

Your Comments

I think this was easier than normal. I felt really good about the capacitance characteristics, although not quite as much about charge and other factors.

The most confusing part was the different capacitor configurations.

The concept of capacitance is difficult. Does it mean the amount of charge that can be contained in the electric field? Does that mean there is a limit?

I am a little confused about the electric potential energy between a capacitor, can u explain it more?

I understand the different types of connections and calculating the capacitance, charge, etc. However, I don't think I'm fully understanding the dielectric and what exactly happens when that is placed between a capacitor. Particularly the last checkpoint question is what I'm confused on. I thought I understood it until I was asked those questions.

If the dielectric capacitor has less potential energy, why do we use dielectrics in capacitors??? Isn't the point to store energy?

Bring on the resistors!

How come a battery isn't defined as a capacitor in a circuit diagram even though the prelecture says that a battery is a capacitor?

Exam Logistics

1) EXAM 1: WED February 19th at 7pm

- Sign Up in Gradebook for Conflict Exam at 5:15pm if desired
- MATERIAL: Lectures 1 - 8

2) EXAM 1 PREPARATION

- Old Exams are a good way to assess what you need to know
- Prelecture of Fall 2010 solutions available

3) Extra Office Hours (Tuesday/ Wednesday next week check room#)

Who is ready for that test... ;_;

Physics 212

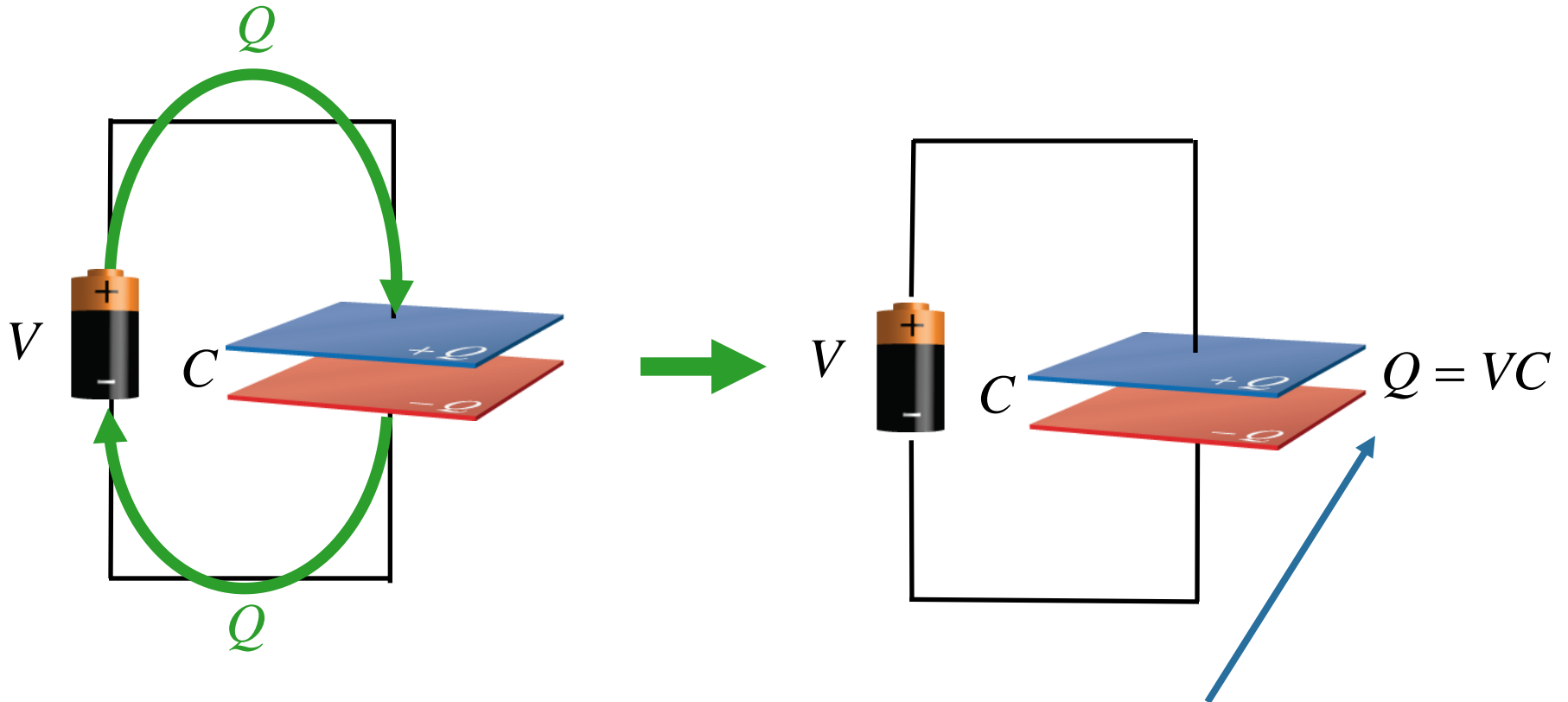
Lecture 8

Today's Concept:

Capacitors

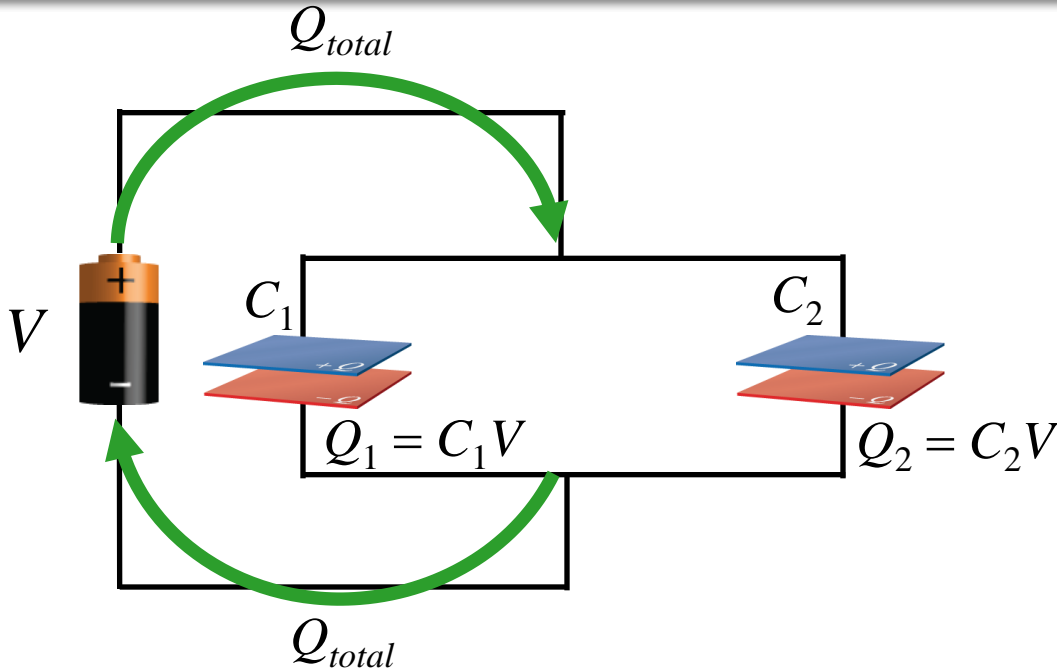
(Capacitors in a circuits, Dielectrics, Energy in capacitors)

Simple Capacitor Circuit



This “ Q ” really means that the battery has moved charge Q from one plate to the other, so that one plate holds $+Q$ and the other $-Q$.

Parallel Capacitor Circuit

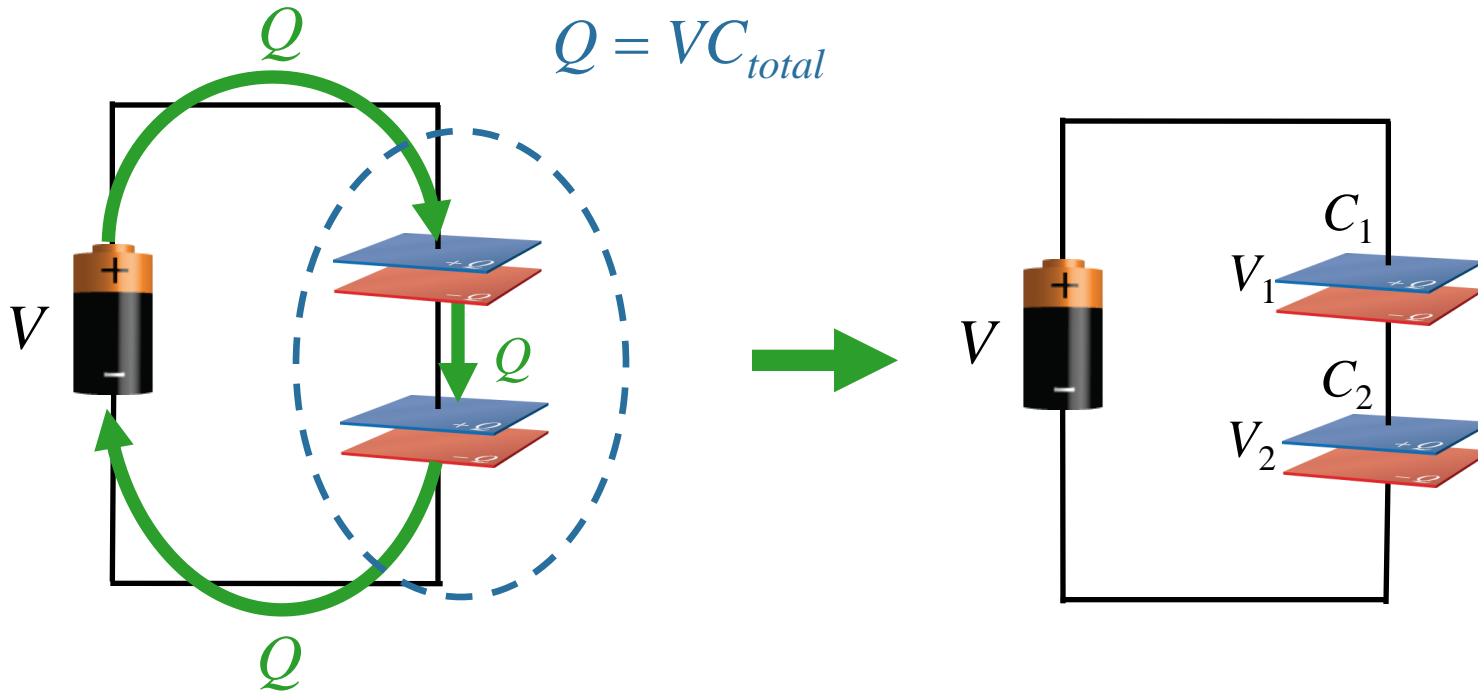


Key point: V is the same for both capacitors

Key Point: $Q_{total} = Q_1 + Q_2 = VC_1 + VC_2 = V(C_1 + C_2)$

$$C_{total} = C_1 + C_2$$

Series Capacitor Circuit



Key point: Q is the same for both capacitors

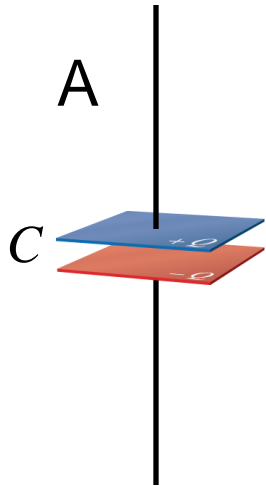
Key point: $Q = VC_{total} = V_1C_1 = V_2C_2$

Also: $V = V_1 + V_2$ $\longrightarrow Q/C_{total} = Q/C_1 + Q/C_2$

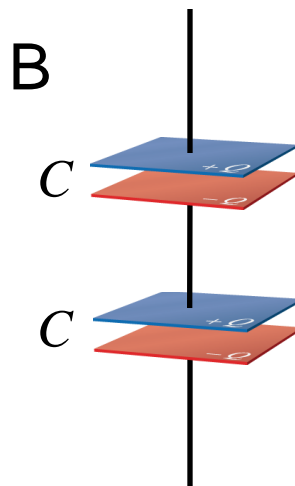
$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Checkpoint 1

Which has lowest total capacitance:

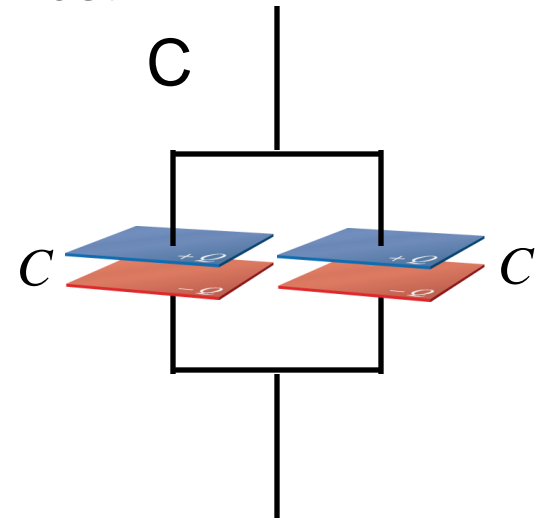


$$C_{total} = C$$

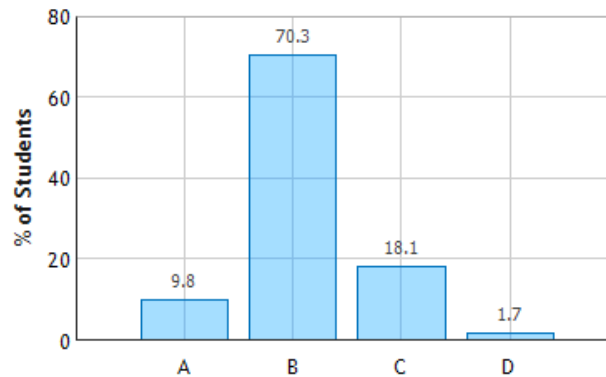


$$\begin{aligned} 1/C_{total} &= 1/C + 1/C \\ &= 2/C \end{aligned}$$

$$C_{total} = C/2$$



$$C_{total} = 2C$$

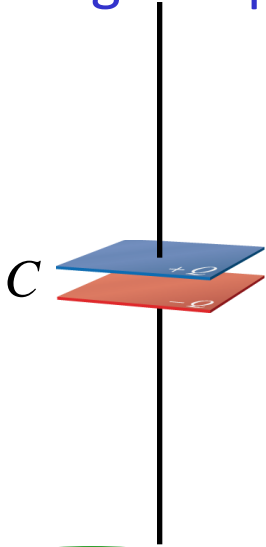


CheckPoint 2

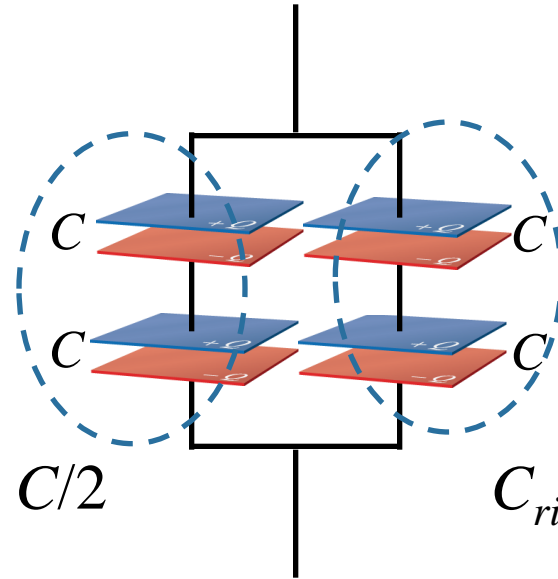
Which has lowest total capacitance?

A) Single Capacitor B) 4 Capacitors C) Same

:



$$C_{total} = C$$

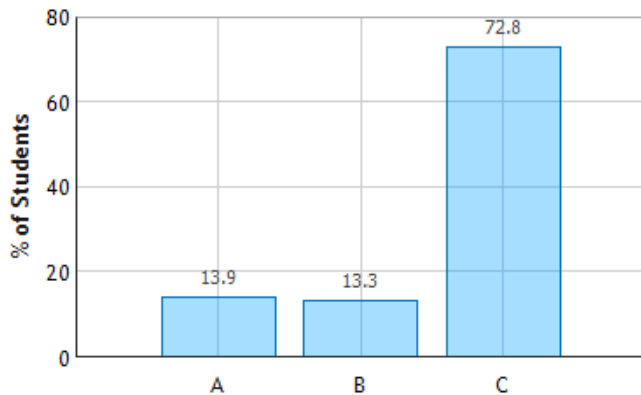


$$C_{left} = C/2$$

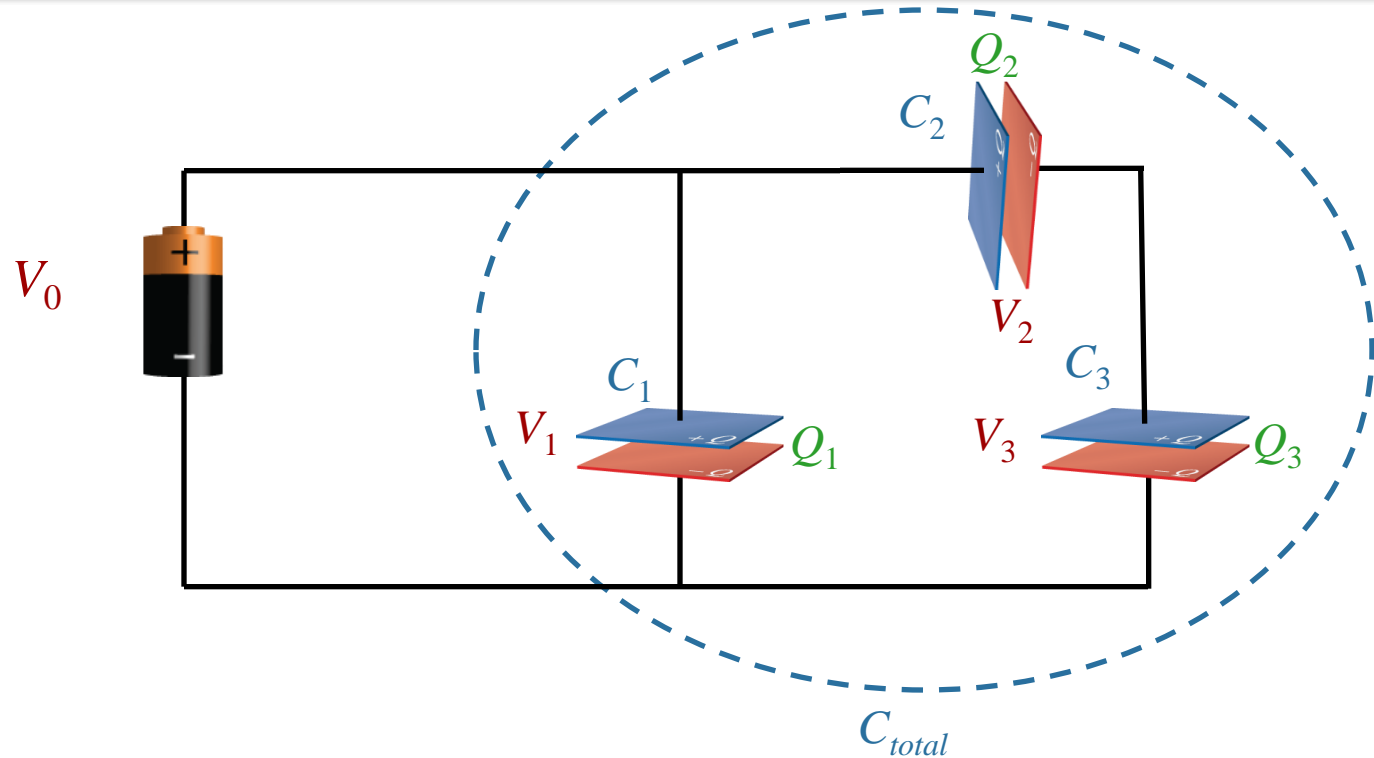
$$C_{right} = C/2$$

$$C_{total} = C_{left} + C_{right}$$

$$C_{total} = C$$



Similar to CheckPoint 3



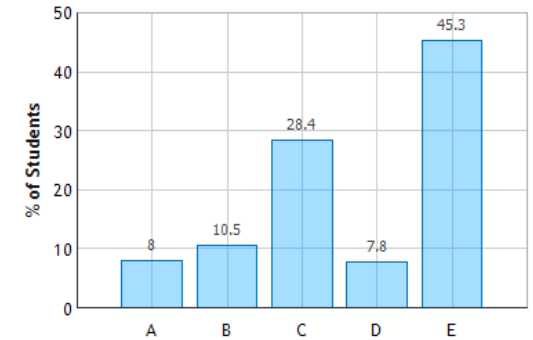
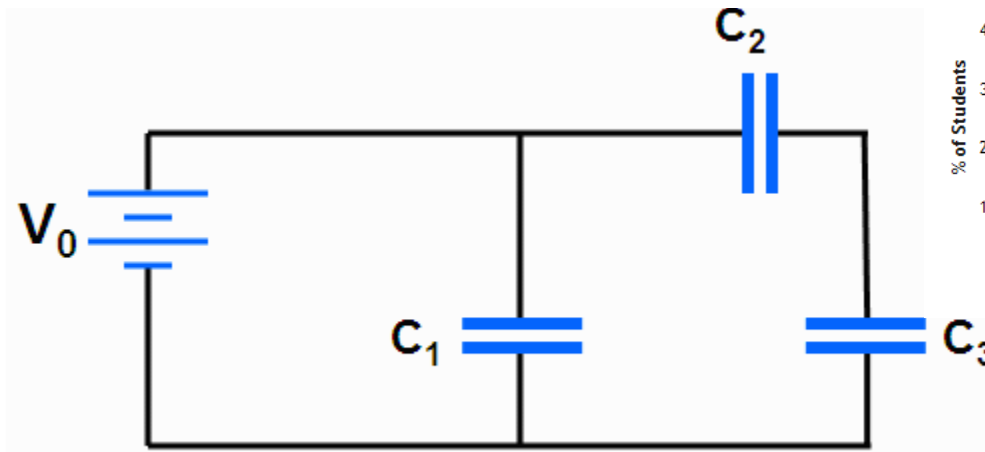
Which of the following is **NOT** necessarily true:

- A) $V_0 = V_1$
- B) $C_{total} > C_1$
- C) $V_2 = V_3$
- D) $Q_2 = Q_3$
- E) $V_1 = V_2 + V_3$

CheckPoint 3



A circuit consists of three unequal capacitors C_1 , C_2 , and C_3 which are connected to a battery of voltage V_0 . The capacitance of C_2 is twice that of C_1 . The capacitance of C_3 is three times that of C_1 . The capacitors obtain charges Q_1 , Q_2 , and Q_3 .



~~A.~~ $Q_1 > Q_3 > Q_2$ ~~B.~~ $Q_1 > Q_2 > Q_3$ **C.** $Q_1 > Q_2 = Q_3$ **D.** $Q_1 = Q_2 = Q_3$ **E.** $Q_1 < Q_2 = Q_3$

1. See immediately: $Q_2 = Q_3$ (capacitors in series)

2. How about Q_1 vs. Q_2 and Q_3 ? Calculate C_{23} first.

$$\frac{1}{C_{23}} = \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{2C_1} + \frac{1}{3C_1} = \frac{5}{6C_1}$$



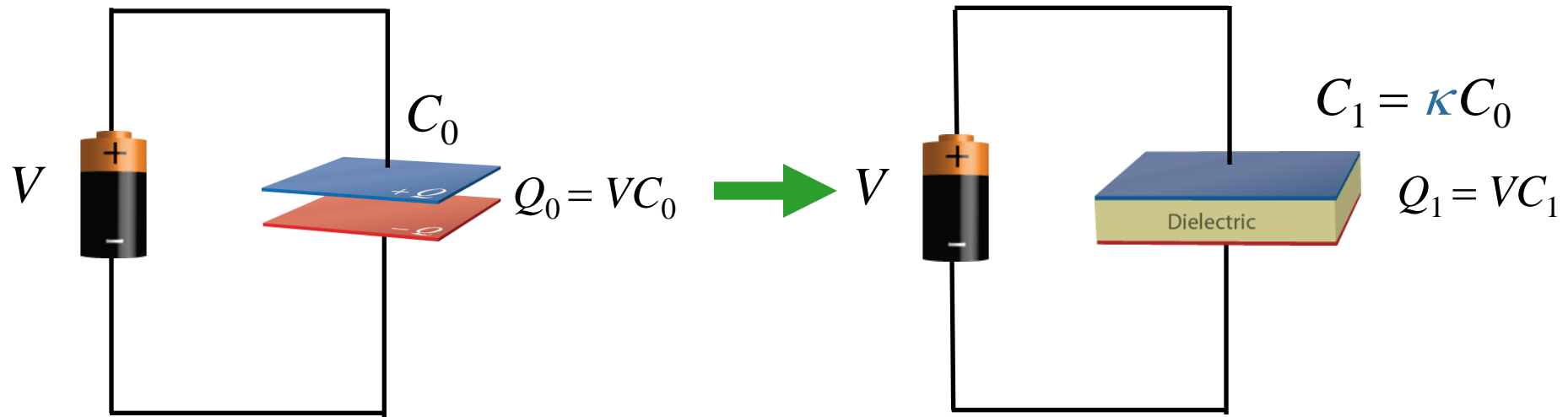
$$C_{23} = \frac{6}{5} C_1$$



$$Q_1 = C_1 V_0$$

$$Q_{23} = Q_2 = Q_3 = C_{23} V_0 = \frac{6}{5} C_1 V_0$$

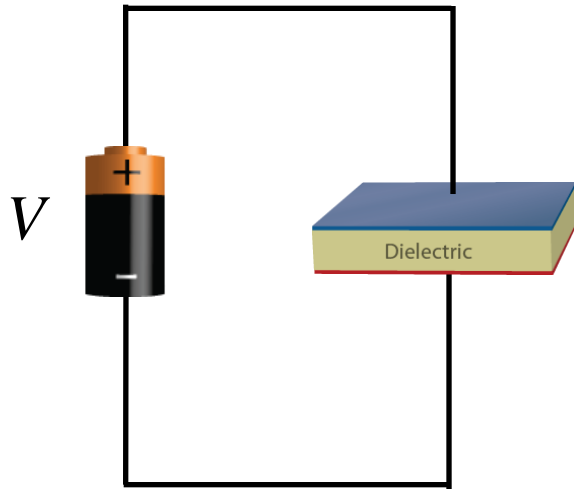
Dielectrics



By adding a dielectric you are just making a new capacitor with larger capacitance (factor of κ)

Messing with Capacitors

If connected to a battery V stays constant



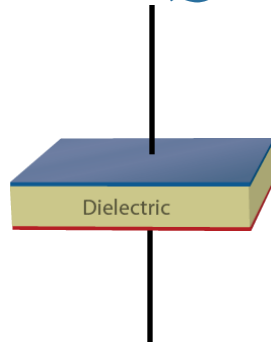
$$V_1 = V$$

$$C_1 = \kappa C$$

$$\left. \begin{array}{l} V_1 = V \\ C_1 = \kappa C \end{array} \right\} \rightarrow Q_1 = C_1 V_1$$

$$= \kappa C V = \kappa Q$$

If isolated then total Q stays constant



$$Q_1 = Q$$

$$C_1 = \kappa C$$

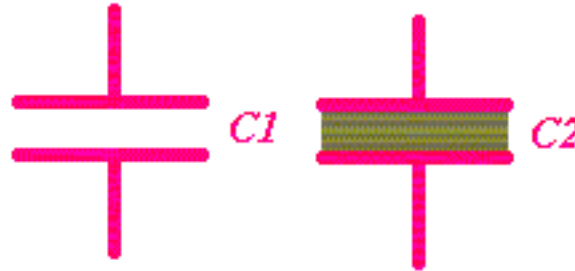
$$\left. \begin{array}{l} Q_1 = Q \\ C_1 = \kappa C \end{array} \right\} \rightarrow V_1 = Q_1 / C_1$$

$$= Q / \kappa C = V / \kappa$$

CheckPoint 4a



Two identical parallel plate capacitors are given the same charge Q , after which they are disconnected from the battery. Then, a dielectric is placed between the plates of C_2



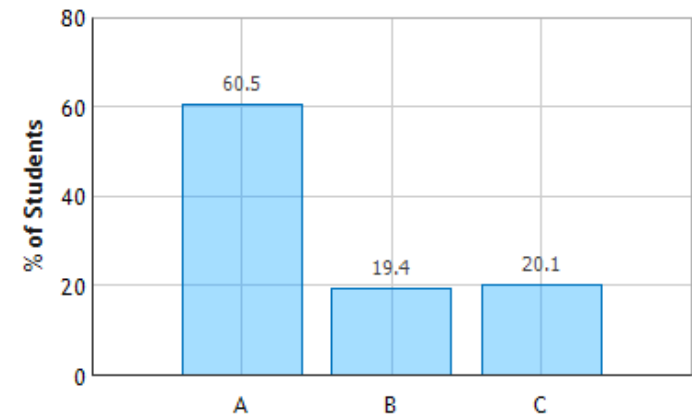
Compare the voltages of the two capacitors.

☒ A $V_1 > V_2$ ☐ B $V_1 = V_2$ ☐ C $V_1 < V_2$

“Both have the same charge but 2 has a bigger capacitance so it has a smaller voltage.”

“Voltage depends on charge not dielectric”

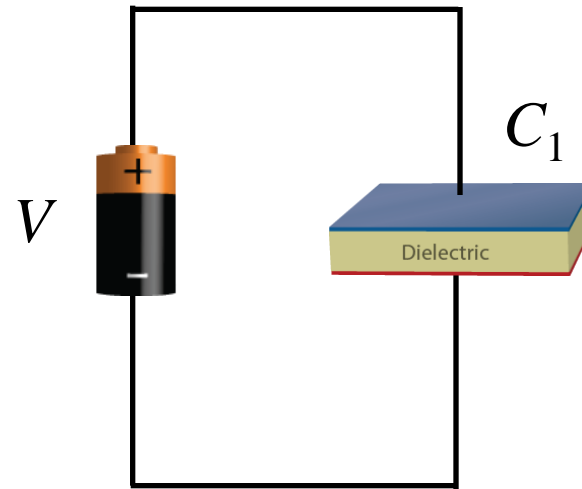
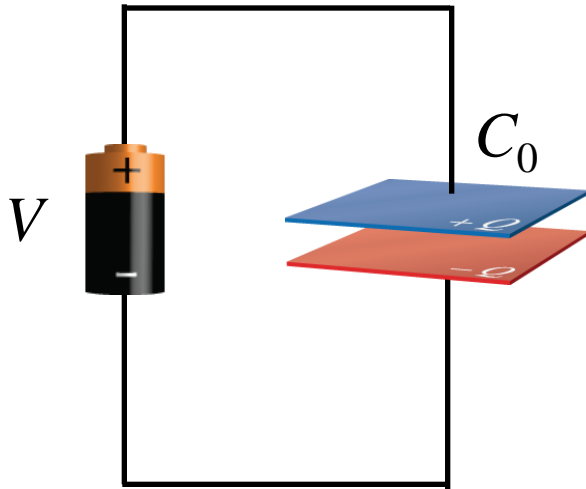
“ $C=Q/V$. Q stays the same while C increases due to the dielectric, so in order to adjust for this increase, we need to decrease the V .”



Messing with Capacitors Clicker Question



Two identical parallel plate capacitors are connected to identical batteries. Then a dielectric is inserted between the plates of capacitor C_1 . Compare the energy stored in the two capacitors.



A) $U_1 < U_0$

B) $U_0 = U_1$

C) $U_1 > U_0$

Compare using $U = \frac{1}{2}CV^2$

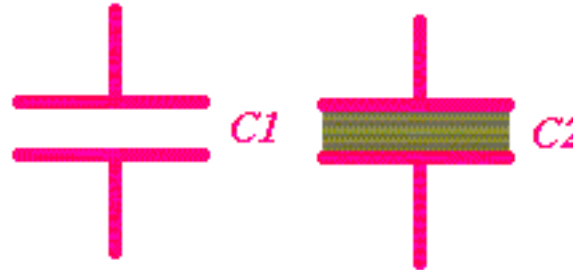
$$U_1/U_0 = \kappa$$

→ Potential Energy goes UP

CheckPoint 4b



Two identical parallel plate capacitors are given the same charge Q , after which they are disconnected from the battery. Then, a dielectric is placed between the plates of C_2



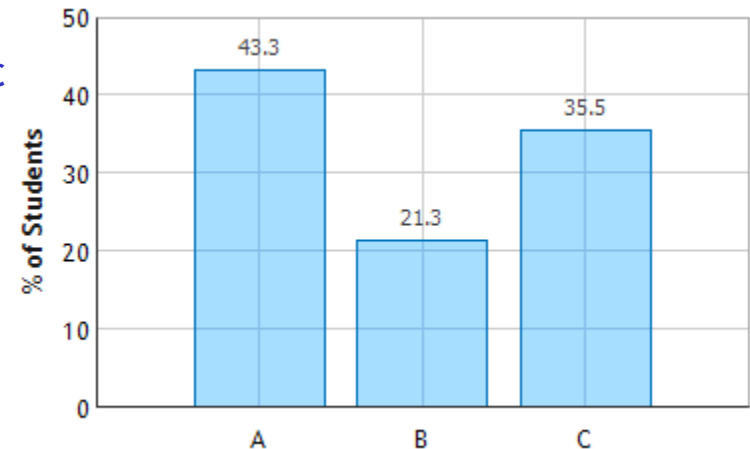
Compare the potential energy stored by the two capacitors.

- A) $U_1 > U_2$ B) $U_1 = U_2$ C) $U_1 < U_2$

The potential energy is directly related to the electric field. The lower the field, the lower the potential energy.

The potential energy depends on the charge only

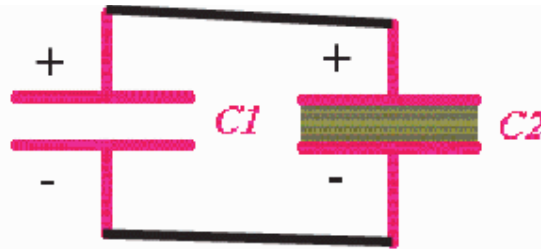
$C = Q/V$ Q remains the same while V reduced, so C increase. since $U = 0.5CV^2$, U is increased.



Checkpoint 4c



Two identical parallel plate capacitors are given the same charge Q , after which they are disconnected from the battery. After C_2 has been charged and disconnected, it is filled with a dielectric. **The two capacitors are now connected to each other by wires as shown. How will the charge redistribute itself, if at all?**

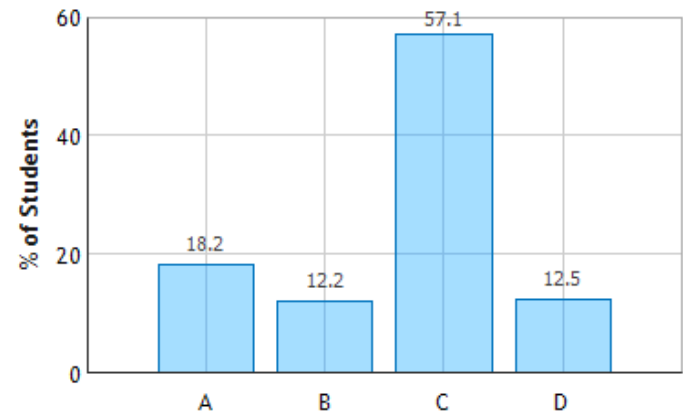


- A. The charges will flow so that the charge on C_1 will become equal to the charge on C_2 .
- B. The charges will flow so that the energy stored in C_1 will become equal to the energy stored in C_2 .
- C. The charges will flow so that the potential difference across C_1 will become the same as the potential difference across C_2 .
- D. No charges will flow. The charge on the capacitors will remain what it was before they were connected.

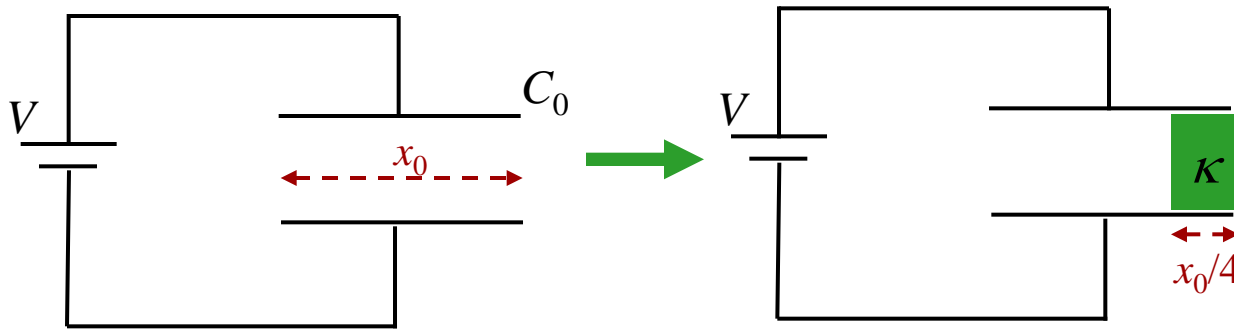
V must be the same !!

Q: $\frac{Q_1}{C_1} = \frac{Q_2}{C_2} \rightarrow Q_1 = \frac{C_1}{C_2} Q_2$

U: $U_1 = \frac{1}{2} C_1 V^2$
 $U_2 = \frac{1}{2} C_2 V^2 \rightarrow U_1 = \frac{C_1}{C_2} U_2$



Calculation



An air-gap capacitor, having capacitance C_0 and width x_0 is connected to a battery of voltage V .

A dielectric (κ) of width $x_0/4$ is inserted into the gap as shown.

What is Q_f , the final charge on the capacitor?

Conceptual Analysis:

$$C \equiv \frac{Q}{V}$$

What changes when the dielectric added?

- A) Only C B) only Q C) only V **D) C and Q** E) V and Q

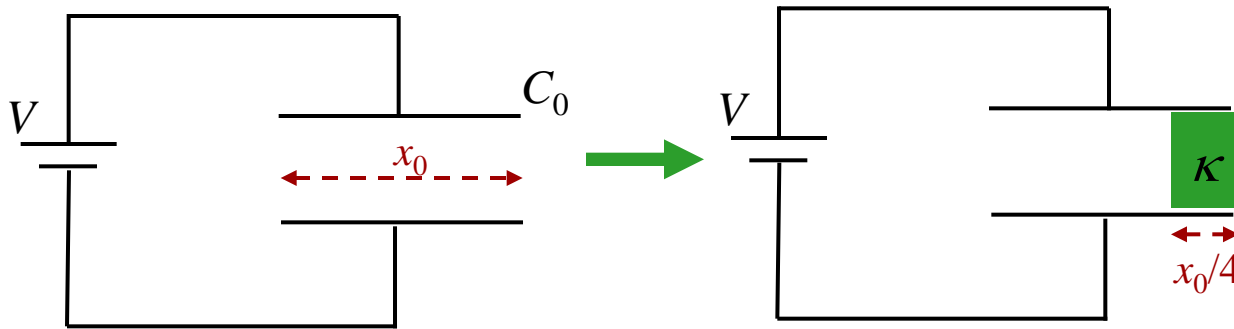
Adding dielectric changes the physical capacitor

→ C changes

V does not change and C changes

→ Q changes

Calculation



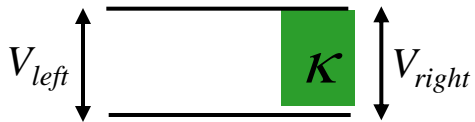
An air-gap capacitor, having capacitance C_0 and width x_0 is connected to a battery of voltage V .

A dielectric (κ) of width $x_0/4$ is inserted into the gap as shown.

Strategic Analysis:

- Calculate new capacitance C
- Apply definition of capacitance to determine Q

To calculate C , let's first look at:



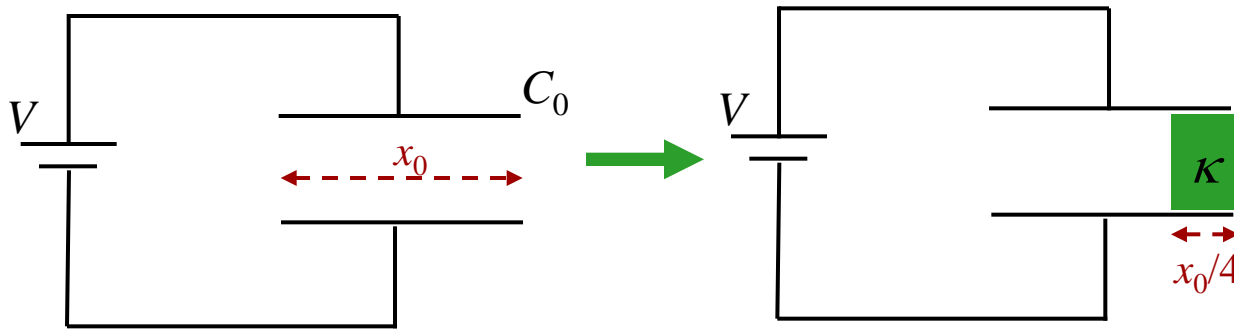
A) $V_{left} < V_{right}$

B) $V_{left} = V_{right}$

C) $V_{left} > V_{right}$

The conducting plate is an equipotential !

Calculation

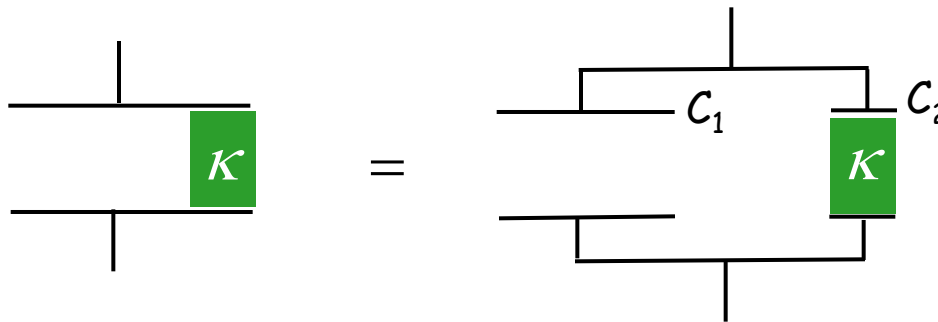


An air-gap capacitor, having capacitance C_0 and width x_0 is connected to a battery of voltage V .

A dielectric (κ) of width $x_0/4$ is inserted into the gap as shown.

What is Q_f , the final charge on the capacitor?

Can consider capacitor to be two capacitances, C_1 and C_2 , in parallel



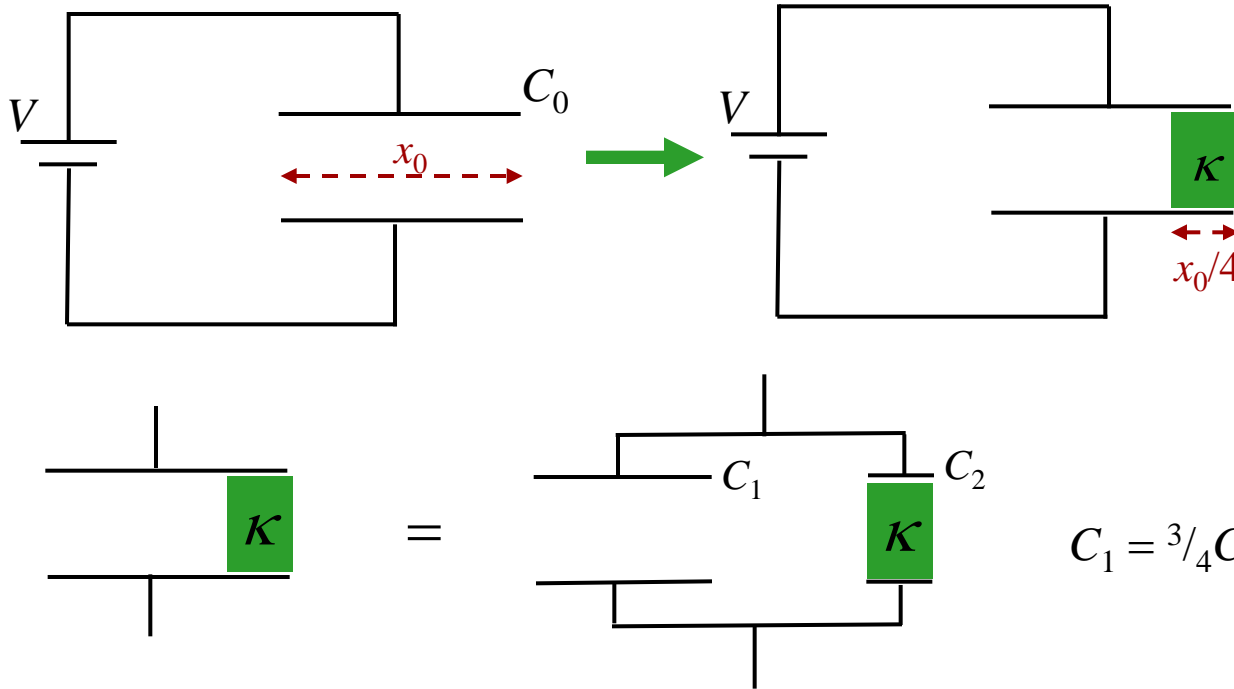
What is C_1 ?

- A) $C_1 = C_0$ B) $C_1 = \frac{3}{4}C_0$ C) $C_1 = \frac{4}{3}C_0$ D) $C_1 = \frac{1}{4}C_0$

In general. For parallel plate capacitor: $C = \epsilon_0 A/d$

$$\begin{array}{l} A = \frac{3}{4}A_0 \\ d = d_0 \end{array} \quad \longrightarrow \quad C_1 = \frac{3}{4}(\epsilon_0 A_0/d_0) \quad \longrightarrow \quad C_1 = \frac{3}{4}C_0$$

Calculation



An air-gap capacitor, having capacitance C_0 and width x_0 is connected to a battery of voltage V .

A dielectric (κ) of width $x_0/4$ is inserted into the gap as shown.

What is Q_f , the final charge on the capacitor?

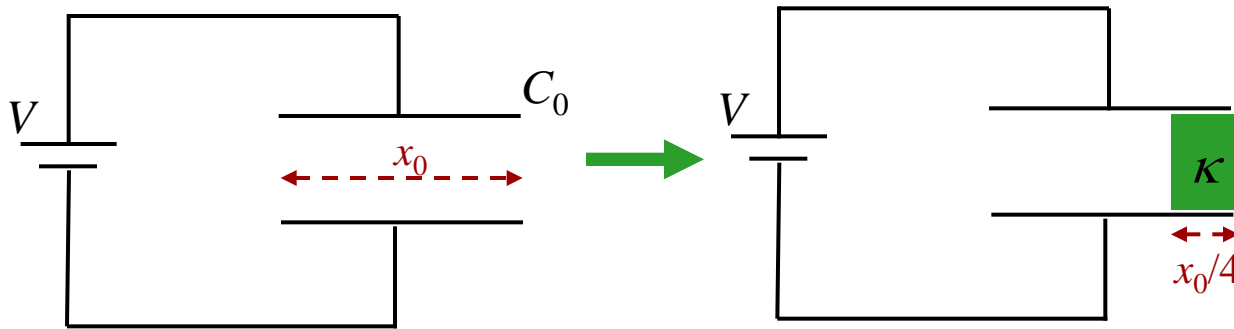
What is C_2 ?

- A) $C_2 = \kappa C_0$
 B) $C_2 = \frac{3}{4} \kappa C_0$
 C) $C_2 = \frac{4}{3} \kappa C_0$
 D) $C_2 = \frac{1}{4} \kappa C_0$

In general. For parallel plate capacitor filled with dielectric: $C = \kappa \epsilon_0 A/d$

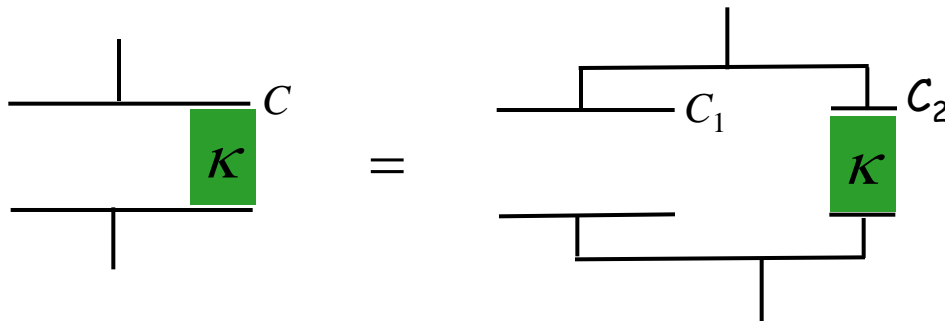
$$\begin{array}{l}
 A = \frac{1}{4} A_0 \\
 d = d_0
 \end{array}
 \quad \Rightarrow \quad
 C = \frac{1}{4} (\kappa \epsilon_0 A_0 / d_0) \quad \Rightarrow \quad
 C_2 = \frac{1}{4} \kappa C_0$$

Calculation



An air-gap capacitor, having capacitance C_0 and width x_0 is connected to a battery of voltage V .

A dielectric (κ) of width $x_0/4$ is inserted into the gap as shown.



$$C_1 = \frac{3}{4}C_0$$

$$C_2 = \frac{1}{4}\kappa C_0$$

What is Q_f , the final charge on the capacitor?

What is C ?

A) $C = C_1 + C_2$

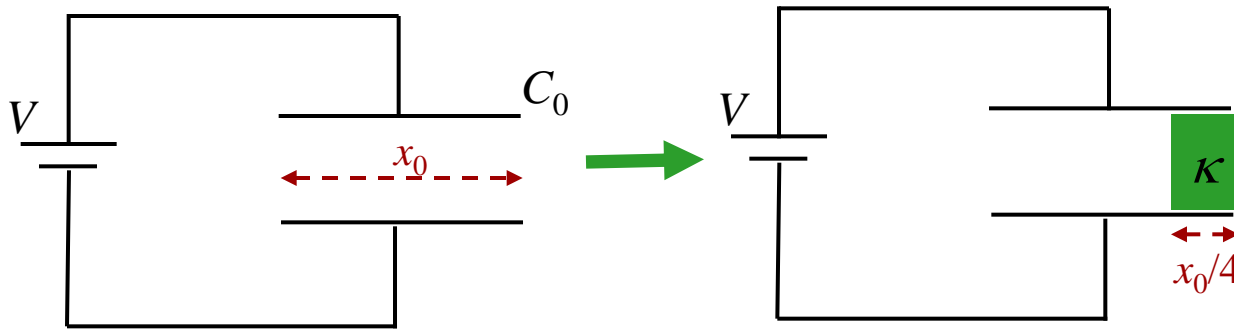
B) $C = C_1 + \kappa C_2$

C) $C = \left(\frac{1}{C_1} + \frac{1}{C_2} \right)^{-1}$

C = parallel combination of C_1 and C_2 : $C = C_1 + C_2$

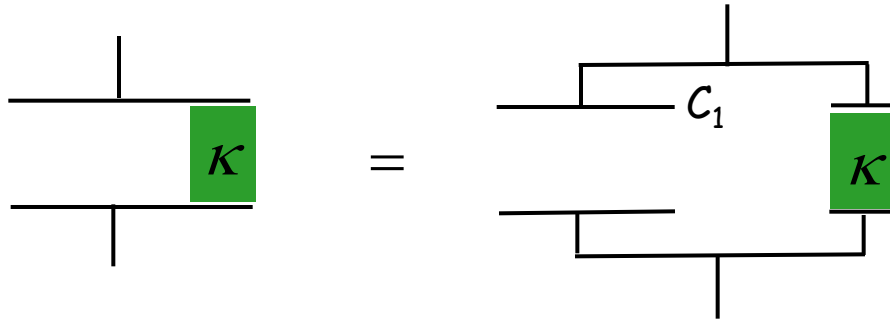
$\rightarrow C = C_0 \left(\frac{3}{4} + \frac{1}{4}\kappa \right)$

Calculation



An air-gap capacitor, having capacitance C_0 and width x_0 is connected to a battery of voltage V .

A dielectric (κ) of width $x_0/4$ is inserted into the gap as shown.



What is Q_f , the final charge on the capacitor?

$$C_1 = \frac{3}{4}C_0$$

$$C_2 = \frac{1}{4}\kappa C_0$$

$$\rightarrow C = C_0 \left(\frac{3}{4} + \frac{1}{4}\kappa \right)$$

What is Q ?

$$C \equiv \frac{Q}{V} \rightarrow Q = VC$$

$$Q_f = VC_0 \left(\frac{3}{4} + \frac{1}{4}\kappa \right)$$