CBSE Test Paper-05

Class - 12 Physics (Electric Charges and Fields)

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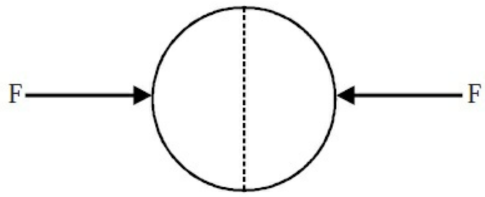
1. A point charge causes an electric flux of $-1.0 \times 10^3 \mathrm{Nm}^2/\mathrm{C}$ to pass through a spherical Gaussian surface of 10.0 cm radius centred on the charge.
   (a) If the radius of the Gaussian surface were doubled, how much flux would pass through the surface?
   (b) What is the value of the point charge?
   a. $-10^3 \mathrm{Nm}^2/\mathrm{C}, -8.8\mathrm{nC}$
   b. $10^3 \mathrm{Nm}^2/\mathrm{C}, -7.8\mathrm{nC}$
   c. $10^3 \mathrm{Nm}^2/\mathrm{C}, -8.8\mathrm{nC}$
   d. $-10^3 \mathrm{Nm}^2/\mathrm{C}, -6.8\mathrm{nC}$
2. Gravitational force is the smallest between
   a. earth and the moon
   b. earth and the sun
   c. two pens weighing 100gms at a distance of 0.4 m
   d. two books of weight 1kg each at a distance of 1 m
3. Electric charge
   a. is a property of neutrons only
   b. is a property of protons only
   c. is a property of particles such as atoms,ions, electrons etc
   d. is a property of electrons only
4. Three concentric metallic spherical shells of radii R, 2R, 3R, are given charges Q_1, Q_2, Q_3, respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells, Q_1: Q_2: Q_3, is
   a. It is 1: 4: 9
   b. It is 1: 8: 18
   c. It is 1: 3: 5
   d. It is 1: 2: 3
5. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F(See figure). F is proportional to

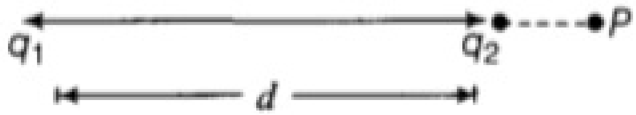


a. $\frac{\sigma^2 R^2}{\epsilon_0}$
b. $\frac{\sigma^2 R}{\epsilon_0}$
c. $\frac{1}{\epsilon_0}\frac{\sigma^2}{R^3}$
d. $\frac{1}{\epsilon_0}\frac{\sigma^2}{R}$

6. What is the flux due to electric field $\mathbf{E} = 3 \times 10^3 \hat{\imath} \mathrm{NC}^{-1}$ through a square of side 10cm, when it is held normal to E?

7. Consider three charged bodies P, Q and R. If P and Q repel each other and P attracts R, what is the nature of force between Q and R?

8. Two point charges q_1 and q_2 are placed at a distance d apart as shown in the figure. The electric field intensity is zero at the point P on the line joining them as shown. Write two conclusions that you can draw from this.



9. At what points, dipole field intensity is parallel to the line joining the charges?

10. The electric field E due to a point charge at any point near it is defined as $E = \lim_{q \to 0} \frac{F}{q}$, 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.

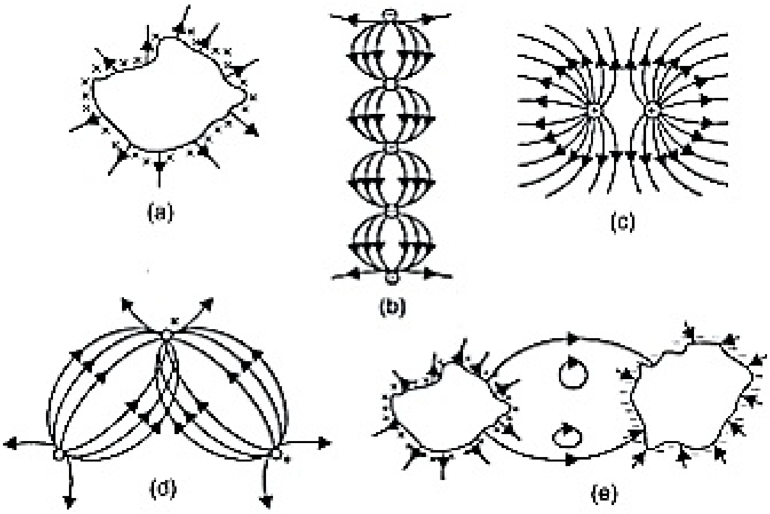
11. Two charged particles having charge $2.0 \times 10^{-8} C$ each are joined by an insulating string of length 1 m and the system is kept on a smooth horizontal table. Find the tension in the string.

12. a. Explain the meaning of the statement electric charge of a body is quantized.
    b. Why can one ignore quantization of electric charge when dealing with

macroscopic i.e. large scale charges?

13. The electrostatic force between charges of $200\mu C$ and $500\mu C$ placed in free space is 5 gf. Find the distance between the two charges. Take g = $10ms^{-2}$.

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



15. i. Define electric flux. Write its SI unit. Gauss' 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.
    ii. Use Gauss' law to prove that the electric field inside a uniformly charged spherical shell is zero.

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Answers

1. a. $-10^3 Nm^2/C$, -8.8nC

   Explanation:

   a. Electric flux is given by $\phi = \frac{q}{\epsilon_0}$ since amount of charge not depends on size and shape so by making radius double the amount of charge remain same so electric flux remain same.

   b.
   $$\phi = \frac{q}{\varepsilon_0} so\, q = \phi\varepsilon_0$$
   $$= -1 \times 10^3 \times 8.85 \times 10^{-12}$$
   $$= -8.85 \times 10^{-9} C$$
   = -8.85nC

2. c. two pens weighing 100gms at a distance of 0.4 m

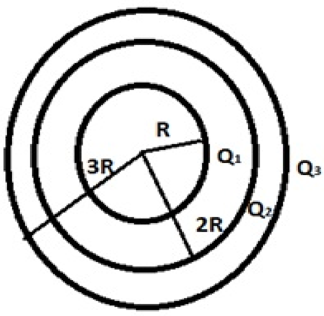
   Explanation: Gravitational force is given by $F = G\frac{m_1 m_2}{r^2}$. Since $\frac{m_1 m_2}{r^2}$ is smallest in case of two pens and $G = 6.67 \times 10^{-11} Nm^2/Kg^2$ so the gravitational force is very small.

3. c. is a property of particles such as atoms,ions,electrons etc

   Explanation: Every matter is made up of atoms which contains protons, electrons and neutrons.
   Protons are +ve charged particles and electrons are -ve charged particles.
   Because of electric charge these particles experience a force in electrical fields.

4. c. It is 1: 3: 5

   Explanation: Since the charge goes to outer surface when given inside so the charges on concentric spherical shells are respectively Q_1, $Q_1 + Q_2$, $Q_1 + Q_2 + Q_3$



Sine their charge densities are equal so

$\sigma_1 = \sigma_2 = \sigma_3$

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

so $Q_1 = 3Q_2 = 5Q_3$

so 1: 3: 5

5. a. $\frac{\sigma^2 R^2}{\epsilon_0}$

Explanation: Outward electric field at the surface of shell is $E = \frac{\sigma}{2\varepsilon_0}$ If Q is the charge on the shell and A is the area,

than the outward pressure is $P = \frac{QE}{A} = \sigma E = \frac{\sigma^2}{2\epsilon_0}$

Force = PX effective area of hemispherical shell $= \frac{\sigma^2}{2\epsilon_0} \times \pi R^2$

So $F \propto \frac{\sigma^2}{\epsilon_0} R^2$

6. According to the question Data Given,

   $\mathbf{E} = 3 \times 10^3 \mathbf{NC}^{-1}$

   Side of square (S)= 10 cm = 0.10 m.

   Area of square (A)= $(\text{side})^2$ = $(0.1)^2$ = $1 \times 10^{-2}\text{m}^2$

   Hence, electric flux through the square,

   $\phi = E \cdot A = \left(3 \times 10^3\right).10^{-2}\hat{i} = 30\text{Nm}^2\text{C}^{-1}$

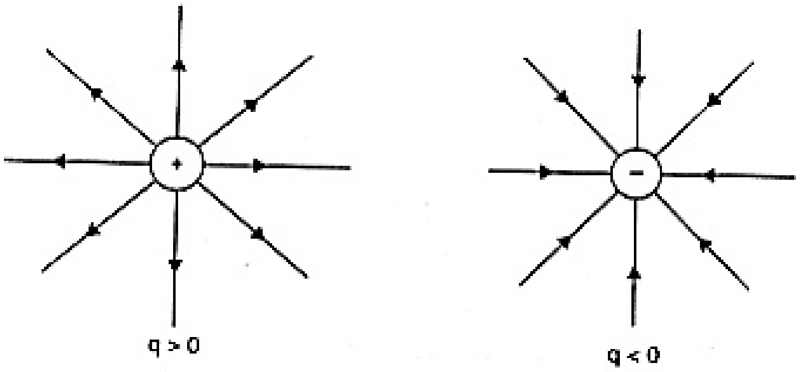
   Electric flux is a scalar quantity,positive value of electric flux denotes that electric field lines are coming out of the loop.

7. Attractive. This is because Q and R are oppositely charged.

8. As the electric field intensity at point P is zero,the electric field produced by both the charges should be equal and opposite in direction which can be possible in following manner:
   i. The two-point charges (q_1 and q_2) should be of opposite nature.
   ii. The magnitude of charge q_1 must be greater than the magnitude of charge q_2 as distance of q1 is greater than q2

9. The dipole field intensity is parallel to the line joining the charges at points on the axial line or equatorial line.

10. It is indicated by the $\lim_{q \to 0}$ that the test charge q is so small that its presence does not disturb the distribution of source charge and therefore, its electric field. The electric field of the point charge Q are shown below.



11. Here $q_1 = q_2 = 2 \times 10^{-8} C$
    r = 1 m
    Tension in the string is the force of repulsion (F) between the two charges.
    According to Coulomb's law.
    $F = \frac{q_1 q_2}{4\pi \in_0 r^2}$
    $= \frac{9 \times 10^9 (2 \times 10^{-8})(2 \times 10^{-8})}{1^2}$
    $F = 3.6 \times 10^{-6} N$

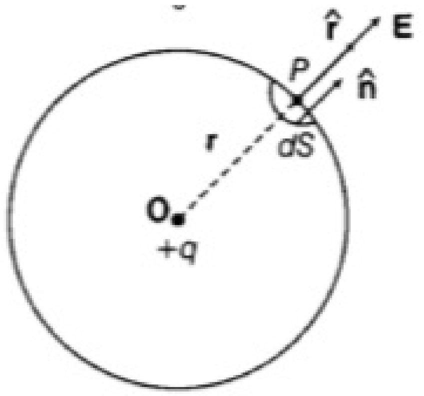
12. a. **Quantisation of Electric Charges:** Electric charge is due to transfer of electron. The electric charge is always an integral multiple of e which is termed as quantization of charge.
    i.e., $q = \pm ne$
    Here +e is taken as charge on a proton while -e is taken as charge on an electron. The charge on a proton and an electron are numerically equal i.e., $1.6 \times 10^{-19} C$ but opposite in sign.
    "Quantisation is a property due to which charge exists in discrete packets in multiple of $\pm 1.6 \times 10^{-19}$ rather than in continuous amounts."
    b. Based on many practical phenomena, we may ignore quantisation of electric charge and consider the charge to be continuous. Large scale electric charge may be considered as integral multiple of the basic unit 'e'. The "graininess" of charge can be ignored and it can be imagined that this large scale charge can be charged continuously and its quantisation is insignificant and can be ignored.

13. $q_1 = 200 \times 10^{-6}C = 2 \times 10^{-4}C$
$q_2 = 500 \times 10^{-6}C = 5 \times 10^{-4}C$
$F = 5\text{gf} = 5 \times 10^{-3}kg\text{f}$
$= 5 \times 10^{-3} \times 10N$
$= 5 \times 10^{-2}N$
r = ?
Using, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ we get
$5 \times 10^{-2} = \frac{9\times 10^9 \times 2\times 10^{-4}\times 5\times 10^{-4}}{r^2}$
or $r = 1.34 \times 10^2 m$

14. a. Figure (a) cannot represent electrostatic field lines since electrostatic field lines start or end only at 90° to the surface of the conductor.
    b. Figure (b) too cannot represent electrostatic field lines as electrostatic field lines do not start from a negative charge.
    c. Electrostatic field lines are represented by figure (c)
    d. Figure (d) cannot represent electrostatic field lines since no two such lines of force can intersect each other.
    e. As electrostatic field lines cannot form closed loop, therefore figure (d) also does not represent electrostatic field lines.
15. Gauss's law states that the net flux of an electric field in a closed surface is directly proportional to the enclosed electric charge. It is one of the four equations of Maxwell's laws of electromagnetism. It was initially formulated by Carl Friedrich Gauss in the year 1835 and relates the electric fields at the points on a closed surface and the net charge enclosed by that surface.
The electric flux is defined as the electric field passing through a given area multiplied by the area of the surface in a plane perpendicular to the field. Yet another statement of Gauss's law states that the net flux of a given electric field through a given surface, divided by the enclosed charge should be equal to a constant. The total electric flux linked with a surface is equal to the total number of electric lines of force passing through the surface when surface is held normal to the direction of electric field. The SI unit of electric flux is Nm^2C^{-1}.
According to Gauss' law in electrostatics, the surface integral of electrostatic field E produced by any sources over any closed surface S enclosing a volume V in vacuum, i

e. total electric flux over the closed surface Sin vacuum, isl $\frac{1}{\varepsilon_0}$ times the total charge (q) contained inside S, i.e. $\phi_E = \oint_S \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$

Maxwell's equations let us calculate the forces charged particles exert on each other. While Newton's laws only hold for particles moving with speeds much less than the speed of light, Maxwell's equations hold for particles moving with any speed. We say that Maxwell's equations are relativistically correct. Maxwell's equations are a set of four equations. The first of these equations is Gauss law -



where, $\hat{r}$ is unit vector directed from 0 to P. Consider a small area element dS of the sphere around P. Let it be represented by the vector $dS + \hat{n} \cdot dS$.

where, $\hat{n}$ is unit vector along out drawn normal to the area element.

$\therefore$ Electric flux over the area element,

$d\phi_E = \mathbf{E} \cdot dS = \left(q/4\pi\varepsilon_0 \cdot \hat{\mathbf{r}}/r^2\right) \cdot (\hat{n} dS)$

$\mathbf{E} \cdot d\mathbf{S} = q/4\pi\varepsilon_0 \quad dS/r^2 \cdot \hat{\mathbf{r}}\hat{\mathbf{n}}$

As normal to a surface of every point is along the radius vector at that point, therefore, $\hat{r} \cdot \hat{n} = 1$

$E \cdot dS = q/4\pi\varepsilon_0 \cdot dS/r^2$

Integrating over the closed surface area of the sphere, we get total normal electric flux over the entire sphere,

$\phi_E = \oint\limits_S E \cdot d\mathbf{S} = \frac{q}{4\pi\varepsilon_0 r^2} \oint\limits_S dS = \frac{q}{4\pi\varepsilon_0 r^2} \times$ total area of surface of sphere..

$= \frac{q}{4\pi\varepsilon_0 r^2}\left(4\pi r^2\right) = \frac{q}{\varepsilon_0}$

Hence, $\oint_S \mathbf{E} d\mathbf{S} = q/\varepsilon_0$, which proves Gauss' theorem.

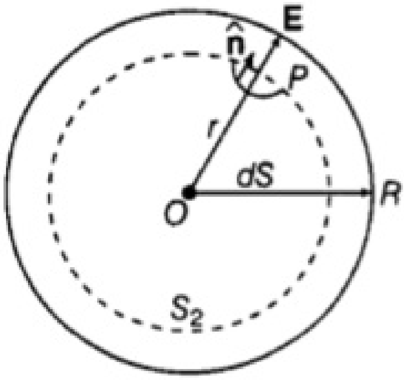
i. Electric field inside a uniformly charged spherical shell.

   According to Gauss' theorem

   $\oint_S \mathbf{E} \cdot d\mathbf{S} = \oint_S E\hat{\mathbf{n}} \cdot dS = \frac{q}{\varepsilon_0}$ or $E \oint_S ds = \frac{q}{\varepsilon_0}$

   $\therefore E \cdot 2\pi r^2 = q/\varepsilon_0 \Rightarrow E = q/4\pi\varepsilon_0 r^2$ .... (i)

In the given figure, the point P where we have to find the electric field intensity is inside the shell. The Gaussian surface is the surface of a sphere S_2 passing through P and with the centre at 0. The radius of the sphere S_2 is r < R. The electric flux through the Gaussian surface, as calculated in Eq. (I),i.e. E x4w2• As,charge inside a spherical shell is zero, the Gaussian surface encloses no charge. The Gauss' theorem gives



$E \times 4\pi r^2 = \frac{q}{\varepsilon_0} = 0 \quad \therefore \quad E = 0 \text{ for } r < R$

Hence, the electric field due to a uniformly charged spherical shell is zero at all points inside the shell as no charge resides inside it and potential will be uniform everywhere but on the surface it will be constant and non zero.