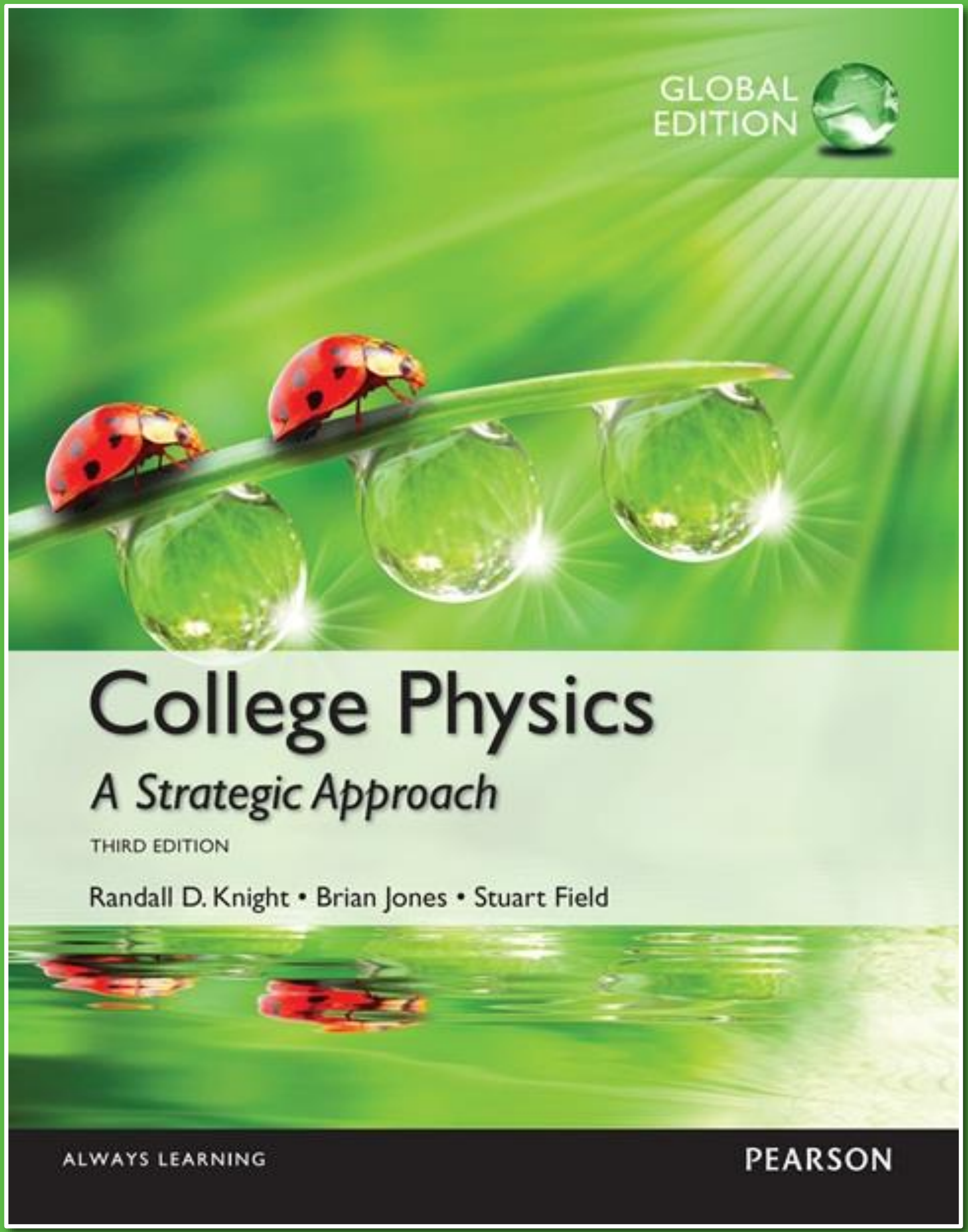


Lecture Presentation

Chapter 21

Electric Potential

Chapter 21 Electric Potential

Section 21.1 Electric Potential Energy and the Electric Potential
Section 21.7 Capacitance and Capacitors

Section 21.1 Electric Potential Energy and Electric Potential

Electric Potential

- The **electric potential** V at a given point is the electric potential energy of a charge divided by the charge itself.

$$V = \frac{U_{elec}}{q}$$

•

$$U_{\text{elec}} = qV$$

Relationship between electric potential and electric potential energy

- The unit of electric potential is the joule per coulomb, or **volt** V:

$$1\text{ volt} = 1\text{ V} = 1\text{ J/C}$$

Example 21.1 Finding the change in a charge's electric potential energy

A 15 nC charged particle moves from point A, where the electric potential is 300 V, to point B, where the electric potential is –200 V. By how much does the electric potential change? By how much does the particle's electric potential energy change?

Example 21.1 Finding the change in a charge's electric potential energy (cont.)

PREPARE The change in the electric potential ΔV is the potential at the final point B minus the potential at the initial point A. From Equation 21.1, we can find the change in the electric potential energy by noting that $\Delta U_{\text{elec}} = (U_{\text{elec}})_{\text{B}} - (U_{\text{elec}})_{\text{A}} = q(V_{\text{B}} - V_{\text{A}}) = q\,\Delta V$.

Example 21.1 Finding the change in a charge's electric potential energy (cont.)

SOLVE We have

$$\Delta V = V_B - V_A = (-200\ \text{V}) - (300\ \text{V}) = -500\ \text{V}$$

This change is *independent* of the charge q because the electric potential is created by source charges.

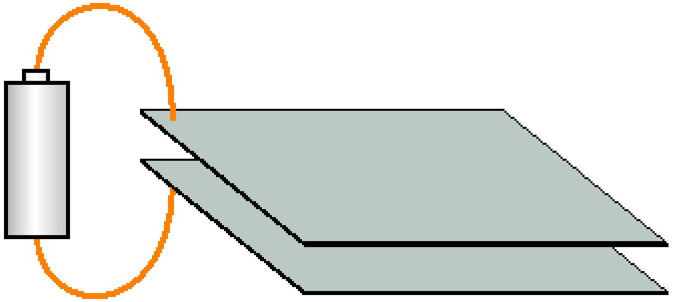
The change in the particle's electric potential energy is

$$\Delta U_{\text{elec}} = q\,\Delta V = (15 \times 10^{-9}\ \text{C})(-500\ \text{V}) = -7.5\ \mu\text{J}$$

Section 21.7 Capacitance and Capacitors

Capacitance and Capacitors

- A **capacitor** is formed by two conductors with equal but opposite charge.
- The two conductors are plates.
- Capacitors can be used to store charge.



Capacitance and Capacitors

- In a capacitor, the potential difference ΔV_C, across a parallel plate capacitor is proportional to the charge, *q*, on the plates.

$$Q = C\,\Delta V_C$$

Charge on a capacitor with potential difference ΔV_C

- The proportionality factor *C*, is the capacitance.
- The SI unit of capacitance is **Farad** (F).
- 1 Farad = 1 F = 1 coulomb/volt = 1 C/V.

Example 21.10 Charging a capacitor

A 1.3 μF capacitor is connected to a 1.5 V battery. What is the charge on the capacitor?

SOLVE

The charge on the capacitor is given by Equation 21.18:

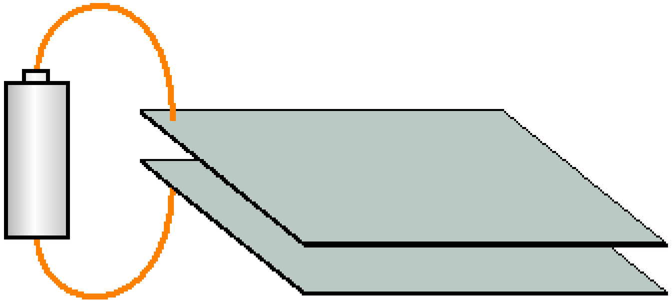
$$Q = C\,\Delta V_C = (1.3 \times 10^{-6}\ \text{F})(1.5\ \text{V}) = 2.0 \times 10^{-6}\ \text{C}$$

The Parallel-Plate Capacitor

- The capacitance (*C*) of a parallel plate capacitor depends only on geometric properties:
- it is proportional to the area of the plates (*A*) , and inversely proportional to the width of the gap (*d*) between the plates.

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

Capacitance of a parallel-plate capacitor with plate area *A* and separation *d*



Example 21.11 Charging a parallel-plate capacitor

The spacing between the plates of a 1.0 μF parallel-plate capacitor is 0.070 mm.

a. What is the surface area of the plates?
b. How much charge is on the plates if this capacitor is attached to a 1.5 V battery?

Example 21.11 Charging a parallel-plate capacitor (cont.)

SOLVE

a. From the definition of capacitance,

$$A = \frac{dC}{\epsilon_0} = \frac{(0.070 \times 10^{-3}\ \text{m})(1.0 \times 10^{-6}\ \text{F})}{8.85 \times 10^{-12}\ \text{F/m}} = 7.9\ \text{m}^2$$

b. The charge is $Q = C\,\Delta V_C = (1.0 \times 10^{-6}\ \text{F})(1.5\ \text{V}) = 1.5 \times 10^{-6}\ \text{C} = 1.5\ \mu\text{C}$.

Dielectrics and Capacitors

- A **dielectric** is an insulator placed between the plates of a capacitor.
- When a dielectric is inserted, The capacitance increases.
- The **dielectric constant** κ of the material determines the factor by which the capacitance is increased:

$$C = \kappa C_0$$

Capacitance of a parallel-plate capacitor with a dielectric of dielectric constant κ

- C_0 is the capacitance without a dielectric present.

Dielectrics and Capacitors

TABLE 21.3 Dielectric constants of some materials at 20°C

Material	Dielectric constant κ
Vacuum	1 (exactly)
Air	1.00054*
Teflon	2.0
Paper	3.0
Pyrex glass	4.8
Cell membrane	9.0
Ethanol	24
Water	80
Strontium titanate	300

*Use 1.00 in all calculations.

Example Problem

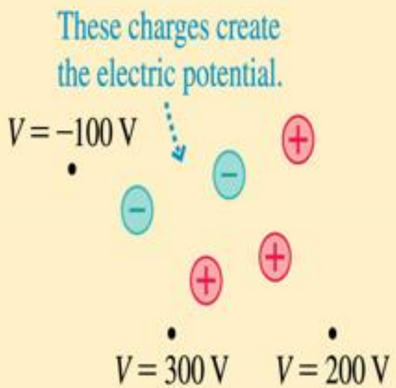
You construct a parallel plate capacitor with a 1.0-mm-thick rutile dielectric layer (κ_{rutile}= 100). If the area of the capacitor plates is 1.0 cm^2, what is its capacitance?

$$C = \kappa\varepsilon_o \frac{A}{d} = 10^2 \times 8.85 \times 10^{-12} \frac{10^{-4}}{10^{-3}} = 8.85 \times 10^{-11}\,\mathrm{F} = 88.5\,\mathrm{pF}$$

Summary: General Principles

Electric Potential and Potential Energy

The electric potential V is created by charges and exists at every point surrounding those charges.

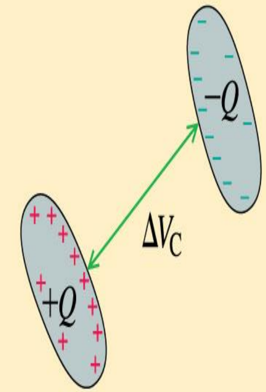


When a charge q is brought near these charges, it acquires an electric potential energy

$$U_{elec} = qV$$

Capacitors and dielectrics

The charge $\pm Q$ on two conductors and the potential difference ΔV_C between them are proportional:



$$Q = C\Delta V_C$$

where C is the **capacitance** of the two conductors.

A **parallel-plate capacitor** with plates of area A and separation d has a capacitance

$$C = \epsilon_0 A/d$$

When a **dielectric** is inserted between the plates of a capacitor, its capacitance is increased by a factor κ, the **dielectric constant** of the material.