

## Lecture 5

CSE250 - Circuits and Electronics

# SOURCE TRANSFORMATION

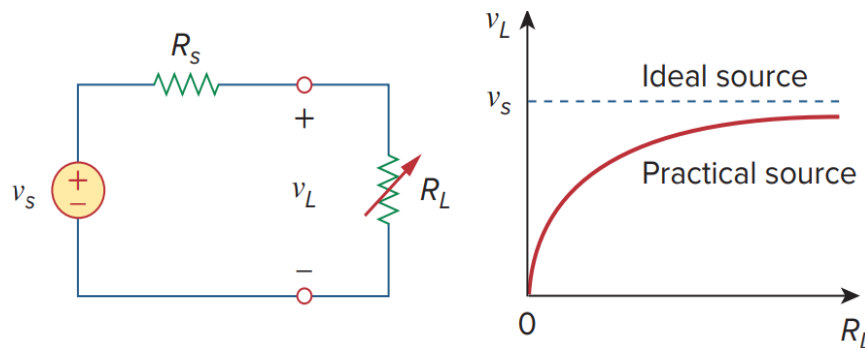


*PURBAYAN DAS, LECTURER  
Department of Computer Science and Engineering (CSE)  
BRAC University*

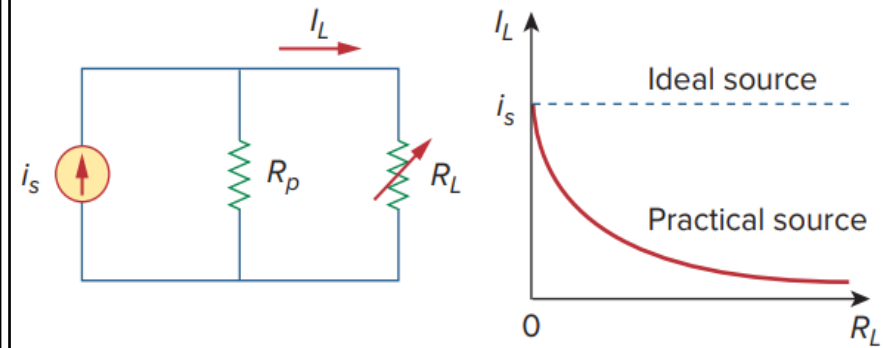
# Ideal and Non-ideal Source

- An *ideal voltage source* provides a constant voltage irrespective of the current drawn by the load, while an *ideal current source* supplies a constant current regardless of the load voltage.
- Practical* voltage and current sources are not ideal, due to their *internal resistances* or *source resistances*  $R_s$  and  $R_p$ . They become ideal as  $R_s \rightarrow 0$  and  $R_p \rightarrow \infty$ .

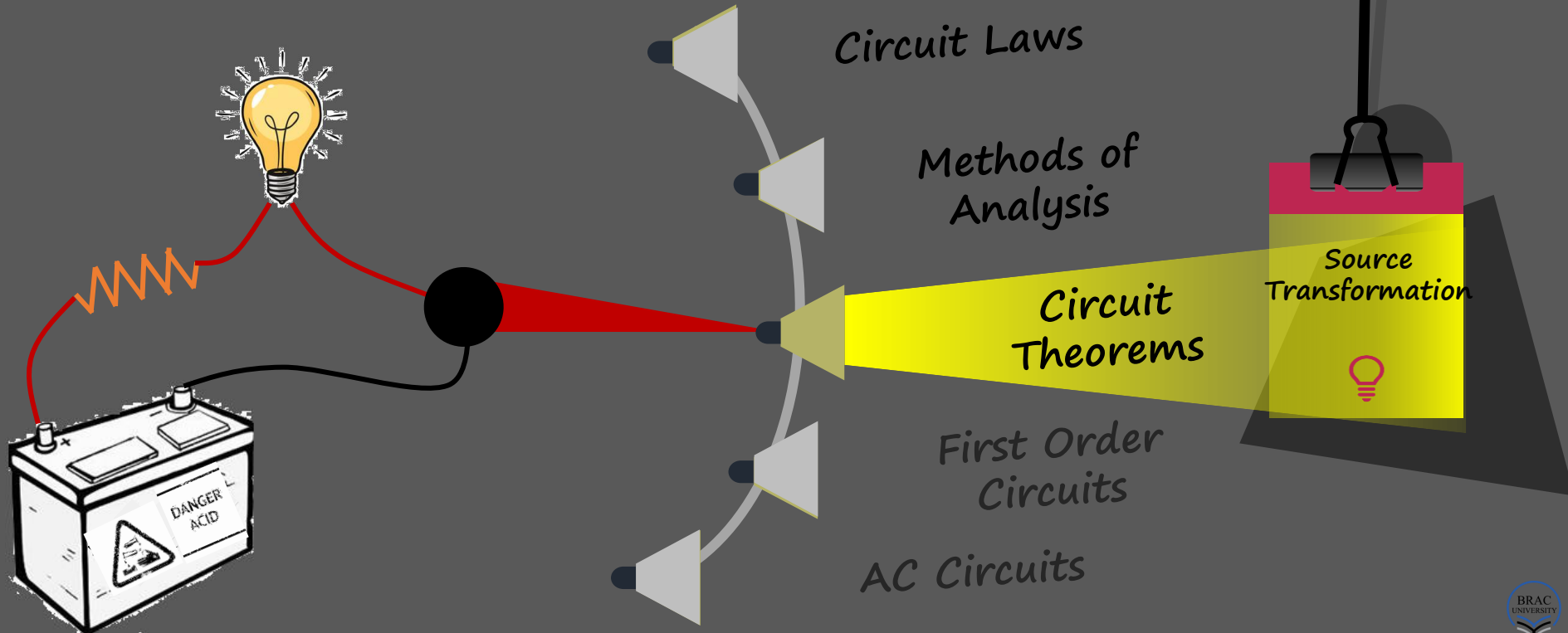
$$v_L = \frac{R_L}{R_s + R_L} v_s, \text{ if } R_s \ll R_L \text{ or } R_L = \infty, v_L \rightarrow v_s$$



$$i_L = \frac{R_p}{R_p + R_L} i_s, \text{ if } R_p \gg R_L \text{ or } R_p \rightarrow \infty, i_L \rightarrow i_s$$

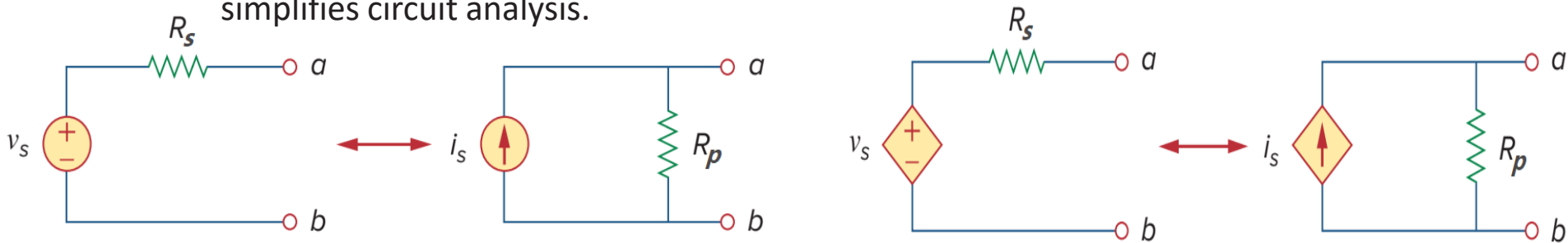


# Course Outline: broad themes



# Source Transformation

- A **source transformation** is the process of replacing a voltage source  $v_s$  in series with a resistor  $R$  by a current source  $i_p$  in parallel with a resistor  $R$ , or vice versa.
- The transformation does not affect the remaining part of the circuit but greatly simplifies circuit analysis.



- Note that the arrow of the current source is directed toward the positive terminal of the voltage source.
- The source transformation is not possible when  $R = 0$  and  $R = \infty$ , which are the cases with an ideal voltage and current source respectively. However, for a practical, nonideal voltage source,  $R \neq 0$ , and for a practical, nonideal current source,  $R \neq \infty$ .

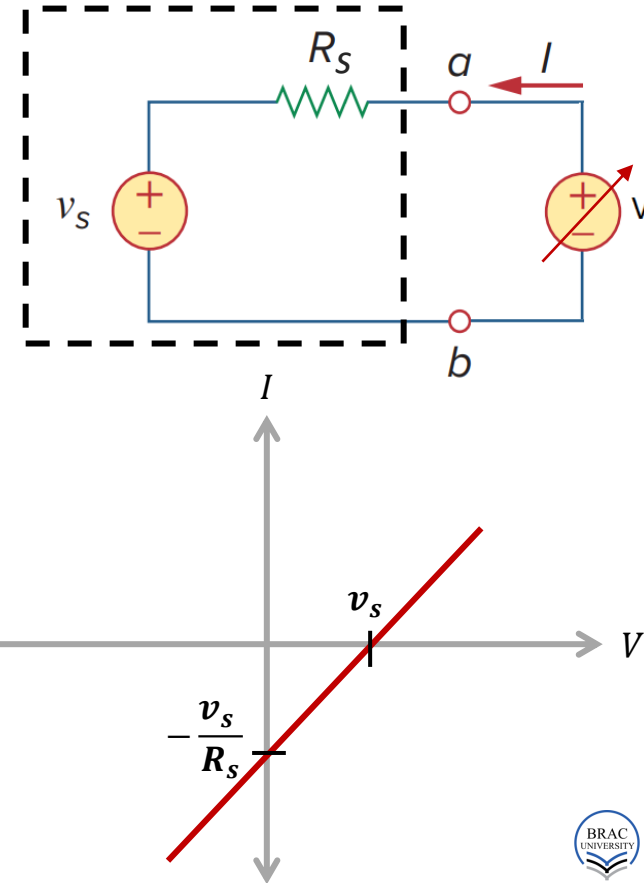
# V and R in Series

- We recall that *an equivalent circuit is one whose  $I - V$  characteristics are identical with the original circuit*. Let's see what conditions make the two circuits to have the same  $I - V$  relations at terminals  $a - b$ .
- Let's say we have a configuration of a voltage source ( $v_s$ ) in series with a resistor ( $R_s$ ) between terminals  $a$  and  $b$ . To determine the configuration's  $I - V$  characteristics, if applying a voltage  $V$  gives rise to a current  $I$ , we can write,

$$V = v_s + IR_s$$

$$\Rightarrow I = \frac{1}{R_s}V - \frac{v_s}{R_s}$$

- The equation results in a linear  $I$  vs  $V$  plot that intersects the axes at  $v_s$  and  $-\frac{v_s}{R_s}$ .



# I and R in Parallel

- For the other configuration: a current source ( $i_p$ ) in parallel with a resistor ( $R_p$ ) between terminals  $a$  and  $b$ , if applying a voltage  $V$  gives rise to a current  $I$ , using KCL the current through the resistor is,

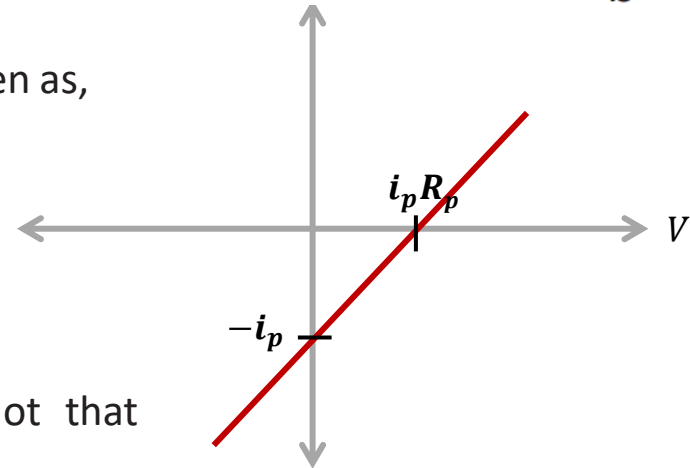
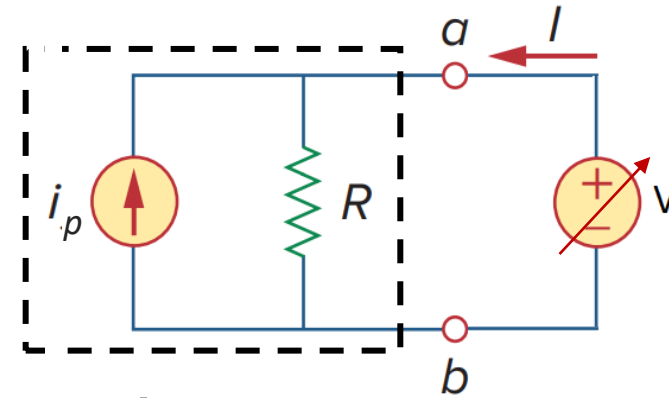
$$I + i_p$$

- So, the voltage across the resistor can be written as,

$$(I + i_p) R_p = V$$

$$\Rightarrow I = \frac{1}{R_p} V - i_p$$

- The equation results in a linear  $I$  vs  $V$  plot that intersects the axes at  $i_p R_p$  and  $-i_p$ .

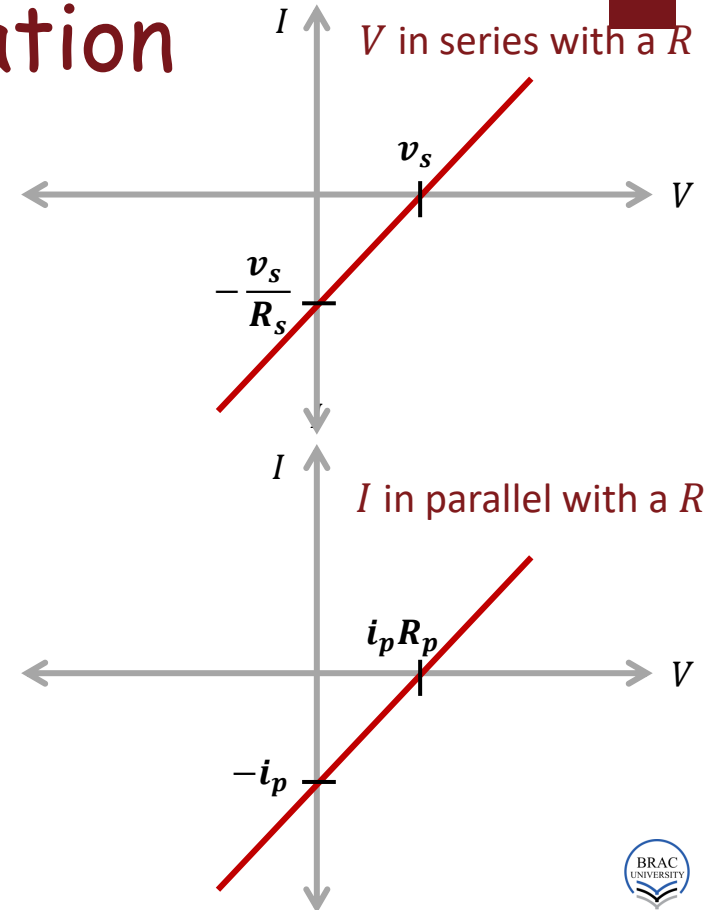
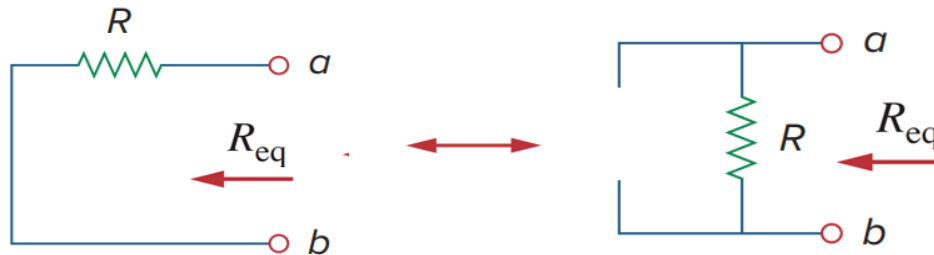


# Conditions for Transformation

- The two configurations will be equivalent to each other if their  $I - V$  characteristics are similar. It can be said by looking at the two plots, they will indeed be similar if the intersecting points are same, that is, if  $v_s = i_p R_p$  and  $-\frac{v_s}{R_s} = -i_p$ . This requires  $R_s = R_p = R$ . Both the equations result in an ohmic relation,

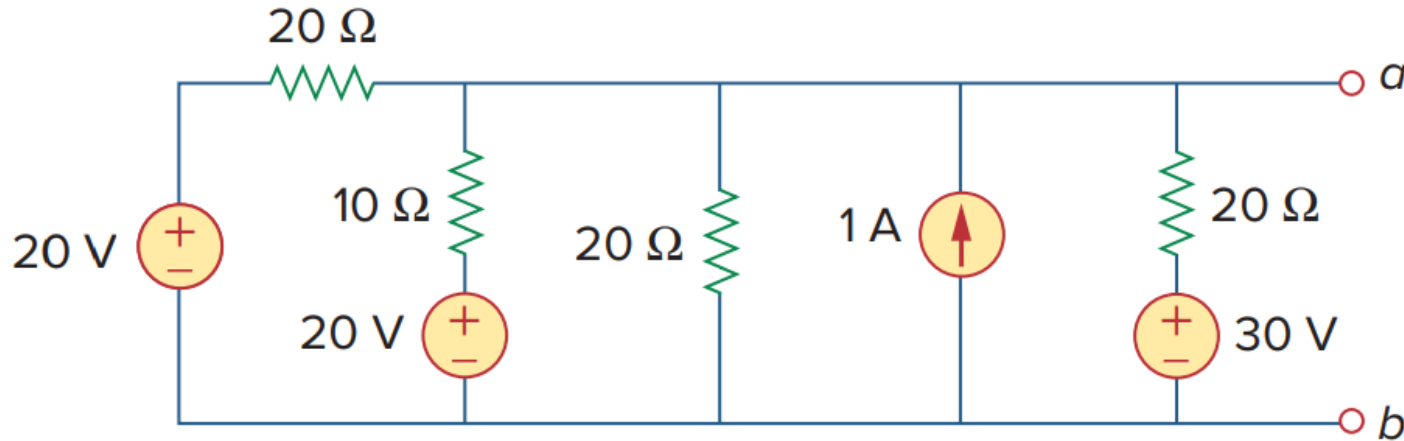
$$v_s = i_p R \text{ or } i_p = \frac{v_s}{R}$$

- So, if the sources are turned off, the equivalent resistance at terminals  $a - b$  in both circuits is  $R$ .



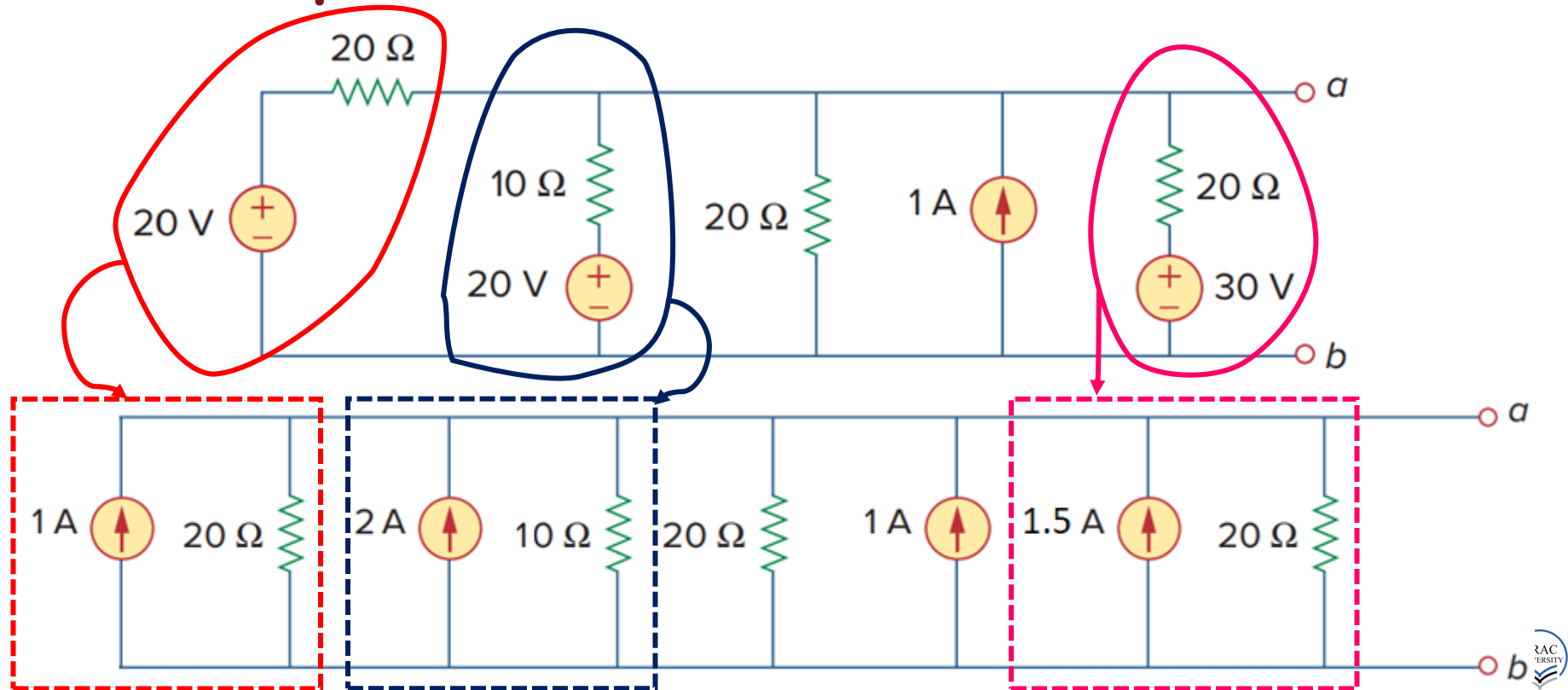
# Example 1 - 1/3

- Use source transformation to reduce the circuit between terminals  $a$  and  $b$  to a single voltage source in series with a single resistor.

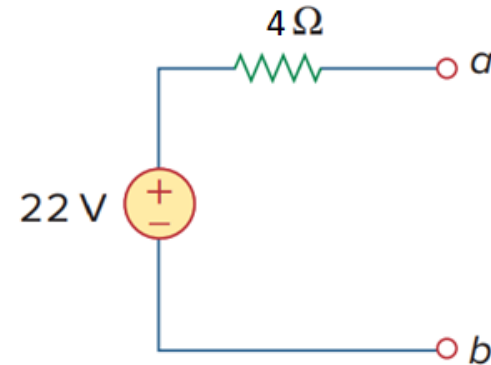
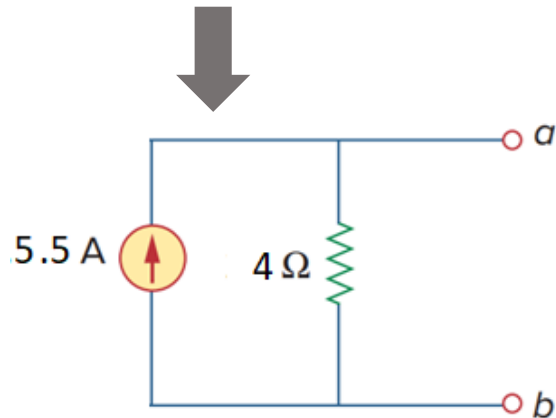
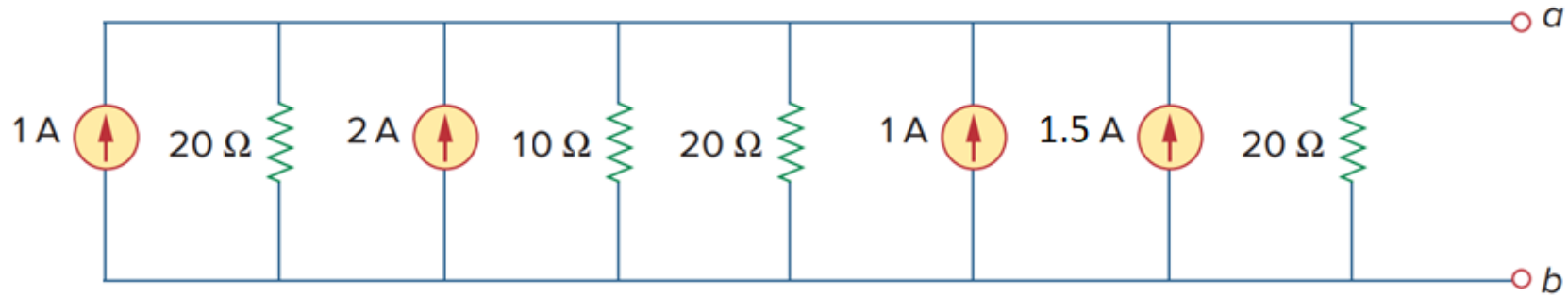




# Example 1 - 2/3

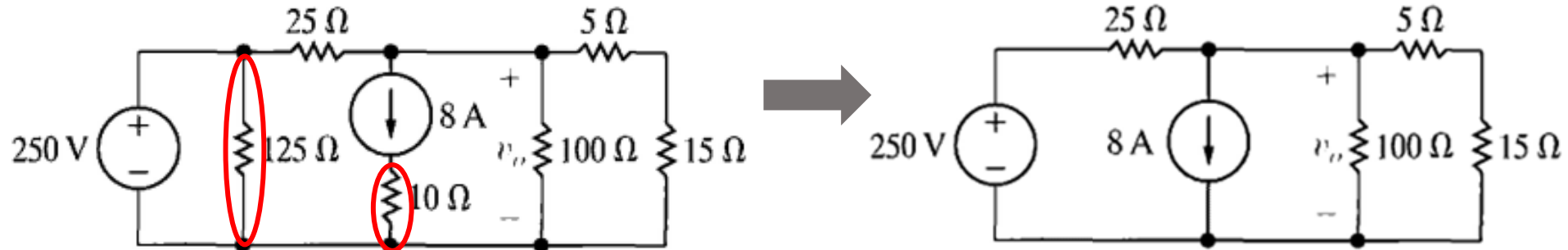


# Example 1 - 3/3



# Problem 1

- Use Source Transformation to find the voltage  $v_0$ . Find the power developed by the 250 V source and 8 A source.

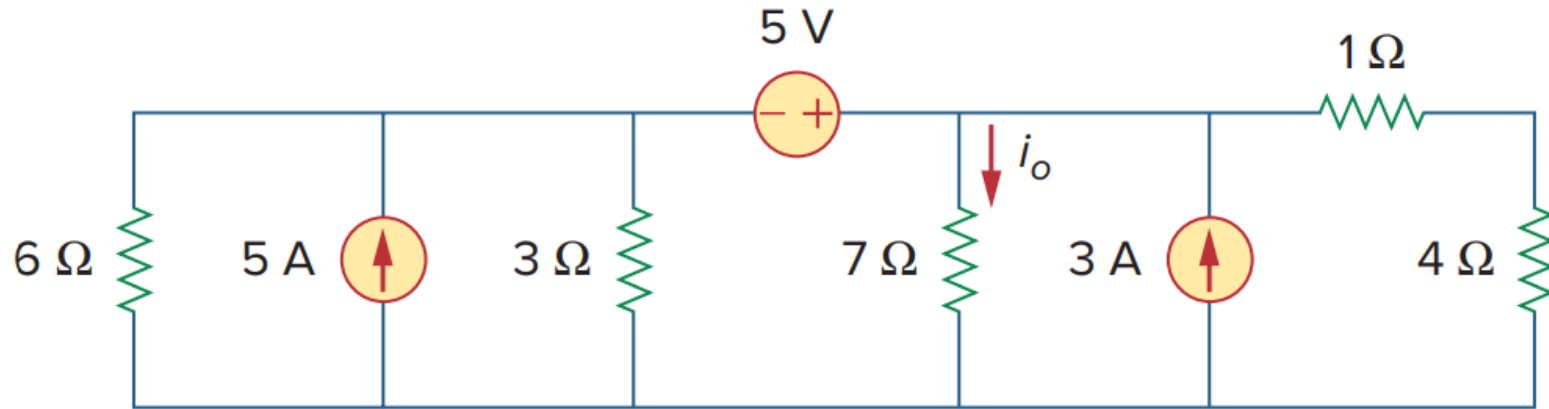


A resistor in series with a current source is redundant, as is a resistor in parallel with a voltage source. We can remove them; this will have no effect on the circuit except for the sources. Opening a resistor parallel to a voltage source will **reduce** the current supplied by the source. Similarly, shorting a resistor in series with a current source **increases** the voltage across the current source. We have to keep in mind those facts while calculating parameters for the sources.

$$\text{Ans: } v_0 = 20 \text{ V}; P_{250\text{V}} = -2.8 \text{ kW}; P_{8\text{A}} = -480 \text{ W}$$

# Problem 2

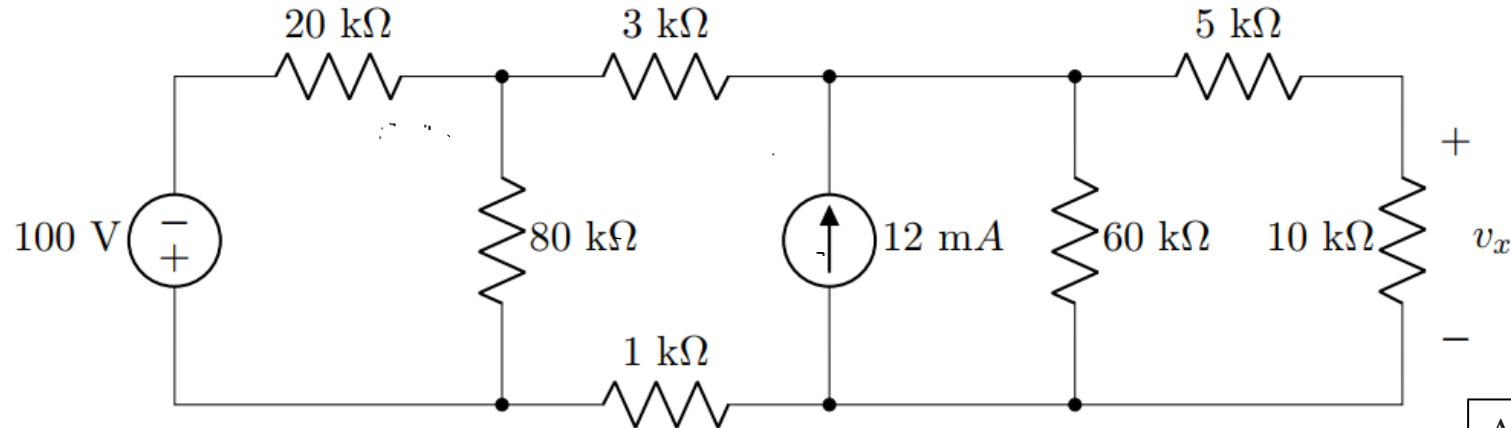
- Find  $i_o$  in the circuit using Source Transformation.



Ans:  $i_o = 1.78 \text{ A}$

# Problem 3

- Determine the voltage  $v_x$  across the  $10\text{ k}\Omega$  resistor by performing a succession of appropriate Source Transformations.

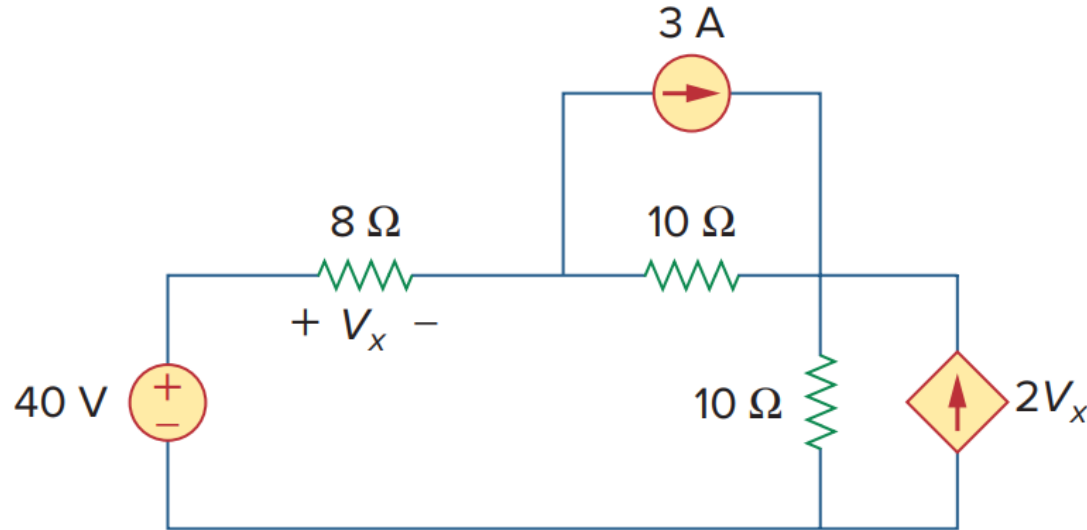


Ans:  $v_x = 40\text{ V}$

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# Problem 4

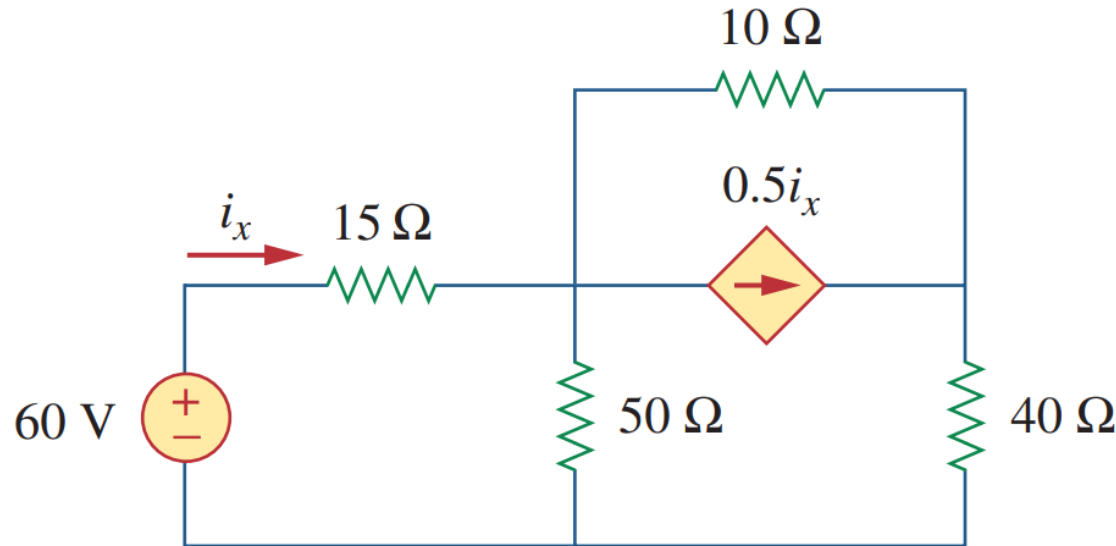
- Use Source Transformation to find  $V_x$ .



Ans:  $V_x = 2.98\text{ V}$

# Problem 5

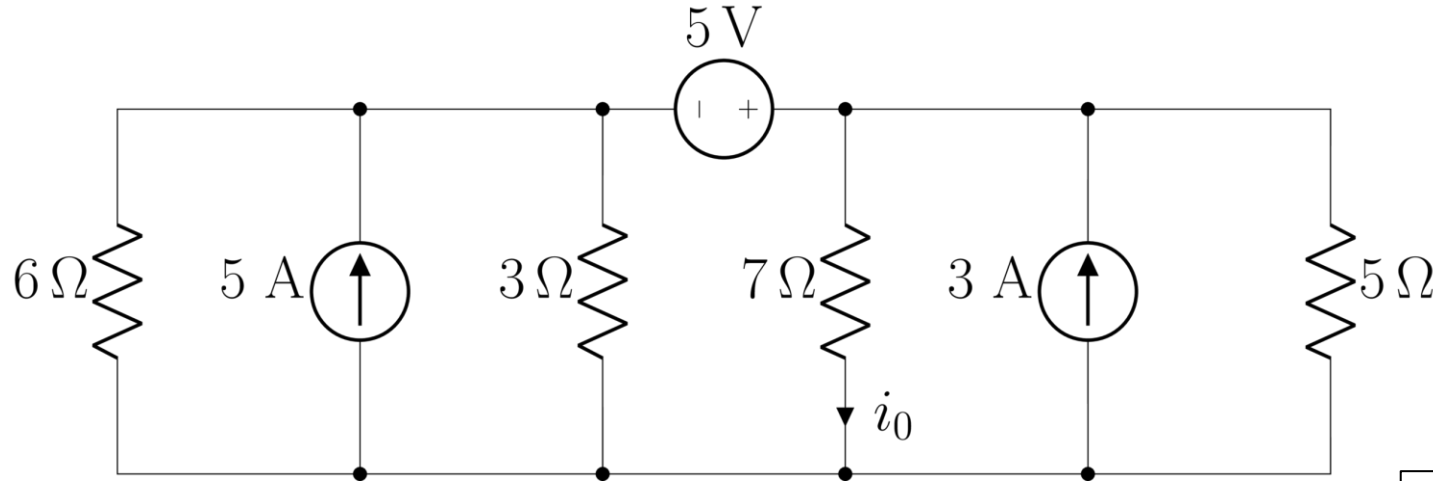
- Use Source Transformation to find  $i_x$  in the following circuit.



Ans:  $i_x = 1.6 \text{ A}$

# Problem 6

- Reduce the circuit to a **2-mesh** circuit using Source Transformation. Then determine  $i_0$ .

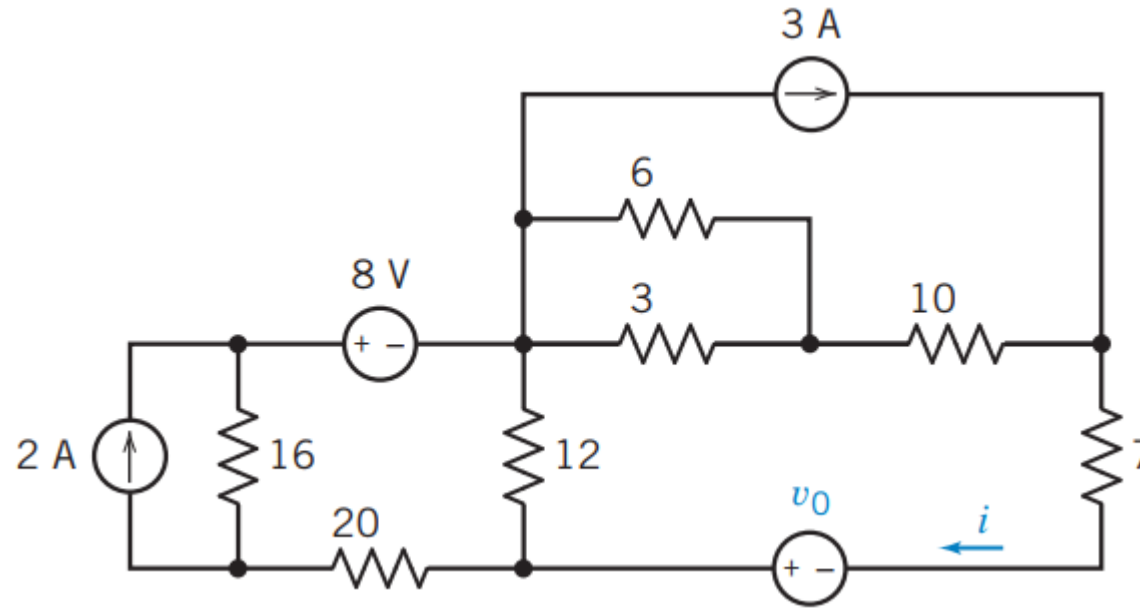


Ans:  $i_0 = 1.78 \text{ A}$



# Problem 7

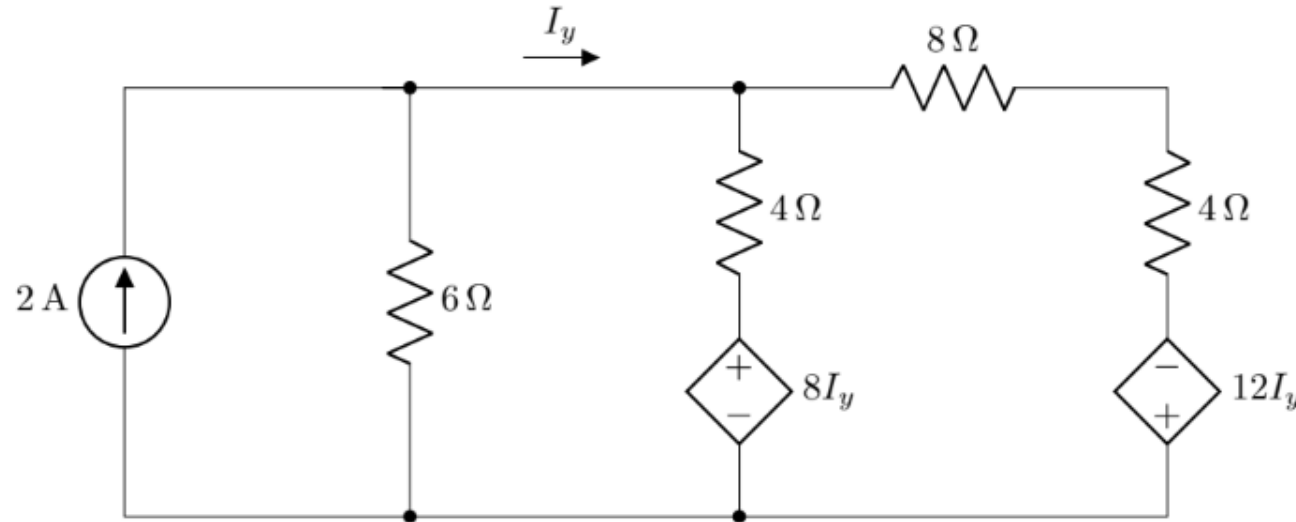
- Reduce the circuit to a single loop. If  $i = 2.5\text{ A}$ , determine  $v_0$ .



Ans:  $v_0 = 28\text{ V}$

# Problem 8

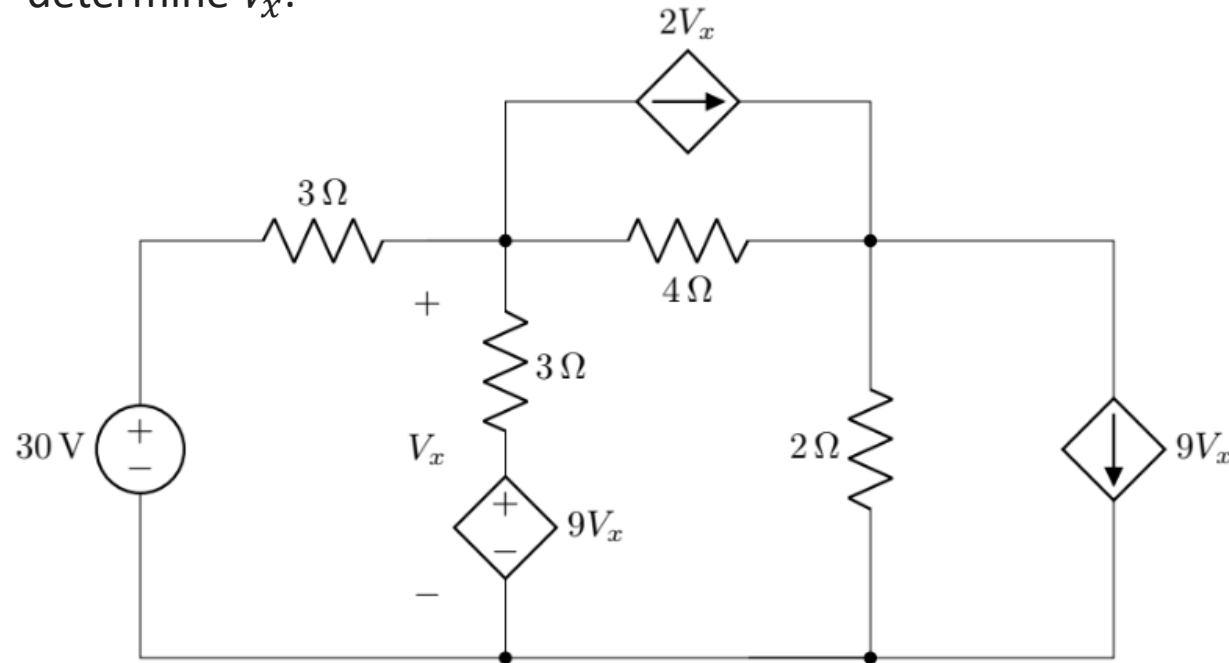
- Reduce the circuit to a single loop using Source Transformation. Then determine  $I_y$ .



Ans:  $I_y = 1\text{ A}$

# Problem 9

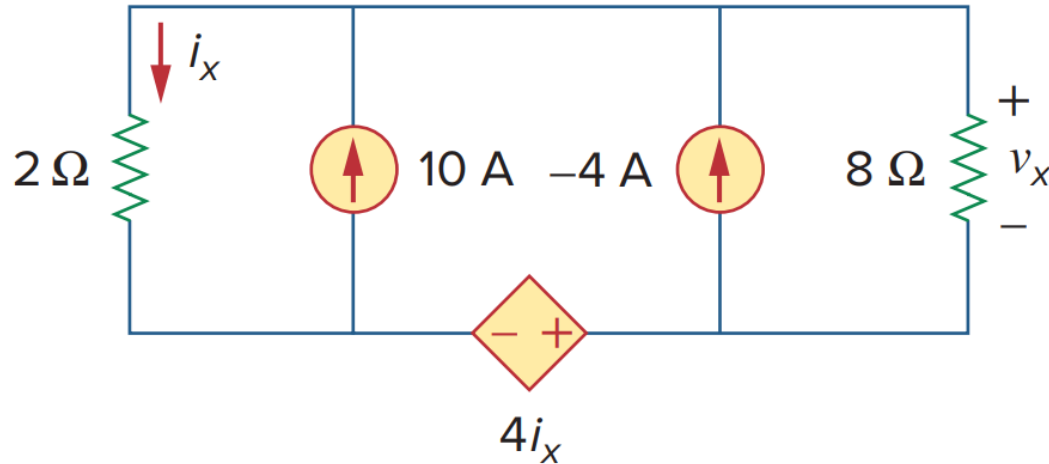
- Reduce the circuit to a single loop using Source Transformation. Then determine  $V_x$ .



Ans:  $V_x = 4.62 \text{ V}$

# Problem 10

- Reduce the circuit to a single loop using Source Transformation. Then determine  $v_x$ . [Hint: careful with the positions of  $i_x$  and  $v_x$  after transformation]



Ans:  $v_x = -16 \text{ V}$

# Practice Problems

- Additional recommended practice problems: [here](#)
- Other suggested problems from the textbook: [here](#)

# Thank you for your attention