

Exercise walk-through

10.3

Capacitors

AP Physics C: Electricity and Magnetism

Capacitors

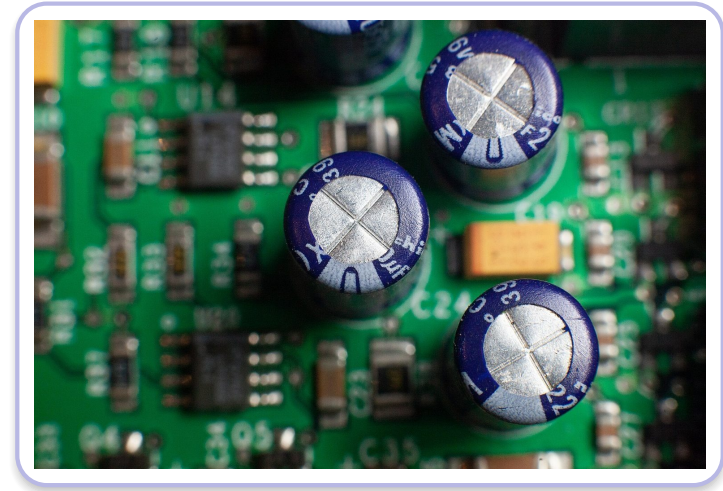
A **capacitor** stores charge $\pm Q$ on two plates:

Capacitance and stored energy

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

$$U = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$$

Energy lives in the field: $u = \frac{1}{2} \epsilon_0 E^2$. Combine **opposite** to resistors – parallel adds.



Pcb capacitors

The parallel-plate derivation, in three steps

1. field

Gauss's law plus **superposition**
and zero outside

give $E = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$ between the plates,

2. potential

the field is uniform, so $\Delta V = Ed = \frac{Qd}{\epsilon_0 A}$

3. capacitance

$$C = \frac{Q}{\Delta V} = \frac{\epsilon_0 A}{d}$$

the energy

$$U = \frac{1}{2} Q \Delta V = \frac{1}{2} C (\Delta V)^2 = \frac{Q^2}{2C}$$

That $\frac{1}{2}$ is the **triangle** under the Q - ΔV line: the first charge moved across costs almost nothing, the last costs the full ΔV . The same $E \rightarrow \Delta V \rightarrow C$ chain does the cylinder and the sphere.

Capacitance is geometry, and nothing else

the definition

$$C = \frac{Q}{\Delta V} - \text{but } C \text{ depends on neither}$$

what sets it

the plate area, the gap, the shape, and the material filling the gap

double Q

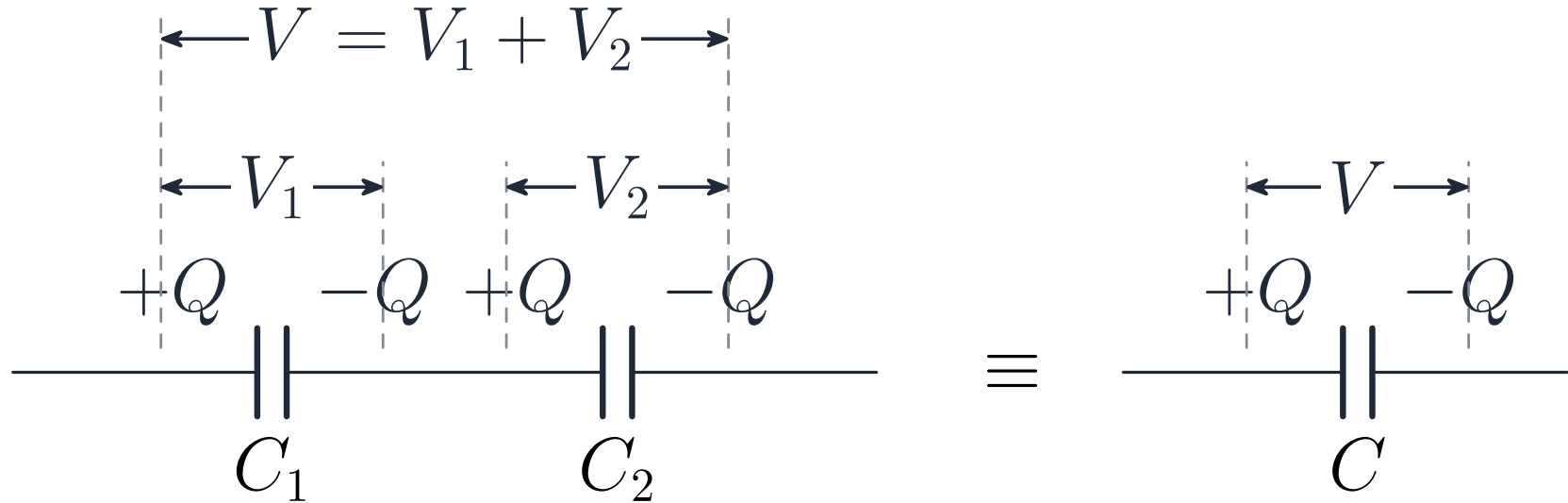
ΔV doubles with it, and C is unchanged

the units

1 F = 1 C/V; real capacitors are pF to μ F because a farad is enormous

If your answer makes C depend on Q or on ΔV , you have made an algebra error. Geometry only.

Capacitors in series carry the same charge – one



Capacitors in series carry the same charge, and their p.d.s add

Inside the plates, a charge is a projectile

the field

uniform between the plates, so the force qE and the acceleration are **constant**

across the gap

velocity along the plates is unchanged; the transverse motion accelerates – exactly **projectile motion**

time in the field

$t = L/v_0$, set entirely by the horizontal motion

deflection

$$y = \frac{1}{2}at^2 = \frac{qEL^2}{2mv_0^2}$$

An electron entering midway at $v_0 = 2.0 \times 10^7$ m/s through $E = 1.0 \times 10^3$ N/C is deflected by exactly this formula. **Split the motion into two perpendicular directions** and the mechanics is already done.

Exercises 2.1-2.3

2.1 A parallel-plate capacitor has area 0.020 m^2 and separation 1.0 mm ($\epsilon_0 = 8.85 \times 10^{-12}$). Find its capacitance. [2]

2.2 Two $4.0 \mu\text{F}$ capacitors are connected in parallel. Find the total capacitance. [1]

2.3 Find the energy stored in a $10 \mu\text{F}$ capacitor at 12 V . [2]

Exercises 2.1-2.3

2.1 A parallel-plate capacitor has area 0.020 m^2 and separation 1.0 mm ($\epsilon_0 = 8.85 \times 10^{-12}$). Find its capacitance. [2]

2.1

- $$C = \frac{\epsilon_0 A}{d} = \frac{(8.85 \times 10^{-12})(0.020)}{1.0 \times 10^{-3}} = 1.8 \times 10^{-10} \text{ F}$$

2.2 Two $4.0 \text{ }\mu\text{F}$ capacitors are connected in parallel. Find the total capacitance. [1]

2.2

- $$C = 4.0 + 4.0 = 8.0 \text{ }\mu\text{F}$$

2.3 Find the energy stored in a $10 \text{ }\mu\text{F}$ capacitor at 12 V . [2]

2.3

- $$U = \frac{1}{2}CV^2 = \frac{1}{2}(10 \times 10^{-6})(12)^2 = 7.2 \times 10^{-4} \text{ J}$$

Exercise 3.1

3.1 The capacitance of a parallel-plate capacitor is

[1]

☐

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

B $\frac{\epsilon_0 A}{d}$

C $\epsilon_0 A d$

D $\frac{A}{\epsilon_0 d}$

Exercise 3.1

3.1 The capacitance of a parallel-plate capacitor is

[1]

- ☐ **A** $\frac{\epsilon_0 d}{A}$
- B** $\frac{\epsilon_0 A}{d}$
- C** $\epsilon_0 A d$
- D** $\frac{A}{\epsilon_0 d}$

3.1 B

• $\frac{\epsilon_0 A}{d}$.

Exercise 3.2

3.2 Two capacitors in series have a total capacitance that is

[1]

☐

A the sum of the two

B less than either one

C the larger of the two

D zero

Exercise 3.2

3.2 Two capacitors in series have a total capacitance that is

[1]

☐

- A** the sum of the two
- B** less than either one
- C** the larger of the two
- D** zero

3.2 B

- less than either one.

Exercise 3.3 (a)

3.3 A $5.0 \mu\text{F}$ capacitor is charged to 100 V .

(a) Find the charge stored.

[2]

Exercise 3.3 (a)

3.3 A $5.0 \mu\text{F}$ capacitor is charged to 100 V .

(a) Find the charge stored.

[2]

(a)

- $Q = CV = (5.0 \times 10^{-6})(100) = 5.0 \times 10^{-4} \text{ C}$

Exercise 3.3 (b)

3.3 A $5.0 \mu\text{F}$ capacitor is charged to 100 V .

(b) Find the energy stored.

[2]

Exercise 3.3 (b)

3.3 A $5.0 \mu\text{F}$ capacitor is charged to 100 V .

(b) Find the energy stored.

[2]

(b)

- $U = \frac{1}{2}CV^2 = \frac{1}{2}(5.0 \times 10^{-6})(100)^2 = 0.025 \text{ J}$