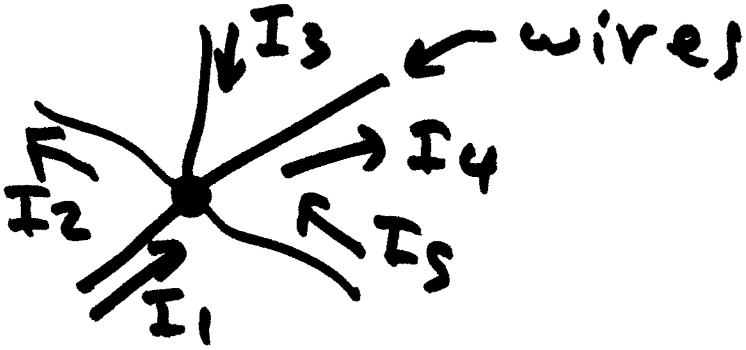
Kirchhoff's Laws

1) Kirchoff's current Law (KCL)



The total current <u>entering</u> the node is equal to the total current <u>leaving</u> the node

Assign $+$ for entering currents
" $-$ for leaving "

$+I_1 + I_5 + I_3$
$-I_2 - I_4$

$|I_1 + I_5 + I_3| = |I_2 + I_4|$

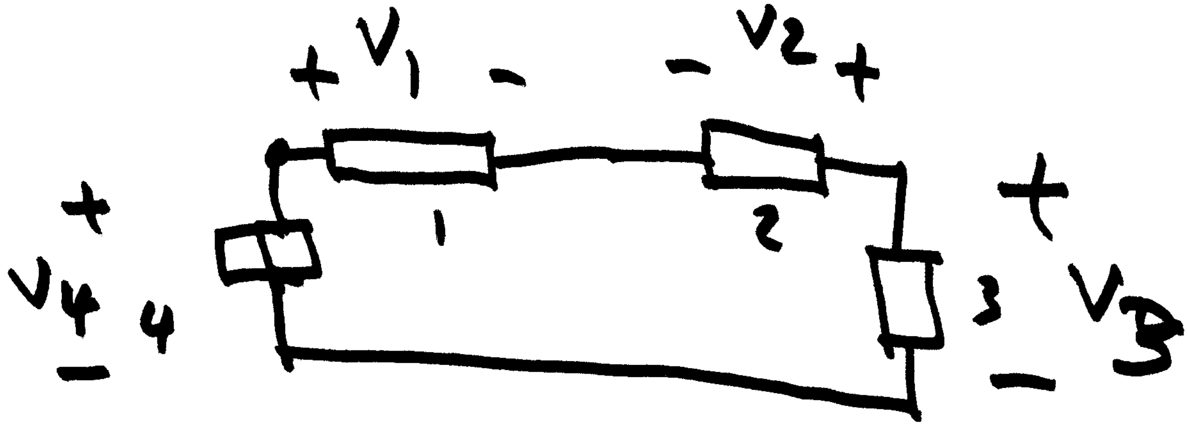
$$\sum_{\text{currents}} = 0$$

$$\Rightarrow I_1 + I_5 + I_3 - I_2 - I_4 = 0$$
$$I_1 + I_5 + I_3 = I_2 + I_4$$

KCL $\sum_{\text{all } k} i_k = 0$ At a node

2) Kirchoff's Voltage law (KVL)

closed path.



KVL:. Algebraic summation of voltages around a <u>closed path</u> is zero

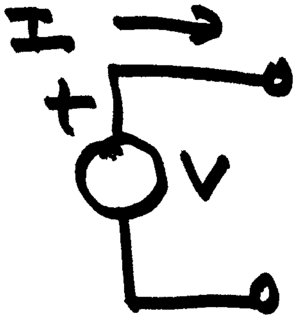
$$+V_1 - V_2 + V_3 - V_4 = 0$$

generalize

KVL:. $\sum_{\text{all } k} V_k = 0$ around a closed path

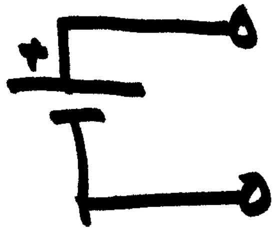
other cirivit elements

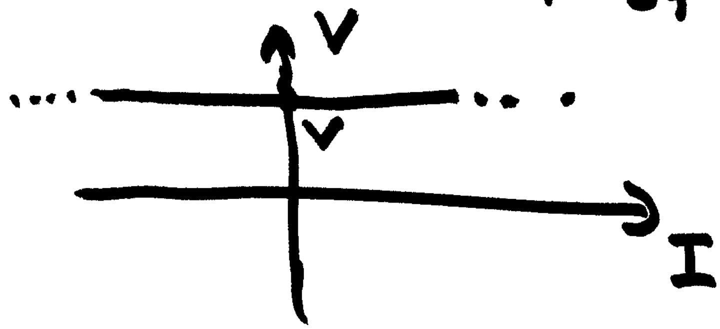
Ideal voltage Source



maintains voltag V accross it's terminals independent of I

OR

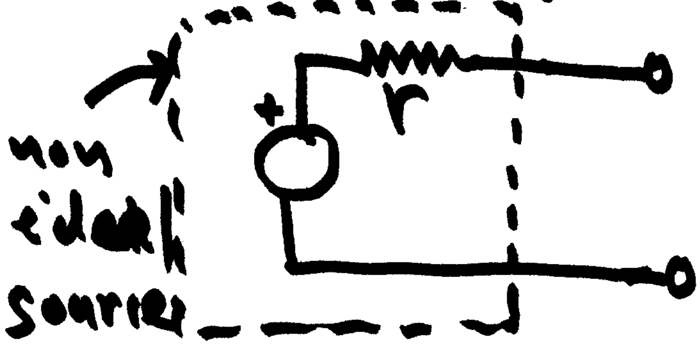




V-I characteri-stic

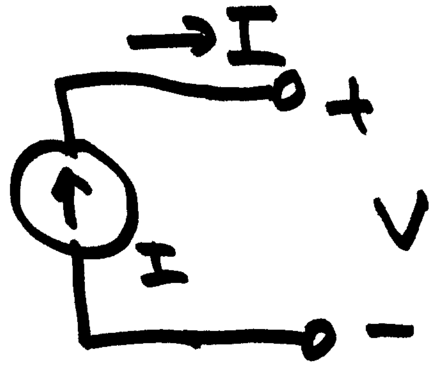
Ideal voltages are usefull in:-

1) College and Engineering Theory
2) Modeling non-ideal (Practical) voltage Sources

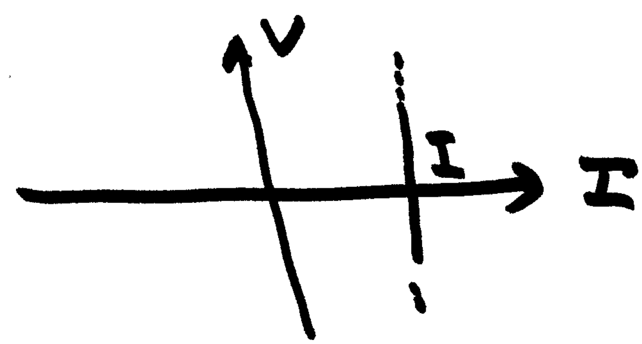


r: internal Resistance

Ideal current source



maintains current I, independent of voltage

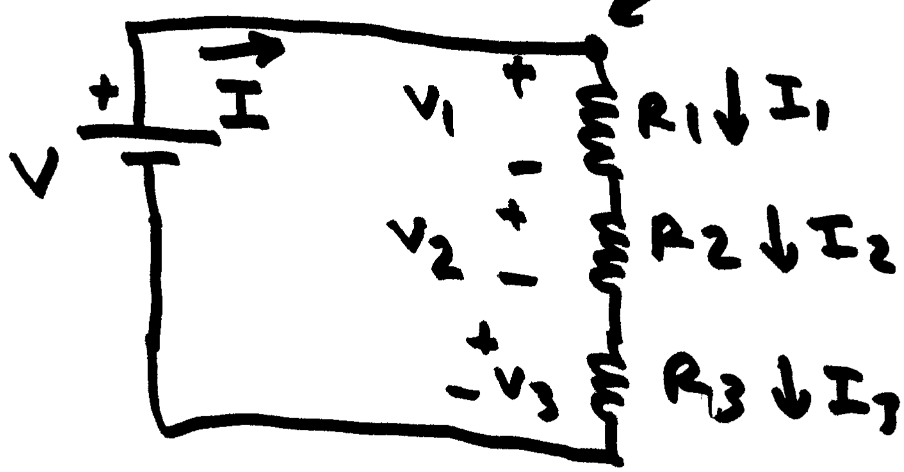


useful in: 1) college
2) TBA

Back to circuits using Resistors and DC sources

Example (1)

$I = I_1$ (KCL)



Circuit analysis:

compute voltage and current of each component in the circuit

In the example:

KCL. $I_1 = I_2 = I_3 = I$ (A)

KVL $+V_1 + V_2 + V_3 - V = 0$

$\Rightarrow V = V_1 + V_2 + V_3$ (B)

By ohm's Law $V_1 = I_1 R_1$

$V_2 = I_2 . R_2$

$V_3 = I_3 . R_3$

(B) $\Rightarrow V = \underbrace{I_1 R_1}_{V_1} + \underbrace{I_2 R_2}_{V_2} + \underbrace{I_3 R_3}_{V_3}$

$\Rightarrow V = I (R_1 + R_2 + R_3)$ (C)

$$\Rightarrow \boxed{I = \frac{V}{R_1 + R_2 + R_3}}$$

(11) $I = I_1 = I_2 = I_3$ (Resistor currents)

Find Resistor voltages

From ohm's Law

$$V_1 = I_1 R_1 = V \cdot \frac{R_1}{R_1+R_2+R_3}$$

$$V_2 = V \frac{R_2}{R_1+R_2+R_3}$$

$$V_3 = V \frac{R_3}{R_1+R_2+R_3}$$

Numerical example

$V = 12V \qquad R_1 = R_2 = R_3 = 4\,\Omega$

$$\Rightarrow I = \frac{12}{4+4+4} = 1A$$

$V_1 = 4V$

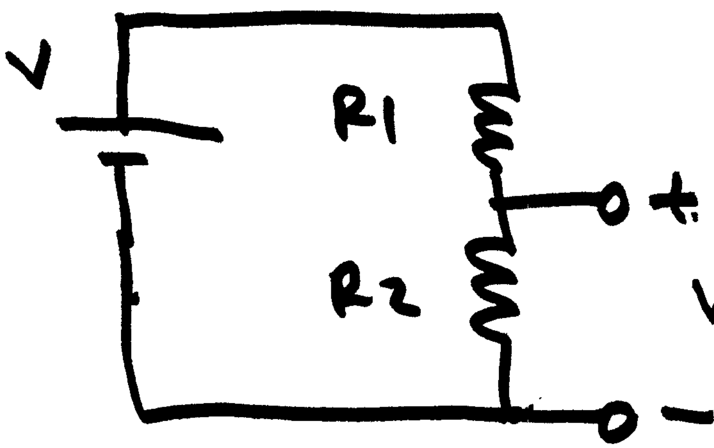
$V_2 = 4V$

$V_3 = 4V$

Special case

Same circuit as in example with only 2 Resistors (make $R_3 = 0\ \Omega$)

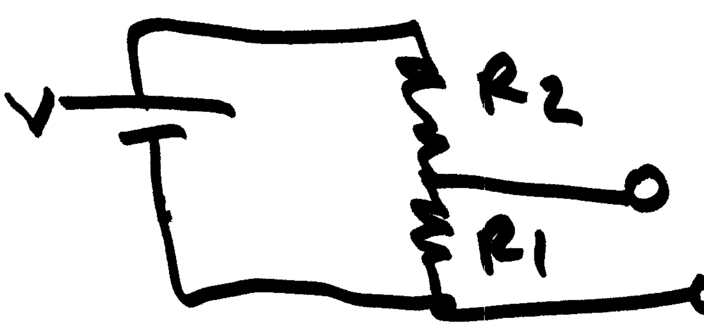
$$I = \frac{V}{R_1 + R_2}, \quad V_1 = V\frac{R_1}{R_1+R_2}, \quad V_2 = V\frac{R_2}{R_1+R_2}$$



$$V_2 = V\frac{R_2}{R_1+R_2}$$

Voltage divider Rule

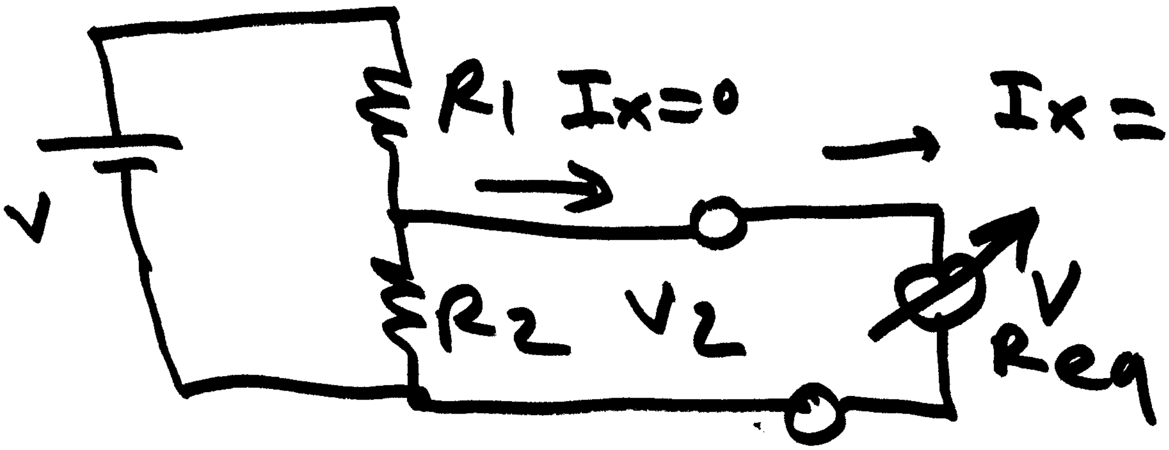
How about V_1



$$V_1 = V\frac{R_1}{R_1+R_2}$$

measurements

measure voltage



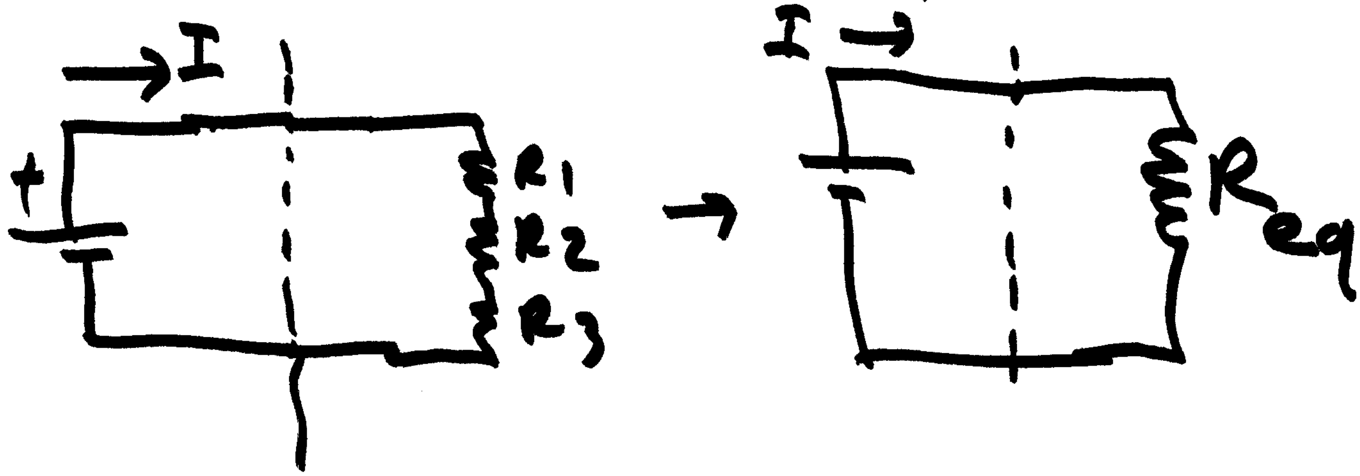
$\rightarrow I_x = \dfrac{V_x}{R_{eq}}$

$$V_2 = V \frac{R_2}{R_1 + R_2}$$

$\Rightarrow R_{eq} \rightarrow \infty$

Connections of resistors

1) Series connection



Req has the same $\underbrace{\text{effect}}_{??}$ current

as R_1, R_2, R_3

$$\underbrace{I = \frac{V}{R_1+R_2+R_3}}_{\text{actual circuit}} \qquad \underbrace{I = \frac{V}{R_{eq}}}_{\text{equivalent}}$$

$$\Rightarrow \boxed{R_{eq} = R_1 + R_2 + R_3}$$

<u>Generalize: - N</u>, Resistor in series

$$R_{eq} = R_1 + R_2 + \cdots R_N = \sum_{k=1}^{N} R_k$$