Electric Charges and Fields

CHAPTER
1

TRY YOURSELF ANSWERS

1. Since 1 molecule of hydrogen has 2 electrons, then 2 mole hydrogen gas will have $2 \times 2 \times 6.023 \times 10^{23}$ electrons.

$\therefore$ Total charge $q = ne$

$= 2 \times 2 \times 6.023 \times 10^{23} \times 1.6 \times 10^{-19}$

$= 0.358 \times 10^{6}$ C

$= 0.358$ MC

2. During landing the tyres of air crafts are highly charged due to the friction between the tyres and the earth. If the tyres are slightly conducting, the charge will not accumulate on them and will leak to the earth.

3. The particles of black powder which is called toner, stick to a tiny carrier bead of the machine on account of electrostatic forces. Then negatively charged toner particles are attracted from carrier bead to rotating drum, where a positively charged image of document being copied has formed. A charged sheet of paper then attracts the toner particles from the drum to itself. They are then heat up to produce the photo copy.

4. The forces are the same for both electron and proton because magnitude of charge is same as distance is constant.

5. Force in vacuum, $F_0 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r^2}$ ....(i)

When placed in water, $k \simeq 80$ (dielectric constant of water)

$$F_w = \frac{q_1 q_2}{4\pi\varepsilon_0 k r^2} \quad \text{....(ii)}$$

$$\therefore \quad \frac{F_w}{F_o} = \frac{1}{k} \Rightarrow F_w = \frac{F_o}{k} \simeq \frac{F_o}{80}$$

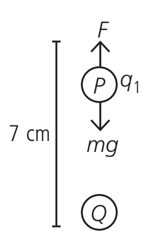
6. $m = 10\text{ g} = 10^{-2}$ kg, $q_1 = 5 \times 10^{-8}$ C, $r = 7$ cm $= 0.07$ m

Second ball q_2 must carry positive charge, so that force of repulsion balances the weight of ball P.

When ball remains stationary

$F = mg$

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



or, $$\frac{9\times10^9 \times 5\times10^{-8}\times q_2}{(0.07)^2} = 10^{-2}\times 9.8$$

$\therefore \quad q_2 = 1.067 \times 10^{-6}$ C

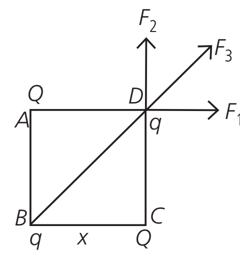
7. The force is attractive, because Q and R will carry opposite charges.

8. No, the Coulomb force due to one charge on another charge is not changed.

9. According to the superposition principle, force between any two charges does not depend upon the presence of any other charge. So force between q_1 and q_2 will remain F only.

10. Let each side of square is x

$BD = \sqrt{x^2 + x^2} = \sqrt{2}.x$



$$F_1 = F_2 = \frac{Qq}{4\pi\varepsilon_0 . x^2}$$

$$F_3 = \frac{qq}{4\pi\varepsilon_0.(x\sqrt{2})^2} = \frac{q^2}{2\times 4\pi\varepsilon_0 .x^2}$$

F_1 and F_2 are perpendicular to each other so, the resultant force is $F = \sqrt{F_1^2 + F_2^2} = F_1.\sqrt{2}$

As net force on q is zero, so

$F_1\sqrt{2} = -F_3$

or $$\frac{Qq\sqrt{2}}{4\pi\in_0 x^2} = \frac{-q^2}{2\times4\pi\in_0 .x^2}$$

$q = -2\sqrt{2}Q$

11. $E \propto \dfrac{1}{r^2}$

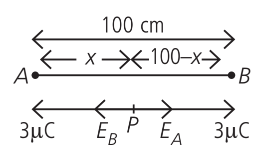
The electric field due to the charge varies inversely proportional to the square of distance from the origin.

12. A proton is '+ve' charged. It will tend to move in the direction of electric field.

13. Given : $AB = 100$ cm,

$q = 3\ \mu$C

Let the electric field is zero at P.



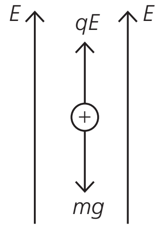
$$\therefore \quad E_A = E_B \Rightarrow \frac{kq}{x^2} = \frac{kq}{(100-x)^2}$$

or $100 = 2x \Rightarrow x = 50$ cm at mid point.

14. A charged circular loop behaves as a point charge, when the observation point on its axis is at a distance very large compared to the radius of the circular loop.

15. The particle has a positive charge twice that of a proton, and mass roughly four times the mass of a proton. Thus for a α-particle, we have

$q = 2 \times (1.6 \times 10^{-19}) = 3.2 \times 10^{-19}$ C
and $m = 4 \times (1.67 \times 10^{-27}) = 6.68 \times 10^{-27}$ kg

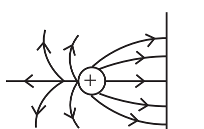


In order to balance the weight mg of the α-particle, which act vertically downwards, the electric force qE on the particle must be vertically upwards. Since the particle is positively-charged, the electric field E exerting on the particle an upward force must be directed vertically upwards. Now for balance

$qE = mg$

$$E = \frac{mg}{q} = \frac{6.68\times10^{-27}\text{kg} \times 98 \text{ N/kg}}{3.2\times10^{-19}\text{C}} = 20\times10^{-7}\text{N/C}.$$

16. The electric field lines are always normal to the surface of a conductor, both while starting or ending on the conductor as shown.



17. As electric field on axial line of dipole varies as

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

as the distance is double, so force reduces to 1/8.

18. $q_1 + q_2 = 0 \Rightarrow q_1 = -q_2$. It is a pair of equal and opposite charges separated by a small distance and form electric dipole.

19. The charges of the dipole experiences equal and opposite forces each qE in the electric field. So, not force on the dipole is zero.

$\tau = pE \sin\theta = 4 \times 10^{-19} \times 5 \times 10^4 \times \sin 30°$

$\tau = 10^{-14}$ N m.

20. If θ is the angle between $\vec{P}$ and $\vec{E}$ then $\theta = 0°$ for stable equilibrium and $\theta = 180°$ for unstable equilibrium.

21. Electric flux through S_1, $\phi_1 = \frac{Q}{\varepsilon_0}$

Electric flux through S_2, $\phi_2 = \frac{Q+3Q}{\varepsilon_0} = \frac{4Q}{\varepsilon_0}$

When air inside S_1 is replaced by a medium of $\varepsilon_r = 10$ then the flux through $S_1 = \phi_3 = \frac{Q}{\varepsilon} = \frac{Q}{\varepsilon_0\varepsilon_r} = \frac{Q}{10\varepsilon_0}$

Now, $\frac{S_1}{S_2} = \frac{Q/10\varepsilon_0}{4Q/\varepsilon_0} = \frac{1}{40}$

22. Flux through one face $= q/6\,\varepsilon_0$

Flux through two opposite faces $= \frac{q}{6\varepsilon_0} + \frac{q}{6\varepsilon_0} = \frac{2q}{6\varepsilon_0} = \frac{q}{3\varepsilon_0}$

23. No, Gauss's law cannot determined the position of charge. It tell us the magnitude of charge enclosed by the Gaussian surface.

24. As $\phi = \frac{q}{\varepsilon_0}$, so flux does not depend upon the radius of the Gaussian surface, it will remain unchanged.

25. Here, $\frac{Q_1}{Q_2} = 1:4$

26. The electric field just outside a charged conductor of surface charge density σ is given by $E = \sigma/\varepsilon_0$

$\sigma = E\varepsilon 0 = 300 \times 8.854\times10^{-12} = 2.65 \times 10^{-9}$ Cm^{-2}.

27. As the enclosed charge is same, so the ratio of flux $\phi_1 : \phi_2 = 1 : 1$