CBSE Test Paper-03

Class - 12 Physics (Electric Charges and Fields)

1. Gauss's law states that

   a. the total electric field flux coming out of an open surface equals the net charge enclosed within the volume divided by ε_0
   b. the total electric field flux coming out of any surface equals the charge enclosed within the volume divided by ε_0
   c. the total electric field flux coming out of a closed surface in vacuum equals the net charge enclosed within the volume divided by ε_0
   d. the total electric field flux coming out of a closed surface equals the net charge enclosed within the volume

2. An electric dipole with dipole moment $4 \times 10^{-9}\mathrm{C}$ m is aligned at 30° with the direction of a uniform electric field of magnitude $5 \times 10^{4}\mathrm{N/C}$. Calculate the magnitude of the torque acting on the dipole.

   a. $1.0 \times 10^{-4}\mathrm{Cm}$
   b. $1.5 \times 10^{-8}\mathrm{Nm}$
   c. $2.5 \times 10^{-4}\mathrm{Cm}$
   d. $3.5 \times 10^{-4}\mathrm{Cm}$

3. There is a uniform field of strength $10^{3}\mathrm{Vm}^{-1}$ along the y-axis. A body of mass 1g and charge 10^{-6} C is projected into the field from the origin along the positive x-axis with a velocity of $10\mathrm{ms}^{-1}$. Its speed (in ms^{-1} after 10 second will be (neglect gravitation)

   a. $10\sqrt{2}$
   b. 20.0
   c. $5\sqrt{2}$
   d. 10.0

4. 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 $8.0 \times 10^{3}\,\mathrm{Nm}^{2}/\mathrm{C}$.

(i) What is the net charge inside the box?

(ii) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box?

a. 0.04 μC, Yes
b. 0.06 μC, Yes
c. 0.05 μC, No
d. 0.07 μC, No

5. A pendulum bob of mass m carrying a charge q is at rest with its string making an angle θ with the vertical in a uniform horizontal electric field E. The tension in the string is

a. $\frac{qE}{cos\theta}$
b. mg
c. $\frac{qE}{sin\theta}$
d. $\frac{mg}{sin\theta}$

6. What is the relevance of large value of K (= 81) for water?

7. Does motion of a body affect its charge?

8. Why does an ebonite rod get negatively charged on rubbing with fur?

9. Can a charged body attract another uncharged body? Explain.

10. A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 μCm^{-2}.

i. Find the charge on the sphere.
ii. What is the total electric flux leaving the surface of the sphere?

11. Dielectric constant of a medium is unity. What will be its permittivity?

12. A polythene piece rubbed with wool is found to have a negative charge of $3.2 \times 10^{-7} C$.

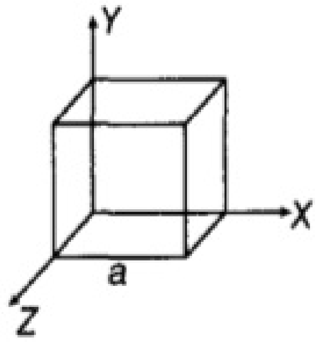
a. Estimate the number of electrons transferred (from which to which)?

b. Is there a transfer of mass from wool to polythene?

13. 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 surface of the plate. Derive the expression for the electric field at the surface of a charged conductor.

14. A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is $1.5 \times 10^3 N/C$ and points radially inward, what is the net charge on the sphere?

15. i. An electric dipole of dipole moment p consists of point charges +qand -q separated by a distance 2a apart. Deduce the expression for the electric field 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 p .Hence, show that in the limit $x >> a, \mathbf{E} \longrightarrow 2p/\left(4\pi\varepsilon_0 x^3\right)$.
    ii. Given the electric field in the region $E = 2x\hat{\mathbf{i}}$, find the net electric flux through the cube and the charge enclosed by it.



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Answers

1. c. the total electric field flux coming out of a closed surface in vacuum equals the net charge enclosed within the volume divided by

   Explanation: Gauss Theorem- According to Gauss theorem the electric flux through a closed surface in vacuum is given by times net charge enclosed within the surface.

   $\oint \overrightarrow{E}.\overrightarrow{ds} = \oint Eds\cos\theta = \frac{q_{enclosed}}{\varepsilon_0}$

2. a. $1.0 \times 10^{-4}\text{Cm}$

   Explanation: $\tau = pESin\theta = 4 \times 10^{-9} \times 5 \times 10^4 Sin\ 30^0 = 1 \times 10^{-4}N$

3. a. $10\sqrt{2}$ **Explanation:** Given v_x=10m/s, since the electric field is in y-direction so the acceleration is in y-direction $a_{y=}\left(\frac{qE}{m}\right) = \frac{10^{-6}\times 10^3}{10^{-3}} = 1\ m/s^2$

   So velocity in y direction v_y = at = 1 $\times 10 = 10m/s$ v_x = 10m/s

   So $v = \sqrt{{v_x}^2 + {v_x}^2} = \sqrt{10^2 + 10^2} = 10\sqrt{2}m/s$

4. d. 0.07 μC, No

   Explanation:

   a. Net outward flux through the surface of the box, ϕ = 8.0 × 10^3 N m^2/C

      For a body containing net charge q,

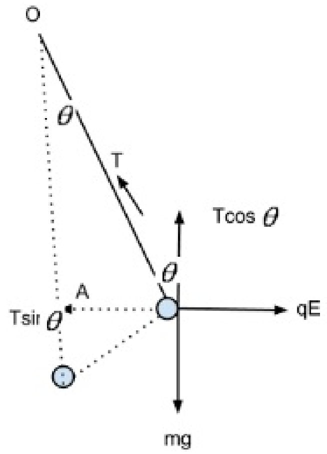
      flux is given by the relation, ϵ_0 = Permittivity of free space = 8.854 × 10^{-12} $N^{-1}C^2\ m^{-2}$

      We have $\phi = \frac{q}{\epsilon_0}$ So, q $= \epsilon_0\phi$

      $= 8.854 \times 10^{-12} \times 8.0 \times 10^3 = 7.08 \times 10^{-8}$ = 0.07 µC Therefore, the net charge inside the box is 0.07 µC.

   b. No Net flux piercing out through a body depends on the net charge contained in the body. If net flux is zero, then it can be inferred that net charge inside the body is zero. The body may have equal amount of positive and negative charges.

5. c. $\frac{qE}{sin\theta}$

Explanation: 

For equilibrium, TCos$\theta = mg$; TSin $\theta = qE$, Hence, $T = \frac{qE}{Sin\theta}$

6. It makes water a great solvent. This is because binding force of attraction between oppositely charged ions of the substance in water becomes 1/81 of the force between these ions in air.

7. No, charge on a body does not change with motion of the body.

8. Electrons are lost by fur while ebonite rod gains them. Electrons in fur are less tightly bound than electrons in ebonite.

9. Yes, a charged body can attract another uncharged body. When the charged body is placed near the uncharged body, the induced charges of opposite kind are produced on the uncharged body and the uncharged body is attract by charged body.

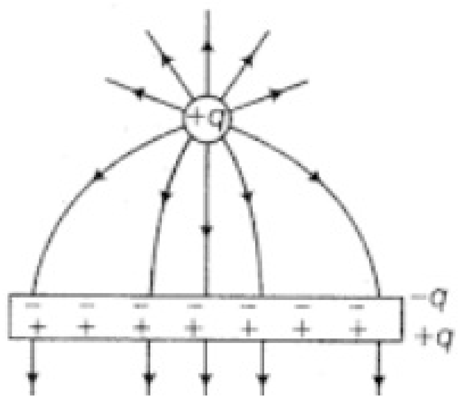
10. i. Data Given -
 Radius of sphere, $R = \frac{d}{2} = \frac{2.4}{2} = 1.2\text{m}$
 Surface charge density, $\sigma = 80 \times 10^{-6}\text{Cm}^{-2}$
 $\therefore \quad \sigma = \frac{q}{4\pi R^2} \quad \text{or} \quad q = 4\pi R^2\sigma$
 Charge on the sphere(q)
 $q = 4 \times 314 \times (1.2)^2 \times 80 \times 10^{-6}\text{C}$
 $q = 1447 \times 10^{-3}\text{C}$
 ii. 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
 Electric flux, $\phi = \frac{q}{\varepsilon_0}$

$\phi=\frac{1.447\times10^{-3}}{8.85\times10^{-12}}\mathrm{Nm}^2\mathrm{C}^{-1}$
$\phi=163\times10^8\mathrm{Nm}^2\mathrm{C}^{-1}$

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.

11. We know that dielectric constant of a medium is
$K=\in_r=\frac{\in}{\in_0}$
$\therefore \in=k\in_0=1\times8.854\times10^{-12}$
$=8.854\times10^{-12}C^2N^{-1}m^{-2}$

12. a. Given, $q=-3.2\times10^{-7}C$
$e=-1.6\times10^{-19}C$
$\therefore$number of electrons transferred
$n=\frac{q}{e}=\frac{-3.2\times10^{-7}}{-1.6\times10^{-19}}=2\times10^{12}$
Electrons are transferred from wool to polythene during rubbing as polythene has negative charge.
b. From wool to polythene, certainly there is a transfer of mass.
Mass of an electron $=9.1\times10^{-31}kg$
Thus, amount of mass transferred $=2\times10^{12}\times9.1\times10^{-31}kg$
$=18.2\times10^{-19}kg$

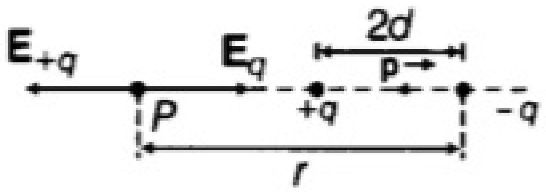
13. 

Electric lines of forces should fall/ normally 90° away on/ from the conducting plate. Electric field lines are always perpendicular to the surface of the conductor and given by $E=\sigma/\epsilon_0$

14. Given, r = 10cm = 0.1m
$E=1.5\times10^3N/C$ at d = 0.2 m

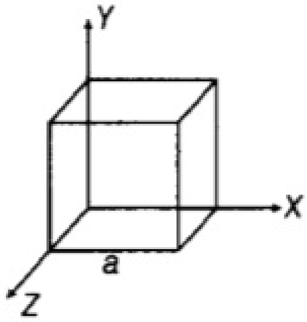
As $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
then, $q = E \cdot 4\pi\varepsilon_0 \cdot r^2$
or, $q = 1.5 \times 10^3 \times 4\pi \times \left(\frac{1}{4\pi \times 9 \times 10^9}\right) \times (0.2)^2$
or, $q = \frac{6}{9} \times 10^{-8} = \frac{60}{9} \times 10^{-9}$
$= 6.67 \times 10^{-9} C$
Here, q is negative since electric field is directed inward.
Thus, $q = 6.67 \times 10^{-9} C$
= -6.67nC

15. An **electric dipole** is a separation of positive and negative charges. The simplest example of this is a pair of **electric** charges of equal magnitude but opposite sign, separated by some (usually small) distance.Electric field on an axial line of an electric dipole can be calculated by computing the electric field due to both the charges and adding them vectorally given the angle between them.



Let P be a point at distance r from the centre of the dipole on the side of charge - q so its distance from +q will be r+d and from +q its distance will be r-d.
Then, the Electric field at point P due to charge - q of the dipole is given by,
$E_{-q} = -\frac{q}{4\pi\varepsilon_0 (r+a)^2}\hat{\mathbf{p}}$
where, $\hat{p}$ is the unit vector along the dipole axis (from -q to q) as shown in the figure
Also, the electric field at point P due to charge +q of the dipole is given by,
$\mathbf{E}_{+q} = \frac{q}{4\pi\varepsilon_0 (r-a)^2}\hat{\mathbf{p}}$
The total field at point P will be the vector sum of all the electric fields
$\mathbf{E} = \mathbf{E}_{+q} + \mathbf{E}_{-q} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{\mathbf{p}}$
$\Rightarrow \quad \mathbf{E} = \frac{q}{4\pi\varepsilon_0} \cdot \frac{4ar}{(r^2-a^2)^2}\hat{\mathbf{P}}$
$\because \quad r = x$
$\mathbf{E} = \frac{q}{4\pi\varepsilon_0}\frac{4ax}{(x^2-a^2)^2}\hat{\mathbf{p}}$
For x >> a, $\mathbf{E} = \frac{4qa}{4\pi\varepsilon_0 x^3}\hat{\mathbf{p}} \Rightarrow \mathbf{E} = \frac{2\mathbf{P}}{4\pi\varepsilon_0 x^3}$

so electric field due a dipole decreases as cube of the distance from the centre of the dipole.

i. 

As per the problem, electric field has only x component, for faces normal to X - direction, the angle between E and ΔS is $\pm \pi/2$ Therefore, the flux is separately zero for each of the cube except the shaded ones. The magnitude of the electric field at the left face will be

$E_l = 0$ (as, x = O at the left face).

The magnitude of the electric field at the right face is E_R = 3a (as, x = a at the right face).

The corresponding fluxes are

$\phi_L = \mathbf{E}_L \cdot \Delta\mathbf{S} = 0$

$\phi_R = \mathbf{E}_R \cdot \Delta\mathbf{S} = E_R \Delta S \cos\theta = E_R \Delta S \quad (\because \theta = 0^\circ)$

$\Rightarrow \quad \phi_R = E_R a^2$

Net flux (ϕ) through the cube

$= \phi_L + \phi_R = 0 + E_R a^2 = E_R a^2 \Rightarrow q = 2a(a)^2 = 2a^3$

Statement of **Gauss's law** is that the net flux of an electric field through a surface divided by the enclosed charge is equal to a constant.

$\phi = q/\varepsilon_0 \quad \therefore \quad q = \phi\varepsilon_0 = 2a^3\varepsilon_0$

that's how we can find the charge which resides inside the cube and $2a^3\varepsilon_0$ is the amount of charge that resides in the cube which is the direct application of gauss law as first flux was calculated then it was related to internal charge multiplied by permittivity of free space.