Chapter 10:Electrostatics

Q.1: Why does an air passenger sometimes get an electric shock when touching the toilet door knob during flight?

Answer: Due to the accumulation of static electricity at high altitudes, there can be a potential difference between the passenger and the metal knob of the toilet door, leading to the flow of current and an electrical shock.

Explanation:
1. At high altitudes, airplanes can accumulate a significant amount of static electricity due to friction between the aircraft and air molecules. The charges may accumulate on a passenger's body due to dry air or walking on carpet.
2. When the passenger touches the metal knob of the toilet door, which is a conductor, a potential difference is created.
3. This potential difference causes current to flow through the passenger's body, resulting in an electrical shock.

Q.2: How will the radius of a flexible ring change if it is given a positive charge?

Answer: Radius of Ring Increases
Reason: Electrostatic force of repulsion.

Explanation:
The charges spread out to minimize electrostatic potential energy. This causes repulsion between like charges, leading to deformation of the ring and an increase in radius.
Uncharged Ring
+ Positively Charged Ring

Q.3: Write some applications of electrostatics in real life.

Answer:1. Inkjet Printers:
Inkjet printers use electrostatics to direct tiny ink droplets with an electrostatic charge onto specific spots on a page.

2. Xerography:
Most photocopiers use the electrostatic process called xerography (Greek: xeros = dry, graphos = writing).

3. Faraday's Cage:
Used for electrostatic shielding, blocking external electric fields from affecting internal contents.

4. Van de Graaff Generator
5. Electrostatic Painting
6. Smoke Precipitators and Electrostatic Air Cleaning

Q.4: What are the limitations of Coulomb's Law?

Answer:

1. Only applicable to point charges that are static (not moving).
2. Valid where inverse square law is obeyed.
3. Not suitable for arbitrarily shaped charges, where distance can't be defined.
4. Can't be directly used to calculate charge on large planetary bodies.
5. Not applicable at sub-nuclear distances where nuclear force dominates over electrostatic force.

Q.5: If two points are at the same potential, are there any electric field lines connecting them?

Answer:

No, there are no electric field lines connecting two points of the same electric potential.

Reason:

If $\Delta V = 0$, then $E = 0$.

Explanation:

Electric field only exists where there is a potential difference. If two points have the same potential, no electric field exists between them, so no field lines are present.

Q.6: What is the difference between electric field and electric field strength?

Answer:

Electric Field:

- The region around a charge where it exerts an electric force on other charges.
- It is a vector quantity (has magnitude and direction).

Electric Field Strength (Intensity):

- The electric force per unit positive test charge at a point in the electric field.
- It indicates the magnitude of the electric field.

SI unit: N/C or V/m.

Formula: $E = F/q$

Q.7: What are ferrofluids?

Answer:

Definition:

A ferrofluid is a liquid that becomes highly magnetized in the presence of a magnetic field.

Composition:

- Colloidal suspensions of magnetic nanoparticles in a carrier liquid.
- Made of nano-sized particles (~10 nm) such as iron oxide, magnetite, or hematite.

- Mixed with liquids like kerosene or oil.

Additional Questions

Q.1: Do electrons tend to go to the region of high potential or low potential?
Answer: Electrons tend to go to the region of high potential because they are negatively charged and are attracted to the positive (high potential) region.

Q.2: A negatively charged balloon clings to the wall but eventually falls down. Why?
Answer: Due to electrostatic induction, the balloon induces a positive charge on the wall, causing attraction. Over time, the charge leaks, and the balloon falls.

Q.3: How can you identify which plate of a capacitor is positively charged?
Answer: Use a gold leaf electroscope. Bring a plate near a positively charged electroscope:
If the divergence increases, the plate is positive.
If it decreases, the plate is negative.

Q.4: Why do electric lines of force never cross each other?
Answer: Because electric field has only one direction at a point. Crossing lines would mean two directions at the same point, which is impossible.

Q.5: Do electric field and potential increase or decrease as we move along the field line of a positive point charge?
Answer: Both electric field and potential decrease as we move away from the positive charge.

Q.6: Why can electrostatic experiments not be conducted on humid days?
Answer: Humid air conducts electricity slightly, causing charge to leak away. This makes electrostatic effects weak or disappear.

Q.7: Why is repulsion the sure test of electrification?
Answer: Because attraction can occur even with uncharged objects, but repulsion only happens between like charges, confirming electrification.

Q.8: Why is electric current taken as the fundamental quantity and not charge?
Answer: Current is easier to measure directly and is more useful in practical applications, so it is taken as a fundamental quantity.

Q.9: What do you mean by quantization of charge?

Answer: Charge exists in fixed amounts and is always an integral multiple of elementary charge ($e = 1.6 \times 10^{-19}$ C).
$q = \pm ne$, where n is an integer.

Q.10: What is the nature of force if both charges are positive?
Answer: The force is repulsive because like charges repel each other.

Q.11: What is the nature of force if one charge is positive and the other is negative?
Answer: The force is attractive because unlike charges attract each other.

Q.12: Two charges (+2 μC and +6 μC) repel with 12 N. After adding -4 μC to both, what is the new force?
Answer: New charges: -2 μC and +2 μC.
New force = 4 N (attractive)

Q.13: What happens when an electron enters along the electric line of force?
Answer: It slows down, stops, and then reverses direction with the same speed.

Q.14: At what distance should charges be kept so that the force becomes 1/9th of the original force at distance d?
Answer: Since force is inversely proportional to square of distance,
New distance = 3d

Q.15: Find the distance between two protons such that their electrostatic repulsion equals their weight.
Answer: Use the formula:
$k \times e^2 / r^2 = m \times g$
Solving gives: $r \approx 0.118$ m

Q.16: Find the ratio of electrostatic to gravitational force between a proton and an electron in a hydrogen atom.
Answer:
Electrostatic force = $k \times e^2 / r^2$
Gravitational force = $G \times m_1 \times m_2 / r^2$
Ratio = $(k \times e^2) / (G \times m_1 \times m_2)$
Final result: 2.25×10^{39}

Chapter 11:Electricity

Q.1: What is meant by drift velocity?

Answer:

Definition: Drift velocity is the average velocity acquired by charge carriers (such as electrons) in a conductor under the influence of an external electric field.
Electrons drift in the opposite direction to the electric field.

Formula:
Drift velocity = I / (n e A)
Where:
I = current
n = number of charge carriers per unit volume
e = charge of an electron
A = cross-sectional area

Depending Factors:

- Directly proportional to current, potential difference, and electric field.
- Inversely proportional to resistance.

Q.2: Why do we use Kirchhoff's laws to solve circuit problems?

Answer:
Kirchhoff's laws are used to analyze complex circuits that contain multiple resistors and more than one source of emf.
They help determine unknown values of currents and voltages where Ohm's law alone is insufficient.
These laws simplify the solution of circuits with multiple loops or junctions.

Q.3: Define Kirchhoff's Current Rule (KCL) and Kirchhoff's Voltage Rule (KVL).

Answer:

Kirchhoff's Current Rule (KCL):
The total current entering a junction (node) equals the total current leaving the junction.
Mathematically: $I_1 + I_2 + I_3 + ... + I_n = 0$
(Represents conservation of charge)

Kirchhoff's Voltage Rule (KVL):
The algebraic sum of all potential differences in a closed loop is zero.
Mathematically: $\sum V = 0$
(Represents conservation of energy)

Q.4: What is the working principle of a galvanometer?

Answer:
Concept: Based on torque on a current-carrying coil in a magnetic field.

When electric current passes through the coil, it experiences a torque which causes it to rotate or deflect.
This deflection indicates the presence and direction of current.

Working Principle:
Galvanometers convert electrical energy into mechanical energy (deflection).
They are used to detect and measure small currents in circuits.

Additional Questions

Q.1Explain why the terminal potential difference of a battery decreases when the current drawn from it increases?

Answer:
When current is drawn from a battery, there is an inherent internal resistance within the battery itself. As the current increases, the potential drop across this internal resistance also increases. The energy dissipated as heat within the battery rises as a result. The terminal potential difference of the battery is the difference between the battery's electromotive force (EMF) and the internal resistance. The EMF of the battery remains constant, but as the current increases, the voltage drop across the internal resistance increases, which leads to a reduction in the terminal potential difference. Hence, the more current is drawn from the battery, the smaller the terminal potential difference becomes.

Q.2Why are birds not electrocuted even when sitting on high tension wires, even when insulation has worn off?

Answer:
For electrocution to happen, the current must flow through the body, and this only occurs when there is a potential difference between different parts of the body. When a bird sits on a high tension wire, both of its feet are on the same wire, and therefore, they are at the same electrical potential. Since there is no potential difference between the feet, no current can flow through the bird's body. Even if the insulation has worn off the wire, the bird will not be electrocuted because there is no path for current to flow through its body. The bird would only be electrocuted if it touched another object or wire with a different potential, allowing current to flow through its body.

Q.3Why does the thin region of a light bulb filament have a higher possibility of burning compared to the thicker region?

Answer:
In a light bulb filament, the thin sections have a higher resistance compared to the thicker sections. This is because resistance is inversely proportional to the cross-sectional area of the conductor. The thinner part of the filament has a smaller area, which increases its resistance. According to the relationship between power dissipation and resistance, the heat generated ($P = I^2R$) is directly proportional to the resistance. Therefore, the thinner part of the filament, where the resistance is higher, generates more heat for the same current. This heat buildup causes the temperature of the thin region to rise more than in the thicker regions. As a result, the thin region is more likely to burn out because it is subjected to higher temperatures and stress.

Q.4A wire of resistance R is stretched until its length is increased n times its original length. What is its resistance now?

Answer:

When a wire is stretched, its length increases, and its cross-sectional area decreases, assuming the volume of the wire remains constant. The resistance of a wire is directly proportional to its length and inversely proportional to its cross-sectional area. When the length increases by a factor of n, the resistance will increase by a factor of n^2 because the area decreases by a factor of n (since the volume remains constant). Thus, if the original resistance was R, the new resistance after stretching will be $R * n^2$. This is because the increase in length causes an increase in resistance, and the decrease in area also contributes to this effect.

Q.5Why does a rise in temperature in a conductor lead to an increase in its resistance?

Answer:When the temperature of a conductor increases, the atoms in the material vibrate more due to the additional thermal energy. These increased vibrations cause more frequent collisions between the free electrons (which carry the electric current) and the atoms in the conductor's lattice. As a result of these collisions, the electrons face more resistance while moving through the conductor. This higher resistance occurs because the vibrating atoms obstruct the flow of electrons, making it harder for the current to pass through. Additionally, the kinetic energy of the free electrons increases with temperature, further contributing to the increase in resistance. Therefore, as the temperature rises, the resistance of the conductor also increases.

Q.6 What happens when current flows through a conductor? Is it charged?

Answer:

When current flows through a conductor, it is essentially the movement of free electrons within the material. The conductor itself does not become charged because the number of electrons leaving one side of the wire is equal to the number of electrons entering from the other side. Thus, there is no net accumulation of charge on the conductor. The electric current results from the movement of these free electrons, but the conductor as a whole remains electrically neutral. The charge on any conductor remains zero as long as the number of electrons entering and leaving the conductor is the same.

Q.7 Why does a thin region of the light bulb filament have a greater likelihood of burning out compared to a thicker region?

Answer:

The filament of a light bulb is typically made from tungsten, and it produces light by resisting the flow of current, generating heat in the process. The resistance of a wire is inversely proportional to its cross-sectional area, so thinner parts of the filament will have a higher resistance than thicker parts. As current flows through the filament, the heat generated is proportional to the resistance ($P = I^2R$). In the thin sections, where the resistance is higher, more heat is produced. This leads to a rise in temperature, and the filament becomes more likely to burn out in the thinner regions because they experience higher temperatures than the thicker sections.

Q.8What is the effect of increasing current on the brightness of light bulbs in a series circuit?

Answer:

In a series circuit, the same current flows through all the components. When the current increases, the brightness of light bulbs also increases because the power dissipated by each bulb is proportional to the square of the current ($P = I^2R$). As the current increases, more power is dissipated by the bulbs, causing them to become brighter. However, if too much current is applied, the bulbs can burn out due to excessive heat generation. So, in a series circuit, increasing the current directly increases the brightness of the bulbs, but this must be done within the limits of the bulbs' rated current capacity.

Q.9What is the difference between a short circuit and an open circuit?

Answer:

A short circuit occurs when the resistance in the circuit is very low or almost zero, leading to a very large current flow. This often happens when the terminals of a battery or power supply are directly connected by a conductor with very little resistance. In such cases, the current can increase to dangerous levels, potentially causing overheating, fire, or damage to the circuit components.

An open circuit, on the other hand, occurs when there is a break in the circuit, such as when a switch is turned off or a wire is disconnected. This results in no current flowing through the circuit. An open circuit essentially means that the circuit is incomplete, and electricity cannot flow through it.

Q.10Why is it dangerous to touch a live wire while standing on the ground barefoot?

Answer:

The earth is considered to be at zero potential. A person standing barefoot on the ground is also at zero potential. If they touch a live wire, which is at a high potential, a potential difference is created across the body. This causes current to flow through the person’s body, which can lead to electrocution. The danger comes from the fact that the body becomes a path for the current, and the current flowing through it can cause serious injury or death. Therefore, it is extremely dangerous to touch a live wire while standing on the ground barefoot, as the body provides a path for the current to flow.

Chapter 12:Electromagnetism

Q.1: What are the various ways to create a magnetic field?

Ans:

Various ways to create a magnetic field include:

1. Bar Magnets: A natural magnet like iron oxide (Fe_3O_4), also known as Magnetite or Lodestone, produces a consistent magnetic field.

2. Current-Carrying Conductors: A straight wire carrying an electric current generates a magnetic field around it.

3. Moving Electric Charges: Any moving charge, such as electrons in a conductor, generates a magnetic field.

4. Changing Electric Fields: According to Maxwell's equations, a time-varying electric field can induce a magnetic field.

5. Solenoids: A coil of wire (solenoid) generates a uniform magnetic field inside when an electric current passes through it.

6. Electromagnets: Coiling a wire around a core (usually iron) and passing an electric current through it generates a magnetic field.

Q.2: In what way is a magnetic field different from an electric field?

Ans:

1. Magnetic Field: The space around a magnet or moving/current-carrying conductor in which it exerts a magnetic force on other magnets and charges.

2. Electric Field: The space around a charge in which it exerts an electric force on other charges.

3. Direction: Magnetic field lines move from the North pole to the South pole outside a magnet and from the South pole to the North pole inside. Electric field lines point from positive to negative charge.

Q.3: Why does a current-carrying conductor experience force in a magnetic field?

Ans:

A current-carrying conductor experiences a force in a magnetic field due to the interaction of the magnetic fields of the conductor and the external magnetic field. The force acts perpendicular to both the current direction and the magnetic field, resulting in movement of the conductor.

Q.4: If a charged particle moves in a straight line through a region of space in which the magnetic field is non-zero, why does it move undeflected?

Ans:

If a charged particle moves parallel or antiparallel to the magnetic field (with an angle of 0° or 180°), the magnetic force is zero. The force on the particle is only non-zero when the angle between its velocity and the magnetic field is not 0° or 180°.

Q.5: When is the magnetic force on a moving charge in a magnetic field maximum, and when is it minimum?
Ans:
1. Maximum Force: When the charge moves perpendicular to the magnetic field (angle = 90°), the magnetic force is maximum:

2. Minimum Force: When the charge moves parallel or antiparallel to the magnetic field (angle = 0° or 180°), the magnetic force is zero:

Q.6: In a region with a homogeneous magnetic field directed normal to the plane into the paper, an alpha particle and a proton are travelling in its plane. What will the ratio of the radii of the two particles' field trajectories be if they have equal linear momenta?
Ans:
The radius of the trajectory of a charged particle in a magnetic field is given by:
Since both particles have equal linear momenta:
For an alpha particle, , so:
Thus, the radius of the alpha particle's trajectory is twice that of the proton.

Q.7: The kinetic energy of a charged particle moving in a uniform magnetic field does not change. Why?
Ans:
The kinetic energy of a charged particle in a magnetic field remains constant because the magnetic force does no work on the particle. The force changes only the direction of the velocity, not its magnitude. Since kinetic energy depends on speed, and the speed remains constant, the kinetic energy does not change.

Q.8: Describe the changes in the magnetic field inside a solenoid carrying a constant current I under the conditions of: (a) doubling the length of the solenoid while maintaining the same number of turns, and (b) doubling the number of turns while maintaining the same length.
Ans:
1. (a) Doubling the Length of the Solenoid: The magnetic field due to a solenoid is given by:
If the length is doubled, the magnetic field will be halved.

2. (b) Doubling the Number of Turns: If the number of turns is doubled while the length remains the same, the magnetic field will also double.

Q.9: Explain how one ampere is defined using the concept of magnetic force between two long parallel current-carrying wires.
Ans:

One ampere is defined as the current that, when flowing through two parallel wires 1 meter apart, produces a magnetic force of between the wires.

Q.10: A circular loop of radius carrying current is in the XY-plane with its center at the origin. What is the magnetic flux through the XY-plane?

Ans:

The magnetic flux through the XY-plane is zero because the magnetic field lines produced by the current-carrying loop are confined to the loop itself. As the magnetic flux entering the loop equals the flux leaving, the net magnetic flux through the loop is zero.

Q.11: In a horizontal plane, a suspended magnet is vibrating freely. When a metal plate is positioned beneath the magnet, the oscillations are significantly dampened. Describe the cause of this by Lenz's law.

Ans:

According to Lenz's Law, the eddy currents induced in the metal plate oppose the motion of the vibrating magnet. This causes the magnet's kinetic energy to decrease, resulting in dampened oscillations.

Q.12: A thin metallic ring is dropped into a vertical bar magnet. Does current in the ring flow clockwise or counterclockwise when seen from above?

Ans:

The induced current in the ring flows clockwise when seen from above. This is because the magnetic flux through the ring changes as it moves, and according to Lenz's Law, the current is induced to oppose the change in flux, resulting in a clockwise current.

Q.13: Prove that the units of electromotive force (emf) and magnetic flux have the same units.

Ans:

The unit of emf is volt (V).

The unit of magnetic flux is Weber (Wb), and .

Thus, emf (volt) and magnetic flux (Weber) both have the same units.

Additional Questions

Q1. A charged particle is moved in a circle under the influence of a uniform magnetic field. If an electric field is turned on that points along the same direction as that of the magnetic field, what path will the charged particle take?

Answer:

Path Taken: The particle moves in a spiral (helical) path.

Reason: The magnetic field forces the particle into circular motion, while the electric field causes it to accelerate along the field direction. Together, these effects form a helix.

Q2. In a lightning strike, there is a rapid movement of negative charges from a cloud to the earth. In what direction is a lightning strike deflected by Earth's magnetic field?

Answer:

Current Direction: The downward flow of electrons is equivalent to an upward current.

Deflection: According to the right-hand rule, with Earth's magnetic field pointing north, the strike is deflected towards the west.

Q3. A beam of alpha particles and protons, having the same velocity, enters a uniform magnetic field at right angle to field lines. They describe circular paths. What is the ratio of radii of their paths?

Answer:

Formula Used: Radius R = mv / qB

For alpha particle: Mass = $4m_p$, Charge = 2e

For proton: Mass = m_p, Charge = e

Ratio of Radii:

R(alpha) / R(proton) = $(4m_p / 2e) / (m_p / e) = 2$

Conclusion: The radius of the alpha particle's path is twice that of the proton.

Q4. Suppose that a charge q is moving in a uniform magnetic field with a velocity. Why is there no work done by the magnetic force acting on the charge q?

Answer:

Direction of Magnetic Force: Magnetic force is always perpendicular to the direction of motion (velocity vector).

Work Done:

Work = F × d × cos(θ), and here θ = 90°

cos(90°) = 0 → Work = 0

Conclusion: No work is done by the magnetic force on the moving charge.

Q5. Why does the picture on a TV screen become distorted when a magnet is brought near the screen?

Answer:

Cause of Picture Formation: The TV screen image is formed by an electron beam hitting specific points.

Effect of Magnet: When a magnet is brought near, it exerts a magnetic force on the moving electrons (F = qv × B).

Result: This deflects the electron beam from its correct path, causing distortion in the picture.

Q6. How can you use a magnetic field to separate isotopes of a chemical element?
Answer:
Working Principle: Ions of different masses but same charge are passed through a uniform magnetic field.
Effect: Magnetic force makes them follow circular paths of different radii.
Key Point:
Radius $r = mv / qB \rightarrow r \propto \sqrt{mass}$ (if q and v are constant)
Result: Heavier isotopes have larger radii, lighter ones have smaller radii, allowing separation.

Q7. A neutron, a proton, an electron, and an alpha particle enter a region of uniform magnetic field with equal velocities. The magnetic field is perpendicular to the plane of paper acting downward. Identify which particle corresponds to which track.
Answer:
Neutron (Track C): No charge → No magnetic force → Moves straight.
Electron (Track D): Negatively charged → Deflects to the right.
Proton (Track A): Positively charged → Deflects to the left, smaller radius.
Alpha Particle (Track B): Positively charged but heavier → Deflects to the left, larger radius.
Conclusion:
Track A → Proton
Track B → Alpha particle
Track C → Neutron
Track D → Electron

Q8. What happens when current is passed through an unstretched spring?
Answer:
Effect of Current: Turns of the spring act like parallel wires carrying current in the same direction.
Result: Due to magnetic attraction between turns, the spring contracts.
Conclusion: Magnetic forces cause the spring to become shorter.