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.
- $\Delta V = \frac{\Delta \text{PE}}{q}$ and $\Delta \text{PE} = q\Delta V$.
- An electron volt is the energy given to a fundamental charge accelerated through a potential difference of 1 V. In equation form,

$$\begin{aligned} 1\text{ eV} &= \left(1.60 \times 10^{-19}\text{ C}\right)(1\text{ V}) = \left(1.60\times10^{-19}\text{ C}\right)(1\text{ J/C}) \\ &= 1.60 \times 10^{-19}\text{ J.} \end{aligned}$$

- Mechanical energy is the sum of the kinetic energy and potential energy of a system, that is, $\text{KE} + \text{PE}$. This sum is a constant.

19.2 Electric Potential in a Uniform Electric Field

- The voltage between points A and B is

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

  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 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 $V = \text{kQ}/r$.
- 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 $C = \varepsilon_0 \frac{A}{d}$, 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
- $C = \kappa\varepsilon_0 \frac{A}{d}$,

  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 $\frac{1}{C_\text{S}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$
- Total capacitance in parallel $C_\text{p} = C_1 + C_2 + C_3 + ...$
- 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:
- $E_\text{cap} = \frac{\text{QV}}{2} = \frac{\text{CV}^2}{2} = \frac{Q^2}{2C}$,

  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.