Department of Computer Science and Engineering (CSE)
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CSE250 – Circuits and Electronics

SOURCE TRANSFORMATION

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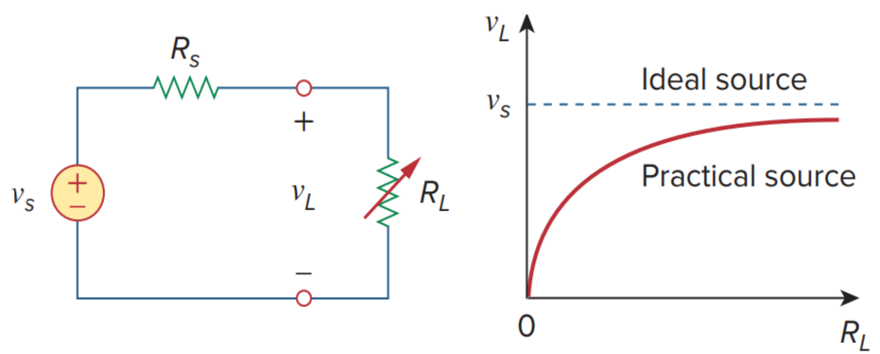
Ideal and non-ideal sources

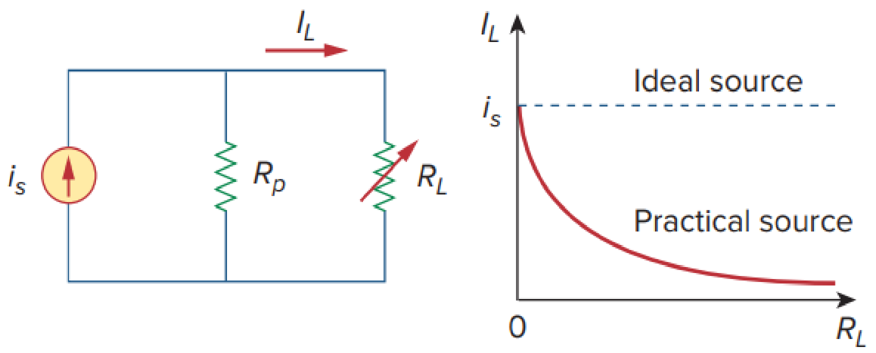
- An *ideal voltage source* provides a constant voltage irrespective of the current drawn by the load, while an *ideal current source* supplies a constant current regardless of the load voltage.

- *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 $R_s \to 0$ and $R_p \to \infty$.

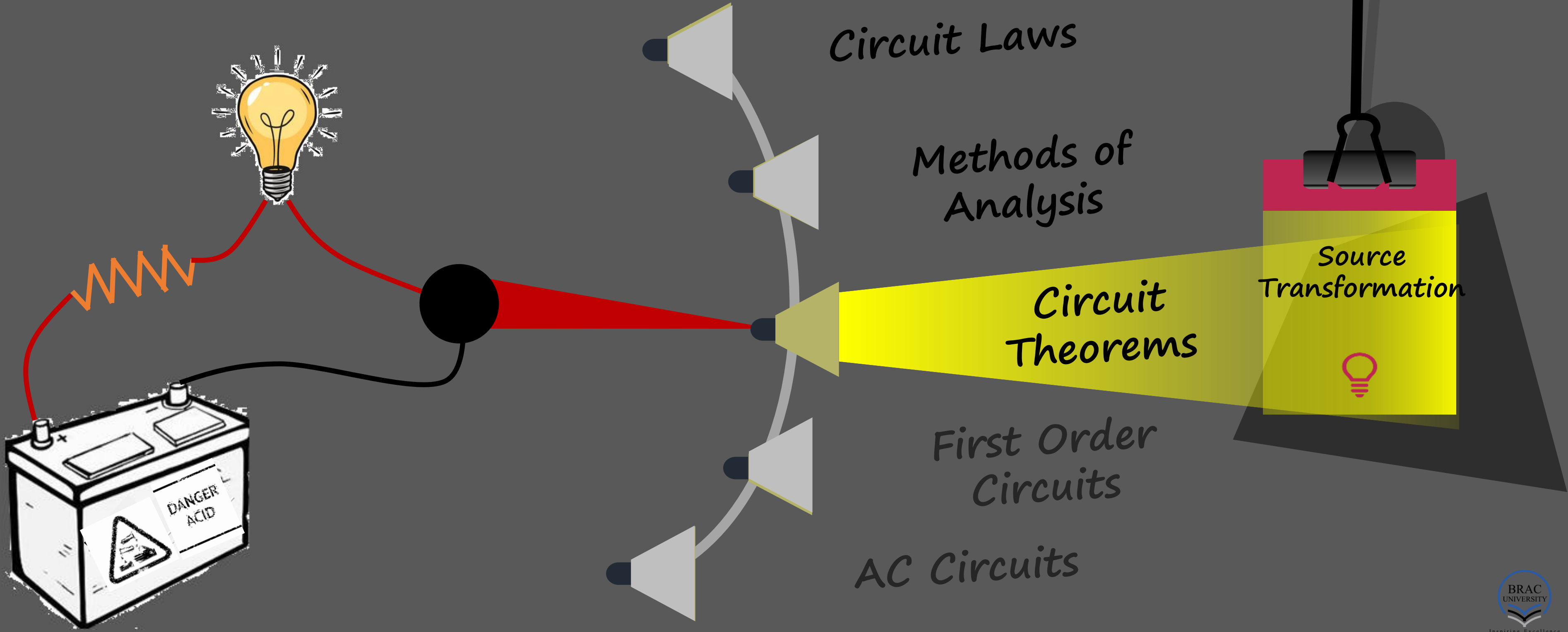
$$v_L = \frac{R_L}{R_s+R_L} v_s, \text{ if } R_s \ll R_L \; or \; R_L = \infty, v_L \to v_s$$



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

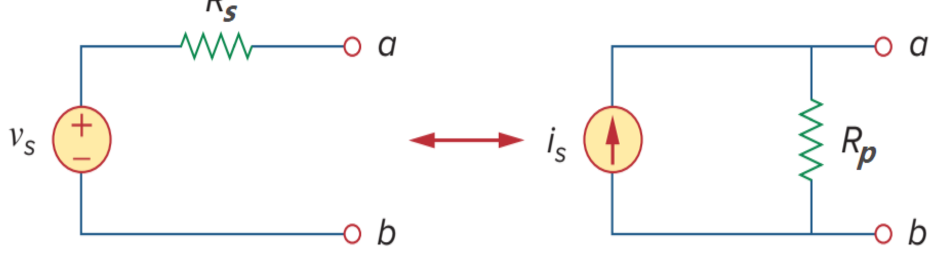


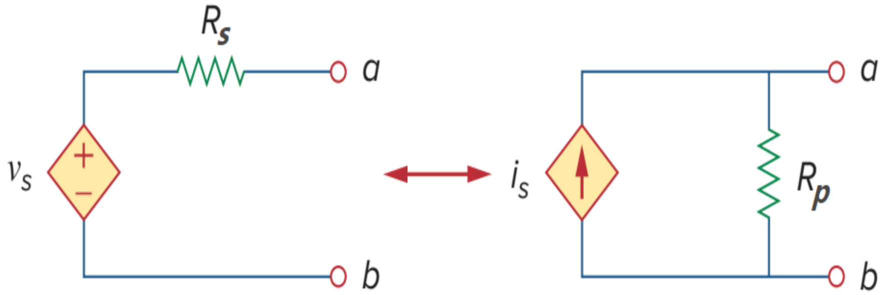
Course Outline: broad themes



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 $R = \infty$ (see next slide), 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 in series with a R

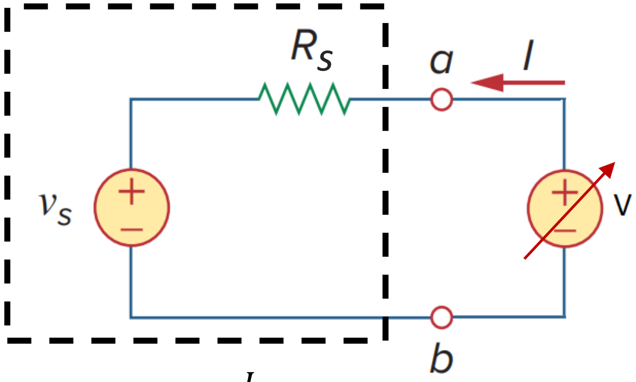
- We recall that *an equivalent circuit is one whose $I-V$ characteristics are identical with the original circuit*. Let's see what conditions make the two circuits to have the same $I-V$ relations at terminals $a-b$.

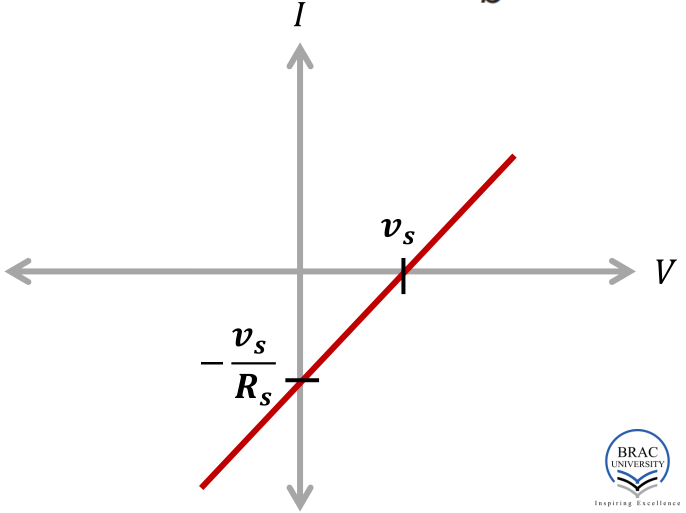
- Let's say we have a configuration of a voltage source (v_s) in series with a resistor (R_s) between terminals a and b. To determine the configuration's $I-V$ characteristics, if applying a voltage V gives rise to a current I, we can write,

$$V = v_s + IR_s$$

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

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





I in parallel with a R

- 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,

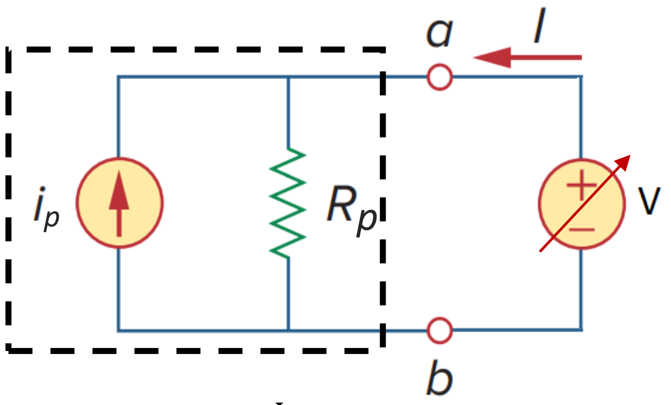
$$I + i_p$$

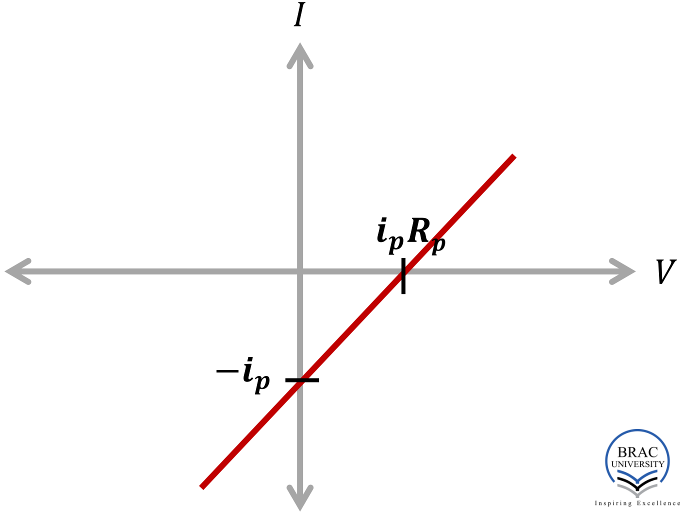
- So, the voltage across the resistor can be written as,

$$\left(I + i_p\right) R_p = V$$

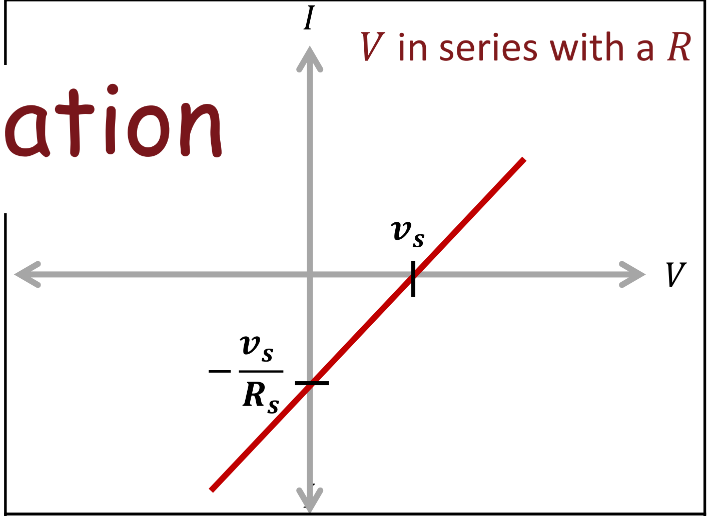
$$\Rightarrow I = \frac{1}{R_p} V - i_p$$

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





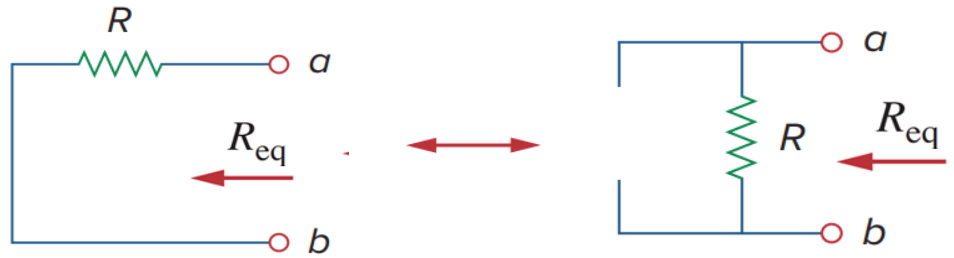
Conditions for transformation

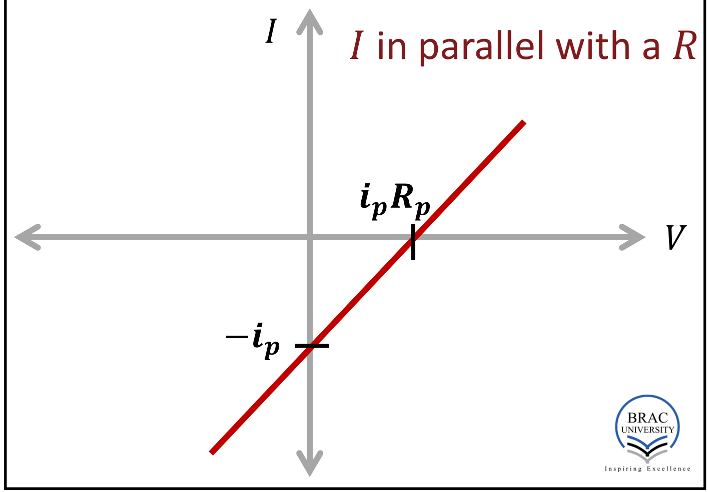


- The two configurations will be equivalent to each other if their $I - V$ characteristics are similar. It can be said by looking at the two plots, they will indeed be similar if the intersecting points are same, that is, if $v_s = i_p R_p$ and $-\frac{v_s}{R_s} = -i_p$. This requires $\boxed{R_s = R_p}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

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

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





Example 1

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

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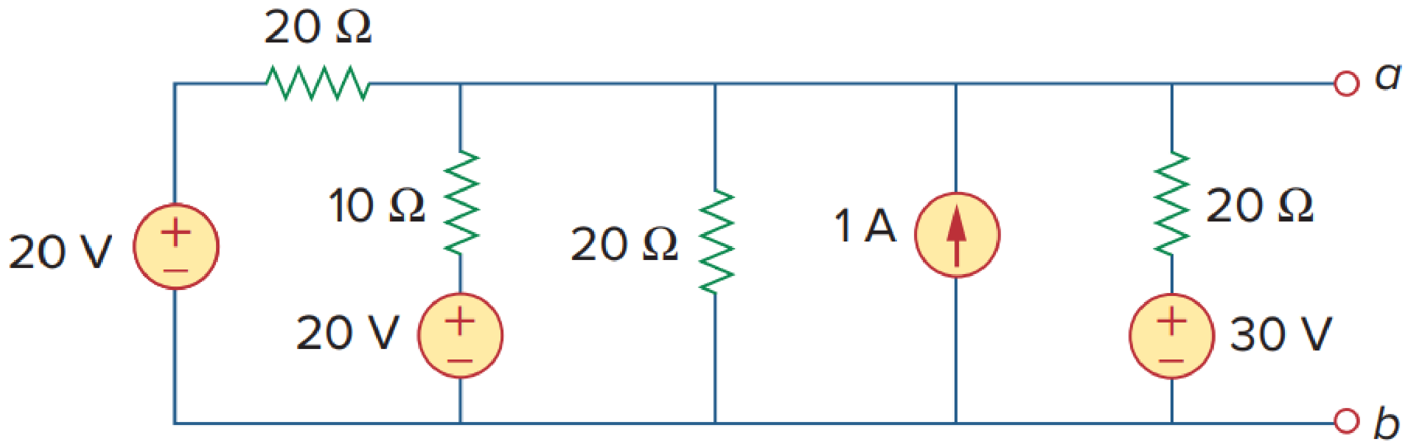
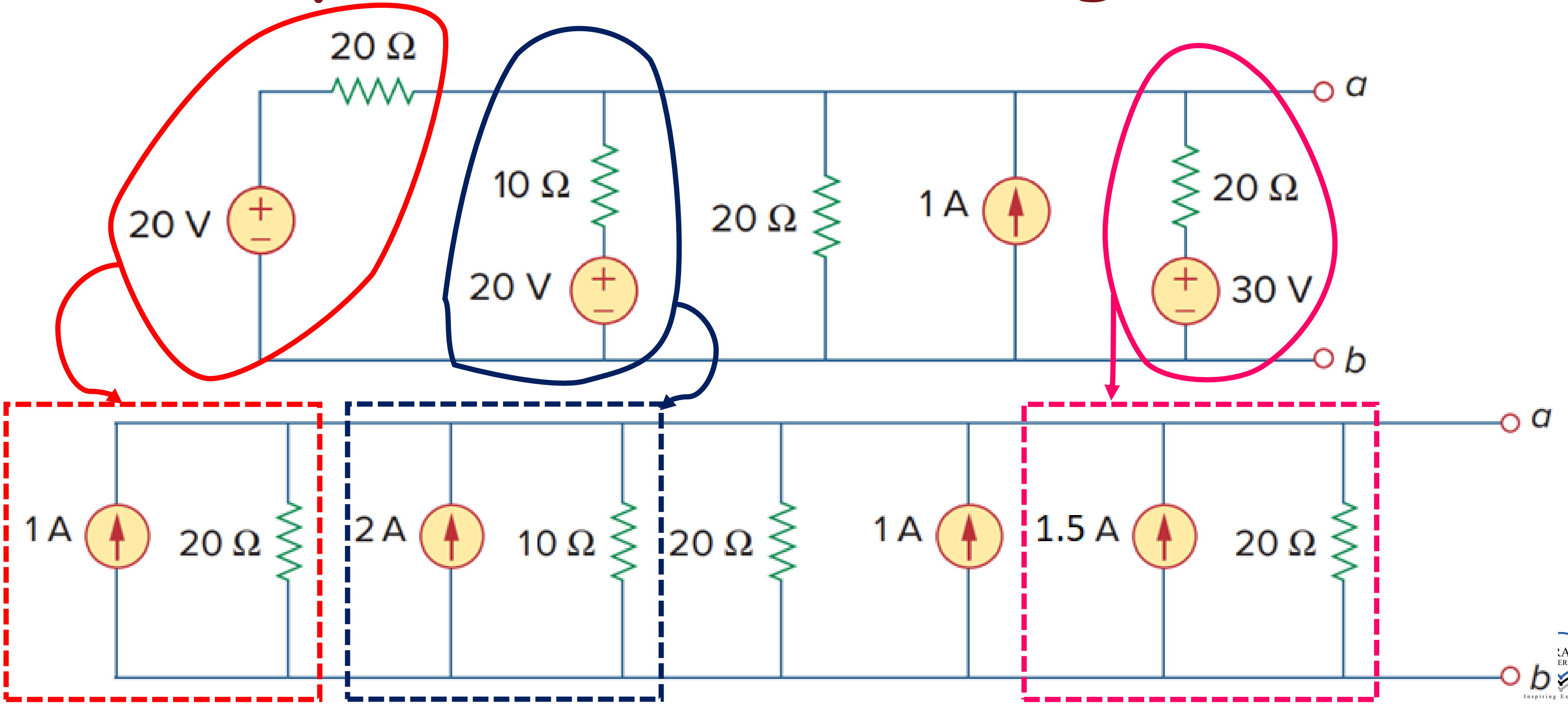
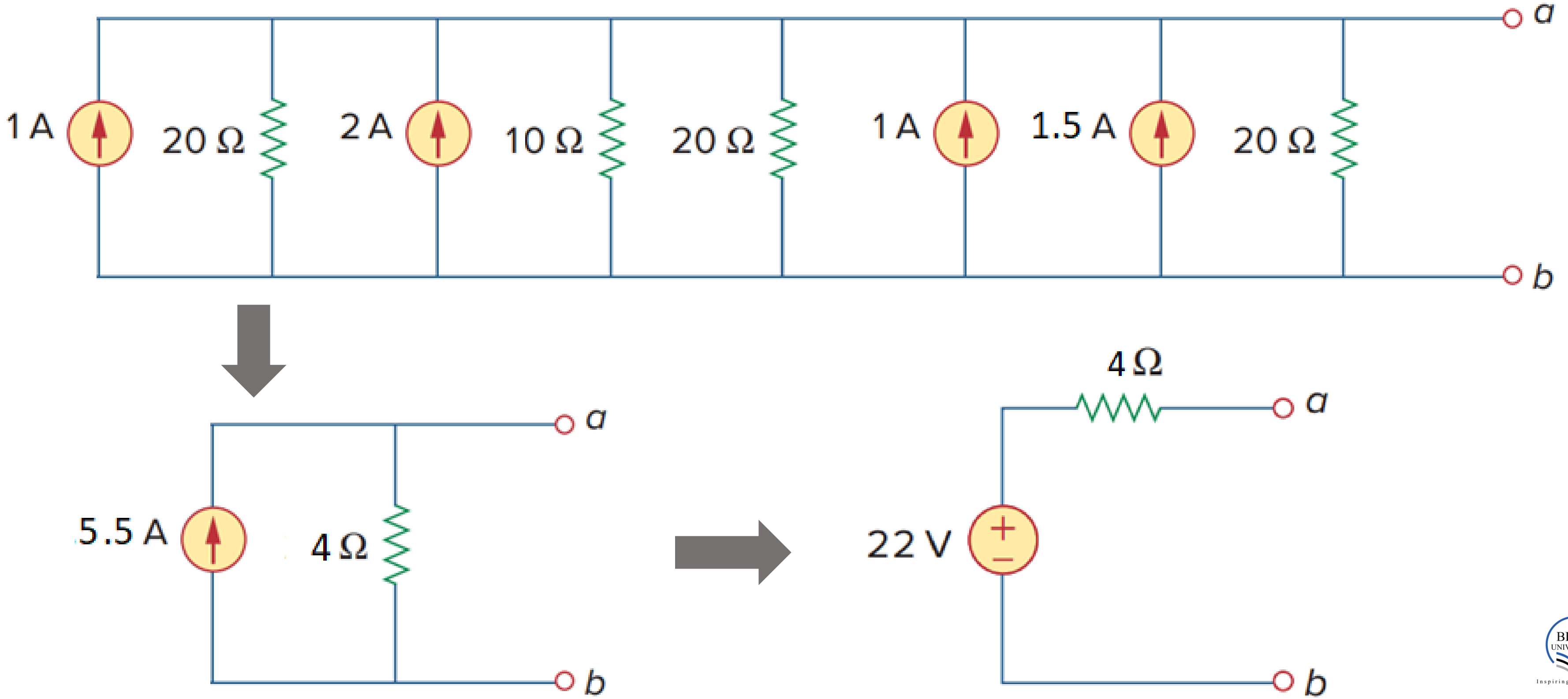


Example 1: transforming sources

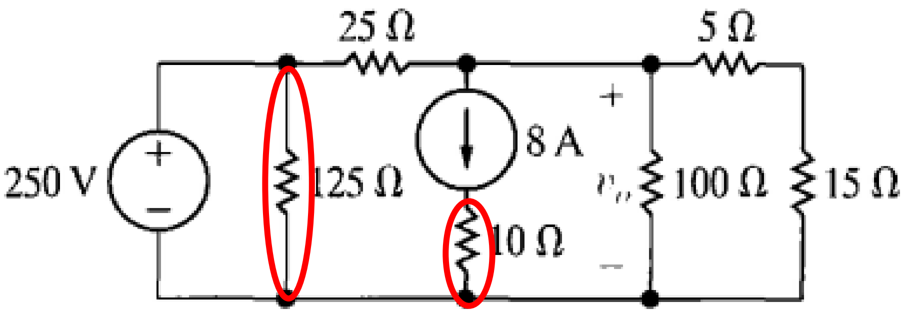


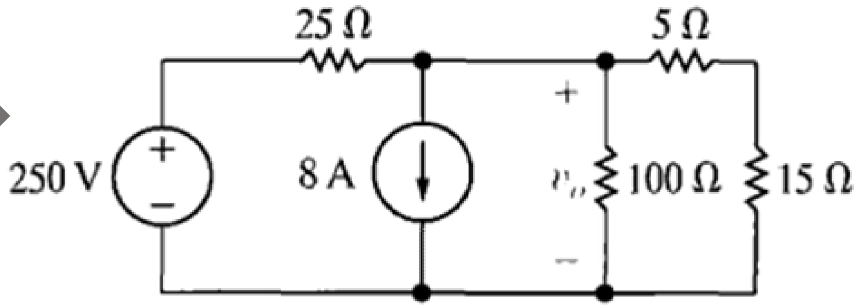
Example 1 (contd … 2)



Problem 1

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



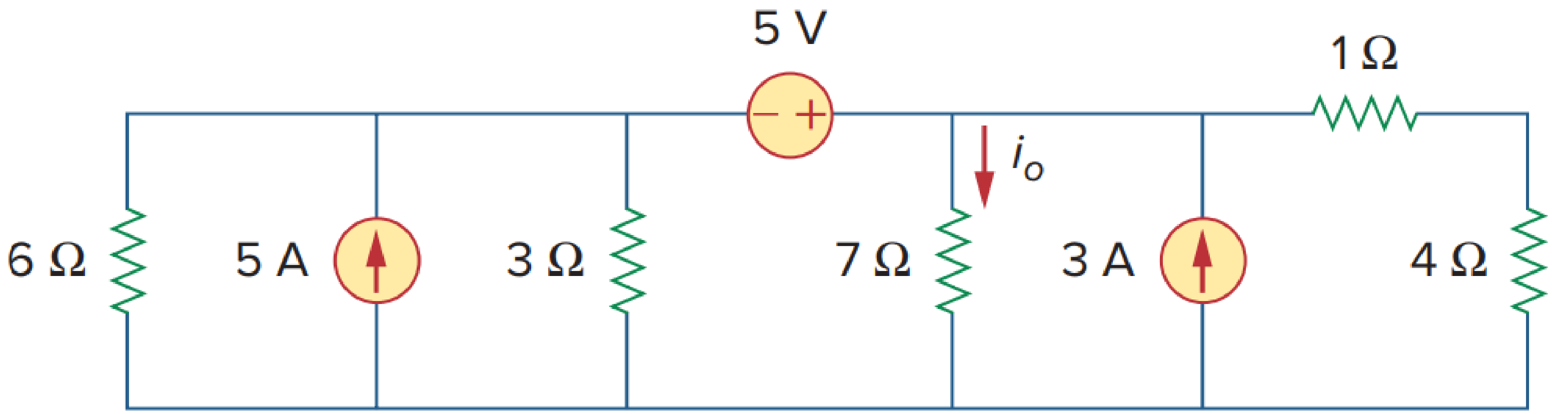


A resistor in series with a current source is redundant, as is a resistor in parallel with a voltage source. We can remove them; this will have no effect on the circuit except for the sources. Opening a resistor parallel to a voltage source will ***reduce*** the current supplied by the source. Similarly, 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.

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

Problem 2

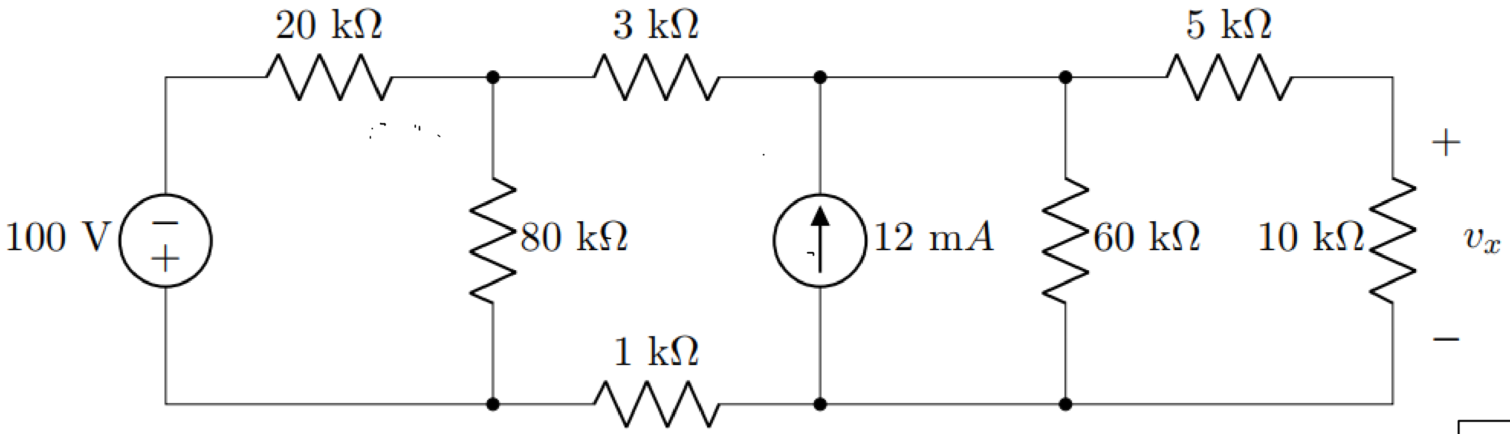
- Find i_o in the circuit using Source Transformation.



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

Problem 3

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



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

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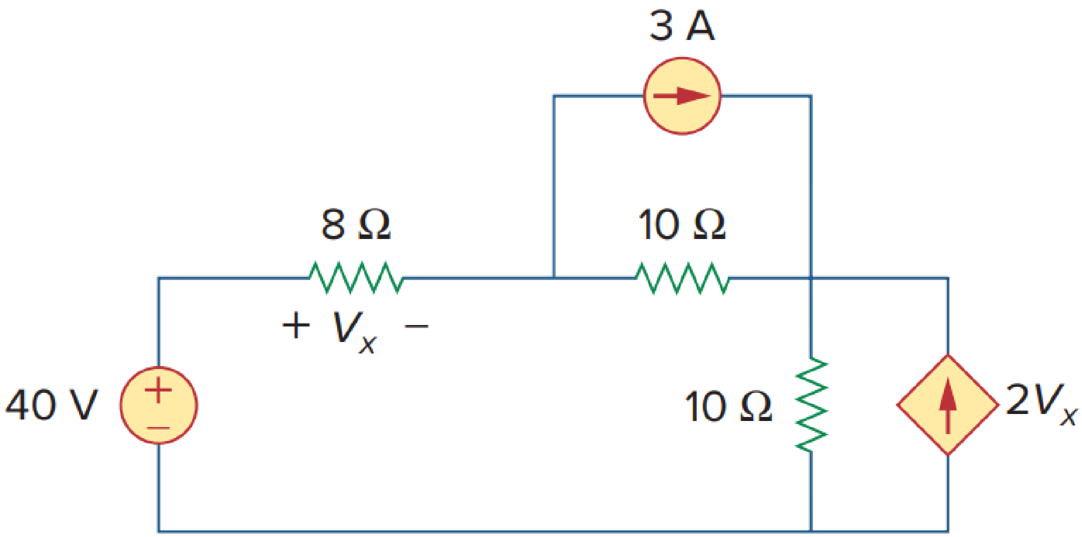
Problem 4

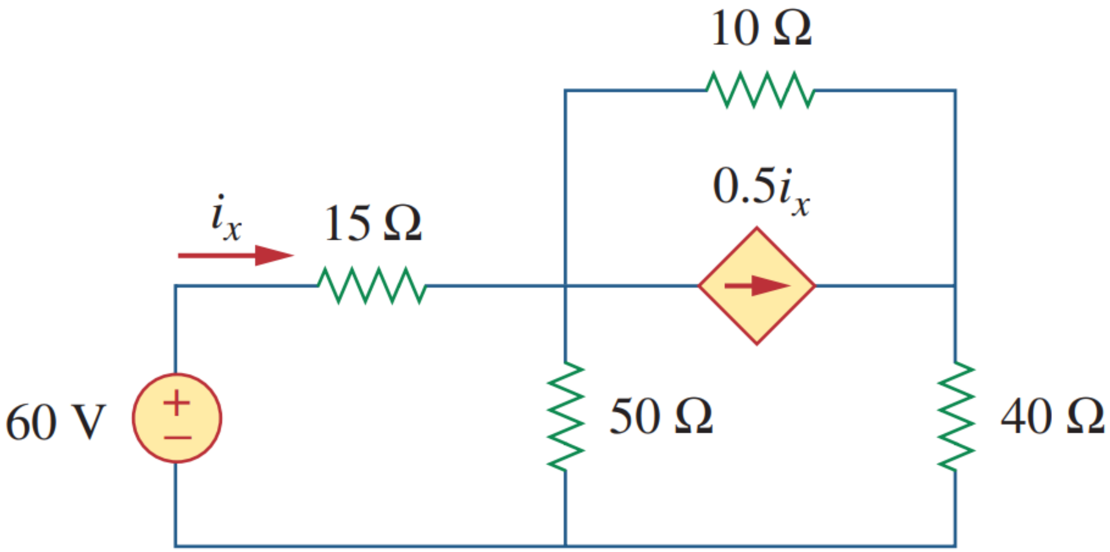
- Use Source Transformation to find V_x.



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

Problem 5

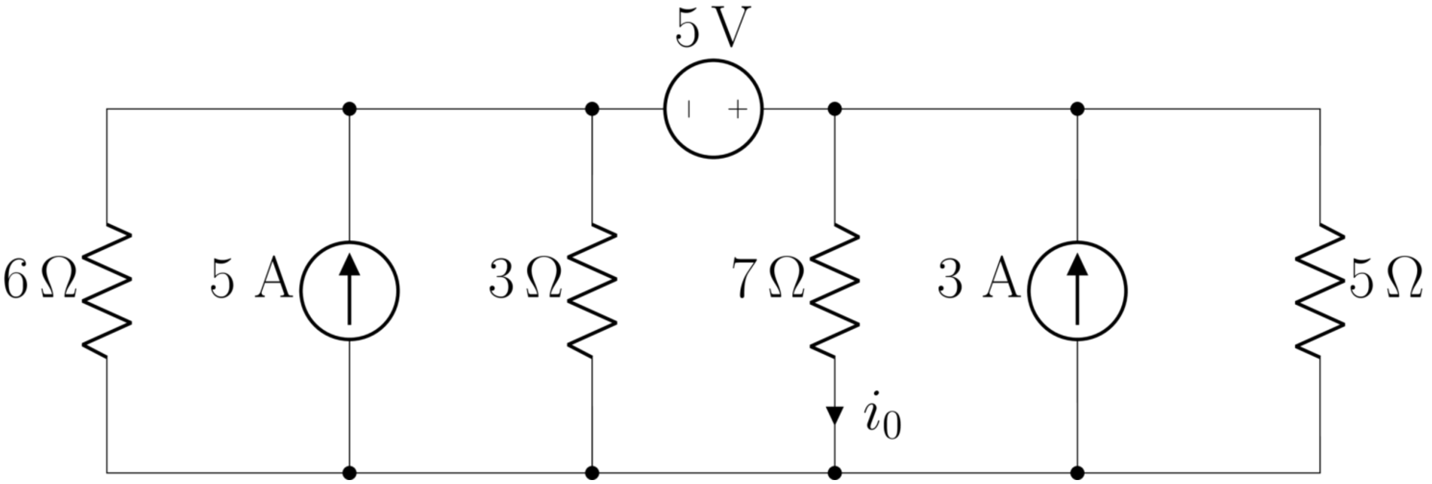
- Use Source Transformation to find i_x in the following circuit.



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

Problem 6

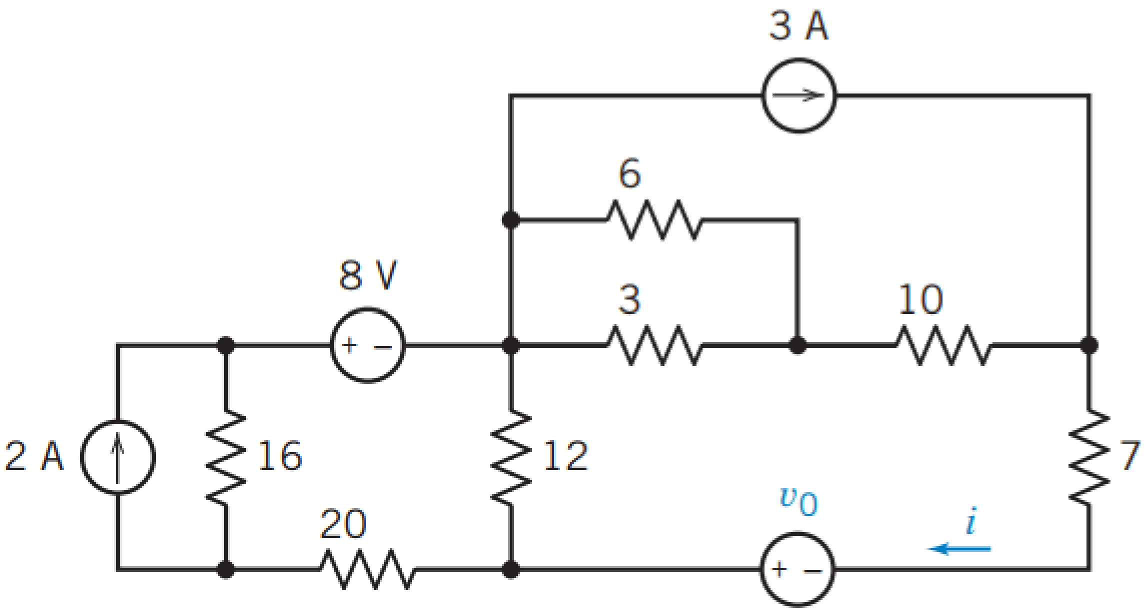
- Reduce the circuit to a single loop using Source Transformation. Then determine i_0.



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

Problem 7

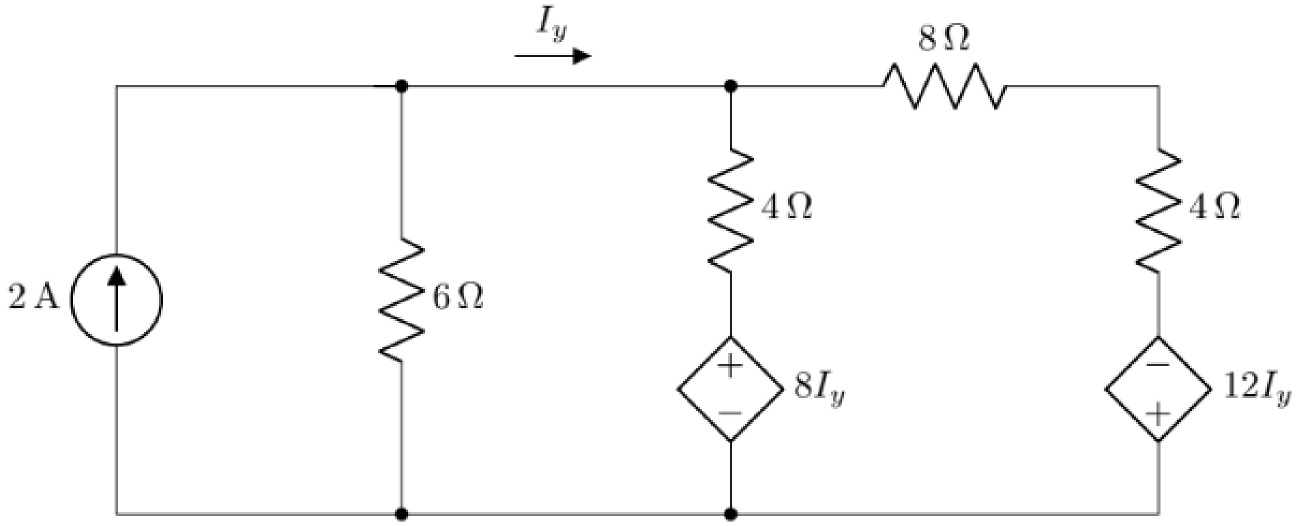
- Reduce the circuit to a single loop. If $i = 2.5\ A$, determine v_0.



Ans: $v_0 = 28\ V$

Problem 8

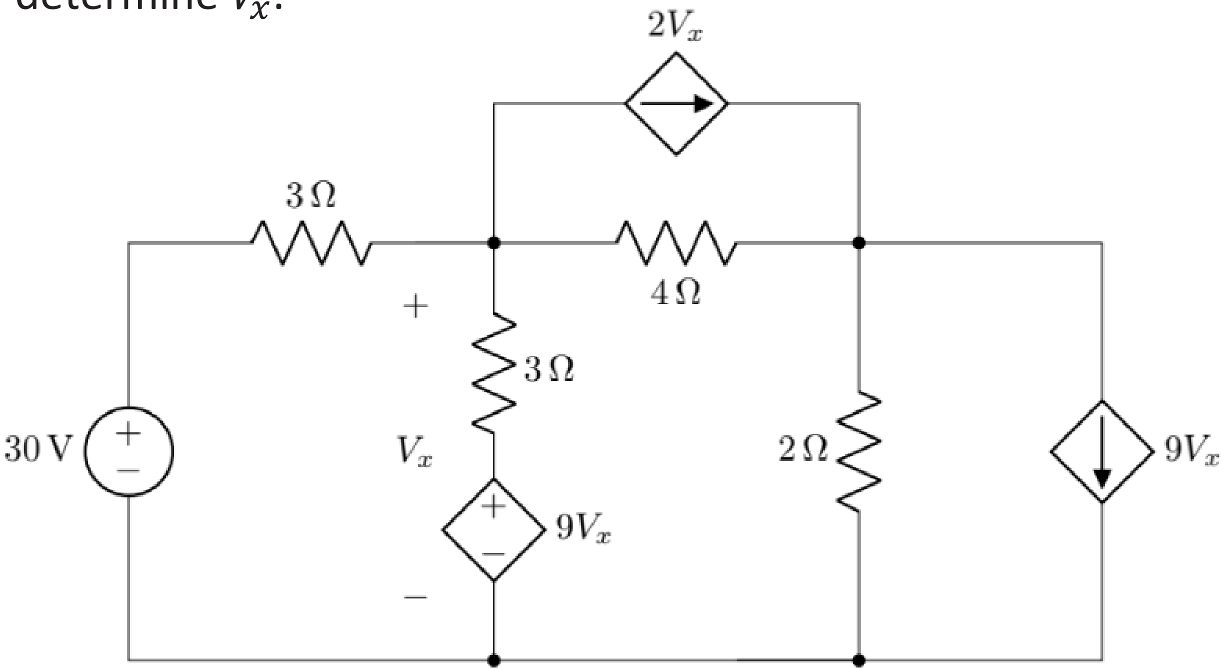
- Reduce the circuit to a single loop using Source Transformation. Then determine I_y.



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

Problem 9

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



Ans: $V_x = 9.5\ V$

Practice Problems

- Additional recommended practice problems: here
- Other suggested problems from the textbook: here

Thank you for your attention