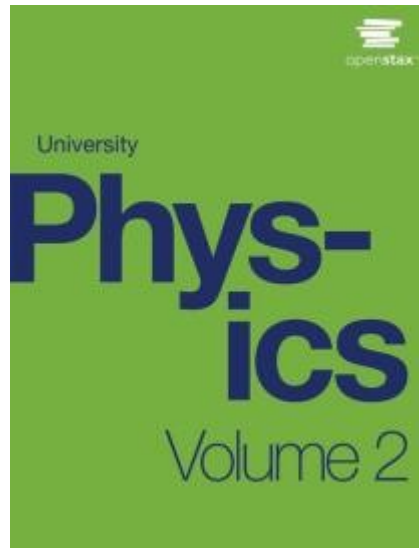


# UNIVERSITY PHYSICS

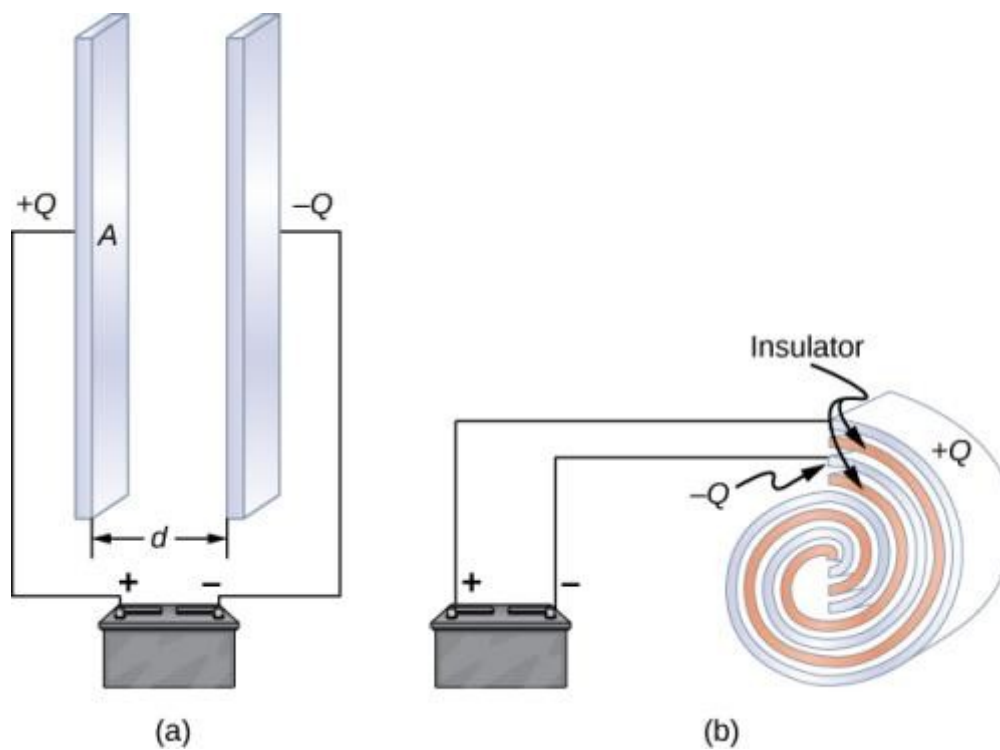
## Chapter 8 CAPACITANCE

PowerPoint Image Slideshow



**What is a capacitor?**

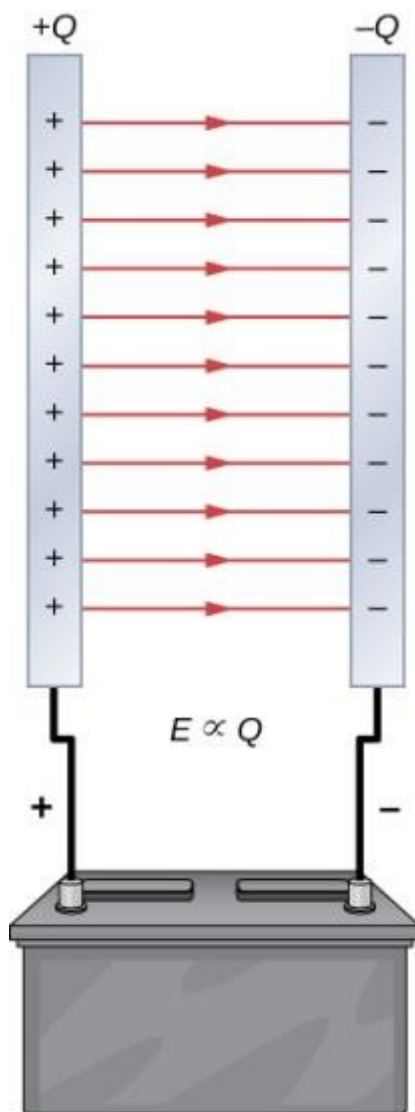
## FIGURE 8.2



Both capacitors shown here were initially uncharged before being connected to a battery. They now have charges of  $+Q$  and  $-Q$  (respectively) on their plates.

- a) A parallel-plate capacitor consists of two plates of opposite charge with area  $A$  separated by distance  $d$ .
- b) A rolled capacitor has a dielectric material between its two conducting sheets (plates).

# FIGURE 8.3



The charge separation in a capacitor shows that the charges remain on the surfaces of the capacitor plates. Electrical field lines in a parallel-plate capacitor begin with positive charges and end with negative charges. The magnitude of the electrical field in the space between the plates is in direct proportion to the amount of charge on the capacitor.

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

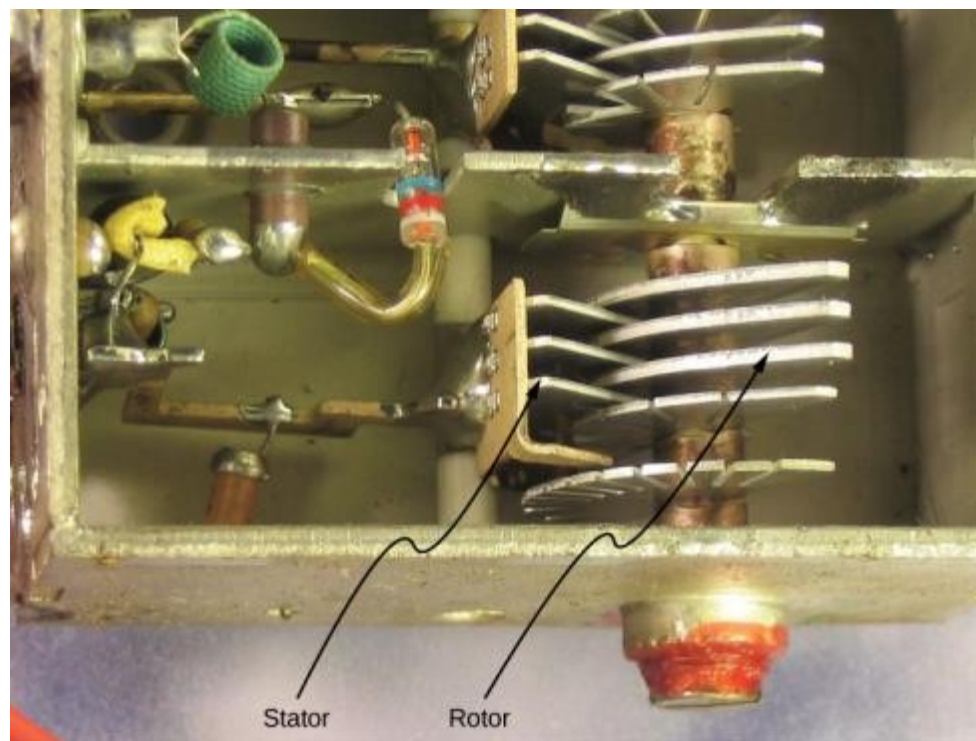
$$E = \frac{\sigma}{\epsilon_0} = \frac{V}{d} = \frac{Q}{\epsilon_0 A}$$

## FIGURE 8.4



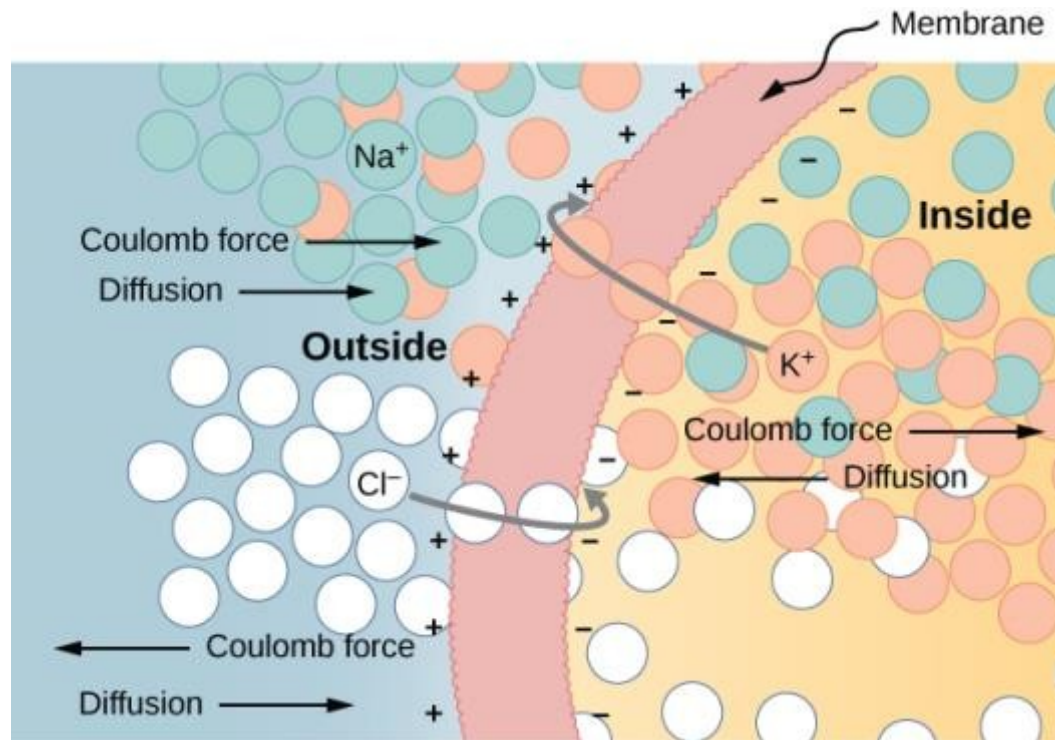
These are some typical capacitors used in electronic devices. A capacitor's size is not necessarily related to its capacitance value.

## FIGURE 8.8



In a variable air capacitor, capacitance can be tuned by changing the effective area of the plates. (credit: modification of work by Robbie Sproule)

## FIGURE 8.10



The semipermeable membrane of a biological cell has different concentrations of ions on its interior surface than on its exterior. Diffusion moves the  $\text{K}^+$  (potassium) and  $\text{Cl}^-$  (chloride) ions in the directions shown, until the Coulomb force halts further transfer. In this way, the exterior of the membrane acquires a positive charge and its interior surface acquires a negative charge, creating a potential difference across the membrane. The membrane is normally impermeable to  $\text{Na}^+$  (sodium ions).

# SQUID GIANT AXON



<https://www.youtube.com/watch?v=CXCGqwdtJ78>

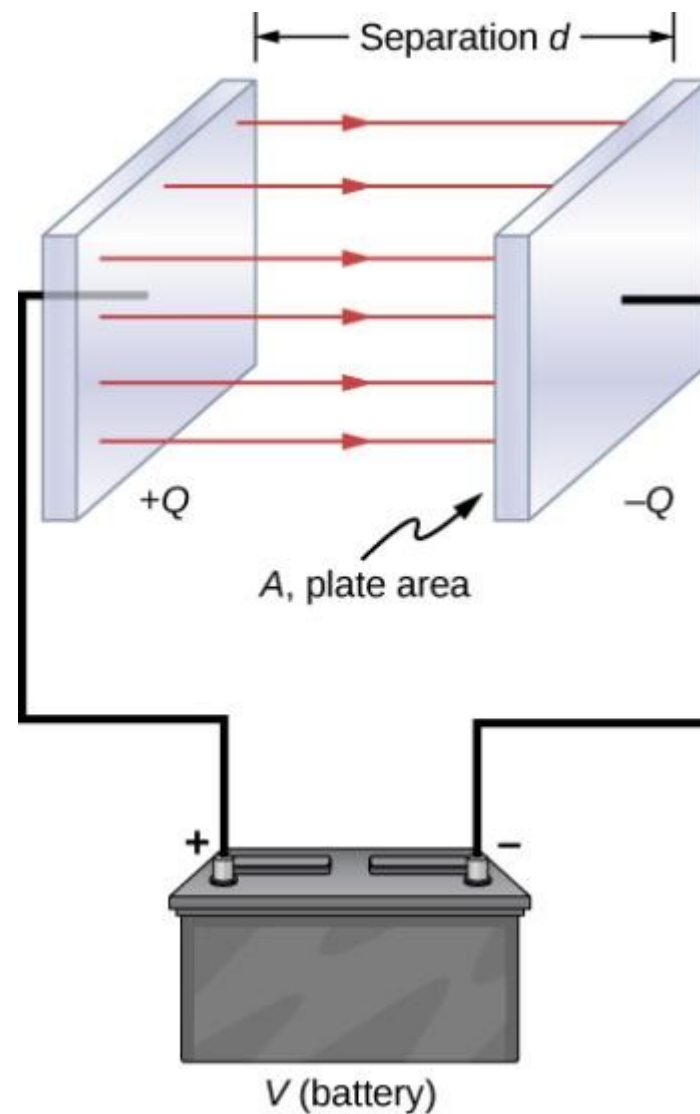


# Capacitor shapes

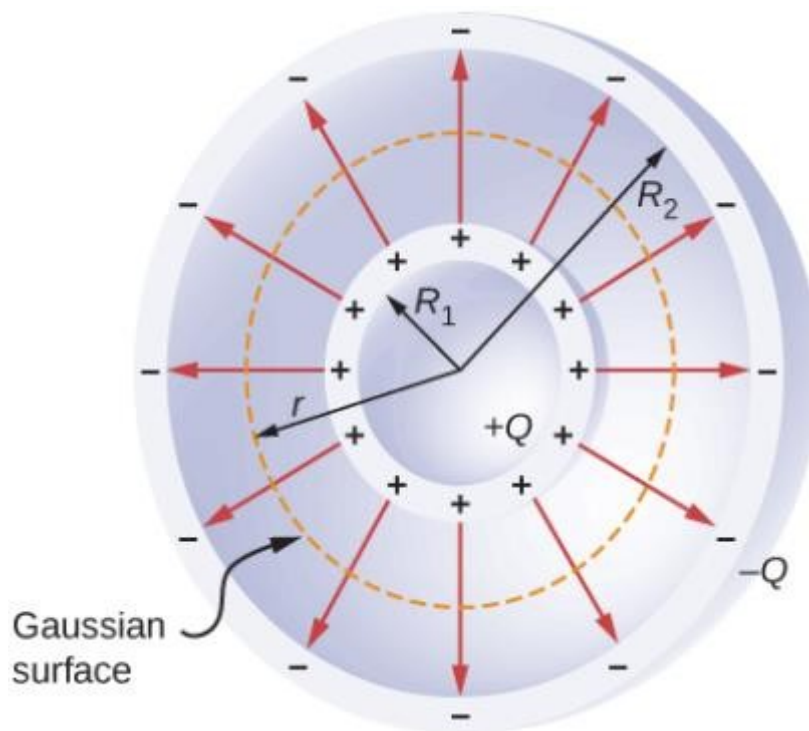
**FIGURE 8.5**

In a parallel-plate capacitor with plates separated by a distance  $d$ , each plate has the same surface area  $A$ .

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



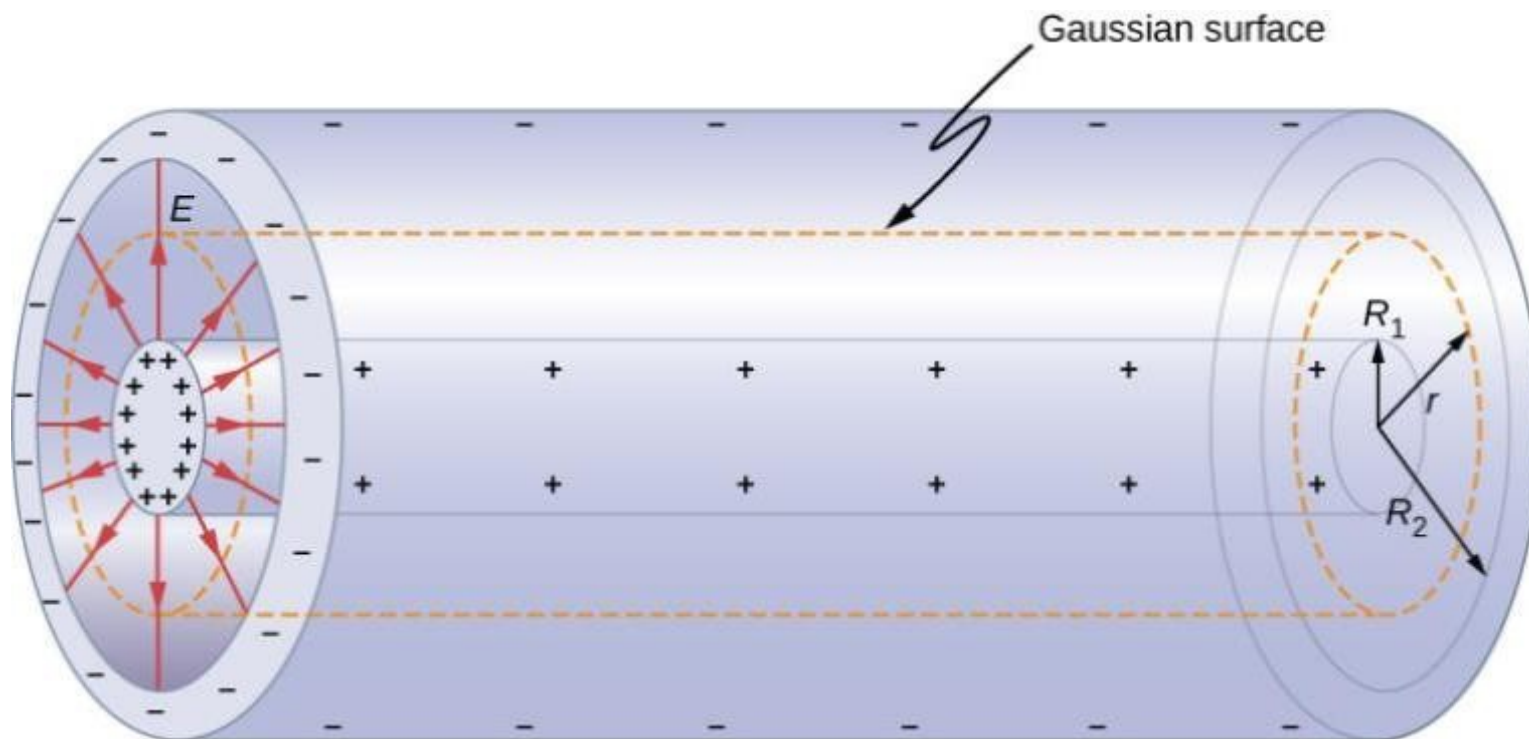
## FIGURE 8.6



A spherical capacitor consists of two concentric conducting spheres. Note that the charges on a conductor reside on its surface.

$$C = \frac{Q}{V} = 4\pi\epsilon_0 \frac{R_1 R_2}{R_2 - R_1}$$

**FIGURE 8.7**

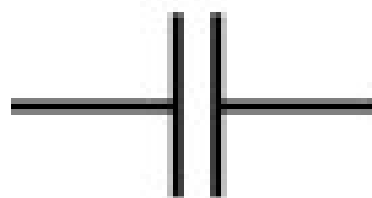


A cylindrical capacitor consists of two concentric, conducting cylinders. Here, the charge on the outer surface of the inner cylinder is positive (indicated by +) and the charge on the inner surface of the outer cylinder is negative (indicated by -).

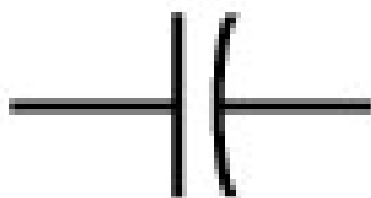
$$C = \frac{Q}{V} = \frac{2\pi\epsilon_0 l}{\ln R_2/R_1}$$

# Circuits

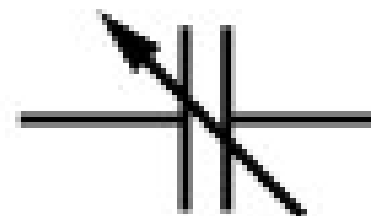
## FIGURE 8.9



(a)



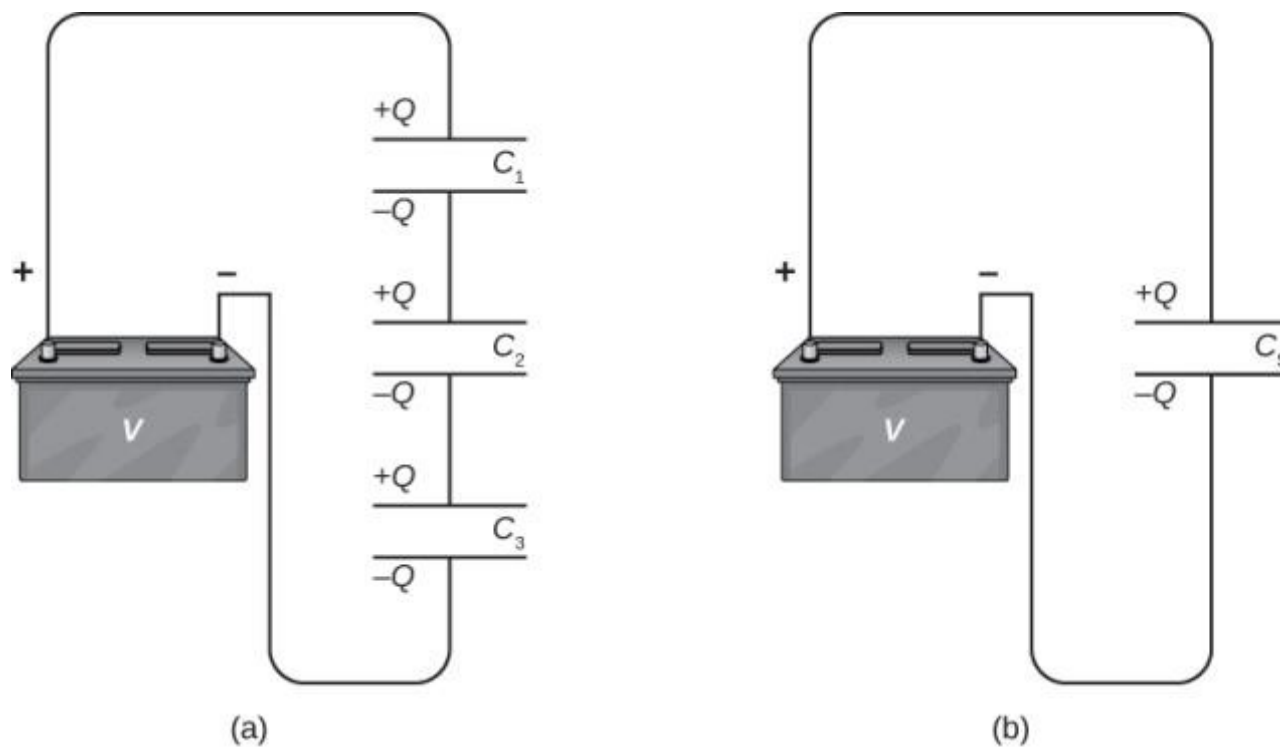
(b)



(c)

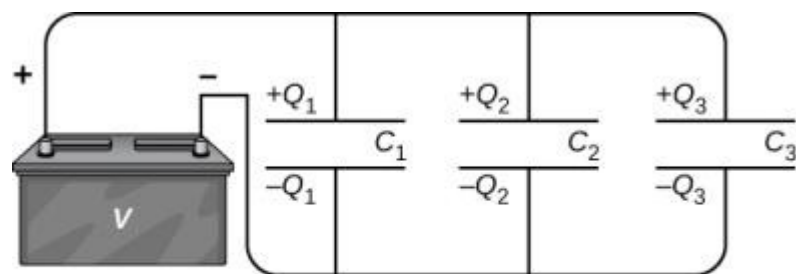
This shows three different circuit representations of capacitors. The symbol in (a) is the most commonly used one. The symbol in (b) represents an electrolytic capacitor. The symbol in (c) represents a variable-capacitance capacitor.

## FIGURE 8.11

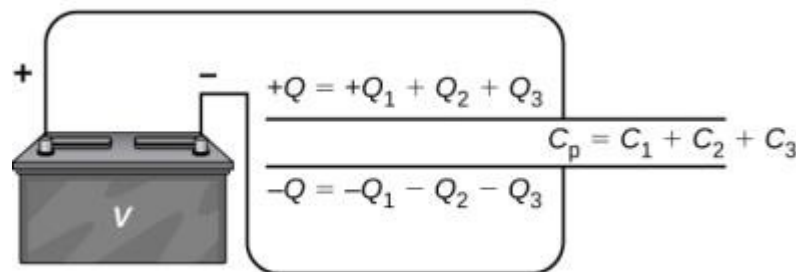


- a) Three capacitors are connected in series. The magnitude of the charge on each plate is  $Q$ .
- b) The network of capacitors in (a) is equivalent to one capacitor that has a smaller capacitance than any of the individual capacitances in (a), and the charge on its plates is  $Q$ .

## FIGURE 8.12



(a)

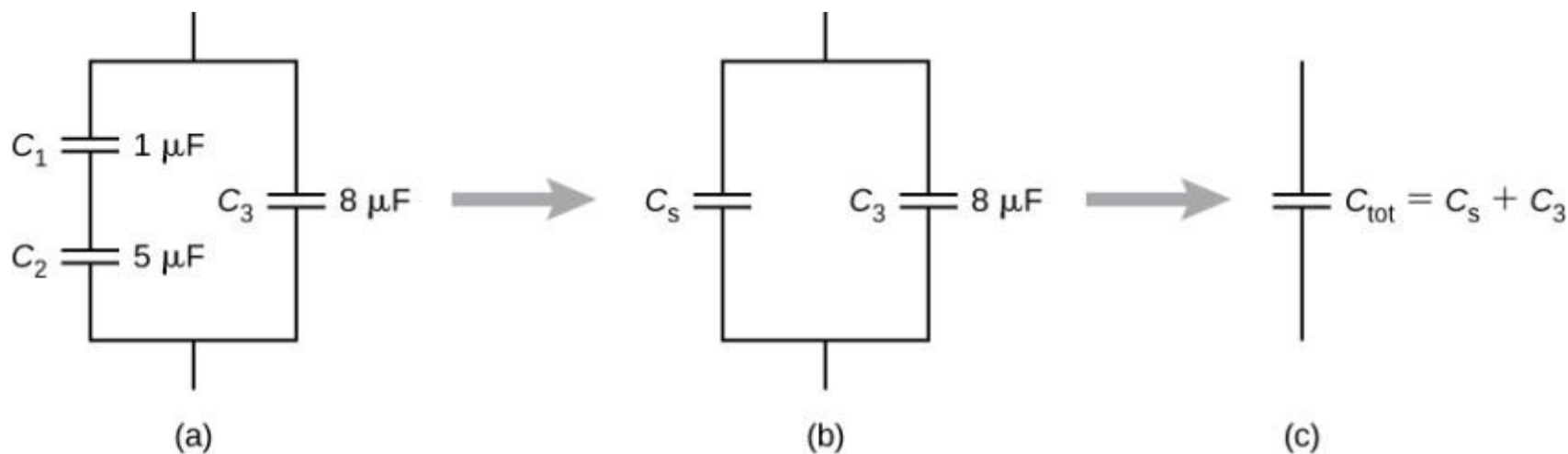


(b)

- a) Three capacitors are connected in parallel. Each capacitor is connected directly to the battery.
- b) The charge on the equivalent capacitor is the sum of the charges on the individual capacitors.

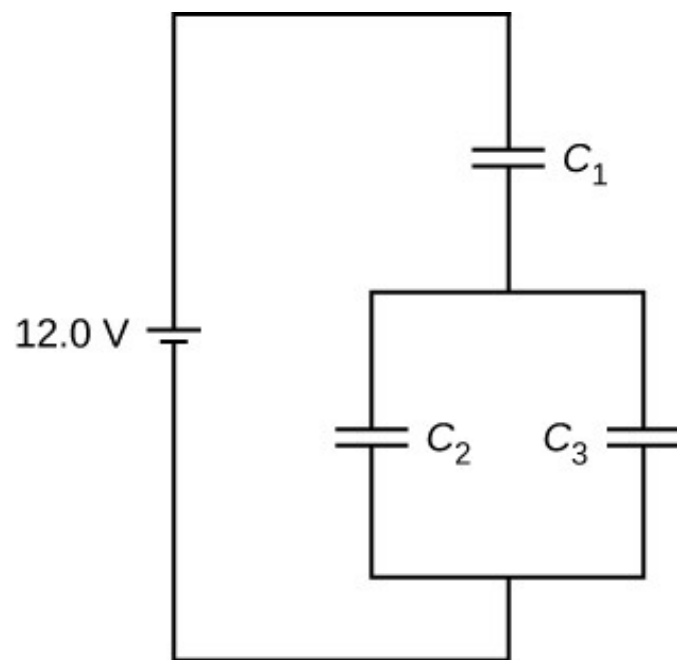


## FIGURE 8.13

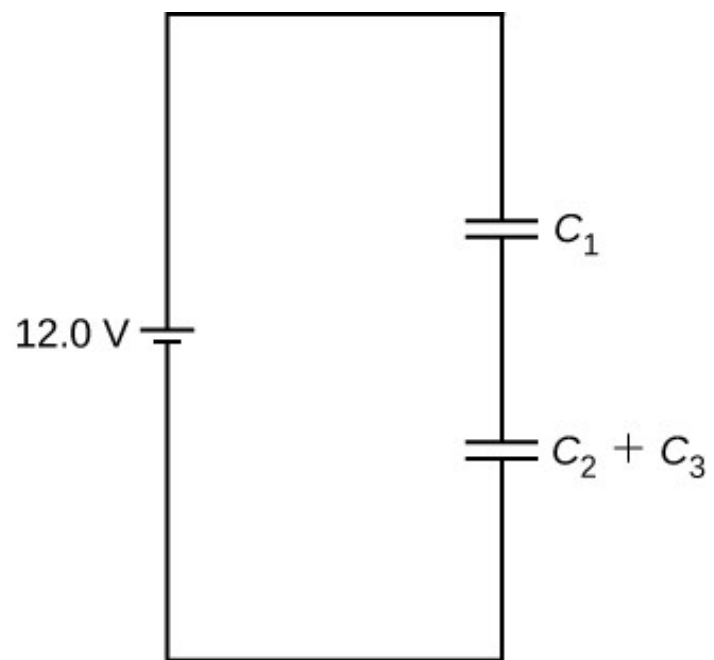


- This circuit contains both series and parallel connections of capacitors.
- $C_1$  and  $C_2$  are in series; their equivalent capacitance is  $C_s$ .
- The equivalent capacitance  $C_s$  is connected in parallel with  $C_3$ . Thus, the equivalent capacitance of the entire network is the sum of  $C_s$  and  $C_3$ .

## FIGURE 8.14



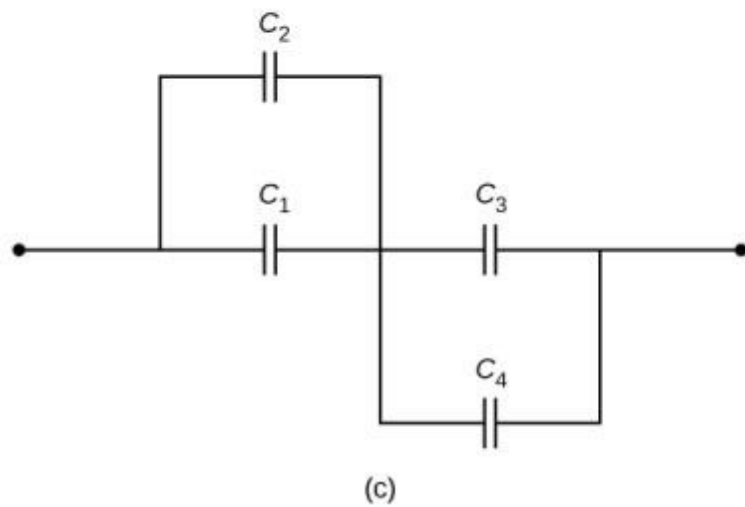
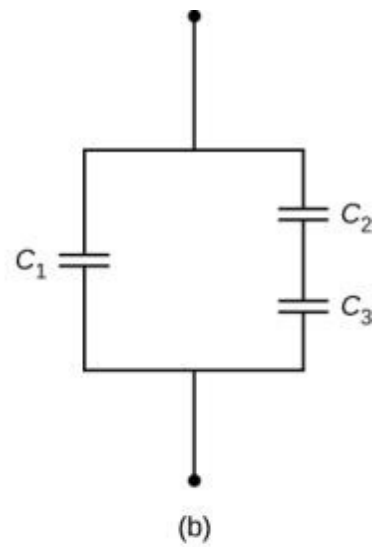
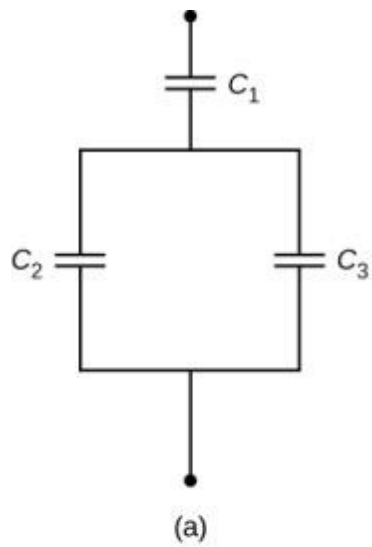
(a)



(b)

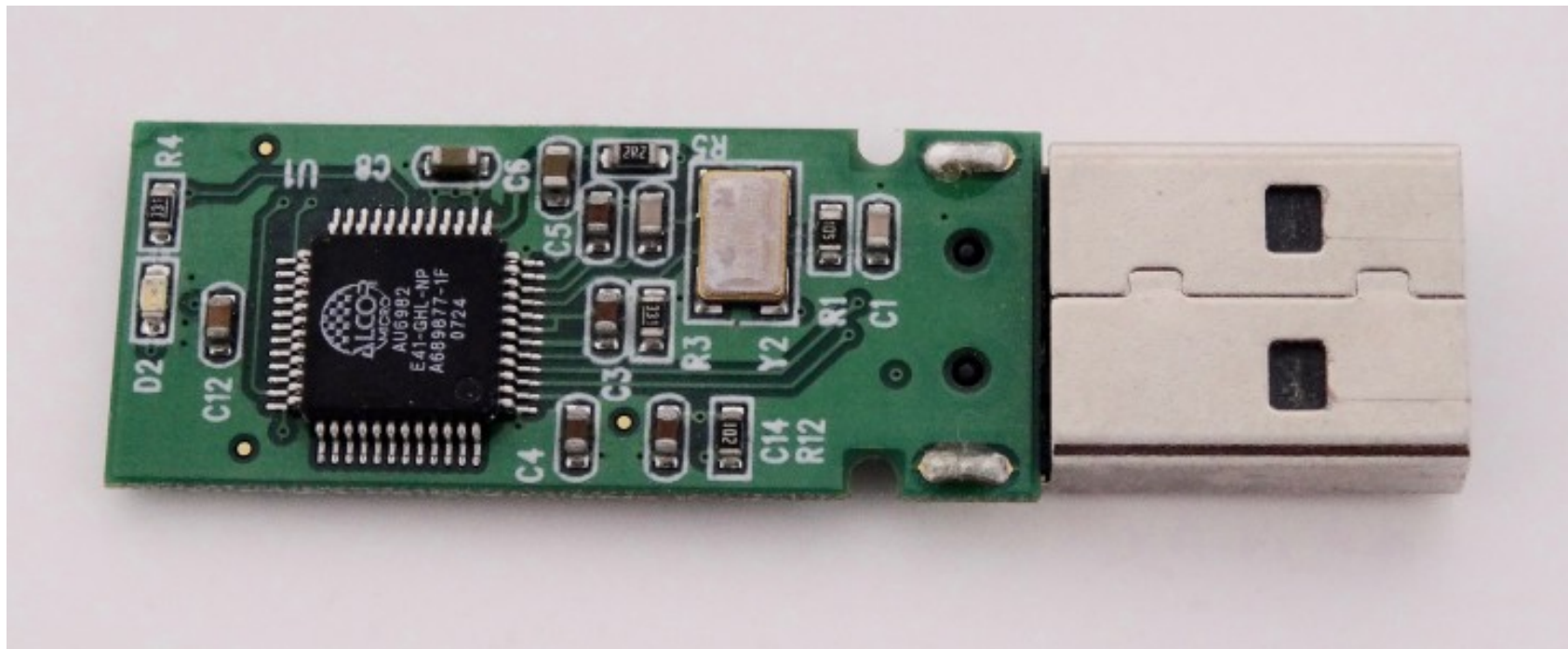
- a) A capacitor combination.
- b) An equivalent two-capacitor combination.

# EXERCISE 8.5



# Applications

## FIGURE 8.15



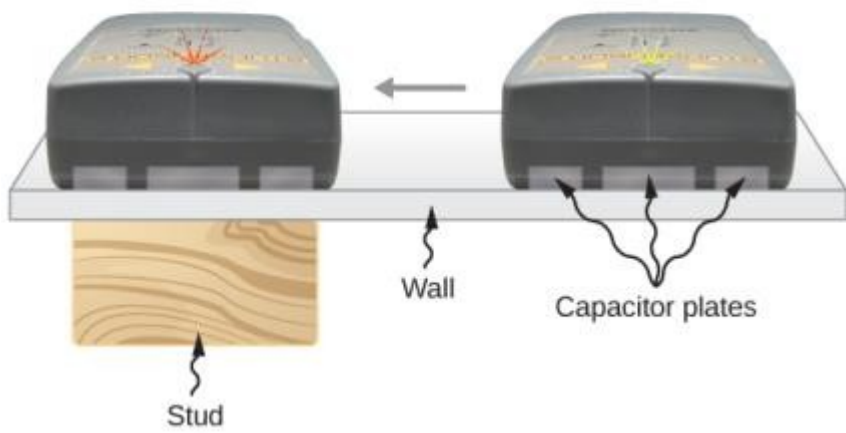
The capacitors on the circuit board for an electronic device follow a labeling convention that identifies each one with a code that begins with the letter “C.”

Automated external defibrillators are found in many public places. These portable units provide verbal instructions for use in the important first few minutes for a person suffering a cardiac attack.



# FIGURE 8.18

An electronic stud finder is used to detect wooden studs behind drywall.

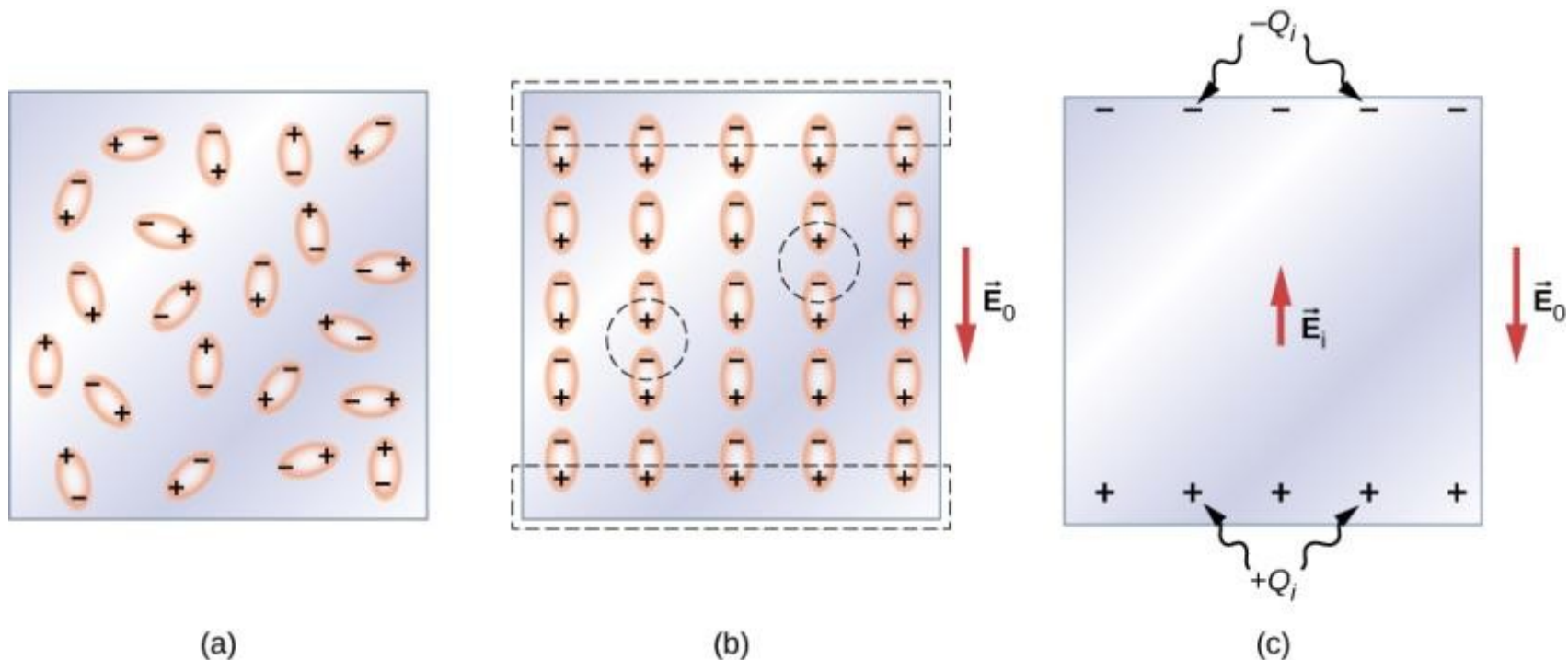


# Dielectric materials



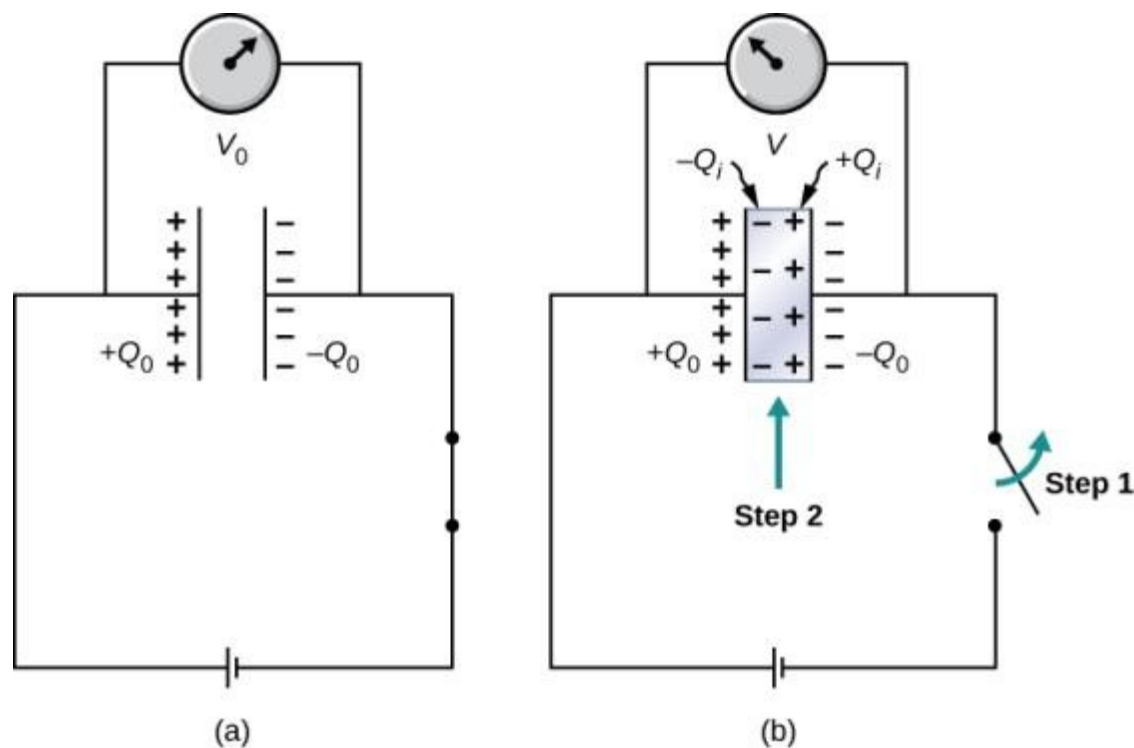


## FIGURE 8.20



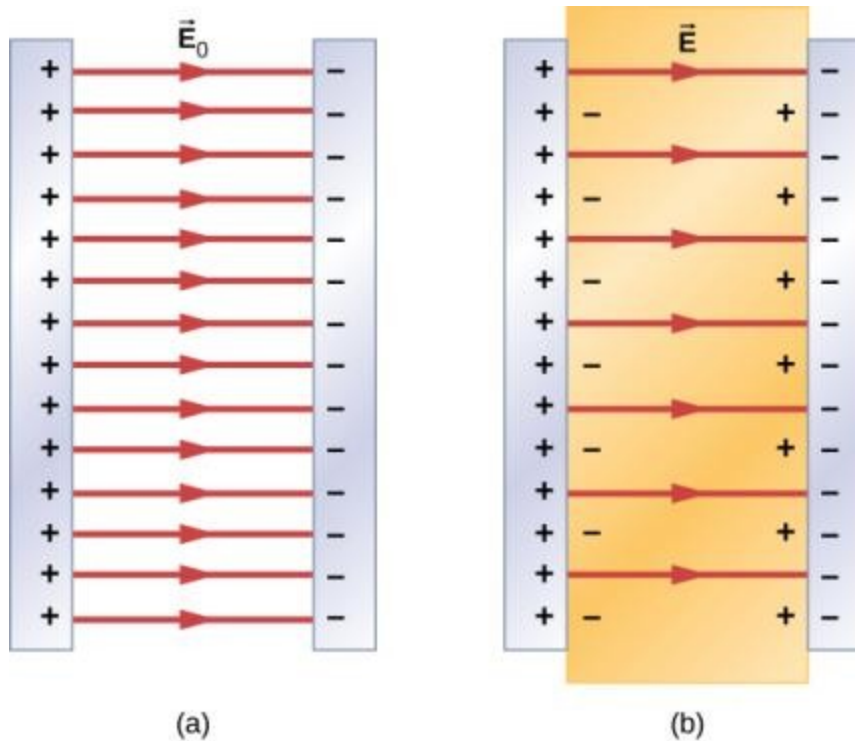
A dielectric with polar molecules: (a) In the absence of an external electrical field; (b) in the presence of an external electrical field  $\vec{E}_0$ . The dashed lines indicate the regions immediately adjacent to the capacitor plates. (c) The induced electrical field  $\vec{E}_i$  inside the dielectric produced by the induced surface charge  $Q_i$  of the dielectric. Note that, in reality, the individual molecules are not perfectly aligned with an external field because of thermal fluctuations; however, the *average* alignment is along the field lines as shown.

## FIGURE 8.17



- When fully charged, a vacuum capacitor has a voltage  $V_0$  and charge  $Q_0$  (the charges remain on plate's inner surfaces; the schematic indicates the sign of charge on each plate).
- In step 1, the battery is disconnected. Then, in step 2, a dielectric (that is electrically neutral) is inserted into the charged capacitor. When the voltage across the capacitor is now measured, it is found that the voltage value has decreased to  $V = V_0/\kappa$ . The schematic indicates the sign of the induced charge that is now present on the surfaces of the dielectric material between the plates.

# FIGURE 8.21

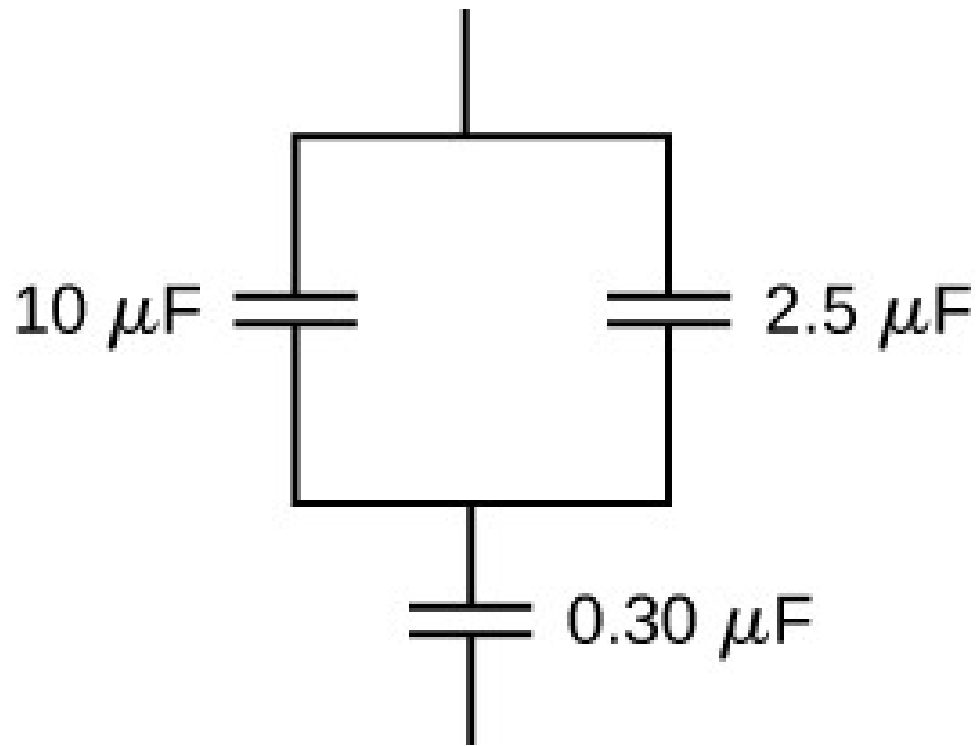


Electrical field:

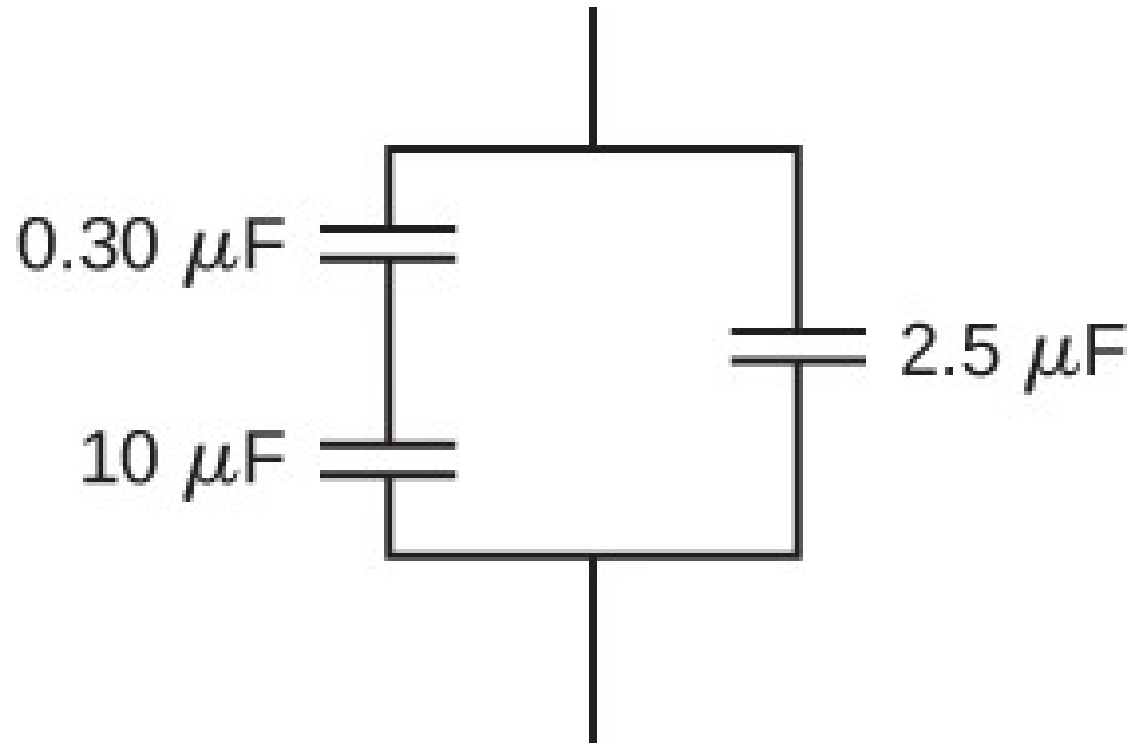
- a) In an empty capacitor, electrical field  $E_0$ .
- b) In a dielectric-filled capacitor, electrical field  $E$ .

# Examples

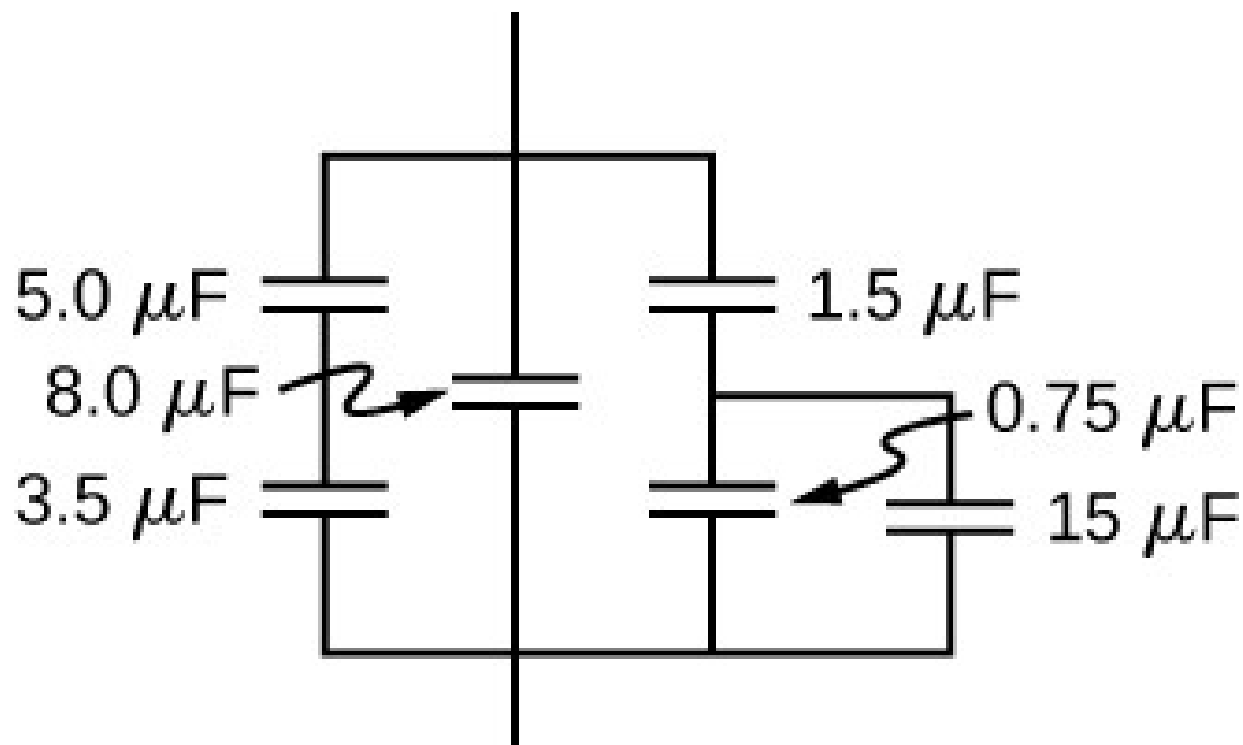
## EXERCISE 33



## EXERCISE 36



## EXERCISE 37





**End**



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