

Chapter 26

1

Capacitance And Dielectrics

Mustafa Al-Zyout - Philadelphia University

10/5/2025

1

Lecture 01

2

Capacitance

Mustafa Al-Zyout - Philadelphia University

10/5/2025

2

Capacitors

3

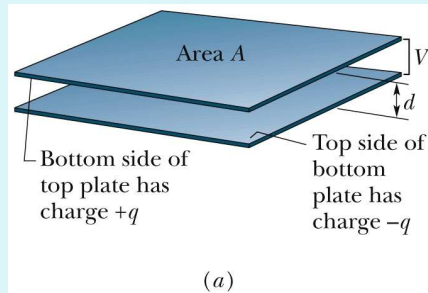
Capacitors are devices that store electric charge.

A capacitor consists of two conductors.

These conductors are called plates.

When the conductor is charged, the plates carry charges of equal magnitude and opposite signs.

A potential difference exists between the plates due to the charge.



Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.

Mustafa Al-Zyout - Philadelphia University

10/5/2025

3

Definition of Capacitance

4

The **capacitance**, C , of a capacitor is defined as the ratio of the magnitude of the charge on either conductor to the potential difference between the conductors.

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

- The SI unit of capacitance is the **Farad** ($F = C/V$).
- Capacitance is a scalar quantity.
- Capacitance will always be a **positive** quantity
- The capacitance of a given capacitor is constant.
- The total charge on a capacitor is ZERO.

Mustafa Al-Zyout - Philadelphia University

10/5/2025

4

Definition of Capacitance

5



Mustafa Al-Zyout - Philadelphia University

10/5/2025

5

Circuit Symbols

6

A circuit diagram is a simplified representation of an actual circuit.

Circuit symbols are used to represent the various elements.

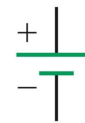
Lines are used to represent wires.

The battery's positive terminal is indicated by the longer line.

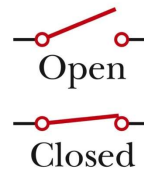
Capacitor
symbol



Battery
symbol



Switch
symbol



© Cengage Learning. All Rights Reserved.

Mustafa Al-Zyout - Philadelphia University

10/5/2025

6

Calculating Capacitance

7

PARALLEL PLATE CAPACITOR
THE CYLINDRICAL CAPACITOR
THE SPHERICAL CAPACITOR
ISOLATED SPHERE

Mustafa Al-Zyout - Philadelphia University

10/5/2025

7

8

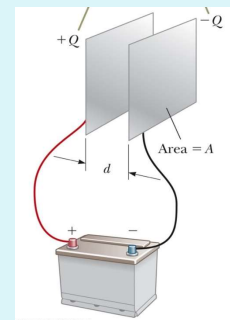
Example 1: Parallel Plate Capacitor

Two parallel, metallic plates of equal area A are separated by a distance d . Each plate is connected to a terminal of the battery. The battery is a source of potential difference. If the capacitor is initially uncharged, the battery establishes an electric field in the connecting wires.

Answer: The capacitance is:

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

The capacitance is **proportional** to the area of its plates and **inversely proportional** to the distance between the plates.



Mustafa Al-Zyout - Philadelphia University

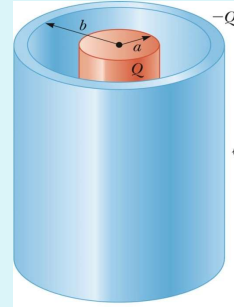
10/5/2025

8

9

Example 2: The Cylindrical Capacitor

A solid cylindrical conductor of radius a and charge $+Q$ is coaxial with a cylindrical shell of negligible thickness, radius $b > a$, and charge $-Q$. Find the capacitance of this cylindrical capacitor if its length is ℓ .



Answer: The capacitance is

$$C = \frac{Q}{\Delta V} = \frac{l}{2k_e \ln(b/a)}$$

- The capacitance depends on the radii (a) and (b) and is proportional to the length of the cylinders

Mustafa Al-Zyout - Philadelphia University

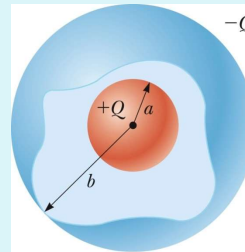
10/5/2025

9

10

Example 3: The Spherical Capacitor

A spherical capacitor consists of a spherical conducting shell of radius b and charge $-Q$ concentric with a smaller conducting sphere of radius a and charge $+Q$. Find the capacitance of this device.



Answer: The capacitance is

$$C = \frac{Q}{\Delta V} = \frac{ab}{k_e(b-a)}$$

- The capacitance depends on the radii (a) and (b)

Mustafa Al-Zyout - Philadelphia University

10/5/2025

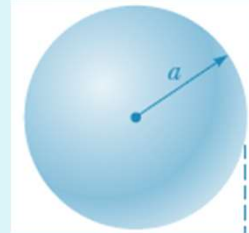
10

11

Example 3: **Isolated Sphere**

Assume a spherical charged conductor with radius (a) and charge (Q). The sphere will have the same capacitance as it would if there were a conducting sphere of infinite radius, concentric with the original sphere. Assume $V = 0$ for the infinitely large shell:

$$C = \frac{Q}{\Delta V} = \frac{Q}{k_e Q/a} = \frac{a}{k_e}$$



Note, this is **independent of the charge on the sphere and its potential**. The capacitance of an isolated sphere is proportional to its radius (a).

Size of a 1-F Capacitor

Tuesday, 6 April, 2021 21:19

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.
 R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
 J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY, 2014.
  H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
 H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

The parallel plates of a 1.0-F capacitor are 1.0 mm apart. What is their area?

This problem uses the relationship among the capacitance C , plate separation d , and plate area A for a parallel-plate capacitor.

$$C = \frac{A\epsilon_o}{d} \rightarrow A = \frac{Cd}{\epsilon_o}$$

$$A = \frac{1 \times 1 \times 10^{-3}}{8.85 \times 10^{-12}} = 113 \times 10^6 m^2$$

$$L = \sqrt{A} = 10.6 \times 10^3 m = 10.6 km$$

This corresponds to a square about **10 km** on a side! The volume of such a capacitor would be at least $Ad = 1.1 \times 10^5 m^3$, equivalent to that of a cube about **50 m** on a side. In fact, it's possible to make 1-F capacitors a few centimeters on a side. The trick is to have an appropriate substance between the plates rather than a vacuum.

properties of a parallel-plate Capacitor

Tuesday, 6 April, 2021 21:20

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.



R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.



J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY, 2014.



H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.



H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

The plates of a parallel-plate capacitor in vacuum are 5 mm apart and 2 m^2 in area. A 10 kV potential difference is applied across the capacitor. Compute

- the capacitance;
- the charge on each plate; and
- the magnitude of the electric field between the plates.

- the capacitance C is:

$$C = \frac{A\epsilon_0}{d} = \frac{2 \times 8 \cdot 85 \times 10^{-12}}{5 \times 10^{-3}} = 3.54 \times 10^{-9} \text{ C} = 3.54 \text{ nC}$$

- The charge on the capacitor is:

$$C = \frac{Q}{\Delta V} \rightarrow Q = C\Delta V = 3.54 \times 10^{-9} \times 10 \times 10^3 = 3.54 \times 10^{-5} \text{ C} = 35.4 \mu\text{C}$$

- The electric-field magnitude is:

$$\Delta V = Ed \rightarrow E = \frac{\Delta V}{d} = \frac{10 \times 10^3}{5 \times 10^{-3}} = 2 \times 10^6 \text{ V/m}$$

a Spherical Capacitor

Tuesday, 6 April, 2021 21:22

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

-  R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
-  J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY, 2014.
-  H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
-  H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

Two concentric spherical conducting shells are separated by vacuum. The inner shell has total charge $+Q$ and outer radius $r_a = 9.5 \text{ cm}$, and the outer shell has charge $-Q$ and inner radius $r_b = 10.5 \text{ cm}$. Find the capacitance of this spherical capacitor.

The spherical capacitance is:

$$\begin{aligned} C &= \frac{ab}{k(b-a)} \\ &= \frac{9.5 \times 10^{-2} \times 10.5 \times 10^{-2}}{9 \times 10^9 \times (10.5 - 9.5) \times 10^{-2}} \\ &= 111 \times 10^{-12} F = 111 pF \end{aligned}$$