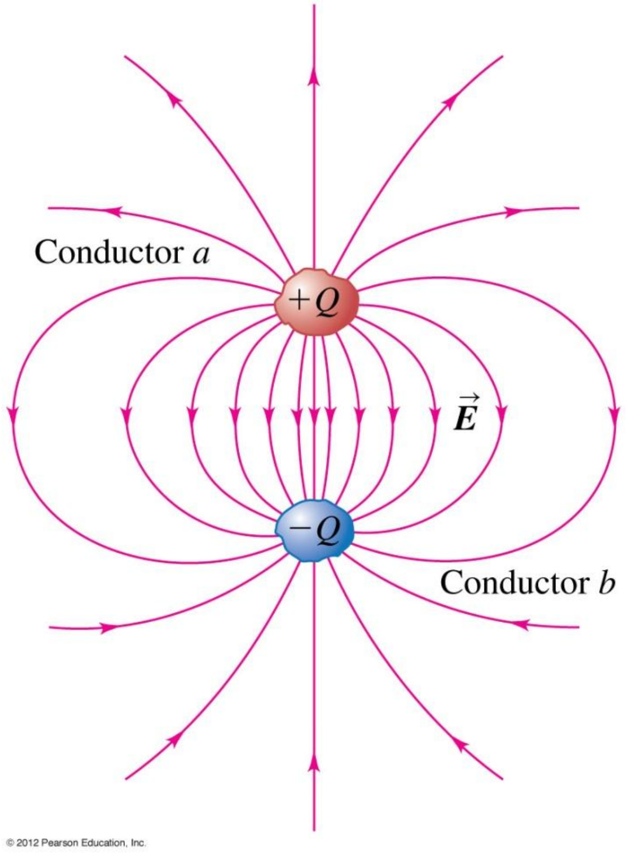
Lecture 19
(Capacitance and Capacitors)

Physics 161-01 Spring 2012

Douglas Fields

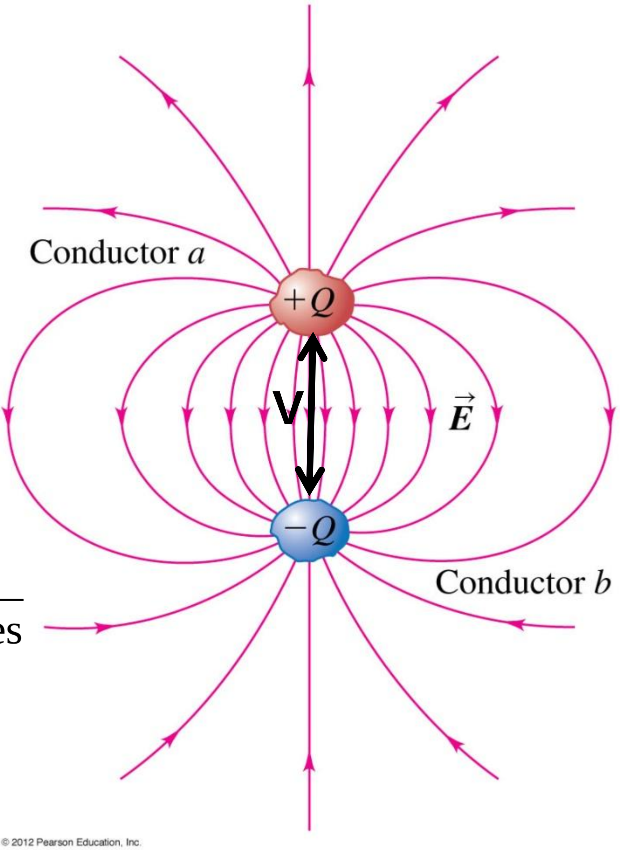
Capacitors

- A capacitor is any object or system of objects which can hold a charge separated from an opposite charge.



Capacitance

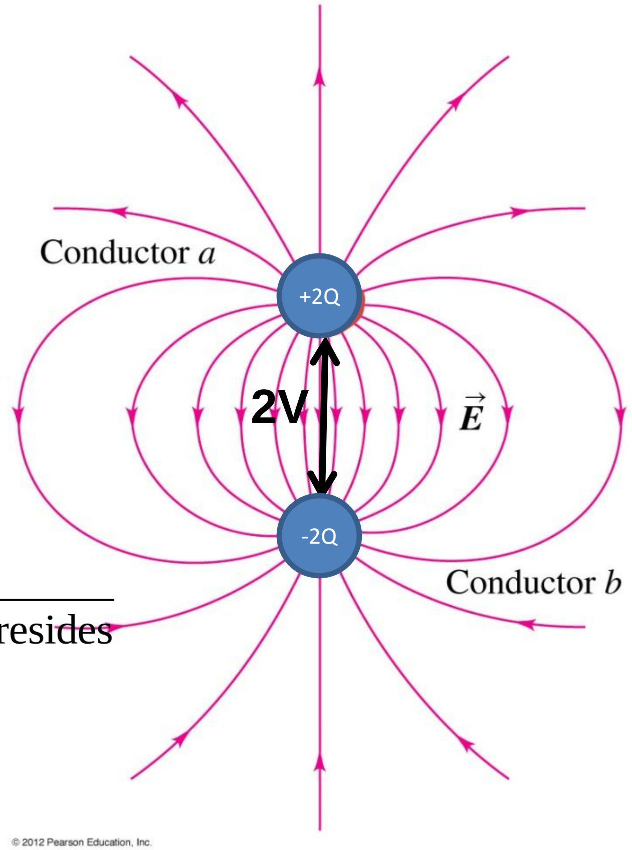
- The capacitance is a property of the ***system*** (not the charge that is put on the system) that relates the amount of charge to the potential difference between the objects.



$$C \equiv \frac{\text{Charge on object}}{\text{Potential of object relative to place where opposite charge resides}}$$

Capacitance

- Remember, the capacitance is a property of the ***system*** (not the charge that is put on the system) that relates the amount of charge to the potential difference between the objects.
- So, if you double the charge, the potential will also double.
- How is the capacitance affected?



$$C \equiv \frac{\text{Charge on object}}{\text{Potential of object relative to place where opposite charge resides}}$$

$$C \equiv \frac{Q}{V} = \frac{2Q}{2V}$$

CPS 19-1

The two conductors *a* and *b* are insulated from each other, forming a capacitor. You increase the charge on *a* to $+2Q$ and increase the charge on *b* to $-2Q$, while keeping the conductors in the same positions.

As a result of this change, the capacitance *C* of the two conductors

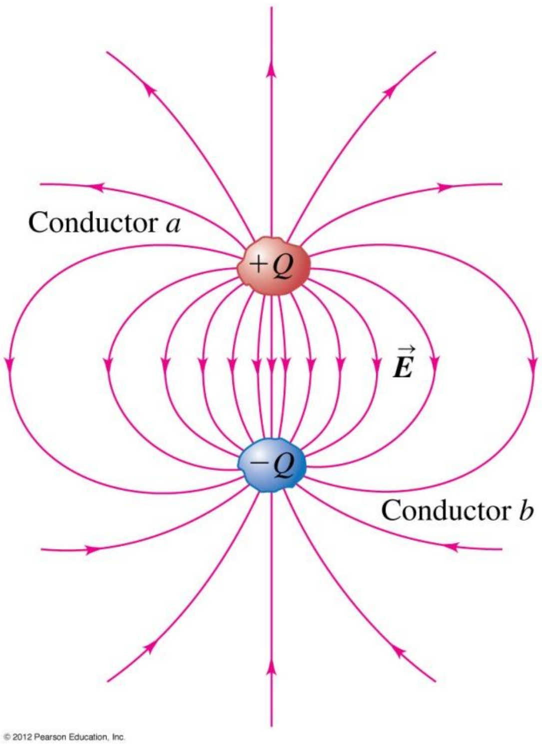
A. becomes 4 times great.

B. B. becomes twice as great.

C. remains the same.

D. becomes 1/2 as great.

E. becomes 1/4 as great.



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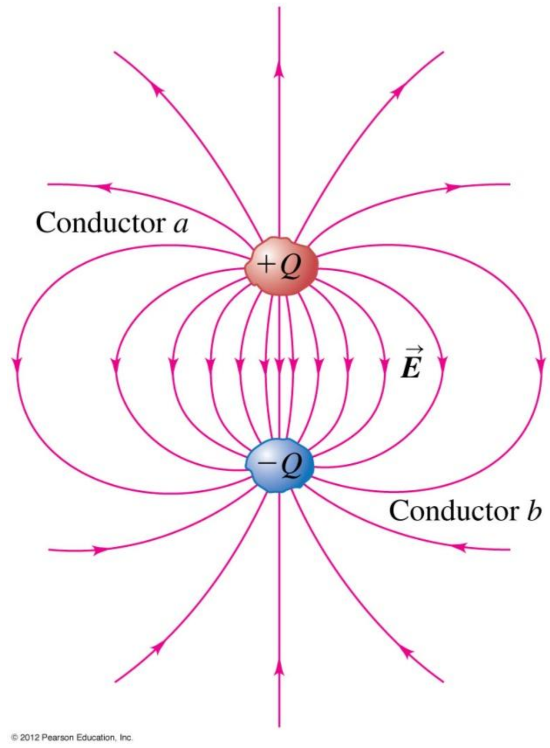

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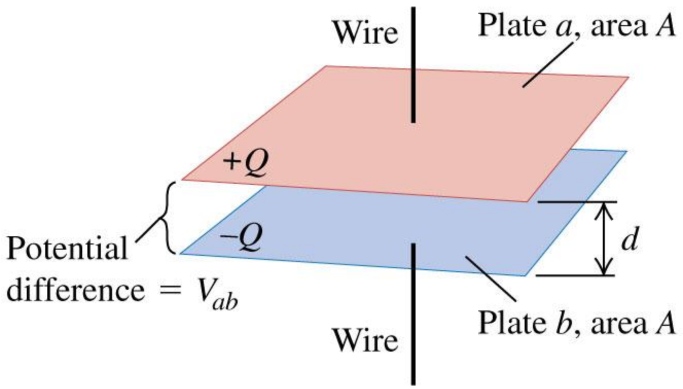
Parallel Plate Capacitor

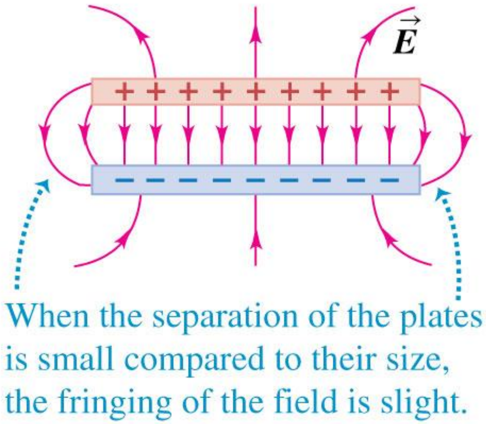
- Steps to find capacitance:
  - Find the potential given a certain amount of charge.
    - Do this by first finding the electric field, then integrating the field to find the potential.
  - Then just divide the charge by the potential.

$$C = \frac{Q}{V} = \frac{\sigma A}{Ed} = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0} d} = \frac{\varepsilon_0 A}{d}$$

(a) Arrangement of the capacitor plates



(b) Side view of the electric field $\vec{E}$



CPS 19-2

You reposition the two plates of a capacitor so that the capacitance doubles. There is vacuum between the plates.

If the charges $+Q$ and $-Q$ on the two plates are kept constant in this process, what happens to the potential difference V_{ab} between the two plates?

A. V_{ab} becomes 4 times as great.

B. V_{ab} becomes twice as great.

C. V_{ab} remains the same.

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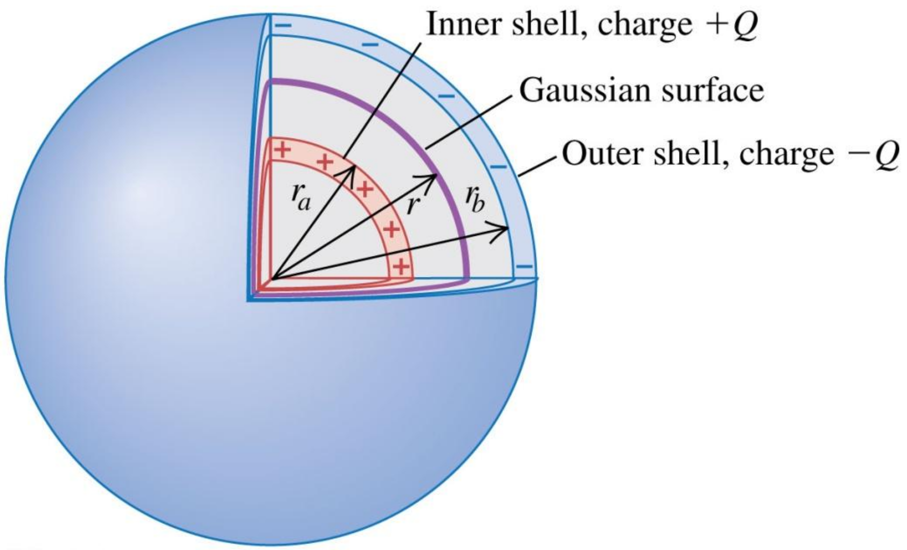
Spherical Capacitor

- Steps to find capacitance:
  - Find the potential given a certain amount of charge.
    - Do this by first finding the electric field, then integrating the field to find the potential.
  - Then just divide the charge by the potential.

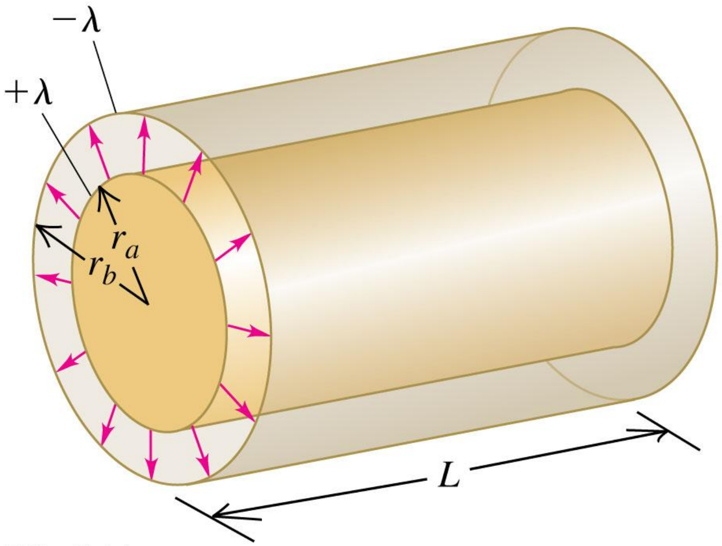
$$C = \frac{Q}{V}$$



Cylindrical Capacitor

- Steps to find capacitance:
  - Find the potential given a certain amount of charge.
    - Do this by first finding the electric field, then integrating the field to find the potential.
  - Then just divide the charge by the potential.

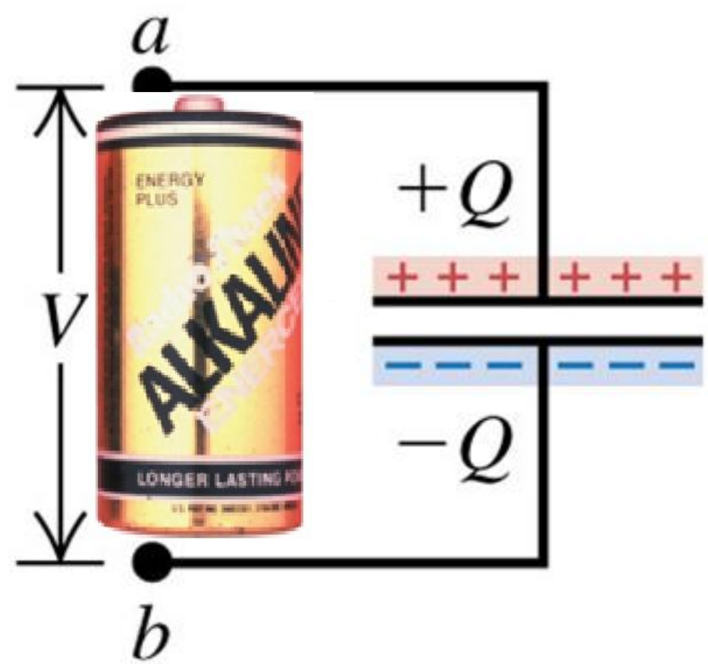
$$C = \frac{Q}{V}$$



Capacitors in Circuits

- Capacitors are used in circuits extensively.

$$Q = CV$$

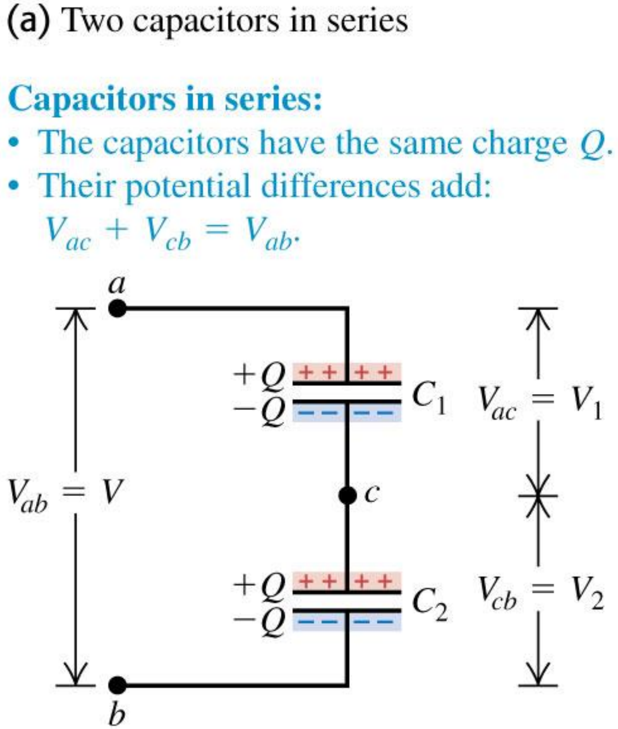


Capacitors in Series

- Capacitors in series:
  - Have the same charge
  - Potential difference across them add

$$V_1 + V_2 = V$$

$$Q_1 = Q_2 = Q$$



Capacitors in Series

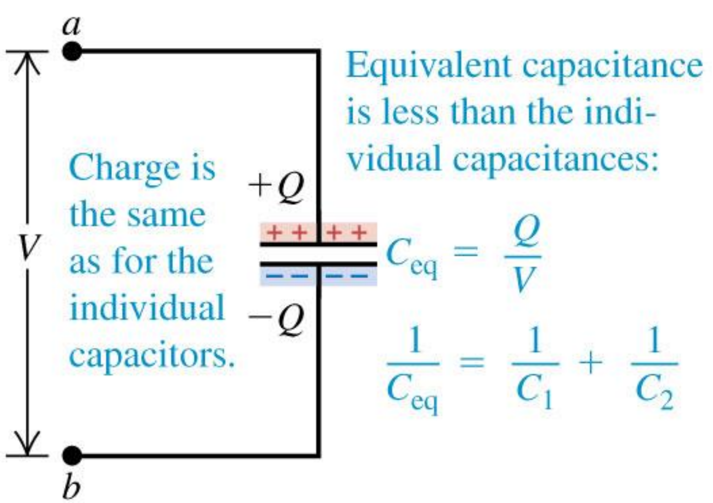
- If you wanted to replace these capacitors with just one equivalent capacitor:

$$C_{\text{eq}} = \frac{Q}{V} = \frac{Q}{V_1 + V_2} \Rightarrow$$

$$\frac{1}{C_{\text{eq}}} = \frac{V_1 + V_2}{Q} = \frac{V_1}{Q} + \frac{V_2}{Q} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow$$

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

(b) The equivalent single capacitor

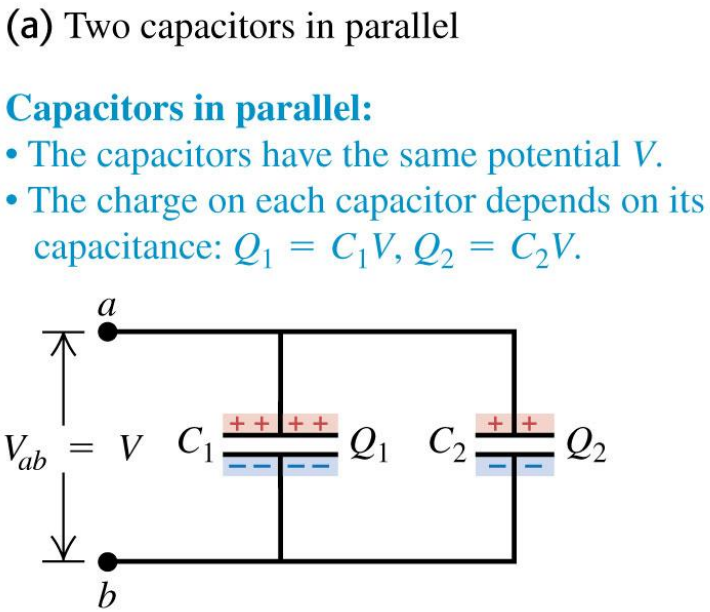


Capacitor in Parallel

- Capacitors in parallel:
  - Have the same potential
  - Charge depends on capacitance

$$V_1 = V_2 = V$$

$$Q_1 = C_1 V$$
$$Q_2 = C_2 V$$



Capacitor in Parallel

- If you wanted to replace these capacitors with just one equivalent capacitor:

$$C_{\text{eq}} = \frac{Q}{V} = \frac{Q_1 + Q_2}{V} \Rightarrow$$

$$C_{\text{eq}} = \frac{Q_1}{V} + \frac{Q_2}{V} = C_1 + C_2 \Rightarrow$$

$$C_{\text{eq}} = C_1 + C_2$$

(b) The equivalent single capacitor