)\hat{\mathbf{j}}}{4\pi\epsilon_0\sqrt{L^2+a^2}}$

- (C) $\frac{b(\sqrt{L^2+a^2}-a)\hat{j}}{\pi\epsilon_0(\sqrt{L^2+a^2})}$
- (D) $\frac{b(\sqrt{L^2+a^2}-a)\hat{j}}{4\pi\epsilon_0\sqrt{L^2+a^2}}$

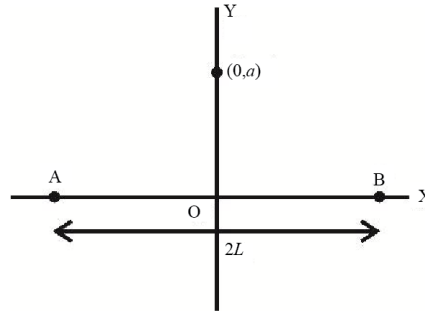


Fig.Q.1.2.1

Q.1.2.5 For a given charge distribution, its Gaussian surface is a surface for which the electric field, due to this charge distribution,

- (A) has the same magnitude at all points of this surface; its direction, at any point, is always inclined at an acute angle to the normal to the surface at that point.
- (B) is always directed along the normal to the surface at all points; its magnitude may, however, differ from point to point.
- (C) has the same magnitude at all points on this surface; its direction, at any point on the surface, is always inclined at an obtuse angle to the normal to the surface at that point.
- (D) has the same magnitude at all points on this surface; its direction at any point is also along the normal to the surface at that point.

Q.1.2.6 A cube, of side a , is located, as shown in Fig. 1.2.2, in a region where an electric field $\mathbf{E} = (c + bx)\hat{i}$ is present. The net outward flux of this electric field, through the cube, equals.

- (A) $(2ca^2 + ba^3)$
- (B) (ba^3)
- (C) $-(ca^2 + ba^3)$
- (D) $(ca^2 + 2ba^3)$

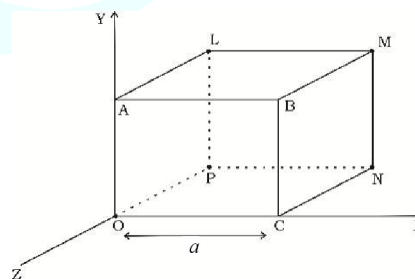


Fig.Q.1.2.2

Q.1.2.7 A solid sphere, of radius R , has a non-uniform radial charge density that varies as $\rho(r) = kr^2$ Where r is the distance of the point from the centre. The flux of the electric field due to this sphere through concentric sphere of radius R_0 ($R_0 > R$), equals

- (A) $\frac{4\pi k R_0^5}{\epsilon_0}$
 (B) $\frac{4\pi k R_0^5}{5\epsilon_0}$
 (C) $\frac{4\pi k R^5}{5\epsilon_0}$
 (D) $\frac{4\pi k R^5}{\epsilon_0}$

Q.1.2.8 A thin wire, of length L , has a linear charge density $\lambda(x)$, that varies with distance from its one end as $\lambda(x) = a \sin\left(\frac{2\pi}{L}x\right)$. If a closed surface S_1 were to enclose one half of this wire (from $x = 0$ to $x = L/2$), and another closed surface S_2 were to enclose the whole of this wire, the electric fluxes, ϕ_1 and ϕ_2 , through the two surfaces S_1 and S_2 , would be, equal, respectively, to

- (A) $\frac{aL}{\pi\epsilon_0}$ and zero
 (B) $\frac{aL}{2\pi\epsilon_0}$ and $\frac{aL}{4\pi\epsilon_0}$
 (C) zero and $\frac{aL}{2\pi\epsilon_0}$
 (D) $\frac{aL}{4\pi\epsilon_0}$ and $\frac{aL}{2\pi\epsilon_0}$

Q.1.2.9 A square planar sheet, OABC, located in the XY plane, as shown in Fig.Q.1.2.3, is charged in such a way that the surface charge density at a distance y from its base side varies as $\sigma(y) = ky$. If this square plane sheet were to be completely enclosed within a sphere of radius R , ($R > 2a$) the flux of its electric field through this sphere, would be

- (A) $\frac{ka^2R}{2\epsilon_0}$
 (B) $\frac{ka^3}{2\epsilon_0}$
 (C) $\frac{ka^2R}{3\epsilon_0}$
 (D) $\frac{ka^3}{3\epsilon_0}$

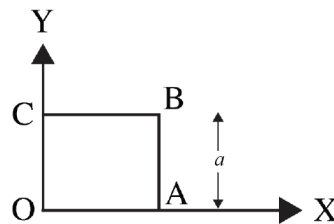


Fig.Q.1.2.3

Q.1.2.10 Two pith balls each of mass m and charge q are suspended from rigid support, they attain equilibrium position as shown in Fig.Q.1.2.4. Where O is the point of suspension and ON is the vertical. This distance between the two pith balls in the equilibrium position is $2a$.

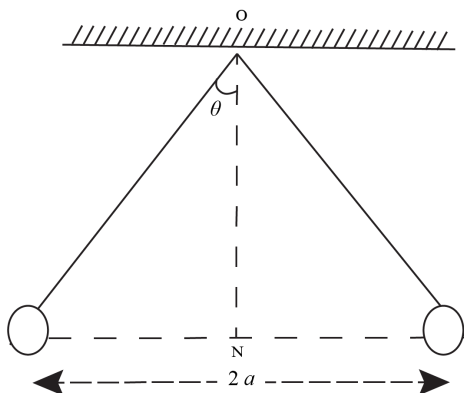


Fig.Q.1.2.4

The angle θ is then given by the relation.

- (A) $\theta = \tan^{-1} \left(\frac{q^2}{4\pi\epsilon_0 a^2 mg} \right)$
- (B) $\theta = \tan^{-1} \left(\frac{q^2}{16\pi\epsilon_0 a^2 mg} \right)$
- (C) $\theta = \tan^{-1} \left(\frac{q^2}{32\pi\epsilon_0 a^2 mg} \right)$
- (D) $\theta = \tan^{-1} \left(\frac{q^2}{64\pi\epsilon_0 a^2 mg} \right)$

Module 3: Electric Dipole

Q.1.3.1 The variation of the electric field (E) and electric potential (V) with distance (r) from the source for a dipole are, respectively, as

- (A) $\left[E(r) \propto \frac{1}{r^2}; V(r) \propto \frac{1}{r^3} \right]$
- (B) $\left[E(r) \propto \frac{1}{r^3}; V(r) \propto \frac{1}{r^2} \right]$
- (C) $\left[E(r) \propto \frac{1}{r^2}; V(r) \propto \frac{1}{r} \right]$
- (D) $\left[E(r) \propto \frac{1}{r}; V(r) \propto \frac{1}{r^2} \right]$

Q.1.3.2 In respect of analysis of an electric dipole the ratio of its size to the distance between the source and field point, plays a crucial role. Given below are three dimensionless quantities corresponding to the said ratio

- I. The first power
- II. The second power
- III. The third power

Which among the following survives in the mathematical treatment?

- (A) Both I & II
- (B) Both II & III
- (C) Only II
- (D) Only I

Q.1.3.3 A dipole is present in a (i) uniform electric field aligned at a certain angle with the dipole. (ii) (highly) non-uniform external electric field. Let τ and F denote the magnitudes of the torque and the force acting on the dipole. We can then say that

- (A) $\tau \neq 0$ and $F = 0$ in case (i)
 $\tau = 0$ and $F = 0$ in case (ii)
- (B) $\tau \neq 0$ and $F = 0$ in case (i)
 $\tau \neq 0$ and $F \neq 0$ in case (ii)
- (C) $\tau = 0$ and $F = 0$ in case (i)
 $\tau \neq 0$ and $F \neq 0$ in case (ii)
- (D) $\tau = 0$ and $F \neq 0$ in case (i)
 $\tau = 0$ and $F \neq 0$ in case (ii)

Q.1.3.4 For a neutral atom/molecule, its monopole moment (= its net charge) and its dipole moment are denoted by q_0 and p_0 , respectively. We can say that for such (neutral) atoms/molecules,

- (A) $q_0 = 0$ and $p_0 = 0$ for all neutral atoms/molecules
- (B) $q_0 = 0$ for all neutral atoms/molecules but p_0 can be non-zero for some neutral atoms/molecules
- (C) q_0 can be non-zero for some neutral atoms/molecules but $p_0 = 0$ for all neutral atoms/molecules
- (D) q_0 as well as p_0 can be non-zero for some neutral atoms/ molecules.

Q.1.3.5 A dipole has its dipole moment oriented (i) parallel (ii) antiparallel to a uniform external electric field. The dipole is (slightly) rotated (a) clockwise (b) anticlockwise, from its equilibrium position in the two cases. The torques acting on the dipole, corresponding to these two types of rotations, in its two (originally) equilibrium orientations, would be directed

- (A) (a) clockwise in case (i) and anticlockwise in case (ii)
 (b) anticlockwise in case (i) and clockwise in case (ii)
- (B) (a) anticlockwise in case (i) and clockwise in case (ii)
 (b) clockwise in case (i) and anticlockwise in case (ii)
- (C) (a) anticlockwise in both cases (i) and (ii)
 (b) clockwise in both case (i) and (ii)
- (D) (a) clockwise in both cases (i) and (ii)
 (b) anticlockwise in both case (i) and (ii)

Q.1.3.6 The polar-coordinates of a field point P with respect to the centre (as origin) and axis (as reference line) of a (small) dipole are r and θ , respectively, as shown here (Fig.1.3.1). The potential, at point P, due to this dipole having moment p , can be expressed as

- (A) $\frac{1}{4\pi\epsilon_0} \left[\frac{p \cos \theta}{r^2} + \frac{p \sin \theta}{(r^2 + a^2)} \right]$
- (B) $\frac{1}{4\pi\epsilon_0} \left[\frac{p \sin \theta}{(r^2 + a^2)} \right]$
- (C) $\frac{1}{4\pi\epsilon_0} \left[\frac{p \cos \theta}{r^2} - \frac{p \sin \theta}{(r^2 + a^2)} \right]$
- (D) $\frac{1}{4\pi\epsilon_0} \left[\frac{p \cos \theta}{r^2} \right]$

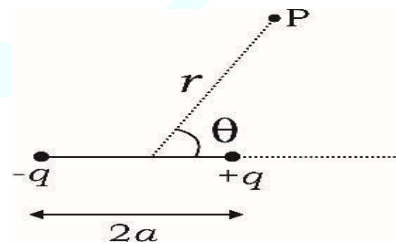
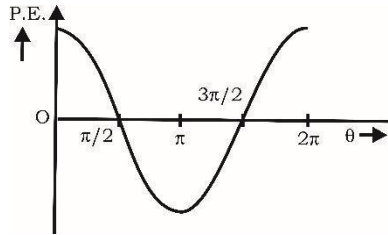
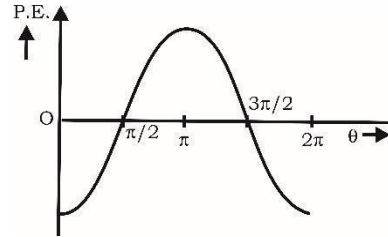


Fig.Q.1.3.1

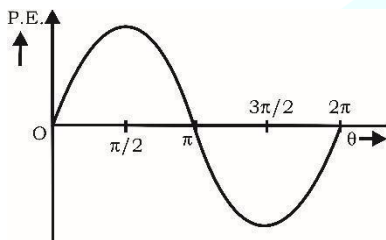
Q.1.3.7 A dipole, of dipole moment, is placed in a uniform electric field. Taking the zero of potential energy of the dipole to correspond to its (first) orientation for which $|\mathbf{p} \times \mathbf{E}| = pE$, the variation of its PE, with the angle of orientation (θ) of, with respect to, would be represented by



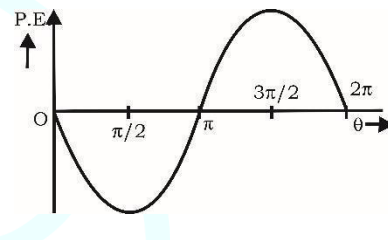
(A)



(B)



(C)



(D)

Q.1.3.8 The polar coordinates of field point P, with respect to the center (as origin) and axis (as reference line) of a (small) dipole, are r and θ , respectively, as shown here Fig.1.3.2. The electric field, at point P, due to this dipole, can be expressed as

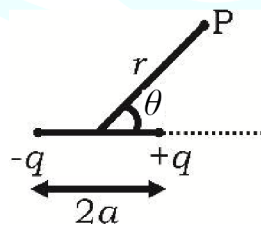


Fig.Q.1.3.2

(A) $\left[\frac{2qa\sqrt{1+3\cos^2\theta}}{4\pi\epsilon_0 r^3} \right]$, inclined at an angle $\left[\theta + \tan^{-1}\left(\frac{1}{2}\tan\theta\right) \right]$ to the dipole axis

- (B) $\left[\frac{2qa\sqrt{1+3\sin^2\theta}}{4\pi\epsilon_0 r^3} \right]$, inclined at an angle $\left[\theta + \tan^{-1}\left(\frac{1}{2}\tan\theta\right) \right]$ to the dipole axis
- (C) $\left[\frac{4qa\sqrt{1+3\cos^2\theta}}{4\pi\epsilon_0 r^3} \right]$, inclined at an angle $\left[\theta + \frac{1}{2}\tan^{-1}\left(\frac{1}{2}\tan\theta\right) \right]$ to the dipole axis
- (D) $\left[\frac{4qa\sqrt{1+3\sin^2\theta}}{4\pi\epsilon_0 r^3} \right]$, inclined at an angle $\left[\theta + \tan^{-1}\left(\frac{1}{2}\tan\theta\right) \right]$ to the dipole axis

Q.1.3.9 Two (small) dipoles are both placed (in the XY plane) placed along the X-axis with their positive charges placed end-to-end, as shown in Fig.Q.1.3.3. The net potential, due to this combination, at the axial and the equatorial lines, would be (nearly) equal, respectively, to

- (A) $\frac{pa}{4\pi\epsilon_0 x^3}$ and zero
- (B) Zero and $\frac{pa}{4\pi\epsilon_0 y^3}$
- (C) $\frac{pa}{\pi\epsilon_0 x^3}$ and $\frac{pa}{2\pi\epsilon_0 y^3}$
- (D) $\frac{pa}{4\pi\epsilon_0 x^3}$ and $\frac{pa}{2\pi\epsilon_0 y^3}$

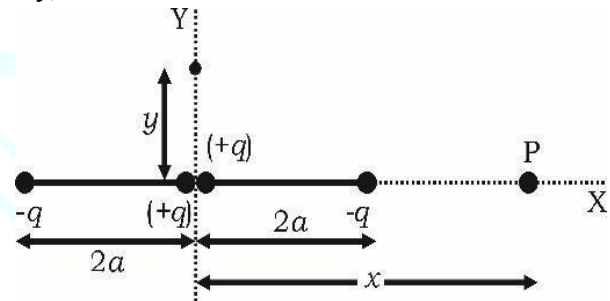


Fig.Q.1.3.3

Q.1.3.10 A combination of two dipoles with their similar charges placed 'end-to-end', as shown, Fig.1.3.4 is known as a quadrupole. The variation of the axial potential $V(r)$ of a very small quadrupole with distance (r) from its centre, would be represented by the curve

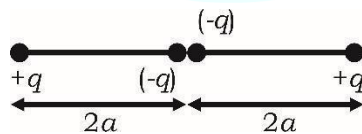
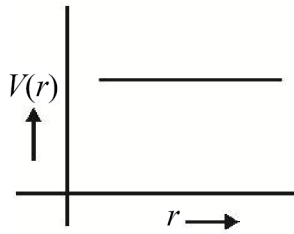
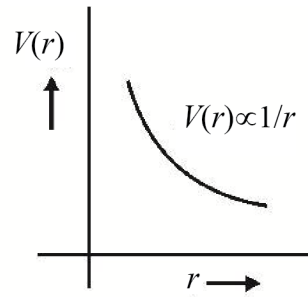


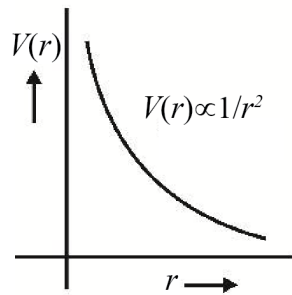
Fig.Q.1.3.4



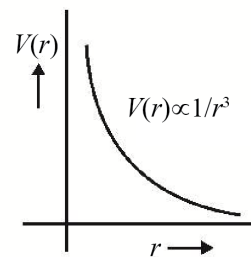
(A)



(B)



(C)



(D)



Development Team

N.K.Sehgal, Former Associate Professor, Hans Raj College, Delhi University

Review Team

C.K. Ghosh, Former Director, NCIDE, IGNOU, New Delhi

K.L.Chopra, Former Associate Professor, Hans Raj College, Delhi University

Surender Kumar, Vice Principal, KVS, Keltron Nagar, Kannur, Kerala

Member- Coordinator

Shashi Prabha, Professor, CIET, NCERT, New Delhi

Technical support

Riya Rani, JPF, CIET, NCERT, New Delhi

Bhawana Bhatt, Technical Content Developer, CIET, NCERT, New Delhi

Rajat Kumar, Graphic Designer, CIET, NCERT, New Delhi