At equilibrium under electrostatic conditions, any excess charge resides on the surface of a conductor.

At equilibrium under electrostatic conditions, the electric field is zero at any point within a conducting material.

The conductor shields any charge within it from electric fields created outside the conductor.
Chapter 19

Electric Potential Energy and the Electric Potential
19.1 Potential Energy

The work done by the gravitational field on the ball in going from A to B equals the difference between the gravitational potential energy at A ($\text{GPE}_A$) and the gravitational potential energy at B ($\text{GPE}_B$)

$$W_{AB} = mgh_A - mgh_B = \text{GPE}_A - \text{GPE}_B$$
19.1 Potential Energy

Analogous situation between the work done by the gravitational field on the ball and the work done by the electric field on the charge.
19.1 Potential Energy

The work done by the electric field on the charge in going from A to B equals the difference between the electric potential energy at A (EPE\textsubscript{A}) and the electric potential energy at B (EPE\textsubscript{B})

$$W_{AB} = \text{EPE}_A - \text{EPE}_B$$

Note that the electric force is a conservative force just like the gravitational force so the work done by it is independent of the path taken between A and B.
19.2 The Electric Potential Difference

\[ W_{AB} = \frac{EPE_A}{q_o} - \frac{EPE_B}{q_o} \]

The potential energy per unit charge is called the electric potential.
DEFINITION OF ELECTRIC POTENTIAL

The electric potential at a given point is the electric potential energy of a small test charge divided by the charge itself:

\[ V = \frac{\text{EPE}}{q_o} \]

( note analogy with definition of electric field, \( E = F/q_0 \) )

**SI Unit of Electric Potential:** joule/coulomb = volt (V)

Potential difference:

as with potential energy, only differences in \( V \) matter physically

\[ \Delta V = \frac{\Delta (\text{EPE})}{q_o} = -\frac{W_{AB}}{q_o} \]
Common usages of electric potential

- flashlight battery: 1.5 V
- car battery: 12 V
- electrical outlet (US): 120 V
- electrical outlet (Europe): 220 V
- small Van de Graaff generator: 100,000 V
- large Van de Graaff generator: 5,000,000 V
- medium lightning bolt: 35,000,000 V
Schematic view of a Van De Graaff generator.

1. hollow metallic sphere
2. electrode connected to the sphere
3. upper roller
4. side of the belt with positive charges (going up)
5. opposite side of the belt with negative charges (going down)
6. lower roller (metal) turned by motor
7. lower electrode (ground)
8. spherical device with negative charges
9. spark produced by the difference of potentials
Example 1 Work, Potential Energy, and Electric Potential

The work done by the electric force as the test charge \(+2.0 \times 10^{-6} \text{C}\) moves from A to B is \(+5.0 \times 10^{-5} \text{J}\).

(a) Find the difference in EPE between these points.

(b) Determine the potential difference between these points.

\[
W_{AB} = \text{EPE}_A - \text{EPE}_B
\]

\[
V_B - V_A = \frac{\text{EPE}_B}{q_o} - \frac{\text{EPE}_A}{q_o} = -\frac{W_{AB}}{q_o}
\]
19.2 The Electric Potential Difference

(a) \[ W_{AB} = EPE_A - EPE_B \]

\[ EPE_B - EPE_A = -W_{AB} = -5.0 \times 10^{-5} \text{ J} \]

(b) \[ V_B - V_A = \frac{-W_{AB}}{q_0} = \frac{-5.0 \times 10^{-5} \text{ J}}{2.0 \times 10^{-6} \text{ C}} = -25 \text{ V} \]
19.2 The Electric Potential Difference

**Conceptual Example 2 The Accelerations of Positive and Negative Charges**

A positive test charge is released from A and accelerates towards B. Upon reaching B, the test charge continues to accelerate toward C. Assuming that only motion along the line is possible, what will a negative test charge do when released from rest at B?
A positive charge accelerates from a region of higher electric potential toward a region of lower electric potential.

A negative charge accelerates from a region of lower potential toward a region of higher potential.
19.2 The Electric Potential Difference

We now include electric potential energy $E_{PE}$ as part of the total energy that an object can have:

$$E = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + mgh + \frac{1}{2}kx^2 + E_{PE}$$

Translational KE  Rotational KE  Gravitational PE  Elastic PE  Electric PE

One electron volt is the magnitude of the amount by which the potential energy of an electron changes when the electron moves through a potential difference of one volt.

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ Joule}$$

The eV is a unit of energy, but not an SI unit -- useful in describing the energies of subatomic particles, e.g. KeV -- thousand eV, MeV -- million eV, GeV -- billion eV
**Example 4 The Conservation of Energy**

A particle has a mass of $1.8 \times 10^{-5}$ kg and a charge of $+3.0 \times 10^{-5}$ C. It is released from point A and accelerates horizontally until it reaches point B. The only force acting on the particle is the electric force, and the electric potential at A is 25 V greater than at B. (a) What is the speed of the particle at point B? (b) If the same particle had a negative charge and were released from point B, what would be its speed at A?
19.2 The Electric Potential Difference

\[
\frac{1}{2} m v_B^2 + EPE_B = \frac{1}{2} m v_A^2 + EPE_A
\]

\[
\frac{1}{2} m v_B^2 = \frac{1}{2} m v_A^2 + EPE_A - EPE_B
\]

\[
\frac{1}{2} m v_B^2 = \frac{1}{2} m v_A^2 + q_o (V_A - V_B)
\]
19.2 The Electric Potential Difference

(a) \[ \frac{1}{2} m v_B^2 = q_o (V_A - V_B) \]

\[ v_B = \sqrt{\frac{2q_o (V_A - V_B)}{m}} \]

\[ = \sqrt{\frac{2(3.0 \times 10^{-5} \text{ C})(25 \text{ V})}{(1.8 \times 10^{-5} \text{ kg})}} = 9.1 \text{ m/s} \]

(b) \[ v_A = \sqrt{-2q_o (V_A - V_B)/m} \]

\[ = \sqrt{-2(-3.0 \times 10^{-5} \text{ C})(25 \text{ V})/(1.8 \times 10^{-5} \text{ kg})} = 9.1 \text{ m/s} \]