Schedule…

Date	Day	Class No.	Title	Chapters	HW Due date	Lab Due date	Exam
13 Oct	Mon	12	Exam 1 Review			LAB 4	EXAM 1
14 Oct	Tue						
15 Oct	Wed	13	Phasors	4.4			
16 Oct	Thu						
17 Oct	Fri		Recitation				
18 Oct	Sat						
19 Oct	Sun						
20 Oct	Mon	14	AC Circuit Analysis	4.5		NO LAB	
21 Oct	Tue					NO LAB	

Examine Yourselves

<u>2 Cor. 13: 5</u>

5 **Examine** yourselves, whether ye be in the
faith; prove your own selves.

Lecture 12 – Exam 1 Review

Chapters 2 - 3

Exam 1

- 20 – 23 February (Tuesday – Friday)
- Chapters 2 and 3
- 18 questions
  - 15 multiple choice (answer on bubble sheet!)
    - 1 point each
  - 3 long answer (show your work!)
    - Up to 5 points each
- Closed book!
  - One 3x5 card allowed
- Calculators allowed
- No time limit
- Study lecture slides and homework

Exam 1 Review…Overview

1. Kirchoff’s current law
2. Kirchoff’s voltage law
3. Passive sign convention
4. Voltage/current dividers (Ohm’s Law)
5. Wheatstone bridge
6. Measuring Devices
7. Node voltage method
8. Mesh current method
9. Principle of superposition
10. Source transformation
11. Thévenin equivalent circuits
12. Norton equivalent circuits
13. Maximum power transfer
14. Dependent Sources

Exam 1 Review…KCL

1. What is Kirchoff’s current law?

Exam 1 Review…KCL

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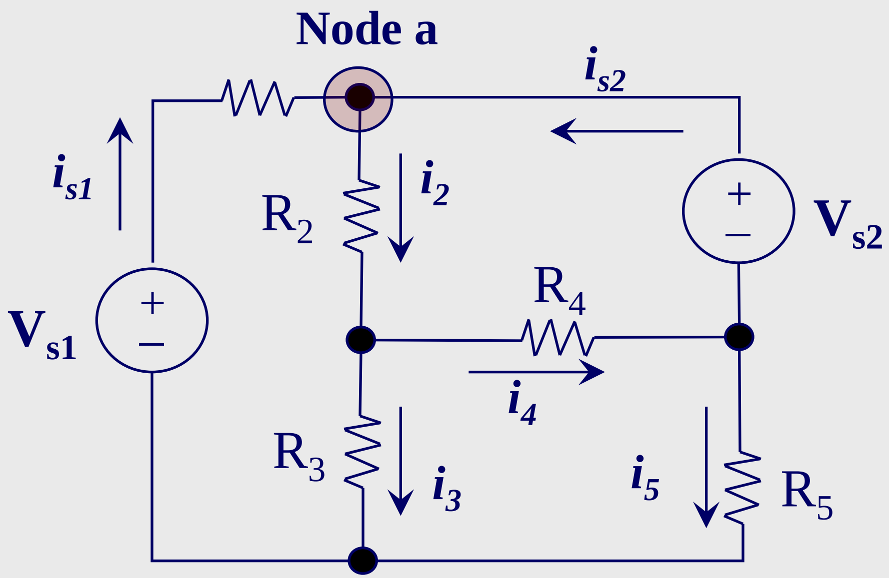
   a) What is an expression for the current at **Node a**?



Exam 1 Review…KCL

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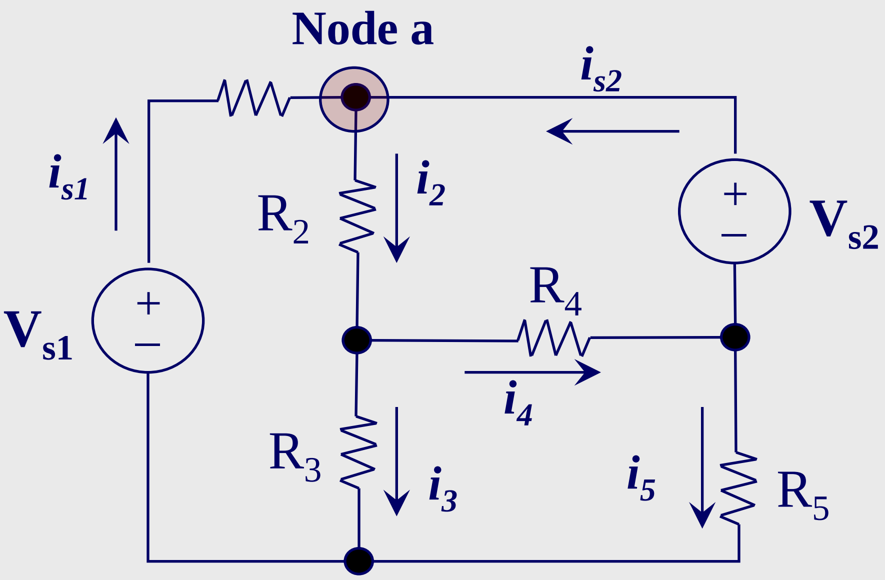
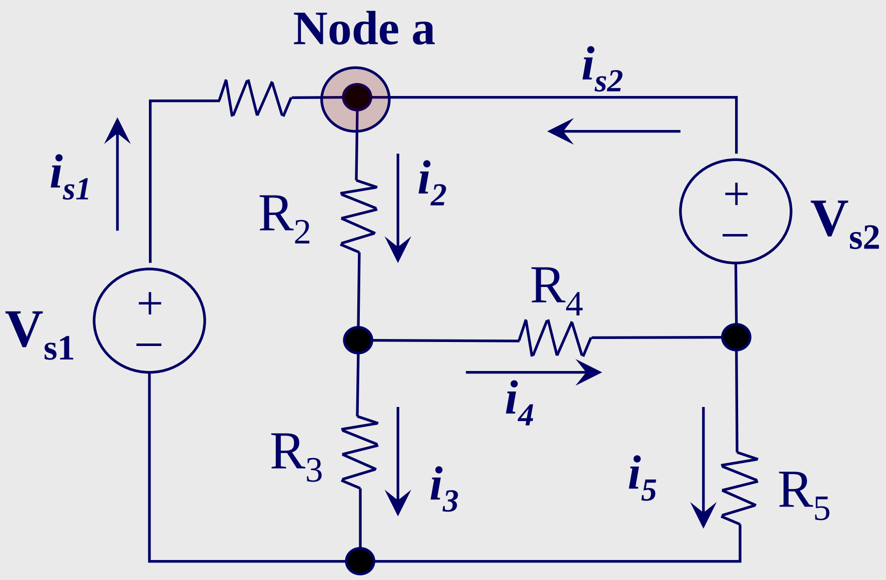


$$i_{s1} + i_{s2} - i_2 = 0$$

Exam 1 Review…KCL

1. What is Kirchoff's current law?
   - a) What is an expression for the current at **Node a**?
   - b) what expressions for the current through R_2 are valid?



Exam 1 Review…KCL

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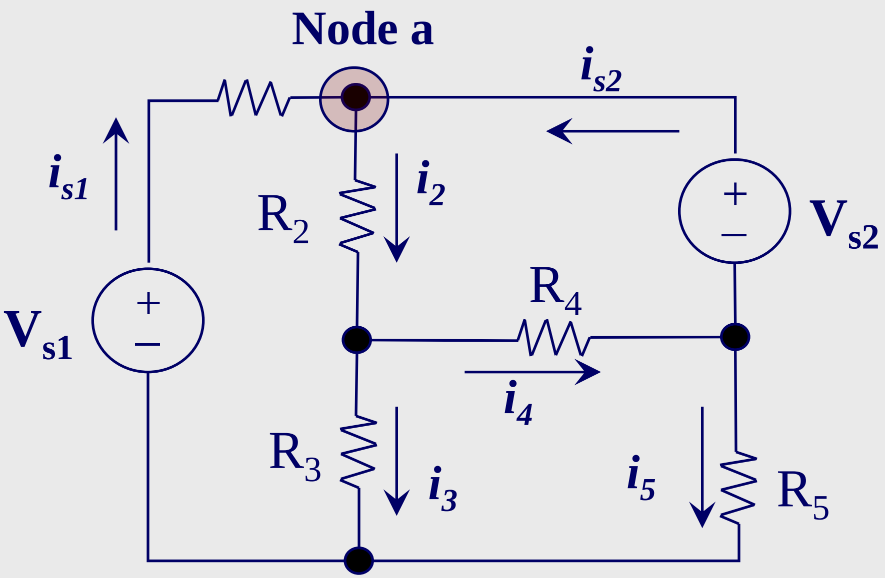

$$i_2 = -i_{s1} + i_{s2}$$

$$i_2 = -i_3 - i_4$$

$$i_2 = i_{s1} + i_4 - i_5$$

$$i_2 = i_3 + i_5 + i_{s2}$$

Exam 1 Review…KCL

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   a) What is an expression for the current at **Node a**?

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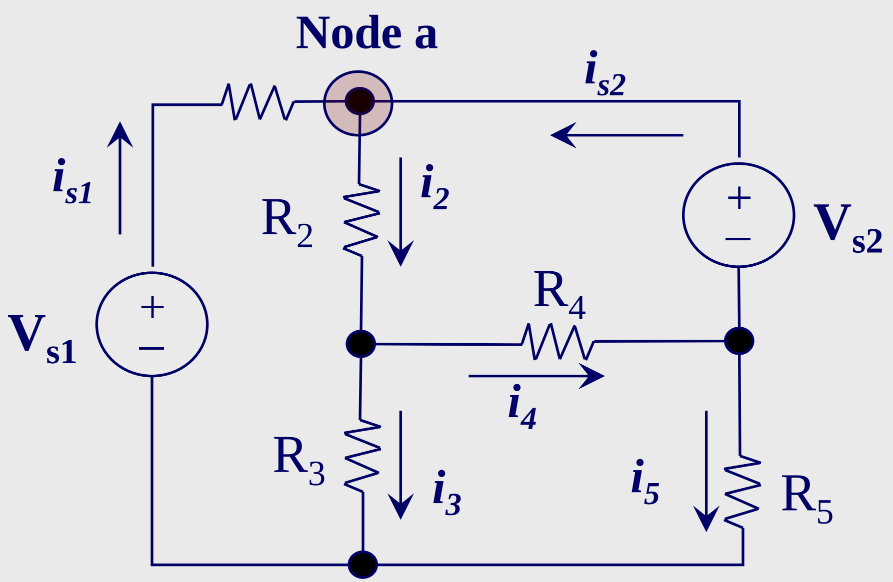


$$\cancel{i_2 = -i_{s1} + i_{s2}}$$

$$\cancel{i_2 = -i_3 - i_4}$$

$$i_2 = i_{s1} + i_4 - i_5$$

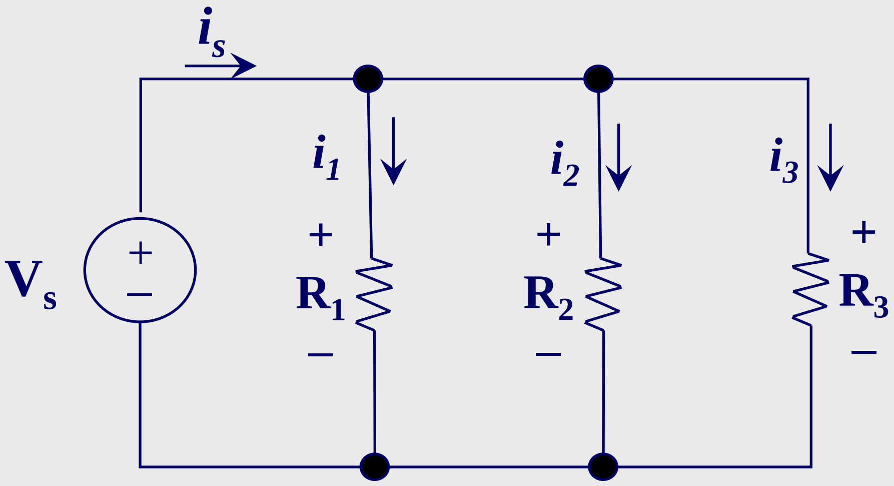
$$i_2 = i_3 + i_5 + i_{s2}$$

Exam 1 Review…KVL

2. What is Kirchoff's voltage law?

Exam 1 Review…KVL

2. What is Kirchoff's voltage law?
   a) If $\mathbf{V_s}$ = 3V, what are the voltages across $\mathbf{R_1}$, $\mathbf{R_2}$, and $\mathbf{R_3}$?



Exam 1 Review…KVL

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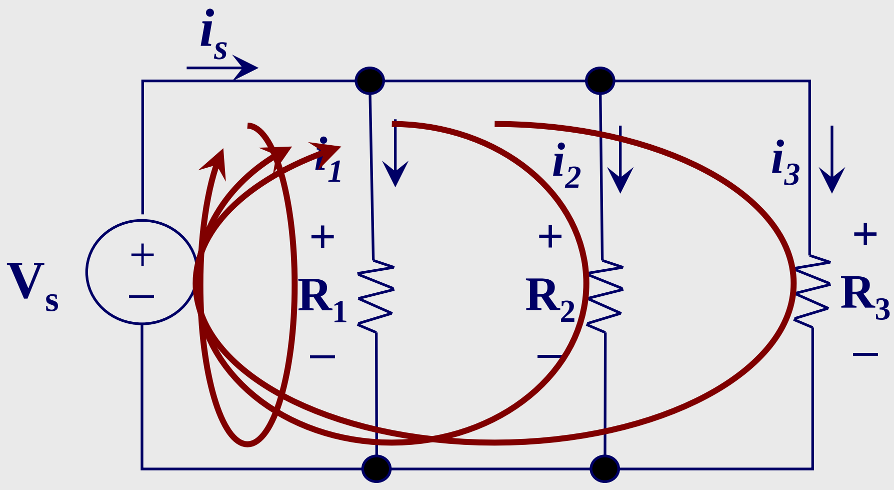


Using KVL:

$$-V_s + v_1 = 0$$

$$v_1 = V_s$$

$$= 3V$$

$$v_2 = 3V$$

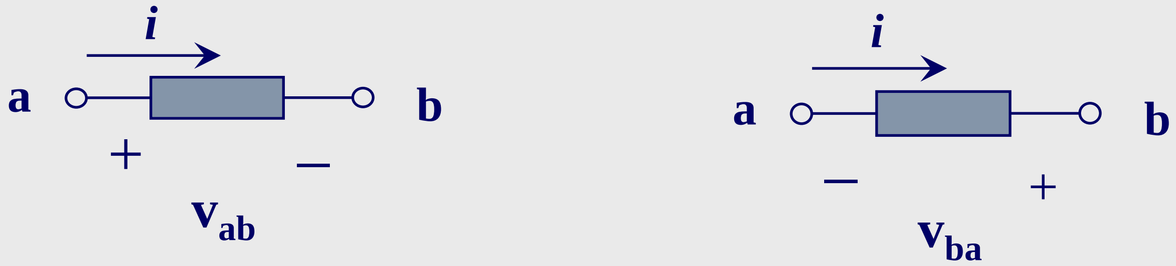
$$v_3 = 3V$$

Exam 1 Review…Passive Sign

3. What is the passive sign convention?

Exam 1 Review…Passive Sign

3. What is the passive sign convention?
   a) Which element dissipates power and which generates power?



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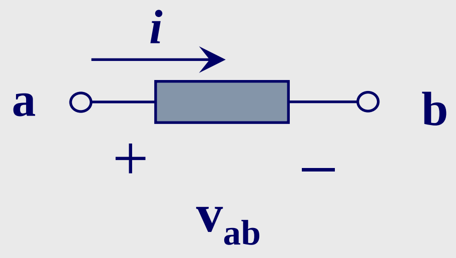
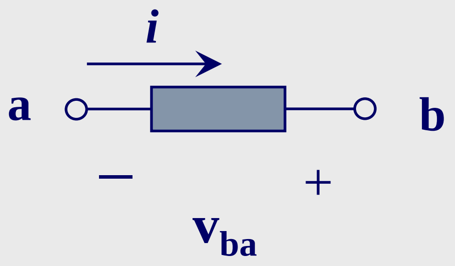




Passive Element (load)
- power dissipated = **v*i***
- power generated = **-v*i***

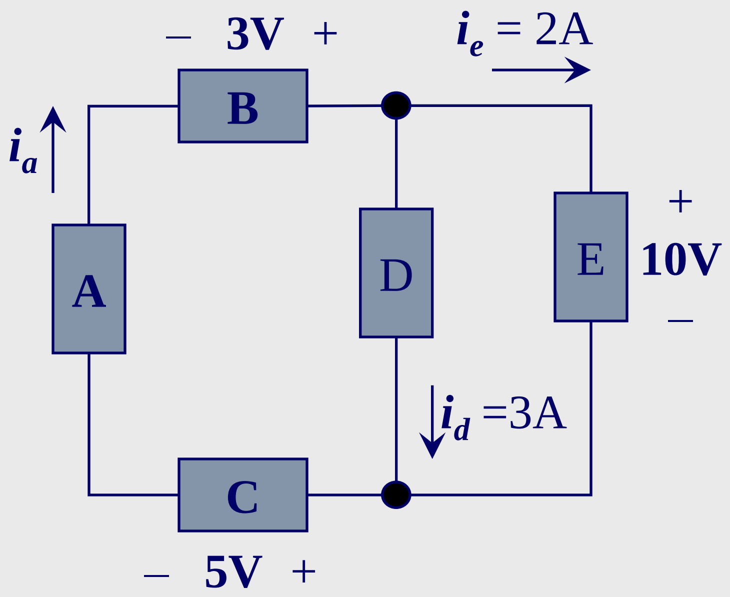
Active Element (source)
- power dissipated = **-v*i***
- power generated = **v*i***

Positive voltage

Negative voltage

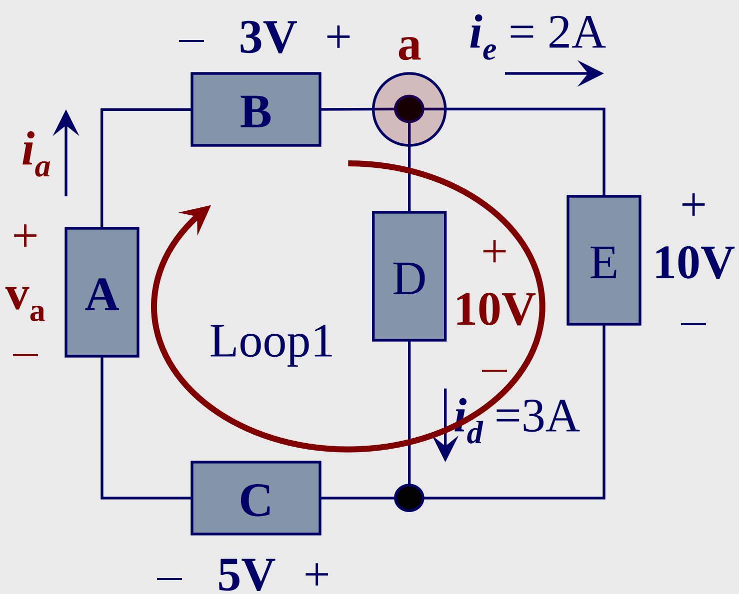
Exam 1 Review…Passive Sign

3. What is the passive sign convention?
   b) Find the power dissipated by each element



Exam 1 Review…Passive Sign

3. What is the passive sign convention?
   b) Find the power dissipated by each element



NB: since **load D** and **load E** share the same nodes their voltages will be the same

KCL at node a :

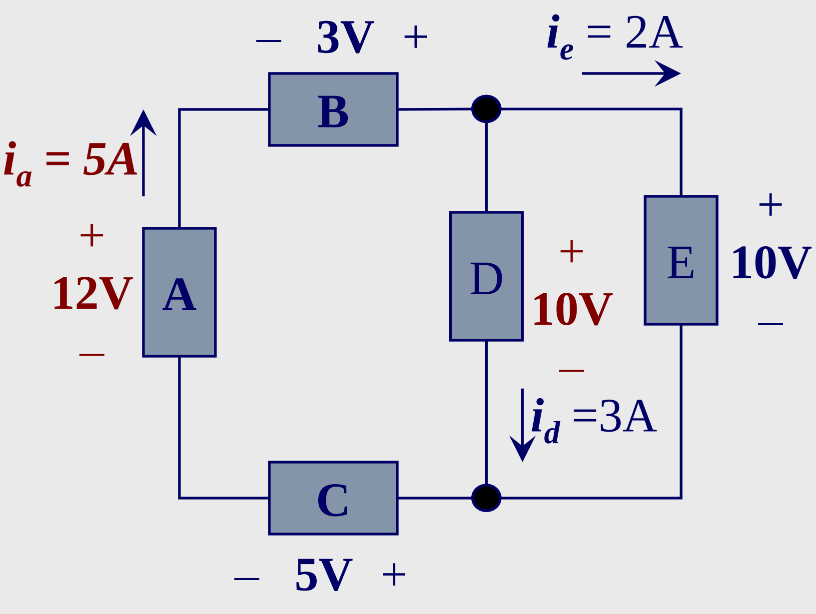
$$i_a - i_d - i_e = 0$$
$$i_a = i_d + i_e$$
$$= 3 + 2$$
$$= 5A$$

KVL at Loop1 :

$$-v_a - v_b + v_e + v_c = 0$$
$$v_a = v_e + v_c - v_b$$
$$= 10 + 5 - 3$$
$$= 12V$$

Exam 1 Review…Passive Sign

3. What is the passive sign convention?
   b) Find the power dissipated by each element



$$P_a = -12V \times 5A = -60W$$
A supplies 60W

$$P_b = -3V \times 5A = -15W$$
B supplies 15W

$$P_c = 5V \times 5A = 25W$$
C absorbs 25W

$$P_d = 10V \times 3A = 30W$$
D absorbs 30W

$$P_e = 10V \times 2A = 20W$$
E absorbs 20W

Total Power Supplied :
$$P_a + P_b = 60W + 15W = 75W$$

Total Power Absorbed :
$$P_c + P_d + P_e = 25W + 30W + 20W = 75W$$

Exam 1 Review…Dividers

4. What is a voltage/current divider?

Exam 1 Review…Dividers

4. What is a voltage/current divider?

$$v_n = \frac{R_n}{R_1 + R_2 + R_3 + \cdots + R_n + \cdots + R_N} V_s$$

$$\boxed{= \frac{R_n}{R_{EQ}} V_s}$$

$$i_n = \frac{\frac{1}{R_n}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n} + \cdots + \frac{1}{R_N}} i_s$$

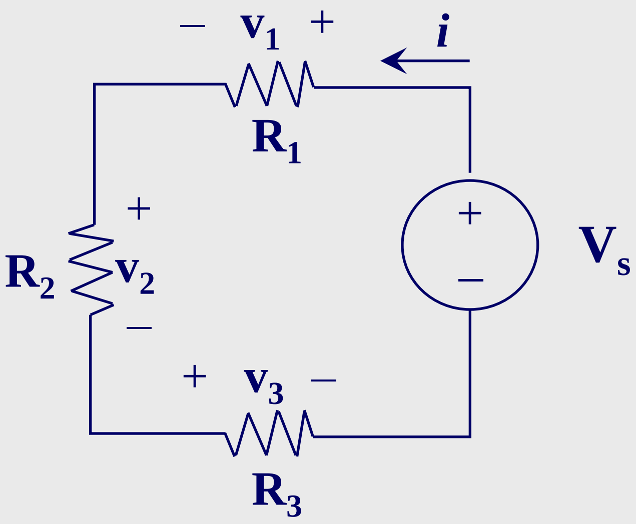
$$= \frac{\frac{1}{R_n}}{\frac{1}{R_{EQ}}} i_s$$

$$\boxed{= \frac{R_{EQ}}{R_n} i_s}$$

Exam 1 Review…Dividers

4. What is a voltage/current divider?
   a) Using a voltage divider find the voltage across $\mathbf{R_3}$

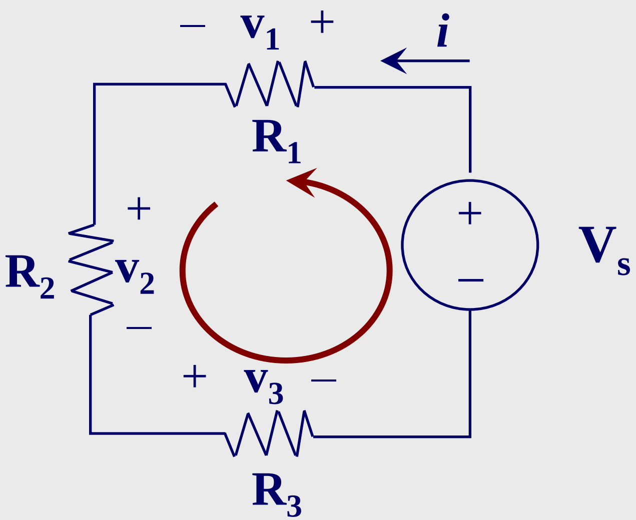
      $\mathbf{V_s} = 3\text{V}$, $\mathbf{R1} = 10\Omega$, $\mathbf{R_2} = 6\Omega$, $\mathbf{R_3} = 8\Omega$



Exam 1 Review…Dividers

4. What is a voltage/current divider?
   a) Using a voltage divider find the voltage across $\mathbf{R_3}$

$\mathbf{V_s}$ **=** 3V, **R1** = 10Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 8Ω



Using Series Rule :

$$R_{EQ} = R_1 + R_2 + R_3$$
$$= 10 + 6 + 8$$
$$= 24\Omega$$

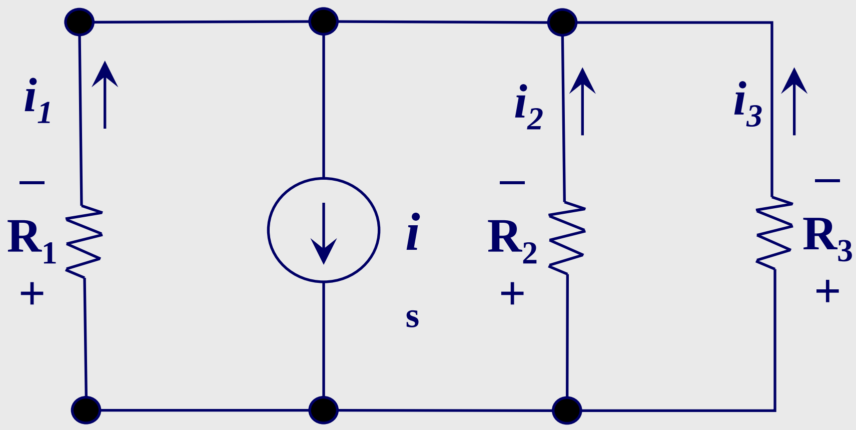
Using Voltage Divider :

$$v_3 = \frac{R_3}{R_{EQ}} \cdot V_s$$
$$= \frac{8}{24} \cdot 3$$
$$= 1V$$

Exam 1 Review…Dividers

4. What is a voltage/current divider?
   a) Using a current divider find $\boldsymbol{i_1}$

   $\mathbf{R_1} = 10\Omega$, $\mathbf{R_2} = 2\ \Omega$, $\mathbf{R_3} = 20\ \Omega$, $\boldsymbol{I_s} = 4\text{A}$



Exam 1 Review…Dividers

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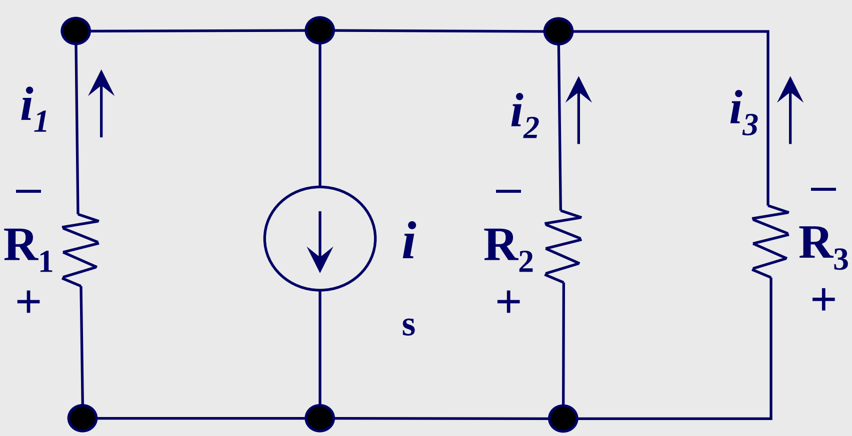


NB: all elements share terminals

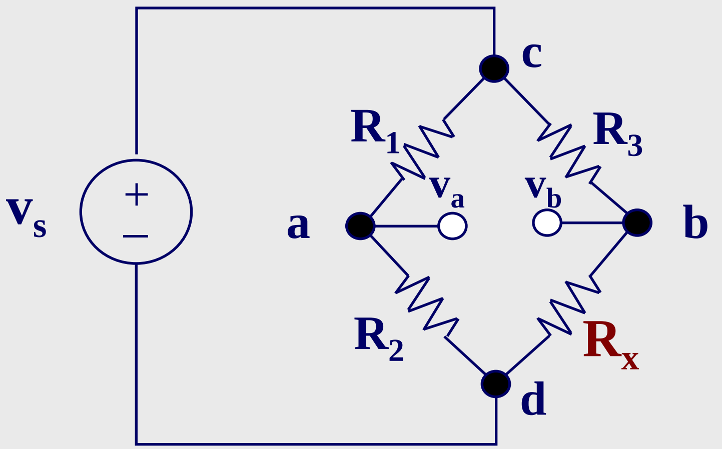
$$R_{EQ} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{10} + \frac{1}{2} + \frac{1}{20}} = \frac{1}{\frac{2+10+1}{20}} = \frac{20}{13}\Omega$$

Using current divider:

$$i_1 = \frac{R_{EQ}}{R_1} i_s = \frac{\frac{20}{13}}{10} \cdot 4 = \frac{40}{65} = 0.615\,A$$

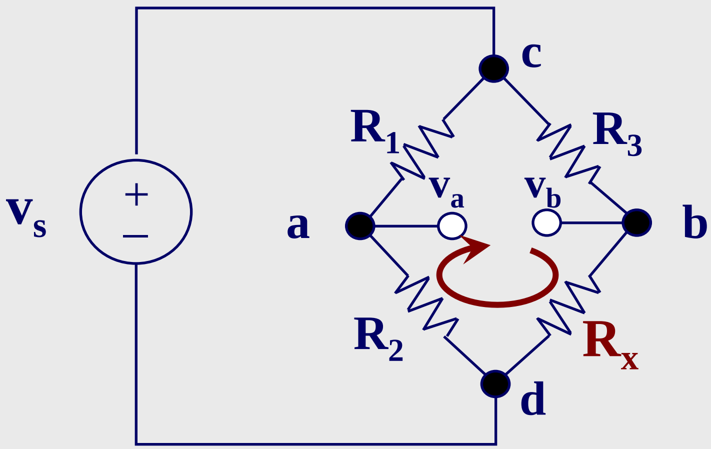
Exam 1 Review…Wheatstone

5. What is the voltage across the terminals a and b of the Wheatstone bridge?



Exam 1 Review…Wheatstone

5. What is the voltage across the terminals a and b of the Wheatstone bridge?



$$v_{ad} = v_s \frac{R_2}{R_1 + R_2}$$

$$v_{bd} = v_s \frac{R_x}{R_3 + R_x}$$

$$v_{ab} = v_{ad} - v_{bd}$$

$$= v_s \left(\frac{R_2}{R_1 + R_2} - \frac{R_x}{R_3 + R_x} \right)$$

Exam 1 Review…Measuring

6. How do measuring devices connect to circuits?

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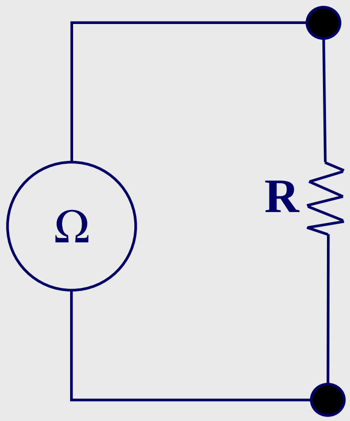
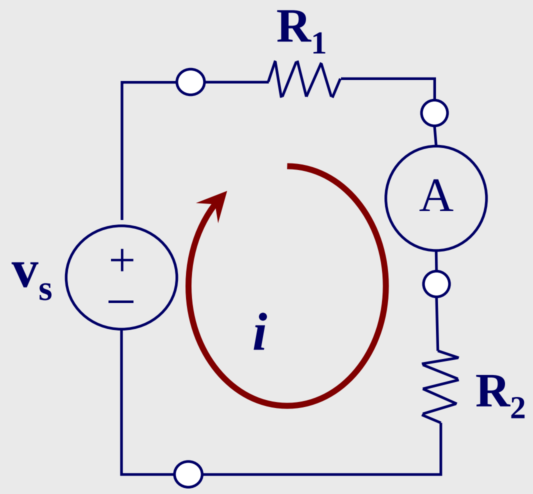


NB: the resistance of an element can only be measured when the element is **disconnected** from **all** other circuit elements

Exam 1 Review…Measuring

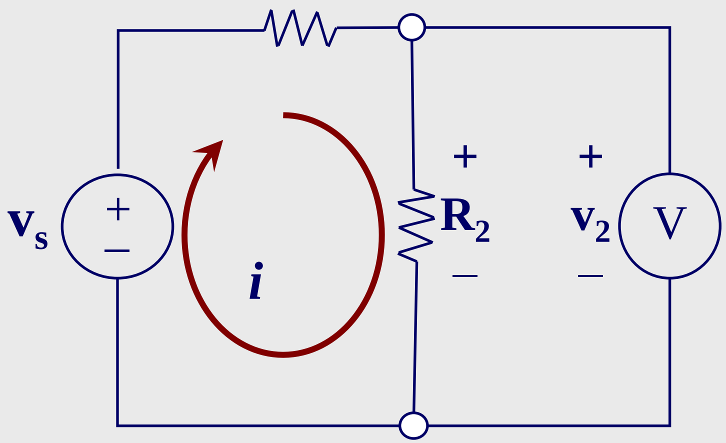
6. How do measuring devices connect to circuits?



NB: 1. the ammeter must be connected in **series** with the circuit element
2. the ammeter should not restrict the flow of current (i.e. cause a voltage drop) – an ideal ammeter has **zero** resistance

Exam 1 Review…Measuring

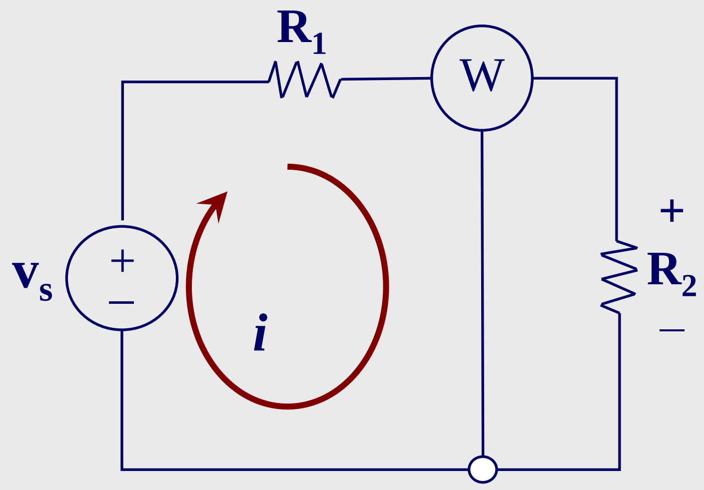
6. How do measuring devices connect to circuits?



NB: 1. the voltmeter must be connected in **parallel** with the circuit element
2. the voltmeter should not draw any current away from the element
– an ideal voltmeter has **infinite** resistance

Exam 1 Review…Measuring

6. How do measuring devices connect to circuits?



NB: 1. the wattmeter must be connected in **parallel** with the circuit element, but also in **series** with the circuit.
– a wattmeter is simply the combination of a voltmeter and an ammeter

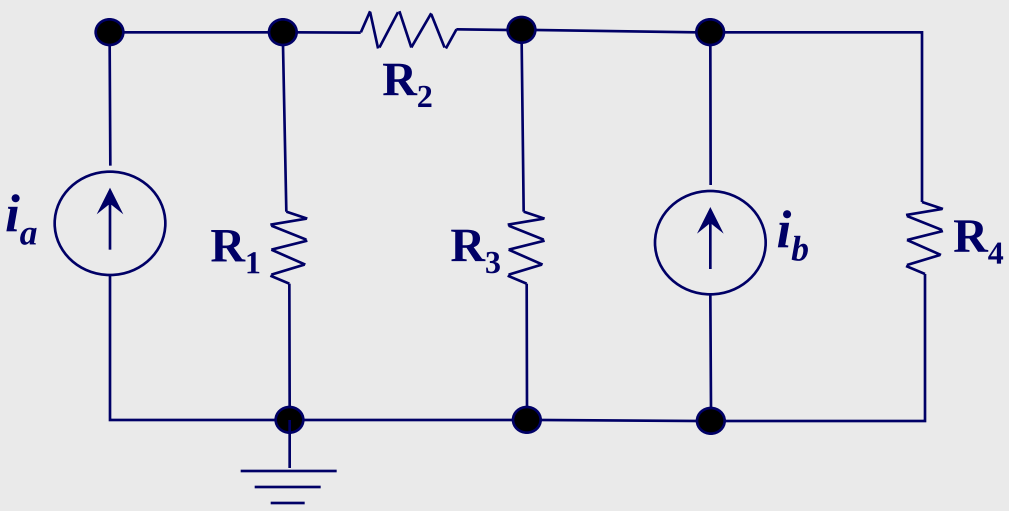
Exam 1 Review…Node Voltage

7. What is the node voltage method of circuit analysis?

Exam 1 Review…Node Voltage

7. What is the node voltage method of circuit analysis?
   a) Find all unknown voltages

i_a = 1mA, i_b = 2mA, R_1 = 1kΩ, R_2 = 500Ω, R_3 = 2.2kΩ, R_4 = 4.7kΩ



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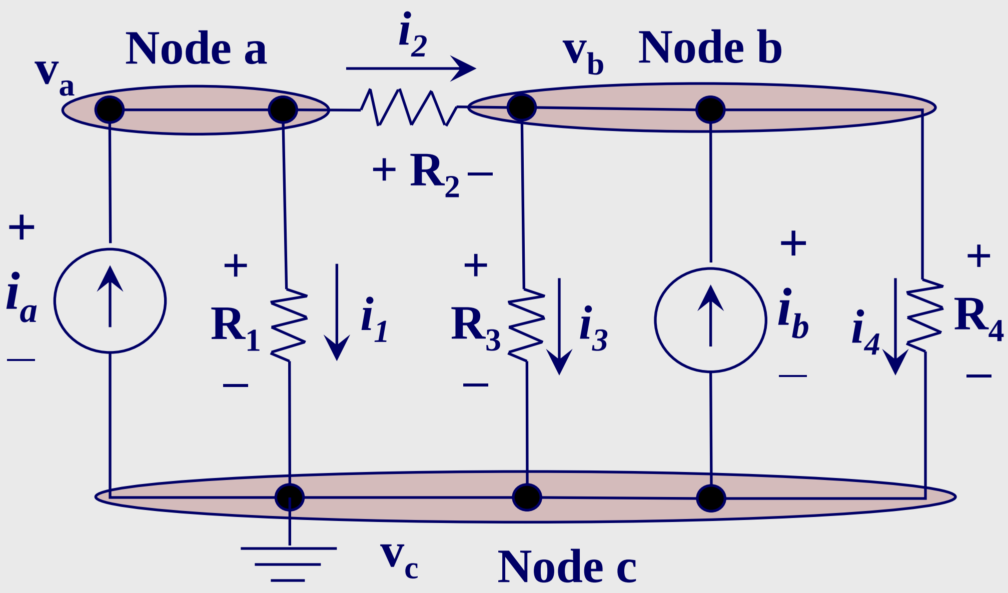

1. Label currents and voltages (polarities "arbitrarily" chosen)
2. Choose **Node c** (**v_c**) as the reference node (**v_c** = 0)
3. Define remaining n – 1 (2) voltages
   - **v_a** is **independent**
   - **v_b** is **independent**
4. Apply KCL at nodes **a** and **b**

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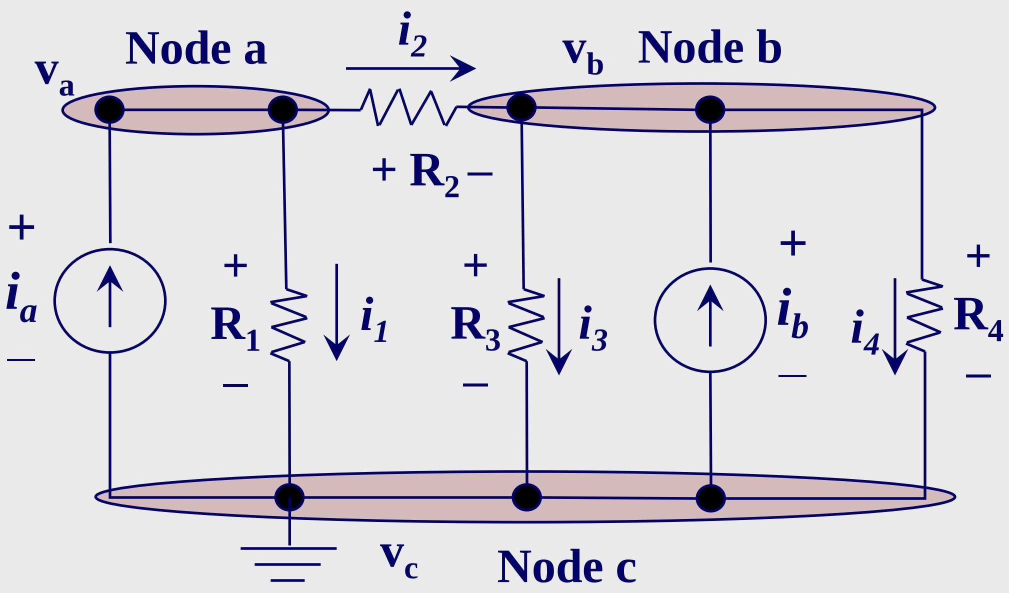

4. Apply KCL at nodes **a** and **b**

KCL at Node a:

$$i_a - i_1 - i_2 = 0$$

$$i_a - \frac{v_a}{R_1} - \frac{v_{ab}}{R_2} = 0$$

KCL at Node b:

$$i_b + i_2 - i_3 - i_4 = 0$$

$$i_b + \frac{v_{ab}}{R_2} - \frac{v_b}{R_3} - \frac{v_b}{R_4} = 0$$

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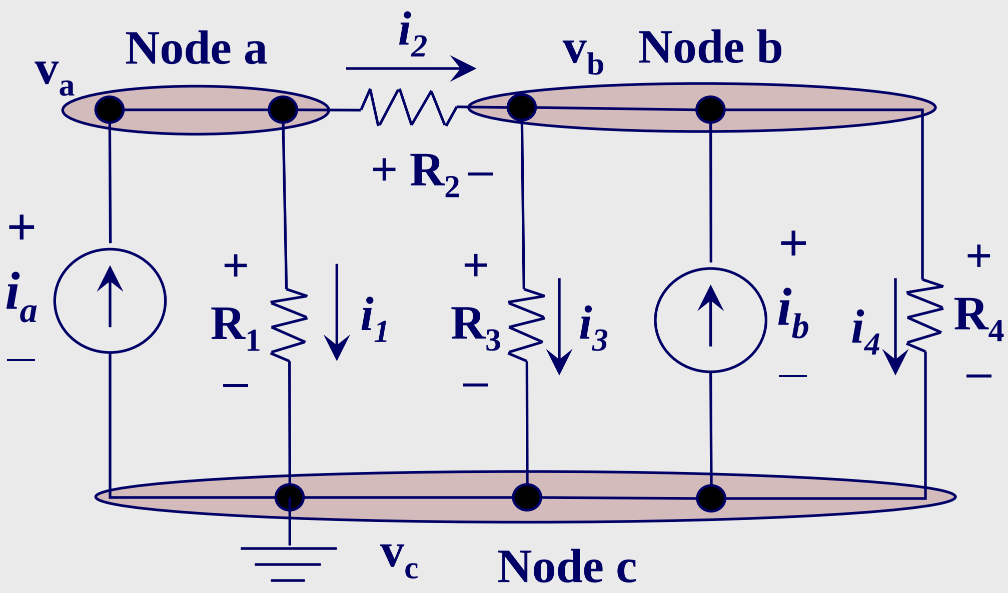

4. Express currents in terms of voltages

$$i_a = v_a\left(\frac{1}{R_1}+\frac{1}{R_2}\right) - v_b\left(\frac{1}{R_2}\right)$$

$$i_b = v_b\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right) - v_a\left(\frac{1}{R_2}\right)$$

Exam 1 Review…Node Voltage

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   a) Find all unknown voltages

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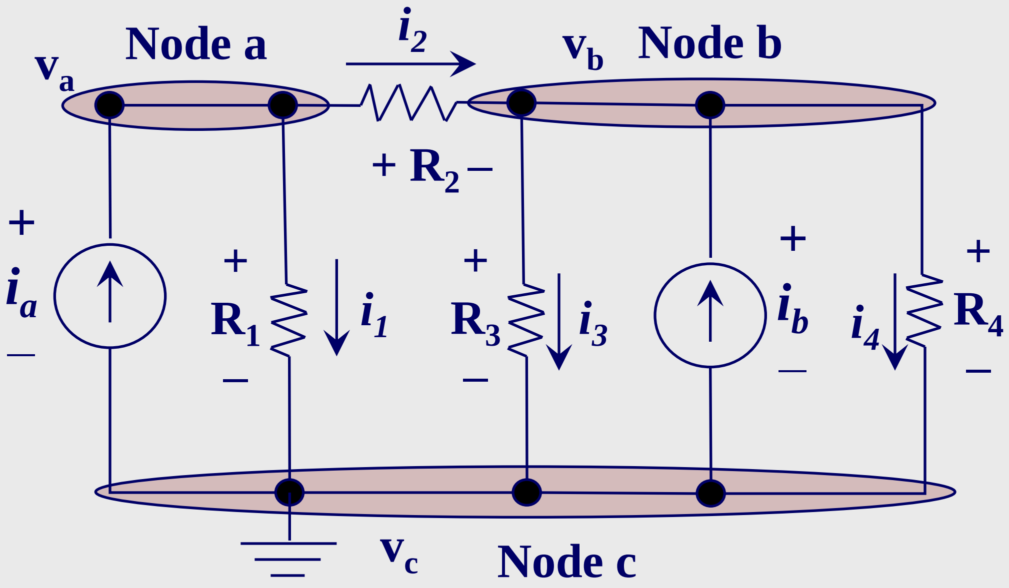


5. Solve the n – 1 – m equations

$$1 = 3v_a - 2v_b$$
$$2 = -2v_a + 2.67v_b$$

$$v_a = 1.67V$$
$$v_b = 2.00V$$

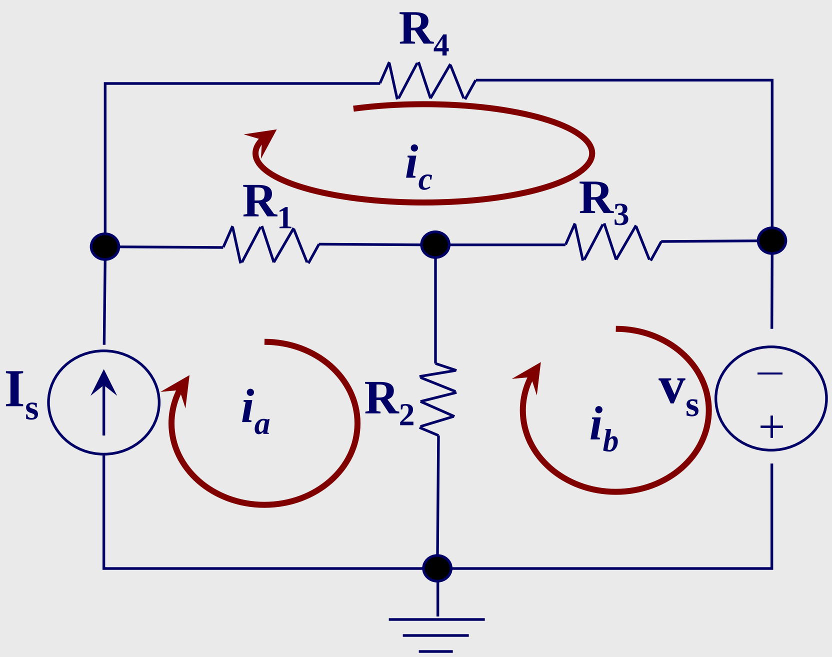
Exam 1 Review…Mesh Current

8. What is the mesh current method of circuit analysis?

Exam 1 Review…Mesh Current

8. What is the mesh current method of circuit analysis?
   a) Find the mesh currents

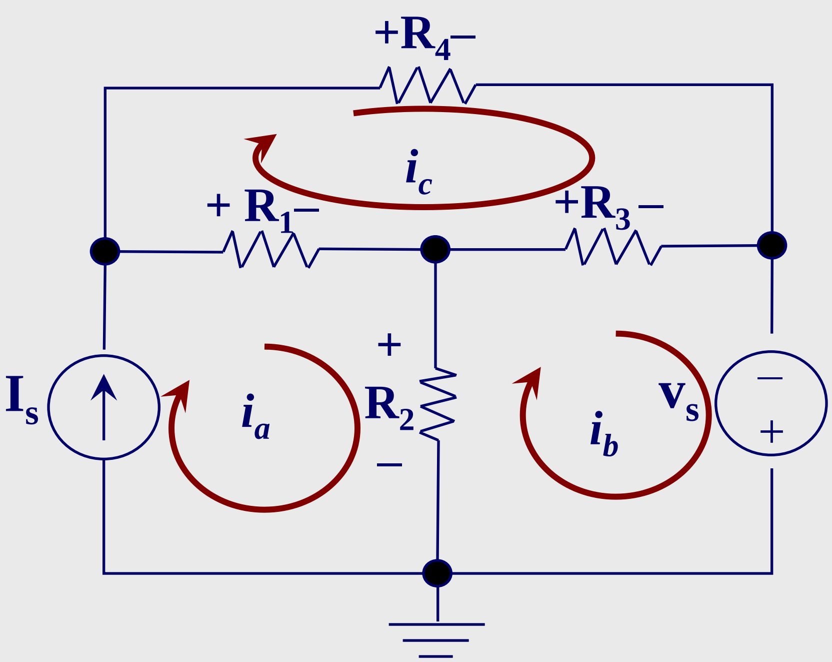
$\mathbf{V_s} = 6\text{V}$, $I_s = 0.5\text{A}$, $\mathbf{R_1} = 3\Omega$, $\mathbf{R_2} = 8\Omega$, $\mathbf{R_3} = 6\Omega$, $\mathbf{R_4} = 4\Omega$



Exam 1 Review…Mesh Current

8. What is the mesh current method of circuit analysis?
   a) Find the mesh currents

$\mathbf{V_s}$ = 6V, I_s = 0.5A, $\mathbf{R_1}$ = 3Ω, $\mathbf{R_2}$ = 8Ω, $\mathbf{R_3}$ = 6Ω, $\mathbf{R_4}$ = 4Ω

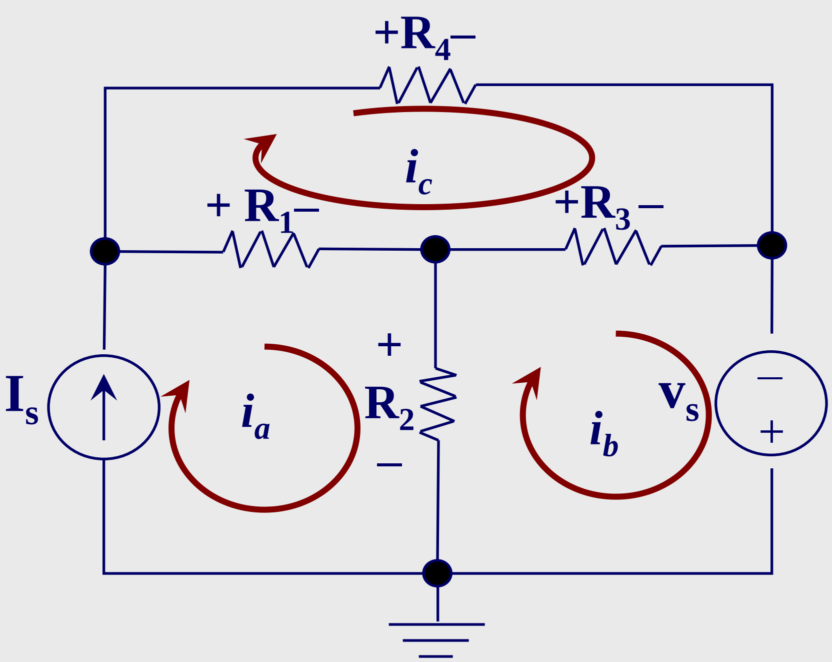


1. Mesh current directions given
2. Voltage polarities chosen and labeled
3. Identify n – m (3) mesh currents
   - i_a is **dependent (i_a = i_s)**
   - i_a is **independent**
   - i_c is **independent**
4. Apply KVL around meshes **b** and **c**

Exam 1 Review…Mesh Current

8. What is the mesh current method of circuit analysis?
   a) Find the mesh currents

$\mathbf{V_s} = 6\text{V}$, $\text{I}_s = 0.5\text{A}$, $\mathbf{R_1} = 3\Omega$, $\mathbf{R_2} = 8\Omega$, $\mathbf{R_3} = 6\Omega$, $\mathbf{R_4} = 4\Omega$



4. Apply KVL at nodes **b** and **c**

KVL around Mesh b:

$$-v_s - v_2 + v_3 = 0$$

$$v_s + (i_s - i_b)R_2 - (i_b - i_c)R_3 = 0$$

KVL around Mesh c:

$$v_4 - v_3 - v_1 = 0$$

$$i_c R_4 - (i_b - i_c)R_3 - (i_s - i_c)R_1 = 0$$

Exam 1 Review…Mesh Current

8. What is the mesh current method of circuit analysis?
   a) Find the mesh currents

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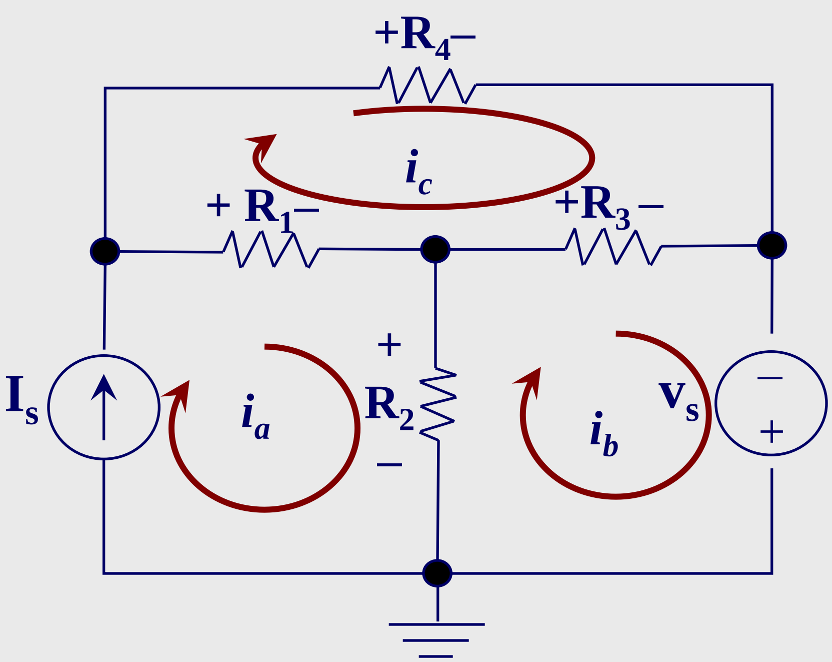


4. Express voltages in terms of currents

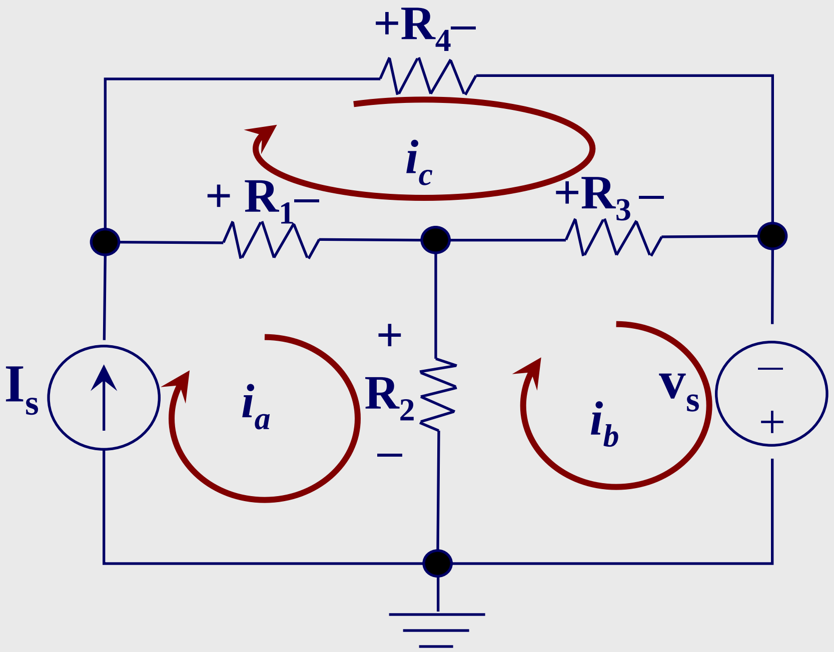
$$i_b(R_2+R_3)-i_cR_3=v_s+i_sR_2$$

$$-i_bR_3+i_c(R_1+R_3+R_4)=i_sR_1$$

Exam 1 Review…Mesh Current

8. What is the mesh current method of circuit analysis?
   a) Find the mesh currents

$\mathbf{V_s}$ = 6V, I_s = 0.5A, $\mathbf{R_1}$ = 3Ω, $\mathbf{R_2}$ = 8Ω, $\mathbf{R_3}$ = 6Ω, $\mathbf{R_4}$ = 4Ω



5. Solve the **n – m** equations

$$14i_b - 6i_c = 10$$
$$-6i_b + 13i_c = 1.5$$

$$i_a = 0.50A$$
$$i_b = 0.95A$$
$$i_c = 0.55A$$

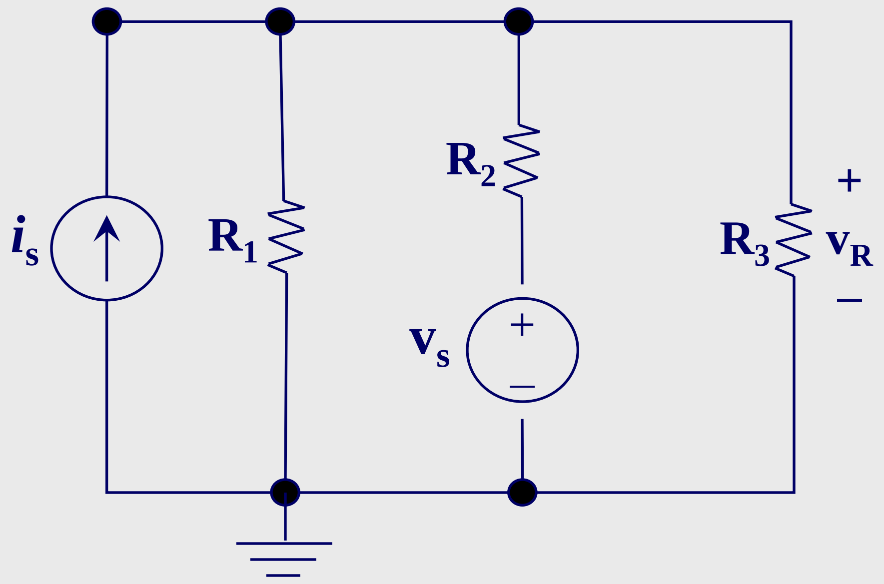
Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?

Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?
   a) Use superposition to find $\mathbf{v_R}$

i_s = 12A, $\mathbf{v_s}$ = 12V, $\mathbf{R_1}$ = 1Ω, $\mathbf{R_2}$ = 0.3Ω, $\mathbf{R_3}$ = 0.23Ω

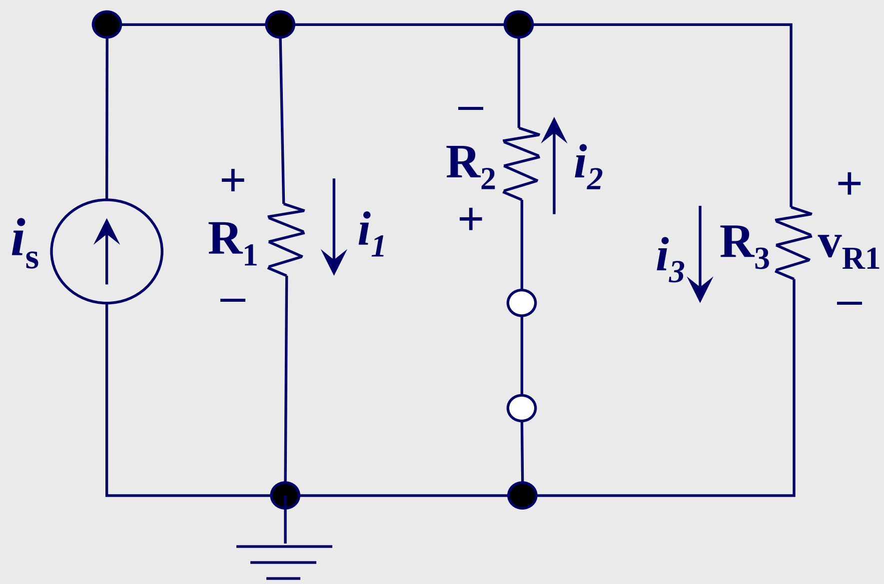


Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?

   a) Use superposition to find $\mathbf{v_R}$

   $i_s = 12\text{A}$, $\mathbf{v_s} = 12\text{V}$, $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.3\Omega$, $\mathbf{R_3} = 0.23\Omega$



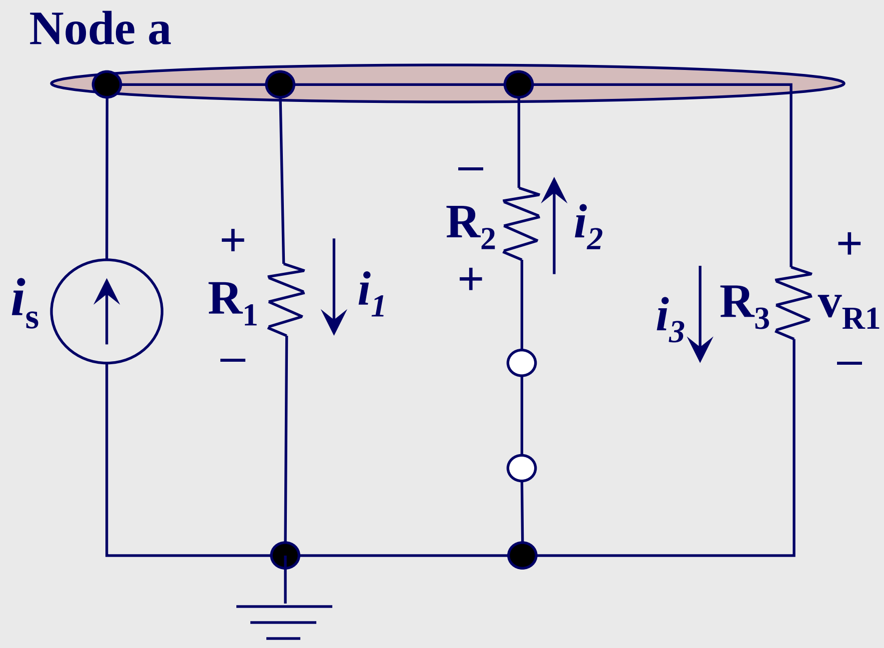
1. Remove all sources except i_s
   - Source $\mathbf{v_s}$ is replaced with short circuit

Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?

   a) Use superposition to find $\mathbf{v_R}$

$i_s = 12\text{A}$, $\mathbf{v_s} = 12\text{V}$, $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.3\Omega$, $\mathbf{R_3} = 0.23\Omega$



KCL at Node a :

$$i_s - i_1 + i_2 - i_3 = 0$$

$$\frac{v_{R1}}{R_1} - \frac{(0 - v_{R1})}{R_2} + \frac{v_{R1}}{R_3} = i_s$$

$$v_{R1}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = i_s$$

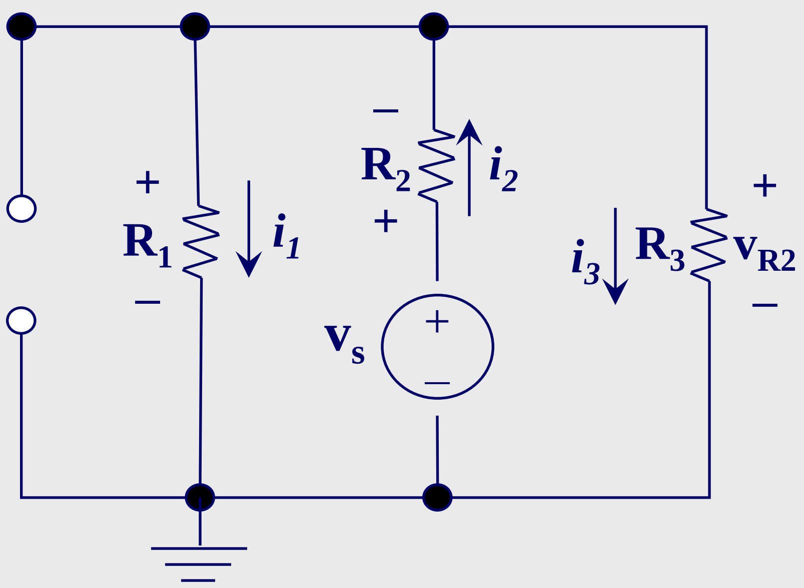
$$v_{R1} = \frac{12}{8.68}$$

$$= 1.38V$$

Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?
   a) Use superposition to find $\mathbf{v_R}$

$\boldsymbol{i_s}$ = 12A, $\mathbf{v_s}$ = 12V, $\mathbf{R_1}$ = 1Ω, $\mathbf{R_2}$ = 0.3Ω, $\mathbf{R_3}$ = 0.23Ω



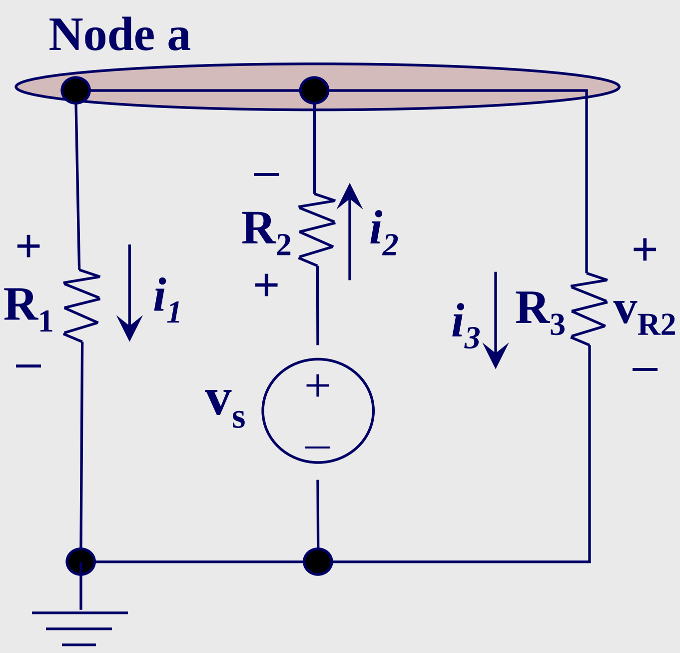
2. Remove all sources except $\mathbf{v_s}$
   - Source $\boldsymbol{i_s}$ is replaced with open circuit

Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?

   a) Use superposition to find $\mathbf{v_R}$

i_s = 12A, $\mathbf{v_s}$ = 12V, $\mathbf{R_1}$ = 1Ω, $\mathbf{R_2}$ = 0.3Ω, $\mathbf{R_3}$ = 0.23Ω



KCL at Node a :

$$-i_1 + i_2 - i_3 = 0$$

$$\frac{v_{R2}}{R_1} - \frac{v_{sR2}}{R_2} + \frac{v_{R2}}{R_3} = 0$$

$$v_{R2}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{v_s}{R_2}$$

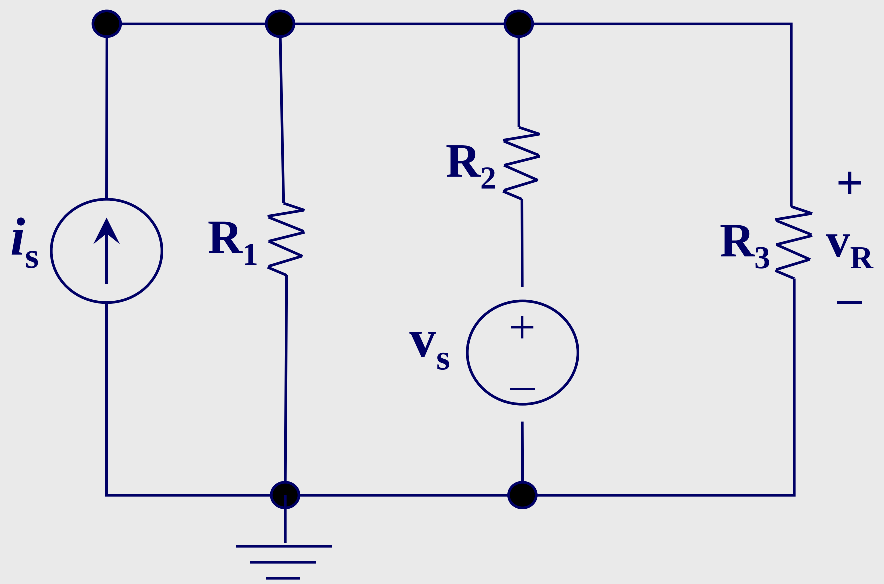
$$v_{R2} = \frac{1}{8.68}\left(\frac{12}{0.3}\right)$$

$$= 4.61V$$

Exam 1 Review…Superposition

9. What is the superposition method of circuit analysis?
   a) Use superposition to find $\mathbf{v_R}$

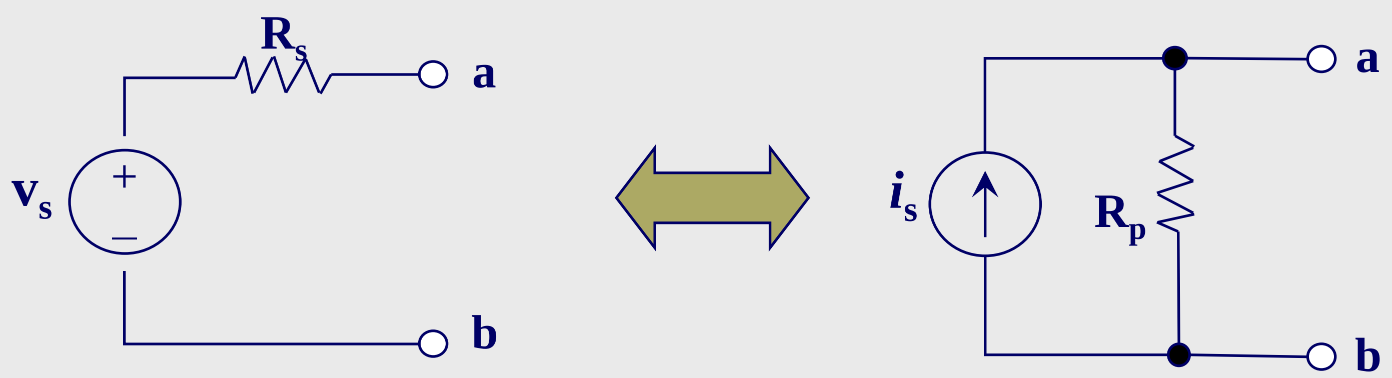
$i_s = 12A$, $\mathbf{v_s} = 12V$, $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.3\Omega$, $\mathbf{R_3} = 0.23\Omega$



$$\begin{aligned} v_R &= v_{R1} + v_{R2} \\ &= 1.38 + 4.61 \\ &= 5.99V \end{aligned}$$

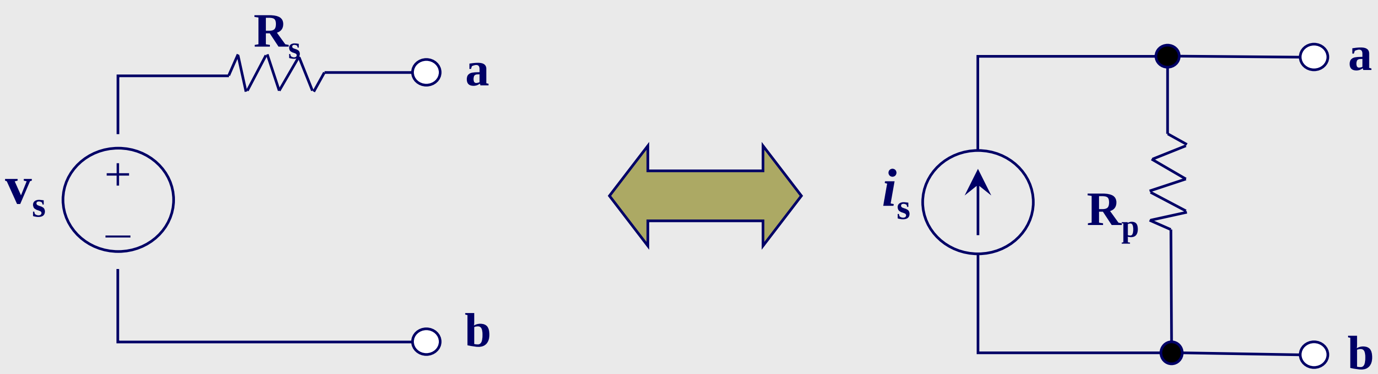
Exam 1 Review…Source Transform

10. How are voltage sources transformed to current sources (and vice-versa)?



Exam 1 Review…Source Transform

10. How are voltage sources transformed to current sources (and vice-versa)?



$v_s = R_s i_s$

$R_s = R_p$

$i_s = \frac{v_s}{R_p}$

$R_p = R_s$

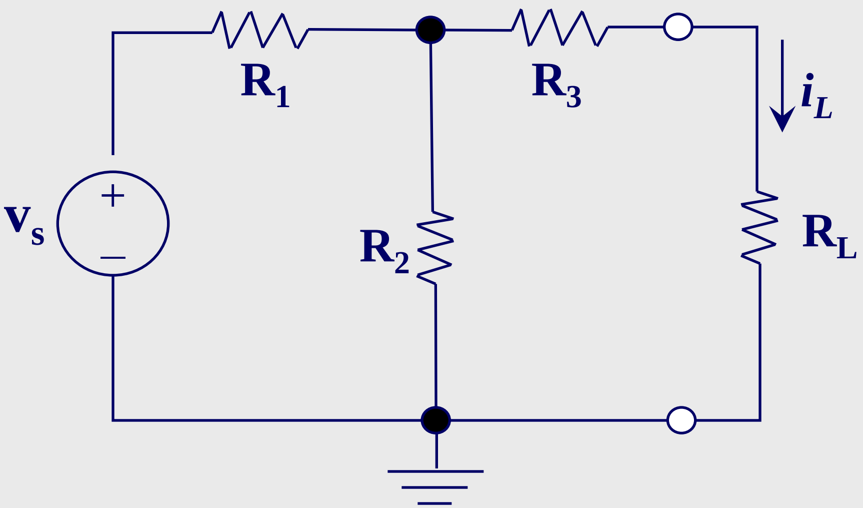
Exam 1 Review…Thévenin

11. What is the Thévenin theorem?

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find i_L by finding the Thévenin equivalent circuit

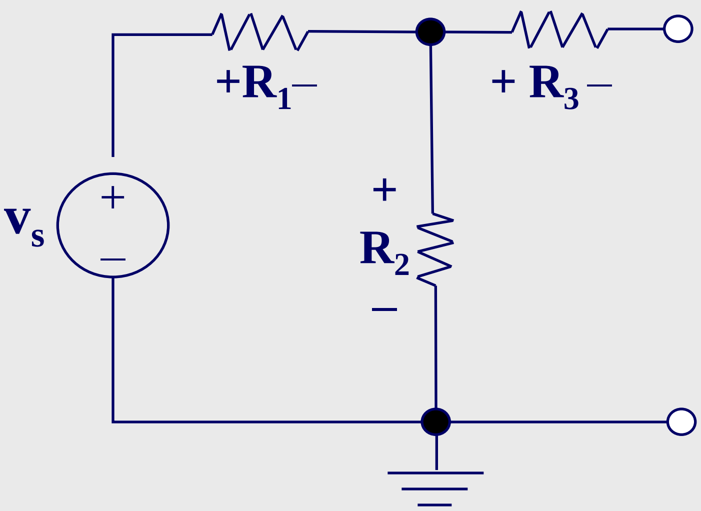
    v_s = 10V, $\mathbf{R_1}$ = 4Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 10Ω, $\mathbf{R_L}$ = 10Ω



Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find $\boldsymbol{i_L}$ by finding the Thévenin equivalent circuit

$v_s = 10\text{V}$, $\mathbf{R_1} = 4\Omega$, $\mathbf{R_2} = 6\Omega$, $\mathbf{R_3} = 10\Omega$, $\mathbf{R_L} = 10\Omega$

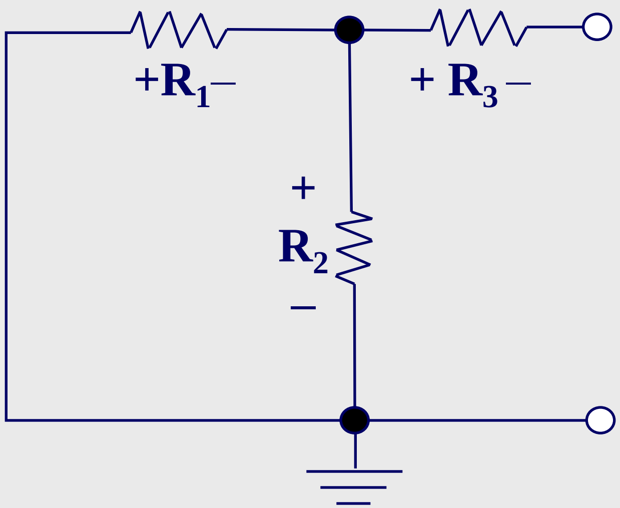


1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find i_L by finding the Thévenin equivalent circuit

$v_s = 10\text{V}$, $\mathbf{R_1} = 4\Omega$, $\mathbf{R_2} = 6\Omega$, $\mathbf{R_3} = 10\Omega$, $\mathbf{R_L} = 10\Omega$

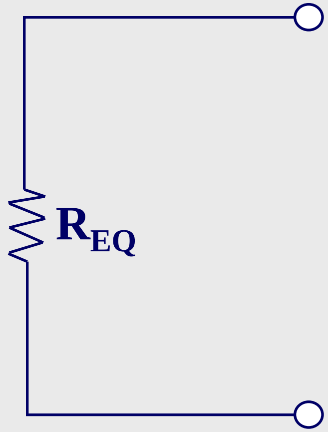


1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$
   - Zero sources

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find $\boldsymbol{i_L}$ by finding the Thévenin equivalent circuit

$v_s = 10V$, $\mathbf{R_1} = 4\Omega$, $\mathbf{R_2} = 6\Omega$, $\mathbf{R_3} = 10\Omega$, $\mathbf{R_L} = 10\Omega$



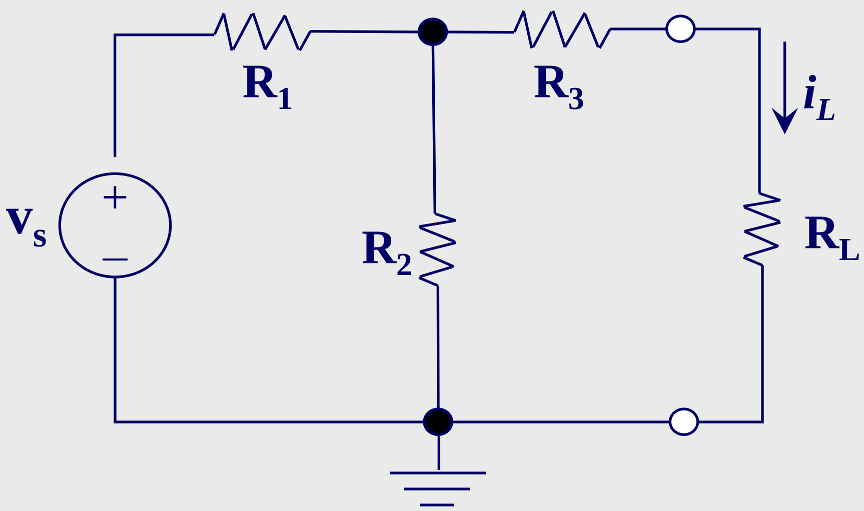
1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$
   - Zero sources
   - Compute $\mathbf{R_T} = \mathbf{R_{EQ}}$

$$R_T = R_3 + R_1 \parallel R_2$$

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find $\boldsymbol{i_L}$ by finding the Thévenin equivalent circuit

$v_s = 10V$, $\mathbf{R_1} = 4\Omega$, $\mathbf{R_2} = 6\Omega$, $\mathbf{R_3} = 10\Omega$, $\mathbf{R_L} = 10\Omega$



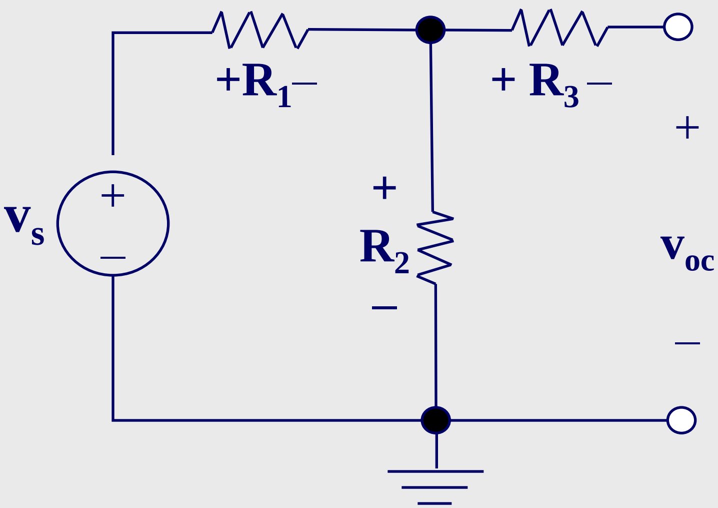
1. Compute $\mathbf{R_T}$
2. Compute $\mathbf{v_T}$

$$\boxed{R_T = R_3 + R_1 \parallel R_2}$$

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find $\boldsymbol{i_L}$ by finding the Thévenin equivalent circuit

v_s = 10V, $\mathbf{R_1}$ = 4Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 10Ω, $\mathbf{R_L}$ = 10Ω



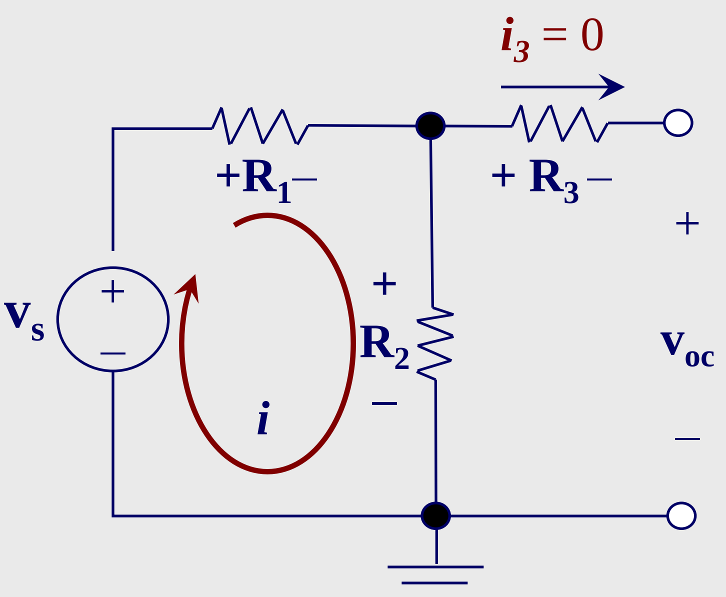
1. Compute $\mathbf{R_T}$
2. Compute $\mathbf{v_T}$
   a) Remove the load
   b) Define $\mathbf{v_{oc}}$

$$\boxed{R_T = R_3 + R_1 \,||\, R_2}$$

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find i_L by finding the Thévenin equivalent circuit

v_s = 10V, $\mathbf{R_1}$ = 4Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 10Ω, $\mathbf{R_L}$ = 10Ω



$$R_T = R_3 + R_1 \parallel R_2$$

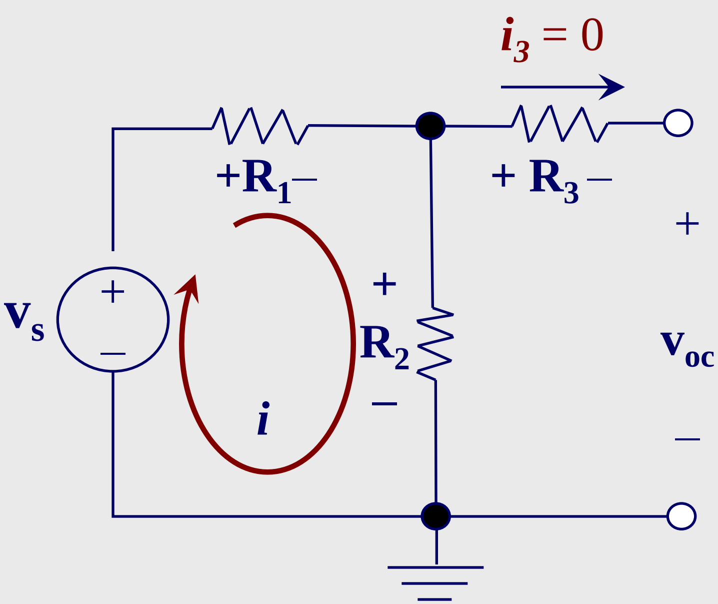
1. Compute $\mathbf{R_T}$
2. Compute $\mathbf{v_T}$
   a) Remove the load
   b) Define $\mathbf{v_{oc}}$
   c) Choose a network analysis method
      - Voltage divider

$$v_{oc} = \frac{R_2}{R_1 + R_2} v_s$$

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find i_L by finding the Thévenin equivalent circuit

v_s = 10V, $\mathbf{R_1}$ = 4Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 10Ω, $\mathbf{R_L}$ = 10Ω



$$R_T = R_3 + R_1 \| R_2$$

1. Compute $\mathbf{R_T}$
2. Compute $\mathbf{v_T}$
   a) Remove the load
   b) Define $\mathbf{v_{oc}}$
   c) Choose a network analysis method
      - Voltage divider
   d) $\mathbf{V_T = V_{oc}}$

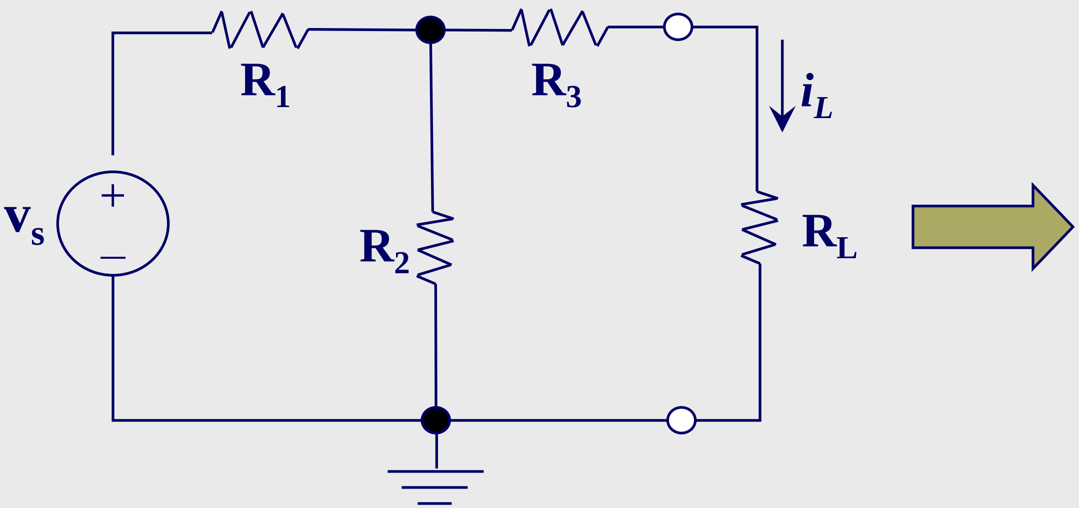
$$v_T = \frac{R_2}{R_1 + R_2} v_s$$

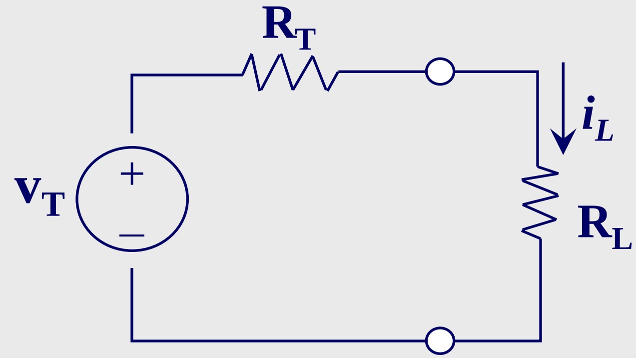
Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find i_L by finding the Thévenin equivalent circuit

v_s = 10V, R_1 = 4Ω, R_2 = 6Ω, R_3 = 10Ω, R_L = 10Ω

$$R_T = R_3 + R_1 \| R_2$$





$$v_T = \frac{R_2}{R_1 + R_2} v_s$$

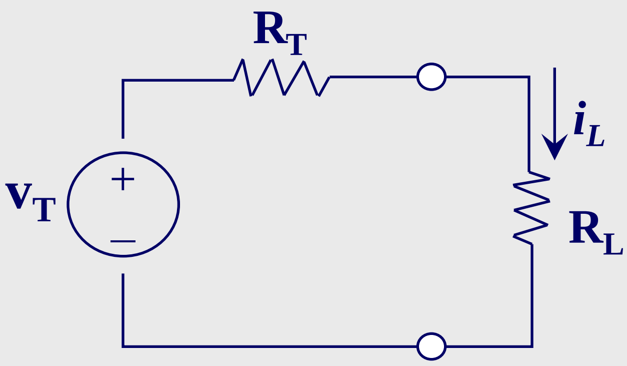
NB: i_L is the same in both circuits

Exam 1 Review…Thévenin

11. What is the Thévenin theorem?
    a) find $\boldsymbol{i_L}$ by finding the Thévenin equivalent circuit

$v_s = 10V$, $\mathbf{R_1} = 4\Omega$, $\mathbf{R_2} = 6\Omega$, $\mathbf{R_3} = 10\Omega$, $\mathbf{R_L} = 10\Omega$

$$R_T = R_3 + R_1 \| R_2$$



$$v_T = \frac{R_2}{R_1 + R_2} v_s$$

$$\begin{aligned}
i_L &= \frac{v_T}{R_T + R_L} \\
&= \left(\frac{R_2}{R_1 + R_2} v_s \right) \cdot \frac{1}{(R_3 + R_1 \| R_2) + R_L} \\
&= \left[\frac{(6)(10)}{(4) + (6)} \right] \cdot \frac{1}{(10) + (4) \| (6) + (10)} \\
&= \left(\frac{60}{10} \right) \cdot \frac{1}{20 + 2.4} \\
&= \frac{6}{22.4} \\
&= 0.27A
\end{aligned}$$

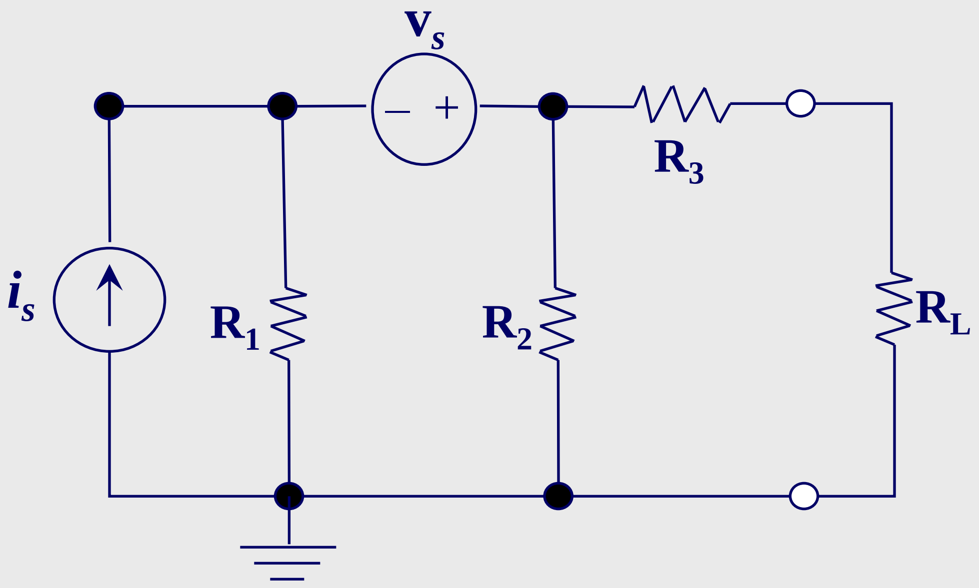
Exam 1 Review…Norton

12. What is the Norton theorem?

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

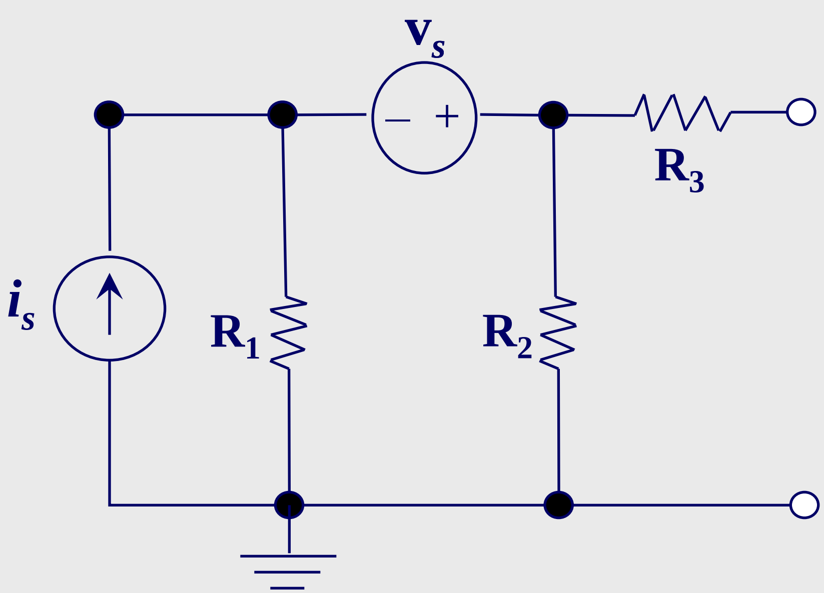
    $v_s = 6V$, $\boldsymbol{i_s} = 2A$, $\mathbf{R_1} = 6\Omega$, $\mathbf{R_2} = 3\Omega$, $\mathbf{R_3} = 2\Omega$, $\mathbf{R_L} = 10\Omega$



Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

v_s = 6V, $\boldsymbol{i_s}$ = 2A, $\mathbf{R_1}$ = 6Ω, $\mathbf{R_2}$ = 3Ω, $\mathbf{R_3}$ = 2Ω, $\mathbf{R_L}$ = 10Ω



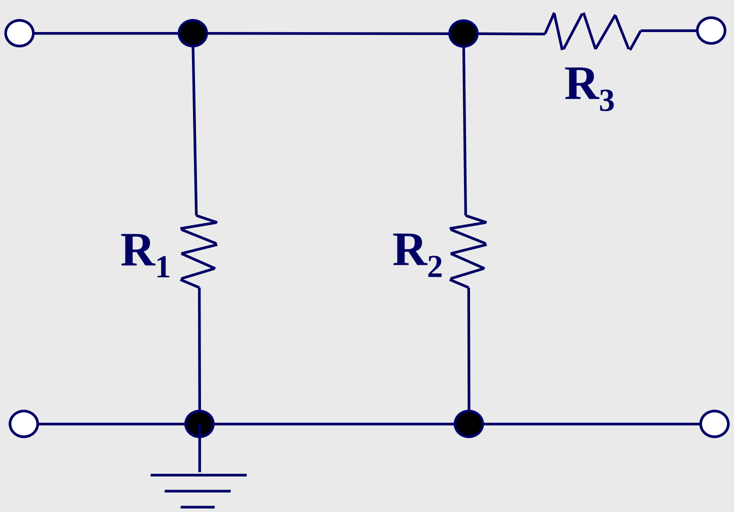
1. Compute $\mathbf{R_N}$
   - Remove $\mathbf{R_L}$

Exam 1 Review…Norton

12. What is the Norton theorem?

    a) Find the Norton equivalent circuit

v_s = 6V, $\boldsymbol{i_s}$ = 2A, $\mathbf{R_1}$ = 6Ω, $\mathbf{R_2}$ = 3Ω, $\mathbf{R_3}$ = 2Ω, $\mathbf{R_L}$ = 10Ω



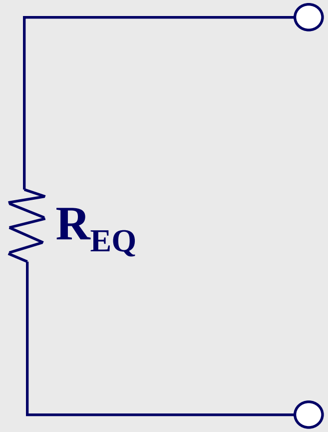
1. Compute $\mathbf{R_N}$
   - Remove $\mathbf{R_L}$
   - Zero sources

Exam 1 Review…Norton

12. What is the Norton theorem?

    a) Find the Norton equivalent circuit

    v_s = 6V, $\boldsymbol{i_s}$ = 2A, $\mathbf{R_1}$ = 6Ω, $\mathbf{R_2}$ = 3Ω, $\mathbf{R_3}$ = 2Ω, $\mathbf{R_L}$ = 10Ω



1. Compute $\mathbf{R_N}$
   - Remove $\mathbf{R_L}$
   - Zero sources
   - Compute $\mathbf{R_N} = \mathbf{R_{EQ}}$

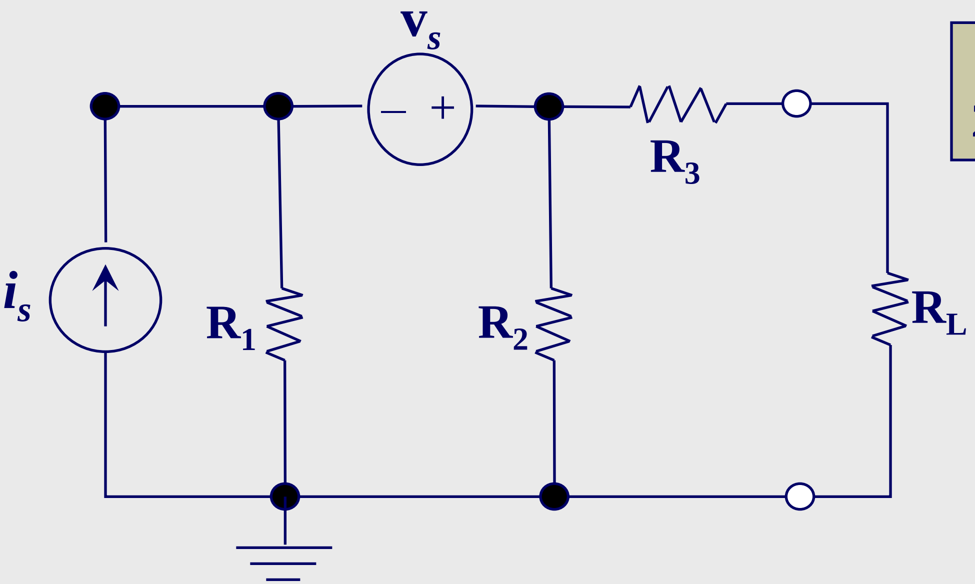
$$R_N = R_3 + R_1 \parallel R_2$$
$$= 4\Omega$$

Exam 1 Review…Norton

12. What is the Norton theorem?

    a) Find the Norton equivalent circuit

    v_s = 6V, $\boldsymbol{i_s}$ = 2A, $\mathbf{R_1}$ = 6Ω, $\mathbf{R_2}$ = 3Ω, $\mathbf{R_3}$ = 2Ω, $\mathbf{R_L}$ = 10Ω



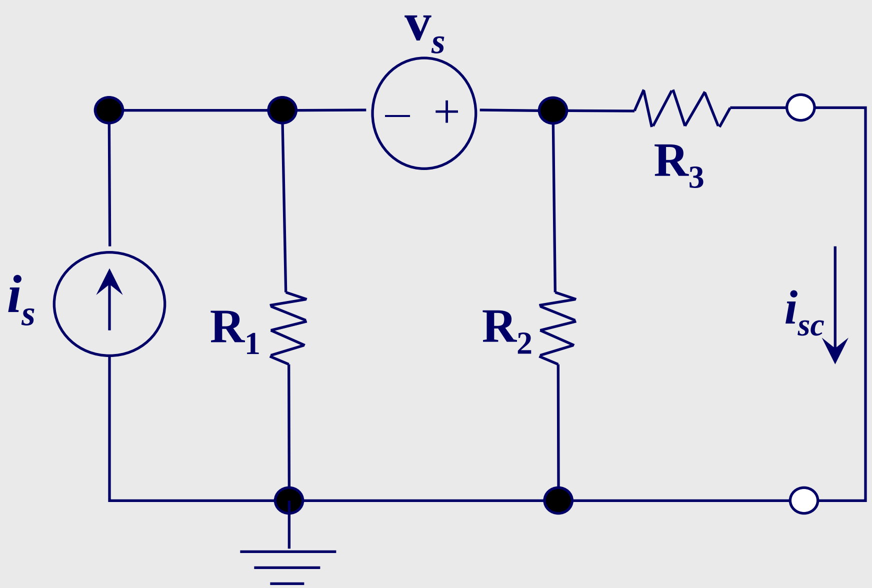
1. Compute $\mathbf{R_N}$
2. Compute $\boldsymbol{i_N}$

$$R_N = 4\Omega$$

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

$v_s = 6\text{V}$, $i_s = 2\text{A}$, $\mathbf{R_1} = 6\Omega$, $\mathbf{R_2} = 3\Omega$, $\mathbf{R_3} = 2\Omega$, $\mathbf{R_L} = 10\Omega$



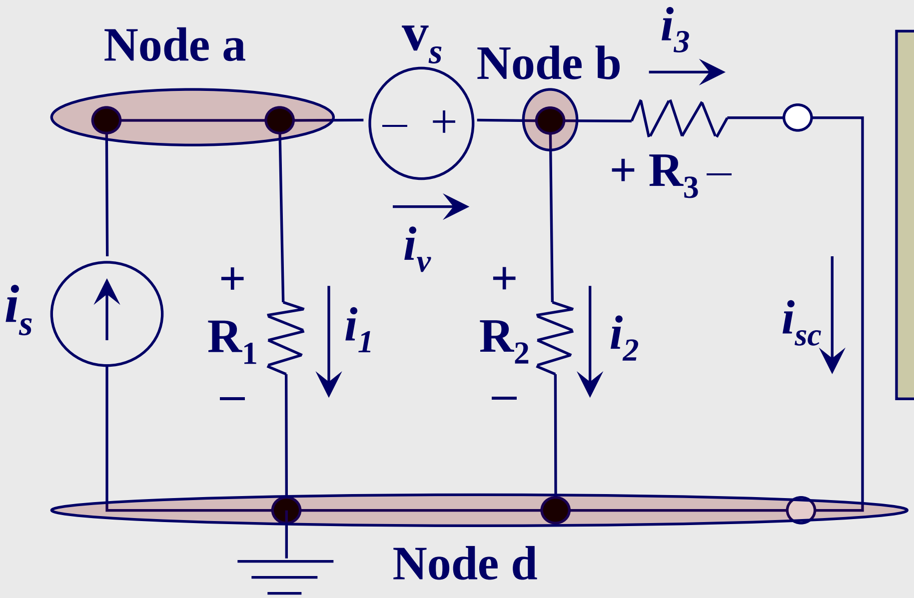
1. Compute $\mathbf{R_N}$
2. Compute i_N
   a) Short circuit the load
   b) Define i_{sc}

$$\boxed{R_N = 4\Omega}$$

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

v_s = 6V, $\boldsymbol{i_s}$ = 2A, $\mathbf{R_1}$ = 6Ω, $\mathbf{R_2}$ = 3Ω, $\mathbf{R_3}$ = 2Ω, $\mathbf{R_L}$ = 10Ω



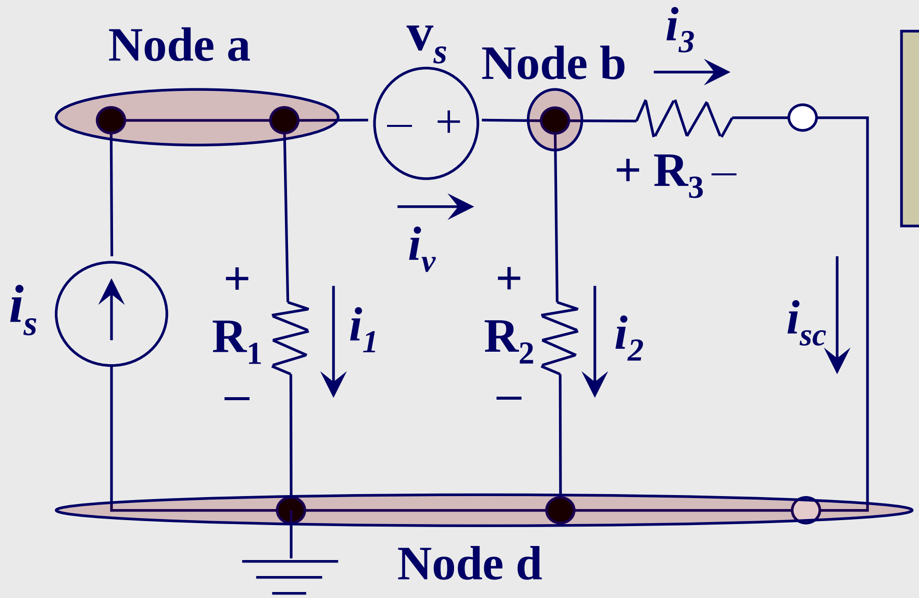
1. Compute $\mathbf{R_N}$
2. Compute $\boldsymbol{i_N}$
   a) Short circuit the load
   b) Define $\boldsymbol{i_{sc}}$
   c) Choose a network analysis method
      - Node voltage

$$\boxed{R_N = 4\Omega}$$

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

v_s = 6V, i_s = 2A, R_1 = 6Ω, R_2 = 3Ω, R_3 = 2Ω, R_L = 10Ω



2. Compute i_N
   c) Choose a network analysis method
      - Node voltage

1. v_a is **independent**
2. v_b is **dependent** (actually v_a and v_b are dependent on each other but choose v_b) $v_b = v_a + v_s$

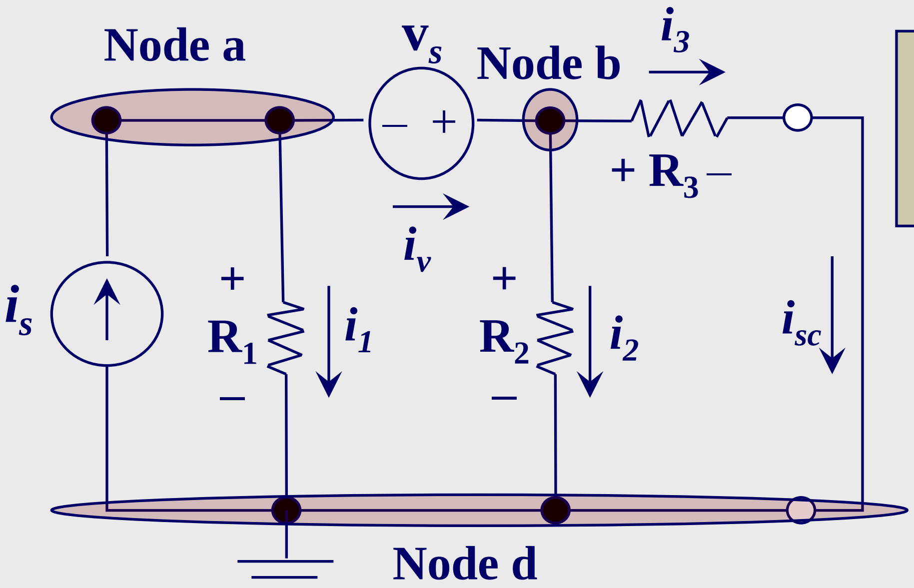
$$\boxed{R_N = 4\Omega}$$

Exam 1 Review…Norton

12. What is the Norton theorem?

  a) Find the Norton equivalent circuit

  v_s = 6V, i_s = 2A, R_1 = 6Ω, R_2 = 3Ω, R_3 = 2Ω, R_L = 10Ω



$$R_N = 4\Omega$$

2. Compute i_N
   c) Choose a network analysis method
      - Node voltage

KCL at node a :

$$i_s - i_1 - i_v = 0$$

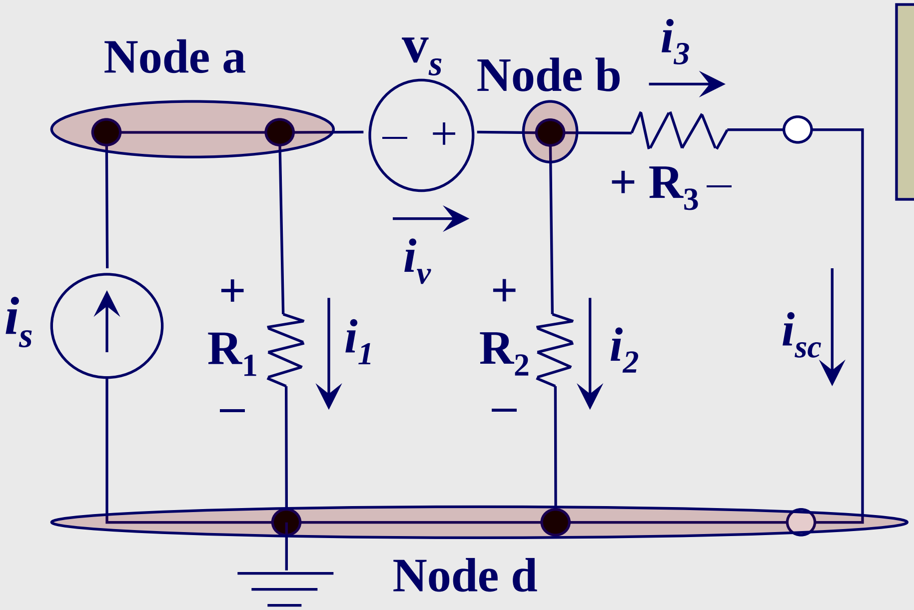
$$\frac{v_a}{R_1} + i_v = i_s$$

Exam 1 Review…Norton

12. What is the Norton theorem?

   a) Find the Norton equivalent circuit

   $v_s = 6V$, $i_s = 2A$, $\mathbf{R_1} = 6\Omega$, $\mathbf{R_2} = 3\Omega$, $\mathbf{R_3} = 2\Omega$, $\mathbf{R_L} = 10\Omega$



$$R_N = 4\Omega$$

2. Compute i_N
   c) Choose a network analysis method
      - Node voltage

KCL at node b:

$$i_v - i_2 - i_3 = 0$$

$$i_v - \frac{v_b}{R_2} - \frac{v_b}{R_3} = 0$$

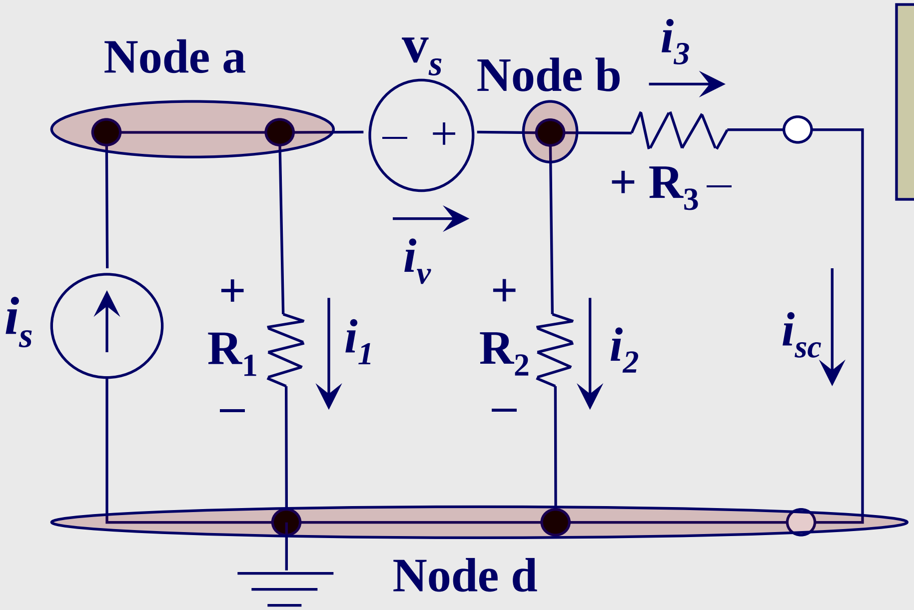
$$i_v - \frac{(v_a + v_s)}{R_2} - \frac{(v_a + v_s)}{R_3} = 0$$

$$i_v - v_a\left(\frac{1}{R_2} + \frac{1}{R_3}\right) = v_s\left(\frac{1}{R_2} + \frac{1}{R_3}\right)$$

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

$v_s = 6V$, $i_s = 2A$, $R_1 = 6\Omega$, $R_2 = 3\Omega$, $R_3 = 2\Omega$, $R_L = 10\Omega$



2. Compute i_N
   c) Choose a network analysis method
      - Node voltage

$$6i_v - 5v_a = 30$$
$$6i_v + v_a = 12$$

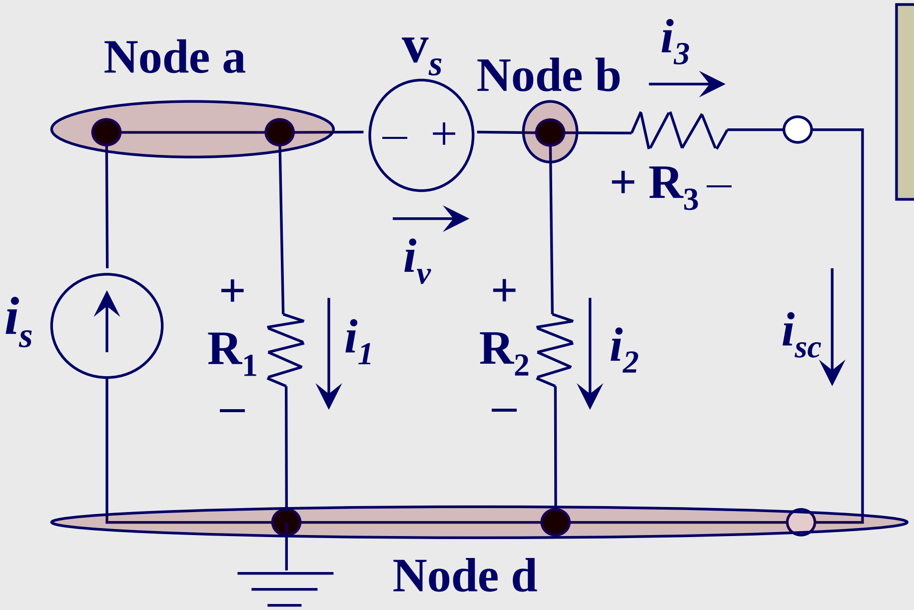
$$i_v = 2.5A$$
$$v_a = -3V$$

$$R_N = 4\Omega$$

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

$v_s = 6V$, $i_s = 2A$, $R_1 = 6\Omega$, $R_2 = 3\Omega$, $R_3 = 2\Omega$, $R_L = 10\Omega$



2. Compute i_N
   c) Choose a network analysis method
      - Node voltage

$$R_N = 4\Omega$$

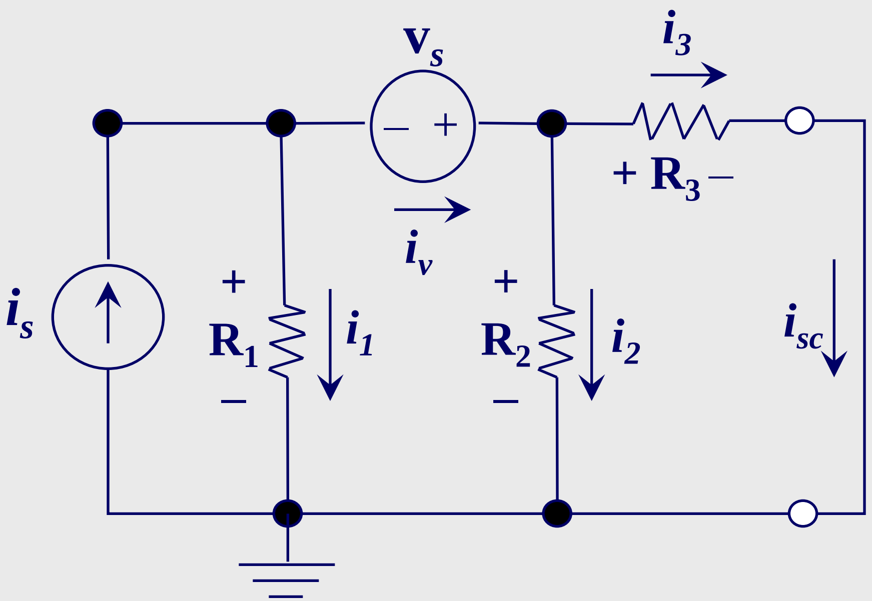
$$\begin{aligned} i_{sc} &= \frac{v_b}{R_3} \\ &= \frac{(v_s - v_b)}{2} \\ &= \frac{3}{2}A \end{aligned}$$

Exam 1 Review…Norton

12. What is the Norton theorem?

    a) Find the Norton equivalent circuit

    $v_s = 6V$, $i_s = 2A$, $R_1 = 6\Omega$, $R_2 = 3\Omega$, $R_3 = 2\Omega$, $R_L = 10\Omega$



2. Compute i_N
   c) Choose a network analysis method
      - Node voltage
   d) $i_N = i_{sc}$

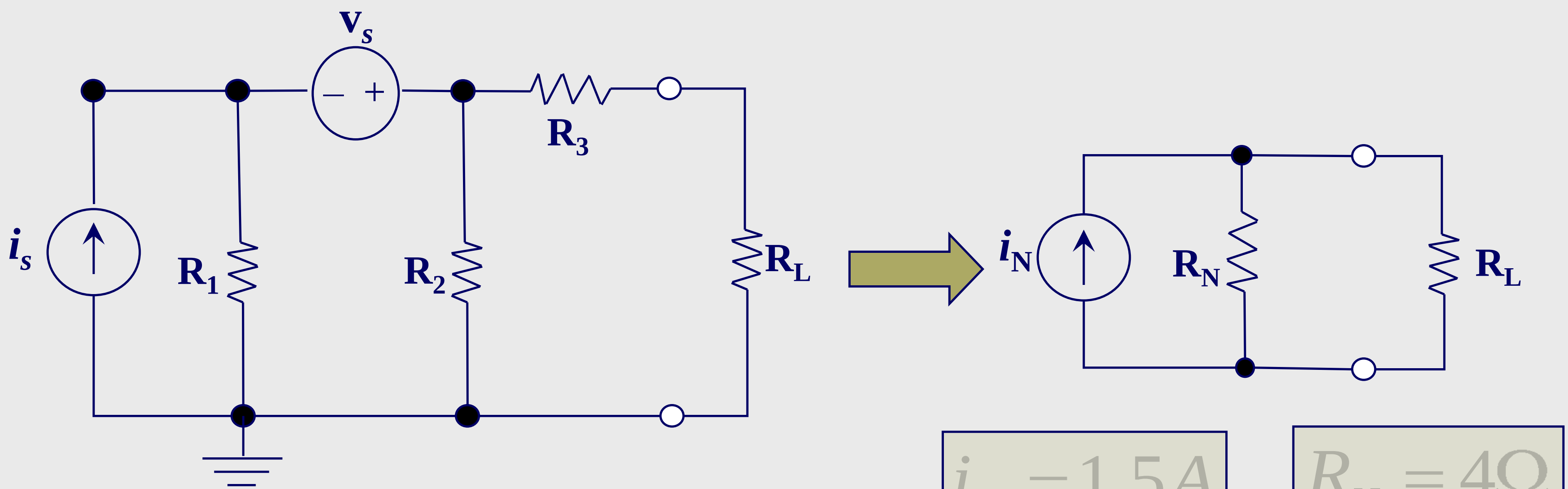
$$i_N = i_{sc} = 1.5A$$

$$R_N = 4\Omega$$

Exam 1 Review…Norton

12. What is the Norton theorem?
    a) Find the Norton equivalent circuit

$v_s = 6V$, $i_s = 2A$, $R_1 = 6\Omega$, $R_2 = 3\Omega$, $R_3 = 2\Omega$, $R_L = 10\Omega$



$i_N = 1.5A$

$R_N = 4\Omega$

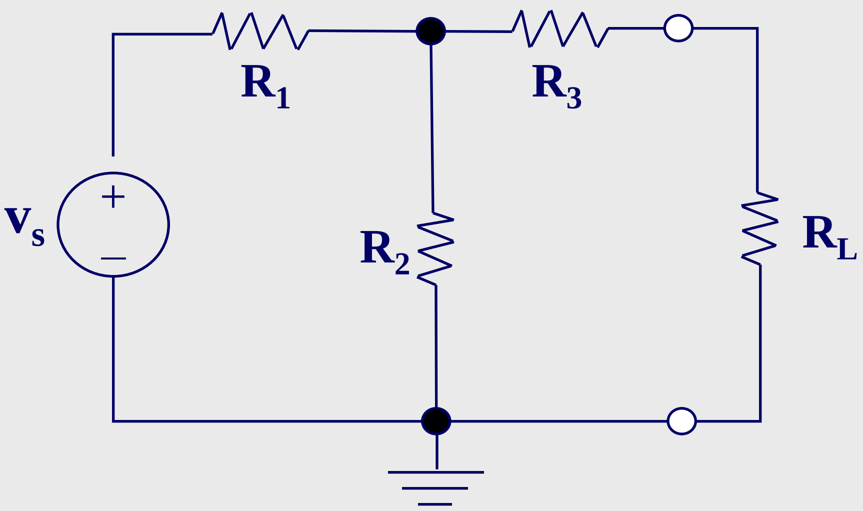
Exam 1 Review…Max Power

13. What is the maximum power theorem?

Exam 1 Review…Max Power

13. What is the maximum power theorem?
    a) Find the maximum power delivered to the load

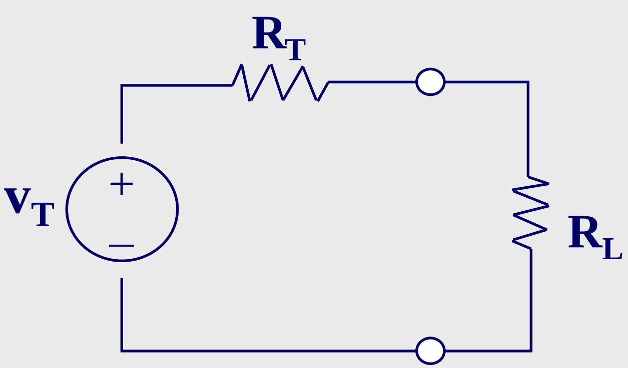
v_s = 18V, $\mathbf{R_1}$ = 3Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 2Ω



Exam 1 Review…Max Power

13. What is the maximum power theorem?
    a) Find the maximum power delivered to the load

$v_s = 18V$, $R_1 = 3\Omega$, $R_2 = 6\Omega$, $R_3 = 2\Omega$



1. Find Thévenin equivalent circuit
   - **(previously found)**

$$v_T = \frac{R_2}{R_1 + R_2} v_s = 12V$$

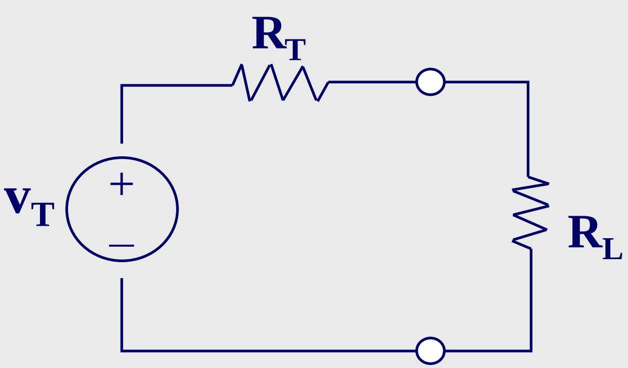
$$R_T = R_3 + R_1 \| R_2 = 4\Omega$$

Exam 1 Review…Max Power

13. What is the maximum power theorem?

   a) Find the maximum power delivered to the load

   v_s = 18V, $\mathbf{R_1}$ = 3Ω, $\mathbf{R_2}$ = 6Ω, $\mathbf{R_3}$ = 2Ω



1. Find Thévenin equivalent circuit
2. Set $\mathbf{R_L} = \mathbf{R_T}$
3. Calculate $\mathbf{P_{LMax}}$

$$
\begin{aligned}
P_{L\max} &= 0.5P_{in\max} \\
&= 0.5\frac{v_T^2}{2R_L} \\
&= 0.5\frac{(12)^2}{8} \\
&= 9W
\end{aligned}
$$

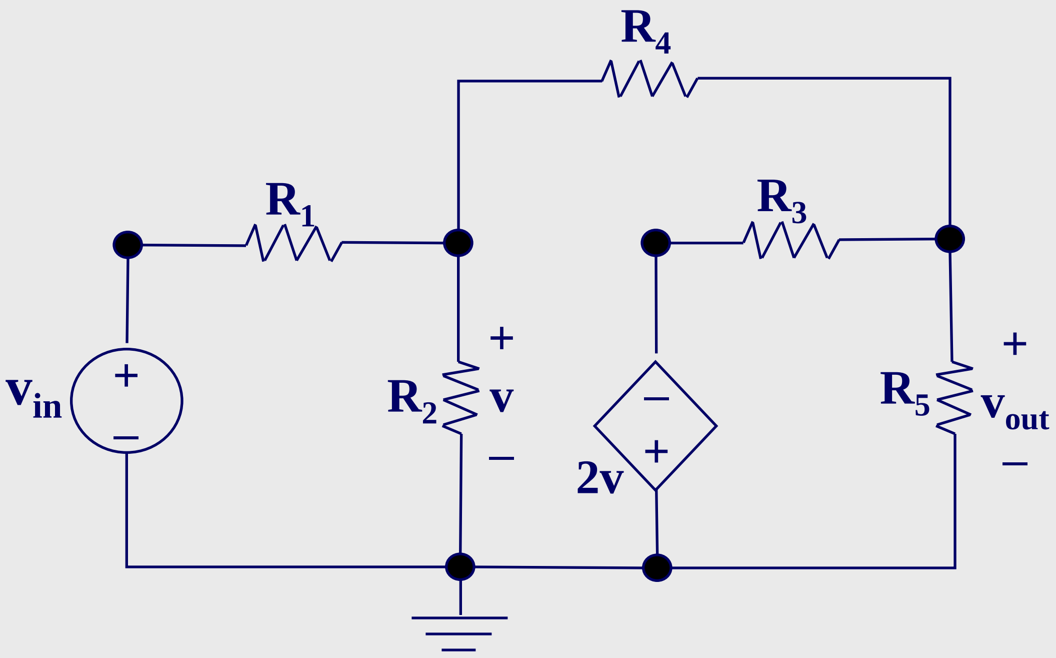
Exam 1 Review… Controlled Sources

- Network analysis with controlled sources:
  - Initially treat controlled sources as ideal sources
  - In addition to equations obtained by node/mesh analysis there will be the **constraint equation** (the controlled source equation)
  - Substitute constraint equation into node/mesh equations

Exam 1 Review… Controlled Sources

14. find the **gain** ($\mathbf{A_v} = \mathbf{v_{out}}/\mathbf{v_{in}}$)

- $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.5\Omega$, $\mathbf{R_3} = 0.25\Omega$, $\mathbf{R_4} = 0.25\Omega$, $\mathbf{R_5} = 0.25\Omega$



Exam 1 Review… Controlled Sources

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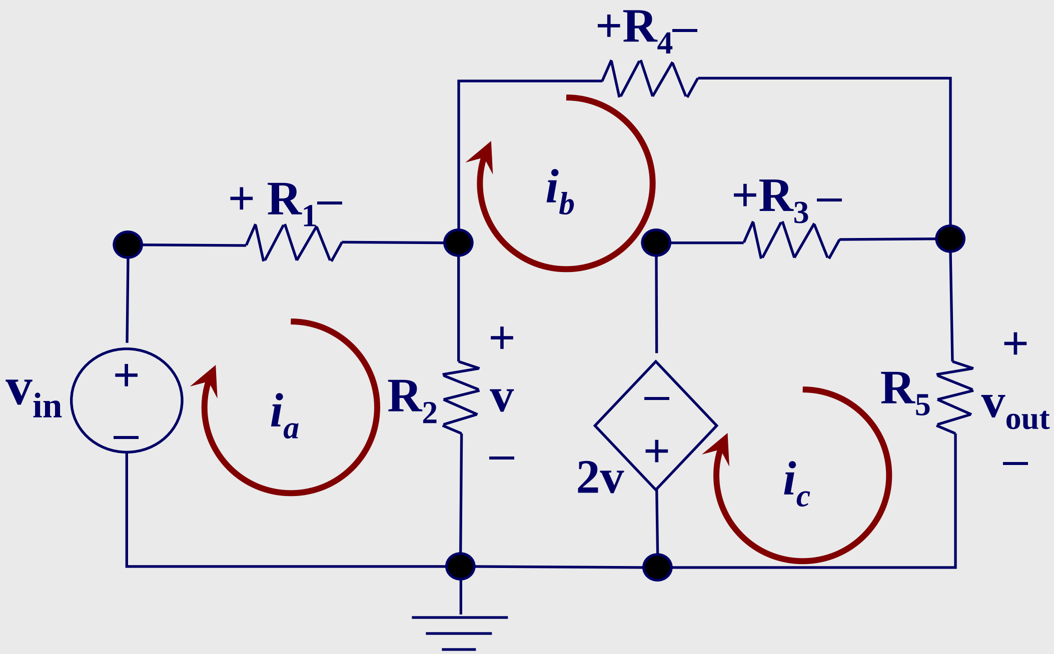


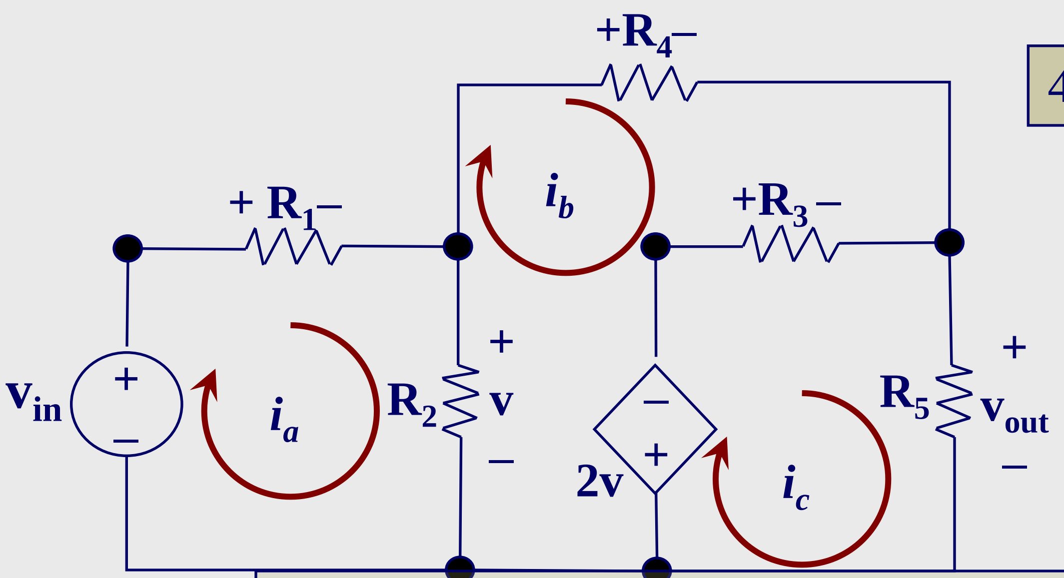
Choose mesh analysis – simpler than node analysis

1. Mesh current directions chosen
2. Voltage polarities chosen and labeled
3. Identify **n – m** (3) mesh currents
   - i_a is independent
   - i_a is independent
   - i_c is independent
4. Apply KVL around meshes **a**, **b**, and **c**

Exam 1 Review… Controlled Sources

14. find the **gain** ($\mathbf{A_v = v_{out}/v_{in}}$)

- $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.5\Omega$, $\mathbf{R_3} = 0.25\Omega$, $\mathbf{R_4} = 0.25\Omega$, $\mathbf{R_5} = 0.25\Omega$



4. Apply KVL at nodes **a**, **b**, and **c**

KVL around Mesh a :

$$-v_{in} + v_1 + v_2 = 0$$

$$v_{in} - i_a R_1 - (i_a - i_b) R_2 = 0$$

$$i_a(R_1 + R_2) - i_b R_2 = v_{in}$$

KVL around Mesh b :

$$-v_2 + v_4 - v_3 - 2v = 0$$

$$-(i_a - i_b)R_2 + i_b R_4 - (i_c - i_b)R_3 = 2\left[(i_a - i_b)R_2\right]$$

$$-3i_a R_2 + i_b(3R_2 + R_3 + R_4) - i_c R_3 = 0$$

KVL around Mesh c :

$$2v + v_3 + v_5 = 0$$

$$2v_2 + (i_c - i_b)R_3 + i_c R_5 = 0$$

$$-i_b R_3 + i_c(R_3 + R_5) = -2\left[(i_a - i_b)R_2\right]$$

$$2i_a R_2 - i_b(2R_2 + R_3) + i_c(R_3 + R_5) = 0$$

Exam 1 Review… Controlled Sources

14. find the **gain** ($\mathbf{A_v = v_{out}/v_{in}}$)

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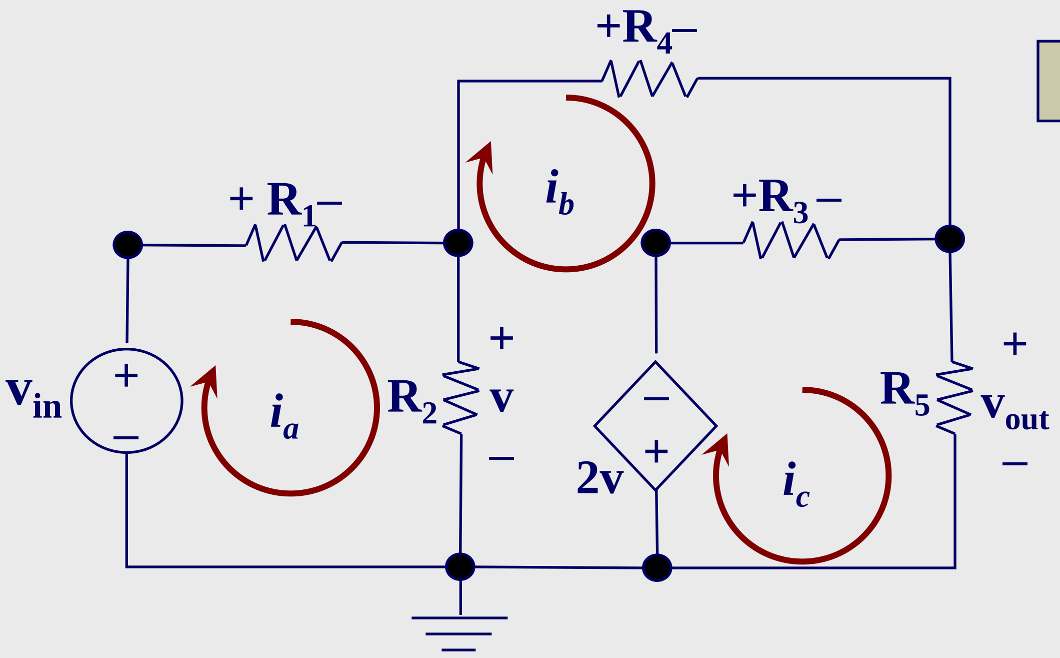


5. Solve the **n – m** equations

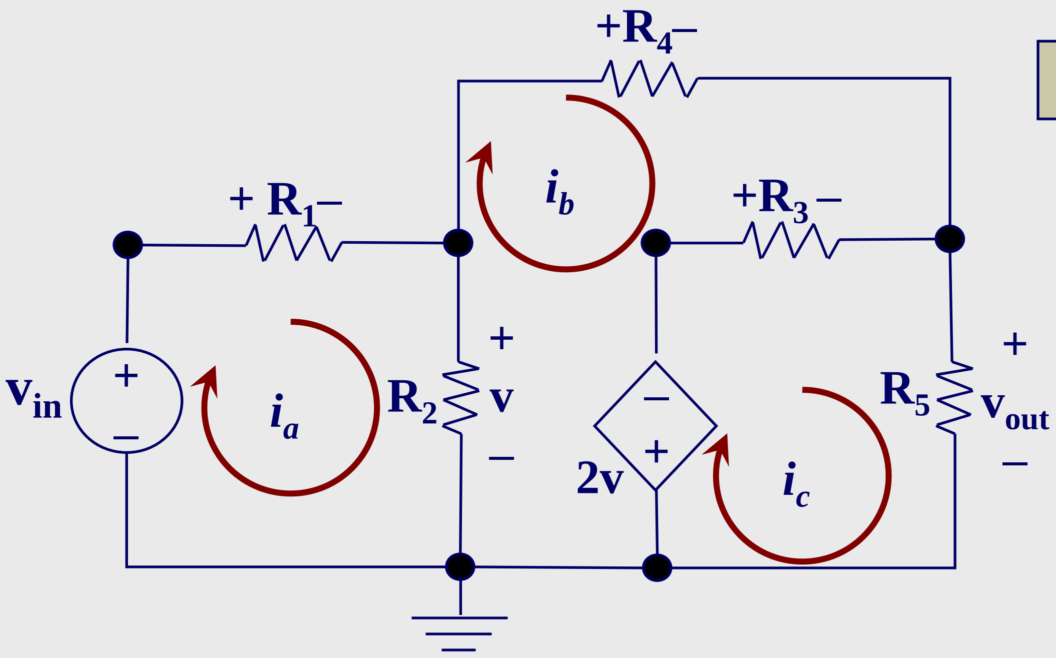
$$1.5i_a - 0.5i_b = v_{in}$$
$$-1.5i_a + 2i_b - 0.25i_c = 0$$
$$i_a - 1.25i_b + 0.5i_c = 0$$

$$i_a = 0.88v_{in}A$$
$$i_b = 0.64v_{in}A$$
$$i_c = -0.16v_{in}A$$

Exam 1 Review… Controlled Sources

14. find the **gain** ($A_v = v_{out}/v_{in}$)

- $R_1 = 1\Omega$, $R_2 = 0.5\Omega$, $R_3 = 0.25\Omega$, $R_4 = 0.25\Omega$, $R_5 = 0.25\Omega$



5. Solve the **n – m** equations (Matrices)

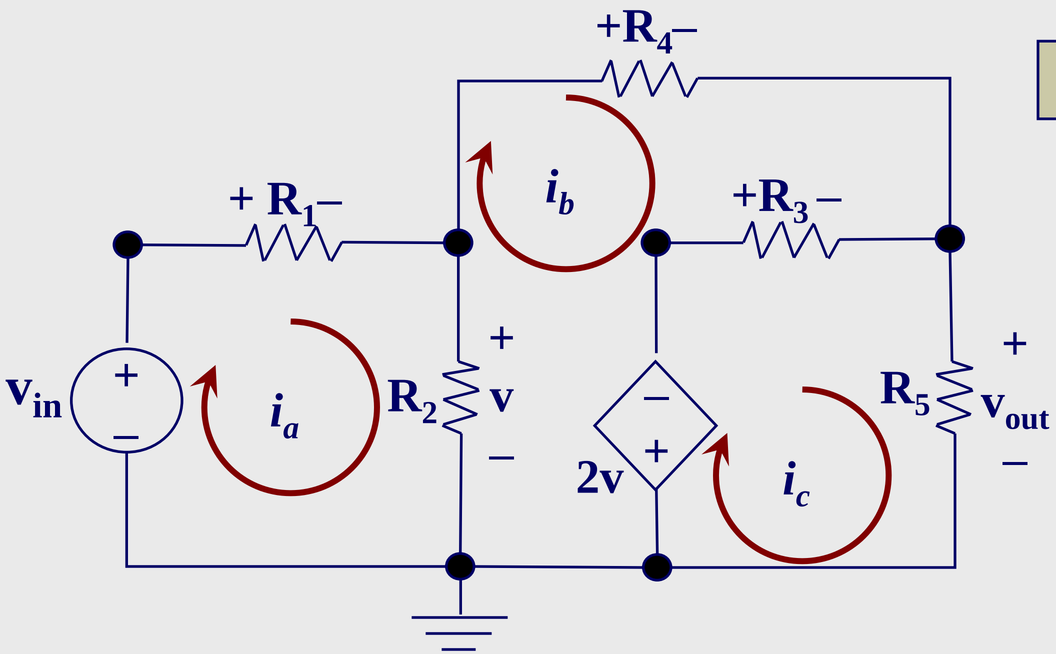
$$\begin{bmatrix} 1.5 & -0.5 & 0 \\ -1.5 & 2 & -0.25 \\ 1 & -1.25 & 0.5 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} v_{in} \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{aligned} AX &= B \\ A^{-1}AX &= A^{-1}B \\ X &= A^{-1}B \end{aligned}$$

Exam 1 Review… Controlled Sources

14. find the **gain** ($\mathbf{A_v} = \mathbf{v_{out}}/\mathbf{v_{in}}$)

- $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.5\Omega$, $\mathbf{R_3} = 0.25\Omega$, $\mathbf{R_4} = 0.25\Omega$, $\mathbf{R_5} = 0.25\Omega$



5. Solve the **n – m** equations (Matrices)

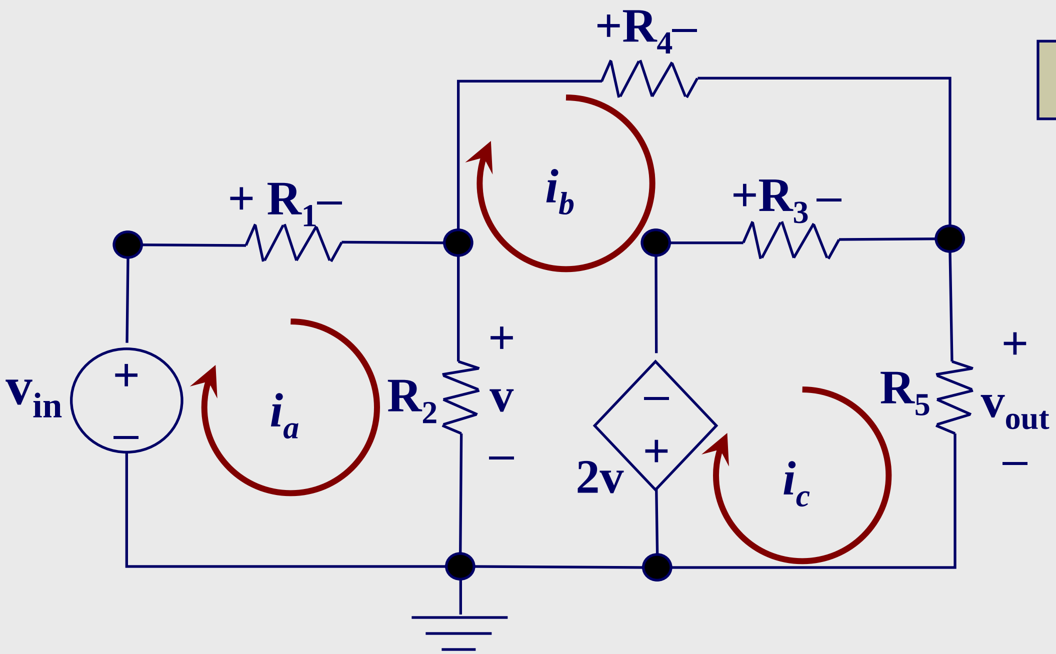
$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} 0.88 & 0.32 & 0.16 \\ 0.64 & 0.96 & 0.48 \\ -0.16 & 1.76 & 2.88 \end{bmatrix} \begin{bmatrix} v_{in} \\ 0 \\ 0 \end{bmatrix}$$

$$i_a = 0.88 v_{in} A$$
$$i_b = 0.64 v_{in} A$$
$$i_c = -0.16 v_{in} A$$

Exam 1 Review… Controlled Sources

14. find the **gain** ($\mathbf{A_v = v_{out}/v_{in}}$)

- $\mathbf{R_1} = 1\Omega$, $\mathbf{R_2} = 0.5\Omega$, $\mathbf{R_3} = 0.25\Omega$, $\mathbf{R_4} = 0.25\Omega$, $\mathbf{R_5} = 0.25\Omega$



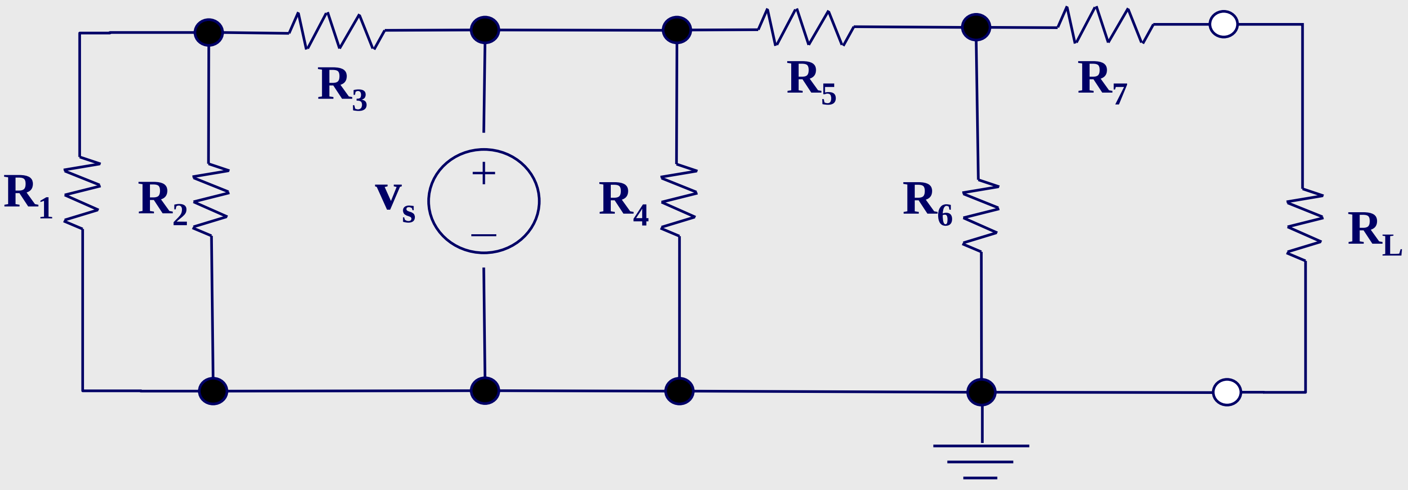
- Find the gain

$$A_v = \frac{v_{out}}{v_{in}} = \frac{R_5 i_c}{v_{in}} = \frac{0.25(-0.16v_{in})}{v_{in}} = -0.04$$

Exam 1 Review…Thévenin P.114

Find the Thévenin equivalent resistance

v_s = 20V, $\mathbf{R_1}$ = 1MΩ, $\mathbf{R_2}$ = 2kΩ, $\mathbf{R_3}$ = 3kΩ, $\mathbf{R_4}$ = 6kΩ, $\mathbf{R_5}$ = 6kΩ, $\mathbf{R_6}$ = 3kΩ, $\mathbf{R_7}$ = 2kΩ, $\mathbf{R_L}$ = 10Ω



NB: the answer to this problem in the book is wrong!!

Exam 1 Review…Thévenin P.114

Find the Thévenin equivalent resistance

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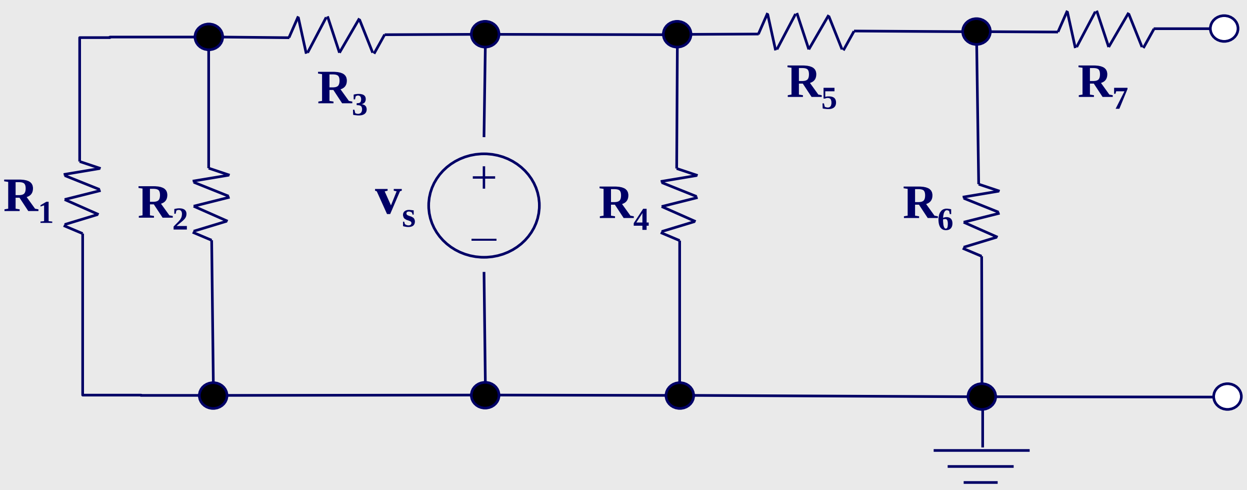
1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$



Exam 1 Review…Thévenin P.114

Find the Thévenin equivalent resistance

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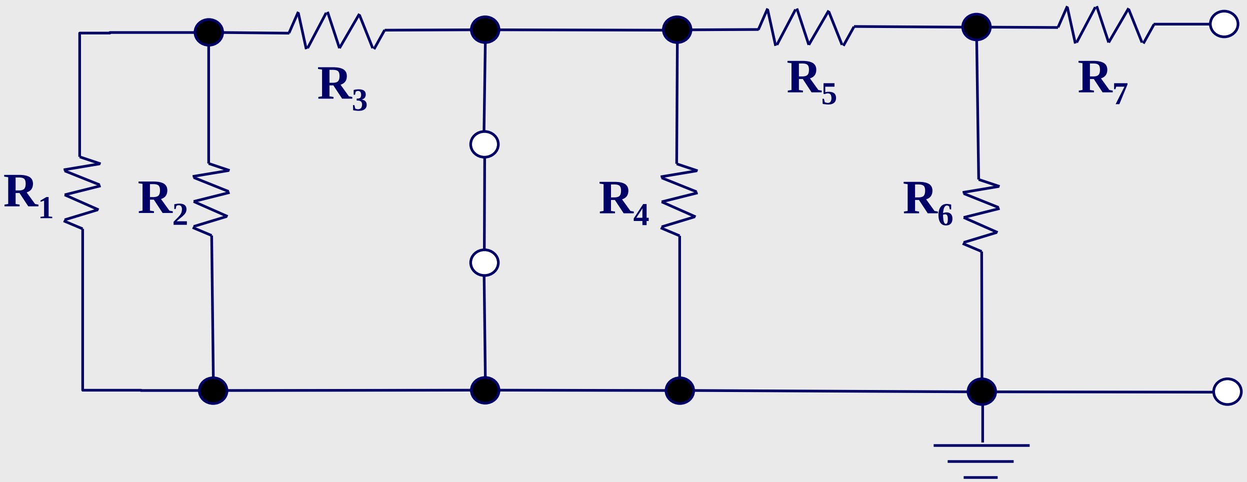

1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$
   - Zero sources

Exam 1 Review…Thévenin P.114

Find the Thévenin equivalent resistance

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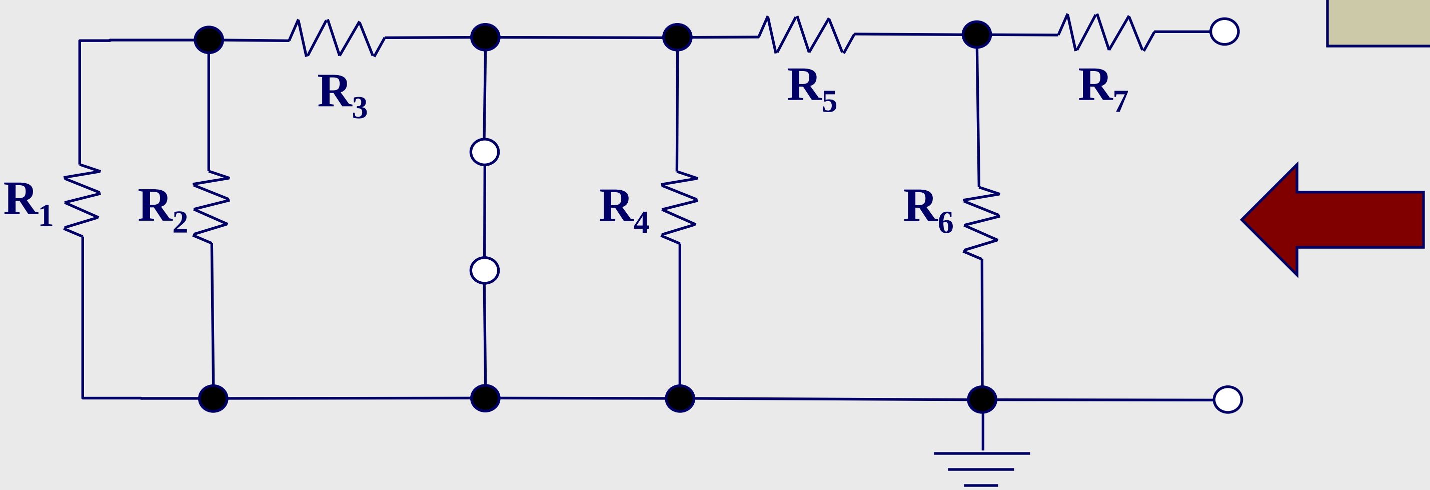

Consider now – what resistance would the LOAD see?

Exam 1 Review…Thévenin P.114

Find the Thévenin equivalent resistance

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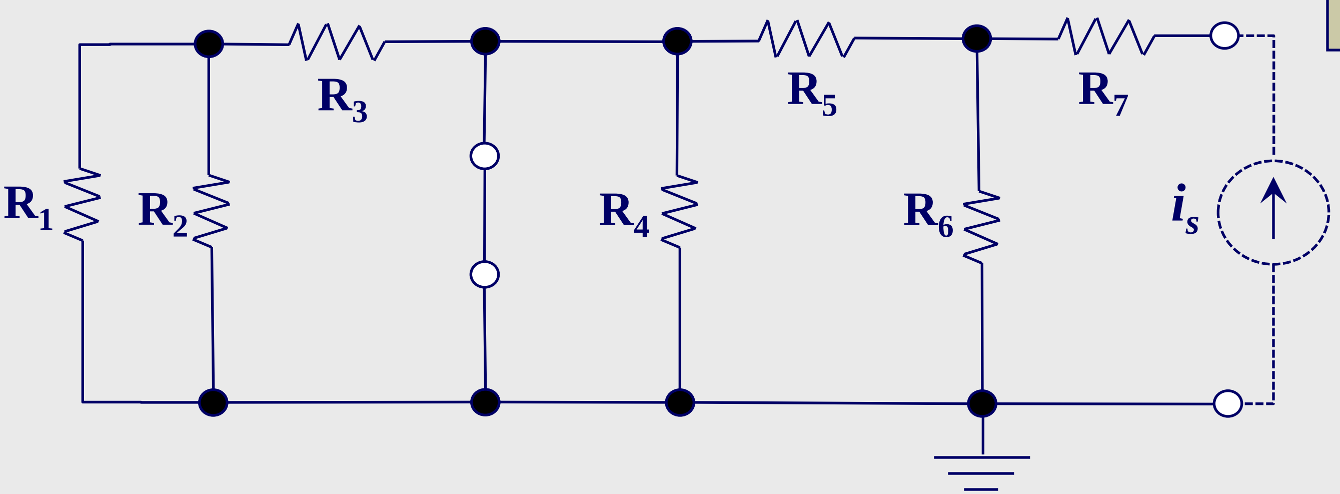

1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$
   - Zero sources

Imagine we connected a 1A current source – in which branches would current flow?

Exam 1 Review…Thévenin P.114

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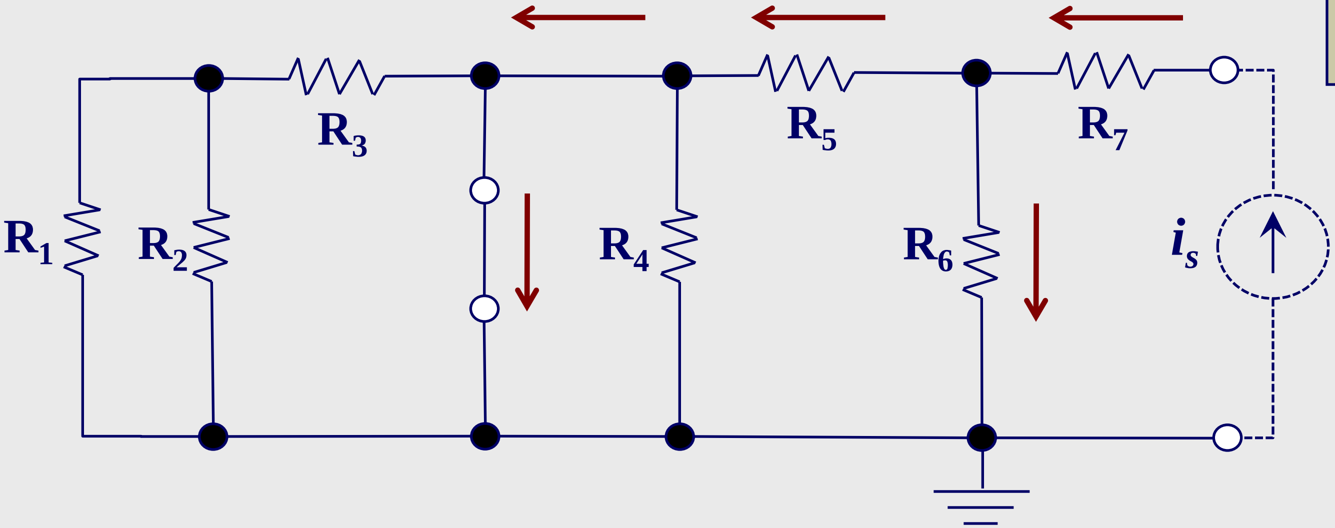
1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$
   - Zero sources



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Exam 1 Review…Thévenin P.114

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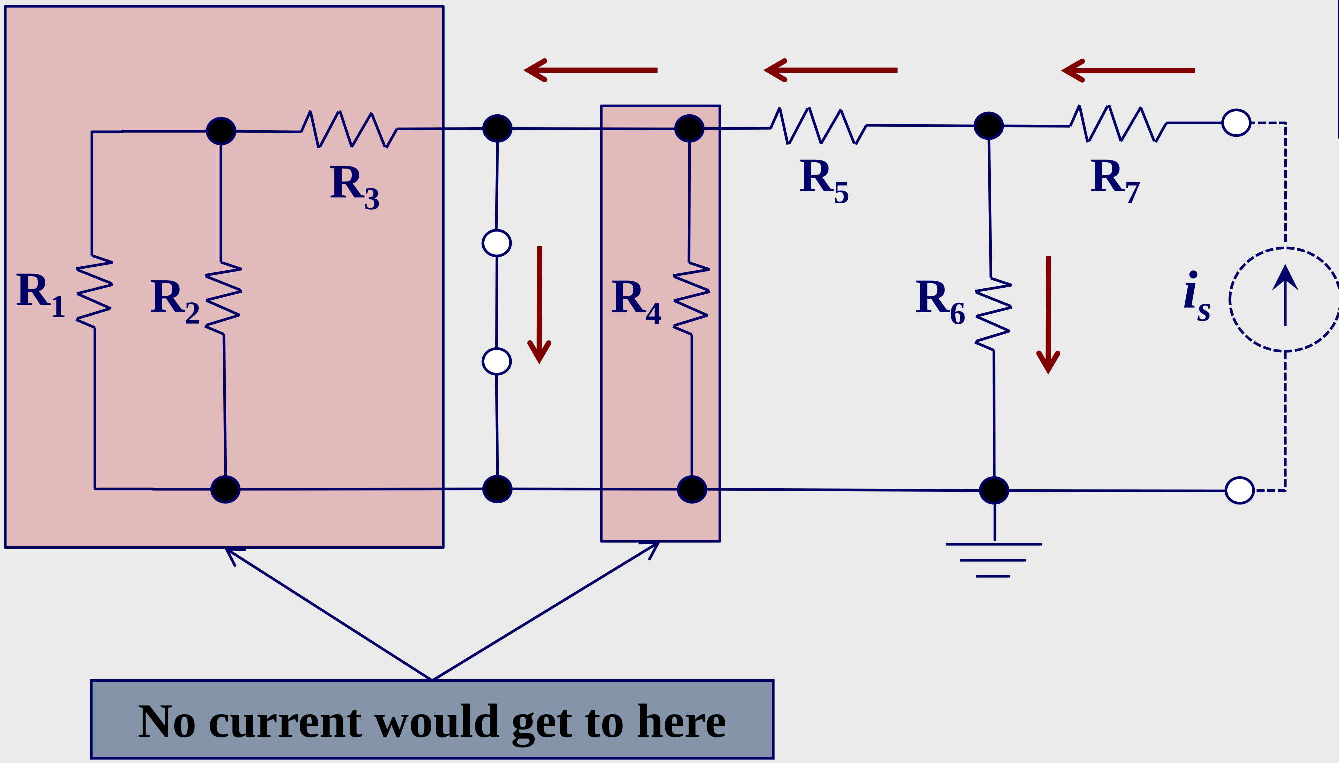

1. Compute $\mathbf{R_T}$
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Exam 1 Review…Thévenin P.114

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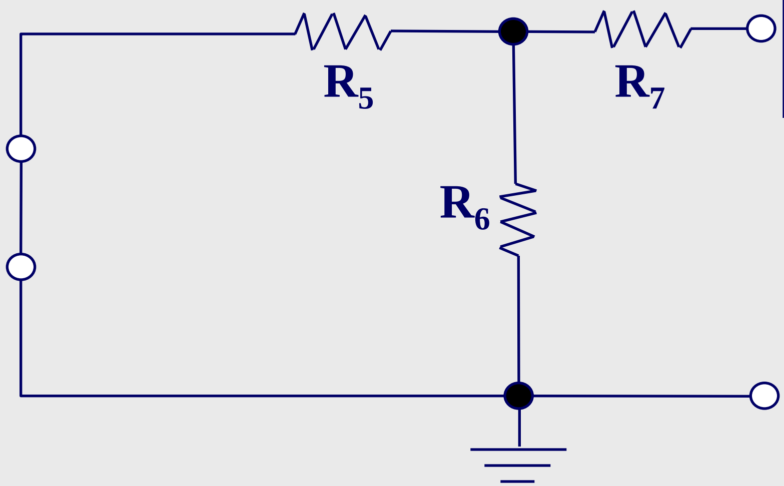

1. Compute $\mathbf{R_T}$
   - Remove $\mathbf{R_L}$
   - Zero sources
   - Compute $\mathbf{R_T} = \mathbf{R_{EQ}}$

$$R_T = R_7 + R_5 \parallel R_6$$
$$= 4k\Omega$$

There are only 3 resistors to consider