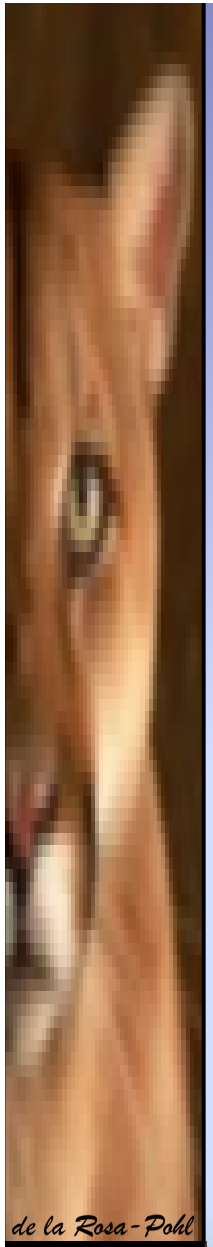


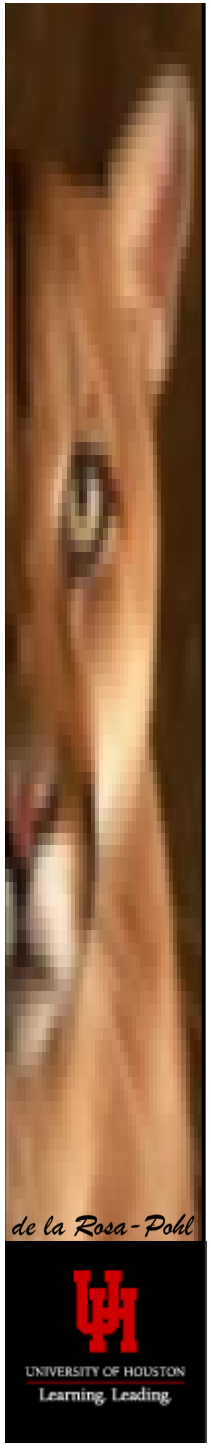
UNIVERSITY OF HOUSTON
Learning. Leading.

ECE 1100H
Introduction to Engineering

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

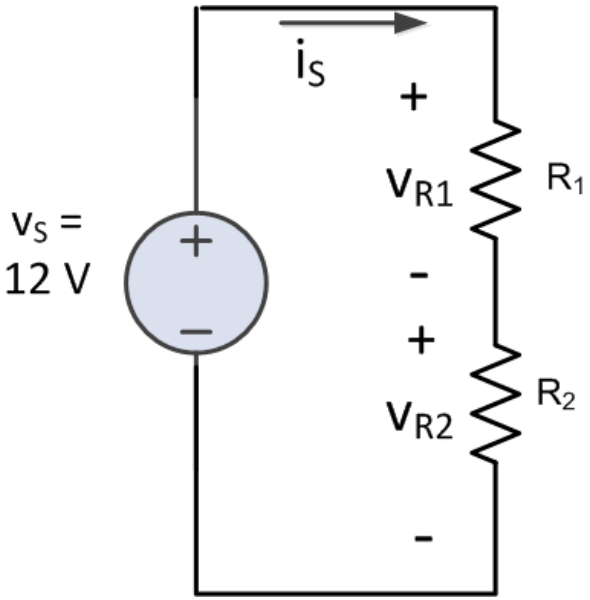
University of Houston
Len Trombetta

WHERE WE'RE GOING



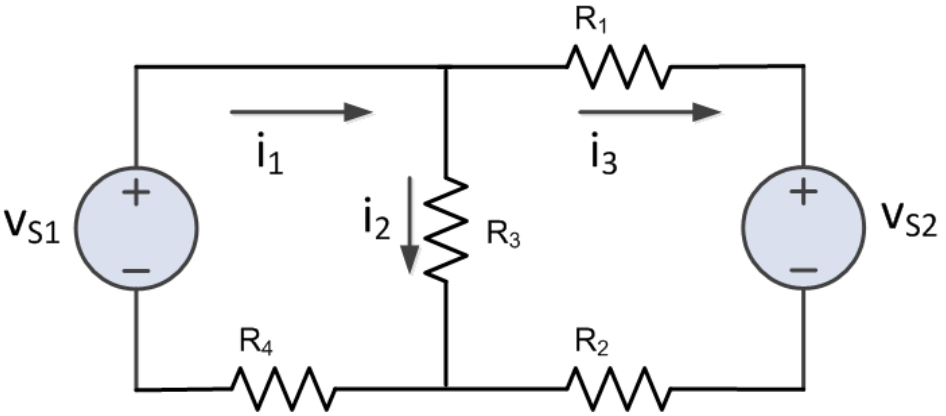
Where Are We Going?

Where we've been:

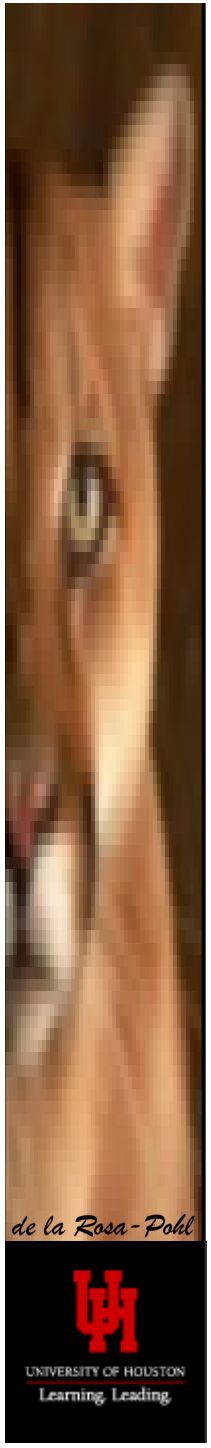


This is a simple circuit with one loop, and one current. We analyzed it using KVL and Ohm's Law.

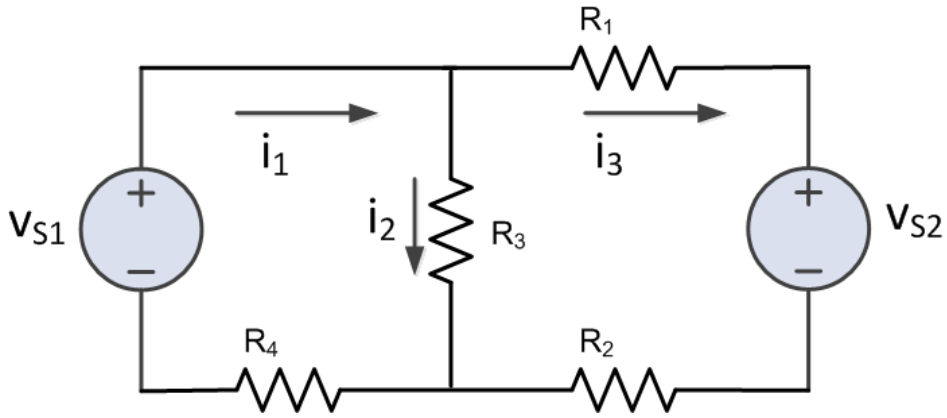
Where we're going:



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



Where Are We Going?



We will look at circuits with voltage sources and resistors only. We will not worry ourselves with

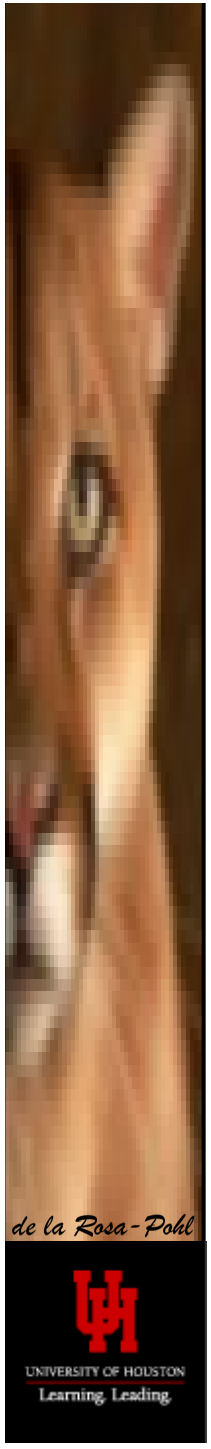
current sources
capacitors or inductors
integrated circuits (LM741, LM386, digital logic devices)
solid state devices (BJT, MOSFET, diode)

These things can be handled easily later if we understand the basics.

OHM'S LAW REVIEW

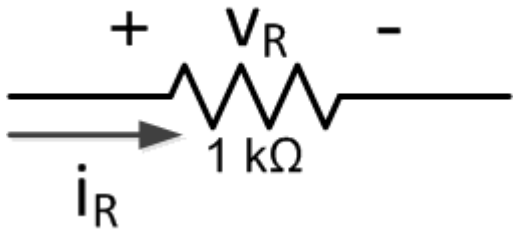
de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

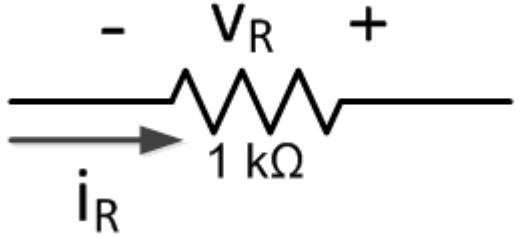


Ohm's Law Review

Ohm's Law depends on how we label current and voltage:

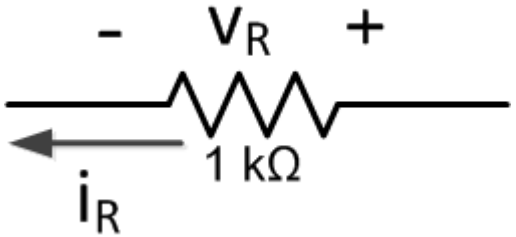


$$v_R = i_R R$$

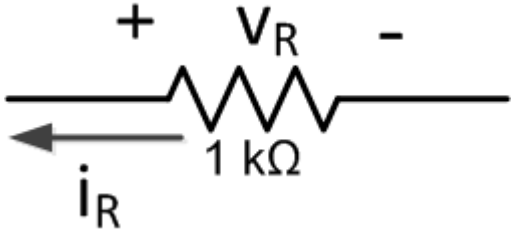


$$v_R = -i_R R$$

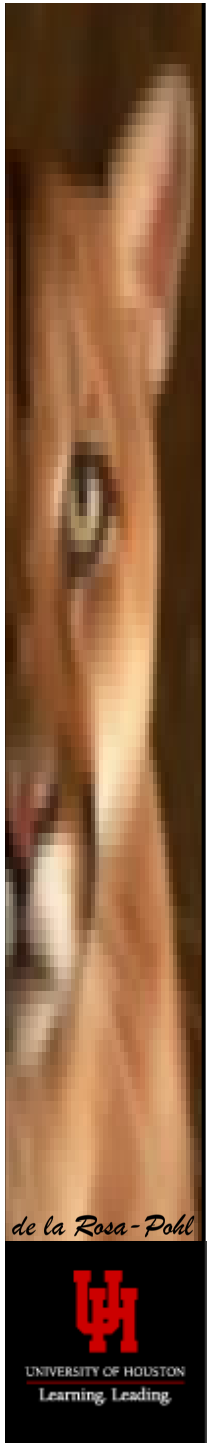
These are of course the same things



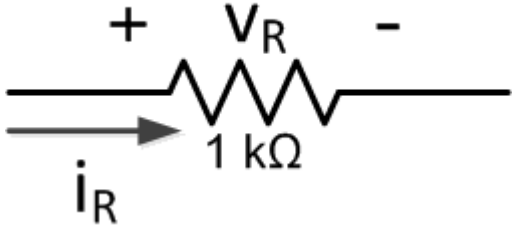
$$v_R = i_R R$$



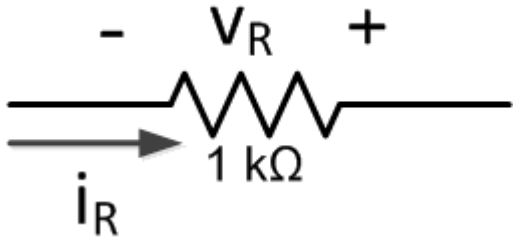
$$v_R = -i_R R$$



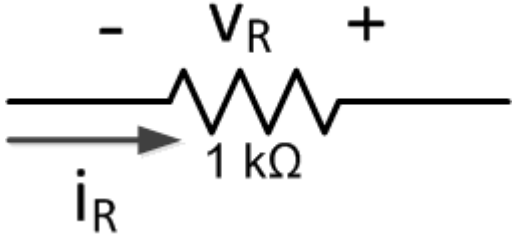
Let's Try Some



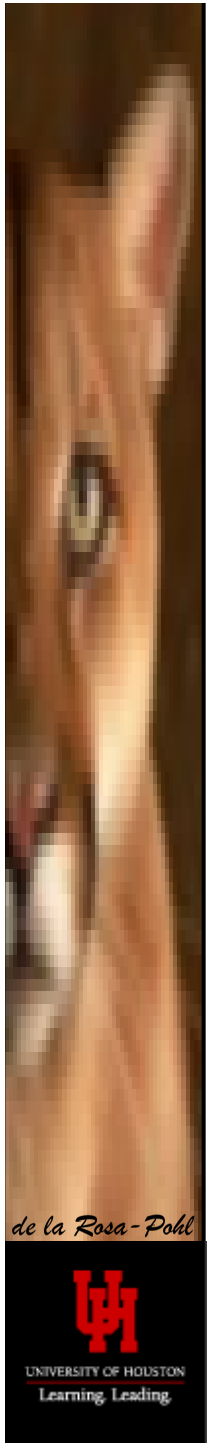
v_R = 7 V i_R = ??



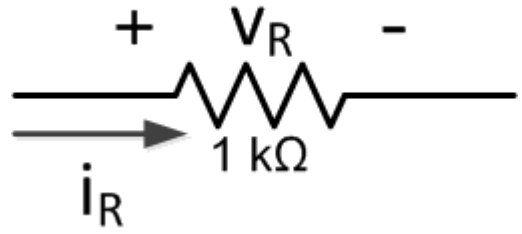
v_R = 120 V i_R = ??



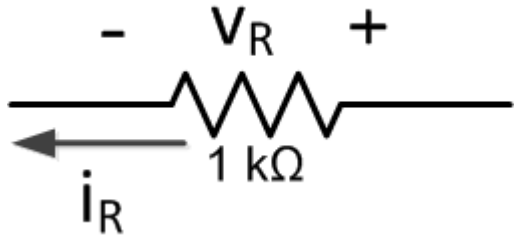
v_R = -120 V i_R = ??



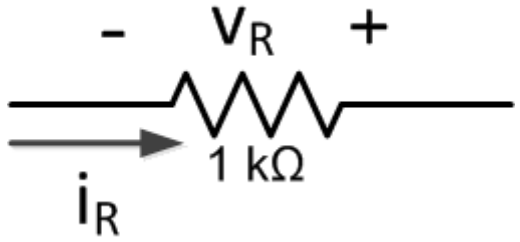
Let's Try Some



i_R = 7 mA v_R = ??



i_R = -12 mA v_R = ??

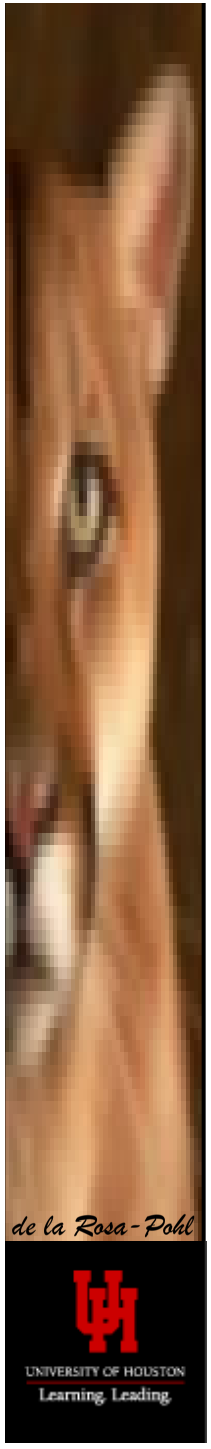


i_R = 50 mA v_R = ??

VOLTAGE DIVIDER RULE REVIEW

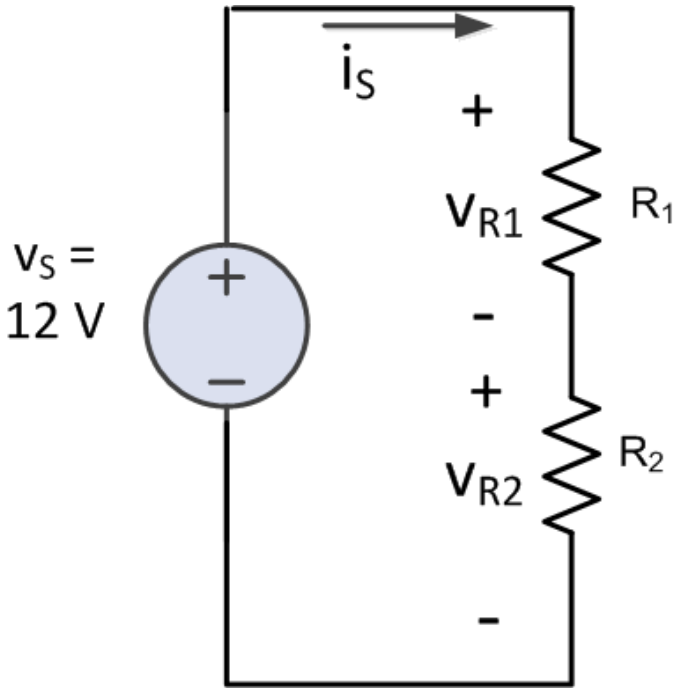
de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.



Voltage Divider Review

- Voltage Divider Rule



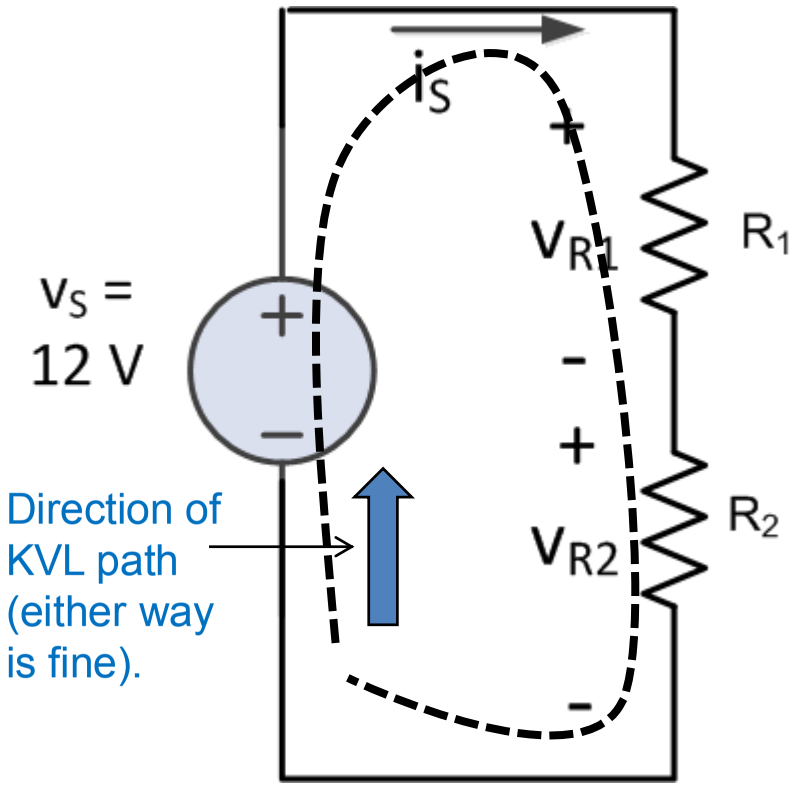
- Ohm's Law and KVL give us the following equations

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

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

How did we get those results?

Voltage Divider Revisited



KVL

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

Ohm's Law

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

Algebra

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

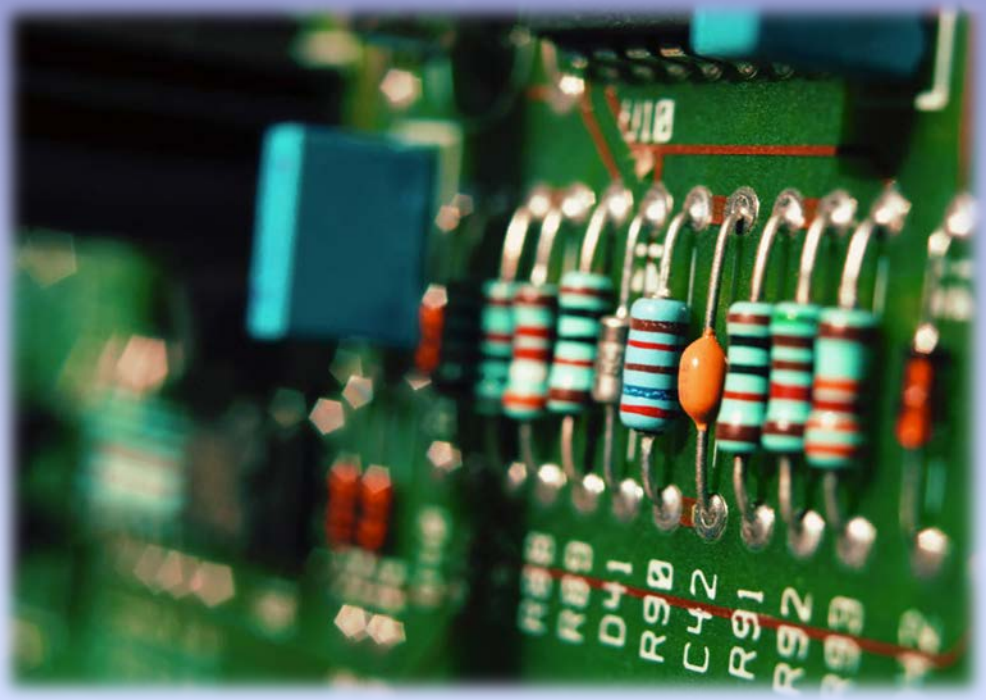
Then

$$v_{R1} = i_S R_1$$

Finally

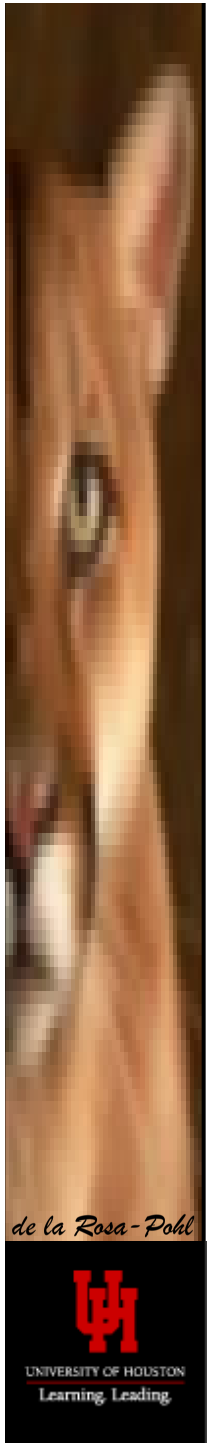
$$v_{R1} = v_S \left(\frac{R_1}{R_1 + R_2} \right)$$

So we substituted Ohm's Law into KVL

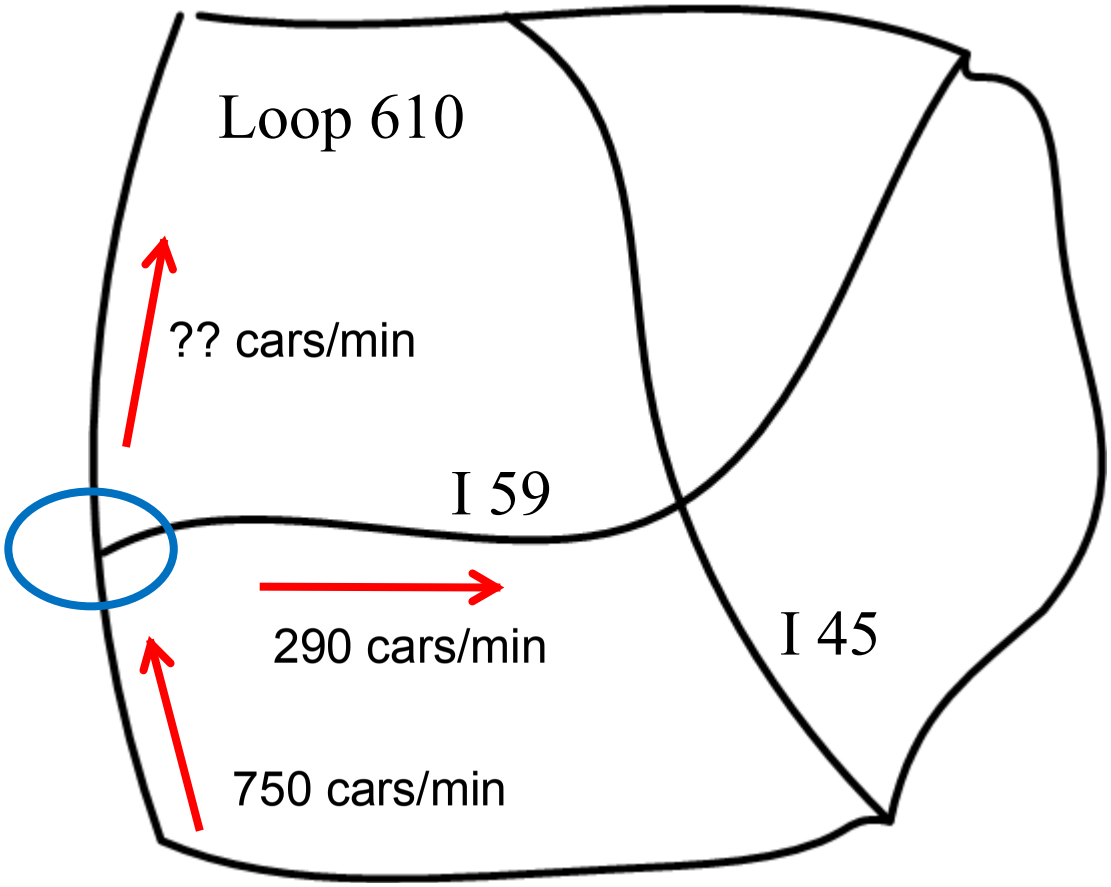


KIRCHHOFF'S CURRENT LAW

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



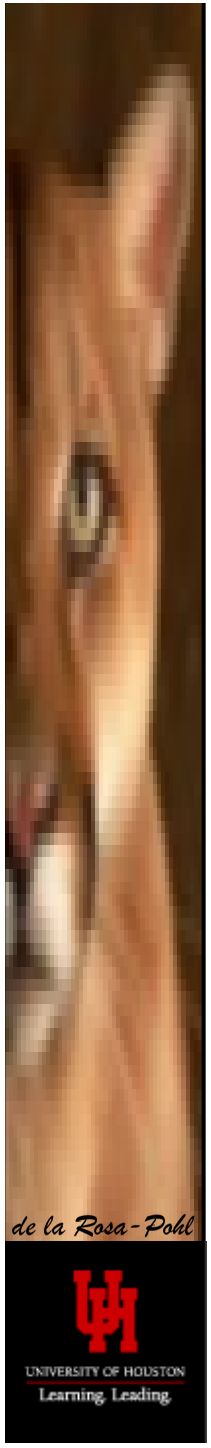
Houston Traffic



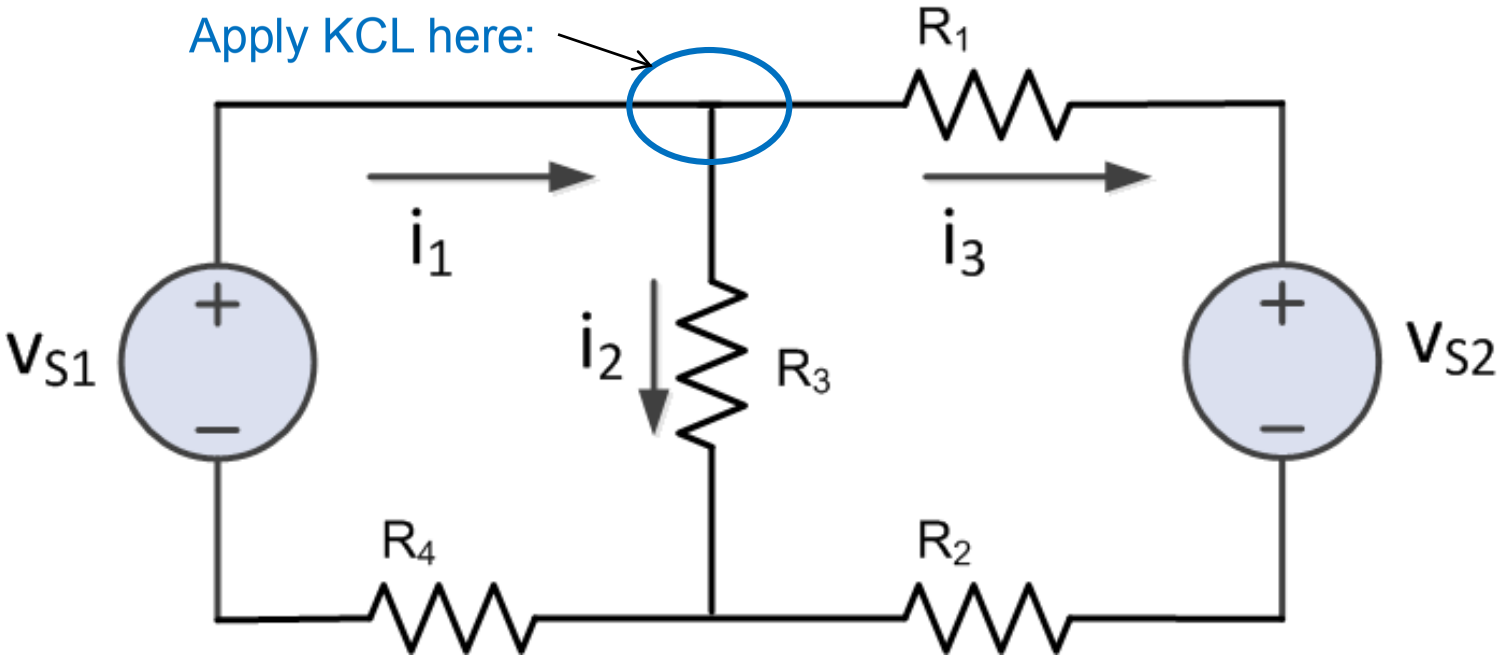
Kirchhoff's Current Law:

in = out

All other roads are closed for repairs!



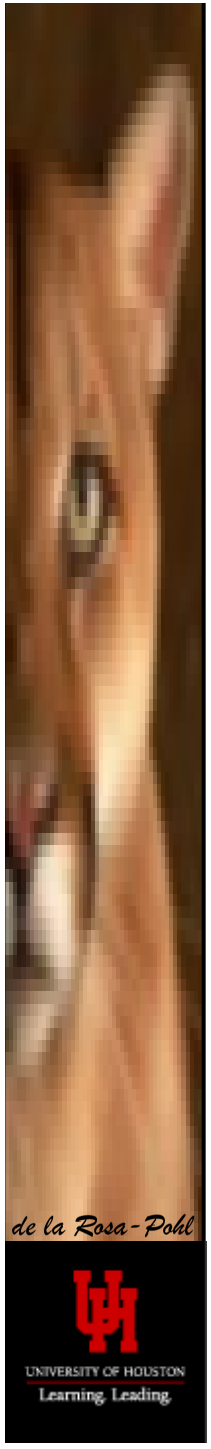
Kirchhoff's Current Law



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

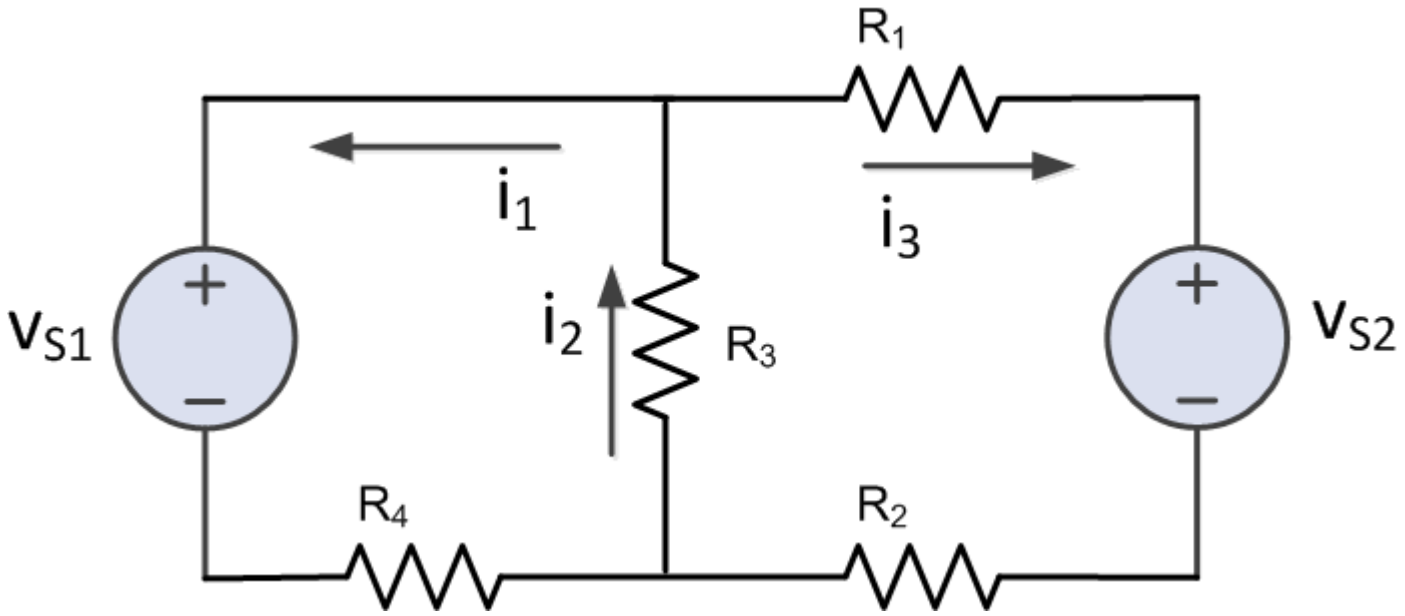
What is the relationship between i_1, i_2, and i_3?

KCL: $\boxed{i_1 = i_2 + i_3}$ In = out



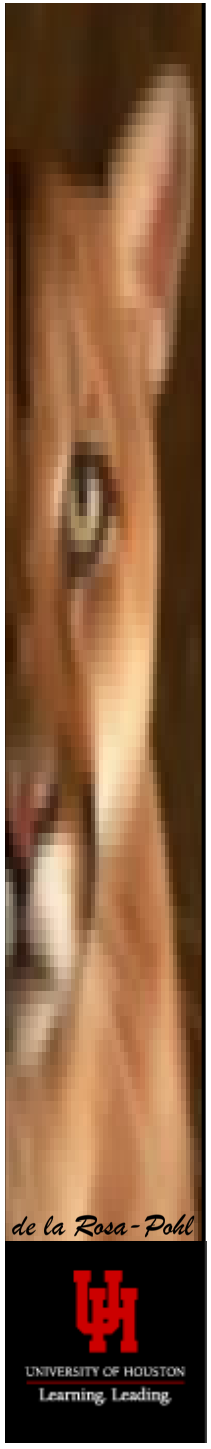
Kirchhoff's Current Law

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



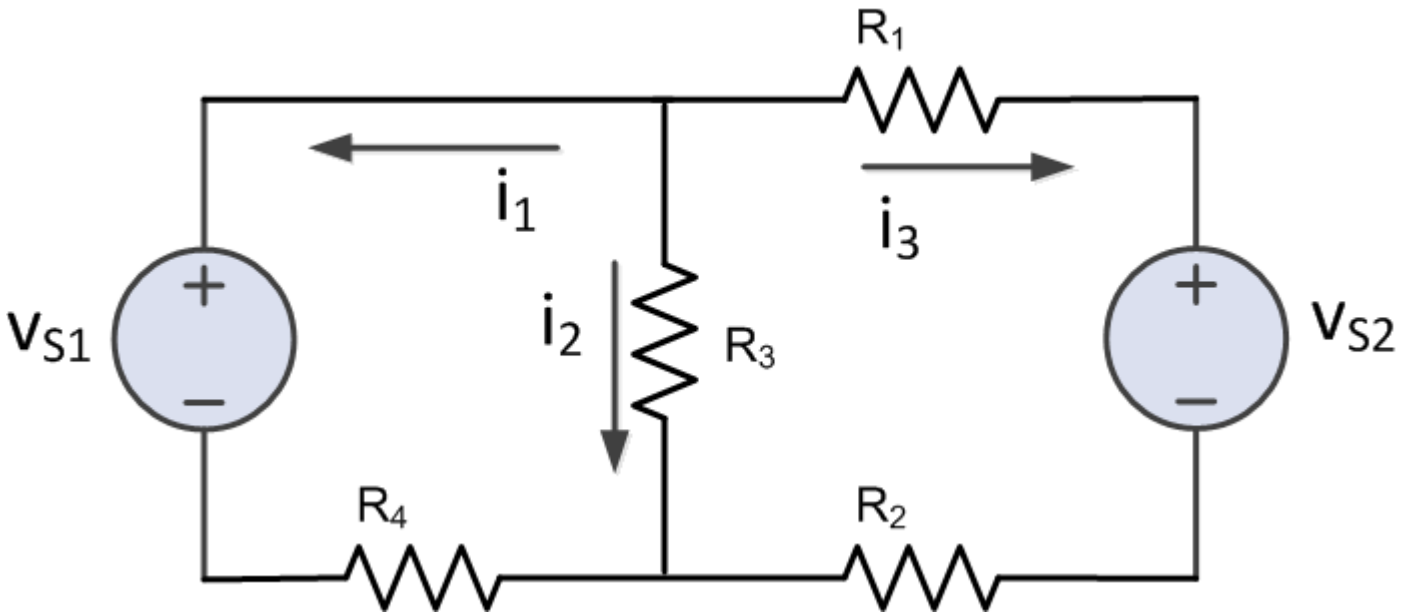
KCL: $i_2 = i_1 + i_3$

in = out



Kirchhoff's Current Law

Can I do THIS????

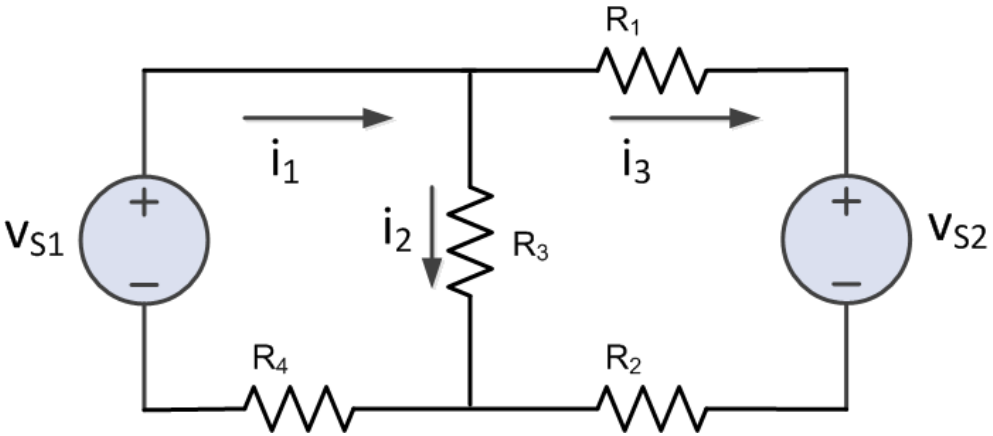


Sure!!

in = out

KCL: $0 = i_2 + i_1 + i_3$

Kirchhoff's Current Law



Find the indicated currents

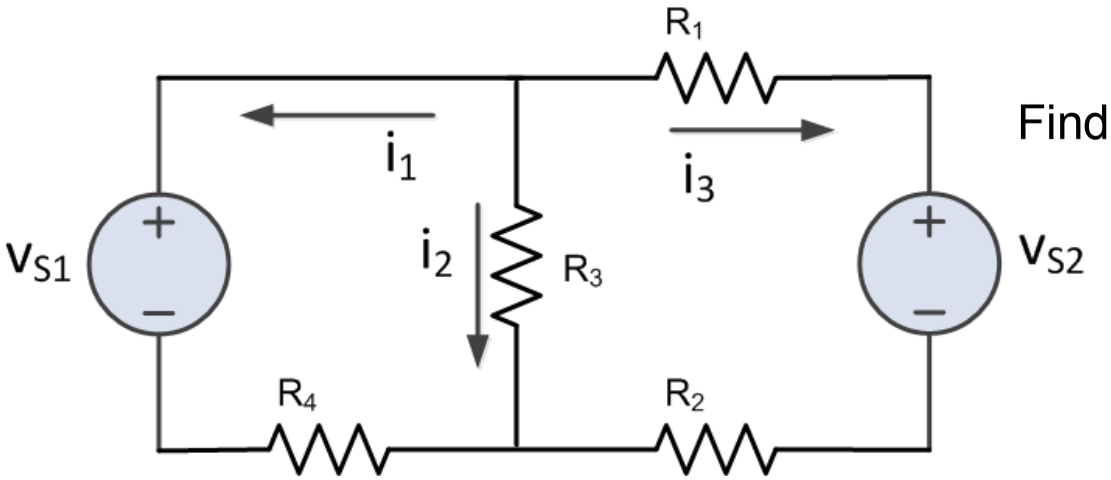
i_1 = 70 mA
i_2 = 15 mA
i_3 = ??

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

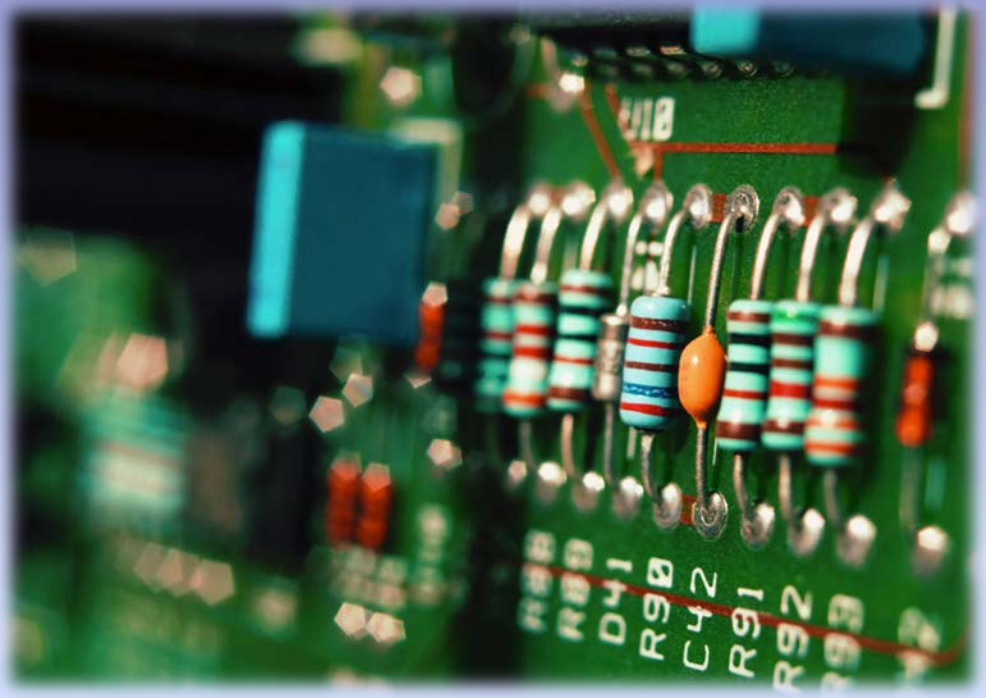


Find the indicated currents

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

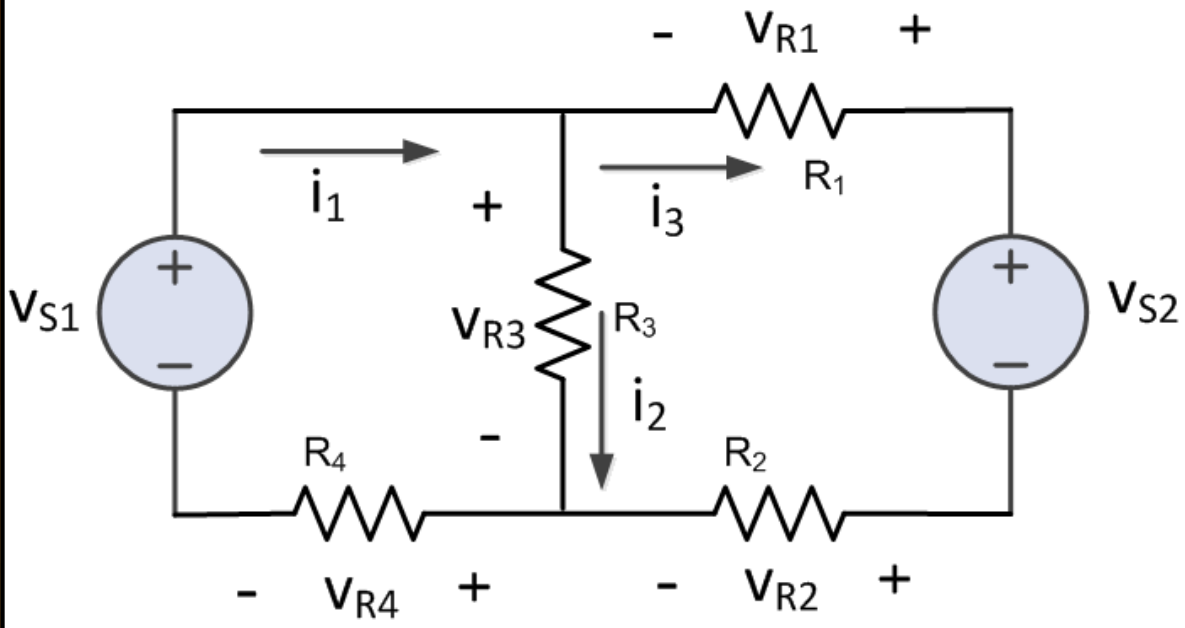


CIRCUIT ANALYSIS USING KVL, KCL, AND OHM'S LAW

de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.

Let's Analyze That Thing

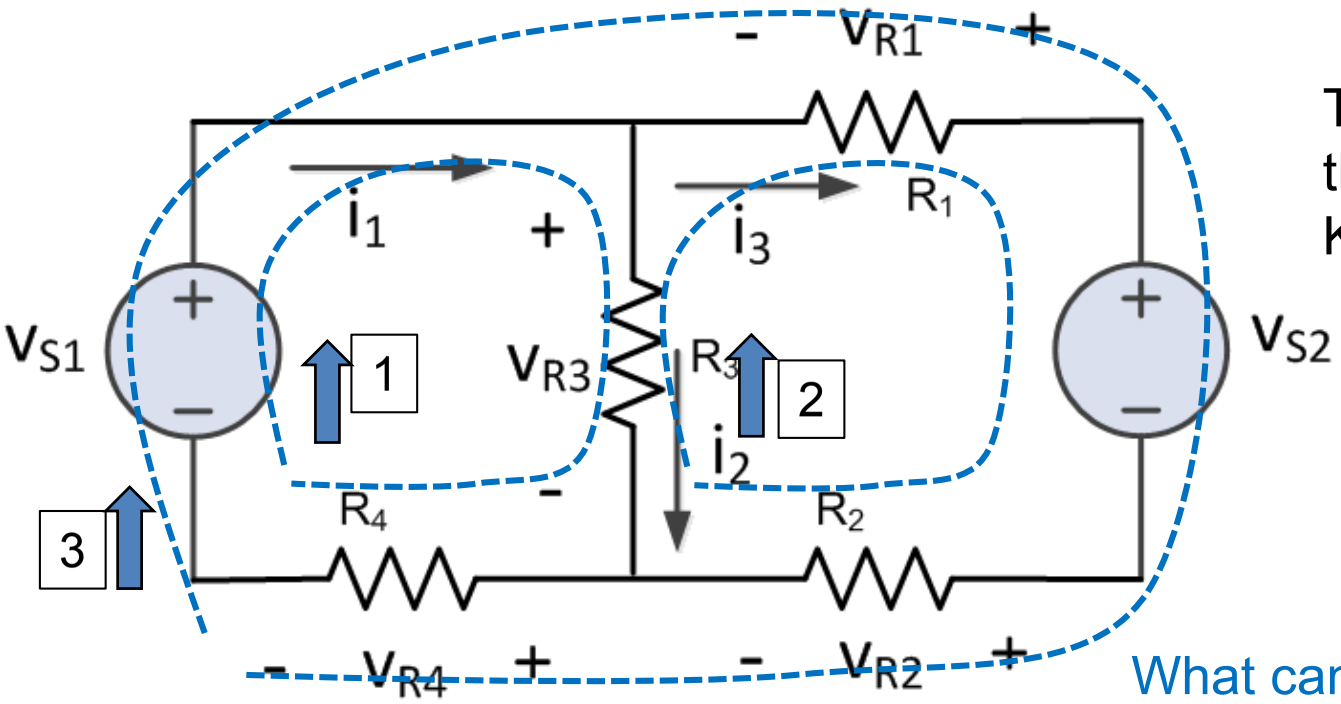


Usually we know the voltage source values and the resistor values. We will assume that here.

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

Let's Do It: KVL



There are three possible KVL paths.

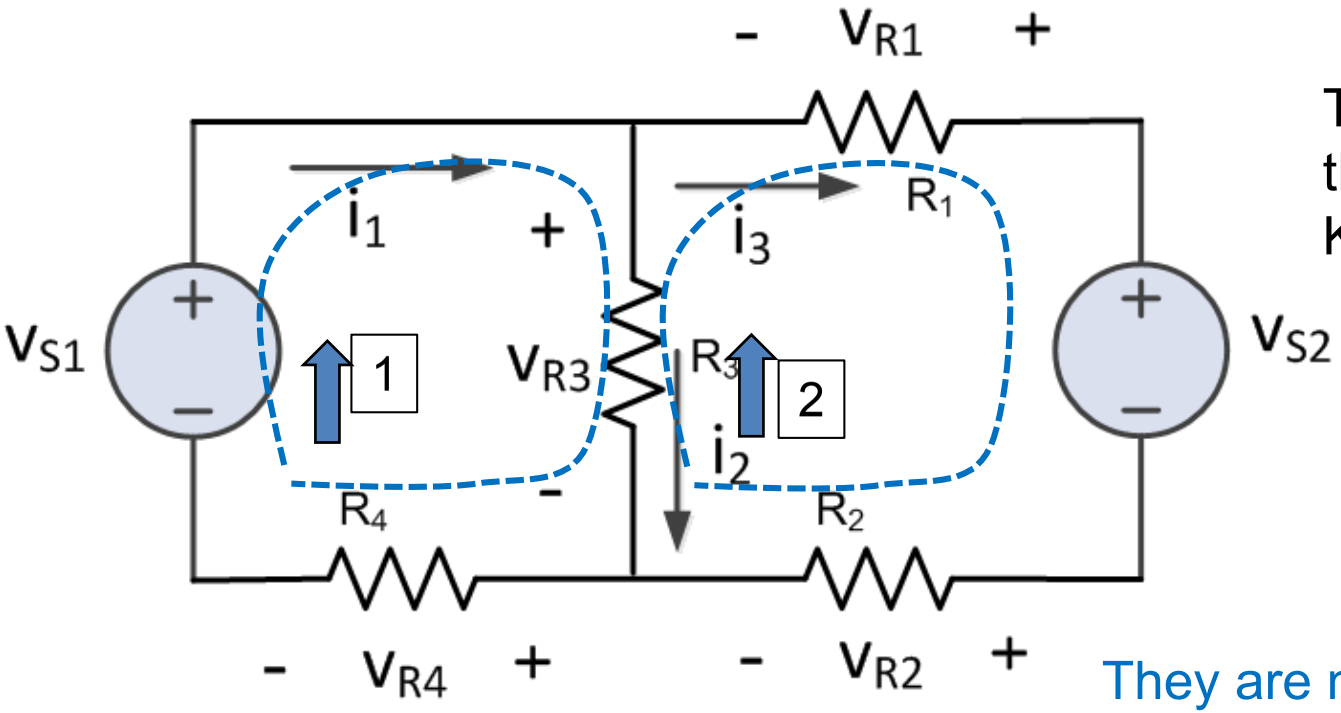
What can we way about the relationship among these three equations?

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

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

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

Let's Do It: KVL



There are three possible KVL paths.

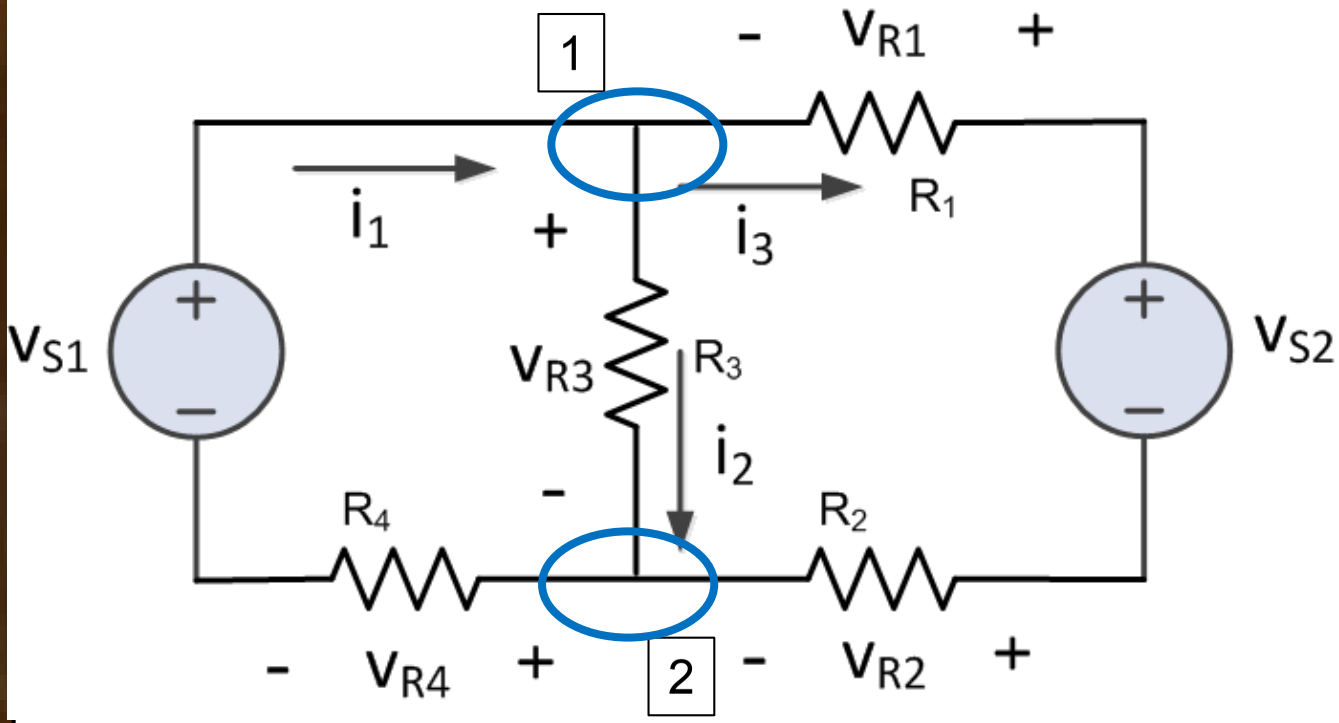
1 $\quad -v_{S1} + v_{R3} + v_{R4} = 0$

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

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

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

Let's Do It: KCL



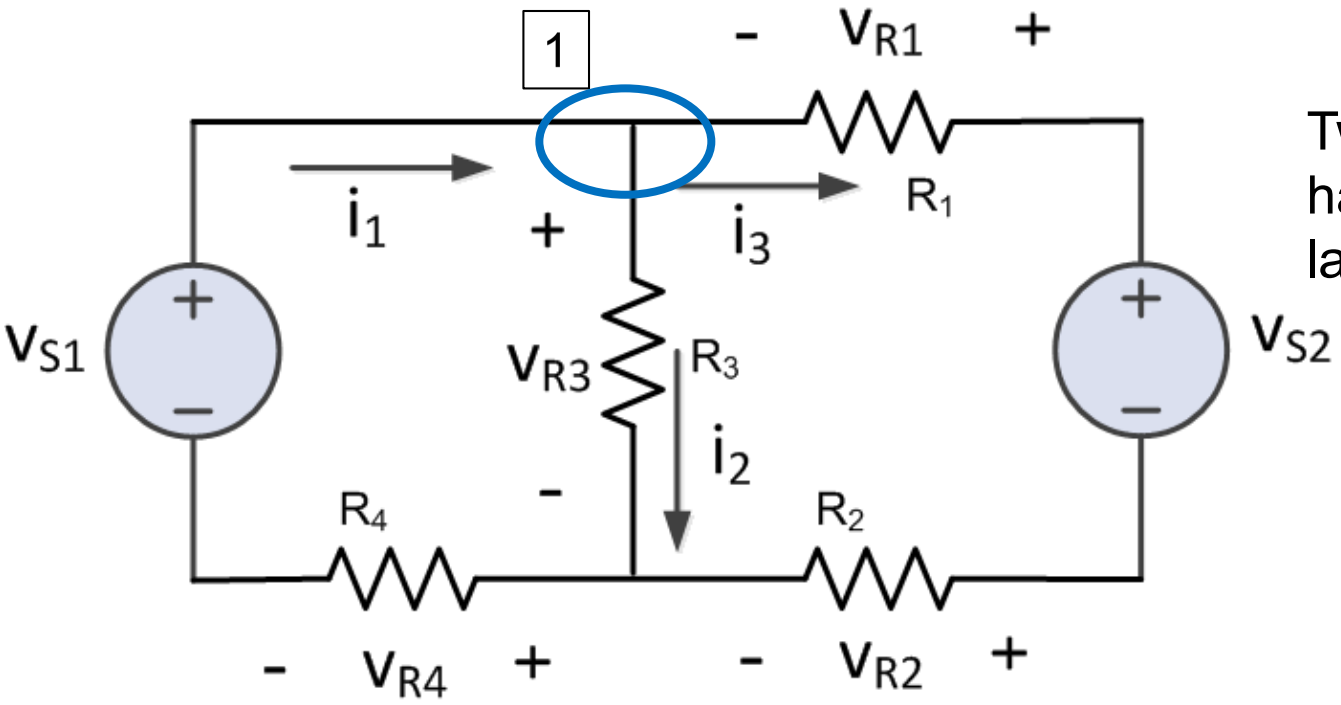
There are two nodes for KCL.

1 $i_1 = i_2 + i_3$

2 $i_2 + i_3 = i_1$

What can we say about these two KCL equations?

Let's Do It: KCL



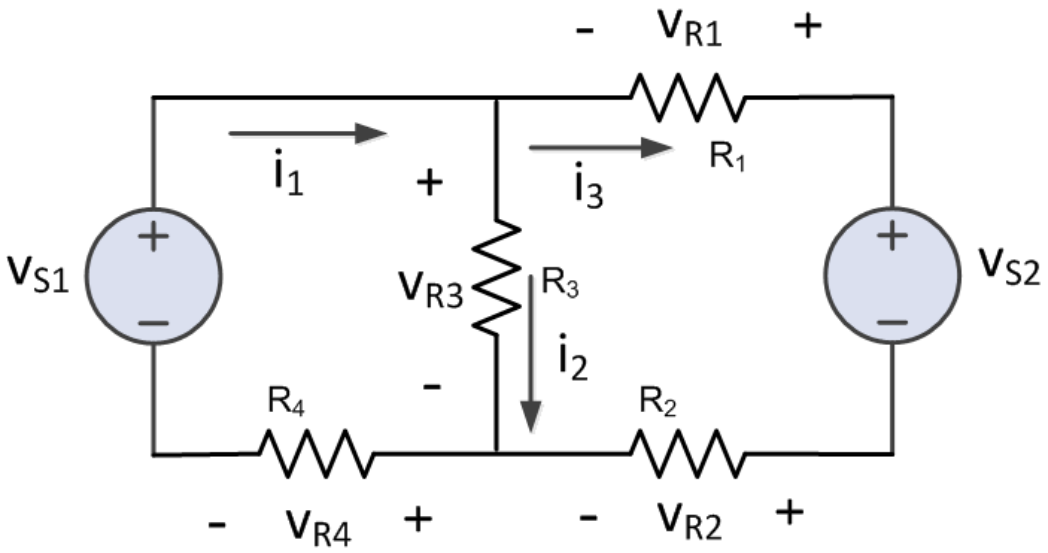
Two nodes have been labeled.

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.

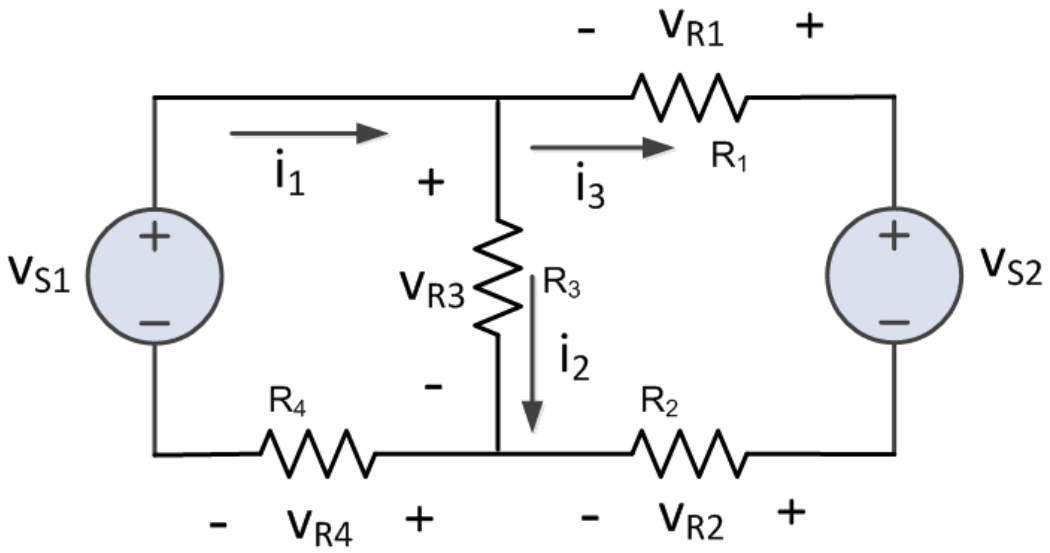
1 $i_1 = i_2 + i_3$

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.

Ohm's Law!!



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

$$v_{R2} = i_3 R_2$$

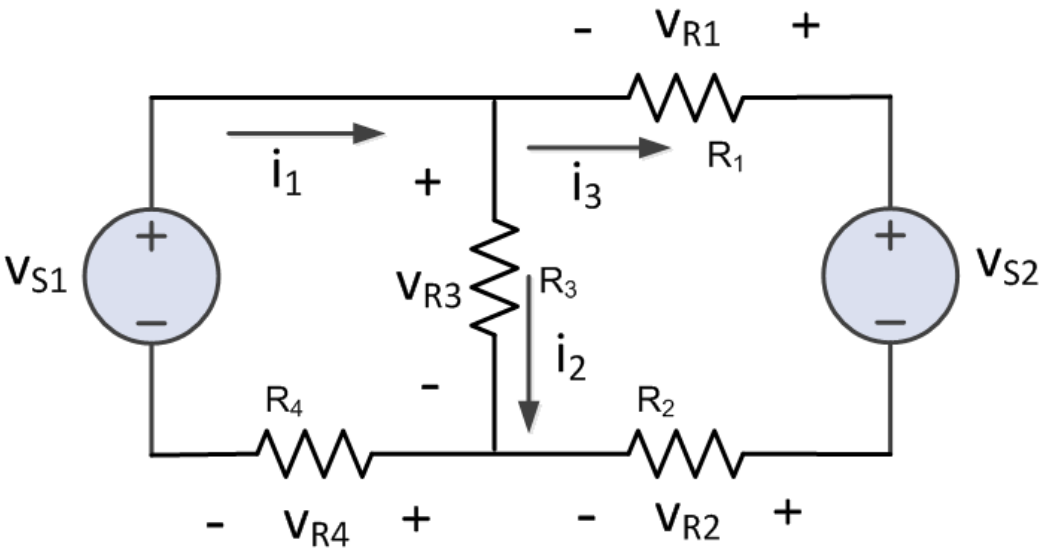
$$v_{R3} = i_2 R_3$$

$$v_{R4} = i_1 R_4$$

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

Substitute these equations into KVL and get

Let's Do It: KCL and KVL

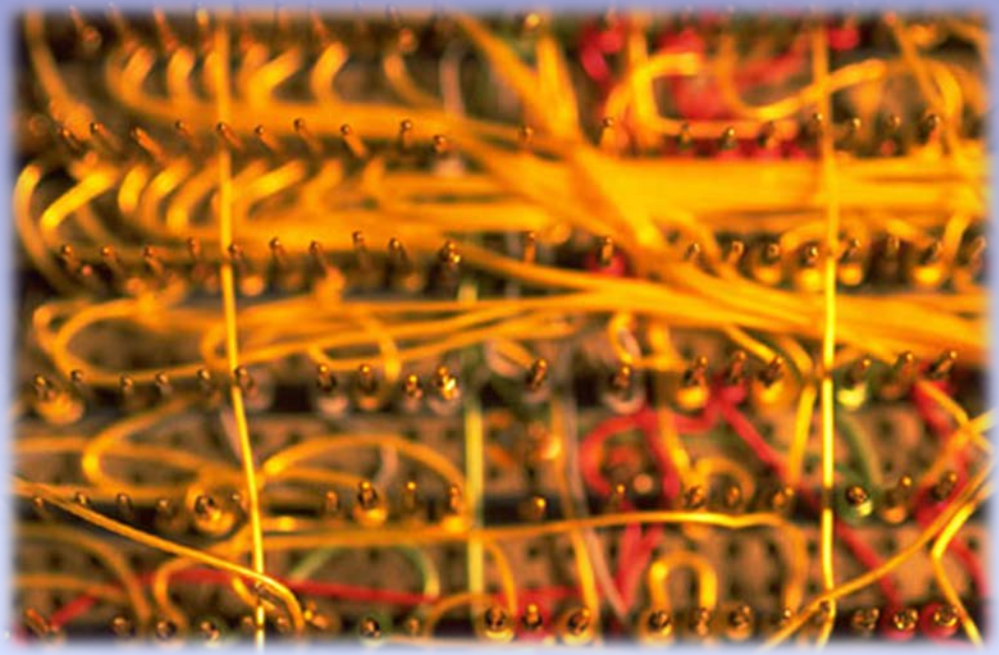


Now we have three equations in three unknown currents! We can solve for the currents and then use Ohm's Law to get the resistor voltages.

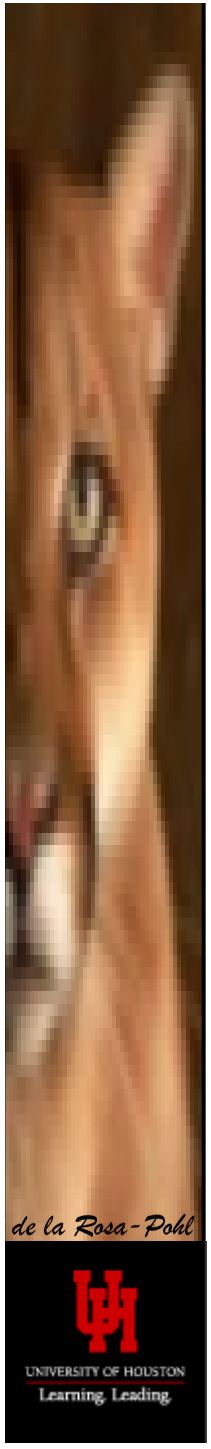
1 $i_1 = i_2 + i_3$

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

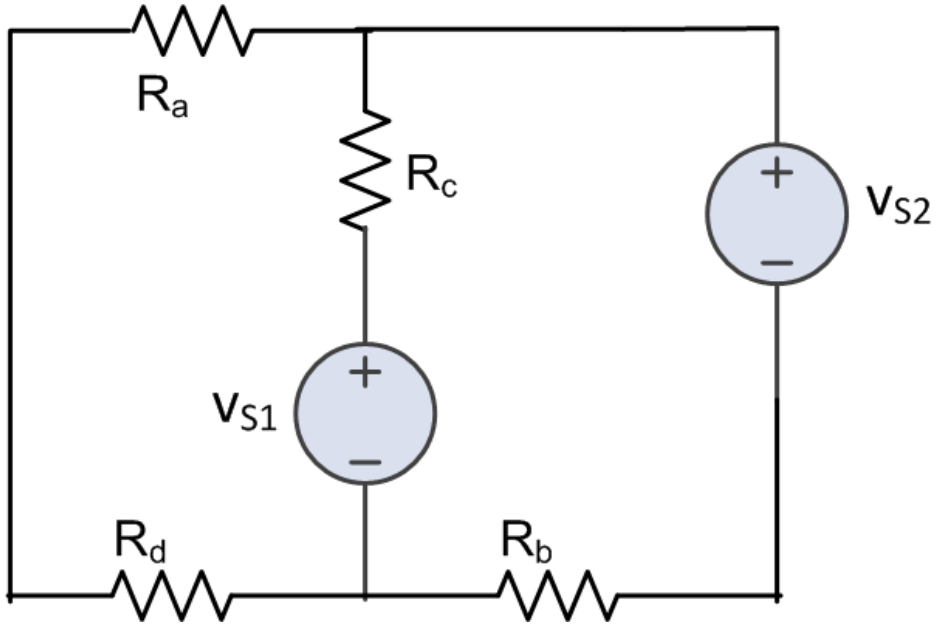
3 $-i_2 R_3 + i_3 R_1 + v_{S2} + i_3 R_2 = 0$



YOU TRY!

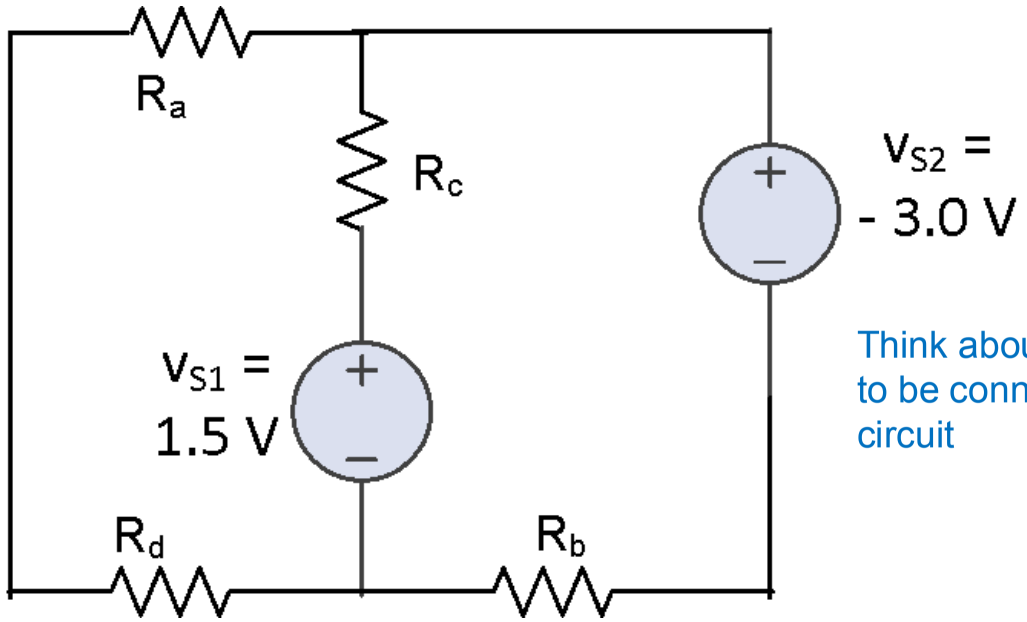


You Try!



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.
5. Solve, given: v_{S1} = 3.5 [V], v_{S2} = - 5.7 [V], R_a = 1 [kΩ], R_b = 2.2 [kΩ], R_c = 470 [Ω], R_d = 4.7 k[Ω].

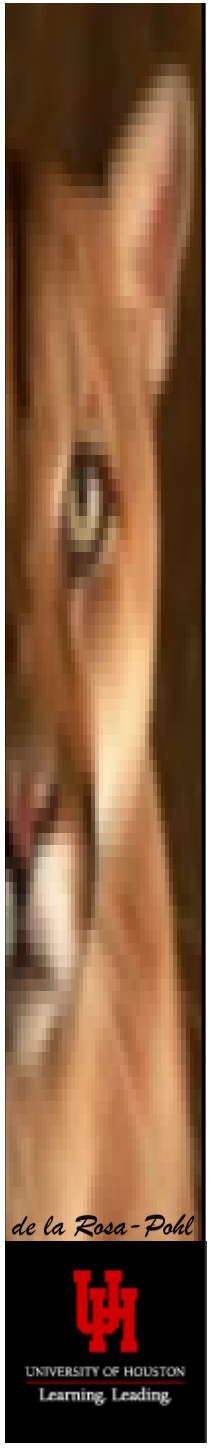
Let's Build It: Practice Circuit!



Use three batteries and the battery pack for the sources.

Think about how v_{S2} needs to be connected into the circuit

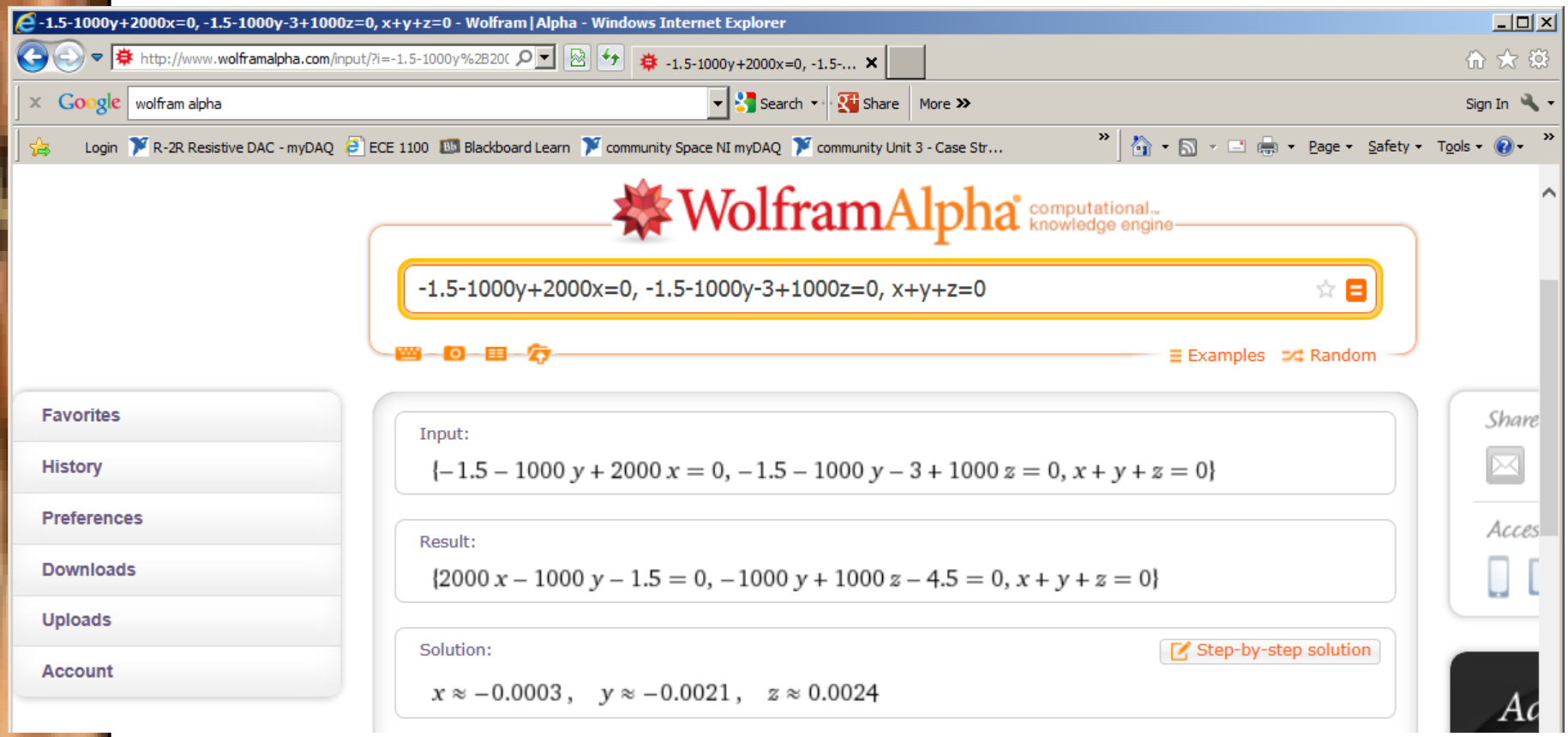
1. Choose four resistors with red or orange in the 3rd band.
2. Use the battery pack to generate the voltages.
3. Solve for the three currents in your circuit (which will of course depend on your R's.)
4. Find the resistor voltages using Ohm's Law.
5. Measure the currents and voltages.



Solving the Practice Circuit

- You need to solve three simultaneous algebraic equations for three unknown currents.
- Once you have the currents you can find the resistor voltages.
  - Wolfram Alpha will solve simultaneous equations. This is available for free on line.
  - MultiSim will solve the circuit.

Wolfram Alpha

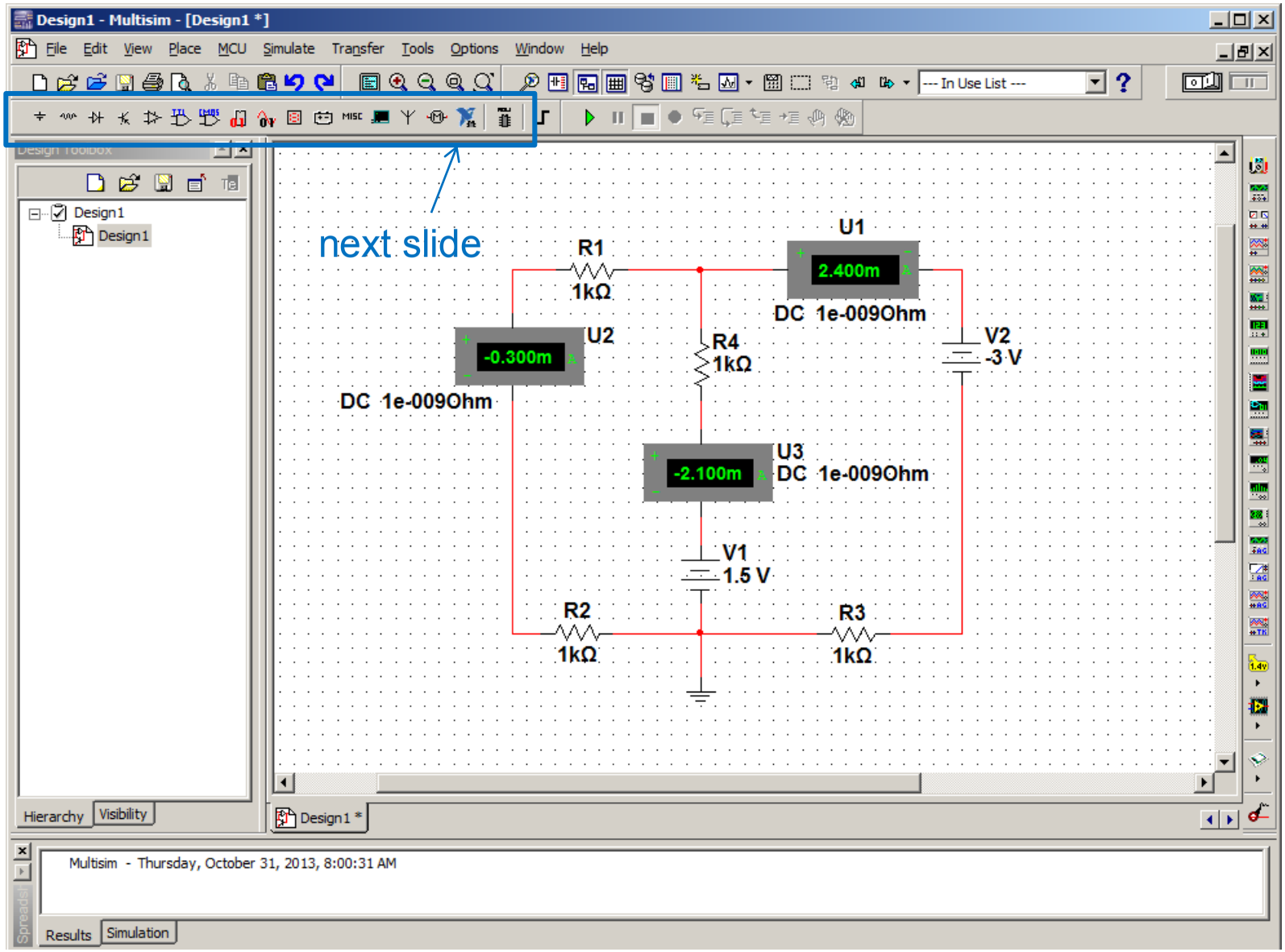


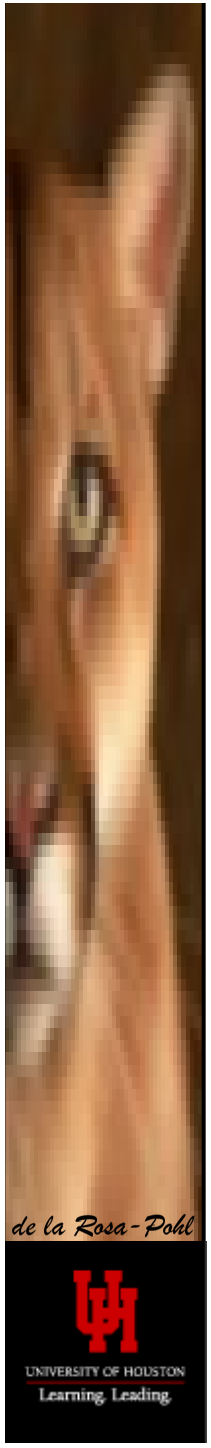
www.wolframalpha.com

!! WolframAlpha interprets “i2” as i * 2 !!

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

Multisim

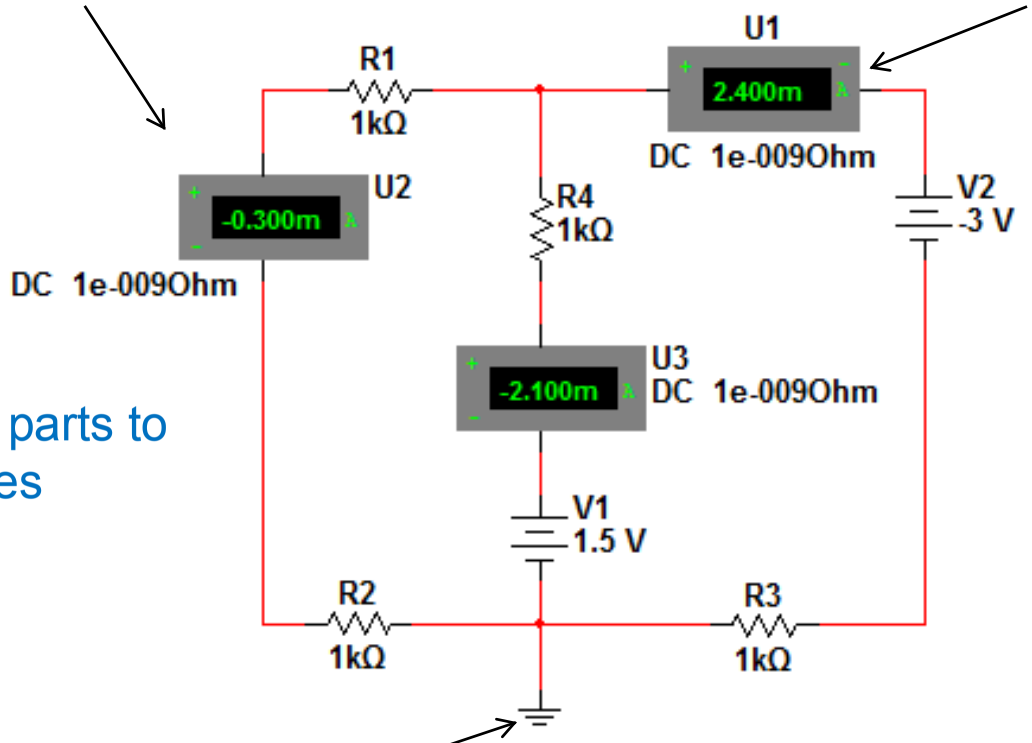




Multisim

Ammeter_V (vertical)

Ammeter_H (horizontal)



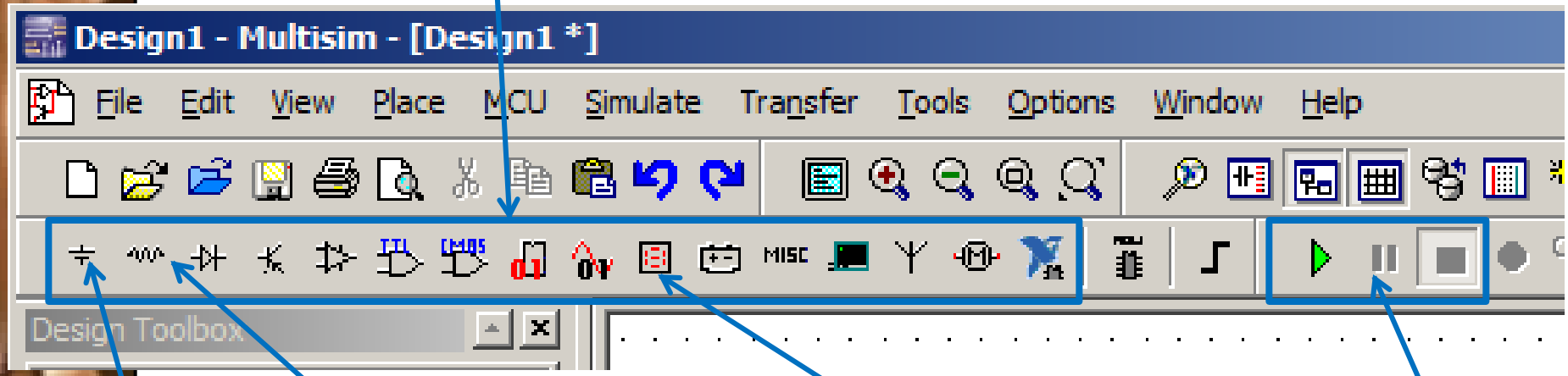
Double-click parts to change values

All circuits need a ground.

Direction of current measurement is + to -

Parts Palette

basic parts lists



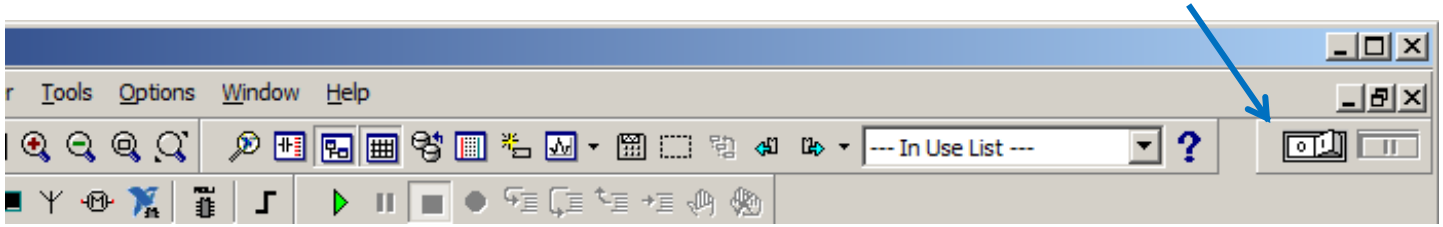
Power supplies and ground

Resistors, caps,

Indicators: ammeter, voltmeter

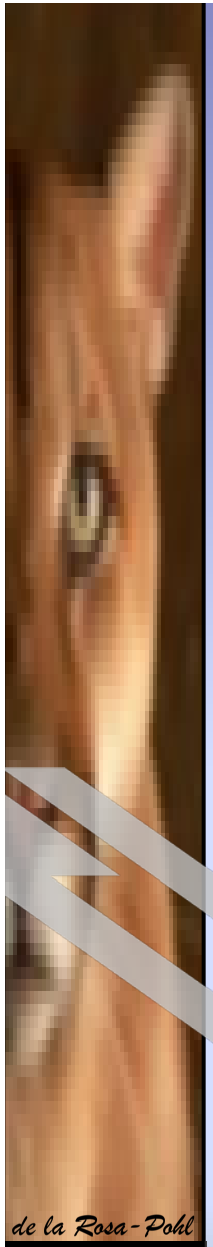
Start, stop, pause

ON/OFF



de la Rosa-Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.



The End

de la Rosa - Pohl

UNIVERSITY OF HOUSTON
Learning. Leading.