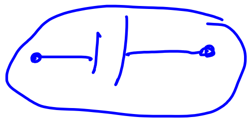
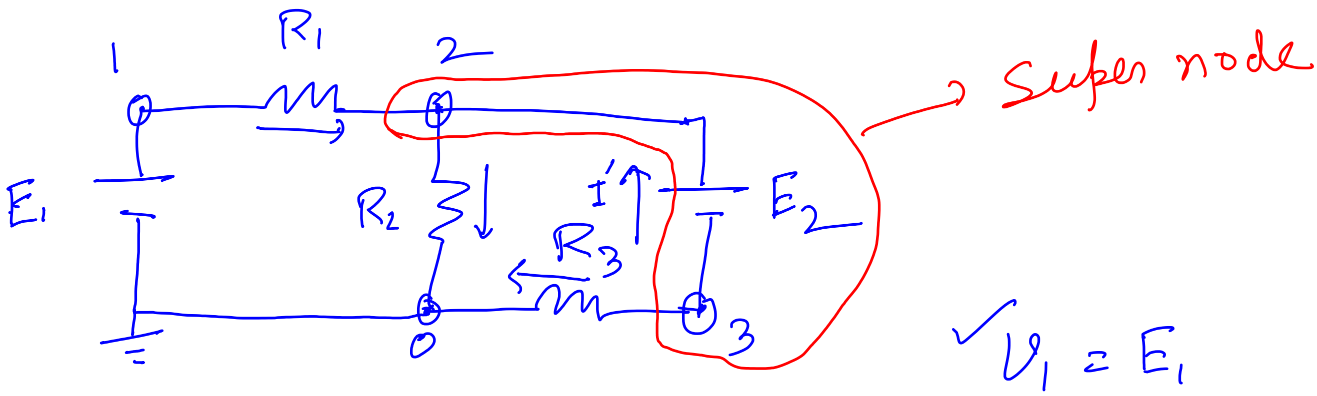
Quick Recap

Node Analysis (using node-to-reference voltages) → $(n-1)$

Mesh Analysis (Mesh currents) → $(b-n+1)$

Super node ()



$$V_1 = E_1$$

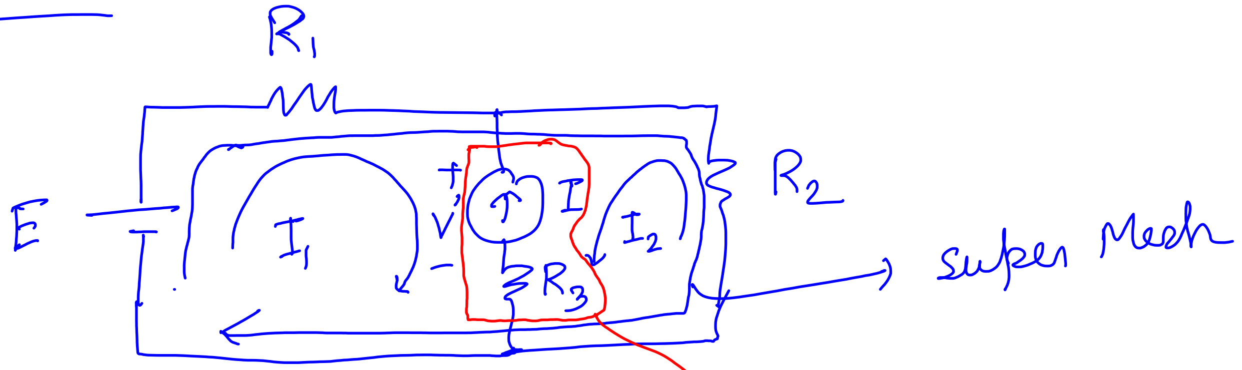
$$\frac{V_1 - V_2}{R_1} + I' = \frac{V_2}{R_2} \quad \text{(KCL at node 2)}$$

$$0 = \frac{V_3}{R_3} + I' \quad \text{(KCL at node 3)}$$

$$V_2 - V_3 = E_2$$

$$\Rightarrow \frac{V_1 - V_2}{R_1} - \frac{V_3}{R_3} = \frac{V_2}{R_2} \quad \text{(KCL at super node)}$$

Super Mesh



KVL for loop 1,

$$E = I_1 R_1 + \underbrace{V' + (I_1 + I_2) R_3}$$

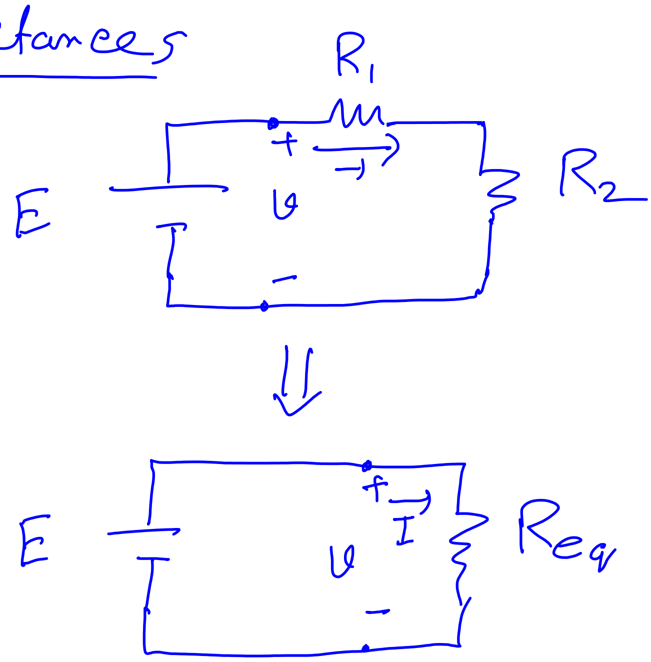
KVL for loop 2,

$$0 = I_2 R_2 + \underbrace{V' + (I_1 + I_2) R_3}$$

$$E = I_1 R_1 - I_2 R_2 \longrightarrow \text{(KVL for Super Mesh)}$$

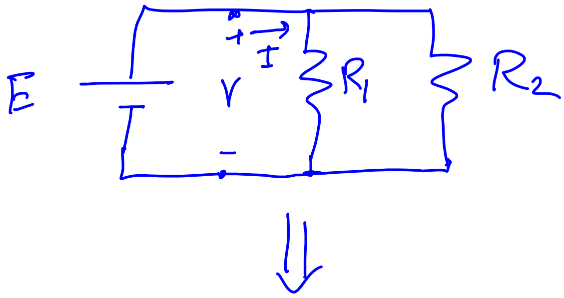
$$I = -I_1 - I_2$$

Series Resistances

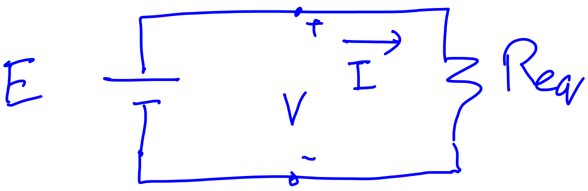


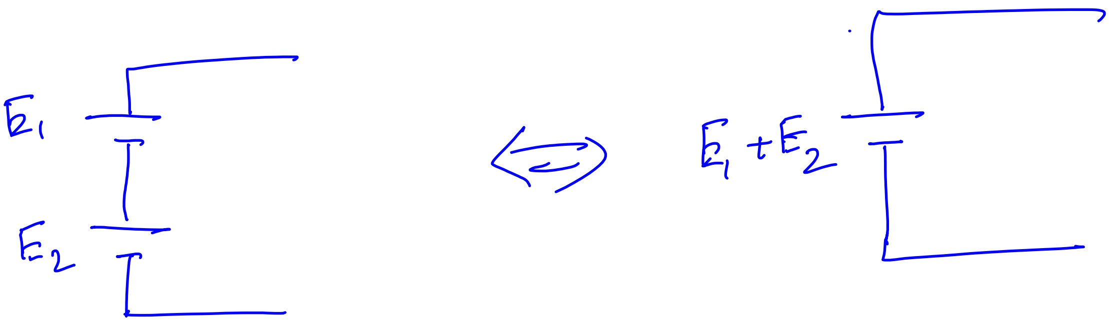
$$R_{eq} = R_1 + R_2$$

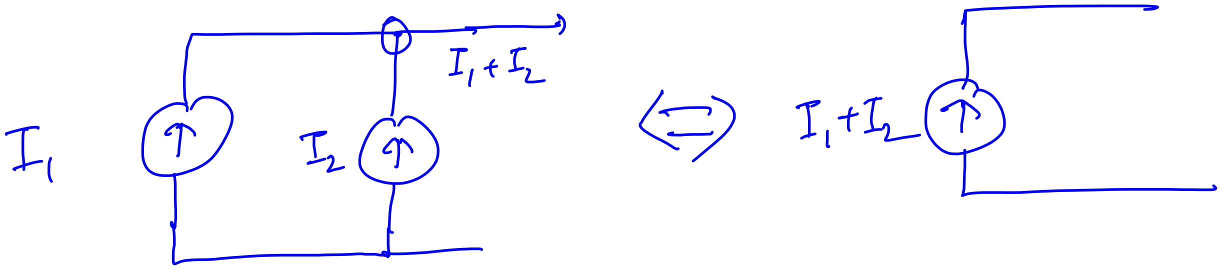
Parallel Resistances

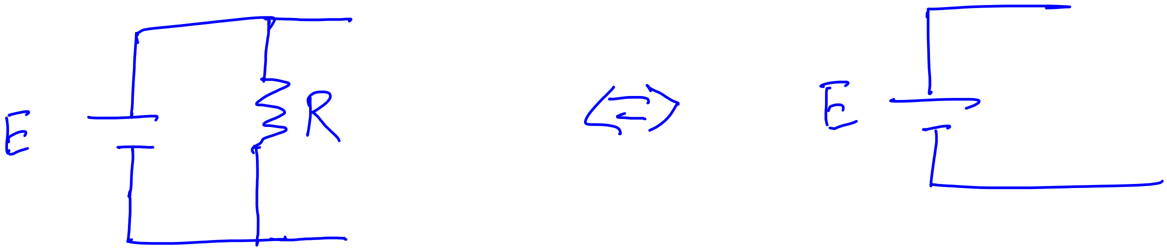


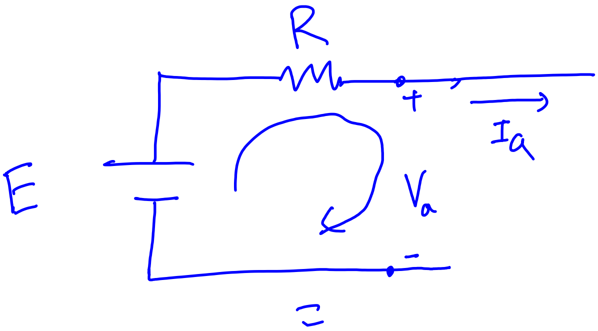
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$



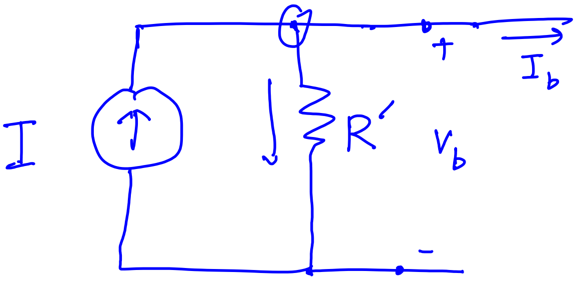








$\Leftrightarrow$

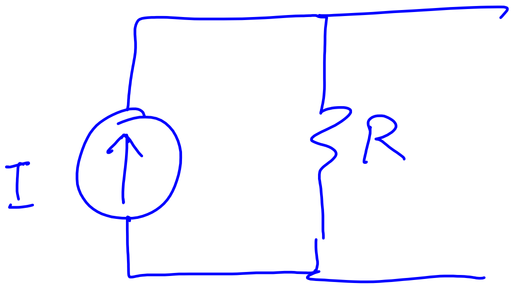


$E = I_a R + V_a$

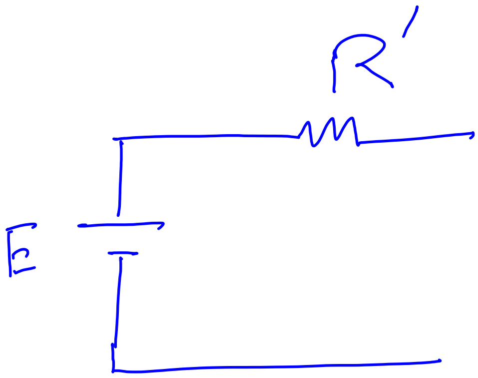
$I = \frac{V_b}{R'} + I_b$

For equivalence $I_a = I_b$ and $V_a = V_b$

$$\left.\begin{aligned} I &= E/R \\ R' &= R \end{aligned}\right\}$$



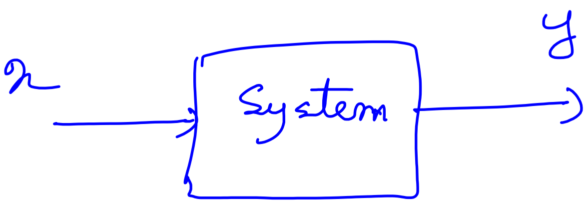
$\Leftrightarrow$



$R' = R$

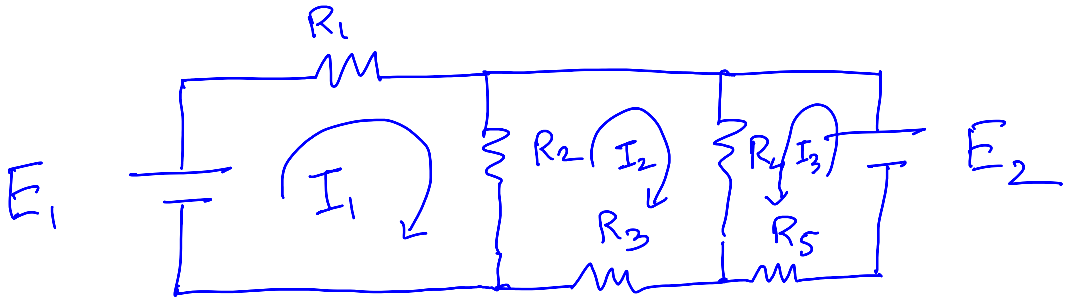
$E = IR$

Superposition Principle



$$\left.\begin{aligned} x_1 &\longrightarrow y_1 \\ x_2 &\longrightarrow y_2 \end{aligned}\right\} \Rightarrow \alpha_1 x_1 + \alpha_2 x_2 \longrightarrow \alpha_1 y_1 + \alpha_2 y_2$$

The system is linear



$$E_1 = I_1 R_1 + (I_1 - I_2) R_2$$

$$0 = -(I_1 - I_2) R_2 + (I_2 + I_3) R_4 + I_2 R_3$$

$$E_2 = (I_2 + I_3) R_4 + I_3 R_5$$

$$A x = b \quad , \quad A \in \mathbb{R}^{3\times 3}$$

$$x = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \qquad x \in \mathbb{R}^{3\times 1}$$

$$b \in \mathbb{R}^{3\times 1}$$

$$A = \begin{bmatrix} R_1 + R_2 & -R_2 & 0 \\ -R_2 & R_2 + R_3 + R_4 & R_4 \\ 0 & R_4 & R_4 + R_5 \end{bmatrix} \qquad b = \begin{bmatrix} E_1 \\ 0 \\ E_2 \end{bmatrix}$$

$$b = \begin{bmatrix} E_1 \\ 0 \\ E_2 \end{bmatrix} = \underbrace{\begin{bmatrix} E_1 \\ 0 \\ 0 \end{bmatrix}}_{b_1} + \underbrace{\begin{bmatrix} 0 \\ 0 \\ E_2 \end{bmatrix}}_{b_2}$$

$$A x = b = b_1 + b_2$$

$$x = \underbrace{A^{-1} b_1}_{x_1} + \underbrace{A^{-1} b_2}_{x_2} \Bigg\} \text{superposition holds}$$

$x_1 \rightarrow$ contribution from E_1

$x_2 \rightarrow$ Contribution from E_2

$$A x = b$$

there are "p" no. of independent sources.

$$b = \sum_{i=1}^{p} b_p$$

Example

$$b = \begin{bmatrix} E_1 - E_2 \\ 0 \\ E_3 \end{bmatrix} = \underbrace{\begin{bmatrix} E_1 \\ 0 \\ 0 \end{bmatrix}}_{b_1} - \underbrace{\begin{bmatrix} E_2 \\ 0 \\ 0 \end{bmatrix}}_{b_2} + \underbrace{\begin{bmatrix} 0 \\ 0 \\ E_3 \end{bmatrix}}_{b_3}$$

Superposition Theorem

Each branch current or voltage can be decomposed into contributions from individual independent current or voltage sources.