

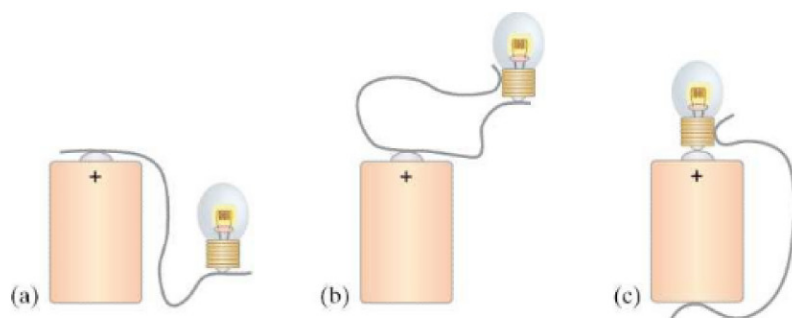
**EXERCISE A** If 1 million electrons per second pass a point in a wire, what is the current in amps?

**CONCEPTUAL EXAMPLE 18-2** **How to connect a battery.** What is wrong with each of the schemes shown in Fig. 18-7 for lighting a flashlight bulb with a flashlight battery and a single wire?

**RESPONSE** (a) There is no closed path for charge to flow around. Charges might briefly start to flow from the battery toward the lightbulb, but there they run into a “dead end,” and the flow would immediately come to a stop.

(b) Now there is a closed path passing to and from the lightbulb; but the wire touches only one battery terminal, so there is no potential difference in the circuit to make the charge move.

(c) Nothing is wrong here. This is a complete circuit: charge can flow out from one terminal of the battery, through the wire and the bulb, and into the other terminal. This scheme will light the bulb.



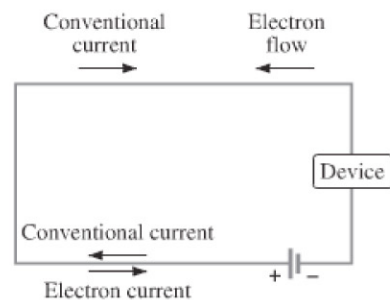
**FIGURE 18-7** Example 18-2.

In many real circuits, wires are connected to a common conductor to provide continuity. This common conductor is called **ground**, usually represented as  $\perp$ , and really is connected to the ground in a building or house. In a car, one terminal of the battery is called “ground,” but is not connected to the ground—it is connected to the frame of the car, as is one connection to each lightbulb and other devices. Thus the car frame is a conductor in each circuit, ensuring a continuous path for charge flow.

We saw in Chapter 16 (Section 16-3) that conductors contain many free electrons. Thus, if a continuous conducting wire is connected to the terminals of a battery, negatively charged electrons flow in the wire. When the wire is first connected, the potential difference between the terminals of the battery sets up an electric field inside the wire<sup>†</sup> and parallel to it. Free electrons at one end of the wire are attracted into the positive terminal, and at the same time other electrons leave the negative terminal of the battery and enter the wire at the other end. There is a continuous flow of electrons throughout the wire that begins as soon as the wire is connected to *both* terminals. However, when the conventions of positive and negative charge were invented two centuries ago, it was assumed that positive charge flowed in a wire. For nearly all purposes, positive charge flowing in one direction is exactly equivalent to negative charge flowing in the opposite direction, as shown in Fig. 18-8. Today, we still use the historical convention of positive charge flow when discussing the direction of a current. So when we speak of the current direction in a circuit, we mean the direction positive charge would flow. This is sometimes referred to as **conventional current**. When we want to speak of the direction of electron flow, we will specifically state it is the electron current. In liquids and gases, both positive and negative charges (ions) can move.

*Grounds, and complete circuits*

**FIGURE 18-8** Conventional current from + to – is equivalent to a negative electron flow from – to +.



**CAUTION**  
Distinguish conventional current from electron flow

<sup>†</sup>This does not contradict what was said in Section 16-9 that in the *static* case, there can be no electric field within a conductor since otherwise the charges would move. Indeed, when there is an electric field in a conductor, charges do move, and we get an electric current.