

Storing charge and energy between two plates

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train capacitance, the parallel-plate formula, energy storage and the effect of dielectrics for AP Physics 2 unit 10. They begin with one-step calculations and unit conversions and move to comparisons where you must decide whether the charge or the voltage stays fixed. Use $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$ and $e = 1.60 \times 10^{-19} \text{ C}$, and write units with every answer.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 10

Problem 1 Capacitance from charge (easy)

A capacitor holds $24 \mu\text{C}$ of charge on its plates when connected to 6.0 V .

1. Calculate its capacitance.
2. Calculate the charge it would hold at 9.0 V .
3. State the unit of capacitance in terms of coulombs and volts.

Problem 2 Prefixes (easy)

Convert each value.

1. $470 \mu\text{F}$ to farads
2. 22 nF to farads
3. 100 pF to microfarads
4. 0.0033 F to millifarads

Problem 3 Plate capacitor in air (easy)

Emma makes a capacitor from two metal sheets of area 0.020 m^2 separated by 0.50 mm of air. Take $\kappa = 1$ and $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$.

1. Calculate its capacitance in pF .
2. State what happens to C if the sheets are moved to 1.0 mm apart.

Problem 4 Energy in a capacitor (easy)

A $100 \mu\text{F}$ capacitor is charged to 12 V .

1. Calculate the charge on a plate.
2. Calculate the energy stored.

Problem 5 Electrons on the plates (easy)

A $2.2 \mu\text{F}$ capacitor is connected to a 9.0 V battery.

1. Calculate the charge on the negative plate.
2. Calculate the number of excess electrons on it. Use $e = 1.60 \times 10^{-19} \text{ C}$.

Problem 6 Scaling capacitance (easy)

A parallel-plate capacitor has capacitance C . State the new capacitance in each case.

1. The plate area is doubled.
2. The plate separation is doubled.
3. A material with $\kappa = 3$ fills the gap.
4. The area is doubled, the separation is doubled and $\kappa = 3$.

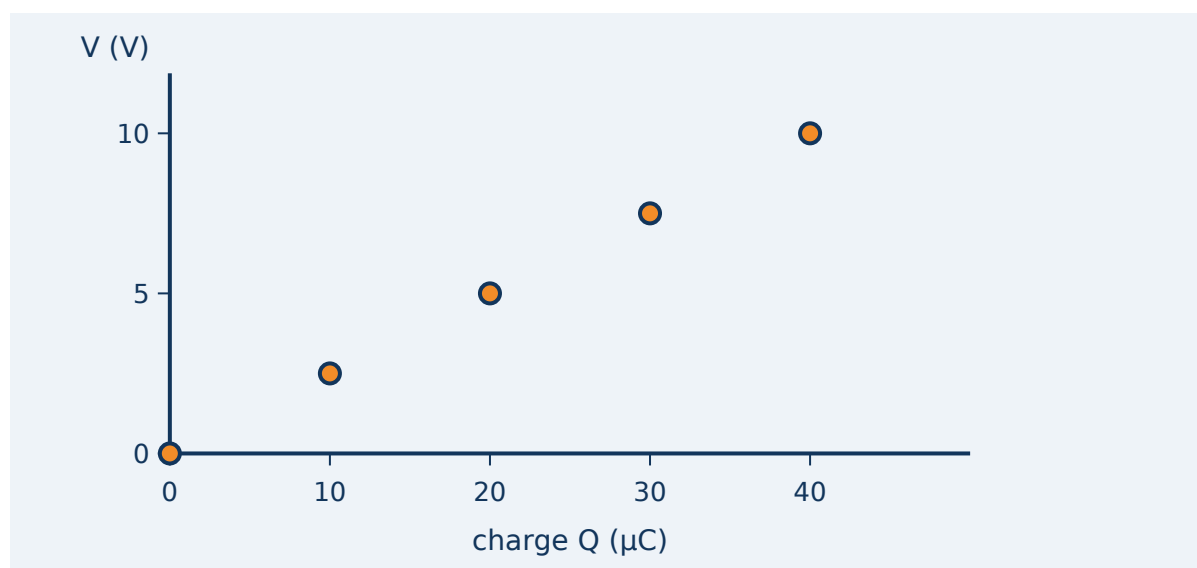
Problem 7 Finding the gap (medium)

A 1.0 nF air capacitor has plates of area 0.050 m².

1. Rearrange the capacitance equation for d .
2. Calculate d in millimetres.

Problem 8 Charging graph (medium)

A student charges a capacitor in steps and records the voltage (graph shown).



Voltage across a capacitor for five values of stored charge.

1. Find the gradient and use it to find the capacitance.
2. Calculate the energy stored at 40 μC and 10 V.
3. State what the area under the graph represents.

Problem 9 Three energy formulas (medium)

A 10 μF capacitor holds 50 μC .

1. Calculate the voltage across it.
2. Calculate the energy using $U = Q^2/2C$.
3. Check your answer using $U = \frac{1}{2}CV^2$.

Problem 10 Dielectric with the battery connected (medium)

A 2.0 nF capacitor is connected to a 9.0 V battery. A dielectric with $\kappa = 4.0$ is slid in while the battery stays connected.

1. Calculate the new capacitance.
2. Calculate the charge before and after.
3. Calculate the energy before and after.
4. State whether the field between the plates changes.

Problem 11 Dielectric in an isolated capacitor (medium)

The same 2.0 nF capacitor is charged to 9.0 V, disconnected from the battery, and then the $\kappa = 4.0$ dielectric is slid in.

1. State the charge afterwards.
2. Calculate the new voltage.
3. Calculate the new stored energy and compare with the original 8.1×10^{-8} J.
4. Explain where the missing energy has gone.

Problem 12 Supercapacitor torch (medium)

Kofi's torch uses a 0.50 F supercapacitor charged to 5.0 V. An LED uses 0.25 W.

1. Calculate the energy stored at 5.0 V.
2. Calculate how long the LED could run if all the energy were used.
3. Calculate the energy released as the voltage falls to 3.0 V.

Problem 13 Air breakdown (medium)

Air breaks down in a field above about 3.0×10^6 V/m. Two plates of area 0.040 m^2 are 2.0 mm apart in air.

1. Calculate the highest voltage the capacitor can take.
2. Calculate its capacitance.
3. Calculate the largest charge and energy it can store.

Problem 14 Inside a dielectric (medium)

A capacitor with air between its plates is charged and disconnected. A slab of glass is inserted.

1. Describe what happens to the glass molecules.
2. Explain why the field in the gap becomes smaller.
3. Explain why the capacitance increases.

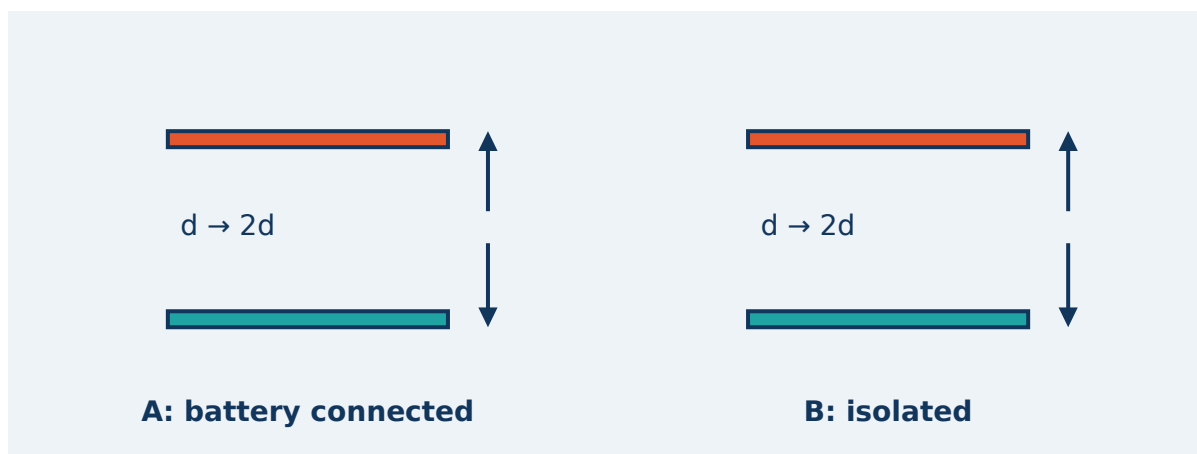
Problem 15 Measuring a dielectric constant (medium)

Bilal measures a capacitor with air between the plates: 52 pF. He then fills the gap with a plastic sheet and measures 190 pF.

1. Calculate κ for the plastic.
2. State which material in a table this resembles.
3. Suggest one reason why the value might be a little off.

Problem 16 Pulling the plates apart (hard)

Two identical $5.0 \mu\text{F}$ capacitors each carry $60 \mu\text{C}$ at 12 V (shown). The battery stays connected to A, while B is disconnected. The plate separation of each is then doubled.

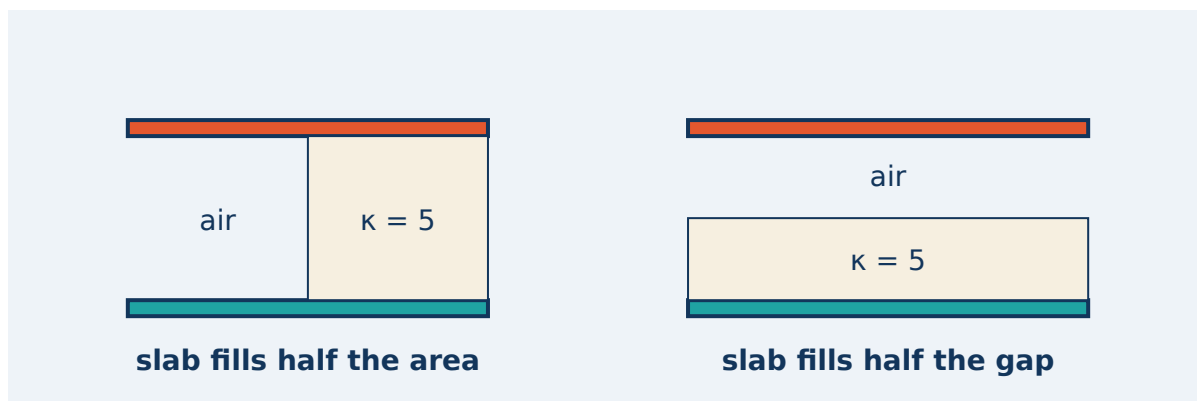


The plates of each capacitor are pulled to twice the original separation.

1. State the new capacitance of each.
2. For A, calculate Q , V and U afterwards.
3. For B, calculate Q , V and U afterwards.
4. Explain why U changes in opposite ways.

Problem 17 Partly filled capacitors (hard)

An air capacitor has plates of area 0.020 m^2 and gap 1.0 mm . A slab with $\kappa = 5$ is inserted in two ways (shown).

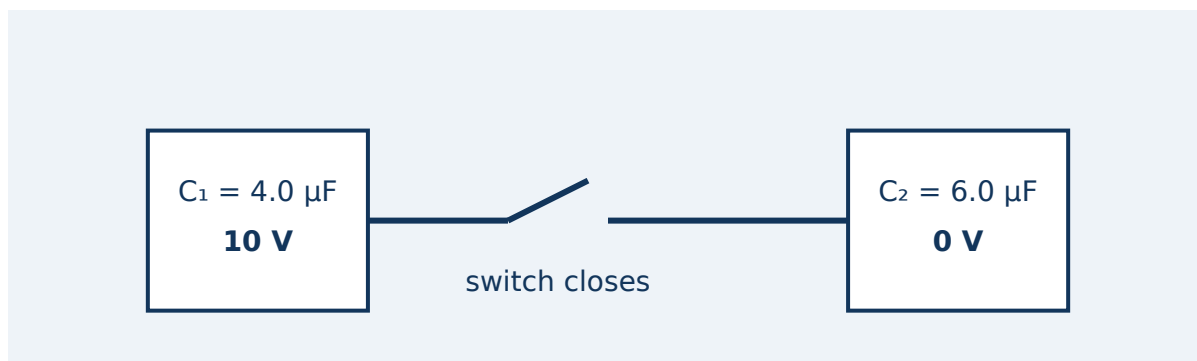


Two ways of placing a slab of $\kappa = 5$ in a capacitor with plate area 0.020 m^2 and gap 1.0 mm .

1. Calculate the capacitance with no slab.
2. Calculate C when the slab fills half of the plate area (side by side).
3. Calculate C when the slab fills half of the gap (stacked).
4. Compare your answers and comment.

Problem 18 Sharing charge (hard)

A $4.0\ \mu\text{F}$ capacitor is charged to $10\ \text{V}$ and then connected through a switch to an uncharged $6.0\ \mu\text{F}$ capacitor (shown).



A charged capacitor shares its charge with an uncharged one when the switch is closed.

1. Calculate the charge and energy before the switch is closed.
2. Calculate the final common voltage.
3. Calculate the final energy and the energy lost.
4. Suggest where the lost energy goes.

Problem 19 Defibrillator capacitor (hard)

A defibrillator uses an $80\ \mu\text{F}$ capacitor charged to $3.0\ \text{kV}$. It delivers $80\ \%$ of its energy to a patient in $5.0\ \text{ms}$.

1. Calculate the energy stored.
2. Calculate the energy delivered and the average power.
3. Calculate the charge on the capacitor and the average current if all of it flows in $5.0\ \text{ms}$.

Problem 20 Doubling the voltage (hard)

Two identical capacitors of capacitance C are charged: one to voltage V and the other to $2V$. Write a paragraph-style argument comparing them.

1. Compare the charge on each.
2. Compare the stored energy.
3. Compare the electric field between the plates.
4. Explain which is more likely to suffer breakdown.