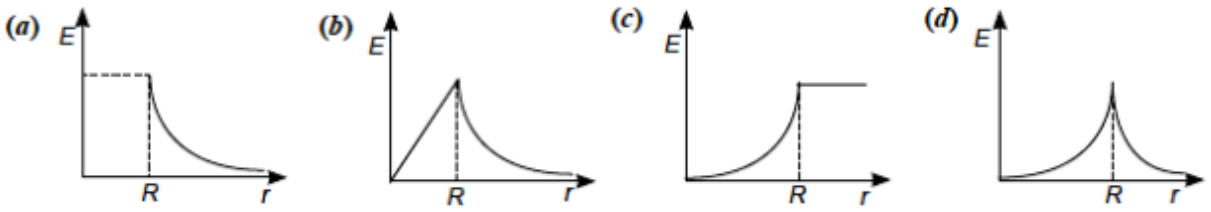
UNIT 01

Electric Charges and Fields

SECTION – A

Questions 1 to 10 carry 1 mark each.

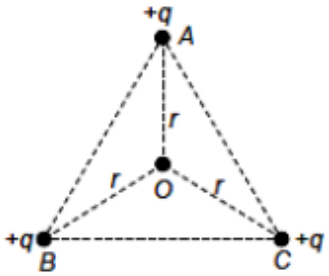
1. Which of the following graphs shows the variation of electric field E due to a hollow spherical conductor of radius R as a function of distance from the centre of the sphere?



2. An electric dipole of moment p is placed in the position of stable equilibrium in uniform electric field of intensity E. It is rotated through an angle θ from the initial position. The potential energy of electric dipole in the final position is

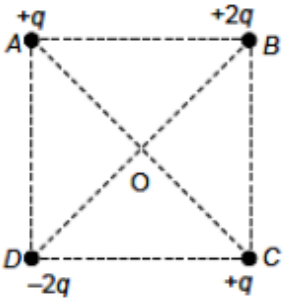
(a) pE cos θ (b) pE sin θ (c) pE(1 − cos θ) (d) −pE cos θ

3. ABC is an equilateral triangle. Three charges +q are placed at each corner. The electric intensity at O will be



(a) 1. $q/4\pi\varepsilon_0 . r^2$ (b) 1. $q/4\pi\varepsilon_0 r$ (c) Zero (d) 1. $3q/4\pi\varepsilon_0 r^2$

4. Four charges are arranged at the corners of a square ABCD, as shown. The force on the charge kept at the centre O is



(a) zero (b) along the diagonal AC
(c) along the diagonal BD (d) perpendicular to side AB

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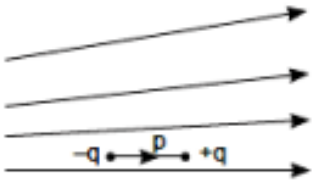
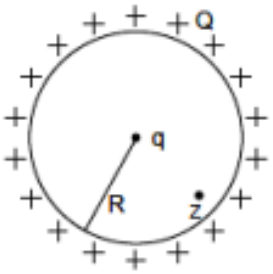
5. Figure shows electric field lines in which an electric dipole p is placed as shown. Which of the following statements is correct?



(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.

6. A positive charge Q is uniformly distributed along a circular ring of radius R. A small test charge q is placed at the centre of the ring.
Which of the following statement is not correct?



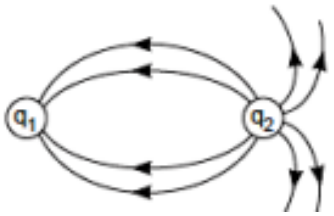
(a) If $q > 0$ and is displaced away from the centre in the plane of the ring, it will be pushed back towards the centre.
(b) If $q < 0$ and is displaced away from the centre in the plane of the ring, it will never return to the centre and will continue moving till it hits the ring.
(c) If $q < 0$, it will perform SHM for small displacement along the axis.
(d) q at the centre of the ring is in an unstable equilibrium within the plane of the ring for $q > 0$.

7. Two similar spheres having +Q and −Q charges are kept at a certain distance. F force acts between the two. If at the middle of two spheres, another similar sphere having +Q charge is kept, then it experiences a force in magnitude and direction as
(a) zero having no direction. (b) 8F towards +Q charge.
(c) 8F towards −Q charge. (d) 4F towards +Q charge.

8. A charge Q is divided into two parts of q and Q − q. If the coulomb repulsion between them when they are separated is to be maximum, the ratio of Q:q should be
(a) 2 : 1 (b) 1 : 2 (c) 4 : 1 (d) 1 : 4

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** In the given figure q_1 is positive and q_2 is negative.
Reason (R): Electric field lines emerge from positive and terminate at negative charge.

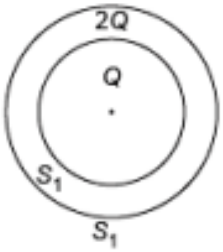


10. **Assertion (A):** An electric dipole is placed in an electric field antiparallel to it. If it is displaced then it will come back to initial position.
Reason (R): Dipole is in stable equilibrium.

SECTION – B

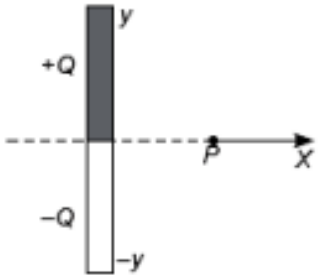
Questions 11 to 14 carry 2 marks each.

11. S_1 and S_2 are two hollow concentric spheres enclosing charge Q and $2Q$ respectively as shown in figure.
(i) What is the ratio of the electric flux through S_1 and S_2?
(ii) How will the electric flux through the sphere S_1 change, if a medium of dielectric constant 5 is introduced in the space inside S_1 in place of air?

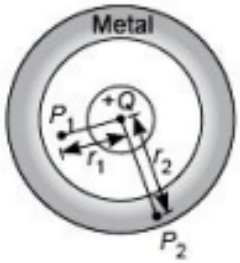


12. Define electric flux. Write its SI units. A spherical rubber balloon carries a charge that is uniformly distributed over its surface. As the balloon is blown up and increases in size, how does the total electric flux coming out of the surface change? Give reason.

13. The figure given below shows a uniformly charged non-conducting rod. What is the direction of electric field at point P due to the charge on the rod?



14. A small metal sphere carrying the charge $+Q$ is located at the centre of a spherical cavity in a large uncharged metal sphere
as shown in the figure.
Use the Gauss's theorem to find the electric flux at points P_1 and P_2.

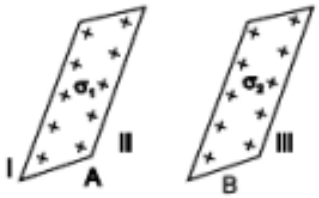


SECTION – C

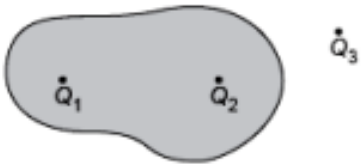
Questions 15 to 17 carry 3 marks each.

15. Define the term 'electric dipole moment'. Is it a scalar or vector?
Deduce an expression for the electric field at a point on the equatorial plane of an electric dipole of length $2a$.

16. (a) A point charge ($+Q$) is kept in the vicinity of uncharged conducting plate. Sketch electric field lines between the charge and the plate.
(b) 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 net fields in the regions marked II and III.



17. Three charges Q_1, Q_2 and Q_3 are placed inside and outside a closed Gaussian surface as shown in the figure.



Answer the following:
(a) Which charges contribute to the electric field at any point on the Gaussian surface?
(b) Which charges contribute to the net flux through this surface?
(c) If $Q_1 = -Q_2$, will electric field on the surface be zero?

SECTION – D

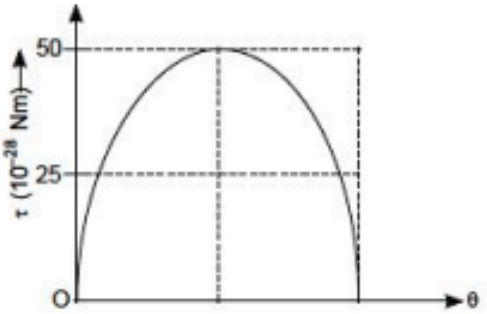
Questions 18 carry 5 marks.

18. (a) State Gauss's law. Use it to deduce the expression for the electric field due to a uniformly charged thin spherical shell at points (i) inside and (ii) outside the shell.
(b) Two identical metallic spheres A and B having charges $+4Q$ and $-10Q$ are kept a certain distance apart. A third identical uncharged sphere C is first placed in contact with sphere A and then with sphere B.
Spheres A and B are then brought in contact and then separated. Find the charges on the spheres A and B.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. An electric dipole consists of two equal and opposite charge separated by a small distance. When an electric dipole is placed in a uniform electric field, it experiences a torque but no force. Consider an electric dipole of dipole moment 'P' is placed in an electric field of magnitude 40 N/C. A graph for torque experienced by a dipole versus its angular position with respect to electric field is shown below.



(i) What is the torque when the dipole is placed perpendicular to the electric field?
(a) 5×10^{28} N-m

(b) 5×10^{-28} N-m
(c) 50×10^{-28} N-m
(d) $50 \times 10^{+28}$ N-m

(ii) What is the value of electric field at the centre of the electric dipole?
(a) It is twice the electric field due to one charge at centre.
(b) It is thrice the electric field due to one charge at centre.
(c) It is half the electric field due to one charge at centre.
(d) Zero.

(iii) What is the value of electric dipole moment calculated with the help of given graph?
(a) 2.25×10^{-28} Cm
(b) 2.5×10^{-29} Cm
(c) 1.25×10^{-28} Cm
(d) 2.5×10^{-29} Cm

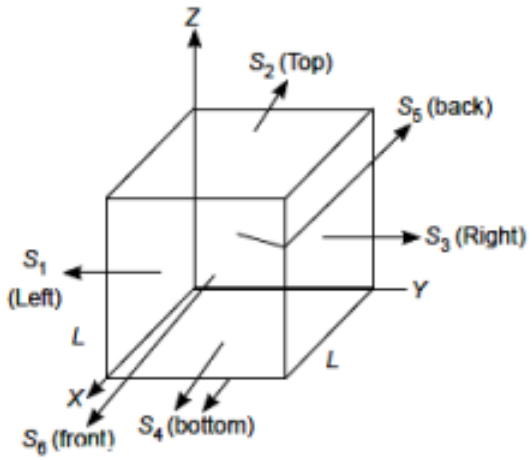
(iv) Two charge 20 C and –20 C are separated from each other by a distance of 2 cm. Then what is the magnitude of electric dipole moment
(a) 0
(b) 0.2 cm
(c) 0.4 cm
(d) 0.8 cm

OR

(iv) An electric dipole of dipole moment P is placed in an electric field E. The torque exerted by the field on the dipole is:
(a) Parallel to both the field and the dipole moment.
(b) Perpendicular to both the field and the dipole moment.
(c) Parallel to the field and perpendicular to the dipole moment.
(d) Parallel to dipole moment and perpendicular to the field.

20. In electrostatics, electric flux is the measure of the electric field through a given surface, although an electric field in itself cannot flow. It is a way of describing the electric field strength at any distance from the charge causing the field. Now, consider a cube of each edge 0.30 m is placed with its one corner at the origin. The cube is placed in a non-uniform electric field.

$$\vec{E} = (-2x\hat{i} + 3\hat{j})\ \text{N/C}$$



(i) The surfaces that have zero electric flux are
(a) S_1 and S_2
(b) S_1 and S_6
(c) S_2 and S_4
(d) S_1 and S_3

(ii) Electric flux passing through surface S_1 is
(a) $-0.27\ Nm^2C^{-1}$
(b) $0.27\ Nm^2C^{-1}$
(c) $-0.18\ Nm^2C^{-1}$
(d) $-0.18\ Nm^2C^{-1}$

(iii)Electric flux passing through surface S_4 is
(a) $-0.18\ Nm^2C^{-1}$
(b) $+0.18\ Nm^2C^{-1}$
(c) $+0.27\ Nm^2C^{-1}$
(d) zero

(iv)Total net flux passing through the cube if $\vec{E} = 2\hat{i}$ N/C
(a) zero
(b) $-0.18\ Nm^2C^{-1}$
(c) $0.18\ Nm^2C^{-1}$
(d) $0.27\ Nm^2C^{-1}$

OR

(iv)Total charge enclosed inside the cube is
(a) 0
(b) –1.62 pC
(c) +1.62 pC
(d) 2.4 pC