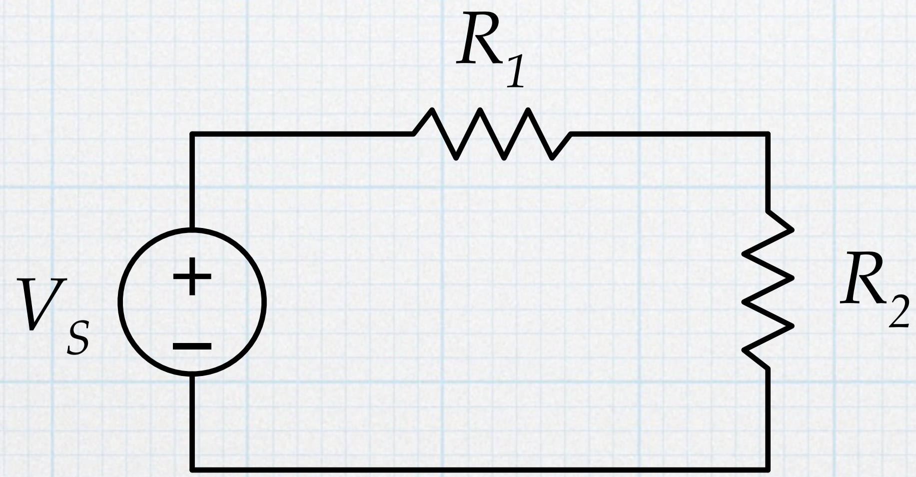
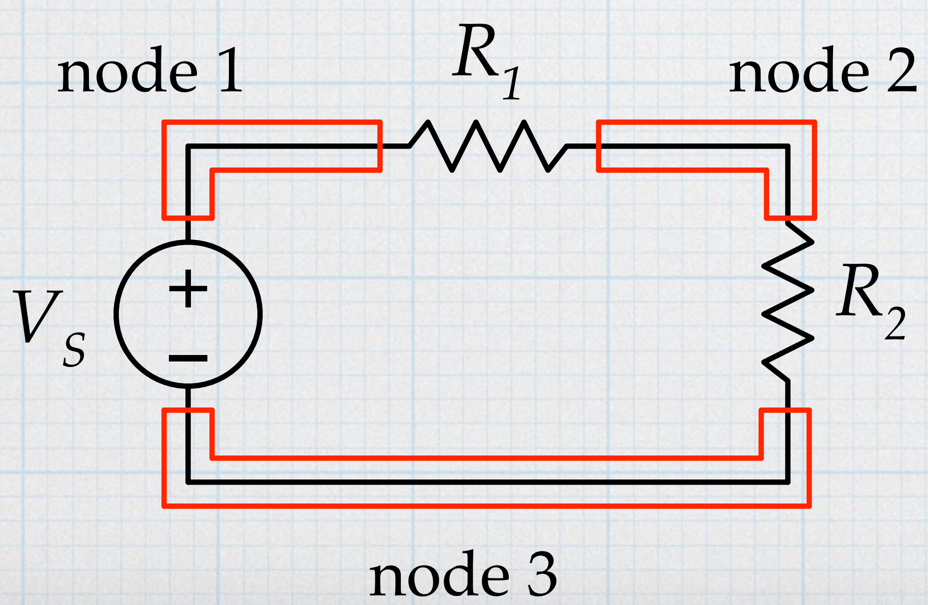
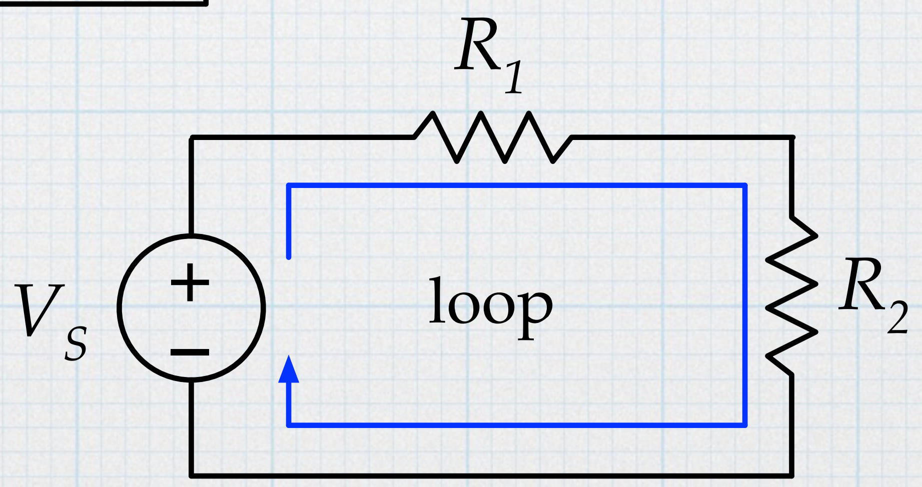
Circuits

A circuit:

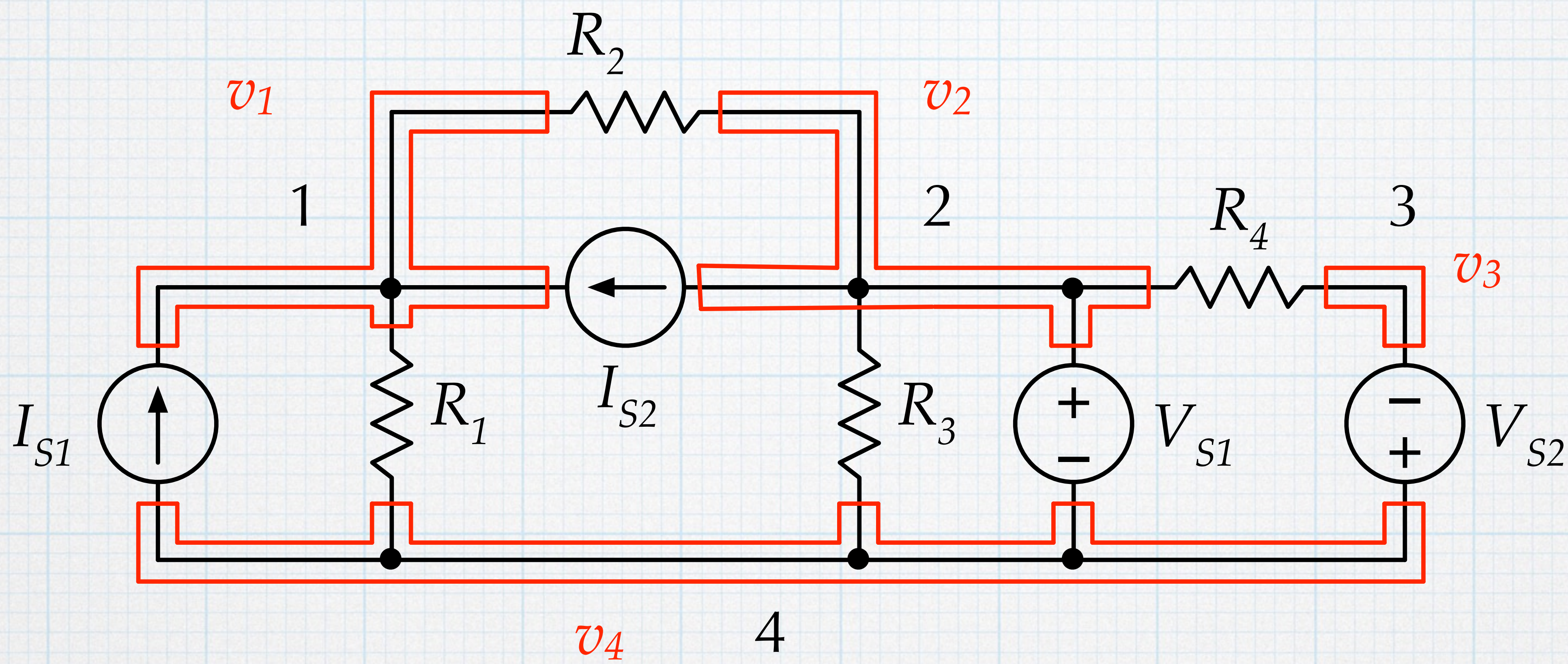
- contains various circuit elements, connected by wires
- connections form nodes, branches and loops (meshes)
- wires carry any amount of current, and the points connected by wires (nodes) have the same voltage.
- Current must have a continuous path to flow. A broken path (open circuit) can have no current. (But there may be voltages present.)







Identifying nodes



All points on the node have the same voltage.

$v_{R1} = v_1 - v_4$

$v_{R2} = v_1 - v_2$

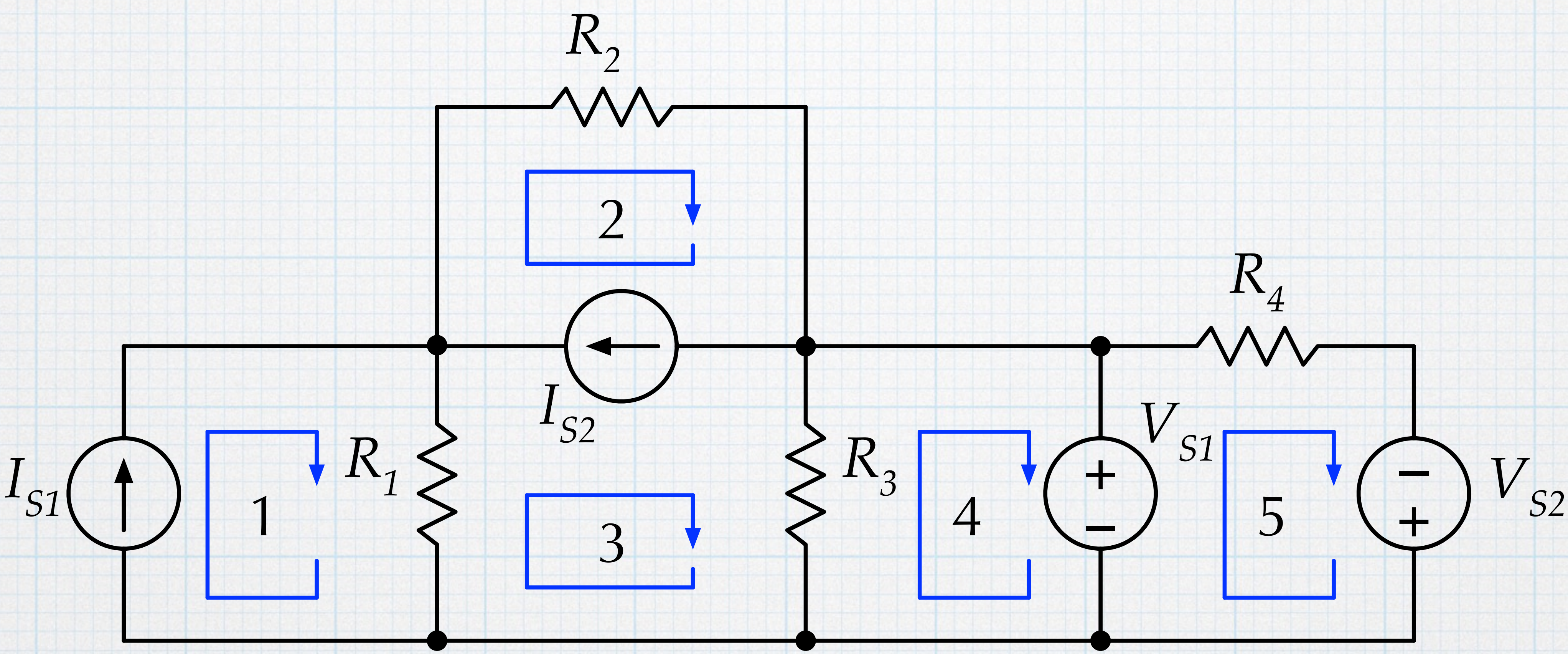
$v_{R3} = v_2 - v_4$

$v_{R4} = v_2 - v_3$

$V_{S1} = v_2 - v_4$

$V_{S2} = v_4 - v_3$

Identifying loops (meshes)



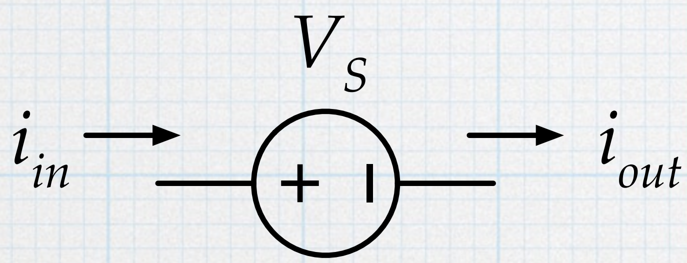
Kirchoff's Laws

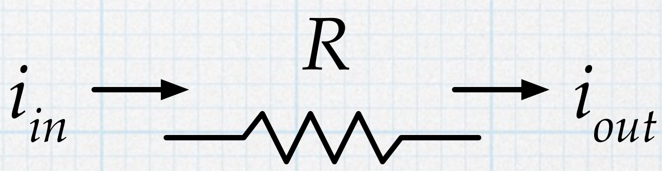
Current Law (KCL)

Current is the flow of matter – charged electrons mostly.

Matter cannot be created or destroyed.

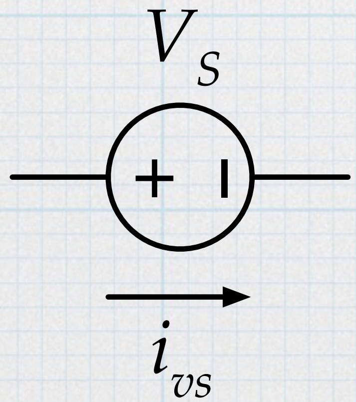
So at any point in a circuit, the current must be continuous – "what flows in must flow out".

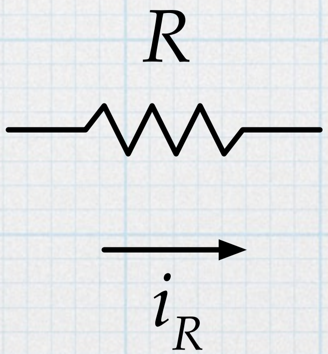




$i_{in} = i_{out} = i_{vs}$

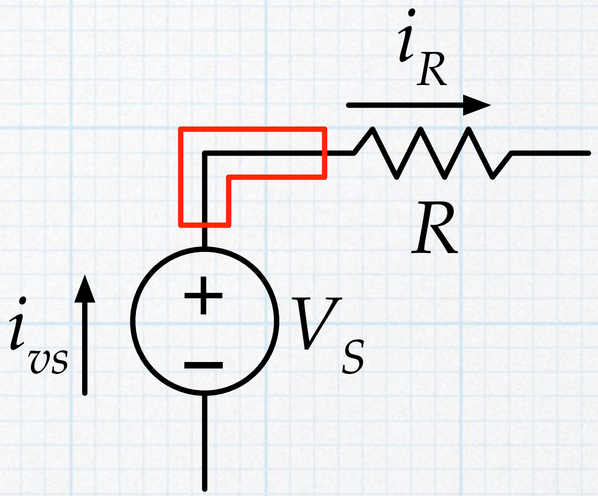
$i_{in} = i_{out} = i_R$





Series connection

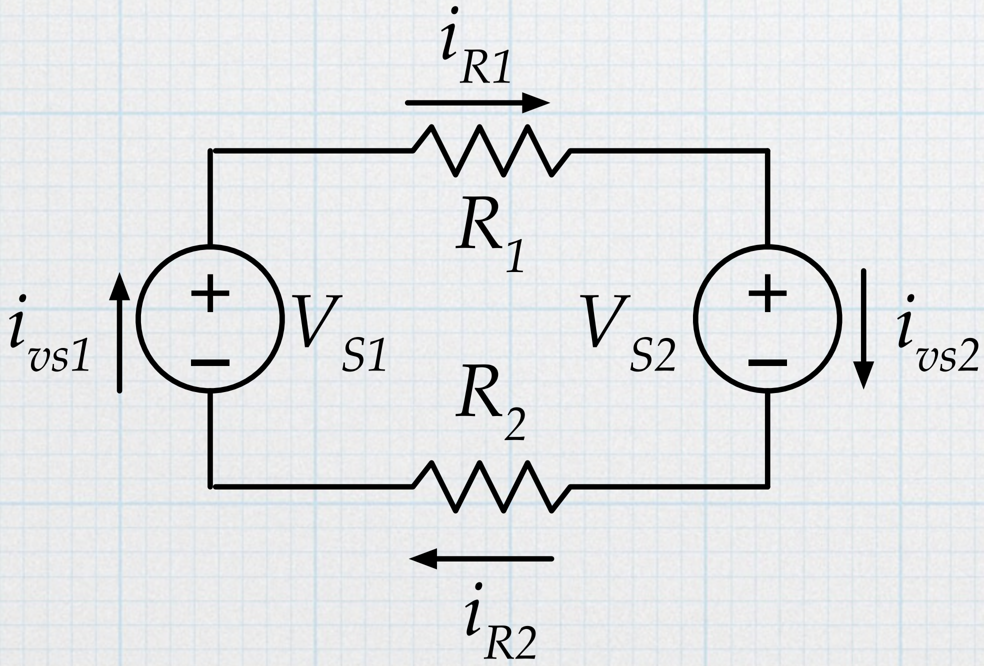
Two components are connected together at a single node.



KCL at the node: $i_{vs} = i_R$.

The same current flows in both components.

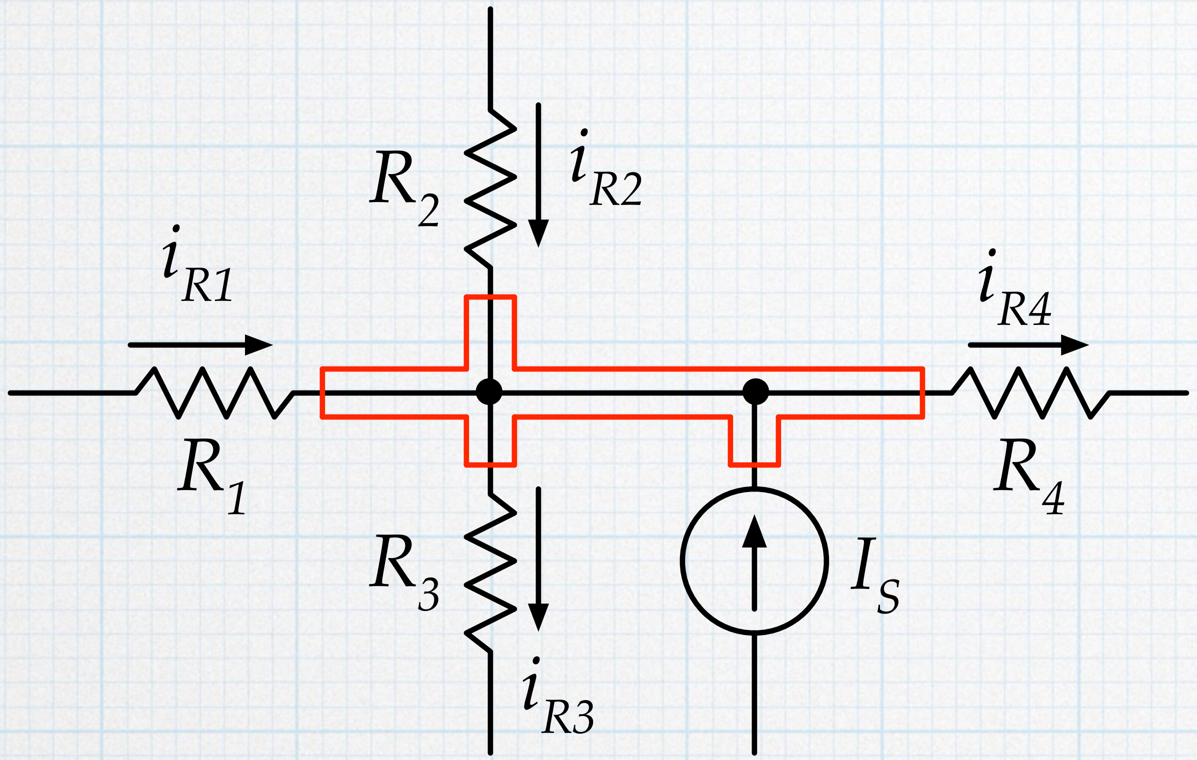
Series-connected components all have the same current.



Applying KCL sequentially around the loop:

$$i_{vs1} = i_{R1} = i_{vs2} = i_{R2}$$

More complex node



What flows in must flow out.

$$i_{R1} + i_{R2} + I_S = i_{R3} + i_{R4}$$

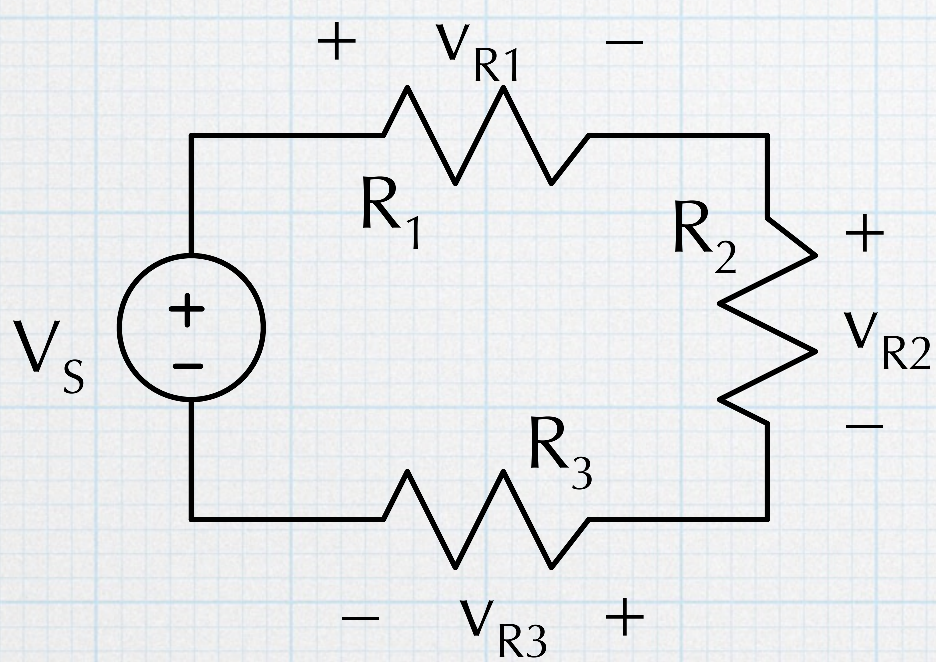
When using Kirchoff's current law (KCL):

- Identify the node and all the associated branches.
- Draw arrows representing the current in each branch. Don't be concerned about the directions of arrows — the sign of the current will work itself in the analysis. (eg. 5 A flowing to the left is the same as –5 A flowing to the right.)
- Add up the currents flowing in and set them equal to the currents flowing out.

voltage law (KVL)

Energy is conserved. Moving around a closed loop brings you back to the same energy. (Recall gravitational potential energy from physics.)

Voltage represent energy in a circuit. Voltage is conserved. The voltages around a closed loop add up to zero.

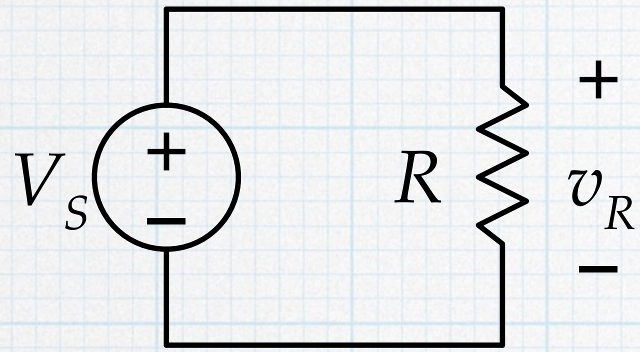


Starting at negative terminal of the source and going clockwise:

$$V_S - v_{R1} - v_{R2} - v_{R3} = 0$$

The starting point and direction are irrelevant. $v_{R1} + v_{R2} + v_{R3} - V_S = 0$

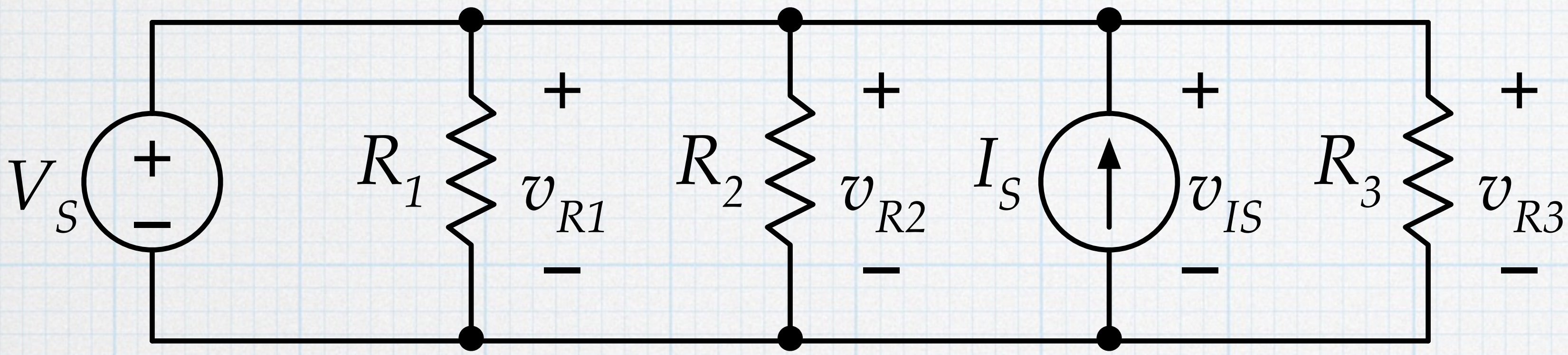
parallel connection (a.k.a shunt connection)



Using KCL:

$V_S - v_R = 0$

$V_S = v_R$



$V_S = v_{R1} = v_{R2} = v_{IS} = v_{R3}$

When using Kirchoff's voltage law (KVL):

- Assign voltages across each element. Don't worry too much about the polarities. If you also have currents defined, make the voltage definitions consistent with those. Otherwise, either polarity is fine — the sign of the voltage will work itself out in the analysis.
- Pick a starting point in the loop.
- Add and subtract voltages as you go around the loop.