Chapter 4 – techniques of circuit analysis

Objectives:

- Know how to use the node voltage method to solve a circuit
- Know how to use the mesh current method to solve a circuit
- Be able to choose the appropriate circuit analysis method to use for a particular circuit
- Know how to use source transformation to simplify a circuit
- Be able to calculate the Thevenin and Norton equivalents for a circuit
- Understand and be able to use the condition for maximum power transfer to a load

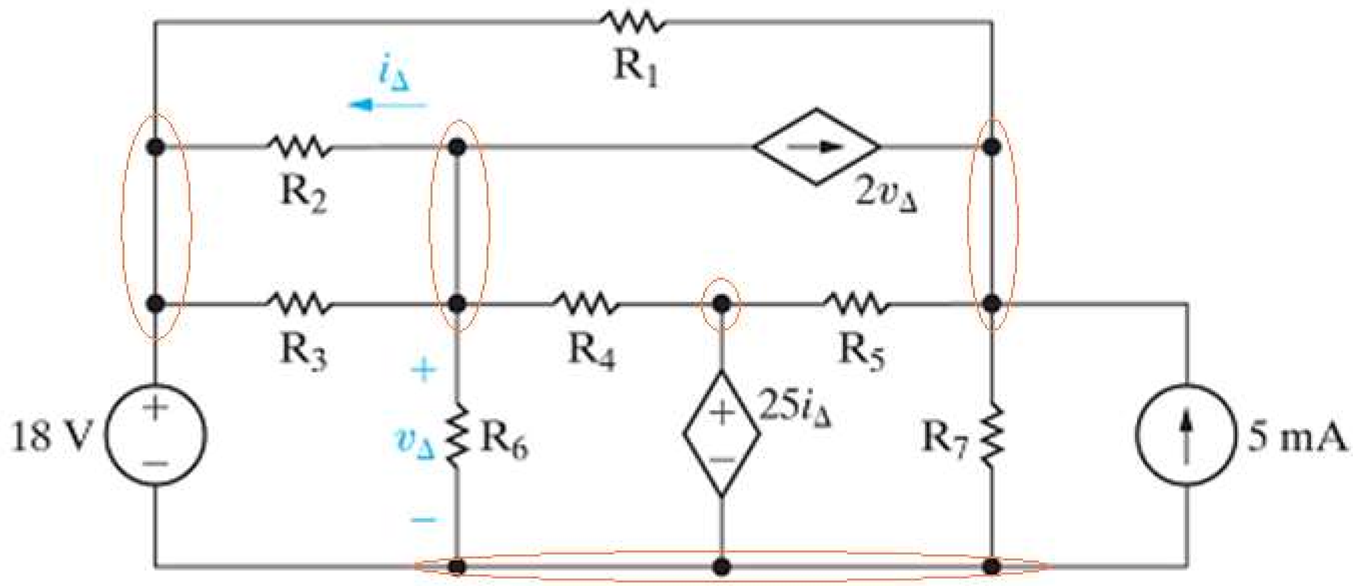
Chapter 4 – techniques of circuit analysis

Terminology:

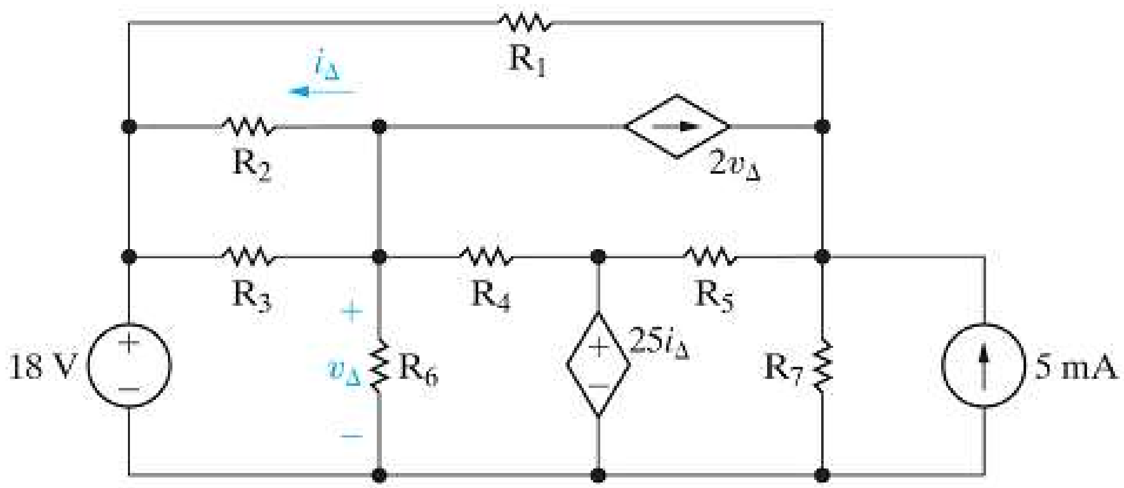
- Node – a point where two or more circuit elements are joined
- Essential node – a point where three or more circuit elements are joined
- Loop – a path whose ending node is the same as its starting node, and does not contain any intermediate nodes more than once
- Mesh – a loop that does not contain any other loops

CHAPTER 4 – TECHNIQUES OF CIRCUIT ANALYSIS

Identify all of the nodes in this circuit.



How many essential nodes does this circuit have?



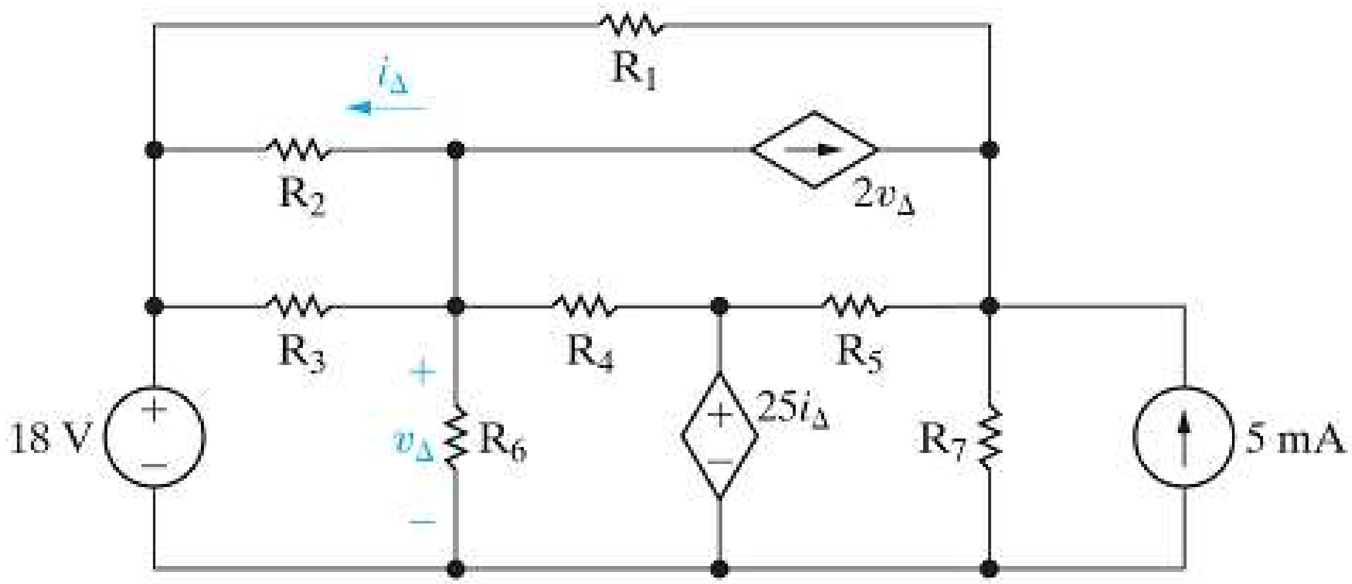
A. 4

B. 5

C. 7

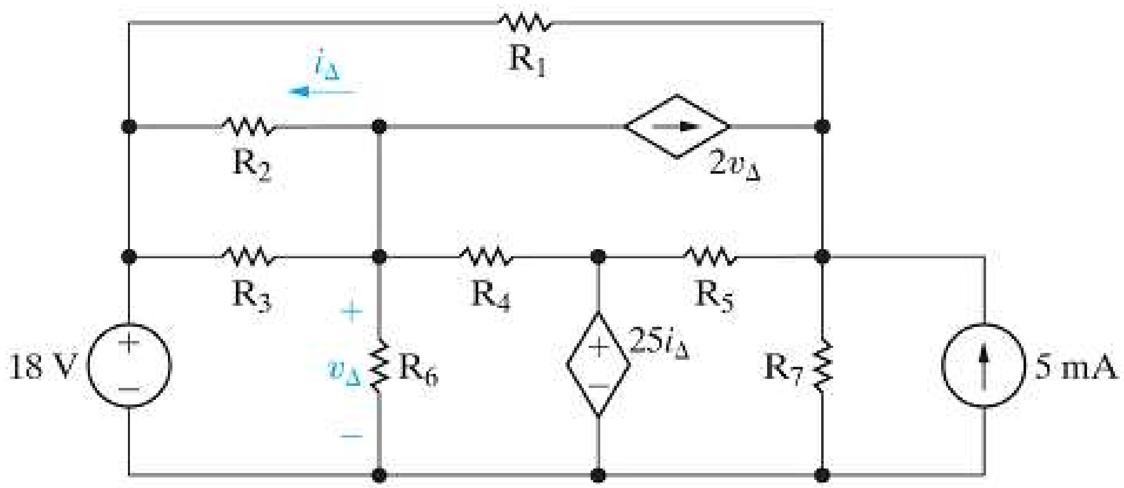
D. 10

Identify all of the loops in this circuit.



R_1, dep. source, R_2
R_1, R_5, R_4, R_2
Dep. Source, R_4, R_5
R_2, dep. source, R_5, R_4, R_3
Etc . . .

HOW MANY MESHES DOES THIS CIRCUIT HAVE?



A. 4

B. 5

C. 7

D. 10

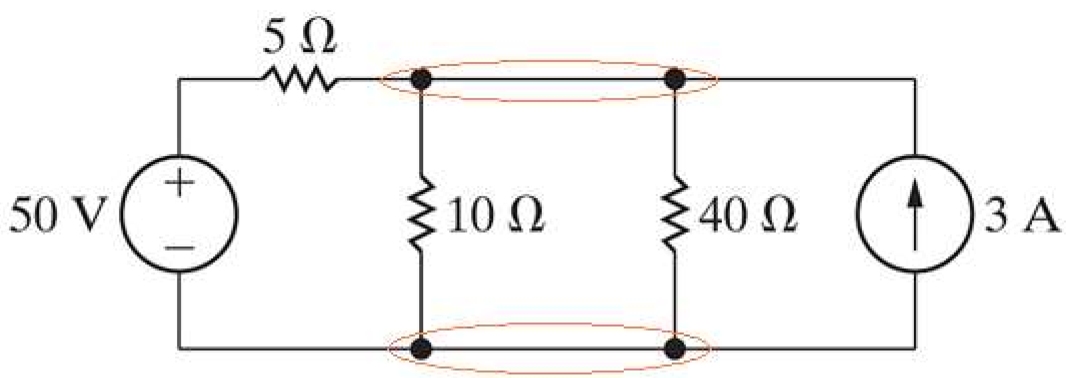
Chapter 4 – techniques of circuit analysis

Node voltage method:

- Based on writing KCL equations at essential nodes
- Solves for node voltages
- The "recipe":
  1. Identify the essential nodes
  2. Pick a reference node
  3. Label remaining essential nodes with voltage values
  4. Write a KCL equation at each non-reference essential node
  5. Put equations in standard form and solve
  6. Check your solutions by balancing power
  7. Calculate quantities of interest

Node voltage method:

Step 1 – identify the essential nodes



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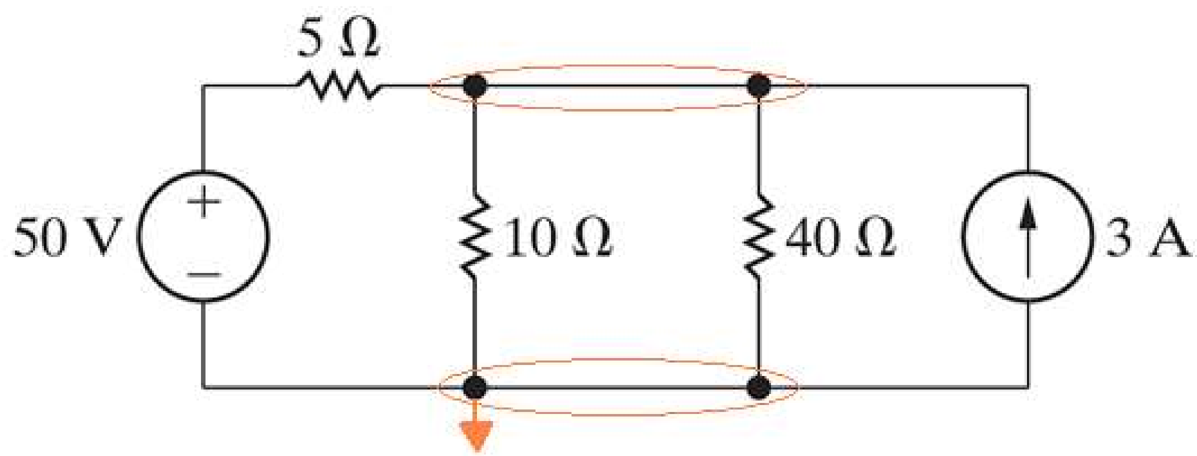
Node voltage method:

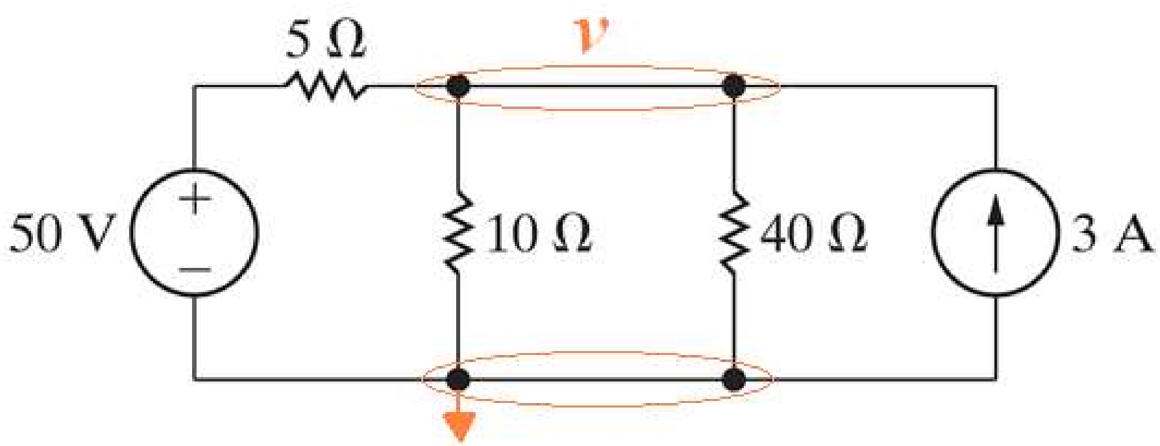
Step 2 – pick a reference node



CHAPTER 4 – TECHNIQUES OF CIRCUIT ANALYSIS

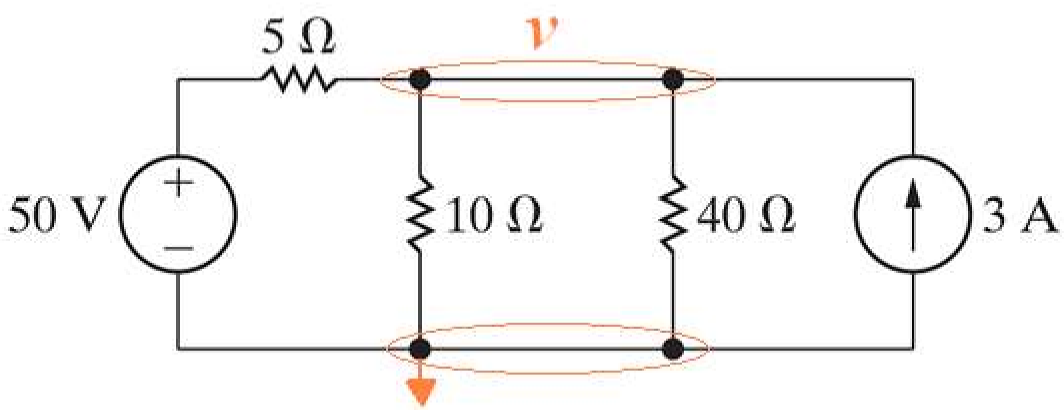
Node voltage method:

Step 3 – label the remaining essential nodes with voltage values



Node voltage method:

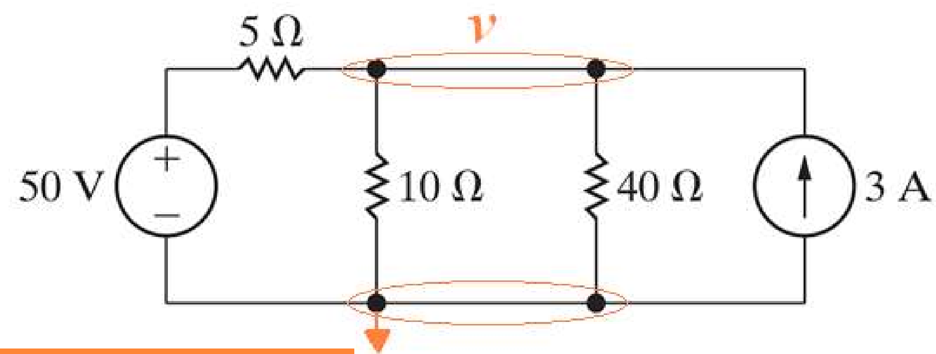
Step 4 – write a KCL equation at each non-reference essential node



$$\text{At } v: \quad \frac{v-50}{5}+\frac{v-0}{10}+\frac{v-0}{40}-3=0$$

Node voltage method:

Step 5 – put the equations in standard form and solve



$$\frac{v-50}{5}+\frac{v-0}{10}+\frac{v-0}{40}-3=0$$

$$\Rightarrow \quad v\left(\frac{1}{5}+\frac{1}{10}+\frac{1}{40}\right)=3+\frac{50}{5}$$

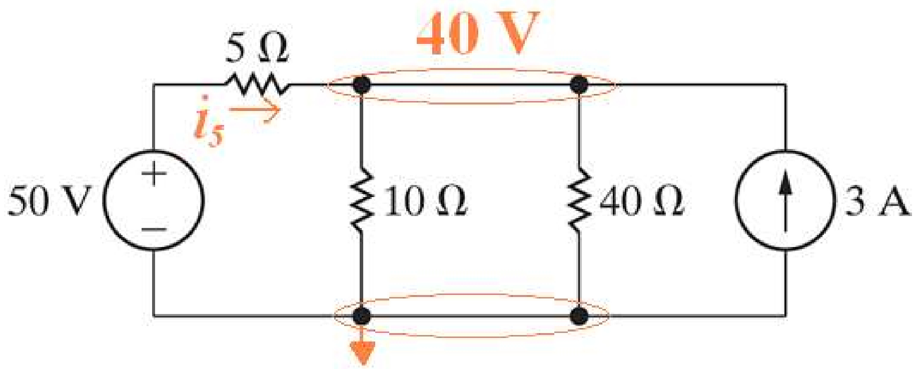
$$\Rightarrow \quad (40)\left[v\left(\frac{1}{5}+\frac{1}{10}+\frac{1}{40}\right)\right]=(40)\left[3+\frac{50}{5}\right]$$

$$\Rightarrow \quad v(8+4+1)=120+400$$

$$\Rightarrow \quad v=520/13=40\text{ V}$$

Node voltage method:

Step 6 – check your solutions



$$i_5 = \frac{50-40}{5} = 2\ \text{A} \qquad p_{50} = -(50)(2) = -100\ \text{W}$$

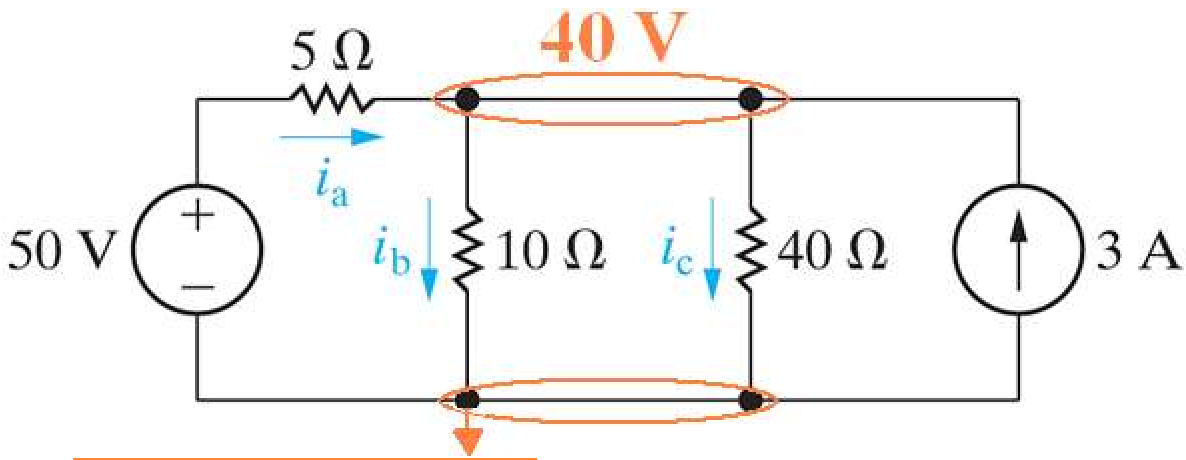
$$p_5 = 5(2)^2 = 20\ \text{W} \qquad p_{10} = (40)^2/10 = 160\ \text{W}$$

$$p_{10} = (40)^2/40 = 40\ \text{W} \qquad p_3 = -(40)(3) = -120\ \text{W}$$

$$\sum p = -100 + 20 + 160 + 40 - 120 = 0$$

Node voltage method:

Step 7 – calculate any other quantities of interest

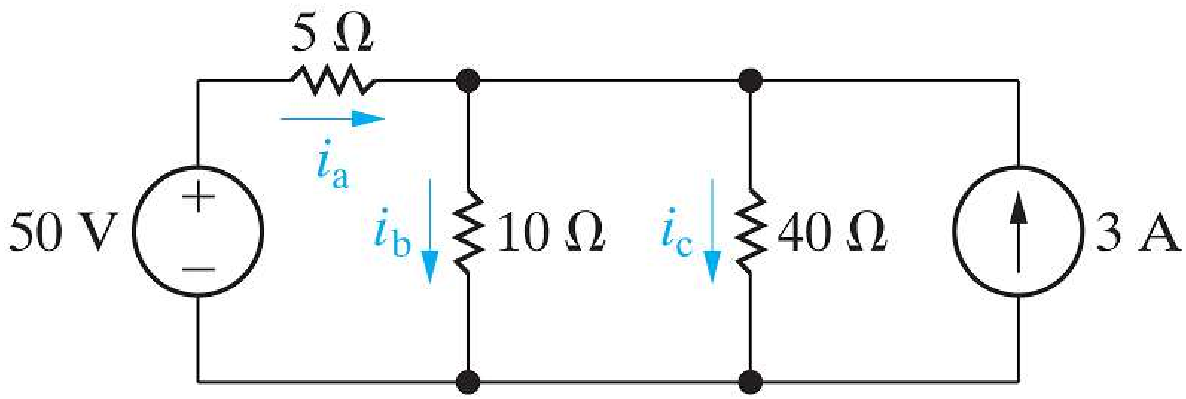


$$i_a = \frac{50-40}{5} = 2\text{ A}$$

$$i_b = \frac{40-0}{10} = 4\text{ A}$$

$$i_a = \frac{40-0}{40} = 1\text{ A}$$

WE JUST SHOWED THAT THE VOLTAGE DROP BETWEEN THE TOP NODE AND THE REFERENCE NODE IN THIS CIRCUIT IS 40 V. FIND i_C



A. 2 A

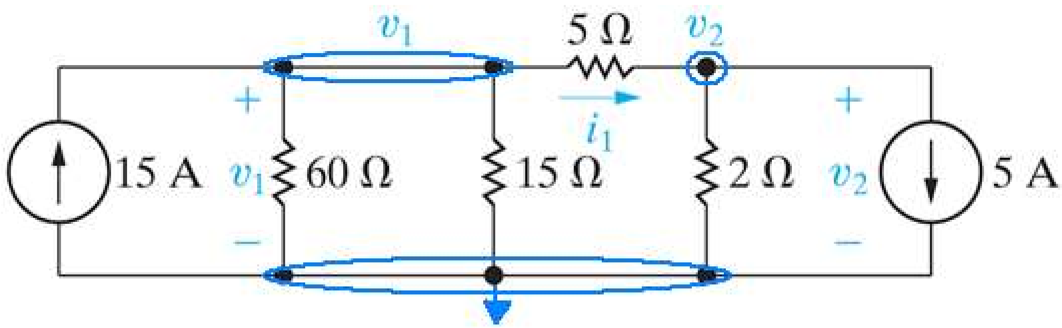
B. 4 A

C. 1 A

D. –1 A

Node voltage method:

Find the two voltages and the current indicated.



$$\text{At } v_1: \; -15 + \frac{v_1}{60} + \frac{v_1}{15} + \frac{v_1 - v_2}{5} = 0$$

$$\text{At } v_2: \; \frac{v_2 - v_1}{5} + \frac{v_2}{2} + 5 = 0$$

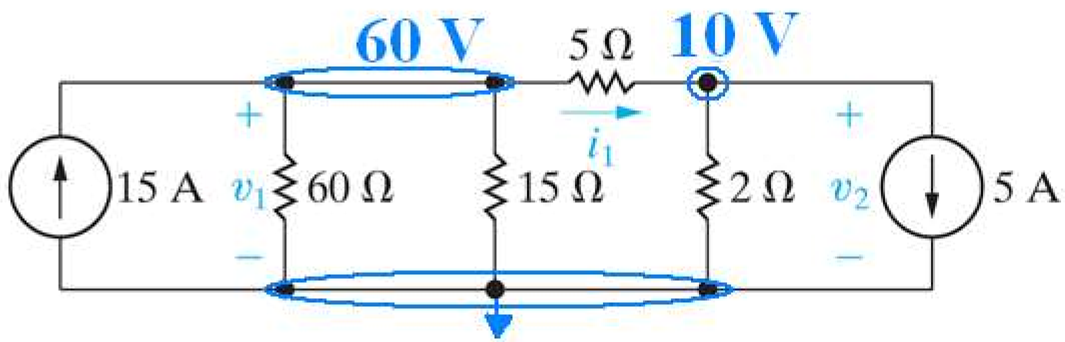
$$\text{Standard form}: v_1\left(\frac{1}{60} + \frac{1}{15} + \frac{1}{5}\right) + v_2\left(-\frac{1}{5}\right) = 15$$

$$v_1\left(-\frac{1}{5}\right) + v_2\left(\frac{1}{5} + \frac{1}{2}\right) = -5$$

Calculator solution: $v_1 = 60 \text{ V}; \quad v_2 = 10 \text{ V}$

Node voltage method (continued):

Find the two voltages and the current indicated.



Power check :

$p_{15A} = -(15)(60) = -900\text{ W};\qquad p_{60} = 60^2/60 = 60\text{ W};$

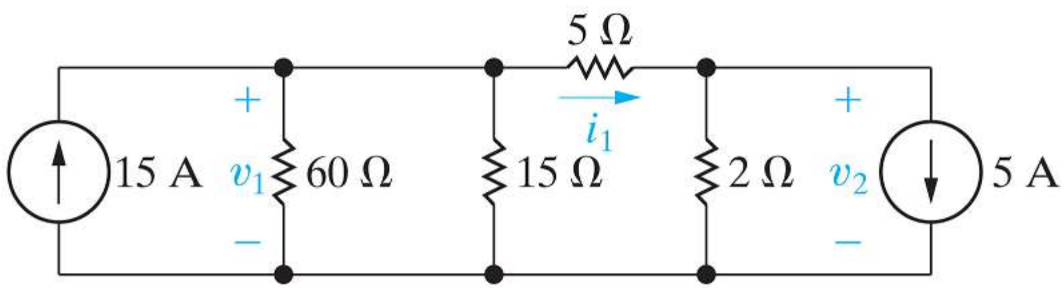
$p_{15\Omega} = 60^2/15 = 240\text{ W};\qquad p_5 = (60-10)^2/5 = 500\text{ W};$

$p_2 = 10^2/2 = 50\text{ W};\qquad p_{5A} = (5)(10) = 50\text{ W}$

$\sum p = -900 + 60 + 240 + 500 + 50 + 50 = 0$

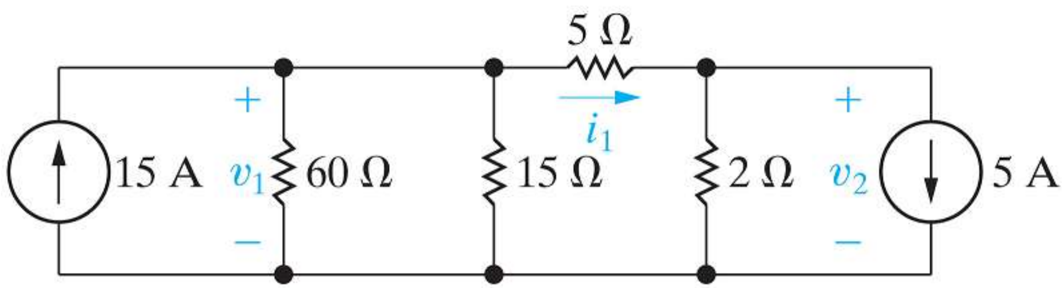
Calculate i_1 : $\qquad i_1 = (60-10)/5 = 10\text{ A}$

If v_1 is 60 V and v_2 is 10 V, what is the power associated with the 60 Ω resistor?



A. 60 W
B. 240 W
C. 3600 W
D. None of the above

If v_1 is 60 V and v_2 is 10 V, what is the power associated with the 5 A source?



A. 900 W

B. –900 W

C. –50 W

D. 50 W