Solution

ELECTRIC CHARGES AND FIELDS WS 1

Class 12 - Physics

1.

   (b) 1.34×10^7 C

   Explanation: 1.34×10^7 C

2.

   (d) both on only on the system of units and only on medium between charges

   Explanation: both on only on the system of units and only on medium between charges.

3.

   (c) four times.

   Explanation: four times.

4.

   (d) charge distribution on the spheres is not uniform

   Explanation: charge distribution on the spheres is not uniform

5.

   (b) 2

   Explanation: F = $\frac{1}{4\pi\varepsilon_0}\frac{q(Q-q)}{x^2}$

   x is constant. For maximum force,

   $\frac{dF}{dq}$ = 0

   $\Rightarrow \frac{d}{dq}$ (qQ - q^2) = 0

   $\therefore$ Q - 2q = 0 $\Rightarrow \frac{Q}{q}$ = 2

6. **(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.

7.

   (c) -q

   Explanation: Force on q due to 4q,

   $F_1 = \frac{1}{4\pi\varepsilon_o}\frac{4q^2}{d^2}$

   Force on q due to Q,

   $F_2 = \frac{1}{4\pi\varepsilon_o}\frac{Qq}{d^2/4} = \frac{1}{4\pi\varepsilon_o}\frac{4Qq}{d^2}$

   For equilibrium, $F_1 + F_2 = 0$ (resultant force is 0)

   $\frac{1}{4\pi\varepsilon_o}\frac{4Qq}{d^2} + \frac{1}{4\pi\varepsilon_o}\frac{4q^2}{d^2} = 0$

   Hence on solving we get, Q = -q

8.

   (b) $\sqrt{3}\frac{a\lambda}{\epsilon_0}$

   Explanation: The maximum length of string that can be fit into cube is $\sqrt{3}a$ which is equal to the length of body diagonal. So, the charge inside the cube is $\sqrt{3}\ \lambda a$

   So, flux $\phi = \frac{q}{\in_0} = \frac{\sqrt{3}\ \lambda a}{\in_0}$

9. **(a)** P_0 (E_2 + E_1) $\hat{k}$

   Explanation: perform the cross product:

   torque = p $\times$ E = |ijk|

So, the torque experienced by the electric dipole in the given electric field is:
$P_0 (E_2 + E_1)\hat{k}$

10.
(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.

11.
(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.

12. **(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, $\frac{|E_z|}{|E_y|} = 2$

13.
(b) $-\kappa\frac{e^2}{r^3}\vec{r}$
Explanation: Charge on an electron = -e
Charge on nucleus of hydrogen = +e
$\therefore \vec{F} = \kappa\frac{(-e)\times e}{r^2}\hat{r} = -\frac{ke^2}{r^3}\vec{r}$
Here $\hat{r} = \frac{\vec{r}}{r}$ is unit vector along the line joining electron to the nucleus. The negative sign shows that the force is of attraction.

14.
(d) $\frac{q}{\epsilon_o}$
Explanation: Since the charge q is placed at the center of the cube, so the electric flux lines move out equally from all sides of the cube. , so by Gauss theorem, the total flux through the cube is $\phi = \frac{q}{\varepsilon_0}$

15.
(b) $\frac{kQ}{r^2}$
Explanation: If the same charges are placed at all corners on polygon than the electric field at centre will be zero. But in the given situation, one charge is missing, so the field at the centre now becomes non zero and the net field at centre must be equal to the field which the missing charge exerts such that the total field become zero.
So, now the field at centre = field due to missing charge = $\frac{Q}{4\pi\in_0 r^2} = k\frac{Q}{r^2}$

16.
(b) $\frac{Q}{6\varepsilon_0}$
Explanation: When a charge Q is placed at one corner of the cube, only one-eighth of the flux emerging from charge Q passes through all the six faces of the cube.
$\therefore \phi_E = \frac{Q}{6\varepsilon_0}$

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

18. **(a)** q Ey
Explanation: Increase in K.E. of the charged particle = Work down on the particle by the electric field
= qE $\times$ y = q Ey

19.
(b) directly proportional to the product of both charges.
Explanation: The magnitude of the electric force F is directly proportional to the amount of an electric charge, q_1, multiplied by the other, q_2, and inversely proportional to the square of the distance 'r' between their centres.

20. **(a)** are imaginary

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

21.

(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' = $\kappa\frac{Q}{r^2}=-\frac{E}{2}$

22. **(a)** $E_a = 2E_q$

Explanation: Electric field at any axial point is twice the electric field at the same distance along the equatorial line

$\therefore E_a = 2E_q$

23.

(b) Giving excess of electrons to it

Explanation: Giving excess of electrons to it.

24.

(c) $1.5\times10^{-2}\mathrm{N}$

Explanation: in the given question ; r= 50 cm = 50 x 10^{-2} cm

$F=\frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}=\frac{9\times10^9\times\left(6.5\times10^{-7}\right)^2}{\left(50\times10^{-2}\right)^2}$

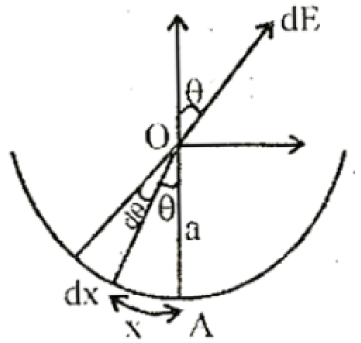
$=1.5\times10^{-2}N$

25.

(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 $\mathrm{dx}=\mathrm{ad}\theta$

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

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

26.

(d) electric field intensity

Explanation: The relation between E, σ and E is E = $\frac{\sigma}{\varepsilon}$

27.

(d) 0.07 μC

Explanation: Net outward flux through the surface of the box, ϕ = 8.0 $\times$ 10^3 N m^2/C

$\in_0$ = Permittivity of free space = 8.854 $\times$ 10^{-12} $N^{-1}C^2$ m^{-2}

For a body containing net charge q, flux is given by the relation,

$\phi = \frac{q}{\in_0}$

So, $q = \in_0 \phi = 8.854 \times 10^{-12} \times 8.0 \times 10^3 = 7.08 \times 10^{-8}$ = 0.07 μC

Therefore, the net charge inside the box is 0.07 μC.

28. **(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 = $\frac{4}{3}\pi$ $R^3\rho$

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

29.

(d) 6.25 $\times$ 10^{18}

Explanation: n = $\frac{q}{e} = \frac{1\text{C}}{1.6 \times 10^{-19}\text{C}}$

= 6.25 $\times$ 10^{18}

30.

(d) 1.0 $\times$ 10^{-7} Cm^{-1}

Explanation: Using $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

E= 1.0 $\times$ 10^{-7} Cm^{-1}

31.

(d) polarity of charge

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

32. **(a)** $\frac{F}{K}$

Explanation: $\frac{F}{K}$

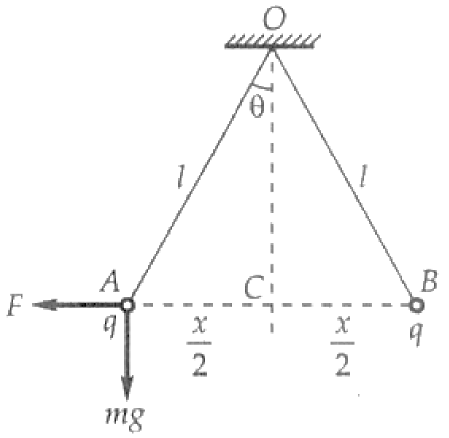
33.

(d) on the outer surface of a charged conductor

Explanation: Electric charge always resides on the outer surface of a charged conductor.

34. **(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

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

35.

(b) electric field

Explanation: Force per unit charge is the electric field.

36.

(b) (i) and (iii)

Explanation: According to Coulomb's law, electric force binds the electrons of an atom to its nucleus and atoms together to form molecules.

37.

(b) decreases κ times

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

38. **(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

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

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

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

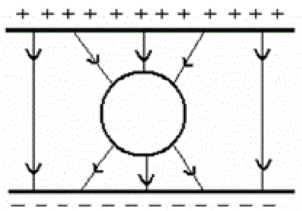
$= -10^{-2}$ N

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.

39.

(c) 

Explanation: Between the plates of capacitor, electric field is uniform. When an uncharged conducting sphere is placed in this region, free charges move within the conductor, polarizing it, until the electric field lines are perpendicular to the surface. The field lines end on excess negative charge on one section of the surface and begin again on excess positive charge on the opposite side. No electric field exists inside the conductor, since free charges in the conductor would continue moving in response to any field until it was neutralize.

40.

(d) Electrons flow from the conductor to the earth

Explanation: After earthing a positively charged conductor electrons flow from earth to conductor and if a negatively charged conductor is earthed then electrons flows from conductor to earth.

41. **(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.

42.

(b) 1.64×10^{-26} N, 2.4×10^{-16} N

Explanation: E = $\frac{F}{q} = \frac{3\times10^{-6}\,\mathrm{N}}{2\times10^{-9}\,\mathrm{C}}$

= 1.5×10^3 NC^{-1}

Electrostatic force on a proton

= eE = $1.6 \times 10^{-19} \times 1.5 \times 10^3$

= 2.4×10^{-16} N

Gravitational force on a proton

= mg = 1.67×10^{-27} kg $\times$ 9.8 ms^{-2}

= 1.64×10^{-26} N

43.

(c) α-particles

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

44.

(b) 2 : 1

Explanation: When the two conducting spheres touch each other there will be a flow of charge until they both have the same potential. Let R_1 and R_2 be the radii of spheres 1 and 2, respectively. Let Q_1 and Q_2 be the charges on spheres 1 and 2, respectively, after they are separated.

Let the common potential=V,

$Q_1 = 4\pi\epsilon_o R_1$

$Q_2 = 4\pi\epsilon_o R_2$

R_1 = 10cm

R_2 = 20cm

Surface charge density on sphere 1,$\sigma_1 = \frac{Q_1}{4\pi R_1^2}$

Surface charge density on sphere 2, $\sigma_2 = \frac{Q_2}{4\pi R_2^2}$

$\frac{\sigma_1}{\sigma_2} = \frac{Q_1}{Q_2} \times \frac{R_2^2}{R_1^2}$

$\frac{\sigma_1}{\sigma_2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2}$

$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$

$\frac{\sigma_1}{\sigma_2} = \frac{20}{10}$

$\sigma_1 : \sigma_2 = 2 : 1$

45.

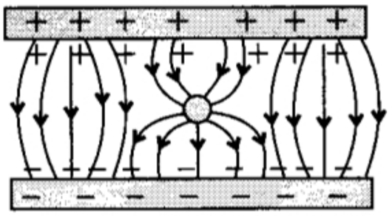
(b) $\frac{F}{8}$

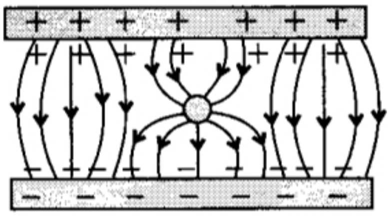
Explanation: As electric field on axial line vaires as

$E \propto \frac{1}{r^3}$ or $\frac{F}{q} \propto \frac{1}{r^3}$ or $F \propto \frac{1}{r^3}$

So, when distance is doubled, force reduces to $\frac{F}{8}$.

46.

(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.

47.

(c) $-\left(1.0 \times 10^{3} \frac{\mathrm{N}}{\mathrm{C}}\right) \hat{\mathrm{i}}$

Explanation: Using $E = \frac{F}{Q}$

E= $-\left(1.0 \times 10^{3} \frac{\mathrm{N}}{\mathrm{C}}\right) \hat{\mathrm{i}}$

48.

(c) 6×10^{18}

Explanation: As we know that,

q = ne

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

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

= 6.02×10^{18}

49.

(d) Zero

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

50.

(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

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

51.

(c) $1.45 \times 10^{-3} \mathrm{C}$

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

Surface charge density is :-

$\sigma = 80 \times 10^{-6} C/m^2$

$\sigma = \frac{q}{4\pi r^2}$

$80 \times 10^{-6} = \frac{q}{4 \times 3.14 \times (1.2)^2}$

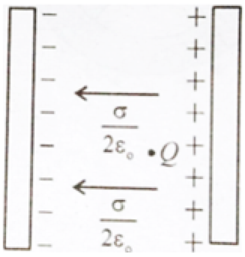
$q = 1.447 \times 10^{-3} C \approx 1.45 \times 10^{-3} C$

52. **(a)** all the charges are in unstable equilibrium

Explanation: The net force on each charge is zero. Therefore, all the charges are in equilibrium. If we slightly displace the charge -q to the right, the net force of attraction will further displace it to the right i.e., away from its mean positive. The equilibrium is, therefore, unstable.

53.

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

Explanation: 

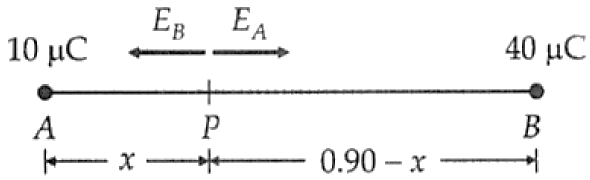
Field due to a parallel infinite non conducting sheet is given by $E = \frac{\sigma}{2\epsilon_0}$

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.

54. **(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

55.

(c) it has lost electrons

Explanation: it has lost electrons

56. **(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.

57.

(d) The angular momentum of the charge −q is constant

Explanation: Since the charge –q is moving in elliptical orbit so to make its motion stable the total angular momentum of the charge is constant since it experience a centripetal force from the charge +Q so it follow the motion as the motion of earth around sun.

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)** $E_D > E_A = E_B = E_C = 0$

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

60.

(c) is the same for all the figures

Explanation: According to the Gauss theorem, the net electric flux through any closed surface S is $\frac{1}{\epsilon_0}$ times the total charge enclosed by S (Irrespective of shape and size of the surface).

All the figures given in the questions have the same charge i.e., +q. So, the electric flux through the surfaces is the same for all the figures.

61.

(b) 4 μC

Explanation: $\tau = pE\sin\theta$

$= q \times 2a \times E\sin\theta$

$q = \frac{\tau}{2a\ E\ \sin\theta} = \frac{8\times10^{-3}}{2\times10^{-2}\times2\times10^{5}\times\sin\ 30^{0}} = 4\mu C$

62.

(b) $\frac{a+b}{a}$

Explanation: Original charge density of the first sphere $\sigma = \frac{Q}{4\pi a^2}$

After the spheres are brought in contact, the charges on the two spheres become Q_1 and Q_2.

The new charge density on the first sphere $\sigma_1 = \frac{Q_1}{4\pi a^2}$

$\frac{\sigma}{\sigma_1} = \frac{Q}{Q_1}$

The spheres also attain a common potential V.

$V = \frac{Q_1}{4\pi\varepsilon_0 a} = \frac{Q_2}{4\pi\varepsilon_0 b}$

$\frac{Q_2}{Q_1} = \frac{b}{a}; \frac{Q_2+Q_1}{Q_1} = \frac{a+b}{a}$

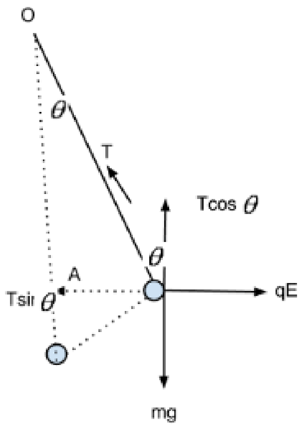
But $Q_2 + Q_1 = Q$

Therefore, $\frac{\sigma}{\sigma_1} = \frac{Q}{Q_1} = \frac{a+b}{a}$

63.

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

Explanation:



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

64.

(c) total charge of the entire universe remains constant

Explanation: total charge of the entire universe remains constant

65. **(a)** $4\pi\varepsilon_0 Ar^3$

Explanation: Flux through sphere,

$\phi = E \times 4\pi r^2$

$\frac{q}{\varepsilon_o} = E \times 4\pi r^2$

$q = 4\pi\varepsilon_o Ar^3$

66.

(d) polarity of charge

Explanation: polarity of charge

67.

(c) it may have formly distributed charge

Explanation: In each of the cases given above, the electric field is not uniform.

68.

(c) 16

Explanation: F = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$

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

$\therefore$ n = 16

69. **(a)** $\frac{Q}{6\varepsilon_0}$

Explanation: Electric flux through 6 faces = $\frac{q}{\varepsilon_0}$

Electric flux through 1 face =$\frac{Q}{6\varepsilon_0}$

70.

(b) 50 V cm^{-1}

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

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

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

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

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

71.

(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.

72. **(a)** 1.0×10^{-4}Nm

Explanation: $\tau = pE sin\theta = 4 \times 10^{-9} \times 5 \times 10^4 sin\ 30^0 = 1 \times 10^{-4} Nm$

73.

(b) rubbing

Explanation: The triboelectric effect is a type of contact electrification on which certain materials become electrically charged after they come into frictional contact with a different material.

Or by rubbing the body having the lower work function loses the electron and becomes positive and another body gains the electron becomes negative.

74. **(a)** 2 units

Explanation: The electrostatic forces are inversely proportional to the square of distance between two charged spheres so on tripling the distance, force decreases by 9 times, hence the force becomes 2 N.

75.

(b) 1.44×10^{11} N/C

Explanation: Charge on a deutron = +e = 1.6×10^{-19} C

E = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$ = $9 \times 10^9 \times \frac{1.6 \times 10^{-19}}{(1 \times 10^{-10})^2}$

= 1.44×10^{11} NC^{-1}