Solution

CET25P1 ELECTRIC CHARGES AND FIELDS

Class 12 - Physics

1.

(d) Each one of these

Explanation: If the electric field is E and the area is A, the electric flux associated with the area is ϕ = EA cos θ.
Where θ represents the angle formed between the surface and the electric field.
The electric flux is clearly dependent on the electric field strength, area, and angle between the surface and the electric field.

2.

(d) 10^{-12} m

Explanation: The distance must be greater than the nuclear size ($\approx 10^{-15}$m). For r $\leq 10^{-15}$m, the much stronger nuclear force makes the coulombic force ineffective.

3. **(a)** 4×10^{-7} Nm

Explanation: $\tau_{\max}$ = pE = q $\times$ 2a $\times$ E

= $2 \times 10^{-10} \times 1 \times 10^{-2} \times 2 \times 10^{5}$ Nm

= 4×10^{-7} Nm

4.

(b) 1.6×10^{-19} coulomb

Explanation: 1.6×10^{-19} coulomb

5.

(b) Electric dipole moment

Explanation: SI units for electric dipole moment are Coulombmeter (Cm), however, the most common unit is the Debye (D).

6.

(d) Zero

Explanation: Electric field is zero at all points inside a hollow charged conducting sphere.

7.

(b) Zero

Explanation: By the symmetry, electric field at center due to each elements will cancel out each other and hence net electric field at center will be zero.

8.

(b) Coulomb

Explanation: The unit of electric charge is Coulomb (C).

9. **(a)** are imaginary

Explanation: An electric line of force is an imaginary continuous line or curve drawn in an electric field.

10.

(b) electrostatic

Explanation: Coulomb force, also called electrostatic force or Coulomb interaction, attraction. or repulsion of particles or objects because of their electric charges. The strength of the electric field is given by the electric field or the Coulomb field which is E = F/q.

11. **(a)** +0.20 C

Explanation: Charge on 1 electron = -1.6×10^{-19} C

So, Charge on 5×10^{18} electrons

= $-5 \times 10^{18} \times 1.6 \times 10^{-19}$ C = -0.8 [$\because$ q = ne]

Already existing charge = 1 C

So, net charge after electron gain = 1 + (-0.8) = 0.2

12.

(c) $\sqrt{\frac{m_p}{m_e}}$

Explanation: t = $\sqrt{\frac{2s}{a}}$

For same s, t $\propto \frac{1}{\sqrt{a}}$

$\therefore \frac{t_2}{t_1} = \sqrt{\frac{a_1}{a_2}} = \sqrt{\frac{F_e/m_e}{F_e/m_p}} = \sqrt{\frac{m_p}{m_e}}$

13.

(b) 4.5 $\times$ 10^6 N/C towards + 5μC

Explanation: At the midpoint, the fields of the two charges are in opposite directions. The resultant field is directed from a larger charge to a smaller charge.

E = $\frac{1}{4\pi\varepsilon_0}\frac{q_2-q_1}{r^2}$

= 9 $\times$ 10^9 $\frac{(10-5)\times10^{-6}}{\left(10\times10^{-2}\right)^2}$ = 4.5 $\times$ 10^6 N/C

14.

(c) zero, $7.5 \times 10^{-8}\mathrm{Cm}$

Explanation: Total charge = $2.5 \times 10^{-7} - 2.5 \times 10^{-7} = 0$

Dipole moment = either charge $\times$ separation between charges

= $2.5 \times 10^{-7} \times 30 \times 10^{-2} = 7.5 \times 10^{-8}\ cm$

15.

(c) Zero

Explanation: On all the dipoles, net charge = 0. Hence net charge enclosed within the surface = 0. So the total electric flux coming out of the surface, $\phi = \frac{q_{net}}{\varepsilon_0} = 0$

16.

(d) polarity of charge

Explanation: The property which differentiates the two types of charges is called the polarity of charge.

17.

(b) 12.83 $\times 10^4$ V/m

Explanation: F_e = mg

4eE = density $\times$ volume $\times$ g = d $\times$ $\frac{4}{3}$ $\times$ π $\times$ r^3 $\times$ g

Given, d = 2g/cc = 2000 kg/m^3; r = 10^{-6} m

Thus, 4 $\times$ 1.6 $\times$ 10^{-19} $\times$ E = 2000 $\times$ $\frac{4}{3}$ $\times$ 3.14 $\times$ 10^{-18} $\times$ 9.8

E = (2000 $\times$ $\frac{4}{3}$ $\times$ 3.14 $\times$ 10^{-18} $\times$ 9.8) / (4 $\times$ 1.6 $\times$ 10^{-19}) = 12.83 $\times$ 10^4 V/m

18. **(a)** 3 NC^{-1}

Explanation: E = $\frac{\sigma}{\varepsilon_0} = \frac{2.56\times10^{-11}}{8.854\times10^{-12}} \simeq$ 3 NC^{-1}

19. **(a)** $E_D > E_A = E_B = E_C = 0$

Explanation: $E_D > E_A = E_B = E_C = 0$

20.

(c) Gaussian surface

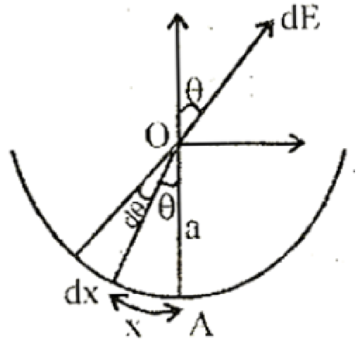
Explanation: The surface that we choose for the application of Gauss's law is called the Gaussian surface.

21.

(c) $\frac{\lambda}{2\pi\varepsilon_0 a}$

Explanation: λ = linear charge density;

Charge on elementary portions is given by dq = λdx



Electric field at O is given by , $dE=\frac{\lambda dx}{4\pi\varepsilon_0 a^2}$

Horizontal electric field, i.e., perpendicular to AO, will cancelled.

Hence, net electric field = addition of all electrical fields in direction of AO

$=\sum \mathrm{dE}\cos\theta$

$\Rightarrow E=\int \frac{\lambda dx}{4\pi\varepsilon_0 a^2}\cos\theta$

Also, $\mathrm{d}\theta=\frac{\mathrm{d}x}{\mathrm{a}}$ or $\mathrm{dx}=\mathrm{ad}\theta$

$E=\int_{-\pi/2}^{\pi/2}\frac{\lambda\cos\theta d\theta}{4\pi\varepsilon_0 a}=\frac{\lambda}{4\pi\varepsilon_0 a}[\sin\theta]_{-\pi/2}^{\frac{\pi}{2}}$

$=\frac{\lambda}{4\pi\varepsilon_0 a}[1-(-1)]=\frac{\lambda}{2\pi\varepsilon_0 a}$

22. **(a)** $3\cdot 3\times 10^{-18}$ C

Explanation: Here, mass of the drop (m) = 9.9 $\times$ 10^{-15} kg; Electric field (E) = 3 $\times$ 10^4 Vm^{-1}

Let q be the charge on the drop. As the drop neither falls nor rises, the force due to the electric field is just equal to its weight i.e.,

qE = mg

or $q=\frac{mg}{\mathrm{E}}=\frac{9\cdot 9\times 10^{-15}\times 10}{3\times 10^4}=3.3\times 10^{-18}$ C

23. **(a)** $-10^3\mathrm{Nm}^2/\mathrm{C}$

Explanation: 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.

24. **(a)** $\frac{\rho r}{3\varepsilon_0}$

Explanation: Electric field inside a uniformly charged sphere (r < R),

E = $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^3}r$

But q = $\frac{4}{3}\pi$ $\mathrm{R}^3\rho$

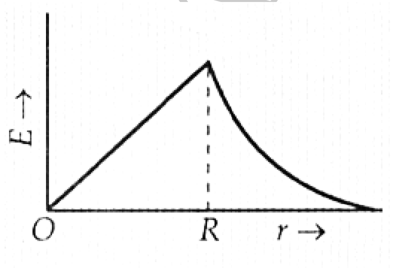
$\therefore$ E = $\frac{\rho r}{3\varepsilon_0}$

25.

(b) $\frac{1}{r^2}$

Explanation: According to Coulomb's law the force between two charges is inversely proportional to the square of distance between the two charges. So $F\alpha\frac{1}{r^2}$.

26.

(b) 

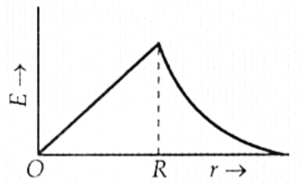
Explanation:

For points inside a charged sphere,

E $\propto$ r

And for points outside a charged sphere,

E $\propto$ $\frac{1}{r^2}$



Hence this option is correct.

27.

(b) $\frac{mg}{e}$

Explanation: Force exerted by electric field = Weight of water drop

eE = mg

or E = $\frac{mg}{e}$

28.

(c) 6 $\times$ 10^{18}

Explanation: As we know that,

q = ne

$\therefore$ No of protons, n = $\frac{q}{e}$

$= \frac{1}{1.66 \times 10^{-19}}$

= 6.02 $\times$ 10^{18}

29.

(b) $\frac{1}{2\pi}\sqrt{\frac{pE}{I}}$

Explanation: Restoring torque for small θ,

τ = -pE sinθ = -pEθ [sin $\theta \simeq \theta$]

or Iα = -pEθ

$\therefore \alpha = -\frac{pE}{I}\theta$ i.e., $\alpha \propto \theta$

$\therefore$ v = $\frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{pE}{I}}$

30.

(b) 50 V cm^{-1}

Explanation: $a = 8.8 \times 10^{14} m/s^2$

$\frac{e}{m} = 1.76 \times 10^{11} C\ kg^{-1}$

$a = \frac{F}{m} = \frac{eE}{m} = \left(\frac{e}{m}\right) E$

$8.8 \times 10^{14} = 1.76 \times 10^{11} \times E$

$E = \frac{8.8 \times 10^{14}}{1.76 \times 10^{11}} = 5000 V m^{-1} = 50 V cm^{-1}$

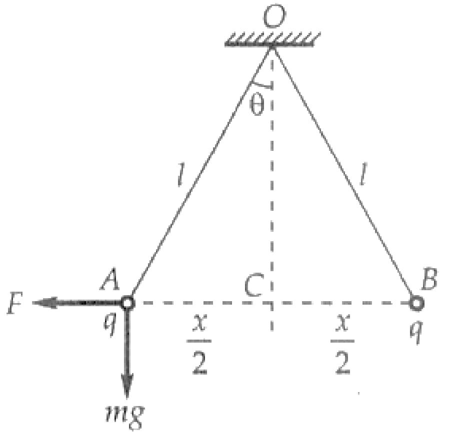
31.

(d) Zero

Explanation: If a charge +q is placed outside, then the electric field lines incident on the conducting sphere induces -q charge on one surface whereas the opposite surface becomes oppositely charged (i.e. +q) and the total charge becomes zero.

32. **(a)** v $\propto x^{-\frac{1}{2}}$

Explanation:



From $\triangle$ACO of forces,

$\frac{F}{AC} = \frac{mg}{OC}$

$\frac{kq^2}{x^2\left(\frac{x}{2}\right)} = \frac{mg}{\sqrt{l^2-\left(\frac{x}{2}\right)^2}}$

$\frac{2kq^2}{x^3} = \frac{mg}{l}$ [$\frac{x}{2}$ << l]

$\therefore q^2 = \frac{mg}{2kl} \cdot x^3$

$\Rightarrow q^2 \propto x^3$

$\Rightarrow q \propto x^{3/2}$

$\Rightarrow \frac{dq}{dt} \propto \frac{3}{2}x^{\frac{1}{2}}\frac{dx}{dt}$

$\Rightarrow \frac{dq}{dt} \propto \frac{3}{2}x^{\frac{1}{2}} \cdot v$

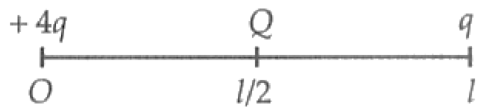
As $\frac{dq}{dt}$ is constant for both spheres, so

$v \propto \frac{1}{x^{\frac{1}{2}}} \Rightarrow v \propto x^{-\frac{1}{2}}$

33.

(b) -q

Explanation:



As the net force on q is zero, so

$k\frac{4q\times q}{l^2} + k\frac{Qq}{(l/2)^2}$ = 0 or Q = -q

34.

(b) Millikan

Explanation: Charge on an electron was calculated by Millikan.

35.

(b) decreases κ times

Explanation: $F_{med} = \frac{F_{air}}{\kappa}$

36.

(d) any closed surface

Explanation: Gauss's law is valid for any closed surface.

37.

(c) $2.26 \times 10^5 \mathrm{Nm}^2/\mathrm{C}$

Explanation: $\phi = \frac{q}{\epsilon_0} = \frac{2\times10^{-6}}{8.85\times10^{-12}} = 2.26 \times 10^5 \mathrm{Nm}^2/\mathrm{C}$

38.

(c) 16

Explanation: F = $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r^2}$
F' = $\frac{1}{4\pi\varepsilon_0}\cdot\frac{2q_1\times 2q_2}{(r/2)^2}$ = 16 F
∴ n = 16

39. **(a)** 2
Explanation: For z >> a, $|E_z| = \frac{2p}{4\pi\varepsilon_0 z^3}$
For y >> a, $|E_y| = \frac{p}{4\pi\varepsilon_0 y^3}$
For z = y >> a, $\frac{|E_z|}{|E_y|}$ = 2

40.
(d) Both $\oint E.dS = 0$ if the charge is outside the surface and $\oint E.dS = \frac{q}{\varepsilon_0}$ if charges of magnitude q is inside the surface
Explanation: If there were only one type of charge in the universe, then also Gauss Law would have been valid.

41.
(d) 1.0×10^{-7} Cm^{-1}
Explanation: Using $E=\frac{\lambda}{2\pi\varepsilon_0 r}$
E= 1.0×10^{-7} Cm^{-1}

42.
(d) $-\frac{E}{2}$
Explanation: Electric field of -2Q at the location of charge Q,
$\kappa\frac{(-2Q)}{r^2}$ = E
Electric field of Q at the location of -2Q,
E' = $\kappa\frac{Q}{r^2}=-\frac{E}{2}$

43.
(c) 1.125 NC^{-1}
Explanation: $E=\frac{F}{q}$
Putting values, $E=\frac{562.5}{500}$ = 1.125 NC^{-1}

44.
(d) $C^2 N^{-1} m^{-2}$
Explanation: $C^2 N^{-1} m^{-2}$

45.
(b) $\frac{2\lambda}{4\pi\varepsilon_0 R}$
Explanation: the field at center is given by $\frac{2\lambda}{4\pi\varepsilon_0 R}$

46.
(b) Coulomb's law
Explanation: Coulomb's law states that, the magnitude of the electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distances between them. The force acts always along the line joining the two charges.

47.
(c) Directed perpendicular to the plane and away from the plane.
Explanation: Let charge +q is placed to the left of isolated conducting plane AB vertical to plane of paper. Due to induction by +q charge, R.H.S. plane will acquire positive charge.
So, line of forces will emerge perpendicularly, outward and parallel to each other.

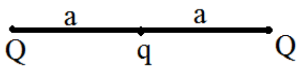
48.
(b) Execute oscillation but not SHM
Explanation: Direction of net electric field due to both the charges at any point on +X axis will be along -X axis, hence the positive charge will experience force in negative X-axis direction.
When it reaches origin, net electric field will become zero, but due to its kinetic energy, positive charge will continue moving

in the -X direction, but now the direction of electric field and hence force on positive charge will be in the +X axis direction, which will tend to bring it back towards origin. So the charge will oscillate about origin. Since force and hence acceleration is not proportional to displacement, its not SHM.

49.

(d) $\frac{-Q}{4}$

Explanation:



The total force on one Q is

$F=\frac{kQ^2}{4a^2}+\frac{kqQ}{a^2}$

For the system to be in equilibrium F = 0

$\frac{kQ^2}{4a^2}+\frac{kqQ}{a^2}=0$

$q=-\frac{Q}{4}$

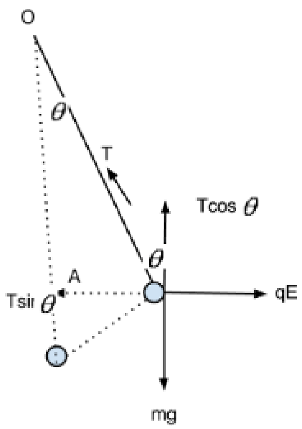
50. **(a)** $\frac{1}{6}\frac{4\pi q}{4\pi\varepsilon_0}$

Explanation: $\phi_E=\frac{q}{\varepsilon_0}=\frac{1}{6}\frac{4\pi q}{(4\pi\varepsilon_0)}$

51.

(c) $\frac{qE}{sin\theta}$

Explanation:



For equilibrium, T cos$\theta=mg$; T sin $\theta=qE$, Hence, $T=\frac{qE}{sin\theta}$

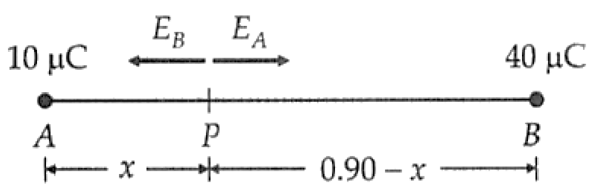
52.

(d) charge distribution on the spheres is not uniform

Explanation: charge distribution on the spheres is not uniform

53. **(a)** 30 cm

Explanation:



At point P, $E_A = E_B$

or $\frac{1}{4\pi\varepsilon_0}\cdot\frac{10\times10^{-6}}{x^2}=\frac{1}{4\pi\varepsilon_0}\cdot\frac{40\times10^{-6}}{(0.90-x)^2}$

or $\frac{1}{x^2}=\frac{4}{(0.90-x)^2}$

or 0.90 - x = 2x

or x = 0.30 m = 30 cm

54. **(a)** 5

Explanation: K = $\frac{E}{E'}$. For an insulator, E' < E, hence K > 1,

$\therefore$ K = 5

55.

(b) Giving excess of electrons to it

Explanation: Giving excess of electrons to it.

56.

(b) decrease

Explanation: Since the spheres are conducting, the surface charge distribution on each sphere will be altered because of the repulsion from the charges on the other sphere. In particular, the charges on each sphere will be pushed away by the charges on the other sphere. This will cause the charges on opposite spheres to be further away from each other, and the force of repulsion to be less than in the case of a uniform surface charge distribution.

57. **(a)** always a force and a torque.

Explanation: always a force and a torque.

58.

(c) (a) - (iv), (b) - (iii), (c) - (i), (d) - (ii)

Explanation: As we know that,

Linear charge density, $\lambda = \frac{q}{L},$ where, L is length of rod

Volume charge density, $\rho = \frac{q}{V},$ where, V is volume

The electric field is quantified by electric field intensity.

The unit of torque is Newton meter.

59. **(a)** -10^{-2} N

Explanation: Dipole moment of the system, p = q $\times$ dl = -10^{-7} Cm

Rate of increase of electric field per unit length,

$\frac{dE}{dl}$ = 10^{+5} NC^{-1}

Force (F) experienced by the system is given by the relation,

F = qE

F = $q\frac{dE}{d1} \times$ dl

= p $\times$ $\frac{dE}{dl}$

= $10^{-7} \times 10^{-5}$

= -10^{-2} N

The force is -10^{-2} N in the negative z-direction i.e., opposite to the direction of electric field. Hence, the angle between electric field and dipole moment is 180^o. Torque (τ) is given by the relation,

T = pE sin 180^o = 0

Therefore, the torque experienced by the system is zero.

60.

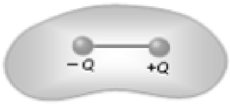
(d) polarity of charge

Explanation: polarity of charge

61.

(c) zero

Explanation: If a dipole is enclosed by a surface, the total electric flux coming out of the sphere is zero because the net charge enclosed by the surface is zero



$\because Q_{enc} = 0$

$\Rightarrow \phi = 0$

(According to Gauss's law, net flux = $\frac{Q_{enclosed}}{\varepsilon_0}$)

62.

(c) 1.45×10^{-3}C

Explanation: $r = \frac{d}{2} = \frac{2.4}{2} = 1.2m$

Surface charge density is :-
$\sigma = 80 \times 10^{-6} C/m^2$
$\sigma = \frac{q}{4\pi r^2}$
$80 \times 10^{-6} = \frac{q}{4 \times 3.14 \times (1.2)^2}$
$q = 1.447 \times 10^{-3} C \approx 1.45 \times 10^{-3} C$

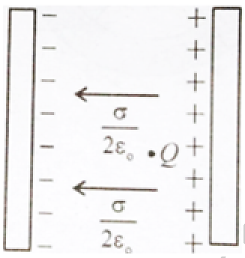
63. **(a)** $30 \mathrm{Nm}^2/\mathrm{C}$

Explanation: Magnitude of electric field intensity, = 3 $\times$ 10^3 N/C
Side of the square, s = 10 cm = 0.1 m
Area of the square, A = s^2 = 0.01 m^2
The plane of the square is parallel to the y-z plane.
Hence, angle between the unit vector normal to the plane and electric field, θ = 0°
Flux (ϕ) through the plane is given by the relation,
ϕ = $\vec{E}.\vec{A} = EA\, cos\theta$ = 3 $\times$ 10^3 $\times$ 0.01 $\times$ cos0° = 30 Nm^2/C

64. **(a)** no net charge is enclosed by the surface
Explanation: Gauss' Law states that net electric flux passing through a closed surface is given by $\oint E.ds = q_{inclosed}/\epsilon_0$ Given that the flux through a surface is zero. So no net charge is enclosed by the surface.

65. **(a)** swings backward & forward hitting each plate in turn
Explanation: When the other plate is connected to the high voltage generator, the negative charge induced on the ball cause attraction. When it strikes the +ve plate charge distribution again takes place. This causes repulsion. Hence, the ball swings backwards and forward hitting each plate in turn.
Or it is attracted by the high voltage plate, when charge is shared, ball is repelled until it goes to other plate and whole of the charge is transferred to the earth and the process is repeated.

66.
(d) $\frac{\sigma}{\varepsilon_0}$

Explanation: 

Field due to a parallel infinite non conducting sheet is given by $E = \frac{\sigma}{2\epsilon_0}$
As two plates are placed parallel, at a point between them field due to positively charged plate will be along the negative plate and due to negatively charged plate field is also towards negatively charged plate.
Thus total field E = $\frac{\sigma}{2\epsilon_0}$ + $\frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}$ towards left.

67.
(d) the inverse square law was not exactly true
Explanation: Gauss's law is based on the inverse square dependence of distance contained in the Coulomb's law. Any violation of Gauss's law will indicate departure from the inverse square law.

68.
(d) $E_1 = 2E_2$

Explanation: The electric field at any axial point is twice the electric field at any equatorial point of the dipole at the same distance. $E_1 = 2E_2$

69. **(a)** $\frac{E^2q^2t^2}{2m}$
Explanation: F = ma = Eq or a = $\frac{Eq}{m}$
v = u + at = 0 + $\frac{Eq}{m} \cdot$ t
K.E. = $\frac{1}{2}$ mv^2 = $\frac{1}{2} m \frac{E^2q^2t^2}{m^2} = \frac{E^2q^2t}{m}$

70.

(b) any enclosed area

Explanation: The Gauss' law is applicable for any closed surface.

71.

(c) $\frac{q}{24\varepsilon_0}$

Explanation: When charge q is placed at one corner, the flux through each of the three faces meeting at this corner will be zero, as $\vec{E}$ is parallel to these faces. One-eighth of the flux emerging from charge q passes through the remaining three faces, so the flux through each such face is $\phi_E = \frac{1}{3} \cdot \frac{1}{8} \frac{q}{\varepsilon_0} = \frac{1}{24} \cdot \frac{q}{\varepsilon_0}$

72. **(a)** $\frac{F}{2}$

Explanation: $F_{liq} = \frac{F_{air}}{\kappa} = \frac{F}{2}$

73. **(a)** $1.125 \times 10^6 \mathrm{N/C}$

Explanation: $E = \frac{q}{4\pi\varepsilon_0 r^2} = \frac{9\times10^9\times500\times10^{-6}}{4}$

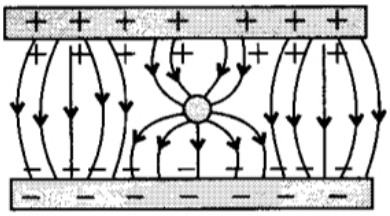
$= 1125 \times 10^3 = 1.125 \times 10^6 N/C$

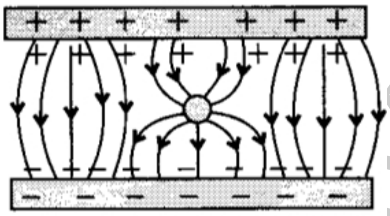
74.

(c) α-particles

Explanation: α-particles are charged particles, so they are deflected by an electric field.

75.

(d) 

Explanation: 

Upper side of the neutral conductor will be negatively charged. Lower side of the neutral conductor will be positively charged. Then the field lines will be from positive to negative as shown in the diagram.