1. Label the current in each separate branch of the given circuit with a different subscript, such as I_1, I_2, I_3 (see Fig. 19–11 or 19–13). Each current refers to a segment between two junctions. Choose the direction of each current, using an arrow. The direction can be chosen arbitrarily: if the current is actually in the opposite direction, it will come out with a minus sign in the solution.

2. Identify the unknowns. You will need as many independent equations as there are unknowns. You may write down more equations than this, but you will find that some of the equations will be redundant (that is, not be independent in the sense of providing new information). You may use $V = IR$ for each resistor, which sometimes will reduce the number of unknowns.

3. Apply Kirchhoff's junction rule at one or more junctions.

4. Apply Kirchhoff's loop rule for one or more loops: follow each loop in one direction only. Pay careful attention to subscripts, and to signs:

(a) For a resistor, apply Ohm's law; the potential difference is negative (a decrease) if your chosen loop direction is the same as the chosen current direction through that resistor; the potential difference is positive (an increase) if your chosen loop direction is opposite to the chosen current direction.

(b) For a battery, the potential difference is positive if your loop direction is from the negative terminal toward the positive terminal; the potential difference is negative if the loop direction is from the positive terminal toward the negative terminal.

5. Solve the equations algebraically for the unknowns. Be careful when manipulating equations not to err with signs. At the end, check your answers by plugging them into the original equations, or even by using any additional loop or junction rule equations not used previously.

EXAMPLE 19–8   Using Kirchhoff's rules. Calculate the currents I_1, I_2, and I_3 in the three branches of the circuit in Fig. 19–13.
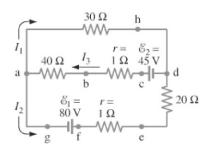
APPROACH and SOLUTION

1. Label the currents and their directions. Figure 19–13 uses the labels I_1, I_2, and I_3 for the current in the three separate branches. Since (positive) current tends to move away from the positive terminal of a battery, we choose I_2 and I_3 to have the directions shown in Fig. 19–13. The direction of I_1 is not obvious in advance, so we arbitrarily chose the direction indicated. If the current actually flows in the opposite direction, our answer will have a negative sign.

2. Identify the unknowns. We have three unknowns and therefore we need three equations, which we get by applying Kirchhoff's junction and loop rules.

3. Junction rule: We apply Kirchhoff's junction rule to the currents at point a, where I_3 enters and I_2 and I_1 leave:

$$I_3 = I_1 + I_2. \qquad (a)$$

This same equation holds at point d, so we get no new information by writing an equation for point d.

> **PROBLEM SOLVING**
> *Choose current directions arbitrarily*

FIGURE 19–13 Currents can be calculated using Kirchhoff's rules. See Example 19–8.