Physics (Theory) - Electric Charges and Fields (CBSE)

Time allowed : 2 hours _____ **Maximum Marks : 41**

Instructions

1. Please check that this question paper contains 3 printed pages.
2. Please check that this question paper contains 19 questions.
3. 10 minutes time has been allotted to read this question paper. The student will read the question paper only and will not write any answer on the answer script during this period.

A. General Instructions :

1. All questions are compulsory.
2. There are 18 questions in total. Questions 1 to 6 carry one mark each, questions 7 to 11 carry two marks each, questions 12 to 16 carry three marks each and questions 17 to 18 carry five marks each.
3. Use of calculators is not permitted.

4. You may use the following values of physical constants wherever necessary:

$c = 3 \times 10^8 ms^{-1}$

$h = 6 \cdot 626 \times 10^{-34} Js$

$e = 1 \cdot 602 \times 10^{-19} C$

$\mu_o = 4\pi \times 10^{-7} TmA^{-1}$

$\epsilon_o = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$

$\frac{1}{4\pi\epsilon_o} = 9 \times 10^9 Nm^2 C^{-2}$

Mass of electron $m_e = 9{\cdot}1 \times 10^{-31} kg$

Mass of neutron $m_n \cong 1{\cdot}675x10^{-27} kg$

Boltzmann's constant $k = 1 \cdot 381 \times 10^{-23} JK^{-1}$

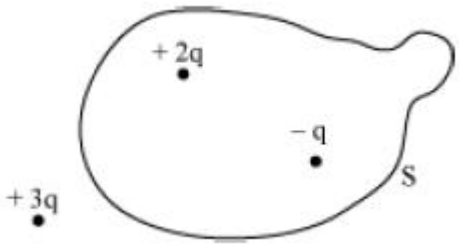
Avogadro's number $N_A = 6 \cdot 022 \times 10^{23} / mol^{-1}$

Section - A

Q1: Why is it necessary that the field lines from a point charge placed in the vicinity of a conductor must be normal to the surface of the conductor at every point ?

Q2: Is the force acting between two point electric charges q_1 and q_2 kept at some distance apart in air, attractive or repulsive when (i) $q_1 q_2 > 0$ (ii) $q_1 q_2 < 0$?

Q3: Figure shows three point charges +2q, −q and + 3q. Two charges + 2q and −q are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S'?



Q4: In which orientation, a dipole placed in a uniform electric field is in (i) stable, (ii) unstable equilibrium?

Q5: An electric dipole of dipole moment $20 \times 10^{-6} C.m$ is enclosed by a closed surface. What is the net flux coming out of the surface ?

Q6: An electrostatic field line cannot be discontinuous. Why ?

For Questions 13 to 16, two statements are given - one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

(A) If both Assertion (A) and and Reason (R) are true and Reason (R) is the correct explaination of Assertion (A).

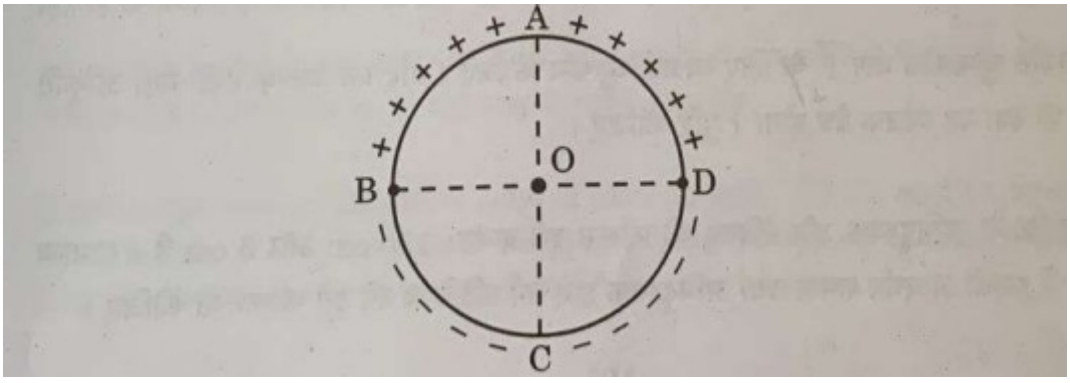
(B) If both Assertion (A) and Reason (R) are true, and Reason (R) is not the correct explaination of Assertion (A).

(C) If Assertion (A) is true but Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

Q1: Assertion (A) : Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC.

Reason (R) : It is so because the net potential at O is not zero.



Section B

Q7: Define Electric Flux. Write its S.I. Unit.

Q8: The sum of two point charges is $7\mu C$. They repel each other with a force of 1 N when kept 30 cm apart in free space. Calculate the value of each charge.

Q9: The electric field E due to a point charge at any point near it is defined as $\lim_{q\to 0}\left(\frac{\mathbf{F}}{q}\right)$ where q is the test charge and F is the force acting on it. What is the physical significance of $\lim_{q\to 0}$ in this expression ? Draw the electric field lines of a point charge Q when (i) Q > 0 and (ii) Q < 0.

Q10: A spherical Gaussian surface encloses a charge of $8.85 \times 10^{-10} C$. (i) Calculate the electric flux passing through the surface. (ii) How would the flux change if the radius of the Gaussian surface is doubled and why ?

Q11: Define 'electric line of force' and give its two important properties.

Q : Four point charges of $1\ \mu C$, $-2\ \mu C$, $1\ \mu C$ and $-2\ \mu C$ are placed at the corners A, B, C and D respectively, of a square of side 30 cm. Find the net force acting on a charge of $4\,\mu C$ placed at the centre of the square.

OR

Three point charges , $1\,pC$ each, are kept at the vertices of an equilateral triangle of side $10\,cm$. Find the net electric field at the centroid of triangle.

Section - C

Q12: A positive point charge (+ q) is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines originating from the point on to the surfaceof the plate. Derive the expression for the electric field at the surface of a charged conductor.

Q13: A thin conducting spherical shell of radius R has charge Q spread uniformly over its surface. Using Gauss's law, derive an expression for an electric field at a point outside the shell.

Draw a graph of electric field **E**(r) with distance r from the centre of the shell for $0 \leq r \leq \infty$.

Q14: Define the term 'electric dipole moment', Is it scalar or vector?

Deduce an expression for the electric field at a point on the equatorial plane of an electric dipole of length 2a.

Q15: State Gauss's theorem in electrostatics. Apply this theorem to derive an expression for electric field intensity at a point near an infinitely long straight charged wire.

Q16: An electric dipole is held in a uniform electric field. (i) Using suitable diagram, show that it does not undergo any translatory motion, and (ii) derive an expression for the torque acting on it and specify its direction.

Q: (a) Define the term 'electric flux' and write its dimensions.

(b) A plane surface, in shape of a square of side 1 cm is placed in an electric field $\overrightarrow{E} = \left(100\frac{N}{C}\right)\hat{i}$ such that the unit vector normal to the surface is given by $\hat{n} = 0.8\hat{i} + 0.6\hat{j}$. Find the electric flux through the surface.

Section D

Q17: (a) Using Gauss' law, derive an expression for the electric field intensity at any point outside a uniformly charge thin spherical shell of radius R and charge densitys $\sigma C/m^2$. Draw the field lines when the charge density of the sphere is (i) positive, (ii) negative.

(b) A uniformly charged conducting sphere of 2.5m in diameter has a surface charge density of $100mC/m^2$. Calculate the (i) Charge on the sphere (ii) Total electric flux passing through the sphere.

Q18: Define the term dipole moment $\overrightarrow{p}$ of an electric dipole indicating its direction. Write its SI unit. An electric dipole is placed in a uniform electric field $\overrightarrow{E}$. Deduce the expression for the torque acting on it. In a particular situation, it has its dipole moment aligned with the electric field. Is the equilibrium stable or unstable ?

Section E

Q : (i) Draw equipotential surfaces for an electric dipole.

(ii) Two point charges q_1 and q_2 are located at $\vec{r_1}$ and $\vec{r_2}$ respectively in an external electric field $\vec{E}$. Obtain an expression for the potential energy of the system.

(iii) The dipole moment of a molecule is $10^{-30}Cm$. It is placed in an electric field $\vec{E}$ of $10^5V/m$ such that it's axis is along the electric field. The direction of $\vec{E}$ is suddenly changed by 60^o at an instant . Find the change in the potential energy of the dipole, at that instant.

OR

Q : (i) A thin spherical shell of radius R has a uniform surface charge density σ . Using Gauss's law , deduce an expression for electric field (i) outside and (ii) inside the shell.

(ii) Two long straight thin wires AB and CD have linear charge densities $10\,\mu C/m$ and $-20\,\mu C/m$, respectively. They are kept parallel to each other at a distance 1 m. Find the magnitude and direction of the net electric field at a point midway between them.