49. An automobile battery has an emf of 12.6 V and an internal resistance of 0.080 Ω. The headlights have total resistance 5.00 Ω (assumed constant). What is the potential difference across the headlight bulbs (a) when they are the only load on the battery, and (b) when the starter motor is operated, taking an additional 35.0 A from the battery?

Solution

(a) When the headlights are the only load connected to the battery, the circuit is as shown in Figure 1. Applying Kirchhoff's loop rule to this single loop circuit gives $+\mathcal{E} - Ir - IR_{\text{lights}} = 0$, or the current in the circuit is

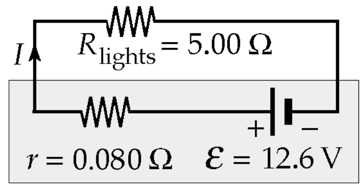

Figure 1

$$I = \frac{\mathcal{E}}{r + R_{\text{lights}}} = \frac{12.6\text{ V}}{5.08\ \Omega} = 2.48\text{ A}$$

The potential difference across the headlight bulbs is then

$$\Delta V_{\text{lights}} = IR_{\text{lights}} = (2.48\text{ A})(5.00\ \Omega) = 12.4\text{ V} \qquad \Diamond$$

(b) When the starter motor is turned on, the circuit is as shown in Figure 2. Using Kirchhoff's junction rule at point a gives $I = I_{\text{lights}} + 35.0\text{ A}$, and applying Kirchhoff's loop rule to the lower loop of this circuit yields

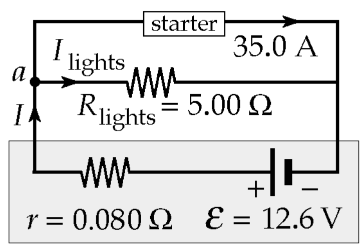

Figure 2

$$+\mathcal{E} - Ir - I_{\text{lights}}R_{\text{lights}} = 0$$

Combining these two equations, one obtains

$$+\mathcal{E} - \left(I_{\text{lights}} + 35.0\text{ A}\right)r - I_{\text{lights}}R_{\text{lights}} = 0$$

or $$I_{\text{lights}} = \frac{\mathcal{E} - (35.0\text{ A})r}{r + R_{\text{lights}}} = \frac{12.6\text{ V - }(35.0\text{ A})(0.080\ \Omega)}{5.00\ \Omega + 0.080\ \Omega} = 1.93\text{ A}$$

The potential difference that now exists across the headlight bulbs is

$$\Delta V_{\text{lights}} = I_{\text{lights}}R_{\text{lights}} = (1.93\text{ A})(5.00\ \Omega) = 9.65\text{ V} \qquad \Diamond$$