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Roll No. ____________ Name of Student: ____________________ Class: ___________ Date: __________

Chapter 15: Electrostatics

Class 10th FBISE - SLO Based Notes

Physicist Hammad Shaukat

15.1 Static Charge

Q1: What is static charge?

Static charge refers to electric charge that stays on the surface of an object and does not move. It is usually produced by friction.

Q2: What is electrostatic force?

Electrostatic force is the force of attraction or repulsion between static charges. It is responsible for effects like hair standing after brushing or a spark from a doorknob.

Q3: How is electric charge measured?

Electric charge is measured in coulombs (C), named after the French physicist Charles A. de Coulomb.

Q4: What are the three types of subatomic particles and their charges?

- **Electron** – Negative charge (-1.6×10^{-19} C)
- **Proton** – Positive charge ($+1.6 \times 10^{-19}$ C)
- **Neutron** – No charge

Q5: What are the types of electric charges?

There are two types:

- **Positive charge**
- **Negative charge**

Like charges repel; opposite charges attract.

Q6: What is meant by electrification?

Electrification is the process of transferring electric charge from one object to another, usually by friction.

Q7: What happens when a glass rod is rubbed with silk?

Electrons move from the glass rod to the silk cloth:

- Glass becomes positively charged.
- Silk becomes negatively charged.

Q8: What happens when an ebonite rod is rubbed with fur?

Electrons move from fur to ebonite:

- Ebonite becomes negatively charged.
- Fur becomes positively charged.

Q9: Can charge be created or destroyed?

No, charge can neither be created nor destroyed. It only transfers between objects. This is called the law of conservation of charge.

Q10: What causes an object to become positively or negatively charged?

- **Positive charge:** Loss of electrons
- **Negative charge:** Gain of electrons

15.2 Conductors and Insulators

Q1: What are conductors?

Conductors are materials that allow electric charge (especially electrons) to flow through them easily. Example: metals like copper and aluminum.

Q2: What are insulators?

Insulators are materials that do not allow electric charge to flow freely. Example: glass, rubber, and plastic.

Q3: Why can conductors conduct electricity?

Conductors have loosely bound valence electrons that can move freely from atom to atom. These free electrons carry electric charge.

Q4: Why can't insulators conduct electricity?

In insulators, even outer electrons are tightly held. They cannot move freely, so electric charge cannot pass through.

Q5: What is the role of free electrons in conductors?

Free electrons are mobile and move throughout the conductor, allowing it to carry electric current easily.

Q6: What happens to charge placed on a conductor?

Charge spreads evenly on the surface, especially on spherical shapes. On irregular shapes, charge gathers more at sharp points.

Q7: What happens to charge placed on an insulator?

The charge remains where it was placed and does not move or spread because electrons cannot flow.

Q8: Give one example showing the difference in charge movement on conductors and insulators.

If you rub a balloon (insulator), the charge stays where rubbed. If you charge a metal rod (conductor), the charge spreads all over its surface.

Q9: What is meant by "charge distribution"?

It refers to how electric charge spreads or stays on the surface of a material:

- **Conductor:** Charge spreads.
- **Insulator:** Charge stays fixed.

Q10: Why do pointed ends on conductors gather more charge?

Due to repulsion, charges tend to move toward pointed areas where there is less nearby charge to repel them.

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15.3 Charging and Discharging

Q1: What is meant by charging and discharging?

Ans: Charging is the process of transferring electrons between materials, leading to a buildup of static electric charge. Discharging is the neutralization of this charge when it escapes, often causing a spark.

- **Example:** Sliding across a car seat transfers electrons to your body. Touching a metal doorknob then releases the charge suddenly, causing a spark.

Q2: What are the three methods of charging objects?

Ans: Objects can be charged in three main ways:

1. Charging by Friction
2. Charging by Contact (Conduction)
3. Charging by Induction

Q3: What is charging by friction?

Ans: Friction causes electrons to be transferred from one object to another due to differences in ionization energy and electron affinity. The object that loses electrons becomes positively charged, and the one that gains becomes negatively charged.

Q4: What is charging by contact (conduction)?

Ans: When a charged object touches a neutral object, electrons are transferred, causing both to share the same type of charge.

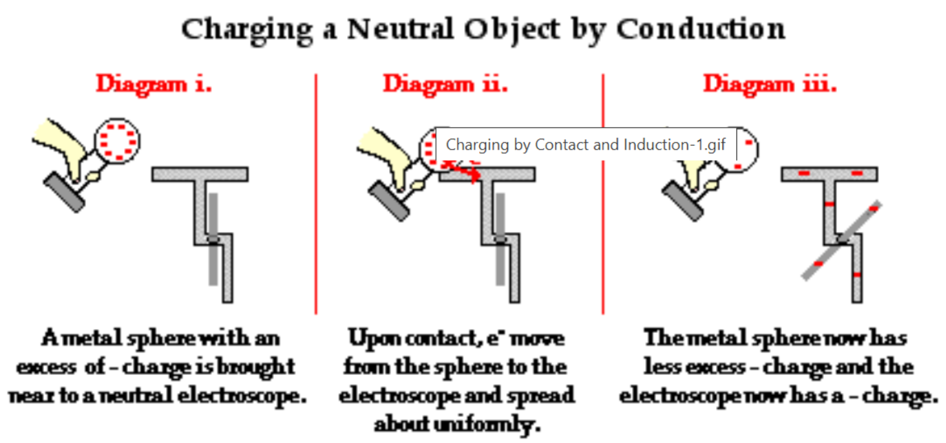

Figure 1: Charging by Contact

Q5: What is charging by induction?

Ans: In induction, a charged object is brought near a neutral conductor without touching it. The nearby charges in the conductor rearrange themselves due to repulsion/attraction, causing temporary polarization. If grounded, a net charge can be left behind.

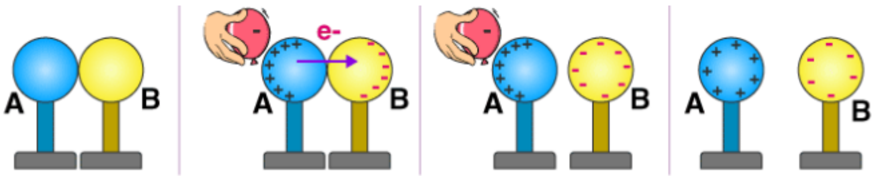

Figure 2: Charging by Induction

Q6: What is grounding in induction?

Ans: Grounding provides a path for excess electrons to leave the object. When the grounded conductor is disconnected, it retains a net positive or negative charge.

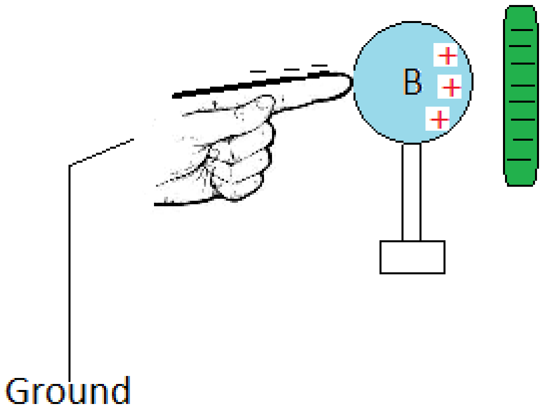

Figure 3: Using finger as ground in induction

Q7: How can insulators be discharged?

Ans: Since insulators resist charge flow, they can be discharged by:

- **Heating over flame:** Heat excites electrons and makes air conductive.
- **Exposure to humidity:** Water molecules help neutralize surface charges.

Q8: What is electrostatic induction?

Ans: It is the process in which the presence of a nearby charged object causes redistribution of charges in a neutral object, without direct contact.

Q9: What is polarization in insulators?

Ans: Polarization is the temporary shift of charges within atoms of an insulator when placed near a charged object, causing one side to become slightly positive and the other slightly negative.

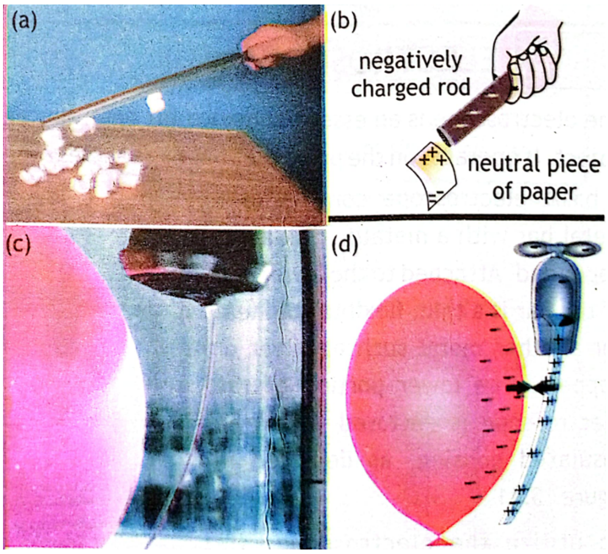

Figure 4: Surface charge induced by polarization

15.4 Electroscope

Q: What is an electroscope?

An electroscope is a device used to detect the presence and nature (positive or negative) of electric charge on an object. It works on the principle that like charges repel.

Q: Describe the construction of a gold-leaf electroscope.

A gold-leaf electroscope consists of a vertical metal rod connected to a metal disk at the top and thin gold or metal foil at the bottom. The lower part is enclosed in a glass container for insulation. The metal disk is the contact point for detecting charge.

Q: How does an electroscope detect charge?

When a charged object touches the metal disk, electrons either enter or leave the electroscope. This causes the metal leaf to repel from the rod due to similar charges. The amount of divergence indicates the presence and amount of charge.

Q: Can an electroscope identify the sign of charge?

Yes, but only if the electroscope is pre-charged. If already negatively charged, bringing a negatively charged rod closer will increase leaf divergence. A positively charged rod will attract electrons, causing the leaf to collapse.

Q: How can an electroscope be charged by induction?

Bring a negatively charged rod near the disk without touching it. Then touch the disk

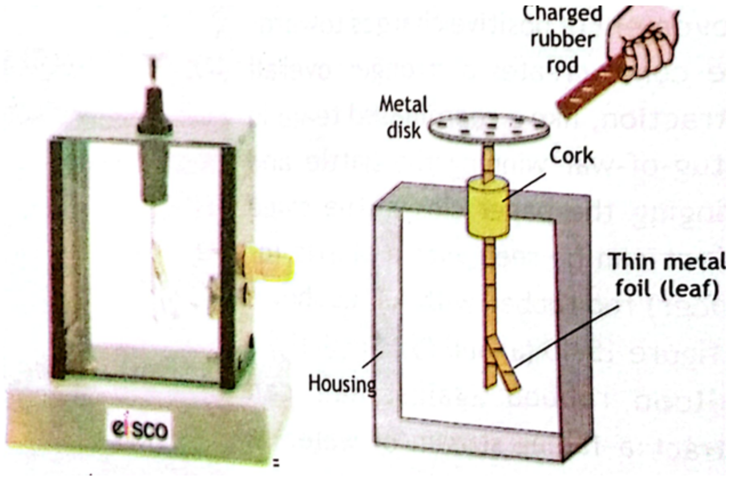

Figure 5: Figure 15.11: Gold-leaf electroscope

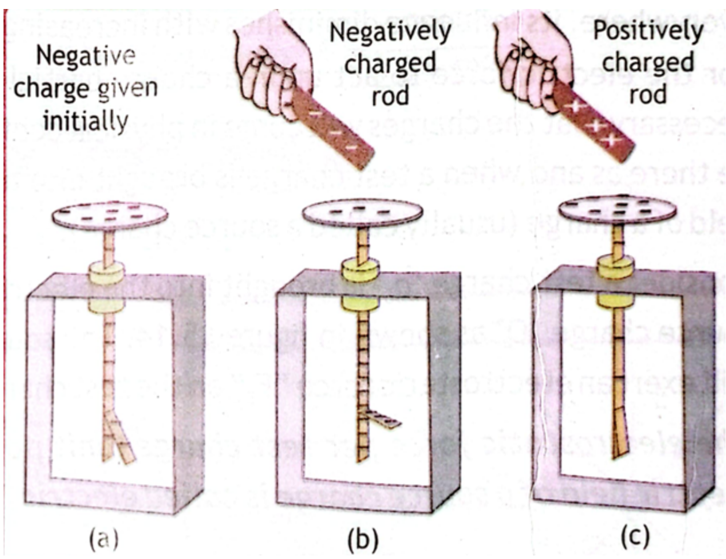

Figure 6: Figure 15.12: Determining the sign of charge using a pre-charged electroscope

with a finger. Electrons flow to the ground. Removing the finger and the rod leaves a net positive charge on the electroscope.

Q: What happens when a positively charged rod is brought near a neutral electroscope?

The positive rod attracts electrons from the electroscope, causing the leaf to rise as a net positive charge develops.

Q: What is the principle behind electroscope operation?

It is based on electrostatic repulsion: like charges repel, causing the metal leaf to move away from the metal rod when similarly charged.

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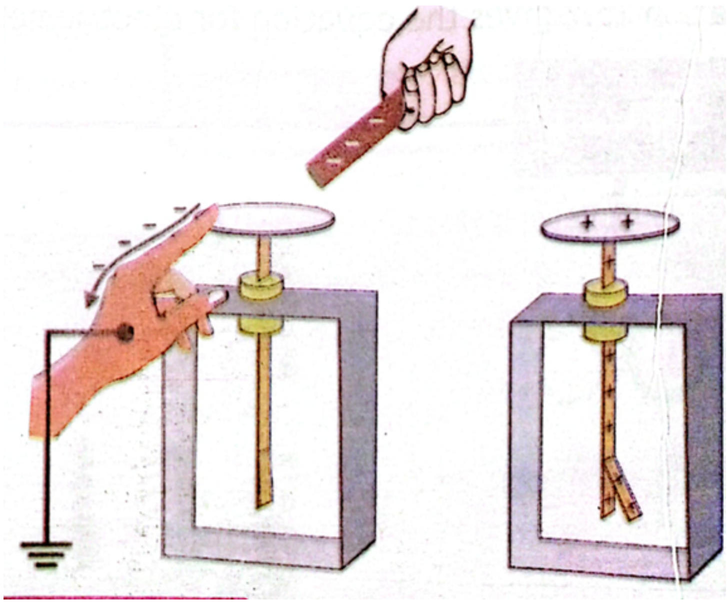

Figure 7: Figure 15.13: Induced charge on electroscope by grounding

1 Electric Field

Q1: What is an electric field?

An electric field is the region around a charge where it exerts a force on other charges. It is a field that exists in space around a charged object and affects other charged objects within the field.

Q2: How does the strength of the electric field vary with distance?

The electric field strength decreases with distance from the source charge. It follows the inverse square law, meaning that the field becomes weaker as distance increases.

Q3: Does the electric field require physical contact to exert force?

No, the electric field exerts force without requiring physical contact. A test charge placed within the field will experience a force due to the field even without touching the source charge.

Q4: How is the electric field intensity defined mathematically?

Electric field intensity E is defined as the electrostatic force F_E per unit positive test charge q_0. It is given by the formula:

$$E = \frac{F_E}{q_0}$$

Its S.I. unit is newton per coulomb (N/C).

Q5: What are electric field lines?

Electric field lines are imaginary lines used to represent the direction and strength of the electric field. These lines show the path a positive test charge would follow in the field.

Q6: Who introduced the concept of electric field lines?

The concept of electric field lines was first introduced by Michael Faraday.

Q7: What is the direction of electric field lines for positive and negative charges?

For a positive charge, the electric field lines point outward, away from the charge. For a negative charge, the field lines point inward, towards the charge.

Q8: What do electric field lines between two opposite charges look like?

Between two opposite charges, electric field lines originate from the positive charge and terminate at the negative charge, forming a dipole pattern.

Q9: How does a charged conducting sphere affect the electric field?

A charged conducting sphere produces a uniform electric field outside the surface. Inside the sphere, the electric field is zero due to the symmetric distribution of charges.

Q10: What is the nature of the electric field between two oppositely charged parallel plates?

The electric field between two oppositely charged parallel plates is uniform. The field lines move in straight paths from the positive plate to the negative plate, maintaining constant direction and magnitude in the region between them.

15.6 Applications of Electrostatics

Electrostatics plays an important role in our daily life, especially in modern technologies. Some practical applications are:

Q: What is an electrostatic precipitator and how does it help in dust extraction?

A: An electrostatic precipitator removes dust and pollution particles from smoke in chimneys. Air mixed with dust is passed through a positively charged mesh, making the dust particles positively charged. Then, these particles are attracted to a negatively charged mesh, where they settle due to electrostatic attraction. **Use:** Commonly used in coal-burning power plants to reduce air pollution.

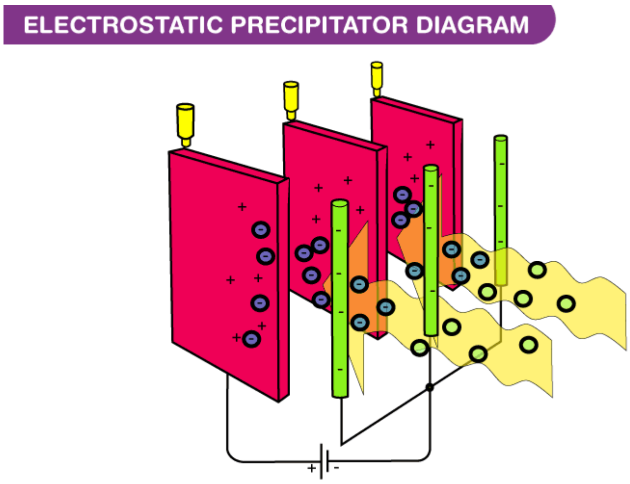

Figure 8: Electrostatic precipitator removing dust particles

Q: How does a photocopier machine work using electrostatics?

A: A photocopier uses the principle of electrostatics called xerography. The steps are:

1. A selenium-coated aluminum drum is sprayed with a positive charge by a device called a corotron.

2. Light reflects off the image onto the drum, causing only dark areas to remain charged.

3. Negatively charged toner particles stick to these charged areas.

4. Paper is pressed against the drum, pulling toner onto it.

5. Heat and pressure fuse the toner to the paper, creating a clear copy.

2 15.7 Electrical Breakdown

Q1: What is electrical breakdown?

Electrical breakdown occurs when an insulating material, such as rubber, glass, or plastic, is subjected to a strong electric field that exceeds its breakdown voltage. This causes electrons to be pulled from atoms, enabling current to flow through the material.

Q2: How do gases behave during electrical breakdown?

Gases are generally poor conductors, but a strong electric field can ionize gas atoms by removing electrons. This process creates free electrons and positively charged ions, allowing the gas to conduct electricity. The resulting chain reaction is called an **avalanche effect**, where freed electrons further ionize other atoms.

Q3: What are visible examples of electrical breakdown?

Two visible examples of electrical breakdown are:

- **Corona Discharge:** It appears as a faint glow around sharp edges of conductors at high voltages. This occurs due to ionization of air molecules near the conductor, causing localized breakdown. It is visible around power lines or during thunderstorms.
- **Lichtenberg Figures:** These are branching patterns formed on insulating surfaces (like acrylic or glass) when exposed to high-voltage discharges. They visually represent the path taken by electric current.

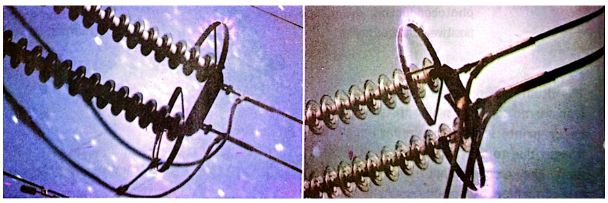

Figure 9: Corona discharge effect

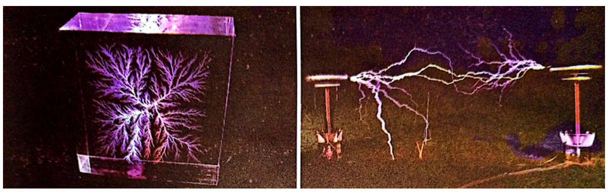

Figure 10: Lichtenberg figures caused by electrical breakdown

Q4: What is lightning and how is it generated?

Lightning is a powerful release of electrical energy due to separation of charges in clouds. Positive charges rise to the top while negative charges sink to the base, creating a potential difference. When the electric field becomes strong enough, electrons travel to the ground in a zigzag path known as a **step leader**. This induces positive charges on the Earth's surface, which rise to meet the step leader as a **streamer**, completing the circuit and resulting in a **lightning strike**.

Q5: What are different varieties of atmospheric lightning?

Various types of lightning include:

- **Sprites:** Short-lived red flashes above thunderstorms.
- **Jets:** Narrow upward bursts of blue light.
- **Elves:** Expanding rings of faint white light.
- Other whimsical names: Trolls, Pixies, Ghosts, Ball Lightning (scientifically observed).

Q6: What is uncontrolled electrical charging and how does a lightning rod help?

Uncontrolled electrical charging in nature, such as during thunderstorms, can cause lightning. A **lightning rod** (invented by Benjamin Franklin) helps protect structures by attracting lightning and safely conducting the charge to the ground through a buried wire. This prevents property damage and electrical surges.

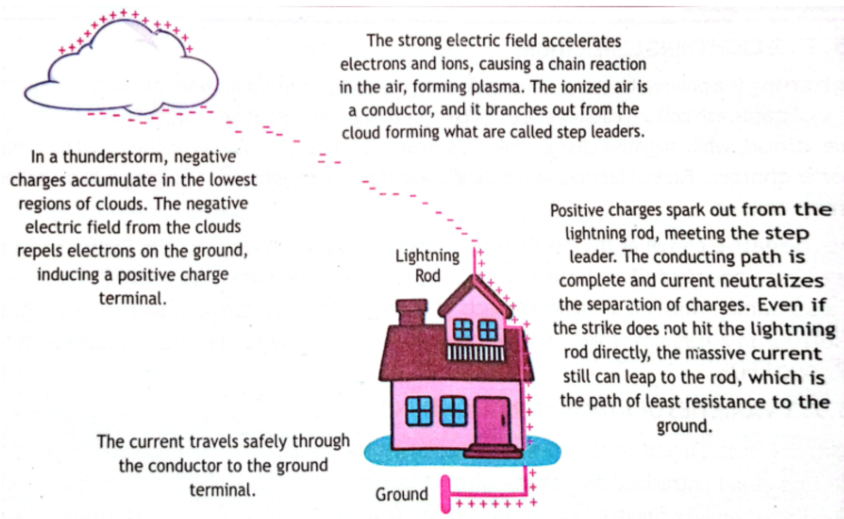

Figure 11: Lightning rod mechanism

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Exercise: Multiple Choice Questions with Explanations

1. A rubber rod is rubbed with fur. The fur is then quickly brought near the bulb of uncharged electroscope. The sign of the charge on the leaves of the electroscope is:
   Correct Option: B. negative
   Explanation: Rubbing a rubber rod with fur makes the rod negatively charged. Bringing it near the electroscope induces a negative charge on the leaves.

2. A negatively charged object is brought close to the surface of a conductor, whose opposite side is then grounded. What kind of charge is left on the conductor's surface?
   Correct Option: A. positive
   Explanation: Electrons are repelled by the nearby negative charge and leave through the ground, leaving the conductor's surface positively charged.

3. A small metal ball hangs from the ceiling by an insulating thread. The ball is attracted to a positively charged rod held near the ball. The ball must be:
   Correct Option: D. negative or neutral
   Explanation: A positive rod attracts a negative or neutral object due to electrostatic attraction or induced charges.

4. A positive ion is formed when:
   Correct Option: A. a neutral atom loses electron
   Explanation: Losing electrons leaves more protons than electrons, resulting in a net positive charge, forming a positive ion.

5. A charged rod is brought near a suspended object, which is repelled by the rod. We can conclude that the suspended object is:
   Correct Option: C. Charged with same sign
   Explanation: Repulsion can only occur when both objects have the same type of charge.

6. Two lightweight metal spheres, one negatively charged and the other neutral, are allowed to touch. What will happen?
   Correct Option: D. neutralize each other
   Explanation: Charge will redistribute when the spheres touch, leading to a balance or partial neutralization.

7. A negative point charge moves along a straight-line path directly toward a stationary positive point charge. Which aspect of the electric force remains constant?
   Correct Option: B. direction

Explanation: Direction is always towards the positive charge, but magnitude changes due to changing distance.

8. To be safe during a lightning storm, it is best to be:
   Correct Option: B. inside a metal car
   Explanation: A metal car acts as a Faraday cage, directing current safely around and away from the passengers.

9. What causes the leaves of an electroscope to move apart when charged?
   Correct Option: B. Repulsion of like charges
   Explanation: Both leaves acquire the same type of charge and repel each other due to electrostatic repulsion.

10. Corona discharge is most likely to occur at which of the following locations on a conductor?
    Correct Option: B. Sharp points
    Explanation: Electric field is strongest at sharp points, leading to ionization of surrounding air and corona discharge.

11. What do Lichtenberg figures typically look like?
    Correct Option: C. Branching tree-like patterns
    Explanation: Lichtenberg figures form tree-like discharge paths left by high-voltage breakdown in insulating materials.

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Short Response Questions with Answers

1. **What is the relationship between charge and mass when a metal becomes charged, and assess whether the mass change is significant?**
   When a metal is charged, electrons are added or removed. This causes a change in charge, but the change in mass is extremely small and practically negligible.

2. **How do grounding systems prevent static buildup in fuel trucks, what are the dangers without grounding?**
   Grounding systems safely discharge excess static electricity into the Earth. Without grounding, static buildup can cause sparks, leading to fire or explosions.

3. **Why do electrons transfer charge instead of protons or neutrons, and how does this affect circuit and device design?**
   Electrons are mobile and lighter than protons or neutrons, so they move easily. This property is used in circuits to transfer current and charge.

4. **Why does a charged balloon stick to a neutral wall due to polarization? Compare the interaction with a conductor vs. an insulator.**
   A charged balloon shifts electrons in the wall, creating attraction due to opposite charges. Conductors allow stronger polarization than insulators.

5. **How do positive and negative charges behave differently in an electric field?**
   Positive charges move in the direction of the electric field, while negative charges move opposite to it.

6. **What are the effects of changing electric field direction or strength in applications like capacitors?**
   Changing field strength affects the energy stored; reversing direction changes the force direction on charges in a capacitor.

7. **Compare electric and gravitational fields in terms of strength, range, and forces, and evaluate situations where both fields affect objects.**
   Electric fields are stronger and act on charge, while gravity is weaker and acts on mass. Electric fields dominate in atomic and circuit-level systems.

8. **Can insulators be charged by induction, under what conditions does this happen, and what are alternative methods for charging insulators?**
   Yes, insulators can be charged if nearby objects induce polarization. Rubbing (friction) is another common method.

9. **What is corona discharge around conductors, especially sharp points?**
   Corona discharge is a faint glow caused by ionization of air near sharp points where electric field strength is high.

10. **How does electric field concentration cause ionization, and what are its practical uses or problems?**
    Concentrated fields can strip electrons, causing air ionization. It's used in air purifiers but can also damage electronics.

11. **What causes Lichtenberg figures to form after lightning strikes, why don't they always appear?**
    Lichtenberg figures form as tree-like patterns when high voltage discharges through insulators. They may not appear if voltage is insufficient or conditions vary.

12. **How do lightning rods protect buildings, what is the role of pointed rods in attracting discharge?**
    Lightning rods attract strikes and direct the current safely to the ground. Pointed rods enhance electric field to start discharge early.

13. **How can lightning rod design and placement be optimized for better protection?**
    The rod should be the highest point on a building and grounded properly. Wider coverage is achieved by using multiple rods at elevated points.

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Numerical Response Questions

Q1: A positive test charge of 30 μC is placed in an electric field. The force on it is 0.600 N. What is the magnitude of the electric field at the location of the test charge?

Given:

- $q = 30\ \mu C = 30 \times 10^{-6}\ C$
- $F = 0.600\ N$

To Find: E (Electric field)

Formula:

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

Solution:

$$E = \frac{0.600}{30 \times 10^{-6}} = 2.00 \times 10^4\ \text{N/C}$$

Result: $\boxed{E = 2.00 \times 10^4\ \text{N/C}}$

Q2: How much force is exerted on a charge of $-1.0 \times 10^{-6}\ C$ in a field of strength 1.7×10^6 N/C? Now when the field strength is doubled, how much force is exerted on a charge of $+1.0 \times 10^{-6}\ C$?

Given:

- $q_1 = -1.0 \times 10^{-6}\ C$, $E_1 = 1.7 \times 10^6$ N/C
- $q_2 = +1.0 \times 10^{-6}\ C$, $E_2 = 2 \times 1.7 \times 10^6 = 3.4 \times 10^6$ N/C

To Find: F_1, F_2

Formula:

$$F = qE$$

Solution:

$$F_1 = (-1.0 \times 10^{-6}) \times (1.7 \times 10^6) = -1.7\ \text{N} \quad \text{[Left]}$$

$$F_2 = (+1.0 \times 10^{-6}) \times (3.4 \times 10^6) = 3.4\ \text{N} \quad \text{[Right]}$$

Result: $\boxed{F_1 = 1.7\ \text{N [Left]}, \quad F_2 = 3.4\ \text{N [Right]}}$

Q3: Find magnitude of the positive test charge that experiences a force of 0.5 N when placed in an electric field of 2.0 N/C.

Given:

- $F = 0.5$ N
- $E = 2.0$ N/C

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To Find: q
Formula:

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

Solution:

$$q = \frac{0.5}{2.0} = 0.25 \text{ C}$$

Result: $\boxed{q = 0.25 \text{ C}}$

Q4: A small charge of 3.0 μC is placed in a uniform electric field of 1.5 N/C. Calculate force on the charge.

Given:

- $q = 3.0\ \mu C = 3.0 \times 10^{-6}$ C
- $E = 1.5$ N/C

To Find: F
Formula:

$$F = qE$$

Solution:

$$F = (3.0 \times 10^{-6}) \times (1.5) = 4.5 \times 10^{-6} \text{ N}$$

Result: $\boxed{F = 4.5\ \mu N}$

Q5: Calculate the electric field strength when an electron enters it and experiences a force of 0.01 N. The charge of an electron is 1.6×10^{-19} C.

Given:

- $F = 0.01$ N
- $q = 1.6 \times 10^{-19}$ C

To Find: E
Formula:

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

Solution:

$$E = \frac{0.01}{1.6 \times 10^{-19}} = 6.25 \times 10^{16} \text{ N/C}$$

Result: $\boxed{E = 6.25 \times 10^{16} \text{ N/C}}$

Q6: What is the magnitude of force on an electron released from rest in a uniform electric field of magnitude 20 N/C?

Given:

- $E = 20$ N/C
- $q = 1.6 \times 10^{-19}$ C

To Find: F
Formula:

$$F = qE$$

Solution:

$$F = (1.6 \times 10^{-19}) \times 20 = 3.2 \times 10^{-18}\ \text{N}$$

Result: $\boxed{F = 3.2 \times 10^{-18}\ \text{N}}$

Important Formulae of Chapter 15: Electrostatics

S.No.	Formula and Description
1	$F = k\frac{q_1 q_2}{r^2}$ (Coulomb's Law: Force between two point charges)
2	$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\ \text{Nm}^2/\text{C}^2$ (Coulomb's constant)
3	$E = \frac{F}{q}$ (Electric field as force per unit charge)
4	$E = k\frac{Q}{r^2}$ (Electric field due to a point charge)
5	$q = ne$ (Quantization of charge, where $n \in \mathbb{Z}$, $e = 1.6 \times 10^{-19}$ C)
6	$F = qE$ (Force on a charge in an electric field)
7	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{Nm}^2$ (Permittivity of free space)
8	$E = \frac{V}{d}$ (Electric field between parallel plates at potential difference V)
9	$p = q \times d$ (Electric dipole moment: product of charge and separation distance)
10	$W = qV$ (Work done or energy in moving charge q through potential V)

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Assessment Questions for Practice

Part A: Conceptual Questions (Short Answers)

1. Define electric field intensity. How is it related to force and charge?
2. What are electric field lines? State their properties.
3. Explain the difference between conductors and insulators using examples.
4. What is meant by polarization? How does a charged balloon stick to a wall?
5. Describe the working principle of an electrostatic precipitator.
6. What is corona discharge? When and where does it occur?
7. How do Lichtenberg figures form? Why are they tree-like?
8. What causes lightning during a thunderstorm? Explain the step leader mechanism.
9. What is the purpose of a lightning rod? How does it ensure safety?
10. How does the strength of electric field vary with distance from a point charge?

Part B: Numerical/Problem-Solving Questions

1. A test charge of 30 μC experiences a force of 0.600 N. Find the electric field strength.
2. Calculate the force on a charge of -1.0×10^{-6} C placed in an electric field of 1.7×10^{6} N/C.
3. A charge experiences a force of 0.5 N in an electric field of 2.0 N/C. Find the charge.
4. A 3.0 μC charge is placed in an electric field of 1.5 N/C. Find the force on it.
5. Find the electric field strength if an electron experiences a force of 0.01 N. (Charge of electron = 1.6×10^{-19} C)
6. Calculate the force on an electron in an electric field of 20 N/C.
7. A charge of 2 μC is placed at a distance of 0.1 m from a 6 μC charge. Find the force between them.
8. What is the direction and magnitude of the force on a positive charge placed between two oppositely charged plates?

9. If a force of 0.2 N acts on a charge of 4 μC, find the electric field intensity.

10. Two equal charges 3×10^{-6} C are placed 0.5 m apart. Find the force between them.

These 20 questions by Physicist Hammad Shaukat include 10 short conceptual and 10 problem-based assessments to help students prepare comprehensively for exams.

Final Thoughts

> "Electricity is not just about charges and fields — it's about the invisible forces that power our world. Keep questioning, keep exploring, and let your curiosity spark the light of discovery."

— Physicist Hammad Shaukat