Class 12 - Physics

Physics Part - I

ELECTROSTATIC POTENTIAL AND CAPACITANCE

CBSE NOTES

ELECTROSTATIC POTENTIAL AND CAPACITANCE - Mastery Worksheet

Strengthen your foundation with key concepts and basic applications.

Mastery Questions

Solve the following questions. Write your answers in the space provided.

1. Define electrostatic potential and derive the expression for the potential due to a point charge. Discuss the significance of potential at infinity.

Hint: Start by recalling the formula for work done and the concept of potential energy.

Mastery Questions

Solve the following questions. Write your answers in the space provided.

2. Two point charges +Q and -Q are placed at a distance d apart. Calculate the electrostatic potential energy of the system and discuss when this energy is zero.

Hint: Consider the nature of potential energy with respect to attractive and repulsive forces.

Solve the following questions. Write your answers in the space provided.

3. Explain the concept of electric field lines and their relationship with electric potential. How can you determine the nature of the charge distribution from these lines?

Hint: Sketch electric field lines for both positive and negative charges.

4. For a parallel plate capacitor, derive the expression for capacitance and discuss the effect of introducing a dielectric material.

Hint: Use Gauss's law to derive the electric field and relate it to voltage and charge.

Mastery Questions

Solve the following questions. Write your answers in the space provided.

5. A test charge is moved in the vicinity of a fixed charge distribution. Explain the relationship between work done, electric potential, and the path taken.

Hint: Consider various paths, both straight and curved, to illustrate your point.

Solve the following questions. Write your answers in the space provided.

6. Discuss how potential energy changes when a positive charge is moved towards another positive charge. Use graphs to support your explanation.

Hint: Plot U vs. r and analyze the slope.

Solve the following questions. Write your answers in the space provided.

7. Compute the energy stored in a capacitor of capacitance C charged to a potential V. Illustrate how energy storage can be calculated and interpreted in practical applications.

Hint: Relate this to real-world devices, such as camera flash circuits.

Mastery Questions

Solve the following questions. Write your answers in the space provided.

8. Consider a configuration of four charges arranged at the corners of a square. Calculate the net potential at the center and explain how symmetry affects your result.

Hint: Analyze potentials from each charge separately before summing them up.

Mastery Questions

Solve the following questions. Write your answers in the space provided.

9. Derive the equation for potential of a uniformly charged sphere at points inside and outside the sphere. Discuss the implications of the results.

Hint: Use Gauss's Law to derive the potential expressions.

10. Explain the concept of equipotential surfaces and their properties. How does this relate to electric field lines?

Hint: Visualize equipotential surfaces for point charges.

Answers

Check your answers with the solutions below.

1. Define electrostatic potential and derive the expression for the potential due to a point charge. Discuss the significance of potential at infinity.

Solution: Electrostatic potential (V) at a point in an electric field due to a point charge Q is defined as the work done in bringing a unit positive charge from infinity to that point. The potential V is given by V = k * (Q / r), where k is Coulomb's constant, Q is the point charge, and r is the distance from the charge. At infinity, V is defined as zero, which serves as a reference point.

2. Two point charges +Q and -Q are placed at a distance d apart. Calculate the electrostatic potential energy of the system and discuss when this energy is zero.

Solution: Electrostatic potential energy (U) of a system of two charges is given by U = k * (Q1 * Q2) / r. For +Q and -Q, U = -k * (Q^2 / d). This energy is zero when the charges are infinitely far apart.

3. Explain the concept of electric field lines and their relationship with electric potential. How can you determine the nature of the charge distribution from these lines?

Solution: Electric field lines represent the direction of the electric field, with potential decreasing in the direction of field lines. The density of lines indicates the strength of the field. Closer lines signify a stronger field, while diverging lines indicate lower potential. The nature of charges can be inferred: lines emanating from a point signify positive charges, while those converging towards a point indicate negative charges.

4. For a parallel plate capacitor, derive the expression for capacitance and discuss the effect of introducing a dielectric material.

Solution: The capacitance (C) of a parallel plate capacitor is given by $C = \varepsilon_0(A/d)$, where ε_0 is the permittivity of free space, A is the area of one plate, and d is the separation between the plates. Introducing a dielectric increases capacitance by a factor equal to the dielectric constant (κ), hence $C' = \kappa C$.

Answers

Check your answers with the solutions below.

5. A test charge is moved in the vicinity of a fixed charge distribution. Explain the relationship between work done, electric potential, and the path taken.

Solution: The work done (W) to move a charge in an electric field is path-independent for conservative forces. The electric potential difference (ΔV) between two points is thus solely dependent on initial and final positions and not on the path taken. This illustrates the conservative nature of electrostatic forces.

6. Discuss how potential energy changes when a positive charge is moved towards another positive charge. Use graphs to support your explanation.

Solution: As a positive charge moves closer to another positive charge, the potential energy of the system increases due to repulsion. The graph of potential energy (U) versus distance (r) shows a positive slope as r decreases, reflecting increasing potential energy and explaining why work must be done against electric force.

7. Compute the energy stored in a capacitor of capacitance C charged to a potential V. Illustrate how energy storage can be calculated and interpreted in practical applications.

Solution: The energy (U) stored in a capacitor is given by $U = (1/2)CV^2$. This equation signifies that the energy is proportional to both capacitance and the square of the voltage. Practical applications include smoothing out voltage fluctuations in power supplies.

8. Consider a configuration of four charges arranged at the corners of a square. Calculate the net potential at the center and explain how symmetry affects your result.

Solution: By symmetry, contributions from opposite charges cancel out. For charges +Q at two corners and -Q at the other two, the net potential at the center remains zero; thus, $V_{net} = 0$. This reflects the geometric distribution of charges.

Check your answers with the solutions below.

9. Derive the equation for potential of a uniformly charged sphere at points inside and outside the sphere. Discuss the implications of the results.

Solution: For a uniformly charged sphere of radius R and total charge Q, the potential outside ($r > R$) is $V = k(Q/r)$ and inside ($r \leq R$) is constant $V = k(Q/R)$. This illustrates that the electric field inside a conducting sphere is zero, ensuring that the field outside behaves as though all the charge were concentrated at a point at the center.

10. Explain the concept of equipotential surfaces and their properties. How does this relate to electric field lines?

Solution: Equipotential surfaces are regions where the electric potential is constant. The critical property is that no work is done by the electric field when moving a charge along these surfaces. Electric field lines are always perpendicular to equipotential surfaces, suggesting that potential changes across these surfaces.

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