

21. Let  $i_1$  be the current in  $R_1$  and take it to be positive if it is to the right. Let  $i_2$  be the current in  $R_2$  and take it to be positive if it is upward. When the loop rule is applied to the lower loop, the result is

$$\mathcal{E}_2 - i_1 R_1 = 0 .$$

and when it is applied to the upper loop, the result is

$$\mathcal{E}_1 - \mathcal{E}_2 - \mathcal{E}_3 - i_2 R_2 = 0 .$$

The first equation yields

$$i_1 = \frac{\mathcal{E}_2}{R_1} = \frac{5.0 \text{ V}}{100 \Omega} = 0.050 \text{ A} .$$

The second yields

$$i_2 = \frac{\mathcal{E}_1 - \mathcal{E}_2 - \mathcal{E}_3}{R_2} = \frac{6.0 \text{ V} - 5.0 \text{ V} - 4.0 \text{ V}}{50 \Omega} = -0.060 \text{ A} .$$

The negative sign indicates that the current in  $R_2$  is actually downward. If  $V_b$  is the potential at point  $b$ , then the potential at point  $a$  is  $V_a = V_b + \mathcal{E}_3 + \mathcal{E}_2$ , so  $V_a - V_b = \mathcal{E}_3 + \mathcal{E}_2 = 4.0 \text{ V} + 5.0 \text{ V} = 9.0 \text{ V}$ .