Ex:

240 kΩ

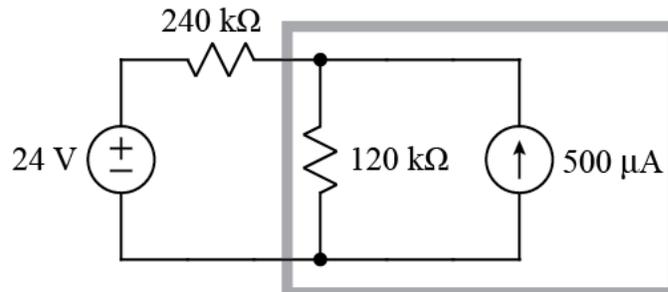24 V (+/−)   120 kΩ   (↑) 500 μA

Find the total power dissipated by the components inside the box.

SOL'N: The power for the box is given by the voltage drop across the box multiplied by the current flowing into the box.

$$p = iv$$

Alternatively, the power may be computed as the sum of the powers for the components inside the box. In either case, the circuit is solved by applying Kirchhoff's laws and Ohm's law. The first step in the solution is to label each resistor with a voltage drop and a current. By the passive sign convention, the arrow for the current measurement must point toward the − sign of the voltage drop. One possible choice of measurement directions is shown below. The measurement directions could be switched for either or both of the resistors so long as the current arrow points to the − sign of the voltage measurement.

240 kΩ

$+ \ v_1 \ -$

24 V (+/−) i_1 120 kΩ $v_2 \downarrow i_2$ (↑) 500 μA
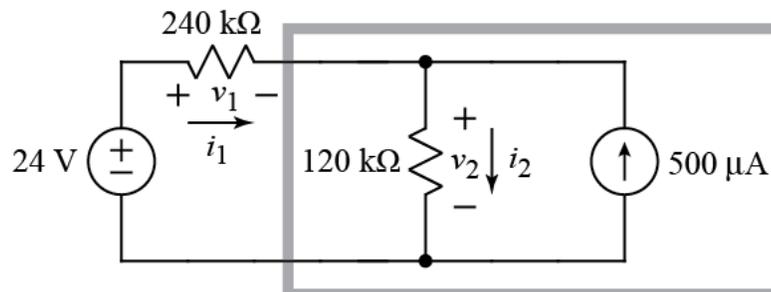
Each resistor obeys Ohm's law:

$$v_1 = i_1(240\text{k}\Omega) \text{ and}$$

$$v_2 = i_2(120\text{k}\Omega).$$

There is one v-loop on the left side that does not go through the current source. Starting at the lower left, proceeding clockwise, and adding or subtracting terms according the sign of the voltage measurement when exiting a component, the following v-loop equation is found:

$$24\,\mathrm{V} - v_1 - v_2 = 0\,\mathrm{V}.$$

There are two nodes where currents might be summed. One of them is redundant, since the currents for both nodes are really the same. For the top node, the current sum, setting currents measured into the node equal to the currents measured flowing out of the node, is as follows:

$$i_1 + 500\,\mu\mathrm{A} = i_2. \tag{1}$$

Substituting the Ohm's law equations into the v-loop equation from earlier, eliminates voltages and leaves two equations in two unknowns, (1) and (2):

$$24\,\mathrm{V} - i_1(120\mathrm{k}\Omega) - i_2(240\mathrm{k}\Omega) = 0\,\mathrm{V}. \tag{2}$$

Using (1) to substitute for i_2 in (2) yields the following single equation:

$$24\,\mathrm{V} - i_1(240\mathrm{k}\Omega) - (i_1 + 500\,\mu\mathrm{A})(120\mathrm{k}\Omega) = 0\,\mathrm{V}$$

The next step is to collect the terms multiplying i_1.

$$24\,\mathrm{V} - i_1(240\mathrm{k}\Omega + 120\mathrm{k}\Omega) = (500\,\mu\mathrm{A})(120\mathrm{k}\Omega)$$

or

$$24\,\mathrm{V} - i_1(360\mathrm{k}\Omega) = 60\,\mathrm{V}.$$

Solving for i_1, the current in the resistor outside the box is found.

$$i_1 = -\frac{60\,\mathrm{V} - 24\,\mathrm{V}}{360\mathrm{k}\Omega} = -\frac{36\,\mathrm{V}}{360\mathrm{k}\Omega} = -100\,\mu\mathrm{A}$$

Using (1), the value of i_2 is found.

$$i_2 = i_1 + 500\,\mu\mathrm{A} = -100\,\mu A + 500\,\mu\mathrm{A} = 400\,\mu\mathrm{A}$$

By Ohm's law, the value of v_2 is found.

$$v_2 = (400\,\mu\mathrm{A})(120\mathrm{k}\Omega) = 48\,\mathrm{V}$$

The voltage across the entire box is v_2. The power for the box is current i_1 times the voltage v_2.

$$p = i_1 v_2 = -100\mu A(48V) = -4.8mW$$

The other way of computing the power is to find the power for each component in the box and sum. For the 120 kΩ resistor, the power is

$$p_{120k\Omega} = 400\mu A(48V) = 19.2mW$$

For the current source, the voltage measurement must be made with the + sign on the bottom so that the current measurement arrow will point to the – sign. Now that the circuit has been solved and voltages and currents for resistors are known, it is possible to find the voltage across the current source. The v-loop on the right, proceeding clockwise, gives the value of the voltage across the current source as the negative of voltage across the 120 kΩ resistor.

$$v_2 + v_{\text{current source}} = 0V \Rightarrow v_{\text{current source}} = -v_2 = -48V$$

The power for the current source will be negative.

$$p_{\text{current source}} = 500\mu A(-48V) = -24mW$$

Taking the sum of the components' power values gives the same total power for the box as before:

$$p = -24mW + 19.2mW = -4.8mW$$