Electric Charges and Fields

1. A thin plastic rod is bent into a circular ring of radius R. It is uniformly charged with charge density λ. The magnitude of the electric field at its centre is: (2024)

(A) $\lambda/(2\varepsilon_0 R)$

(B) Zero

(C) $\lambda/(4\pi\varepsilon_0 R)$

(D) $\lambda/(4\varepsilon_0 R)$

Ans. (B) Zero

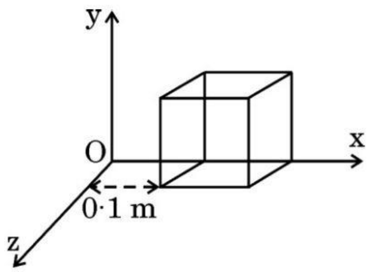
2. A cube of side 0·1 m is placed, as shown in the figure, in a region where electric field $\vec{E} = 500\, x\, \hat{i}$ exists. Here x is in meters and E in NC^{-1}.

(2024)

Calculate:

(a) the flux passing through the cube, and

(b) the charge within the cube.



Ans. Calculating

(a) the flux passing through the cube

(b) the charge within the cube

a) $\varphi_L = \vec{E_L} \cdot \vec{A} = -[500 \times 0.1] \times [(0.1)^2] = -0.5\ N\ m^2\ C^{-1}$

$\varphi_R = \vec{E_R} \cdot \vec{A} = [500 \times 0.2] \times [(0.1)^2] = 1\ N\ m^2\ C^{-1}$

Net flux $= \varphi_L + \varphi_R = 0.5\ N\ m^2\ C^{-1}$

b) flux, $\varphi = \dfrac{q}{\varepsilon_o}$

charge, $q = \varphi \times \varepsilon_o$
$= 0.5\ \varepsilon_o$
$= 4.4 \times 10^{-12}$ C

Previous Years' CBSE Board Questions

1.2 Electric Charges

MCQ

1. A negatively charged object *X* is repelled by another charged object *Y*. However an object *Z* is attracted to object *Y*. Which of the following is the most possibility for the object *Z*?
   (a) Positively charged only.
   (b) Negatively charged only.
   (c) Neutral or positively charged.
   (d) Neutral or negatively charged.

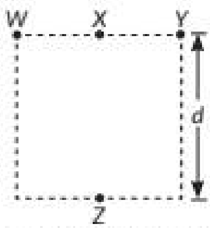
   (Term I 2021-22) U

1.4 Basic Properties of Electric Charge

MCQ

2. In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges +3*e*, +5*e* and –3*e* respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres?

5. Four objects *W*, *X*, *Y* and *Z* each with charge +*q* are held fixed at four points of a square of side *d* as shown in the figure. Objects *X* and *Z* are on the midpoints of the sides of the square. The electrostatic force exerted by object *W* on object *X* is *F*. Then the magnitude of the force exerted by object *W* on *Z* is



   (a) F/7 (b) F/5 (c) F/3 (d) F/2

   (Term I 2021-22) Ap

VSA (1 mark)

6. Two identical conducting balls *A* and *B* have charges –*Q* and +3*Q* respectively. They are brought in contact with each other and then separated by a distance *d* apart. Find the nature of the Coulomb force between them.

   (2019) R

7. Two equal balls having equal positive charge '*q*' coulombs are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two?

(a) $+5e, -4e, +5e$ (b) $+6e, +6e, -7e$
(c) $-4e, +3.5e, +5.5e$ (d) $+5e, -8e, +7e$

(Term I 2021-22) U

3. An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes
(a) -0.80 C (b) $+0.80$ C
(c) $+1.80$ C (d) $+0.20$ C

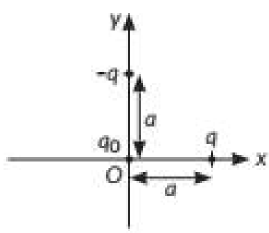
(Term I 2021-22) R

1.5 Coulomb's Law

MCQ

4. Three charges q, $-q$ and q_0 are placed as shown in figure. The magnitude of the net force on the charge q_0 at point O is

$$\left[k = \frac{1}{(4\pi\varepsilon_0)}\right]$$



(a) 0 (b) $\frac{2kqq_0}{a^2}$

(c) $\frac{\sqrt{2}kqq_0}{a^2}$ (d) $\frac{1}{\sqrt{2}}\frac{kqq_0}{a^2}$

(Term I 2021-22)

(AI 2014) U

LA (5 marks)

8. Two identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of q.

(3/5, Delhi 2019) An

1.7 Electric Field

MCQ

Question No. 9 is Assertion (A) and Reason (R) type questions. Given below are the two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below.

9. **Assertion (A) :** A negative charge in an electric field moves along the direction of the electric field.
Reason (R) : On a negative charge a force acts in the direction of the electric field.
(a) Both (A) and (R) are true and (R) is correct explanation of (A).
(b) Both (A) and (R) are true, and (R) is not correct explanation of (A).
(c) (A) is true, but (R) is false.
(d) (A) is false and (R) is also false.

(Term I 2021-22) U

SA II (3 marks)

10. A particle of charge 2 μC and mass 1.6 g is moving with a velocity $4\hat{i}\,\text{ms}^{-1}$. At $t = 0$ the particle enters in a region having an electric field $\vec{E}$ (in N C^{-1}) $= 80\hat{i} + 60\hat{j}$. Find the velocity of the particle at $t = 5$ s. *(2/3, 2020)*

LA (5 marks)

11. Two point charges of $+1\ \mu$C and $+4\ \mu$C are kept 30 cm apart. How far from the $+1\ \mu$C charge on the line joining the two charges, will the net electric field be zero? *(2/5, 2020)*

12. A thin circular ring of radius r is charged uniformly so that its linear charge density becomes λ. Derive an expression for the electric field at a point P at a distance x from it along the axis of the ring. Hence, prove that at large distances ($x >> r$), the ring behaves

(a) a^4c (b) $\frac{1}{3}a^3c$ (c) $\frac{1}{3}a^4c$ (d) 0

(Term I 2021-22) R

SA I (2 marks)

21. An electric field along the x-axis is given by $\vec{E} = 100\hat{i}$ N/C for $x > 0$ and $\vec{E} = -100\hat{i}$ N/C for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm lies parallel to the x-axis, with its centre at the origin and one face at $x = +10$ cm, the other face at $x = -10$ cm. Calculate the net outward flux through the cylinder. *(AI 2019C)*

22. (i) Define the term 'electric flux'. Write its SI unit.
(ii) What is the flux due to electric field $\vec{E} = 3\times10^3\hat{i}$ N/C through a square of side 10 cm, when it is held normal to $\vec{E}$? *(AI 2015C)* Ap

23. Given a uniform electric field $\vec{E} = 5\times10^3\,\hat{i}$ N/C. Find

as a point charge. (3/5, 2020) Ev

13. Consider a system of n charges $q_1, q_2 .... q_n$ with position vectors $\vec{r}_1, \vec{r}_2, \vec{r}_3, ... \vec{r}_n$ relative to some origin 'O'. Deduce the expression for the net electric field $\vec{E}$ at a point P with position vector $\vec{r}_p$ due to this system of charges. (3/5, Foreign 2015)

1.8 Electric Field Lines

VSA (1 mark)

14. Draw the pattern of electric field lines, when a point charge $-Q$ is kept near an uncharged conducting plate. (2019) U

15. Draw the pattern of electric field lines when a point charge $+q$ is kept near an uncharged conducting plate. (Delhi 2019) U

16. Why do the electrostatic field lines not form closed loops? (AI 2014) R

17. Why do the electric field lines never cross each other? (AI 2014)

SA II (3 marks)

18. Two electric field lines cannot cross each other. Also, they cannot form closed loops. Give reasons. (1/3, 2020)

19. A point charge $(+Q)$ is kept in the vicinity of an uncharged conducting plate. Sketch the electric field lines between the charge and the plate. (1/3, Foreign 2014) U

1.9 Electric Flux

MCQ

20. A square sheet of side 'a' is lying parallel to XY plane at $z = a$. The electric field in the region is $\vec{E} = cz^2\hat{k}$. The electric flux through the sheet is

the flux of this field through a square of 10 cm on a side whose plane is parallel to the y-z plane. What would be the flux through the same square if the plane makes a 30° angle with the x-axis? (Delhi 2014) An

1.10 Electric Dipole

MCQ

24. An electric dipole consisting of charges $+q$ and $-q$ separated by a distance L is in stable equilibrium in a uniform electric field . The $\vec{E}$ electrostatic potential energy of the dipole is

(a) qLE (b) zero (c) $-qLE$ (d) $-2qEL$ (2020)

VSA (1 mark)

25. Torque acting on an electric dipole placed in an electric field is maximum when the angle between the electric field and the dipole moment is ______. (2020)

SA I (2 marks)

26. Obtain the expression for the electric field at a point on the equatorial line of an electric dipole. (2019C)

SA II (3 marks)

27. Derive an expression for the electric field due to dipole of dipole moment $\vec{p}$ at a point on its perpendicular bisector. (2/3, Delhi 2019)

OR

Derive the expression for electric field at a point on the equatorial line of an electric dipole. (2/3, Delhi 2019, 2017)

OR

Find the resultant electric field due to an electric dipole of dipole moment $2aq$ ($2a$ being the separation between the charges $\pm q$) at a point distance x on its equator. (2/5, Foreign 2015) Ev

LA (5 marks)

28. (a) Derive an expression for the electric field E due to a dipole of length '$2a$' at a point distant r from the centre of the dipole on the axial line.
(b) Draw a graph of E versus r for $r >> a$. (3/5, AI 2017) An

29. An electric dipole of dipole moment $\vec{p}$ consists of

SA II (3 marks)

34. Two small identical electric dipoles AB and CD, each of dipole moment $\vec{p}$ are kept at an angle of 120° to each other in an external electric field $\vec{E}$ pointing along the x-axis as shown in the figure. Find the
(a) dipole moment of the arrangement, and
(b) magnitude and direction of the net torque acting on it

point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit $x >> a$, $\vec{E} \longrightarrow 2\vec{p}/(4\pi\varepsilon_0 x^3)$. (3/5, Delhi 2015) Ev

1.11 Dipole in a Uniform External Field

MCQ

30. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2×10^5 N/C. If the dipole experiences a torque of 8×10^{-3} Nm, the magnitude of either charge of the dipole is
(a) 4 μC (b) 7 μC (c) 8 mC (d) 2 mC
(2023)

31. An electric dipole placed in a non-uniform electric field can experience
(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 (2020) R

VSA (1 mark)

32. Write the expression for the torque $\vec{\tau}$ acting on a dipole of dipole moment $\vec{p}$ placed in an electric field $\vec{E}$. (Foreign 2015)

SA I (2 marks)

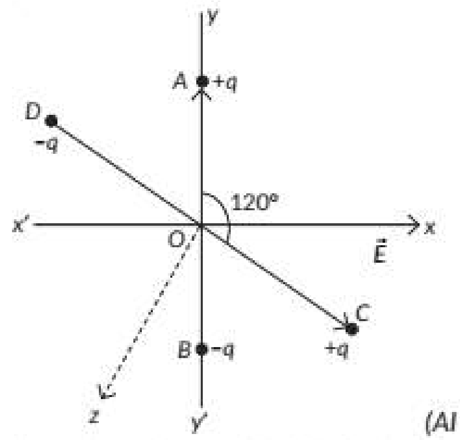
33. Derive the expression for the torque acting on an electric dipole, when it is held in a uniform electric field. Identify the orientation of the dipole in the electric field, in which it attains a stable equilibrium. (2020)

OR

If dipole were kept in a uniform external electric field E_0, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases. (2/5, AI 2017)

OR

Deduce the expression for the torque acting on a dipole of dipole moment $\vec{p}$ in the presence of a uniform electric field $\vec{E}$. (3/5, AI 2014) Cr



(AI 2020)

35. Depict the orientation of the dipole in (a) stable, (b) unstable equilibrium in a uniform electric field. (1/3, Delhi 2017) R

36. (a) Obtain the expression for the torque $\vec{\tau}$ experienced by an electric dipole of dipole moment $\vec{p}$ in a uniform electric field, $\vec{E}$.
(b) What will happen if the field were not uniform? (Delhi 2017)

37. An electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. Obtain the expression for the torque $\vec{\tau}$ experienced by the dipole. Identify two pairs of perpendicular vectors in the expression. (Delhi 2015C) Cr

LA (5 marks)

38. (a) Define torque acting on a dipole of dipole moment $\vec{p}$ placed in a uniform electric field $\vec{E}$. Express it in the vector form and point out the direction along which it acts.
(b) What happens if the field is non-uniform?
(c) What would happen if the external field $\vec{E}$ is increasing (i) parallel to $\vec{p}$ and (ii) anti-parallel to $\vec{p}$? (Foreign 2016)

1.13 Gauss's Law

MCQ

39. If the net electric flux through a closed surface is zero, then we can infer
(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.
(2020) R

40. The electric flux through a closed Gaussian surface depends upon

(a) net charge enclosed and permittivity of the medium

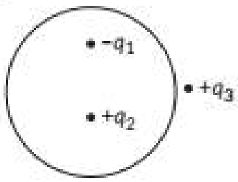
(b) net charge enclosed, permittivity of the medium and the size of the Gaussian surface

(c) net charge enclosed only

(d) permittivity of the medium only. *(2020)* U

VSA (1 mark)

41. Electric flux through a spherical surface shown in the figure, is ______.



(2020) U

42. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased? *(Delhi 2016)*

43. What is the electric flux through a cube of side 1 cm which encloses an electric dipole? *(Delhi 2015)* U

LA (5 marks)

44. An electric field is uniform and acts along +x direction in the region of positive x. It is also uniform with the same magnitude but acts in $-x$ direction in the region of negative x. The value of the field is $E = 200\ \text{N C}^{-1}$ for $x > 0$ and $E = -200\ \text{N C}^{-1}$ for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at $x = +10$ cm and the other is at $x = -10$ cm.

Find :

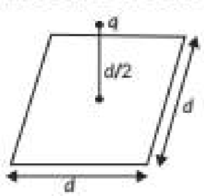
(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder.

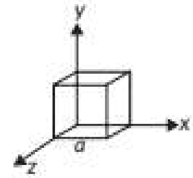
(2/5, 2020) Ap

45. (a) Define electric flux. Is it a scalar or a vector quantity?

A point charge q is at a distance of $d/2$ directly above the centre of a square of side d, as shown in the figure. Use Gauss's law to obtain the expression for the electric flux through the square.



(b) If the point charge is now moved to a distance 'd' from the centre of the square and the side of the



(2/5, Delhi 2015)

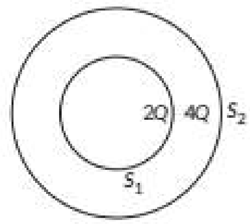
47. Define electric flux. Write its S.I. unit.

"Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is". Justify this statement with the help of a suitable example. *(AI 2015)* An

48. Consider two hollow concentric spheres S_1 and S_2, enclosing charges 2Q and 4Q respectively as shown in figure.

(i) Find out the ratio of the electric flux through them.

(ii) How will the electric flux through the sphere S_1 change if a medium of dielectric constant 'ε_r' is introduced in the space inside S_1 in place of air? Deduce the necessary expression.



(AI 2014) Ap

1.14 Applications of Gauss's Law

MCQ

49. The magnitude of electric field due to a point charge $2q$, at distance r is E. Then the magnitude of electric field due to a uniformly charged thin spherical shell of radius R with total charge q at a distance $\frac{r}{2}(r >> R)$ will be

(a) $\frac{E}{4}$ (b) 0 (c) $2E$ (d) $4E$

(Term I 2021-22) U

VSA (1 mark)

50. A point charge is placed at the centre of a hollow conducting sphere of internal radius 'r' and outer radius '$2r$'. The ratio of the surface charge density of the inner surface to that of the outer surface will be ______. *(2020)* U

51. 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 shell. What will be the surface charge density

square is doubled, explain how the electric flux will be affected. (2018) An

46. Given the electric field in the region $\vec{E}=2x\hat{i}$, find the electric flux through the cube and the charge enclosed by it.

on the (i) inner surface, and (ii) outer surface of the shell? (AI 2019)

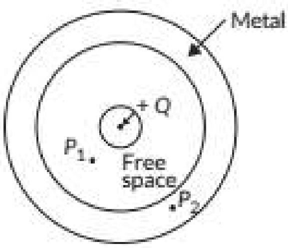
52. Does the charge given to a metallic sphere depend on whether it is hollow or solid. Give reason for your answer. (Delhi 2017)

SA I (2 marks)

53. Apply Gauss's law to show that for a charged spherical shell, the electric field outside the shell is, as if the entire charge were concentrated at the centre. (AI 2019) R

54. Two large parallel plane sheets have uniform charge densities $+\sigma$ and $-\sigma$. Determine the electric field (i) between the sheets, and (ii) outside the sheets. (AI 2019)

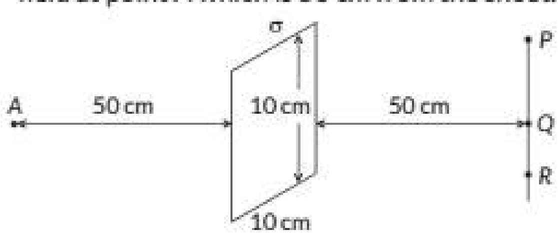
55. A small metal sphere carrying charge $+Q$ is located at the centre of a spherical cavity inside a large uncharged metallic spherical shell as shown in the figure. Use Gauss's law to find the expressions for the electric field at points P_1 and P_2.



(AI 2014) Ap

SA II (3 marks)

56. (a) A uniformly charged large plane sheet has charge density $\sigma=\left(\frac{1}{18\pi}\right)\times10^{-15}\,C/m^2$. Find the electric field at point A which is 50 cm from the sheet.

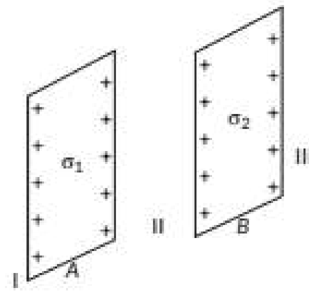


Consider a straight line with three points P, Q and R, placed 50 cm from the charged sheet on the right side as shown in the figure. At which of these points, does the magnitude of the electric field due to the sheet remain the same as that at point A and why?

(b) Two small identical conducting spheres carrying charge 10 μC and- 20 μC when separated by a distance of r, experience a force F each. If they

58. A hollow conducting sphere of inner radius r_1 and outer radius r_2 has a charge Q on its surface. A point charge $-q$ is also placed at the centre of the sphere.
(a) What is the surface charge density on the (i) inner and (ii) outer surface of the sphere?
(b) Use Gauss' law of electrostatics to obtain the expression for the electric field at a point lying outside the sphere. (AI 2020)

59. Two infinitely large plane thin parallel sheets having surface charge densities σ_1 and σ_2 $(\sigma_1 > \sigma_2)$ are shown in the figure. Write the magnitudes and directions of the net electric fields in the regions marked II and III.



(Foreign 2014) Ev

LA (5 marks)

60. State Gauss's law on electrostatics and derive an expression for the electric field due to a long straight thin uniformly charged wire (linear charge density λ) at a point lying at a distance r from the wire. (3/5, 2020)

61. Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance x from the centre of shell, such that
(i) $0 < x < R$, and
(ii) $x > R$ (3/5, 2020)

OR

Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for $r \le R$ and $r \ge R$. (3/5, 2020)

Consider a straight line with three points P, Q and R, placed 50 cm from the charged sheet on the right side as shown in the figure. At which of these points, does the magnitude of the electric field due to the sheet remain the same as that at point A and why?

(b) Two small identical conducting spheres carrying charge 10 μC and- 20 μC when separated by a distance of r, experience a force F each. If they are brought in contact and then separated to a distance of $r/2$ what is the new force between them in terms of F? *(2021C)* U

57. (a) An infinitely long thin straight wire has a uniform linear charge density λ. Obtain the expression for the electric field (E) at a point lying at a distance x from the wire, using Gauss' law.

(b) Show graphically the variation of this electric field E as a function of distance x from the wire. *(2020)*

OR

Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for $r \leq R$ and $r \geq R$. *(3/5, 2020)*

62. (a) Using Gauss' law, obtain expressions for the electric field (i) inside, and (ii) outside a positively charged spherical shell.

(b) Show graphically variation of the electric field as a function of the distance r from the centre of the sphere.

(c) A square plane sheet of side 10 cm is inclined at an angle of 30° with the direction of a uniform electric field of 200 NC^{-1}.
Calculate the electric flux passing through the sheet. *(AI 2019C)*

63. (a) Use Gauss' law to derive the expression for the electric field ($\vec{E}$) due to a straight uniformly charged infinite line of charge density λ C m^{-1}.

(b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.

(c) Find the work done in bringing a charge q from perpendicular distance r_1 to r_2 ($r_2 > r_1$). *(2018)*

64. Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ. *(2/5, AI 2017)*

OR

Use Gauss's law to find the electric field due to a uniformly charged infinite plane sheet. What is the direction of field for positive and negative charge densities? *(3/5, AI 2016)* An

65. Use Gauss's law to prove that the electric field inside a uniformly charged spherical shell is zero. *(3/5, AI 2015)*

66. A small conducting sphere of radius 'r' carrying a charge $+q$ is surrounded by a large concentric conducting shell of radius R on which a charge $+Q$ is placed. Using Gauss's law derive the expressions for the electric field at a point 'x'

(i) between the sphere and the shell ($r < x < R$).

(ii) outside the spherical shell.

(3/5, Foreign 2015) An

CBSE Sample Questions

Charging by Induction

MCQ

1. Consider an uncharged conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then,

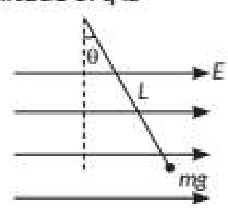
(a) negative and uniformly distributed over the surface of sphere

(b) positive and uniformly distributed over the surface of sphere

(c) negative and appears at a point surface of sphere closest to point charge

(d) zero. *(Term I 2021-22)* U

string makes a constant angle θ with the vertical. The sign and magnitude of q is



(a) positive with magnitude mg/E

(b) positive with magnitude $(mg/E)\tan\theta$

(c) negative with magnitude $mg/E \tan\theta$

(d) positive with magnitude $E \tan\theta/mg$

(Term I 2021-22) An

1.5 Coulomb's Law

MCQ

2. According to Coulomb's law, which is the correct relation for the following figure?

(a) $q_1 q_2 > 0$ (b) $q_1 q_2 < 0$
(c) $q_1 q_2 = 0$ (d) $1 > q_1/q_2 > 0$

(2022-23)

1.7 Electric Field

MCQ

3. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$ respectively. The point on x axis at which net electric field is zero due to these charges is
(a) $8L$ (b) $4L$ (c) $2L$ (d) L

(Term I 2021-22)

4. A small object with charge q and weight mg is attached to one end of a string of length 'L' attached to a stationary support. The system is placed in a uniform horizontal electric field 'E', as shown in the accompanying figure. In the presence of the field, the

1.8 Electric Field Lines

MCQ

Question 5 is Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

5. Faraday Cage : A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage.

(2020-21) An

(i) Which of the following material can be used to make a Faraday cage?
(a) Plastic (b) Glass
(c) Copper (d) Wood

(ii) Example of a real-world Faraday cage is
(a) car (b) plastic box
(c) lightning rod (d) metal rod

(iii) What is the electrical force inside a Faraday cage when it is struck by lightning?
(a) The same as the lightning
(b) Half that of the lightning
(c) Zero
(d) A quarter of the lightning

(iv) An isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have charge equal to
(a) Zero (b) $+q$
(c) $-q$ (d) $+2q$

(v) A point charge of 2 C is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be
(a) 1.9×10^5 Nm^2/C entering the surface
(b) 1.9×10^5 Nm^2/C leaving the surface
(c) 2.0×10^5 Nm^2/C leaving the surface

(c) A is true but R is false.
(d) A is false and R is also false.

(2020-21) An

1.13 Gauss's Law

MCQ

8. Which of the statement is true for Gauss law?
(a) All the charges whether inside or outside the gaussian surface contribute to the electric flux.
(b) Electric flux depends upon the geometry of the gaussian surface.
(c) Gauss theorem can be applied to non-uniform electric field.
(d) The electric field over the gaussian surface remains continuous and uniform at every point.

(Term I 2021-22) U

1.14 Applications of Gauss's Law

MCQ

(d) $2.0 \times 10^5\ Nm^2/C$ entering the surface

1.9 Electric Flux

MCQ

6. A cylinder of radius r and length l is placed in an uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by

(a) zero (b) πr^2
(c) $E\pi r^2$ (d) $2E\pi r^2$

(Term I 2021-22) Ap

1.11 Dipole in a Uniform External Field

MCQ

For question below two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below :

7. **Assertion (A) :** In a non-uniform electric field, a dipole will have translatory as well as rotatory motion

Reason (R) : In a non-uniform electric field, a dipole experiences a force as well as torque.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true, and R is not the correct explanation of A.

9. Two parallel large thin metal sheets have equal surface densities $26.4 \times 10^{-12}\ C/m^2$ of opposite signs. The electric field between these sheets is

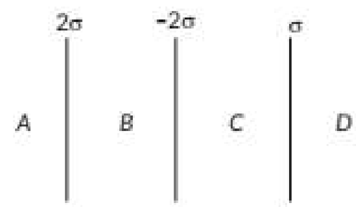
(a) 1.5 N/C (b) 1.5×10^{-16} N/C
(c) 3×10^{-10} N/C (d) 3 N/C

(Term I 2021-22) Ap

SA II (3 marks)

10. (a) State Gauss's law in electrostatics. Show that with help of suitable figure that outward flux due to a point charge Q, in vacuum within gaussian surface, is independent of its size and shape.

(b) In the figure there are three infinite long thin sheets having surface charge density $+2\sigma$, -2σ and $+\sigma$ respectively. Give the magnitude and direction of electric field at a point to the left of sheet of charge density $+2\sigma$ and to the right of sheet of charge density $+\sigma$.



(2020-21) Ev

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (c) : As X is repelled by Y, so Y is negatively charged. Now Z is attracted to Y, so either it is positively charged or neutral.

2. (b) : $q_1 = 3e, q_2 = +5e, q_3 = -3e$
The total charge, $q = q_1 + q_2 + q_3 = 3e + 5e - 3e = 5e$
As the charge is conserved, so,
in option (a), $q = 5e - 4e + 5e = 6e$
in option (b), $q = 6e + 6e - 7e = 5e$
in option (c), $q = -4e + 3.5e + 5.5e = 5e$
But, from quantisation of charge, charge $3.5e$ and $5.5e$ is not possible.
in option (d), $q = 5e - 8e + 7e = 4e$

Key Points

- According to quantisation of charge, only integral multiple of elementary charge, e is possible.

6. Final charge on each ball $= \frac{q_A + q_B}{2} = \frac{-Q + 3Q}{2} = +Q$
As both the balls have same nature of charges, hence nature of the Coulomb force is repulsive.

7. As in air, $F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$

In medium, $F' = \frac{1}{4\pi\varepsilon_0 K}\frac{q^2}{r^2}$

$\therefore F' = \frac{F}{K}$

where K is dielectric constant (or relative permittivity) of material and $K > 1$ for insulators.
Hence, the force is reduced, when a plastic sheet is inserted.

8. Let us suppose that the third charge 'Q' is placed on the line joining the first and second charge such that $AO = x$ and $OB = (2 - x)$.
Net force on each of the three charges must be zero for the system of charges to be in equilibrium.

3. (d): Initial charge, $q = 1$ C
Number of electrons gained, $n = 5 \times 10^{18}$
Charge transferred, $Q = ne$
$Q = -5 \times 10^{18} \times 1.6 \times 10^{-19} = -0.8$ C
So, net charge on object $= q + Q = 1 - 0.8 = 0.2$ C

4. (c): Force on q_0 due to $-q$

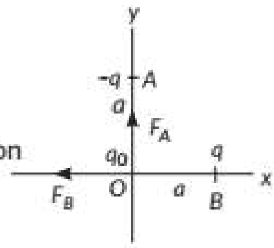
$F_A = \frac{kqq_0}{a^2}$; along y-direction

Force on q_0 due to $+q$

$F_B = \frac{kqq_0}{a^2}$ along negative x-direction

Net force on q_0

$$F = \sqrt{F_A^2 + F_B^2} = \frac{kqq_0\sqrt{2}}{a^2}$$



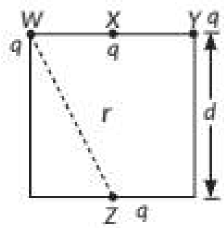
5. (b) :

Shortcut

- Here, we do not need to find force due to all the charges, only use the given condition and find force between W and Z.

Force on X by W is F.

$$F = \frac{Kq^2}{\left(\frac{d}{2}\right)^2} = \frac{4Kq^2}{d^2} \quad \text{...(i)}$$

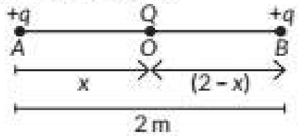


Force on Z by W,

$$r = \sqrt{d^2 + \frac{d^2}{4}} = \sqrt{\frac{5d^2}{4}}$$

$$F' = \frac{Kq^2}{\left(\sqrt{\frac{5d^2}{4}}\right)^2} = \frac{Kq^2 \times 4}{5d^2} = \frac{1}{5}F \quad \text{(Using (i)}$$

If we assume that 'Q' is positive in nature then it will experience forces due to other two charges in opposite direction and the net force on 'Q' becomes zero. But, the repulsive force acting on either 'q' will not be zero as the forces acted in same direction.



However, if charge 'Q' is taken as negative then, on a charge q forces due to other two charges will act in opposite directions. Hence, the third charge must be negative in nature.
For charge $-Q$ to be in equilibrium, the force acting on $-Q$ due to $+q$ at A and $+q$ at B should be equal and opposite.

$$\frac{1}{4\pi\varepsilon_0}\frac{Qq}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{(2-x)^2}$$

$\Rightarrow x^2 = (2 - x)^2$
$x = \pm(2 - x)$
$x = 1$ m

i.e., the position of third charge is at 1 m from either charge 'q'.

Answer Tips

- If we need to find the position of third charge between two charges, we should consider third charge placed at the centre.

9. (d): Force on a negative charge in electric field $\vec{F} = -q\vec{E}$, so it moves along the opposite direction of the electric field. So, (A) and (R) both false.

10. Given $q = 2\ \mu$C, $m = 1.6$ g $= 1.6 \times 10^{-3}$ kg,
$u = 4\hat{i}$ m s^{-1}, $\vec{E} = 80\hat{i} + 60\hat{j}$ and $t = 5$ s

$F = m\vec{a}$ (From Newton's law)
or $q\vec{E} = m\vec{a}$

$\Rightarrow 2\times10^{-6}(80\hat{i}+60\hat{j}) = (1.6\times10^{-3})\vec{a}$

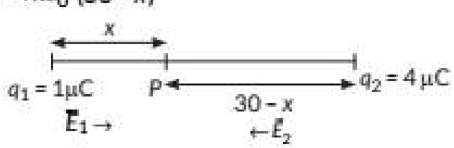
$\Rightarrow \vec{a} = 100\times10^{-3}\hat{i} + 75\times10^{-3}\hat{j}$

Now from equation of motion,

$\vec{v} = \vec{u} + \vec{a}t = 4\hat{i} + (100\times10^{-3}\hat{i} + 75\times10^{-3}\hat{j})5$
$= 4.5\hat{i} + 0.375\hat{j}$

11. Let at point P, the net electric field is zero, then

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{(30-x)^2}$$



$$\vec{F}_1 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 q_0}{r_1^2}\hat{r}_{1P}$$

where $\hat{r}_{1P}$ is a unit vector in the direction from q_1 to P and r_{1P} is the distance between q_1 and P. Hence, the electric field at point P due to charge q_1 is

$$\vec{E}_1 = \frac{\vec{F}_1}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1P}^2}\hat{r}_{1P}$$

Similarly, electric field at P due to charge q_2 is

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_2}{r_{2P}^2}\hat{r}_{2P}$$

If $\vec{E}$ is the electric field at point P due to the system of charges, then by the principle of superposition of electric fields,

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + ... + \vec{E}_n$$

$$\frac{1}{x^2}=\frac{4}{(30-x)^2}\Rightarrow x=10\text{ cm}$$

12.

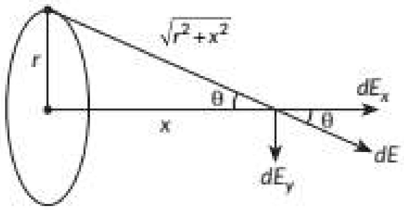
Concept Applied

- First consider an elementary charge and find associated electric field. Now, integrate the field to find net field of the ring.

Given radius = r,

$\therefore$ Circumference = $2\pi r = l$

$\therefore$ Elementary charge = $dq = \lambda dl$



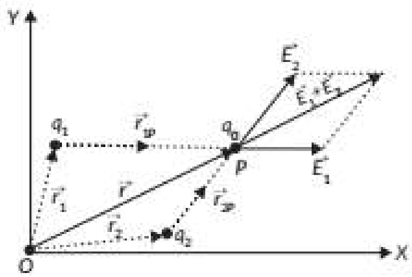
$$dE_x = dE\cos\theta = \frac{\lambda x dl}{4\pi\varepsilon_0(r^2+x^2)^{3/2}}$$

$$\therefore\ E_x = \int dE\cos\theta = \int\frac{\lambda x dl}{4\pi\varepsilon_0(r^2+x^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{x\lambda l}{(r^2+x^2)^{3/2}}$$

when $x >> r$, then

$$E=\frac{1}{4\pi\varepsilon_0}\frac{x\lambda l}{(x^2)^{3/2}}=\frac{1}{4\pi\varepsilon_0}\frac{\lambda l}{x^2}$$

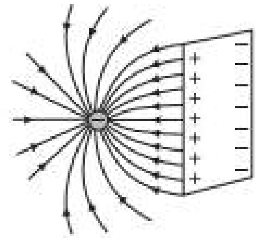
13. Consider a system of n point charges $q_1, q_2, ..., q_n$ having position vectors $\vec r_1, \vec r_2, ..., \vec r_n$ with respect to the origin O. According to Coulomb's law, the force on test charge q_0 due to charge q_1 is



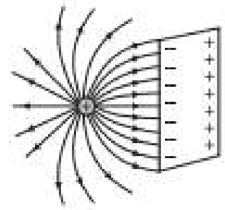
$$=\frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{q_2}\hat r_{1P}+\frac{q_1}{q_2}\hat r_{2P}+...+\frac{q_n}{r_{nP}^2}\hat r_{nP}\right]$$

or $\vec E=\frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_{iP}^2}\hat r_{iP}$

14.



15.



16. Electrostatic field lines do not form closed loops due to conservative nature of electric field.

17. At the point of intersection of two field lines, there will be two directions for the resultant electric field. This is not acceptable.

18. Electrostatic field lines do not form closed loops due to conservative nature of electric field.

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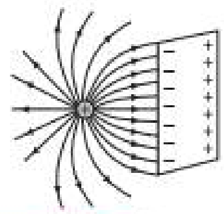
19.



Answer Tips

- Electric field lines originate from positive charge and terminate at negative charge.

20. (a): Side of square sheet = a is XY plane

$\vec E = cz^2\hat k$; Electric flux, $\phi=\vec E\cdot d\vec s$

$\phi=(cz^2\hat k)\cdot(a^2)\hat k$

$\phi = cz^2a^2$ (put $z = a$)

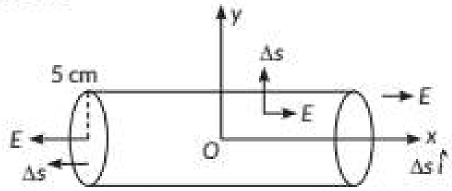
$\phi = a^4c$

26. Strength of an electric dipole is measured by its electric dipole moment, whose magnitude is equal to product of magnitude of either charge and separation between the two charges *i.e.*,

$\vec p = q\cdot(2\vec a)$

21. Flux through right circular surface, $\phi_1 = \vec{E}\cdot\Delta\vec{s}$

$\phi_1 = 100\,\Delta s$



Flux through left circular surface, $\phi_2 = \vec{E}\cdot\Delta\vec{s}$

$\phi_2 = 100\,\Delta s$

Flux through the curved surface, $\phi_3 = \vec{E}\cdot\Delta\vec{s}$

$\phi_3 = 0$

Net flux, $\phi = \phi_1 + \phi_2 + \phi_3 = 200\,\Delta s = 200 \times 3.14 \times (0.05)^2$
$= 1.57\ \text{Nm}^2/\text{C}$

22. (i) Electric flux : Total number of electric field lines crossing a surface normally is called electric flux. SI unit of electric flux is $\text{N m}^2\,\text{C}^{-1}$.

(ii) The area of a surface can be represented as a vector along normal to the surface.

Here, $\vec{E} = 3\times10^3\,\hat{i}\,\text{NC}^{-1}$

Area of the square $\Delta S = 10 \times 10\ \text{cm}^2$

$\Delta S = 100\ \text{cm}^2 = 10^{-2}\ \text{m}^2$

Since normal to the square is along x-axis, we have

$\Delta S = 10^{-2}\,\hat{i}\ \text{m}^2$

Electric flux through the square,

$\phi = \vec{E}\cdot\Delta\vec{S} = (3\times10^3\hat{i})\cdot(10^{-2}\hat{i})$

$\phi = 30\ \text{N m}^2\,\text{C}^{-1}$

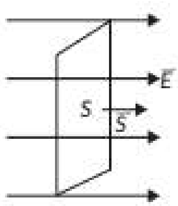
23. Here, $\vec{E} = 5\times10^3\,\hat{i}$ N/C

Side of square $= a = 10$ cm $= 0.1$ m

Area of square, $S = a^2 = (0.1)^2 = 0.01\ \text{m}^2$

Case I : Area vector is along x-axis,

$\vec{S} = 0.01\hat{i}\ \text{m}^2$



Required flux, $\phi = \vec{E}\cdot\vec{S}$

$\Rightarrow \phi = (5\times10^3\hat{i})\cdot(0.01\hat{i}) \Rightarrow \phi = 50\ \text{N m}^2/\text{C}$

Case II : Plane of the square makes a 30° angle with the x-axis. Here, angle between area vector and the electric field is 60°.

So, required flux $\phi' = E\cdot S\cos\theta$

$= (5\times10^3)(10^{-2})\cos 60° = 25\ \text{N m}^2/\text{C}$

Concept Applied

- Electric field is always perpendicular to an equipotential surface.

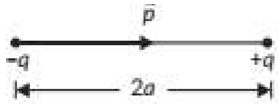
24. (d) : For stable equilibrium, $\theta = 0°$

Potential energy, $U = -\vec{p}\cdot\vec{E} = -pE\cos0° = -pE = -2qLE$

25. $\vec{\tau} = \vec{p}\times\vec{E}$

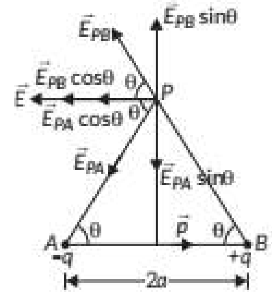
τ is maximum, when angle between electric field and the dipole moment is 90°.

and is directed from negative to positive charge, along the line joining the two charges. Its SI unit is C m.



(Vertical component cancel each other)

or $E_{net} = 2E_{PA}\cos\theta \quad (E_{PA} = E_{PB})$



$$E_{net} = 2\cdot\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\cdot\frac{a}{(r^2+a^2)^{1/2}}$$

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{q.2a}{(r^2+a^2)^{3/2}}$$

or $$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}}$$

directed antiparallel to dipole moment $\vec{p}$. For short dipole, when $r >>> a$, then electric field at point P is

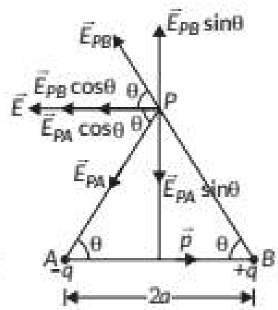
$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

In vectorial form, the electric field intensity at point P on the perpendicular bisector of short electric dipole is then given by $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{-\vec{p}}{r^3}\cdot\hat{r}$

Concept Applied

- Electric field on the equatorial line of an electric dipole : Magnitude of electric field at any point on the perpendicular bisector of an electric dipole at distance r from its centre is, $E_{net} = E_x$

27. Electric field on the equatorial line of an electric dipole : Electric field at any point on the perpendicular bisector of an electric dipole at distance r from its centre is



$E_{net} = E_x = E_{PA}\cos\theta + E_{PB}\cos\theta$

(Vertical component cancel each other)

or $E_{net} = 2E_{PA}\cos\theta \quad (E_{PA} = E_{PB})$

$$E_{net} = 2\cdot\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\cdot\frac{a}{(r^2+a^2)^{1/2}}$$

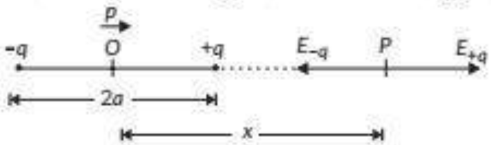
$$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{q.2a}{(r^2+a^2)^{3/2}} \quad \text{or } E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}}$$

directed antiparallel to dipole moment $\vec{p}$. For short dipole, when $r >>> a$, then electric field at point P is

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

In vectorial form, the electric field intensity at point P on the perpendicular bisector of short electric dipole is then given by $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{-\vec{p}}{r^3}\cdot\hat{r}$

28. (a) Electric field at an axial point of an electric dipole. Let us consider an electric dipole consisting of charges $+q$ and $-q$, separated by distance $2a$ and placed in vacuum. Let P be a point on the axial line at distance r from the centre O of the dipole on right side of the charge $+q$.



Electric field at an axial point of dipole

$$\vec{E}_{-q} = \frac{-q}{4\pi\varepsilon_0(r+a)^2}\hat{p} \text{ (towards left)}$$

where $\hat{p}$ is a unit vector along the dipole axis from $-q$ to $+q$.

Electric field due to charge $+q$ at point P is

$$\vec{E}_{+q} = \frac{q}{4\pi\varepsilon_0(r-a)^2}\hat{p} \text{ (towards right)}$$

Hence the resultant electric field at point P is

$$\vec{E}_{axial} = \vec{E}_{+q} + \vec{E}_{-q} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$$

$$= \frac{q}{4\pi\varepsilon_0}\cdot\frac{4ar}{(r^2-a^2)^2}\hat{p}$$

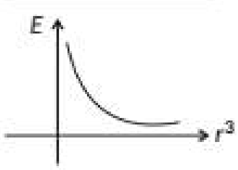
or $\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2pr}{(r^2-a^2)^2}\hat{p}$

Here $p = q \times 2a$ = dipole moment

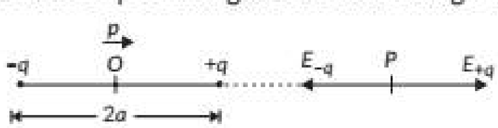
For $r >> a$, a^2 can be neglected as compared to r^2.

or $\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3}\hat{p}$ (towards right)

(b)



29. Electric field at an axial point of an electric dipole. Let us consider an electric dipole consisting of charges $+q$ and $-q$, separated by distance $2a$ and placed in vacuum. Let P be a point on the axial line at distance r from the centre O of the dipole on right side of the charge $+q$.



where $\hat{p}$ is a unit vector along the dipole axis from $-q$ to $+q$.

Electric field due to charge $+q$ at point P is

$$\vec{E}_{+q} = \frac{q}{4\pi\varepsilon_0(x-a)^2}\hat{p} \text{ (towards right)}$$

Hence the resultant electric field at point P is

$$\vec{E}_{axial} = \vec{E}_{+q} + \vec{E}_{-q} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(x-a)^2} - \frac{1}{(x+a)^2}\right]\hat{p}$$

$$= \frac{q}{4\pi\varepsilon_0}\cdot\frac{4ar}{(x^2-a^2)^2}\hat{p} \text{ or } \vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2pr}{(x^2-a^2)^2}\hat{p}$$

Here $p = q \times 2a$ = dipole moment

For $x >> a$, a^2 can be neglected as compared to r^2.

or $\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2\vec{p}}{x^3}$ (towards right)

30. (a): Given : $2l = 2$ cm, $\theta = 30°$, $E = 2 \times 10^5$ N/C

$\tau = 8 \times 10^{-3}$ Nm

$\tau = PE \sin\theta$

$8 \times 10^{-3} = p \times 2 \times 10^5 \times \sin 30°$

$p = 8 \times 10^{-8}$ cm

Let the charge is q

$p = q \times 2l$

$8 \times 10^{-8} = q \times 2 \times 10^{-2} \Rightarrow q = 4\mu C$

31. (c) : An electric dipole in a non-uniform electric field always experience a force and a torque.

32. The torque $\vec{\tau}$ acting on a dipole of dipole moment $\vec{p}$ placed in an electric field $\vec{E}$ is given by

$\vec{\tau} = \vec{p} \times \vec{E}$

$\tau = pE \sin\theta$

where θ = Angle between dipole moment and electric field.

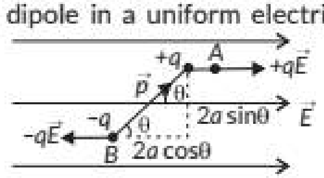
33.

Concept Applied

- To find the torque on the dipole, find torque of force on each of the charges individually.

Torque on a dipole in uniform electric field:

When electric dipole is placed in a uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on an electric dipole in a uniform electric field is zero.



However these forces are not collinear, so they give rise to some torque on the dipole given by

Electric field at an axial point of dipole

$$\vec{E}_{-q} = \frac{-q}{4\pi\varepsilon_0 (x+a)^2}\hat{p} \quad \text{(towards left)}$$

Torque = Magnitude of either force

× Perpendicular distance between them

$\tau = Fr_{\perp} = qE.2a \sin\theta = q2a.E \sin\theta$

or $\tau = pE \sin\theta$

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

In vectorial form, $\vec{\tau} = \vec{p} \times \vec{E}$

(a) When $\theta = 0°$ or $180°$ then $\tau_{min} = 0$

(b) When $\theta = 90°$ then $\tau_{max} = pE$

Thus, torque on a dipole tends to align it in the direction of uniform electric field.

If the field is not uniform in that condition the net force on electric dipole is not zero.

When $\theta = 0$; $\tau = 0$ and $\vec{p}$ and $\vec{E}$ are parallel and the dipole is in a position of stable equilibrium.

34. Given, AB and CD are dipoles kept at an angle of 120° to each other.

Resultant magnetic dipole moment is given by,

$$\vec{p}_r = \sqrt{p^2 + p^2 + 2pp\cos 120°}$$

$$= \sqrt{2p^2 + 2p^2 \cos 120°}$$

$$= \sqrt{2p^2 + (2p^2) \times \left(-\frac{1}{2}\right)}$$

$$= \sqrt{2p^2 - p^2} = p$$

Resultant magnetic dipole makes an angle 60° with Y-axis or 30° with x-axis.

Now, torque is given by

$\tau = \vec{p} \times \vec{E}$

$= pE \sin\theta$

$= pE \sin 30°$

$= \frac{1}{2} pE$

Direction of torque is along negative Z-direction.

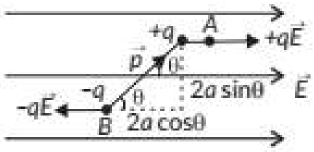
Thus, torque on a dipole tends to align it in the direction of uniform electric field.

(b) If the field is not uniform in that condition the net force on electric dipole is not zero.

When $\theta = 0$; $\tau = 0$ and $\vec{p}$ and $\vec{E}$ are parallel and the dipole is in a position of stable equilibrium.

37. Torque on a dipole in uniform electric field:

When electric dipole is placed in a uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on an electric dipole in a uniform electric field is zero.



However these forces are not collinear, so they give rise to some torque on the dipole given by

Torque = Magnitude of either force

× Perpendicular distance between them

$\tau = Fr_{\perp} = qE.2a \sin\theta = q2a.E \sin\theta$

or $\tau = pE \sin\theta$

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

In vectorial form, $\vec{\tau} = \vec{p} \times \vec{E}$, here $\vec{\tau}$ is perpendicular to $\vec{p}$ and $\vec{\tau}$ is perpendicular to $\vec{E}$ also.

Answer Tips

- If the field is not uniform in that condition the net force on electric dipole is not zero.

When $\theta = 0$; $\tau = 0$ and $\vec{p}$ and $\vec{E}$ are parallel and the dipole is in a position of stable equilibrium.

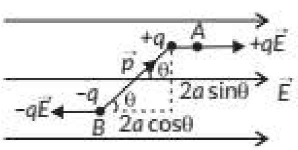
35. (a) We know, torque $\tau = pE\sin\theta$

when $\theta = 0$; $\tau = 0$ and $\vec{p}$ and $\vec{E}$ are parallel and the dipole is in a position of stable equilibrium.

(b) When $\theta = 180°$, $\tau = 0$ and $\vec{p}$ and $\vec{E}$ are anti-parallel and the dipole is in a position of unstable equilibrium.

36. (a) Torque on a dipole in uniform electric field:

When electric dipole is placed in a uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on an electric dipole in a uniform electric field is zero.



However these forces are not collinear, so they give rise to some torque on the dipole given by

Concept Applied

- $\vec{\tau} = \vec{p} \times \vec{E}$

Here, $\vec{\tau}$ is perpendicular to both $\vec{p}$ and $\vec{E}$

∴ Pairs of perpendicular vectors are

(a) $(\vec{\tau}, \vec{p})$ (b) $(\vec{\tau}, \vec{E})$

38. (a) Suppose an electric dipole of dipole moment $\vec{p}$ is placed along a direction, making an angle θ with the direction of an external uniform electric field $\vec{E}$. Then, the torque acting on the dipole is defined as $pE \sin\theta$ or $\vec{\tau} = \vec{p} \times \vec{E}$.

Its direction will be perpendicular to both $\vec{p}$ and $\vec{E}$.

(b) If the field is non-uniform there would be a net force on the dipole in addition to the torque and the resulting

Torque = Magnitude of either force

× Perpendicular distance between them

$\tau = Fr_{\perp} = qE.2a\sin\theta = q2a.E\sin\theta$

or $\tau = pE\sin\theta$

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

In vectorial form, $\vec{\tau} = \vec{p} \times \vec{E}$

(i) When $\theta = 0°$ or $180°$ then $\tau_{min} = 0$

(ii) When $\theta = 90°$ then $\tau_{max} = pE$

motion would be a combination of translation and rotation.

(c) (i) $\vec{E}$ is increasing parallel to $\vec{p}$ then $\theta = 0°$.

So torque becomes zero but the net force on the dipole will be in the direction of increasing electric field and hence it will have linear motion along the dipole moment.

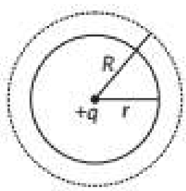
(ii) $\vec{E}$ is increasing anti-parallel to $\vec{p}$. So, the torque still remains zero but the net force on the dipole will be in the direction of increasing electric field which is opposite to the dipole moment, hence it will have linear motion opposite to the dipole moment.

39. (a): As $\phi = \frac{q}{\varepsilon_0}, \phi = 0 \Rightarrow q = 0$

40. (a): Net charge enclosed and permittivity of the medium.

41. The total electric flux through a surface, $\phi = \frac{Q}{\varepsilon_0}$, where Q is the charge enclosed by the surface. Here $\phi = \frac{q_2 - q_1}{\varepsilon_0}$.

42. According to Gauss's law, the electric flux passing through a closed surface is given by



$\oint \vec{E} \cdot d\vec{s} = \frac{q_{enclosed}}{\varepsilon_0}$

When radius of spherical Gaussian surface is increased, its surface area will be increased but point charge enclosed in the sphere remains same. Hence there will be no change in the electric flux.

43. According to Gauss's law,

Total charge enclosed, $q_{en} = 0$

as net charge on dipole is zero.

$\therefore \quad \phi_E = \frac{0}{\varepsilon_0} = 0$

Key Points

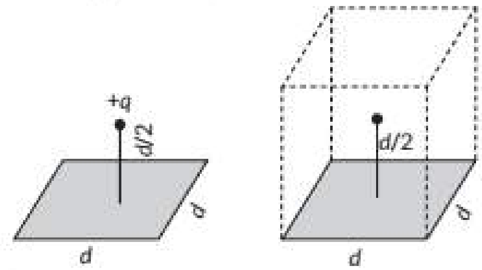
- Net flux through a closed surface,

  $\phi_E = \oint \vec{E} \cdot d\vec{s} = \frac{q_{en}}{\varepsilon_0}$

44. (i) Given $l = 20$ cm, $r = 5$ cm $= 0.05$ m

Net flux, $\phi = \int E \cdot dA + \int E \cdot dA = 200\pi(0.05)^2 \cos 0 \times 2$

Let us assume that the given square be one face of the cube of edge d cm. As charge of q is at distance of $d/2$ above the centre of a square, so it is enclosed by the cube. Hence by Gauss's theorem, electric flux linked with the cube is



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

So, the magnitude of the electric flux through the square is

$\phi_{sq} = \frac{\phi}{6} = \frac{q}{6\varepsilon_0}$

(b) Here distance of point charge becomes doubled and also sides of square gets doubled.

Same kind of symmetry is still here with sides of cube $2d$, hence electric flux through the square will not be affected

i.e., $\phi_{sq} = \frac{q}{6\varepsilon_0}$.

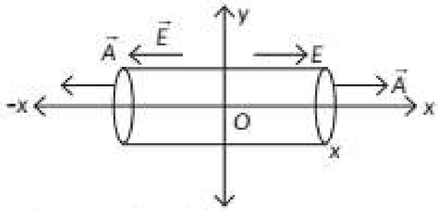
Hence, there will be no change in electric flux.

Concept Applied

- To find electric field in such cases, we have to assume a symmetrical Gaussian surface. Then, find the electric flux associated with the Gaussian surface. Now, find the flux through the asked surface by using unitary method.

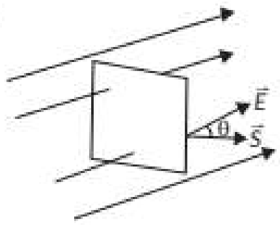
46. $\vec{E} = 2x\hat{i}$

$= \pi \text{ N m}^2\text{C}^{-1}$



(ii) The net charge enclosed, $q = \phi_1 \varepsilon_0$
$= \pi \text{ N m}^2 \text{C}^{-1} \times 8.85 \times 10^{-12} \text{C}^2 \text{N}^{-1} \text{m}^{-2}$
$= 27.789 \times 10^{-12}$ C

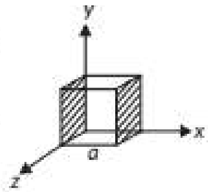
45. (a) Electric flux linked with a surface is the number of electric lines of force cutting through a surface normally and is measured as surface integral of electric field over that surface S *i.e.*,



$$\phi = \int_s \vec{E} \cdot d\vec{S}$$

It is a scalar quantity.

So, flux passes through faces of cube which are perpendicular to x-axis.



The magnitude of electric field at the left face ($x = 0$), $E_L = 0$

The magnitude of electric field at the right face,
($x = a$), $E_R = 2a$

So, net flux, $\phi = \vec{E} \cdot \Delta\vec{s}$
$= E_L \Delta s \cos 180° + E_R \Delta s \cos 0°$
$= 0 + 2a \times a^2 = 2a^3$

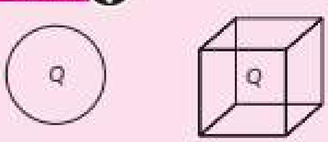
Assume enclosed charge is q.

Use Gauss's law, $\phi = \frac{q}{\varepsilon_0}$; $q = \varepsilon_0 \phi \therefore q = 2a^3 \varepsilon_0$

47. Electric flux linked with a surface is the number of electric lines of force cutting through the surface normally. Its SI unit is N m^2 C^{-1} or V m. On decreasing the radius of spherical surface to half there will be no effect on the electric flux.

Let us take a charge Q inside a cube or a sphere.

Key Points



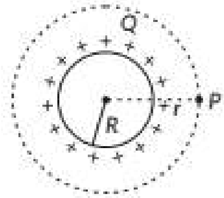
The flux through both the closed surfaces will be same. *i.e.*, $\phi_{net} = \frac{Q}{\varepsilon_0}$

48. (i) Charge enclosed by sphere $S_1 = 2Q$
By Gauss law, electric flux through sphere S_1 is
$\phi_1 = 2Q/\varepsilon_0$
Charge enclosed by sphere,
$S_2 = 2Q + 4Q = 6Q$
$\phi_2 = 6Q/\varepsilon_0$
The ratio of the electric flux is
$\phi_1 : \phi_2 = 2 : 6 = 1 : 3$

(ii) When a medium of dielectric constant ε_r is introduced in sphere S_1, the flux through S_1 would be $\phi_1' = \frac{2Q}{\varepsilon_0 \varepsilon_r}$

Charge will be distributed uniformly over the surface of the sphere.

53. Using Gauss's theorem at point P,



$$\oint \vec{E} \cdot d\vec{s} = \frac{Q}{\varepsilon_0}$$

$$\int E \, 4\pi r^2 \cos 0° = \frac{Q}{\varepsilon_0}$$

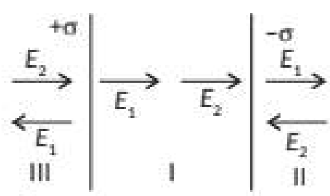
($\because$ E is constant throughout the surface)

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

Key Points

- This is same as electric field due to a point charge which can be assumed to be concentrated at the centre.

54. The direction of electric field in various regions is given as follows :



$$E_1 = E_2 = \frac{\sigma}{2\varepsilon_0}$$

(i) $E_{net} = |\vec{E_1} + \vec{E_2}| = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

49. (c): Electric field due to a point charge (2q) at distance r is E.

So, $E = \frac{K \cdot 2q}{r^2}$ ...(i)

Electric field due to thin shell at $r/2$ charge q is

$E' = \frac{K \cdot q}{(r/2)^2} = \frac{Kq \times 4}{r^2}$ ...(ii)

On dividing eqn. (i) by (ii),

$\frac{E}{E'} = \frac{K \cdot 2q}{r^2} \times \frac{r^2}{Kq \times 4} = \frac{1}{2}$; $E' = 2E$

50. Let the charge on inner surface be q, then $\sigma_{in} = \frac{q}{4\pi r^2}$

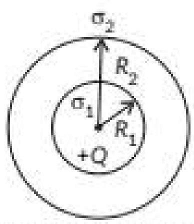
Then charge on outer surface will be $-q$, then

$\sigma_{out} = \frac{-q}{4\pi(2r)^2} = \frac{-q}{16\pi r^2}$

$\therefore \frac{\sigma_{in}}{\sigma_{out}} = \frac{\frac{q}{4\pi r^2}}{\frac{-q}{16\pi r^2}} = \frac{-4}{1}$

51. (i) Charge induced on the inner surface = $-Q$

$\therefore \sigma_1 = \frac{-Q}{4\pi R_1^2}$



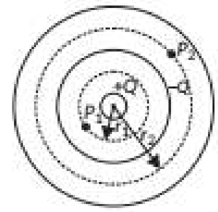
(ii) Charge induced on the outer surface = $+Q$

$\therefore \sigma_2 = \frac{Q}{4\pi R_2^2}$

52. No, the charge given to a metallic sphere does not depend on whether it is hollow or solid because all the charges will move to the outer surface of the sphere.

(ii) $E_{net} = E_1 - E_2 = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

55. Using Gauss's theorem, electric field at P_1



$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_1^2}$

Again field at P_2,

$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_2^2} = 0$

Because electric field inside a conductor is zero.

Commonly Made Mistake

- Here, while applying the Gauss law over a Gaussian surface, students might think that the calculated electric field is only due to the charges inside the Gaussian surface, but it is the resultant electric field of all the charges, present there.

56. (a) Electric field due to a uniformly charged sheet

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

$E = \frac{1 \times 10^{-15} \times 4\pi \times 9 \times 10^9}{18\pi \times 2}$ $\left(\because \frac{1}{\varepsilon_0} = 4\pi \times 9 \times 10^9\right)$

$E = 10^{-6}$ N/C outwards.

Point is Q

As, for the finite plane sheet, electric field is uniform in the middle and the edges it will be curved.

(b) $q_1 = 10\,\mu$C, $q_2 = -20\,\mu$C

$F = \frac{kq_1q_2}{r^2} = \frac{k \times 10 \times 20 \times 10^{-12}}{r^2}$

Whey they bought in contact,

$q_1' = q_2' = \frac{10-20}{2} = -5\,\mu\text{C}, r' = \frac{r}{2}$

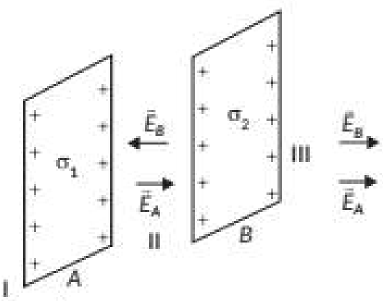
$F' = \frac{k \times 5 \times 5 \times 10^{-12} \times 4}{r^2}$

$\frac{F'}{F} = \frac{5 \times 5 \times 4 \times 10^{-12}}{10 \times 20 \times 10^{-12}} \Rightarrow F' = \frac{F}{2}$

57. (a) Electric field intensity due to line charge or infinite long uniformly charged wire at point P at distance r from it is obtained as :

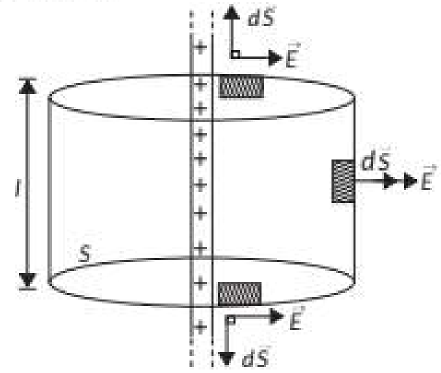
Assume a cylindrical gaussian surface S with charged wire on its axis and point P on its surface, then net electric flux

59.



In region II :

The electric field due to the sheet of charge A will be from left to right (along the positive direction) and that due to the sheet of charge B will be from right to left (along the negative direction). Therefore, in region II, we have through surface S is



$$\phi = \oint_S \vec{E}\cdot d\vec{S} = \int_{\substack{\text{upper}\\\text{plane}\\\text{face}}} EdS\cos 90^\circ + \int_{\substack{\text{curved}\\\text{surface}}} EdS\cos 0^\circ + \int_{\substack{\text{lower}\\\text{plane}\\\text{face}}} EdS\cos 90^\circ$$

or $\phi = 0 + EA + 0$ or $\phi = E.2\pi rl$

But by Gauss's theorem $\phi = \dfrac{q}{\varepsilon_0} = \dfrac{\lambda l}{\varepsilon_0}$

Where q is the charge on length l of wire enclosed by cylindrical surface S, and λ is uniform linear charge density of wire.

$\therefore \quad E \times 2\pi rl = \dfrac{\lambda l}{\varepsilon_0}$ or $E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$

directed normal to the surface of charged wire.

(b) Since $E = \dfrac{\lambda}{2\pi\varepsilon_0 r} \Rightarrow E \propto \dfrac{1}{r}$

Therefore, plot of E versus r will be as shown.

58. (a) Surface charge density on the inner surface $= \dfrac{-q}{4\pi r_1^2}$

On the outer surface $= \dfrac{Q-q}{4\pi r_2^2}$

(b) For a spherical Gaussian surface $x > r_2$

$$\oint \vec{E}\,\overline{ds} = \frac{Q-q}{\varepsilon_0}$$

$$E \times 4\pi x^2 = \frac{Q-q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q-q}{x^2}$$

$$E = \frac{\sigma_1}{2\varepsilon_0} + \left(-\frac{\sigma_2}{2\varepsilon_0}\right)$$

$\vec{E} = \dfrac{1}{2\varepsilon_0}(\sigma_1 - \sigma_2)$ along positive direction

In region III :

The electric fields due to both the charged sheets will be from left to right, *i.e.*, along the positive direction. Therefore, in region III, we have

$$E = \frac{\sigma_1}{2\varepsilon_0} + \frac{\sigma_2}{2\varepsilon_0}$$

$\vec{E} = \dfrac{1}{2\varepsilon_0}(\sigma_1 + \sigma_2)$ along positive direction

Commonly Made Mistake

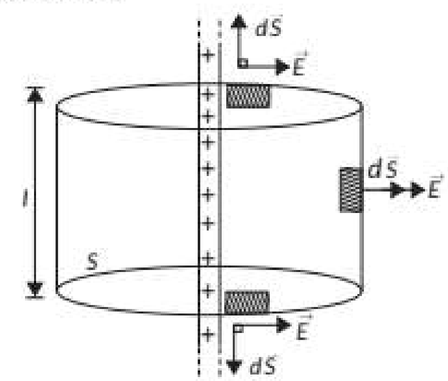
- Electric field due to a non conducting sheet is $\dfrac{\sigma}{2\varepsilon_0}$, but for conducting surface it is $\dfrac{\sigma}{\varepsilon_0}$.

60. According to Gauss's law, total flux over a closed surface S in vacuum is $\dfrac{1}{\varepsilon_0}$ times the total charge enclosed by closed surface S

$$\phi = \oint_S \vec{E}\cdot\overline{ds} = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$

Electric field intensity due to line charge or infinite long uniformly charged wire at point P at distance r from it is obtained as :

Assume a cylindrical gaussian surface S with charged wire on its axis and point P on its surface, then net electric flux through surface S is



$$\phi = \oint_S \vec{E}\cdot d\vec{S} = \int_{\substack{\text{upper}\\\text{plane}\\\text{face}}} EdS\cos 90^\circ + \int_{\substack{\text{curved}\\\text{surface}}} EdS\cos 0^\circ + \int_{\substack{\text{lower}\\\text{plane}\\\text{face}}} EdS\cos 90^\circ$$

However there is no charge enclosed by this Gaussian surface. Hence using Gauss's Law

$E \times 4\pi r^2 = 0$ Gaussian

or $\phi = 0 + EA + 0$ or $\phi = E.2\pi rl$

But by Gauss's theorem $\phi = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$

Where q is the charge on length l of wire enclosed by cylindrical surface S, and λ is uniform linear charge density of wire.

$\therefore \quad E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}$ or $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

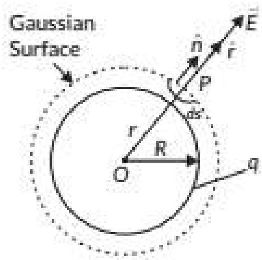
directed normal to the surface of charged wire.

61. Consider a thin spherical shell of radius R carrying charge q. To find the electric field outside the shell, we consider a spherical Gaussian surface of radius r (> R), concentric with given shell.

The electric field $\vec{E}$ is same at every point of Gaussian surface and directed radially outwards (as is unit vector $\hat{n}$ so that $\theta = 0°$)

According to Gauss's theorem,

$$\oint_s \vec{E} \cdot \vec{ds} = \oint_s \vec{E} \cdot \hat{n}\, ds = \frac{q}{\varepsilon_0}$$



or $E \oint_s ds = \frac{q}{\varepsilon_0}$

$\therefore \quad E(4\pi r^2) = \frac{q}{\varepsilon_0}$

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

Vectorially, $\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$

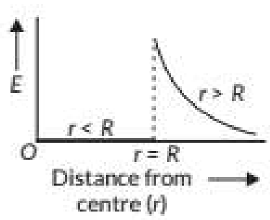
Special cases

At the point on the surface of the shell, $r = R$

$\therefore \quad E = \frac{1}{4\pi\varepsilon_0} \frac{q}{R^2}$

If σ is the surface charge density on the shell then $q = 4\pi R^2 \sigma$

$\therefore \quad E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4\pi R^2 \sigma}{R^2} = \frac{\sigma}{\varepsilon_0}$



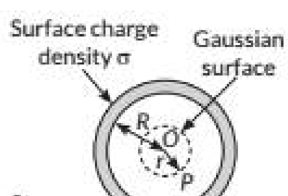
If the point P lies inside the spherical shell then the Gaussian surface encloses no charge.

i.e., $r < R$

$\because \quad q = 0$, hence $E = 0$

62. (a) (i) Inside

The point P is inside the spherical shell. The Gaussian surface is a sphere is a sphere through P centered at 'O'

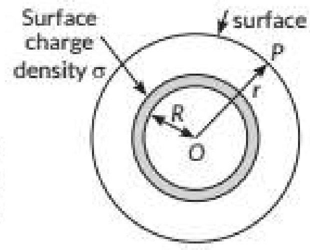


Flux through this surface = $E \times 4\pi r^2$

$\Rightarrow \quad E = 0$

Outside

To calculate Electric Field $\vec{E}$ at the outside point P, we take the Gaussian surface to be a sphere of radius 'r' and with center O, passing through P.



(a)

Electric flux through the Gaussian surface

$\phi = E \times 4\pi r^2$

Charge enclosed by this Gaussian surface = $\sigma \times 4\pi R^2$

By Gauss's Law

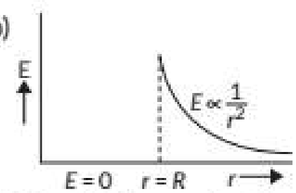
$$E \times 4\pi r^2 = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} = \frac{q}{\varepsilon_0}$$

Where q = total charge on the spherical shell.

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

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

(b)



(c) Electric flux passing through the square sheet

$\phi = \int \vec{E} \cdot \vec{ds}$

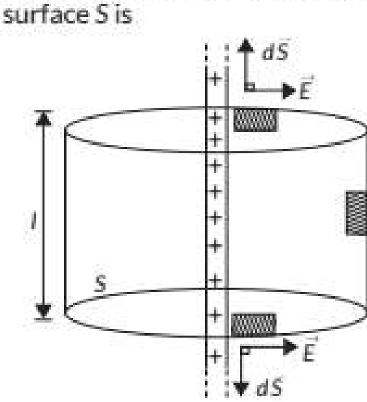
$= EA\cos\theta$

$= 200 \times 0.01 \times \cos 60°$

$= 1.0\ \text{Nm}^2/\text{C}$

63. (a) Electric field intensity due to line charge or infinite long uniformly charged wire at point P at distance r from it is obtained as :

Assume a cylindrical gaussian surface S with charged wire on its axis and point P on its surface, then net electric flux through surface S is



$$\phi = \oint_S \vec{E} \cdot \vec{dS} = \int_{\substack{\text{upper}\\\text{plane}\\\text{face}}} EdS\cos 90° + \int_{\substack{\text{curved}\\\text{surface}}} EdS\cos 0° + \int_{\substack{\text{lower}\\\text{plane}\\\text{face}}} EdS\cos 90°$$

or $\phi = 0 + EA + 0$ or $\phi = E.2\pi rl$

But by Gauss's theorem, $\phi = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$

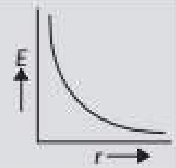
Where q is the charge on length l of wire enclosed by cylindrical surface S, and λ is uniform linear charge density of wire.

$\therefore \quad E \times 2\pi r l = \frac{\lambda l}{\varepsilon_0}$ or $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

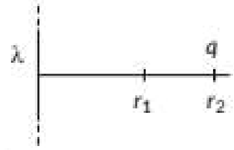
directed normal to the surface of charged wire.

(b) Since $E = \frac{\lambda}{2\pi\varepsilon_0 r} \Rightarrow E \propto \frac{1}{r}$

Therefore plot of E versus r will be as shown.



(c) As per the situation, charge q is kept at a distance r_2 from line charge.



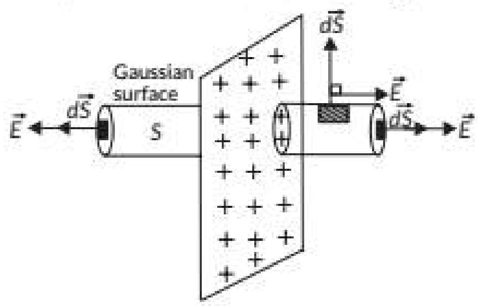
$E_{(r_2)} = \frac{\lambda}{2\pi\varepsilon_0 r_2}$ and $E'_{(r_1)} = \frac{\lambda}{2\pi\varepsilon_0 r_1}$

Work done in moving charge q form r_2 to r_1.

$$W = \int_{r_2}^{r_1} \vec{F} \cdot d\vec{r} = \int_{r_2}^{r_1} \frac{q\lambda}{2\pi\varepsilon_0 r} dr \cos 0^\circ = \frac{q\lambda}{2\pi\varepsilon_0} \int_{r_2}^{r_1} \frac{dr}{r}$$

$$= \frac{q\lambda}{2\pi\varepsilon_0} [\ln r]_{r_2}^{r_1} = \frac{q\lambda}{2\pi\varepsilon_0} \ln \frac{r_1}{r_2}$$

64. Assume a cylindrical Gaussian surface S cutting through plane sheet of charge, such that point P lies on its plane face, then net electric flux through surface S is



$$\phi = \oint_S \vec{E} \cdot d\vec{s} = \int_{\substack{\text{left}\\\text{plane}\\\text{face}}} \vec{E} \cdot d\vec{s} + \int_{\substack{\text{curved}\\\text{surface}}} \vec{E} \cdot d\vec{s} + \int_{\substack{\text{right}\\\text{plane}\\\text{face}}} \vec{E} \cdot d\vec{s}$$

or $\phi = \int_{\substack{\text{left}\\\text{plane face}}} E ds \cos 0^\circ + \int_{\substack{\text{curved}\\\text{surface}}} E ds \cos 90^\circ + \int_{\substack{\text{right}\\\text{plane face}}} E ds \cos 0^\circ$

or $\quad \phi = EA + 0 + EA = 2EA$

But by Gauss's theorem $\phi = \frac{q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0}$

Commonly Made Mistake

- Students think that, here the shape of Gaussian surface is only cylindrical, but it can be cuboidal also.

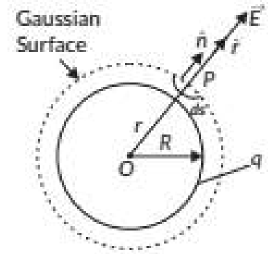
65. Consider a thin spherical shell of radius R carrying charge q. To find the electric field outside the shell, we consider a spherical Gaussian surface of radius r (> R), concentric with given shell.

The electric field $\vec{E}$ is same at every point of Gaussian surface and directed radially outwards (as is unit vector $\hat{n}$ so that $\theta = 0°$)

According to Gauss's theorem,

$\oint_s \vec{E} \cdot \overline{ds} = \oint_s \vec{E} \cdot \hat{n}\, ds = \frac{q}{\varepsilon_0}$

or $E \oint_s ds = \frac{q}{\varepsilon_0} \therefore \quad E(4\pi r^2) = \frac{q}{\varepsilon_0}$



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

Vectorially, $\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$

Special cases

At the point on the surface of the shell, $r = R$

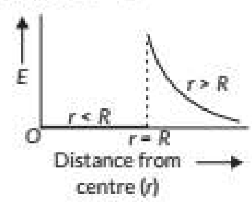
$\therefore \quad E = \frac{1}{4\pi\varepsilon_0} \frac{q}{R^2}$

If σ is the surface charge density on the shell then $q = 4\pi R^2 \sigma$

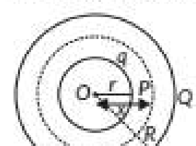
$\therefore \quad E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4\pi R^2 \sigma}{R^2} = \frac{\sigma}{\varepsilon_0}$

If the point P lies inside the spherical shell then the Gaussian surface encloses no charge.

i.e., $r < R \because q = 0$, hence $E = 0$



66. (i) Consider a sphere of radius r with centre O surrounded by a large concentric conducting shell of radius R.



To calculate the electric field intensity at any point P, where $OP = x$, imagine a Gaussian surface with centre O and radius x, as shown in the figure.

The total electric flux through the Gaussian surface is given by where q is the charge in area A of sheet enclosed by cylindrical surface S and σ is uniform surface charge density of sheet.

$\therefore \quad 2EA = \frac{\sigma A}{\varepsilon_0}$ or $E = \frac{\sigma}{2\varepsilon_0}$

directed normal to surface of charged sheet (i) away from it, if it is positively charged and (ii) towards it, if it is negatively charged.

$\phi = \oint E ds = E \oint ds$

Now, $\oint ds = 4\pi x^2$

$\therefore \quad \phi = E \times 4\pi x^2$ ...(i)

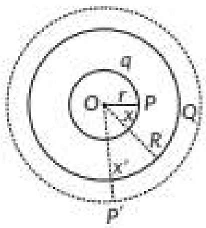
Since the charge enclosed by the Gaussian surface is q, according to Gauss's theorem,

$\phi = \frac{q}{\varepsilon_0}$ ...(ii)

From (i) and (ii), we get

$E \times 4\pi x^2 = \frac{q}{\varepsilon_0} \Rightarrow E = \frac{q}{4\pi\varepsilon_0 x^2}$

(ii) To calculate the electric field intensity at any point P', where point P' lies outside the spherical shell, imagine a Gaussian surface with centre O and radius x', as shown in the figure.



According to Gauss's theorem,

$E'(4\pi x'^2) = \frac{q+Q}{\varepsilon_0} \Rightarrow E' = \frac{q+Q}{4\pi\varepsilon_0 x'^2}$

Concept Applied

- Here, $-q$ charge will induce on inner surface of lager shell. Thus, net charge on outer surface of the larger shell will be $Q + q$.

CBSE Sample Questions

1. (d) : Equal and opposite charges appear on the nearby conductor due to induction, but still net charge on the conductor is zero. (1)

2. (b): According to Coulomb's law, $\vec{F}_{12} = -\vec{F}_{21}$

There is a force of attraction which shows that the charges must be unlike charges.

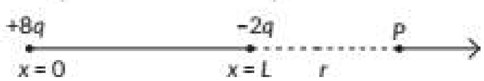
Also, $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

For attractive force, $q_1 q_2 < 0$, (1)

q_1 = +ve and q_2 = −ve

$\therefore \quad q_1 q_2 < 0$

3. (c): Let P is the observation point at a distance $(L + r)$ from $8q$ and at r from $-2q$.



Net electric field at P = 0

$\therefore \quad \vec{E}_1$ = EFI (electric field intensity) at P due to +8q

$\vec{E}_2$ = EFI (electric field intensity) at P due to −2q

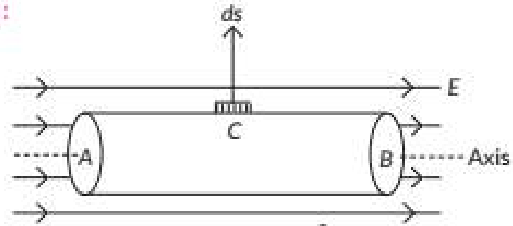
$|\vec{E}_1| = |\vec{E}_2|$

(iii) (c): zero (1)

(iv) (c): Its surface must have charge equal to $-q$. (1)

(v) (b): 1.9×10^5 Nm^2/C, leaving the surface. (1)

6. (a):



Flux through surface A, $\phi_A = E \times \pi R^2$

Flux through surface B, $\phi_B = E \times \pi R^2$

$\therefore$ Flux through curved surface, $C = \int E \cdot ds$ (1)

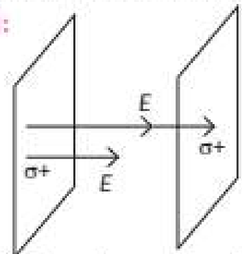
$= \int E ds \cos 90° = 0$

$\therefore$ Total flux through cylinder $= \phi_A + \phi_B + \phi_C = 0$

7. (a): An electric dipole placed in non-uniform electric field experiences both torque and force. (1)

8. (d): The electric field over the Gaussian surface remains continuous and uniform at every point. (1)

9. (d):



Here : Surface charge density, $\sigma = 26.4 \times 10^{-12}$ C/m^2

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

$= \frac{26.4 \times 10^{-12}}{8.85 \times 10^{-12}} \quad (\because \varepsilon_0 = 8.85 \times 10^{-12}\, C^2/N\text{-}m^2)$

$\therefore \quad E = 3$ N/C (1)

10. (a) Gauss's law in electrostatics states that the total electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of that charge.

$\phi = \oint \vec{E} \cdot d\vec{s} = \frac{q}{\varepsilon_0}$ (1)

$\therefore \frac{k(8q)}{(L+r)^2}=\frac{k(2q)}{r^2} \therefore \frac{4}{(L+r)^2}=\frac{1}{r^2} \Rightarrow 4r^2=(L+r)^2$

$\Rightarrow 2r = L + r \Rightarrow r = L$ **(1)**

$\therefore$ P is at $x = L + L = 2L$ from origin.

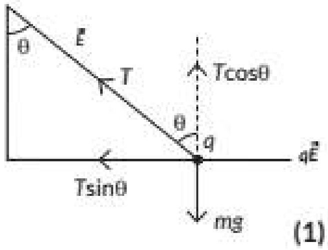
4. (b): From figure,

$T\cos\theta = mg$

$T\sin\theta = qE$

$\therefore qE = mg\tan\theta$

$q=\left(\frac{mg}{E}\right)\tan\theta$

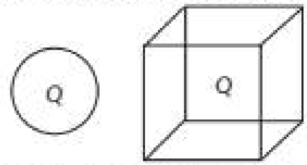


$\tan\theta=\frac{F_e}{mg}$ **(1)**

5. (i) (c) : Copper **(1)**

(ii) (a): car **(1)**

Let us take a charge Q inside a cube or a sphere.



The flux through both the closed surfaces will be same.

i.e., $\phi_{net}=\frac{Q}{\varepsilon_0}$

Thus, outward flux due to a point charge in vacuum is independent of the shape of gaussian surface. **(1)**

(b) Net electric field towards left = $\frac{\sigma}{2\varepsilon_0}$ **(1/2)**

Net electric field towards right = $\frac{\sigma}{2\varepsilon_0}$ **(1/2)**