ELECTRIC CHARGES AND FIELDS

IMPORTANT FORMULAE

1. Coulomb's force F between two point charges kept in a medium of electric constant,

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

For air between the charges, dielectric constant $K = 1$.

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

In vector form $$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}_{21}$$

Where F_{21} is the force on charge q_1 due to q_2 and $\hat{r}_{21}$ is the unit vector in the direction from q_1 to q_2.

2. Electric field strength $\vec{E}$ at any point in the field where $\vec{F}$ is the force experienced by a test charge q_0 kept at that point, $\vec{E} = \lim_{q_0 \to 0}\frac{\vec{F}}{q_0}$

(*a*) Electric field strength due to a point charge at a distance r

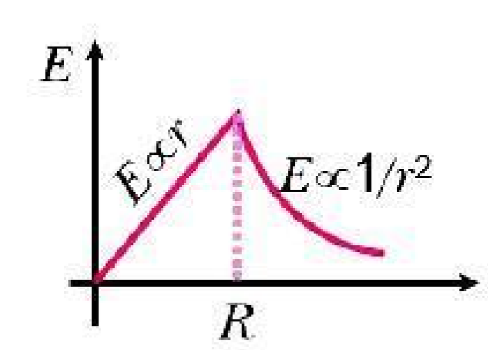
$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^3}\vec{r} \quad \left[\text{where } \hat{r} \text{ is unit vector along } \vec{r};\ \hat{r} = \frac{\vec{r}}{r}\right]$$

(*b*) Due to sphere charge

(*i*) Inside point ($r \le R$) $\quad E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^3}r;\ E \propto r$

(*ii*) Outside point ($r \ge R$) $\quad E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2};\ E \propto \frac{1}{r^2}$

(*iii*) On the surface ($r = R$) $\quad E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$

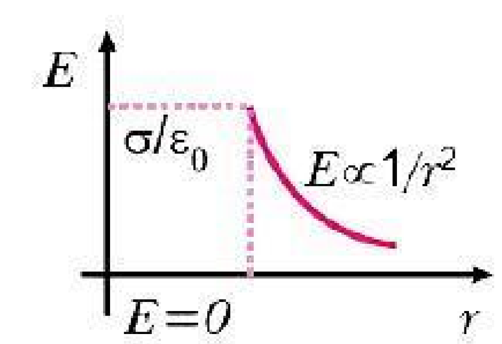


(*c*) Due to hollow sphere of charge

(*i*) Inside point ($r \le R$), $E = 0$

(*ii*) Outside, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

(*iii*) On the surface, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2} = \frac{\sigma}{\varepsilon_0}$



(*d*) Electric field strength due to infinite line charge having linear charge density (λ) coulomb/ metre.

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{r}$$

(e) Electric field strength near an infinite thin sheet of charge.

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

(*f*) Electric field strength near a conductor $\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$, where $\hat{n}$ is a unit vector normal to the surface in the outer direction. Electric field strength inside a conductor $E = 0$.

7. Electric Dipole:

(*a*) Dipole moment $\left|\vec{p}\right| = q.2l$ ($2l$ being the separation from $-q$ to $+q$)

(*b*) Torque on a dipole in uniform electric field $\vec{\tau} = \vec{p}\times\vec{E}$

(*c*) Potential energy of dipole, $U = -\vec{p}.\vec{E} = -pE\cos\theta$

where θ is the angle between $\vec{p}$ and $\vec{E}$

(*d*) Work done in rotating the dipole in uniform electric field from orientation θ_1 to θ_2 is

$$W = U_2 - U_1 = pE(\cos\theta_1 - \cos\theta_2)$$

Work done in rotating the dipole from equilibrium position $\theta = 0$ to orientation θ is

$$W = pE\,(1 - \cos\theta)$$

(e) **Electric field** due to a short dipole.

(*i*) at axial point $E_{axis} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

(*ii*) at an equitorial point $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

8. Total electric flux, $\phi = \int_S \vec{E}.\vec{dS} = \frac{1}{\varepsilon_0}\times$ net charge enclosed by the closed surface.

MULTIPLE CHOICE QUESTIONS

Choose and write the correct option in the following questions.

1. A body can be negatively charged by

(*a*) giving excess of electrons to it
(*b*) removing some electron from it
(*c*) giving some protons to it
(*d*) removing some neutrons from it.

2. The unit of permittivity of free space (ε_0) is

(*a*) $CN^{-1}m^{-1}$
(*b*) Nm^2C^{-2}
(*c*) $C^2N^{-1}m^{-2}$
(*d*) $C^2N^{-2}m^{-2}$

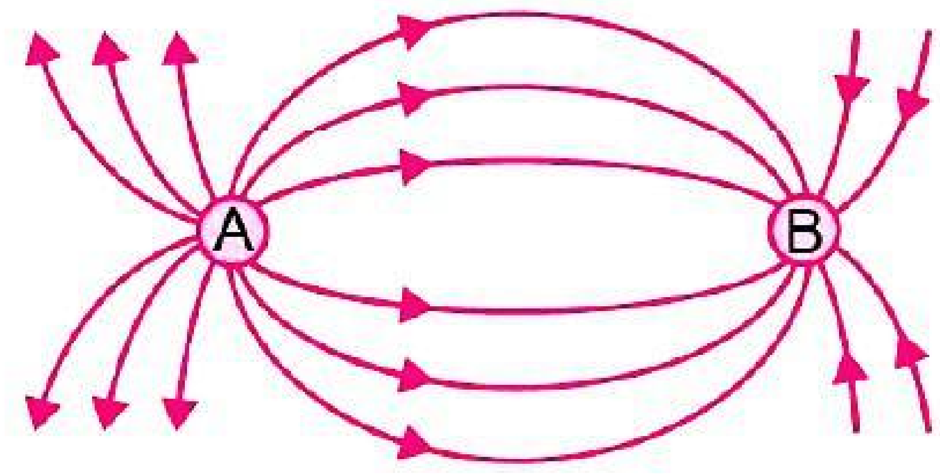
3. Which of the following is not a property of field lines?

(*a*) Field lines are continuous curves without any breaks
(*b*) Two field lines cannot cross each other
(*c*) Field lines start at positive charges and end at negative charges
(*d*) They form closed loops

4. Gauss's law is valid for

(*a*) Any closed surface
(*b*) Only regular closed surfaces
(*c*) Any open surface
(*d*) Only irregular open surfaces.

5. **The spatial distribution of the electric field due to two charges (*A*, *B*) is shown in figure.**



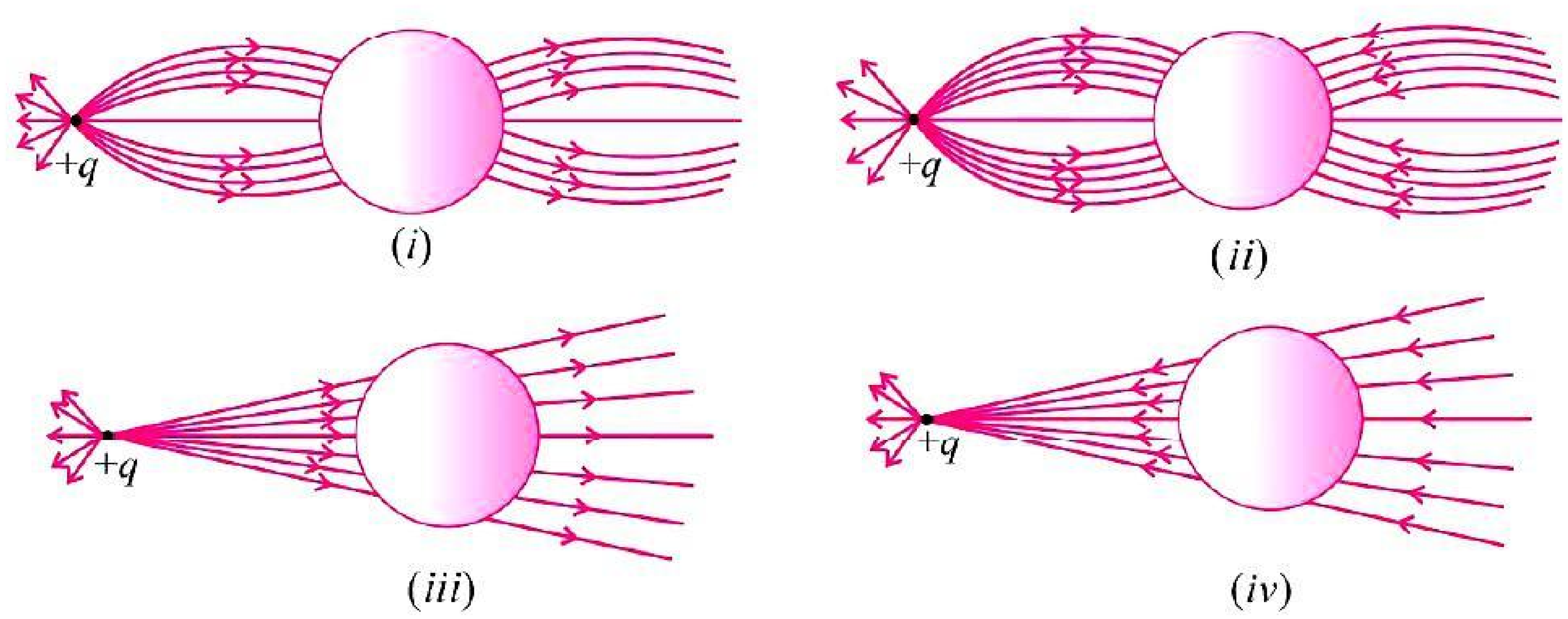
Which one of the following statements is correct?

(*a*) *A* is + ve and *B* is – ve and $|A| > |B|$
(*b*) *A* is – ve and *B* is + ve, $|A| = |B|$
(*c*) Both are + ve but $A > B$
(*d*) Both are – ve but $A > B$

6. **When air is replaced by a medium of dielectric constant *K*, the force of attraction between two charges separated by a distance *r***

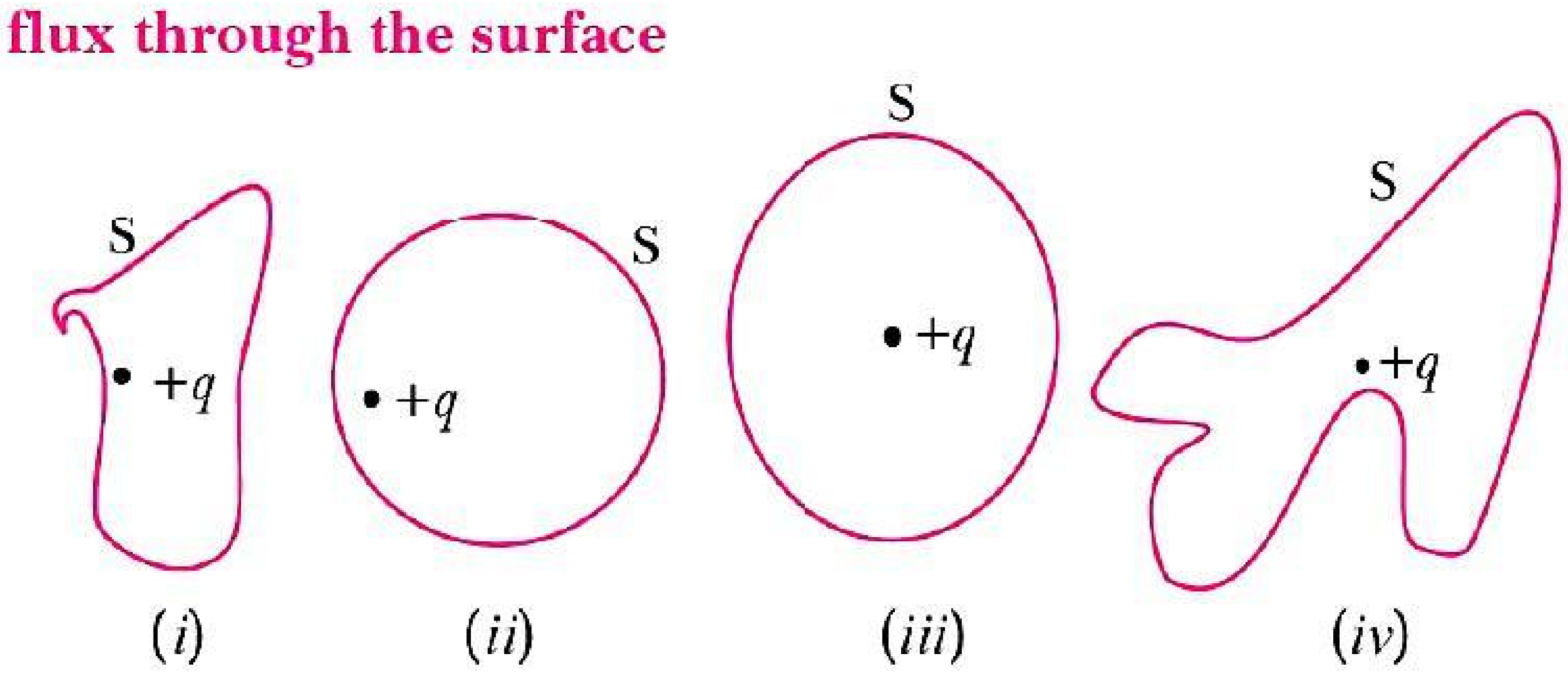
(*a*) decreases *K* times
(*b*) remains unchanged
(*c*) increases *K* times
(*d*) increases K^{-2} times

7. **A point positive charge is brought near an isolated conducting sphere (Fig. given below). The electric field is best given by** [*NCERT Exemplar*]



(*a*) Fig (*i*)
(*b*) Fig (*ii*)
(*c*) Fig (*iii*)
(*d*) Fig (*iv*)

8. **The Electric flux through the surface** [*NCERT Exemplar*]

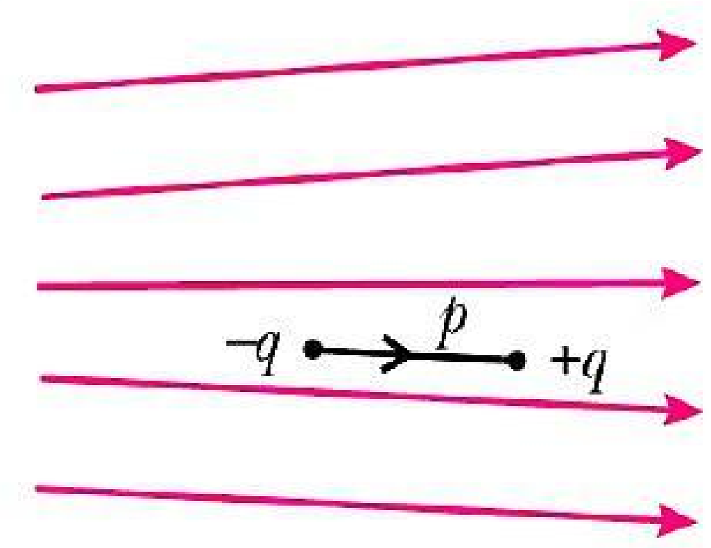


(*a*) in Fig. (*iv*) is the largest.
(*b*) in Fig. (*iii*) is the least.
(*c*) in Fig. (*ii*) is same as Fig. (*iii*) but is smaller than Fig. (*iv*)
(*d*) is the same for all the figures.

9. **A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the centre is directed** [*NCERT Exemplar*]

(*a*) perpendicular to the diameter
(*b*) parallel to the diameter
(*c*) at an angle tilted towards the diameter
(*d*) at an angle tilted away from the diameter

10. Figure shows electric field lines in which an electric dipole *p* is placed as shown. Which of the following statements is correct? [*NCERT Exemplar*]



(*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.

11. A point charge +*q*, is placed at a distance *d* from an isolated conducting plane. The field at a point *P* on the other side of the plane is [*NCERT Exemplar*]

(*a*) directed perpendicular to the plane and away from the plane.

(*b*) directed perpendicular to the plane but towards the plane.

(*c*) directed radially away from the point charge.

(*d*) directed radially towards the point charge.

12. There are two kinds of charges—positive charge and negative charge. The property which differentiates the two kinds of charges is called

(*a*) amount of charge (*b*) polarity of charge

(*c*) strength of charge (*d*) field of charge

13. A method for charging a conductor without bringing a charged object in contact with it is called

(*a*) electrification (*b*) magnetisation

(*c*) electromagnetic induction (*d*) electrostatic induction

14. If $\oint \vec{E}.d\vec{S} = 0$ over a surface, then [*NCERT Exemplar*]

(*a*) the electric field inside the surface and on it is zero.

(*b*) all charges must necessarily be outside the surface.

(c) the number of flux lines entering the surface must be equal to the number of flux lines leaving it.

(*d*) both (*b*) and (*c*)

15. A cup contains 250 g of water. The number of negative charges present in the cup of water is

(*a*) 1.34×10^7 C (*b*) 1.34×10^{19} C

(*c*) 3.34×10^7 C (*d*) 1.34×10^{-19} C

16. When the distance between two charged particles is halved, the Coulomb force between them becomes

(*a*) one-half (*b*) one-fourth (*c*) double (*d*) four times.

17. Two charges are at distance *d* apart in air. Coulomb force between them is *F*. If a dielectric material of dielectric constant *K* is placed between them, the Coulomb force now becomes

(*a*) F/K (*b*) FK (*c*) F/K^2 (*d*) K^2F

18. Two point charges q_1 and q_2 are at separation *r*. The force acting between them is given by $F = K\dfrac{q_1q_2}{r^2}$. The constant *K* depends upon

(*a*) only on the system of units (b) only on medium between charges

(*c*) both on (*a*) and (*b*) (*d*) neither on (*a*) nor on (*b*)

19. Three charges +4q, Q and q are placed in a straight line of length l at points at distance 0, l/2, and l respectively. What should be Q in order to make the net force on q to be zero?

(*a*) $-q$ (*b*) $-2q$ (*c*) $-\frac{q}{2}$ (*d*) $4q$

20. An electron falls from the rest through a vertical distance h in a uniform and vertically upward directed electric field E. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance h. The time of fall of the electron, in comparison to the time of fall of the proton is

(*a*) smaller (*b*) 5 times bigger

(*c*) 10 times bigger (*d*) equal

21. Which of the following is the unit of electric charge?

(*a*) Coulomb (C) (*b*) Statcoulomb (stat C)

(*c*) Abcoulomb (abC or aC) (*d*) All the above

22. A body is positively charged. It has

(*a*) excess of positrons (*b*) excess of electrons

(*c*) deficiency of electrons (*d*) deficiency of protons

23. A proton at rest has a charge e. When it moves with a high speed, its charge

(*a*) $> e$ (*b*) $< e$

(*c*) $= e$ (*d*) may increase or decrease

24. Two charges 3×10^{-5} C and 5×10^{4} C are placed at a distance of 10 cm from each other. Find the value of electrostatic force acting between them.

(*a*) 13.5×10^{11} N (*b*) 40×10^{11} N (*c*) 180×10^{9} N (*d*) 13.5×10^{10} N

25. What is the value of minimum force (in N)acting between two charges placed at 1 m apart from each other?

(*a*) ke^2 (*b*) ke (*c*) $\frac{ke}{4}$ (*d*) $\frac{ke^2}{2}$

26. A glass rod acquires charge by rubbing it with silk cloth. The charge on glass rod is due to

(*a*) friction (*b*) conduction (*c*) induction (*d*) radiation

27. Find the thickness of a dielectric material which has relative permittivity ε_r when two charges experience the same force as in air by a distance r.

(*a*) $t = \sqrt{\varepsilon_r}\, r$ (*b*) $t = \sqrt{r\varepsilon_r}$ (*c*) $t = r\varepsilon_r$ (*d*) $t = \frac{r}{\sqrt{\varepsilon_r}}$

28. What will be the value of electric field at the centre of the electric dipole?

(*a*) Zero

(*b*) Equal to the electric field due to one charge at centre

(*c*) Twice the electric field due to one charge at centre

(*d*) Half the value of electric field due to one charge at centre

29. Which physical quantity have unit newton /coulomb?

(*a*) Electric charge (*b*) Electric field

(*c*) Electric force (*d*) Electric potential

30. In the process of charging, the mass of the negatively charged body

(*a*) increases (*b*) decreases

(*c*) remains constant (*d*) none of the above

31. Charge on a body is integral multiple of ±e. It is given by the law of

(*a*) conservation of charge (*b*) conservation of mass

(*c*) conservation of energy (*d*) quantisation of charge

32. Electric field intensity due to a short dipole remains directly proportional to (*r* is the distance of a point from centre of dipole)

(*a*) r^2 (*b*) r^3 (*c*) r^{-2} (*d*) r^{-3}

33. Electric field lines contracts lengthwise, It shows

(*a*) repulsion between same charges
(*b*) attraction between opposite charges
(*c*) no relation between force & contraction
(*d*) electric field lines does not move in straight path

34. Force *F* between charges Q_1 and Q_2 separated by *r* is 25 N. It can be reduced to 5 N if the separation between them is made

(*a*) $\frac{r}{\sqrt{5}}$ (*b*) $\frac{r}{2}$ (*c*) 2r (*d*) $\sqrt{5}r$

35. Which of the following is the unit of electric field intensity?

(*a*) NC (*b*) Nm (c) NC^{-2} (*d*) NC^{-1}

36. The unit of electric dipole moment is

(*a*) C/m (*b*) C-m (*c*) C/m^2 (*d*) $C\text{-}m^2$

37. A slab of dielectric is introduced between two equal positive charges with a fixed separation. As a result

(*a*) the force between the two charges decreases
(*b*) the two charges start attracting each other
(*c*) the slab starts moving
(*d*) an electric current passes from one charge to the other

38. Two like point charges separated by a certain distance exert a force of 0.04 N on each other. When the distance of separation between them is halved, the force exerted by each on the other will be

(*a*) 0.16 N (*b*) 0.02 N (*c*) 0.08 N (*d*) 0.01 N

39. When a glass rod is rubbed with a dry silk cloth, the glass rod is positively charged due to the transfer of

(*a*) protons from silk cloth to glass rod (*b*) electrons from silk cloth to glass rod
(*c*) protons from glass rod to silk cloth (*d*) electrons from glass rod to silk cloth

40. The unit of electric permittivity ε of a medium is

(*a*) Nm^2/C^2 (*b*) Nm^2/C (*c*) C^2/Nm^2 (*d*) C/Nm^2

41. The dimensions of electric permittivity is

(*a*) $ML^3T^4A^{-2}$ (*b*) $ML^{-3}T^4A^2$ (*c*) $M^{-1}L^3T^4A^2$ (*d*) $M^{-1}L^{-3}T^4A^2$

42. An insulated conical shaped metallic conductor is charged positively. The surface charge density on it is

(*a*) uniform throughout (*b*) minimum at the apex
(*c*) maximum at the apex (*d*) maximum at its base

43. The magnitude of force experienced by an electron placed at a point in the electric field $\vec{E}$ is equal to its weight *mg*. The magnitude of $\vec{E}$ is

(*a*) *mge* (*b*) *e*/(*mg*) (*c*) *mg*/*e* (*d*) mg/e^2

44. An electric dipole is placed at an angle of 30° with an electric field intensity 2×10^5 NC^{-1}. It experiences a torque equal to 4 Nm. The charge on the dipole, if the dipole length is 2 cm, is

(*a*) 8 mC (*b*) 2 mC (*c*) 5 mC (*d*) 7 mC

45. What is the SI unit of electric flux?

(*a*) $\frac{N}{C}\times m^2$ (*b*) $N \times m^2$

(*c*) $\frac{N}{m^2}\times C$ (*d*) $\frac{N^2}{m^2}\times C^2$

46. The dimentional formula of electric flux is

(*a*) $[M^1L^1T^{-2}]$ (*b*) $[M^1L^3T^{-3}A^{-1}]$

(*c*) $[M^2L^2T^{-2}A^{-2}]$ (*d*) $[M^1L^{-3}T^3A^1]$

47. Which of the following statements is not true about Gauss's law?

(*a*) Gauss's law is true for any closed surface.

(*b*) The term *q* on the right side of Gauss's law includes the sum of all charges enclosed by the surface.

(*c*) Gauss's law is not much useful in calculating electrostatic field when the system has some symmetry.

(*d*) Gauss's law is based on the inverse square dependence on distance contained in the Coulomb's law.

48. The surface considered for Gauss's law is called

(*a*) closed surface (*b*) spherical surface

(*c*) Gaussian surface (*d*) plane surface

49. Charge on a conducting metal sphere is present

(*a*) on the surface of sphere (*b*) inside the sphere

(*c*) outside the sphere (*d*) both inside and outside of sphere

50. Charge *Q* is kept in a sphere of 5 cm first, then it is kept in a cube of side 5 cm, the outgoing flux will be

(*a*) more in case of sphere (*b*) more in case of cube

(*c*) same in both case (*d*) information incomplete

51. A sphere encloses an electric dipole within it. The total flux across the sphere is

(*a*) zero (*b*) half that due to a single charge

(*c*) double that due to a single charge (*d*) dependent on the position of the dipole

52. A charge *q* is placed at the centre of a cube, what is the electric flux passing through one of its faces?

(*a*) $\frac{q}{6\varepsilon_0}$ (*b*) $\frac{q}{\varepsilon_0}$ (*c*) $\frac{6q}{\varepsilon_0}$ (*d*) $\frac{q}{3\varepsilon_0}$

53. According to Gauss law, electric field of an infinitely long straight wire is proportional to

(*a*) r (*b*) $\frac{1}{r^2}$ (*c*) $\frac{1}{r^3}$ (*d*) $\frac{1}{r}$

54. A charge *q* μC is placed at the centre of a cube of side 0.1 m. Then the electric flux diverging from each face of this cube is

(*a*) $\frac{q\times 10^{-6}}{\varepsilon_0}$ (*b*) $\frac{q}{\varepsilon_0}\times 10^{-4}$ (*c*) $\frac{q\times 10^{-6}}{6\varepsilon_0}$ (*d*) $\frac{q\times 10^{-4}}{6\varepsilon_0}$

55. An electric charge *q* is placed at one of the corners of a cube of side *a*. The electric flux on one of its faces will be

(*a*) $\frac{q}{a\varepsilon_0}$ (*b*) $\frac{q}{\varepsilon_0 a^2}$ (*c*) $\frac{q}{4\pi\varepsilon_0 a^2}$ (*d*) $\frac{q}{24\varepsilon_0}$

56. 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.

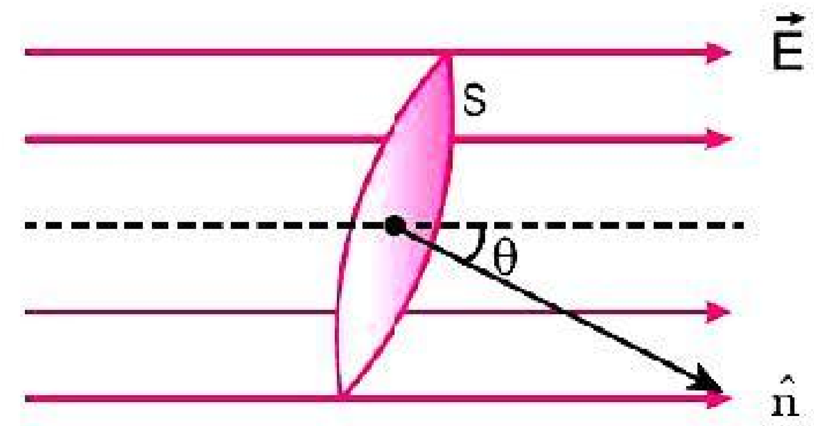
(*c*) the work done to move a charged particle along a closed path, away from the region, will be zero.

(*d*) None of these

57. If electric field is uniform, then the electric lines of forces are

(*a*) divergent (*b*) convergent (*c*) circular (*d*) parallel

58. A plane of surface area S is placed in an electric field such that the direction of normal on surface 'S' makes an angle 'θ' with the direction of electric field $\vec{E}$. The electric flux through the surface is



(*a*) ES (*b*) $ES \sin \theta$

(*c*) $ES \cos \theta$ (*d*) zero

59. In which of the following cases the electric field strength is independent of distance?

(*a*) Due to a point charge (*b*) Due to a line charge

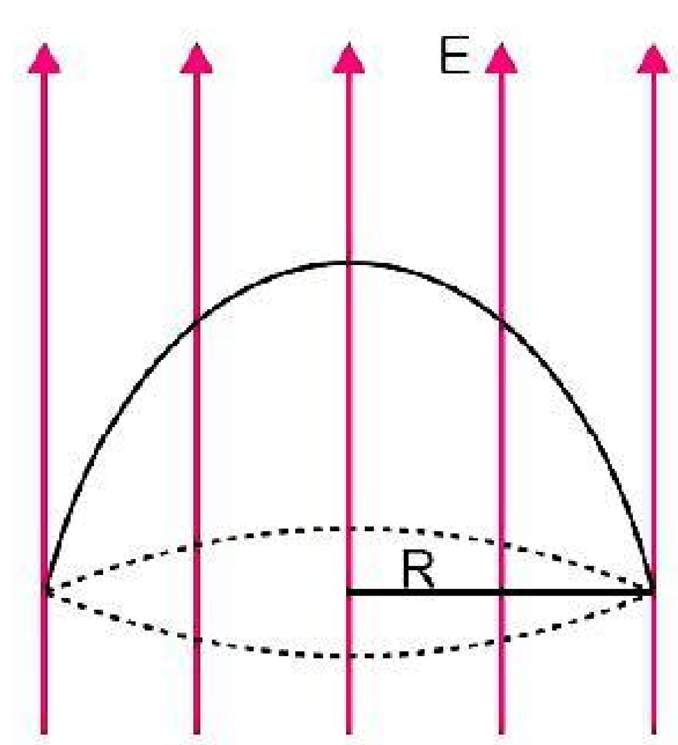
(*c*) Due to a spherical charge (*d*) Due to infinite flat sheet of charge

60. A cylinder of radius R and length L is placed in a uniform electric field E parallel to cylinder axis. The total flux through the surface of the cylinder is given by

(*a*) $2\pi R^2 E$ (*b*) $2\pi RLE$

(*c*) $(2\pi R^2 + 2\pi RL)E$ (*d*) zero

61. A hemispherical surface of radius R is placed with its cross-section perpendicular to a uniform electric field as shown in figure. The electric flux through the surface is



(*a*) $\pi R^2 E$

(*b*) $2\pi R^2 E$

(*c*) $4\pi R^2 E$

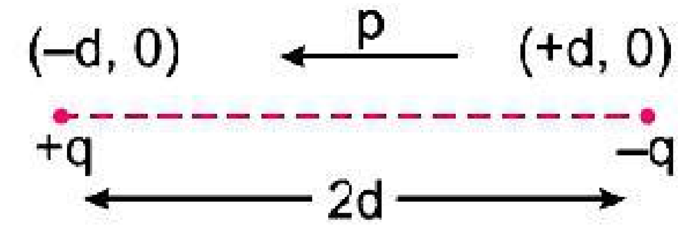
(*d*) zero

62. A small metal ball is suspended in a uniform electric field with the help of an insulated thread. If high energy X-ray beam falls on the ball, it will

(*a*) be deflected in the direction of field (*b*) be deflected opposite to direction of field

(*c*) not deflect at all (*d*) fly to infinity

63. Two point charges $+q$ and $-q$ are held fixed at $(-d, 0)$ and $(+d, 0)$ respectively of a (x, y) coordinate system. Then



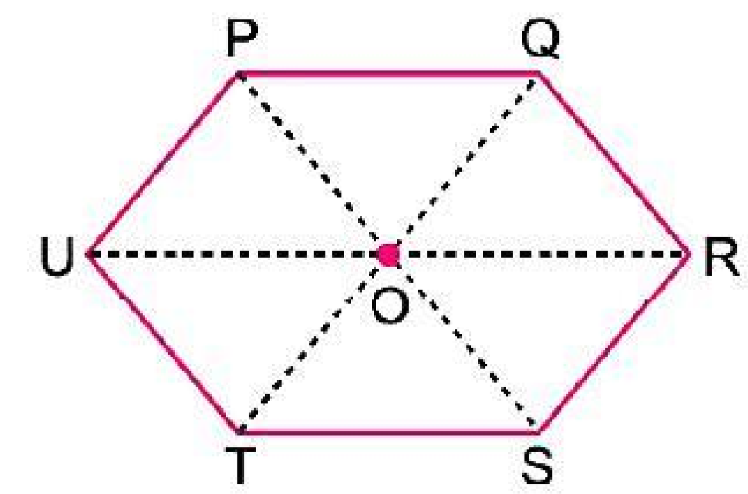
(*a*) the dipole moment is qd along positive X-axis

(*b*) the dipole moment is $q(2d)$ along positive X-axis

(*c*) the dipole moment is $q(2d)$ along positive Y-axis

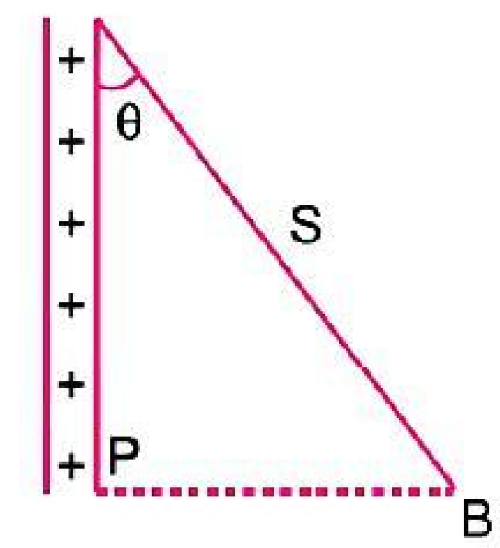
(*d*) the dipole moment is $q(2d)$ along negative X-axis

64. Six charges, three positive and three negative are to be placed at the vertices of a regular hexgon such that the electric field at *O* is double the electric field when only one positive charge of same magnitude is placed at *R*. Which of the following arrangements of charges is possible for *P, Q, R, S, T* and *U* respectively?



(*a*) +, –, +, –, –, – (*b*) +, –, +, –, +, –
(*c*) +,+, –, +, –, – (*d*) –, +, +, –, +, –

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



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

66. Force between two identical charges placed at a distance *r* in vacuum is *F*. Now a slab of dielectric of dielectric constant 4 is inserted between these two charges. If the thickness of the slab is $\frac{r}{2}$ then the force between the charges will become

(*a*) F (*b*) $\frac{F}{4}$ (*c*) $\frac{F}{2}$ (*d*) $\frac{4}{9}F$

67. Electric flux is

(*a*) scalar quantity (*b*) vector quantity
(*c*) sometimes scalar and sometimes vector (*d*) neither scalar nor vector.

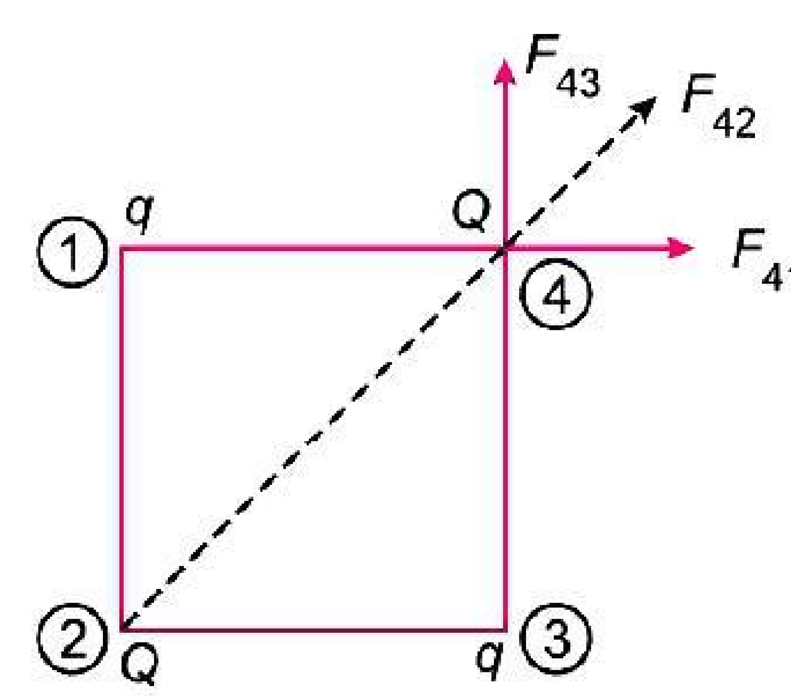
68. The minimum value of charge on any charged body may be

(*a*) 1.6×10^{-19} coulomb (*b*) 1 coulomb
(*c*) 1μC (*d*) 4.8×10^{-12} coulomb

69. The number of electrons contained in 1 coulomb of charge is equal to

(*a*) 6.25×10^{17} (*b*) 6.25×10^{18}
(*c*) 1.6×10^{-19} (*d*) 0.625×10^{18}

70. A charge *Q* is placed at each of the opposite corners of a square. A charge *q* is placed at each of the other two corners. If the net electrical force on *Q* is zero, then $\frac{Q}{q}$ equals

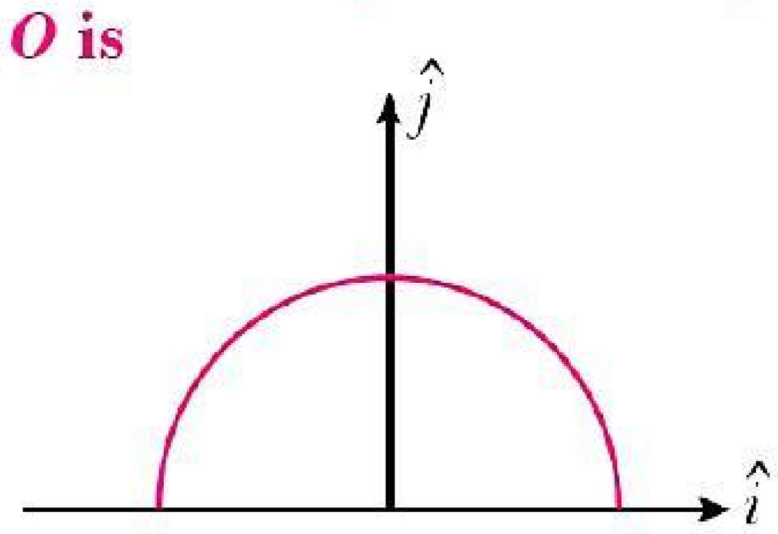


(*a*) $-2\sqrt{2}$ (*b*) –1
(*c*) 1 (*d*) $-\frac{1}{\sqrt{2}}$

71. Three concentric metallic spherical shells of radii *R*, 2*R* and 3*R* are given charges Q_1, Q_2, Q_3 respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then the ratio of the charges given to the shells $Q_1 : Q_2 : Q_3$ is

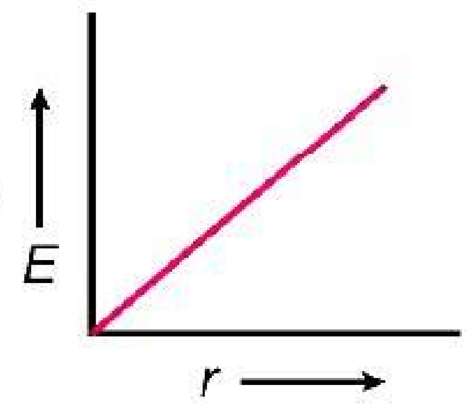
(*a*) 1 : 2 : 3 (*b*) 1 : 3 : 5 (*c*) 1 : 4 : 9 (*d*) 1 : 8 : 18

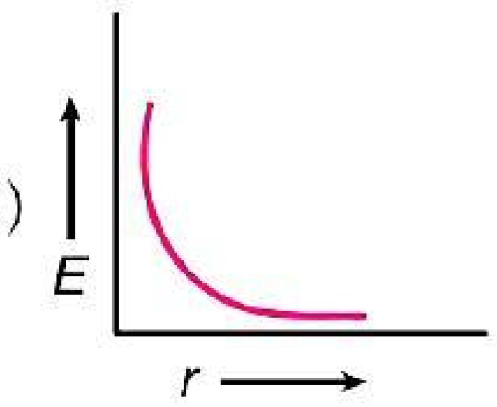
72. A thin semicircular ring of radius *r* has a positive charge '*q*' uniformly distributed over it. The net electric field $\vec{E}$ at centre *O* is

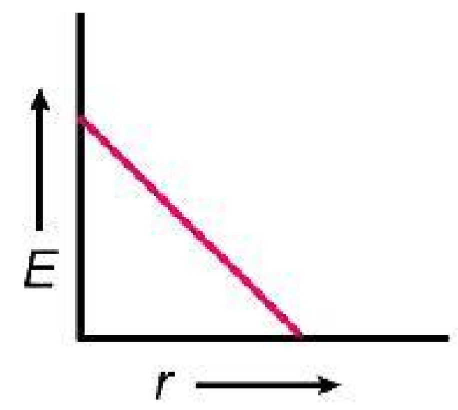


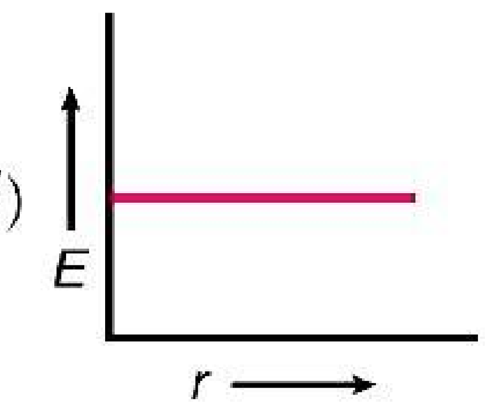
(*a*) $\frac{q}{2\pi^2 \varepsilon_0 r^2}\hat{j}$ (*b*) $\frac{q}{4\pi^2 \varepsilon_0 r^2}\hat{i}$ (*c*) $-\frac{q}{4\pi^2 \varepsilon_0 r^2}\hat{i}$ (*d*) $\frac{-q}{2\pi^2 \varepsilon_0 r^2}\hat{j}$

73. For a point charge, the graph between electric field versus distance is given by

(*a*) 

(*b*) 

(*c*) 

(*d*) 

74. An infinite number of identically charged bodies are kept along the *x*-axis at points $x = 0$, 1 m, 2 m, 4 m, 8 m, 16 m and so on. All other charges repel the charge at the origin with a force of 1.2 N. Find magnitude of each charge.

(*a*) 9 μC (*b*) 10 μC (*c*) 11 μC (*d*) 12 μC

75. If the net electric flux through a closed surface is zero, then we can infer *[CBSE 2020 (55/1/1)]*

(*a*) no net charge is enclosed by the surface.
(*b*) uniform electric field exists within the surface.
(*c*) electric potential varies from point to point inside the surface.
(*d*) charge is present inside the surface.

76. An electric dipole placed in a non-uniform electric field can experience *[CBSE 2020 (55/1/2)]*

(*a*) a force but not a torque. (*b*) a torque but not a force.
(*c*) always a force and a torque. (*d*) neither a force nor a torque.

77. A point charge is situated at an axial point of a small electric dipole at a large distance from it. The charge experiences a force *F*. If the distance of the charge is doubled, the force acting on the charge will become *[CBSE 2020 (55/1/3)]*

(*a*) $2F$ (*b*) $F/2$ (*c*) $F/4$ (*d*) $F/8$.

78. The electric flux emerging out from 1C charge is *[CBSE 2020 (55/3/1)]*

(*a*) $\frac{1}{\varepsilon_0}$ (*b*) 4π (*c*) $\frac{4\pi}{\varepsilon_0}$ (*d*) ε_0

79. An electric dipole consisting of charges $+q$ and $-q$ separated by a distance *r*, is kept symmetrically at the centre of an imaginary sphere of radius R ($> r$), Another point charge *Q* is also kept is also kept at the centre of the sphere. The net electric flux coming out of the sphere will be *[CBSE 2020 (55/3/2)]*

(*a*) $\frac{-(2q+Q)}{4\pi\varepsilon_0}$ (*b*) $\frac{Q}{\varepsilon_0}$ (*c*) $\frac{2q+Q}{\varepsilon_0}$ (*d*) $\frac{-Q}{\varepsilon_0}$

80. Two large conducting spheres carrying charges Q_1 and Q_2 are kept with their centres *r* distance apart. The magnitude of electrostatic between them is not exactly $\frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$ because *[CBSE 2020 (55/3/3)]*

(*a*) these are not point charges.
(*b*) charge distribution on the spheres is not uniform.
(*c*) charges on spheres will shift towards the centres of their respective spheres.
(*d*) charges will shift towards the portions of the spheres which are closer and facing towards each other.

81. The electric flux through a closed Gaussian surface depends upon *[CBSE 2020 (55/5/1)]*

(*a*) net charge enclosed and permittivity of the medium

(*b*) net charge enclosed, permittivity of the medium and the size of the Gaussian surface

(*c*) net charge enclosed only

(*d*) permittivity of the medium only

Answers

1. (*a*)	**2.** (*c*)	**3.** (*d*)	**4.** (*a*)	**5.** (*a*)	**6.** (*a*)	**7.** (*a*)	**8.** (*d*)
9. (*a*)	**10.** (*c*)	**11.** (*a*)	**12.** (*b*)	**13.** (*d*)	**14.** (*d*)	**15.** (*a*)	**16.** (*d*)
17. (*a*)	**18.** (*c*)	**19.** (*a*)	**20.** (*a*)	**21.** (*d*)	**22.** (*c*)	**23.** (*c*)	**24.** (*a*)
25. (*a*)	**26.** (*a*)	**27.** (*d*)	**28.** (*c*)	**29.** (*b*)	**30.** (*a*)	**31.** (*d*)	**32.** (*d*)
33. (*b*)	**34.** (*d*)	**35.** (*d*)	**36.** (*c*)	**37.** (*a*)	**38.** (*a*)	**39.** (*d*)	**40.** (*c*)
41. (*d*)	**42.** (*c*)	**43.** (*c*)	**44.** (*b*)	**45.** (*a*)	**46.** (*b*)	**47.** (*c*)	**48.** (*c*)
49. (*a*)	**50.** (*c*)	**51.** (*a*)	**52.** (*a*)	**53.** (*d*)	**54.** (*c*)	**55.** (*d*)	**56.** (*c*)
57. (*d*)	**58.** (*c*)	**59.** (*d*)	**60.** (*d*)	**61.** (*a*)	**62.** (*a*)	**63.** (*d*)	**64.** (*d*)
65. (*c*)	**66.** (*d*)	**67.** (*a*)	**68.** (*a*)	**69.** (*b*)	**70.** (*a*)	**71.** (*b*)	**72.** (*d*)
73. (*b*)	**74.** (*b*)	**75.** (*a*)	**76.** (*c*)	**77.** (*d*)	**78.** (*a*)	**79.** (*b*)	**80.** (*b*)
81. (*a*)							

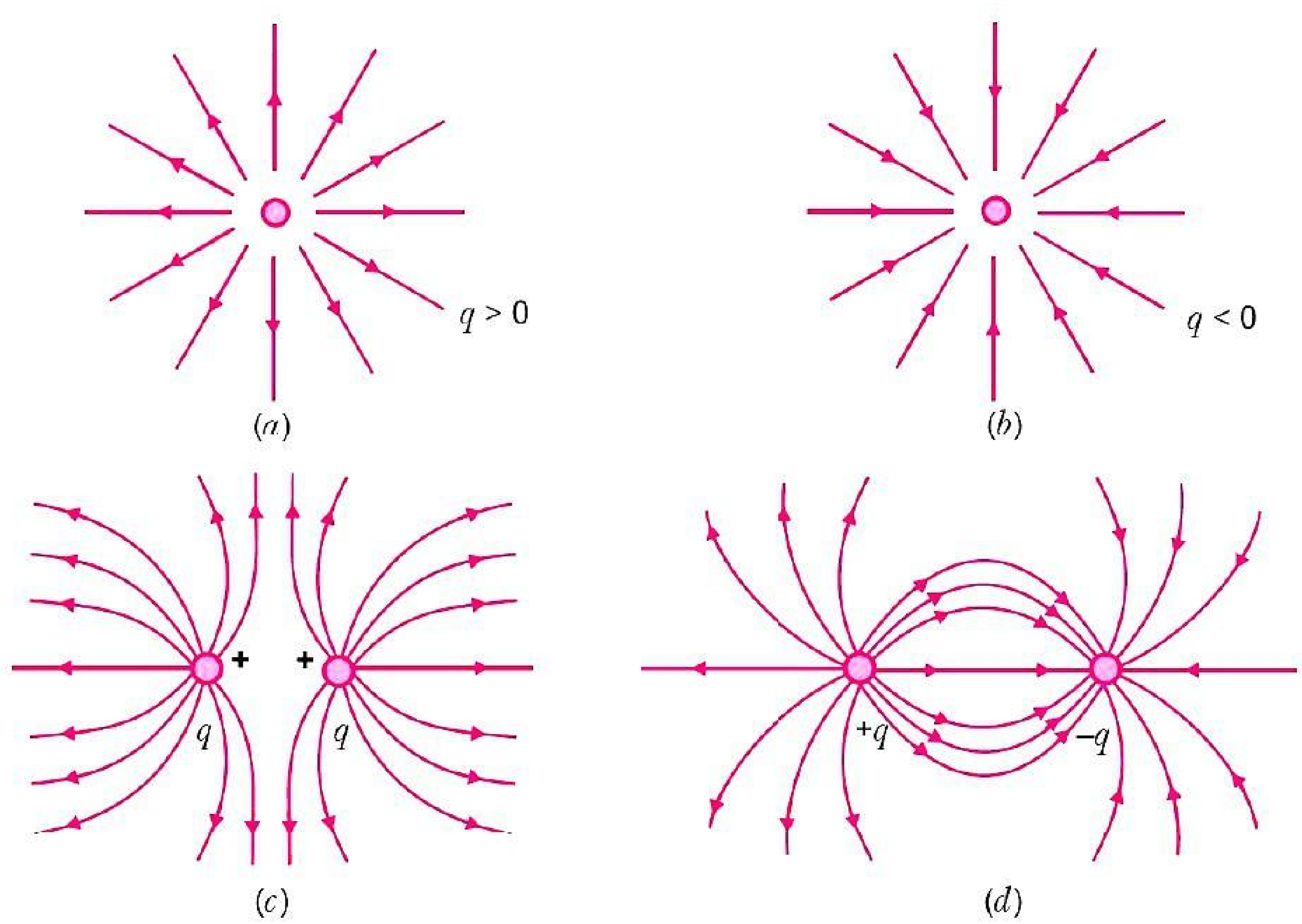
CASE-BASED QUESTIONS

Attempt any 4 sub-parts from each question. Each question carries 1 mark.

1. COULOMB'S FIELD:

The electrostatic field around an electrically charged body or particle is called Coulomb field. According to Coulomb's law, "The force of attraction or repulsion between two point charges is directly proportional to the product of the charges and inversely proportional to the square of distance between them. The direction of this force is along the line of joining the two charges."

After all, for any system of charges, the measurable quantity is the force on a charge which can be directly determined using Coulomb's law and the superposition principle.



For electrostatic, the concept of electric field is convenient, but not really necessary. Electrical field is an elegant way of characterising the electrical environment of a system of charges. Electric field at a point in the space around a system of charges tells you the force a unit positive test charge would experience if placed at that point. The true physical significance of the concept of electric field, however, emerges only when we go beyond electrostatics and deal with time dependent electromagnetic phenomena. The concept of field was first introduced by Faraday and is now the central concept in physics.

(*i*) The vector form of Coulomb's force ($\vec{F}_{12}$) is

(*a*) $\frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$ (*b*) $\frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r_{12}}\hat{r}_{12}$

(*c*) $\frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r_{12}^3}\hat{r}_{12}$ (*d*) none of these

(*ii*) The Coulomb force between a proton and an electron separated by 0.8×10^{-15} m is

(*a*) 300 N (*b*) 320 N

(*c*) 340 N (*d*) 360 N

(*iii*) The Coulomb 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*) continuous if there is a charge at that point

(*iv*) A point charge $+q$, is placed at a distance *d* from an isolated conducting plane. The field at a point *P* on the other side of the plane is

(*a*) directed radially towards the point charge

(*b*) directed radially away from the point charge

(*c*) directed perpendicular to the plane but towards the plane

(*d*) directed perpendicular to the plane and away from the plane

(*v*) An infinite number of charges each equal to 4 μC are placed along the X-axis at $x = 1$ m, $x = 2$ m, $x = 4$ m, $x = 8$ m, and so on, the Coulomb field at origin for all these charges is

(*a*) 4.8×10^3 N/C (*b*) 4.8×10^4 N/C

(*c*) 4.8×10^5 N/C (*d*) 4.8×10^6 N/C

Answers

1. (*i*) (*a*); The Coulomb's force is directly proportional to the product of charges and inversely proportional to the square of distance between them. In vector form, it is represented as

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} = \frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

(*ii*) (*d*); According to Coulomb's law, $F_e = K\frac{q_1 q_2}{r^2}$

where, charge on particle, $e^- = -1.6 \times 10^{-19}$ C, $p^+ = +1.6 \times 10^{-19}$ C

$$K = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

$$\therefore \quad F_e = \frac{9 \times 10^9 (-1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(0.8 \times 10^{-15})^2}$$

$$F_e = -360 \text{ N}$$

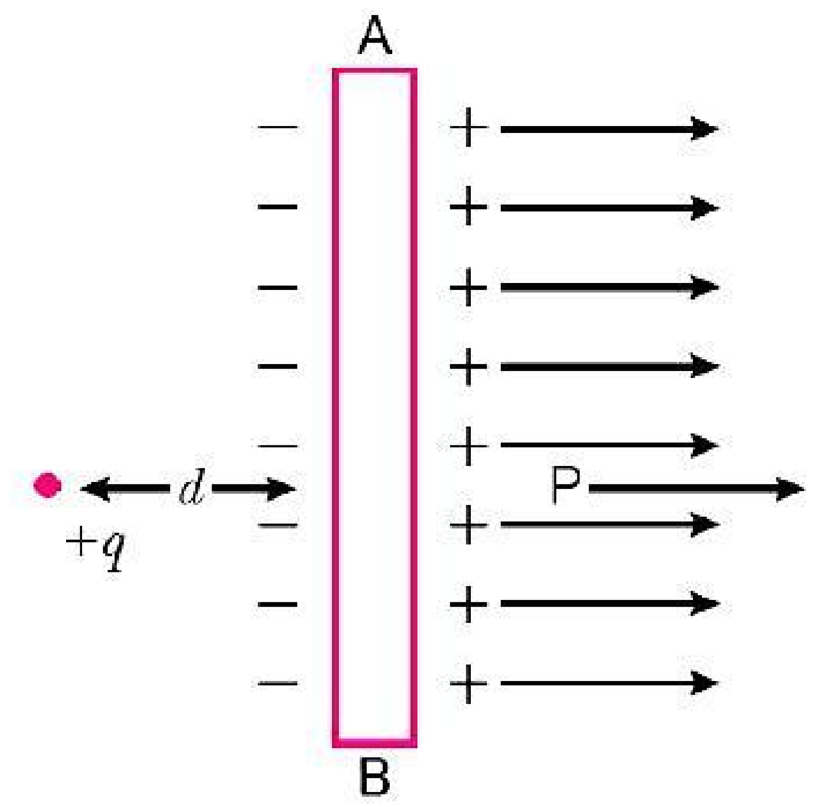
$$|F_e| = 360 \text{ N}$$

(*iii*) (*b*); Either positive or negative charges will interact with the lines of electric field to make the electric field discontinuous.

If there is no charge inside the electric field then the lines will not be affected. So, electric field becomes continuous.

(*iv*) (*d*); Let charge $+q$ is placed to the left of isolated conducting plane AB vertical to plane of paper.

Due to induction by $+q$, R.H.S. of plane acquire positive charge. So, lines of force will emerge perpendicularly outward and parallel to each other.



(*v*) (*b*); Electric field (Coulomb field) due to point charge,

$$E = \frac{KQ}{r^2}$$

Now, Coulomb field due to system of charges, $Q = 4\ \mu C$

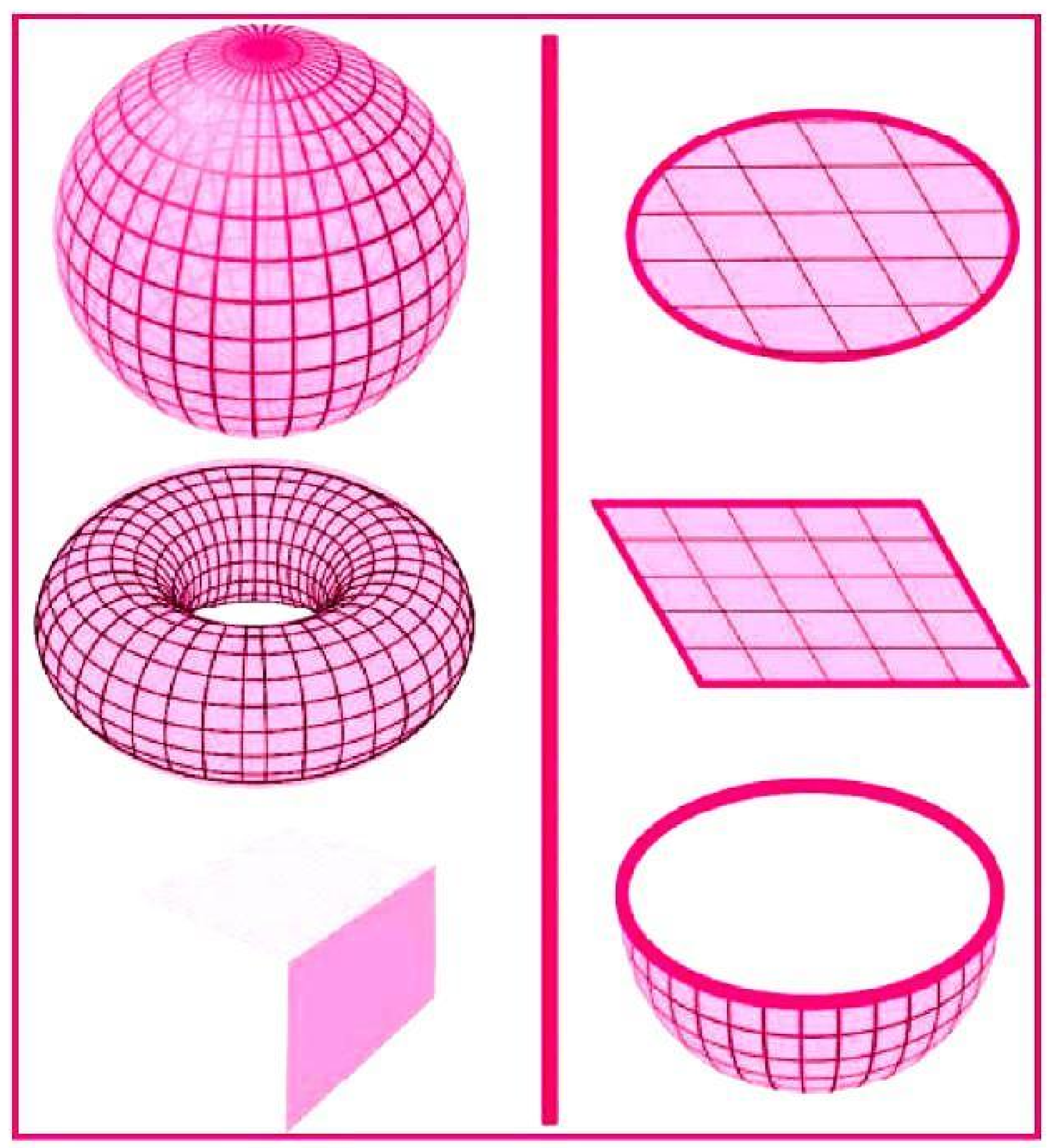
i.e., $$E = KQ\left[\frac{1}{r_1^2} + \frac{1}{r_2^2} + \frac{1}{r_3^2} + \ldots\ldots\ldots + \infty\right]$$

$$E = 9\times10^9 \times 4\times10^{-6}\left[1 + \frac{1}{4} + \frac{1}{16} + \frac{1}{64} + \ldots.\infty\right]$$

$$E = \frac{36\times10^3}{1-1/4} = 4.8\times10^4 \text{ N/C}$$

2. GAUSSIAN SURFACES:

Johann Carl Friendrich Gauss (1777–1855) was German mathematician and physicist who made significant contribution to many fields in mathematics and science. In physics Gauss's law, also known as Gauss's flux theorem, is a law relating the distribution of electric charge to the resulting electric field. In the integral form, it states that the flux of the electric field out of an arbitrary closed surface is proportional to the electric charge enclosed by the surface, irrespective of how that charge is distributed.



A Gaussian surface (sometimes abbreviated as G.S) is a closed surface in three-dimensional space through which the flux of a vector field is calculated, usually gravitational field, the electric field, or magnetic field. It is an arbitrary closed surface used in conjunction with Gauss's law for the corresponding field by performing a surface integral, in order to calculate the total amount of the sources quantity enclosed; *e.g.*, amount of electric charge as the source of the electrostatic field.

(*i*) The type of physical quantity electric flux and its dimensions respectively are

(*a*) vector, $[M^2L^2T^3A^1]$ (*b*) scalar, $[M^2L^2T^3A^1]$

(*c*) vector, $[ML^3T^{-3}A^{-1}]$ (*d*) scalar, $[ML^3T^{-3}A^{-1}]$

(*ii*) **The electric flux through a cubical Gaussian surface enclosing net charge q is q/ε_0, while the electric flux through one face of the cube is**

(*a*) q/ε_0 (*b*) $q/4\varepsilon_0$

(*c*) $q/6\varepsilon_0$ (*d*) $q/8\varepsilon_0$

(*iii*) **The electric flux of a flat square having an area of 10 m^2 placed in a uniform electric field of 8000 N/C passing perpendicular to it is**

(*a*) 8×10^5 Nm^2/C (*b*) 8×10^4 Nm^2/C

(*c*) 16×10^5 Nm^2/C (*d*) 4×10^4 Nm^2/C

(*iv*) **Gauss's law is valid for**

(*a*) any open surface (*b*) any closed surface

(*c*) only regular closed surface (*d*) only irregular open surface

(*v*) **If the electric flux entering and leaving an enclosed surface respectively is f_1 and f_2. The electric charge inside the surface will be**

(*a*) $\dfrac{\phi_2 - \phi_1}{\varepsilon_0}$ (*b*) $\varepsilon_0 (\phi_2 - \phi_1)$

(*c*) $\dfrac{\phi_1 - \phi_2}{\varepsilon_0}$ (*d*) $\varepsilon_0(\phi_1 + \phi_2)$

Answers

2. (*i*) (*d*); scalar quantity, $[\phi_E] = [ML^3T^{-3}A^{-1}]$

(*ii*) (*c*); According to Gauss's law, $\phi = \dfrac{q}{\varepsilon_0}$. In cubical Gaussian surface, electric flux passes equally from each face. So, electric flux through one face is $\dfrac{q}{6\varepsilon_0}$ (*as the* no. of faces of cube = 6).

(*iii*) (*b*); $\phi_E = EA\cos\theta$ $[\because \theta = 0° \Rightarrow \cos\theta = 1]$

$\phi_E = EA \Rightarrow \phi_E = 8000 \times 10 = 8 \times 10^4$ Nm^2/C

(*iv*) (*b*); Gauss's law is applicable for all types of closed surfaces.

(*v*) (*b*) Net flux diverging $\phi_2 - \phi_1 = \dfrac{q}{\varepsilon_0}$

$\Rightarrow q = \varepsilon_0(\phi_2 - \phi_1)$

ASSERTION-REASON QUESTIONS

In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

1. Assertion (A) : The charge given to a metallic sphere does not depend on whether it is hollow or solid.

Reason (R) : Since the charge resides only on the surface of the conductor.

2. Assertion (A) : Charge is quantized because only integral number of electrons can be transferred.

Reason (R) : There is no possibility of transfer of some fraction of electron.

3. **Assertion (A) :** Electrons moves away from a region of lower potential to a region of higher potential.

Reason (R) : An electron has a negative charge.

4. **Assertion (A) :** When a body acquires negative charge, its mass decreases.

Reason (R) : A body acquires positive charge when it gains electrons.

5. **Assertion (A) :** Surface charge density of an irregularly shaped conductor in non-uniform.

Reason (R) : Surface density is defined as charge per unit area.

6. **Assertion (A) :** Total flux through a closed surface is zero if no charge is enclosed by the surface.

Reason (R) : Gauss law is true for any closed surface, no matter what its shape or size is.

7. **Assertion (A) :** Net electric field inside a conductor is zero. *[AIIMS 2018]*

Reason (R) : Total positive charge equals to total negative charge in a charged conductor.

8. **Assertion (A) :** If the bob of a simple pendulum is kept in a horizontal electric field, its period of oscillation will remain same, *[AIIMS 2012]*

Reason (R) : If bob is charged and kept in horizontal electric field, then the time period will be decreased.

9. **Assertion (A) :** All the charge in a conductor gets distributed on whole of its outer surface. *[AIIMS 2018]*

Reason (R) : In a dynamic system, charges try to keep their potential energy minimum.

10. **Assertion (A) :** Acceleration of charged particle in non-uniform electric field does not depend on velocity of charged particle. *[AIIMS 2017]*

Reason (R) : Charge is an invariant quantity. That is the amount of charge on particle does not depend on frame of reference.

Answers

1. (*a*) **2.** (*b*) **3.** (*a*) **4.** (*d*) **5.** (*a*) **6.** (*a*) **7.** (*c*) **8.** (*c*)
9. (*a*) **10.** (*a*)

HINTS/SOLUTIONS OF SELECTED MCQs

1. (*a*) A body can be negatively charged by giving excess of electrons to it.
2. (*c*) According to Coulomb's law,

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

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

SI unit of $\varepsilon_0 = \frac{\text{C.C}}{\text{Nm}^2} = \text{C}^2\,\text{N}^{-1}\,\text{m}^{-2}$

3. (*d*) Electrostatic field lines do not form any closed loops.
4. (*a*) Gauss's law is valid for any closed surface.
5. (*a*) The electric field lines start from charge A and on charge B. So A is +ve and B is –ve.
6. (*a*) In air, the force of attraction between two charges in given by

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

In dielectric medium, the force of attraction between two charges is given by

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

$$= \frac{F_{air}}{K}$$

So, force decreases K-times.

7. (*a*) When a point positive charge is brought near an isolated conducting sphere, then due to induction there develops some negative charge on the leftside of the sphere and an equal positive charge on the right side of the sphere. The electric field lines emanating from the point positive charge end normally on the left side of the sphere. Due to accumulation of positive charge on the right side of the sphere, the field lines emerge outward normally. So, option (*a*) is correct.

As electric field lines are not perpendicular to the surface of sphere, so (*iii*) and (*iv*) are rejected.

8. (*d*) According to Gauss law, the electric flux (ϕ) through the closed surface depends only on the amount of charge enclosed inside the surface. It does not depend on size and shape of the surface.

Here, charge enclosed inside all the figures are same.

So, electric flux $\left(\phi = \frac{q}{\varepsilon_0}\right)$ will remain same.

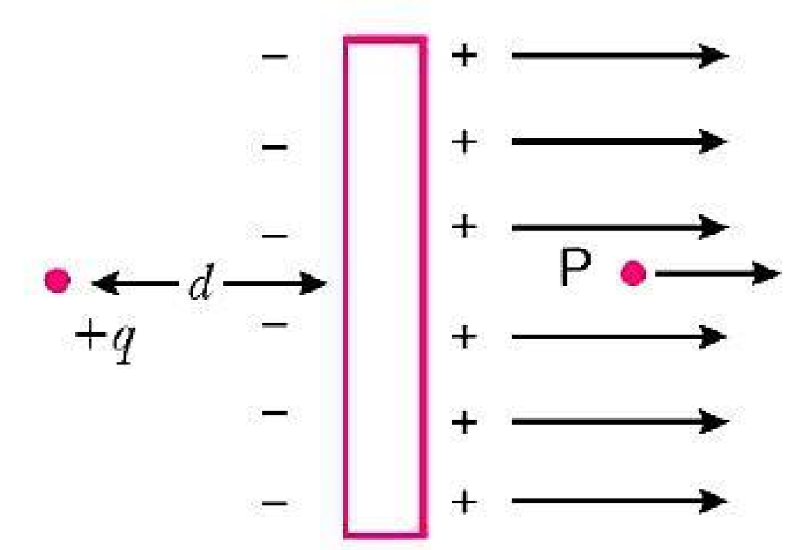
9. (*a*) As the diameter of hemisphere is plane surface, and whole hemisphere is uniformally charged positively, so the electric field lines emerging outward will be perpendicular to the surface.

10. (*c*) The density of electric field lines decreases from left to right, so electric field (E) on $+q$ charge will be smaller than q charge.

Since, $\vec{F} = q\vec{E}$, therefore force on $+q$ will be smaller than $-q$.

The direction of force $+q$ charge is along the direction of electric field, so the force on $-q$ will be towards left. Hence net force on dipole will be towards left.

11. (*a*) When a point charge $+q$ is placed at a distance d from an isolated conducting plane, due to induction by $+q$ charge, the other side (RHS) of the plane acquire positive charge, so, field lines will emerge perpendicular to the plane and away from the plane.



15. (*a*) Let us assume that the mass of one cup of water is 250 g.

The molecular mass of water is 18 g.

Number of molecules in 18 g of water = 6.02×10^{23}

Number of molecules in one cup of water = $\frac{250}{18} \times 6.02 \times 10^{23}$

Each molecule of water contains two hydrogen atoms and one oxygen atom, *i.e.*, 10 electrons and 10 protons. Hence, the total positive and total negative chage has the same magnitude and is

$$= \frac{250}{18} \times 6.02 \times 10^{23} \times 10 \times 1.6 \times 10^{-19}\,\text{C}$$

$$= 1.34 \times 10^7\ \text{C}.$$

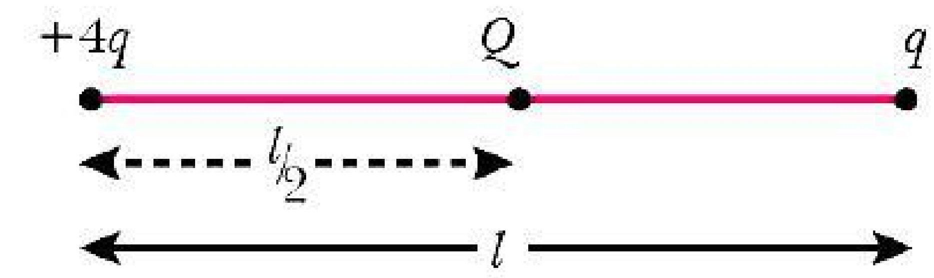
17. (*a*) In air, $$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{d^2} \qquad ...(1)$$

In material, $$F' = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{d^2} \qquad ...(2)$$

Dividing equation (1) and (2)

$$\frac{F'}{F} = \frac{1}{K} \Rightarrow F' = \frac{F}{K}$$

19. (*a*) For net force on q to be zero



$$\frac{k(4q)(q)}{l^2} + \frac{k(Q)(q)}{(l/2)^2} = 0$$

$$\Rightarrow \quad \frac{4kq^2}{l^2} + \frac{4kQq}{l^2} = 0$$

$$\Rightarrow \quad Q = -q$$

20. (*a*) Force experienced by a charged particle in an electric field, $F = qE$

As $F = ma$

$$\therefore \quad ma = qE \Rightarrow a = \frac{qE}{m} \qquad \text{... } (i)$$

As electron and proton both fall from same height at rest, then initial velocity, $u = 0$.

From $s = ut + \frac{1}{2}at^2$

$$\therefore \quad h - \frac{1}{2}at^2 \qquad (\because u = 0)$$

$$\Rightarrow h = \frac{1}{2}\frac{qE}{m}t^2 \qquad \text{[Using } (i)\text{]}$$

$$\therefore \; t = \sqrt{\frac{2hm}{qE}} \quad \Rightarrow t \propto \sqrt{m}$$ as 'q' is same for electron and proton.

$\therefore$ Electron has smaller mass so it will take smaller time.

21. (*d*) Unit of charge is coulomb, statcoulomb and abcoulomb.

22. (*c*) A body can be charged negatively or positively by giving or taking out the electrons respectively. Positive charge indicates that some electrons are taken out and the body has deficiency of electrons.

23. (*c*) As charge is invariant.

24. (*a*)

$k = 9 \times 10^9$ N– ms^2/C^2, $q_1 = 3 \times 10^{-5}$ C, $q_2 = 5 \times 10^4$ C, $r = 10$ cm $= 0.1$ m

As we know that

$$F = \frac{kq_1q_2}{r^2} = \frac{9\times10^9\times3\times10^{-5}\times5\times10^4}{(0.1)^2}$$

$$= \frac{3\times45\times10^8}{0.1\times0.1} = 135 \times 10^{10} \text{ N} = 13.5 \times 10^{11} \text{ N}$$

25. (*a*) Smallest charge $= e = 1.6 \times 10^{-19}$

As charge is small force is minimum

$$F = \frac{k\times e\times e}{(1)^2} = ke^2$$

26. (*a*) As glass rod is rubbed with silk, so relative motion and friction comes to play.

27. (*d*) $F_{air} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

$$F_{medium} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{t^2}$$

According to question

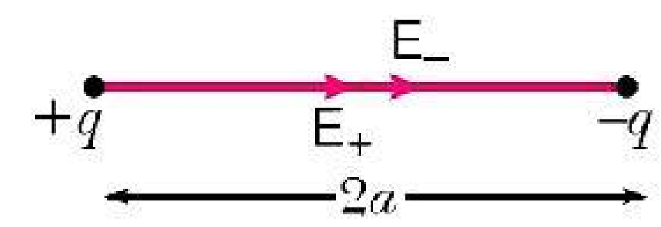
$$F_{air} = F_{medium}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0 \varepsilon_r}\frac{q_1 q_2}{t^2}$$

$$\varepsilon_r t^2 = r^2$$

$$t = \frac{r}{\sqrt{\varepsilon_r}}$$

28. (*c*) As we know that



$$E_{\text{axial}} = \frac{2kp}{r^2}$$

$$E_+ = E_- = \frac{k \times q}{a^2} = \frac{kq}{a^2}$$

$$E_{\text{net}} = \sqrt{E_+^2 + E_-^2 + 2E_+ . E_- \cos 0}$$

$$= E_+ + E_-$$

$$= \frac{2\,kq}{a^2}$$

As due to point charge $E = kq/a^2$

29. (*b*) As $E = \frac{F}{q}$; unit = N/C

30. (*a*) A negatively charged body has more electrons than the neutral body and these excess electrons results in an increase in mass.

31. (*d*) Quantisation mean integral multiple of any smallest thing

32. (*d*) As electric field due to dipole

$E_a = \frac{2kp}{r^3}$ in both cases $E \propto \frac{1}{r^3}$

$$E_{eq} = \frac{kp}{r^3}$$

33. (*b*) Electric field lines initiate from positive charge and terminate on negative charge.

34. (*d*) $F - \frac{kQ_1 Q_2}{r^2}$

$$25 = \frac{KQ_1 Q_2}{r^2} \qquad ...(i)$$

$$5 = \frac{KQ_1 Q_2}{(r')^2} \qquad ...(ii)$$

$$= \sqrt{5}\,r$$

Divide equation (*i*) and (*ii*)

$$5 = \left(\frac{r'}{r}\right)^2 \Rightarrow r' = \sqrt{5}\,r$$

35. (*d*) $E = \frac{F}{q} \quad \Rightarrow$ N/C

36. (*b*) $\vec{p} = q.2a = \text{C - m}$

37. (*a*) Force between two charges, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

When dielectric slab is introduced

$$F' = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}, \quad \text{Here } \varepsilon > \varepsilon_0$$

$\Rightarrow$ $F' < F$

38. (*a*) $F = \dfrac{kq_1 q_2}{r^2}$

$$0.04 = \frac{kq_1 q_2}{r^2} \qquad ...(i)$$

When $r' = r/2$

$$F' = \frac{kq_1 q_2}{(r/2)^2} \qquad ...(ii)$$

Divide equation (*i*) and (*ii*)

$$\frac{F'}{0.04} = \frac{4r^2}{r^2} = 4$$

$$F' = 0.16 \text{ N}$$

39. (*d*) Electrons from glass rod to silk cloth

40. (*c*) $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2} \Rightarrow \varepsilon_0 = \dfrac{q_1 q_2}{4\pi F.r^2}$

$$\text{Unit} = \frac{\text{C}}{\text{Nm}^2}$$

41. (*d*) $[\varepsilon_0] = \dfrac{[\text{AT}][\text{AT}]}{[\text{MLT}^{-2}][\text{L}^2]} = \text{A}^2\text{T}^2\text{M}^{-1}\text{L}^{-3}\text{T}^2$

$$= \text{M}^{-1}\,\text{L}^{-3}\,\text{T}^4\,\text{A}^2$$

42. (*c*) $\sigma = \dfrac{Q}{A}$

$$\sigma \propto \frac{1}{r^2}$$

43. (*c*) As $F = q\vec{E}$

$$mg = e\vec{E}$$

$$\vec{E} = mg/e$$

44. (*b*) Given, $t = 4$ Nm, $l = 2$ cm $= 0.02$ m, $E = 2 \times 10^5$ N/C, $\theta = 30°$

$$t = pE \sin\theta = ql\,E \sin\theta$$

$\Rightarrow$ $4 = q(0.02) \times 2 \times 10^5 \times \sin 30°$

$\Rightarrow$ $q = \dfrac{4}{0.02 \times 2 \times 10^5 \times \frac{1}{2}}$ C

$\Rightarrow$ $q = 0.002$ C

$\Rightarrow$ $q = 2$ mC

45. (*a*) $\phi = \vec{E}\,.\,d\vec{S}$

$$= \frac{\text{N}}{\text{C}} \times \text{m}^2$$

46. (*b*) ϕ = Electric field. Area

$= [\text{ML T}^{-3}\text{ A}^{-1}]\ [\text{L}^2]$

$= [\text{M1L}^3\text{ T}^{\ 3}\text{ A}^{\ 1}]$

47. (*c*) Gauss's law is based on the inverse square dependence on distance contained in the Coulomb's law.

48. (*c*) Gaussian surface encloses the charge.

49. (*a*) Electric field inside a conductor is zero.

50. (*c*) According to Gauss's law electric flux is $\frac{1}{\varepsilon_0}$ times the charge enclosed by the surface and is independent of the shape and size of the surface.

51. (*a*) Net charge carried by electric dipole = 0

$\therefore$ flux = 0.

52. (*a*) Electric flux through whole cube $= \frac{q}{\varepsilon_0}$

Electric flux through one surface $= \frac{q}{6\varepsilon_0}$

53. (*d*) As we know

$$E = \frac{2k\lambda}{r} \qquad \Rightarrow \quad E \propto \frac{1}{r}$$

54. (*c*) Flux through whole cube $= \frac{q}{\varepsilon_0}$

through one surface $= \frac{q}{6\varepsilon_0} = \frac{q \times 10^{-6}}{6\varepsilon_0}$

55. (*d*) As we know that one face 4 corner $\frac{1}{4} \times q_{\text{face}}$

$$\frac{1}{4} \times \frac{q}{6\varepsilon_0} = \frac{q}{24\varepsilon_0}$$

59. (*d*) For an infinite sheet to charge, $E = \frac{\sigma}{2\varepsilon_0}$ (independent of distance)

60. (*d*) The electric flux entering and leaving the cylindrical surface is same $\phi = E\pi R^2 - E\pi R^2 = 0$

61. (*a*) $\phi = E \times$ (Normal surface area) $= E \times \pi R^2 = \pi R^2 E$

63. (*d*) The direction of dipole moment from $-q$ to $+q$.

66. (*a*) $F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$

For a dielectric of dielectric constant K between the charges, the effective separation in air r_{eff} is given by

$$\frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{eff}^2} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{Kr^2}$$

$$\Rightarrow \qquad r_{\text{eff}} = \sqrt{K}\,r$$

$$\therefore \qquad F' = \frac{1}{4\pi\,\varepsilon_0} \frac{q_1 q_2}{\left(\frac{r}{2} + \frac{\sqrt{K}\,r}{2}\right)^2}$$

$$\Rightarrow \qquad \frac{F'}{F} = \frac{1}{\left(\frac{1}{2} + \frac{\sqrt{4}}{2}\right)^2} = \frac{4}{9}$$

$$\Rightarrow \qquad F' = \frac{4}{9} F$$

68. (*a*) The smallest charge is charge on electron = 1.6×10^{-19} C.

69. (*b*) $Q = ne$

$1 = n \times 1.6 \times 10^{-19}$

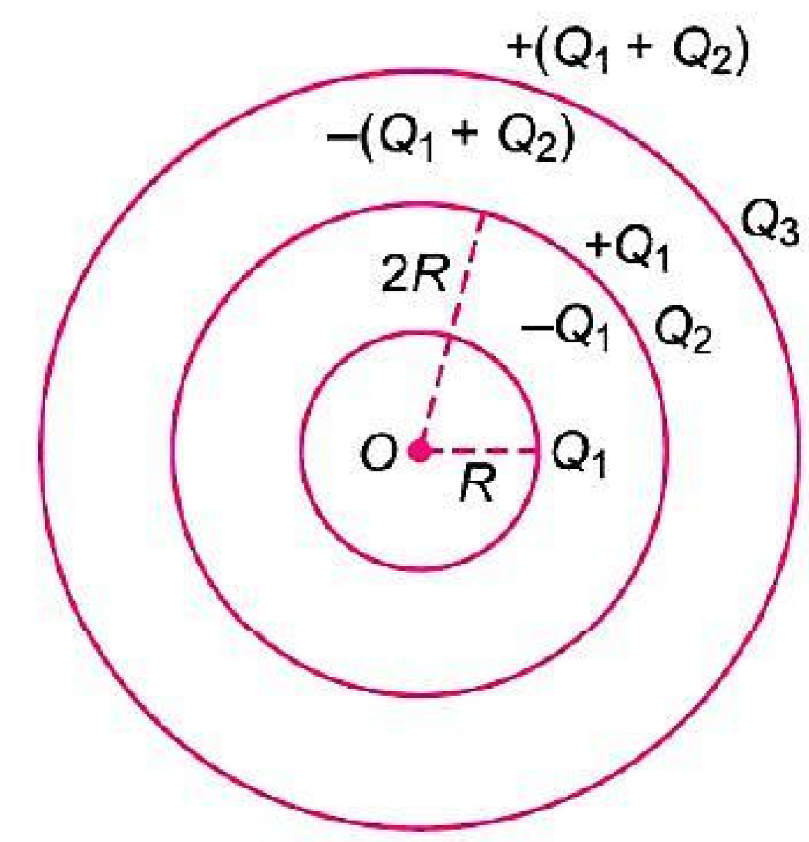
$n = 6.25 \times 10^{18}$

70. (*a*) Here, $|\vec{F}_{42}| = |\vec{F}_{43} + \vec{F}_{41}|$

$$\Rightarrow \frac{KQ^2}{(\sqrt{2}a)^2} = \frac{2KQq}{a^2} \times \frac{1}{\sqrt{2}}$$

$$\Rightarrow \frac{Q}{q} = 2\sqrt{2} \text{ (where } Q \text{ and } q \text{ is opposite in sign)}$$

71. (*b*) Charges given plus charges induced on outer surfaces of the spheres are Q_1, $Q_1 + Q_2$ and $Q_1 + Q_2 + Q_3$.



As surface charge densities on outer surfaces of the spheres are equal, *i.e.*,

$s_1 = s_2 = s_3$

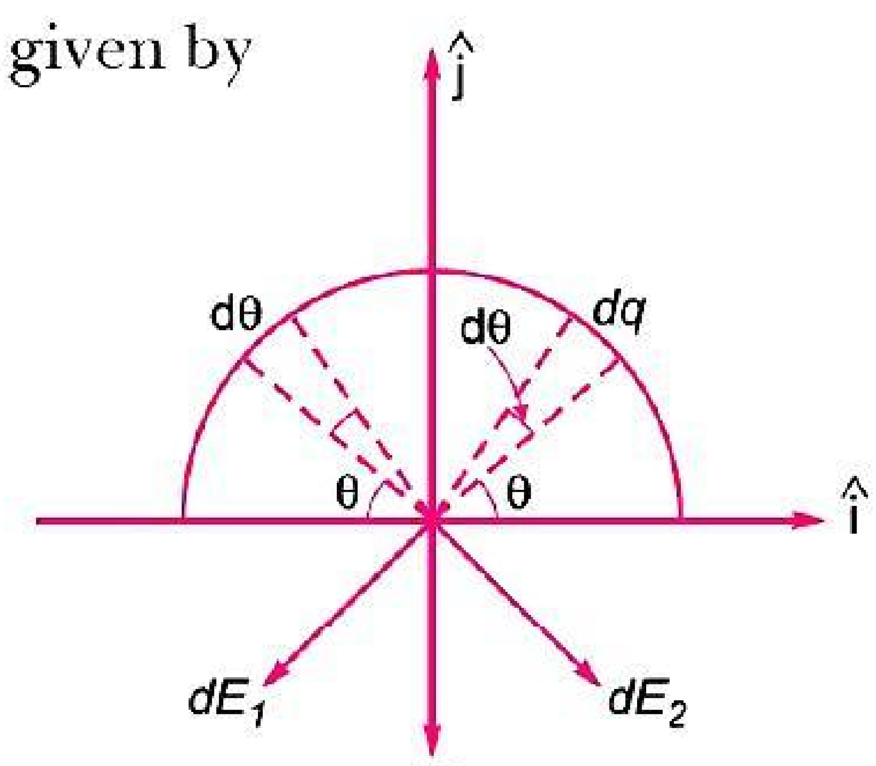
$$\Rightarrow \frac{Q_1}{4\pi R^2} = \frac{Q_1 + Q_2}{4\pi(2R)^2} = \frac{Q_1 + Q_2 + Q_3}{4\pi(3R)^2}$$

$$\Rightarrow \frac{Q_1}{1} = \frac{Q_1 + Q_2}{4} = \frac{Q_1 + Q_2 + Q_3}{9}$$

By Solving, we get

$$\frac{Q_1}{1} = \frac{Q_2}{3} = \frac{Q_3}{5} \Rightarrow Q_1 : Q_2 : Q_3 = 1 : 3 : 5$$

72. (*d*) By symmetry, the net electric field is in negative *y*-axis and is given by



$$\vec{E} = -\int dE_1 \sin\theta \,\hat{j}$$

$$= -\int \frac{dq}{4\pi\varepsilon_0 r^2} \sin\theta . \hat{j}$$

But $d\theta = \frac{q}{\pi r} . r\, d\theta = \frac{q}{\pi} d\theta$

$$\vec{E} = \int_0^{\pi} \frac{(q/\pi) d\theta}{4\pi\varepsilon_0 r^2} \sin\theta \,\hat{j}$$

$$= \frac{q}{4\pi^2 \varepsilon_0 r^2} \int_0^{\pi} \sin\theta\, d\theta \,\hat{j} = \frac{q}{4\pi^2 \varepsilon_0 r^2} [-\cos\theta]_0^{\pi} \hat{j}$$

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

73. (*b*) As we know that electric field due to point change

$$E = \frac{KQ}{r^2} \;\; i.e., \;\; E \propto \frac{1}{r^2}$$

74. (*b*) Given: $F = 1.2$ N; $x = 0$, 1 m, 4 m, 8 m, 16 m....

Now, $F = \frac{kq^2}{x^2}$

So, net force that is sum of forces by other charges is given as:

$$F = kq^2\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{4^2} + \frac{1}{8^2} + \frac{1}{16^2} + ...\right]$$

$$\Rightarrow \quad F = kq^2\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{2^4} + \frac{1}{2^6} + \frac{1}{2^8} + ...\right] = kq^2\left[\frac{1}{1-\frac{1}{4}}\right] = kq^2 \times \frac{4}{3}$$

$$\Rightarrow \quad q^2 = \frac{3}{4}\times\frac{F}{k} = \frac{3}{4}\times\frac{1.2}{9\times 10^9} \Rightarrow q^2 = \frac{1}{10\times 10^9} = 10^{-10}$$

$\because \quad q = 10^{-5}\,\text{C} = 10\,\mu\text{C}$

75. (*a*) no net charge is enclosed by the surface.

76. (*c*) always a force and a torque

78. (*a*) Electric flux $= \dfrac{Q_{\text{enclosed}}}{\varepsilon_0}$

$Q_{\text{enclosed}} = 1\text{ C}$

$\therefore \quad \phi = \dfrac{1}{\varepsilon_0}$

80. (*b*) Charge distribution on the spheres is not uniform.

81. (*a*) $Flux = \dfrac{Q_{enc}}{E_0}$

Net charge enclosed and permittivity of medium.