ENGR 065 Electric Circuits

Lecture 8: The Source Transformation

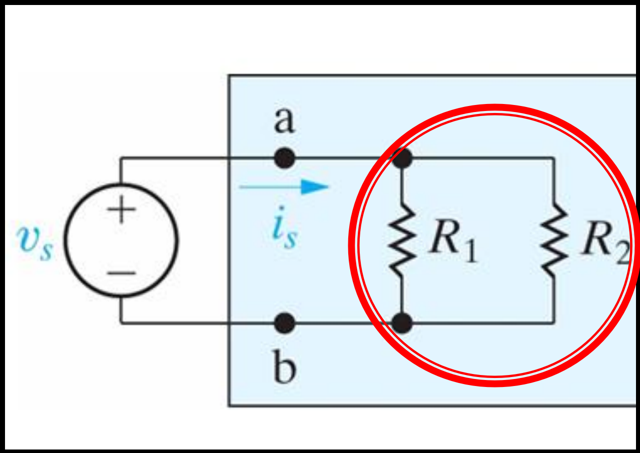
Today's Topics

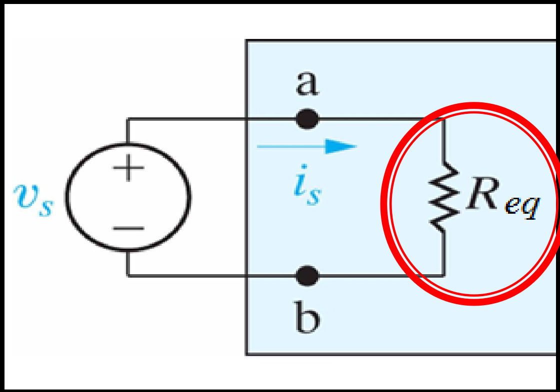
- Equivalent circuit review
- The source transformation
  - Exchange a real voltage source for a real current source and vice versa.
- Some additional source transformation

The topics are covered in Section 4.9

Equivalent Circuit Review

- Let's review the equivalent circuits discussed in Chapter 3.





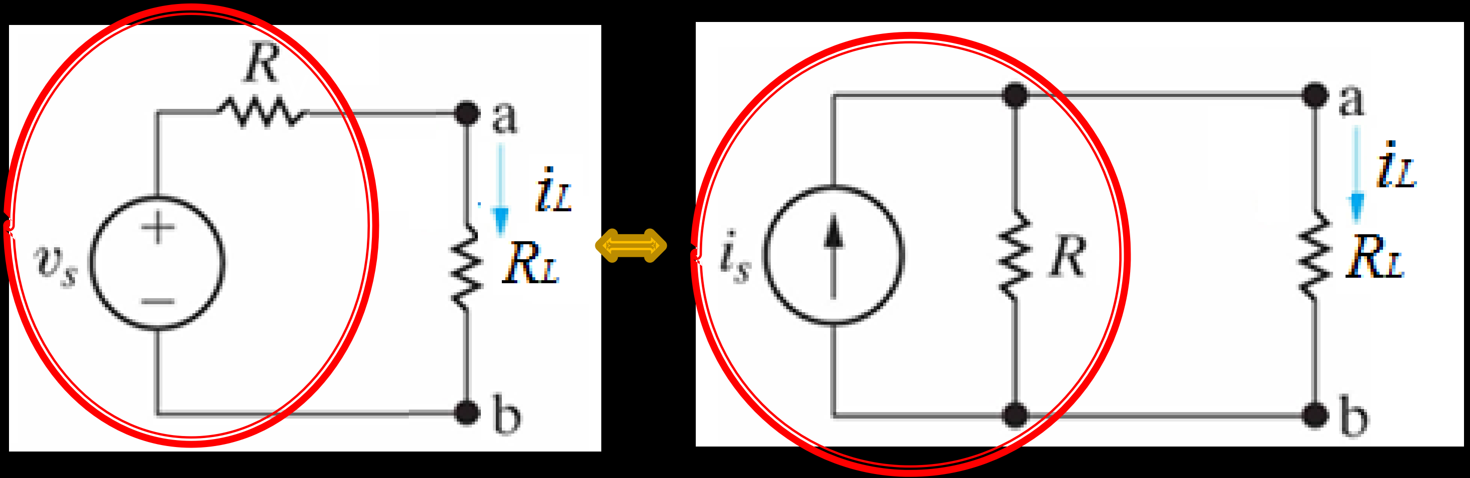
$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

In the circuits above, the parallel-connected R_1 and R_2 can be replaced by R_{eq} while the currents i_s in both circuits remians the same. The two circuits in the red circles are called the equivalent circuits.

Two circuits are considered to be equivalent if they behave the same with respect to what they are connected.

The Source Transformation

The source transformation is another example of equivalent circuits but occurs at the source side.

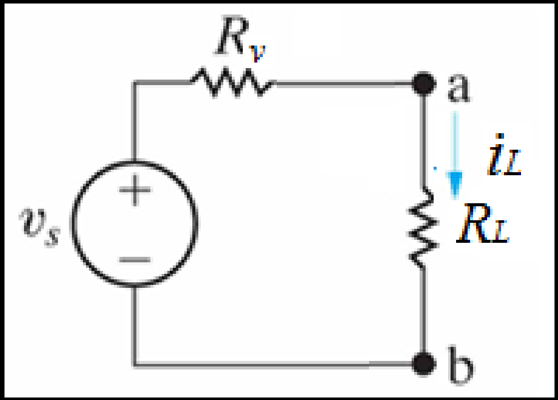


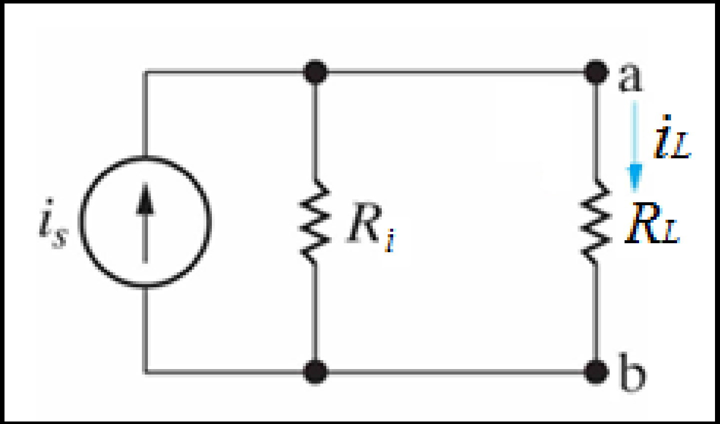
The above circuits are considered to be equivalent if and only if

$$\boxed{v_s = R i_s}$$ **and** $$\boxed{R_v = R_i = R}$$

Why?

- R_L in the both circuits is identical





$$i_L = \frac{v_s}{R_v + R_L}$$

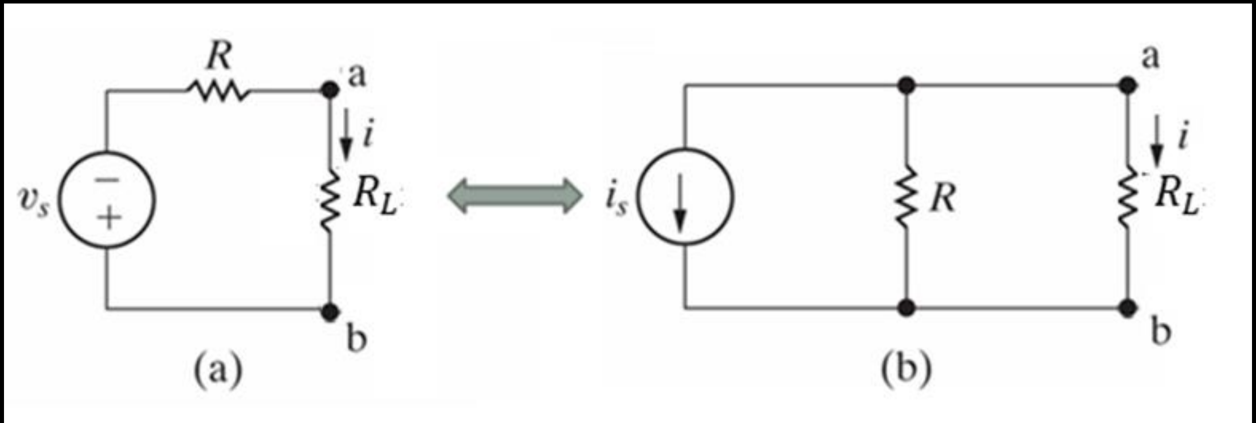
$$i_L = \frac{i_s R_i}{R_i + R_L}$$

If $R_v = R_i = R$ and $v_s = i_s R$

then: $\dfrac{v_s}{R_v + R_L} = \dfrac{i_s R_i}{R_i + R_L}$,

Because the currents in the R_L are the same, the voltage source in the top left circuit is equivalent to the current source in the top right circuit, and vice versa.

The Source Transformation

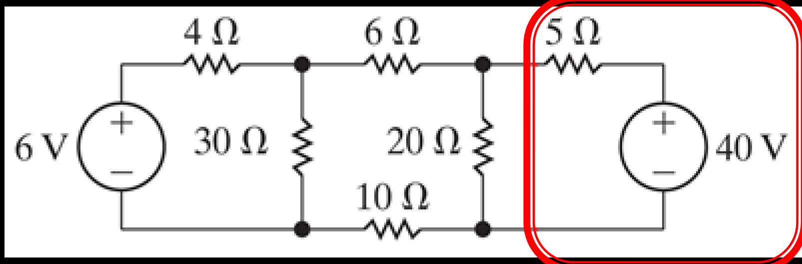


Some notes:

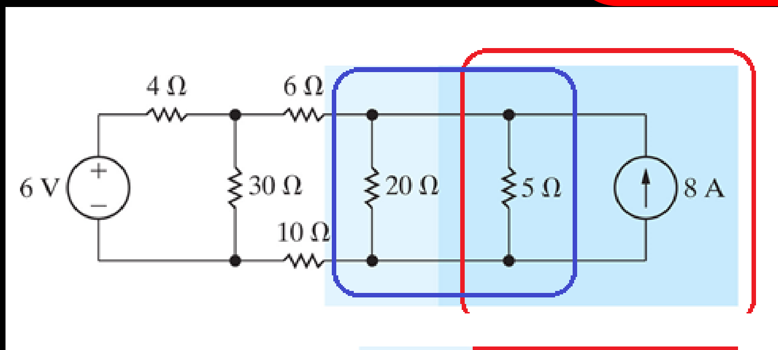
1. If the polarity reference of the voltage source is inversed, the direction reference of the current source must be inversed too.
2. R_L could be an equivalent resistor or a circuit.
3. The currents in the two ideal sources are different. One is $i = \frac{v_s}{R+R_L}$ and another is i_s.

Example #1

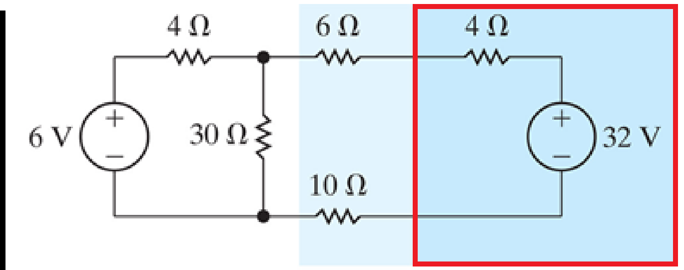
Find the power associated with the voltage source 6 V.



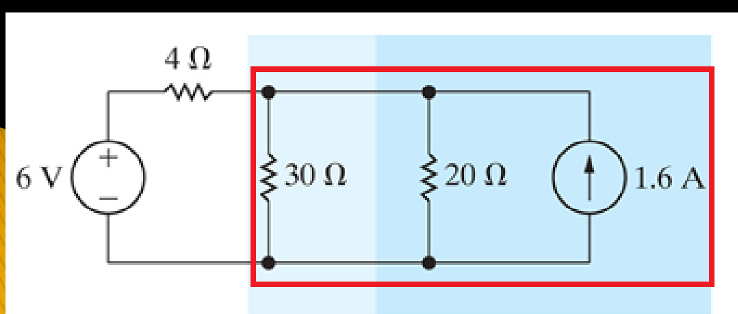
Analysis: because we need to find the current in 6 V voltage source for calculating its power, the 6 V voltage source should stay the same.

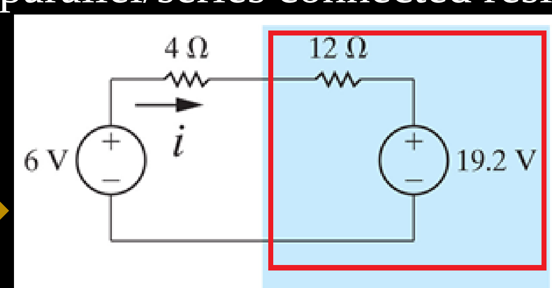


Let's transform the voltage source on the right side of the circuit to a current source. Then, you will find, after the transformation, 5 Ω resistor is parallel with 20 Ω resistor and you can combine these two into one resistor $\frac{5\times 20}{5+20} = 4\ \Omega$. The circuit is simplified.



You just repeat the same process: performing a transformation and then combining parallel/series connected resistors.

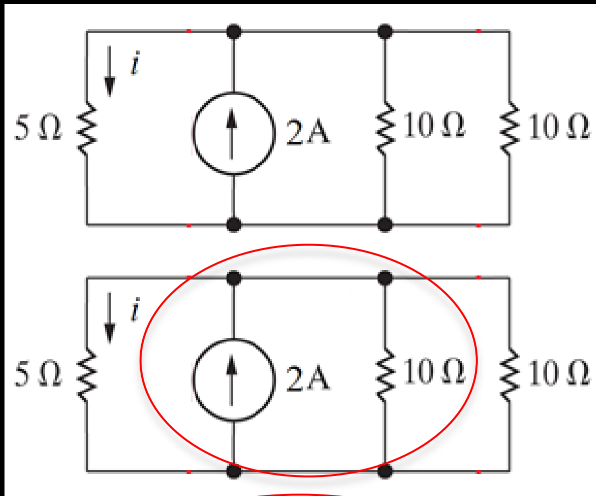




$$i = \frac{-19.2+6}{12+4}$$
$$= -0.825\ \text{A}$$

$$p = -6i = 4.95\ W$$

Example # 2



Find the current i in the circuit

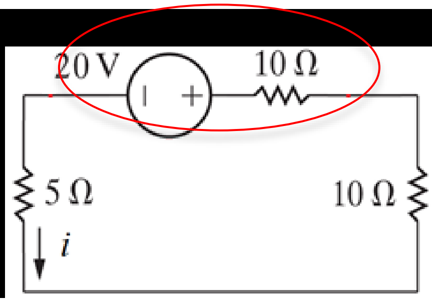
1. Let's use the current division formula.

10//10 = 5 Ω

$$i = \frac{2 \times 5}{5+5} = 1\ A$$

2. Let's use the source transformation.

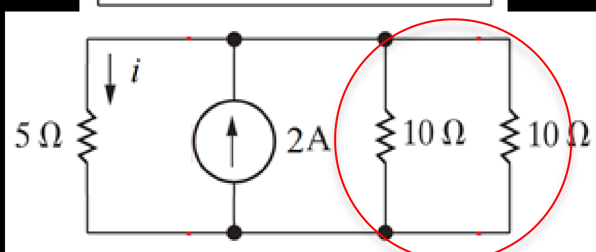
a. Transform the current source in the middle of the circuit to a voltage source



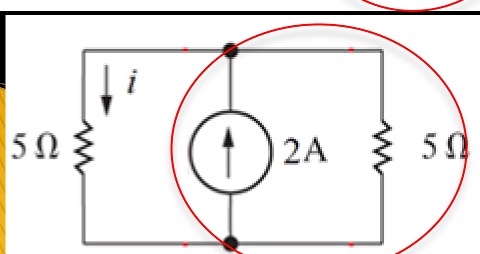
$$i = -\frac{20}{5+10+10} = -0.8\ A.$$

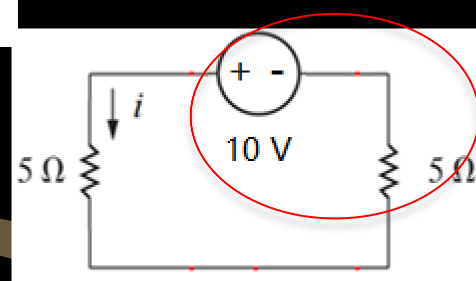
The solutions are different! Why?

Voltage/current sources must be on the one side of circuits!



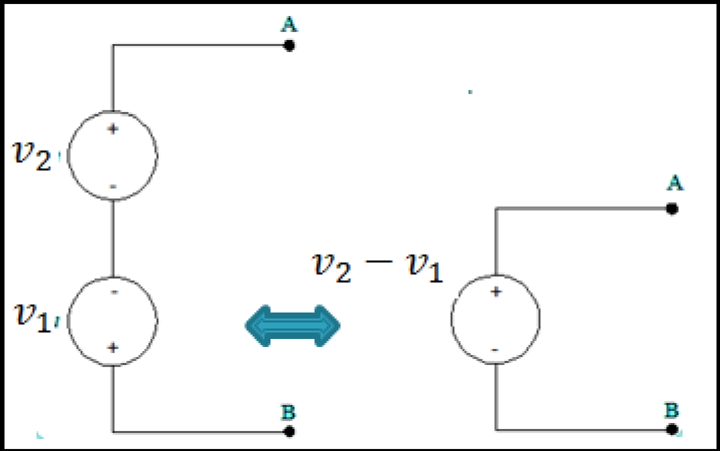
b. Combine two 10 Ω resistors and then transform the current source.

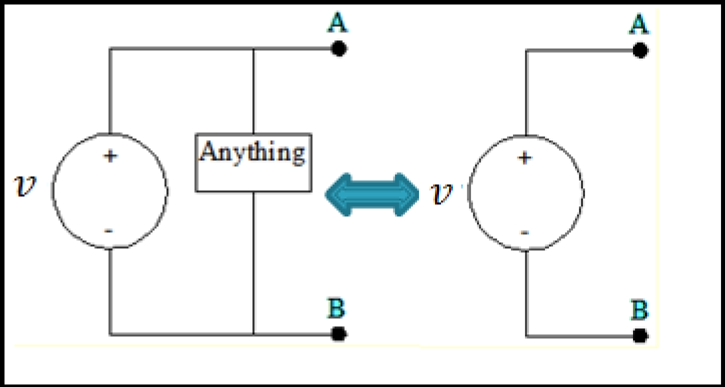


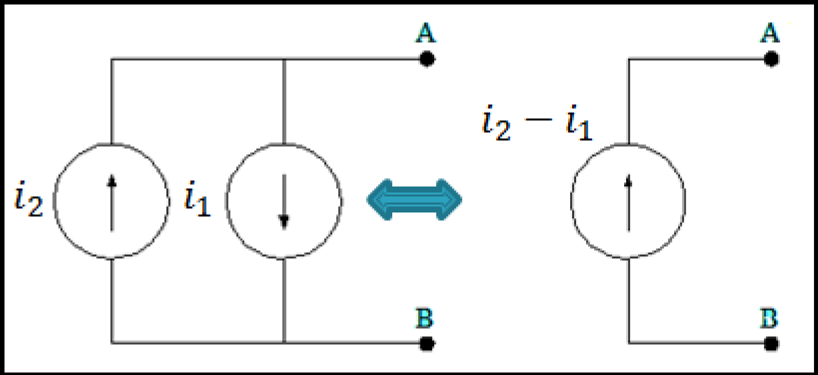


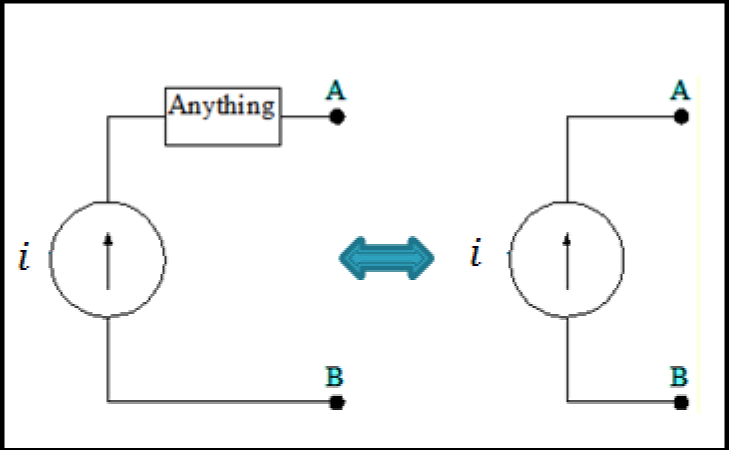
$$i = \frac{10}{5+5} = 1\ A$$

Other Useful Source Transformations(Equivalents)

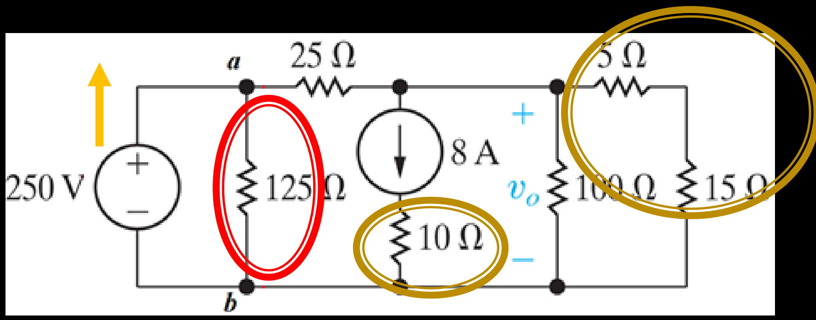






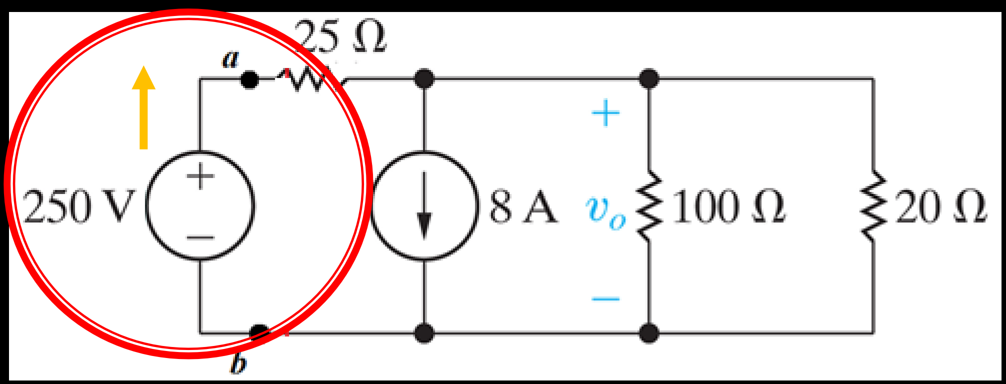


Example # 3



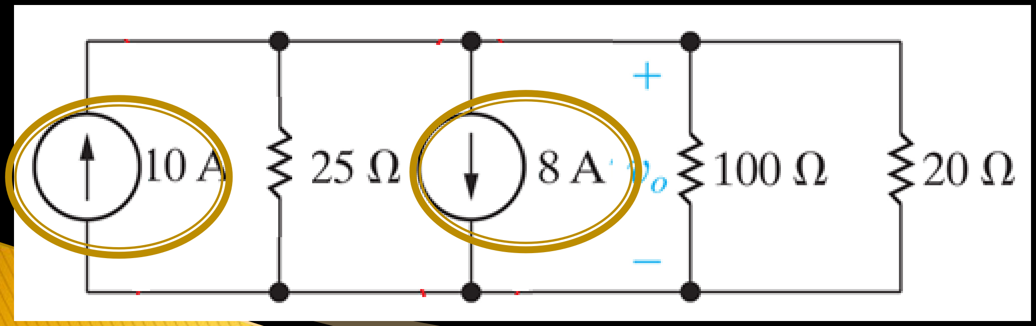
Find the voltage $v_{0.}$

1. 125 Ω can be removed
2. 10 Ω can be removed
3. Combine 5 Ω and 15 resistors



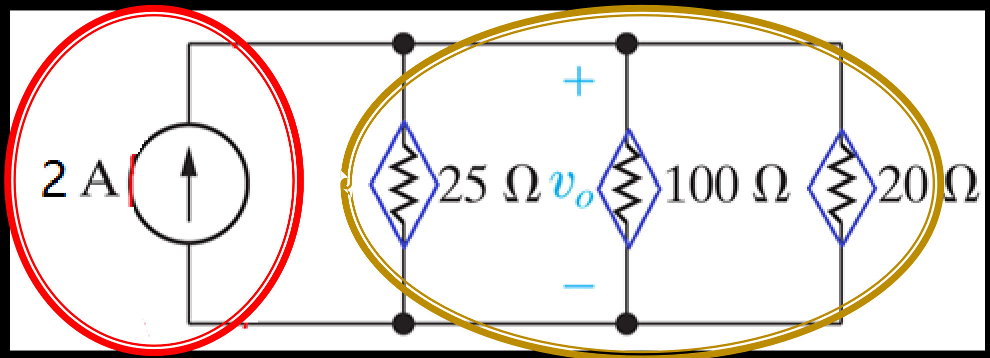
4. 250 V voltage source is transformed to a current source

$$\frac{250}{25} = 10\ A$$



Question: in the both circuits above, are the currents through the 250 V voltage source different?

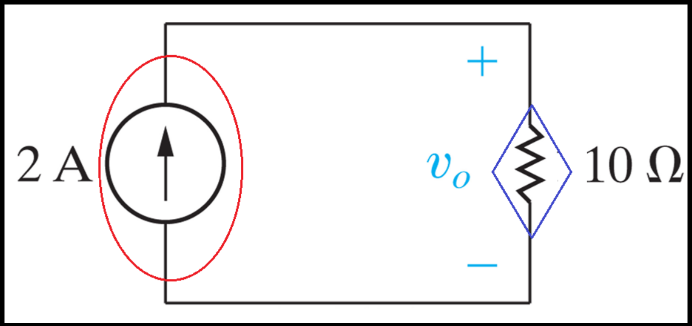
Example # 3 (cont.)



5. Combine 10 A and 8 A current sources

$$10 - 8 = 2\,A$$

6. Combine 25 Ω, 100 Ω, and 20 Ω resistors



$$\frac{1}{25} + \frac{1}{100} + \frac{1}{20} = 0.1 \quad R_{eq} = \frac{1}{0.1} = 10\ \Omega$$

5. Calculate v_0 by using Ohm's law

$$v_0 = 2 \times 10 = 20\ V$$

Summary

The source transformation can be used to transform a real voltage source to a real current source and vice versa. It helps simplify the process for solving circuits.

The topics in next lecture are:

1. The Thévenin equivalent circuits
2. The Norton equivalent circuits