NOTES | PHYSICS - 10

Chapter 15

ELECTROSTATICS

(The branch of physics which deals with charge at rest)

Key concepts:

- Electric Charge
- Applications of Electrostatics
- Electric field
- Accumulation of charges
- Electrostatic induction
- Coulomb's law
- Conduction of Electric Charges

Q.1 What is meant by electric charge? State that unlike charges attract and like charges repel. Also discuss properties of an electric charge.

Key points: Electric charge, (Examples, Types, Properties)

Electric Charge

Definition: *"Electric charge is a fundamental property of matter that causes it to experience a force when placed in an electric field leading to attraction or repulsion."*

1. Explanation

- The 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.
- There are two types of electric charges, known as positive and negative, which can be demonstrated through a simple experiment (Fig. 15.1).
- The SI unit of charge is the coulomb (C).

2. Experiment

- Figure 15.1 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 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.

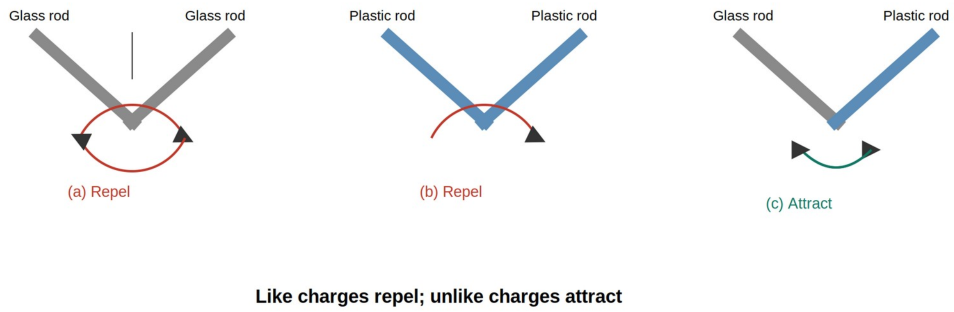


Fig. 15.1: Electrostatic interactions between glass rods and plastic rods after being charged by friction

Conclusion

This set of experiments clearly demonstrates the basic electrostatic rule that like charges repel while opposite charges attract.

3. Properties of Charges

a. Nature of Charge

- 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.
- Since everything is composed of atoms, every material carries either a positive charge, a negative charge, or neutral.

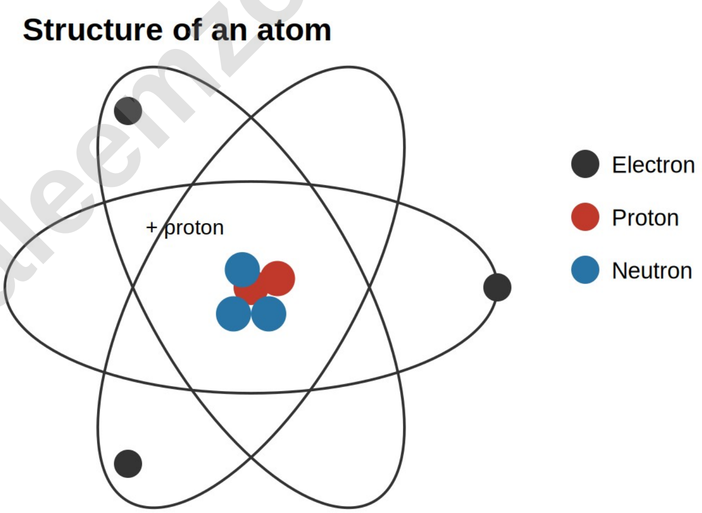


Fig. 15.2: Structure of an atom

b. Transfer of Charge

- 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.

c. Conservation of Charge

The total amount of charge in an isolated system remains constant.

Q.2 Describe experiments to show electrostatic charging by friction.

Key points: Experiments to show electrostatic charging by friction

Experiments to Show Electrostatic Charging by Friction

- a. When a plastic comb (or rod) is rubbed through dry hair and is brought near small pieces of paper, it attracts them.
- b. Similarly, amber rod when rubbed with silk attracts small pieces of paper.
- c. 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.

Q.3 What is meant by electrostatic induction? Explain.

Key point: Electrostatic induction

Electrostatic Induction

Definition: *"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."*

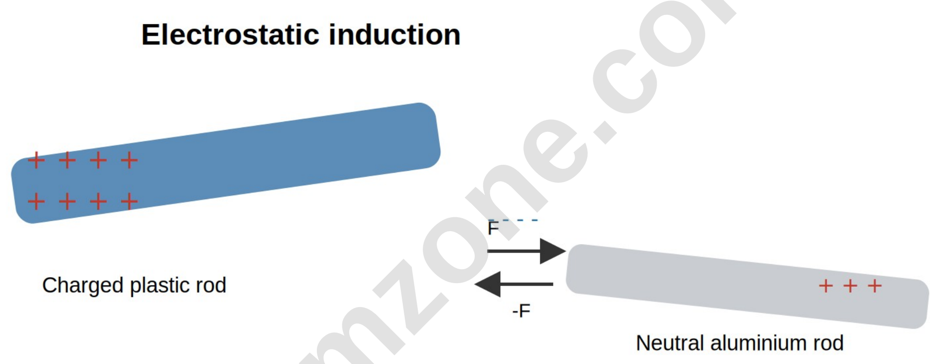


Fig. 15.4: Charged plastic rod attracts neutral aluminium rod

1. Activity

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.

Do You Know? Q. What happens when a charged rod is brought near a conductor without touching it? Ans. When a charged rod is brought near a conductor without touching it, the conductor becomes charged through electrostatic induction. The presence of the charged rod causes a redistribution of charges within the conductor. For example, a negatively charged rod will repel electrons to the far side of the conductor, leaving the near side positively charged, even though the conductor's total charge remains zero.

2. Explanation

- 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. (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.

Charging two spheres by induction

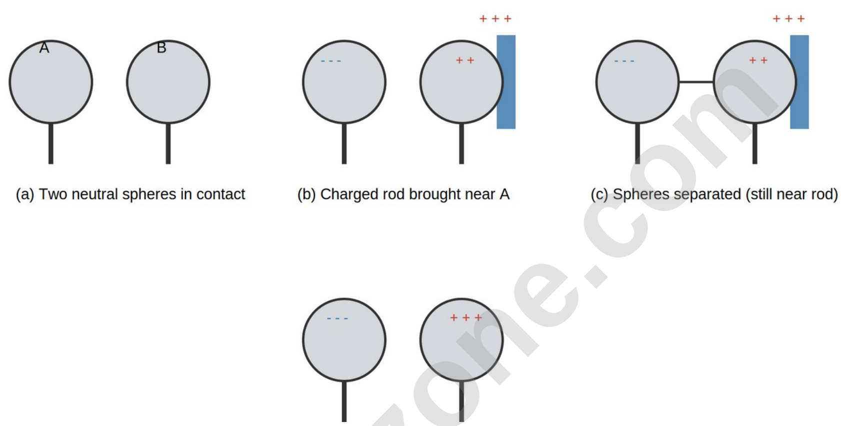


Fig. 15.5: Charging two spheres by electrostatic induction

Q.4 Explain how a conductor can be charged by induction and Earthing.

Key points: Charging by Induction and Earthing

Charging by Induction

Definition: *"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."*

Explanation

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.

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. 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.

Charging a conductor by induction and earthing

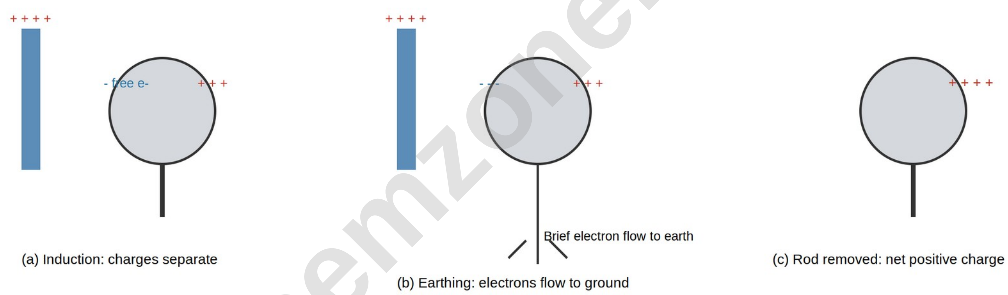


Fig. 15.6: Charging a conductor by induction and Earthing

Q.5 What is a gold leaf electroscope? Give its construction and working.

Key points: Electroscope, electroscope construction and working

Electroscope

Definition: *"The gold leaf electroscope is a sensitive device which is used to detect electric charges."*

1. 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 aluminium foil is attached to the lower part of the inside of the jar.
- This aluminium foil is typically grounded by connecting it to a copper wire, which helps in protecting the gold leaves from external electrical interference.

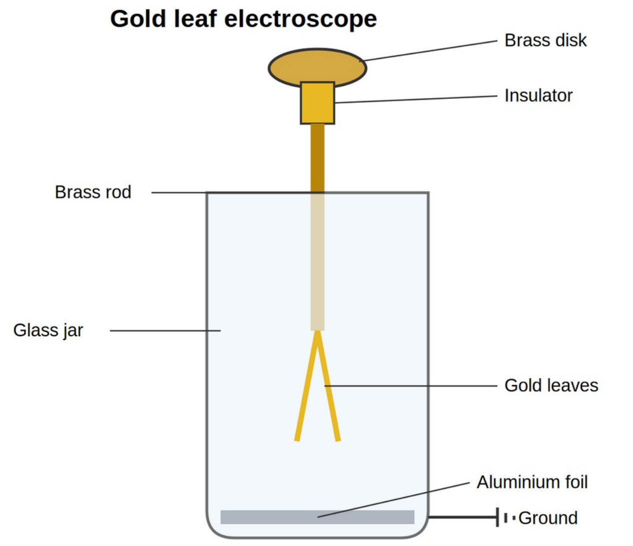


Fig. 15.7: Uncharged electroscope

2. Working

- 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.
- 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. Since both leaves carry the same charge, they will repel each other and move apart.

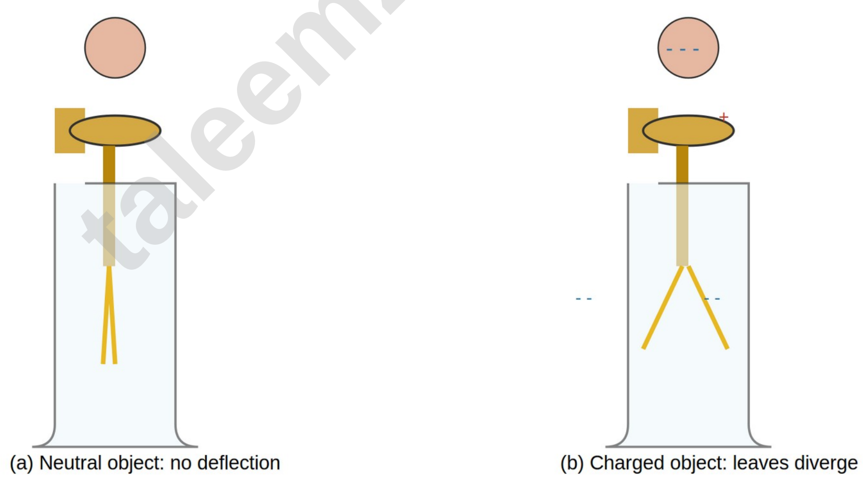


Fig. 15.8: Detecting charge using a gold leaf electroscope

- 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.

Brain Teaser — Q. 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. The balloon becomes charged (usually negative) after rubbing. When it is brought near the neutral wall, it causes electrostatic induction. The wall remains neutral overall, but the charges within it redistribute. The positive charges in the wall are attracted to the negatively charged balloon, creating a net attractive force that makes the balloon stick.

Brain Teaser — Q. 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. This happens due to electrostatic induction. The charged object (e.g., a negatively charged rod) repels like charges in the electroscope's metal parts. This causes negative charge to accumulate on the gold leaves. Since both leaves now have the same type of charge, they repel each other, causing them to diverge.

Q.6 Explain applications of electrostatics in photocopier and electrostatic precipitator.

Key point: Applications of electrostatics

Applications of Electrostatics

There are many applications of electrostatics with conductors, such as electrostatic precipitators, capacitors, electrophotography, Faraday cages, electrostatic speakers, and Van de Graaff generators. Charging and discharging are fundamental processes in the operation of various devices, such as photocopiers and electrostatic precipitators, which rely on electrostatic principles.

1. Photocopier

Definition: *"A photocopier is an electronic machine used to make copies of documents and images."*

a. Working Principle

It works on a process called xerography. The xerography is derived from the Greek words "xeros" (dry) and "graphos" (writing), meaning "dry writing."

b. Construction

- 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.

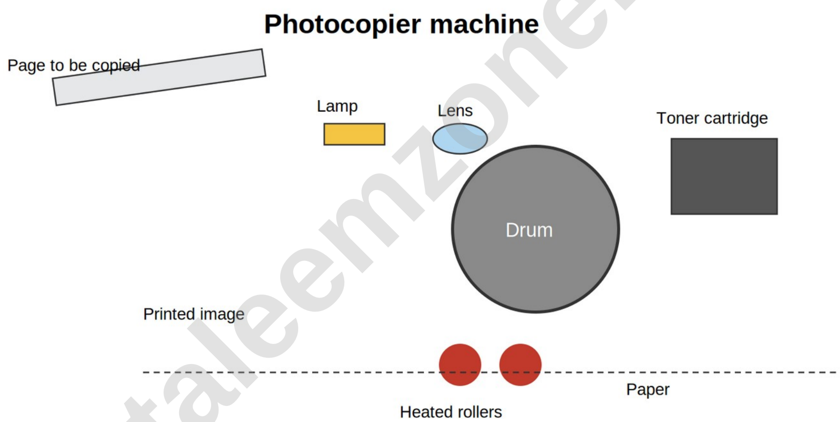


Fig. 15.10: Labelled diagram of a multifunction photocopier machine

c. Working

- 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.

2. Electrostatic Precipitator

Definition: *"An electrostatic precipitator (ESP) is a device used to remove particulate matter from industrial exhaust gases."*

a. 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.

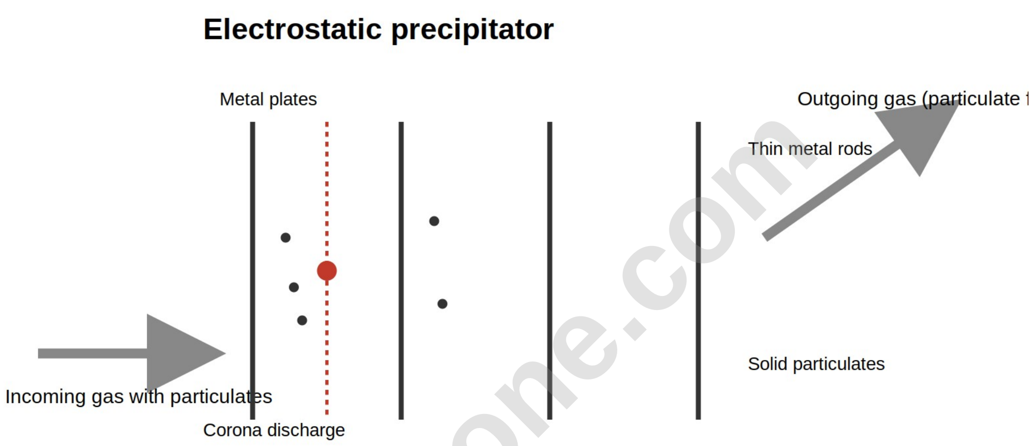


Fig. 15.11: Electrostatic precipitator

- 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.

b. Importance

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.

Q.7 State and explain Coulomb's law. (OR) State Coulomb's law of electrostatics. Write its mathematical form.

Key points: Coulomb's law and its mathematical form

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;

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.

Explanation

Consider two charges q_1 and q_2, separated by distance r. Mathematically;

$F \propto q_1q_2$ ……………. (15.1)

$F \propto 1/r^2$ ……………. (15.2)

$F \propto q_1q_2/r^2$

$$F = k\, q_1q_2 / r^2 \quad \text{……………. (15.3)}$$

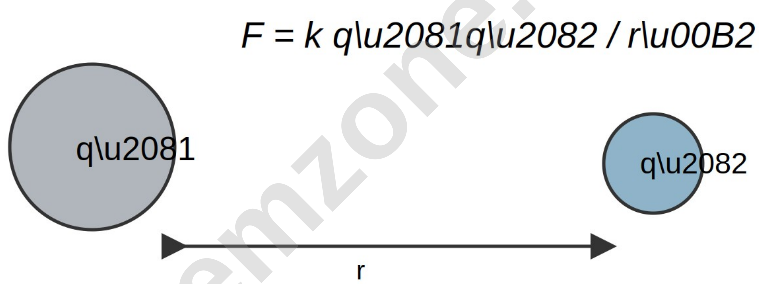


Fig. 15.12: Coulomb's law

- Where 'k' is a constant of proportionality which quantifies the strength of the electrostatic force between two point charges.
- The value of k is determined by the medium between the charges.
- In vacuum or air, k is approximately 9×10^9 N m² C⁻².
- Coulomb's law is applicable primarily to point charges whose sizes are negligible compared to the distance separating them.

Do You Know? Q. How do Newton's law of gravitation and Coulomb's law compare? Ans. Both laws are inverse-square laws (force ∝ 1/distance²). However, gravitational forces are only attractive and are significant for large masses and distances. Electrical forces can be both attractive and repulsive and are important when dealing with small charges and distances.

Q.8 Define electric field and electric field intensity. Write formula, SI unit and direction of electric field intensity.

Key points: Electric field and electric field intensity its formula, SI unit and direction

Electric Field

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

Explanation

- 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.
- The region around a charge where it can attract or repel another charge is described by the concept of the electric field.

Tidbit: 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.

Electric Field Intensity

Definition: *"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;

$E = F / q^{\circ}$ .... *(15.4)*

Unit

The SI unit of electric field intensity is newton per coulomb ($N\,C^{-1}$).

Explanation

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

Mathematically;

$E = kq / r^2$ .... *(15.5)*

Fig. 15.13: Electric field intensity

- Consider a test charge q is brought into the electric field of a source charge Q. The source charge will exert an electrostatic force F_E on the test charge.
- 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.

Do You Know? Q. What do electric field lines represent and what are their key properties? Ans. Electric field lines are imaginary lines that show the direction of the force on a positive test charge at any point. Their key properties are: they point away from positive charges and toward negative charges, they never cross each other, and they represent the path a positive test charge would follow.

Q.9 Explain electric field pattern in following: (i) Around a point charge (ii) Around a charged conductor (iii) Between two oppositely charged parallel conducting plates.

Key point: Electric field patterns

Electric Field Lines

Definition: *"The imaginary lines which give the information about strength and direction of electric field at any point in space is called electric field lines." (OR) "It represents the path followed by a small positive test charge in an electric field."*

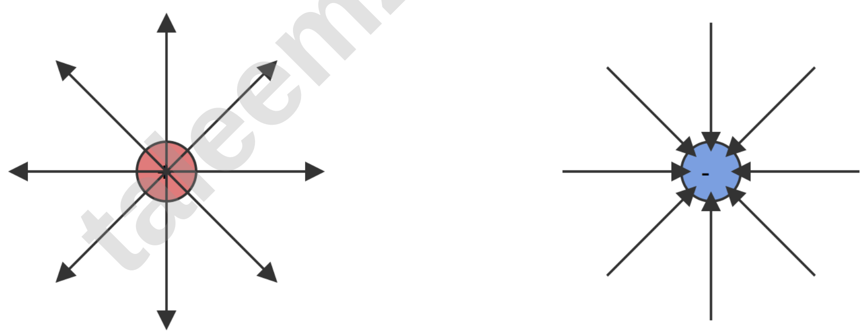
Explanation

- The concept of an electric field demonstrates how a charged object affects other 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, the electric field lines radiate outward, indicating that a positive test charge placed nearby would be repelled.
- In contrast, for a negative point charge, 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.



Positive point charge (lines radiate outward)   Negative point charge (lines point inward)

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.
- Inside the sphere, the electric field is zero because the charges on the surface rearrange to cancel any internal electric field.

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. The electric field lines point from the positively charged plate to the negatively charged plate.
- 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.

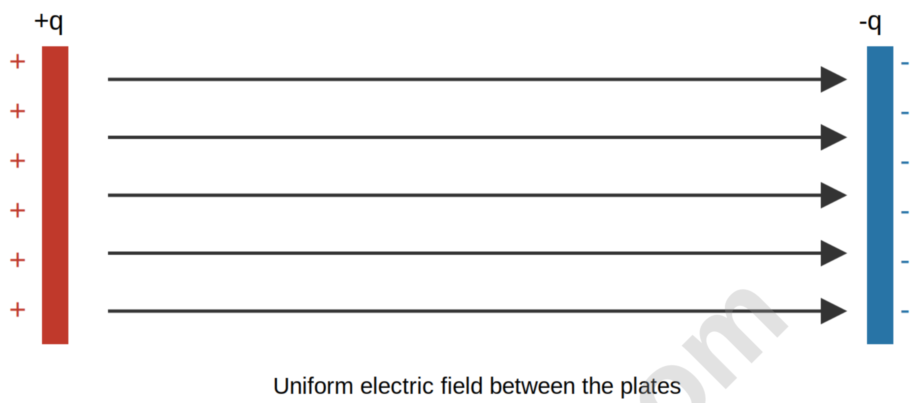


Fig. 15.16: Electric field between two oppositely charged parallel plates

Do You Know? Q. Why is the electric field inside a charged conducting sphere always zero? (OR) Why people inside metal car or airplanes are safe during lightning strikes. Ans. When a conductor is charged, the charges reside only on its outer surface. These charges rearrange themselves in such a way that the electric field they produce inside the conductor cancels out completely. This is also why the interiors of metal cars or airplanes are safe during lightning strikes.

Q.10 Differentiate between electrical conductors and insulators with examples.

Key points: Electrical conductors and insulators

Electrical Conductors and Insulators

1. Electrical Conductors

Definition: *"Electrical conductors are materials that allow electric charge to flow freely through them."*

a. Atomic Structure

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

b. Examples

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

c. Use

These are used in power transmission, kitchen pans, electronics and wiring etc.

2. Electrical Insulators

Definition: *"Electrical insulators are materials that resist or prevent the flow of electric charge."*

a. Atomic Structure

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.

b. Examples

Examples of electrical insulators include rubber, plastic, glass, wood, and ceramics.

c. Uses

These materials are used to block the flow of electricity and provide safety in electrical systems.

d. 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.

Differentiation (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.

Do You Know? Electric Fields

Q. Write the characteristics of electric field lines. Ans. Characteristics of electric field lines:

• 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.

Q.11 How accumulation of charge occurs? What are its consequences? How risks are minimized? (OR) What are dangers of static electricity?

Key point: Accumulation of charge

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.

1. Consequences

- 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.

2. Precautions

Proper grounding, antistatic measures, and humidity control are often employed to mitigate these risks and prevent the harmful effects of charge accumulation.

Q.12 What is an electrical breakdown? How it occurs? State that corona discharge and Lichtenberg figures are visible examples of electrical breakdown.

Key points: Electrical breakdown, (Occurrence, Examples)

Electrical Breakdown

Definition: *"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."*

Explanation

- 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.

Tidbit: Q. Why do we see a bluish light near the sharp edges of electrical equipment in the dark? Ans. 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.

Examples

a. 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.
- 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.

b. 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. 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.

Q.13 How lightning rod can protect structure and human from lightning strikes?

Key point: Lightning rod

Lightning Conductors

- 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 occupants.

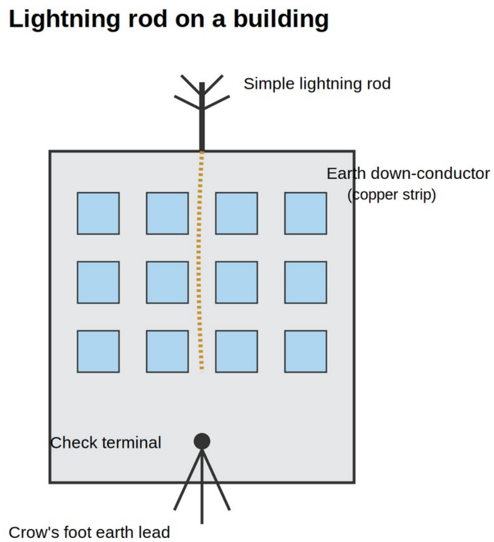


Fig. 15.19: Lightning conductors installed in a building

Q.14 How is lightning generated? Explain.

Key point: Generation of lightning

Generation of Lightning

- 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? Lichtenberg figures are fern-like patterns that may appear on the skin of lightning strike victims that disappear in 24 hours. Q. What are Lichtenberg figures? Ans. Lichtenberg figures are branching, fern-like patterns. They can form on insulating materials (like wood or acrylic) when a high-voltage electrical discharge passes through them, leaving a visible trace of the discharge path. They can also appear temporarily on the skin of lightning strike victims.

Formula Sheet

Sr. #	Formula	Description
1	$F = kq_1q_2 / r^2$	Coulomb's Law
2	$E = kq / r^2$, $E = F/q_o$	Electric field intensity

Solved Examples

Example 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:

$k = 9.0 \times 10^9$ N m² C⁻²

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

and $r = 0.5$ m

To find: E = ?

Using the formula: $E = kq / r^2$

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

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

Result: Thus, the electric field of a point charge is 3.6×10^5 N C^{-1}.

Multiple Choice Questions Exercise

#	Question	Option A	Option B	Option C	Option D
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
2	Which of the following is a visible example of electrical breakdown?	(a) Corona discharge	(b) Electric current	(c) Magnetic field	(d) Electric potential
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
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
5	The device which works on the principle of electrostatics:	(a) electric bell	(b) photocopier	(c) electric heater	(d) transformer

Answer Key

1	2	3	4	5			
a	a	a	a	b			

SLO Based Additional MCQs + Past Papers MCQs of Punjab Boards

Electric Charge and its Properties

#	Question	Option A	Option B	Option C	Option D
1	What is the SI unit of electric charge?	(a) Ampere	(b) Coulomb	(c) Volt	(d) Ohm
2	When a plastic comb is rubbed through dry hair, what type of charge does it typically acquire?	(a) Positive	(b) Negative	(c) Neutral	(d) Both positive and negative
3	The fundamental principle illustrated when two similarly charged glass rods repel each other is:	(a) Like charges attract	(b) Unlike charges attract	(c) Like charges repel	(d) Charges can be created
4	Which of the following is not a method of transferring electric charge between objects?	(a) Radiation	(b) Rubbing	(c) Direct contact	(d) Induction
5	The total amount of charge in an isolated system is always:	(a) Increasing	(b) Decreasing	(c) Constant	(d) Zero

Electrostatic Induction and Earthing

#	Question	Option A	Option B	Option C	Option D
6	When a charged rod is brought near a neutral conductor without touching, the conductor gets charged. This is due to:	(a) Conduction	(b) Induction	(c) Friction	(d) Radiation
7	In the process of charging by induction and then Earthing, the conductor finally acquires a charge that is:	(a) Opposite to the inducing charge	(b) Same as the inducing charge	(c) Neutral	(d) Double the inducing charge
8	What is the purpose of connecting a conductor to the earth during charging by induction?	(a) To add more electrons	(b) To remove unwanted charge	(c) To increase the charge	(d) To measure the charge
9	A gold leaf electroscope can be used to detect charge because its leaves diverge when:	(a) A neutral object is brought near	(b) A charged object is brought near	(c) It is placed in the dark	(d) It is heated
10	If the leaves of an electroscope collapse when a charged object is brought near (without touch), the object is likely a:	(a) Good conductor	(b) Good insulator	(c) Charged negatively	(d) Charged positively

Electric Field

#	Question	Option A	Option B	Option C	Option D
11	An electric field is defined as a region where a charge experiences a:	(a) Mass	(b) Force	(c) Current	(d) Potential
12	The direction of the electric field at a point is the direction of the force on a:	(a) Negative test charge	(b) Neutral test charge	(c) Positive test charge	(d) Magnetic pole
13	Inside a charged conducting sphere, the electric field is:	(a) Maximum	(b) Uniform	(c) Zero	(d) Radial
14	The electric field lines between two oppositely charged parallel plates are:	(a) Circular	(b) Radial	(c) Parallel and uniform	(d) Non-existent
15	The SI unit of electric field intensity is:	(a) Newton (N)	(b) Coulomb (C)	(c) Newton per Coulomb (N/C)	(d) Joule (J)

Conductors, Insulators, and Free Electron Model

#	Question	Option A	Option B	Option C	Option D
16	Which of the following is an electrical conductor?	(a) Rubber	(b) Plastic	(c) Copper	(d) Wood
17	In the free electron model, the electrons responsible for conduction are called:	(a) Valence electrons	(b) Core electrons	(c) Free electrons	(d) Bound electrons
18	In an insulator, electrons are:	(a) Loosely bound and free to move	(b) Tightly bound and cannot move	(c) Always in the nucleus	(d) Shared between atoms
19	A simple circuit with a battery, bulb, and a gap is used to test materials. If the bulb lights up, the material inserted is a:	(a) Conductor	(b) Insulator	(c) Semiconductor	(d) Resistor

Applications and Hazards of Electrostatics

#	Question	Option A	Option B	Option C	Option D
20	Which device uses a positively charged drum and negatively charged toner to create copies?	(a) Electrostatic precipitator	(b) Photocopier	(c) Lightning rod	(d) Electroscope
21	An electrostatic precipitator removes particulate matter from industrial gases by:	(a) Heating them	(b) Charging them and attracting	(c) Dissolving them in	(d) Filtering mechanically

			to plates	water	
22	The visible glow sometimes seen around high-voltage power lines due to ionization of air is called:	(a) Lichtenberg figure	(b) Corona discharge	(c) Lightning streamer	(d) Electric arc
23	A lightning rod protects a building by providing:	(a) A high-resistance path to the ground	(b) A low-resistance path to the ground	(c) An insulating barrier	(d) A charged point to attract lightning
24	Which of the following is a danger of static electricity accumulation?	(a) Improved conductivity	(b) Dust explosions	(c) Increased magnetism	(d) Reduced friction

Coulomb's Law and Force

#	Question	Option A	Option B	Option C	Option D
25	According to Coulomb's law, the force between two point charges is directly proportional to the:	(a) Sum of the charges	(b) Product of the charges	(c) Square of the sum of charges	(d) Square root of the distance
26	The constant k in Coulomb's law depends on:	(a) The amount of charge	(b) The medium between the charges	(c) The shape of the charges	(d) The temperature
27	If the distance between two charges is doubled, the electrostatic force becomes:	(a) Half	(b) One-fourth	(c) Double	(d) Four times

Answer Key

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

Exercise Short Questions

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

Ans. Coulomb's law states that the magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.

Formula: $F = k(q_1q_2 / r^2)$

Unit: Force is measured in Newton (N).

15.2 What is an electric field?

Ans. An electric field is the region around a charged object where it exerts a force on another charge.

The electric field strength decreases with distance from the charge, following an inverse square law for point charges. The electric field is responsible for attraction or repulsion between charges.

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

Ans. Electrical conductors: Copper and aluminium are good conductors because they have free electrons that can move easily.

Electrical insulators: Rubber and plastic are insulators because their electrons are tightly bound and cannot move freely.

15.4 List some applications of electrostatics in daily life.

Ans. Electrostatics is used in photocopiers to produce images.

- (i) Electrostatic precipitators are used to remove dust from industrial gases.
- (ii) Electrostatic spray painting provides uniform coating.
- (iii) Lightning rods protect buildings from lightning.

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

Ans. Like charges repel each other when brought close. Unlike charges attract each other when brought near. This behaviour is due to electrostatic force between charges. It is a basic property of electric charge.

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

Ans. Electrical breakdown occurs when a strong electric field passes through a gas and ionizes its atoms.

It occurs when the electric field becomes strong enough to free electrons. This results in a sudden flow of electric current. Lightning is a natural example of electrical breakdown.

15.7 What are the dangers of static electricity?

Ans. Dangers of static electricity:

- Electrical shock: Sudden discharge of accumulated charge can cause painful shocks when touching metal objects or other people.
- Fire hazard: Static electricity can ignite flammable substances, gases, or dust in industrial environments, causing explosions.
- Damage to electronic components: Sensitive electronic devices and microchips can be permanently damaged by static discharge.
- Disruption of manufacturing: Static charges can interfere with precision manufacturing processes, affecting product quality.
- Health risks: In certain environments, accumulated static electricity can pose serious safety hazards to workers.
- Lightning danger: Large accumulation of charges in the atmosphere can lead to lightning strikes, which can be fatal and cause structural damage.

SLO Based Additional Short Questions + Past Papers Short Questions of Punjab Boards

Electric Charge

Q.1 Define electric charge and state its SI unit.

Ans. The property of matter due to which it produces attraction or repulsion between objects is called electric charge. Electric charge is an intrinsic property of matter. Unit: The SI unit of electric charge is coulomb (C).

Q.2 Describe an experiment to show that like charges repel and unlike charges attract.

Ans. When two glass rods rubbed with silk are brought close, they repel each other showing like charges repel. When two plastic rods rubbed with wool are brought close, they also repel. When a glass rod and a plastic rod are brought together, they attract, showing unlike charges attract.

Q.3 Write any three properties of electric charge.

Ans. Electric charge exists in two types: positive and negative. (i) Like charges repel each other. (ii) Unlike charges attract. (iii) Electric charge can be transferred from one body to another by friction, contact, or induction.

Electrostatic Induction

Q.4 What is electrostatic induction? Explain briefly.

Ans. The process in which a conductor gets charged without direct contact with a charged body is called electrostatic induction. A charged body causes redistribution of charges inside the conductor while the total charge remains unchanged. (OR) In the presence of a charged body, an insulator conductor develops positive charge at one end and negative charge at another end is called electrostatic induction.

Q.5 Why is attraction not a sure test of electrification?

Ans. A charged object can attract a neutral object due to electrostatic induction. The neutral object develops opposite charges on its near side, causing attraction. Therefore, attraction alone does not confirm that both objects are charged.

Q.6 Explain charging by induction with the help of Earthing.

Ans. A charged rod is brought near a neutral conductor causing separation of charges. The conductor is then connected to Earth, allowing unwanted charges to flow away. After removing the earth connection and rod, the conductor remains charged.

Electroscope

Q.7 What is a gold leaf electroscope? Describe its construction.

Ans. A gold leaf electroscope is a device used to detect electric charge. It consists of a brass rod, brass disc, two thin gold leaves, an insulating stopper, and a glass jar.

Q.8 How does an electroscope detect electric charge?

Ans. When a charged object is brought near the disc, charges redistribute by induction. Both gold leaves acquire similar charges and repel each other. The divergence of leaves indicates the presence of electric charge.

Applications of Electrostatics

Q.9 Write a short note on the electrostatic precipitator.

Ans. An electrostatic precipitator removes solid particles from exhaust gases. Particles are charged using corona discharge and attracted to oppositely charged plates. This device helps in reducing air pollution.

Q.10 Explain the working principle of a photocopier.

Ans. A photocopier works on electrostatic charging and discharging. A charged drum forms an image when light falls on it. Negatively charged toner sticks to charged areas and transfers the image to paper.

Coulomb's Law

Q.11 State Coulomb's law and write its mathematical form.

Ans. Statement: The electrostatic force between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them. Formula: $F = kq_1q_2 / r^2$

Q.12 Define electric field intensity and write its unit.

Ans. The electrostatic force per unit positive test charge at a point is called electric field intensity. Formula: $E = F / q$ Unit: Newton per Coulomb ($N\ C^{-1}$)

Q.13 Describe the direction of electric field lines.

Ans. Electric field lines originate from positive charges and terminate at negative charges. The direction of the electric field is the direction of force on a positive test charge. Electric field lines never intersect each other.

Conductors and Insulators

Q.14 What is a corona discharge and where is it commonly observed?

Ans. Corona discharge is a visible form of electrical breakdown where a high-voltage electric field ionizes the air surrounding a conductor. Observation: It produces a faint glow and is commonly observed around sharp points or edges of high-voltage power lines, transformers, or antennas, especially in dark or humid conditions.

Q.15 Differentiate between electrical conductors and insulators.

Conductors	Insulators
Allow electric charge to flow	Resist the flow of charge
Have free electrons	Electrons are tightly bound
Example: Copper, Aluminium	Example: Rubber, Plastic

Electrical Breakdown

Q.16 What is electrical breakdown? Write two examples.

Ans. Electrical breakdown occurs when a strong electric field ionizes a gas, making it conductive. Examples: Corona discharge, Lichtenberg figures.

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. Some materials gain electrons while others lose electrons when rubbed together because of differences in their atomic structure and how tightly bound their electrons are.

Reason: Different materials have different numbers of valence electrons (outermost electrons) and varying degrees of binding strength. When two materials are rubbed together, the material with electrons that are more loosely bound will transfer its electrons to the material with more tightly bound electrons. The property that determines this behaviour is the electron-binding property of the material. Materials like plastic tend to gain electrons easily (become negatively charged), while materials like wool or silk tend to lose electrons easily (become positively charged). This difference in electron-binding properties is due to the different atomic structures and the varying number of valence electrons in each material.

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 pieces fall off because they become charged by the comb through electrostatic induction.

Reason: Initially, the charged comb attracts the neutral paper pieces by inducing opposite charges on them (the side of the paper closest to the comb becomes oppositely charged). However, once the paper touches the comb, electrons transfer to (or from) the paper, giving it the same type of charge as the comb. Since like charges repel, the comb now repels the paper pieces, and they fall off.

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

Ans. Dust particles get attracted to screens because the screens develop an electric charge when operating.

Reason: When television or computer monitors are turned on, they generate electric charges on their surfaces due to the flow of electrons. Dust particles, particularly those suspended in the air, become charged through electrostatic induction. Since the screen has an electric charge and the dust particles develop opposite charges, the electrostatic force of attraction pulls the dust particles toward the screen. This is why we often see a layer of dust accumulation on screens.

15.4 If we rub a balloon on 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 water toward the balloon reveals that water molecules are polar molecules.

Reason: When the balloon is rubbed on dry hair, it becomes negatively charged. When this charged balloon is placed near a stream of water, the water bends toward the balloon, indicating attraction. This happens because water molecules have a polar structure — they have a slightly positive charge on one end and a slightly negative charge on the other end. Even though the water stream itself is neutral overall, the water molecules can rotate and align themselves in the electric field created by the charged balloon. The slightly negative charges in the water molecules are repelled to the far side, while the slightly positive charges orient toward the negatively charged balloon, resulting in a net attraction.

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

Ans. The conductor allows free electrons to move, causing charge redistribution, while the insulator does not.

Reason: In a conductor, free electrons move easily. When placed in an electric field, electrons redistribute — accumulating on one side and leaving the opposite side positively charged (electrostatic induction). In an insulator, electrons are tightly bound and cannot move freely, so no significant charge redistribution occurs; it remains practically unaffected by the external field.

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. See Q.#5 of theory.

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

Ans. See Q.#7 of theory.

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. See Q.#8 of theory.

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

Ans. See Q.#10 of theory.

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. See Q.#6 of theory.

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?

Solution

Given Data:

Test charge, $q = 25\ \mu C = 25 \times 10^{-6}$ C

Force on the charge = $F = 0.500$ N

To Find:

Magnitude of the electric field = E = ?

Solution:

The formula for electric field intensity is: $E = F / q_o$

Substituting the values: $E = 0.500 / (25 \times 10^{-6}) = 20000\ NC^{-1} = 2 \times 10^{4}\ NC^{-1}$

Result:

The magnitude of the electric field is $2.0 \times 10^{4}\ N\ C^{-1}$.

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.

Solution

Given Data:

Charge 1 = $q_1 = 8\ \mu C = 8 \times 10^{-6}$ C

Charge 2 = $q_2 = 4\ \mu C = 4 \times 10^{-6}$ C

Distance between charges = r = 120 cm = 1.20 m

Coulomb's constant = $k = 9 \times 10^{9}\ N\ m^2\ C^{-2}$

To Find:

Coulomb's force = F = ?

Nature of the force = ?

Solution:

Using Coulomb's Law: $F = kq_1q_2 / r^2$

$F = (9 \times 10^{9}) \times (8 \times 10^{-6}) \times (4 \times 10^{-6}) / (1.20)^2$

$F = (9 \times 10^{9}) \times 32 \times 10^{-12} / 1.44$

$F = (9 \times 10^{9}) \times (22.22 \times 10^{-12})$

$F = 199.98 \times 10^{-3}\ N \approx 0.2\ N$

Since both charges are positive, the force is repulsive.

Result:

The Coulomb's force is 0.2 N and it is repulsive.

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

Solution

Given Data:

Initial force = $F_1 = 0.2$ N

Initial distance = r_1 = 9 cm = 0.09 m

Final distance = r_2 = 3 cm = 0.03 m

Charges q_1 and q_2 remain the same.

To Find:

Final force = F_2 = ?

Solution:

From Coulomb's law: $F \propto 1/r^2$

Therefore: $F_2/F_1 = r_1^2/r_2^2$

$F_2 = F_1 \times (r_1^2/r_2^2)$

$F_2 = 0.2 \times (0.09)^2/(0.03)^2 = 0.2 \times 0.0081/0.0009$

F_2 = 1.8 N

Result:

The force when they are 3 cm apart is 1.8 N.

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

Solution

Given Data:

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

Distance from charge = r = 0.5 m

Coulomb's constant = $k = 9 \times 10^9$ N m^2 C^{-2}

To Find:

Electric field intensity = E = ?

Solution:

The formula for electric field due to a point charge is: $E = kq / r^2$

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

$E = (9 \times 10^9) \times (10 \times 10^{-6}) / 0.25$

$E = (9 \times 10^9) \times (40 \times 10^{-6})$

$E = 360 \times 10^3$ NC^{-1} = 3.6×10^5 NC^{-1}

Result:

The electric field at 0.5 m is 3.6×10^5 NC^{-1}.

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.

Solution

Given Data:

Charge on each sphere = q = 3 µC = 3×10^{-6} C

Distance between spheres = r = 2.0 cm = 0.02 m

Coulomb's constant = $k = 9 \times 10^9$ N m^2 C^{-2}

To Find:

Repulsive force = F = ?

Solution:

Using Coulomb's Law: $F = k(q \times q) / r^2$

$F = (9 \times 10^9) \times (3 \times 10^{-6})^2 / (0.02)^2$

$F = (9 \times 10^9) \times (9 \times 10^{-12}) / 0.0004$

$F = (9 \times 10^9) \times (2.25 \times 10^{-8})$

$F = 20.25 \times 10^1$ N = 202.5 N

Result:

The magnitude of the repulsive force is 202.5 N.

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.

Solution

Given Data:

Force = F = 0.5 N

Distance between spheres = r = 3 cm = 0.03 m

Coulomb's constant = $k = 9 \times 10^9$ Nm^2C^{-2}

Charges are equal = $q_1 = q_2 = q$

To Find:

Charge on each sphere = q = ?

Solution:

From Coulomb's law: $F = kq^2 / r^2$

Rearranging for q^2: $q^2 = F \times r^2 / k$

$q^2 = 0.5 \times (0.03)^2 / (9 \times 10^9) = 0.5 \times 0.0009 / (9 \times 10^9)$

$q^2 = 0.00045 / (9 \times 10^9) = 5 \times 10^{-14}$

$q = \sqrt{(5 \times 10^{-14})} = 2.236 \times 10^{-7}$ C = 0.2236×10^{-6} C

Result:

The charge on each sphere is ≈ 224 μC.

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.

Solution

Given Data:

Force = F = 85 N

Distance = r = 3.2 cm = 0.032 m

Charge 1 = q_1 = 25 μC = 25×10^{-6} C

Coulomb's constant = $k = 9 \times 10^9$ Nm^2C^{-2}

To Find:

Charge 2 = q_2 = ?

Solution:

From Coulomb's law: $F = k(q_1 \times q_2) / r^2$

Rearranging for q_2: $q_2 = F \times r^2 / (k \times q_1)$

$q_2 = 85 \times (0.032)^2 / (9 \times 10^9 \times 25 \times 10^{-6})$

$q_2 = 85 \times 0.001024 / (9 \times 10^9 \times 25 \times 10^{-6}) = 0.08704 / (225 \times 10^3)$

$q_2 = 3.868 \times 10^{-7}$ C ≈ 3.87×10^{-6} C

Result:

The other charge is 3.87 μC.

Important Questions of Board Examination

(i) Explain the phenomenon of electrostatic induction. How is an insulated conductor charged by electrostatic induction?

(ii) Describe Gold Leaf electroscope. By using Gold Leaf electroscope how can we find that:

(i) Presence of the charge on the body.

(ii) The nature of the charge on the body.

(iii) State and explain coulomb's law and write it in mathematical form.

(iv) Define and explain:

(i) Electric field.

(ii) Electric field intensity.

(v) Discuss practical applications of electrostatics phenomenon in:

(i) Photocopier

(ii) Electrostatic precipitator

(vi) State two hazards of electrostatics phenomenon in detail.

(vii) What is difference between conductors and insulators?

Important Short Questions of Board Examination

(i) Define electrostatics.

(ii) Define electric charge.

(iii) Define electric field.

(iv) Define electric field intensity and its formula.

(v) State two properties of electric charge.

(vi) Define electrostatics induction.

(vii) Define Earthing in electrostatics.

(viii) State two applications of electrostatics.

(ix) State dangers of electrostatics.

(x) Define conductor and insulator.

(xi) Define electrical breakdown. What are its practical examples?

(xii) How lightning conductor protect buildings and humans from strike?

(xiii) State coulomb's law.

(xiv) Why does a charged balloon attract a stream of water?

(xv) Why it is important for a lightning rod to be connected to ground?

(xvi) Why charging could be problematic in situation like lightning?

(xvii) State uses of a gold leaf electroscope.