ECE 205 “Electrical and Electronics Circuits”

Spring 2024 – LECTURE 11

MWF – 12:00pm

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2062 ECE Building

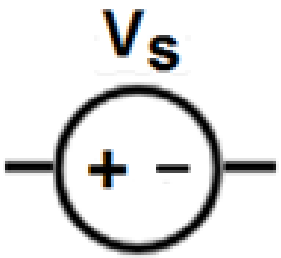
Lecture 11 – Summary

Learning Objectives

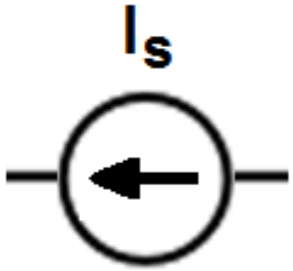
1. Introduction to “dependent” sources
2. Solution strategies with “loop” and “node” analysis

Independent Sources

These are sources whose behavior does not depend on the circuit they are connected to.

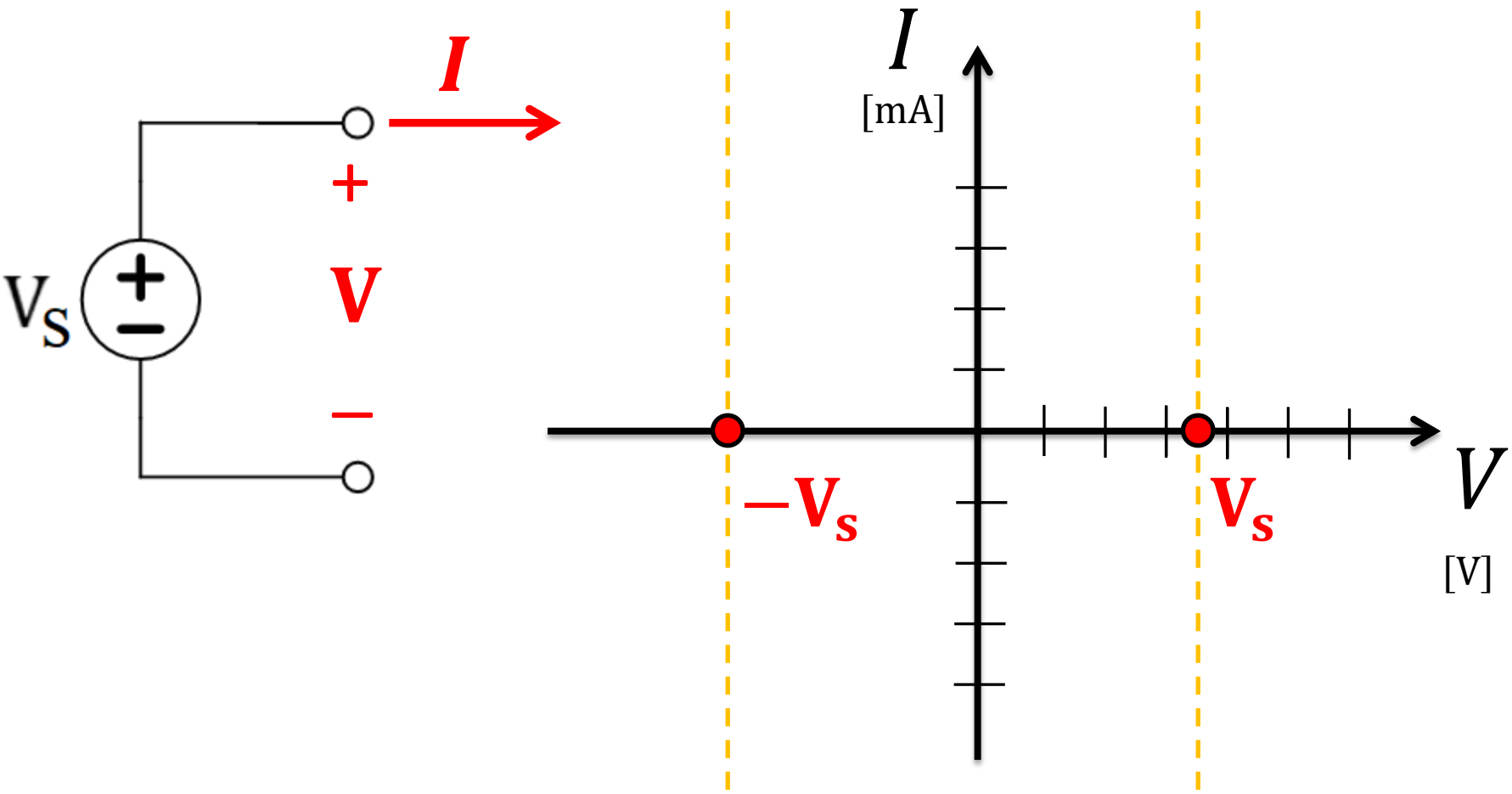


Voltage source

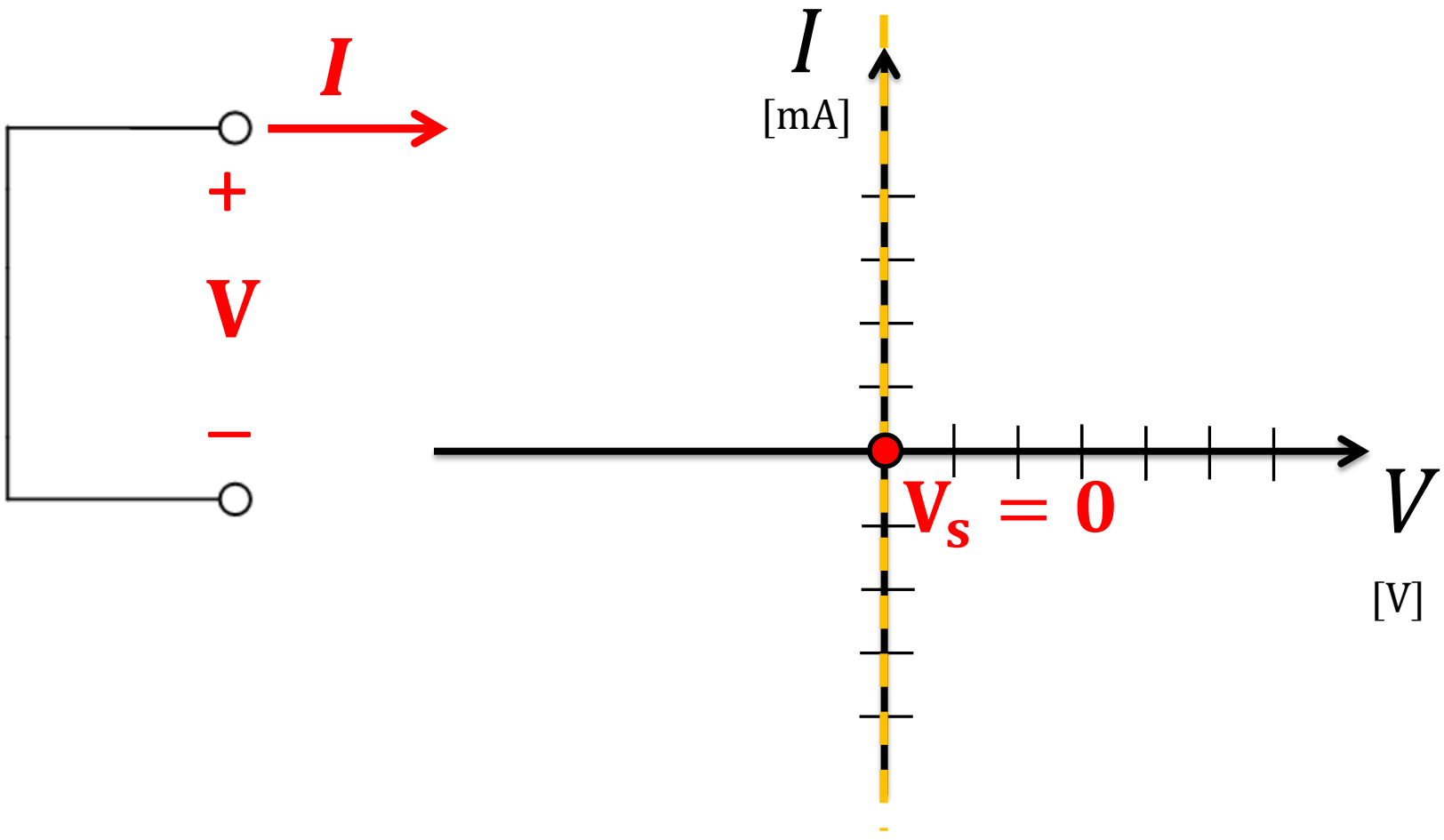


Current source

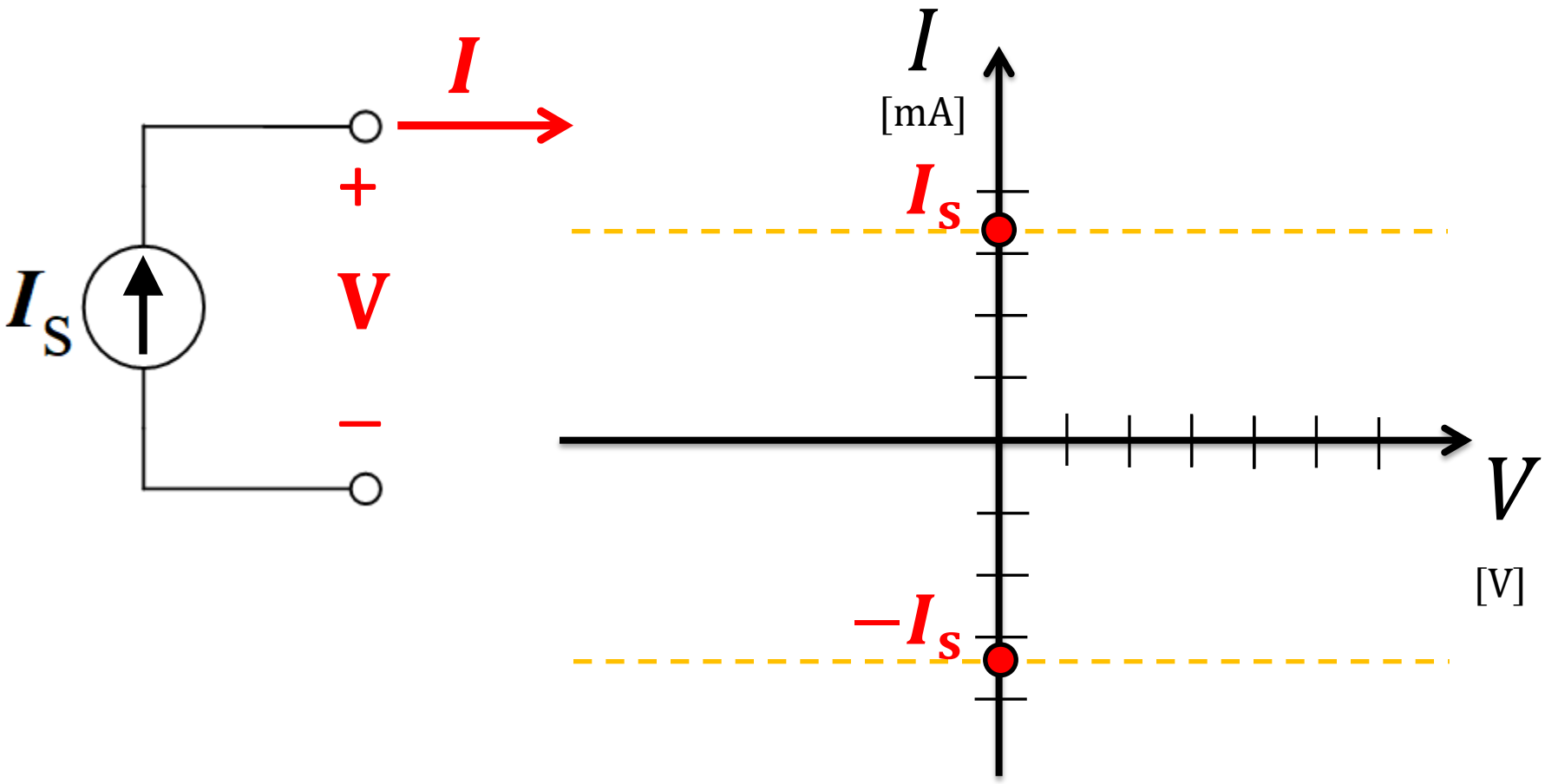
I-V Curves of ideal voltage sources



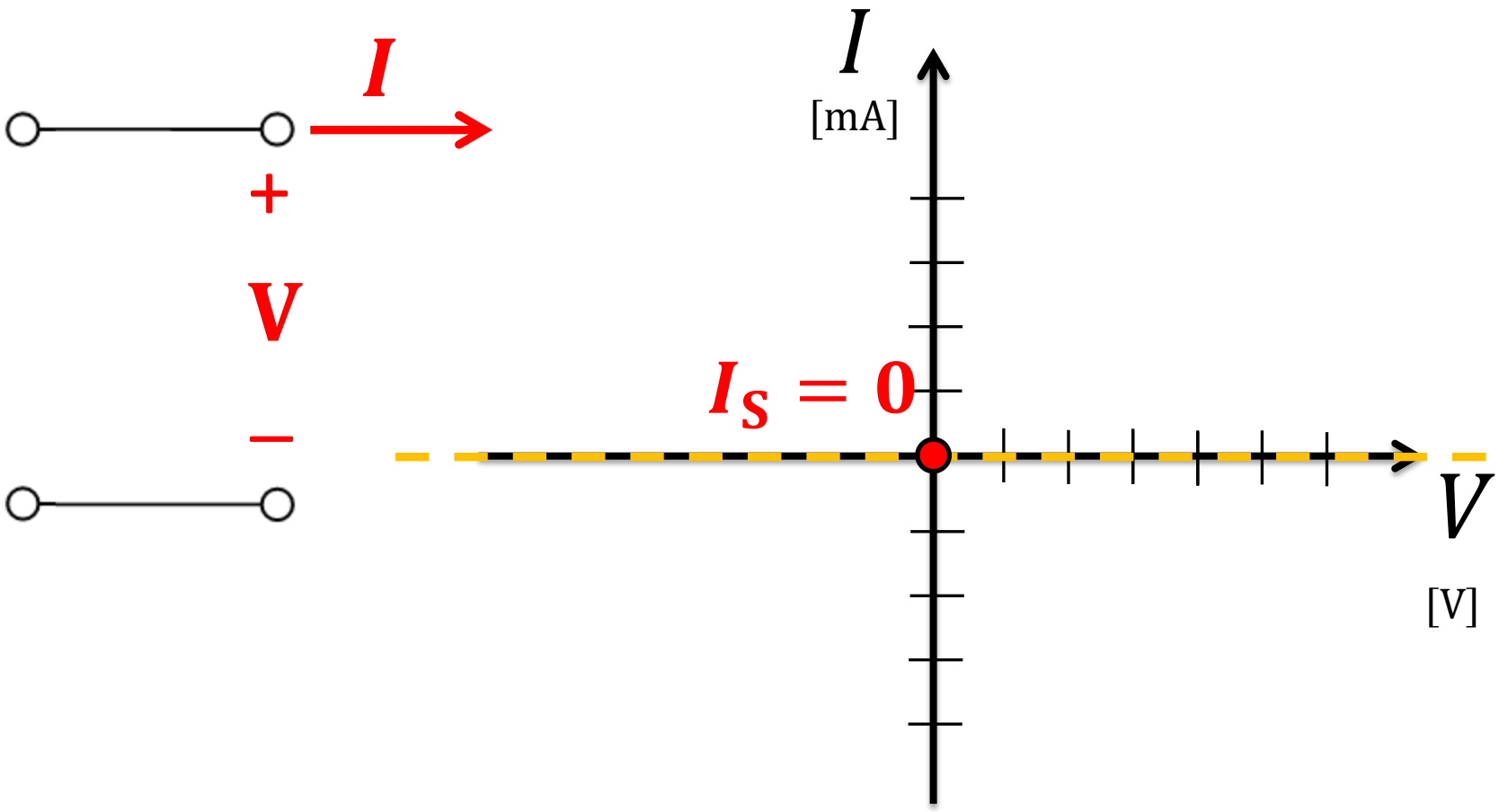
I-V Curve of a short circuit



I-V Curves of ideal current sources

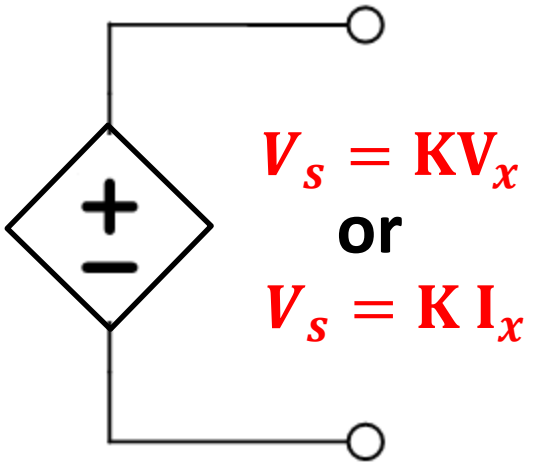


I-V Curve of an open circuit



Dependent Sources

These are sources which are "controlled" by a current or a voltage in another part of the circuit.

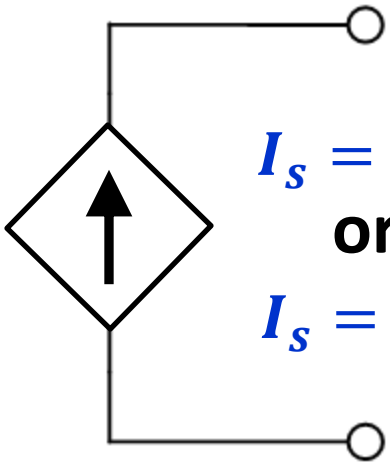


$V_s = \mathrm{K}V_x$

or

$V_s = \mathrm{K}\,I_x$

Dependent Voltage source



$I_s = \mathrm{K}V_x$

or

$I_s = \mathrm{K}\,I_x$

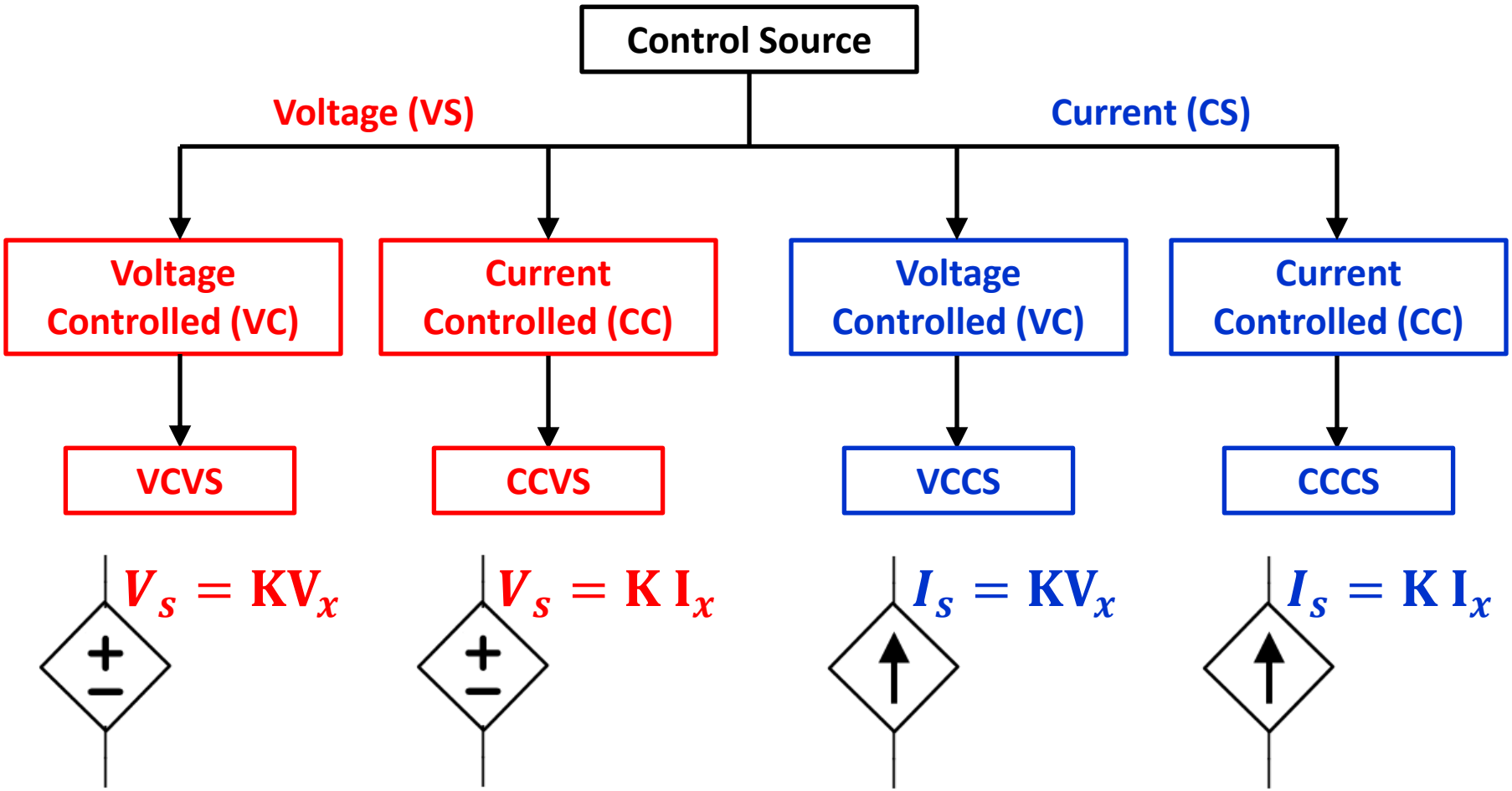
Dependent Current source

Common representations of dependent sources. Other symbols may be used by practitioners.

Possible Configurations

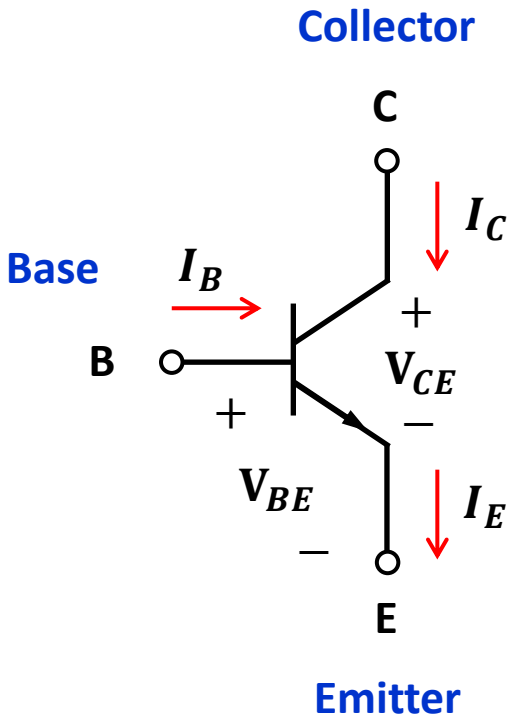
We have the following types of dependent sources

1. **Voltage Controlled Voltage Source (VCVS)**
2. **Current Controlled Voltage Source (CCVS)**
3. **Voltage Controlled Current Source (VCCS)**
4. **Current Controlled Current Source (CCCS)**

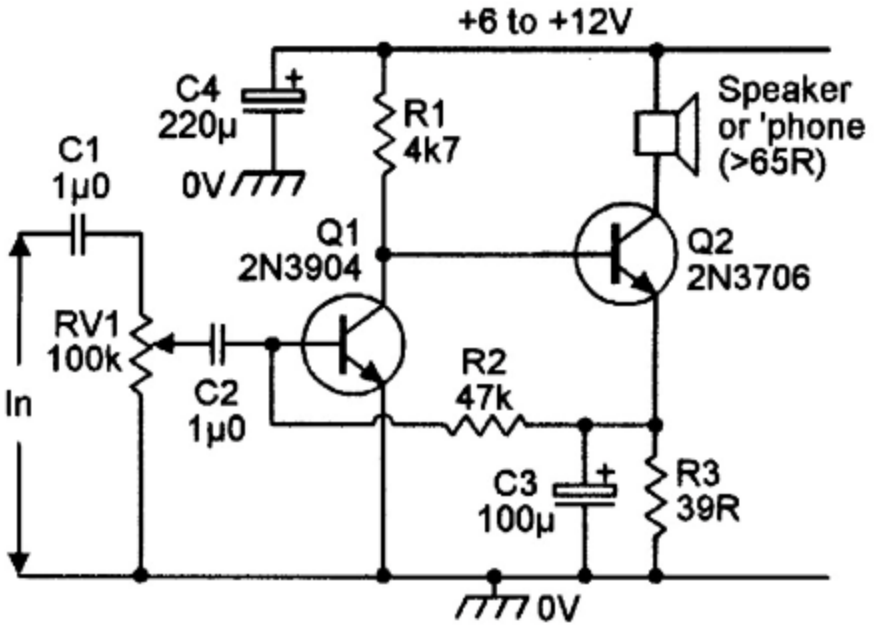

Control Source
Voltage (VS)
Current (CS)
Voltage Controlled (VC)
Current Controlled (CC)
Voltage Controlled (VC)
Current Controlled (CC)
VCVS
CCVS
VCCS
CCCS
$V_s = \mathrm{K}V_x$
$V_s = \mathrm{K}\,I_x$
$I_s = \mathrm{K}V_x$
$I_s = \mathrm{K}\,I_x$

Where do we find dependent sources?

Example: bipolar junction transistor (BJT)



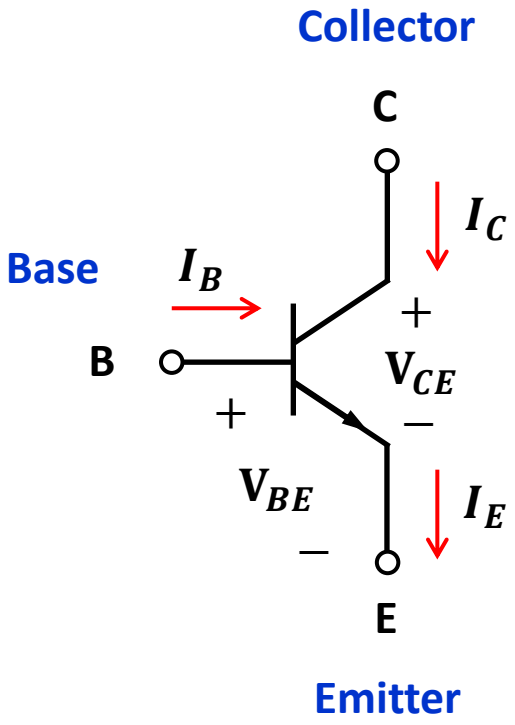
n-p-n BJT transistor symbol



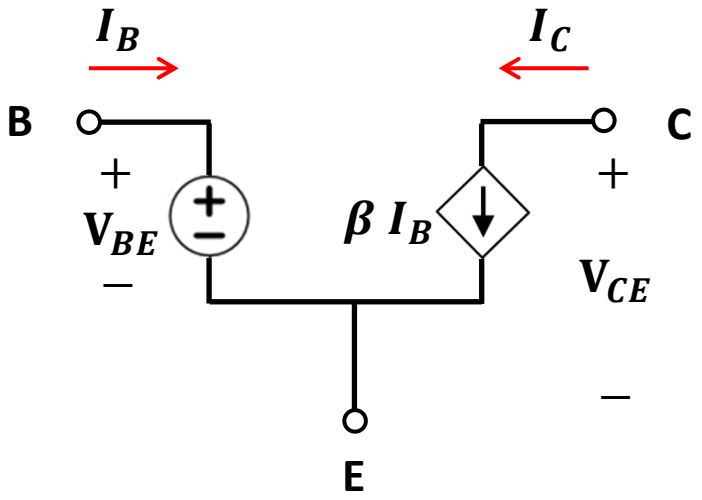
Basic low-power transistor audio amplifier circuit

Where do we find dependent sources?

Example: Simple DC equivalent circuit model of a bipolar transistor

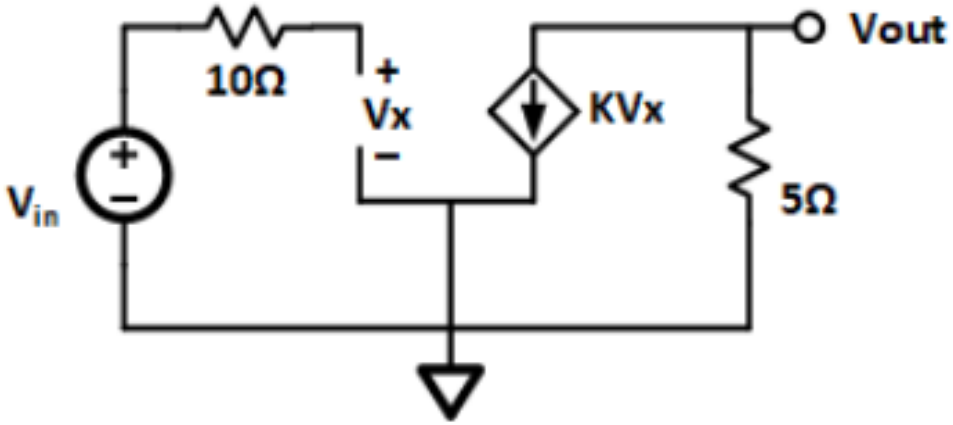


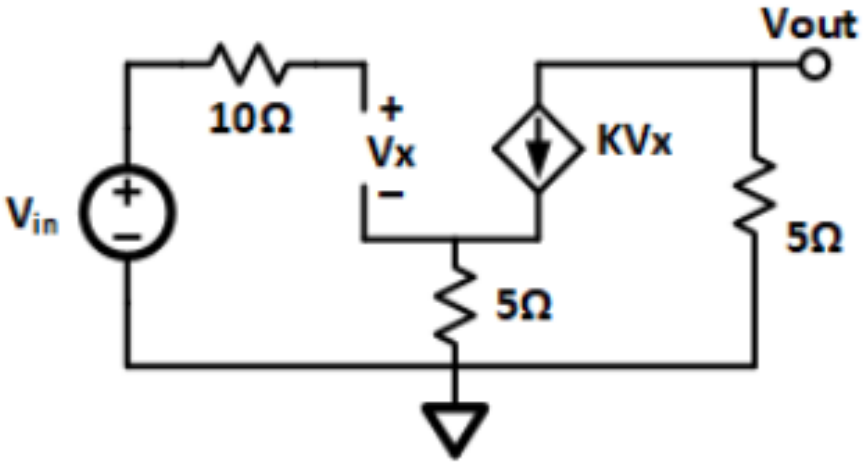
n-p-n BJT transistor symbol



equivalent DC electrical circuit

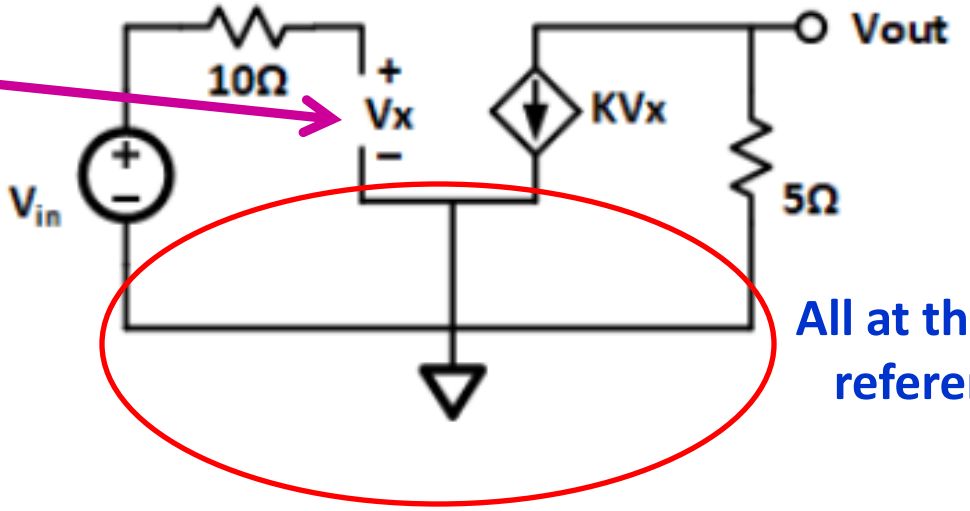
Homework 4 PL – Problem 4



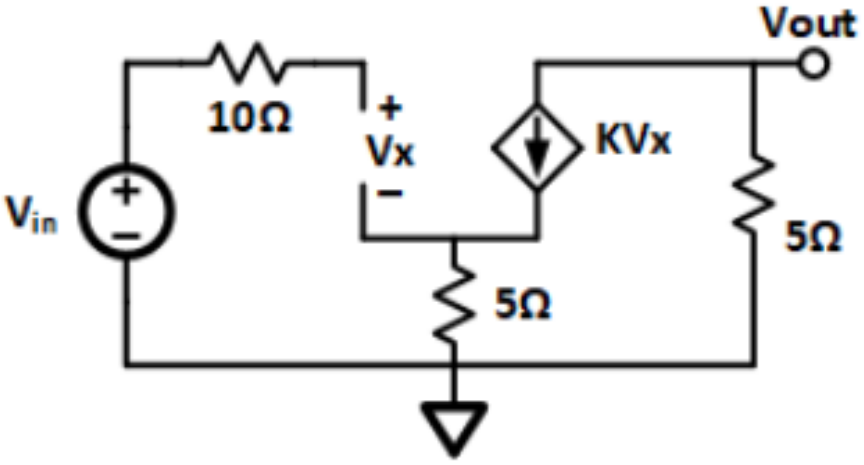


Homework 4 PL – Problem 4

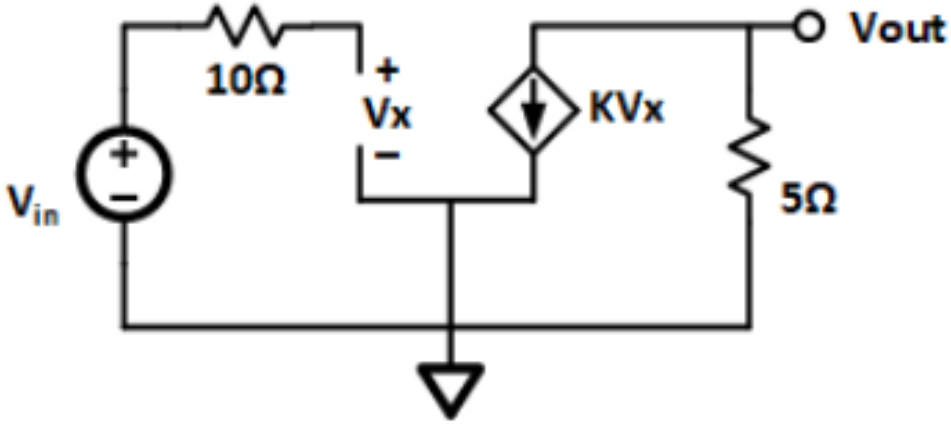
Open circuit, no current flows (capacitive structure)

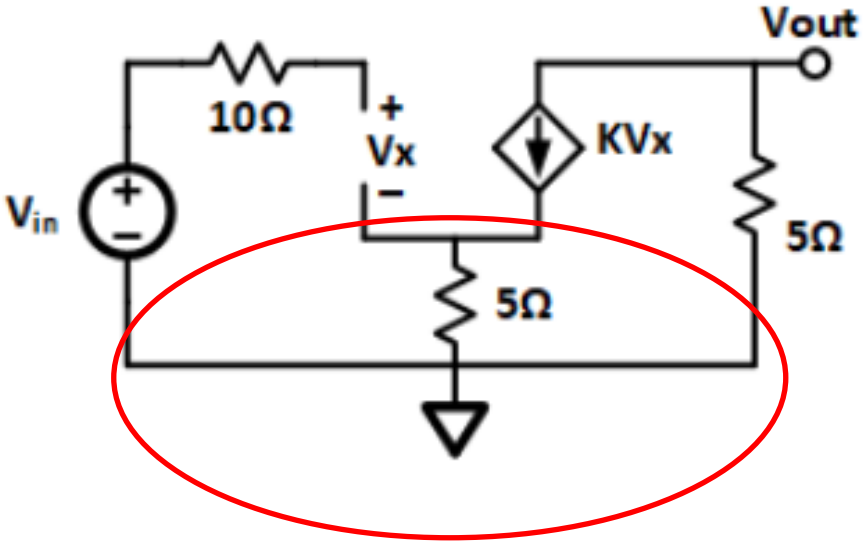


All at the same ground reference potential



Homework 4 PL – Problem 4

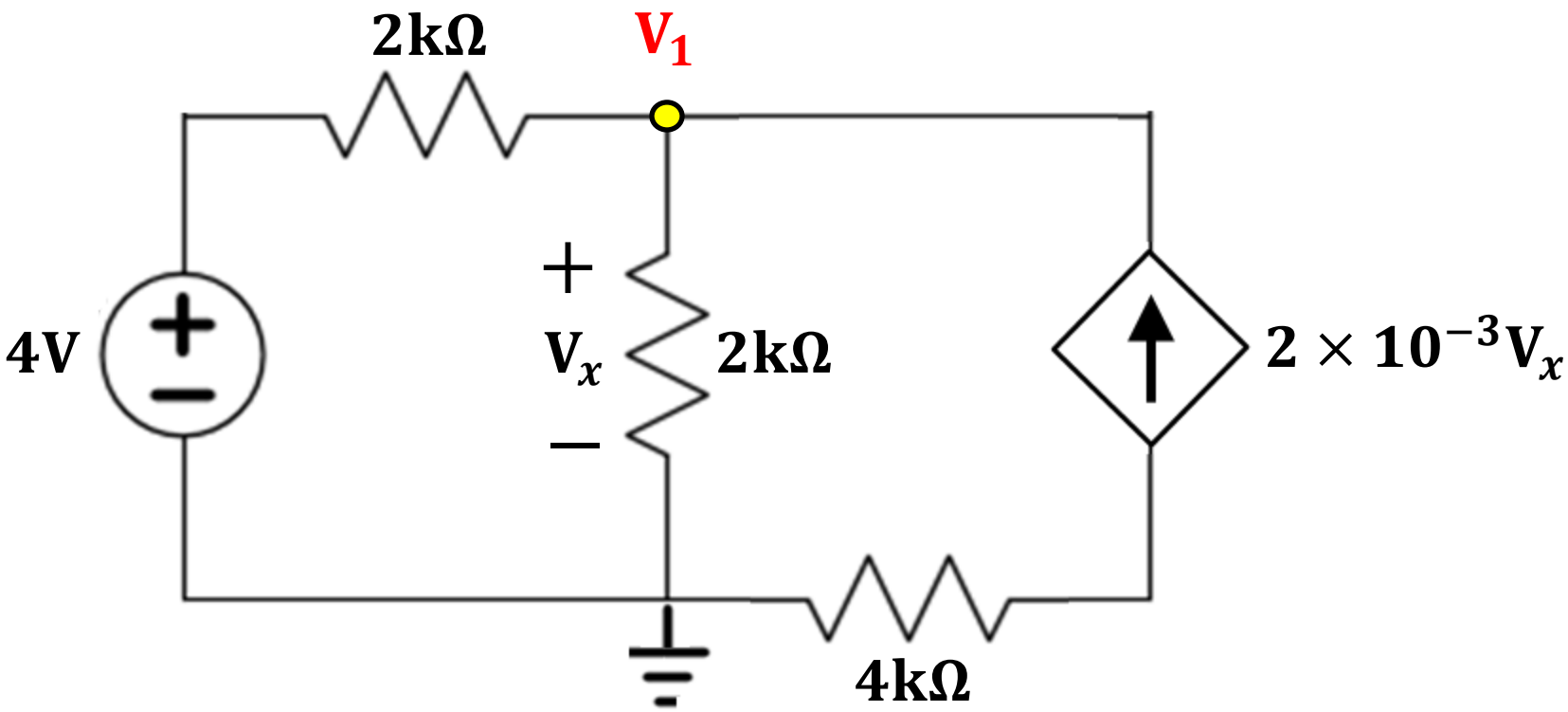




Additional resistor increases coupling between right and left sides of circuit

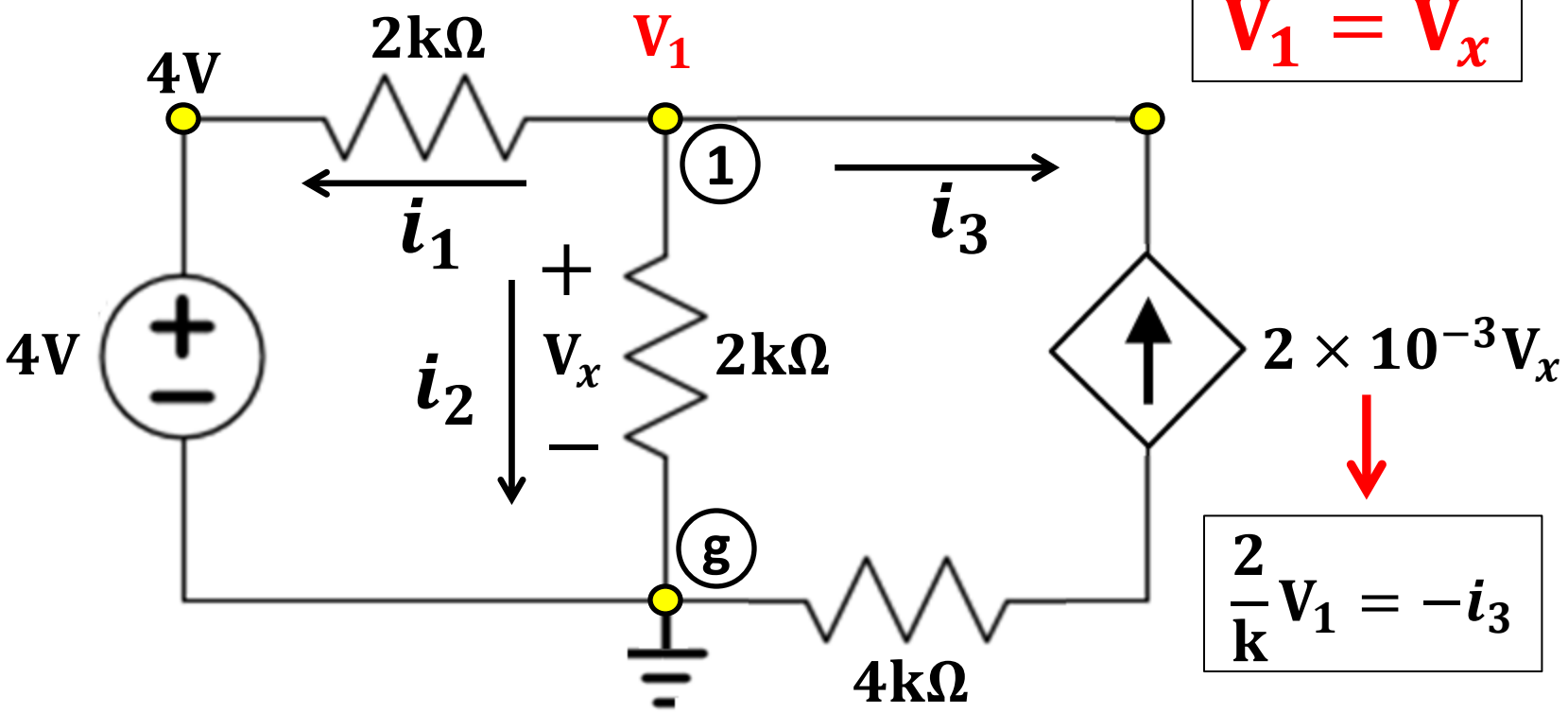
Example 1

Find the Voltage V_1



Example 1

Find the Voltage V_1

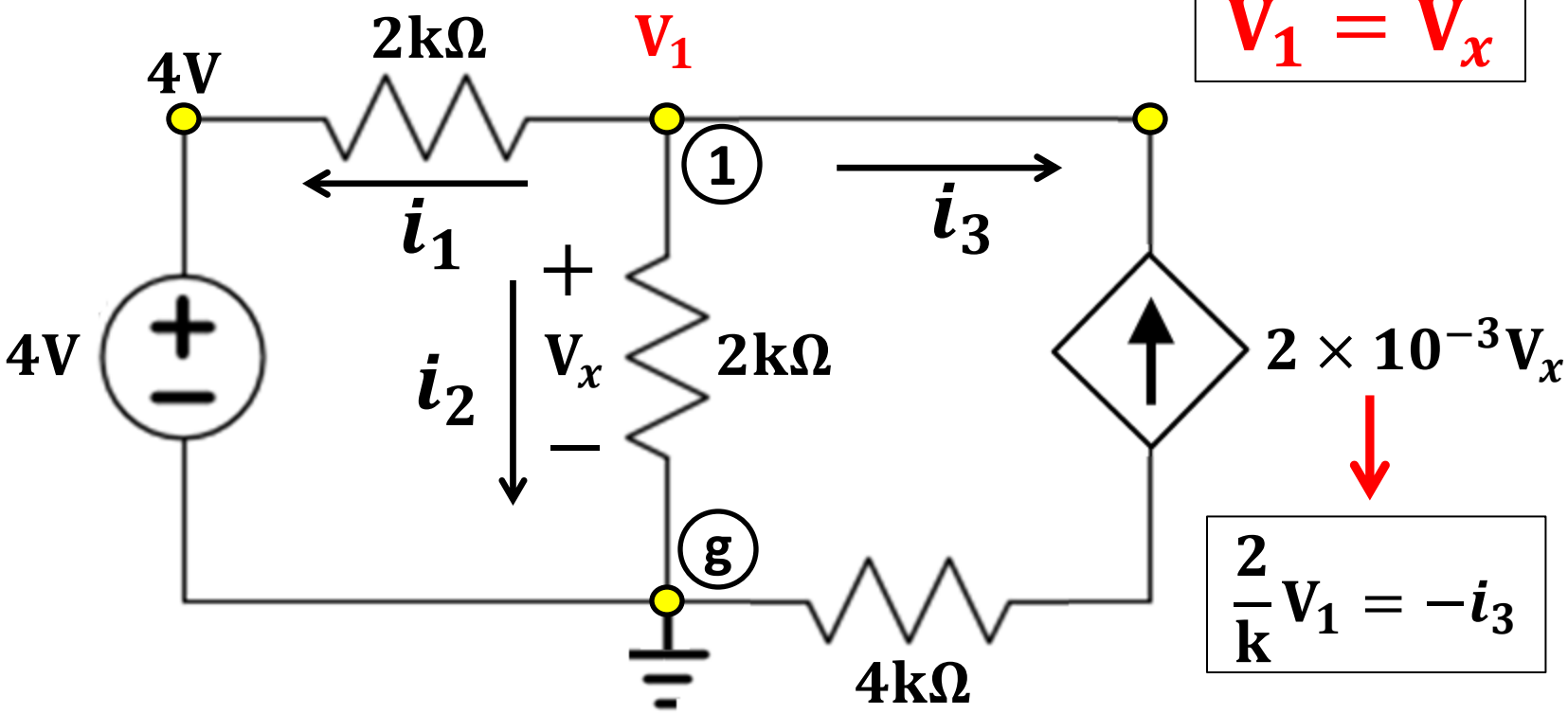


$$V_1 = V_x$$

$$\frac{2}{k} V_1 = -i_3$$

Example 1

Find the Voltage V_1



$$V_1 = V_x$$

$$\frac{2}{k} V_1 = -i_3$$

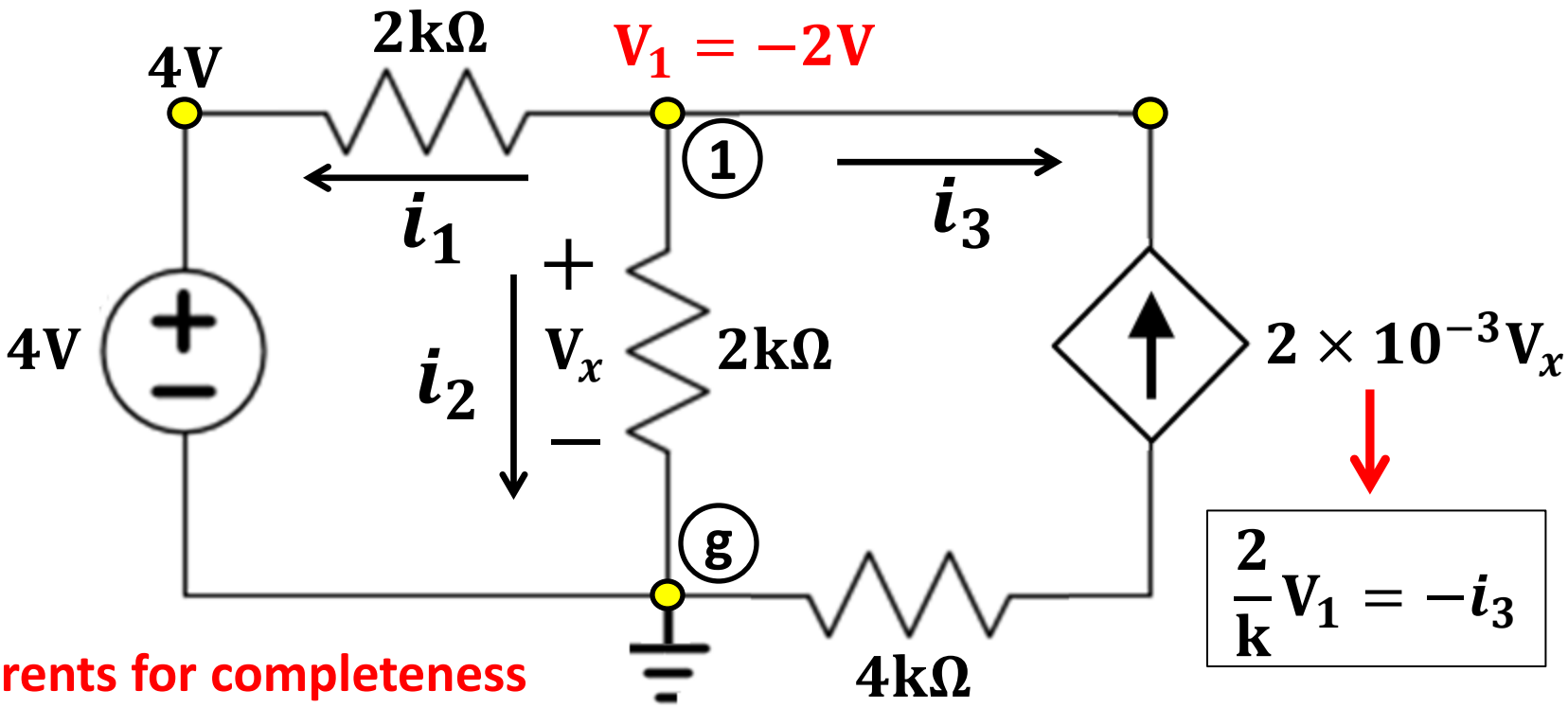
Node (1) $\quad \dfrac{V_1 - 4}{2k} + \dfrac{V_1}{2k} - \dfrac{2}{k} V_1 = 0 \rightarrow V_1 - 2V_1 = 2$

$$i_1 + i_2 + i_3 = 0$$

$$V_1 = -2V$$

Example 1

Find the Voltage V_1



$$\frac{2}{\mathrm{k}} V_1 = -i_3$$

Find currents for completeness

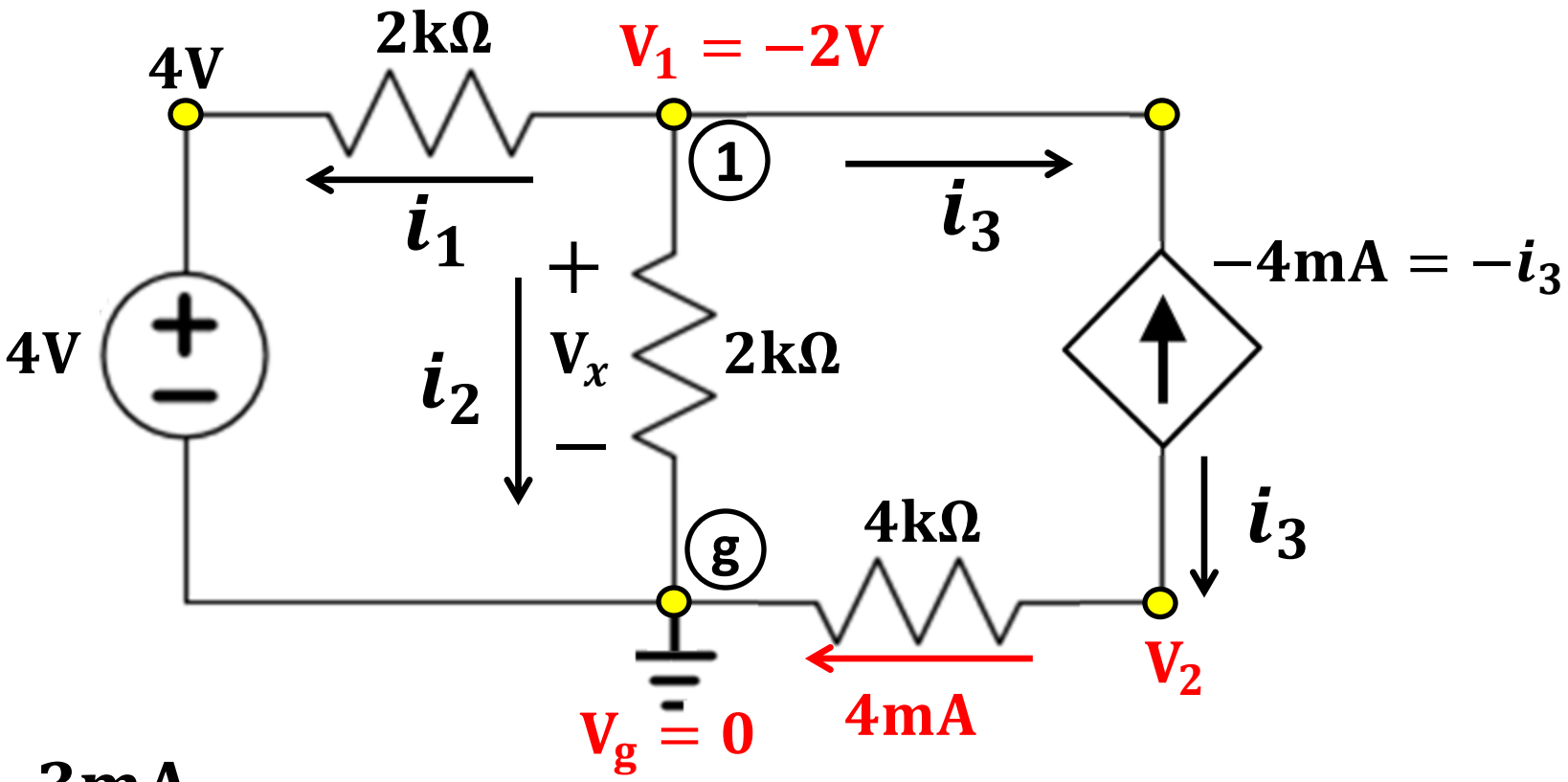
$$i_1 = \frac{V_1 - 4}{2\mathrm{k}} = \frac{-2 - 4}{2\mathrm{k}} = -3\mathrm{mA}$$

$$i_2 = \frac{V_1}{2\mathrm{k}} = \frac{-2}{2\mathrm{k}} = -1\mathrm{mA}$$

$$i_3 = -i_1 - i_2 = 4\ \mathrm{mA}$$

Example 1

Find the Voltage V_1



$i_1 = -3\text{mA}$

$i_2 = -1\text{mA}$

$i_3 = 4\ \text{mA}$

Across the 4kΩ resistor

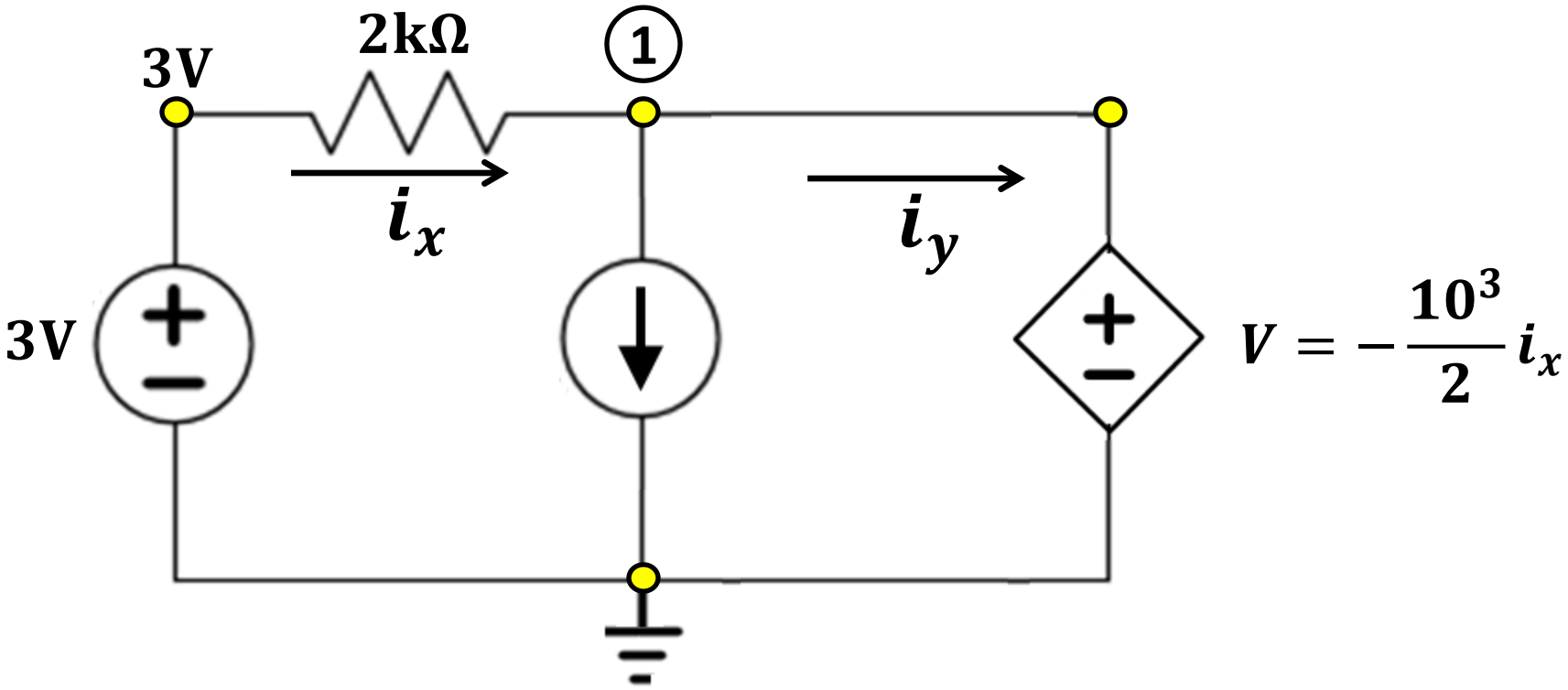
$V_2 - V_g = 4\text{k}\Omega \times 4\text{mA} = 16V$

Across the current source

$V_2 - V_1 = 16 - (-2) = 18V$

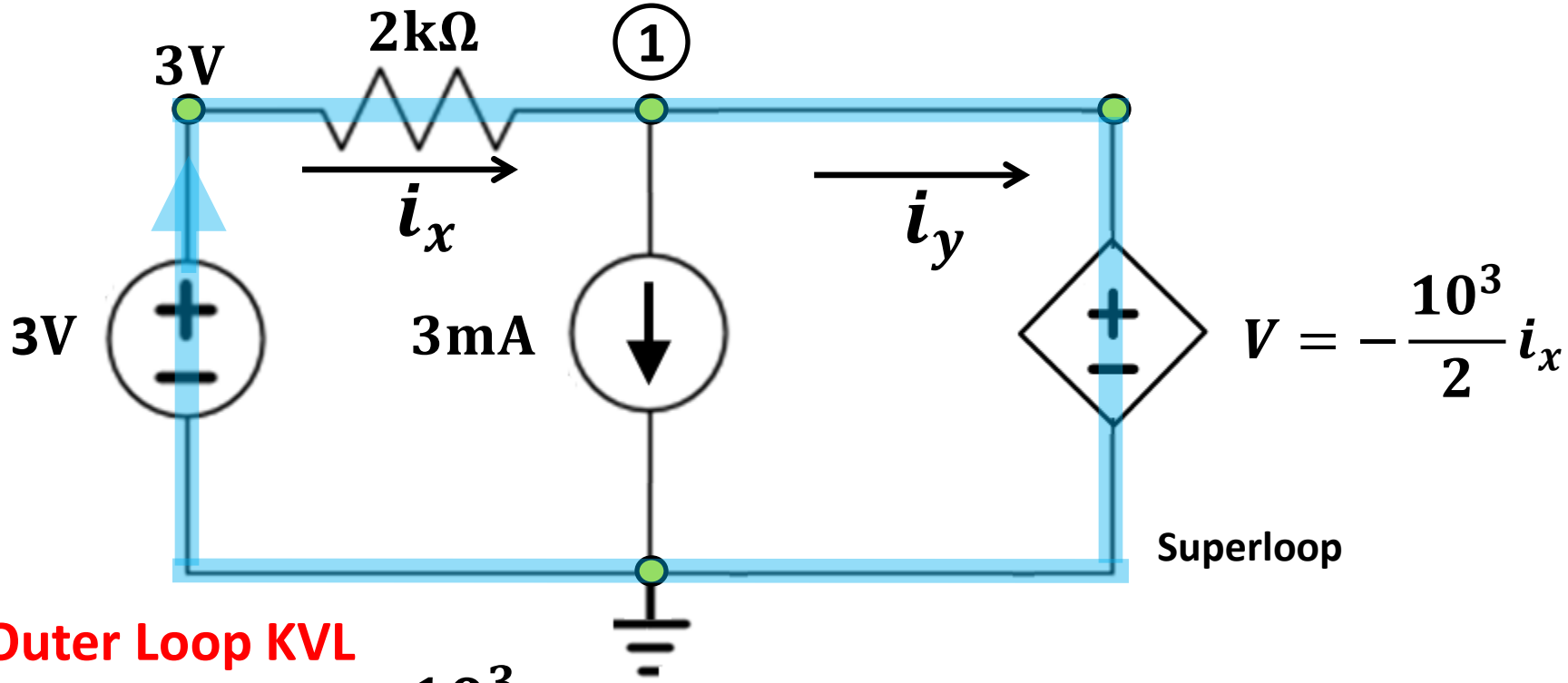
Example 2

Find the currents i_x and i_y



Example 2

Find the currents i_x and i_y



Outer Loop KVL

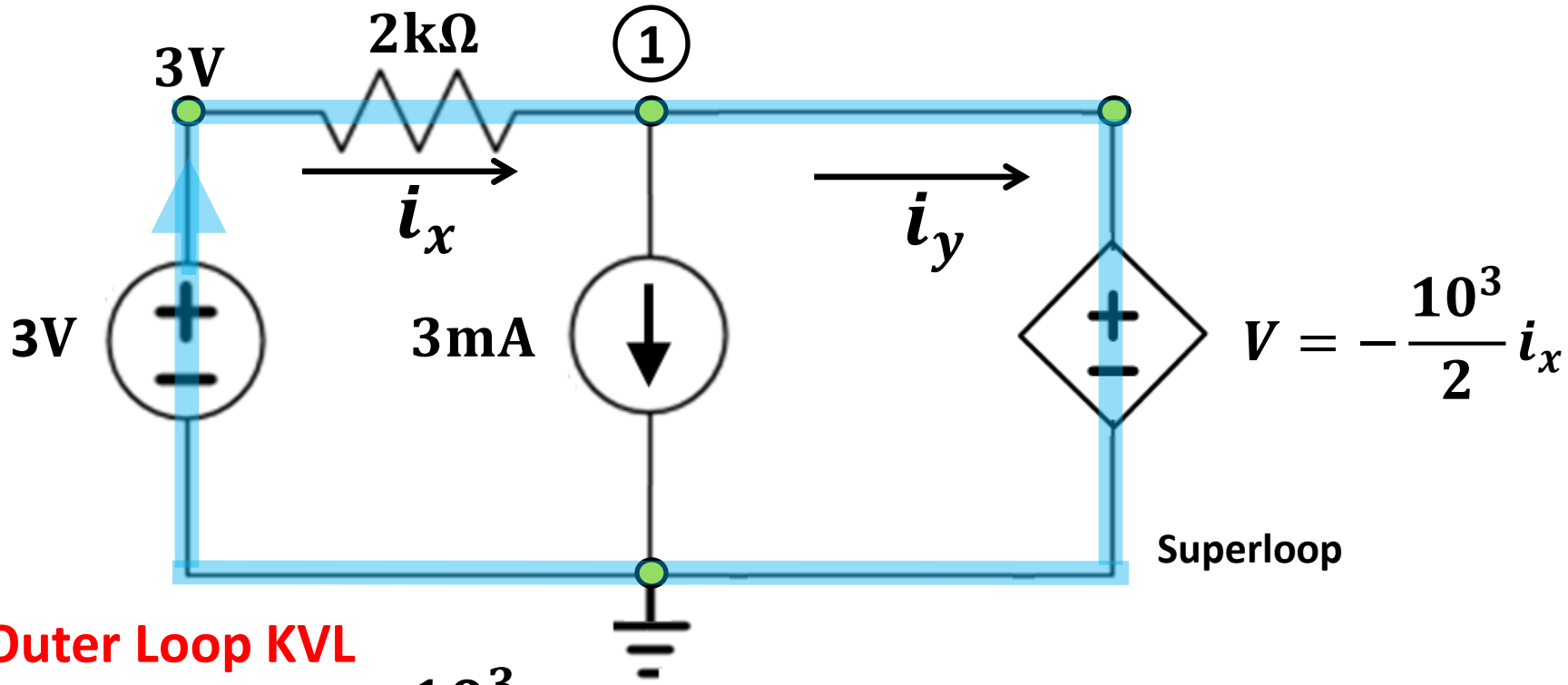
$$-3 + 2\text{k}\, i_x - \frac{10^3}{2} i_x = 0$$

$$1.5\, i_x = 3\text{m}$$

$$i_x = 2\text{mA}$$

Example 2

Find the currents i_x and i_y



Outer Loop KVL

$$-3 + 2\text{k}\, i_x - \frac{10^3}{2} i_x = 0$$

$$1.5\, i_x = 3\text{m}$$

$$i_x = 2\text{mA}$$

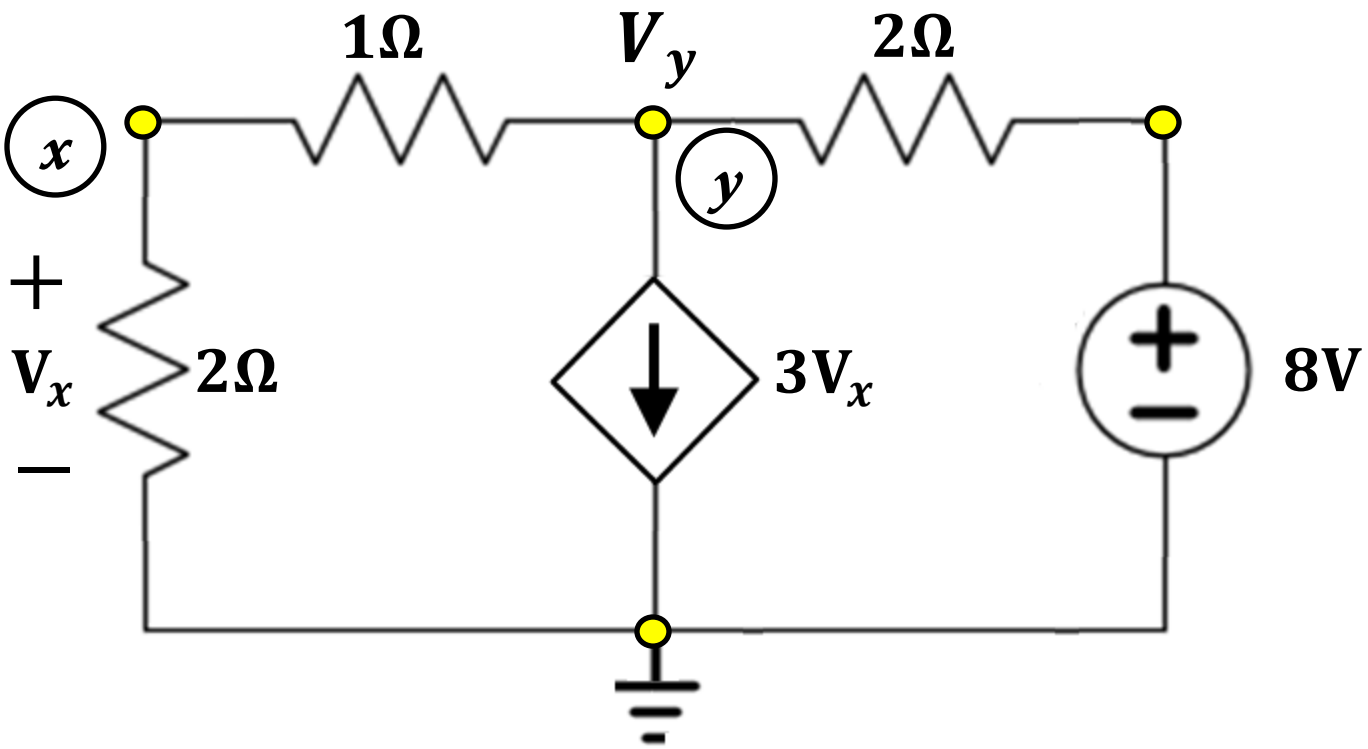
Node (1) KCL

$$-i_x + i_y + 3\text{mA} = 0$$

$$i_y = -1\ \text{mA}$$

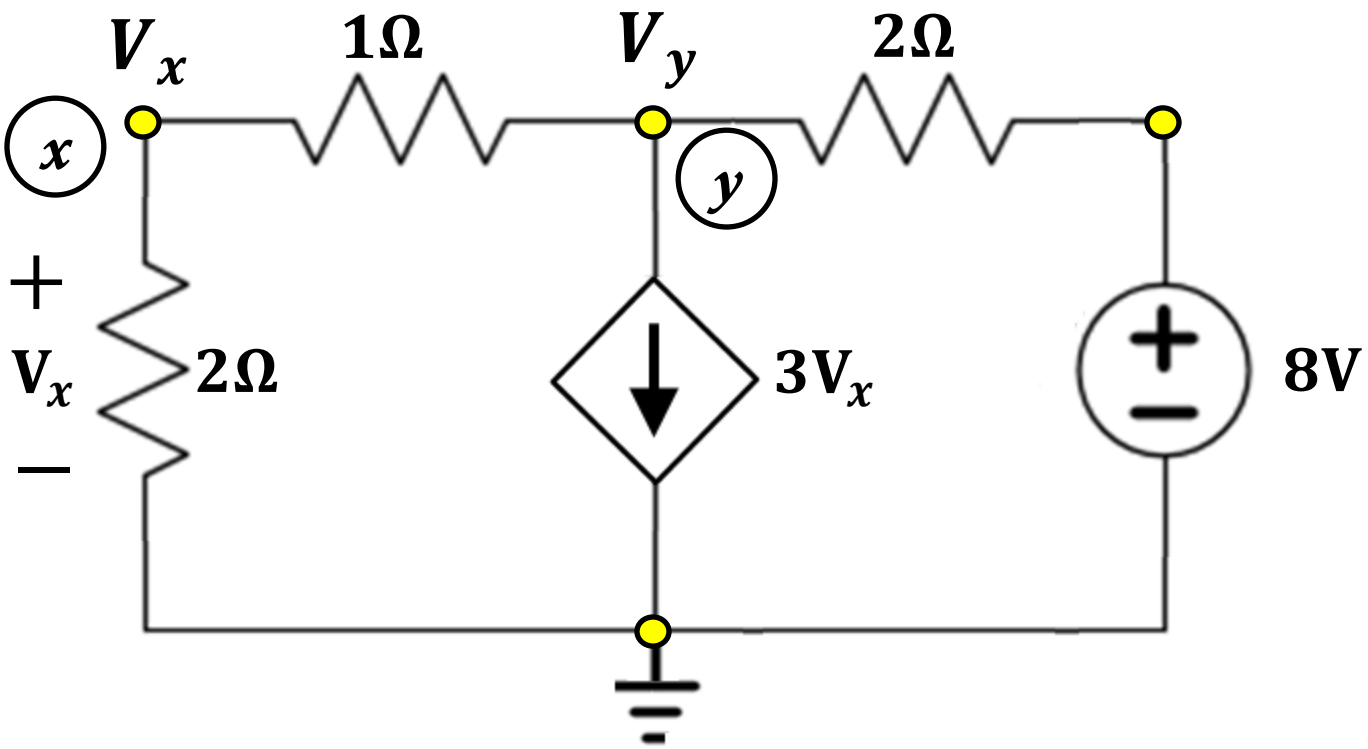
Example 3

Find V_y



Example 3

Find V_y

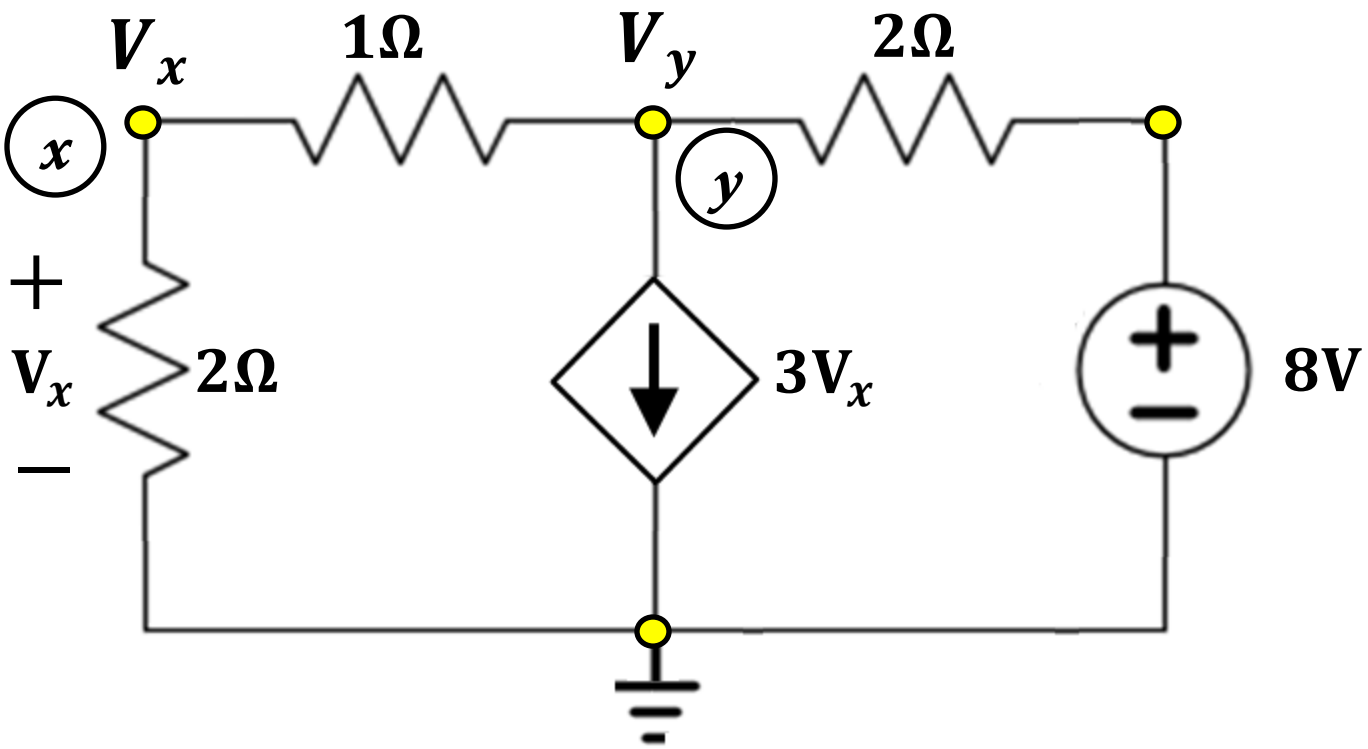


Node x

$$\frac{V_x - 0}{2} + \frac{V_x - V_y}{1} = 0$$

Example 3

Find V_y

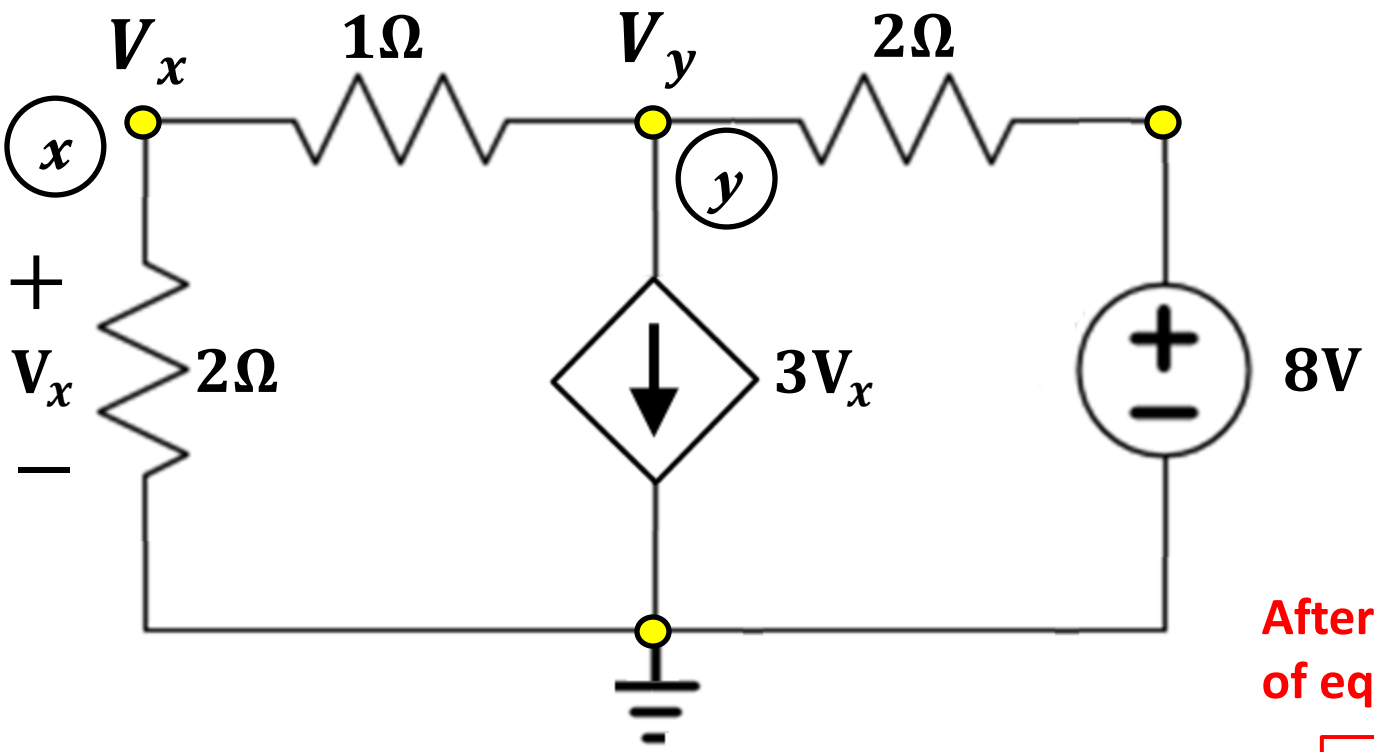


Node x $$\frac{V_x - 0}{2} + \frac{V_x - V_y}{1} = 0$$

Node y $$\frac{V_y - V_x}{1} + 3V_x + \frac{V_y - 8}{2} = 0$$

Example 3

Find V_y



Node x

$$\frac{V_x - 0}{2} + \frac{V_x - V_y}{1} = 0$$

Node y

$$\frac{V_y - V_x}{1} + 3V_x + \frac{V_y - 8}{2} = 0$$

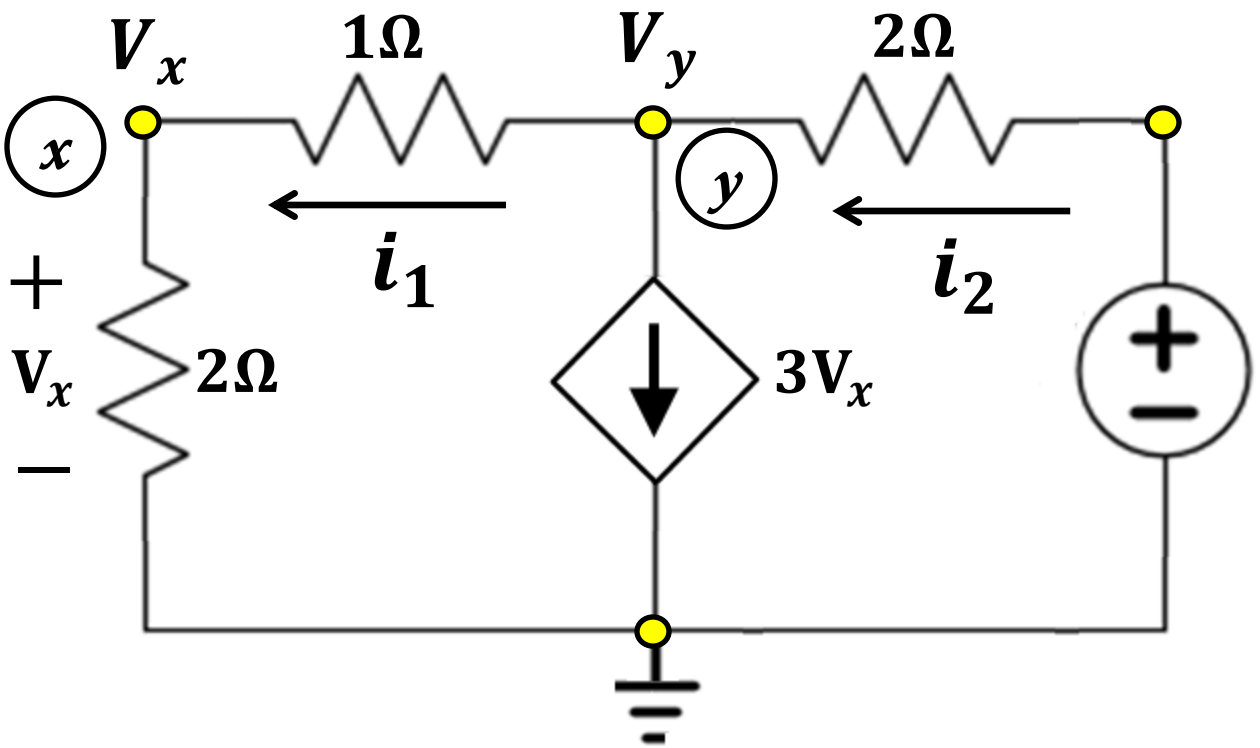
After solving system of equations

$$V_x = \frac{16}{17}\text{V}$$

$$V_y = \frac{24}{17}\text{V}$$

Example 3

Verification



$$V_x = \frac{16}{17}\text{V}$$

$$V_y = \frac{24}{17}\text{V}$$

$$i_1 = \frac{V_x}{2} = \frac{1}{2} \times \frac{16}{17} = \frac{8}{17}\text{A}$$

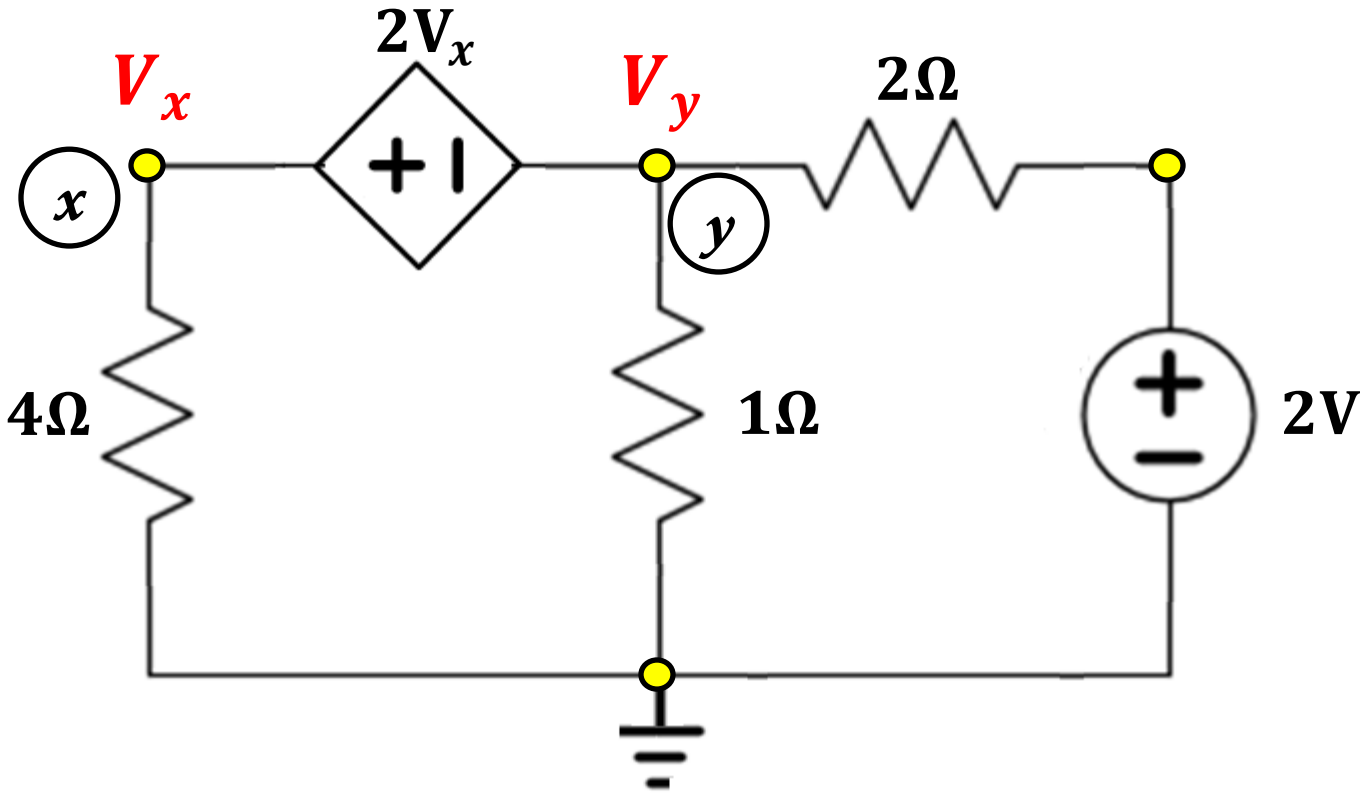
$$i_1 = \frac{V_y - V_x}{1\Omega} = \frac{24}{17} - \frac{16}{17} = \frac{8}{17}\text{A}$$

$$i_2 = \frac{8 - V_y}{2} = 4 - \frac{12}{17} = \frac{56}{7}\text{A}$$

$$i_2 = i_1 + 3V_x = \frac{8}{17} + 3\frac{16}{17} = \frac{56}{7}\text{A}$$

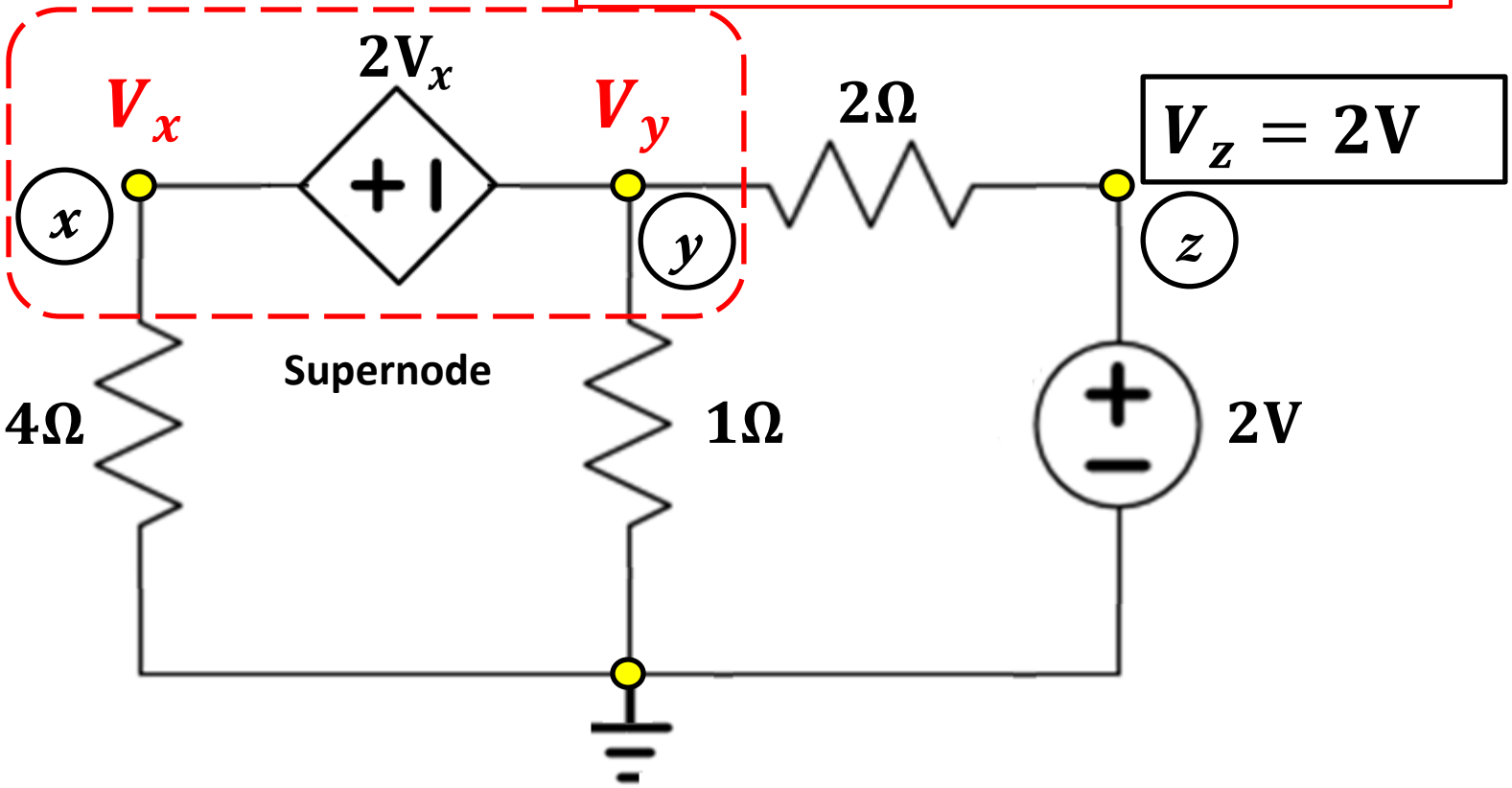
Example 4

Find V_x , V_y



Example 4

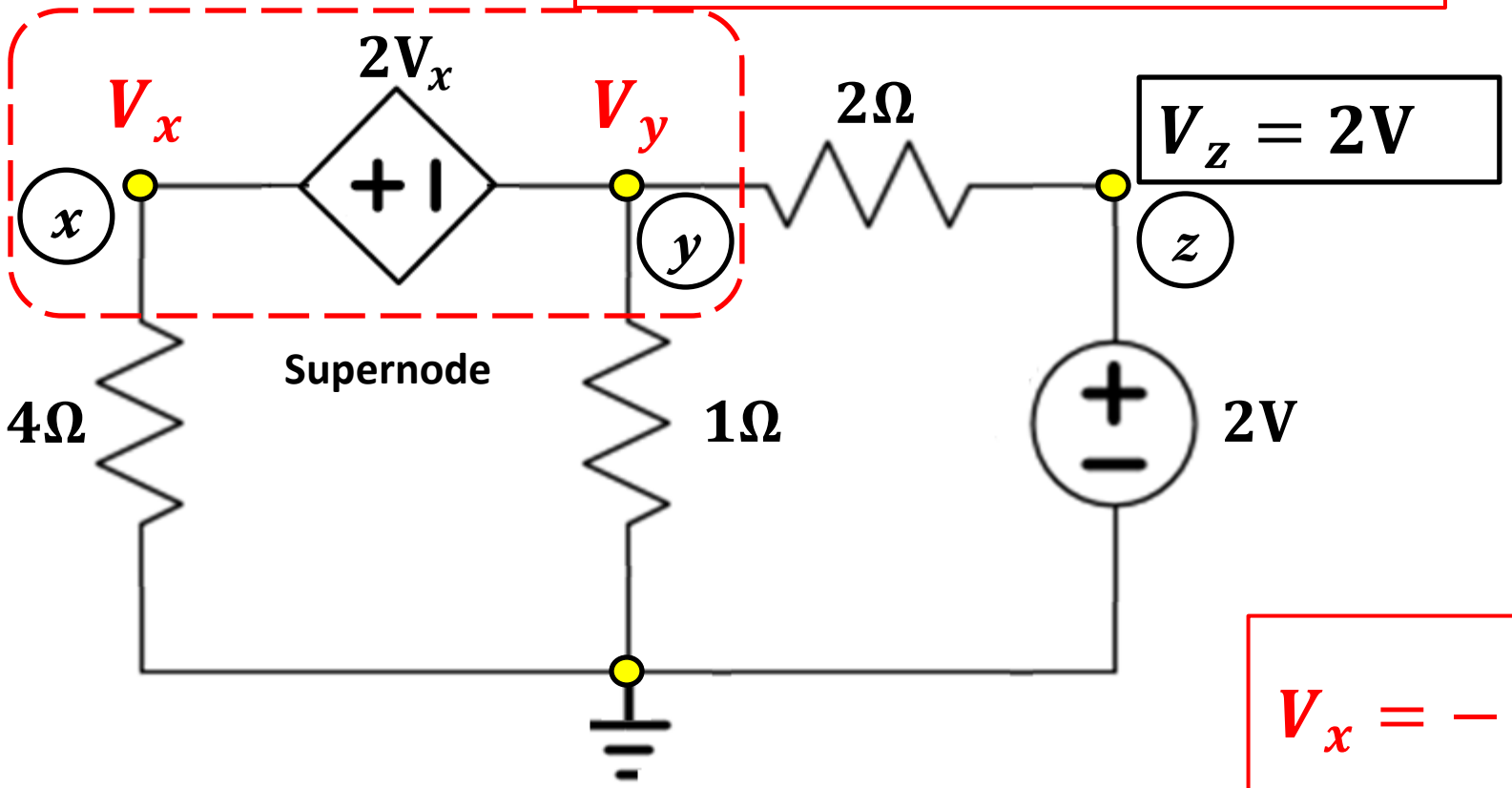
Find V_x , V_y



Node x $\quad V_x = V_y + 2V_x \rightarrow \boxed{V_x = -V_y}$

Example 4

Find V_x , V_y



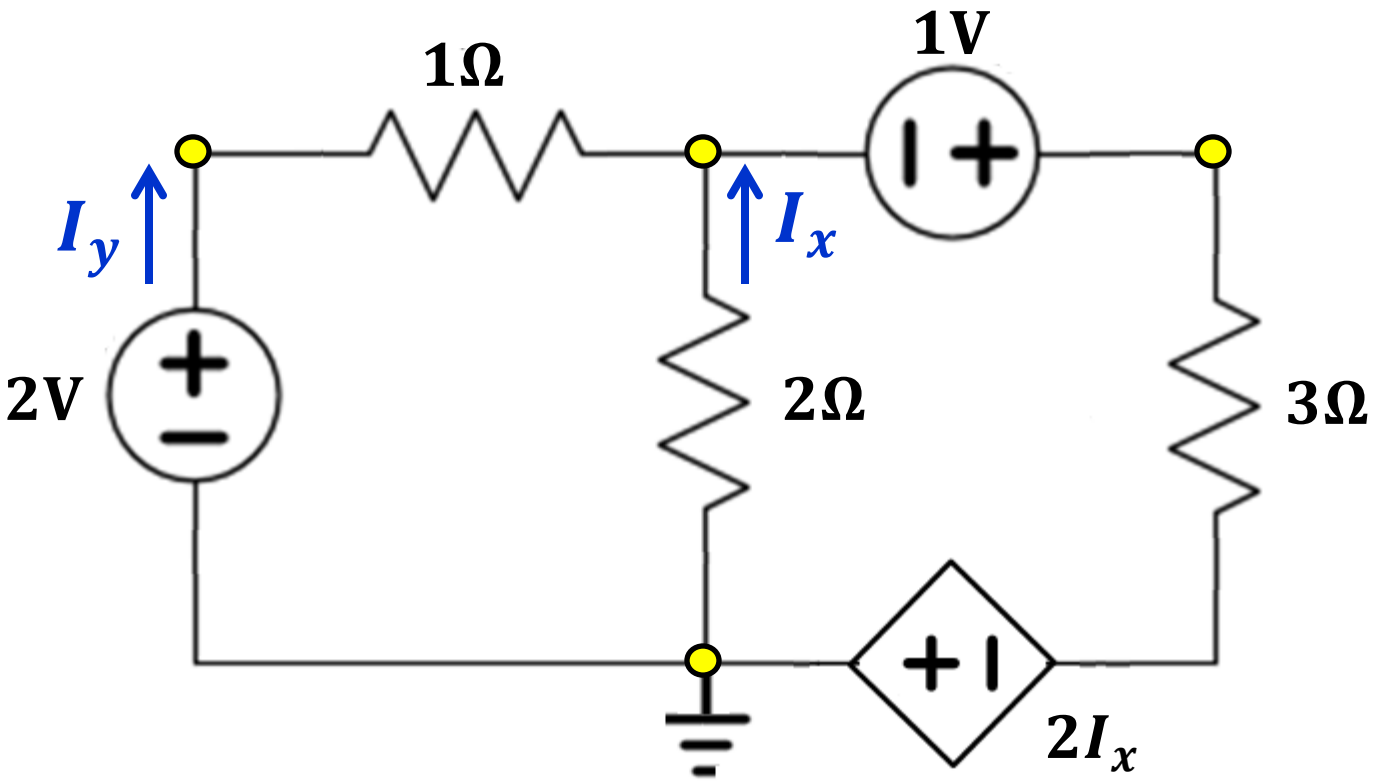
Node x $\quad V_x = V_y + 2V_x \rightarrow V_x = -V_y$

Supernode KCL $\quad \dfrac{V_y - 2}{2} + \dfrac{V_y}{1} + \dfrac{V_x}{4} = 0$ $\Rightarrow$ $V_y = \dfrac{4}{5}V$

$V_x = -\dfrac{4}{5}V$

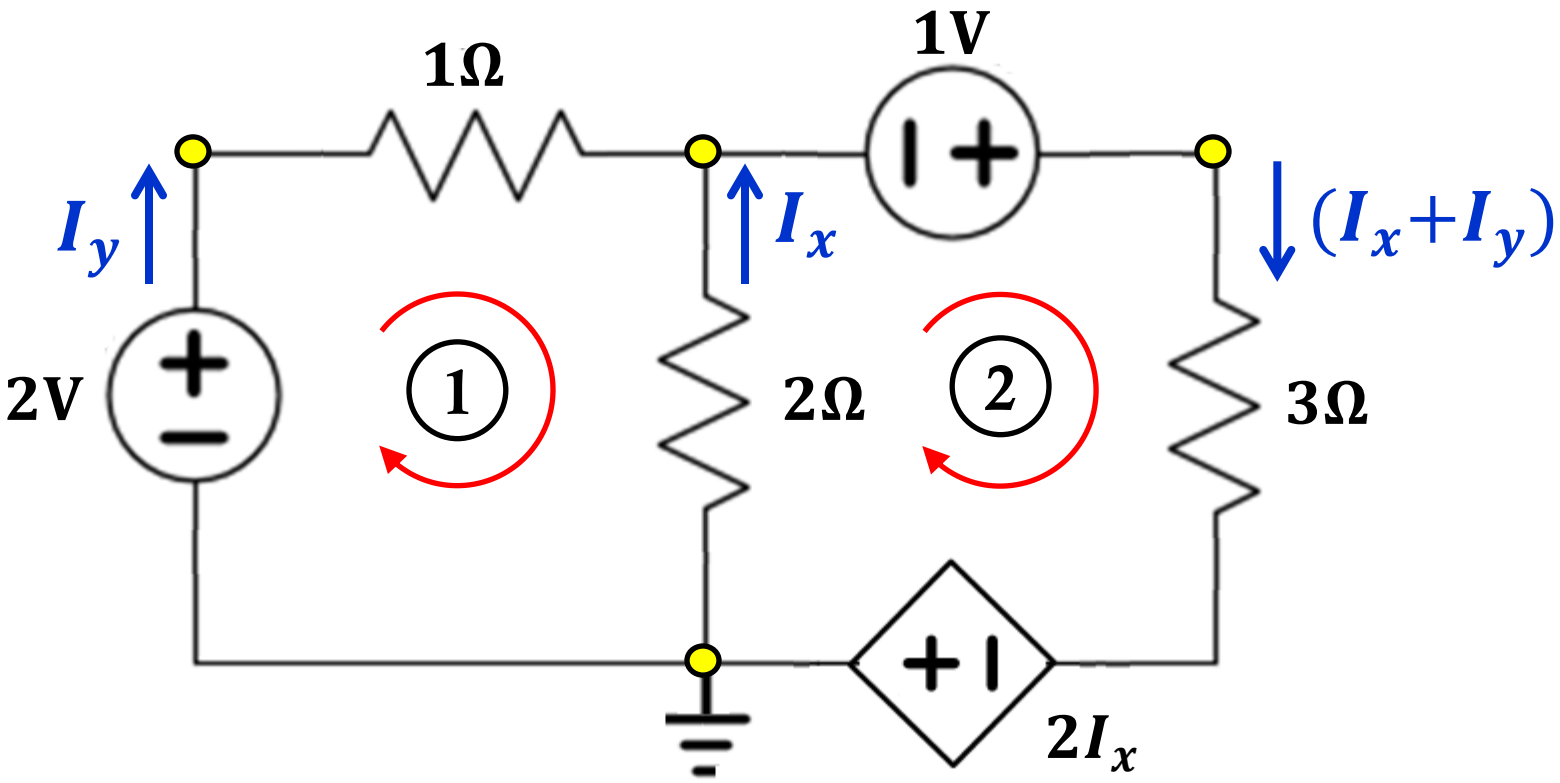
Example 5

Find I_x, I_y



Example 5

Find I_x, I_y

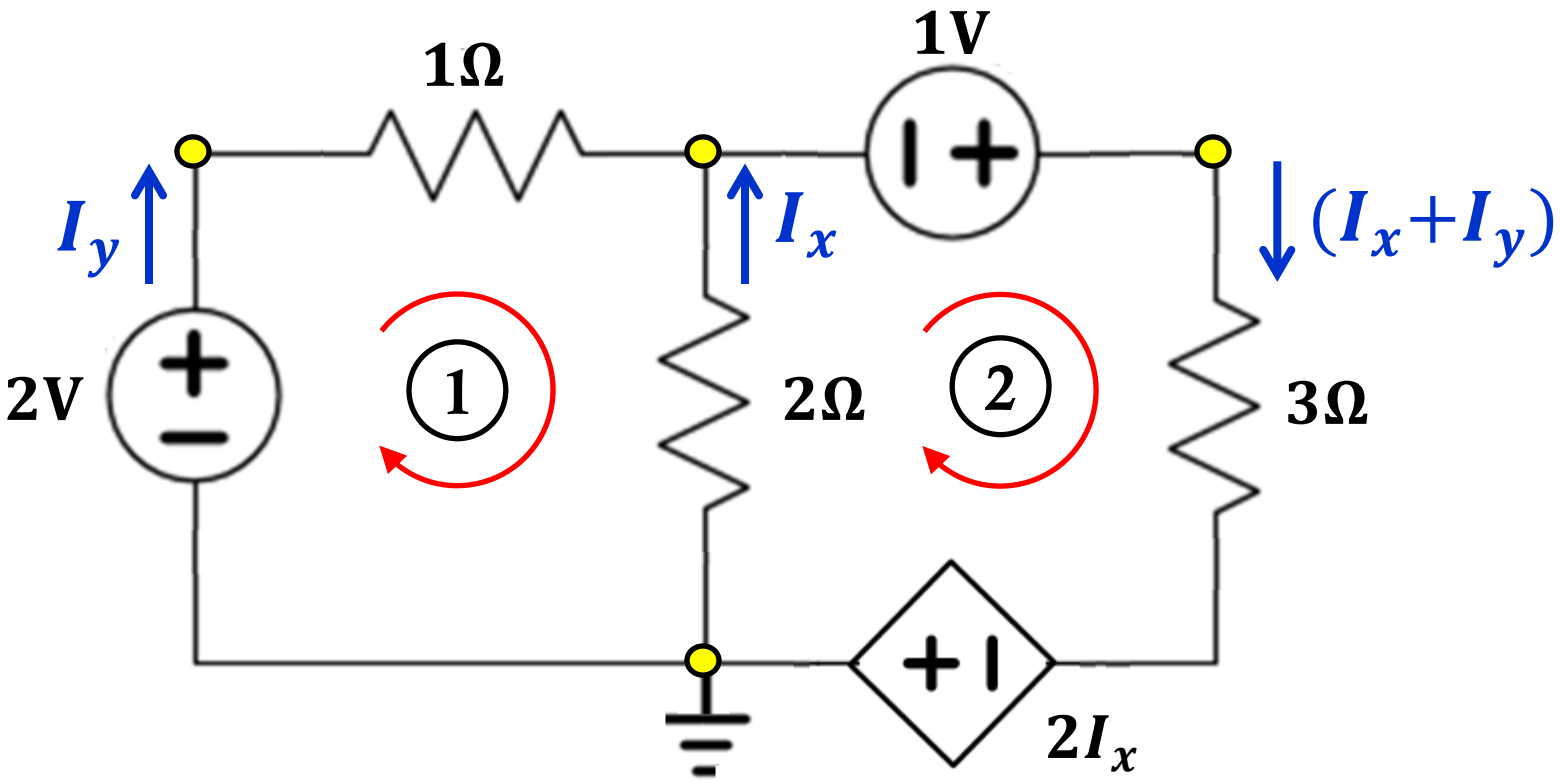


Loop (1) $-2\text{V} + 1\Omega\, I_y - 2\Omega\, I_x = 0$

Loop (2) $-1\text{V} + 3\Omega(I_x + I_y) - 2I_x + 2\Omega I_x = 0$

Example 5

Find I_x, I_y



Loop (1) $-2I_x + I_y = 2$

Loop (2) $I_x + I_y = 1/3$

Example 5

Find I_x, I_y

Loop ① $-2I_x + I_y = 2$

Loop ② $I_x + I_y = \frac{1}{3}$

① $I_y = 2 + 2I_x$

② $I_x + 2 + 2I_x = \frac{1}{3}$

$3I_x = -2 + \frac{1}{3} = -\frac{5}{3}$

$\Rightarrow \boxed{I_x = -\frac{5}{9}}$

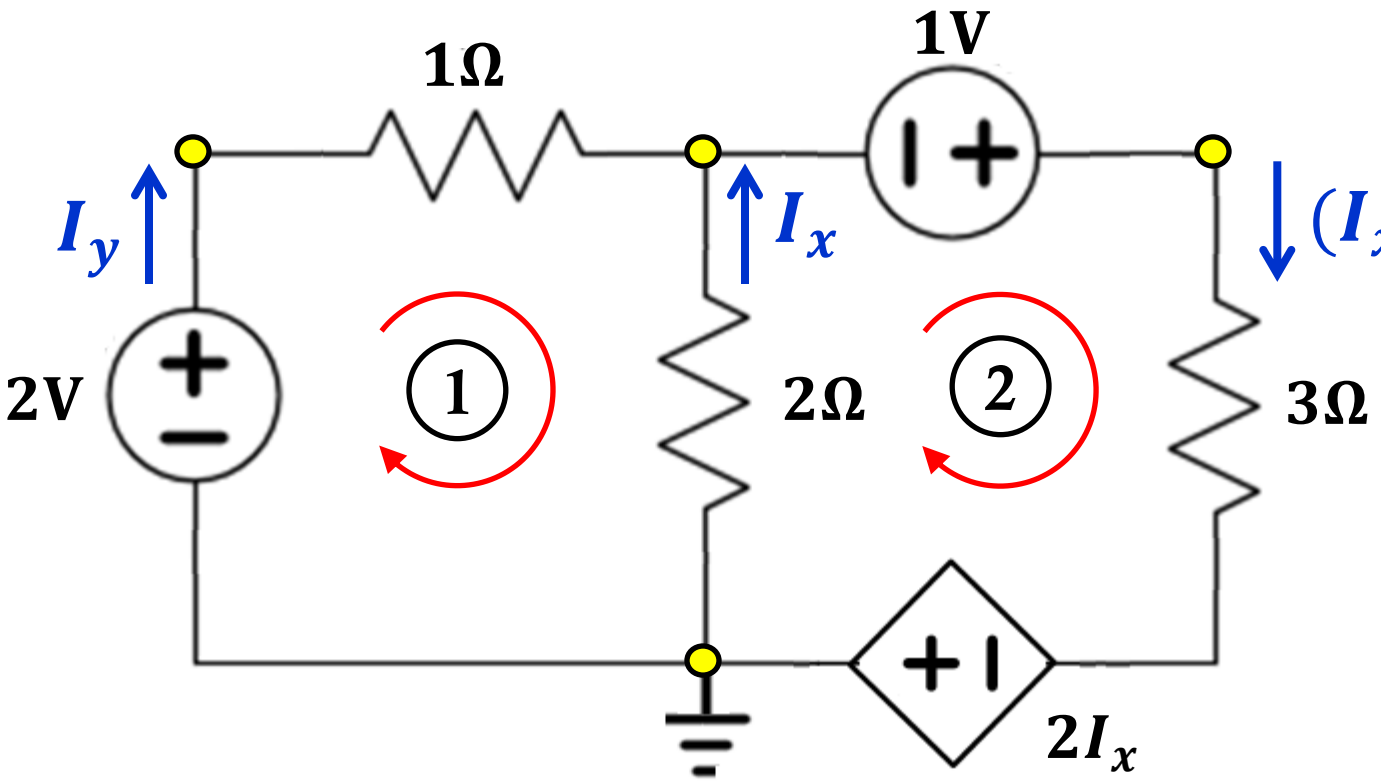
① $-2 \times \left(-\frac{5}{9}\right) + I_y = 2$

$I_y = 2 - \frac{10}{9}$

$\Rightarrow \boxed{I_y = \frac{8}{9}}$

Example 5

Verification



$$I_x = -\frac{5}{9}$$

$$I_y = \frac{8}{9}$$

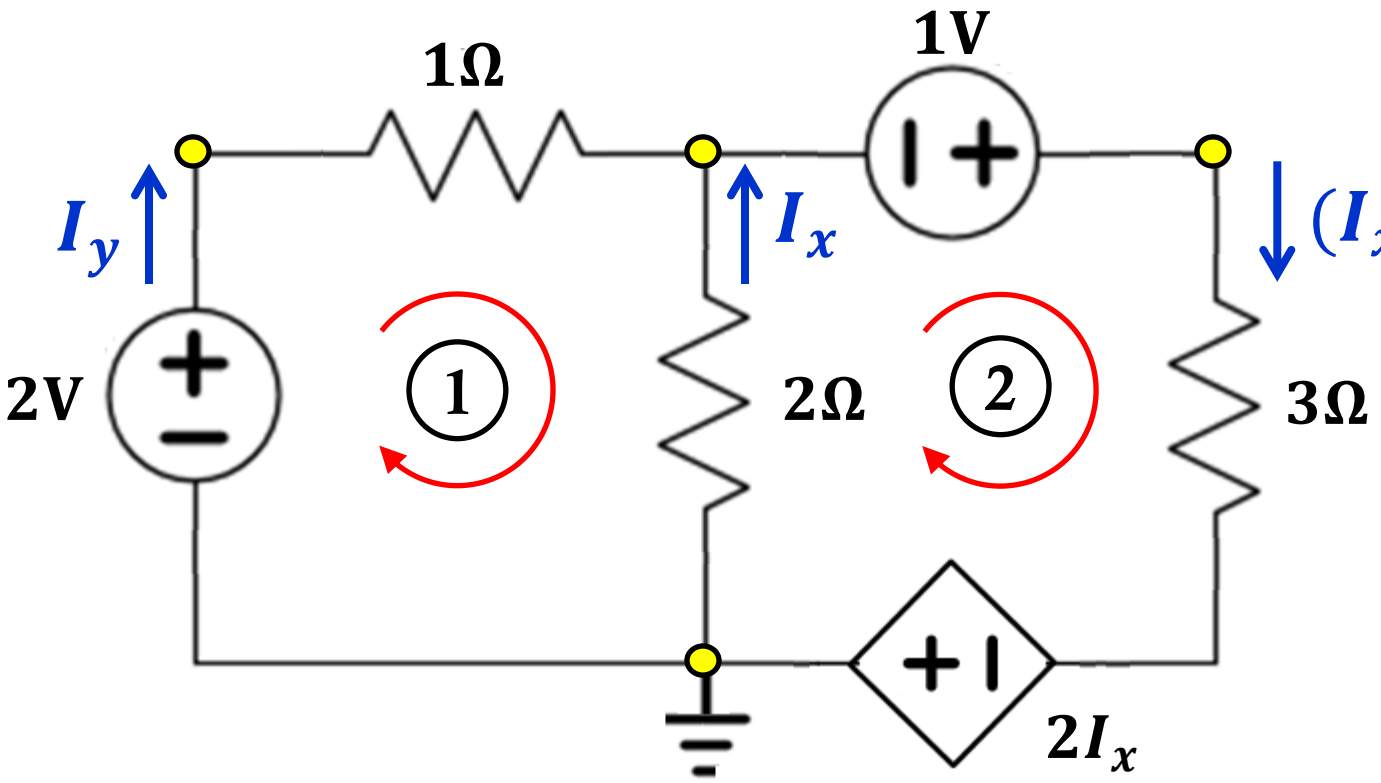
Loop (1) $-2 + I_y - 2I_x = 0$

$$-2 + \frac{8}{9} - 2\left(-\frac{5}{9}\right) = 0$$

$$-2 + 2 = 0$$

Example 5

Verification



$$I_x = -\frac{5}{9}$$

$$I_y = \frac{8}{9}$$

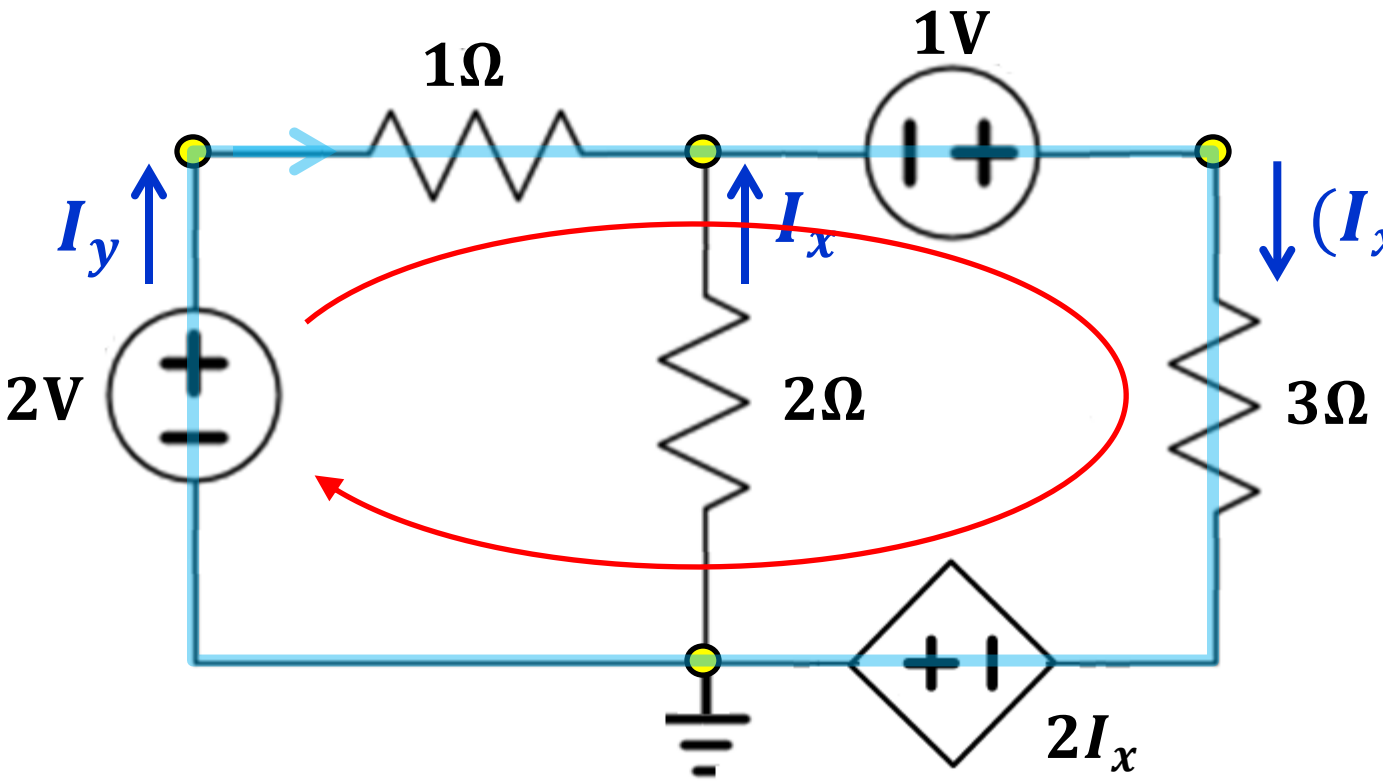
Loop (2) $-1 + 3(I_x + I_y) - 2I_x + 2I_x = 0$

$$-1 + 3\left(-\frac{5}{9} + \frac{8}{9}\right) = 0$$

$$-1 + 1 = 0$$

Example 5

Verification



$$I_x = -\frac{5}{9}$$

$$I_y = \frac{8}{9}$$

Superloop $-2 + I_y - 1 + 3(I_x + I_y) - 2I_x = 0$

$$-2 + \frac{8}{9} - 1 + 3\left(-\frac{5}{9} + \frac{8}{9}\right) - 2\left(-\frac{5}{9}\right) = 0$$

$$-3 + 27/9 = -3 + 3 = 0$$