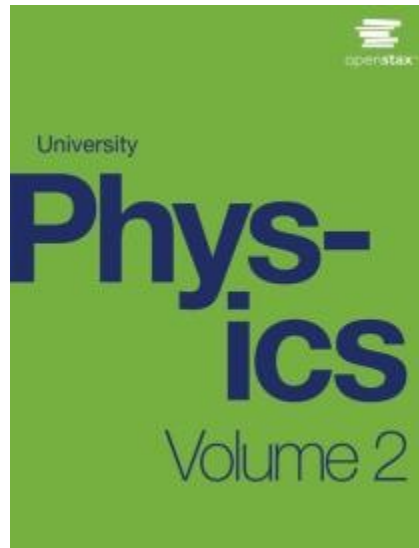


UNIVERSITY PHYSICS

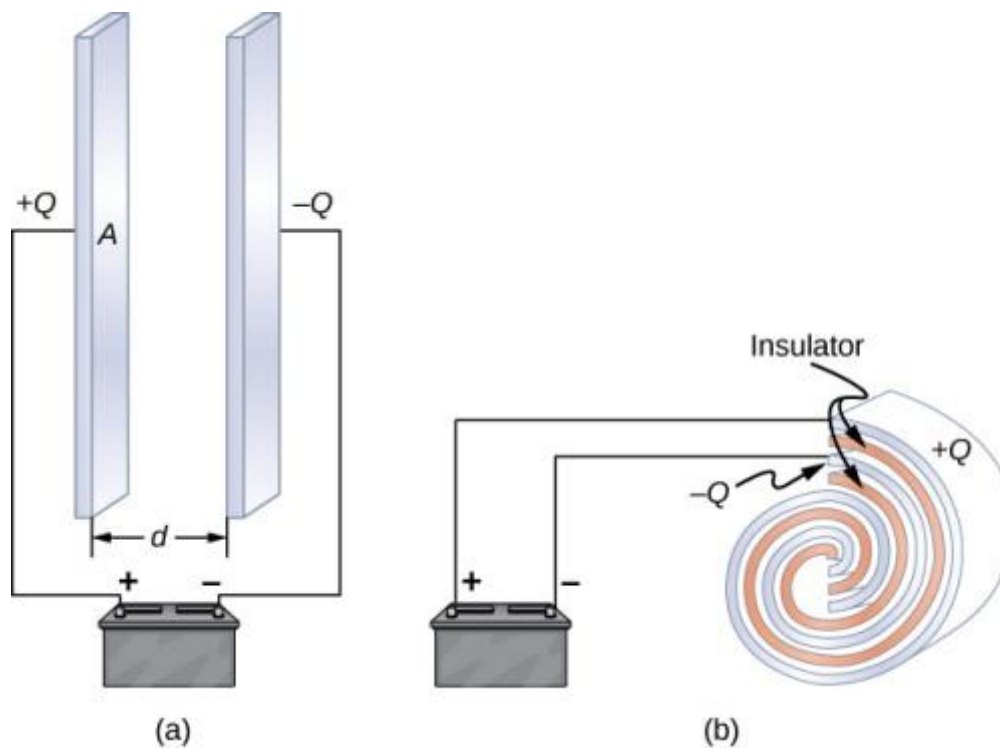
Chapter 8 CAPACITANCE

PowerPoint Image Slideshow



What is a capacitor?

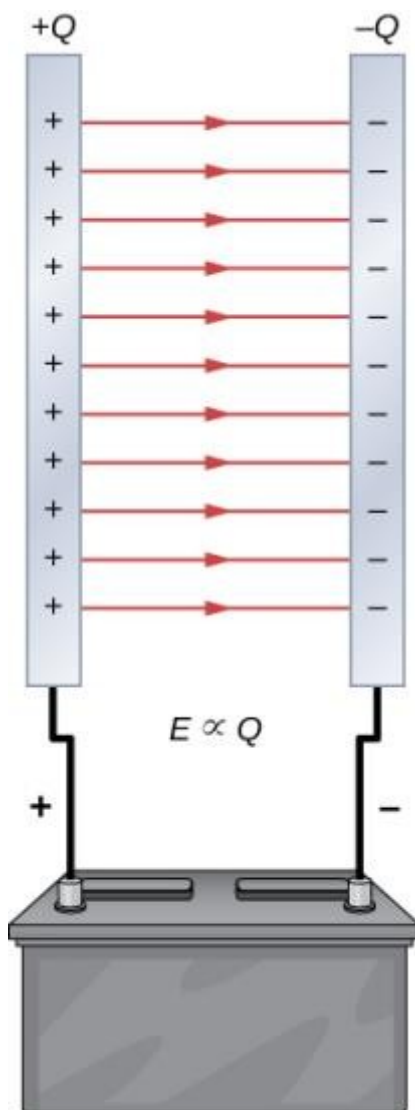
FIGURE 8.2



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

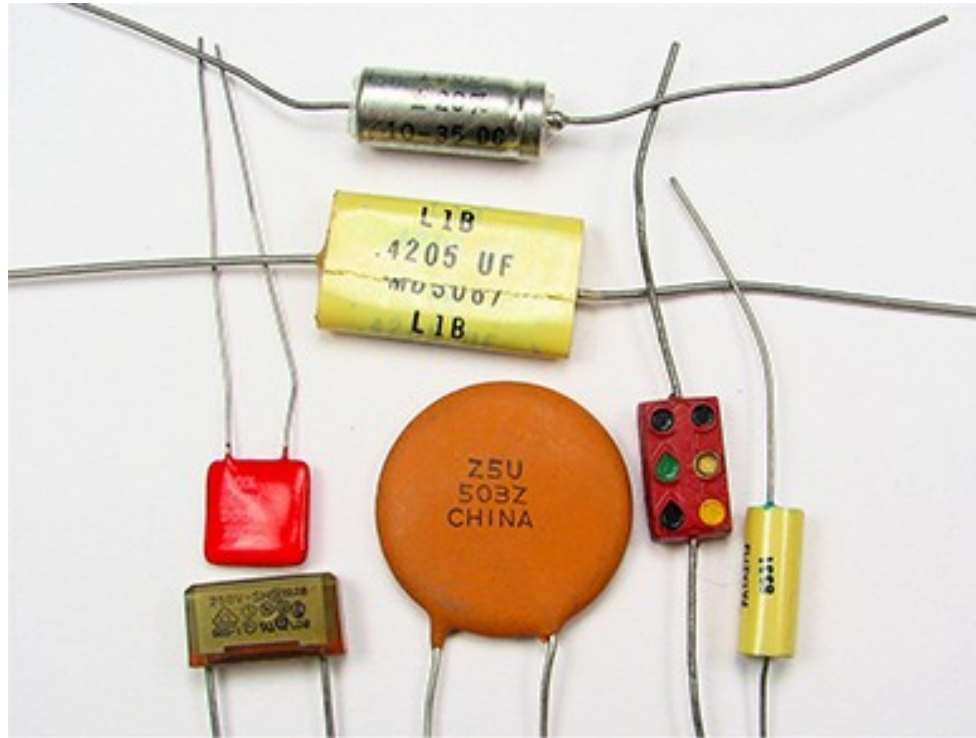


The charge separation in a capacitor shows that the charges remain on the surfaces of the capacitor plates. Electrical field lines in a parallel-plate capacitor begin with positive charges and end with negative charges. The magnitude of the electrical field in the space between the plates is in direct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

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

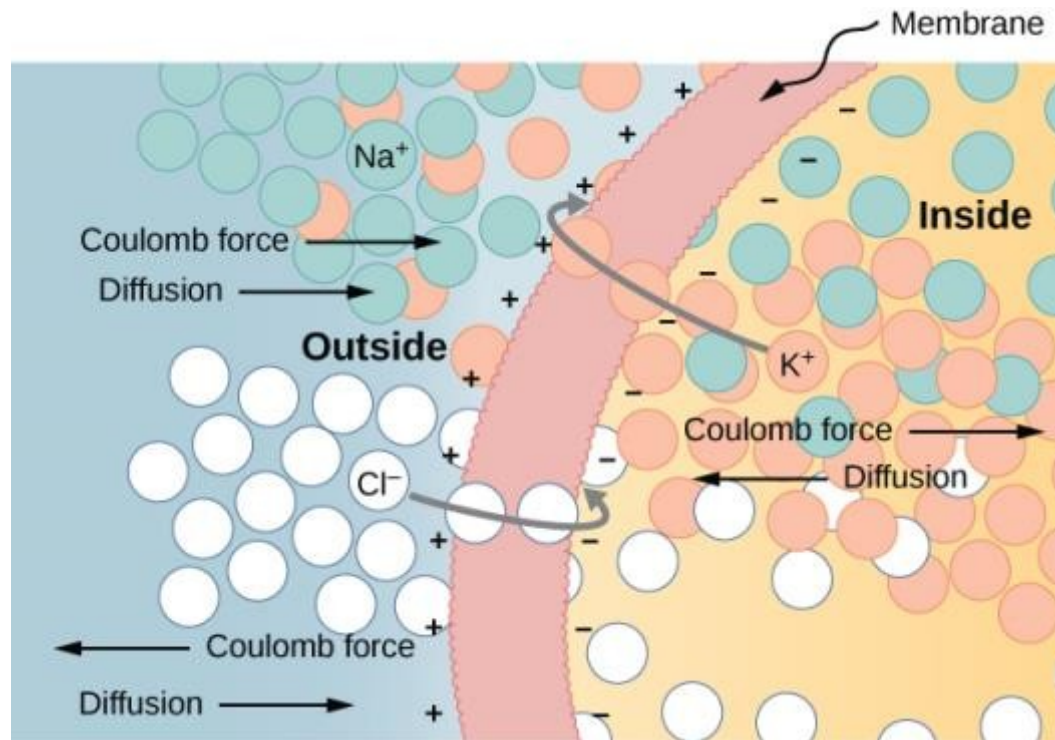
$$E = \frac{\sigma}{\epsilon_0} = \frac{V}{d} = \frac{Q}{\epsilon_0 A}$$

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 8.10



The semipermeable membrane of a biological cell has different concentrations of ions on its interior surface than on its exterior. Diffusion moves the K^+ (potassium) and 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 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 .

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

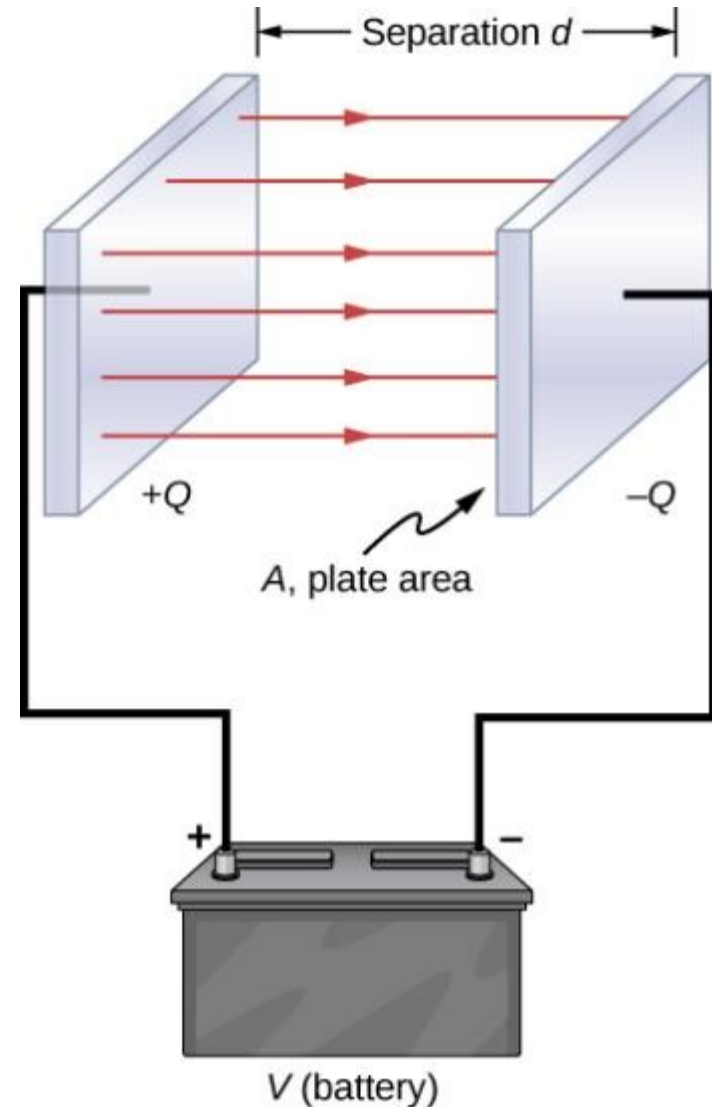
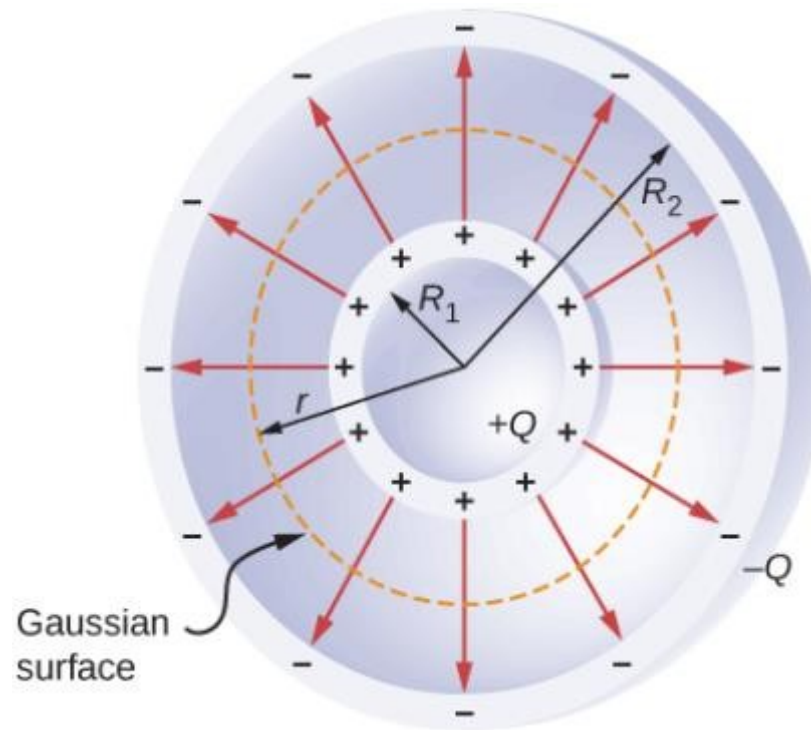


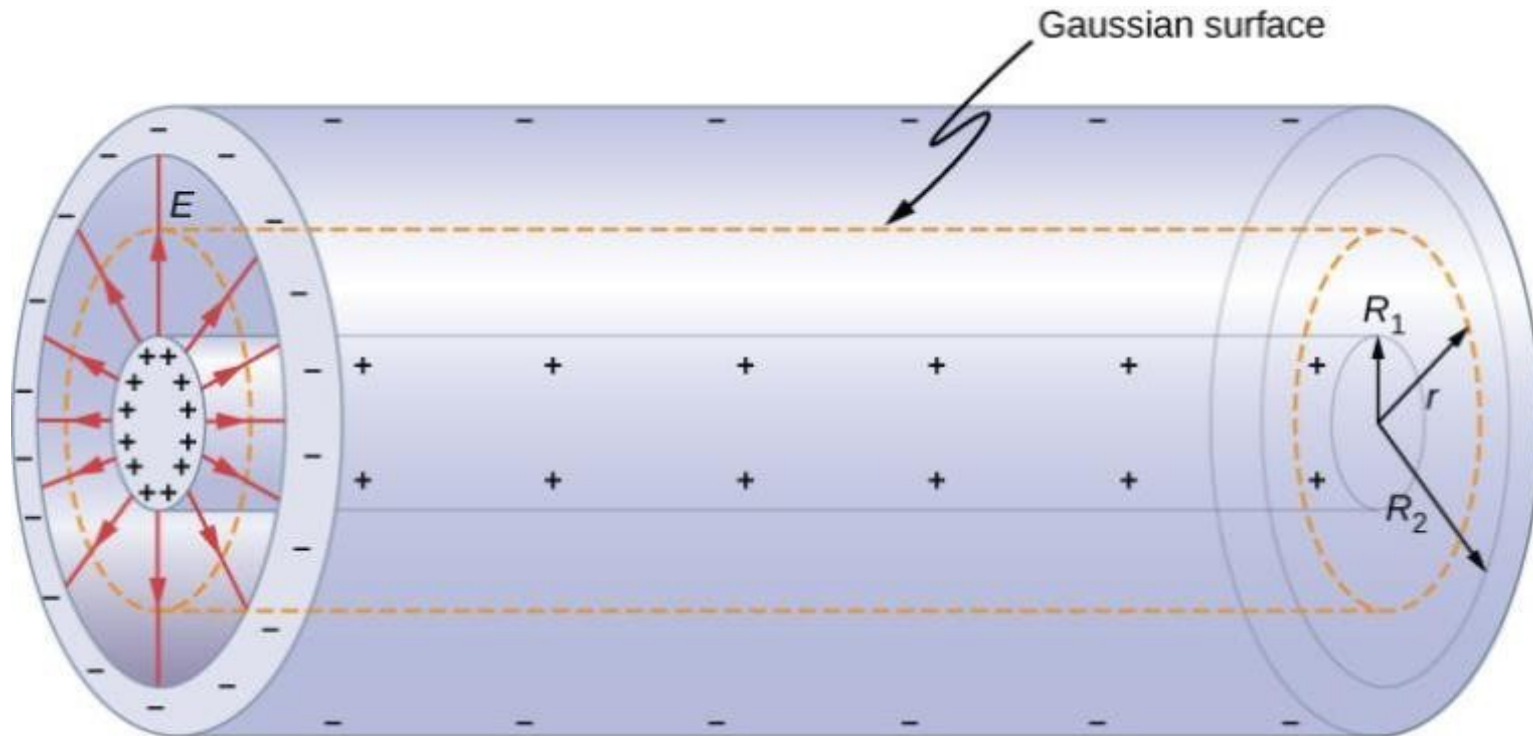
FIGURE 8.6



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

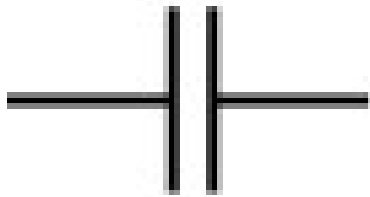


A cylindrical capacitor consists of two concentric, conducting cylinders. Here, the charge on the outer surface of the inner cylinder is positive (indicated by +) and the charge on the inner surface of the outer cylinder is negative (indicated by -).

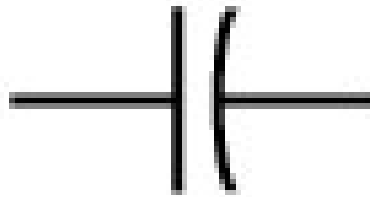
$$C = \frac{Q}{V} = \frac{2\pi\epsilon_0 l}{\ln R_2/R_1}$$

Circuits

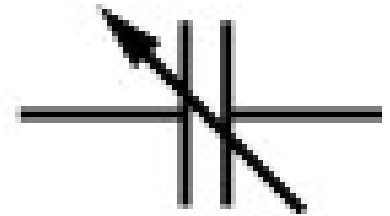
FIGURE 8.9



(a)



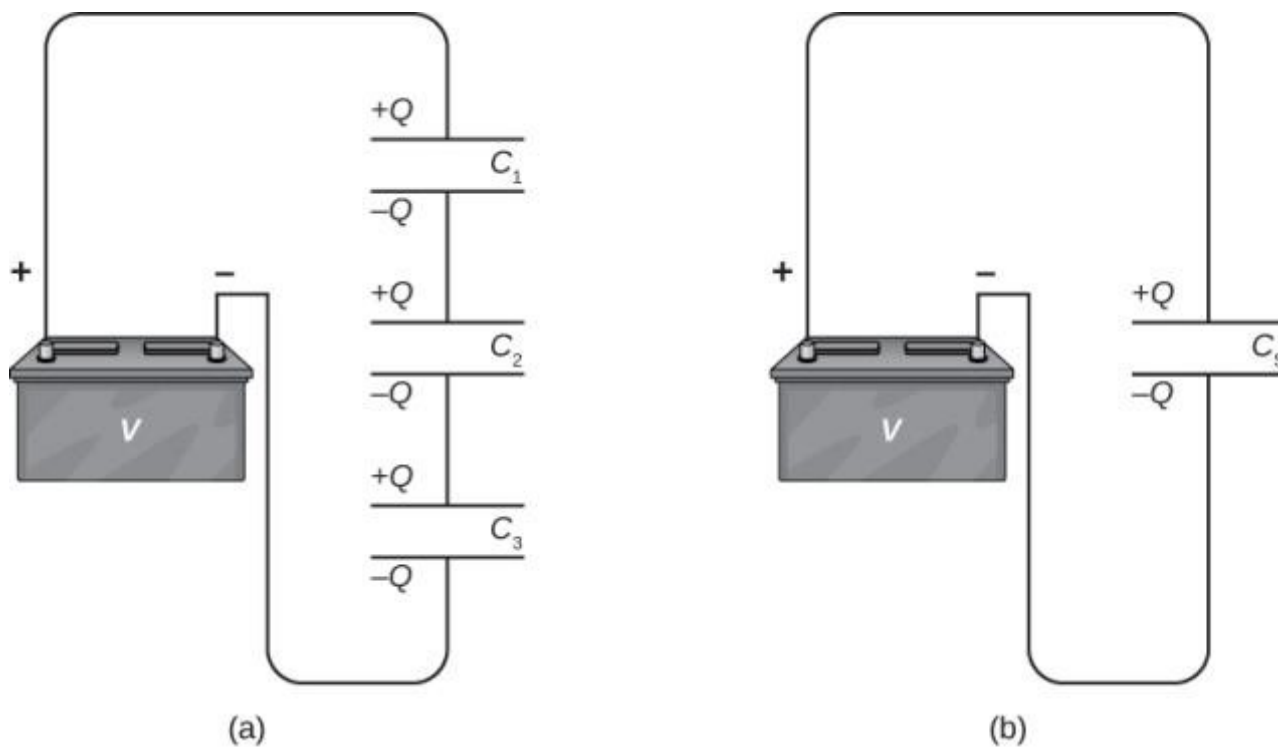
(b)



(c)

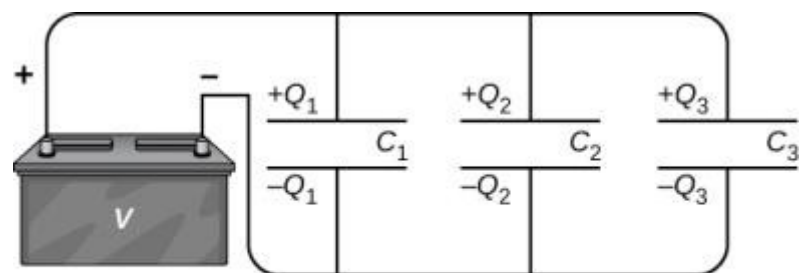
This shows three different circuit representations of capacitors. The symbol in (a) is the most commonly used one. The symbol in (b) represents an electrolytic capacitor. The symbol in (c) represents a variable-capacitance capacitor.

FIGURE 8.11

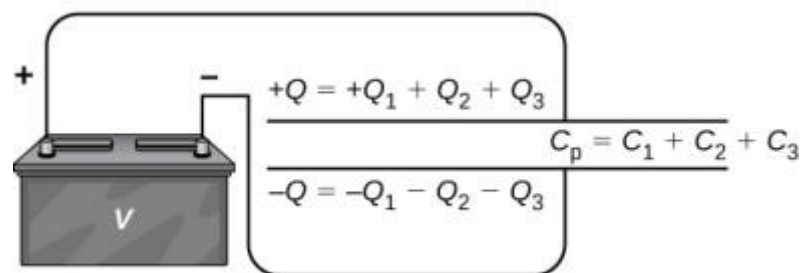


- a) Three capacitors are connected in series. The magnitude of the charge on each plate is Q .
- b) The network of capacitors in (a) is equivalent to one capacitor that has a smaller capacitance than any of the individual capacitances in (a), and the charge on its plates is Q .

FIGURE 8.12



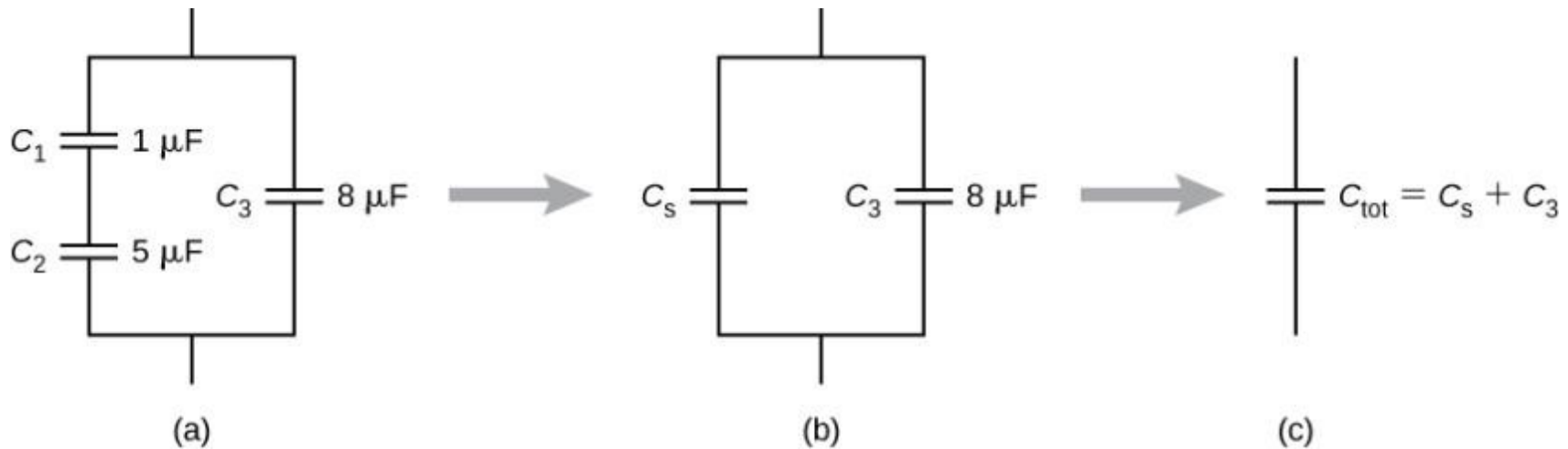
(a)



(b)

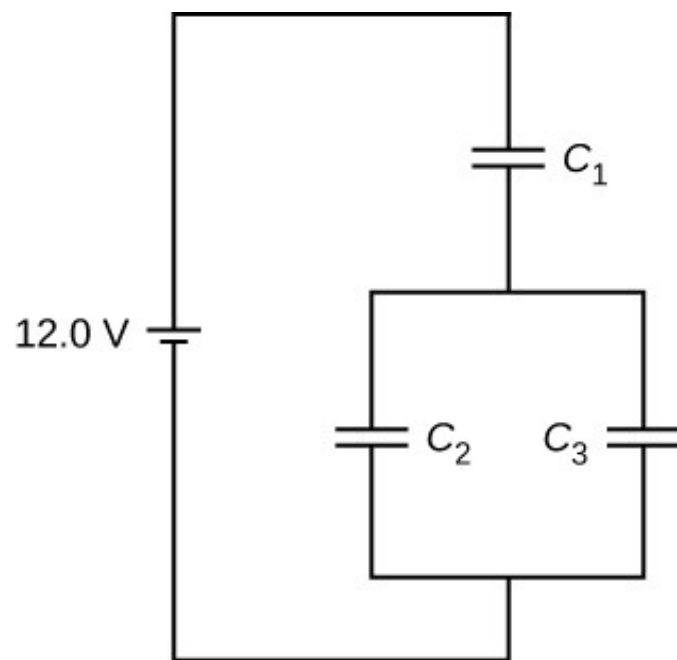
- a) Three capacitors are connected in parallel. Each capacitor is connected directly to the battery.
- b) The charge on the equivalent capacitor is the sum of the charges on the individual capacitors.

FIGURE 8.13

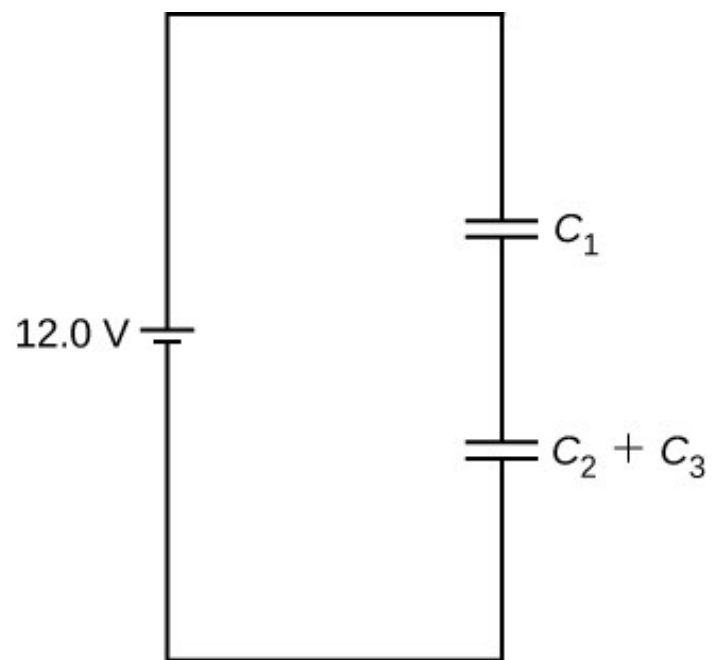


- a) This circuit contains both series and parallel connections of capacitors.
- b) C_1 and C_2 are in series; their equivalent capacitance is C_s .
- c) The equivalent capacitance C_s is connected in parallel with C_3 . Thus, the equivalent capacitance of the entire network is the sum of C_s and C_3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

FIGURE 8.14



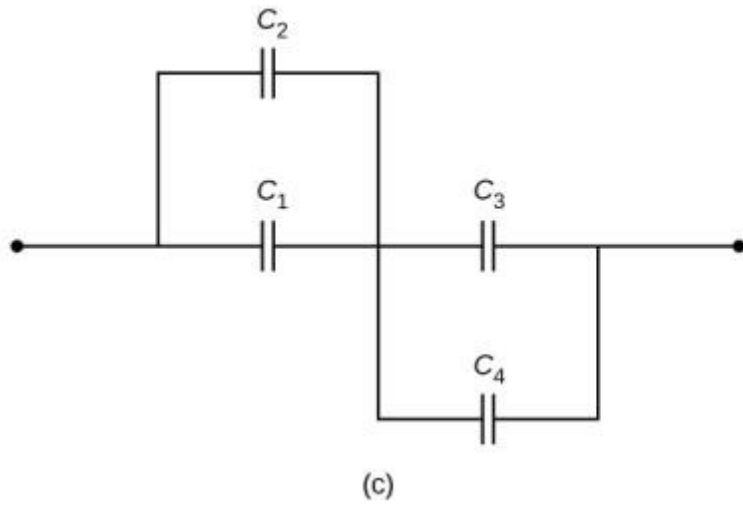
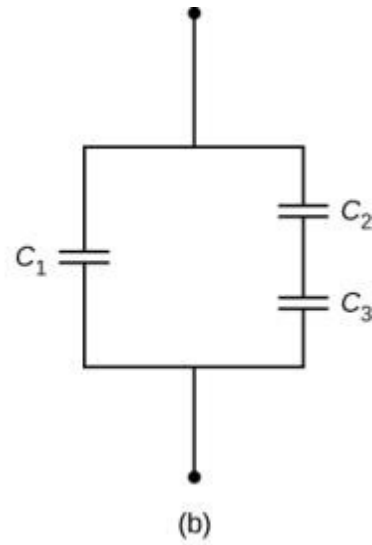
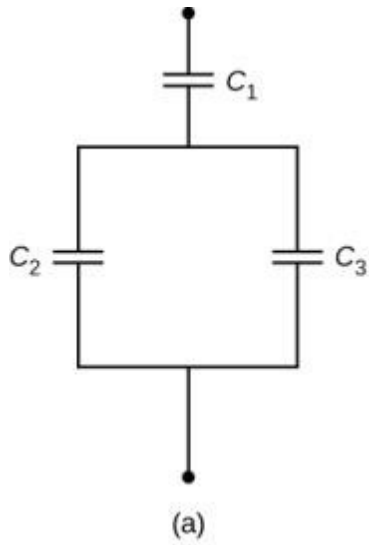
(a)



(b)

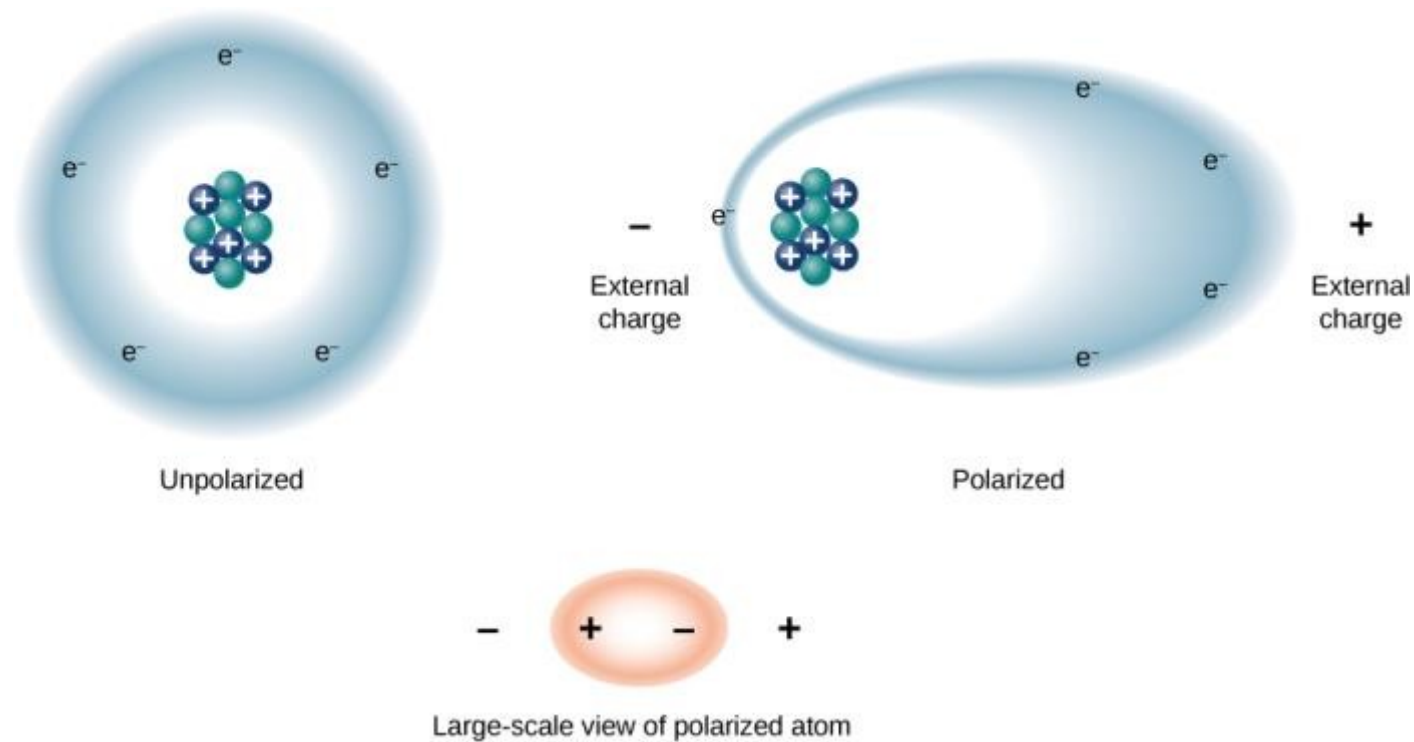
- a) A capacitor combination.
- b) An equivalent two-capacitor combination.

EXERCISE 8.5



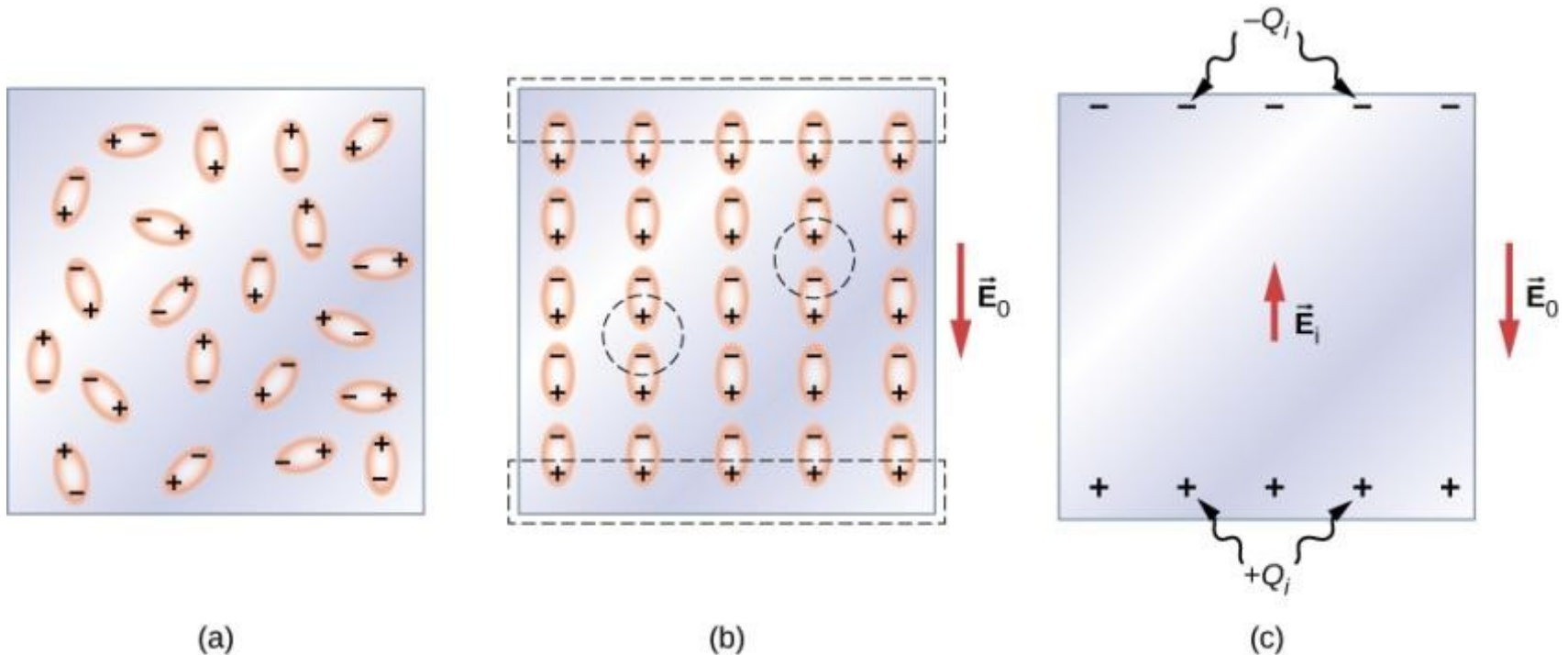
Dielectric materials

FIGURE 8.19



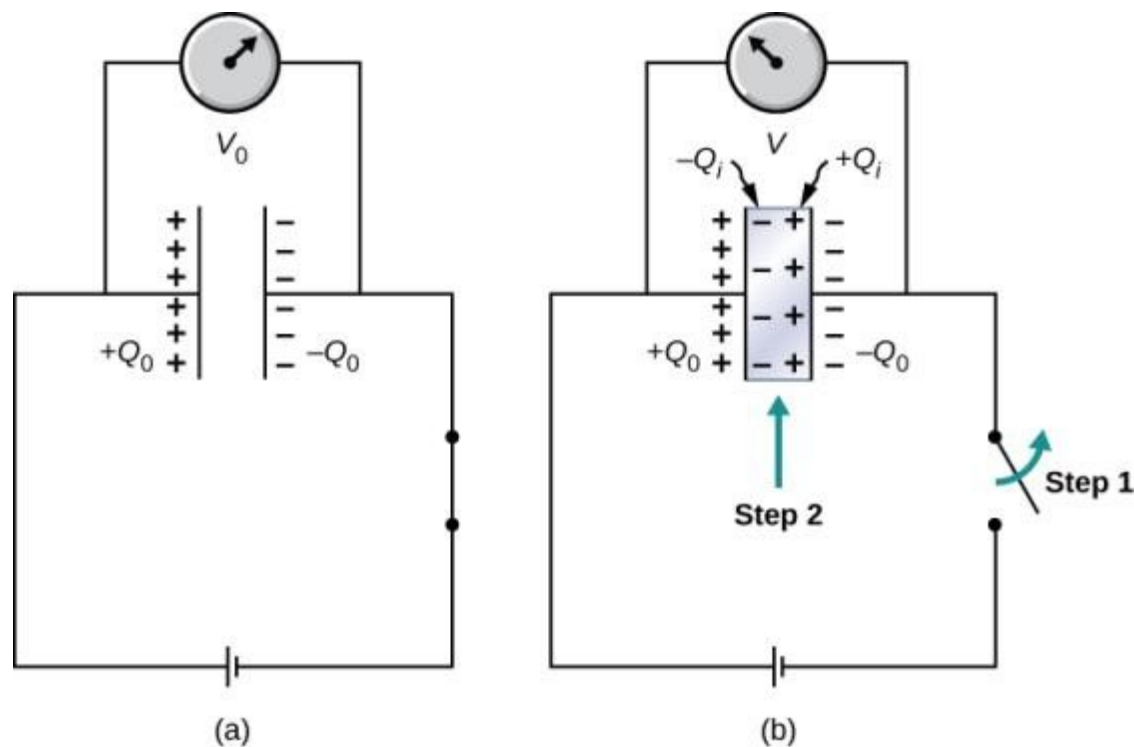
The concept of polarization: In an unpolarized atom or molecule, a negatively charged electron cloud is evenly distributed around positively charged centers, whereas a polarized atom or molecule has an excess of negative charge at one side so that the other side has an excess of positive charge. However, the entire system remains electrically neutral. The charge polarization may be caused by an external electrical field. Some molecules and atoms are permanently polarized (electric dipoles) even in the absence of an external electrical field (polar molecules and atoms).

FIGURE 8.20



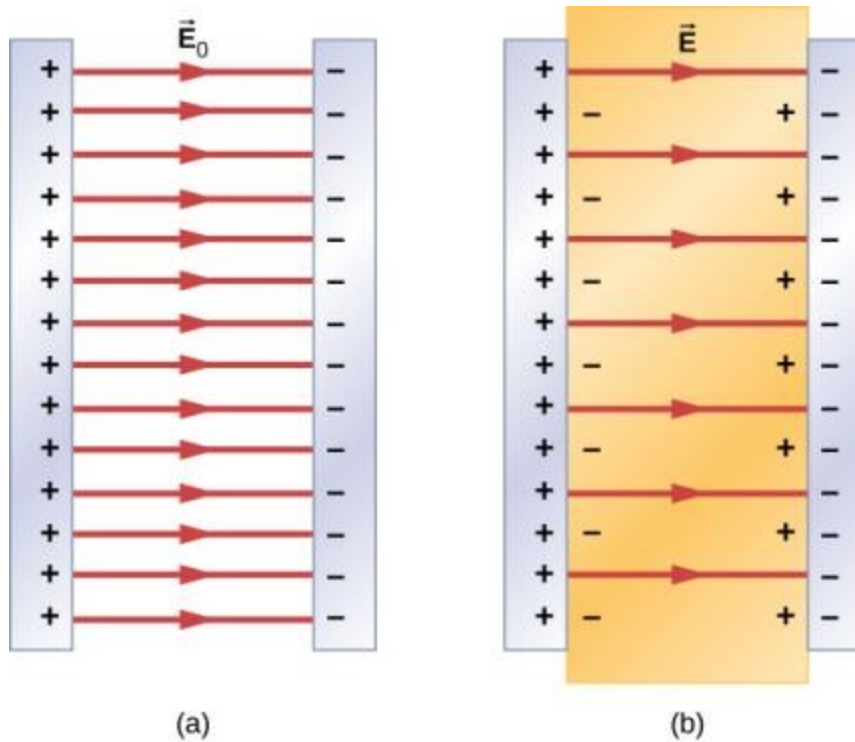
A dielectric with polar molecules: (a) In the absence of an external electrical field; (b) in the presence of an external electrical field \vec{E}_0 . The dashed lines indicate the regions immediately adjacent to the capacitor plates. (c) The induced electrical field \vec{E}_i inside the dielectric produced 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

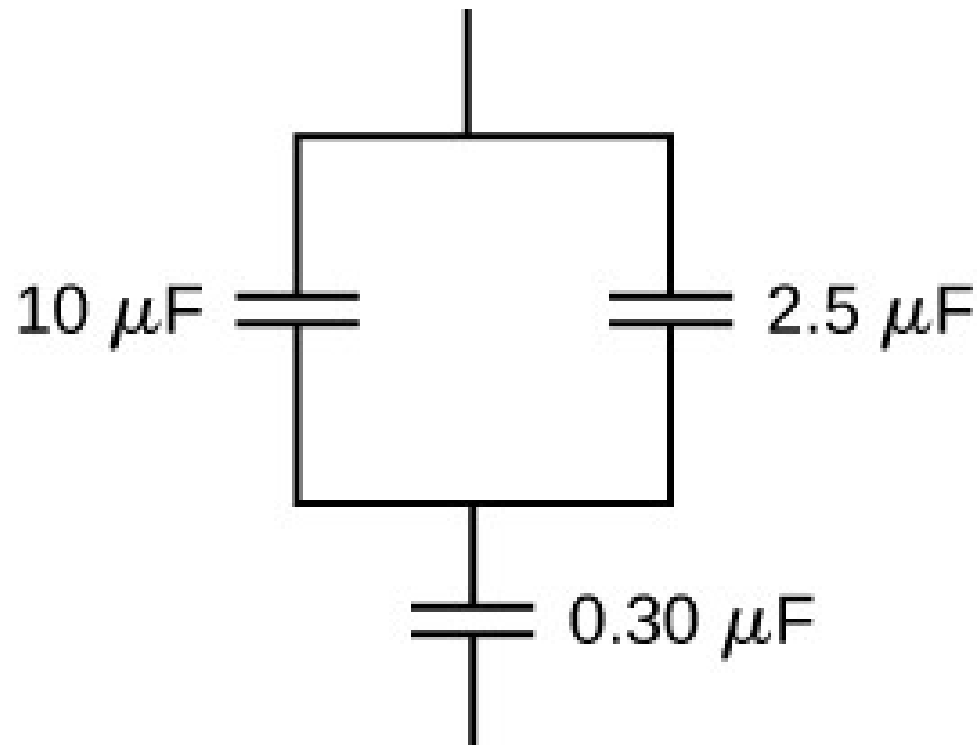


Electrical field:

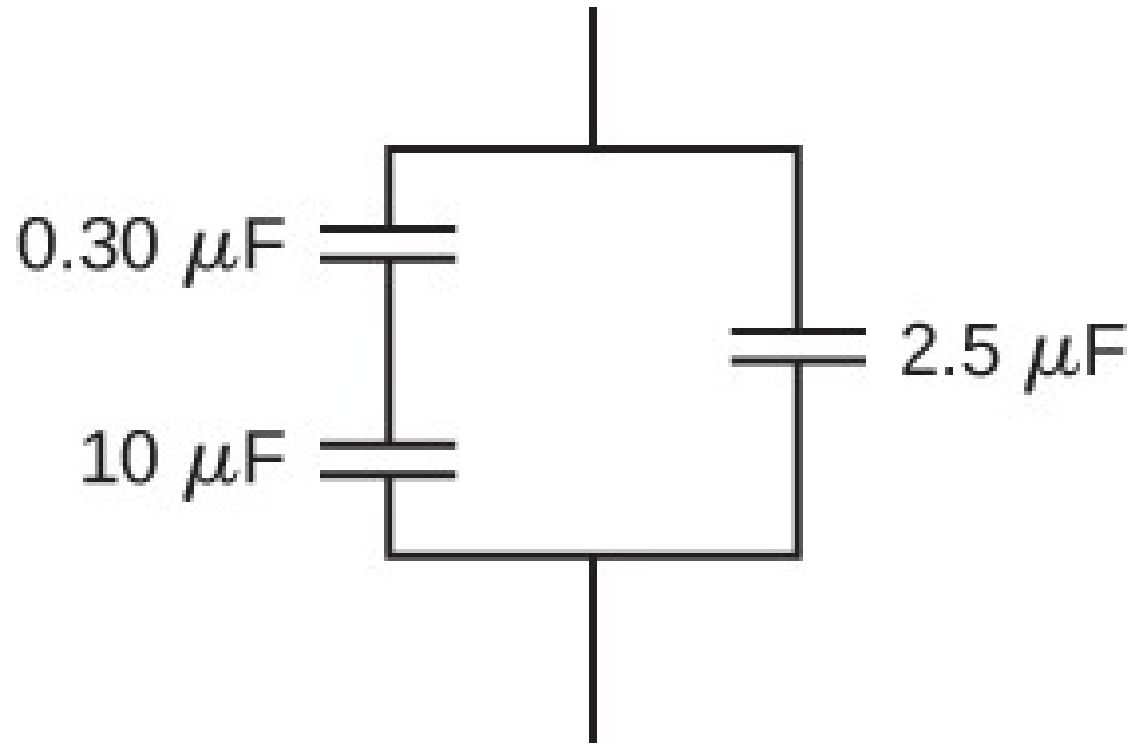
- a) In an empty capacitor, electrical field E_0 .
- b) In a dielectric-filled capacitor, electrical field E .

Examples

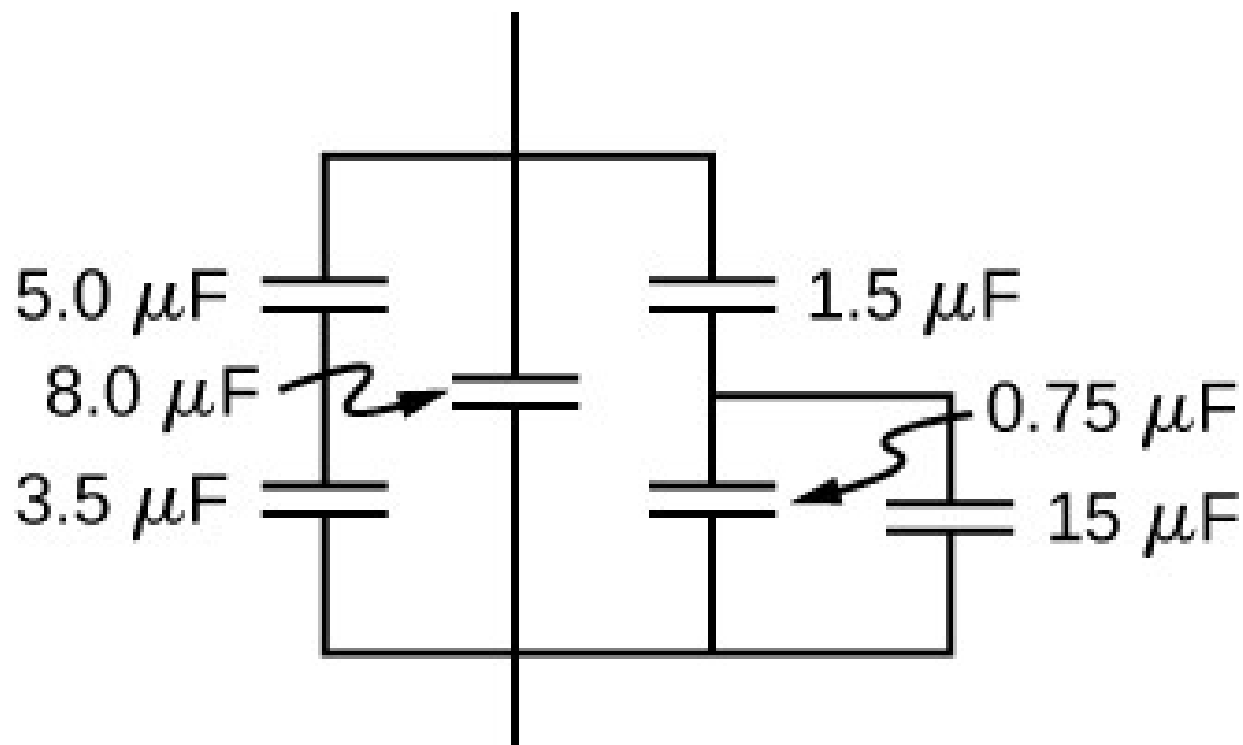
EXERCISE 33



EXERCISE 36



EXERCISE 37





This OpenStax ancillary resource is © Rice University under a CC-BY 4.0 International license; it may be reproduced or modified but must be attributed to OpenStax, Rice University and any changes must be noted.