31.25. Model: Assume ideal connecting wires but not an ideal battery.

Visualize: The circuit for an ideal battery is the same as the circuit in Figure Ex31.25, except that the 1 Ω resistor is not present.

Solve: In the case of an ideal battery, we have a battery with $\mathcal{E}$ = 15 V connected to two series resistors of 10 Ω and 20 Ω resistance. Because the equivalent resistance is R_{eq} = 10 Ω + 20 Ω = 30 Ω and the potential difference across R_{eq} is 15 V, the current in the circuit is

$$I = \frac{\Delta V}{R_{eq}} = \frac{\mathcal{E}}{R_{eq}} = \frac{15\text{ V}}{30\ \Omega} = 0.5\text{ A}$$

The potential difference across the 20 Ω resistor is

$$\Delta V_{20} = IR = (0.5\text{ A})(20\ \Omega) = 10\text{ V}$$

In the case of a real battery, we have a battery with $\mathcal{E}$ = 15 V connected to three series resistors: 10 Ω, 20 Ω, and an internal resistance of 1.0 Ω. Now the equivalent resistance is

$$R'_{eq} = 10\ \Omega + 20\ \Omega + 1.0\ \Omega = 31\ \Omega$$

The potential difference across R_{eq} is the same as before ($\mathcal{E}$ = 15 V). Thus,

$$I' = \frac{\Delta V'}{R'_{eq}} = \frac{\mathcal{E}}{R'_{eq}} = \frac{15\text{ V}}{31\ \Omega} = 0.4839\text{ A}$$

Therefore, the potential difference across the 20 Ω resistor is

$$\Delta V'_{20} = I'R = (0.4839\text{ A})(20\ \Omega) = 9.68\text{ V}$$

That is, the potential difference across the 20 Ω resistor is reduced from 10 V to 9.68 V due to the internal resistance of 1 Ω of the battery. The percentage change in the potential difference is

$$\left(\frac{10\text{ V} - 9.68\text{ V}}{10\text{ V}}\right)\times 100 = 3.23\%$$