Department of Computer Science and Engineering (CSE)
BRAC University

Lecture 5

CSE250 - Circuits and Electronics

SOURCE TRANSFORMATION

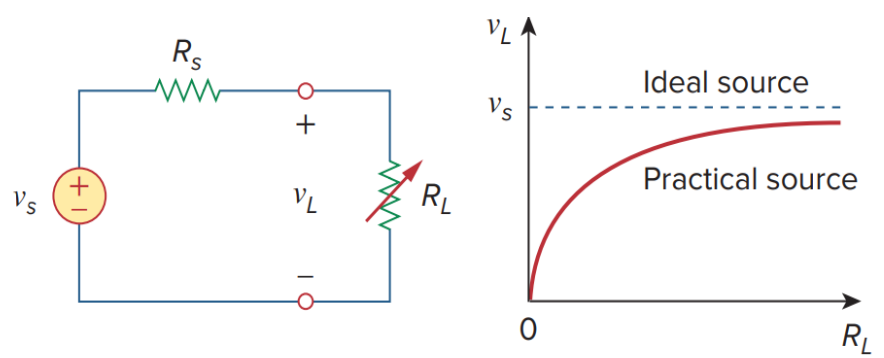
Inspiring Excellence

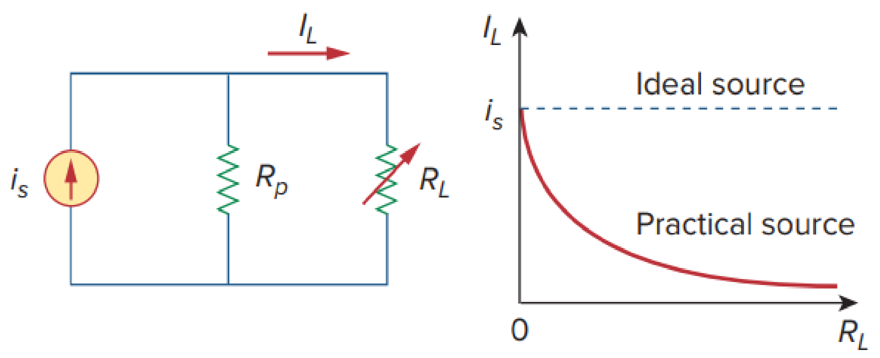
PURBAYAN DAS, LECTURER
Department of Computer Science and Engineering (CSE)
BRAC University

Ideal and Non-ideal Source

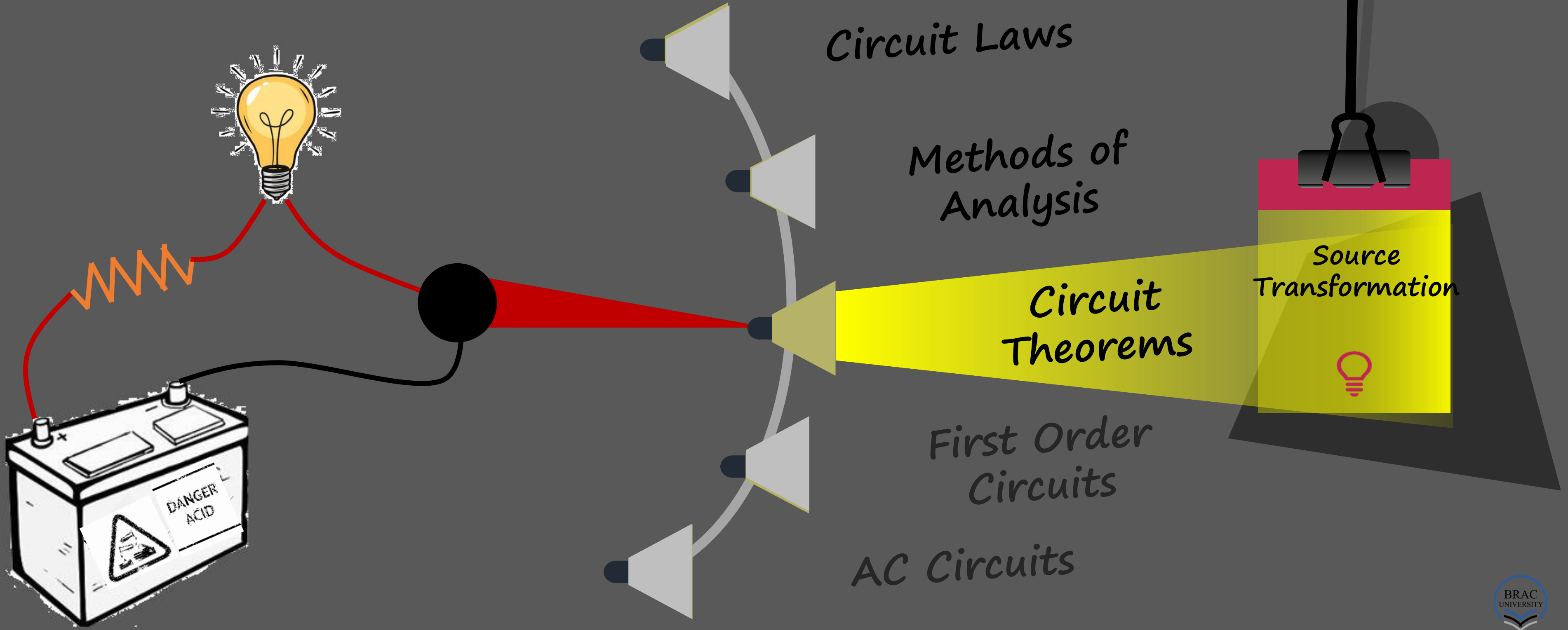
- An *ideal voltage source* provides a constant voltage irrespective of the current drawn by the load, while an *ideal current source* supplies a constant current regardless of the load voltage.
- *Practical* voltage and current sources are not ideal, due to their *internal resistances* or *source resistances*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

$v_L = \frac{R_L}{R_s+R_L} v_s$, if $R_s \ll R_L$ or $R_L = \infty, v_L \rightarrow v_s$	$i_L = \frac{R_p}{R_p+R_L} i_s$, if $R_p \gg R_L$ or $R_p \rightarrow \infty, i_L \rightarrow i_s$



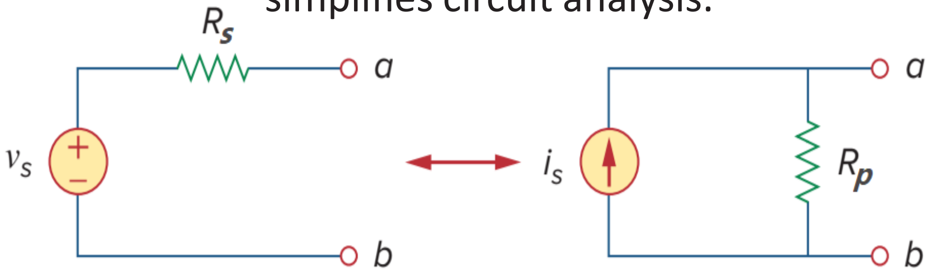


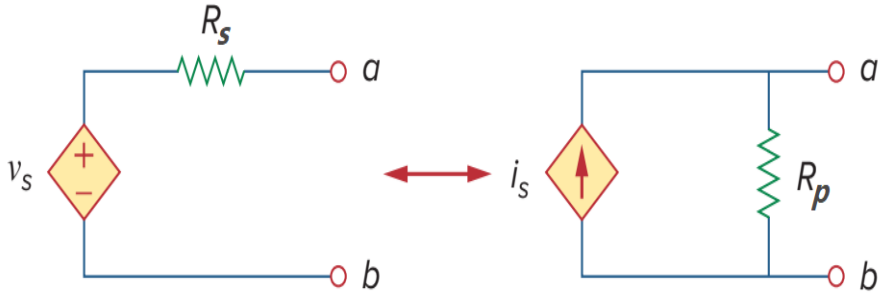
Course Outline: broad themes



Source Transformation

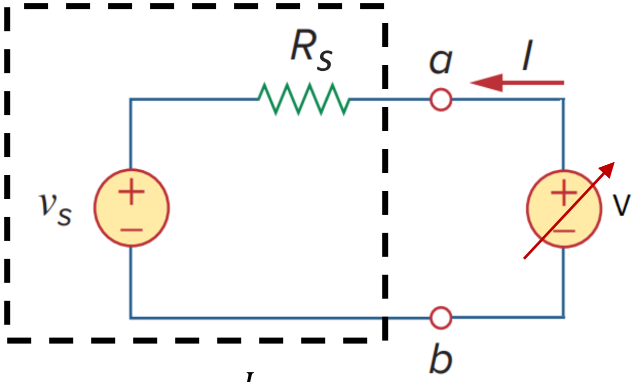
- A source transformation is the process of replacing a voltage source v_s in series with a resistor R by a current source i_p in parallel with a resistor R, or vice versa.
- The transformation does not affect the remaining part of the circuit but greatly simplifies circuit analysis.





- 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

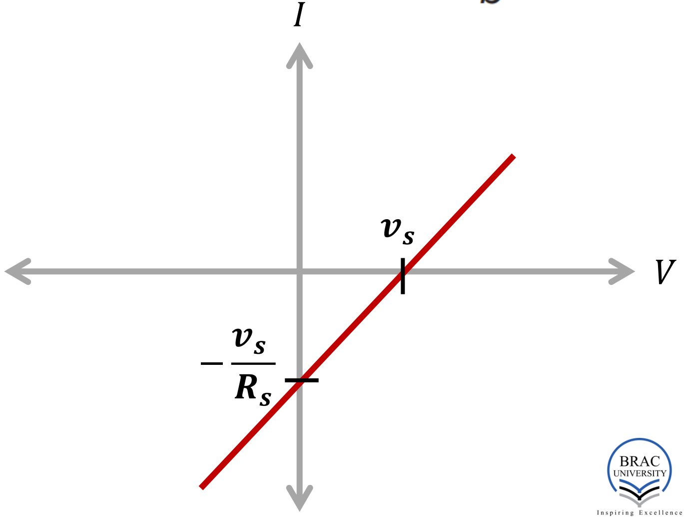


- We recall that *an equivalent circuit is one whose $I - V$ characteristics are identical with the original circuit*. Let's see what conditions make the two circuits to have the same $I - V$ relations at terminals $a - b$.

- 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,

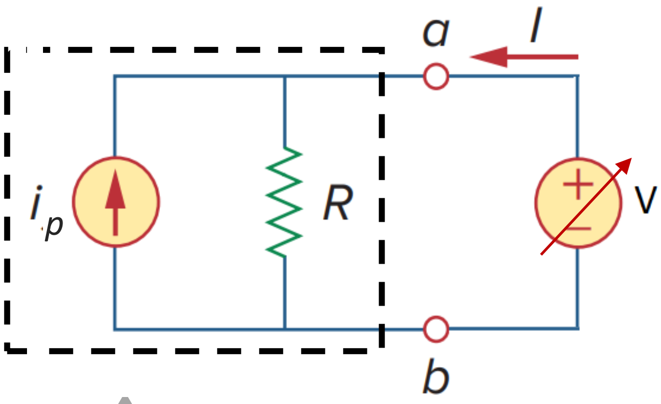
$$V = v_s + IR_s$$

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



- 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



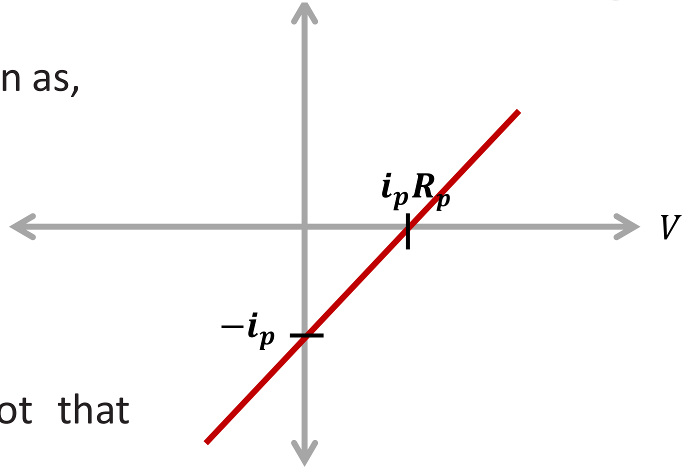
- For the other configuration: a current source (i_p) in parallel with a resistor (R_p) between terminals a and b, if applying a voltage V gives rise to a current I, using KCL the current through the resistor is,

$$I + i_p$$

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

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

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



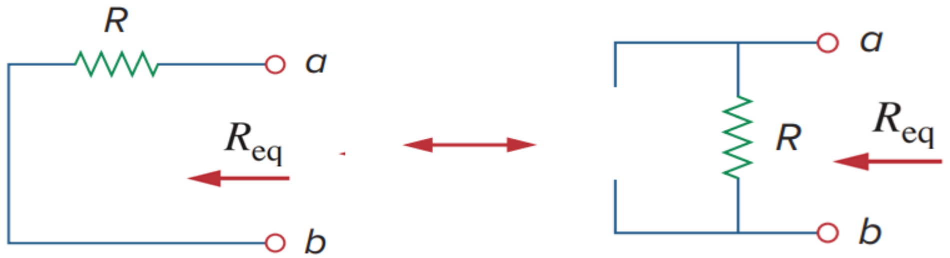
- The equation results in a linear I vs V plot that intersects the axes at $i_p R_p$ and $-i_p$.

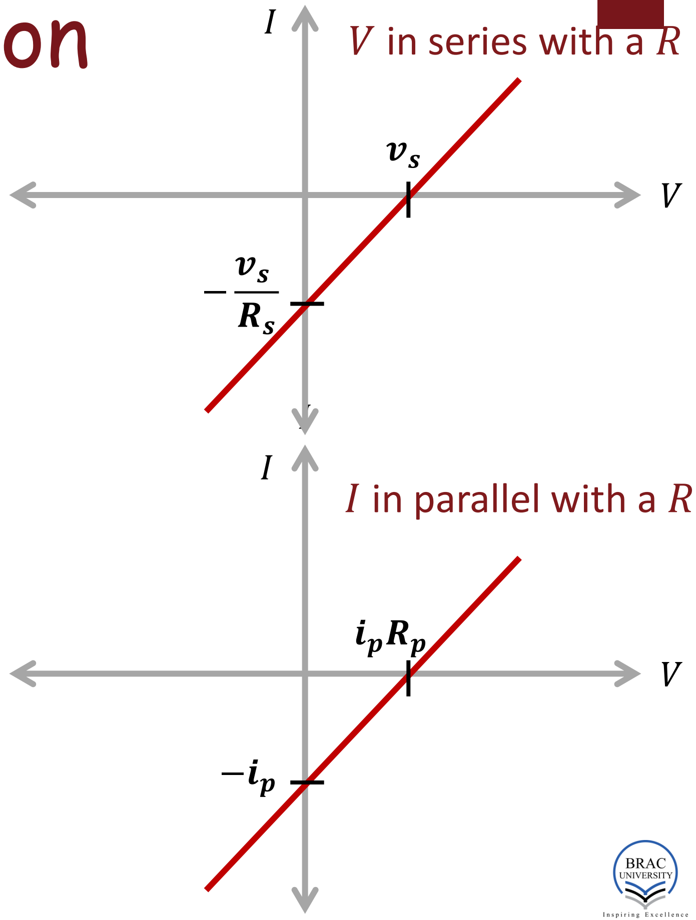
Conditions for Transformation

- 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,

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

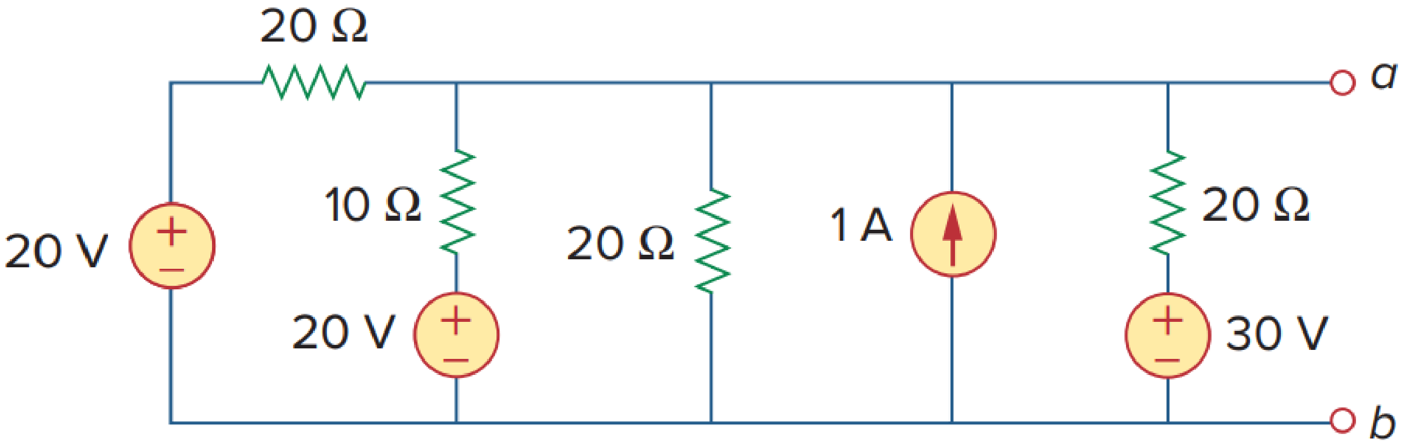
- So, if the sources are turned off, the equivalent resistance at terminals $a - b$ in both circuits is R.



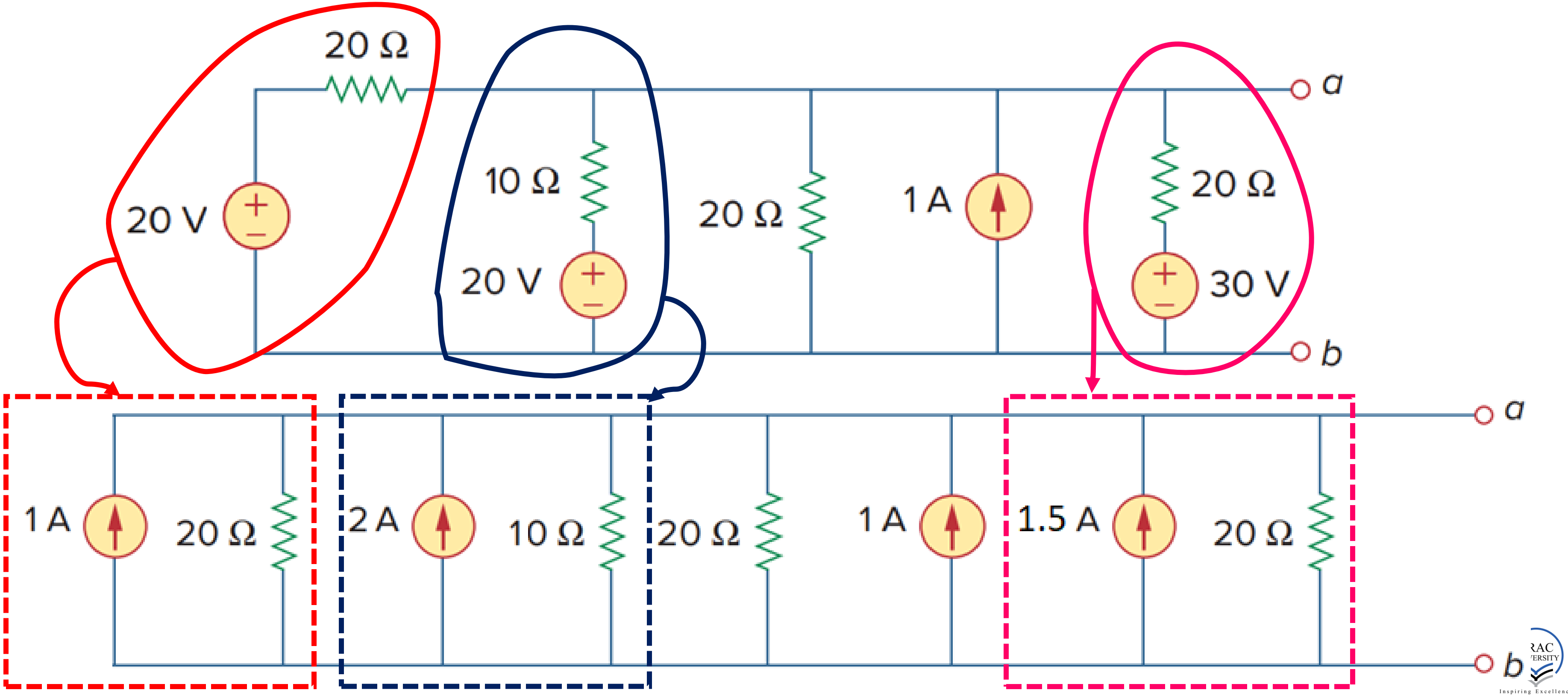


Example 1 - 1/3

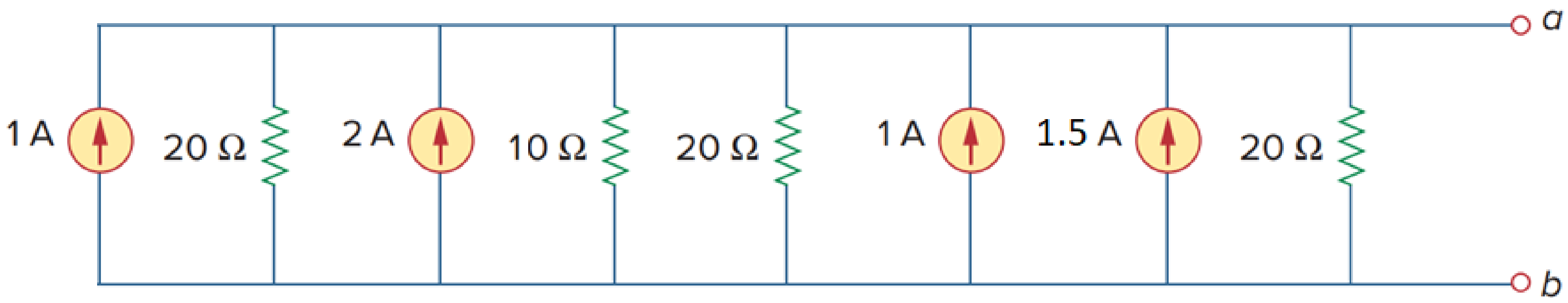
- Use source transformation to reduce the circuit between terminals *a* and *b* to a single voltage source in series with a single resistor.

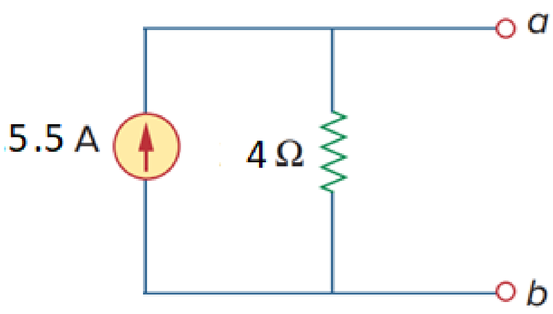


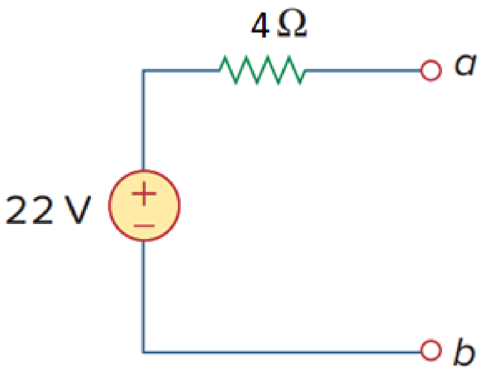
Example 1 – 2/3



Example 1 – 3/3

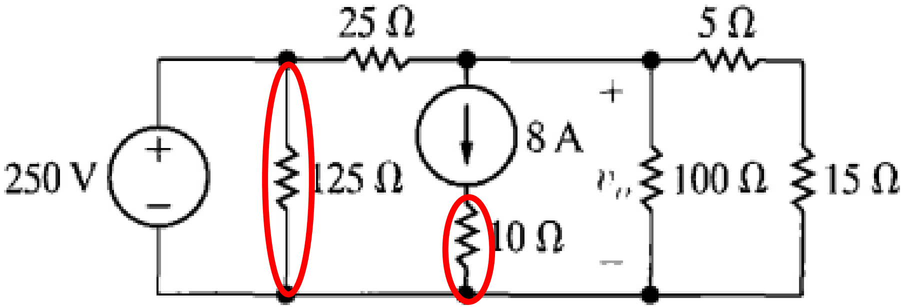


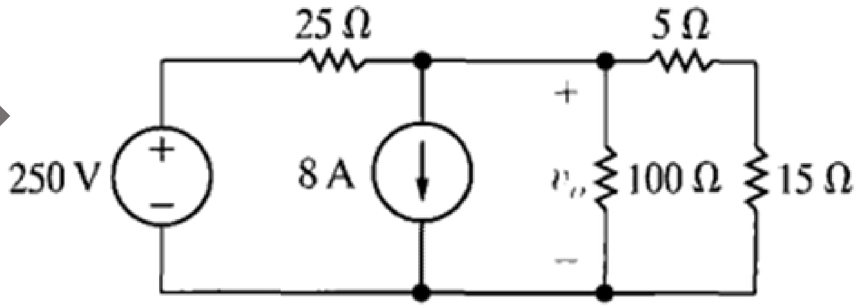




Problem 1

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



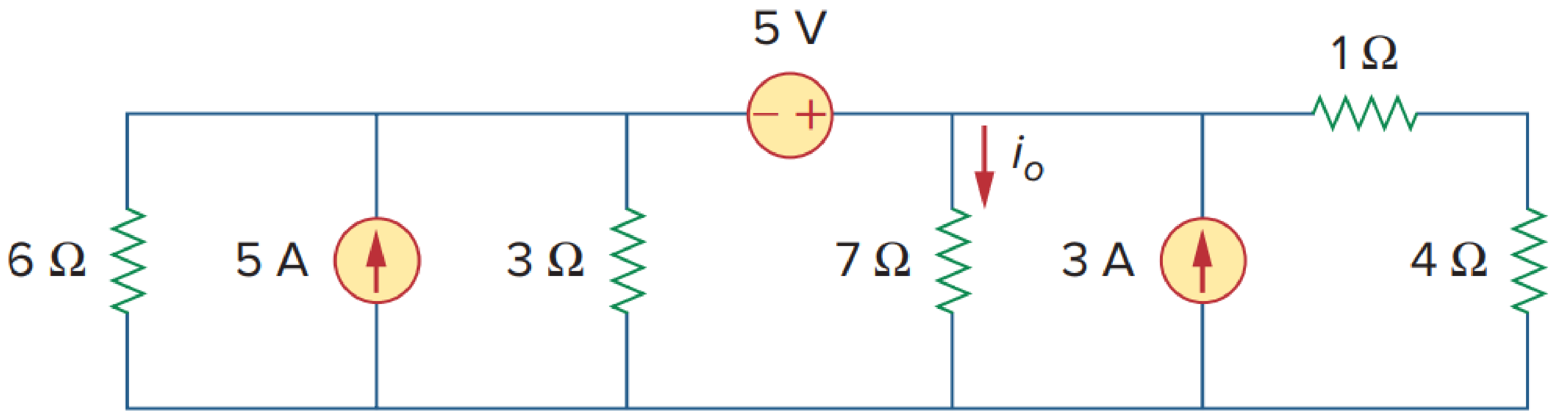


A resistor in series with a current source is redundant, as is a resistor in parallel with a voltage source. We can remove them; this will have no effect on the circuit <u>except for the sources</u>. Opening a resistor parallel to a voltage source will ***reduce*** the current supplied by the source.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

<u>Ans</u>: $\boldsymbol{v_0 = 20\,V;\ P_{250V} = -2.8\,kW;\ P_{8A} = -480\,W}$

Problem 2

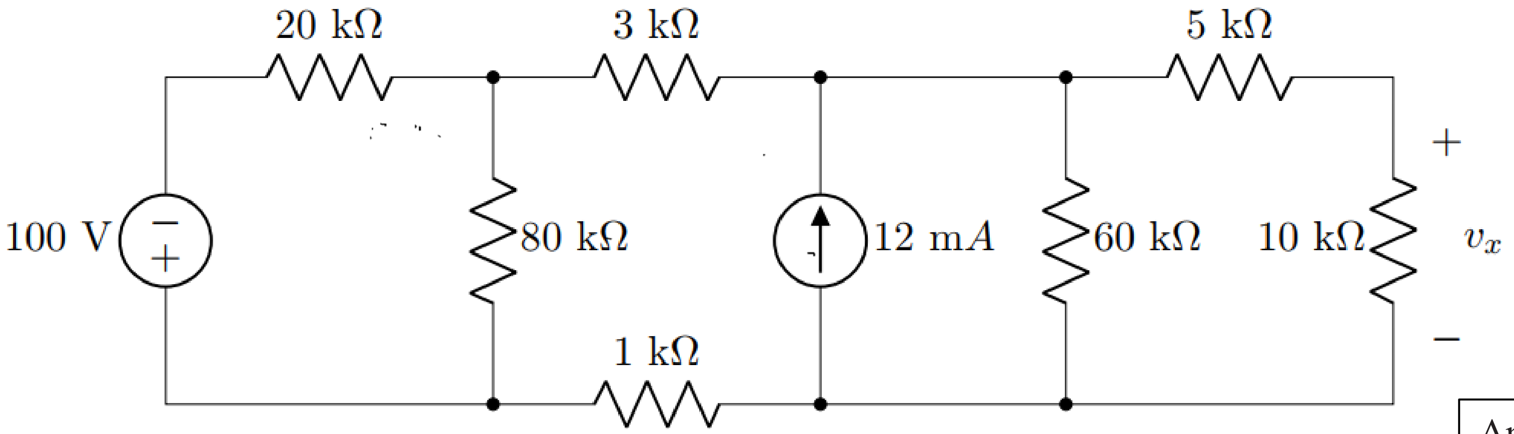
- Find i_o in the circuit using Source Transformation.



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.

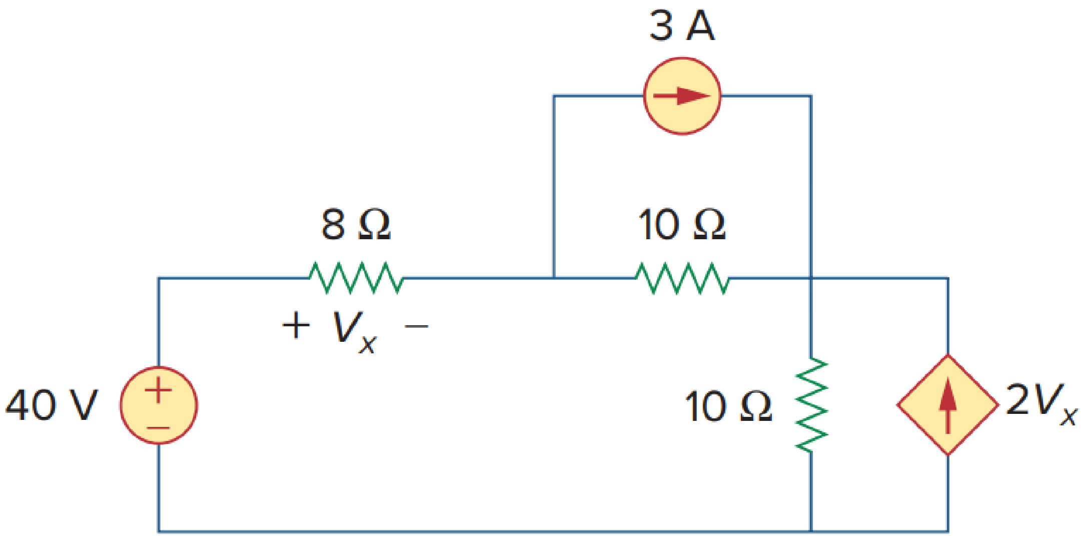


Ans: $v_x = \mathbf{40\ V}$

Fall 2022

Problem 4

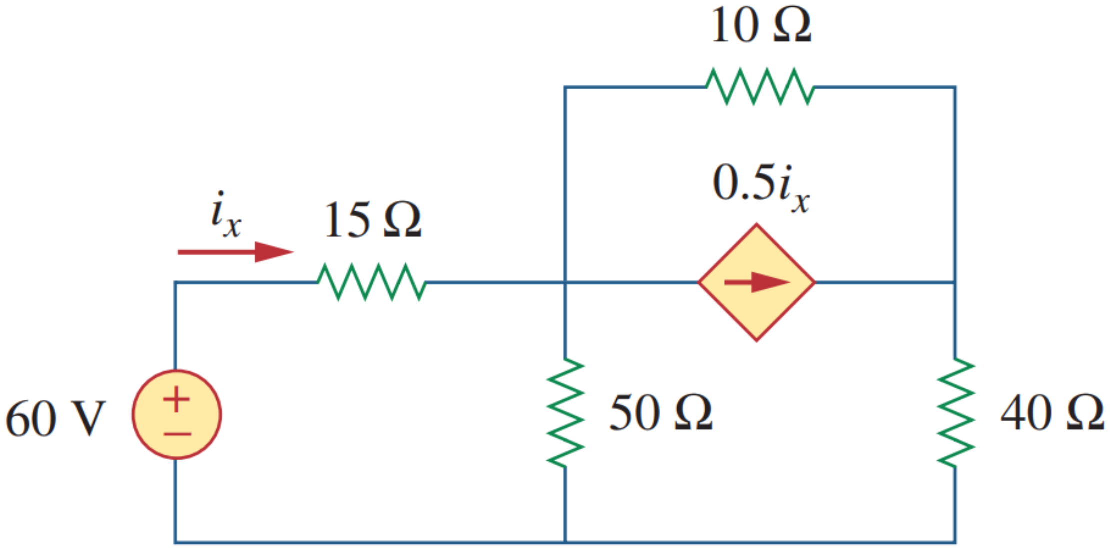
- Use Source Transformation to find V_x.



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

Problem 5

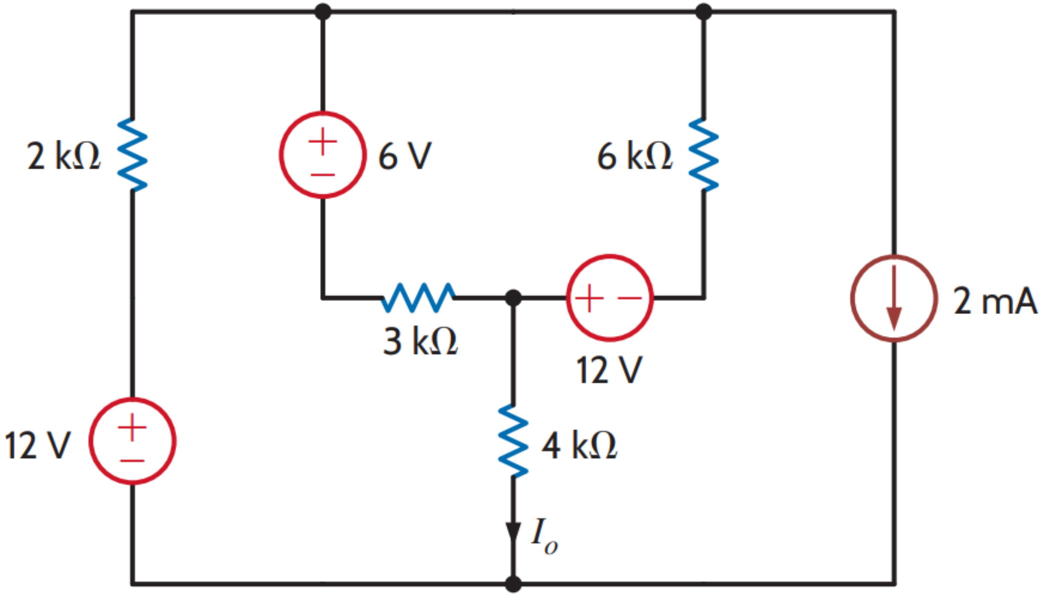
- Use Source Transformation to find i_x in the following circuit.



Ans: $i_x = 1.6\ A$

Problem 6

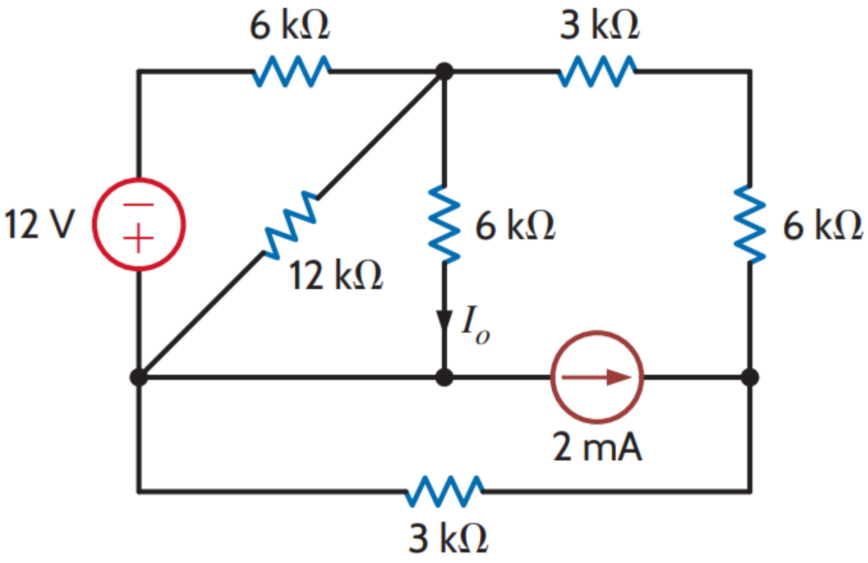
- Reduce the circuit to a single loop circuit using Source Transformation. Then determine I_0.



Ans: $I_0 = 1\,mA$

Problem 7

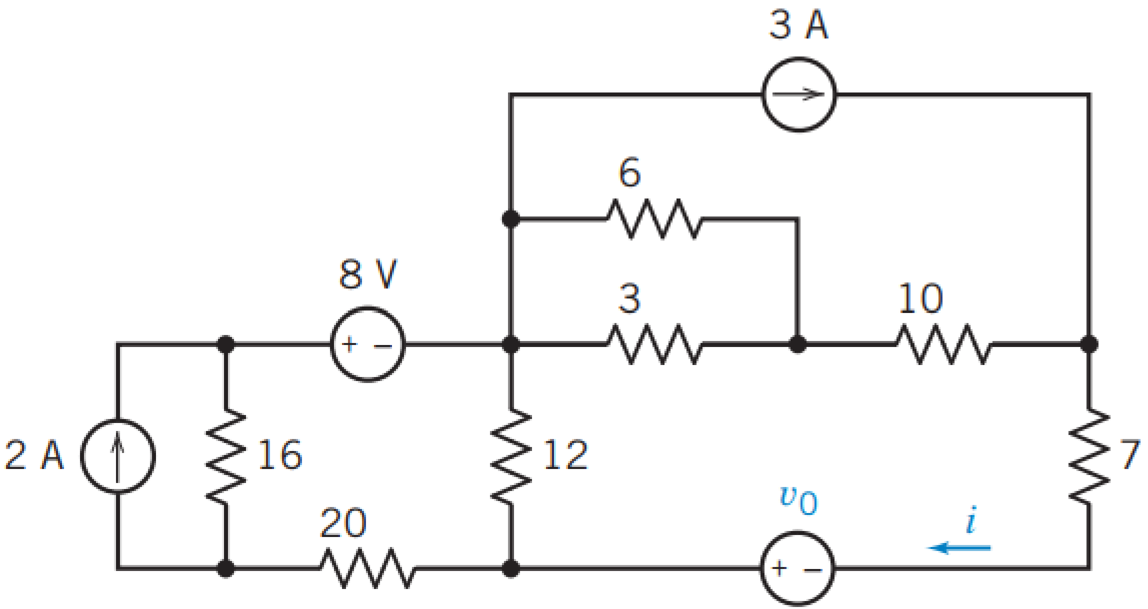
- Reduce the circuit to a single loop using Source Transformation. Then determine I_0.



Ans: $I_0 = -{}^{1}/_{2}\ mA$

Problem 8

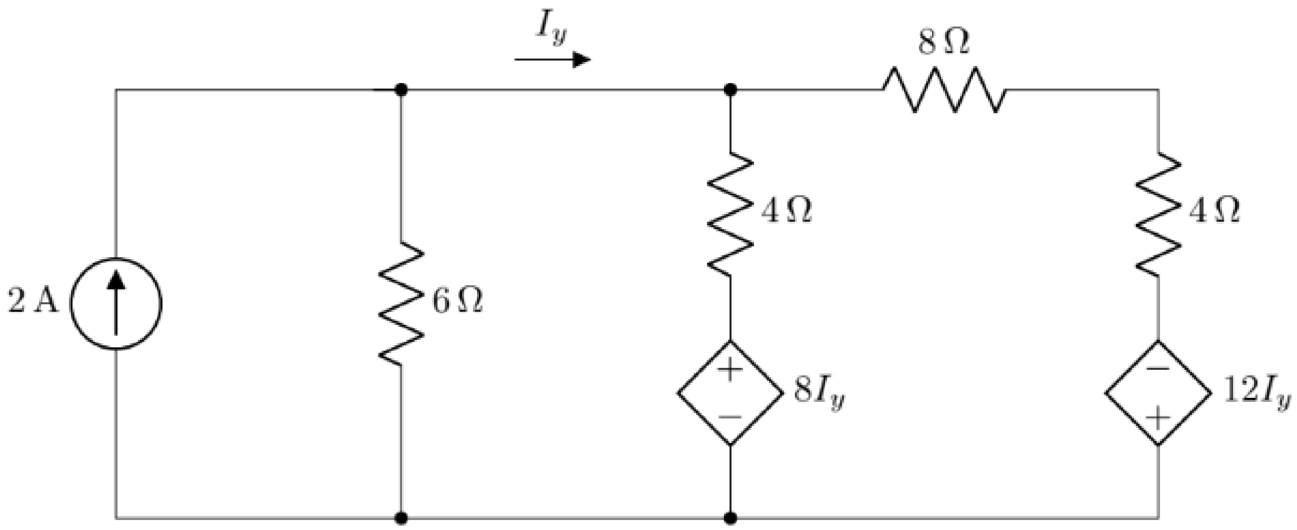
- Reduce the circuit to a single loop. If $i = 2.5\ A$, determine v_0.



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

Problem 9

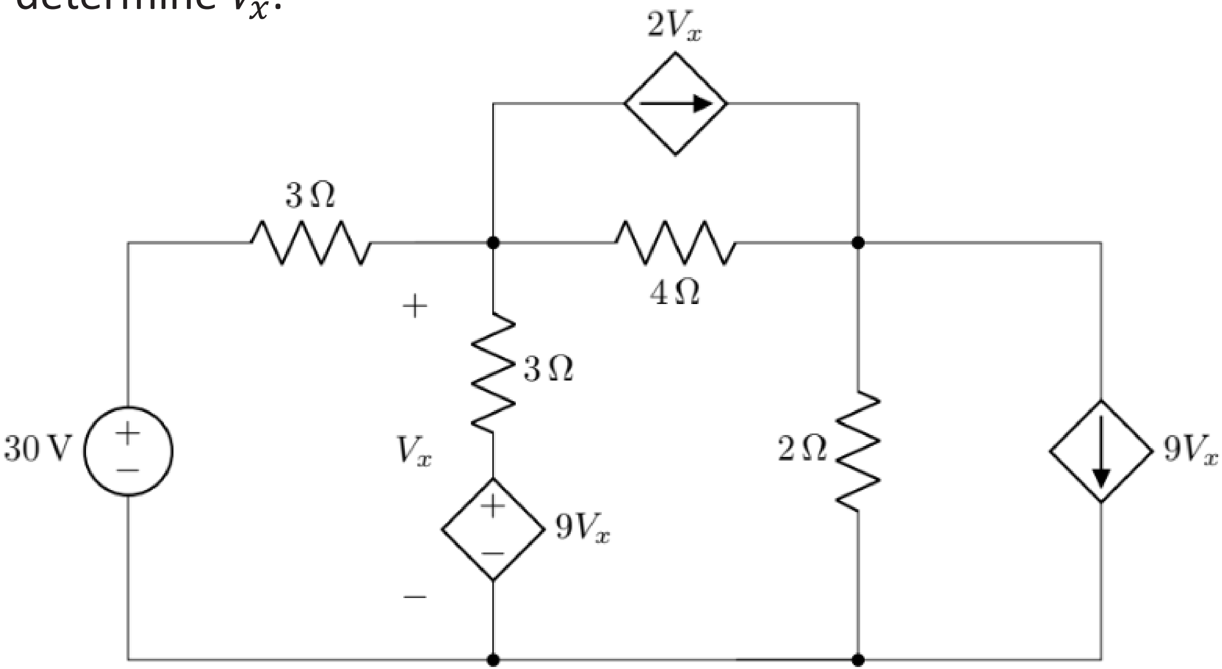
- Reduce the circuit to a single loop using Source Transformation. Then determine I_y.



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

Problem 10

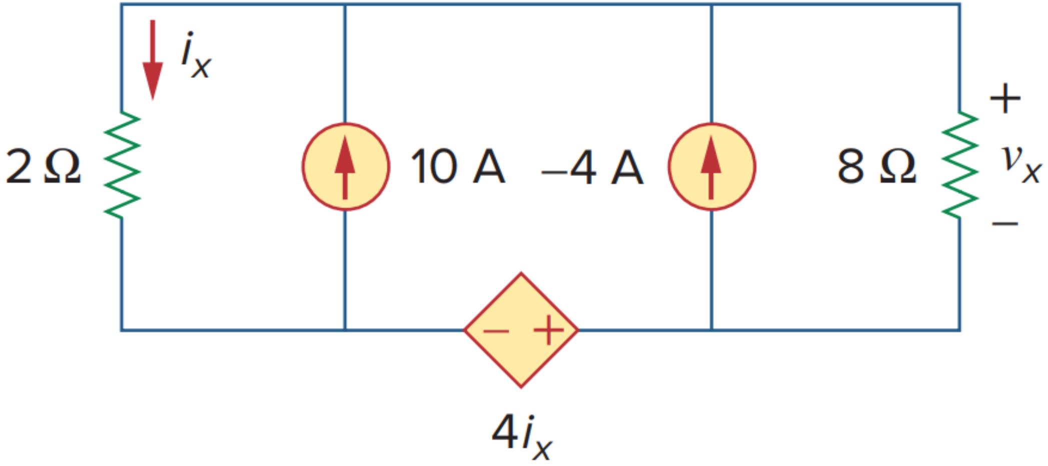
- Reduce the circuit to a single loop using Source Transformation. Then determine V_x.



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

Problem 11

- Reduce the circuit to a single loop using Source Transformation. Then determine i_x and v_x. *[Hint: current through the 2 Ω will not be i_x after transformation. Voltage across 8 Ω will not be v_x after transformation.]*



Ans: $v_x = -16\ V$

Additional Problems

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

Acknowledgements and References

- Some of the problems, illustrations, and concepts in this lecture are taken from the following sources:

1. Sadiku, M. N. O., Fundamentals of Electric Circuits, McGraw-Hill
2. Nilsson, J. W., & Riedel, S. A., Electric Circuits, Pearson Education
3. Irwin, J. D., & Nelms, R. M., Basic Engineering Circuit Analysis, Wiley

Thank you for your attention