ENEE2301

Network Reduction Techniques and Network Theorems 1

Ch4

Reading Assignment: Sections 4.9 - 4.16, in *Electric Circuits, 10th Ed.* by Nilsson

Network Reduction Techniques and Network Theorems

Chapter 4, Sections 9-16, in the text by Nilsson covers several useful network reduction techniques and network theorems.

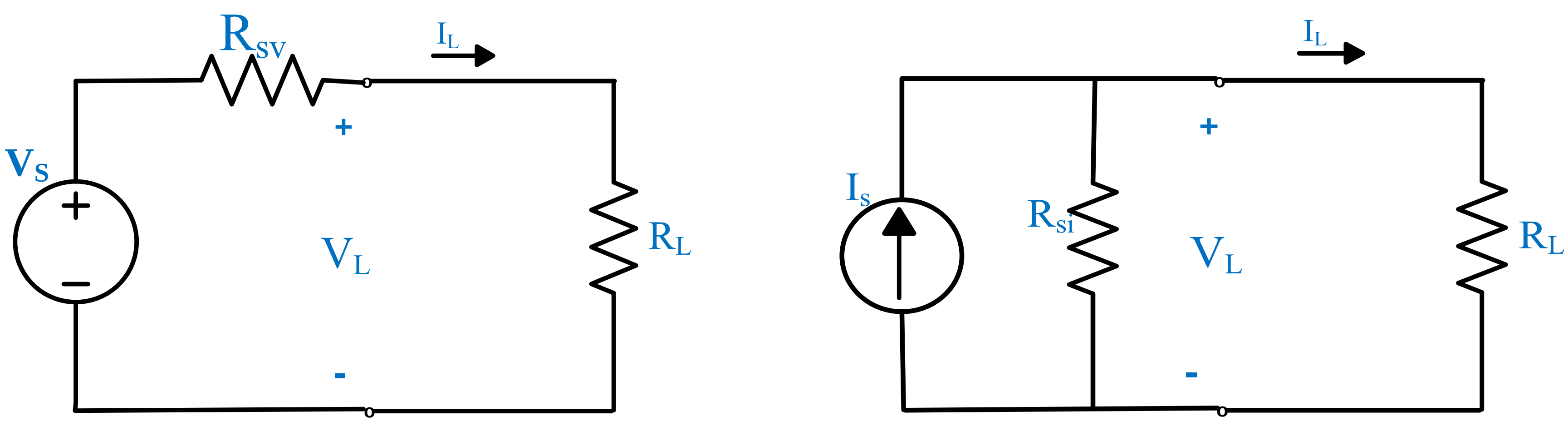
The purposes of these techniques and theorems are:

- To provide alternate analysis methods
- To provide methods for simplifying circuits
- To provide methods for representing circuits in the simplest possible form
- To gain insight into circuit behavior

Topics to be covered

- Source Transformations
- Superposition
- Thevenin's and Norton's Theorems
- Maximum Power Transfer Theorem

Source Transformation



Two sources are equivalent, if each produces identical current and identical voltage in any load which is placed across its terminal.

•Let *RL=0* (short circuit)

$$I_{sc1} = \frac{V_s}{R_{Sv}}$$

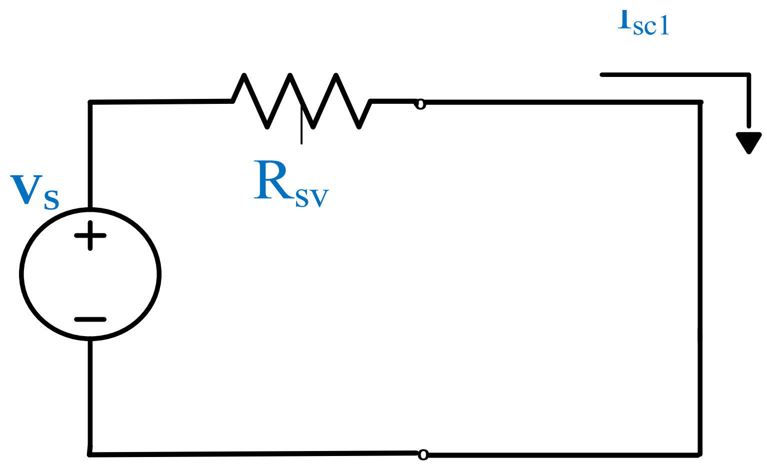


Figure12 "a":short circuit current

$$I_{sc2} = I_s$$

For

$$I_{sc1} = I_{sc2}$$

❖ $\frac{V_s}{R_{Sv}} = I_s$ -----(1)

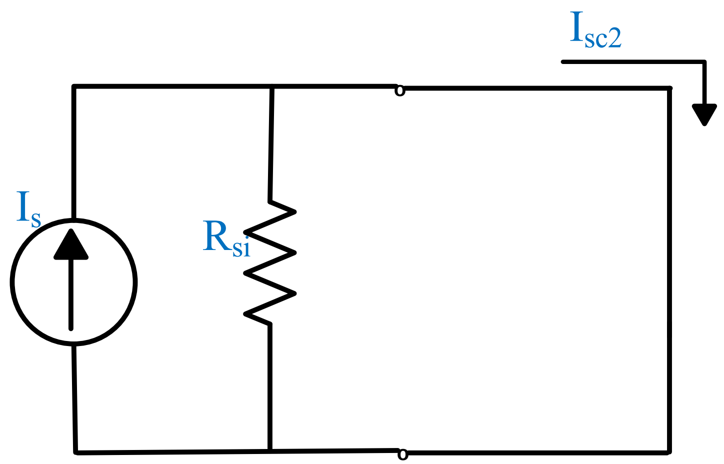


Figure12 "b":short circuit current

2. Let $R_L = \infty$ (open circuit)

$$V_{oc1} = V_s$$

$$V_{oc2} = I_s R_{si}$$

For $V_{oc1} = V_{oc2}$

❖ $\boldsymbol{V_s = I_s R_{si}}$ ----------- (2)

Using equation (1), we get

$$V_s = I_s R_{sv}$$

❖ $\boldsymbol{R_{si} = R_{sv}}$

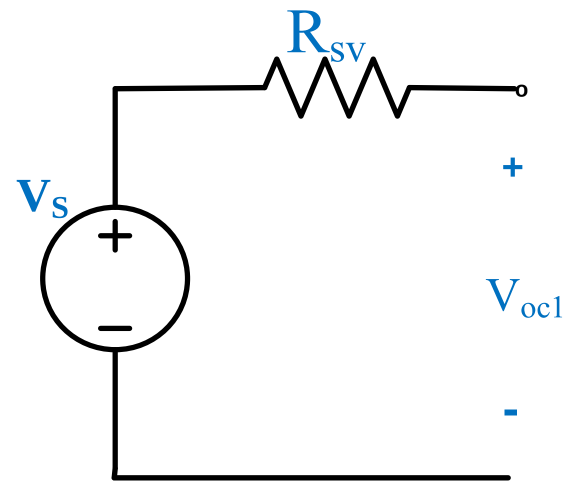


Figure13 “a”: open circuit voltage

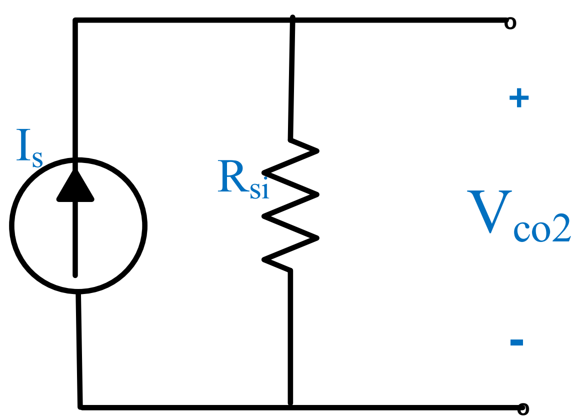


Figure13 “b”:open circuit voltage

Example

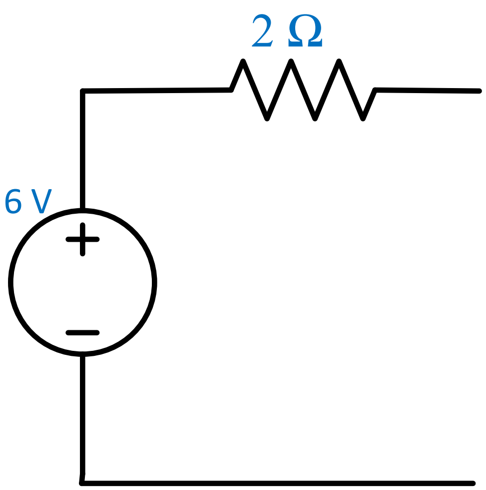


Figure14 “a”

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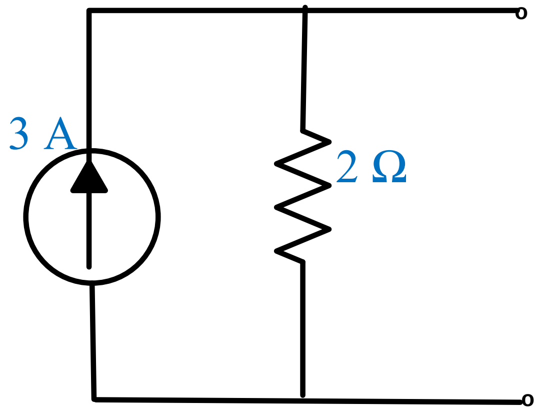


Figure14 “b”

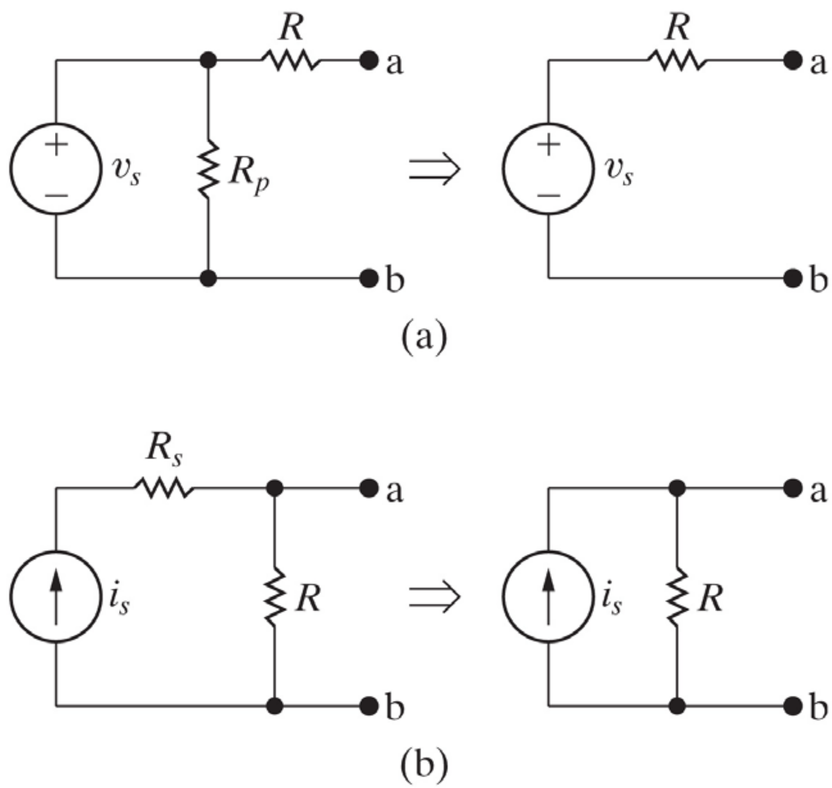
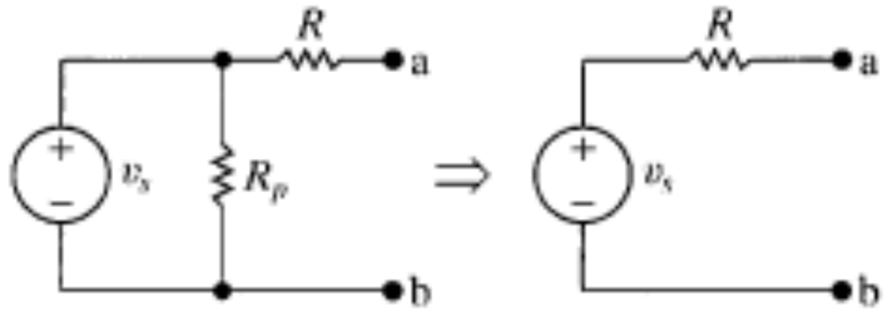
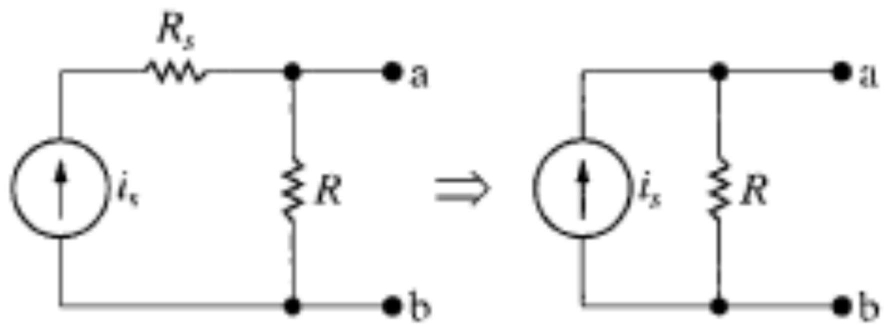


Figure: 04-39a,b



(a)



(b)

- The two circuits depicted in Fig. 4.39(a) are equivalent with respect to terminals a,b because they produce the same voltage and current in any resistor *RL* inserted between nodes a,b.
- The same can be said for the circuits in Fig. 4.39(b).

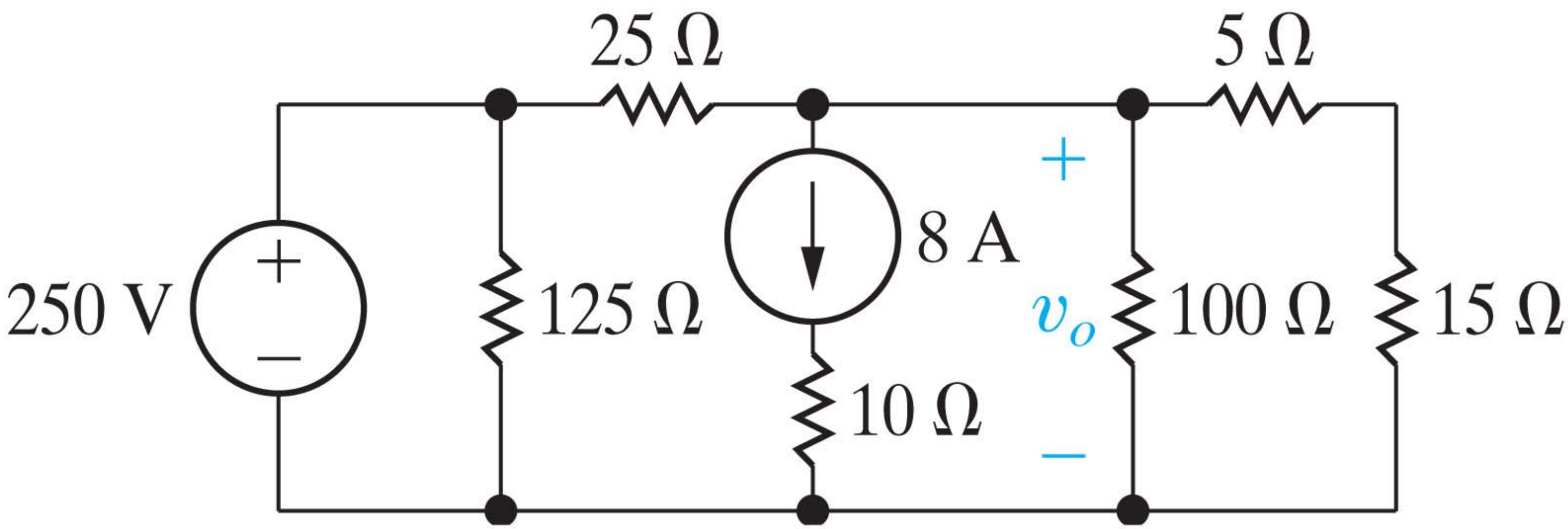


Figure: 04-40Ex4.9

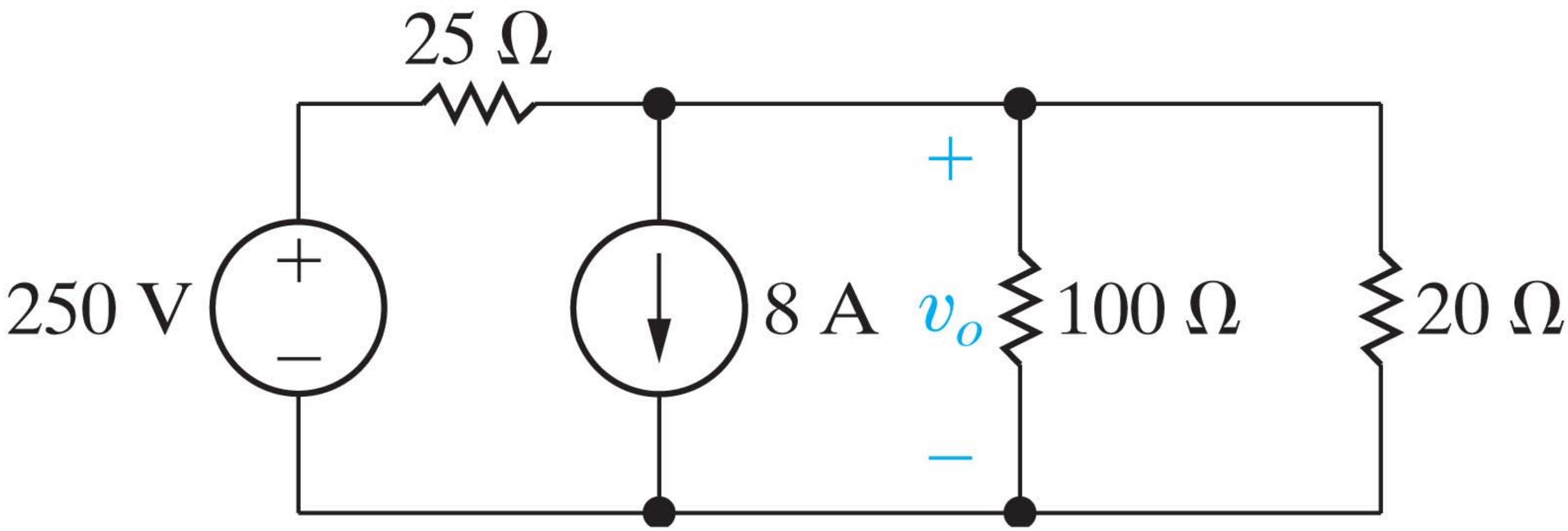
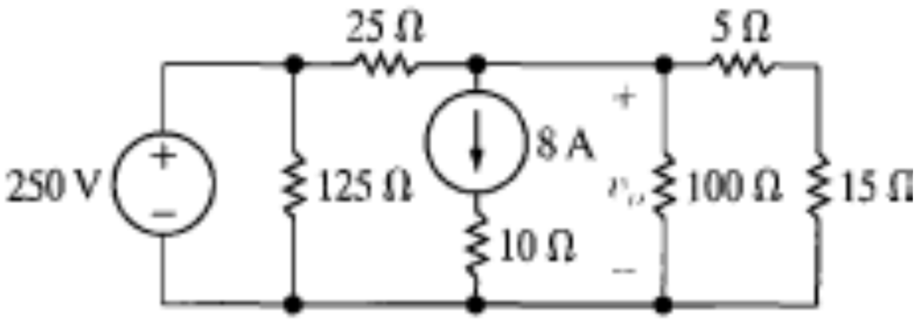
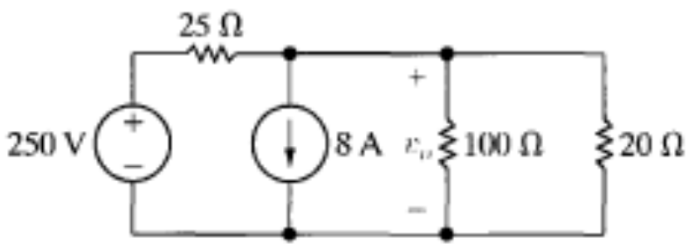


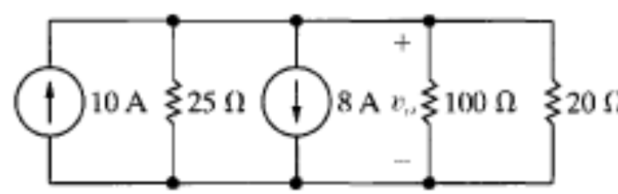
Figure: 04-41Ex4.9

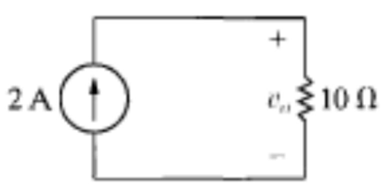
Example: Find Vo using source transformation



- Simplified circuit



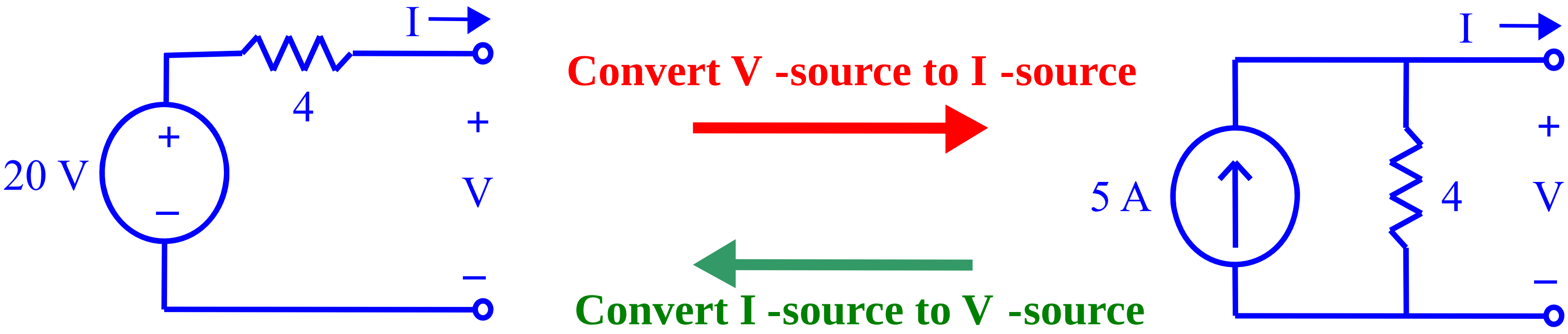




Vo=20V

Source Transformations -

Simple Example:



Find *I* using source transformation

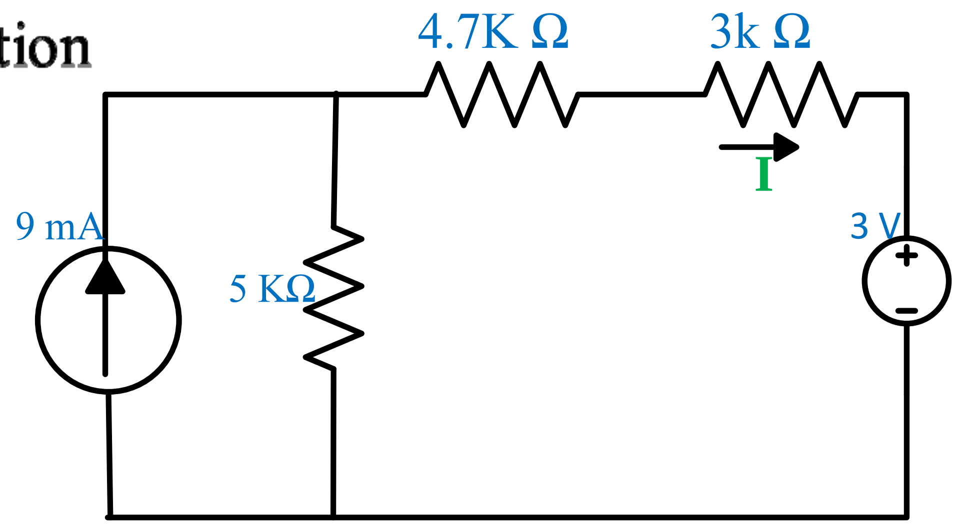


Figure15 “a”

$$I = \frac{45 - 3}{5k + 4.7k + 3k} = 3.3\ mA$$

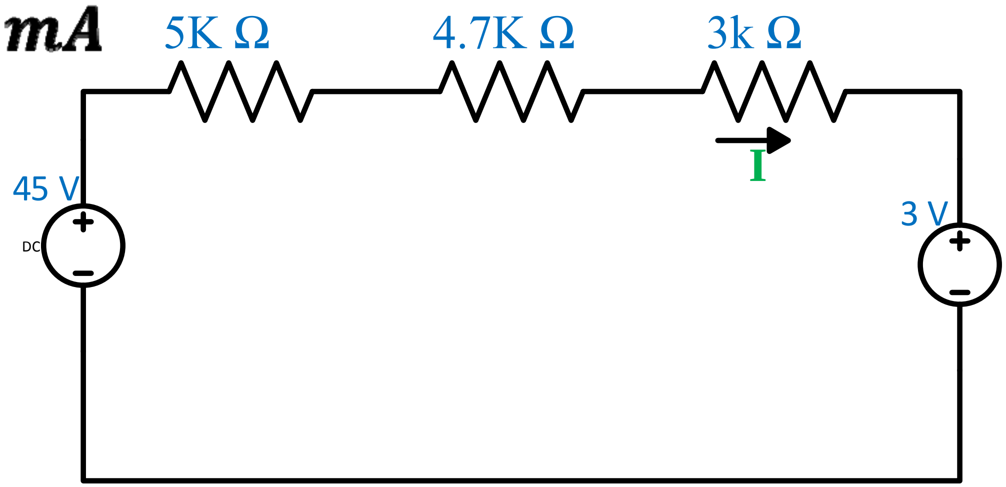


Figure15 “b”

Dependent sources

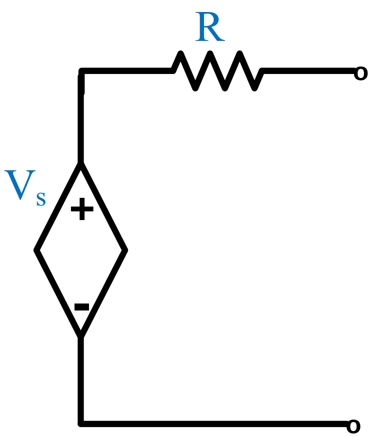


Figure 16 a

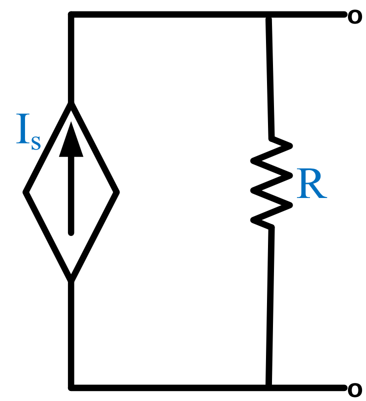


Figure 16 b

$$I_s = \frac{V_s}{R}$$

The control variable must be outside the transformation.

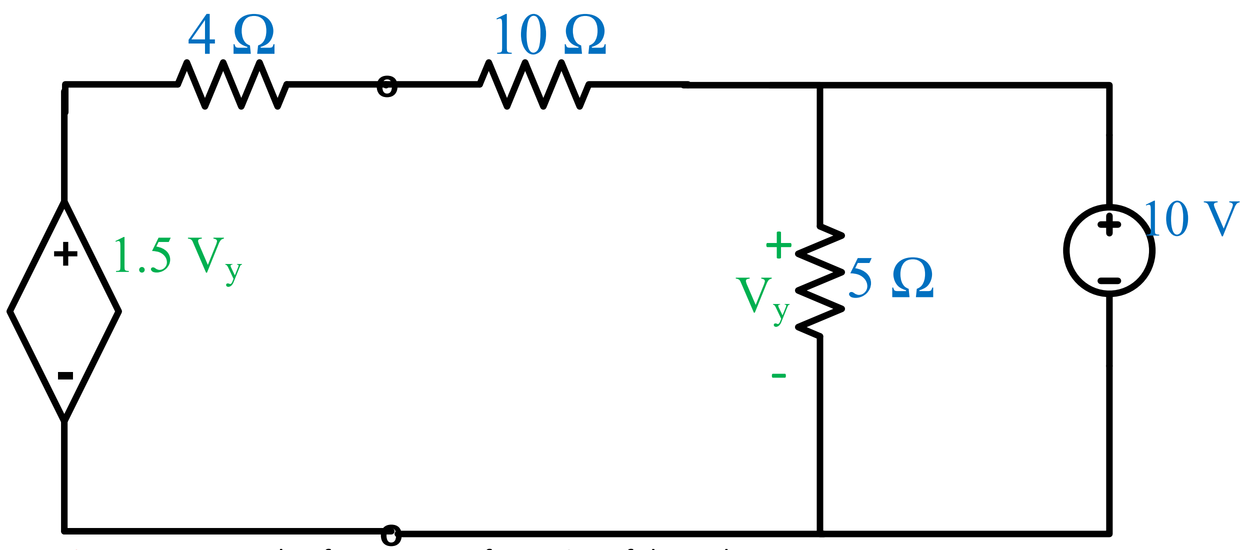


Figure 17 a:examole of source transformation of dependent sources

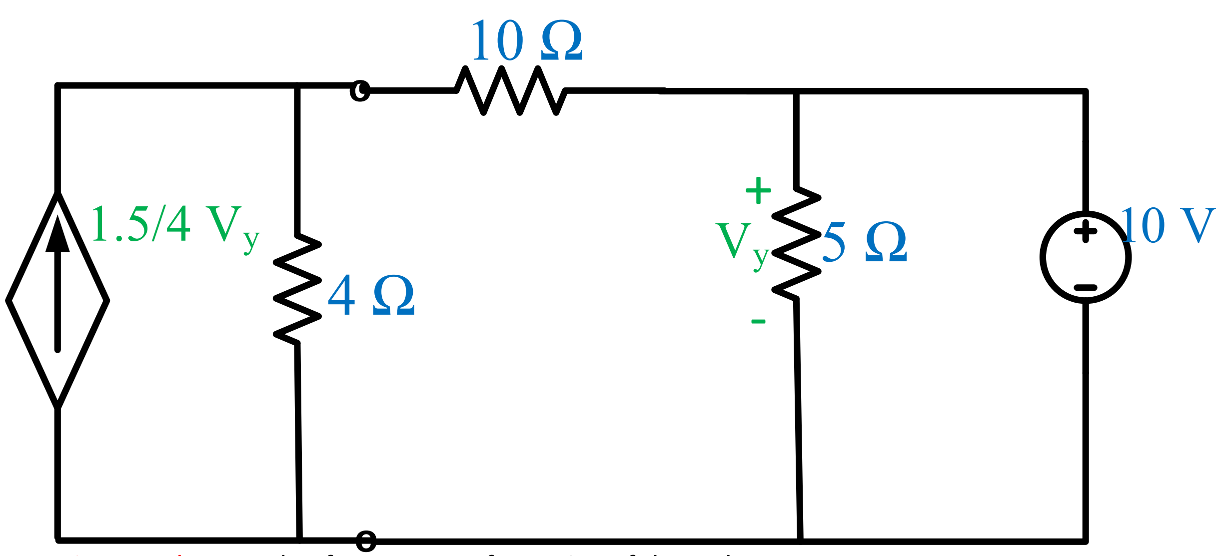


Figure 17 b:examole of source transformation of dependent sources

Find V_o using source transformation

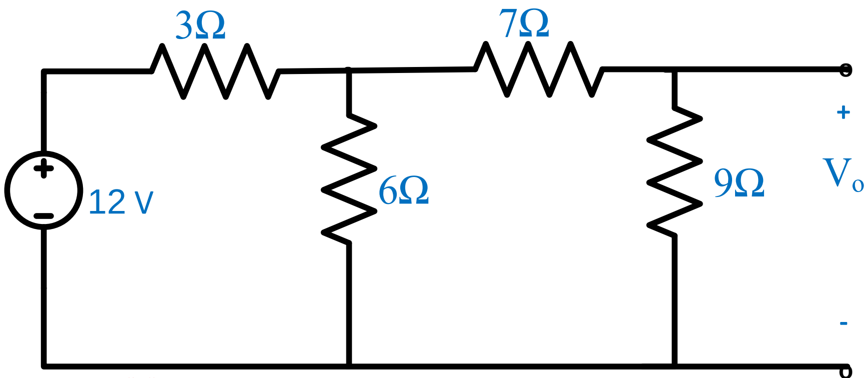


Figure18"a":example

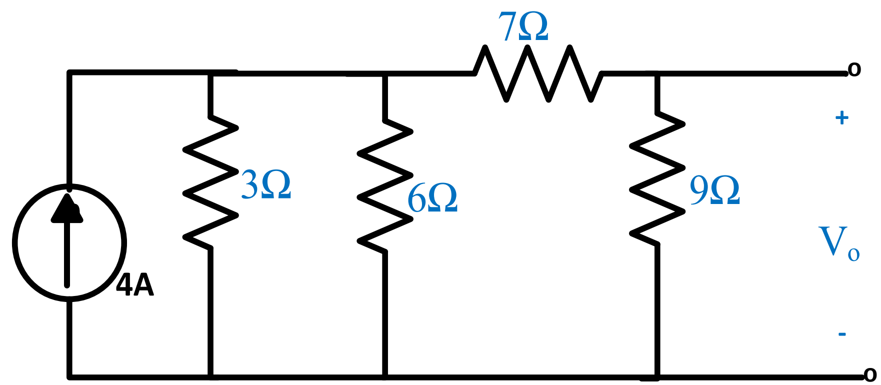


Figure18"b":example

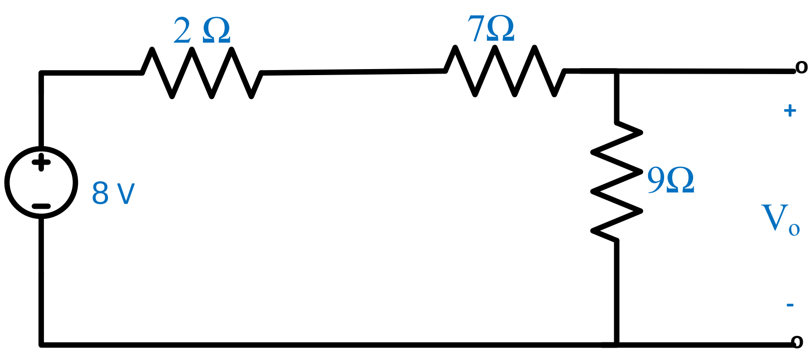


Figure18:"c":example

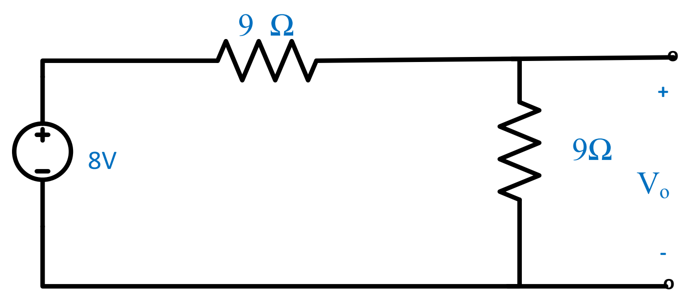


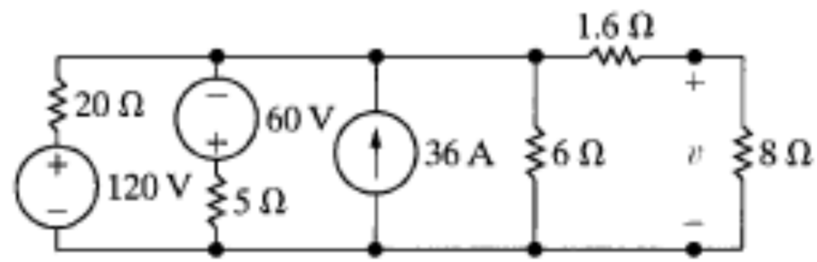
Figure18:"d":example

$$V_o = \frac{9}{9+9} * 8 = 4 \quad volt$$

Assessment 4.15

a) Use a series of source transformations to find the voltage ***v*** in the circuit shown.

b) How much power does the 120 V source deliver to the circuit?

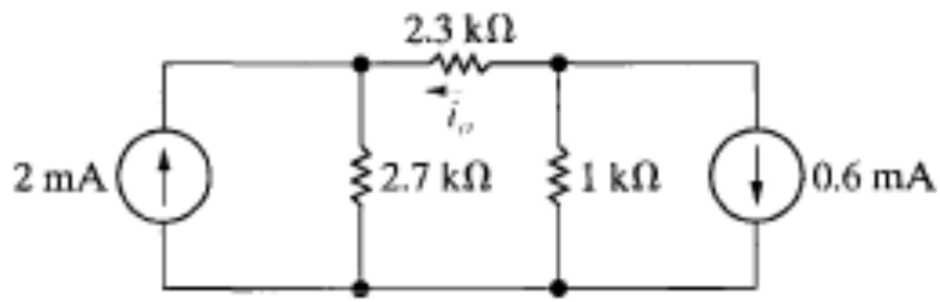


Answer: (a) 48 V;

(b) 374.4 W.

Problem 4.59

a) Use a series of source transformations to find PSPICE the current i_o.



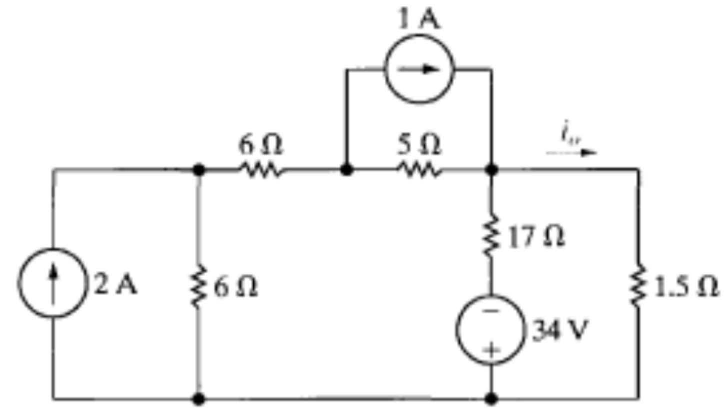
b) Verify your solution by using the node-voltage method to find i_o.

Answer -1 mA

Problem 4.60

a) Use a series of source transformations to find PSPICE the current *io*.

b) Verify your solution by using the mesh current method to find *io*.



Answer -0.85 A

The Superposition Theorem

In a linear network, the voltage across or the current through any element may be calculated by adding algebraically all the individual voltages or currents caused by the separate independent sources acting alone, i.e. with:

1) All other independent voltage sources replaced by short circuits.
2) All other independent current sources replaced by open circuits.

- Dependent sources are left intact because they are controlled by circuit variables.

Linear element and circuits

- A linear circuit element has a linear voltage-current relationship

$$V(t) = R.i(t)$$

$$V(t) = \frac{1}{C}\int_{-\infty}^{t} i(t)\,dt$$

$$V(t) = L\frac{di(t)}{dt}$$

- Independent sources are linear elements.
- Dependent sources need linear control equation to be linear elements.
- Linear circuit is a circuit composed entirely of independent sources, linear dependent source, and linear elements

Steps to apply superposition principle

- Turn off all independent sources except one source. Find the output (voltage or current) due to that source using nodal, mesh…. .
- Repeat step 1 for each of the other independent sources.
- Find the total contribution by adding algebraically all contributions due to each independent sources.

Use superposition to solve for ***ix***

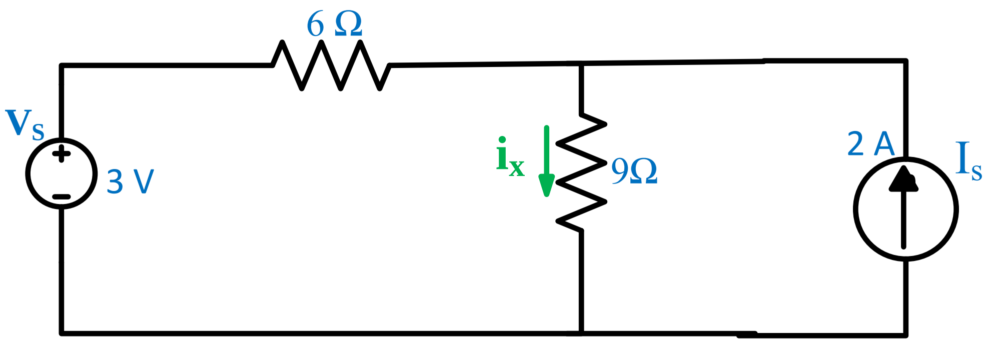


Figure1:"a":example of superposition

1) **Let V_s on, and turn off I_s** (kill Is – replace it by open circuit)

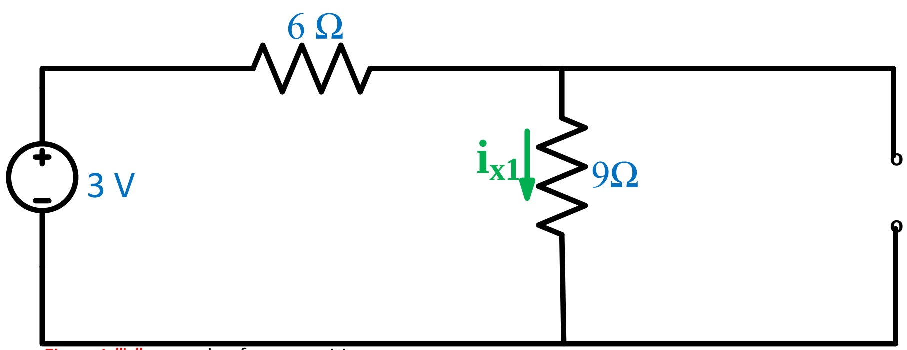


Figure1:"b":example of superposition

$$i_{x1} = \frac{3}{6+9} = \frac{3}{15} = 0.2\ A$$

2) Let $\boldsymbol{I_s}$ on, and turn off $\boldsymbol{V_s}$ (kill Vs – replace it by short circuit)

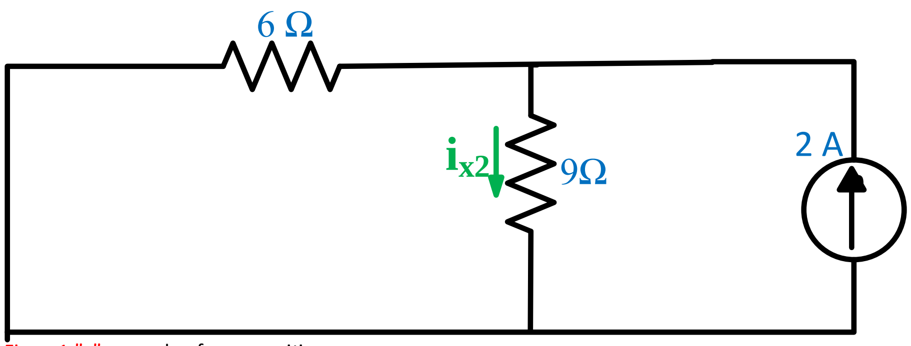


Figure1:"c":example of superposition

$$i_{x2} = \frac{6}{6+9} * 2 = 0.8\ A$$

Finally, combine the results:

$$i_x = i_{x1} + i_{x2}$$
$$= 0.2\ A + 0.8\ A$$

❖ $i_x = 1\ A$

Superposition with a dependent source

Find *Ix* using superposition

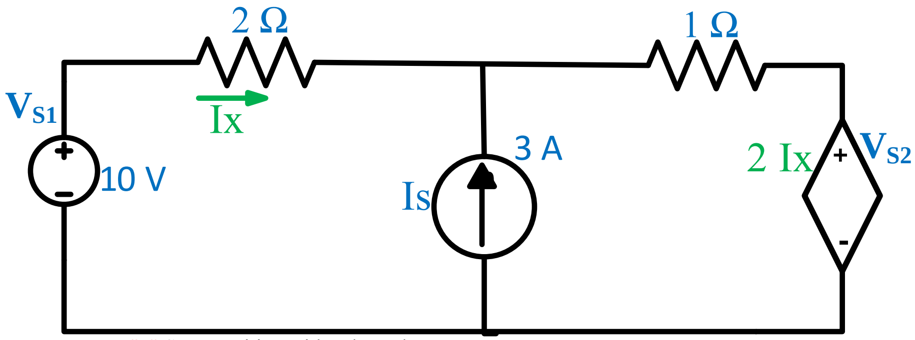


Figure1"a":Superposition with a dependent source

1 - Let *Vs1* on, and turn off *Is:*

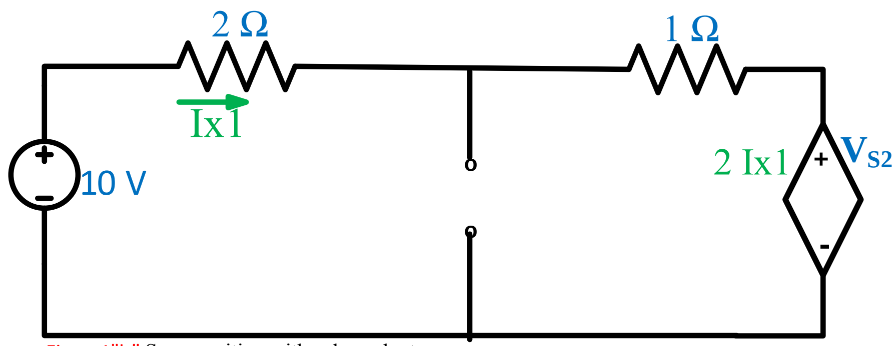


Figure1"b":Superposition with a dependent source

$$2I_{x1} + I_{x1} + 2I_{x1} - 10 = 0$$

$$I_{x1} = 2\ A$$

2 - Let *Is* on, and turn off *Vs1*

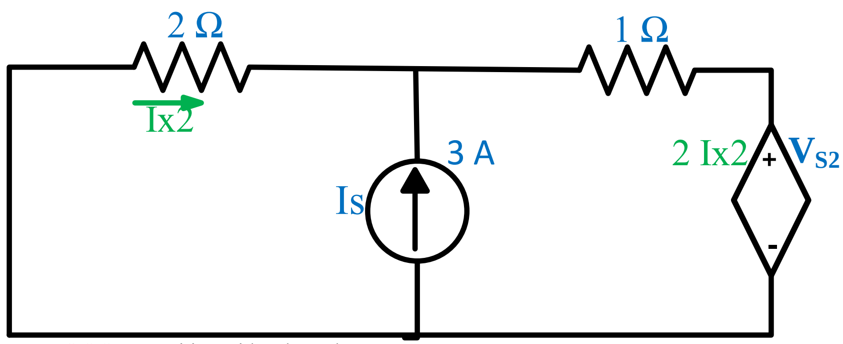


Figure1"c":Superposition with a dependent source

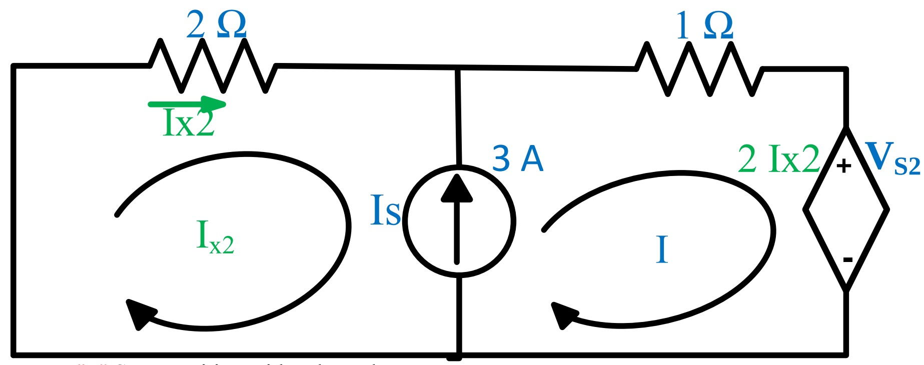


Figure1"d":Superposition with a dependent source

$3 = I - I_{x2}$ Constrain equation.

$-2I_{x2} = 2I_{x2} + I$ Super mesh equation.

- $I_{x2} = -0.6\ A$

$I_x = I_{x1} + I_{x2} = 2 - 0.6$

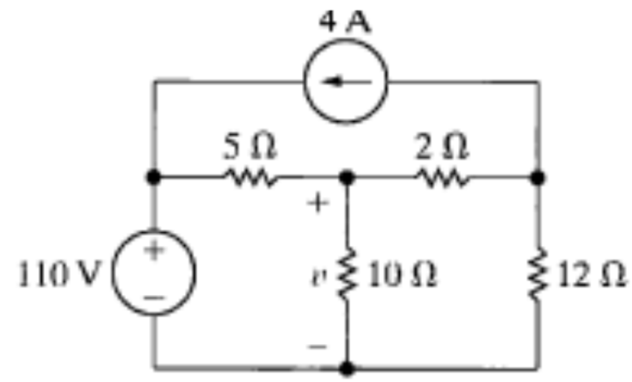
- $I_x = 1.4\ A$

- When applying superposition to circuits with dependent sources, these dependent sources are **never** turned off.

Problem 4.91

a) Use the principle of superposition to find the voltage *v* in the circuit

b) Find the power dissipated in the 10 Ω resistor.

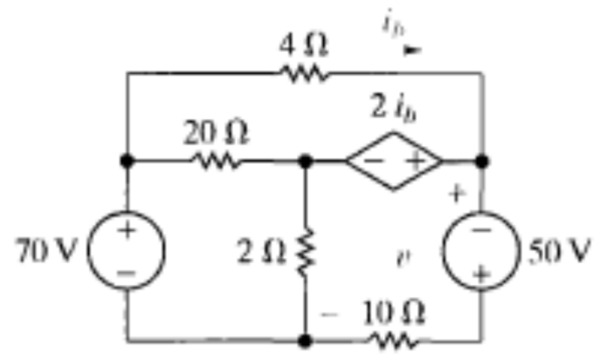


Answer

$\therefore$a) $v = v' + v'' = \frac{770}{13} - \frac{120}{13} = 50 \text{ V}$

b) $p = \frac{v^2}{10} = 250 \text{ W}$

Problem 4.96
Use the principle of superposition to find the voltage *v* in the circuit



Answer

$$v = v' + v'' = \frac{1610}{47} - \frac{200}{47} = \frac{1410}{47} = 30 \text{ V}$$