

Section Summary

19.1 Electric Potential Energy: Potential Difference

- Electric potential is potential energy per unit charge.
- The potential difference between points A and B, $V_B - V_A$, defined to be the change in potential energy of a charge q moved from A to B, is equal to the change in potential energy divided by the charge. Potential difference is commonly called voltage, represented by the symbol ΔV .

$$\Delta V = \frac{\Delta PE}{q} \text{ and } \Delta PE = q\Delta V.$$

- An electron volt is the energy given to a fundamental charge accelerated through a potential difference of 1 V. In equation form,
$$\begin{aligned} 1 \text{ eV} &= (1.60 \times 10^{-19} \text{ C})(1 \text{ V}) = \\ &= (1.60 \times 10^{-19} \text{ C})(1 \text{ J/C}) \\ &= 1.60 \times 10^{-19} \text{ J}. \end{aligned}$$
- Mechanical energy is the sum of the kinetic energy and potential energy of a system, that is, $KE + PE$. This sum is a constant.

19.2 Electric Potential in a Uniform Electric Field

- The voltage between points A and B is

$$\left. \begin{aligned} V_{AB} &= Ed \\ E &= \frac{V_{AB}}{d} \end{aligned} \right\} (\text{uniform } E \text{ - field only}),$$

where d is the distance from A to B, or the distance between the plates.

- In equation form, the general relationship between voltage and electric field is

$$E = -\frac{\Delta V}{\Delta s},$$

where Δs is the distance over which the change in potential, ΔV , takes place. The minus sign tells us that \mathbf{E} points in the direction of decreasing potential.) The electric field is said to be the *gradient* (as in grade or slope) of the electric potential.

19.3 Electrical Potential Due to a Point Charge

- Electric potential of a point charge is $V = kQ/r$.
- Electric potential is a scalar, and electric field is a vector. Addition of voltages as numbers gives the voltage due to a combination of point charges, whereas addition of individual fields as vectors gives the total electric field.

19.4 Equipotential Lines

- An equipotential line is a line along which the electric potential is constant.
- An equipotential surface is a three-dimensional version of equipotential lines.
- Equipotential lines are always perpendicular to electric field lines.
- The process by which a conductor can be fixed at zero volts by connecting it to the earth with a good conductor is called grounding.

19.5 Capacitors and Dielectrics

- A capacitor is a device used to store charge.
- The amount of charge Q a capacitor can store depends on two major factors—the voltage applied and the capacitor's physical characteristics, such as its size.
- The capacitance C is the amount of charge stored per volt, or

$$C = \frac{Q}{V}.$$

- The capacitance of a parallel plate capacitor is $C = \epsilon_0 \frac{A}{d}$, when the plates are separated by air or free space. ϵ_0 is called the permittivity of free space.
- A parallel plate capacitor with a dielectric between its plates has a capacitance given by

$$C = \kappa \epsilon_0 \frac{A}{d},$$

where κ is the dielectric constant of the material.

- The maximum electric field strength above which an insulating material begins to break down and conduct is called dielectric strength.

19.6 Capacitors in Series and Parallel

- Total capacitance in series $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$
- Total capacitance in parallel $C_p = C_1 + C_2 + C_3 + \dots$
- If a circuit contains a combination of capacitors in series and parallel, identify series and parallel parts, compute their capacitances, and then find the total.

19.7 Energy Stored in Capacitors

- Capacitors are used in a variety of devices, including defibrillators, microelectronics such as calculators, and flash lamps, to supply energy.
- The energy stored in a capacitor can be expressed in three ways:

$$E_{\text{cap}} = \frac{QV}{2} = \frac{CV^2}{2} = \frac{Q^2}{2C},$$

where Q is the charge, V is the voltage, and C is the capacitance of the capacitor. The energy is in joules when the charge is in coulombs, voltage is in volts, and capacitance is in farads.