10.2 Electric Charges

Q.2. Explain: Atoms are electrically neutral.

Ans:

i. Matter is made up of atoms which in turn consists of elementary particles proton, neutron and electron.

ii. A proton is considered to be positively charged and electron to be negatively charged.

iii. Neutron is electrically neutral i.e., it has no charge.

iv. An atomic nucleus is made up of protons and neutrons and hence is positively charged.

v. Negatively charged electrons surround the nucleus so as to make an atom electrically neutral.

***Q.9. What is the magnitude of charge on a electron?**

Ans: The magnitude of charge on an electron is 1.6×10^{-19} C.

Q.10. What is quantization of charge?

Ans:

i. Protons (+ve) and electrons (–ve) are the charged particles constituting matter, hence the charge on an object must be an integral multiple of $\pm$ e i.e., $q = \pm ne$, where n is an integer.

i. Charge on an object can be increased or decreased in multiples of e.

ii. It is because, during the charging process an integral number of electrons can be transferred from one body to the other body. This is known as quantization of charge or discrete nature of charge.

Q.16. Define point charge. Which law explains the interaction between charges at rest?

Ans:

A point charge is a charge whose dimensions are negligibly small compared to its distance from another bodies.

Coulomb's law explains the interaction between charges at rest.

Q.17. State and explain Coulomb's law of electric charge in scalar form.

Ans: Coulomb's law:

The force of attraction or repulsion between two point charges at rest is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them. This force acts along the line joining the two charges.

Explanation:

i. Let q_1 and q_2 be the two point charges at rest with each other and separated by a distance r. F is the magnitude of electrostatic force of attraction or repulsion between them.

ii. According to Coulomb's law,

$$F \propto \frac{q_1 q_2}{r^2}$$

$$F = K\frac{q_1 q_2}{r^2}$$

where, K is the constant of proportionality which depends upon the units of F, q_1, q_2, r and medium in which charges are placed.

Q.18. State conditions for electrostatic force to be attractive or repulsive.

Ans:

i. The force between the two charges will be attractive, if the charges are unlike (one positive and one negative).

ii. The force between the two charges will be repulsive, if the charges are similar (both positive or both negative).

***Q.19. What is relative permittivity?**

Ans:

i. Relative permittivity or dielectric constant is the ratio of absolute permittivity of a medium to the permittivity of free space.
It is denoted as K or ε_r.

i.e., $K \text{ or } \varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$

ii. It is the ratio of the force between two point charges placed a certain distance apart in free space or vacuum to the force between the same two point charges when placed at the same distance in the given medium.

i.e., $K \text{ or } \varepsilon_r = \frac{F_{vacuum}}{F_{medium}}$

iii. It is also called as specific inductive capacity or dielectric constant

Q.24. Explain Coulomb's law in vector form.

Ans:

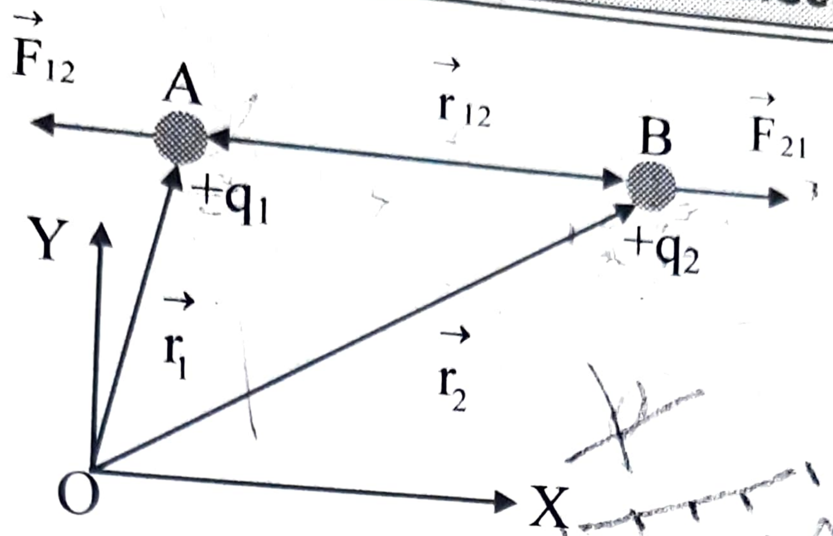
Let q_1 and q_2 be the two similar point charges situated at points A and B and let $\vec{r}_{12}$ be the distance of separation between them.

The force $\vec{F}_{21}$ exerted on q_2 by q_1 is given by,

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{|r_{12}|^2} \times \hat{r}_{12}$$

where, $\hat{r}_{12}$ is the unit vector from A to B.

$\vec{F}_{21}$ acts on q_2 at B and is directed along BA, away from B.



iii. Similarly, the force $\vec{F}_{12}$ exerted on q_1 by q_2 is given by, $\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{|r_{12}|^2} \times \hat{r}_{21}$

where, $\hat{r}_{21}$ is the unit vector from B to A. $\vec{F}_{12}$ acts on q_1 at A and is directed along BA, away from A.

iv. The unit vectors $\hat{r}_{12}$ and $\hat{r}_{21}$ are oppositely directed i.e., $\hat{r}_{12} = -\hat{r}_{21}$

Hence, $\vec{F}_{21} = -\vec{F}_{12}$

Thus, the two charges experience force of equal magnitude and opposite in direction.

v. These two forces form an action-reaction pair.

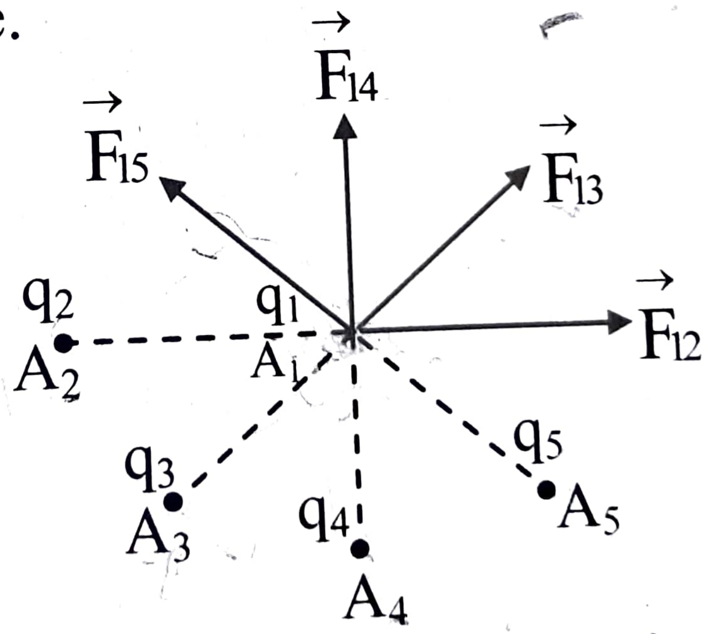
vi. As $\vec{F}_{21}$ and $\vec{F}_{12}$ act along the line joining the two charges, the electrostatic force is a central force.

Q.33. State and explain principle of superposition.

Ans: Statement: *When a number of charges are interacting, the resultant force on a particular charge is given by the vector sum of the forces exerted by individual charges.*

Explanation:

i. Consider a number of point charges q_1, q_2, q_3 ...... kept at points A_1, A_2, A_3 ...... as shown in figure.



Principle of superposition

ii. The force exerted on the charge q_1 by q_2 is $\vec{F}_{12}$

The value of $\vec{F}_{12}$ is calculated by ignoring the presence of other charges. Similarly, force $\vec{F}_{13}$, $\vec{F}_{14}$ can be found, using the Coulomb's law.

iii. Total force $\vec{F}_1$ on charge q_1 is the vector sum of all such forces.

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots.$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{|r_{21}|^2} \times \hat{r}_{21} + \frac{q_1 q_3}{|r_{31}|^2} \times \hat{r}_{31} + \ldots.\right]$$

where $\hat{r}_{21}$, $\hat{r}_{31}$ are unit vectors directed to q_1 from q_2, q_3 respectively and r_{21}, r_{31} r_{41} are the distances from q_1 to q_2, q_3 respectively.

iv. If $q_1, q_2, q_3, \ldots, q_n$ are the point charges then the force $\vec{F}$ exerted by these charges on a test charge q_0 is given by,

$$\vec{F}_{test} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots. + \vec{F}_n$$

$$= \sum_{n=1}^{n} F_n = \frac{1}{4\pi\varepsilon_0} \sum_{n=1}^{n} \frac{q_0 q_n}{r_n^2} \hat{r}_n$$

Where, $\hat{r}_n$ is a unit vector directed from the n^{th} charge to the test charge q_0 and r_n is the separation between them, $\vec{r}_n = r_n \hat{r}_n$

Q.39. Explain the concept of electric field.

Ans:

i. The space around a charge gets modified when a test chargesssss is brought in that region, it experiences a coulomb force. The region around a charged object in which coulomb force is experienced by another charge is called electric field.

ii. Mathematically, electric field is defined as the force experienced per unit charge.

iii. The coulomb force acts across an empty space (vacuum) and does not need any intervening medium for its transmission.

iv. The electric field exists around a charge irrespective of the presence of other charges.

v. Since the coulomb force is a vector, the electric field of a charge is also a vector and is directed along the direction of the coulomb force, experienced by a test charge.

Q.40. Define electric field. State its SI unit and dimensions.

Ans:

i. *Electric field is the force experienced by a test charge in presence of the given charge at the given distance from it.*

$$\vec{E} = \lim_{q \to 0} \frac{\vec{F}}{q}$$

ii. SI unit: newton per coulomb (N/C) or volt per metre (V/m).

iii. Dimensions: $[L^1M^1T^{-3}A^{-1}]$