

Solution

Class 12 - Physics

ELECTRIC CHARGES AND FIELDS

Section A

1. (a) 2 mC

Explanation: $\tau = pE \sin \theta = q(2a) E \sin \theta$

$$4 = q \times 2 \times 10^{-2} \times 2 \times 10^5 \sin 30^\circ$$

$$q = 2 \times 10^{-3} \text{ C} = 2 \text{ mC}$$

2. (a) shall increase along the positive x-axis.

Explanation: The total force acting on a given charge is given by the vector sum of individual forces acting on that charges. Net force on charge q_1 , by other charges q_2 and q_3 is along the + x-direction, so nature of force between q_1 and q_2 and q_1 and q_3 is attractive. This is possible when charge q_1 is negative.

Now, if a positive charge Q is placed at $(x, 0)$, then, the force on q_1 shall increase. The direction will be along the positive x-axis.

3. (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 ,

$$Q_1 = 4\pi\epsilon_0 R_1 V$$

$$Q_2 = 4\pi\epsilon_0 R_2 V$$

$$R_1 = 10 \text{ cm}$$

$$R_2 = 20 \text{ cm}$$

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

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

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

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

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

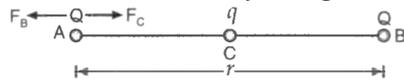
$$\frac{\sigma_1}{\sigma_2} = \frac{20}{10}$$

$$\sigma_1 : \sigma_2 = 2 : 1$$

4. (c) $-\frac{Q}{4}$

Explanation:

Two equal charges of Q each are placed at the points A and B at a distance r apart and the charge q , at the centre C of the line joining the two equal charges as shown in the figure.



Let us first consider the equilibrium of the charge Q placed at point A. Let F_B and F_C be the forces on it due to the charges at the points B and C. For the equilibrium of charge Q at the point A, the net force on it must be zero i.e.

$$F_B + F_C = 0$$

$$\frac{1}{4\pi\epsilon_0} \cdot \frac{Q \times Q}{r^2} + \frac{1}{4\pi\epsilon_0} \cdot \frac{Q \times q}{(r/2)^2} = 0$$

$$\text{or } Q + 4q = 0$$

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

It follows that the forces due to charges at the points A and B on the charge q are equal and opposite and hence it will also be in equilibrium.

5. **(c)** +1.6 C

Explanation: $q = ne = 10^{19} \times 1.6 \times 10^{-19} \text{ C} = +1.6 \text{ C}$

6. **(a)** both a torque and a net force

Explanation: In a non-uniform electric field, an electric dipole experiences both a torque and a net force.

7. **(b)** $-\kappa \frac{e^2}{r^3} \vec{r}$

Explanation: Charge on an electron = -e

Charge on nucleus of hydrogen = +e

$$\therefore \vec{F} = \kappa \frac{(-e) \times e}{r^2} \hat{r} = -\frac{\kappa e^2}{r^3} \vec{r}$$

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.

8. **(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.

9. **(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.

10. **(c)** $1.88 \times 10^5 \text{ Nm}^2/\text{C}$

Explanation: The square can be considered as one face of a cube of edge 10 cm with a center where charge q is placed.

According to Gauss's theorem for a cube, total electric flux $\phi = \frac{q}{\epsilon_0}$ is through all its six faces.

Since the charge lies at the center of cube, so by symmetry flux through each of the 6 faces will be equal.

Hence, electric flux through one face of the cube i.e., through the square, $\phi = \frac{q}{6\epsilon_0}$

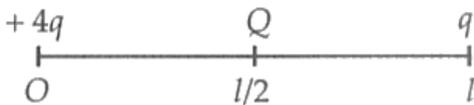
Where, $\epsilon_0 =$ Permittivity of free space = $8.854 \times 10^{-12} \text{ N}^{-1}\text{C}^2 \text{ m}^{-2}$

charge is given by ; $q = 10 \mu\text{C} = 10 \times 10^{-6} \text{ C} = 10^{-5} \text{ C}$

$$\therefore \phi = \frac{q}{6\epsilon_0} = \frac{10 \times 10^{-6}}{6 \times 8.854 \times 10^{-12}} = 1.88 \times 10^5 \text{ Nm}^2 \text{ C}^{-1}$$

11. **(b)** -q

Explanation:



As the net force on q is zero, so

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

12. **(d)** energy will be provided by external source displacing the charge

Explanation: Because the work done by the external force is the change in potential energy and work done by the external force is positive. Hence energy will be provided by external source displacing the charge.

13. **(c)** $\frac{Q}{2\epsilon_0}$

Explanation: If Q is the charge enclosed by conical flask than the flux is given by $\phi = \frac{Q}{\epsilon_0}$

But the charge is placed at the mouth of flask, so if we draw another imaginary flask over it, the charge is surrounded by two flasks now, so the charge through the flask now half of the previous value (shared by

two flask).

So, the flux is given by $\phi = \frac{Q}{2\epsilon_0}$

14. (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.

15. (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

$$\therefore E_a = 2E_q$$

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

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

17. (c) $\frac{q}{8\epsilon_0}$

Explanation: When the charge q is placed at one corner of the cube, only one-eighth of the flux emerging from the charge q passes through the cube.

$$\therefore \phi_E = \frac{q}{8\epsilon_0}$$

18. (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, $\phi = \frac{q_{net}}{\epsilon_0} = 0$

19. (a) $4\pi\epsilon_0 Ar^3$

Explanation: Flux through sphere,

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

$$\frac{q}{\epsilon_0} = E \times 4\pi r^2$$

$$q = 4\pi\epsilon_0 Ar^3$$

20. (b) zero

Explanation: The net charge acquired during induction is zero. There is only the transfer of electrons from one part to another.

21. (d) Zero

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

22. (c) 16

Explanation: $F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r^2}$

$$F' = \frac{1}{4\pi\epsilon_0} \cdot \frac{2q_1 \times 2q_2}{(r/2)^2} = 16 F$$

$$\therefore n = 16$$

23. (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 $\sqrt{3} \lambda a$

$$\text{So, flux } \phi = \frac{q}{\epsilon_0} = \frac{\sqrt{3} \lambda a}{\epsilon_0}$$

24. (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.

25. (c) $-q$

Explanation: Force on q due to $4q$,

$$F_1 = \frac{1}{4\pi\epsilon_0} \frac{4q^2}{d^2}$$

Force on q due to Q ,

$$F_2 = \frac{1}{4\pi\epsilon_0} \frac{Qq}{d^2/4} = \frac{1}{4\pi\epsilon_0} \frac{4Qq}{d^2}$$

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

$$\frac{1}{4\pi\epsilon_0} \frac{4Qq}{d^2} + \frac{1}{4\pi\epsilon_0} \frac{4q^2}{d^2} = 0$$

Hence on solving we get, $Q = -q$

26. **(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.

27. **(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 $E = F/q$.

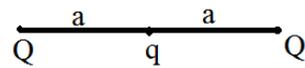
28. **(b)** $\frac{kQ}{r^2}$

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 = $\frac{Q}{4\pi\epsilon_0 r^2} = k \frac{Q}{r^2}$

29. **(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 $F = 0$

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

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

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

Explanation: Restoring torque for small θ ,

$$\tau = -pE \sin\theta = -pE\theta \quad [\sin\theta \simeq \theta]$$

$$\text{or } I\alpha = -pE\theta$$

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

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

31. **(b)** Giving excess of electrons to it

Explanation: Giving excess of electrons to it.

32. **(a)** 6.67 nC

$$\text{Explanation: } E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

$$1.5 \times 10^3 = \frac{9 \times 10^9 q}{(20 \times 10^{-2})^2}$$

So, net charge is given by :-

$$q = 6.67 \times 10^{-9} C = 6.67 nC$$

Since the electric field is inwards so charge is negative.

33. **(b)** $1.64 \times 10^{-26} \text{ N}$, $2.4 \times 10^{-16} \text{ N}$

$$\text{Explanation: } E = \frac{F}{q} = \frac{3 \times 10^{-6} \text{ N}}{2 \times 10^{-9} \text{ C}}$$

$$= 1.5 \times 10^3 \text{ NC}^{-1}$$

Electrostatic force on a proton

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

$$= 2.4 \times 10^{-16} \text{ N}$$

Gravitational force on a proton

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

$$= 1.64 \times 10^{-26} \text{ N}$$

34. **(d)** $\vec{p} \times \vec{E}$

Explanation: Torque on a dipole,

$$\vec{\tau} = \vec{p} \times \vec{E}$$

35. **(b)** 2

Explanation: As we know, $F = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2}$

On putting values, $F = 40\text{N}$, $r = 3 \text{ cm} = 0.03 \text{ m}$, we get

$$q^2 = 40 \times (0.03)^2 / 9 \times 10^9$$

$$q = 2 \times 10^{-6} \text{ C} = 2 \mu\text{C}$$

36. **(d)** smaller

Explanation: $F = ma = eE \Rightarrow a = \frac{eE}{m}$

$$s = ut + \frac{1}{2} at^2$$

$$h = 0 + \frac{1}{2} \frac{eE}{m} t^2$$

$$\therefore t = \sqrt{\frac{2hm}{eE}} \Rightarrow t \propto \sqrt{m}$$

As electron has a smaller mass, its time of fall will be smaller than that of a proton.

37. **(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.

38. **(b)** $4.5 \times 10^6 \text{ N/C}$ towards $+5\mu\text{C}$

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.

$$E = \frac{1}{4\pi\epsilon_0} \frac{q_2 - q_1}{r^2}$$

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

39. **(d)** 4

Explanation: The electric field is always normal to the surface of a conductor. On the surface of a metallic solid sphere, the electrical field is oriented normally (i.e. directed towards the centre of the sphere) and inside the conductor electric field is zero. So, 4th line is correct.

40. **(a)** 2

Explanation: For $z \gg a$, $|E_z| = \frac{2p}{4\pi\epsilon_0 z^3}$

$$\text{For } y \gg a, |E_y| = \frac{p}{4\pi\epsilon_0 y^3}$$

$$\text{For } z = y \gg a, \frac{|E_z|}{|E_y|} = 2$$

41. **(d)** any closed surface

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

42. **(d)** A potential difference appears between the two cylinders when inner cylinder is charged.

Explanation: When the charge is given to inner cylinder, then an electric field is produced between cylinders which is given by $E = \frac{\lambda}{2\pi\epsilon_0 r}$ and due to this a potential difference is developed between two cylinders.

43. **(b)** $\frac{mg}{e}$
Explanation: Force exerted by electric field = Weight of water drop
 $eE = mg$
 or $E = \frac{mg}{e}$
44. **(b)** Both A and R are true but R is NOT the correct explanation of A
Explanation: If a material contains polar molecules, they will generally be in random orientations when no electric field is applied. An applied electric field will polarize the material by orienting the dipole moment of polar molecules.
45. **(c)** Assertion is correct statement but reason is wrong statement.
Explanation: When the uncharged bob is placed in an electric field, its time period does not change. For the charged bob, the time period increases in an electric field because of the increase in restoring force.
46. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation: $\vec{a} = \frac{q\vec{E}}{m}$
 As \vec{E} changes, \vec{a} also change but it does not depend on the velocity of the charged particle.
47. **(c)** A is true but R is false
Explanation: Energy conservation does not fail during the sharing of charges between two bodies. Some energy is lost in the form of heat or light or sparking.
48. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.
49. **(b)** Both A and R are true but R is NOT the correct explanation of A
Explanation: Coulomb attraction exists even when one body is charged and the other is uncharged.
50. **(d)** A is false and R is also false
Explanation: The whole charge of a conductor can be transferred to another isolated conductor, if it is placed inside the hollow insulated conductor and connected with it.
51. **(d)** A is false and R is also false
Explanation: The rate of decrease in the electric field is different in the two cases. In the case of a point charge, it decreases as $(\frac{1}{r^2})$ but in the case of electric dipole, it decreases more rapidly, as $E \propto \frac{1}{r^3}$.
52. **(b)** Both A and R are true but R is NOT the correct explanation of A
Explanation: Both assertion and reason are true but reason is not the correct explanation of assertion.
 As, $\sigma_1 = \sigma_2$ (given)
 $\therefore \frac{q_1}{4\pi r_1^2} = \frac{q_2}{4\pi r_2^2}$ or $\frac{q_1}{q_2} = \frac{r_1^2}{r_2^2}$ [[Let r_1 and r_2 be two different radii.]
 Then the ratio of electric field intensifies near the surface of spherical conductors,
 $\frac{E_1}{E_2} = \frac{q_1}{4\pi\epsilon_0 r_1^2} \times \frac{4\pi\epsilon_0 r_2^2}{q_2}$
 $= \frac{q_1}{q_2} \times \frac{r_2^2}{r_1^2} = \frac{q_1}{q_2} \times \frac{q_2}{q_1} = 1$
 i.e., $E_1 = E_2$
53. **(c)** A is true but R is false
Explanation: When high energy X-ray beam falls on the ball, the metal will emit photo-electrons, thus, leaving the positive charge on the ball. As a result of this, the ball is deflected in the direction of the electric field.
54. **(a)** Both A and R are true and R is the correct explanation of A
Explanation: Inside the charged metallic sphere every point is at the same electric potential, hence, $W = q \Delta V = 0$. But outside the sphere, there exists a potential gradient at every point, hence, $W \neq 0$.
55. **(b)** Both A and R are true but R is NOT the correct explanation of A
Explanation: The electric flux through the cube,
 $\frac{\phi=q}{\epsilon_0}$

A cube has six face equal area, therefore electric flux through each face = $= \frac{1}{6} \cdot \phi = \frac{1}{6} \left(\frac{q}{\epsilon_0} \right)$
= $\frac{1}{6} \times$ total flux.

Section B

56. i. (b) the actual transfer of electrons
ii. (b) The glass rod gives electrons to silk when they are rubbed against each other.
iii. (a) $1.97 \times 10^{-8} N$
iv. (c) both electric and magnetic effects
v. (c) transfer of an integral number of electrons
57. i. (c) a vector quantity
ii. (b) cylindrical symmetric
iii. (a) C-m
iv. (a) $10^{-10} C\cdot m$
v. (b) torque but no net force
58. i. (c) $-3.2 \times 10^{-17} C$
ii. (a) $-1.6 \times 10^{-18} C$
iii. (a) $9.1 \times 10^{-31} kg$
iv. (b) there is positive as well as negative charge in the body but the positive charge is more than a negative charge
v. (a) valence electron only.
59. i. (c) Spherically symmetric
ii. (b) N/C
iii. (c) Electric field lines can intersect with each other.
iv. (d) path 'd'
v. (d) all of the above
60. i. (b) continuous if there is no charge at that point
ii. (a) $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{x^2}$
iii. (c) $8 \times 10^{-15} N$
iv. (a) source charge Q only
v. (a) Zero