ECE 2300
Circuit Analysis

Circuit analysis made easy
Part III: KVL, KCL, and Ohm's Law

University of Houston
Len Trombetta

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

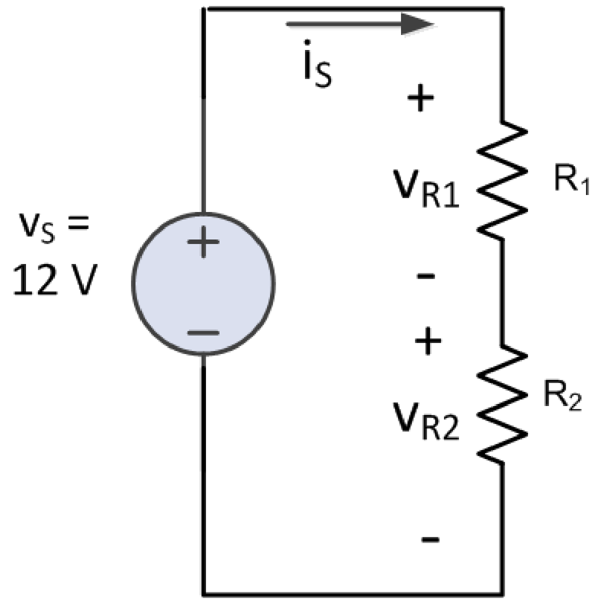
WHERE WE'RE GOING…

de la Rosa-Pohl

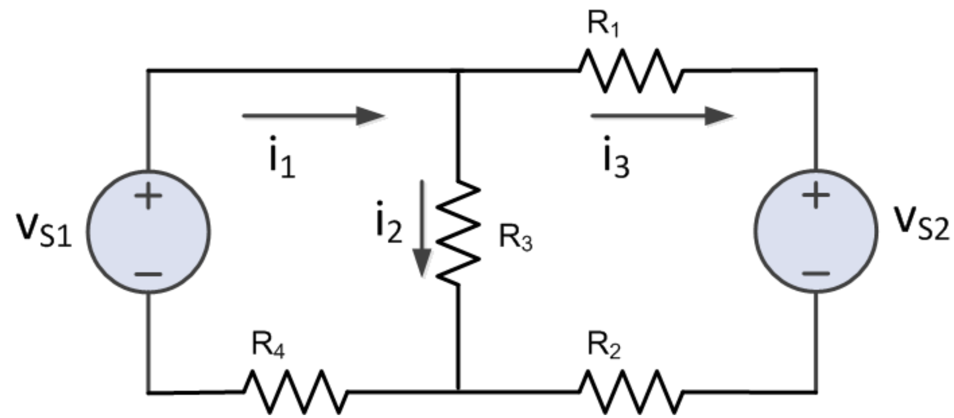
UNIVERSITY OF HOUSTON
Learning. Leading.

Where Are We Going?

Where we've been:

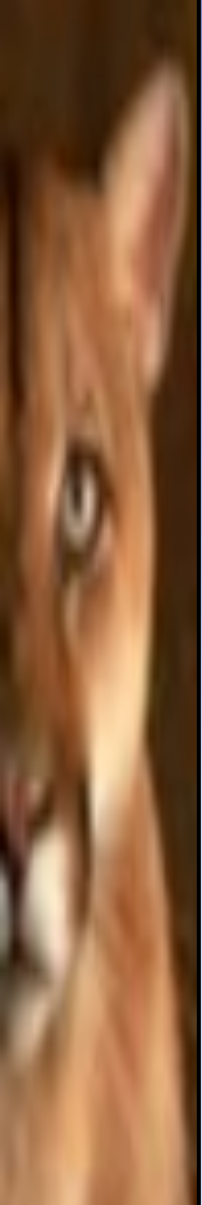


Where we're going:



This is a simple circuit with one loop, and one current. We analyzed it using KVL and Ohm's Law.

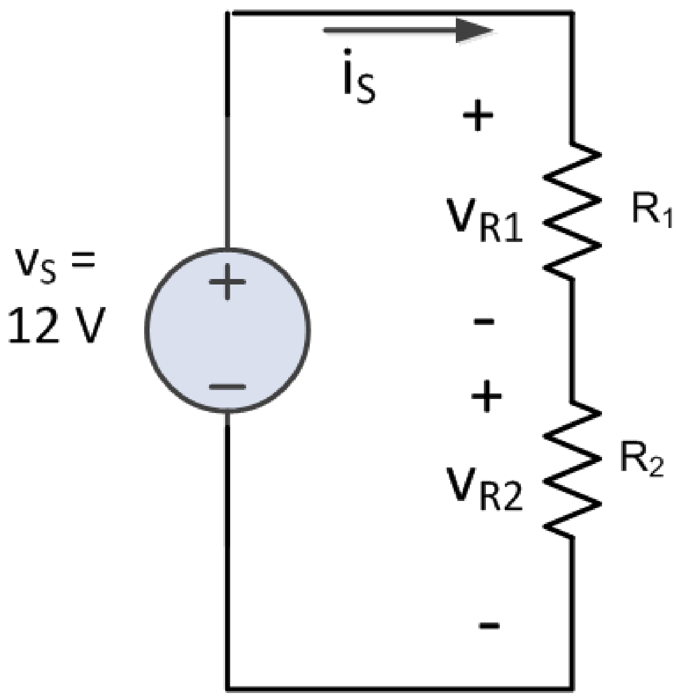
We will analyze circuits like this one, which has three currents. This will require Kirchhoff's Current Law (KCL).



VOLTAGE DIVIDER RULE

de la Rosa-Pohl

Voltage Divider Rule



- Ohm's Law and KVL give us the following equations…

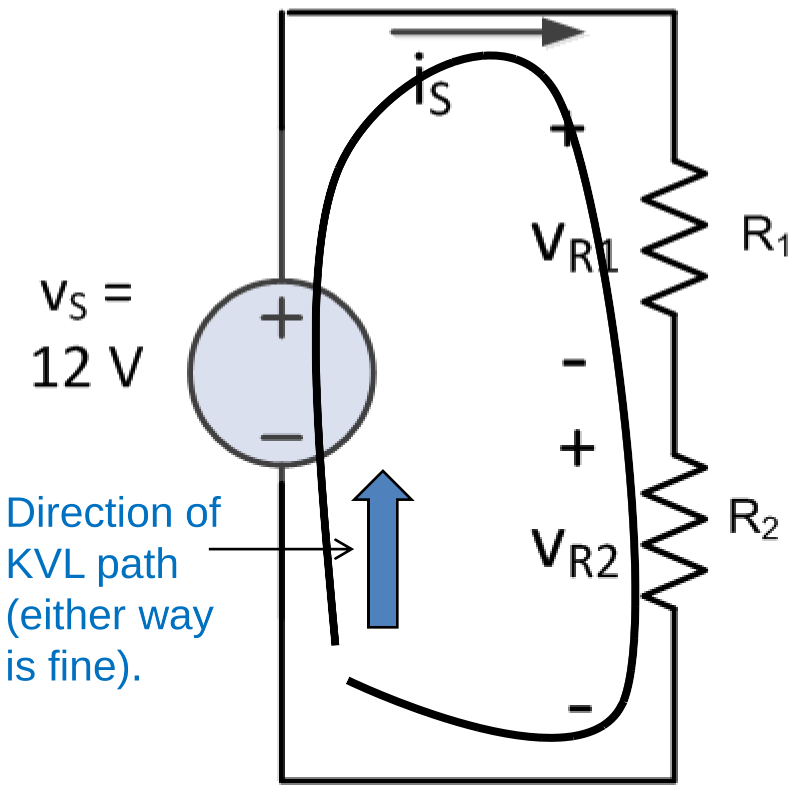
$$v_{R1} = v_S\left(\frac{R1}{R1+R2}\right)$$

$$v_{R2} = v_S\left(\frac{R2}{R1+R2}\right)$$

How can we derive those results?

de la Rosa-Pohl
UNIVERSITY OF HOUSTON
Learning. Leading.

Voltage Divider Rule



KVL

$$v_S = v_{R1} + v_{R2}$$

Ohm's Law

$$v_{R1} = i_S R_1 \qquad v_{R2} = i_S R_2$$

Algebra

$$i_S = \frac{v_S}{R_1 + R_2}$$

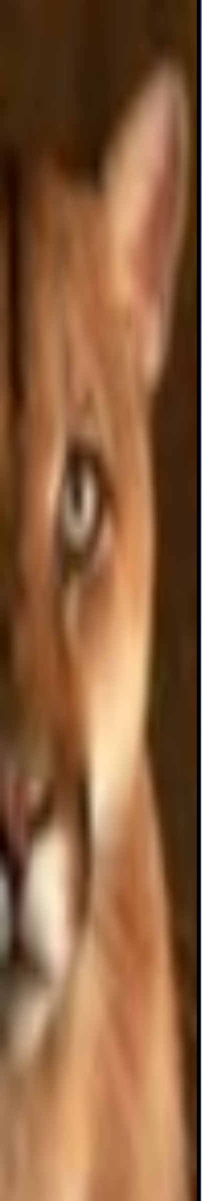
Then…

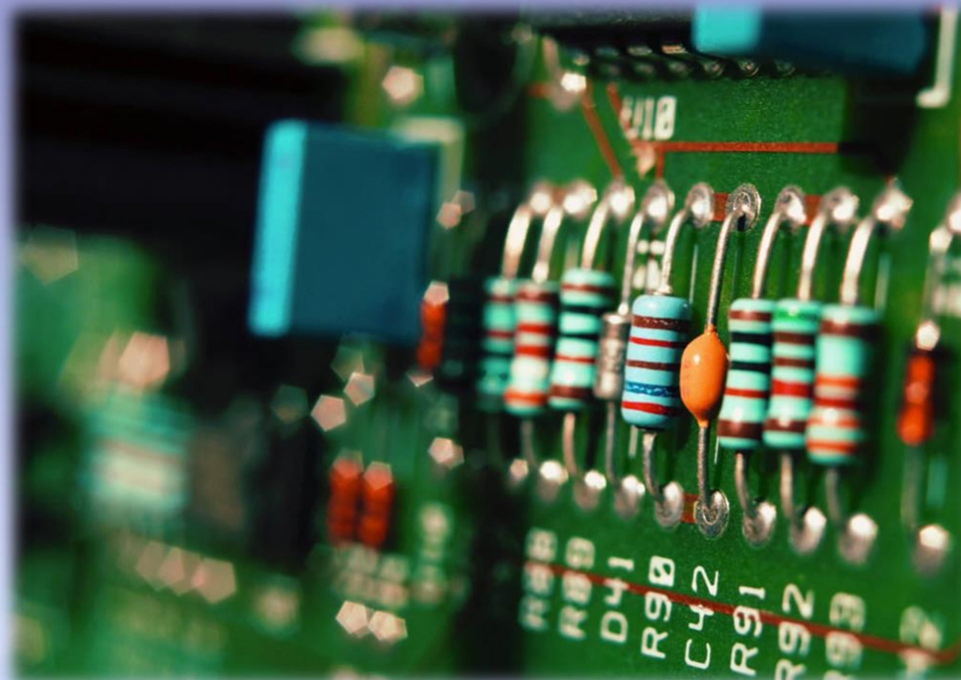
$$v_{R1} = i_S R_1$$

Finally…

$$v_{R1} = v_S \left(\frac{R_1}{R_1 + R_2} \right)$$

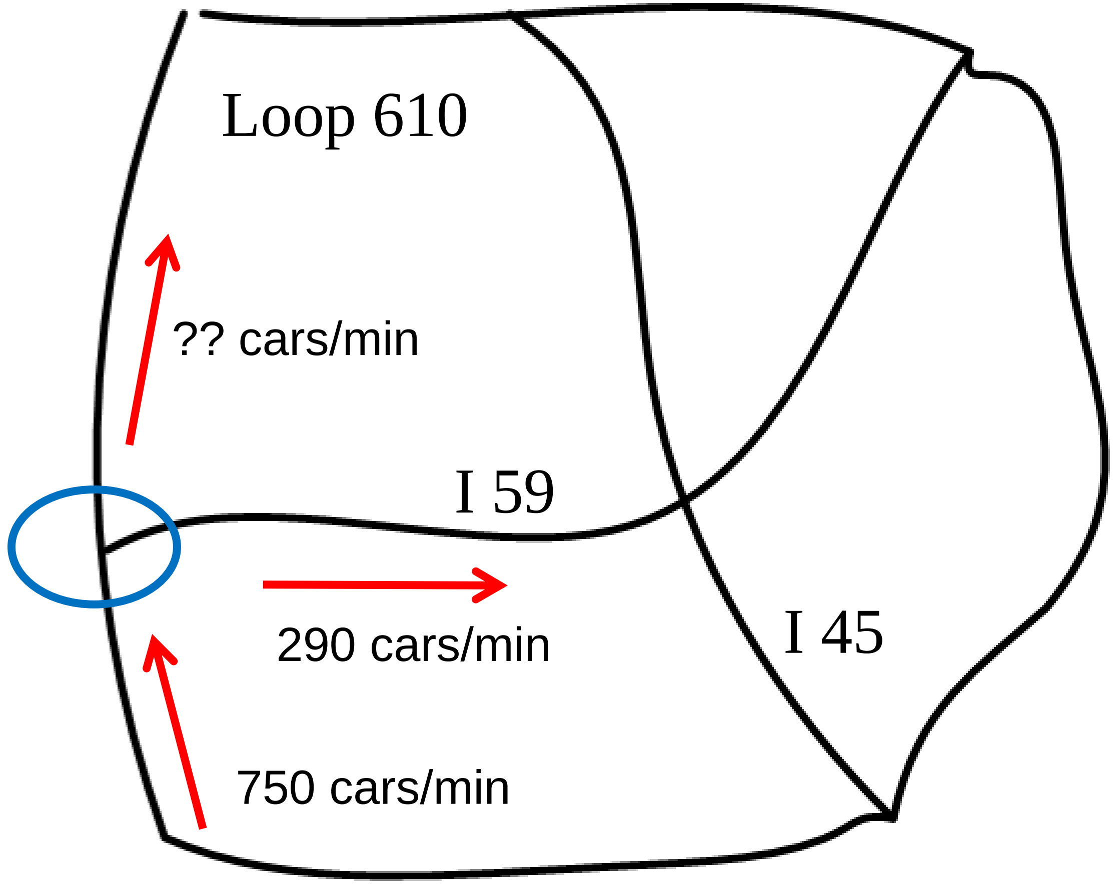
de la Rosa-Pohl
UNIVERSITY OF HOUSTON
Learning. Leading.





KIRCHHOFF'S CURRENT LAW

Houston Traffic

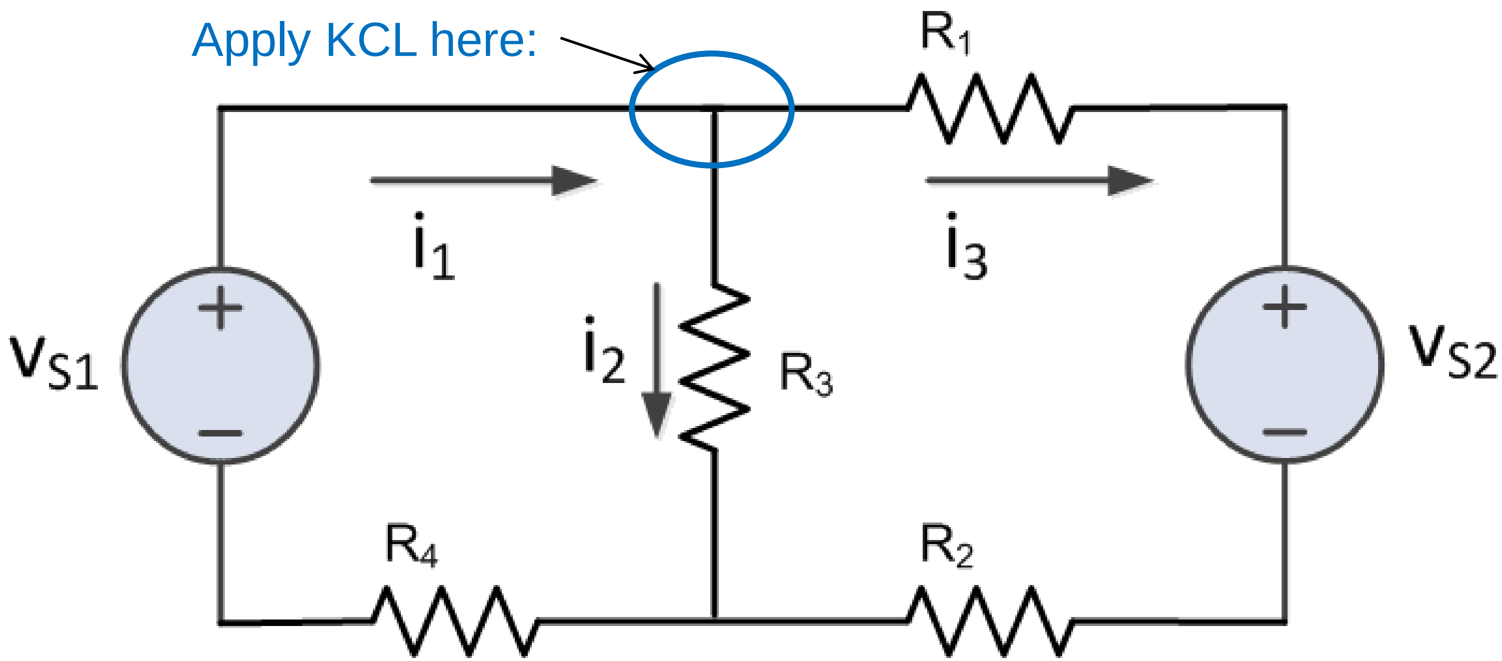


Kirchhoff's Current Law:

in = out

All other roads are closed for repairs!

Kirchhoff's Current Law



What current is flowing in R_4? …R_2?...v_{S2}…v_{S1}?

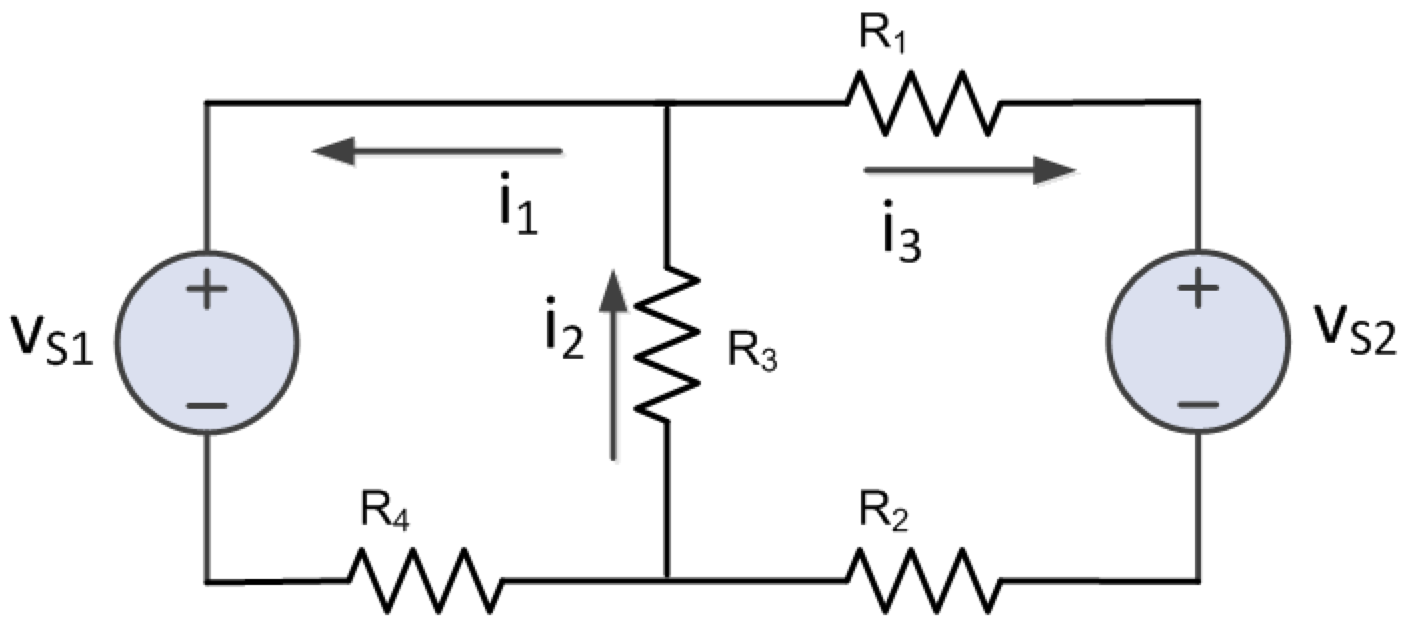
What is the relationship between i_1, i_2, and i_3?

KCL: $i_1 = i_2 + i_3$

In = out

Kirchhoff's Current Law

What if we had drawn it this way? Now what is KCL?

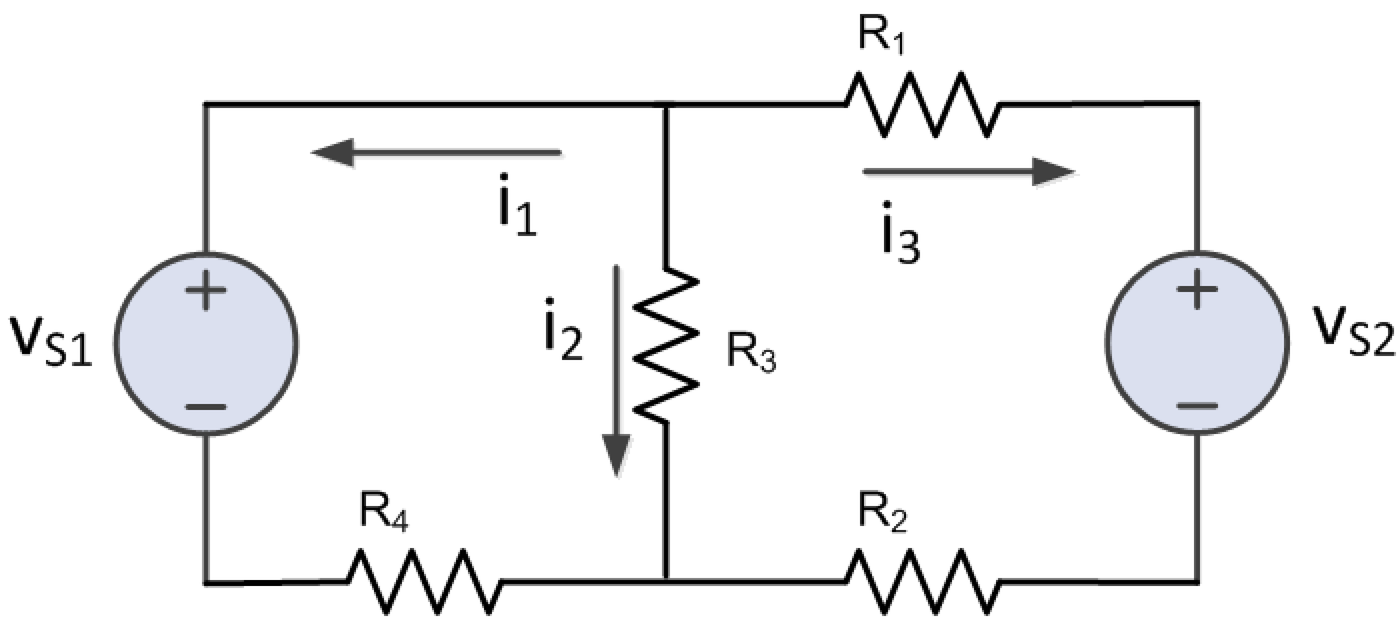


KCL: $i_2 = i_1 + i_3$

in = out

Kirchhoff's Current Law

Can I do THIS????



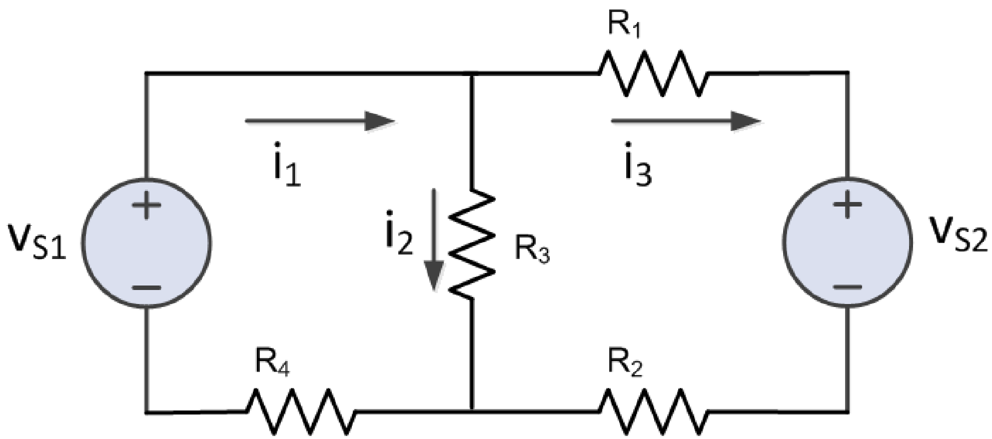
Sure!!

in = out

KCL: $0 = i_2 + i_1 + i_3$

de la Rosa-Pohl
UNIVERSITY OF HOUSTON
Learning. Leading.

Kirchhoff's Current Law



Find the indicated currents…

i_1 = 70 mA
i_2 = 15 mA
i_3 = ??

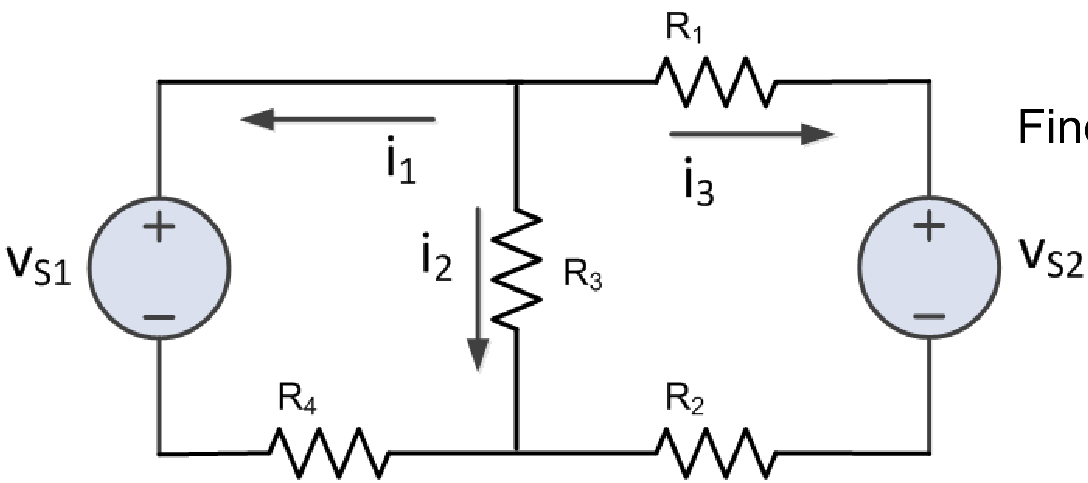
i_1 = -24 mA
i_2 = ??
i_3 = 10 mA

i_1 = ??
i_2 = 0.25 mA
i_3 = 0.20 mA

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

Kirchhoff's Current Law



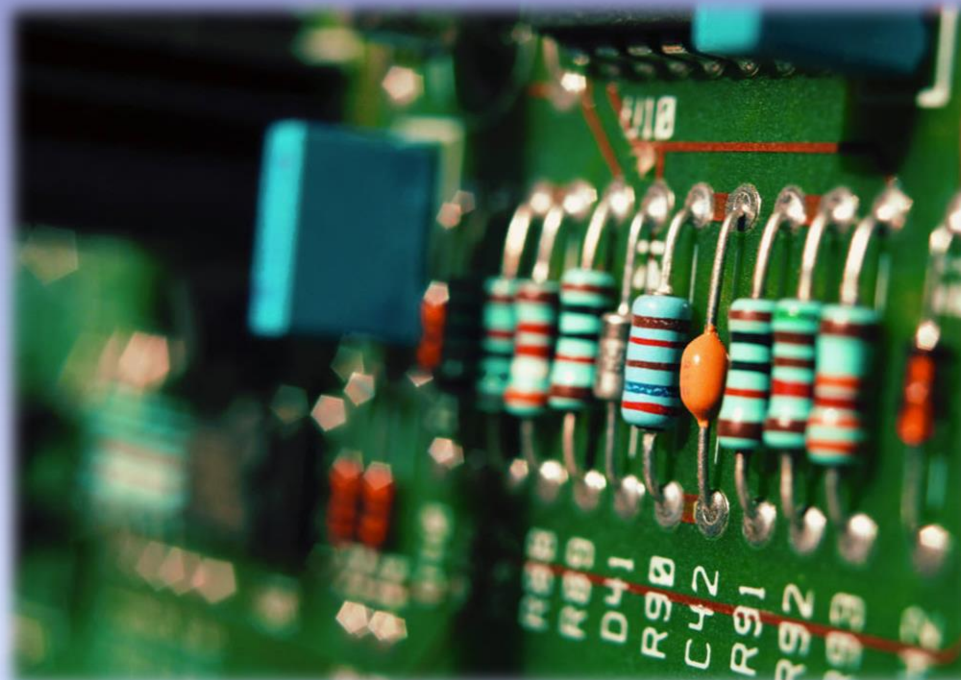
Find the indicated currents…

i_1 = 240 mA
i_2 = -150 mA
i_3 = ??

i_1 = -240 mA
i_2 = ??
i_3 = 150 mA

i_1 = ??
i_2 = 0.75 mA
i_3 = 0.20 mA

de la Rosa-Pohl

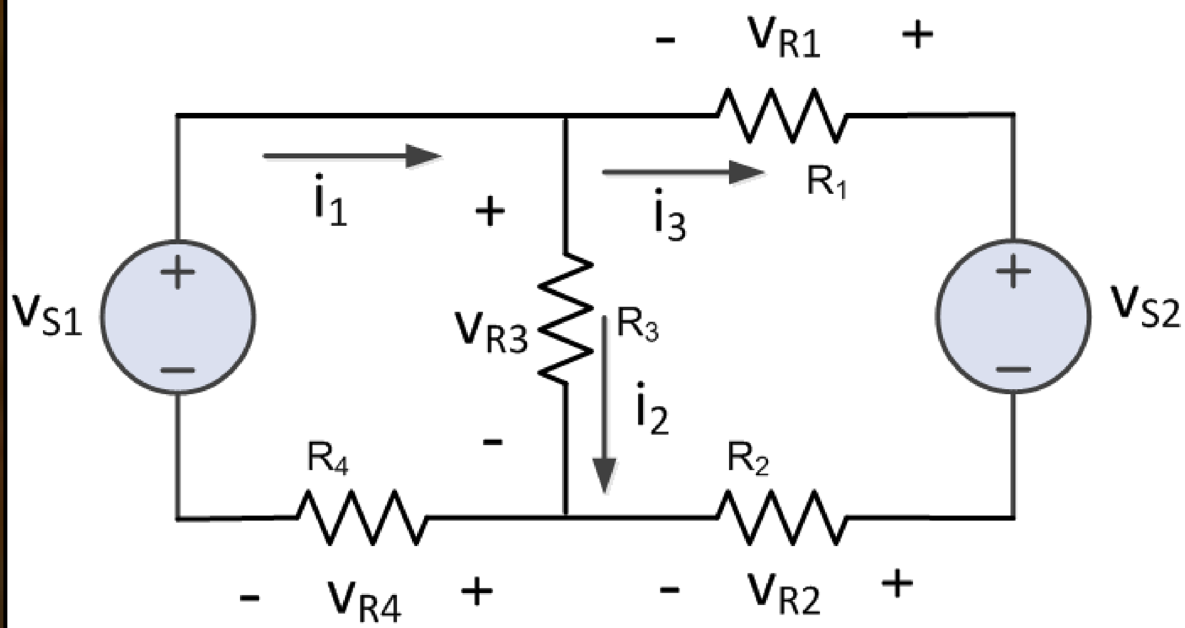


CIRCUIT ANALYSIS USING KVL, KCL, AND OHM'S LAW

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

Analyze This!



Usually we know the voltage source values and the resistor values. We will assume that here.

How many KVL's can we write for this circuit?

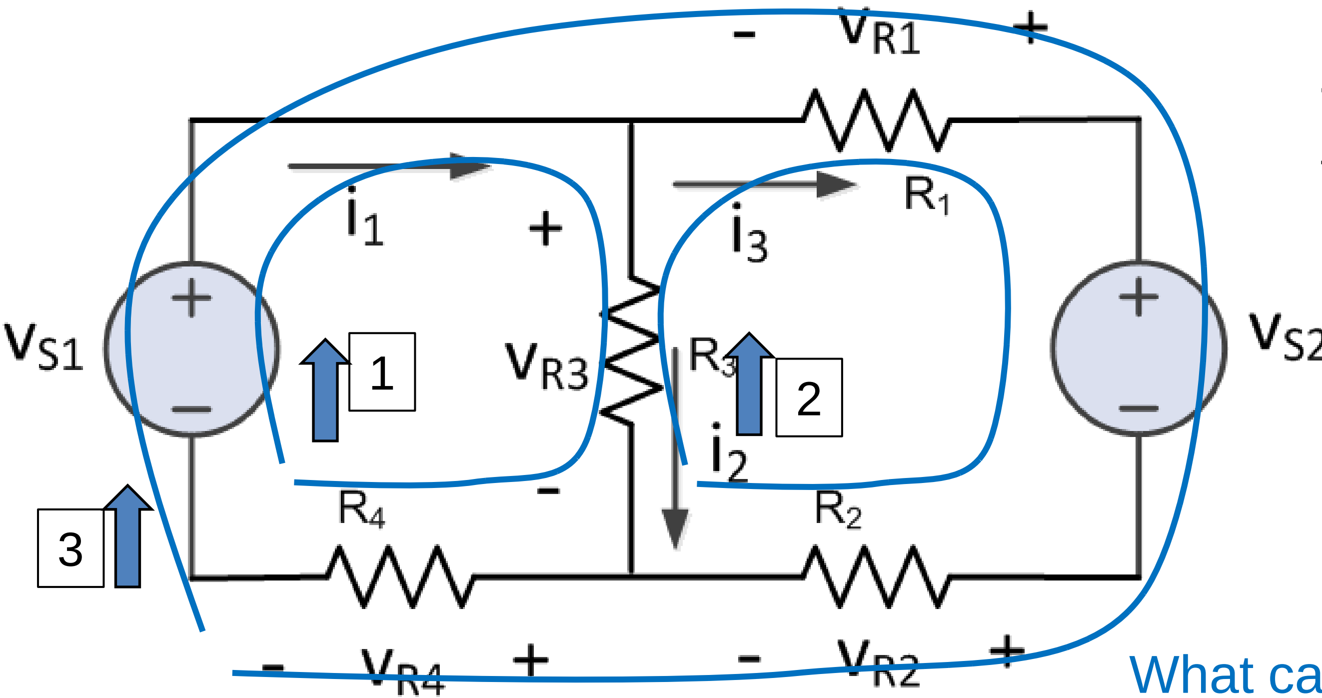
\# of KVL's: 3

How many KCL's can we write for this circuit?

\# of KCL's: 2

de la Rosa-Pohl

Let’s Do It: KVL



There are three possible KVL paths.

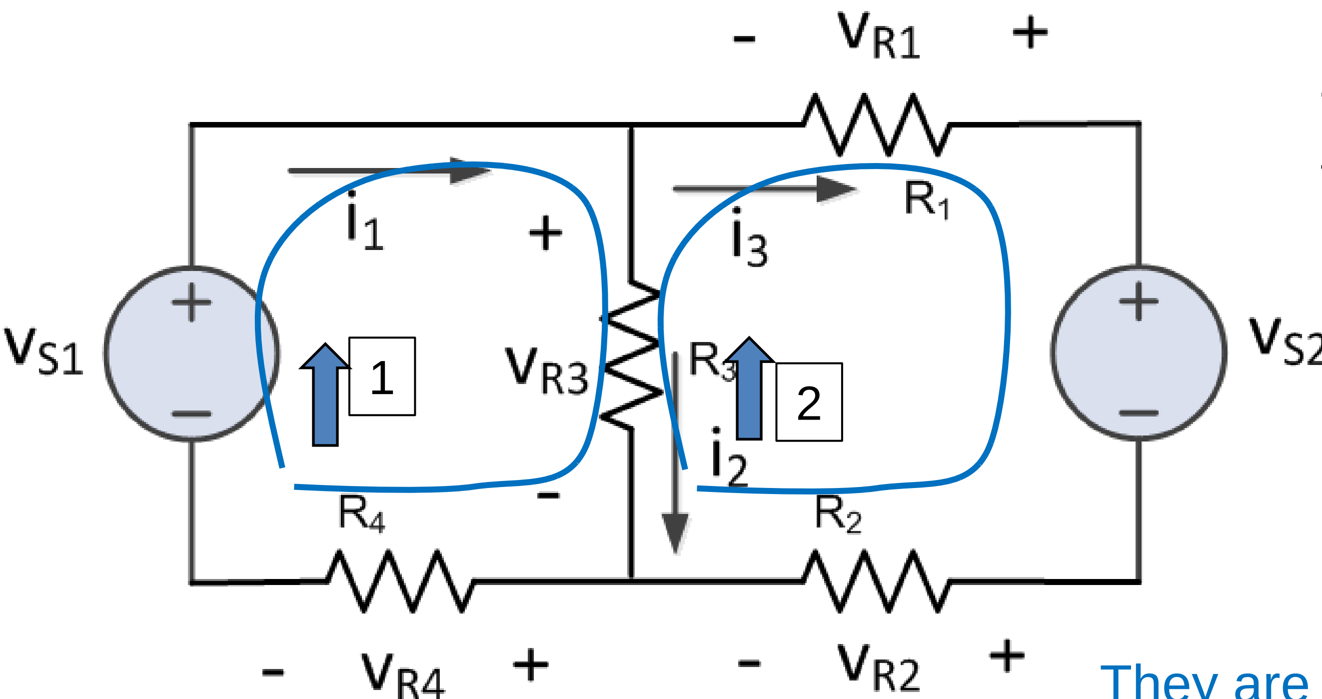
What can we way about the relationship among these three equations?

1 $$-v_{S1} + v_{R3} + v_{R4} = 0$$

2 $$-v_{R3} - v_{R1} + v_{S2} + v_{R2} = 0$$

3 $$-v_{S1} - v_{R1} + v_{S2} + v_{R2} + v_{R4} = 0$$

Let's Do It: KVL



There are three possible KVL paths.

They are not algebraically independent – we can only use two of them (any two will do).

1 $$-v_{S1} + v_{R3} + v_{R4} = 0$$

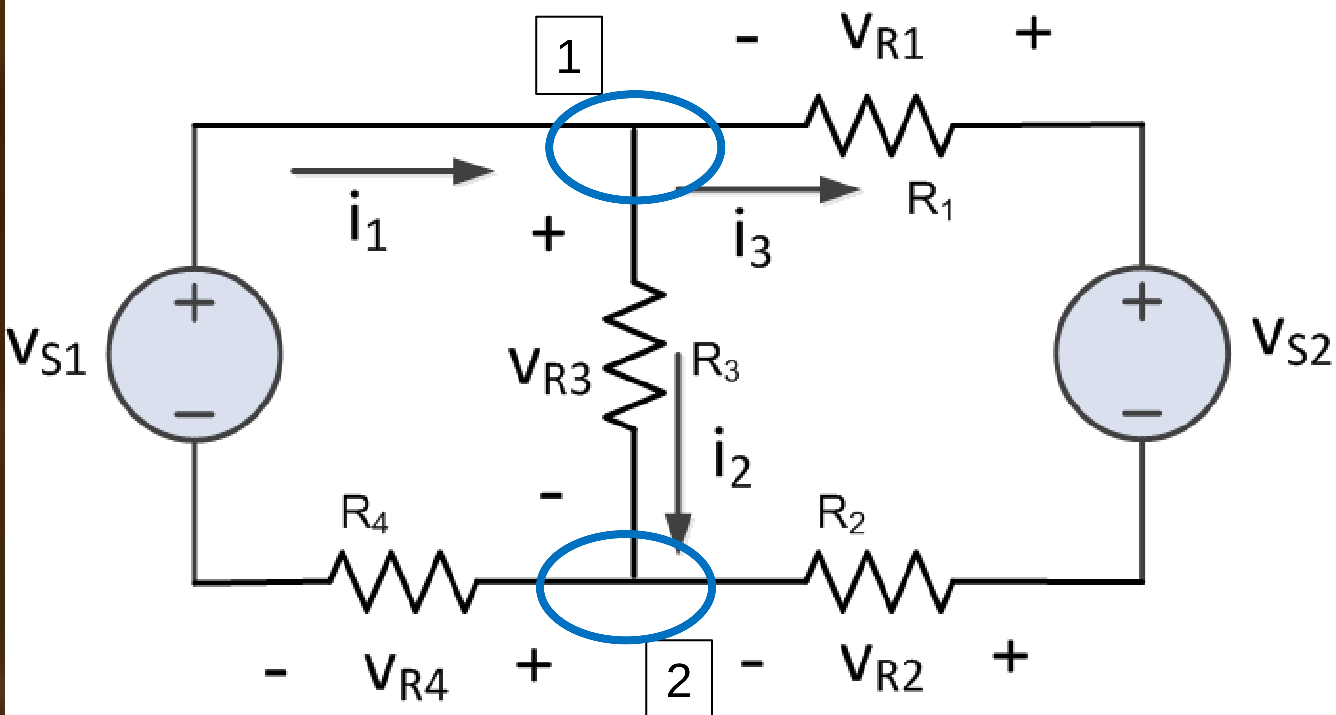
2 $$-v_{R3} - v_{R1} + v_{S2} + v_{R2} = 0$$

~~3 $-v_{S1} - v_{R1} + v_{S2} + v_{R2} + v_{R2} = 0$~~

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

Let's Do It: KCL



There are two nodes for KCL.

1 $i_1 = i_2 + i_3$

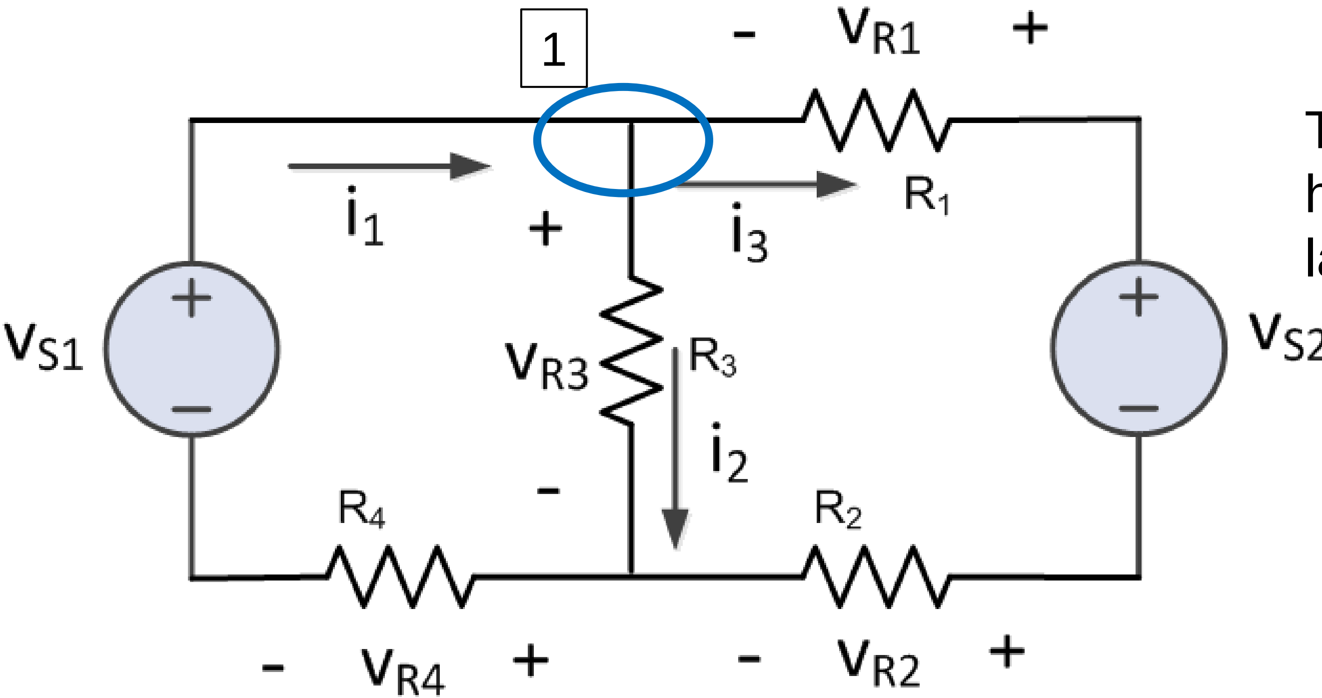
2 $i_2 + i_3 = i_1$

What can we say about these two KCL equations?

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

Let’s Do It: KCL



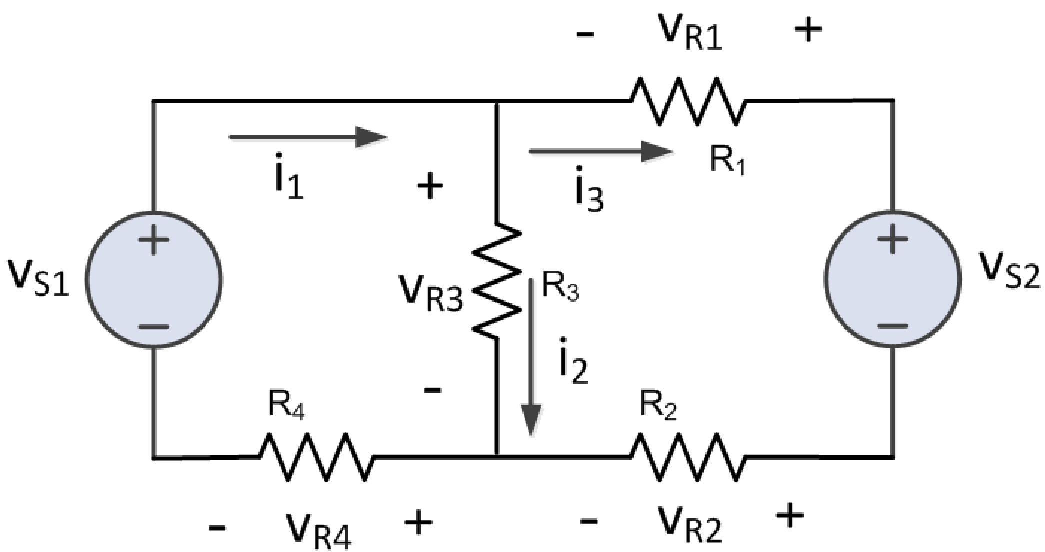
Two nodes have been labeled.

1 $i_1 = i_2 + i_3$

~~2 $i_2 + i_3 = i_1$~~

They are algebraically identical. We can only use one of them.

Let's Do It: KCL and KVL



We have three equations: 2 KVL's and 1 KCL.

Remember: we assume we know the voltage sources and resistor values.

1. $i_1 = i_2 + i_3$

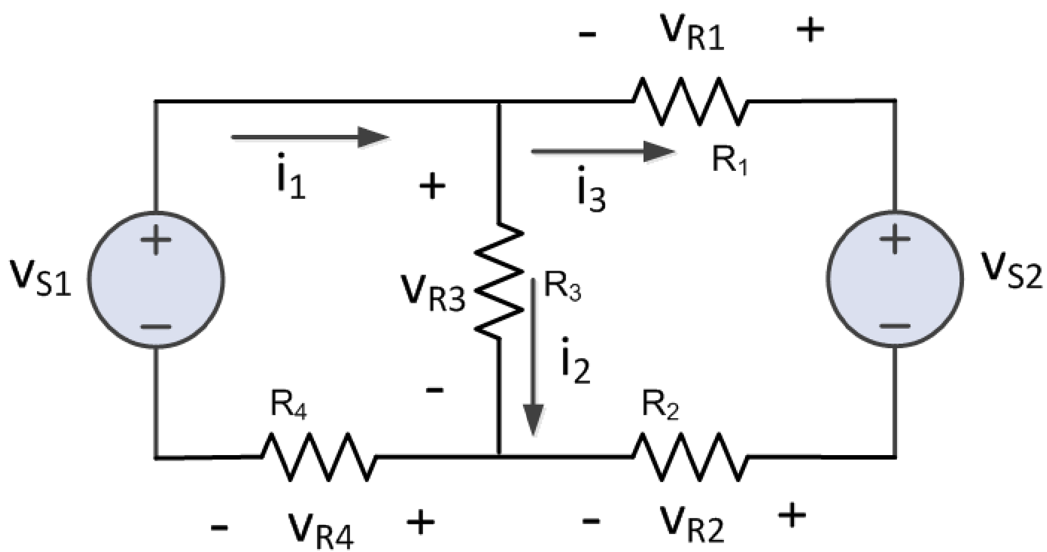
2. $-v_{S1} + v_{R3} + v_{R4} = 0$

3. $-v_{R3} - v_{R1} + v_{S2} + v_{R2} = 0$

But now what? We have too many unknowns to go further – the resistor voltages and the three currents are all unknown.

de la Rosa-Pohl

Ohm's Law!!



$$v_{R1} = -i_3 R_1$$

$$v_{R2} = i_3 R_2$$

$$v_{R3} = i_2 R_3$$

$$v_{R4} = i_1 R_4$$

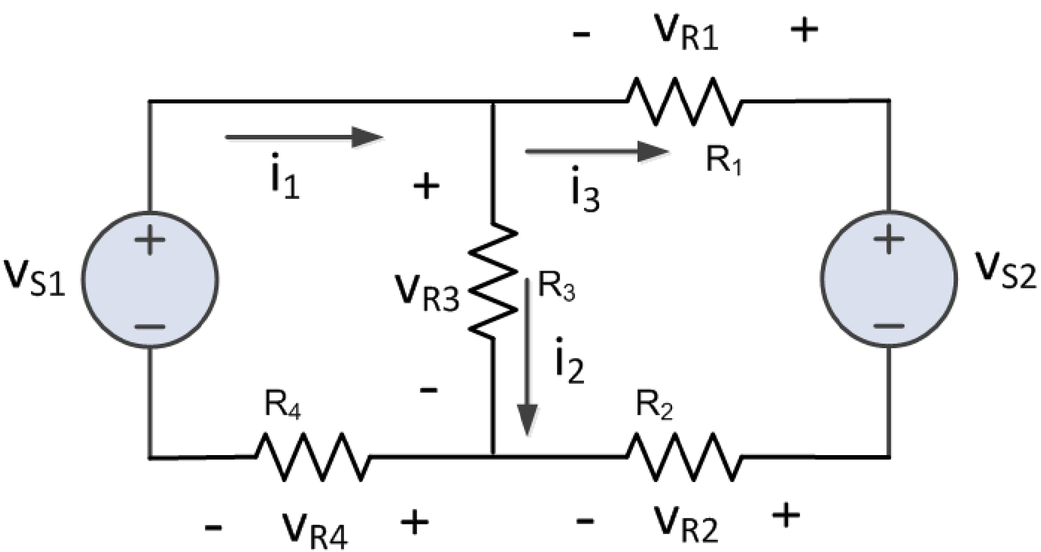
We can use Ohm's Law to eliminate the resistor voltages…watch the signs!

Substitute these equations into KVL and get…

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

Let's Do It: KCL and KVL



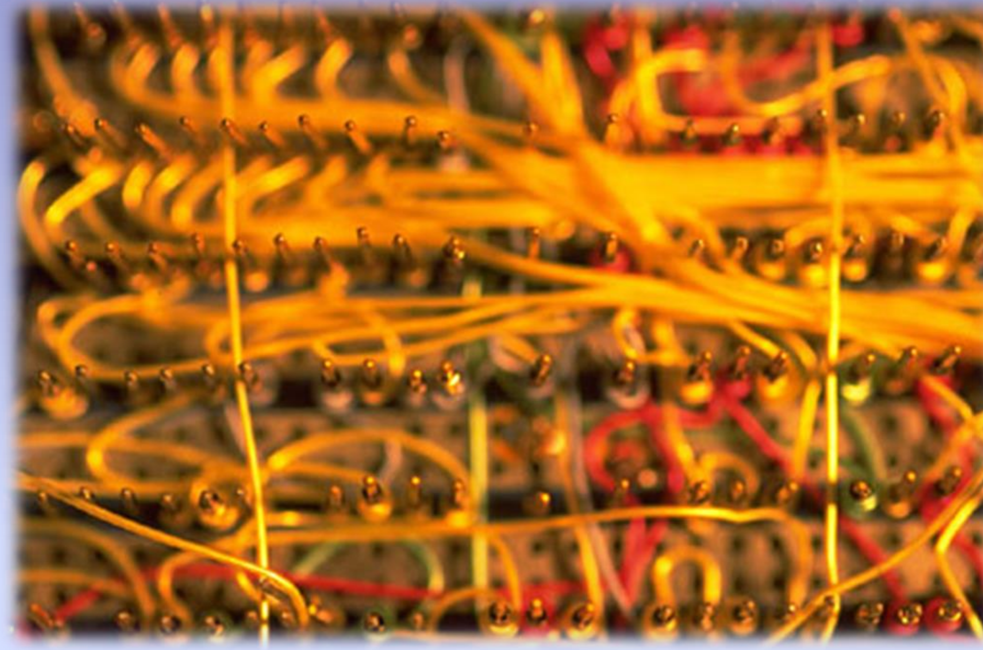
Now we have three equations in three unknown currents! We can solve for the currents and then use Ohm's Law to get the resistor voltages.

1 $i_1 = i_2 + i_3$

2 $-v_{S1} + i_2 R_3 + i_1 R_4 = 0$

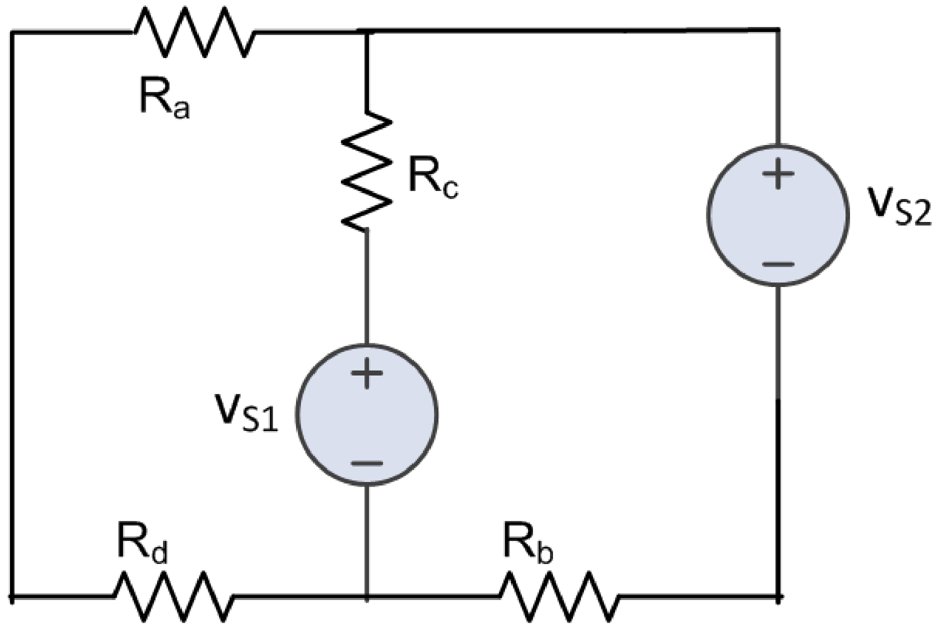
3 $-i_2 R_3 + i_3 R_1 + v_{S2} + i_3 R_2 = 0$

de la Rosa-Pohl



YOU TRY!

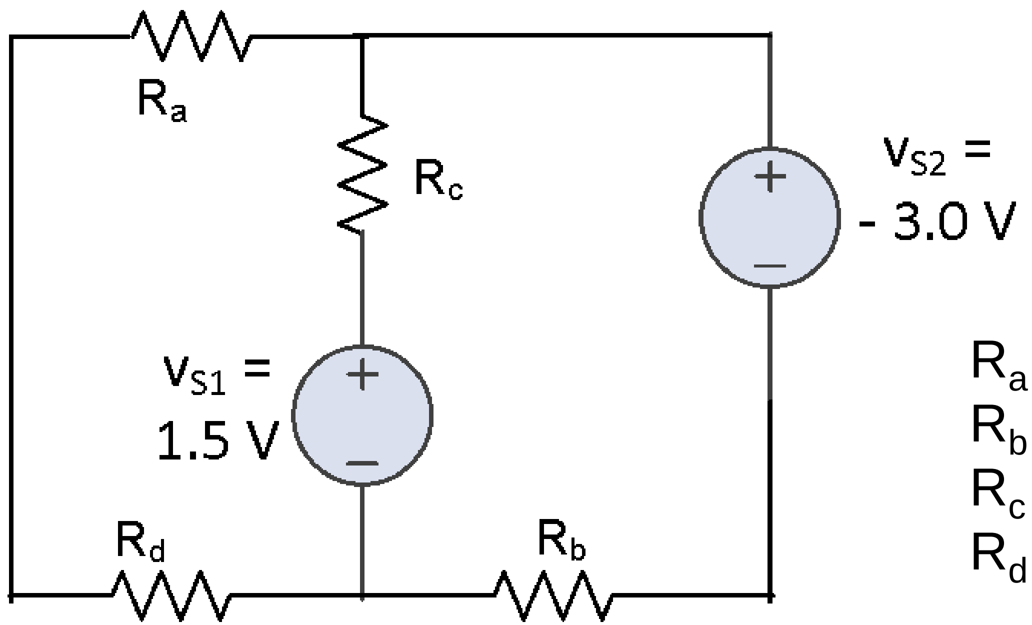
You Try!



1. Label 3 currents and all resistor voltages. Watch the label rules!
2. Write 2 KVL equations and 1 KCL equation.
3. Write Ohm's Law for each of the resistor voltage variables.
4. Re-write your equations in terms of three unknown currents.

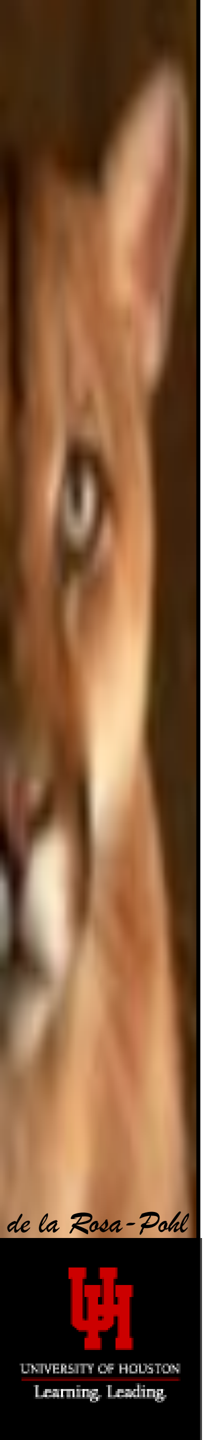
de la Rosa-Pohl

Numerical Values

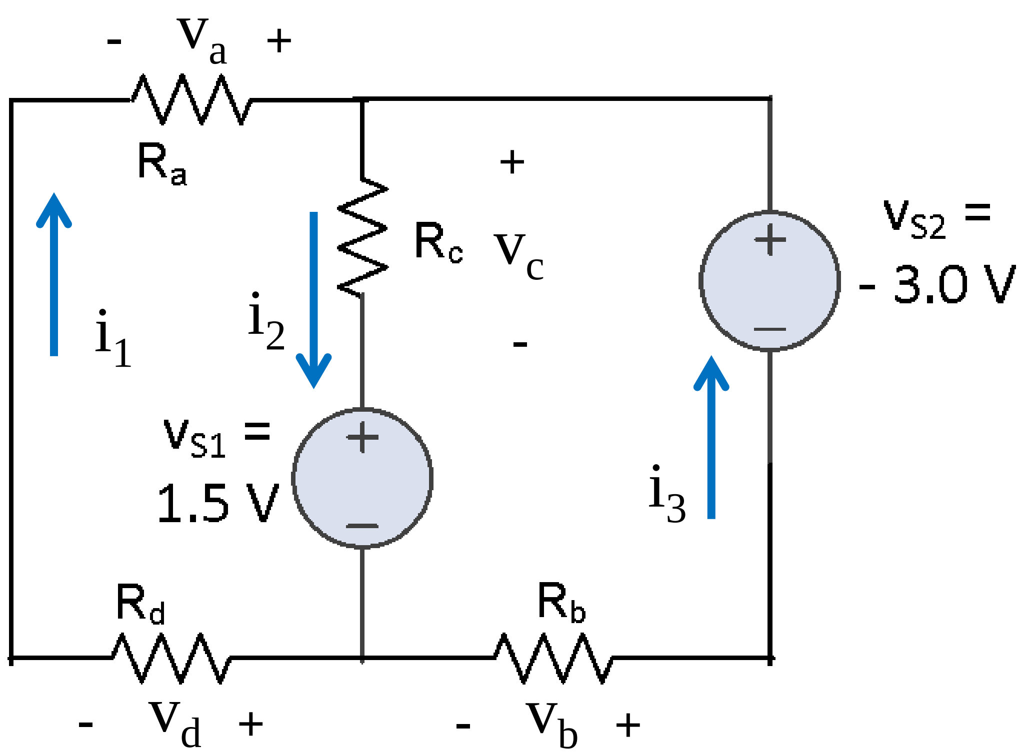


R_a = 1.1 [kΩ]
R_b = 4.7 [kΩ]
R_c = 150 [Ω]
R_d = 2.2 [kΩ]

de la Rosa-Pohl



My Answers



$R_a = 1.1$ [kΩ]
$R_b = 4.7$ [kΩ]
$R_c = 150$ [Ω]
$R_d = 2.2$ [kΩ]

If your currents and voltages are labeled the way I have them, then the circuit variables are…

$i_1 = -0.39497$ [mA]
$i_2 = -1.31070$ [mA]
$i_3 = -0.91562$ [mA]

$v_a = 0.4345$ [V]
$v_b = 4.3034$ [V]
$v_c = -0.1966$ [V]
$v_d = -0.8689$ [V]

If you have labeled things differently, your results will be different.

The End

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.