電子電工學
Lecture 5

Midterm Exam Information

Date: Oct 14, 2020
Time: 3:10 ~ 6:00 pm (in class)
Location: 化工系館柏林講堂/93156
Coverage: Textbook Chapters 1-4

Recap: Superposition

KCL, KVL, Ohm's → eqn's $\xrightarrow{\text{Solve}}$ V, I, P (10 eqn's)

Simplify: NODAL → Voltages (3eq)

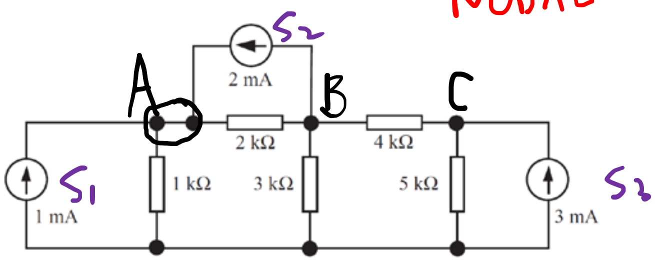


Figure 4.1 The circuit to be analysed

Want only V_A

Apply only one src

Then sum-up

Zero sources

I=0 -> Open ckt

V=0 -> Short Ckt

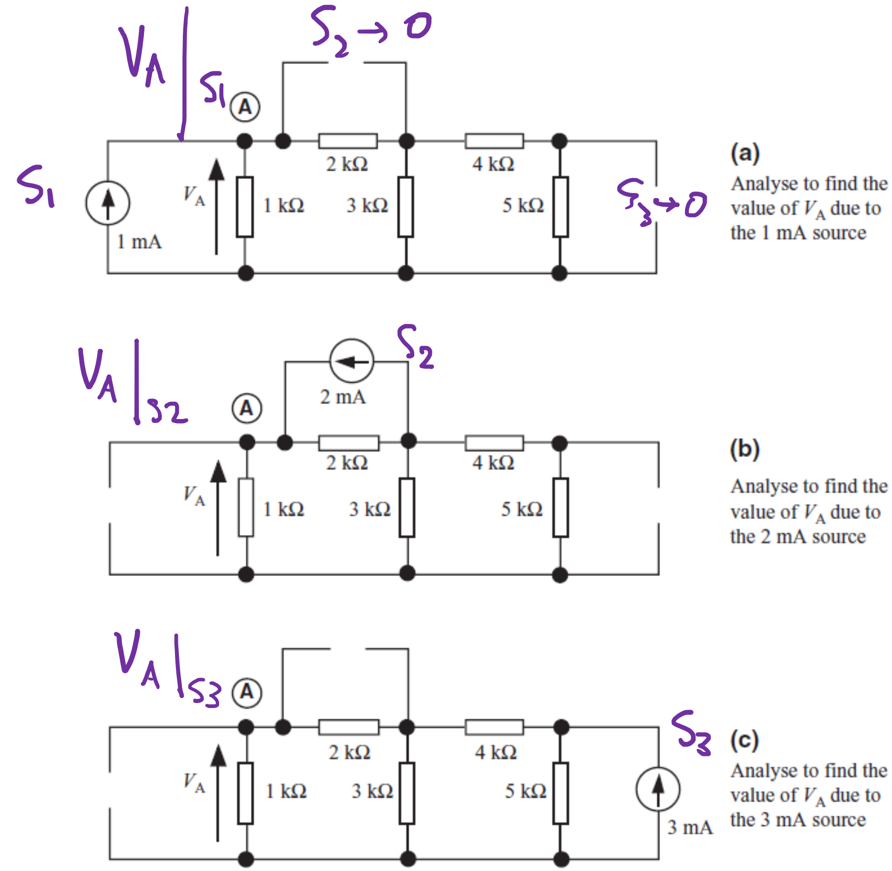


Figure 4.10 Illustration of the use of the superposition principle to find the voltage V_A at node A in the circuit of Figure 4.4. The three calculated voltages are added together to find the actual value of V_A.

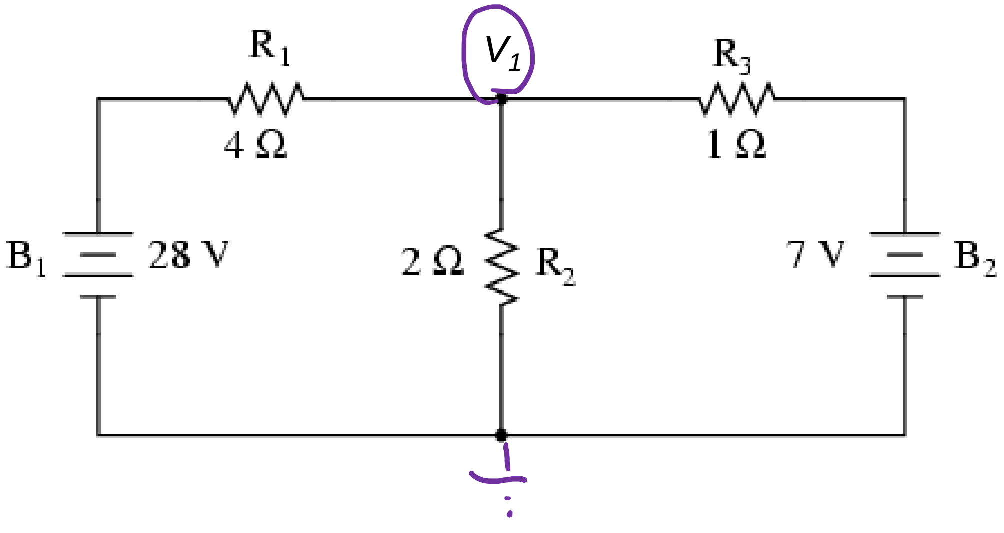
Quiz review

Find the voltage V_1 by applying the principle of superposition.

$$V_1 = V_1\Big|_{B_1} + V_2\Big|_{B_2}$$

Voltage Src → 0

Short Ckt.



Quiz review

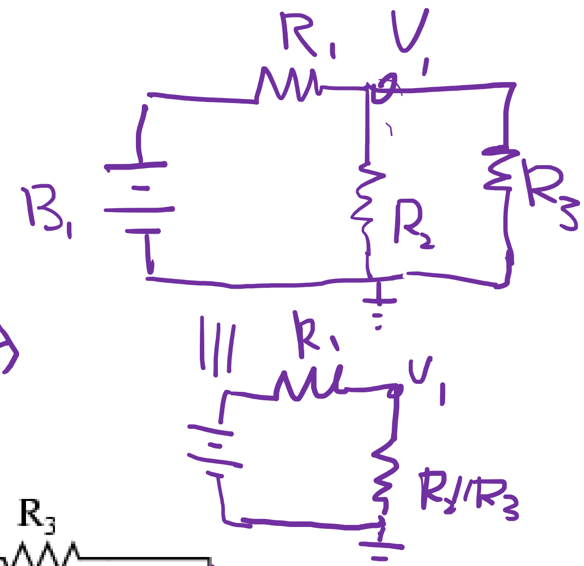
Apply only B_1 28V

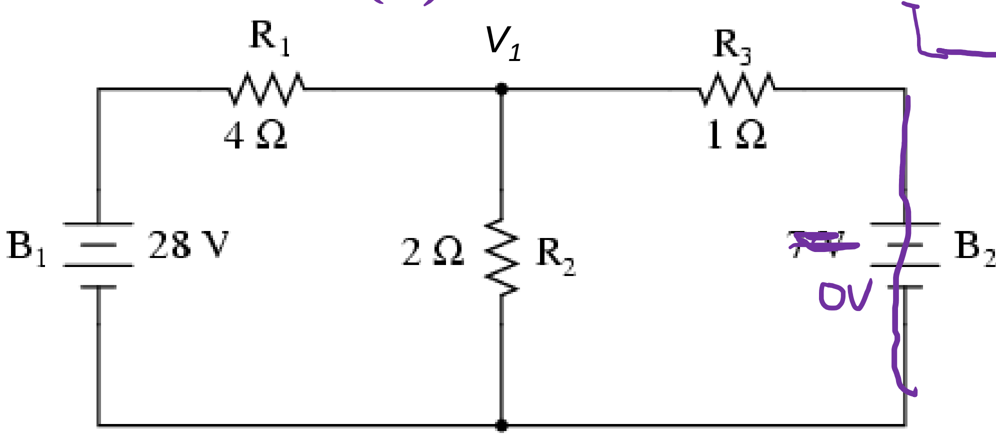
$B_2 \rightarrow 0V \rightarrow$ Short ckt

$$V_1\Big|_{B1} = 28 \times \frac{R_2 // R_3}{R_1 + (R_2 // R_3)}$$

$$= 28 \times \frac{2/3}{4 + 2/3}$$

$$= 4 \ (V)$$





Quiz review

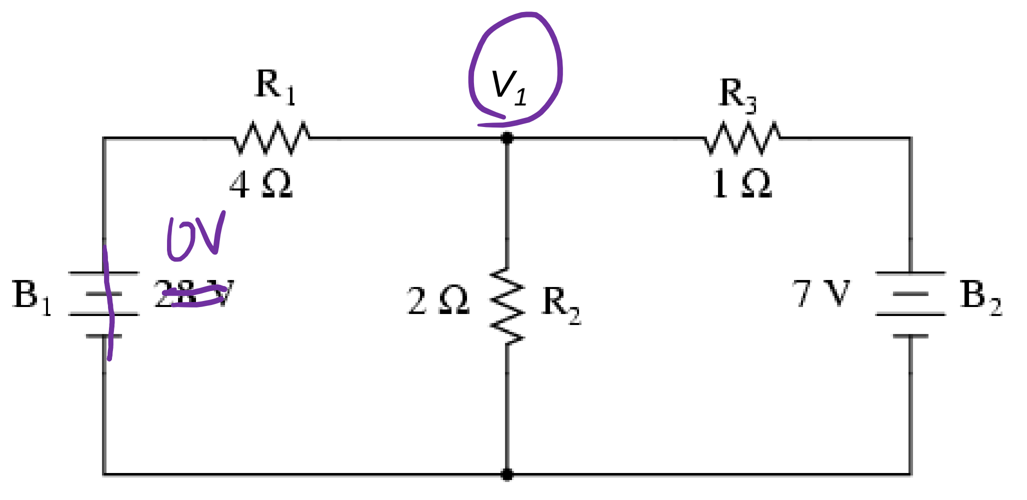
Apply only B_2

Set $B_1 \to 0$

$$V_1\Big|_{B2} = 7 \times \frac{R_1 /\!/ R_2}{R_3 + (R_1 /\!/ R_2)}$$

$$= 7 \times \frac{4/3}{1 + 4/3}$$

$$= 4 \text{ (V)}$$

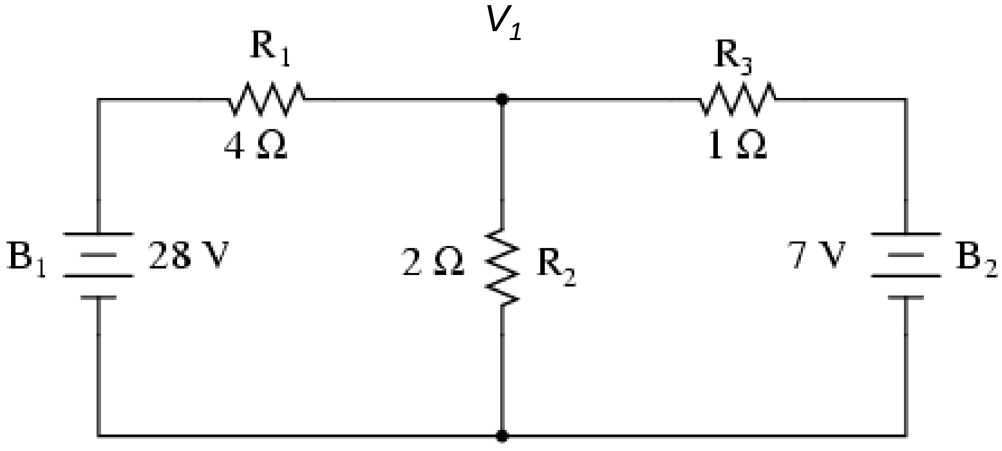


Quiz review

$$V_1 = V_1\big|_{B_1} + V_1\big|_{B_2}$$

$$= 4 + 4$$

$$= ?$$

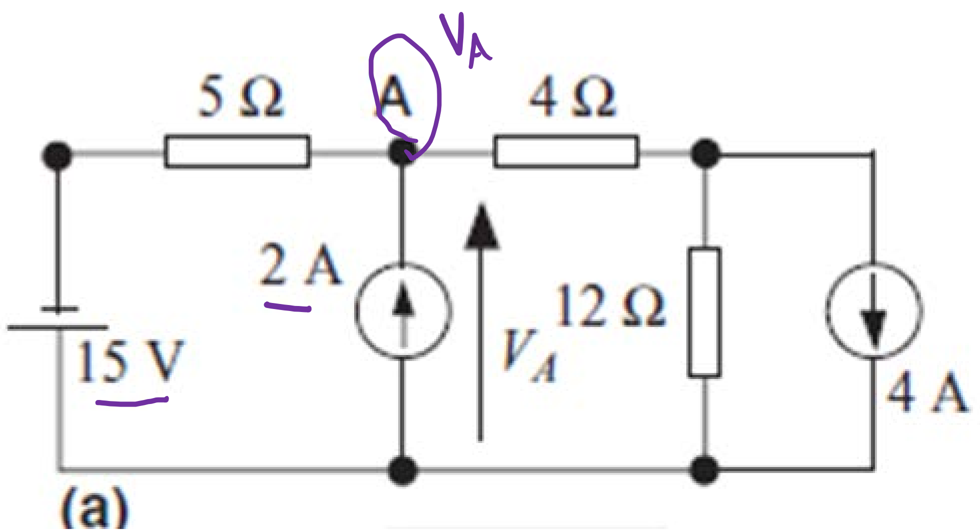


Example 4.2 Superposition with voltage source

Aim: Find V_A.

Voltage Sources=0 -> Short

Current Sources=0 -> Open



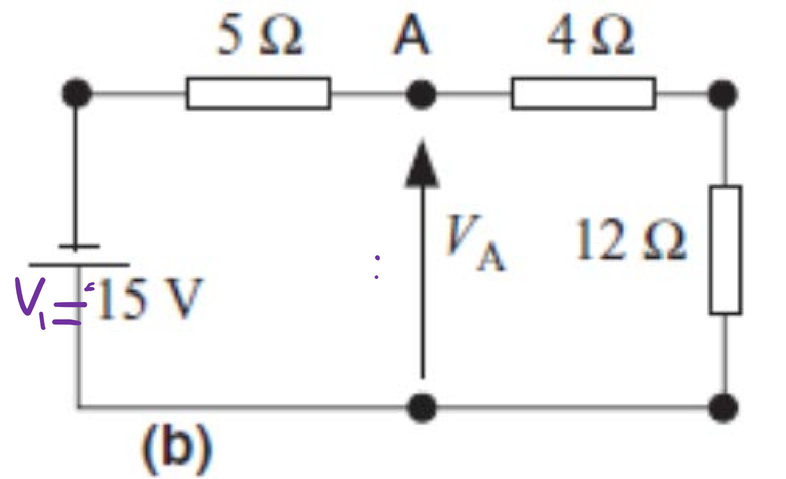
Example 4.2 (source 1)

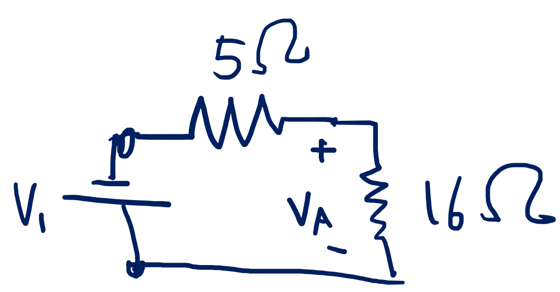
S_1 : $V_1 = 15V$

$S_2 \to 0$ } Open
$S_3 \to 0$

$$V_A \big|_{S_1} = (-15) \times \frac{4+12}{5+(4+12)}$$

$$= -\frac{80}{7} \; (V)$$





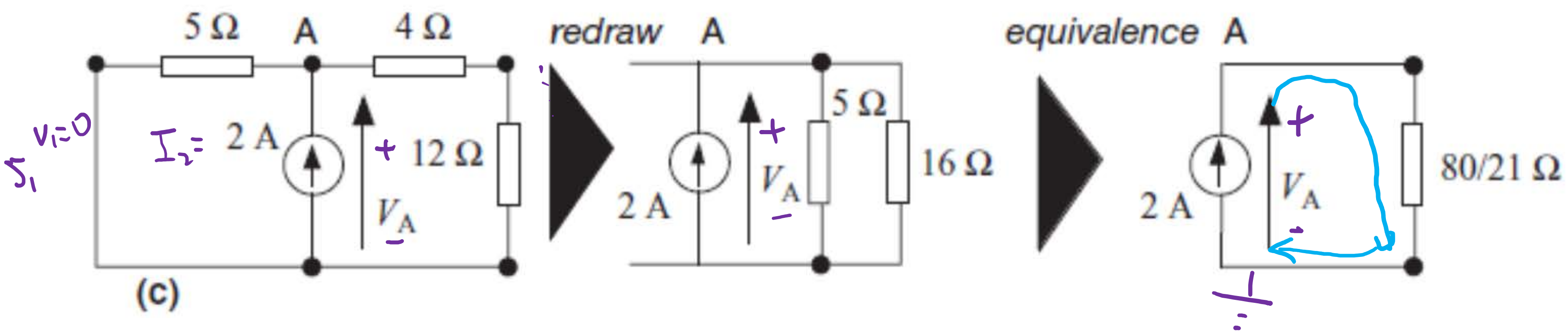
Example 4.2
(source 2)

$S_2 : I_2 = 2\,A$

$S_1 \to 0 \quad V_1 = 0$ short ckt.

$S_3 \to 0 \quad I_3 = 0$ Open ckt

$$V_A\Big|_{S2} = 2 \times \frac{80}{21} = \frac{160}{21} \ (V)$$



Example 4.2 (source 3)

$S_3 : I_3 = 4A$

$S_1 : V_1 = 0 \rightarrow$ Short

$S_2 : I_1 = 0 \rightarrow$ Open

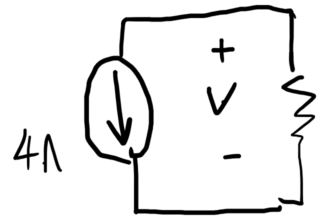
$$V_A\big|_{S_3} = V \times \frac{5}{5+4}$$

$$= \left(-\frac{144}{7}\right) \times \frac{5}{9}$$

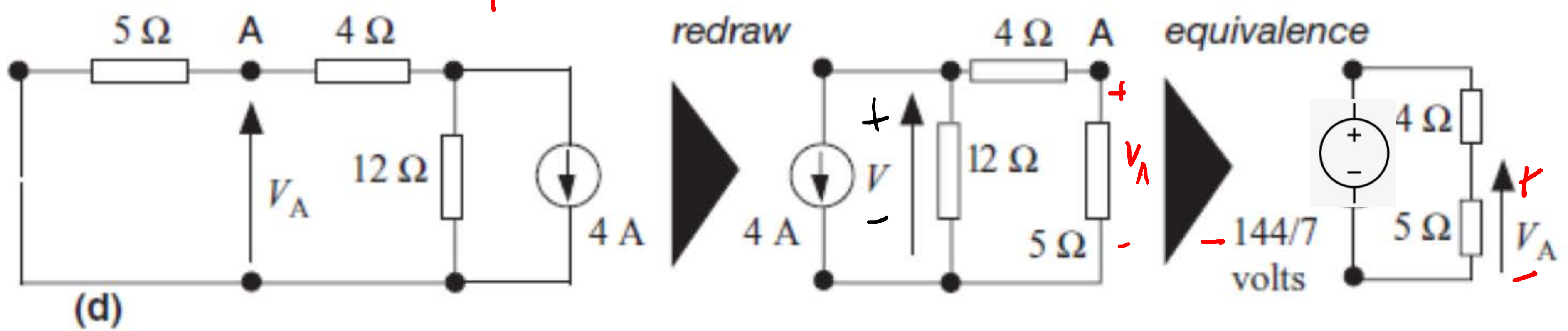
$$= -\frac{80}{7} \ (V)$$

$$V = -4 \times R$$

$$= -\frac{144}{7} \ (V)$$



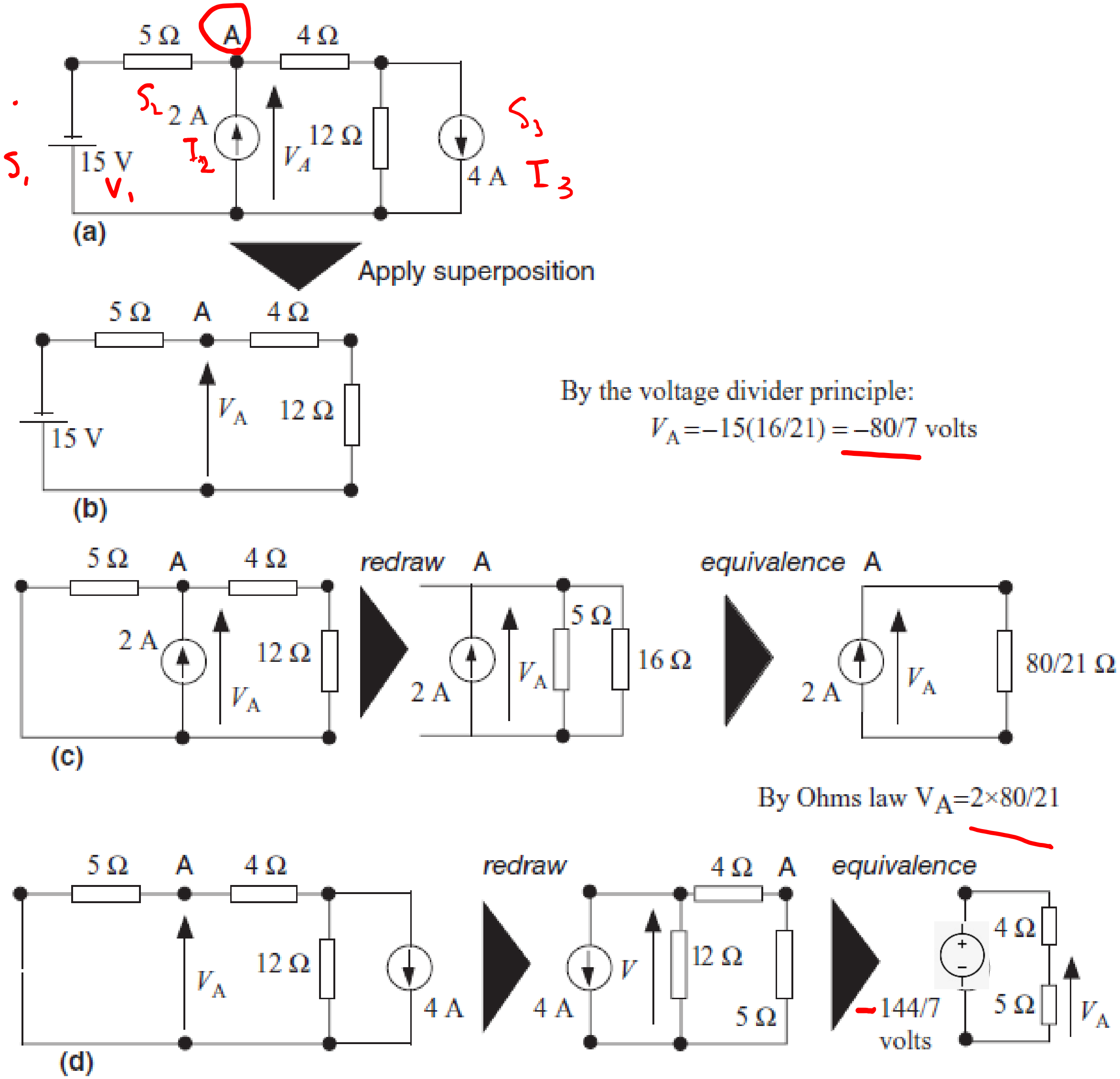
$R = 12 \parallel (4+5)$



Example 4.2 (superposition)

$$V_A = V_A\big|_{S_1} + V_A\big|_{S_2} + V_A\big|_{S_3}$$

$$= -\frac{320}{21}\ (V)$$



By Ohms Law $V = 4(108/21) = 144/7$ volts

By voltage divider principle $V_A = (5/9)(144/7) = -80/7$ volts

By Superposition, actual V_A in the circuit of Figure 4.6 $= -80/7 + 160/21 - 80/7 = -320/21$ volts

Figure 4.11 Illustrating the use of superposition to analyse circuit behaviour

Basic circuit analysis: variable loads

R_L Load varies $\rightarrow$ V_{AB} change

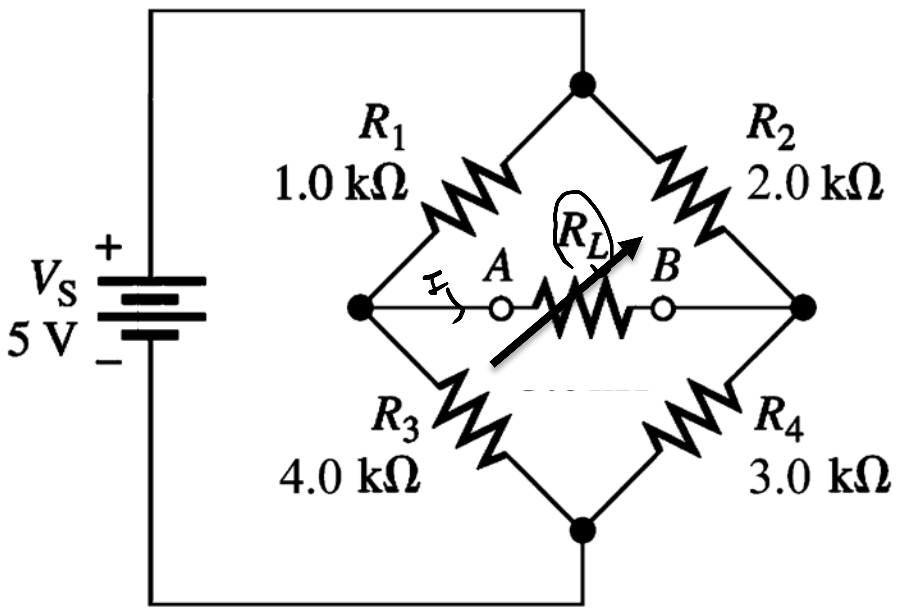
I

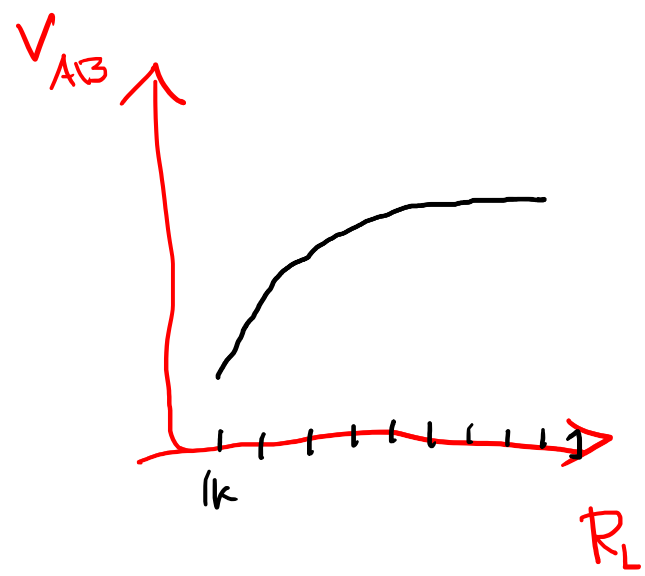
$R_L = 1K \rightarrow V_{AB}$

$R_L = 2K \rightarrow V_{AB}$

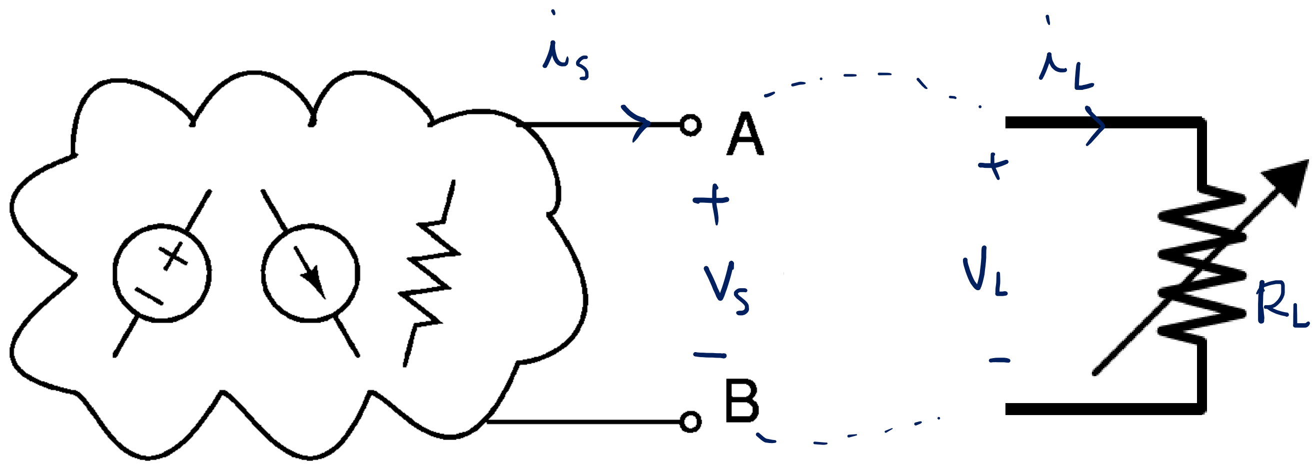
$\vdots$

$R_L = 10K \rightarrow V_{AB}$





Equivalent circuit



v_L varies according to R_L

$R_L = 1k \rightarrow V_L = G_{1k}^{-1} \cdot S$

$R_L = 2k \rightarrow V_L = G_{2k}^{-1} \cdot S$

$R_L = 3k \rightarrow V_L = G_{3k}^{-1} \cdot S$

$\vdots$

$R_L = 10k \rightarrow V_L = G_{10k}^{-1} \cdot S$

Find i_s - v_s characteristic

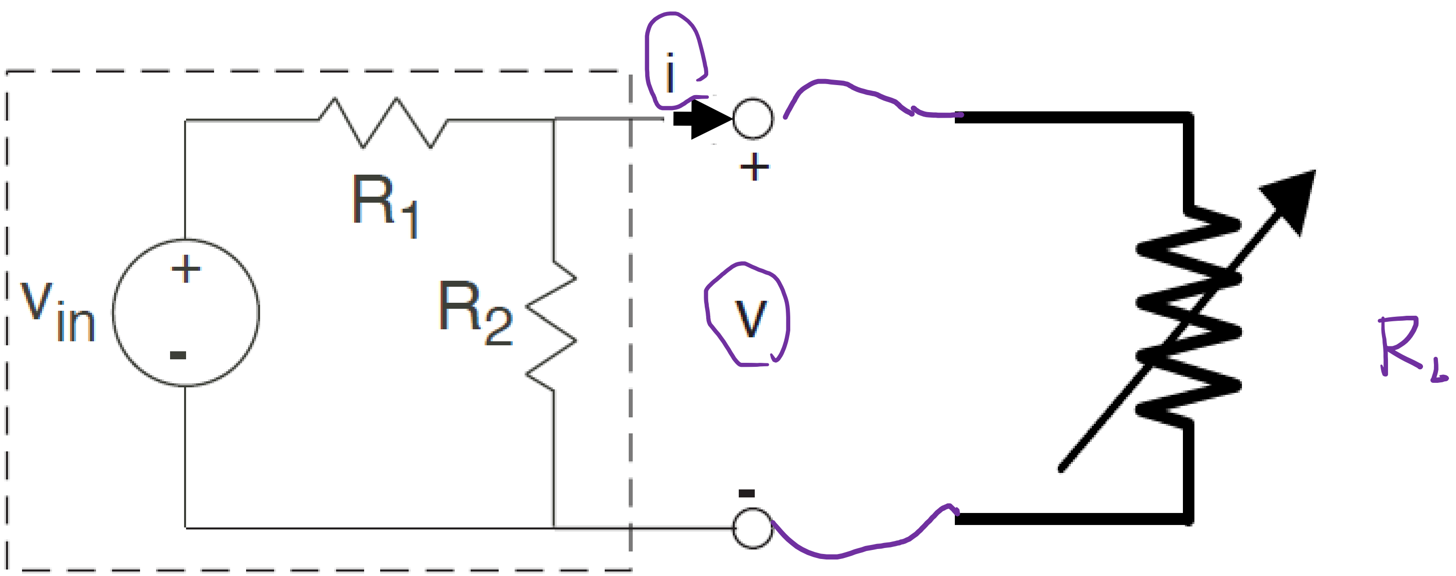
$$v_s = f(i_s)$$

$V_L = i_L \cdot R_L$

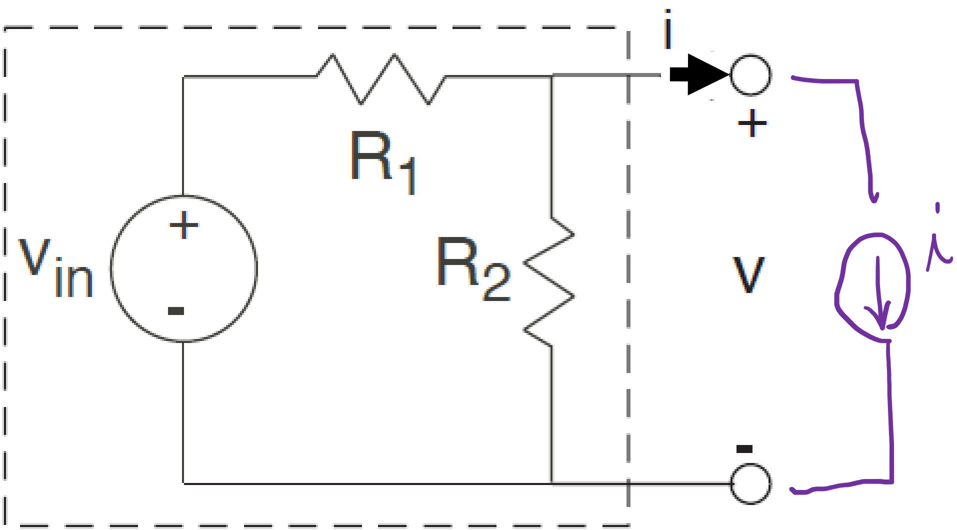
i_L - V_L characterist.

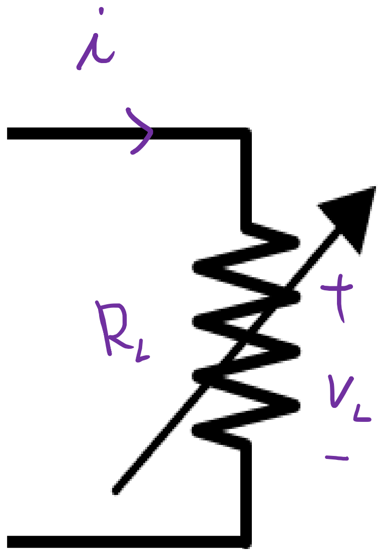
Equivalent circuit

$v = f(i)$? for any R_L



Equivalent circuit





Apply a current source with i amp

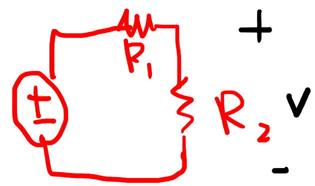
find $v = \underline{\underline{f(i)}}$?

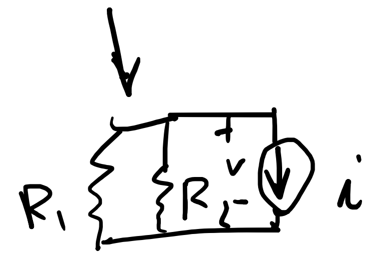
Principle of superposition

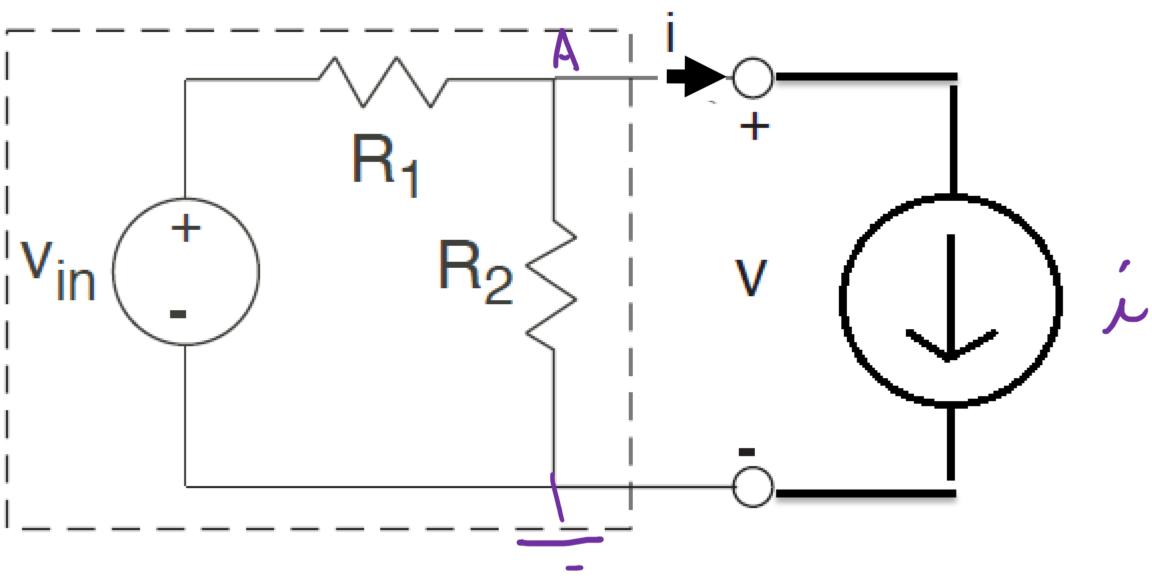
$$v = v_A\Big|_{v_{in}} + v_A\Big|_{i}$$

$$= v_{in} \times \frac{R_2}{R_1+R_2} + (-i) \times (R_1 \| R_2)$$

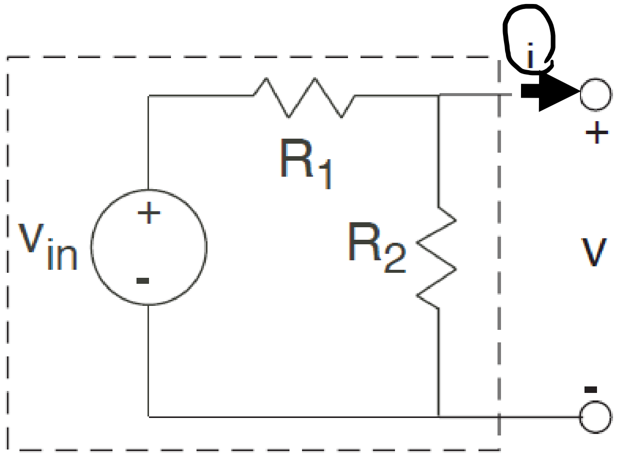
$$\Rightarrow v = f(i)$$





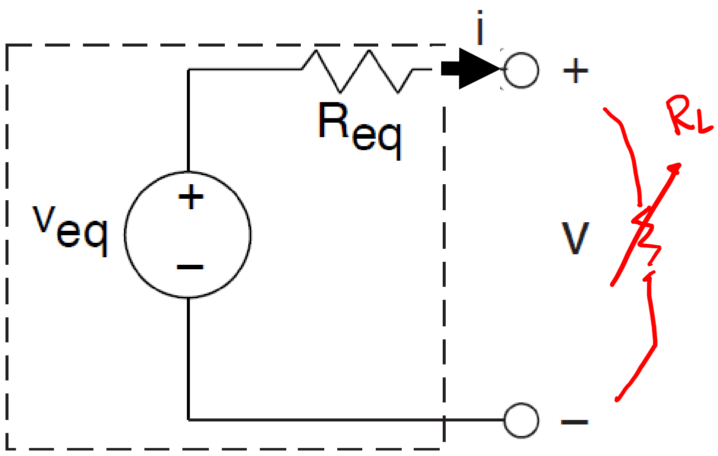


Thevenin equivalent circuit



For any i

$$v = v_{in} \times \underbrace{\frac{R_2}{R_1+R_2}}_{v_{eq}} - i \times \underbrace{(R_1 // R_2)}_{R_{eq}}$$



$$v = v_{eq} - i \cdot R_{eq}$$

$$v = f(i)$$

voltage divider $V = V_{eq} \cdot \dfrac{R_L}{R_{eq} + R_L}$

Multiple sources

Apply superposition + virtual current src i

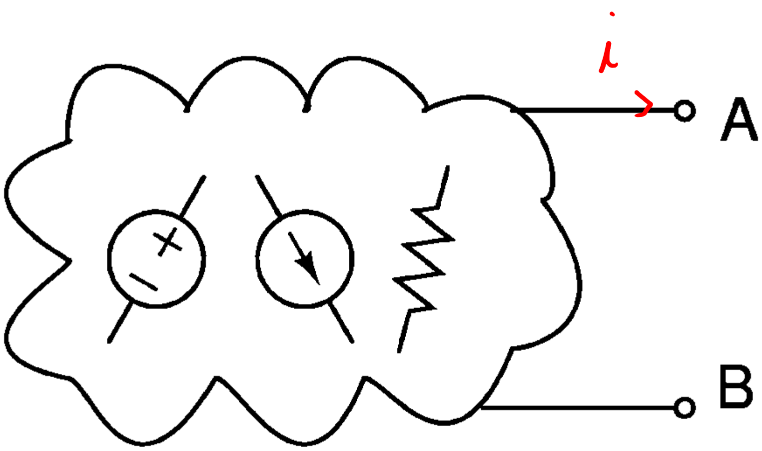
$$V_{AB} = V_{AB}\big|_{S_1} + V_{AB}\big|_{S_2} + \cdots + V_{AB}\big|_{S_N} + V_{AB}\big|_{i}$$

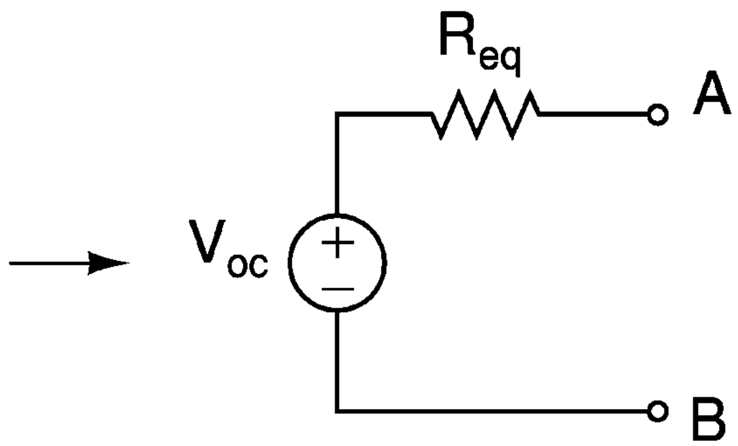
$$= (V_1 + V_2 \cdots + V_N) - i \cdot R_{eq}$$

$$= V_{eq} - i R_{eq}$$

$$= \underline{\underline{V_{oc}}} - i \cdot R_{eq}$$

Thevenin Equivalent





Thevenin's theorem

Any Linear circuit N

Can be modeled by

$$V = f(I) = V_{oc} - I \cdot R_O$$

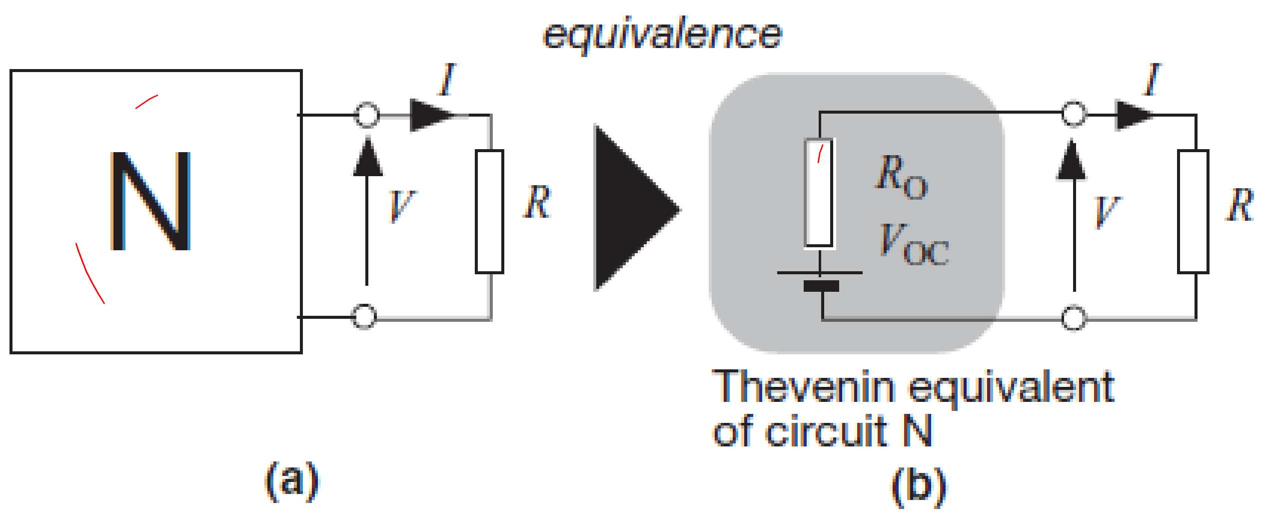
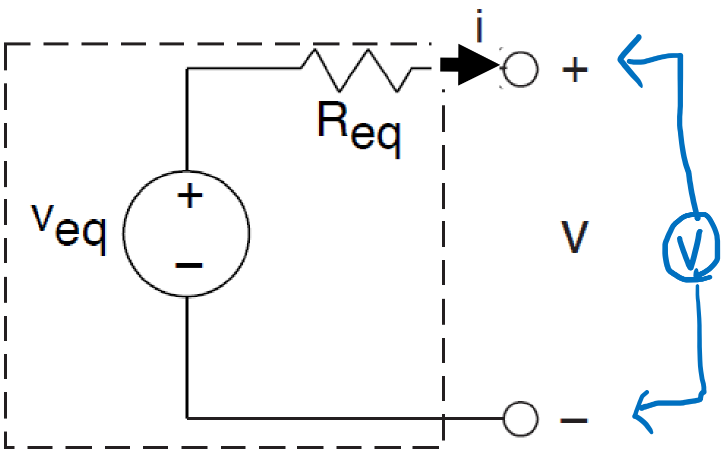
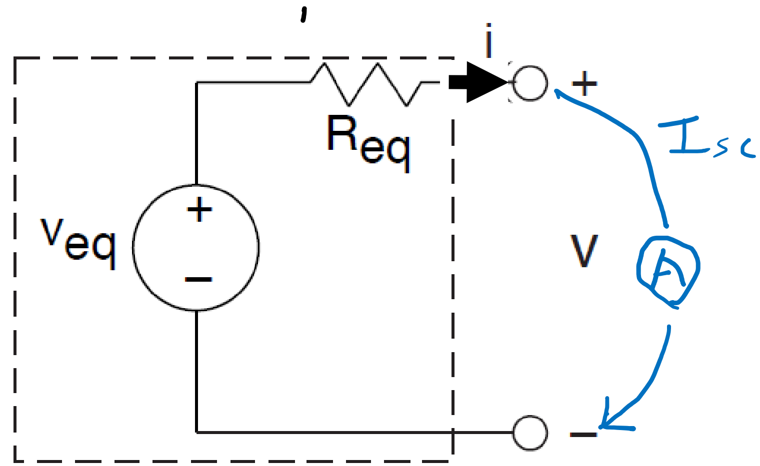


Figure 4.12 A linear circuit N can be represented by a Thevenin equivalent circuit consisting of a voltage source and a resistor

Thevenin equivalent circuit





apply Voltmeter

Open-Circuit Voltage

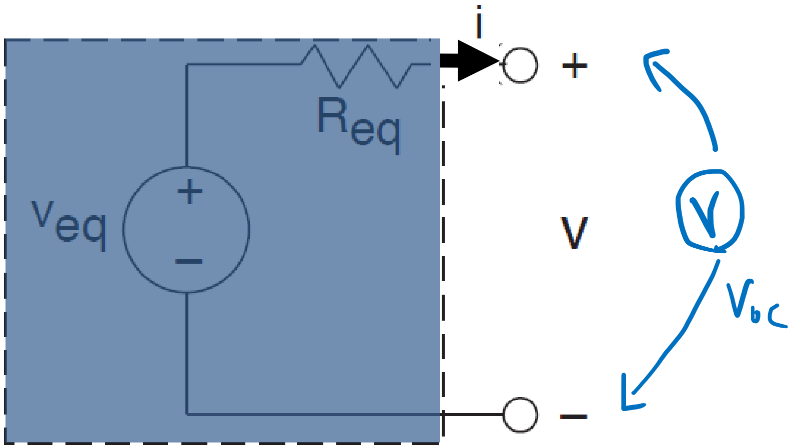
$V_{OC} = V_{eq}$

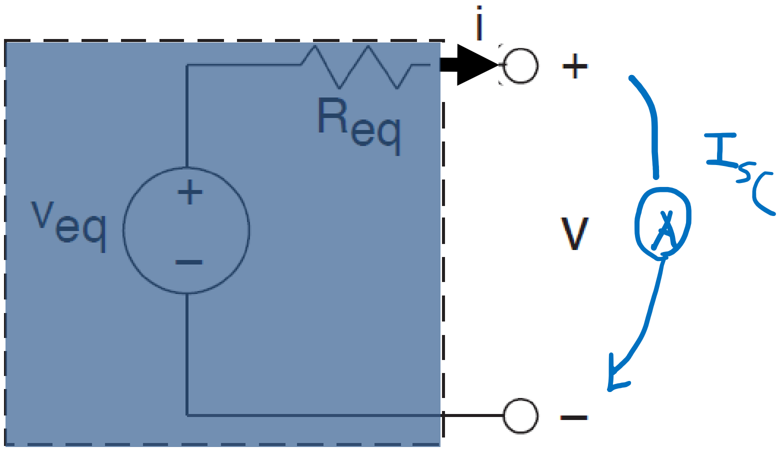
apply Amperemeter

I_{sc} : Short-ckt current

$R_{eq} = V_{oc} / I_{sc}$

Thevenin equivalent circuit





Black-box

$V_{eq} = V_{oc}$

$R_{eq} = V_{oc} / I_{sc}$

Thevenin equivalent circuit

1. Find
Open-ckt
Voltage
Voc

2. Find equiv. resistance
Voltage Src → Short.
Current Src → Open

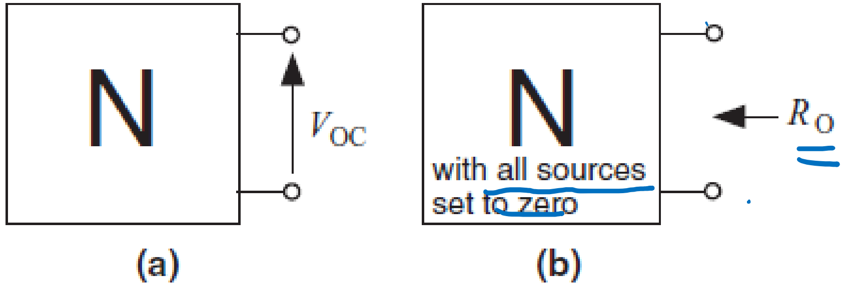
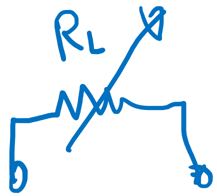
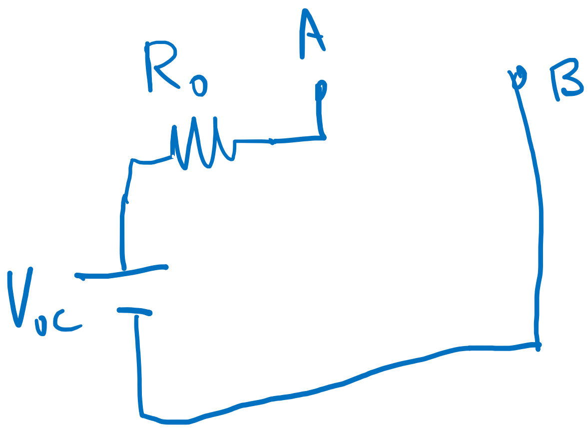


Figure 4.13 Calculations required to find the two parameters defining a Thevenin equivalent circuit

Example 4.3





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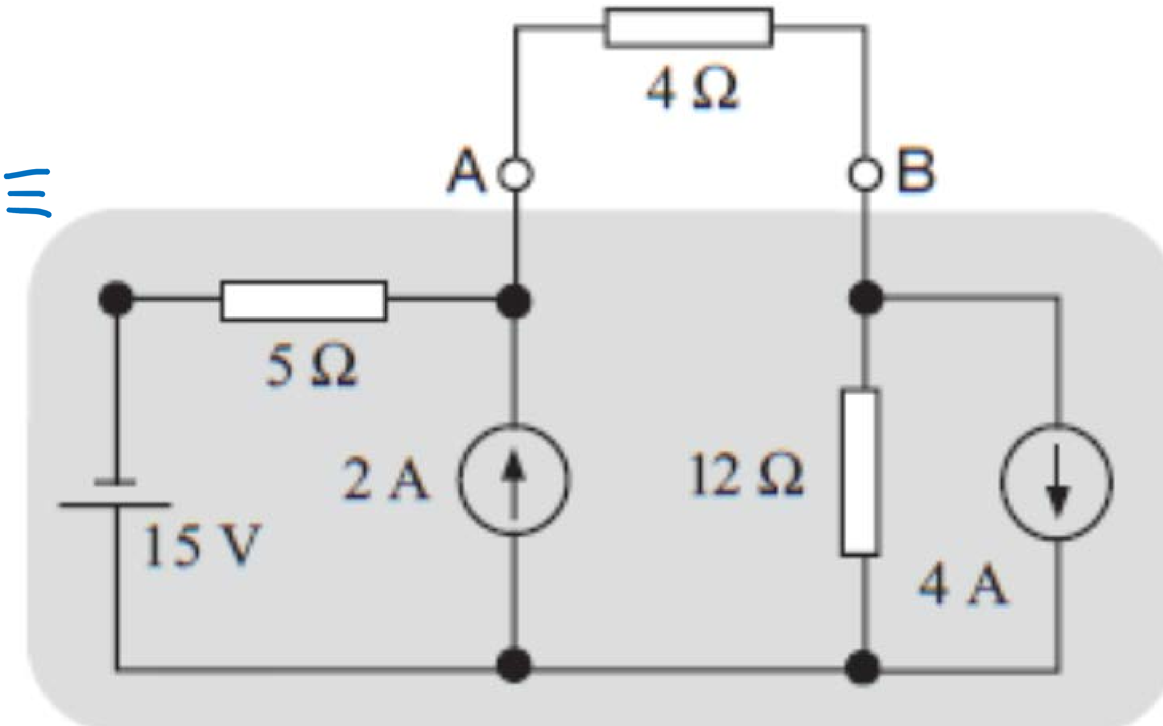


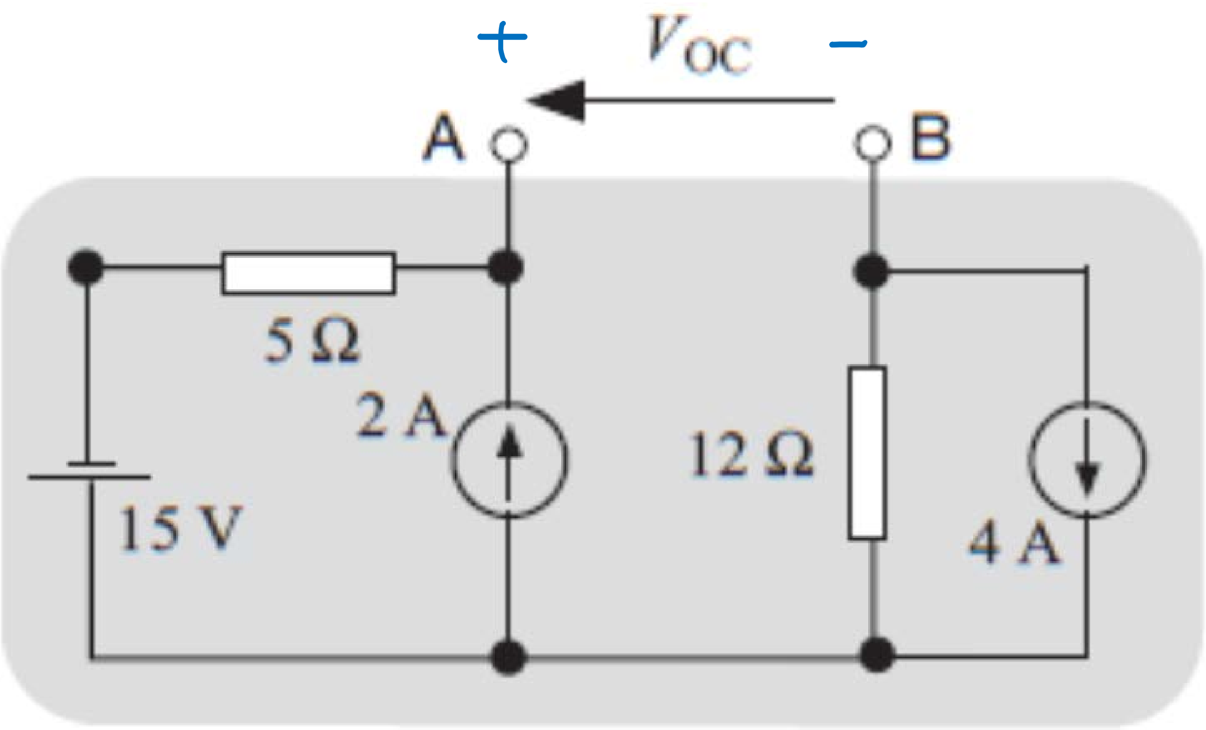
Find $V_{oc} = ?$

$R_o = ?$

Example 4.3

Nodal Analysis

Superposition

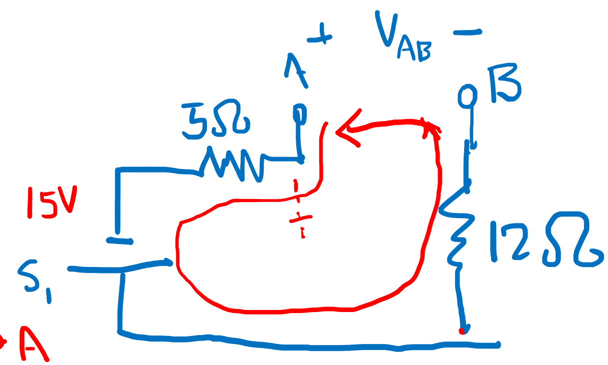


Example 4.3

Apply only $S_1 = 15V$

Set $S_2 \rightarrow 0A$ $S_3 \rightarrow 0A$

$V_{AB}|_{S_1} = -15V$



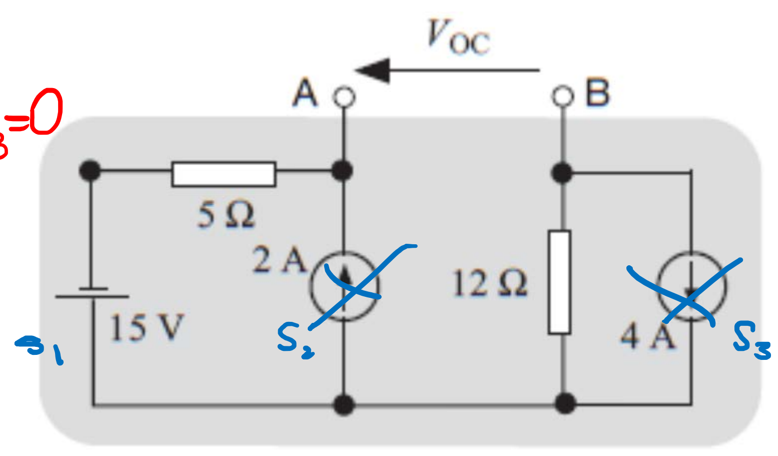
KVL:

$A \rightarrow 5\Omega \rightarrow S_1 \rightarrow 12\Omega \rightarrow B \rightarrow A$

$I \approx 0$

$V_A - I\cdot 5 + 15V - I\cdot 12 + V_{AB} = 0$

$\Rightarrow V_{AB} = -15V$

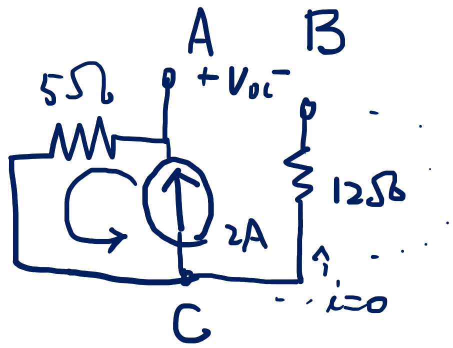


Example 4.3

Apply only $S_2 = 2A$

Set $S_1 = 0\ V \rightarrow$ short

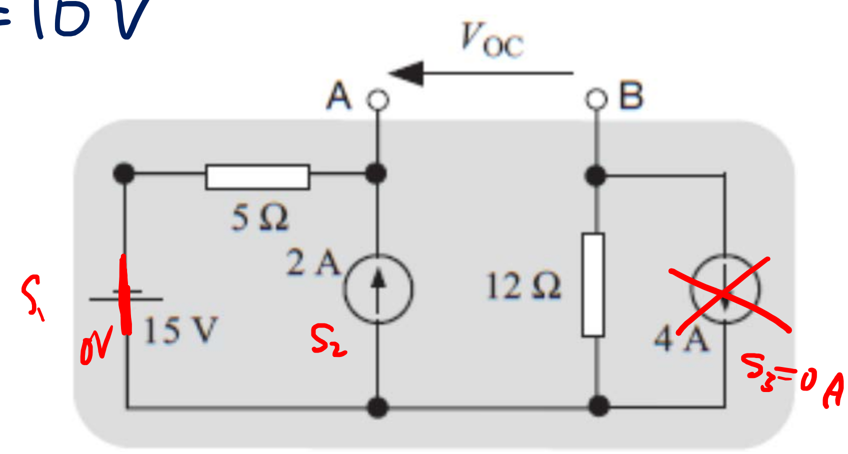
$S_3 = 0\ A \rightarrow$ Open



$\Rightarrow V_{AC} = 2 \times 5 = 10\ V$

$V_B \simeq V_C$

$\Rightarrow V_{AB}\big|_{S_2} \cong V_{AC} = 10\ V$

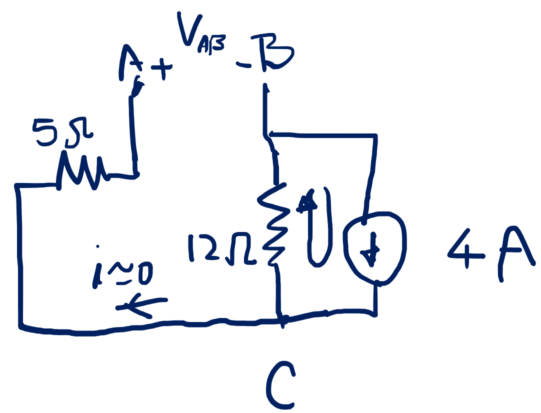


Example 4.3

Apply only $S_3 = 4A$

Set $S_1 \to 0$ V $\to$ short

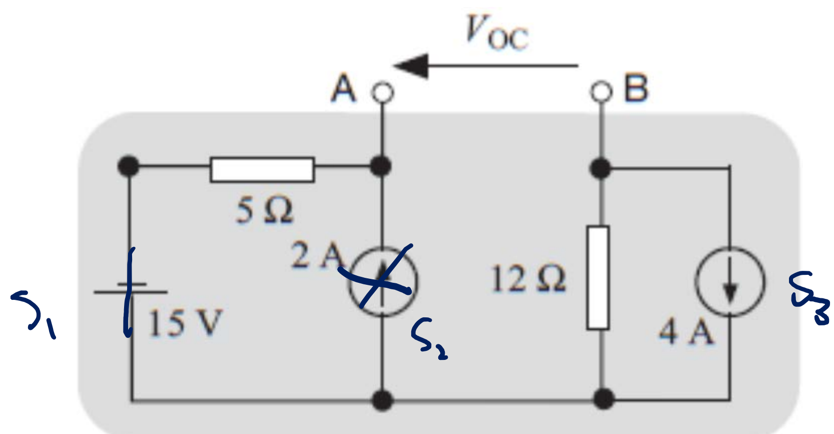
$S_2 \to 0$ A $\to$ open



$V_{BC} = -4\times12 = -48$ V

$V_A \simeq V_c$

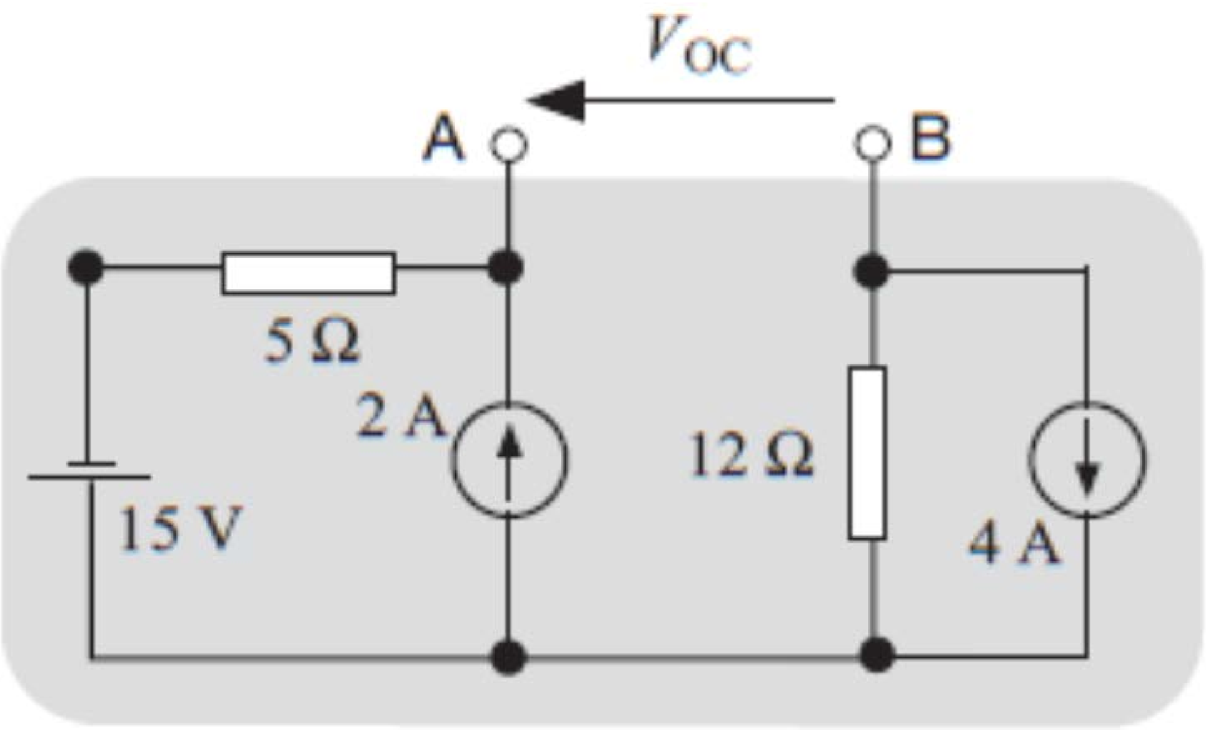
$V_{AB}\big|_{S_3} = +48$ V



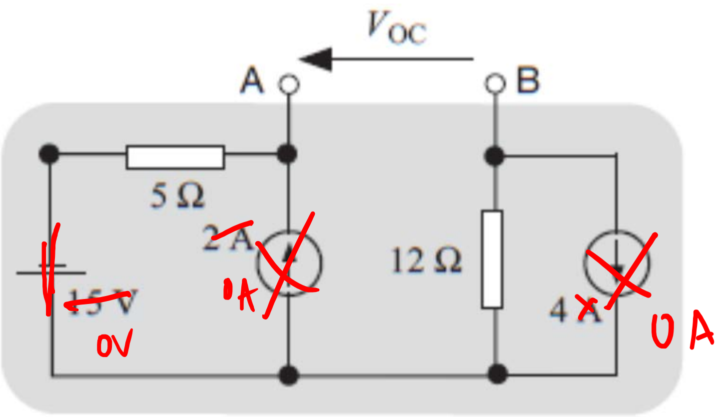
Example 4.3

$$V_{oc} = -15 + 10 + 48 = 43\,(V)$$

S_1 S_2 S_3



Example 4.3



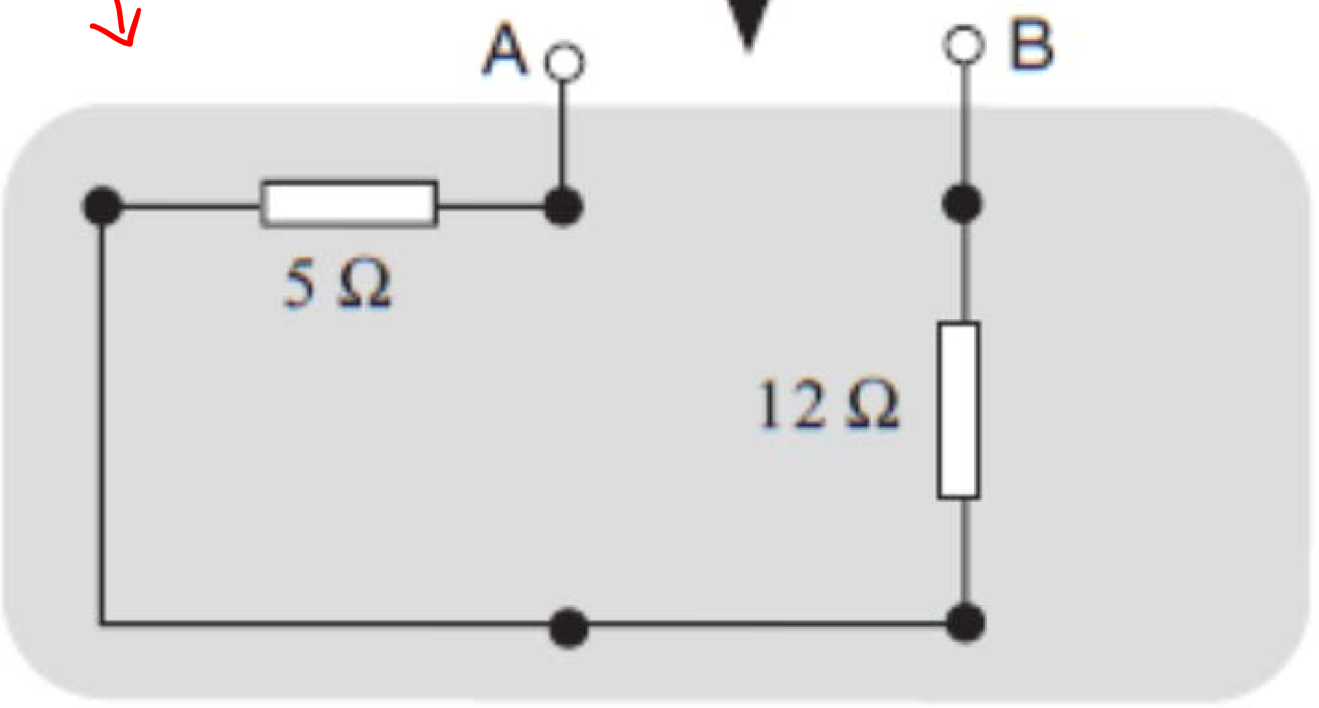
Find R_o

$S_1 \rightarrow 0\,V$ Short

$S_2 \rightarrow 0\,A$ Open

$S_3 \rightarrow 0\,A$ Open

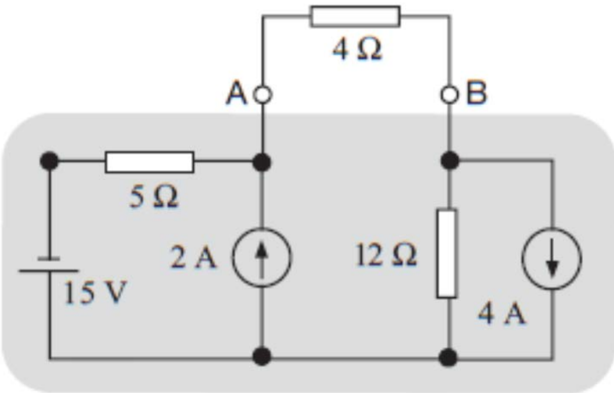
$R_O = 17\,\Omega$



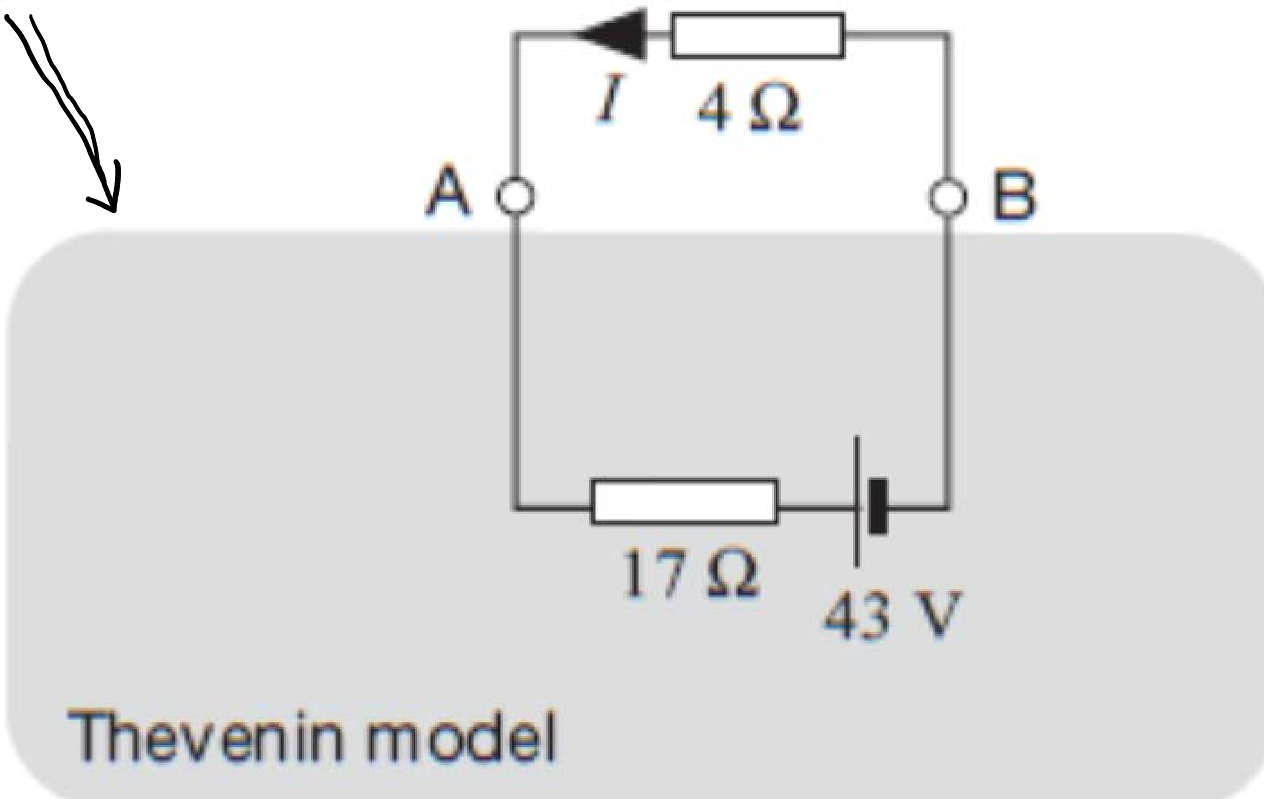
Example 4.3

$$V_{AB} = 43 \times \frac{4}{17+4} = \frac{172}{21} \ (V)$$

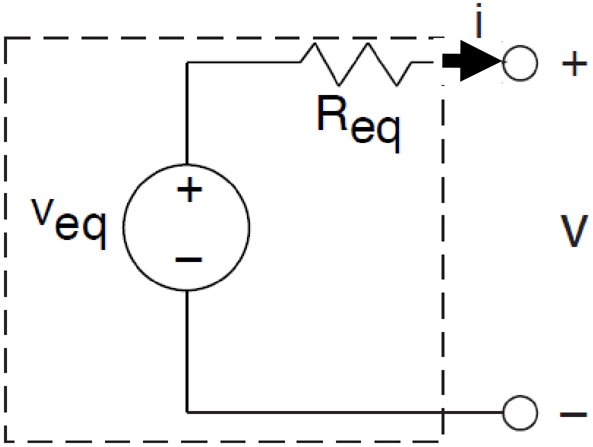
$$I = -\frac{43}{4+17} = -\frac{43}{21} \ (A)$$



Equiv. ckt



Norton Equivalent circuit

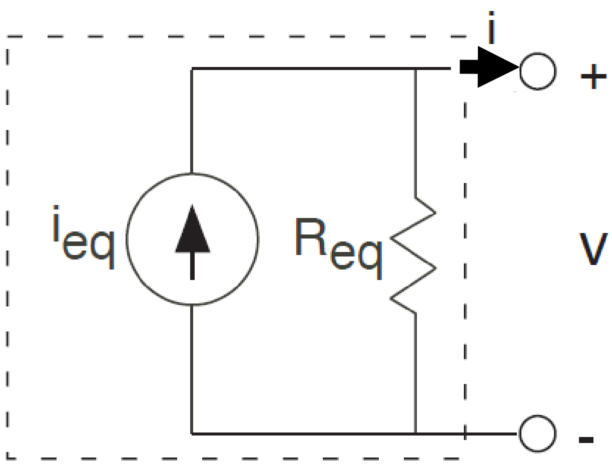


Thévenin

$$v = v_{eq} - i \cdot R_{eq}$$

$$\Rightarrow i = \underbrace{\left[\frac{v_{eq}}{R_{eq}}\right]}_{i_{eq}} - \frac{v}{R_{eq}}$$

$$i = i_{eq} - \frac{v}{R_{eq}}$$



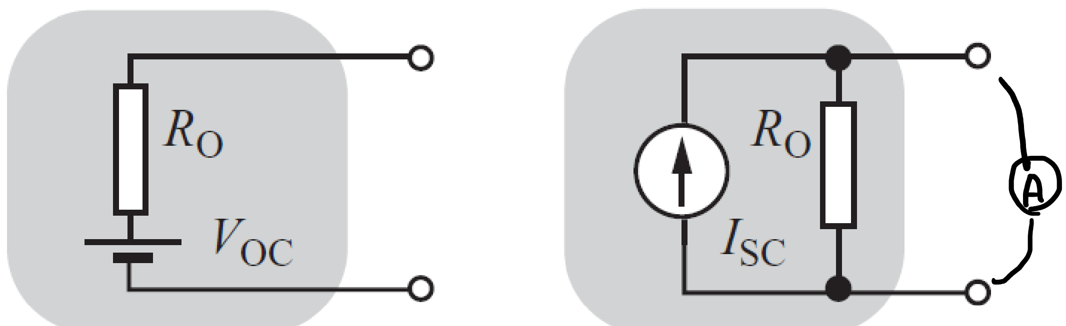
$\Rightarrow$ Norton equiv. ckt.

Norton equivalent circuit

Short-Ckt Current

I_{sc}

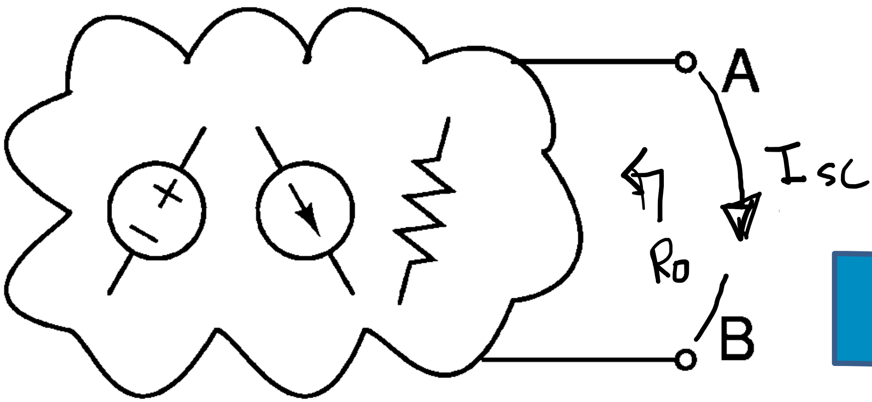
$$R_o = \frac{V_{oc}}{I_{sc}}$$



(a) (b)

Thevenin Norton

Norton Equivalent circuit



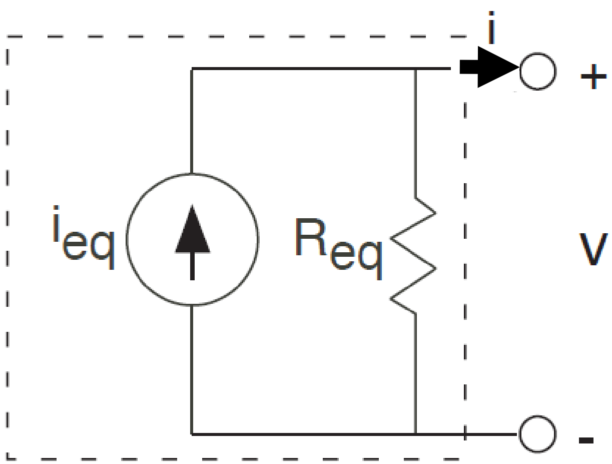
1. Find i_{eq}

$I_{sc} = i_{eq}$

2. Find R_{eq}

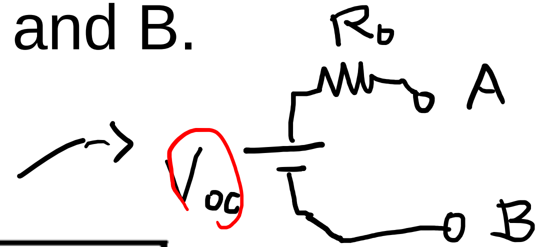
$R_{eq} = R_0$.

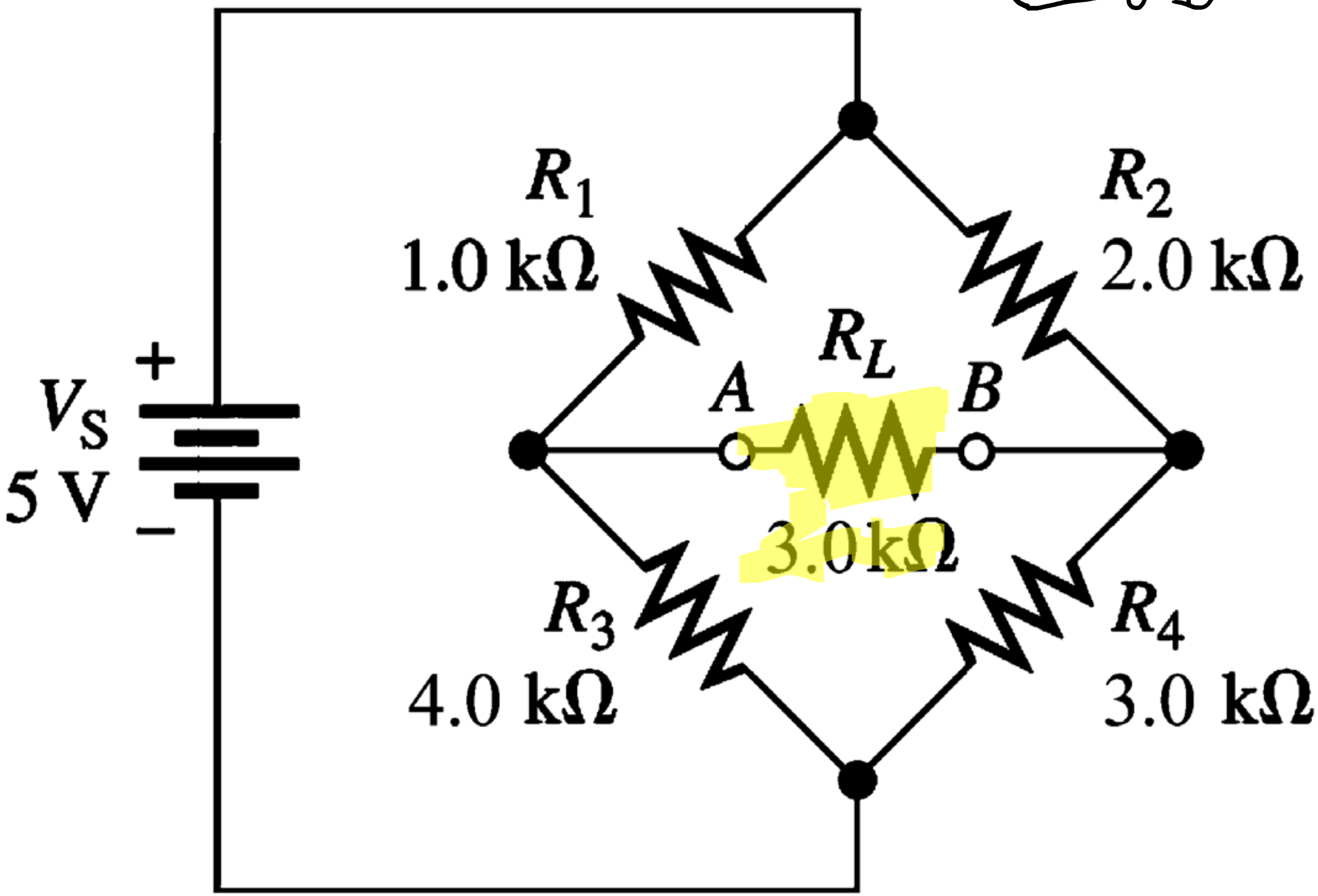
Source → 0



Quiz

Remove R_L, draw the Thevenin equivalent circuit between nodes A and B.

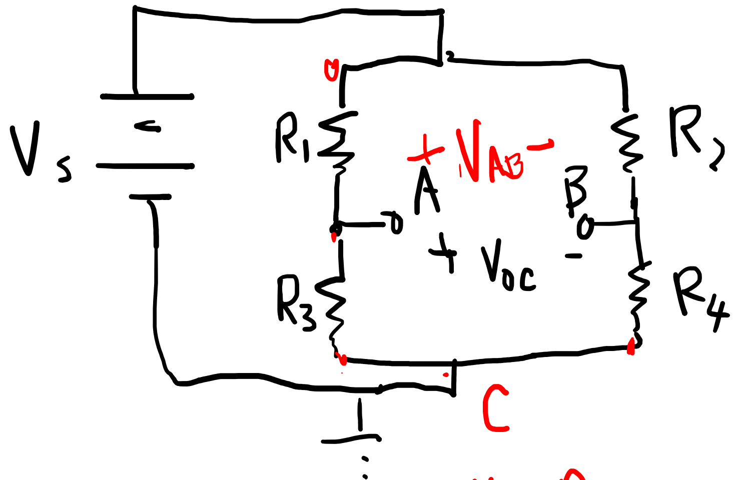




Quiz Review

$V_{AB} = V_{AC} - V_{BC}$

$= V_A - V_B$



$V_C = 0$

V_{AC}

$\parallel$

$$V_A = V_s \cdot \frac{R_3}{R_1+R_3}$$

$$V_B = V_s \cdot \frac{R_4}{R_2+R_4}$$

$\parallel$

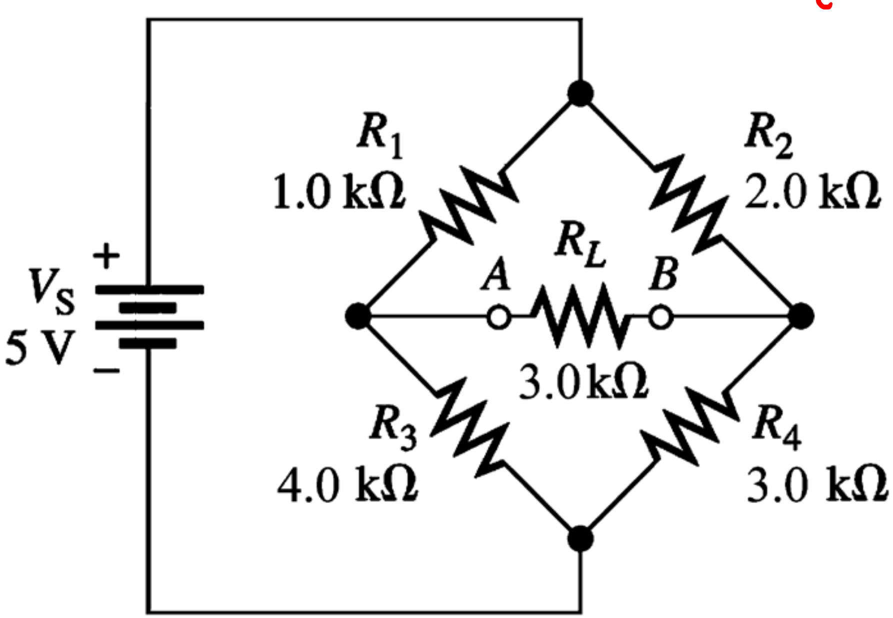
V_{BC}

$$V_{oc} = V_{AB}$$

$$= V_s \left[\frac{R_3}{R_1+R_3} - \frac{R_4}{R_2+R_4} \right]$$

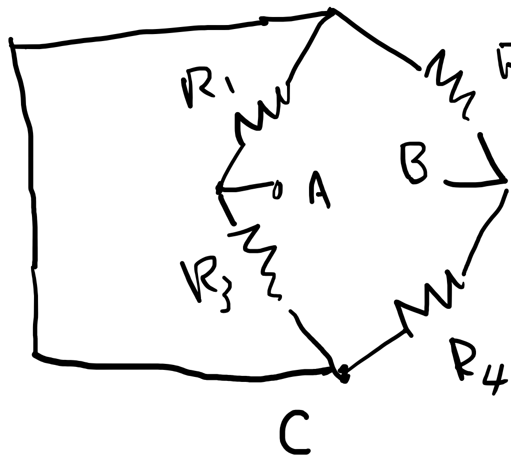
$$= V_s \left[\frac{4}{5} - \frac{3}{5} \right]$$

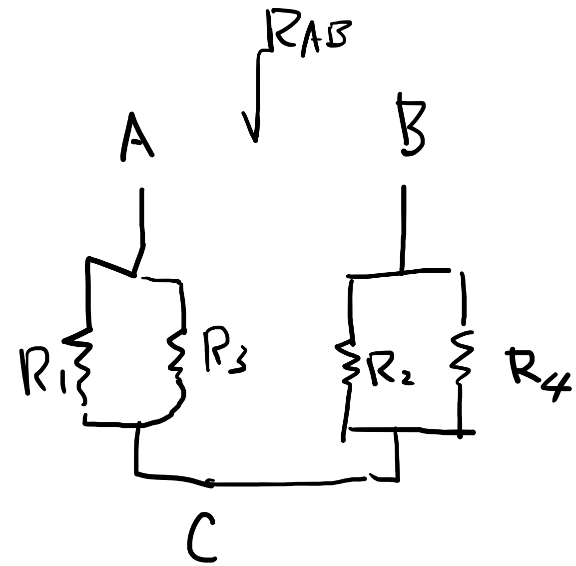
$$= V_s \cdot \frac{1}{5} = 1\ (V)$$

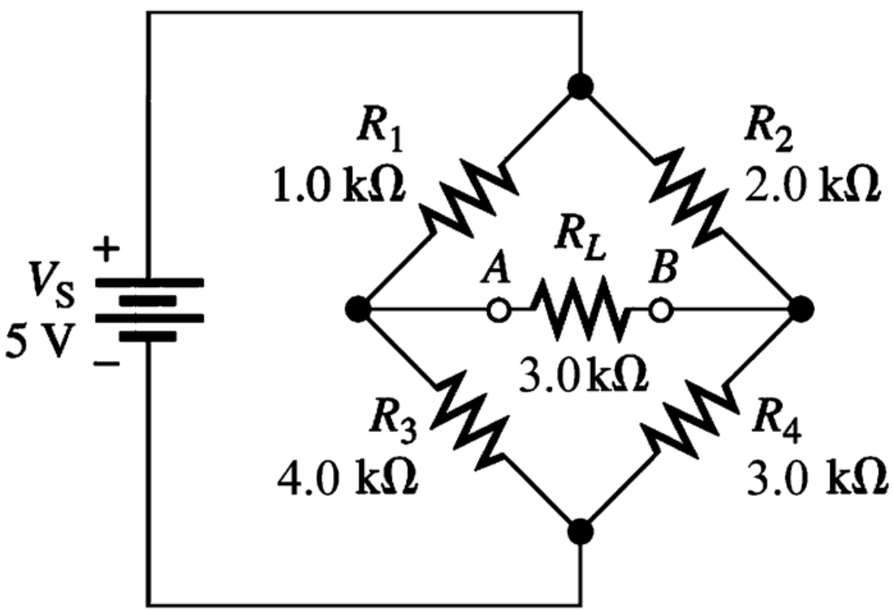


Quiz Review

$V_s \to 0$







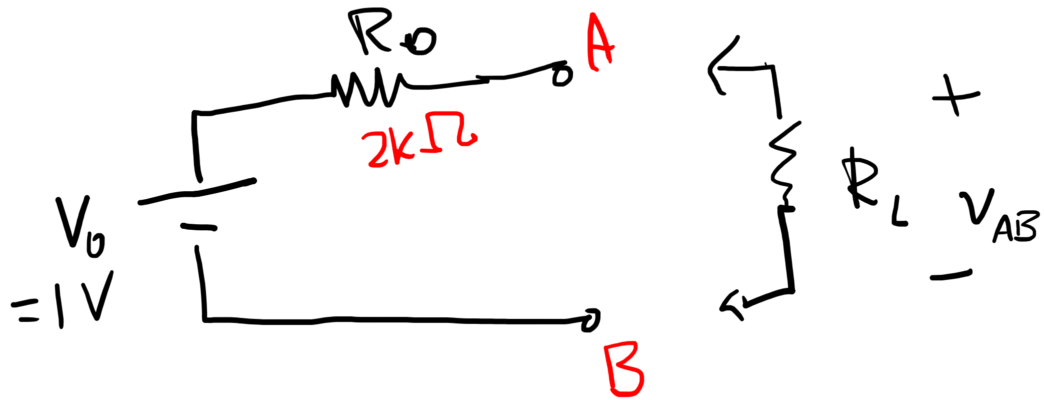
$$R_0 = R_{AB}$$

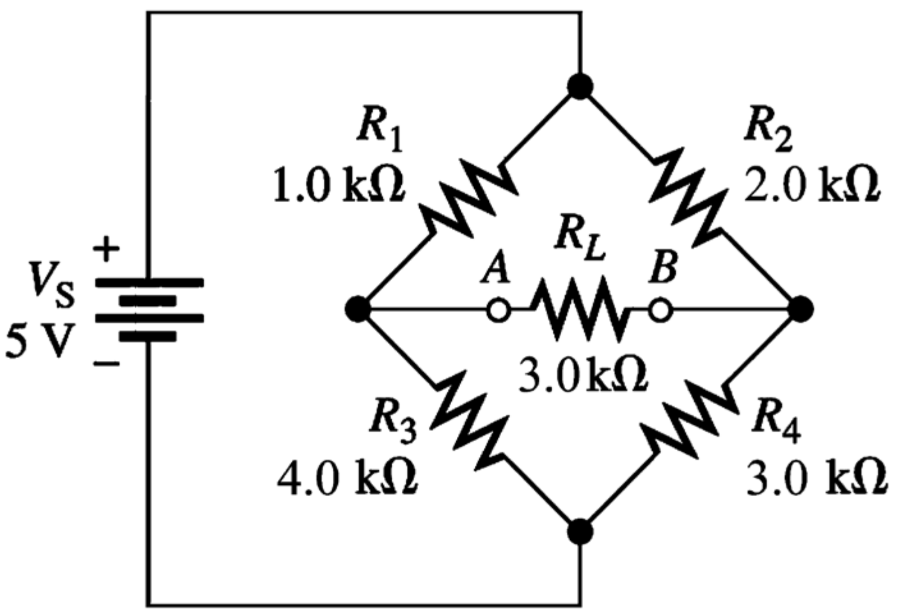
$$= (R_1 \| R_3) + (R_2 \| R_4)$$

$$= 2\,k\Omega$$

Quiz Review

Thevenin Equiv. Ckt





$$V_{AB} = V_0 \cdot \frac{R_L}{R_0 + R_L}$$