CLASS – 12

WORKSHEET- ELECTRIC CHARGE AND FIELD

A. ELECTRIC CHARGE

(1 Mark Questions)

1. If a body contains n_1 electrons and n_2 protons then what is the total charge on the body?

2. What is the total positive or negative charge present in 1 molecule of water?

(2 Marks Questions)

3. How can you charge a metal sphere positively without touching it?

4. If 10^9 electrons move out of a body to another body every second, how much time is required to get a total charge of 1 C on the other body?

5. What is electric charge? Is it scalar or vector? Name its SI unit.

6. What is meant by quantization of electric charge? What is its cause?

7. State the law of conservation of charge. Give its two examples to illustrate it.

(3 Marks questions)

8. How much positive and negative charge is there in a cup of water?

9. (i) Explain the meaning of the statement 'electric charge of a body is quantised'. (ii) Why can one ignore quantisation of electric charge when dealing with macroscopic i.e., large scale charges?

10. When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.

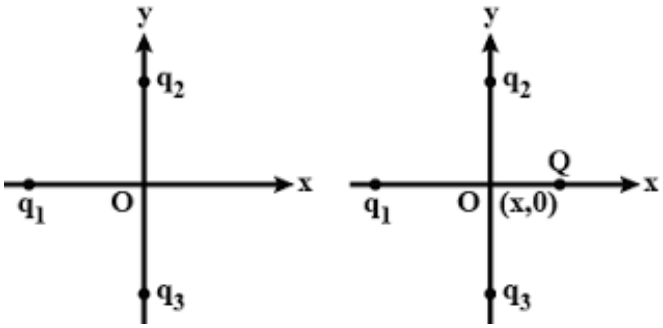
11. A polythene piece rubbed with wool is found to have a negative charge of $3\times10^{-7}C$. (i) Estimate the number of electrons transferred (from which to which?) (ii) Is there a transfer of mass from wool to polythene? [Ans. 2×10^{12}, 1.82×10^{-18} kg]

12. It is now believed that protons and neutrons are themselves built out to more elementary units called quarks. A proton and neutron consists of three quarks, the so called 'up' quark (denoted by u of charge +(2/3) e, and the 'down' quark (denoted by d) of charge (-1/3)e, together with electrons build up ordinary matter. Suggest a positive quark composition of a proton and neutron.

B. COULOMB'S LAW

(1 Mark Questions)

1. In Fig., two positive charges q_2 and q_3 fixed along the y axis, exert a net electric force in the + x direction on a charge q_1 fixed along the x axis. If a positive charge Q is added at (x, 0), the force on q_1.



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

2. Two identical conducting balls A and B have charges – Q and +3Q 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.

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3. 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?

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(2 Marks Questions)

4. Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will be the force between them when placed the same distance apart in air?

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5. Plot a graph showing the variation of coulomb force (F) versus $(1/r^2)$, where r is the distance between the two charges of each pair of charges: (1μC, 2μC) and (2μC, - 3μC), interpret the graphs obtained.

6. What is the force between two small charged spheres having charges of 2×10^{-7}C and 3×10^{7} C placed 30 cm apart in the air? [Ans. 6×10^{-3}N]

(3 Marks questions)

7. State Coulomb's law of force between two electric charges and state its limitations. Also define the SI unit of electric charge.

8. Write Coulomb's law in vector form. What is the importance of expressing it in vector form?

9. The electrostatic force on a small sphere of charge 0.4 μC due to another small sphere of charge –0.8 μC in the air is 0.2 N.
(a) What is the distance between the two spheres?
(b) What is the force on the second sphere due to the first? [Ans. 12cm, 0.2N (attractive)]

10. Check that the ratio $ke^2/G\ m_e m_p$ is dimensionless. Look up a Table of Physical Constants and determine the value of this ratio. What does the ratio signify? [Ans. 2.287×10^{39}]

11. Four point charges $q_A = 2\ \mu C$, $q_B = -5\ \mu C$, $q_C = 2\ \mu C$, and $q_D = -5\mu C$ are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of 1 μC placed at the centre of the square? [Ans. Zero N]

12. (i) Two insulated charged copper spheres A and B have their centres separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is 6.5×10^{-7}C each? The radii of A and B are negligible compared to the distance of separation.
(ii) What is the force of repulsion if each sphere is charged double the above amount, and the distance between them is halved? [Ans. 1.52×10^{-2}N, 0.243N]

13. Suppose the spheres A and B in Exercise 12 have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B? [Ans. 5.703×10^{-3}N]

(5 Marks Questions)

14. Four equal point charges each of 15 μC are placed on the four corners of a square of side 0.2m. Calculate the force on any of the charges.

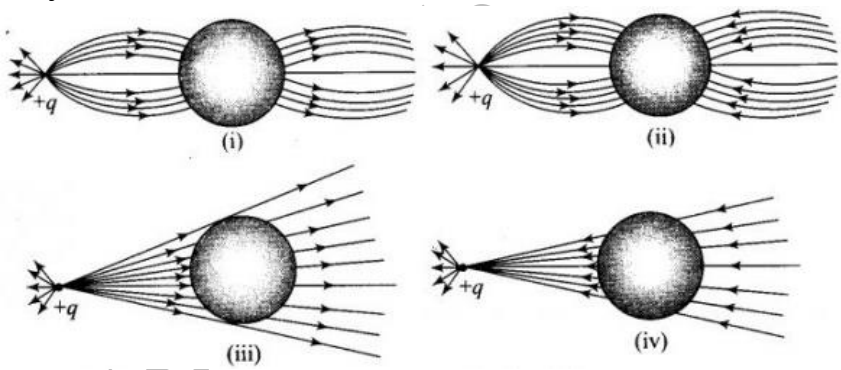
15. Two identical point charges, q each, are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

16. Two point charges q_A = 3 μC and q_B= –3 μC are located 20 cm apart in a vacuum. (i) What is the electric field at the midpoint O of the line AB joining the two charges? (ii) If a negative test charge of magnitude 1.5×10^{-9} C is placed at this point, what is the force experienced by the test charge? [Ans. 5.4×10^{6} NC^{-1}, along OB, 8.1×10^{-3} N, along OA]

C. ELECTRIC FIELD

(1 Mark Questions)

1. A point positive charge is brought near an isolated conducting sphere. The electric field is best given by



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

[Ans. (a)]

2. Draw the pattern of electric field lines when a point charge +q is kept near an unchanged conducting plate.

3. Why do the electrostatic field lines not form closed loops?

4. Why do the electric field lines never cross each other?

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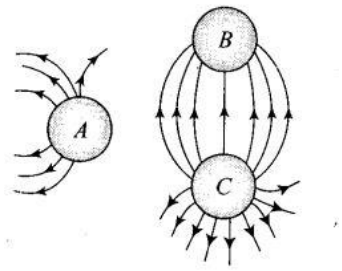
(2 Marks Questions)

5. Figure shows the electric field lines around three point charges A, B and C.



(i) Which charges are positive? (ii) Which charge has the largest magnitude? Why?
(iii) In which region or regions of the picture could the electric field be zero? Justify your answer.

(a) Near A (b) Near B (c) Near C (d) Nowhere

[Ans. (a)]

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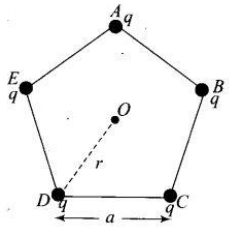
(3 Marks questions)

6. Five charges, q each are placed at the comers of a regular pentagon of side a.



(a) (i) What will be the electric field at O, the centre of the pentagon?
(ii) What will be the electric field at O if the charge from one of the corners (say A) is removed?
(iii) What will be the electric field at O if the charge q at A is replaced by – q?

(b) How would your answer to (a) be affected if pentagon is replaced by n-sided regular polygon with charge q at each of its comers?

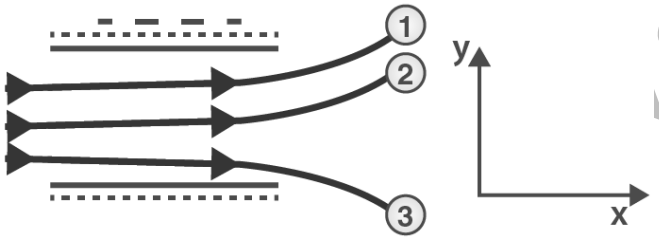
7. Two point charges of +16μC and – 9μC are placed 8cm apart in air. Determine the position of the point at which the resultant field is zero.

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

9. Two electric field lines cannot cross each other. Also, they cannot form closed loops. Give reasons.

10. (i) An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?
(ii) Explain why two field lines never cross each other at any point.

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

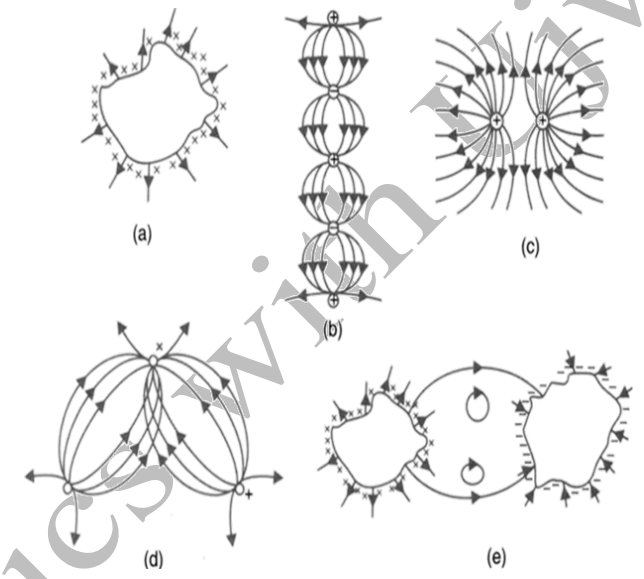


12. An oil drop of 12 excess electrons is held stationary under a constant electric field of 2.55×10^{4} Vm^{-1} in Millikan's oil drop experiment. The density of the oil is 126 g cm^{-3}. Estimate the radius of the drop (g= 9.81 ms^{-2}; e = 1.60×10^{-19}C) [Ans. 9.81×10^{-4} mm]

(5 Marks Questions)

13. Four charges +q, +q, - q, - q are placed respectively at the four corners A, B, C and D of a square of side 'a'. Calculate the electric field at the centre of the square.

14. Which among the curves shown in Figure cannot possibly represent electrostatic field lines?



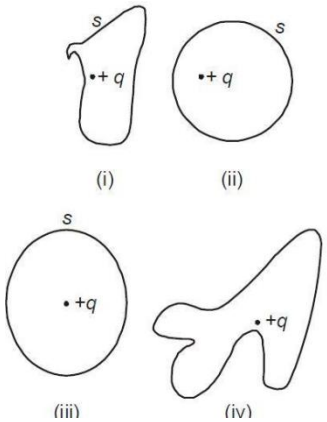
15. Two point charges of +1 μC and +4μC are kept 30cn apart. How far from the +1μC charge on the line joining the two charges, will the net electric field be zero?

16. 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.

D. ELECTRIC FLUX AND GAUSS THEOREM

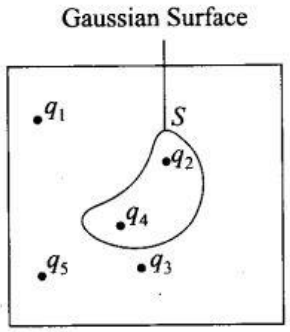
(1 Mark Questions)

1. The Electric flux through the surface



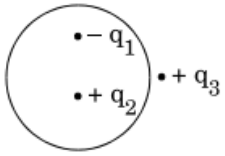
(a) Fig. (iv) is the largest. (b) in Fig. (iii) is the least.
(c) in Fig. (ii) is same as Fig.(iii) but is smaller than Fig. (iv)
(d) is the same for all the figures. [Ans. (d)]

2. Five charges q_1 , q_2 , q_3 , q_4, and q_5 are fixed at their positions as shown in Fig. S is a Gaussian surface. The Gauss's law is given by : $\oint_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$



Which of the following statements is correct?
(a) E on the LHS of the above equation will have a contribution from q_1, q_5 and q3 while q on the RHS will have a contribution from q_2 and q_4 only.
(b) E on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_2 and q_4 only.
(c) E on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_1, q_3 and q_5 only.
(d) Both E on the LHS and q on the RHS will have contributions from q_2 and q_4 only.
[Ans. (b)]

3. Electric flux through a spherical surface shown in the figure, is _____



4. 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 _____.

5. 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

6. 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 eth size of the Gaussian surface.
(c) net charge enclosed only
(d) permittivity of the medium only

7. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased?

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8. A charge 'q' is placed at the centre of a cube of side *l*. What is the electric flux passing through each face of the cube?

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9. Does the charge given to a metallic sphere depend on whether it si hollow or solid. Give reason for your answer.

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10. Two charges of magnitudes -2Q and +Q are located at points (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '3a' with its centre at the origin?

(2 Marks Questions)

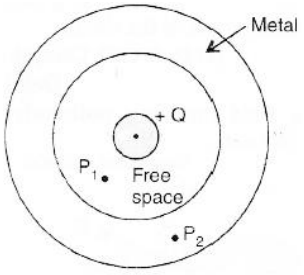
11. (i) Define the term 'electric flux'? Write its SI unit.
(ii) What is the flux due to electric field $\vec{E} = 3\times10^{3}\hat{i}\ N/C$ through a square of side 10cm, when it is held normal to $\vec{E}$?

12. Given a uniform electric field $\vec{E} = 5\times10^{3}\hat{i}\ N/C$. Find the flux of this field through a square of 10cm 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?

13. 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.

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

15. 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.

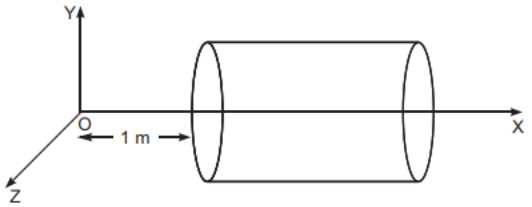


16. An infinite line charge produces a field of 9×10^4 N/C at a distance of 2 cm. Calculate the linear charge density. [Ans. 0.1 μCm^{-1}]

(3 Marks questions)

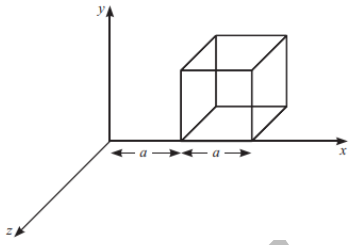
17. A point charge (+Q) is kept in the vicinity of an uncharged conducting plate. Sketch the electric field lines between the charge and the plate.

18. A hollow cylindrical box of length 1m and area of cross-section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50x\hat{i}$, where E is in NC^{-1} and x is in metres. Find



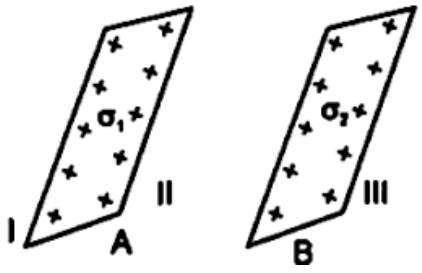
(i) net flux through the cylinder (ii) charge enclosed by the cylinder.

19. State Gauss's law in electrostatic. A cube with each side 'a' is kept in an electric field given by $\vec{E} = Cx\hat{i}$ (as shown in figure) where C is a positive dimensional constant. Find out



(i) the electric flux through the cube (ii) the net charge inside the cube.

20. 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.

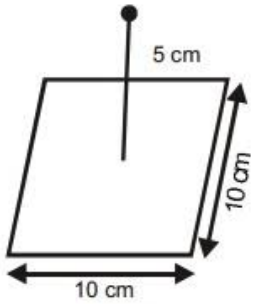


21. Consider a uniform electric field $E = 3 \times 10^3 \hat{i}$ N/C.
(a) What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the y z – plane?
(b) What is the flux through the same square if the normal to its plane makes a 60 ° angle with the x-axis? [Ans. 30 Nm^2C^{-1}, 15 Nm^2C^{-1}]

22. What is the net flux of the uniform electric field of Question 21 through a cube of side 20 cm oriented so that its faces are parallel to the coordinate planes?

23. Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is 8.0×10^3 N m^2 /C.
(a) What is the net charge inside the box?
(b) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box? Why or Why not? [Ans. 0.07 μC, No]

24. A point charge + 10 μC is at a distance 5 cm directly above the centre of a square of side 10 cm, as shown in Fig. What is the magnitude of the electric flux through the square?



25. A point charge of 2.0 μC is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface? [Ans. 2.26×10^5 Nm^2 C^{-1}]

26. A point charge causes an electric flux of -1.0×10^3 N m^2 /C to pass through a spherical Gaussian surface of 10.0 cm radius centred on the charge.
(a) If the radius of the Gaussian surface were doubled, how much flux would pass through the surface?
(b) What is the value of the point charge? [Ans. -10^3 N m^2 /C, -8.84 nC]

27. A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5×10^3 N/C and points radially inward, what is the net charge on the sphere? [Ans. 6.67 nC]

28. A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 μC /m ^{2}. (a) Find the charge on the sphere. (b) What is the total electric flux leaving the surface of the sphere? [Ans. 1.45×10^{-3}C, 1.6×10^{8} Nm^2 C^{-1}]

29. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 17.0×10^{-22} C /m ^{2}

What is E :

(a) In the outer region of the first plate,

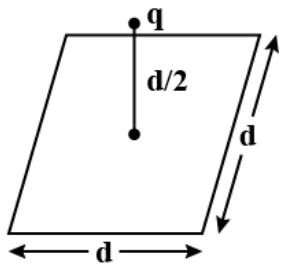
(b) In the outer region of the second plate, and (c) between the plates?

[Ans. Zero, zero, 19.2×10^{-10} NC^{-1}]

(5 Marks Questions)

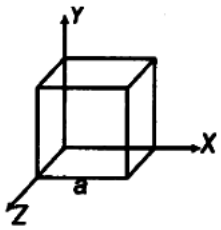
30. An electric field is uniform and acts along +x direction in the region of positive x. it is also uniform with the same magnitude but acts in –x direction in the region of negative x. The value of field is E = 200 NC^{-1} for x >0 and E = - 200 NC^{-1} for x < 0. A right circular cylinder of length 20cm and radius 5cm has its centre at the origin and its axis along the x-axis so that one flat face is at x = +10cm and the other is at x = - 10cm. Find (i) the net outward flux through the cylinder. (ii) the net charge present inside the cylinder.

31. (a) Define electric flux, Is it a scalar or a vector quantity? A point charge q is at a distance 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.



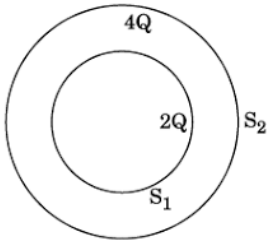
(b) If the net point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected?

32. 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.



33. Define electric flux. Write its Si 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.

34. Consider two hollow concentric spheres S_1 and S_2 enclosing charges 2Q and 4Q respectively as shown in the 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 outside S_1 in place of air? Deduce the necessary expression.

35. 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.

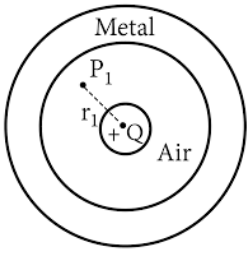
36. Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

37. A small conducting sphere of radius 'f' 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.

38. State and Prove Gauss's law.

39. (i) Define electric flux. Write its SI unit.

(ii) 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.



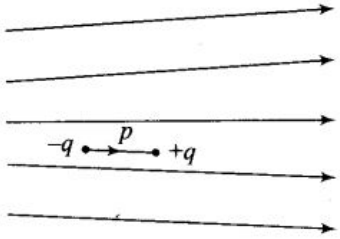
(iii) Draw the pattern of electric field lines in this arrangement.

40. A hollow charged conductor has a tiny hole cut into its surface. Show that the electric field in the hole is $\frac{\sigma}{2\varepsilon_0}\hat{n}$ where $\hat{n}$ is the unit vector in the outward normal direction, and σ is the surface charge density near the hole.

E. ELECTTIC DIPOLE

(1 Mark Questions)

1. Figure shows electric field lines in which an electric dipole p is placed as shown.



Which of the following statements is correct?
(a) The dipole will not experience any force.
(b) The dipole will experience a force towards right.
(c) The dipole will experience a force towards left.
(d) The dipole will experience a force upwards. [Ans. (c)]

2. Define the term electric dipole moment of a dipole. State its SI unit.

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3. 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

4. Write the expression for a torque $\vec{\tau}$ acting on a dipole moment $\vec{p}$ placed in an electric field $\vec{E}$.

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5. What is the electric flux through a cube of side 1cm which encloses an electric dipole?

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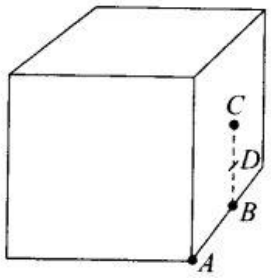
(2 Marks Questions)

6. What will be the total flux through the faces of the cube as given in the figure with side of length a if a charge q is placed at



(a) A corner of the cube (b) B mid-point of an edge of the cube
(c) C centre of a face of the cube (d) D mid-point of B and C

7. 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.

(3 Marks questions)

8. Derive the expression for the electric field due to dipole of dipole moment $\vec{P}$ at a point on its perpendicular bisector.

9. Derive the expression for electric field at a point on the equatorial line of an electric dipole.

10. Depict the orientation of the dipole in (a) stable, (b)unstable equilibrium in a uniform electric field.

11. A system has two charges $q_A = 2.5 \times 10^{-7}C$ and $q_B = -2.5 \times 10^{-7}C$ located at points A :(0, 0, -15 cm) and B (0, 0, + 15 cm), respectively. What is the total charge and electric dipole moment of the system? [Ans. $0.75 \times 10^{-7}Cm$]

12. An electric dipole with dipole moment $4 \times 10^{-9}Cm$ is aligned at 30° with the direction of a uniform electric field of magnitude $5 \times 10^{4} NC^{-1}$. Calculate the magnitude of the torque acting on the dipole. [Ans. $10^{-4}Nm$]

(5 Marks Questions)

13. Define electric dipole moment. Is it a scalar or a vector quantity? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.

F. CHALLENGING PROBLEMS

1. In a certain region of space, electric field is along the Z-direction throughout. The magnitude of electric field is, however, not constant but increases uniformly along the positive Z-direction at the rate of 10^5 NC^{-1} m^{-1}. What are the force and torque experienced by a system having a total dipole moment equal to 10^{-7} C m in the negative Z-direction? [Ans. -10^{-2} N, 0]

2. 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 as a point charge.

3. Obtain the formula for the electric field due to a long thin wire of uniform linear charge density λ without using Gauss's law. [Hint: Use Coulomb's law directly and evaluate the necessary integral].

4. A particle of mass m and charge (- q) enters the region between two charged plates initially moving along x-axis with speed v_x. The length of plate is L and a uniform electric field E is maintained between the plates. Show that the vertical deflection of ht particle at the far edge of the plate is $qEL^2/2mv_x^2$.

SPACE FOR ROUGH WORK

SPACE FOR NOTES