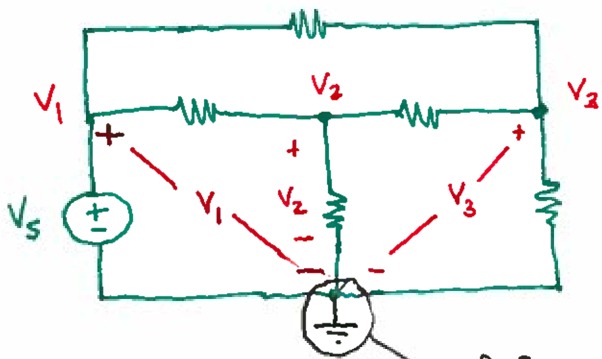


Reference node:

- This is our zero-volt reference; all node voltages are relative to the reference node.
- Always makes the job easier by choosing one side of a voltage source.

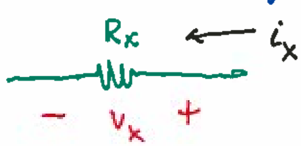
Note that reference node as above, node voltage V_1 automatically becomes

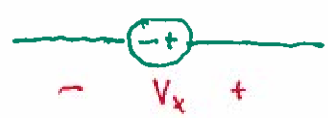
$$V_1 = V_s$$

Step 2 Apply KCL at nodes

Node voltages vs. branch voltages

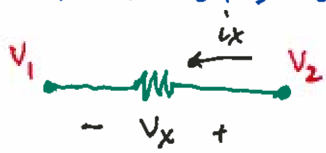
So far, we have always labeled branch voltages for circuit elements



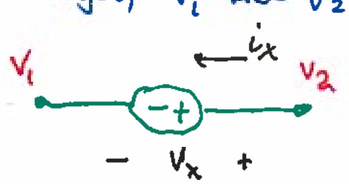


$V_x = i_x R_x$

Here, node voltages are our only variables, so we must express V_x and i_x in terms of node voltages, V_1 and V_2.



$i_x = \dfrac{V_x}{R_x}$

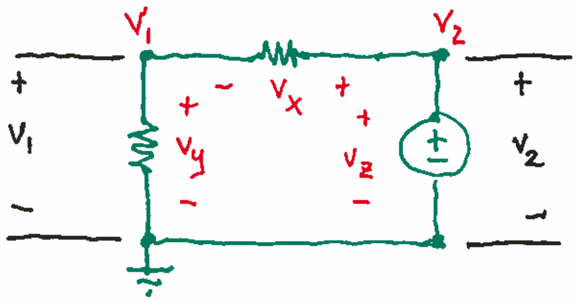


(generally unknown i_x)

Common-sense interpretation: Voltage V_2 appears to be at a higher potential than V_1. Therefore, the branch voltage V_x is the <u>difference</u> between the higher voltage (V_2) and lower voltage (V_1).

$$\boxed{V_x = V_2 - V_1}$$

KVL interpretation: Consider a loop



KVL in terms of branch voltages

$$-V_y - V_x + V_z = 0$$

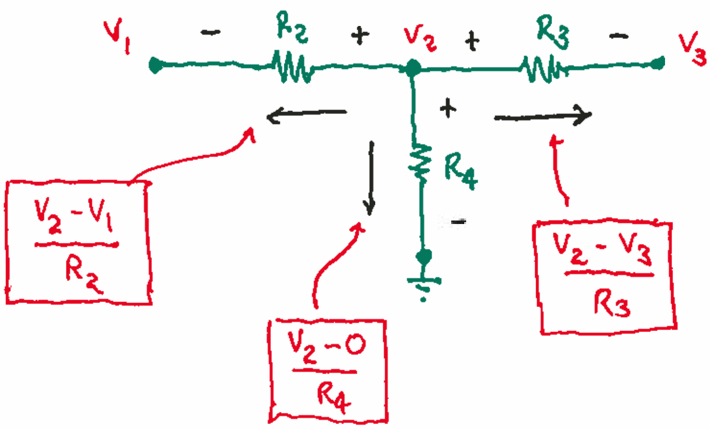
But: $V_1 = V_y$, and $V_2 = V_z$

so $-V_1 - V_x + V_2 = 0$

$$\boxed{V_x = V_2 - V_1}$$

In a <u>resistor</u>: $\boxed{i_x = \frac{V_2 - V_1}{R_x}}$ current in terms of node voltages

Now consider node V_2 in our original circuit



By convention, always point the arrows <u>away</u> from node of interest

Note: each boxed current term is found using KVL and Ohm's Law.

Now sum currents at node 2 by KCL

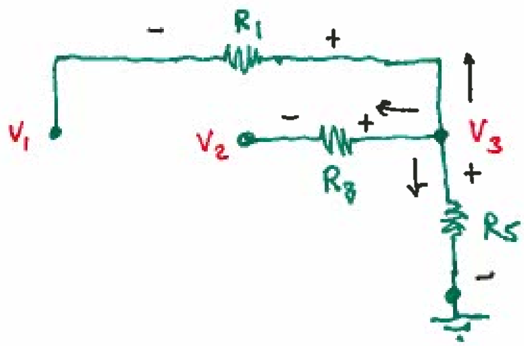
$$-\left(\frac{V_2 - V_1}{R_2}\right) - \left(\frac{V_2 - 0}{R_4}\right) - \left(\frac{V_2 - V_3}{R_3}\right) = 0$$

or, more conveniently, multiply by -1 to get

$$\boxed{\frac{V_2 - V_1}{R_2} + \frac{V_2 - 0}{R_4} + \frac{V_2 - V_3}{R_3} = 0}$$

NODE EQUATION FOR NODE 2.

Now, forget about node 2, and repeat analysis at node 3.



← currents pointing away from node 3.

$$\boxed{\frac{V_3 - V_1}{R_1} + \frac{V_3 - V_2}{R_3} + \frac{V_3 - 0}{R_5} = 0}$$

NODE EQUATION FOR NODE 3

Notice the pattern when writing a node equation with resistor branches

subtract connecting node

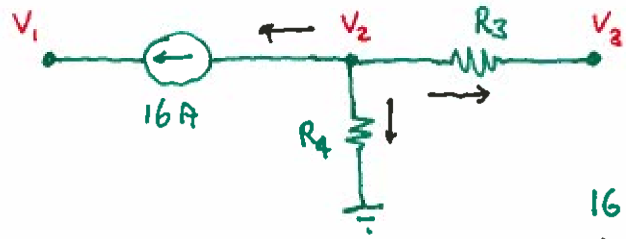
$$\frac{V_3 - V_1}{R_1} + \frac{V_3 - V_2}{R_3} + \frac{V_3 - 0}{R_5} = 0$$

node of interest comes first

connecting resistance

- All terms in this equation represent current leaving a node, summed to zero by KCL (and multiplied by -1 for convenience!)

Things other than resistors connected to nodes:



$$16 + \frac{V_2 - 0}{R_4} + \frac{V_2 - V_3}{R_3} = 0$$

a constant
(positive if leaving a node)