### Sample Problem 25.01 Charging the plates in a parallel-plate capacitor

In Fig. 25-7*a*, switch S is closed to connect the uncharged capacitor of capacitance $C = 0.25\ \mu\text{F}$ to the battery of potential difference $V = 12$ V. The lower capacitor plate has thickness $L = 0.50$ cm and face area $A = 2.0 \times 10^{-4}\ \text{m}^2$, and it consists of copper, in which the density of conduction electrons is $n = 8.49 \times 10^{28}$ electrons/m$^3$. From what depth $d$ within the plate (Fig. 25-7*b*) must electrons move to the plate face as the capacitor becomes charged?

#### KEY IDEA

The charge collected on the plate is related to the capacitance and the potential difference across the capacitor by Eq. 25-1 ($q = CV$).

***Calculations:*** Because the lower plate is connected to the negative terminal of the battery, conduction electrons move up to the face of the plate. From Eq. 25-1, the total charge magnitude that collects there is

$$q = CV = (0.25 \times 10^{-6}\ \text{F})(12\ \text{V}) = 3.0 \times 10^{-6}\ \text{C}.$$

Dividing this result by $e$ gives us the number $N$ of conduction electrons that come up to the face:

$$N = \frac{q}{e} = \frac{3.0 \times 10^{-6}\ \text{C}}{1.602 \times 10^{-19}\ \text{C}} = 1.873 \times 10^{13}\ \text{electrons}.$$

These electrons come from a volume that is the product of the face area $A$ and the depth $d$ we seek. Thus, from the density of conduction electrons (number per volume), we can write

$$n = \frac{N}{Ad},$$

or

$$d = \frac{N}{An} = \frac{1.873 \times 10^{13}\ \text{electrons}}{(2.0 \times 10^{-4}\ \text{m}^2)(8.49 \times 10^{28}\ \text{electrons/m}^3)}$$

$$= 1.1 \times 10^{-12}\ \text{m} = 1.1\ \text{pm}. \qquad \text{(Answer)}$$

We commonly say that electrons move from the battery to the negative face but, actually, the battery sets up an electric field in the wires and plate such that electrons very close to the plate face move up to the negative face.

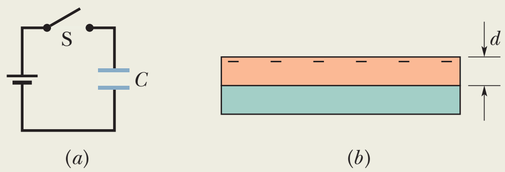


**Figure 25-7** (*a*) A battery and capacitor circuit. (*b*) The lower capacitor plate.

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## 25-3 CAPACITORS IN PARALLEL AND IN SERIES

### Learning Objectives

*After reading this module, you should be able to . . .*

**25.06** Sketch schematic diagrams for a battery and (a) three capacitors in parallel and (b) three capacitors in series.

**25.07** Identify that capacitors in parallel have the same potential difference, which is the same value that their equivalent capacitor has.

**25.08** Calculate the equivalent of parallel capacitors.

**25.09** Identify that the total charge stored on parallel capacitors is the sum of the charges stored on the individual capacitors.

**25.10** Identify that capacitors in series have the same charge, which is the same value that their equivalent capacitor has.

**25.11** Calculate the equivalent of series capacitors.

**25.12** Identify that the potential applied to capacitors in series is equal to the sum of the potentials across the individual capacitors.

**25.13** For a circuit with a battery and some capacitors in parallel and some in series, simplify the circuit in steps by finding equivalent capacitors, until the charge and potential on the final equivalent capacitor can be determined, and then reverse the steps to find the charge and potential on the individual capacitors.

**25.14** For a circuit with a battery, an open switch, and one or more uncharged capacitors, determine the amount of charge that moves through a point in the circuit when the switch is closed.

**25.15** When a charged capacitor is connected in parallel to one or more uncharged capacitors, determine the charge and potential difference on each capacitor when equilibrium is reached.

### Key Idea

- The equivalent capacitances $C_{eq}$ of combinations of individual capacitors connected in parallel and in series can be found from

$$C_{eq} = \sum_{j=1}^{n} C_j \quad (n \text{ capacitors in parallel})$$

and

$$\frac{1}{C_{eq}} = \sum_{j=1}^{n} \frac{1}{C_j} \quad (n \text{ capacitors in series}).$$

Equivalent capacitances can be used to calculate the capacitances of more complicated series – parallel combinations.