

## **CHAPTER # 14**

### **ELECTROSTATICS**



#### **Q1. Define Electrostatics and Electric charge.**

**Electrostatics or Static Electricity:** The study of charges while they are not moving is referred to as electrostatics or static electricity.

#### **Electric charge**

Electric charge is a basic characteristic of matter that causes electrical processes.

**Nature:** Electric charge is a scalar quantity.

**Unit:** Its SI unit is coulomb.

**Charge of one electron:** the electron has a negative charge of  $1.6 \times 10^{-19}$  coulomb.

**Repulsion:** Like charges repel each other.

**Attraction:** Opposite charges attract each other.

#### **Q2. Name the Types of charges .**

**Types of charges:** There are two types of charges.

1. Positive charge
2. Negative charge

#### **Q3. Describe the methods of charge formation.**

#### **Methods of charge formation**

There are three methods of formation of charges on a body.

1. Induction
2. Conduction
3. Friction

#### **Induction**

It is a charging method in which a neutral object is charged without actually touching another charged object.

**Conduction:** It is charging by contact where charge is transferred to the object.

**Friction:** The imbalance of electrons and protons can be easily created by friction when two objects rubbing over one another. This process of charging is called charging by friction.

#### **Q4. What do you know about Electrostatic charging by induction?**

#### **Electrostatic charging by induction**

Consider two metal spheres A and B which are touching in the illustration. Take a rubber balloon that is negatively charged.

When we put the charged balloon close to the spheres, the repulsion between the balloon's electrons and spheres' electrons causes electrons in the two-sphere system to move away from the balloon. Following that, electrons from sphere A are transported to sphere B. As electrons migrate, sphere A becomes positively charged, whereas sphere B becomes negatively charged. As a result, the entire two-sphere system is electrically neutral. As depicted in the diagram, the spheres are

then separated using an insulated covering such as gloves or a stand. When the balloon is removed, the charge is redistributed throughout the spheres.

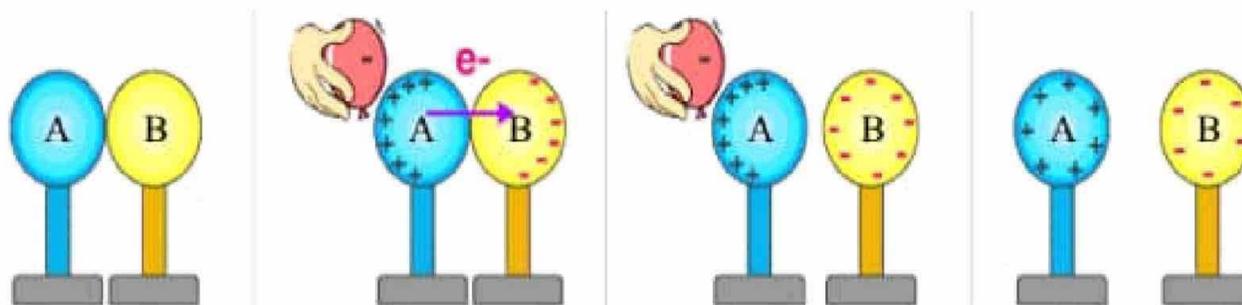


Fig: 14.5 Electric Charge

**Q5. what is Electroscope? Describe its construction.**

**Electroscope**

**Introduction:** In 1600, British physician William Gilbert constructed the first electroscope with a pivoting needle, called verborum.

**Definition:** An electroscope is a scientific instrument for detecting the presence of an electric charge on a body.

**Principle:** The operation of an electroscope is based on the atomic structure of elements; charge induction, the internal structure of metal elements, and the concept that similar charges repel each other while unlike charges attract each other. These four concepts form the basis of the electroscope's working principle.

**Construction:** An electroscope has a metal detector knob on top and metal leaves on the connecting rod. When there is no charge present, the metals' leaves are allowed to hang

**Working:** When an item with a charge is brought near an electroscope, one of two things may happen. Positive charges attract electrons in the electroscope's metal, which migrate upward out of the leaves. This causes the leaves to have a transient positive charge, and since similar charges repel, the leaves split as illustrated in figure (a). When the charge is released, the electrons return to their normal places and the leaves relax, figure (b).

When the charge is negative, the electrons in the electroscope metal reject and migrate toward the leaves. When the leaves are temporarily negatively charged, they split once again because opposite charges repel one another figure (c). If the charge is removed, the electrons return to their original location and the leaves relax.

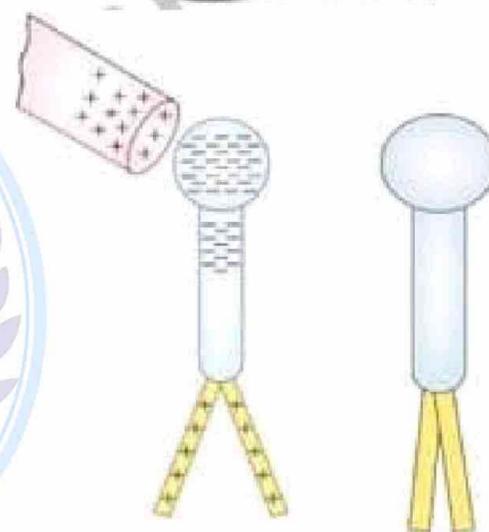
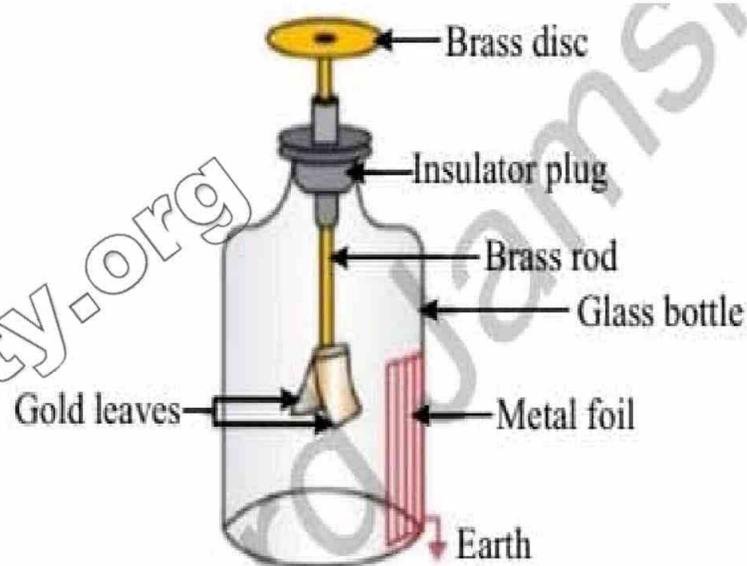
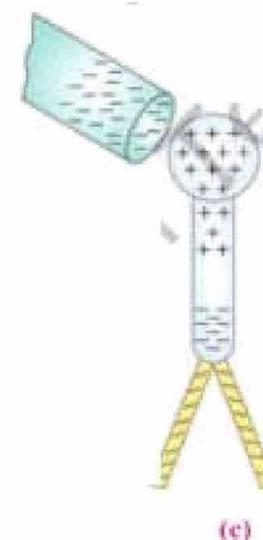


Fig: 14.9 (a)

Fig: 14.9 (b)



(c)

An electroscope reacts to a charge by moving electrons into or out from the leaves. In both circumstances, the leaves separate. The electroscope cannot tell whether a charge item is positive or negative; it just detects an electrical charge

**Q6.State and explain Coulomb's law. Also derive its formula and give value of its constant.**

### Coulomb's law

#### **STATEMENT:**

Coulomb's law states that:

The magnitude of the electrostatic force of attraction or repulsion between two points charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distance between them.

#### **MATHEMATICALLY:**

Magnitude of the electrostatic force is

Directly proportional to the product of the magnitudes of charges

$$F \propto q_1 q_2$$

Inversely proportional to the square of the distance between them

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

#### **Combining eq 1 and 2**

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

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

Where “k” is constant and its value is  $9 \times 10^9 \text{ Nm}^2/\text{C}^2$

Where is the constant of proportionality

**For value of  $\epsilon$ :**

$$K = \frac{1}{4\pi\epsilon}$$

Where K is the constant of proportionality

$$F = \frac{1}{4\pi\epsilon} \frac{q_1 q_2}{r^2}$$

For value of  $\epsilon$

$$K = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

$$\epsilon = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

**Q7.Define Electric field. Give its formula and unit.**

**Electric field**

A region around the charged particle or object within which a force would be exerted on other charged particles or objects.

**Mathematically:** The formula of electric field is given as

$$E = \frac{F}{Q}$$

Whereas,

E = electric field.

F = force.

Q = charge

**Unit:** The SI unit of electric field is N/C

### Q8. Define Electric field lines

#### Electric field lines

The electric field that surrounds a charge may be imagined as the existence of a line of force all the way around it. Electric or electrostatic lines of force refer to a system of imaginary lines around a charged object and indicating the stress on that object.

### Q9. What is Point charge and test charge?

Point charge is an electric charge. When the linear sizes of charge bodies are much smaller than the distance between them, their sizes may be ignored and considered as a point charge.

**Test charge:** Test charge is a charge with a magnitude so small that placing it at a point has a negligible effect on the field around the point.

**Quantization of electric charge:** The fact that all observable charges are always some integral multiple of elementary charge  $e = 1.6 \times 10^{-19}$  C is known as quantization of electric charge.

**Mathematically:**

Where,

$n=1,2,3,4,\dots$

$e = 1.6 \times 10^{-19}$  C

$$q = ne$$



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**Q10. Define Electrostatic potential. Also give its unit.**

**Definition:** The amount of work that is done in order to transport a unit charge from a reference point to a given location within the field without causing an acceleration.

**Unit:** The SI unit of electrostatic potential is volt

**Mathematically**

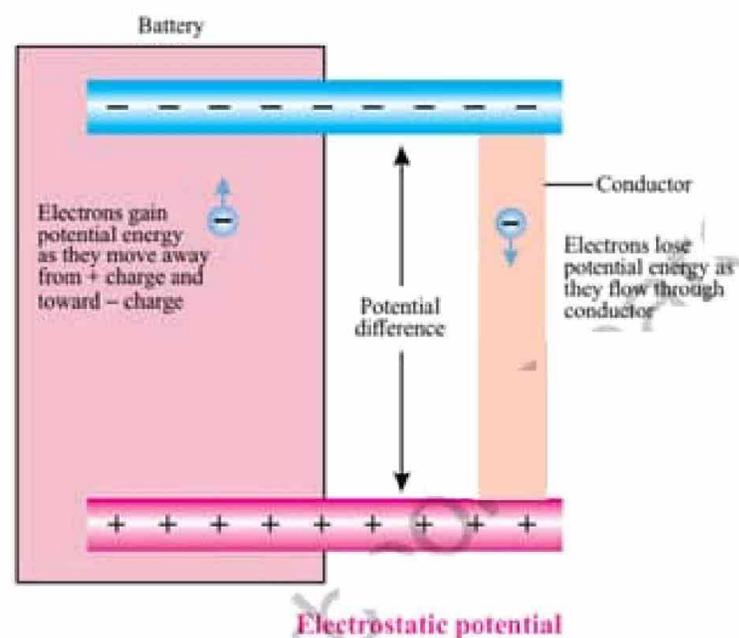
$$V = \frac{W}{q}$$

Where,

W = electric potential energy

q = charge

V = potential difference



**Q11. What are Factors on which electrostatic?**

**potential depends:** The magnitude of electrostatic potential depends on the amount of work done in moving the object from one point to another against the electric field

**Q12. Define Electric potential energy or electrical energy**

**Electric potential energy or electrical energy**

When an object is moved against the electric field it gains some amount of energy which is defined as the electric potential energy or electrical energy.

**Factors on which electric potential energy depends:**

A charge with higher potential will have more electric potential energy and the charge with lesser potential will have less electric potential energy

**Q13. List down the Applications of electrostatics**

**Applications of electrostatics**

There are many applications of electrostatics which are given below:

- The Van de Graaff Generator
- Xerography
- Laser Printers
- Ink Jet Printers and Electrostatic Painting
- Smoke Precipitators and Electrostatic Air Cleaning

**Q14. Write short note on Spray painting and Electrostatic Air Cleaning.**

**Spray painting**

The friction that occurs when the spray exits the nozzle gives it an electrical charge. The droplets all have the same charge, which means that they will repel each other since similar charges repel; as a result, the droplets disperse themselves equally throughout the surface.

**Electrostatic Air Cleaning**

Electrostatic precipitators is another name for these types of devices. It is possible to ionize the dust and smoke particles in the air by passing them through an electric cell. By bringing a charge collecting plate into touch with the charged dust and smoke particles, an attraction is created between the two. Thus, these particles are collected on the plate

**Q15. Define Capacitor. Describe the construction and working of a capacitor**

**Capacitor**

The capacitor is a simple electronic device or component that is used to store charge.

**Construction**

Two conductors of any shape (plates) carrying equal and opposite charges, separated from each other by an insulating material medium called Dielectric form a capacitor.

**Working**

First, we can note that a metal typically has an equal amount of positively and negatively charged particles, which means it's electrically neutral. If we connect a power source or a battery to the metal plates of the capacitor, a current will try to flow, or the electrons from the plate connected to the positive lead of the battery will start moving to the plate connected to the negative lead of the battery. However, because of the dielectric between the plates, the electrons won't be able to pass through the capacitor, so they will start accumulating on the plate.

After a certain number of electrons accumulated on the plate, the battery will have insufficient energy to push any new electrons to enter the plate because of the repulsion of those electrons which are already there. At this point, the capacitor is actually fully charged. The first plate has developed a net negative charge, and the second plate has developed an equal net positive charge, creating an electric field with an attractive force between them which holds the charge of the capacitor.

**Q16. What is Capacitance? Write its formula and unit.**

**Capacitance**

The ability of storing charges in a capacitor is known as capacitance.

**Mathematically**

$$Q \propto V$$

$$Q = CV$$

The constant C is called capacitance of the capacitor and the equation  $Q = CV$  is called equation of capacitor.

So,

$$C = Q/V$$

**Unit:** The unit of capacitance is Farad(1Coul/Volt).

**Q17. What are the Factors on which capacitance depends**

**Factors on which capacitance depend**

Capacitance depends on these factors.

1. Area of the plate. Capacitance increases if area of the plate increases. Hence  $C \propto A$   
Distance between the plates.
2. Capacitance increases if the separation distance between the plates decreases. Hence  $C \propto 1/d$
3. Dielectric constant  $\epsilon_r$  capacitance increases if insulating medium of high dielectric constant is used.  
Hence  $C \propto \epsilon_r$

**Q18. Five a formula for Energy of capacitor.**

#### Energy of capacitor

The energy of capacitor can be calculated by

$$E = \frac{1}{2} CV^2$$

**Q19. Name the different Combination of capacitors**

#### Combination of capacitors

Combinations of capacitors are as follows.

1. Parallel combination
2. Series combination

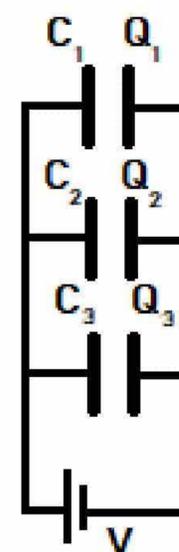
**Q20. what is Parallel combination of capacitors. Derive the formula for equivalent capacitance of capacitor.**

#### Parallel combination of capacitors

A combination of capacitors in which the positive terminal of each capacitor is connected with the positive terminal of the other capacitor and the negative terminal of each capacitor is connected with the negative terminal of the other capacitor, is said to be a parallel combination.

#### Derivation

If three capacitors  $C_1$ ,  $C_2$  and  $C_3$  are connected in parallel and further connected with a battery of  $V$  volts as shown in figure



then:  $C_1$  draws charge  $Q_1$ ,  $C_2$  draws charge  $Q_2$ , and  $C_3$  draws charge  $Q_3$ .

Since the capacitor connected in parallel total charge is equal to the sum of individual charge through capacitors

$$Q = Q_1 + Q_2 + Q_3$$

As we know that

$$Q = CV, Q_1 = C_1V, Q_2 = C_2V, Q_3 = C_3V$$

Putting in above

$$CV = C_1V + C_2V + C_3V$$

$$CV = V(C_1 + C_2 + C_3)$$

$$C = C_1 + C_2 + C_3$$

**Q21. What is Parallel combination of capacitors. Derive the formula for equivalent capacitance of capacitor**

### Series combination of capacitors

A combination in which the positive terminal of one capacitor connected with the negative terminal of the other capacitor and the negative terminal of first capacitor is connected with the positive terminal of the other capacitor, is said to be a series combination.

### Derivation

If three capacitors  $C_1$ ,  $C_2$  and  $C_3$  are connected in series and further connected with a battery of  $V$  volts, as shown in figure

Since the capacitor connected in series the total potential difference is equal to the sum of individual potential difference through capacitors

$$V = V_1 + V_2 + V_3$$

$$Q = CV, \text{ OR } V = \frac{Q}{C}$$

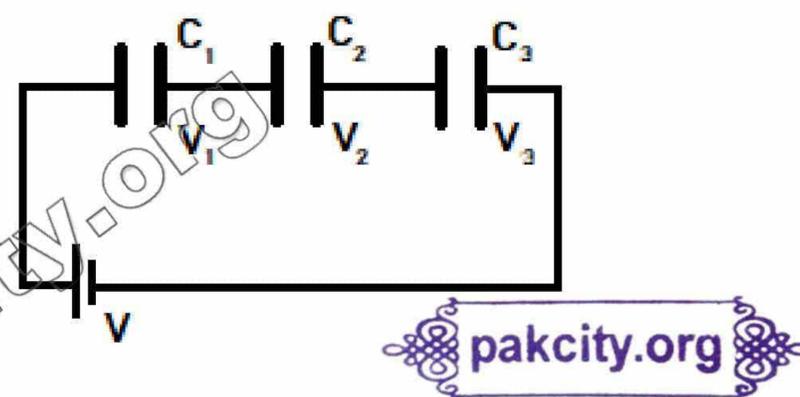
$$V_1 = \frac{Q_1}{C}, V_2 = \frac{Q_2}{C}, V_3 = \frac{Q_3}{C}$$

Putting in above

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_2}$$

$$\frac{Q}{C} = Q \left( \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_2} \right)$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_2}$$



**Q22. Give some Uses of capacitors**

### Uses of capacitors

1. They are utilized in the process of tuning transmitters, receivers, and transistor radios.
2. They are utilized to run table fans, ceiling fans, exhaust fans, air conditioner, motors and many other appliances to keep them running at a high efficiency.
3. It is also common to find capacitors in the electronics circuitry of computers and other products like smartphones.
4. It is possible to utilize capacitors to distinguish between high and low frequency signals, which makes them valuable in electronics circuits.

# Chapter = 14

## Multiple Choice Questions (MCQs)

- Branch of physics which deals with the charges at rest is called  
(a) Electricity (b) Electrostatic (c) Quantum (d) Magnetism
- The magnitude of force between two unit positive charges when the distance between them is 1 m would be  
(a) 0 N (b) 1 N (c) 2 N (d) Coulomb's Constant
- Coulomb's law most closely resembles with  
(a) Law of Conservation of Energy (b) Newton's Law of Gravitation  
(c) Newton's 2nd Law of Motion (d) Faraday's law
- If the electrostatic force between two electrons is F Newton, then the electrostatic force between two protons at the same distance is  
(a) 0 N (b) 2F (c)  $\frac{2}{3} F$  (d) F
- The direction of electric force and electric field intensity is  
(a) Parallel to each other (b) Perpendicular to each other  
(c) Opposite to each other (d) In any direction
- The word done on a unit charge against electric field intensity is called  
(a) Electric field (b) Electric current (c) Electric potential (d) Electric field
- Capacitance of capacitors increases when they connected in  
(a) Parallel (b) Series (c) both (d) none of them
- Two capacitors of 8  $\mu\text{F}$  are connected in series then the equivalent capacitance is  
(a) 4  $\mu\text{F}$  (b) 2  $\mu\text{F}$  (c) 3  $\mu\text{F}$  (d) 6  $\mu\text{F}$
- The presence of a dielectric between the plates of capacitors, the capacitance of capacitor  
(a) increases (b) decreases (c) remains constant (d) remains uncharged
- If the area of the parallel plate capacitor is doubled then the capacitance will be  
(a) remains uncharged (b) half (c) double (d) increased two times Ans:

1.Electrostatic	2.Coulomb's Constant	3.Newton's Law of Gravitation	4.F	5.Parallel to each other
6.Electric potential	7.Parallel	8. 4 $\mu\text{F}$	9.increases	10.double

**Numerical**

1. What is the electric force of repulsion between two electrons at a distance of 1m? ( $2.3 \times 10^{-28}$  N)
2. Two-point charges  $q_1 = 5\mu\text{C}$  and  $q_2 = 3\mu\text{C}$  are placed at a distance of 5 cm. What will be the coulomb's force between them? (54 N)
3. If  $2\mu\text{C}$  charge is placed in the field of  $3.42 \times 10^{11}\text{N/C}$ , what will be the force on it? ( $684 \times 10^3$  N)
4. What is the charge on the capacitor, if a  $40\mu\text{F}$  capacitor has a potential difference of 6 V across it? ( $2.4 \times 10^{-4}$ )
5. The potential difference between two points is 100 V. If an unknown charge is moved between these points, the amount of work done is 500J. Find the amount of charge. (5 C)
6. Find the equivalent capacitance when a  $4\mu\text{F}$ ,  $3\mu\text{F}$  and  $2\mu\text{F}$  capacitor are connected in series. (0.92  $\mu\text{F}$ )

**Worked Example 1** Calculate the force of attraction between two point charge of  $+2\text{mC}$  and  $-3\text{mC}$ , if they are apart of 1cm.

**Worked Example 2** Calculate the electric field intensity if  $9\mu\text{N}$  force acting on  $3\mu\text{C}$  charge.

**Worked Example 3** Calculate the p.d of 300mJ of work done on a 150 mC charge?

**Worked Example 4** Calculate the coulombs force between two protons 10cm apart from each other? Charge on proton is  $1.69 \times 10^{-19}$  C and  $K = 9.0 \times 10^9$  N-m<sup>2</sup>/C<sup>2</sup>

