CHAPTER

1

Electric Charge and Fields

A Quick Recapitulation of the Chapter

1. **Electric charge** is quantised. SI unit of charge is coulomb (C). The minimum unit of charge, which may reside independently is the electronic charge e having a value 1.60×10^{-19} C. Charge on any other body is given by $q = \pm ne$, where n is any integer. It is additive in nature. Charge is conserved, invariant and radiates energy.
2. **Coulomb's law** states that if q_1 and q_2 are two stationary point charges in free space separated by a distance r, then force of attraction/repulsion between them is given by
$$F = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 q_2}{r^2}$$
In vector form, $\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 q_2}{r^3}\mathbf{r}$
where, $\mathbf{r} = r\,\hat{\mathbf{r}}$ (vector form)
ε_0 = Permittivity of free space and $k = \frac{1}{4\pi\varepsilon_0} = 9\times 10^9$
The value of ε_0 in SI units is 8.854×10^{-12} $C^2\,N^{-1}m^{-2}$.
3. The force between two charges q_1 and q_2 located at a distance (r) in a medium is expressed as
$$F_{\text{medium}} = \frac{1}{4\pi\varepsilon}\cdot\frac{q_1 q_2}{r^2}$$
(where, ε = absolute permittivity of the medium)
$$\frac{F_{\text{vacuum}}}{F_{\text{medium}}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\bigg/\frac{1}{4\pi\varepsilon}\cdot\frac{q_1 q_2}{r^2} = \frac{\varepsilon}{\varepsilon_0} = \varepsilon_r = K$$
(where, ε_r = relative permittivity of the medium)
i.e., the ratio of permittivity of the medium to the permittivity of free space is called relative permittivity.
4. **Superposition principle** Resultant force on a point charge due to a number of point charges
$$\mathbf{F}_0 = \mathbf{F}_{01} + \mathbf{F}_{02} + \mathbf{F}_{03} + \ldots + \mathbf{F}_{0n}$$
5. **Electric field** is the region surrounding an electric charge or a group of charges, in which another charge experiences a force. Its unit is N/C . It is a vector quantity.
6. **Electric field vector E** (also known as electric field intensity) at any point is given by
$$\mathbf{E} = \lim_{q_0 \to 0}\frac{\mathbf{F}}{q_0}$$
where, q_0 is a small positive test charge which experiences a force, $\mathbf{F}$ at given point. Electric field at a distance r from a point charge q is given by
$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$$
7. **Electric field lines** are a way of pictrorially mapping the electric field around a configuration of charge(s). These lines start on positive charge and end on negative charge. The tangent on these lines at any point gives direction of field at that point.
8. **Electric flux** is a measure of flow of electric field through a surface. Mathematically, electric flux is the product of an area element $d\mathbf{S}$ and normal component of $\mathbf{E}$ integrated over a surface,
i.e., $\phi_E = \int E\,dS\cos\theta = \int \mathbf{E}\cdot d\mathbf{S} = \int \mathbf{E}\cdot\hat{\mathbf{n}}\,dS$
where $\hat{\mathbf{n}}$ is the unit vector normal to area element dS.

Electric flux is a scalar having SI unit Nm^2C^{-1} or Vm. Its dimensional formula is $[ML^3T^{-3}A^{-1}]$.

9. The arrangement of two equal and opposite point charges at a fixed distance is called an **electric dipole**.
10. The product of the magnitude of either charge (q) and the distance between the charges ($2a$) is called **electric dipole moment.**

$$\mathbf{p} = q \times 2\,\mathbf{a}$$

It is a vector quantity and its SI unit is C-m.

11. Electric field at a point distant r from centre of dipole along its axial line is given by

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\mathbf{p}r}{(r^2 - a^2)^2}$$

(direction of **E** is same as of **p**)

12. Electric field at a point distant r from centre of dipole along its equatorial line is given by

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\mathbf{p}}{(r^2 + a^2)^{3/2}}$$

(direction of **E** is opposite to that of **p**)

13. When a dipole is placed at an angle θ from the direction of a uniform electric field E, it experiences a torque given by

$$\tau = pE\sin\theta \quad \text{or} \quad \tau = \mathbf{p} \times \mathbf{E}$$

14. **Gauss' law** states that the surface integral of the electric field intensity over any closed surface (called Gaussian surface) in free space is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed within the surface.

$$\phi_E = \oint \mathbf{E} \cdot d\mathbf{S} = \frac{1}{\varepsilon_0} \sum_{i=1}^{n} q_i = \frac{q}{\varepsilon_0}$$

where, $q = \sum_{i=1}^{i=n} q_i$ is the algebraic sum of all the charges inside the closed surface.

15. Electric field due to an infinitely long straight uniformly charged wire,

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

16. Electric field due to a thin infinite plane sheet of charge,

$$E = \frac{\sigma}{2\varepsilon_0}$$

17. Electric field due to a uniformly charged thin spherical shell

(i) Outside the shell,

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

(ii) Inside the shell, $E = 0$

Objective Questions Based on NCERT Text

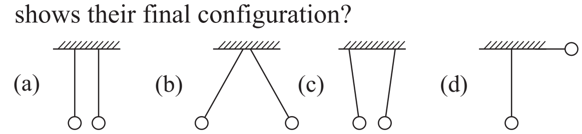
Topic 1 Electric Charge

1. While taking off synthetic clothes, seeing a spark or hearing a crackle, are due to
(a) motion of ions through air
(b) production of shock waves due to motion of electrons
(c) electric discharge
(d) cannot be explained

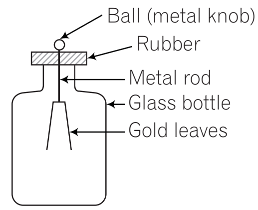
2. Out of gravitational, electromagnetic, van der Waals', electrostatic and nuclear forces, which two are able to provide an attractive force between two neutrons?
(a) Electrostatic and gravitational
(b) Electrostatic and nuclear
(c) Gravitational and nuclear
(d) Some other forces like van der Waals'

3. In general, metallic ropes are suspended from the carriers to the ground which take inflammable material. The reason is
(a) their speed is controlled
(b) to keep the gravity of the carrier nearer to the earth
(c) to keep the body of the carrier in contact with the earth
(d) nothing should be placed under the carrier

4. If a plastic rod rubbed with fur is made to touch two small pith balls suspended nearby, then which figure shows their final configuration?



5. For the figure shown, the instrument



(a) is used to measure quantity of a fluid
(b) is used to measure wind velocity is called windmeter
(c) is used to measure viscosity of a fluid
(d) is used to detect presence of charge on a body, is called electroscope

6. When a body is connected to earth, electrons from the earth flow into the body. This means the body is …… .
(a) unchanged (b) charged positively
(c) charged negatively (d) as insulator

7. One metallic sphere A is given positive charge whereas another identical metallic sphere B of exactly same mass as of A is given equal amount of negative charge. Then,
(a) mass of A and mass of B still remain equal
(b) mass of A increases
(c) mass of B decreases
(d) mass of B increases

8. A glass rod rubbed with silk is used to charge a gold leaf electroscope and the leaves are observed to diverge. The electroscope thus charged is exposed to X-rays for a short period. Then,
(a) the divergence of leaves will not be affected
(b) the leaves will diverge further
(c) the leaves will collapse
(d) the leaves will melt

9. Electric wiring in our houses has
(a) only one wire : live
(b) two wires : neutral, earth
(c) three wires, live, neutral, earth
(d) no wire

10. A soap bubble is given a negative charge, then its radius
(a) decreases
(b) increases
(c) remains unchanged
(d) nothing can be predicted as information is insufficient

11. If two bodies are rubbed and one of them acquires q_1 charge and another acquires q_2 charge, then ratio $q_1 : q_2$ is
(a) 1 : 2 (b) 2 : 1
(c) – 1 : 1 (d) 1 : 4

12. Two bodies are rubbed and one of them is negatively charged. For this body, if m_i = initial mass, m_f = mass after charging, then
(a) $m_i = m_f$ (b) $m_i < m_f$
(c) $m_i > m_f$ (d) $m_i + m_f = 2m_f$

13. When we touch a pith ball with an electrified plastic rod, some of the negative charges on the rod are transferred to the pith ball and it also gets charged. Thus, pith ball is charged by
(a) induction (b) contact
(c) repulsion (d) None of these

14. In charging by induction,
(a) body to be charged must be an insulator
(b) body to be charged must be a semiconductor
(c) body to be charged must be a conductor
(d) any type of body can be charged by induction

15. Charge on a body is q_1 and it is used to charge another body by induction. Charge on second body is found to be q_2 after charging. Then,
(a) $\frac{q_1}{q_2} = 1$ (b) $\frac{q_1}{q_2} < 1$ (c) $\frac{q_1}{q_2} \leq 1$ (d) $\frac{q_1}{q_2} \geq 1$

16. A body A is being charged by another charged body B by induction process. Then, charge acquired by A depends on
(a) nature of material of A
(b) distance between A and B
(c) nature of medium separating A and B
(d) All of the above

17. Additive nature of charge means
(a) total charge on a system remains constant
(b) total charge on an isolated system is always zero
(c) charges are of two types positive and negative
(d) it tells about the scalar nature of charge

18. Conservation of charge follows from law of conservation of mass. Above statement is
(a) correct
(b) incorrect
(c) nothing can be said
(d) mass and charge are two different physical quantities following conservation law

19. Charge of a body is always an integral multiple of
(a) charge present in its one atom
(b) charge present in one mole of material of body
(c) charge present on an electron
(d) charge of its one nucleus

20. The minimum charge on an object is
(a) 1 C (b) 1 stat C
(c) 1.6×10^{-19} C (d) 3.2×10^{-19} C

21. When a glass rod is rubbed with a silk cloth, charge appears on both. This observation is consistent with law of conservation of charge as

(a) charge on both causes attraction
(b) charge on both causes repulsion
(c) charges appearing on both bodies are equal and opposite
(d) charge on first body is more than that of second body

22. If a body gives out 10^9 electrons per second, how much time is required to get a total charge of 1 C from it?

(a) Around 198 min (b) Around 198 h
(c) Around 198 days (d) Around 198 yr

23. The number of electrons that must be removed from an electrically neutral silver dollar to give it a charge of + 2.4 C is

(a) 2.5×10^{19} (b) 1.5×10^{19}
(c) 1.5×10^{-19} (d) 2.5×10^{-19}

24. An object of mass 1 kg contains 4×10^{20} atoms. If one electron is removed from every atom of the solid, the charge gained by the solid of 1 g is

(a) 2.8 C (b) 6.4×10^{-2} C
(c) 3.6×10^{-3} C (d) 9.2×10^{-4} C

Topic 2
Force between Two Charges : Coulomb's Law

25. Magnitude of force between two point charges q_1 and q_2 which are separated by a distance r is given by

(a) $F = \frac{k\ |q_1 q_2|}{r}$ (b) $F = \frac{k\ |q_1 q_2| r}{r^2}$

(c) $F = k\left(\left|\frac{q_1 q_2}{r}\right|\right)^2$ (d) $F = \frac{k\ |q_1 \cdot q_2|}{r^2}$

26. Suppose charge on a metallic sphere is q. If the sphere is put in contact with an identical uncharged sphere, the charge will spread over the two spheres. By symmetry charge on each sphere will be ……

When distance between two charged spheres is varied so that it becomes half the initial distance, force between them will become ……

(a) $\frac{q}{2}$, half (b) $\frac{q}{2}$, four times
(c) $2q$, half (d) $2q$, double

27. Force between two charges q_1 and q_2 separated by a distance r is proportional to $q_1 q_2 / r^2$. Proportionality constant is

(a) $\frac{\varepsilon_0}{4\pi}$ (b) $4\pi\varepsilon_0$ (c) $\frac{1}{4\pi\varepsilon_0}$ (d) 1

28. In the following configuration of charges, force on charge q_2 by q_1 is given by

(a) $\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\cdot\hat{\mathbf{r}}_{21}$ (b) $\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}(-\hat{\mathbf{r}}_{21})$

(c) $\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^3}\cdot\hat{\mathbf{r}}_{21}$ (d) $\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^3}\cdot(-\hat{\mathbf{r}}_{21})$

(here, $r = r_{21} = |\mathbf{r}_2 - \mathbf{r}_1|$)

29. F_g and F_e represents gravitational and electrostatic force respectively between electron and proton at a distance of 10 cm. The ratio of F_g / F_e is of the order of

(a) 10^{42} (b) 10^{-39} (c) 1 (d) 10^{-43}

30. For charges q_1 and q_2, if force between them for some separation in air is F, then force between them in a medium of permittivity ε will be

(a) $\frac{\varepsilon_0}{\varepsilon}F$ (b) $\frac{\varepsilon}{\varepsilon_0}F$

(c) $\varepsilon\varepsilon_0 F$ (d) $\frac{F}{\varepsilon_0\varepsilon}$

31. Two identical charged spheres suspended from a common point by two massless strings of lengths l, are initially at a distance d ($d << l$) apart because of their mutual repulsion. The charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity v. Then, v varies as a function of the distance x between the sphere, as **[NEET 2016]**

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

32. Suppose the spheres A and B with charge 6.5×10^{-7} C and distance between centres is 50 cm have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second and finally removed from both. What is the new force of repulsion between A and B?

(a) 5.7×10^{-3} N (b) 1.5×10^{-2} N
(c) 0.24 N (d) 0.24×10^{-2} N

33. The ratio of the forces between two small spheres with constant charge (a) in air (b) in a medium of dielectric constant K is

(a) $1:K$ (b) $K:1$ (c) $1:K^2$ (d) $K^2:1$

34. Two point charges placed at a certain distance r in air exert a force F on each other. Then, the distance r' at which these charges will exert the same force in a medium of dielectric constant K is given by

(a) r (b) r/K (c) $r/\sqrt{K}$ (d) $r\sqrt{K}$

35. 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) $-y$

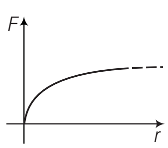
(c) $\frac{1}{y}$ (d) $-\frac{1}{y}$

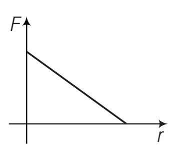
36. Two small spheres each having the charge $+Q$ are suspended by insulating threads of length L from a hook. This arrangement is taken in space where there is no gravitational effect, then the angle between the two suspensions and the tension in each will be

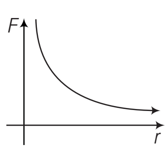
(a) $180°, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(2L)^2}$ (b) $90°, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$

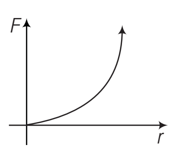
(c) $180°, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{2L^2}$ (d) $180°, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$

37. Force between two charges varies with distance between them as

(a)


(b)


(c)


(d)


38. Two electrically charged particles, having charges of different magnitudes, when placed at a distance d from each other, experience a force of attraction F.

These two particles are put in contact and again placed at the same distance from each other.

What is the nature of new force between them?

(a) Attractive
(b) Repulsive
(c) Attractive or repulsive depending upon magnitude of charges present on them
(d) Cannot predicted

39. Three charges q_1, q_2 and q_3 each of 1 C are at the vertices of an equilateral triangle of side l. Force on a charge $q=2\mu C$ placed at the centroid of the triangle is

(a) 3 N (b) 3 μN

(c) zero (d) 3×10^{-2} N

40. If charges q, q and $-q$ are placed at vertices of an equilateral triangle of side l. If $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ are the forces on the charges respectively, then

(a) $|\mathbf{F}_1+\mathbf{F}_2+\mathbf{F}_3|=\sqrt{3}\frac{kq^2}{l^2}$

(b) $|\mathbf{F}_1+\mathbf{F}_2+\mathbf{F}_3|=0$

(c) $|\mathbf{F}_1+\mathbf{F}_2+\mathbf{F}_3|=3\sqrt{2}\frac{kq^2}{l^2}$

(d) $|\mathbf{F}_1+\mathbf{F}_2+\mathbf{F}_3|=\sqrt{2}\frac{kq^2}{l^2}$

41. Four charges $q_A=2\mu C, q_B=-5\mu C, q_C=2\mu C$ and $q_D=-5\mu C$ are placed at corners of a square $ABCD$ of side 10 cm. What is the force on a charge of $1\mu C$ placed at centre of the square?

(a) 10×10^{-7} N (b) 10×10^{-5} N

(c) 10×10^{-3} N (d) Zero

42. 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

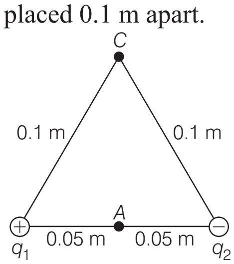
(a) $-\frac{Q}{4}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

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

Topic 3
Electric Field

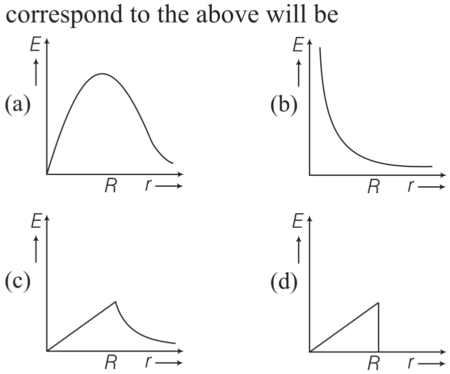
43. A force of 2.25 N acts on a chrage of 15×10^{-4} C. The intensity of electric field at that point is
(a) 150 NC^{-1} (b) 15 NC^{-1}
(c) 1500 NC^{-1} (d) 1.5 NC^{-1}

44. Two point charges q_1 and q_2 of $+10^{-8}$C and -10^{-8}C, respectively are placed 0.1 m apart.



Then, ratio of magnitudes of electric fields at A and C is
(a) 4 : 1 (b) 1 : 4 (c) 8 : 1 (d) 1 : 8

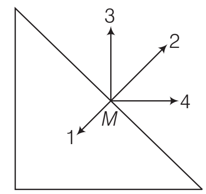
45. In a uniformly charged sphere of total charge Q and radius R, the electric field E is plotted as function of distance from the centre. The graph which would correspond to the above will be **[AIEEE 2012]**



46. An electron of mass m_e initially at rest moves through a certain distance in a uniform electric field in time t_1. A proton of mass m_p also initially at rest takes time t_2 to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio of t_2/t_1 is nearly equal to
(a) 1836 (b) $(m_e/m_p)^{1/2}$
(c) $(m_p/m_e)^{1/2}$ (d) 1

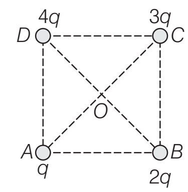
47. The electric field in a certain region is acting radially outward and is given by $E = Ar$. A charge contained in a sphere of radius a centred at the origin of the field will be given by **[CBSE AIPMT 2015]**
(a) $4\pi\varepsilon_0 Aa^2$ (b) $A\varepsilon_0 a^2$
(c) $4\pi\varepsilon_0 Aa^3$ (d) $\varepsilon_0 Aa^3$

48. Three identical point positive charges, as shown are placed at the vertices of an isosceles right angled triangle. Which of the numbered vectors coincides in direction with the electric field at the mid-point M of the hypotenuse?



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

49. Charges $q, 2q, 3q$ and $4q$ are placed at the corners A, B, C and D of a square as shown in the alongside figure. The direction of electric field at the centre of the square is along



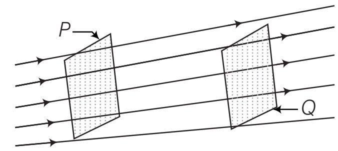
(a) AB (b) CB
(c) BD (d) AC

50. Electric field of a system of charges does not depend on
(a) position of charges forming the system
(b) distance of point (at which field is being observed) from the charges forming system
(c) value of test charge used to find out the field
(d) separation of charges forming the system

51. A field line is a space curve, means
(a) field lines are hypothetical curves
(b) field lines are two-dimensional curves
(c) field lines are three-dimensional curves
(d) field lines are straight lines

52. Two field lines can never cross each other because
(a) field lines are closed curves
(b) field lines repels each other
(c) field lines crowded only near the charge
(d) field has a unique direction at each point

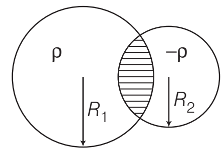
53. In the diagram shown below,



(a) field strength at P is less than field strength at Q
(b) field strength at P and Q are equal
(c) field is more strong at P and less strong at Q
(d) cannot be tell from the figure

54. A charged particle is free to move in an electric field. It will travel
(a) always along a line of force
(b) along a line of force, if its initial velocity is zero
(c) along a line of force, if it has some initial velocity in the direction of an acute angle with the line of force
(d) None of the above

55. Two non-conducting solid spheres of radii R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$ respectively, are placed such that they partially overlap, as shown in the figure.
At all points in the overlapping region
[JEE Advanced 2013]



(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

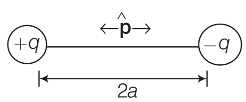
Topic 4
Electric Flux and Electric Dipole

56. If an area is tilted to direction of field such that normal to plane of area makes θ angle with the direction of field, then number of field lines passing through the area is
(a) equal to $E\Delta S$ (b) proportional to $E\Delta S\cos\theta$
(c) equal to $E\Delta S\cos\theta$ (d) proportional to $E\Delta S\cos\theta / r^2$

57. An area vector is a vector of magnitude equal to the area and it is directed
(a) parallel to area
(b) at an angle of 45° with the plane of area
(c) at an angle of 90° with the area
(d) at an angle of 45° with the normal to the area

58. Electric flux ϕ through an element area $\Delta\mathbf{S}$ when area is placed in region of uniform field $\mathbf{E}$ is
(a) $E \times \Delta S$ (b) $E \cdot \Delta S$ (c) $\Delta S \times E$ (d) $E(\Delta S)\cdot\sin\theta$

59. For the dipole shown,

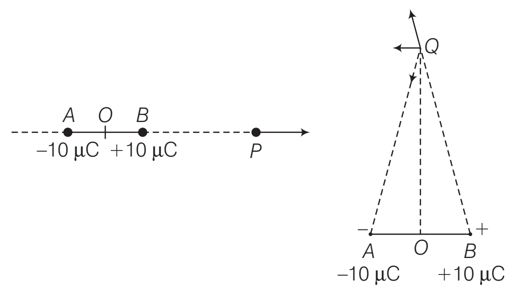


Dipole moment is given by
(a) $\mathbf{p} = q \times 2a\hat{\mathbf{p}}$ (b) $\mathbf{p} = \frac{1}{2}q \times 2a\hat{\mathbf{p}}$
(c) $\mathbf{p} = -q \times 2a\hat{\mathbf{p}}$ (d) $\mathbf{p} = 4q \times 2a\hat{\mathbf{p}}$

60. Electric field of a dipole at a distance r is proportional to
(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) $\frac{1}{r^4}$

61. If the centre of mass of positive charge does not coincide with that of the molecule, then
(a) molecule is called polar and it have an intrinsic dipole moment
(b) molecule is called polar but it does not have any dipole moment
(c) molecule is called non-polar and it has a dipole moment of its own
(d) molecule is called non-polar and it has a zero dipole moment

62.



In given figures, $OP = OQ = 15\,\text{cm}, OA = OB = 2.5\,\text{mm}$
Magnitudes of electric field at P and Q are respectively
(a) $2.6 \times 10^5\ \text{NC}^{-1}, 2.6 \times 10^5\ \text{NC}^{-1}$
(b) $1.3 \times 10^5\ \text{NC}^{-1}, 1.3 \times 10^5\ \text{NC}^{-1}$
(c) $2.6 \times 10^5\ \text{NC}^{-1}, 1.3 \times 10^5\ \text{NC}^{-1}$
(d) $1.3 \times 10^5\ \text{NC}^{-1}, 2.6\ \text{NC}^{-1}$

63. What is the angle between the electric dipole moment and the electric field strength due to it on the equatorial line?
(a) 0° (b) 90° (c) 180° (d) None of these

64. The ratio of electric fields on the axis and at equator of an electric dipole will be
(a) 1 : 1 (b) 2 : 1 (c) 4 : 1 (d) None of these

65. Two electric dipoles of moment p and $64p$ are placed in opposite direction on a line at a distance of 25 cm. The electric field will be zero at point between the dipoles whose distance from the dipole of moment p is
(a) 5 cm (b) $\frac{25}{9}$ cm (c) 10 cm (d) $\frac{4}{13}$ cm

66. Electric charges $q, q, -2q$ are placed at the corners of an equilateral ΔABC of side l. The magnitude of electric dipole moment of the system is
(a) ql (b) $2ql$ (c) $\sqrt{3}ql$ (d) $4ql$

67. An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when $\theta = 90°$, the torque and the potential energy of the dipole will respectively be **[CBSE AIPMT 2012]**

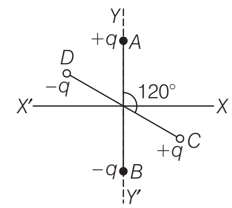
(a) $pE\sin\theta, -pE\cos\theta$ (b) $pE\sin\theta, -2pE\cos\theta$
(c) $pE\sin\theta, 2pE\cos\theta$ (d) $pE\cos\theta, -pE\sin\theta$

68. When a dipole is placed in an uniform external field, then
(a) net force on dipole is zero but torque is non-zero
(b) torque is zero but net force is non-zero
(c) torque and net force both are non-zero
(d) both torque and net force are zero

69. If field is non-uniform and a dipole is placed in it. Then,
(a) dipole keeps on rotating
(b) dipole shows rotation and translation both as there is net force on dipole
(c) dipole shows only translation
(d) dipole does not show any rotation or translation

70. When an electric dipole $\mathbf{p}$ is placed in a uniform electric field $\mathbf{E}$, then at what angle between $\mathbf{p}$ and $\mathbf{E}$ the value of torque will be maximum?
(a) 90° (b) 0° (c) 180° (d) 45°

71. Two small identical electrical dipoles AB and CD, each of dipole moment p are kept at an angle of 120° as shown in the figure. If this system is subjected to electric field ($\mathbf{E}$) directed along direction which makes $\theta°$ with XY plane. Then, the magnitude and direction of the torque acting on this is



(a) $pE\sin\theta$, along Z-axis
(b) $2pE\sin\theta$, along Z-axis
(c) $\frac{\sqrt{3}}{2}pE\sin\theta$, along Z-axis
(d) $\frac{1}{2}pE\sin\theta$, along Z-axis

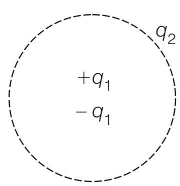
72. An electric dipole is situated in an electric field of uniform intensity E whose dipole moment is p and moment of inertia is I. If the dipole is displaced slightly from the equilibrium position, then the angular frequency of its oscillations is

(a) $\left(\frac{pE}{I}\right)^{1/2}$ (b) $\left(\frac{pE}{I}\right)^{3/2}$
(c) $\left(\frac{I}{pE}\right)^{1/2}$ (d) $\left(\frac{p}{IE}\right)^{1/2}$

Topic 5
Gauss' Law

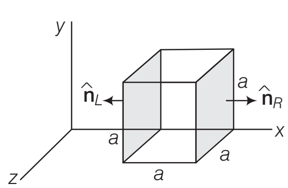
73. Gauss' law is true only if force due to charges varies as
(a) r^{-1} (b) r^{-2}
(c) r^{-3} (d) r^{-4}

74. Consider the charge configuration and spherical Gaussian surface as shown in the figure. When calculating the flux of the electric field over the spherical surface, the electric field will be due to



(a) q_2 (b) only the positive charges
(c) all the charges (d) $+q_1$ and $-q_1$

75. The electric field components in the given figure are $E_x = \alpha x^{1/2}$, $E_y = E_z = 0$ in which $\alpha = 800\ \text{NC}^{-1}\text{m}^{-1/2}$. The charge within the cube is if net flux through the cube is $1.05\ \text{Nm}^2\text{C}^{-1}$ (assume $a = 0.1$ m)



(a) 9.27×10^{-12} C (b) 9.27×10^{12} C
(c) 6.97×10^{-12} C (d) 6.97×10^{12} C

76. It is not convenient to use a spherical Gaussian surface to find the electric field due to an electric dipole using Gauss' theorem because
(a) Gauss' law fails in this case
(b) this problem does not have spherical symmetry
(c) Coulomb's law is more fundamental than Gauss' law
(d) spherical Gaussian surface will after the dipole moment

77. Total electric flux coming out of a unit positive charge put in air is
(a) ε_0 (b) ε_0^{-1} (c) $(4p\varepsilon_0)^{-1}$ (d) $4\pi\varepsilon_0$

78. An electric charge $+q$ is placed at the centre of a cube of side a. The electric flux on one of its faces will be

(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{q}{\varepsilon_0 q^2}$
(c) $\frac{q}{4\pi\varepsilon_0 a^2}$ (d) $\frac{q}{\varepsilon_0}$

79. For a given surface, the $\oint \mathbf{E} \cdot d\mathbf{S} = 0$. From this, we can conclude that
(a) E is necessarily zero on the surface
(b) E is perpendicular to the surface at every point
(c) the total flux through the surface is zero
(d) the flux is only going out of the surface

80. A charge q is placed at the centre of the open end of the cylindrical vessel. The flux of the electric field through the surface of the vessel is
(a) zero (b) $\frac{q}{\varepsilon_0}$ (c) $\frac{q}{2\varepsilon_0}$ (d) $\frac{2q}{\varepsilon_0}$

81. A cube of side l is placed in a uniform field $\mathbf{E}$, where $\mathbf{E} = E\,\hat{\mathbf{i}}$. The net electric flux through the cube is
(a) zero (b) l^2E (c) $4l^2E$ (d) $6l^2E$

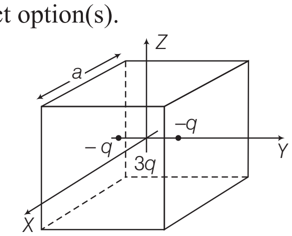
82. Eight dipoles of charges of magnitude e each are placed inside a cube. The total electric flux coming out of the cube will be
(a) $\frac{8e}{\varepsilon_0}$ (b) $\frac{16e}{\varepsilon_0}$ (c) $\frac{e}{\varepsilon_0}$ (d) zero

83. Two infinite plane parallel sheets separated by a distance d have equal and opposite uniform charge densities σ. Electric field at a point between the sheets is
(a) zero
(b) $\frac{\sigma}{\varepsilon_0}$
(c) $\frac{\sigma}{2\varepsilon_0}$
(d) depends upon the location of the point

84. A simple pendulum has a length l and the mass of the bob is m. The bob is given a charge q coulomb. The pendulum is suspended between the vertical plates of a charged parallel plate capacitor. If E is the electric field strength between the plates, the time period of the pendulum is given by
(a) $2\pi\sqrt{\frac{l}{g}}$ (b) $2\pi\sqrt{\frac{l}{\sqrt{g + \frac{qE}{m}}}}$
(c) $2\pi\sqrt{\frac{l}{\sqrt{g - \frac{qE}{m}}}}$ (d) $2\pi\sqrt{\frac{l}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$

85. Charge q_2 of mass m revolves around a stationary charge q_1 in a circular orbit of radius r. The orbital periodic time of q_2 would be
(a) $\left(\frac{4\pi^3 mr^2}{kq_1q_2}\right)^{1/2}$ (b) $\left(\frac{kq_1q_2}{4\pi^2 mr^2}\right)^{1/2}$
(c) $\left(\frac{4\pi^2 mr^4}{kq_1q_2}\right)^{1/2}$ (d) $\left(\frac{4\pi^2 mr^3}{kq_1q_2}\right)^{1/2}$

86. 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 option(s). **[IIT JEE 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 $x = +a/2$

Special Format Questions

I. Assertion and Reason

■ **Directions** (Q. Nos. 87-92) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*
(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

87. **Assertion** If a point charge be revolved in a circle around another charge as the centre of circle, then work done by electric field will be zero.
Reason Work done is equal to dot product of force and displacement.

88. **Assertion** A positive point charge initially at rest in a uniform electric field starts moving along electric lines of force. (Neglect all other forces except electric forces).
Reason A point charge released from rest in an electric field always moves along the line of force.

89. **Assertion** When a neutral body acquires positive charge, its mass decreases.
Reason A body acquires positive charge when it loses electrons.

90. **Assertion** **E** outside vicinity of a conductor depends only on the local charge density σ and it is independent of the other charges present anywhere on the conductor.
Reason **E** in outside vicinity of a conductor is given by $\frac{\sigma}{\varepsilon_0}$.

91. **Assertion** Upon displacement of charges within a closed surface, **E** at any point on the surface does not change.

Reason The flux crossing through a closed surface is independent of the location of charge within the surface.

92. **Assertion** If Gaussian surface does not enclose any charge, then **E** at any point on the Gaussian surface must be zero.
Reason No net charge is enclosed by Gaussian surface, so net flux passing through the surface is zero.

II. Statement Based Questions Type I

■ **Directions** (Q. Nos. 93-97) *In the following questions, statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(c) Statement I is correct but Statement II is incorrect.
(d) Statement I is incorrect but Statement II is correct.

93. **Statement I** When we produce charge q_1 on a body by rubbing it against another body which gets a charge q_2 in the process, then $q_1 + q_2 = 0$.
Statement II Charge on an isolated system remains constant.

94. **Statement I** SI unit of charge is coulomb, denoted by C. One coulomb is the charge flowing through a wire in 1s, if the current is 1 A.
Statement II -1 C has 6×10^{10} electrons.

95. **Statement I** At macroscopic level, quantisation of charge has no practical consequence and can be ignored.

Statement II -1μC charge contains 10^{13} times electronic charge e approximately.

96. **Statement I** A piece of matter having polar molecules does not have any net dipole moment in ordinary condition.

Statement II When there is no external field, the polar molecules are randomly oriented due to their thermal energies.

97. **Statement I** Polarisation is not possible under action of an external field if molecules of matter are non-polar.
Statement II In presence of an external field , the polar molecules tend to align with the field and a net dipole moment results.

Statement Based Questions Type II

98. I. When we rub a glass rod with silk, some of electrons from the rod are transferred to the silk cloth.
II. Rod gets positively charged and silk gets negatively charged.
III. Only less tightly bound electrons in rod are transferred to silk by rubbing.

Correct statements are
(a) I and II (b) II and III
(c) I and III (d) I, II and III

99. I. If a system contains two point charges q_1 and q_2, the total charge of the system is obtained simply by adding algebraically q_1 and q_2, *e.g.,* (− 2units charge) + (6 units charge) = 4 units charge.
II. (− 2units charge) + (6 units charge) = 8 units charge.
III. Charge has magnitude but no direction, similar to mass.
IV. Mass of a body is always positive whereas a charge can be either positive or negative.

Incorrect statement is
(a) only I (b) only III (c) only IV (d) only II

100. I. Charge is conserved.
II. When bodies are charged by rubbing, there is a transfer of electrons from one body to other, no new charges are created nor destroyed.
III. Within an isolated system consisting of many charged bodies, due to interaction among the bodies charges may get redistributed but it is found that the total charge of the isolated system is always conserved.
IV. When a neutron turns into a proton and an electron. The proton and electron thus created have equal and opposite charges and the total charge is zero before and after the creation.

Correct statements are
(a) I and IV (b) I and II
(c) I, II and IV (d) I, II, III and IV

101. I. The charge q on a body is always given by $q = ne$, where n is any integer, positive or negative.

II. By convention, the charge on an electron is taken to be negative.

III. The fact that electric charge is always an integral multiple of e is termed as quantisation of charge.

IV. The quantisation of charge was experimentally demonstrated by Newton in 1912.

Which of the statements is incorrect?

(a) Only I (b) Only II
(c) Only IV (d) Only III

102. I. Magnitude of electric field at a point decreases inversely as square of distance of that point from the charge.

II. **E** is strong near the charge.

III. Away from the charge field gets weaker and density of field lines is less, resulting in well separated lines.

IV. Only a finite number of lines can be drawn from charge.

Which of the following statements is incorrect?

(a) Only I (b) Only III (c) Only IV (d) Only II

III. Matching Type

103. Match the first part of a sentence given in Column I with its second part in Column II, so that sentence is complete meaningful and electrostatically true.

Column I	Column II
A. Like charges	1. Of two types
B. Unlike charges	2. Repel each other
C. Charge can be	3. Attract each other
D. Charges are	4. Neutralised, if they are equal and opposite

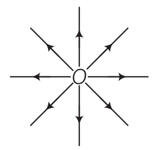
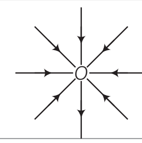
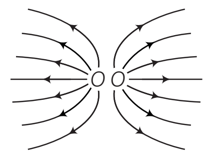
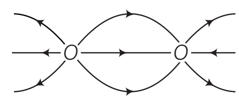
	A	B	C	D
(a)	1	2	3	4
(b)	2	1	3	4
(c)	4	1	3	2
(d)	2	3	4	1

104. Electric field due to

Column I	Column II
A. Infinite plane sheet of charge	1. 0
B. Infinite plane sheet of uniform thickness	2. $\dfrac{\sigma}{2\varepsilon_0}$
C. Non-conducting charged solid sphere at its surface	3. $\dfrac{R\rho}{3\varepsilon_0}$
D. Conducting charged solid sphere at its centre	4. $\dfrac{\sigma}{\varepsilon_0}$

	A	B	C	D
(a)	2	4	3	1
(b)	3	2	1	4
(c)	1	4	2	3
(d)	2	1	4	3

105. Match the field lines given in Column I with the charge configuration due to which field lines exist in Column II.

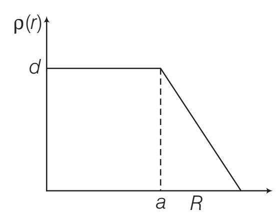
Column I	Column II
A. 	1. A pair of equal and opposite charges
B. 	2. A pair of positive charges
C. 	3. A single positive charge
D. 	4. A single negative charge

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	1	4
(c)	3	4	1	2
(d)	3	4	2	1

IV. Passage Based Questions

■ **Directions** (Q. Nos. 106-108) *These questions are based on the following situation. Choose the correct options from those given below.*

The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density $\rho(r)$ [charge per unit volume is dependent only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction.



106. 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

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

(a) $\dfrac{3Ze^2}{4\pi R^3}$ (b) $\dfrac{3Ze}{\pi R^3}$ (c) $\dfrac{4Ze}{3\pi R^3}$ (d) $\dfrac{Ze}{3\pi R^3}$

108. The electric field within the nucleus is generally observed to be linearly dependent on *r*. This implies

(a) $a = 0$ (b) $a = \frac{R}{2}$

(c) $a = R$ (d) $a = \frac{2R}{3}$

■ **Directions** (Q. Nos. 109-110) *These questions are based on the following situation. Choose the correct options from those given below.*

A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of $80.0\ \mu Cm^{-2}$.

109. What is the charge on the sphere?

(a) 0.7×10^{-1} C (b) 1.4×10^{-2} C

(c) 1.4×10^{-3} C (d) 1.7×10^{4} C

110. What is the total electric flux leaving the surface of the sphere?

(a) $0.8 \times 10^4\ Nm^2/C$

(b) $1.6 \times 10^4\ Nm^2/C$

(c) $0.8 \times 10^8\ Nm^2/C$

(d) $1.6 \times 10^8\ Nm^2/C$

■ **Directions** (Q. Nos. 111-113) *These questions are based on the following situation. Choose the correct options from those given below.*

Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude $17.0 \times 10^{-22}\ Cm^{-2}$.

111. What is **E** in the outer region of the first plate?

(a) 17×10^{-22} N/C

(b) 1.5×10^{-15} N/C

(c) 1.9×10^{-10} N/C

(d) Zero

112. What is **E** in the outer region of the second plate?

(a) 17×10^{-22} N/C (b) 1.5×10^{-15} N/C

(c) 1.9×10^{-10} N/C (d) Zero

113. What is **E** between the plates?

(a) 17×10^{-22} N/C

(b) 1.5×10^{-15} N/C

(c) 1.9×10^{-10} N/C

(d) Zero

V. More than One Option Correct

114. Which of these are properties of charge?

(a) Charges are additive in nature

(b) Charges are conservative in nature

(c) Charges are quantised in nature

(d) Charges can be transformed from one type to another

115. Dipoles are

(a) natural

(b) induced

(c) hypothetical

(d) exist only in presence of a strong field.

116. 10 C of charge is given to a conducting spherical shell and a −3 C point charge is placed inside the shell. For this arrangement, mark out the correct statement(s).

(a) The charge on the inner surface of the shell will be + 3 C and it can be distributed uniformly or non-uniformly

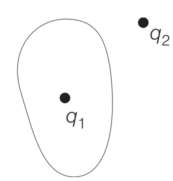
(b) The charge on the inner surface of the shell will be + 3 C and its distribution would be uniform

(c) The net charge on outer surface of the shell will be + 7 C and its distribution can be uniform or non-uniform

(d) The net charge on outer surface of the shell will be + 7 C and its distribution would be uniform

117. Consider Gauss's law,

$$\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$$



Then for the situation shown above at the Gaussian surface,

(a) E due to q_2 would be zero.

(b) E due to both q_1 and q_2 would be non-zero.

(c) ϕ due to both q_1 and q_2 would be non-zero.

(d) ϕ due to q_2 would be zero.

118. For a thin spherical shell of radius *R* having a surface charge density σ, which of these are true?

(a) Field at a distance *r* from the centre $r > R$ is given by $E = \frac{\sigma}{\varepsilon_0}$

(b) Field at a distance *r* from the centre $r < R$ given by $E = \frac{kq}{r^2}$, where $q = \sigma\ (4\pi R^2)$

(c) Field at a distance *r* from the centre $r > R$ is given by $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$, where $q = \sigma \cdot 4\pi R^2$

(d) Field at surface of shell is given by $E = \frac{\sigma}{\varepsilon_0}$

NCERT & NCERT Exemplar Questions

NCERT

119. What is the force between two small charged spheres having charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air?
(a) 5×10^{-2} N (b) 6×10^{-3} N
(c) 7×10^{-4} N (d) 8×10^{-4} N

120. The electrostatic force on a small sphere of charge $0.4\,\mu$C due to another small sphere of charge $-0.8\,\mu$C in air is 0.2 N. What is the distance between the two spheres?
(a) 5 cm (b) 10 cm
(c) 12 cm (d) 15 cm

■ **Directions** (Q. Nos.121-122) *These questions are based on the following situation. Choose the correct options from those given below.*

Two point charges $q_A = 3\mu$C and $q_B = -3\mu$C are located 20 cm apart in vacuum.

121. What is the electric field at the mid-point O of the line AB joining the two charges?
(a) 0 (b) 2.7×10^6 N/C
(c) 5.4×10^6 N/C (d) 10.2×10^6 N/C

122. If a negative test charge of magnitude 1.5×10^{-9} C is placed at this point, what is the force experienced by the test charge?
(a) 8×10^{-3} N (b) 4×10^{-2} N
(c) 2×10^{-1} N (d) 0

123. A system has two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B = -2.5 \times 10^{-7}$ C located at points A : (0, 0, −15 cm) and B (0, 0, +15 cm), respectively.
The total charge and electric dipole moment of the system are
(a) 5.0×10^{-7} C, 7.5×10^{-8} C-m
(b) 2.5×10^{-7} C, 7.5×10^{-8} C-m
(c) 0,0
(d) 0, 7.5×10^{-8} C-m

124. An electric dipole with dipole moment 4×10^{-9} C-m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^4 N/C. What is the magnitude of the torque acting on the dipole?
(a) 10^{-2} Nm (b) 10^{-3} Nm
(c) 10^{-4} Nm (d) 10^{-5} Nm

125. A polythene piece rubbed with wool is found to have a negative charge of 3×10^{-7} C. The number of electrons transferred is
(a) 1.6×10^9 (b) 1.8×10^{10}
(c) 1.6×10^{11} (d) 1.8×10^{12}

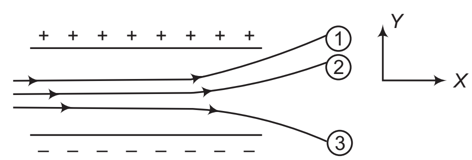
■ **Directions** (Q. Nos.126-127) *These questions are based on the following situation. Choose the correct options from those given below.*

Two insulated charged copper spheres A and B have their centres separated by a distance of 50 cm.

126. What is the mutual force of electrostatic repulsion if the charge on each is 6.5×10^{-7} C?
(a) 1.5×10^{-2} N (b) 3×10^{-3} N
(c) 1.5×10^{-4} N (d) 3×10^{-5} N

127. What is the force of repulsion if each sphere is charged double the above amount and the distance between them is halved?
(a) 0 (b) 0.12 N (c) 0.24 N (d) 0.48 N

128. The given figure shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to mass ratio?



(a) 1 (b) 2 (c) 3 (d) All are equal

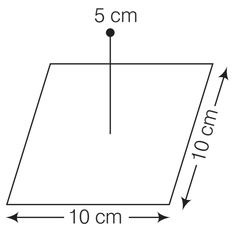
■ **Directions** (Q. Nos.129-130) *These questions are based on the following situation. Choose the correct options from those given below.*

Consider a uniform electric field $\mathbf{E} = 3 \times 10^3\ \hat{\mathbf{i}}$ N/C.

129. What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the YZ- plane?
(a) 0 (b) 10 Nm^2/C
(c) 20 Nm^2/C (d) 30 Nm^2/C

130. What is the flux through the same square if the normal to its plane makes a 60° angle with the X-axis?
(a) 0 (b) 5 Nm^2 / C
(c) 10 Nm^2 / C (d) 15 Nm^2 / C

131. A point charge $+10\mu C$ is at a distance 5 cm directly above the centre of a square of side 10 cm, as shown in figure. What is the magnitude of the electric flux through the square?



(a) 0 (b) $1.8\times10^2\ Nm^2/C$
(c) $1.8\times10^4\ Nm^2/C$ (d) $1.8\times10^5\ Nm^2/C$

132. A point charge of $2.0\mu C$ is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface?

(a) 0 (b) $2\times10^2\ Nm^2/C$
(c) $2\times10^4\ Nm^2/C$ (d) $2\times10^5\ Nm^2/C$

133. A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5×10^3 N/C and points radially inwards, what is the net charge on the sphere?

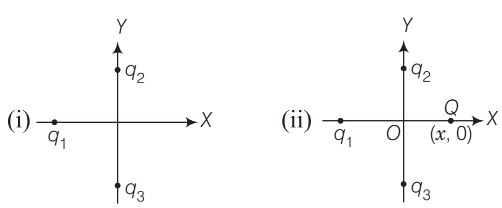
(a) 0 (b) 5×10^{-5} C
(c) 6×10^{-9} C (d) 8×10^{-10} C

134. An infinite line charge produces a field of 9×10^4 N/C at a distance of 2 cm. Calculate the linear charge density.

(a) 10^{-5} C/m (b) 10^{-6} C/m
(c) 10^{-7} C/m (d) 10^{-8} C/m

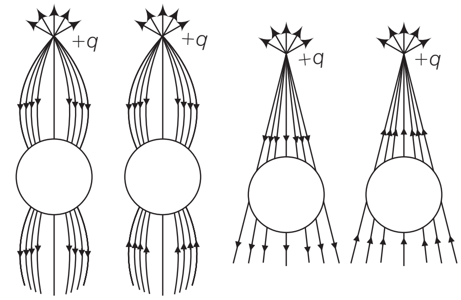
NCERT Exemplar

135. In figure two positive charges q_2 and q_3 fixed along the Y-axis, exert a net electric force in the positive X-direction on a charge q_1 fixed along the X-axis. If a positive charge Q is added at $(x, 0)$, the force on q_1



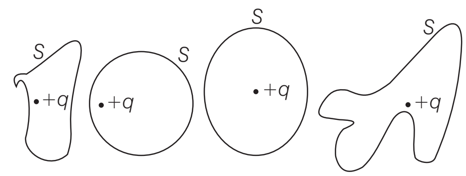
(a) shall increase along the positive X-axis
(b) shall decrease along the positive X-axis
(c) shall point along the negative X-axis
(d) shall increase but the direction changes because of the intersection of Q with q_2 and q_3

136. A point positive charge is brought near an isolated conducting sphere (figure). The electric field is best3 given by



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

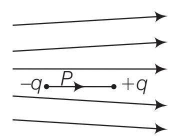
137. The electric flux through the surface



(i) (ii) (iii) (iv)

(a) in Fig. (iv) is the largest
(b) in Fig. (iii) is the least
(c) in Fig. (ii) is same as Fig. (iii) but is smaller than Fig. (iv)
(d) is the same for all the figures

138. Figure shows electric field lines in which an electric dipole P is placed as shown. Which of the following statements is correct?



(a) The dipole will not experience any force
(b) The dipole will experience a force towards right
(c) The dipole will experience a force towards left
(d) The dipole will experience a force upwards

139. If $\int_s \mathbf{E}\cdot d\mathbf{S}=0$ over a surface, then

(a) the electric field inside the surface and on it is zero.
(b) the electric field inside the surface is necessarily uniform.
(c) the number of flux lines entering the surface must be equal to the number of flux lines leaving it.
(d) all charges must necessarily be outside the surface.

140. The electric field at a point is

(a) always continuous
(b) continuous if there is no charge at that point
(c) discontinuous only if there is a negative charge at that point
(d) discontinuous if there is a charge at that point

141. Consider a region inside in which there are various types of charges but the total charge is zero. At points outside the region,

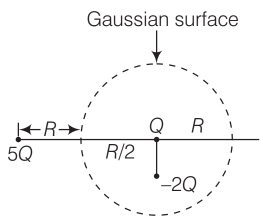
(a) the electric field is necessarily zero

(b) the electric field is due to the dipole moment of the charge distribution only

(c) the dominant electric field is $\propto \frac{1}{r_3}$, for large r, where r is the distance from a origin in this region

(d) the work done to move a charged particle along a closed path, away from the region will be zero

142. Refer to the arrangement of charges in figure and a Gaussian surface of radius R with Q at the centre. Then,



(a) total flux through the surface of the sphere is $\frac{-Q}{\varepsilon_0}$

(b) field on the surface of the sphere is $\frac{-Q}{4\pi\varepsilon_0 R^2}$

(c) flux through the surface of sphere due to $5Q$ is zero

(d) field on the surface of sphere due to $-2Q$ is same everywhere

143. An arbitrary surface encloses a dipole. What is the electric flux through this surface?

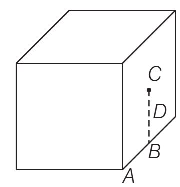
(a) $q/10$ (b) $2q/10$

(c) zero (d) $-q/\varepsilon_0$

144. A metallic spherical shell has an inner radius R_1 and outer radius R_2. A charge Q is placed at the centre of the spherical cavity. What will be surface charge density on the outer surface?

(a) $\frac{-Q}{4\pi R_1^2}$ (b) $\frac{Q}{4\pi R_1^2}$ (c) $\frac{Q}{4\pi R_2^2}$ (d) $\frac{-Q}{4\pi R_2^2}$

145. What will be the total flux through the faces of the cube as given in the figure with side of length a if a charge q is placed at B, mid-point of an edge of the cube?



(a) $\frac{q}{8\varepsilon_0}$ (b) $\frac{q}{3\varepsilon_0}$

(c) $\frac{q}{4\varepsilon_0}$ (d) $\frac{q}{2\varepsilon_0}$'

146. Two charges q and $-3q$ are placed fixed on X-axis separated by distance d. Where should a third charge $2q$ be placed such that it will not experience any force?

(a) $\frac{d}{3}(1+\sqrt{3})$ to the right of q

(b) $\frac{d}{3}(1+\sqrt{3})$ to the left of q

(c) $\frac{d}{2}(1+\sqrt{3})$ to the left of q

(d) $\frac{d}{2}(1+\sqrt{3})$ to the right of q

Answers

1.	(c)	2.	(c)	3.	(c)	4.	(b)	5.	(d)	6.	(b)	7.	(d)	8.	(c)	9.	(c)	10.	(b)	11.	(c)	12.	(b)	13.	(b)	14.	(c)	15.	(d)
16.	(d)	17.	(d)	18.	(d)	19.	(c)	20.	(c)	21.	(c)	22.	(d)	23.	(b)	24	(b)	25.	(d)	26.	(b)	27.	(c)	28.	(a)	29.	(b)	30.	(a)
31.	(b)	32.	(a)	33.	(b)	34.	(c)	35.	(a)	36.	(a)	37.	(c)	38.	(b)	39.	(c)	40.	(b)	41.	(d)	42.	(b)	43.	(c)	44.	(c)	45.	(c)
46.	(c)	47.	(c)	48.	(b)	49.	(b)	50.	(c)	51.	(c)	52.	(d)	53.	(c)	54.	(b)	55.	(c,d)	56.	(b)	57.	(c)	58.	(b)	59.	(a)	60.	(c)
61.	(a)	62.	(c)	63.	(c)	64.	(b)	65.	(a)	66.	(c)	67.	(a)	68.	(a)	69.	(b)	70.	(a)	71.	(a)	72.	(a)	73.	(b)	74.	(c)	75.	(a)
76.	(b)	77.	(b)	78.	(a)	79.	(c)	80.	(c)	81.	(a)	82.	(d)	83.	(b)	84.	(d)	85.	(d)	86.	(a,c)	87.	(a)	88.	(c)	89.	(a)	90.	(d)
91.	(d)	92.	(d)	93.	(a)	94.	(c)	95.	(a)	96.	(a)	97.	(d)	98.	(d)	99.	(d)	100.	(d)	101.	(c)	102.	(c)	103.	(d)	104.	(a)	105.	(d)
106.	(a)	107.	(b)	108.	(c)	109.	(c)	110.	(d)	111.	(d)	112.	(d)	113.	(c)	114.	(a,b,c)	115.	(a,b)	116.	(b,d)	117.	(b,d)	118.	(c,d)	119.	(b)	120.	(c)

Hints *and* Explanations

1. (*c*) The reason for these experiences is a discharge of electric charges which were accumulated due to rubbing of insulating surfaces.

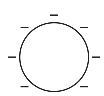
3. (*c*) During its motion, body of carrier is charged due to rubbing with dry air and dust. If spark occurs near container, then inflammable material may catch fire. So, metallic ropes are suspended so that excess charge flows away from carrier, to ground (for earthing).

4. (*b*) Each pith ball acquires same charge due to the conduction (transfer) from plastic rod. So, they repel each other.

7. (*d*) When a body is negatively charged, more electrons are given to it, so its mass increases.

8. (*c*) X-ray has high ionising power. It will ionise the gas inside so the gas becomes partially conducting. The charge on the leaves will start leaking out to atmosphere and they will collapse gradually.

10. (*b*) Due to mutual repulsion, surface of a soap bubble shows expansion.



Negative charges at diametrically opposite ends repel.

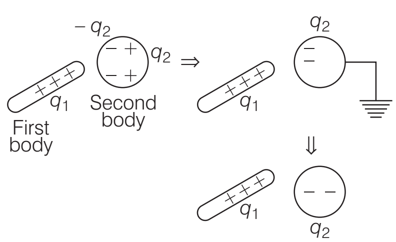
11. (*c*) Due to friction, if one body loses few electrons, other gains them and so charges appearing on both are equal and opposite.

12. (*b*) A negatively charged body acquires some electrons, so its mass is more than its neutral mass.

13. (*b*) When bodies are physically touched to transfer charge from one body to other body, then this is process of charging by contact or conduction.

14. (*c*) Induction requires shifting of free charge carrier which are present only in conductors.

15. (*d*)



Numerically, $q_1 \geq q_2 \quad \Rightarrow \quad \dfrac{q_1}{q_2} \geq 1$

17. (*d*) If a system contains two point charges q_1 and q_2 and total charge of the system is obtained simply by adding algebraically, *i.e.*, charge add up like real numbers or they are scalars like mass of the body.

21. (*c*) Initially, both the glass rod and silk cloth are electrically neutral. Net charge is zero. Finally, the positive charge on glass rod is exactly equal to the negative charge on the silk cloth. So, net charge is again zero.

22 (*d*) 1 coulomb of charge is made of $n = \dfrac{q}{e} = \dfrac{1\text{C}}{1.6\times 10^{-19}\text{ C}}$

$$= 6.25\times 10^{18} \text{ electrons}$$

$$\therefore \text{ Time required} = \frac{6.25\times 10^{18}}{10^9}\text{ s}$$

$$= 6.25\times 10^{9}\text{s} \approx 198 \text{ yr } (\because 1\text{yr} = 3.17\times 10^{7}\text{ s})$$

23. (*b*) Charge on single electron is $e = 1.6\times 10^{-19}$ C

Total charge, $q = +\ 2.4$ C

Then, by quantisation of charge, $q = ne$

$$\therefore \quad \text{Number of electrons, } n = \frac{q}{e} = \frac{2.4\text{ C}}{1.6\times 10^{-19}\text{ C}} = 1.5\times 10^{19}$$

24. (*d*) Here, number of electrons removed = number of atoms in 1 g

or $$n = \frac{4\times 10^{20}}{10^3} = 4\times 10^{17}$$

$$\therefore\text{Charge,} \quad q = ne = 4\times 10^{17}\times 1.6\times 10^{-19}\text{ C} = 6.4\times 10^{-2}\text{ C}$$

26. (*b*) Charges on both spheres will be equal, each $q/2$. When distance is made half of original, force becomes four times of original because force varies inversely with square of distance.

29. (*b*) The electric force between an electron and proton at a distance r apart is

$$F_e = \frac{-\,ke^2}{r^2} \qquad \ldots\text{(i)}$$

where, the negative sign indicates that the force is attractive. The corresponding gravitational force (always attractive) is

$$F_G = -\,G\,\frac{m_p m_e}{r^2} \qquad \ldots\text{(ii)}$$

where, m_p and m_e are the masses of the proton and electron. On comparing Eqs. (i) and (ii), we get

$$\left|\frac{F_e}{F_G}\right| = \frac{k\,e^2}{Gm_p m_e} = 2.4\times 10^{39}$$

$$\Rightarrow \qquad F_G/F_e \approx 10^{-39}$$

30. (*a*) Force in air,

i.e., $$F = \frac{1}{4\pi\varepsilon_0}\,\frac{q_1 q_2}{r^2}$$

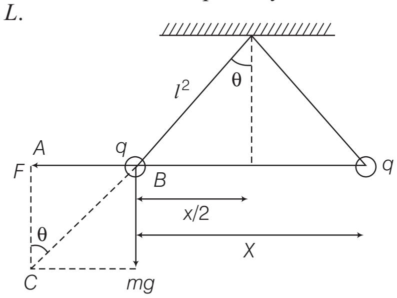
and force in medium, *i.e.*, $F_m = \dfrac{1}{4\pi\varepsilon_0\varepsilon_r}\,\dfrac{q_1 q_2}{r^2} \quad \left(\because \dfrac{\varepsilon}{\varepsilon_0} = \varepsilon_r\right)$

$$= \frac{1}{4\pi\varepsilon}\,\frac{q_1 q_2}{r^2}$$

$$= \frac{\varepsilon_0}{\varepsilon}\cdot\frac{1}{4\pi\varepsilon_0}\,\frac{q_1 q_2}{r^2}$$

$$\Rightarrow \qquad F_m = \frac{\varepsilon_0}{\varepsilon}F$$

31. (*b*) According to question, two identical charged spheres suspended from a common point by two massless strings of length L.



$\because$ In ΔABC, $\tan\theta = \dfrac{F}{mg}$ or $\dfrac{F}{mg} = \tan\theta$ ...(i)

Since, the charge begins to leak from both the spheres at a constant rate. As a result, the spheres approach each other with velocity v.

Therefore, Eq. (i) can be rewritten as

$$\frac{kq^2}{x^2 mg} = \frac{x/2}{\sqrt{l^2 - \frac{x^2}{4}}}$$

$$\Rightarrow \quad \frac{kq^2}{x^2 mg} = \frac{x}{2l} \quad \text{or} \quad q^2 \propto x^3$$

$$\Rightarrow \quad \frac{dq}{dt} \propto \frac{d(x^{3/2})}{dx} \cdot \frac{dx}{dt}$$

$$\Rightarrow \quad \frac{dq}{dt} \propto x^{1/2} v \Rightarrow v \propto \frac{1}{x^{1/2}} \text{ or } v \propto x^{-1/2}$$

32. (*a*) When A and C are touched, charge is distributed equally on them,

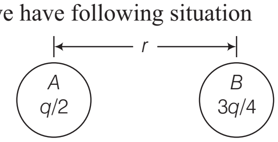
$$\therefore \quad q_A = q_C = \frac{q}{2}, \; q = 6.5 \times 10^{-7}\,\text{C}$$

When C is touched with B, total charge of B and C

$$= q + q/2 = \frac{3q}{2}$$

When B and C are separated, then charge is equally shared between them, $q_B = q_C = \dfrac{3q}{4}$

So, finally we have following situation



$$q = 6.5 \times 10^{-7}\,\text{C and } r = 50 \times 10^{-2}\ \text{m}$$

$\therefore$ Net force of attraction between A and B, *i.e.,*

$$F = \frac{9 \times 10^9 \times q_A q_B}{r^2}$$

$$= \frac{9 \times 10^9 \times \frac{1}{2} \times \frac{3}{4} \times (6.5 \times 10^{-7})^2}{(0.5)^2}$$

$$= 5.7 \times 10^{-3}\ \text{N}$$

33. (*b*) Relative permittivity ε_r is also called dielectric constant.

$$F_{\text{air}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}, \quad F_m = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2}$$

$$\frac{F_{\text{air}}}{F_m} = \frac{\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}}{\frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2}} = \frac{K}{1}$$

34. (*c*) Force exerted between two point charges

i.e., $$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

So, force exerted between two point charges in a dielectric medium is K *i.e.,* $F' = q_1 q_2 / 4\pi\varepsilon_0 K (r')^2$

Given, *i.e.,* $F = F'$

$$\text{or} \quad \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} = \frac{q_1 q_2}{4\pi\varepsilon_0 K (r')^2}$$

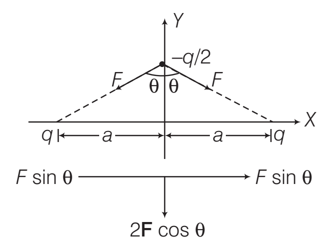
$$\Rightarrow \quad \frac{1}{r^2} = \frac{1}{K(r')^2}$$

$$\Rightarrow \quad r^2 = K(r')^2$$

$$\Rightarrow \quad r = \sqrt{K}\, r'$$

$$\therefore \quad r' = \frac{r}{\sqrt{K}}$$

35. (*a*) The situation is shown below.



Net force in negative Y-direction,

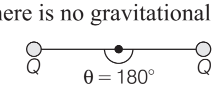
$$\mathbf{F}_{\text{net}} = 2\mathbf{F}\cos\theta$$

$$\mathbf{F}_{\text{net}} = \frac{2kq\left(\frac{q}{2}\right)}{(\sqrt{y^2 + a^2})^2} \cdot \frac{y}{\sqrt{y^2 + a^2}}$$

$$\mathbf{F}_{\text{net}} = \frac{2kq\left(\frac{q}{2}\right)y}{(y^2 + a^2)^{3/2}} \Rightarrow \mathbf{F}_{\text{net}} = \frac{2kq^2 y}{a^3}$$

$$\Rightarrow \quad \mathbf{F}_{\text{net}} \propto y$$

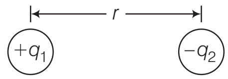
36. (*a*) In space, there is no gravitational force, so



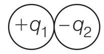
Tension in each thread, *i.e.,* $F = \dfrac{kQQ}{(2L)^2} = \dfrac{kQ^2}{4L^2}$

37. (*c*) According to Coulomb's law, force between two point charges, *i.e.,* $F \propto \frac{1}{r^2}$. Therefore, the graph between F and r will be as shown in Fig.(c).

38. (*b*) Force of attraction is caused by dissimilar charges. So initially,



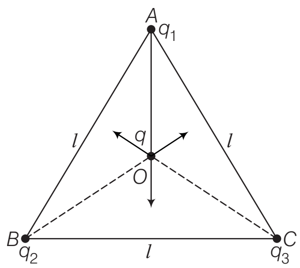
They are then touched



Net value of charge $q_{\text{net}} = |q_1 - q_2|$

When separated, they share same type of charge.

39. (*c*)



Force on q due to $q_1 = \frac{1}{4\pi\varepsilon_0} \frac{qq_1}{AO^2} \hat{\mathbf{AO}}$

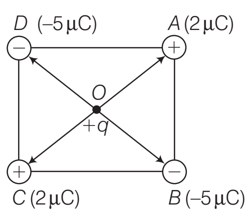
Force on q due to $q_2 = \frac{1}{4\pi\varepsilon_0} \frac{qq_2}{BO^2} \hat{\mathbf{BO}}$

Force q due to $q_3 = \frac{1}{4\pi\varepsilon_0} \frac{qq_3}{CO^2} \hat{\mathbf{CO}}$

Total force on $q = \frac{qq}{4\pi\varepsilon_0 AO^2} (\hat{\mathbf{AO}} + \hat{\mathbf{BO}} + \hat{\mathbf{CO}}) = 0$

It is clear by symmetry that the three forces will sum to zero.

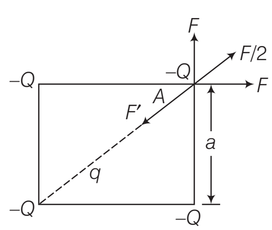
41. (*d*) While forces acting on OD and OB are equal and opposite in nature. Similarly, forces acting on OC and OA are equal and opposite forces. So, they cancel out each other.



$\therefore \quad F_{\text{net}} = 0$

42. (*b*) At point A, net resultant force is

$F' = \sqrt{2}F + \frac{F}{2} = F\left(\sqrt{2} + \frac{1}{2}\right)$



$\Rightarrow \quad \frac{qQ}{\left(\frac{\sqrt{2}a}{2}\right)^2} = \frac{Q^2}{a^2}\left(\sqrt{2} + \frac{1}{2}\right)$

$\Rightarrow \quad q = \frac{Q}{2}\left(\frac{2\sqrt{2}+1}{2}\right) \quad \Rightarrow \quad q = \frac{Q}{4}(2\sqrt{2}+1)$

43. (*c*) Electric field, $E = \frac{F}{q} = \frac{2.25\text{ N}}{15 \times 10^{-4}\text{ C}} = 1500\text{ NC}^{-1}$

44. (*c*) The electric field vector $\mathbf{E}_1$ at A due to the positive charge q_1 points towards the right and has a magnitude

$$E_1 = \frac{(9 \times 10^9\text{ Nm}^2\text{ C}^{-2}) \times (10^{-8}\text{C})}{(0.05\text{ m})^2} = 3.6 \times 10^4 \text{NC}^{-1}$$

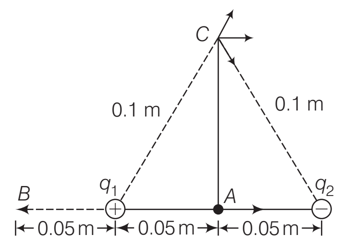
The electric field vector $\mathbf{E}_2$ at A due to the negative charge q_2 points towards the right and has a magnitude

$$E_2 = \frac{(9 \times 10^9\text{ Nm}^{-2}\text{C}^{-2}) \times (10^{-8}\text{C})}{(0.05\text{ m})^2} = 3.6 \times 10^4 \text{NC}^{-1}$$

The magnitude of the total electric field at A is

$$E_A = E_1 + E_2 = 7.2 \times 10^4\text{ NC}^{-1}$$

$\mathbf{E}_A$ is directed towards the right.



The magnitude of each electric field vector at point C, due to charge q_1 and q_2 is

$$E_1' = E_2' = \frac{(9 \times 10^9\text{ Nm}^2\text{ C}^{-2}) \times (10^{-8}\text{C})}{(0.10\text{ m})^2} = 9 \times 10^3\text{ NC}^{-1}$$

The resultant of these two vectors is

$$E_C = E_1' \cos\frac{\pi}{3} + E_2' \cos\frac{\pi}{3} = 9 \times 10^3\text{ NC}^{-1}$$

E_C points towards right

$\therefore \quad \frac{E_A}{E_C} = \frac{8}{1}$

45. (*c*) Electric field inside the uniformly charged sphere varies linearly, $E = \frac{kQ}{R^3} \cdot r, (r \leq R)$, while outside the sphere, it varies as inverse square of distance, $E = \frac{kQ}{r^2}; (r \geq R)$ which is correctly represented in option (c).

46. (*c*) For electron acceleration $= \frac{eE}{m_e}$

$$s = 0(t_1) + \frac{1}{2}\frac{eEt_1^2}{m_e}$$

Similarly for proton,

$$s = 0(t_2) + \frac{1}{2}\frac{eEt_2^2}{m_p}$$

For electron, $s = \frac{eE}{m_e} \times t_1^2$

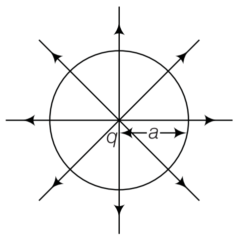
For proton, $s = \frac{eE}{m_p} \times t_2^2$

$$\therefore \qquad \frac{t_2^2}{t_1^2} = \frac{m_p}{m_e}$$

$$\Rightarrow \qquad \frac{t_2}{t_1} = \sqrt{\frac{m_p}{m_e}} = \left(\frac{m_p}{m_e}\right)^{1/2}$$

47. (*c*) Given,

$$E = Ar \qquad \ldots(\text{i})$$



Here, $\quad r = a \quad \Rightarrow \quad E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{a^2}$

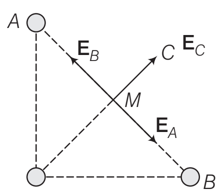
From Eq. (i), we get

$$\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{a^2} = Aa \quad \Rightarrow \quad q = 4\pi\varepsilon_0 A a^3$$

48. (*b*) E_A = Electric field at M due to charge placed at A.

E_B = Electric field at M due to charge placed at B.

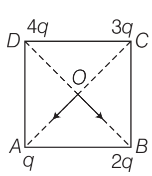
E_C = Electric field at M due to charge placed at C.



As seen from figure $|\mathbf{E}_B| = |\mathbf{E}_A|$, so net electric field at M, $E_{\text{net}} = \mathbf{E}_C$, in the direction of vector 2.

49. (*b*) E_{net} along **CB**

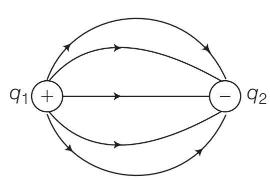
Charges at A,C produce net electric field along OA. Charges at B, D produce net electric field along OB.



So, total electric field is along bisector of angle AOB which parallel to CB.

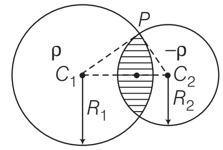
51. (*c*) Field lines exist in 3-D space, we draw field lines on paper but actual they are in space.

Field lines are in space around line joining q_1 and q_2.



53. (*c*) Areas of P-Q are equal but more lines pass through area at P. So, field is stronger at P as compared to Q.

55. (*c*,*d*) According to the question,



For electrostatic field, $\mathbf{E}_P = \mathbf{E}_1 + \mathbf{E}_2$

$$= \frac{\rho}{3\varepsilon_0}\mathbf{C}_1\mathbf{P} + \frac{(-\rho)}{3\varepsilon_0}\mathbf{C}_1\mathbf{P}$$

$$= \frac{\rho}{3\varepsilon_0}(\mathbf{C}_1\mathbf{P} + \mathbf{C}_2\mathbf{P})$$

$$\mathbf{E}_P = \frac{\rho}{3\varepsilon_0}\mathbf{C}_1\mathbf{C}_2$$

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

61. (*a*) If the centre of mass of the positive charge does not coincide with that of the negative charge, the molecule has intrinsic (or permanent) dipole moment. Such molecules are called polar molecules.

62. (*c*) Here, $a = 2.5$ mm, $r = 15$ cm $= 150$ mm

As, $\quad r >> a$

$$E_{\text{axis}} = \frac{2p}{4\pi\varepsilon_0 r^3} = \frac{2\,(5 \times 10^{-3} \times 10 \times 10^{-6}) \times (9 \times 10^9)}{(15 \times 10^{-2})^3}$$

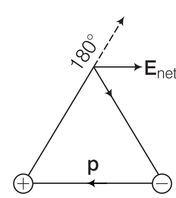
$$= 2.6 \times 10^5 \text{ NC}^{-1}$$

$$E_{\text{equatorial plane}} = \frac{p}{4\pi\varepsilon_0 r^3} = \frac{1}{2} E_{\text{axis}}$$

$$= \frac{1}{2} \times 2.6 \times 10^5$$

$$= 1.3 \times 10^5 \text{ NC}^{-1}$$

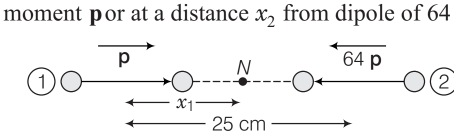
63. (*c*)



Observing $\mathbf{E}_{\text{net}}$ and **p** are in opposite directions, so angle between them is 180°.

64. (*b*) As we know, $\frac{E_{\text{axis}}}{E_{\text{equator}}} = \frac{2p/4\pi\varepsilon_0 r^3}{p/4\pi\varepsilon_0 r^3} = \frac{2}{1}$

65. (*a*) Suppose neutral point N lies at a distance x from dipole of moment **p** or at a distance x_2 from dipole of 64 **p**.



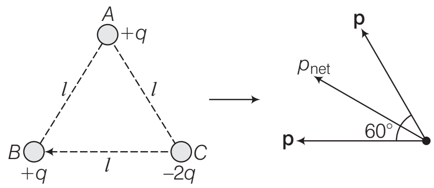
At N, | Electric field due to dipole (1) |

= |Electric field due to dipole (2)|

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{x^3} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2(64p)}{(25-x)^3}$$

$$\Rightarrow \quad \frac{1}{x^3} = \frac{64}{(25-x)^3} \Rightarrow x = 5\,\text{cm}$$

66. (*c*)

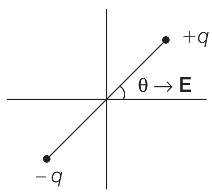


Net dipole moment, *i.e.,*

$$p_{\text{net}} = \sqrt{p^2 + p^2 + 2pp\cos 60^\circ} = \sqrt{3}p$$

$$= \sqrt{3}\,ql \qquad (\because p = ql)$$

67. (*a*) Here, torque $\tau = pE\sin\theta$



Potential energy of the dipole

$$U = \int \tau\, d\theta = \int_{\pi/2}^{\theta} pE\sin\theta\, d\theta = -pE[\cos\theta]_{\pi/2}^{\theta}$$

$$= -pE\cos\theta$$

70. (*a*) Torque, $\tau = pE\sin\theta\hat{\mathbf{n}}$

$|\tau| = pE\sin\theta$

$\therefore$ Torque is maximum, when $\theta = 90^\circ$

71. (*a*) Net dipole moment, $p_{\text{net}} = \sqrt{p_1^2 + p_2^2 + 2p_1 p_2\cos\theta}$

$$\theta = 120^\circ$$

$$p_1 = p = p_2$$

$$p_{\text{net}} = p$$

So, $\tau = pE\sin\theta$ and it is along positive Z-axis.

τ is perpendicular to plane along **p** and **E**.

72. (*a*) As, torque *i.e.,* $\tau = pE\sin\theta = I\alpha$

For small θ, $\alpha = \frac{pE}{I}\theta \Rightarrow \frac{\alpha}{\theta} = \frac{pE}{I}$

$$\omega = \sqrt{\frac{\theta}{\alpha}} = \sqrt{\frac{pE}{I}}$$

74. (*c*) As flux $= \frac{q_{\text{enclosed}}}{\varepsilon_0}$. So, flux is due to only charges $+q_1$ and $-q_1$ that makes a sum zero. But q_2 produces its own flux and net flux linked with sphere is zero. Electric field will be due to all the charges.

75. (*a*) By Gauss' law,

$$\phi = \frac{q}{\varepsilon_0}$$

or $\quad q = \phi\varepsilon_0 = 1.05 \times 8.854 \times 10^{-12}$ C

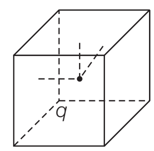
$$= 9.27 \times 10^{-12}\text{ C}$$

77. (*b*) By Gauss' law, ϕ = Electric flux through closed surface area

$$= \frac{q_{\text{enclosed}}}{\varepsilon_0} \text{ if } q_{\text{enclosed}} = 1 \text{ unit}$$

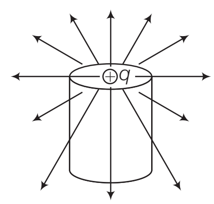
$$\Rightarrow \quad \phi = \frac{1}{\varepsilon_0} = \varepsilon_0^{-1}$$

78. (*a*) As, electric charge q is placed at the centre of a cube of side.



As all six faces are symmetrically located with respect to charge. So, the total flux will be equally divided among 6 faces of cube, flux through each face $= \frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$.

80. (*c*)



Flux through the cylinder will be half of the total flux

$$= \frac{1}{2}\frac{q}{\varepsilon_0} = \frac{q}{2\varepsilon_0}$$

82. (*d*) Net charges of one dipole $= -e + e = 0$

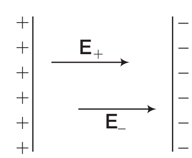
Net charge of 8 dipoles $= 8 \times 0 = 0$

$\Rightarrow$ Net charge inside cube $= 0 = q$

By Gauss' law,

Total flux emerging from surface $= \frac{q}{\varepsilon_0} = \frac{0}{\varepsilon_0} = 0$

83. (*b*)

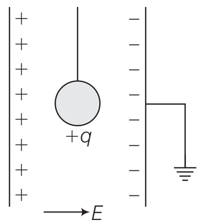


$$E_+ = E_- = \frac{\sigma}{2\varepsilon_0}$$

$$\Rightarrow \quad E_{\text{net}} = 2\left(\frac{\sigma}{2\varepsilon_0}\right) = \left(\frac{\sigma}{\varepsilon_0}\right)$$

84. (*d*) Time period of simple pendulum in air.

When it is suspended between vertical plates of a charged parallel plate capacitor, then acceleration due to electric field, $a = \frac{qE}{m}$



This acceleration is acting horizontally and acceleration due to gravity is acting vertically. So, effective acceleration

$$g' = \sqrt{g^2 + a^2} = \sqrt{g^2 + \left(\frac{qE}{m}\right)^2}$$

Hence, $T' = 2\pi \sqrt{\dfrac{l}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$

85. (*d*) Coulomb's attraction = Centripetal force

$$\therefore \quad \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = mr\omega^2 = \frac{4\pi^2 mr^2}{T^2}$$

$$T^2 = \frac{4\pi^2 mr^3}{kq_1q_2}$$

$$\Rightarrow \quad T = \left(\frac{4\pi^2 mr^3}{kq_1 q_2}\right)^{1/2}$$

86. (*a,c*) Option (a) is correct due to symmetry,
Option (b) is wrong again due to symmetry.
Option (c) is correct because as per Gauss' theorem, net electric flux passing through any closed surface = $\frac{q_{\text{in}}}{\varepsilon_0}$

Here, $q_{\text{in}} = 3q - q - q = q$

:. Net electric flux = $\frac{q}{\varepsilon_0}$

Option (d) is wrong because there is no symmetry in two given planes.

87. (*a*) Force by electric field will be perpendicular to the displacement.

88. (*c*) If the field lines are curved, then the charged particle follows the straight line path along the direction of tangent drawn to electric field lines at its starting point.

90. (*d*) **E** in outside vicinity of conductor's surface depends on all the charges present in the space, but expression E = $\frac{\sigma}{\varepsilon_0}$.

91. (*d*) Due to displacement of charge within closed surface *E* at any point may change. But net flux crossing the surface will not change.

92. (*d*) E at any point on Gaussian surface may be due to outside charges also.

94. (*c*) Current is the flow of charge per unit time, $I = \frac{q}{t}$

$\Rightarrow \quad q = It$

$\Rightarrow \quad I = 1, t = 1$ gives $q = 1$ unit

-1 C has $\frac{1}{1.6 \times 10^{-19}} = 6 \times 10^{18}$ electrons approximately.

95. (*a*) At macroscopic level, we deal with charges of order $1\mu C = 10^{-6}$ C, which has $\frac{10^{-6}}{1.6 \times 10^{-19}} = 0.625 \times 10^{13} = 10^{13}$ charges. Addition of a few hundred of *e* charges do not make any physically observable effect of attraction repulsion, so quantisation can be ignored.

97. (*d*) Without an external field, the dipole moment of different molecules in a piece of matter are randomly oriented, so there is no net total dipole moment. In the presence of an external field, the polar molecules tend to align with the field and a net dipole moment results. We say that the matter has got polarised. Non-polar molecules develop dipole moment in presence of electric field.

104. (*a*) A→2, B→4, C→3 D→1

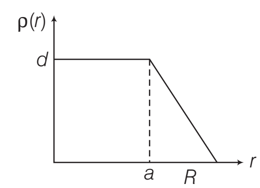
A. Infinite plane sheet of charge = $\frac{\sigma}{2\varepsilon_0}$

B. Infinite plane sheet of uniform thickness = $\frac{\sigma}{\varepsilon_0}$

C. Non-conducting charged solid sphere at its surface = $\frac{R\rho}{3\varepsilon_0}$

D. Non-conducting charged solid sphere at its centre = 0.

106. (*a*) Electric field at $r = R$

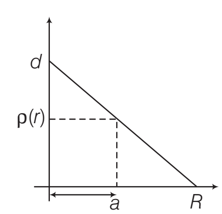


$$E = \frac{KQ}{R^2}; Q = \text{Total charge within the nucleus} = Ze$$

So, $E = \frac{KZe}{R^2}$

So, electric field is independent of *a*..

107. (*b*) $Q = \int \rho_r\, 4\pi r^2\, dr$,



$$\frac{d}{R} = \frac{\rho_r}{R - r}$$

$$Q = \int_0^R \frac{d}{R}(R - r)\, 4\pi r^2 dr$$

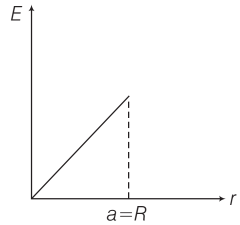
$$= \frac{4\pi d}{R}\left(R\int_0^R r^2 dr - \int_0^R r^3 dr\right)$$

$$= \frac{4\pi d}{R}\left(\frac{R^4}{3} - \frac{R^4}{4}\right) = \frac{\pi d R^3}{3}$$

$$Q = Ze = \frac{\pi d R^3}{3}$$

108. (*c*) From the formula of uniformly (volume) charged sphere

$$E = \frac{\rho r}{3\varepsilon_0}$$



For $E \propto r, \rho$ should be constant throughout that of nucleus. This will be possible only when $a = R$.

109. (*c*) Radius of shpere, $r = \frac{2.4}{2} = 1.2\,\text{m}$

Surface charge density, $\sigma = 80\ \mu\text{C/m}^2$

$$= 80 \times 10^{-6}\ \text{Cm}^{-2}$$

$$\text{Surface charge density} = \frac{\text{Charge}}{\text{Surface area}}$$

$$\sigma = \frac{q}{4\pi r^2}$$

$$q = \sigma \times 4\pi r^2 = 80 \times 10^{-6} \times 4 \times 3.14 \times 1.2 \times 1.2$$

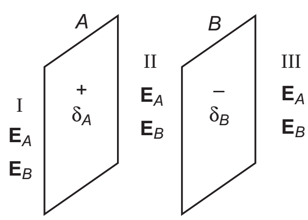
$$q = 1.4 \times 10^{-3}\ \text{C}$$

110. (*d*) Total flux leaving the surface, $\phi = \frac{\text{Total charge}}{\varepsilon_0}$

$$\phi = \frac{q}{\varepsilon_0} = \frac{1.45 \times 10^{-3}}{8.854 \times 10^{-12}}$$

$$\phi = 1.6 \times 10^{8}\ \text{N-m}^2/\text{C}$$

111. (*d*) There are two plates *A* and *B* having surface charge densities $\sigma_A = 17.0 \times 10^{-22}\ \text{C/m}^2$ on *A* and $\sigma_B = -17.0 \times 10^{-22}\ \text{C/m}^2$ on *B*, respectively.



According to Gauss' theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$$\mathbf{E}_{\text{I}} = \mathbf{E}_A + \mathbf{E}_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

112. (*d*) From the ans. 109, the electric field in region III is also zero.

$$\mathbf{E}_{\text{III}} = \mathbf{E}_A + \mathbf{E}_B$$

$$= \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

113. (*c*) From the ans. 109, in region II, the electric field

$$\mathbf{E}_{\text{II}} = \mathbf{E}_A + \mathbf{E}_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

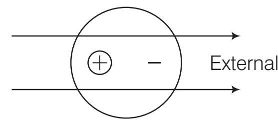
$$= \frac{\sigma}{\varepsilon_0} = \frac{\sigma_A \text{ or } \sigma_B}{\varepsilon_0} = \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$$

$$E = 1.92 \times 10^{-10}\ \text{NC}^{-1}$$

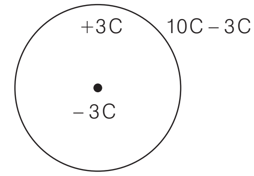
114. (*a,b,c*) Charges are additive, conservative and quantised in nature.

115. (*a,b*) Natural occurring molecular dipoles have atoms with different electronegativity and so electron cloud is tilted to one side.

e.g., HCl, H_2O etc. Induced dipoles are formed when a neutral atom is placed in a region of strong field.



116. (*b,d*) Due to induction, charge on various faces are as shown alongside in figure.



Charge on the inner surface of shell = + 3 C

Net charge on outer surface of shell = – 3 C + 10 C = + 7 C

Distribution of charge on inner surface would be uniform

117. (*b,d*) In LHS of Gauss' law, **E** is due to all point charges present in space and ϕ depends only on the enclosed charges.

118. (*c,d*) $E_{\text{inside}} = 0, E_{\text{outside}} = k\frac{q}{r^2}, E_{\text{surface}} = \frac{\sigma}{\varepsilon_0}$

119. (*b*) Using Coulomb's law, the force between two charges is given by

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{d^2}$$

$$F = \frac{9 \times 10^9 \times 2 \times 10^{-7} \times 3 \times 10^{-7}}{0.3 \times 0.3}$$

$$= \frac{9 \times 2 \times 3 \times 10^{-5}}{3 \times 3 \times 10^{-2}} = 6 \times 10^{-3}\ \text{N} \qquad \text{(Repulsion)}$$

120. (*c*) We have to find the value of *r*. Using Coulomb's law, the force between two charges is

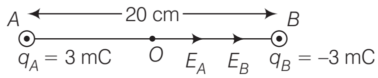
$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

Putting the values of F, $\frac{1}{4\pi\varepsilon_0}$, q_1 and q_2, we get

$$0.2 = 9 \times 10^9 \times \frac{0.4 \times 10^{-6} \times 0.8 \times 10^{-6}}{r^2}$$

$$r^2 = 16 \times 9 \times 10^{-4} \Rightarrow r = 12\,\text{cm}$$

121. (*c*) Given, $AB = 20\,\text{cm}$



$$AO = OB = 10\,\text{cm} = 0.1\,\text{m}$$
$$q_A = 3\,\mu\text{C} = 3\times10^{-6}\ \text{C}$$
$$q_B = -3\,\mu\text{C} = -3\times10^{-6}\ \text{C}$$

The electric field at a point due to a charge q is $E = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{q}{r^2}$

where, r is the distance between charge and the point.

Electric field due to q_A at O is E_A.

$$E_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_A}{(AO)^2}$$
$$E_A = \frac{9\times10^9\times3\times10^{-6}}{(0.1)^2} = \frac{27\times10^3}{0.1\times0.1} = 2.7\times10^{-6}\ \text{N/C}$$

The direction of E_A is A to O, *i.e.,* towards O or towards OB as the electric field is always directed away from positive charge.

Electric field due to q_B at O is E_B.

$$E_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_B}{(OB)^2}$$
$$E_B = \frac{9\times10^9\times3\times10^{-6}}{(0.1)^2}$$
$$= \frac{27\times10^3}{0.1\times0.1} = 2.7\times10^6\ \text{N/C}$$

The direction of E_B is O to B *i.e.,* towards O or towards OB as the electric field is always directed towards the negative charge.

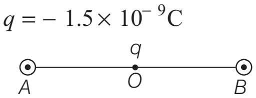
Now, we see that both E_A and E_B are in same direction. So, the resultant electric field at O is E. Hence,

$$E = E_A + E_B = 2.7\times10^6 + 2.7\times10^6$$
$$= 5.4\times10^6\ \text{N/C}$$

The direction of E (resultant electric field) will be from O to B or towards B.

122. (*a*) Let us consider, the charge q is placed at the mid-point O. According to the question,

$$q = -1.5\times10^{-9}\text{C}$$



By the basic definition of electric field, $E = \dfrac{F}{q}$

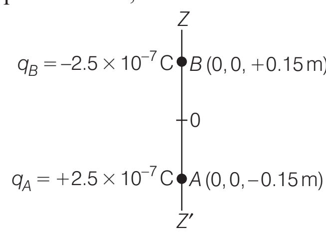
or $F = qE$, where E is the net electric field at point O.

$$F = -1.5\times10^{-9}\times5.4\times10^6$$
$$= -8.1\times10^{-3}\ \text{N}$$

The direction of force is opposite to the direction of field because the charge q is negatively charged. Thus, the direction of force is from O to A.

123. (*d*) Total charge $= 2.5\times10^{-7} - 2.5\times10^{-7} = 0$

Electric dipole moment,



$$p = \text{Either charge}\times\text{Separation between charges}$$
$$= 2.5\times10^{-7}(0.15+0.15)\ \text{C-m}$$
$$= 7.5\times10^{-8}\ \text{C-m}$$

The direction of dipole moment is from B to A, *i.e.*, along negative Z-axis.

124. (*c*) Torque applied on a dipole in the electric field,

$$\tau = \mathbf{p}\times\mathbf{E} = pE\sin\theta$$

or $$\tau = 4\times10^{-9}\times5\times10^4\sin30^\circ$$
$$= \frac{20\times10^{-5}}{2} = 10^{-4}\ \text{Nm}$$

The direction of torque is perpendicular to both electric field and dipole moment.

125. (*d*) The charge on an object is given by

$q = \pm ne$

The number of electrons transferred

$$n = \frac{\text{Total charge }(q)}{\text{Charge of electron }(e)}$$
$$n = \frac{-3\times10^{-7}}{-1.6\times10^{-19}} = 1.875\times10^{12}$$

126. (*a*) From the Coulomb's law, the force between the two spheres is

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_Aq_B}{r^2} = \frac{9\times10^9\times6.5\times10^{-7}\times6.5\times10^{-7}}{(50\times10^{-2})^2}$$
$$= \frac{9\times6.5\times6.5\times10^{-5}}{50\times50\times10^{-4}} = 1.521\times10^{-2}\ \text{N(Repulsion)}$$

127. (*c*) According to the question, if the charge is doubled

$$q'_A = 2q_A \quad\text{and}\quad q'_B = 2q_B$$

Distance between them is halved, *i.e.*, $r' = \dfrac{r}{2}$

Now, the force between the two spheres is

$$F' = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q'_Aq'_B}{r'} = \frac{1}{4\pi\varepsilon_0}\frac{(2q_A)(2q_B)}{(r/2)^2}$$
$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{4q_Aq_B}{r^2/4} = 16\frac{1}{4\pi\varepsilon_0}\frac{q_Aq_B}{r^2}$$
$$= 16F = 16\times1.521\times10^{-2} = 0.24\ \text{N}$$

This force is also repulsive in nature because both the charges are similar (positive) in nature.

128. (*c*) As the deflection in the path of a charged particle is directly proportional to the charge/mass ratio.

$$y \propto \frac{q}{m}$$

Here, the deflection in particle 3 is maximum, so the charge to mass ratio of particle 3 is maximum.

129. (*d*) Electric flux, $\phi = \mathbf{E}\cdot\mathbf{S} = ES\cos\theta$

$$= ES \qquad (\because \text{ angle between } \mathbf{E} \text{ and } \mathbf{S} \text{ is } 0°)$$

$$\phi = 3\times 10^3 \times 10^{-2} = 30\,\text{Nm}^2\text{C}^{-1}$$

130. (*d*) The area vector makes an angle of 60° with *X*-axis.

$$\mathbf{E} = 3\times 10^3\,\hat{\mathbf{i}}\,\text{NC}^{-1}$$

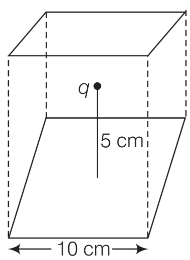
$$\mathbf{S} = 100\,\text{cm}^2 = 10^{-2}\,\text{m}^2, \theta = 60°$$

Using the formula of electric flux, $\phi = \mathbf{E}\cdot\mathbf{S}$

$$\phi = ES\cos\theta = 3\times 10^3 \times 10^{-2}\cos 60°$$

$$= 3\times 10 \times \frac{1}{2} = 15\,\text{Nm}^2\text{C}^{-1}$$

131. (*d*) The total flux enclosed through the cube is



According to Gauss' theorem

$$\phi = \frac{q}{\varepsilon_0} \qquad \ldots\text{(i)}$$

Here, $q = 10\,\mu\text{C}$

The flux enclosed by one face, *i.e.*, square is 1/6 of total flux (because the cube has six square shaped faces).

The flux linked with each square

$$\phi' = \frac{\phi}{6} = \frac{1}{6}\cdot\frac{q}{\varepsilon_0} \qquad \text{[From Eq. (i)]}$$

$$\phi' = \frac{1}{6}\times\frac{10\times 10^{-6}}{8.854\times 10^{-12}}$$

$$= 1.88\times 10^5\,\text{Nm}^2\text{C}^{-1}$$

Thus, the flux linked with the square is $1.88\times 10^5\,\text{Nm}^2\text{C}^{-1}$.

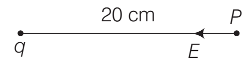
132. (*d*) According to Gauss' theorem, the net electric flux (ϕ) through the surface is

$$\phi = \frac{q}{\varepsilon_0} = \frac{2\times 10^{-6}}{8.854\times 10^{-12}}$$

$$= 2.26\times 10^5\,\text{Nm}^2\text{C}^{-1}$$

Thus, the net electric flux through the surface is $2.26\times 10^5\,\text{Nm}^2/\text{C}$.

133. (*c*) Electric field, $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$



$$1.5\times 10^3 = \frac{9\times 10^9 \times q}{(20\times 10^{-2})^2}$$

$$q = \frac{1.5\times 10^3 \times 20\times 20\times 10^{-4}}{9\times 10^9} = 6.67\times 10^{-9}\,\text{C}$$

134. (*c*) Electric field due to infinite line charge, $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

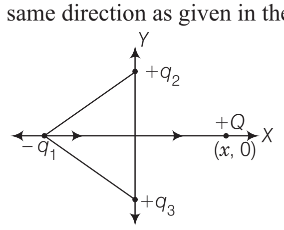
$$E = \frac{2}{2}\times\frac{\lambda}{2\pi\varepsilon_0 r} = \frac{2\lambda}{4\pi\varepsilon_0 r}$$

Putting the values, we get

$$9\times 10^4 = \frac{2\times 9\times 10^9 \times\lambda}{2\times 10^{-2}}$$

$$\lambda = \frac{9\times 10^4 \times 2\times 10^{-2}}{2\times 9\times 10^9} = 10^{-7}\,\text{Cm}^{-1}$$

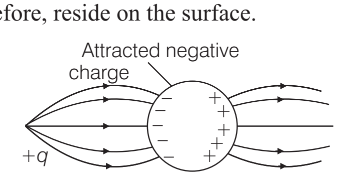
135. (*a*) The net force on q_1 by q_2 and q_3 is along the $+X$-direction. Hence, q_1 is a negative charge. Thus, nature of force between q_1 and newly introduced charge Q (positive) is attractive and net force on q_1 by (q_2, q_3 and Q) are along the same direction as given in the diagram below.



136. (*a*) When a positive point charge is brought near an isolated conducting sphere without touching the sphere, then the free electrons in the sphere are attracted towards the positive charge. This leaves an excess of positive charge on the far (right) surface of sphere.

Both kinds of charges are bound in the metal sphere and cannot escape. They, therefore, reside on the surface.

Thus, the left surface of sphere has an excess of negative charge and the right surface of sphere has an excess of positive charge as given in the figure below



An electric field line starts from positive charge and ends at negative charge (in this case from point positive charge to negative charge created inside the sphere).

Also, electric field line emerges from a positive charge, in case of single charge and ends at infinity.

Here, all these conditions are fulfilled in Fig. (a).

137. (*d*) Electric flux through a surface doesn't depend on the shape, size or area of a surface but it depends on charges enclosed by the surface.

138. (*c*) The space between the electric field lines is increasing, here from left to right and its characteristics states that, strength of electric field decreases with the increase in the space between electric field lines. As a result force on charges also decreases from left to right.

Thus, the force on charge $-q$ is greater than force on charge $+q$ in turn dipole will experience a force towards left.

139. (*c,d*) $\oint_s \mathbf{E} \cdot d\mathbf{S} = 0$ represents electric flux over the closed surface.

In general, $\oint_s \mathbf{E} \cdot d\mathbf{S}$ means the algebraic sum of number of flux lines entering the surface and number of flux lines leaving the surface.

When $\oint_s \mathbf{E} \cdot d\mathbf{S} = 0$, it means that the number of flux lines entering the surface must be equal to the number of flux lines leaving it.

Now, from Gauss' law, we know that $\oint_s \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$, where q is charge enclosed by the surface. When $\int_s \mathbf{E} \cdot d\mathbf{S} = 0$, $q = 0$

i.e., net charge enclosed by the surface must be zero. Therefore, all other charges must necessarily be outside the surface. This is because charges outside the surface do not contribute to the electric flux.

140. (*b,d*) The electric field due to a charge Q at a point in space may be defined as the force that a unit positive charge would experience if placed at that point. Thus, electric field due to the charge Q will be continuous, if there is no charge at that point. It will be discontinuous if there is a charge at that point.

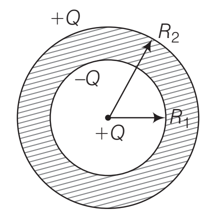
141. (*c,d*) When there are various types of charges in a region, but the total charge is zero, the region can be supposed to contain a number of electric dipoles. Therefore, at points outside the region (may be anywhere w.r.t. electric dipoles), the dominant electric field $\propto \frac{1}{r^3}$ for large r. Further, as electric field is conservative, work done to move a charged particle along a closed path, away from the region will be zero.

142. (*a,c*) Total charge inside the surface is $= Q - 2Q = -Q$

$\therefore$ Total flux through the surface of the sphere $= \frac{-Q}{\varepsilon_0}$

Charge $5Q$ lies outside the surface, thus it makes no contribution to electric flux through the given surface.

144. (*c*)

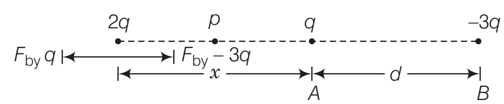


Now, surface charge density on the inner surface $= \frac{-Q}{4\pi R_1^2}$

surface charge density on the outer surface $= \frac{+Q}{4\pi R_2^2}$

145. (*c*) When the charge q is placed at B, middle point of an edge of the cube, it is being shared equally by 4 cubes. Therefore, total flux through the faces of the given cube $= q / 4\varepsilon_0$.

146. (*c*) Here, let us keep the charge $2q$ at a distance r from A.



Thus, charge $2q$ will not experience any force.

When force of repulsion on it due to q is balanced by force of attraction on it due to $-3q$, at B, where $AB = d$.

Thus, force of attraction by $-3q$ = Force of repulsion by q

$$\Rightarrow \quad \frac{2q \times q}{4\pi\varepsilon_0 x^2} = \frac{2q \times 3q}{4\pi\varepsilon_0 (x+d)^2}$$

$$\Rightarrow \quad (x+d)^2 = 3x^2 \Rightarrow x^2 + d^2 + 2xd = 3x^2$$

$$\Rightarrow \quad 2x^2 - 2dx - d^2 = 0$$

$$x = \frac{d}{2} \pm \frac{\sqrt{3}d}{2}$$

(Negative sign between q and $-3q$ is unadaptable.)

$$\therefore \quad x = -\frac{d}{2} + \frac{\sqrt{3}d}{2} = \frac{d}{2}(1 + \sqrt{3}) \text{ to the left of } q.$$