CHAPTER 15

Electrostatics

Student's Learning Outcomes (SLOs)

After studying this chapter, students will be able to:

- state that there are positive and negative charges [and charge is measured in coulombs].
- state that unlike-charges attract and like charges repel.
- describe experiments to show electrostatic changing by friction.
- explain that charging of solids by friction involves only a transfer of negative charge (electrons).
- explain how a conductor can be charged by electrostatic induction and then "earthing".
- suggest how charging and discharging is used in the application of various devices (e.g, photocopier and electrostatic precipitator).
- describe an electric field as a region in which an electric charge experiences a force.
- state that the direction of an electric field line at a point is the direction of the force on a positive charge at that point.
- discuss and illustrate simple electric field patterns (including the direction of the field):
  (a) around a point charge
  (b) around a charged conducting sphere
  (c) between two oppositely charged parallel conducting plates (end effects will not be examined).
- state examples of electrical conductors and insulators.
- describe an experiment to distinguish between electrical conductors and insulators.
- state and use a simple electron model to explain the difference between electrical conductors and insulators.
- explain how a lightning rod can protect humans.
- explain electrical breakdown (it occurs when a strong electric field passes through a gas and causes its atoms to ionize).
- state that corona discharge and Lichtenberg figures are visible examples of electrical breakdown.

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

Introduction

Q.1: What is electrostatics?

Ans. "Electrostatics is a branch of physics which deals with the study of charges at rest."

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If focuses on understanding the interaction between charges and electric field they create. Electrostatics plays an important role in everyday life.

15.1 Electric Charge

Q.2: How charge produced on a body by rubbing?

OR

How can you show by simple experiment that there are two types of charges?

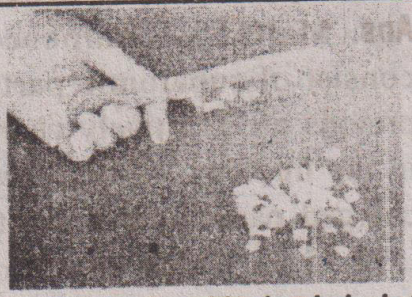


Fig. 15.1: Combs rubbed with dry hair attracts small pieces of paper

Ans. When a plastic comb (or rod) is rubbed through dry hair and is brought near small pieces of paper, it attracts them. Similarly, amber rod when rubbed with silk attracts small pieces of paper. We often experience a shock when we touch a metal doorknob, after sliding across a car seat or walking on a synthetic carpet. In each of these cases, the electrostatic force, resulting from electric charges, is in action.

Electric Charge: This phenomenon of attraction or repulsion between objects is due to a property called electric charge. We have already learnt that an object's mass is an inherent property. Objects with smaller mass have less inertia than those with larger mass. Similarly, another intrinsic property of an object is its electrical charge.

Types of charges:

There are two types of electric charges:

- Positive Charge
- Negative Charge

SI Unit:

The SI unit of charge is the coulomb (C).

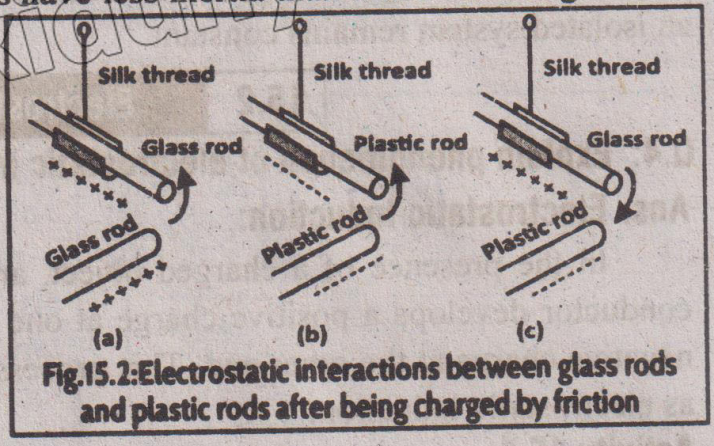


Fig.15.2:Electrostatic interactions between glass rods and plastic rods after being charged by friction

Experiment:

Figure. 15.2 shows electrostatic interactions between glass and plastic rods after being charged by friction. In the first scenario (a), two glass rods that have been rubbed with silk cloth are brought close to each other. Since both rods acquire a positive charge, they repel each other due to the fundamental principle that like charges repel. In the second scenario (b).

Two plastic rods, likely rubbed with wool or fur, are placed near each other. Both rods gain a negative charge, leading to repulsion, as similar charges push away from each other. Lastly, in scenario (c).

A positively charged glass rod (rubbed with silk) is brought near a negatively charged plastic rod (rubbed with fur or wool). Unlike the previous cases, attraction is observed because opposite charges attract. This set of experiments clearly demonstrates the basic electrostatic rule that like charges repel while opposite charges attract.

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Conclusion:

(i) Charge is a basic property of material body due to which it attract or repel another object.

(ii) Friction produce different type of charges on different material.

(iii) Like charges always repel each other.

(iv) Unlike charges always attract each other.

Q.3: Explain the properties of charges.

Ans. Matter is composed of atoms, which consist of subatomic particles. Among these, protons are positively charged particles located in the nucleus, while electrons are negatively charged particles that orbit around the nucleus (Fig.15.3). Since everything is composed of atoms, every material carries either a positive charge, a negative charge, or neutral. Charge is an essential property of materials that causes them to either attract or repel. Charge can be transferred between objects through various processes, including rubbing, direct contact, or induction. The total amount of charge in an isolated system remains constant.

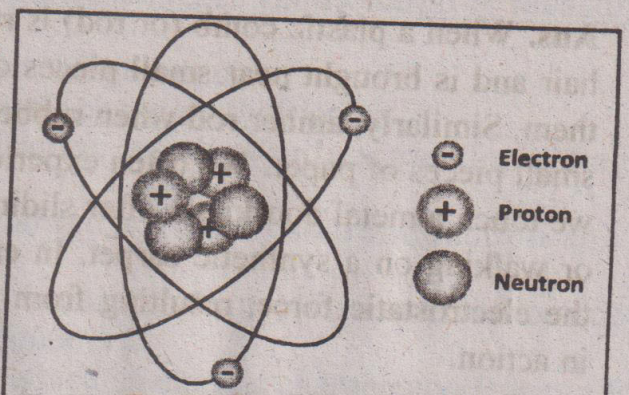


Fig. 15.3: Structure of an atom

15.2 Electrostatic induction

Q.4: Explain phenomenon of electrostatic induction by some experiments.

Ans. Electrostatic Induction:

In the presence of a charged object, an insulated conductor develops a positive charge at one end and a negative charge at the other end. This process is known as electrostatic induction.

Activity 15.1:

When a charged plastic rod is brought near a suspended neutral aluminium rod, both rods are drawn toward each other, as shown in Fig. 15.4. At first glance, this attraction suggests that the rods have opposite charges. However, this is not the case. The charged plastic rod causes a redistribution of positive and negative charges within the neutral aluminium rod, leading to the attraction. Despite this, the total charge on the aluminium rod remains zero. This indicates that attraction alone is not a reliable method to determine if an object is charged. The observed behaviour is an example of a phenomenon known as electrostatic induction.

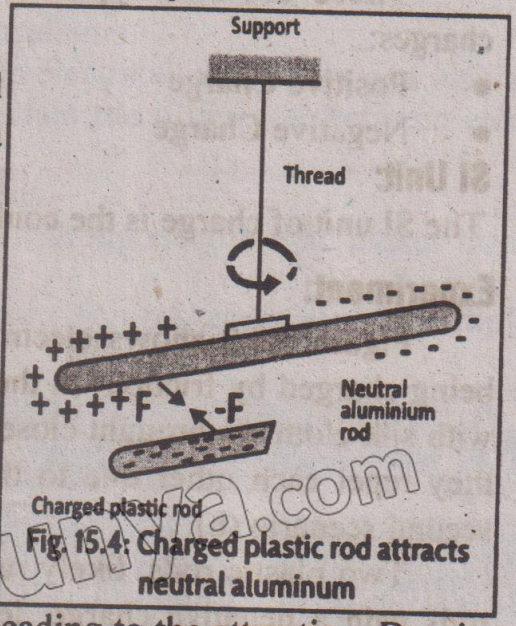


Fig. 15.4: Charged plastic rod attracts neutral aluminum

Activity 15.2:

Take two metal spheres, A and B, and place them on insulated stands so that they

are in contact with each other, as shown in Fig. 15.5(a). Now bring a positively charged rod close to sphere A, as shown in Fig. 15.5(b). The charged rod will attract the negative charges towards it and repel the positive charges away from it. This clearly shows that unlike charges attract each other, while like charges repel each other. As a result, negative charge accumulates on the left surface of sphere A, which is closer to the rod, while positive charge appears on the right surface of sphere B.

Now separate the spheres while keeping the charged rod near sphere A. Upon testing the two spheres, we will find that they are oppositely charged, as shown in Fig. 15.5(c). After removing the rod, the charges are evenly distributed across the surfaces of the spheres, as seen in Fig. 15.5(d). In this process, equal and opposite charges appear on each sphere. This phenomenon is known as charging by induction.

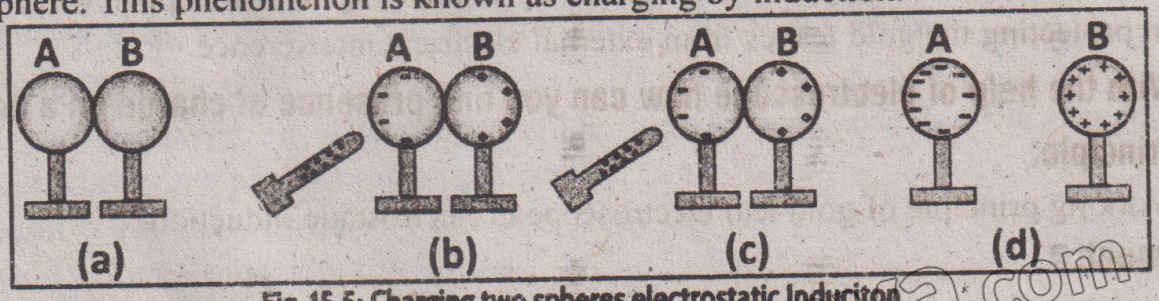


Fig. 15.5: Charging two spheres electrostatic Induciton

Q.5: Describe the method charging bodies by induction and Earthing.

Ans. Charging by induction:

Charging by induction is a method of charging a conductor without directly touching it with a charged object. It involves the redistribution of electric charges within a conductor when exposed to a nearby electric field. Suppose we bring a negatively charged rod near a neutral metal sphere (conductor). The presence of the negatively charged rod causes free electrons in the conductor to move away due to repulsion, leaving the side near the rod positively charged and the far side negatively charged.This separation of charges is called electrostatic induction.

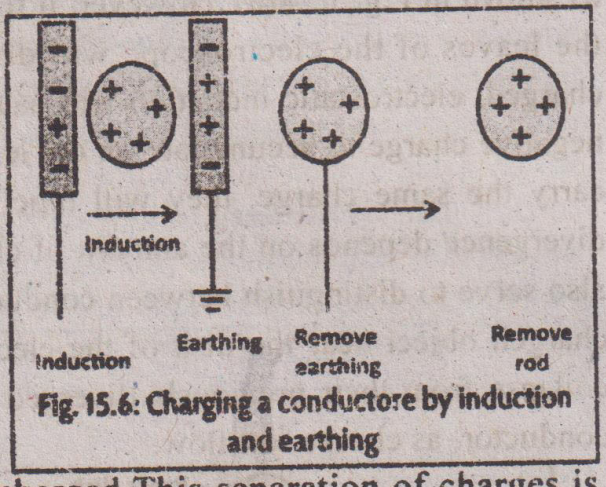


Fig. 15.6: Charging a conductore by induction and earthing

Charging by Earthing:

Earthing is the process of connecting a conductor to the Earth using a conducting wire. While the charged rod is still in place, the conductor is connected to the Earth using a wire (Fig 15.6). Since the far side of the sphere is negatively charged, electrons flow from the sphere to the Earth, neutralizing the negative charge. After the unwanted charges have flowed away, the grounding connection is removed. The excess positive charge remains near the rod because the negative charges have left. Finally, the charged rod is taken away. The conductor now has a net positive charge, even though it was never touched by the rod.

Q.6: What is gold leaf electroscope? Write its construction.

Ans. Gold leaf electroscope:

The gold leaf electroscope is a sensitive device which is used to detect electric charges.

Construction:

It consists of a brass rod with a brass disk at the top and two thin gold leaves suspended at the bottom, as shown in Fig. 15.7. The rod passes through an insulating material, which holds it in place. Charges can move freely from the disk to the leaves via rod. Additionally, a thin aluminum foil is attached to the lower part of the inside of the jar. This aluminum foil is typically grounded by connecting it to a copper wire, which helps in protecting the gold leaves from external electrical interference.

Q.7: With the help of electroscope how can you find presence of charge on a body?

Ans. Principle:

Working principle of gold leaf electroscope is electrostatic induction.

Experiment:

To detect the presence of charge on an object, bring the object near the disk of an uncharged electroscope. If the object is neutral, there will be no deflection of the leaves, as shown in Fig. 15.8(a). However, if the object is charged either positively or negatively the leaves of the electroscope will diverge. For example, if the object is negatively charged, electrostatic induction will cause a positive charge to appear on the disk and a negative charge to accumulate on the leaves, as shown in Fig. 15.8(b). Since both leaves carry the same charge, they will repel each other and move apart. The extent of the divergence depends on the amount of charge present on the object. An electroscope can also serve to distinguish between conductors and insulators. To perform this test, bring a charged object near the disk of the electroscope without allowing contact. If the leaves collapse from their previously diverged position, it indicates that the material is a good conductor, as charge can flow.

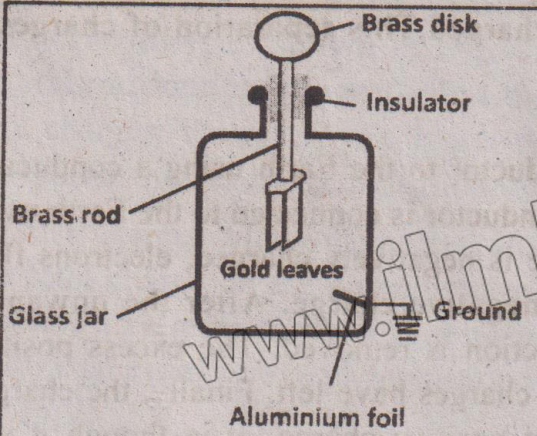


Fig. 15.7: Unchanged electroscope

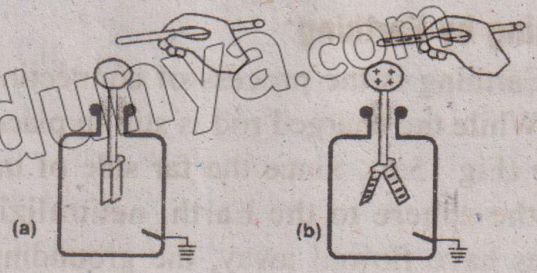


Fig. 15.8: Detecting charge using a gold leaf electroscope

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Q.8: Write some applications of electrostatic.

Ans. There are many application of electrostatics with conductors, as shown in Fig 15.9. Charging and discharging are fundamental processes in the operation of various devices, such as photocopiers and electrostatic precipitators, which rely on electrostatic principles.

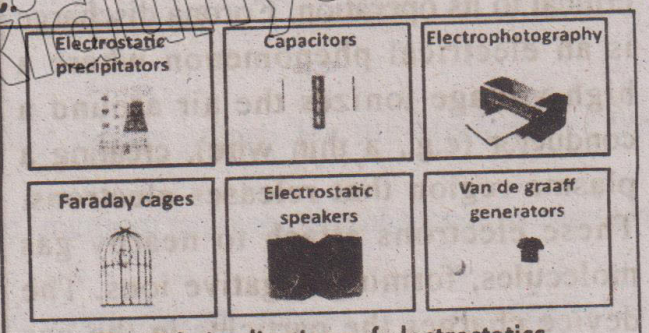


Fig. 15.9: Applications of electrostatics

Q.9: Write a note on photocopier. Write about its working principal.

Ans. Photocopier:

A photocopier is an electronic machine used to make copies of documents and images. It works on a process called xerography.

Xerography: The xerography is derived from the Greek words "xeros" (dry) and "graphos" (writing), meaning "dry writing".

Principle: Working principle of photocopier is based on electrostatics.

Construction and working:

The central part of the photocopier machine contains a rotating drum which is composed of aluminium and coated with a layer of selenium. Aluminium is a good conductor of electricity, while selenium is a photoconductor, it behaves like an insulator in the dark but conducts electricity when exposed to light. The process of photocopier begins by applying a positive charge to the drum. In the dark, this charge stays on the surface of the drum because selenium does not allow current to pass. When light falls on the drum, electrons from the aluminium move through the selenium and remove the positive charge from those areas. When the image of the document is projected on the drum, the bright (light) areas lose their charge, and the dark areas remain positively charged. This creates an invisible electrostatic image on the drum. A fine, dry black powder called toner is given a negative charge and spread over the drum. It sticks only to the positively charged image areas. A neutral sheet of paper passes under the drum with a slightly positive roller behind it, which pulls the toner onto the paper. Finally, the paper goes through heated rollers that melt and press the toner into the paper, making the image permanent.

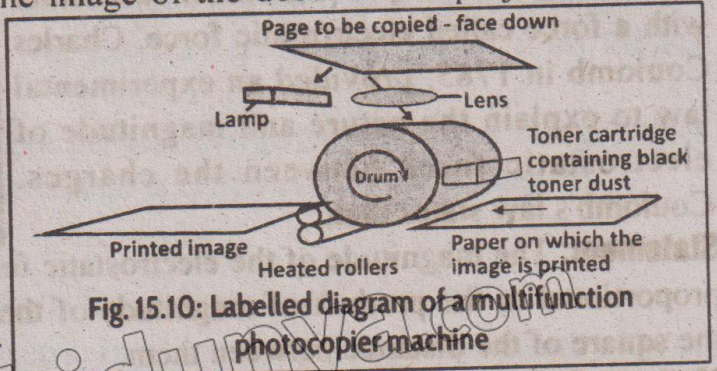


Fig. 15.10: Labelled diagram of a multifunction photocopier machine

Q.10: What is electrostatic precipitator? Write its working.

Ans. Electrostatic precipitator:

An electrostatic precipitator (ESP) is a device used to remove particulate matter

from industrial exhaust gases.

Working: Charging and discharging are critical to its operation. Corona discharge is an electrical phenomenon where a high-voltage ionizes the air around a conductor (e.g., a thin wire), creating a plasma region that releases electrons. These electrons attach to nearby gas molecules, forming negative ions. The device charges the particles in the gas stream by passing them through a corona discharge, which imparts a negative charge to the particles. These charged particles are then attracted to positively charged collection plates, where they adhere and are removed from the gas stream. Periodically, the collection plates are discharged to remove the accumulated particles, which fall into a hopper for disposal. This process ensures efficient removal of pollutants from the air, making electrostatic precipitators essential in reducing industrial emissions. Both applications demonstrate how controlled charging and discharging can be harnessed for practical and environmentally beneficial purposes. The diagram of an electrostatic precipitator is shown in Fig. 15.11.

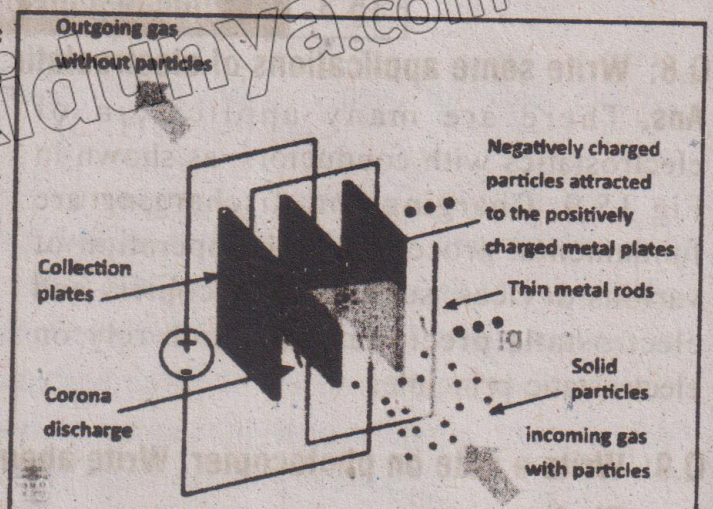


Fig. 15.11: Electrostatic precipitator

15.4 Coulomb's Law

Q.11: State and explain coulomb's law.

OR Explain coulamb's electrostatics law and write its mathematical form.

Ans. Coulomb's Law:

Charges can repel and attract each other with a force called electrostatic force. Charles Coulomb in 1785, provided an experimental law to explain the nature and magnitude of electrostatic force between the charges. Coulomb's law states that;

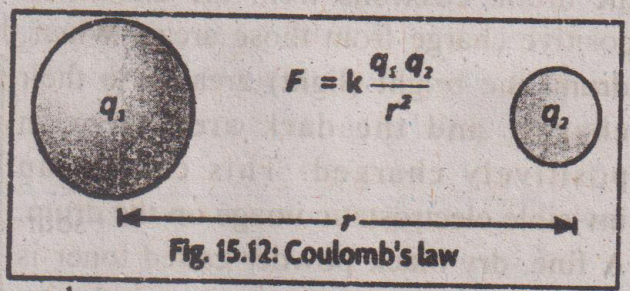


Fig. 15.12: Coulomb's law

Statement: The magnitude of the electrostatic force between two point charges is directly proportional to the product of magnitude of these charges and inversely proportional to the square of the distance between them.

Mathemetical derivation:

Consider two charges q_1 and q_2, seperated by distance r (Fig.15.12).

Mathematically;

$$F \propto q_1 q_2 \quad \text{..... (15.1)}$$

and $$F \propto \frac{1}{r^2} \quad \text{..... (15.2)}$$

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

or $F = k\frac{q_1 q_2}{r^2}$ ..... (15.3)

Where k is a constant of proportionality which quantifies the strength of the electrostatic force between two point charges.

Value of k: The value of k is determined by the medium between the charges. In vacuum or air, k is approximately 9×10^9 N m^2 C^{-2}.

Note: Coulomb's law is applicable primarily to point charges whose sizes are negligible compared to the distance separating them.

15.5 Electric Field

Q.12: What is electric field and electric field intensity?

Ans. Electric Field:

"An electric field is the region around a charge where it exerts a force on other charges".

One charge exerts a force on another charge. This force is present everywhere around the charge, theoretically extending to infinity. However, the strength of the force decreases with distance.

Explanation: The electric field strength decreases with distance from the charge, following an inverse square law for point charges.

Mathematically;

$$E = k\frac{q}{r^2} \quad .....(15.4)$$

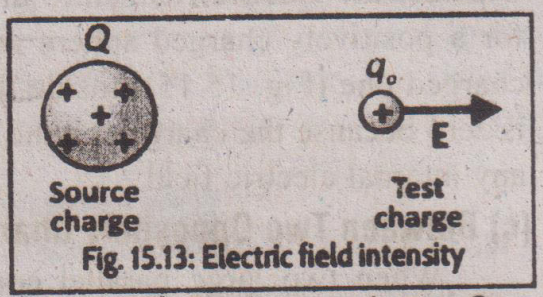


Fig. 15.13: Electric field intensity

Consider a test charge q_o is brought into the electric field of a source charge Q as shown in Fig. 15.13. The source charge will exert an electrostatic force **F** on the test charge.

Electric field intensity: The electrostatic force per test charge (unit positive charge) when it is brought to the electric field of a source charge is called electric field intensity.

Mathematically:

$$E = F/q_o \quad ..... (15.5)$$

SI unit: The SI unit of electric field intensity is Newton per coulomb (NC^{-1}).

Vector quantity: Electric field intensity (electric field strength) is a vector quantity having both magnitude and direction. The direction of electric field intensity at a point will be the direction of force on a positive test charge at that point.

Q.13: What are electric field lines or electric line of forces? Briefly explain for different situations.

Ans. Electric Field Lines:

The concept of an electric field demonstrates how a charged object affects other

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nearby charged objects. The electric field is a vector field, which means it has both magnitude and direction. The direction of the electric field at any point is the direction in which a positive test charge would move if placed at that location. Here, we will explain and show the electric field patterns for three common situations:

(a) Around a Point Charge:

Around a point charge, the electric field is radial, extending outward in all directions. For a positive point charge (Fig. 15.14-a), the electric field lines radiate outward, indicating that a positive test charge placed nearby would be repelled. In contrast, for a negative point charge (Fig. 15.14-b), the electric field lines point inward, showing that a positive test charge would be attracted towards it. This reflects the repulsive force around positive charges and the attractive force around negative charges.

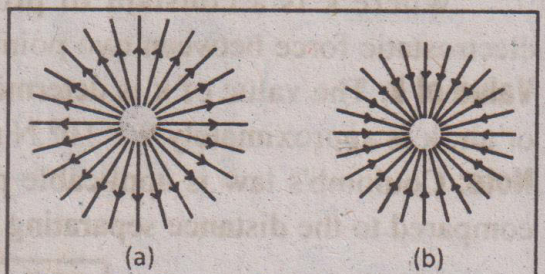
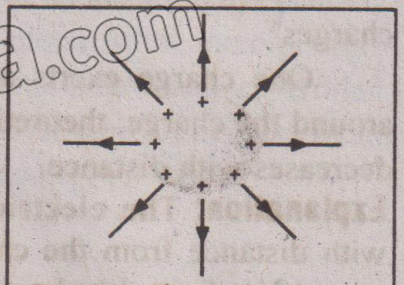


Fig. 15.14: Electric field lines for isolated positive and negative point charges

(b) Around a Charged Conducting Sphere:

A charged conducting sphere distributes its charge evenly on its surface, and the electric field around it behaves similar to that of a point charge, but only outside the sphere. Outside, the electric field lines are radial, radiating outward for a positively charged sphere and inward for a negatively charged one (Fig. 15.15). Inside the sphere, the electric field is zero because the charges on the surface rearrange to cancel any internal electric field.


Fig. 15.15: Charge distribution on a positively charged sphere

(c) Between Two Oppositely Charged Parallel Conducting Plates:

When two large parallel conducting plates are given equal and opposite charges, a uniform electric field is created between them, commonly used in capacitors (Fig. 15.16). The electric field lines point from the positively charged plate to the negatively charged plate, and they are parallel and equally spaced, showing a uniform electric field. This uniformity means the electric field has the same magnitude and direction at all points between the plates, which is due to the plates being large and close together, minimizing edge effects.

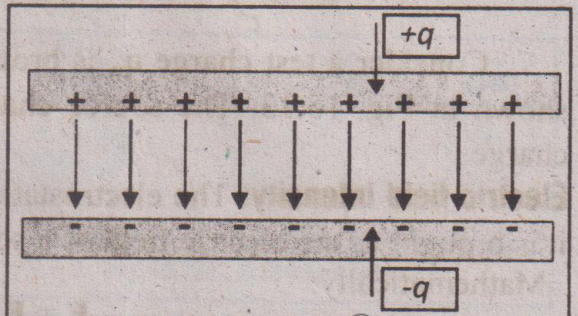


Fig. 15.16: Electric field between two oppositely charged parallel plates

15.6 Conduction of Electric Charges

Q.14: Explain how and why electrical conductors and insulators behave differently in terms of charge transfer and movement of electrons.

Ans. Electrical Conductors:

Electrical conductors are materials that allow electric charge to flow freely through

them. They have loosely bound electrons in their atomic structure, which can flow easily when a voltage is applied, creating an electric current.

Examples: Examples of electrical conductors include metals, such as copper, aluminum, and silver, as well as materials like graphite and electrolytes.

Electrical Insulators: Electrical insulators are materials that resist or prevent the flow of electric charge. In insulators, electrons are tightly bound to their atoms and cannot move freely. As a result, they do not allow electric current to pass through them.

Example: Examples of electrical insulators include rubber, plastic, glass, wood, and ceramics. These materials are used to block the flow of electricity and provide safety in electrical systems.

Experiment: To explore this concept, we can conduct a simple experiment: Build a circuit with a battery, a bulb, and a gap to test materials. Insert objects like a metal key, a plastic spoon, or a wooden stick into the gap. If the bulb lights up, the material is a conductor; if it stays OFF, it is an insulator. This hands-on activity turns us into an electricity detective, revealing the hidden properties of everyday items.

Free Electron Model:

Electrical conductors and insulators can be explained using a simple electron model. In conductors, such as metals, the outermost electrons of atoms are loosely bound and can move freely throughout the material. These "free electrons" act like a sea of mobile charges, allowing electric current to flow easily when a voltage is applied. In contrast, insulators, like rubber or plastic, have electrons that are tightly bound to their atoms and cannot move freely. When a voltage is applied to an insulator, the electrons remain fixed, preventing the flow of electric current. This difference in electron behaviour explains why conductors allow electricity to flow while insulators block it.

15.7 Accumulation of Charges

Q.15: What is meant by accumulation of charges? Explain it.

Ans. Accumulation of Charges:

The accumulation of charges, often referred to as static electricity, occurs when electrons are transferred from one object to another, leading to an imbalance of positive and negative charges.

Explanation: This buildup can have several consequences. In everyday life, it can cause minor shocks when touching metal objects or make clothes cling together. In industrial settings, accumulated charges can be more serious, potentially damaging electronic components, igniting flammable substances, or disrupting manufacturing processes. Proper grounding, anti-static measures, and humidity control are often employed to mitigate these risks and prevent the harmful effects of charge accumulation.

Q.16: When electrical breakdown occurs? Explain in details.

Ans. Electrical breakdown

Electrical breakdown occurs when a strong electric field passes through a gas (or insulating material), causing its atoms to ionize. This ionization creates free electrons and ions, which can conduct electricity. When the electric field is strong enough, it can

lead to a sudden, dramatic increase in conductivity, often resulting in a spark or arc. This phenomenon is responsible for natural events like lightning, where the electric field in the atmosphere ionizes air, creating a conductive path for the discharge.

i- Corona discharge:

Corona discharge is a visible form of electrical breakdown that occurs when a high-voltage electric field ionizes the air around a conductor, typically near sharp points or edges where the electric field is the strongest (Fig . 15.17). This ionization produces a faint glow or "corona" and is often seen around high-voltage power lines or antennas, while less intense than a full spark.



Fig. 15.17: Corona discharge

ii- Lichtenberg Figures:

These are branching, tree-like patterns that form on insulating materials (like wood or acrylic), when a high-voltage electrical discharge passes through them as shown in Fig 15.18. The patterns result from the electrical breakdown of the material, leaving behind visible traces of the discharge path. They are named after the German physicist Georg Christoph Lichtenberg, who first documented them. Both corona discharge and Lichtenberg figures are visible examples of electrical breakdown, demonstrating how strong electric fields can ionize materials and create conductive paths.



A sequence of zooms showing the "self-similar" property of lichtenberg figures

Fig.15.18: Self-Similarity in lichtenberg figures

iii- Lightning conducotrs:

Lightning conductors, or lightning rods, are protective devices installed on tall structures to safeguard them from lightning strikes. A lightning rod provides a low-resistance path for the electrical discharge to follow, directing the massive current safely into the ground. This prevents the lightning from passing through the building, which could cause fires, structural damage, or harm to humans. By channeling the lightning's energy safely away, the rod protects both the structure and its occupant.

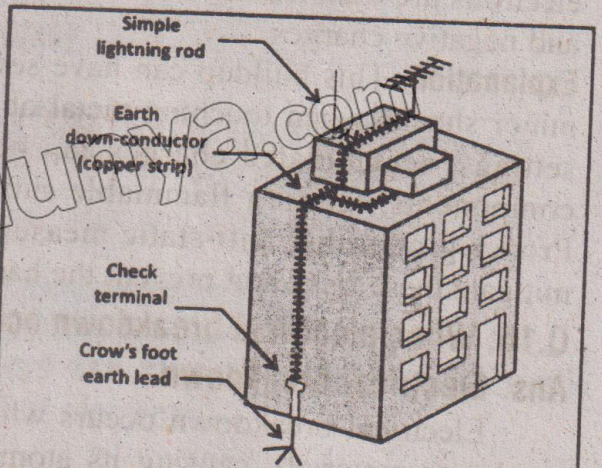


Fig.15.19: Lighting conductors installed in building

Lightning is generated through a complex process involving charge separation, electric field buildup, and discharge. It begins with friction between water molecules suspended in clouds during thunderstorms or between smoke particles in volcanic plumes, leading to the accumulation of electric charge. As these charges separate within the cloud, an intense electric field develops. When this field reaches a critical level, the surrounding air undergoes electrical breakdown, forming lightning streamers ionized channels that create a conductive path for current flow. In the case of cloud-to-ground lightning, the strong electric field from the charged clouds induces an opposite charge on the Earth's surface, particularly in conductive materials. When the electric potential difference becomes large enough, it overcomes air resistance, allowing a rapid discharge of electricity between the cloud and the ground. This discharge results in the brilliant flash and thunder that characterize lightning, with some strikes occurring from cloud to cloud or even from the ground to the cloud in response to charge redistribution.

DO YOU KNOW?

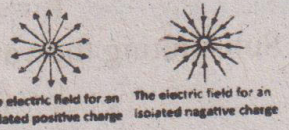
When a charged rod is brought near a conductor without touching it, the conductor still gets charged. That is the amazing effect of electrostatic induction.

Newton Vs Coulomb

- Similar formulae inverse square laws
- Gravitational forces are only attractive
- Are important when dealig with large masses and distances
- Electrical forces are attractive and repulsive
- Are important when dealing with small ma sses and distances

Electric Fields

- Electric fields are represented by electric field lines,
- (imaginary) and show the direction of the force at that point.
- Electric field direction is from a positive charge to a negative charge.
- Electric field lines (also known as electric flux) do not cross each other.
- Electric field lines represent the path that a small positive test charge would follow in an electric field.


The electric field for an isolated positive charge

The electric field for an isolated negative charge

The electric field inside a charged conducting sphere is always zero, that is why people inside metal cars or airplanes are safe during lightning strikes.

Lichtenberg figures are fern-like patterns that may appear on the skin of lightning strike victims that disappear in 24 hours.



Tidbits

If the charges are opposite in sign (one positive and one negative), they will attract each other. If the signs are reversed, making both charges positive or both negative, they will repel each other. The magnitude of the force will remain the same, but the direction of the force will change. This Is an example of how Coulomb's law works with both attraction and repulsion.

When the electric field around a high- voltage power line becomes intense, it can ionize nearby air molecules. This causes a phenomenon known as corona discharge, where the air gives off a faint blue or violet glow. This is why we may see a bluish light near sharp edges of electrical equipment in the dark.

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Brain Teaser

1. Rub a balloon on your dry hair and then hold it close to a wall. The balloon sticks to the wall. But why does this happen when the wall is not charged?

Ans. When a balloon is rubbed on dry hair, it becomes negatively charged due to friction. When this charged balloon is brought near a neutral wall, it causes electrostatic induction in the wall. The charges inside the wall rearrange positive charges come closer to the balloon and negative charges move away. This creates attractive force between balloon and wall.

2. Why do the leaves of an electroscope diverge when a charged object is brought near, even If the object does not touch the electroscope?

Ans. When a charged object is brought near the metal cap of an electroscope, electrostatic induction occurs, charges inside the electroscope redistribute. Both gold leaves acquire similar types of charge. So they repel each other. Due to this repulsion, the leaves diverge, even though the charged object does not touch the electroscope.

Examples

15.1 A point charge q = 10 μC is placed in air. Calculate the electric field at a distance of 0.5 m from the charge.

Solution:

Given that;

$k = 9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$

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

and $r = 0.5 \text{ m}$

To find; $E = ?$

Using the formula:

$$E = kq / r^2$$

Substituting the values

$$E = (9.0 \times 10^9 \times 10 \times 10^{-6}) / (0.5)^2$$

$$E = 3.6 \times 10^5 \text{ N C}^{-1}$$

Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

15.1 Electric Charge

1. A positive electric charge:

(a) Attracts other positive charge (b) Repels other positive charge
(c) Attract a neutral charge (d) Repels a neutral charge

2. An object gains excess negative charge after being rubbed against other object which is:

(a) neutral (b) negatively charged

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(c) positively charged (d) both b & c

3. **Two uncharged objects A and B are rubbed agianst each other when object B is placed near a negatively charged object C, the two objects repel each other. Which of these statements is true for object A?**
(a) remain uncharged (b) become positively charged
(c) become negatively charged (d) unpredictable

15.2 Electrostatic induction

4. **To protect the gold leaves of electroscope from the external electric disturbances the aluminum foil is grounded by a thin wire which is made up of:**
(a) Aluminum (b) Copper (c) Silver (d) Brass

5. **Electroscop is used for detecting:**
(a) Charge (b) Current (c) Voltage (d) Resistance

15.3 Applications of Electrostatic

6. **The xerography is derived from the _____ words.**
(a) Latin (b) Greek (c) French (d) German

7. **The meaning of xerography is:**
(a) Photocopy (b) Self writing (c) Dry writing (d) None of these

8. **In photocopier machine drum dark areas have _____.**
(a) positive charge (b) negative charge (c) no charge (d) both a & b

15.4 Coulomb's Law

9. **According to coulomb's Law what happen to the attraction of two oppositely charged object as their distance of separation increase?**
(a) increase (b) decrease
(c) remain unchanged (d) can not be determined

10. **The coulomb's Law is valid for the charges which are:**
(a) moving and point charges (b) moving and non-point charges
(c) stationary and point charges (d) stationary and large size charges

11. **One micro coulomb charge is equal to:**
(a) 10^{-3} C (b) 10^{-4} C (c) 10^{-6} C (d) 10^{-10} C

12. **The SI unit of charge is:**
(a) Watt (b) Newton (c) ms^{-1} (d) Coulomb

13. **One coulomb is equal to charge of electrons:**
(a) 6.25×10^{-19} (b) 6.25×10^{-18} (c) $6.25 \times 10^{+19}$ (d) $6.25 \times 10^{+18}$

14. **If we double the distance between two charges then force bocome:**
(a) 4 times (b) double (c) $\frac{1}{4}$ times (d) half

15.5 Electric Field

15. **Electric field lines.**
(a) always cross each other (b) cross each other in region of strong field

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(c) never cross each other (d) cross each other in region of weak field

16. SI unit of electric intensity is:

(a) NC (b) NC^{-3} (c) NC^{-2} (d) NC^{-1}

17. Electric intenstiy is a quantity:

(a) Scalar (b) Vector (c) Base (d) None

15.6 Conduction of Electric Charges

18. Electrical conductors are materials:

(a) Store electric current (b) allow to flow charge
(c) Produce electricity (d) None

19. In insulators electrons are:

(a) Free to move (b) Tightly bound to their atoms
(c) Completely absent (d) Flowing like water

20. Which of the following is electrical conductors?

(a) Aluminum (b) Brass (c) Glass (d) Plastic

21. Which of the following is insulators?

(a) Copper (b) Silver (c) Plastic (d) Gold

22. In free electrone model the outer most electron in metals are:

(a) Fixed in position (b) Strongly bound
(c) Loosely bound and free to move (d) Destroyed during conduction

23. Which of the following has tightly bound electrons?

(a) Copper (b) Plastic (c) Iron (d) Silver

15.7 Accumulation of Charges

24. Static electricity is cause by:

(a) Flow of proton (b) Movement of Neutrons
(c) Flow of current (d) Accumulation of electric charege

25. In metals, free electrons behave like:

(a) Fixed particles (b) A sea of mobile charges
(c) Neutral atoms (d) Solid blocks

26. Lightning conductors are installed on tall building to:

(a) Increase electric charge (b) Attract rain
(c) Store electricity (d) Protect buildings from lightning demage

27. Lightning occurs when electric field becomes:

(a) Very weak (b) Neutral (c) Cold
(d) Critical enough to over come air resistance

Answers

1.	(b)	2.	(b)	3.	(b)	4.	(b)	5.	(a)	6.	(b)	7.	(c)
8.	(a)	9.	(b)	10.	(c)	11.	(c)	12.	(d)	13.	(d)	14.	(c)
15.	(c)	16.	(d)	17.	(b)	18.	(b)	19.	(b)	20.	(a)	21.	(c)
22.	(c)	23.	(b)	24.	(d)	25.	(b)	26.	(d)	27.	(d)		

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Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

15.1 Electric Charge

1. Define electrostatics?

Ans. Electrostatics is a branch of physics which deal with the study of charges at rest.

2. What is electric charge?

Ans. The phenomenon of attraction or repulsion between objects is due to property called electric charge.

3. How many types of charges?

Ans. There are two types of charges:

(i) Positve charge (ii) Negative charge

4. What is system international unit of charge?

Ans. The SI unit of charge is coulomb and represent with "C".

5. How can charge transfered between objects?

Ans. Through rubbing, direct contact or induction.

15.2 Electrostatic induction

6. Atraction is not reliable method to detemine if an object is charged? Why?

Ans. When a charged plastic rod is brought near a suspended neutral aluminum rod, both rods are drawn toward each other. At first glance, this attraction suggest that the rods have opposite charge.

The plastic rods causes a redistribution of positive and negative charges within the neutral aluminum rod remains zero.

7. Show by experiment charging induction?

Ans. Take two metals sphere A and B, and place them on insulated stands. So that they are contact each other.

Now bring positively charged, rod close to sphere A. The charged rod will attract the negative charges toward it and repel positive charges away from it. As a result negative charge accumulate on the left surface of sphere A. Which is closer to the rod, while positive charge appear on the right surface of sphere B.

Now separate spheres, upon testing the two spheres we will find that they are oppositely charged after removing rod charges are evenly distributed. This phenomenon is known as charging by induction.

8. Define charging by Induction.

Ans. Charging by induction is a method of charging a conductor without directly touching it with a charge object. It involves the redistribution of electric charge with in a conductor when exposed to nearby electric field.

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9. Define chargning by Earthing.

Ans. Earthing is the process of connecting a conductor to the Earth using a conducting wire. While the charged rod is still in place, the conductor is connected to Earth using a wire.

10. For what purpose electroscope used?

Ans. The gold leaf electroscope is a sensitive device used to detect electric charges.

11. What is the working principle of electroscope?

Ans. Electroscope worked on the principle of electrostatic induction.

12. How we can detect presence of charge on an object?

Ans. To detect the presence of charge on an object in electroscope, bring near the disk of an uncharged electroscope. If the object is neutral there will be no deflection.
If the object is charged either positive or negative the leaves of electroscope will diverge.

15.3 Applications of Electrostatics

13. Write applications of electrostatics.

Ans.
- Photocopiers
- Electrostatic Precipitators
- Electrostatic Speaker
- Capacitors

14. What is xerography?

Ans. The xerography is derived from the Greek word xeros (dry) and graphos (writing) meaning "dry writing".

15. Write parts of photocopier machine.

Ans.
- Heated rollers
- Printed image
- Drum
- Paper on which image is printed
- Lens
- Page to be copied
- Toner cartridge containing black tooner dust.

16. What is electrostatic precipitator?

Ans. An electrostatic precipitator (ESP) is used to remove particulate matter from industrial exhaust gases. Charging and discharging are critical to its operation.

15.4 Coulomb's Law

17. State coulomb's Law.

Ans. The magnitude of the electrostatic force between two point charges is directly proportional to the product of magnitude of these charges and inversely proportional to the square of the distance between them.

$$F \propto q_1 q_2$$

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

15.5 Electric Field

18. Define electric field.

Ans. An electric field is the region around a charge where it exerts a force on other charges.

$$E = k\frac{q}{r^2}$$

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19. Define electric field intensity.

Ans. The electrostatic force per test charge (unit positive charge) when it is brought to the electric field of a source charge is called electric field intensity.

$$E = F/q_o$$

The SI unit of electric field intensity is Newton per coulomb (NC^{-1}).

20. Does electric field intensity is vector quantity or scalar?

Ans. Electric field intensity is a vector quantity having both magnitude and direction. The direction of a electric field intensity at a point will be the direction of force on a positive test charge at that point.

21. Where will be the direction of electric field?

Ans. The direction of electric field at any point is in the direction in which positive charge test move if placed at location.

15.6 Conduction of Electric Charges

22. What is electrical conductors?

Ans. Electrical conductors are materials that allow electric charge to flow freely through them.

e.g cooper, aluminum and silver etc.

23. What is insulators?

Ans. Electrical insulators are materials that resist to prevent the flow of electric charge.

e.g rubber, plastic glass.

15.7 Accumulation of Charges

24. What is Accumulation of charges?

Ans. The accumulation of charges often referred to as static electricity, occur when electrons are transferred from one object to another, leading to an imbalance of positive and negative charges. In everyday life, it can cause minor shocks when touching metal objects or make clothes cling together.

Exercise Questions (Solved)

A. Multiple Choice Questions

☆ **Tick (✓) the correct answer.**

15.1 Electrical breakdown is:

(a) the process of ionizing a gas due to a strong electric field
(b) the process of neutralizing a charged object
(c) the process of charging an insulator
(d) the process of discharging a conductor

15.2 Which of the following is a visible example of electrical breakdown?

(a) Corona discharge
(b) Electric current
(c) Magnetic field
(d) Electric potential

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15.3 What happens when two unlike charges are brought close to each other?

(a) They attract (b) They repel

(c) They neutralize each other (d) Nothing happens

15.4 According to Coulomb's law, what happens to the attraction of two oppositely charged objects as their distance of separation increases?

(a) Decreases (b) Increases

(c) Remains unchanged (d) Cannot be determined

15.5 The device which works on the principle of electrostatics:

(a) electric bell (b) photocopier (c) electric heater (d) transformer

Answers

15.1 (a) 15.2 (a) 15.3 (a) 15.4 (a) 15.5 (b)

B. Short Answer Questions

15.1 State Coulomb's law of electrostatics and write its mathematical form.

Ans. Coulomb's law states that the electrostatic force of attraction or repulsion between two charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

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

15.2 What is an electric field?

Ans. An electric field is the region around an electric charge where a force would exerted on other electric charges placed within that region.

15.3 Give two examples each of electrical conductors and electrical insulators.

Ans. Conductors: Copper, Aluminium

Insulators: Rubber, Plastic

15.4 List some applications of electrostatics in daily life.

Ans.
- Photocopeier
- Laser printers
- Electrostatic spray painting
- Air purifiers

15.5 What happens when like charges and unlike charges are brought close to each other?

Ans.
- Like charges repel each others.
- Unlike charges attract each others.

15.6 What is meant by electrical breakdown, and when does it occur?

Ans. Electrical breakdown is the sudden flow of current through an insulating medium due to a very strong electric field. It occur when the electric field becomes strong enough to ionize the medium.

15.7 What are the dangers of static electricity?

Ans.
- Can cause electric shocks.
- Can start fires and explosions.
- Can damage electronic devices.

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C. Constructed Response Questions

15.1 Why do some materials gain electrons while others lose electrons when rubbed together? What property of the materials determines this behaviour?

Ans. The difference in electron affinity between the materials determines which gains or loses electrons. The triboelectric property of the materials dictates this behavior.

15.2 A charged comb attracts small pieces of paper, but after some time, the paper pieces fall off. Why does this happen?

Ans. The paper falls off because the charge on the comb dissipates over time, weakening the attractive force. Also, the paper can acquire the same charge as the comb through contact, leading to repulsion.

15.3 Why do dust particles often get attracted to television screens or computer monitors after they are turned ON?

Ans. The screen becomes charged when turned on, inducing a charge separation in the dust particles, leading to electrostatic attraction.

15.4 If we rub a balloon on our dry hair and place it near a thin stream of water, the water bends toward the balloon. What does this tell us about the Nature of water molecules?

Ans. The bending of the water stream indicates that water molecules are polar, possessing a slightly positive and a slightly negative end.

15.5 A conductor and an insulator are both placed in an electric field. How will their behaviour differ, and why?

Ans. In a conductor, free electrons move to cancel the external electric field internally. In an insulator, electrons are displaced within atoms (polarization), reducing but not eliminating the external electric field.

D. Comprehensive Questions

15.1 Discuss the working of a gold leaf electroscope. How can it be used to determine the nature and magnitude of charge on a body?

Ans. For Answer See Q # 7

15.2 How does Coulomb's law help in understanding the interaction between charged particles? What factors affect the force between them?

Ans. For Answer See Q # 11

15.3 Explain the concept of electric field intensity. How can the electric field of a point charge and a parallel plate capacitor be represented using field lines?

Ans. For Answer See Q # 12, 13

15.4 Explain how and why electrical conductors and insulators behave differently in terms of charge transfer and movement of electrons.

Ans. For Answer See Q # 14

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15.5 Discuss how electrostatics plays a role in real-life hazards, such as dust explosions in factories and static shocks from synthetic clothing. How can these hazards be minimized?

Ans. Electrostatic causes dust explosions via static discharge igniting dust clouds and static shocks from charge buildup on synthetic clothing.

Hazards are minimized by grounding, humidification, inerting, dust collection, using conductive materials, wearing, natural fibers, antistatic sprays and fabric softeners.

E. Numerical Problems

15.1 A positive test charge of 25 μC is placed in an electric field. The force on it is 0.500 N. What is the magnitude of the electric field at the location of the test charge?

Given:

$$\text{Force} = F = 0.500\ \text{N}$$
$$\text{Charge} = q = 25\ \mu\text{C} = 25 \times 10^{-6}\ \text{C}$$

To find:

$$\text{electric field} = E = ?$$

Solution:

As we know

$$F = qE$$
$$E = \frac{F}{q}$$
$$= \frac{0.500\text{N}}{25\times10^{-6}\text{C}} = \frac{0.500\text{N}}{0.000025\text{C}}$$
$$= 20{,}000\ \text{N/C}$$

$$\boxed{E = 2.0 \times 10^4\ \text{N/C Ans}}$$

15.2 Two point charges, $q_1 = 8\ \mu C$ and $q_2 = 4\ \mu C$, are placed at a distance of 120 cm. What will be the Coulomb's force between them? Also, find the nature of the force.

Given:

$$q_1 = 8\ \mu\text{C} = 8 \times 10^{-6}\ \text{C}$$
$$q_2 = 4\ \mu\text{C} = 4 \times 10^{-6}\ \text{C}$$
$$r = 120\ \text{cm} = 1.2\ \text{m}$$
$$k = 9 \times 10^9\ \text{Nm}^2/\text{C}^2$$

To find:

$$F = ?$$

Solution:

As we known

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

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$$= \frac{(9\times10^{+9}\,Nm^2C^{-2})(8\times10^{-6}C)(4\times10^{-6}C)}{(1.2m)^2}$$

$$= \frac{(9\times10^{9})(32\times10^{-12})N}{1.44}$$

$$\boxed{E = 0.2\ N}\ \text{Ans}$$

Nature of force: Both charges are positive, So the force between them is repulsive.

15.3 Two identical charges repel each other with a force of 0.2 N when they are 9cm apart. Find the force between them when they are 3 cm apart.

Given:

$F_1 = 0.2\ N$

$r_1 = 9\ cm = 0.09\ m$

$r_2 = 3\ cm = 0.03\ m$

To find:

$F_2 = ?$

Solution:

Since the charges are identical and constant, So we can write:

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

Therefore

$$\frac{F_2}{F_1} = \left(\frac{r_1}{r_2}\right)^2$$

$$F_2 = F_1 \times \left(\frac{r_1}{r_2}\right)^2$$

Substitute the above values

$$F_2 = (0.2N) \times \left(\frac{0.09m}{0.03m}\right)^2$$

$$F_2 = (0.2N) \times 9N$$

$$\boxed{F_2 = 1.8N}\ \text{Ans}$$

15.4 A point charge q=10 μC is placed in air. Calculate the electric field strength at a distance of 0.5 metres from the charge.

Given:

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

$r = 0.5\ m$

$k = 9 \times 10^9\ Nm^2C^{-2}$

To find:

$E = ?$

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Solution:

As we know that

$$E = k\frac{q}{r^2}$$

Substitute the above values

$$E = \frac{(9\times10^9\ Nm^2C^{-2})(10\times10^{-6}C)}{(0.5m)^2}$$

$$= \frac{9\times10^1\times10^9\times10^{-6}}{0.25}\ NC^{-1}$$

$$E = \frac{9\times10^4}{0.25}\ NC^{-1}$$

$$E = 36\times10^4\ NC^{-1}$$

$$\boxed{E = 3.6\times10^5\ NC^{-1}}\ \text{Ans}$$

15.5 Two small equally charged metal spheres having charge 3 μC are brought close together such that the distance between them is 2.0 cm. Calculate the magnitude of repulsive force that each sphere exerts on the other.

Given:

$q_1 = q_2 = 3\times10^{-6}C$

$r = 2\ cm = 0.02\ m$

$k = 9\times10^9\ Nm^2C^{-2}$

To be find: $F = ?$

Solution:

As we know that

$$F = \frac{kq^2}{r^2}$$

$$F = \frac{9\times10^9\ Nm^2C^{-2}\times(3\times10^{-6}C)^2}{(0.02m)^2}$$

$$F = \frac{0.081}{0.0004}\ N$$

$$\boxed{F = 202.5\ N}\ \text{Ans}$$

15.6 Two small equally charged metal spheres repel each other with a force of 0.5 N when placed 3 cm apart in the air. Calculate the charge on each sphere.

Given:

$F = 0.5\ N$

$r = 3\ cm = 0.03\ m$

$k = 9\times10^9\ Nm^2C^{-2}$

To find: $q = ?$

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Solution:

As we know that

$$F = \frac{kq^2}{r^2}$$

$$q^2 = \frac{Fr^2}{k}$$

$$q = \sqrt{\frac{Fr^2}{k}}$$

$$q = \sqrt{\frac{0.5N \times (0.03m)^2}{9\times10^9\,Nm^2C^{-2}}}$$

$$q = \sqrt{5 \times 10^{-14}}C$$

$$q = 2.24 \times 10^{-7}C$$

$$q = 224 \times 10^{-9}C$$

$$\boxed{q = 224\ nC}$$ Ans

15.7 A force of 85 N acts between two charges placed 3.2 cm apart. If one charge is 25 μC, determine the other charge.

Given:

Force = F = 85 N

distance = r = 3.2 cm = 0.032 m

charge = q_1 = 25 μC = 25 × 10^{-6}C

k = 9 × 10^9 Nm^2/C^2

To find: q_2 = ?

Solution:

As we know by Coulom's law:

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

rearrange $$q_2 = \frac{Fr^2}{kq_1}$$

$$q_2 = \frac{85N \times (0.032m)^2}{(9\times10^9\,Nm^2C^{-2})(25\times10^{-6}C)}$$

$$q_2 = 3.87 \times 10^{-4} \times 10^{-3}\ C$$

$$q_2 = 3.87 \times 10^{-7}C$$

$$q_2 = 0.387 \times 10^{-6}C$$

$$\boxed{q_2 = 0.387\ \mu C}$$ Ans

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