전기회로 (가, 다)

Chapter 4 : Circuit Theorems

2017. 1학기

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4.1 Introduction

- Nodal/mesh analysis + Ohm's law & KCL, KVL ➔ good analysis method

- 아주 복잡하고 큰 회로에 대해서는 어떨까?
- 부하가 변경되는 경우는 그 때마다 다시 분석해야 할까?
- 좀 더 단순화할 수는 없을까?

- 몇 가지 방법 제시
  - 선형성
  - 중첩
  - 전원변환
  - Thevenin의 정리
  - Norton의 정리

4.2 Linearity (선형성)

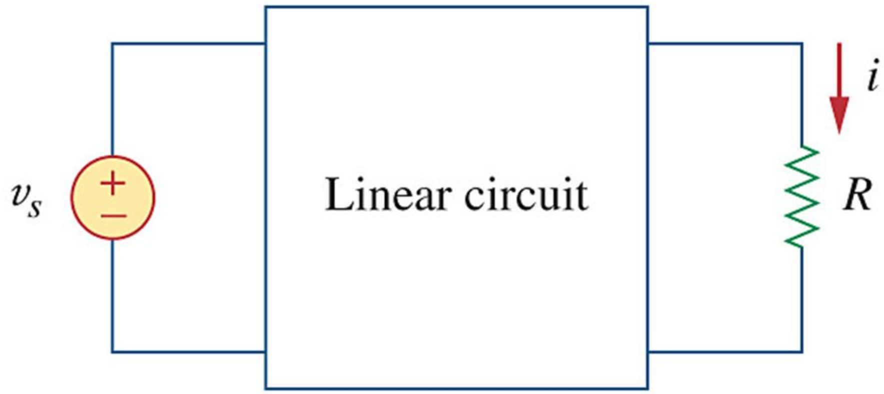
선형성

- 비례성 (scaling, homogeneity)
  - 입력이 어떤 비율로 증가하면 출력도 같은 비율로 증가

$$\boxed{v = iR \rightarrow (\text{전류가 } k\text{배 커지면}) \rightarrow v' = (ki)R = kv}$$

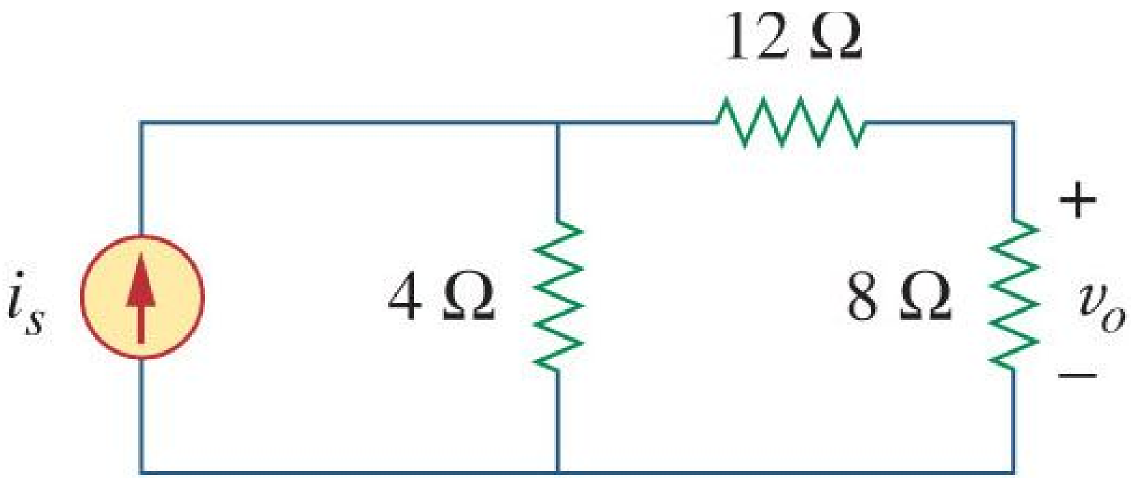
- 가산성 (additivity)
  - 입력의 합에 대한 응답은 각 입력에 대한 응답의 합

$$\boxed{v_1 = i_1 R,\ v_2 = i_2 R \rightarrow v' = (i_1 + i_2)R = v_1 + v_2}$$



Practice 4.1

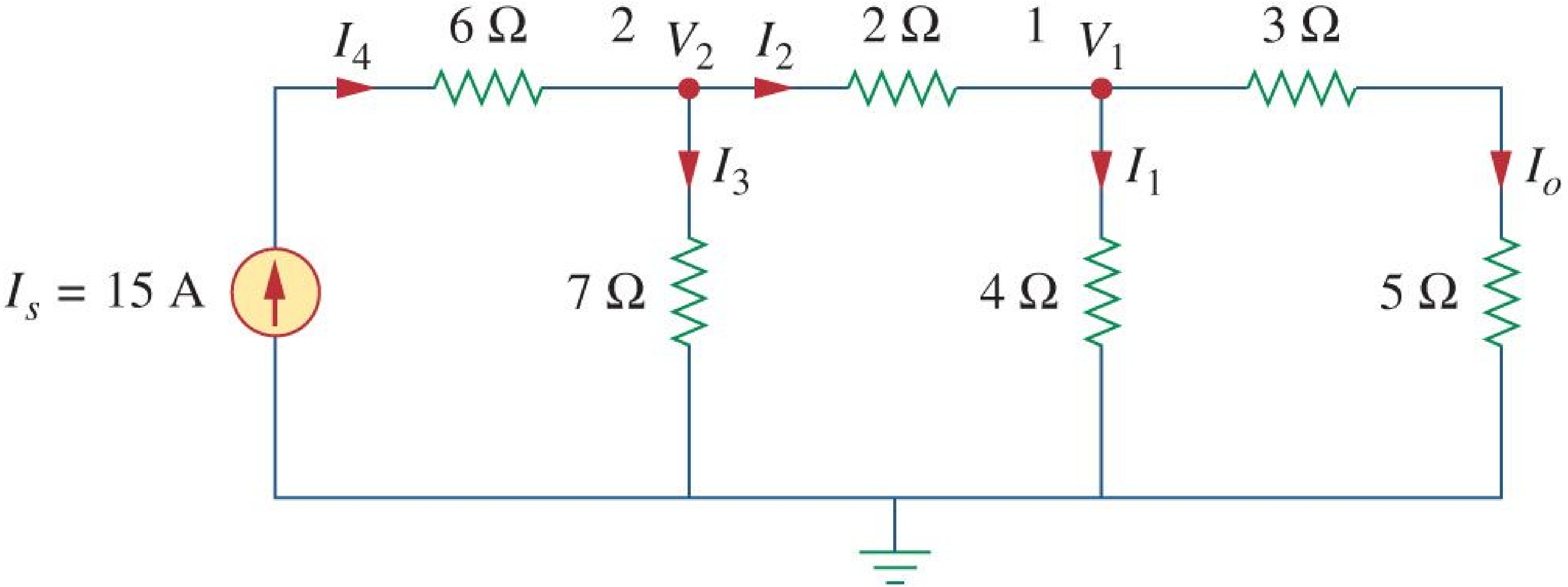
각각 $i_s = 30A, i_s = 45A$일 때, v_0 는?



Example 4.2

$I_0 = 1\text{A}$ 라고 가정하고, 선형성을 이용하여,

I_0의 실제값을 구하라



4.3 Superposition (중첩)

- 중첩의 원리 (Superposition principle)

선형회로에서 어떤 소자의 전압 및 전류는 각각의 독립전원에 의한 출력의 대수적인 합과 같다.

- 활용
  - 하나의 전원을 남기고 나머지 전원 OFF
  - 그 전원에 대한 출력 계산
  - 나머지 전원에 대해서도 하나씩 위의 과정 반복
  - 모든 각각의 출력을 대수적으로 더함.

4.3 Superposition (중첩)

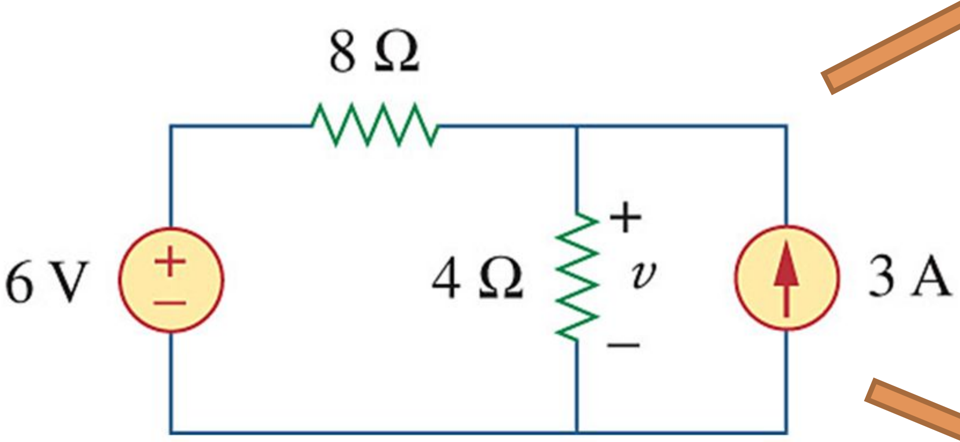
- 독립전원 제거의 의미

  - 전압원 제거 → 0V 공급 → **Short** or Open ?
  - 전류원 제거 → 0A 공급 → Short or **Open** ?

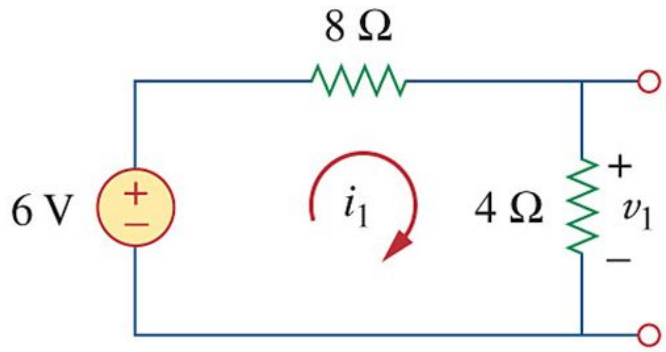
- (주의) 종속전원은 제거하지 않고 그대로 두어야! Why?

Example 4.3

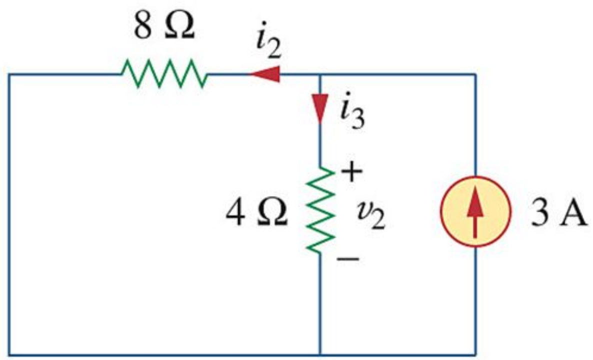
- Use superposition!



전류원 제거

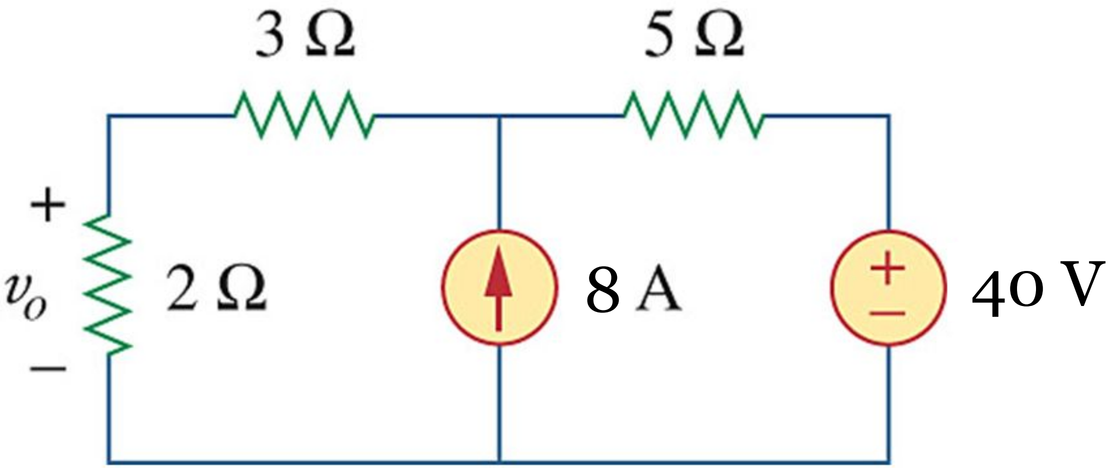


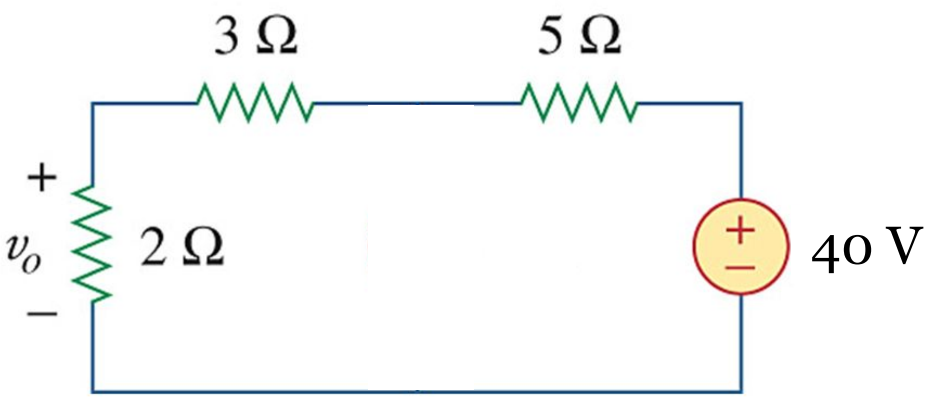
전압원 제거



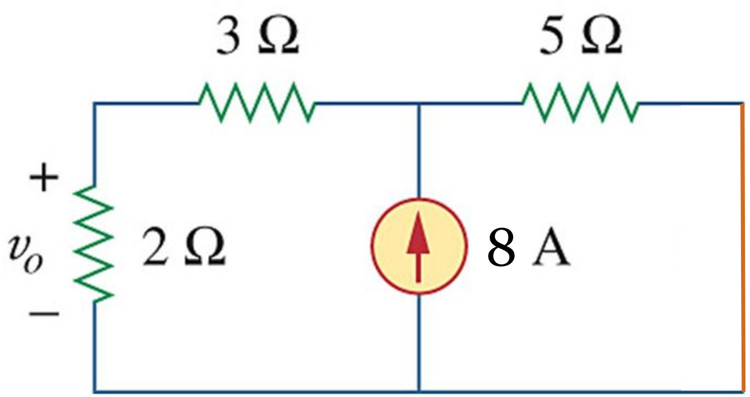
$$v = v_1 + v_2$$

Practice 4.3



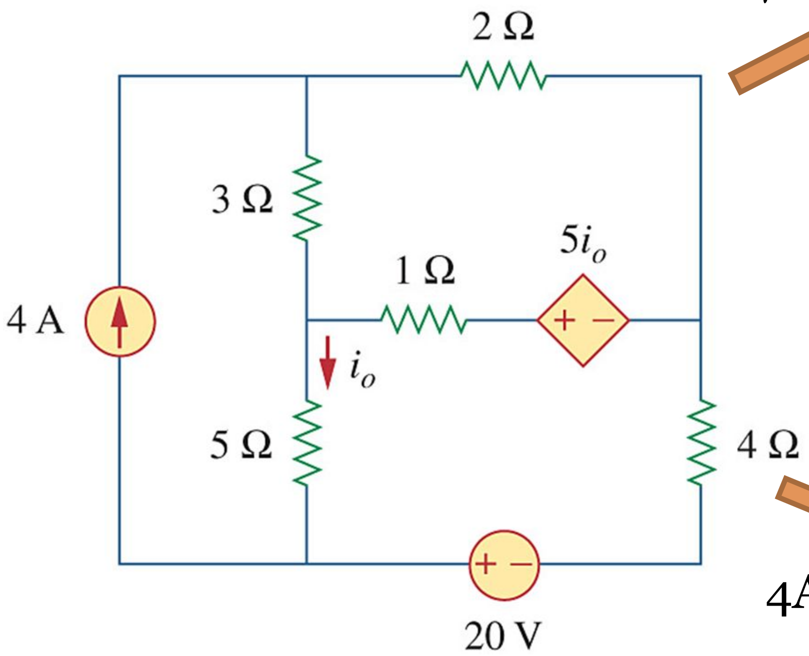


[전류원 제거]

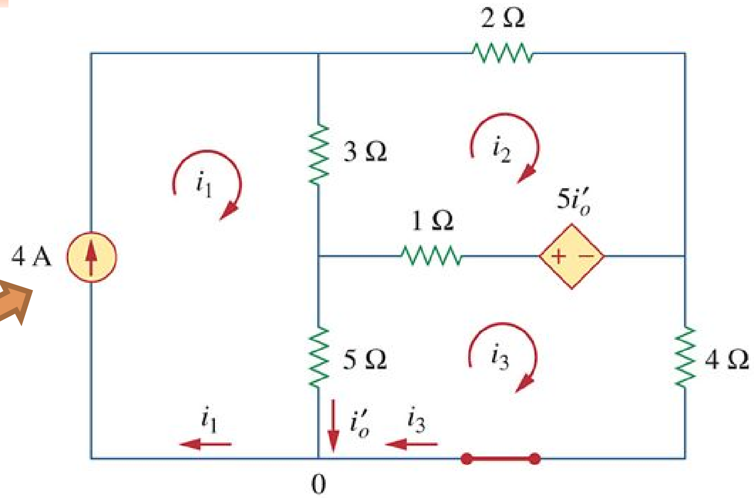


[전압원 제거]

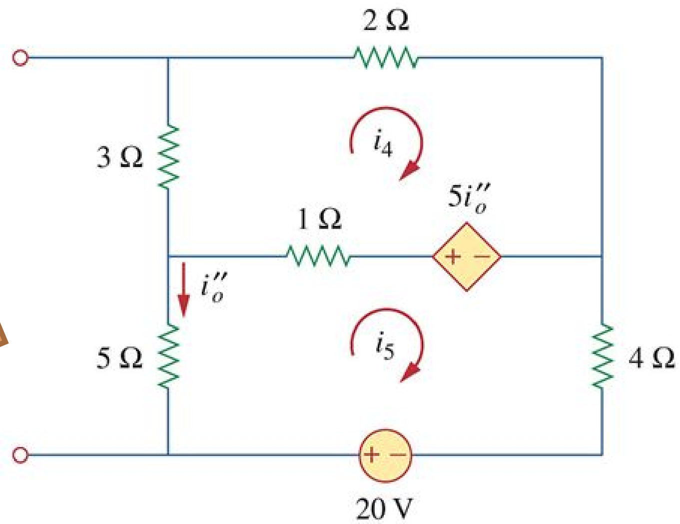
Example 4.4



20V 제거



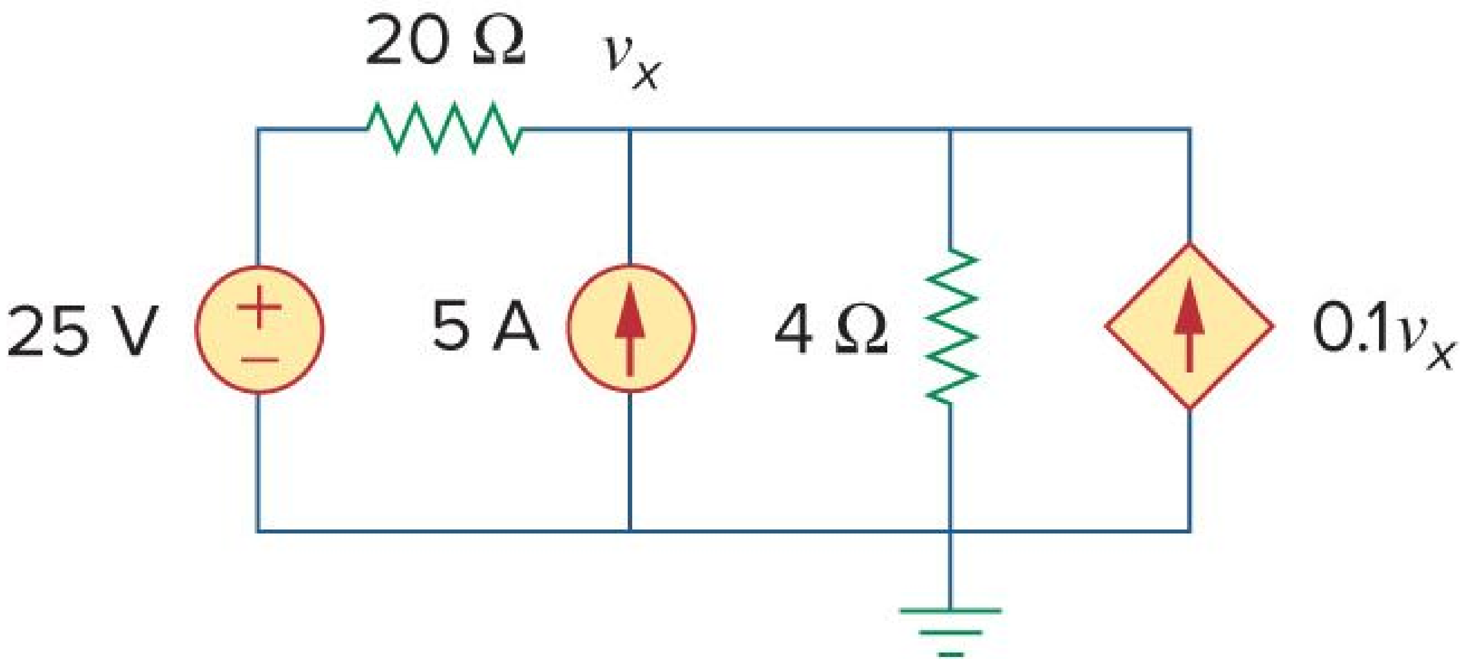
4A 제거



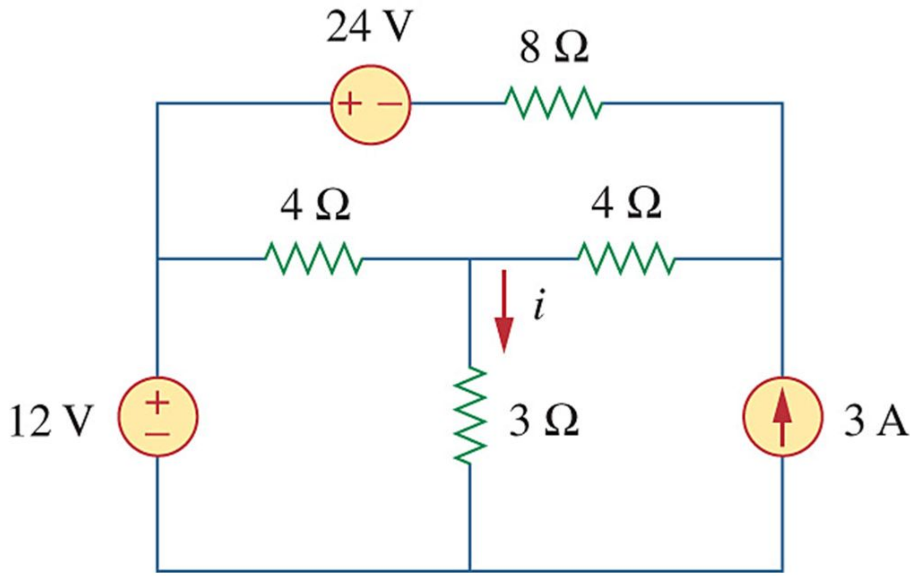
$$i_0 = i'_0 + i''_0$$

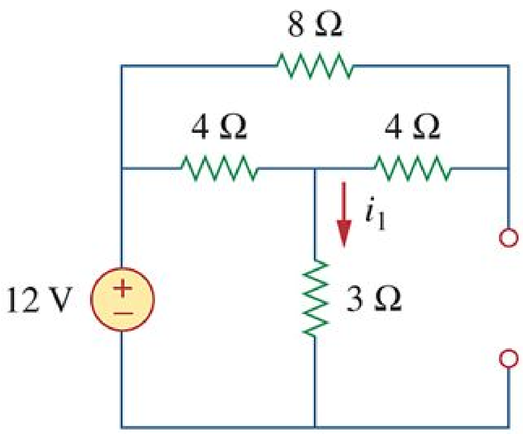
Practice 4.4

중첩의 원리를 이용하여 v_x 를 구하라

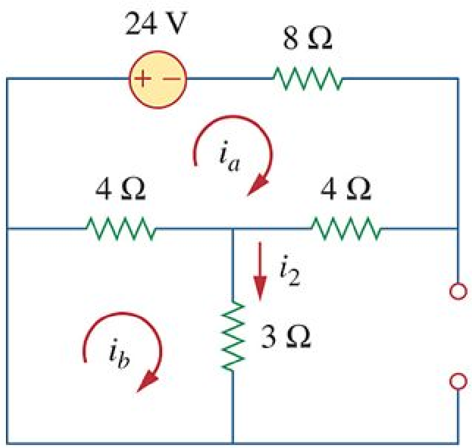


Example 4.5

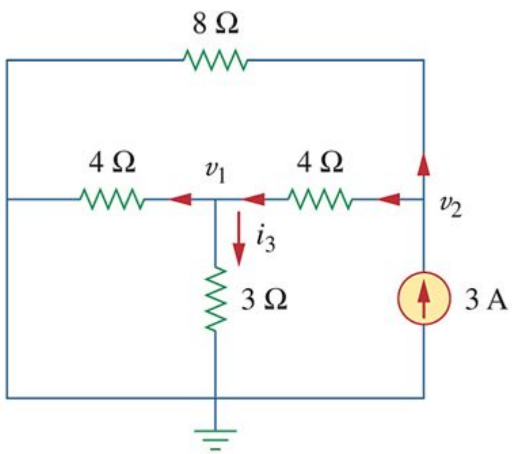




[12V only]



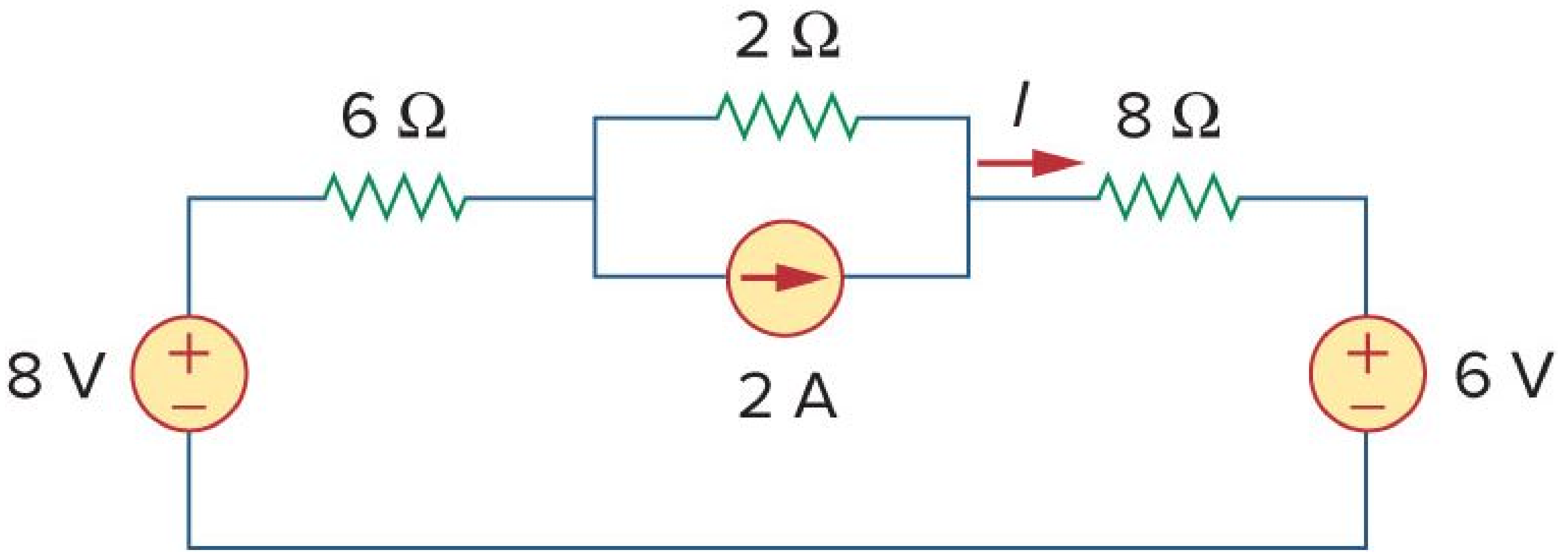
[24V only]



[3A only]

Practice 4.5

중첩의 원리를 이용하여 *I*를 구하라



4.4 Source Transformation (전원변환)

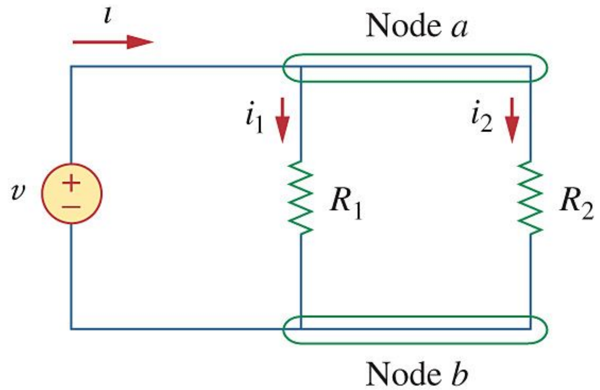
- 등가회로(Equivalent circuit)란?

원래의 회로와 v-i 특성이 동일한 회로

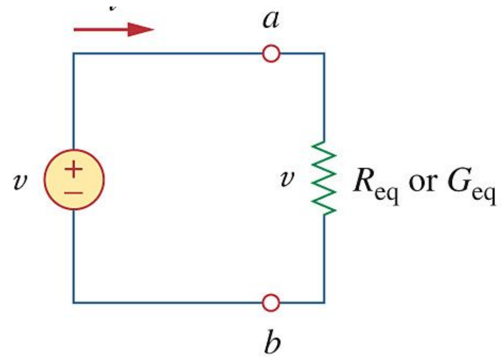
- 예
  - 직렬저항의 등가저항
  - 병렬저항의 등가저항
  - 와이-델타 변환

  - 전원변환
  - Thevenin 등가회로
  - Norton 등가회로

원래 회로



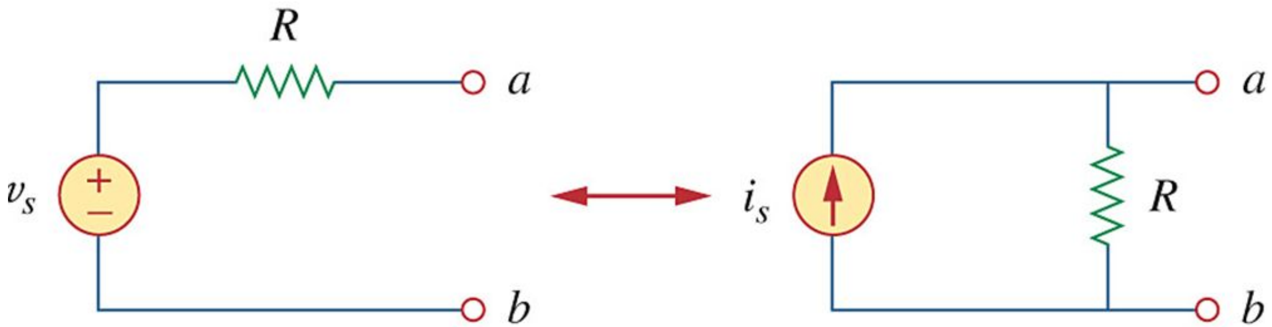
등가 회로



4.4 전원 변환

전원 변환

- 전압원 + 직렬저항 ←→ 전류원 + 병렬저항



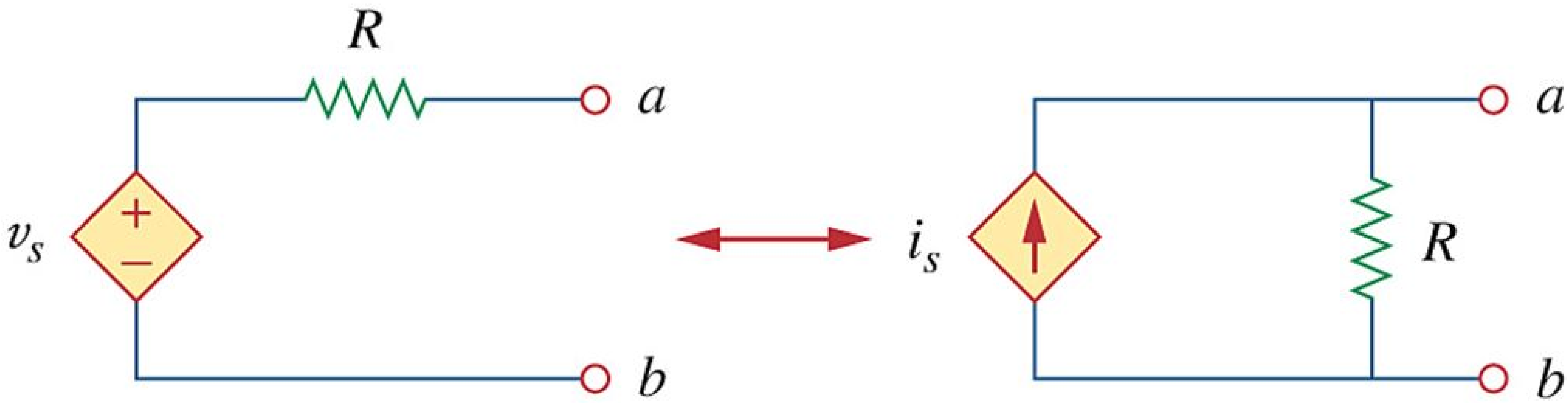
[3 extreme cases]

1) 전원 OFF : a-b에서 본 저항 = R
2) a-b 단락(short) : a-b에 흐르는 전류 = ($i_s = v_s / R$)
3) a-b 개방(open) : a-b에 걸리는 전압 = ($v_s = i_s R$)

$$\boxed{v_s = i_s R \quad or \quad i_s = \frac{v_s}{R}}$$

4.4 전원변환

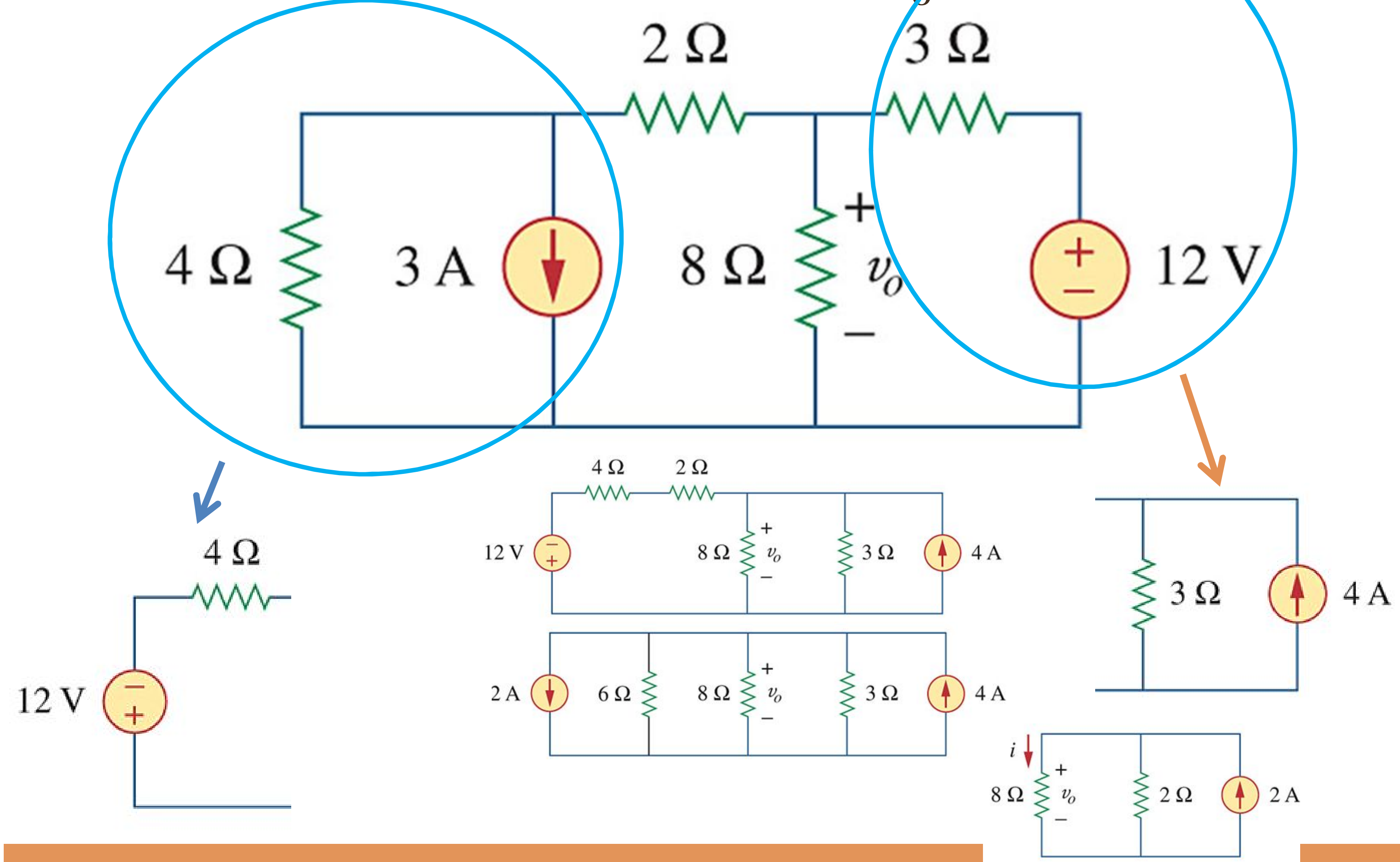
- 종속전원에 대해서도 마찬가지로 적용



$$\boxed{v_s = i_s R \quad or \quad i_s = \frac{v_s}{R}}$$

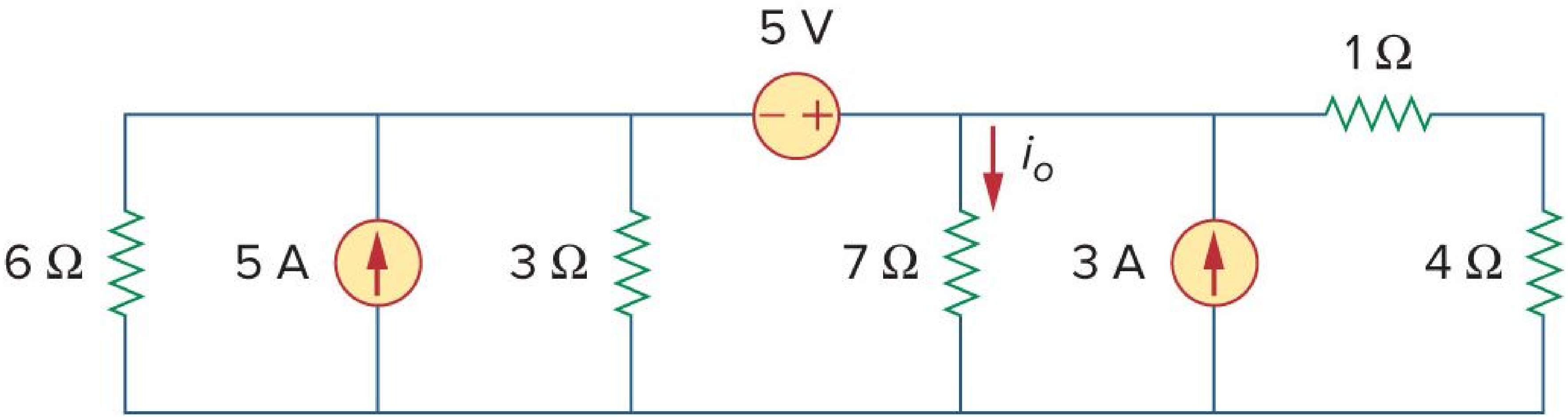
Example 4.6

- Use source transformation to find v_o



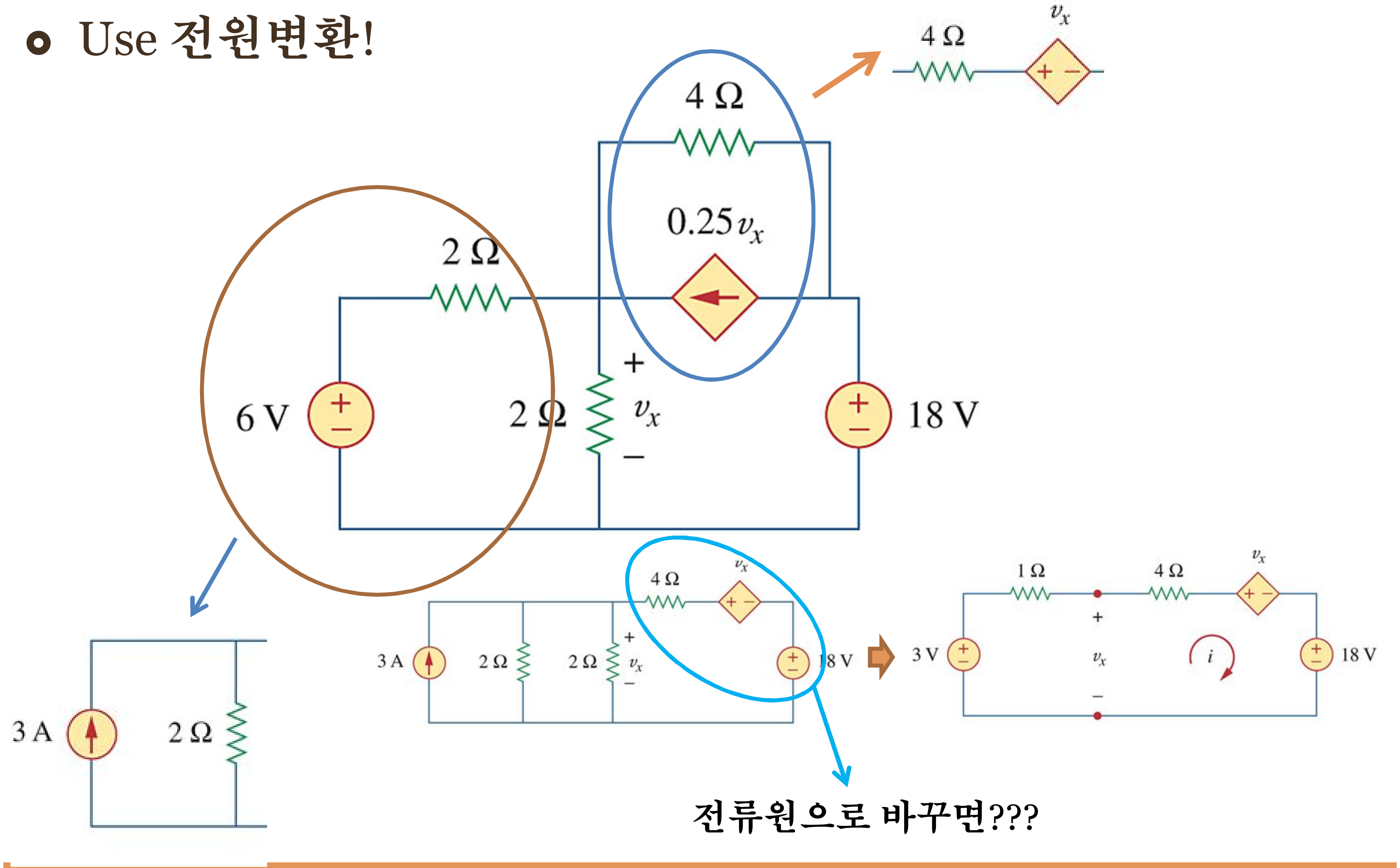
Practice 4.6

전원 변환을 이용하여 i_0 를 구하라



Example 4.7

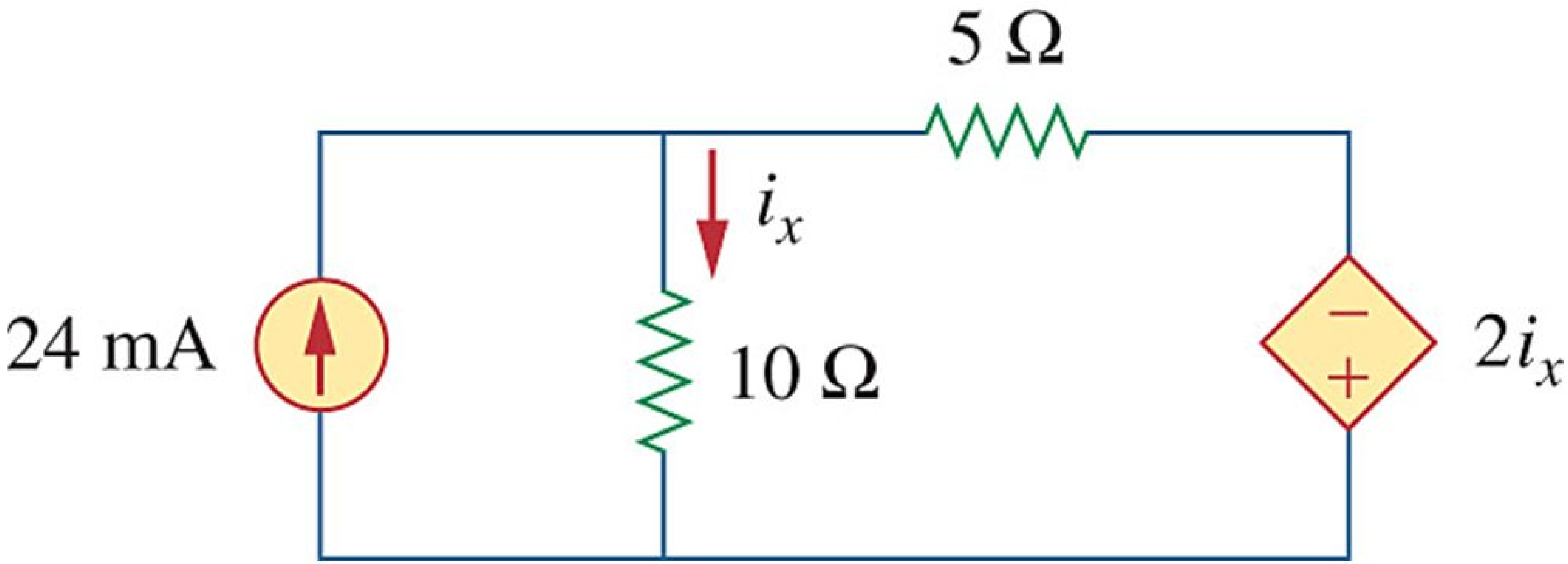
- Use 전원변환!



전류원으로 바꾸면???

Practice 4.7

- 전류원 ➔ 전압원 또는 전압원 ➔ 전류원 ?



Homework #6

- 다음 수업시간까지 다음 5문제 풀이 제출
  - Problem 4.3, 4.7, 4.12, 4.27, 4.32 (5문제)

- **Quiz#2 실시**
  - **5문제**
  - **범위 HW#4, HW#5, HW#6**

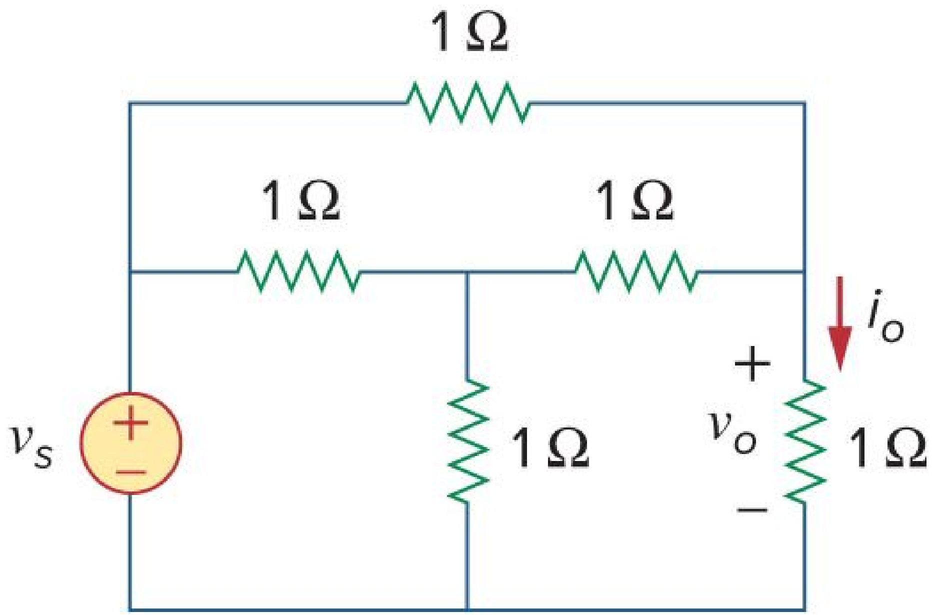
Homework #6

#1. Problem 4.3

(a) 다음 회로에서 $v_s = 1V$일 때, v_o와 i_o를 구하라

(b) $v_s = 10V$일 때, v_o와 i_o를 구하라

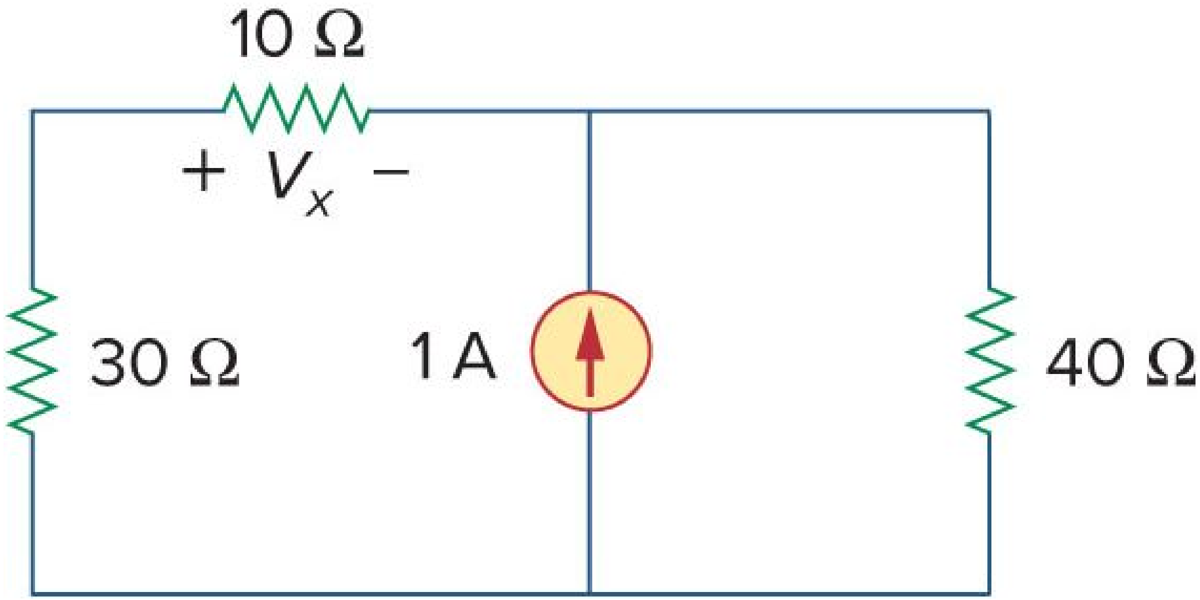
(c) 각각의 1Ω 저항을 10Ω으로 교체하고, $v_s = 10V$일 때, v_o와 i_o를 구하라



Homework #6

#2. Problem 4.7

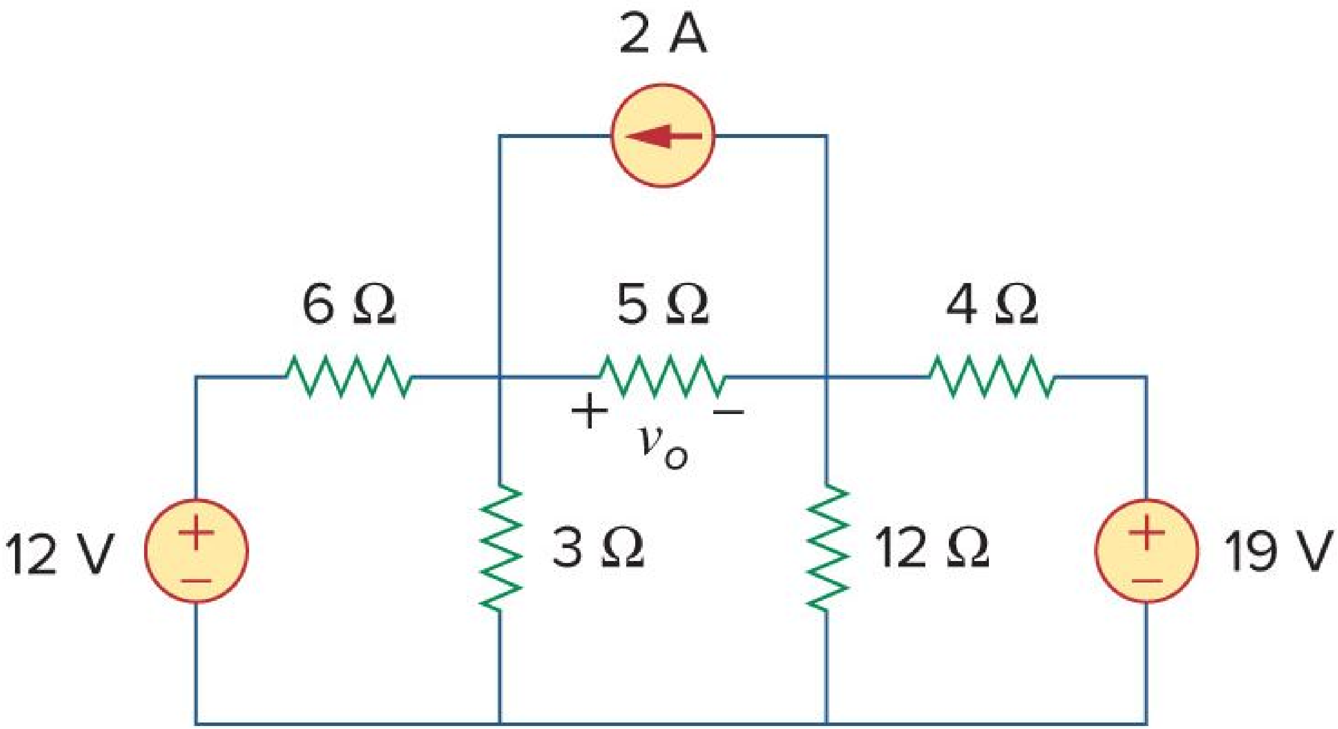
다음 회로에서 $V_x = 1V$ 라 가정하고, 선형성을 이용하여 V_x를 구하여라



Homework #6

#3. Problem 4.12

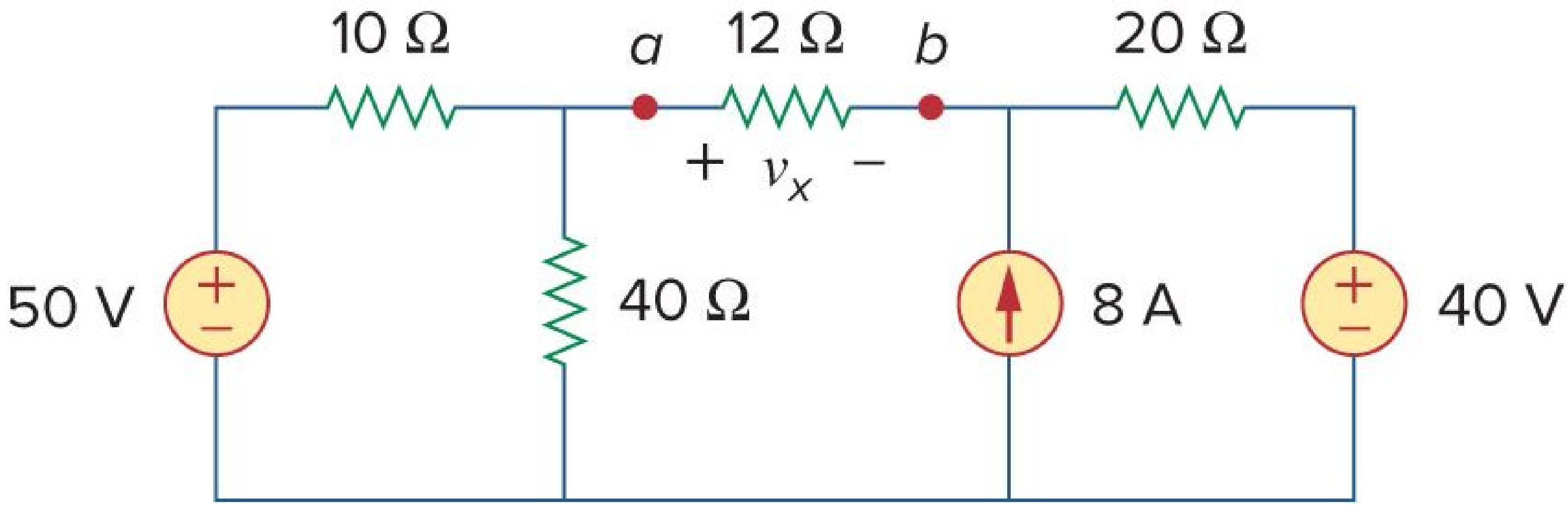
다음 회로에서 중첩의 원리를 이용하여 v_o를 구하여라



Homework #6

#4. Problem 4.27

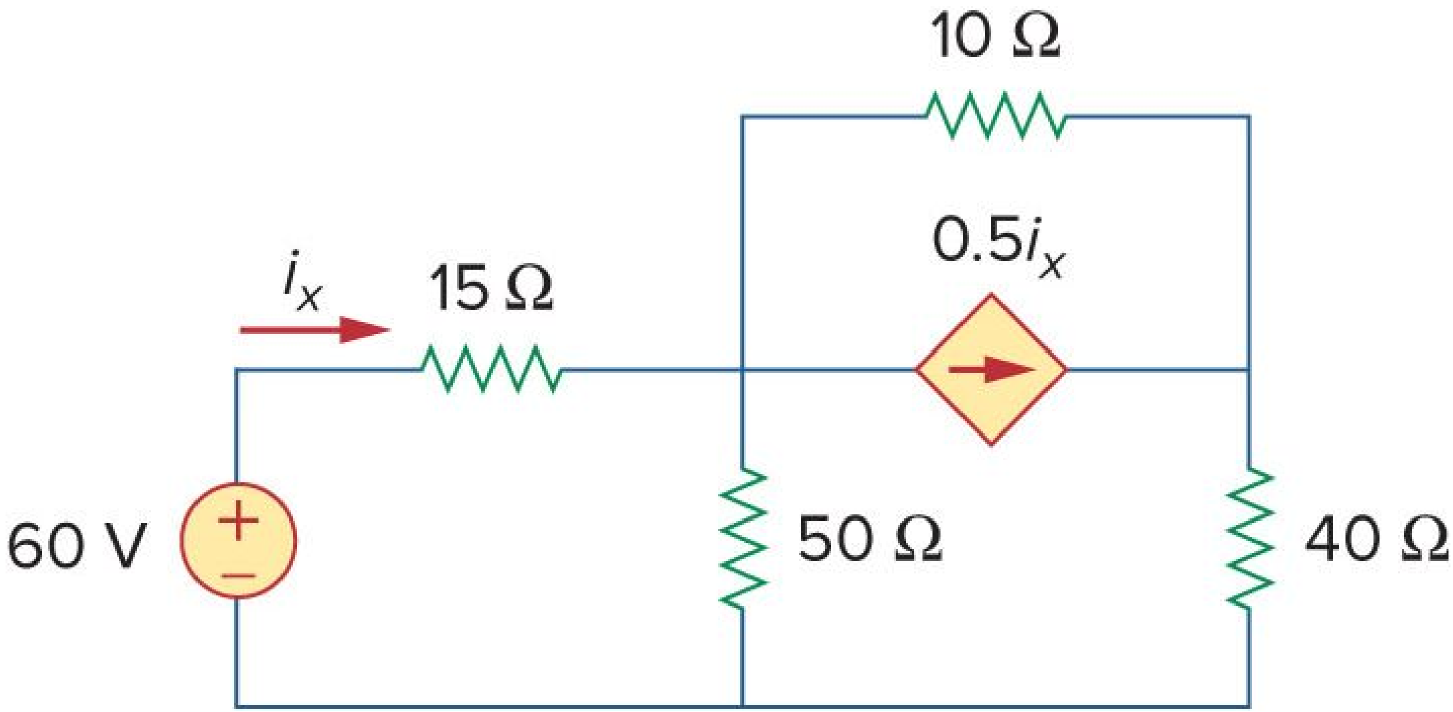
다음 회로에서 전원 변환을 이용하여 v_x를 구하여라



Homework #6

#5. Problem 4.32

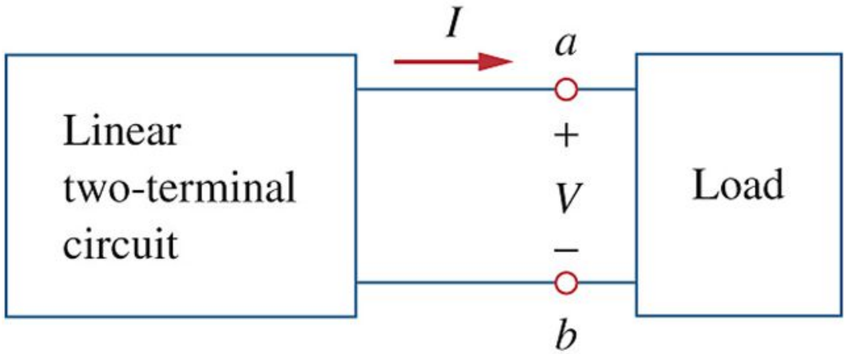
다음 회로에서 전원 변환을 이용하여 i_x를 구하여라



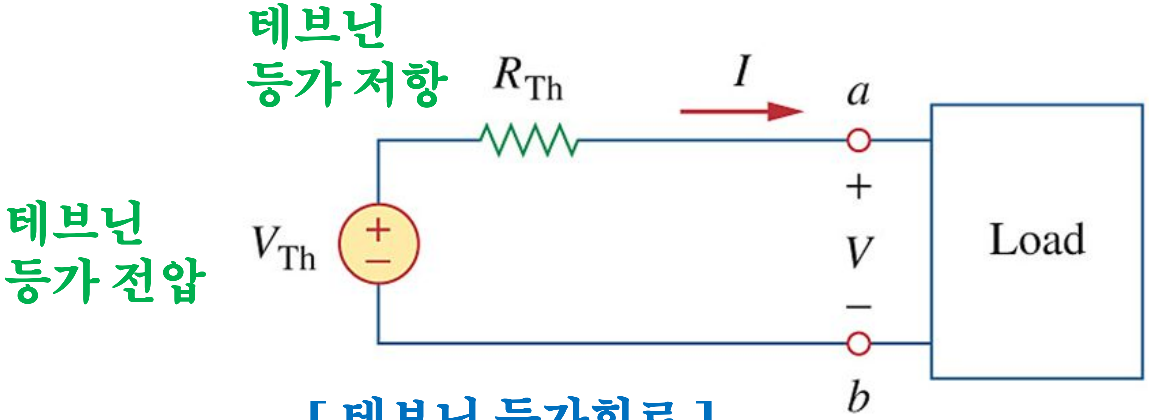
4.5 Thevenin's Theorem

- 테브닌의 정리란?

복잡한 회로를 하나의 전압원과 하나의 직렬저항으로 표현



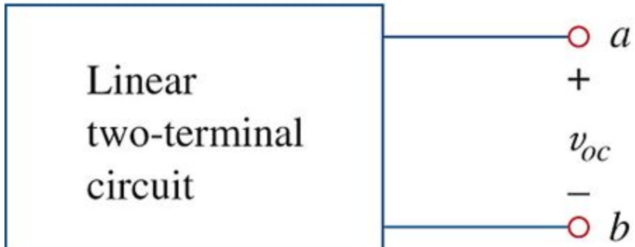
load(부하)
- 전력을 사용하는 요소
- 보통 가변적



[테브닌 등가회로]

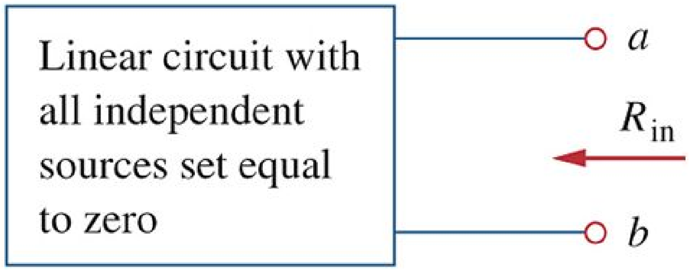
4.5 Thevenin's theorem

- 어떻게 V_{th}와 R_{th}를 구할 것인가?



$V_{Th} = v_{oc}$

단자를 개방했을 때의 전압



$R_{Th} = R_{in}$

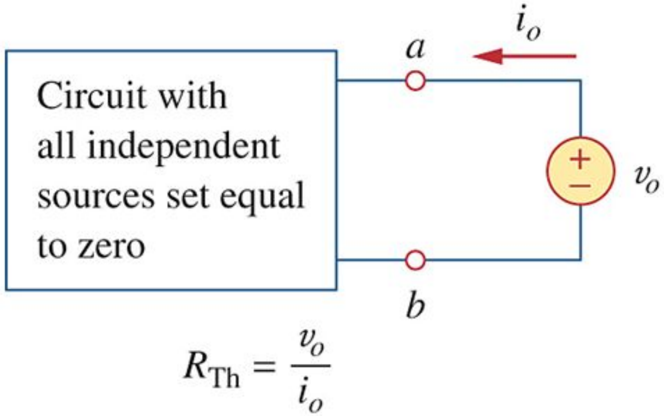
독립전원을 모두 OFF했을 때의 저항

(*) 종속전원은 OFF하면 안 됨.

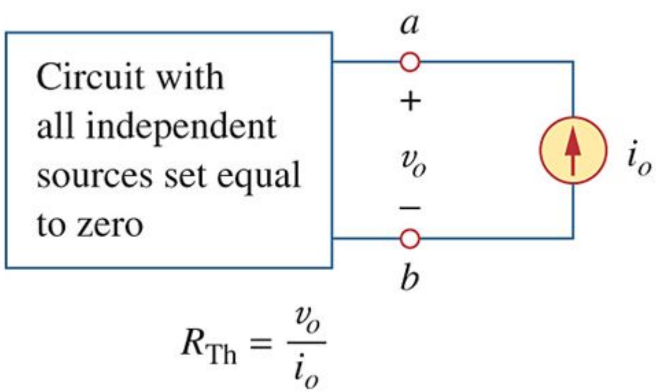
4.5 Thevenin's theorem

종속전원이 있는 경우

- V_{th} : Same!
- R_{th} :



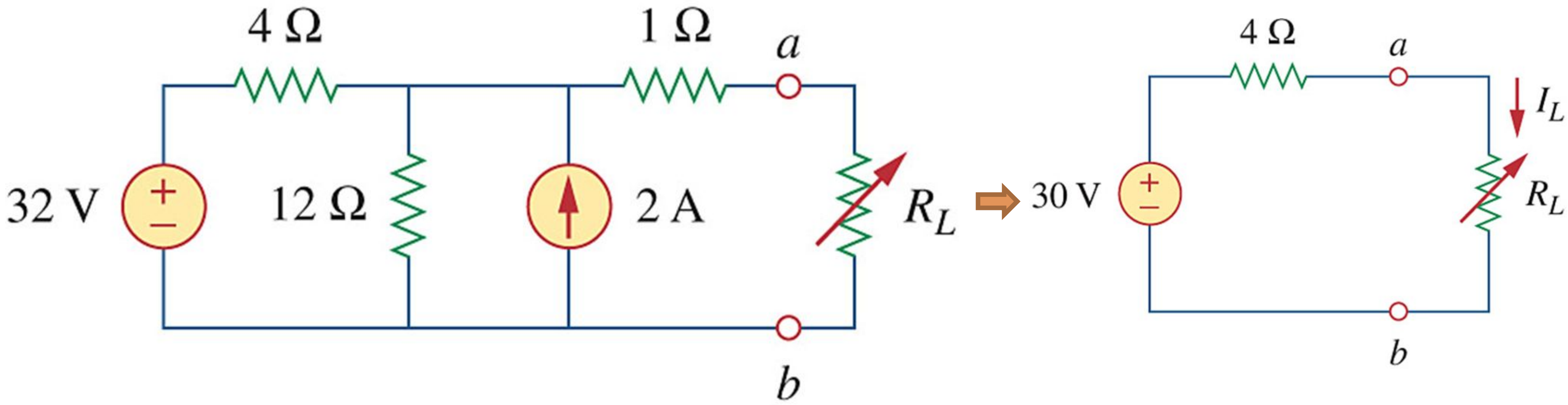
임의의 전압 인가

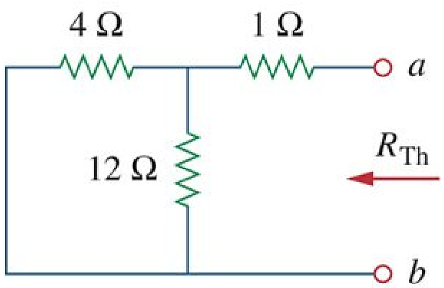


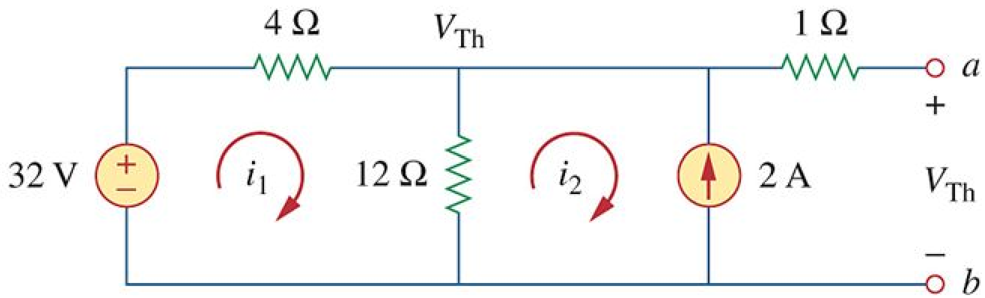
임의의 전류 투입

Example 4.8

- R_L=6, 16, 36Ω



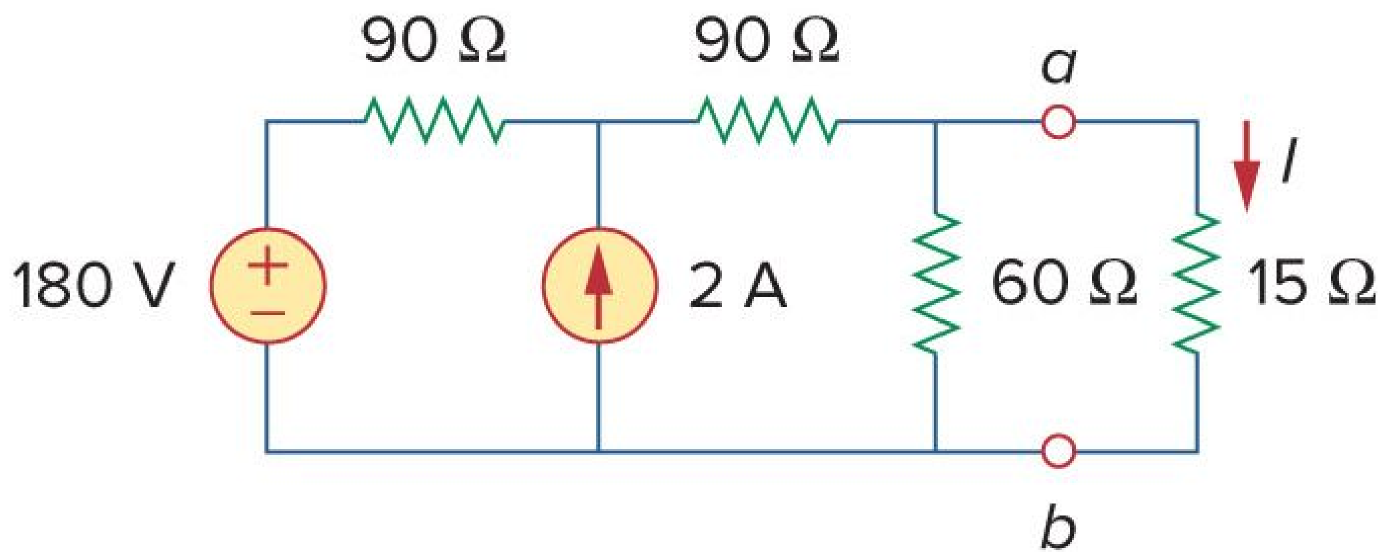




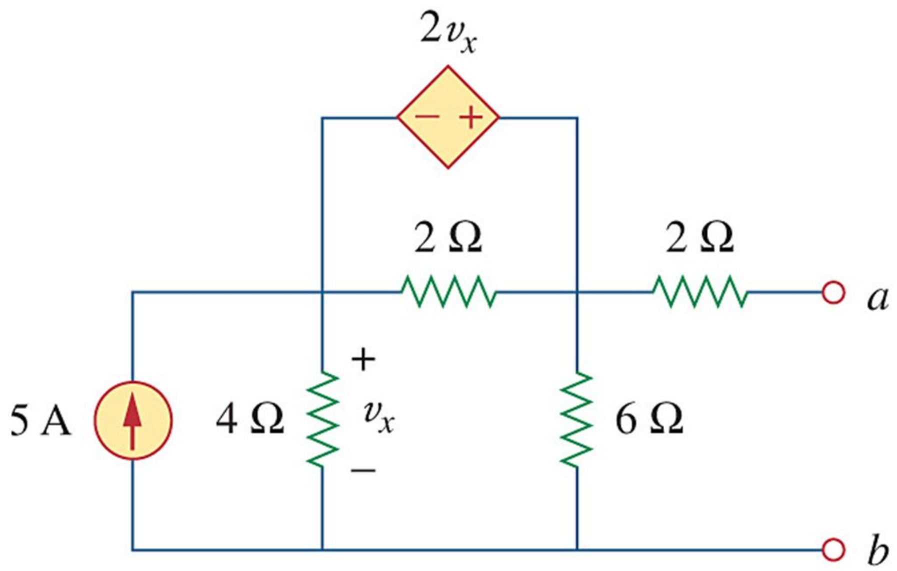
-mesh analysis
-nodal analysis
-전원변환

Practice 4.8

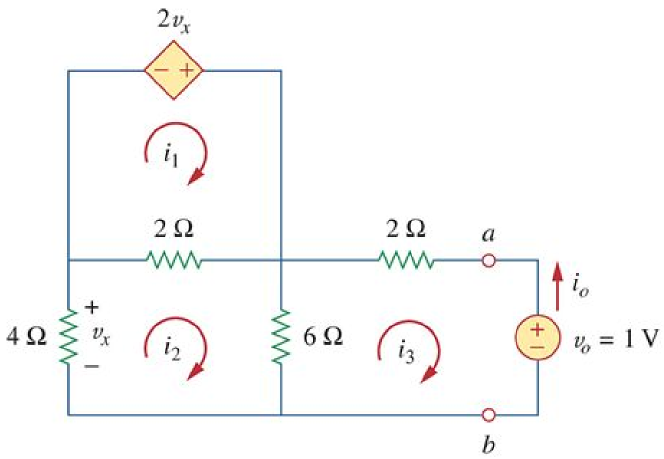
- V_{th}, R_{th}, I?



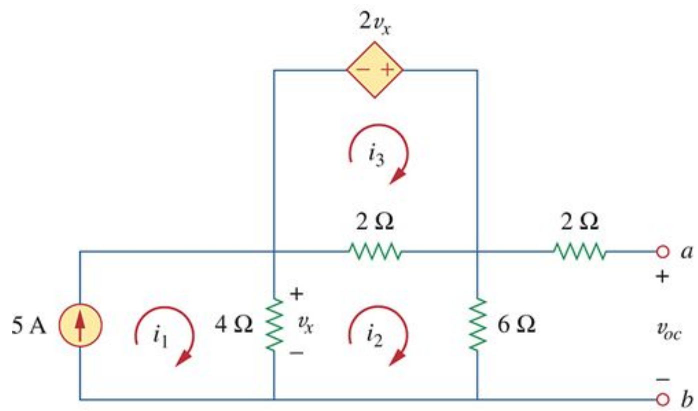
Example 4.9



2vx
2 Ω
2 Ω
a
5 A
4 Ω
+
vx
−
6 Ω
b

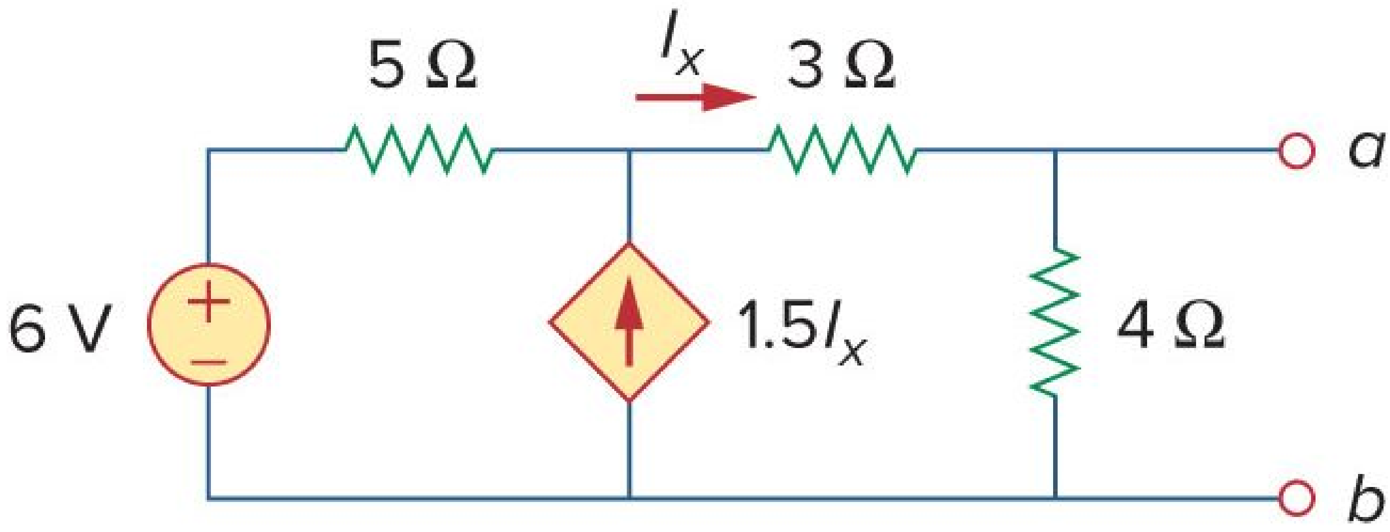


2vx
i1
2 Ω
2 Ω
a
io
4 Ω
vx
i2
6 Ω
i3
vo = 1 V
b

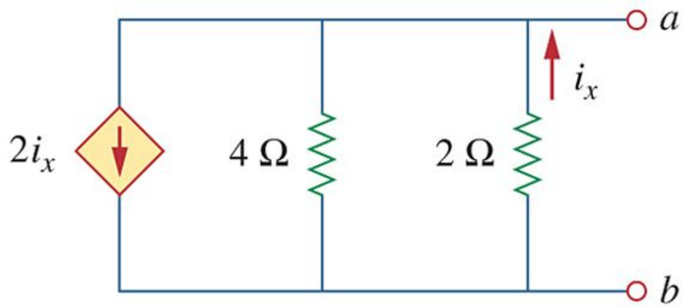


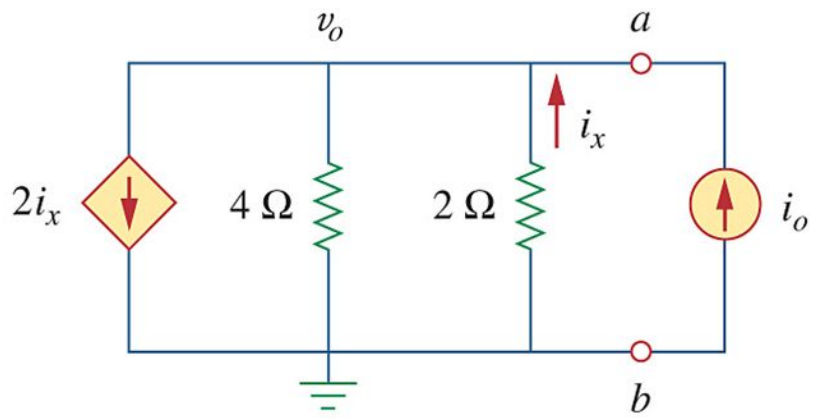
2vx
i3
2 Ω
2 Ω
a
5 A
i1
4 Ω
vx
i2
6 Ω
voc
b

Practice 4.9

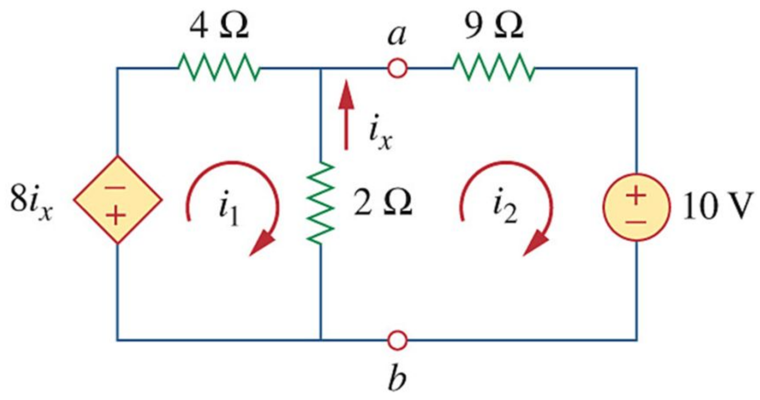


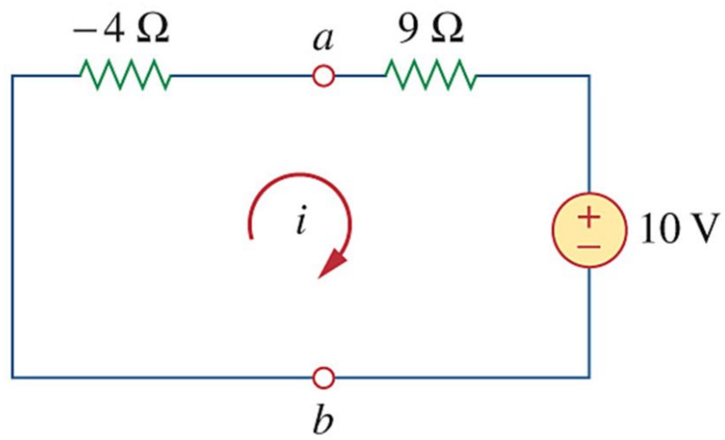
Example 4.10





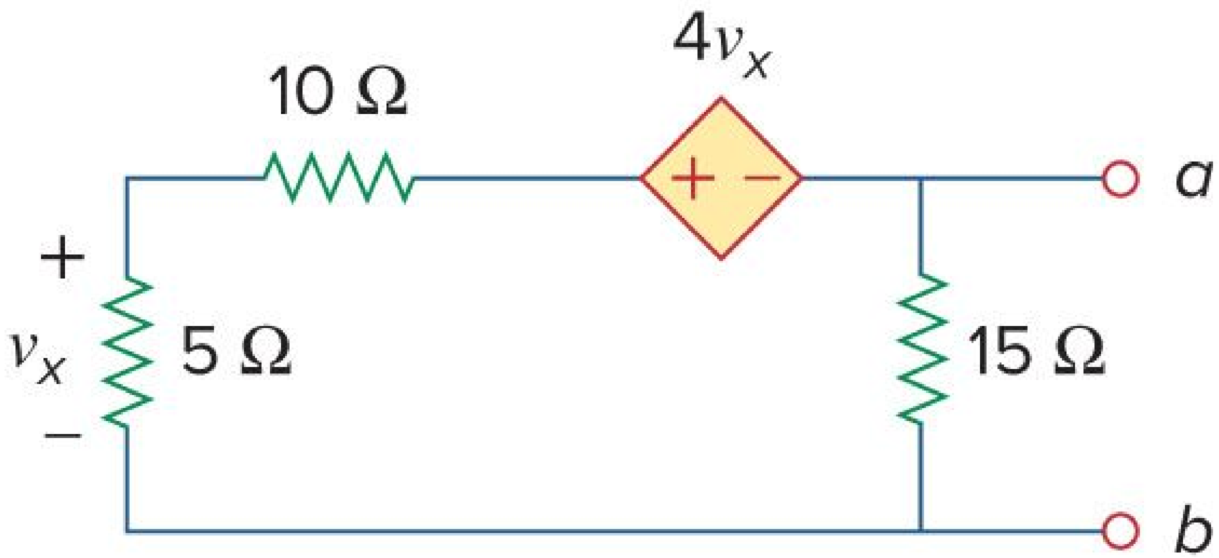
[R_{th} 구하기]





[V_{th}는?]

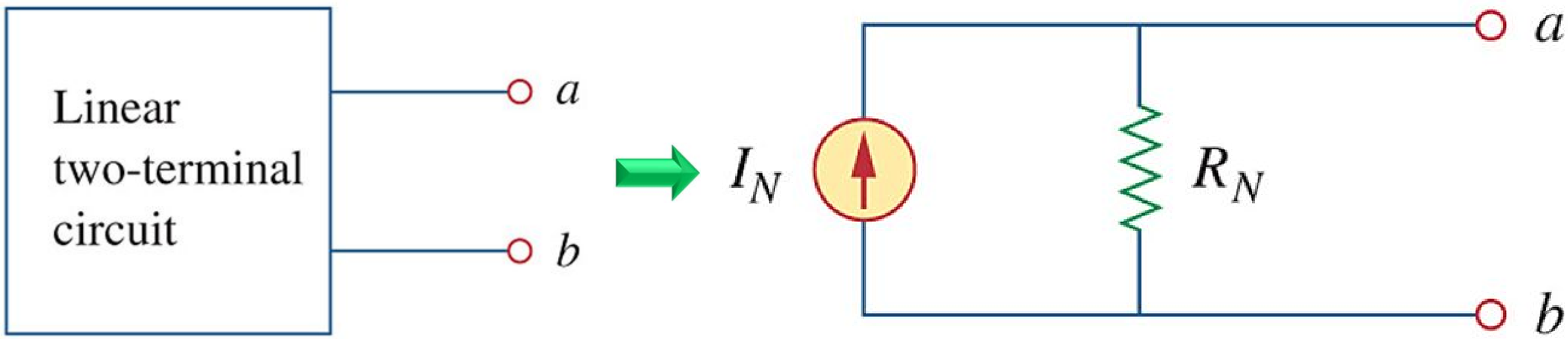
Practice 4.10



4.6 Norton's Theorem

- 노턴의 정리란?

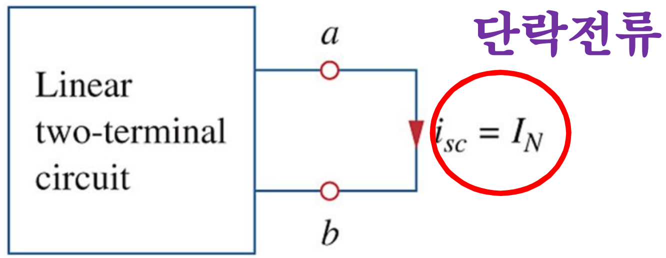
복잡한 회로를 하나의 전류원과 하나의 병렬 저항으로 표현



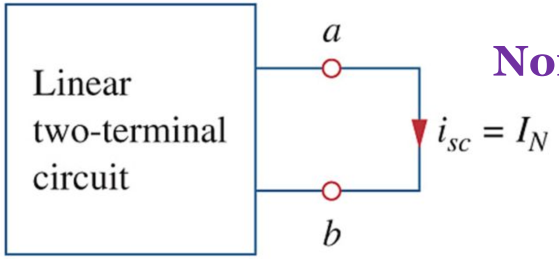
테브닌 등가회로 & 노턴 등가회로 ← 전원변환의 관계

$$\boxed{R_N = R_{Th}}$$

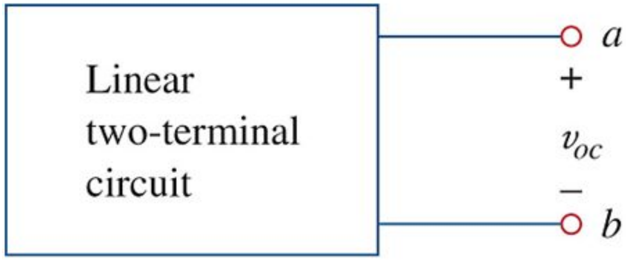
$$\boxed{I_N = \frac{V_{Th}}{R_{Th}}}$$



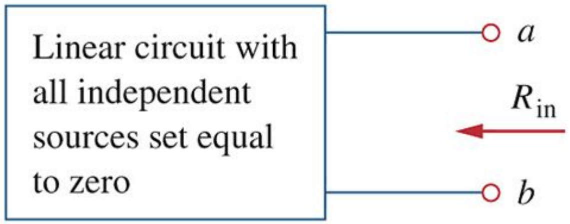
4.6 Thevenin-Norton Transformation



Norton 등가 전류



$V_{\mathrm{Th}} = v_{oc}$ **Thevenin 등가 전압**



$R_{\mathrm{Th}} = R_{\mathrm{in}}$ **Thevenin/Norton 등가 저항**

단락전류 i_{sc}
개방전압 v_{oc}
입력저항 R_{in}

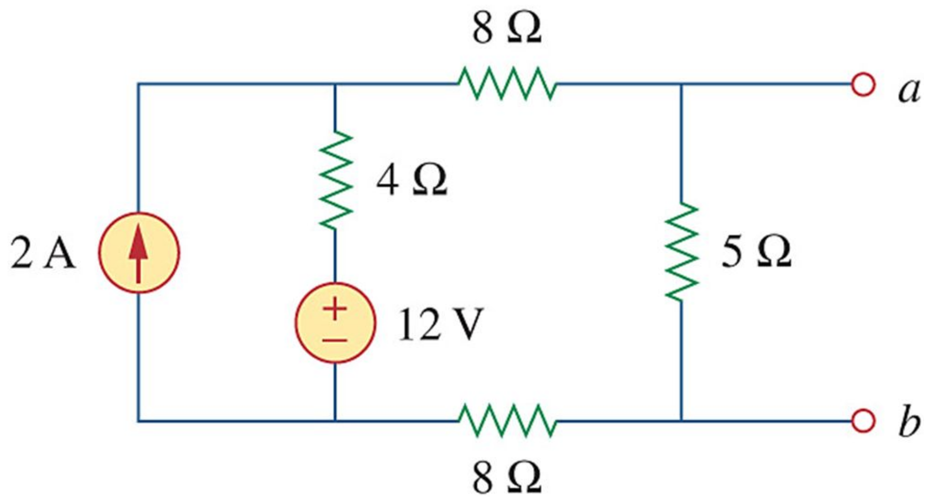
셋 중에 둘만 알면
등가회로 구성 가능

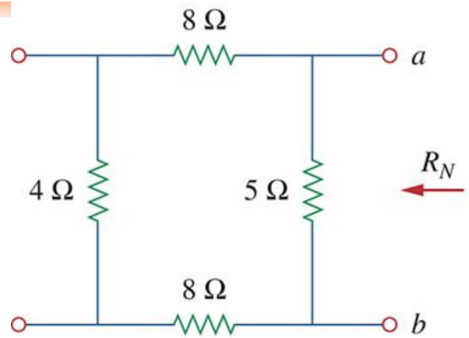
$$V_{Th} = v_{oc}$$

$$I_N = i_{sc}$$

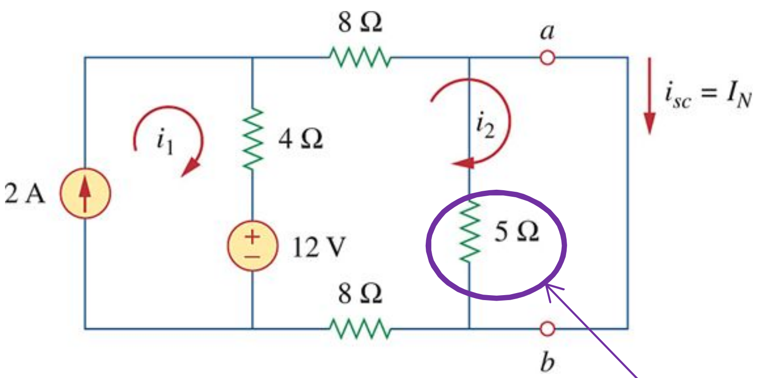
$$R_{Th} = \frac{v_{oc}}{i_{sc}} = R_N$$

Example 4.11



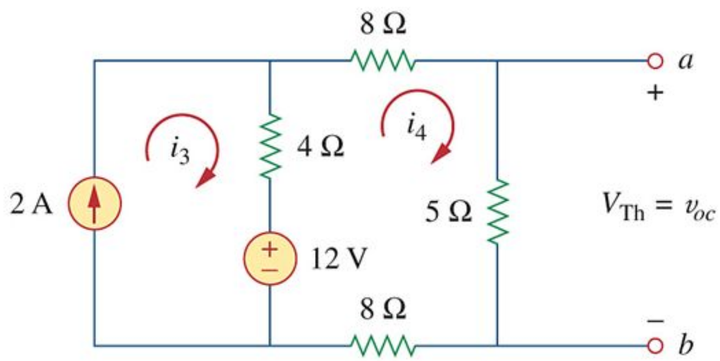


[R_N 구하기]



[I_N 구하기]

meaningless

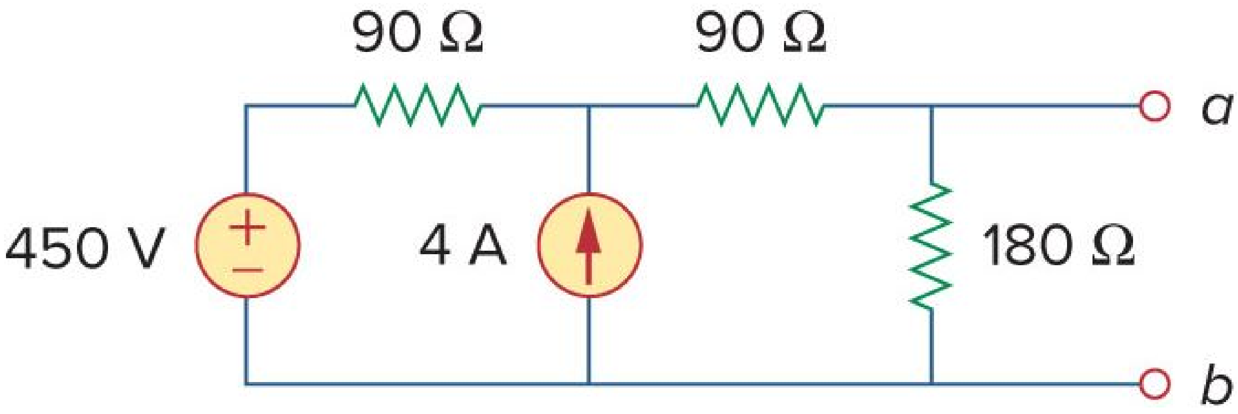


[I_N 구하기 (2)]

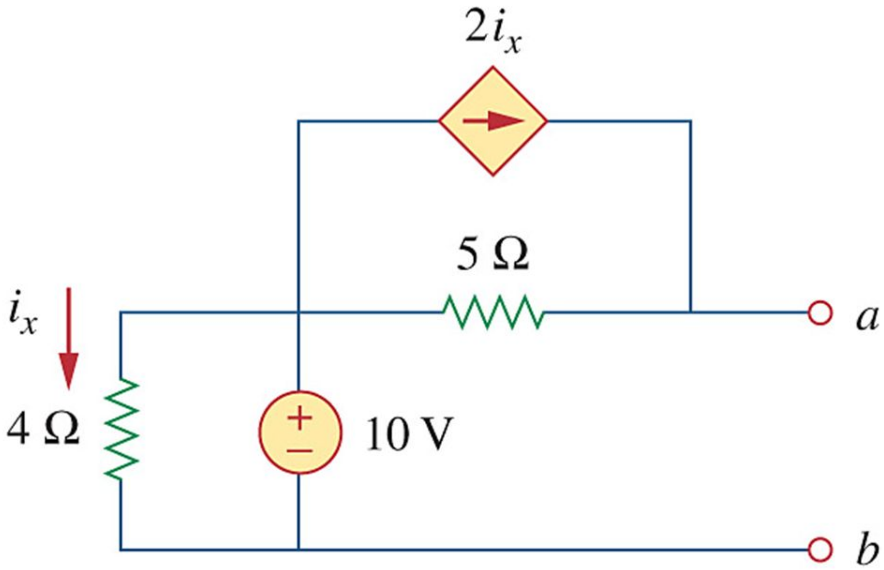
$I_N = V_{Th}/R_N$

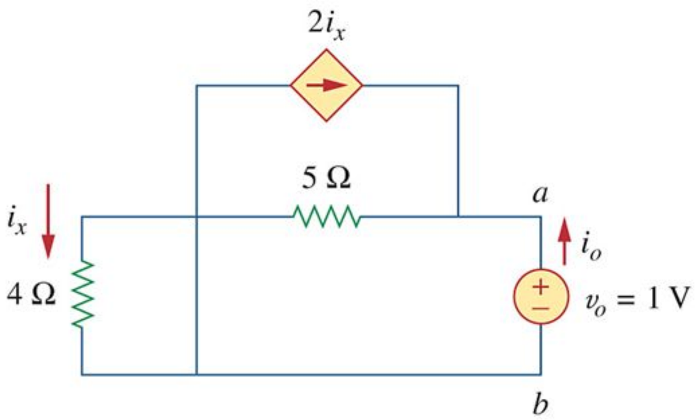
Practice 4.11

- Norton 등가회로?

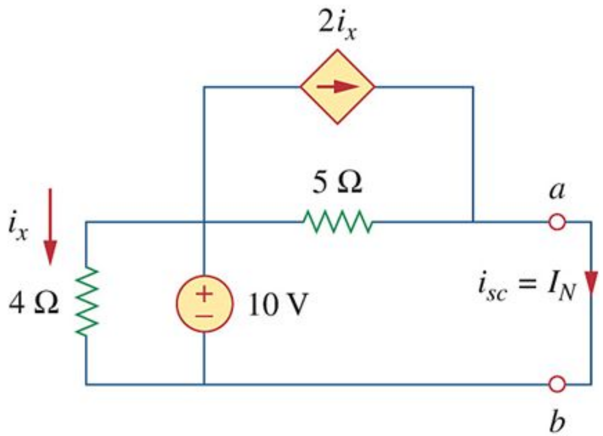


Example 4.12



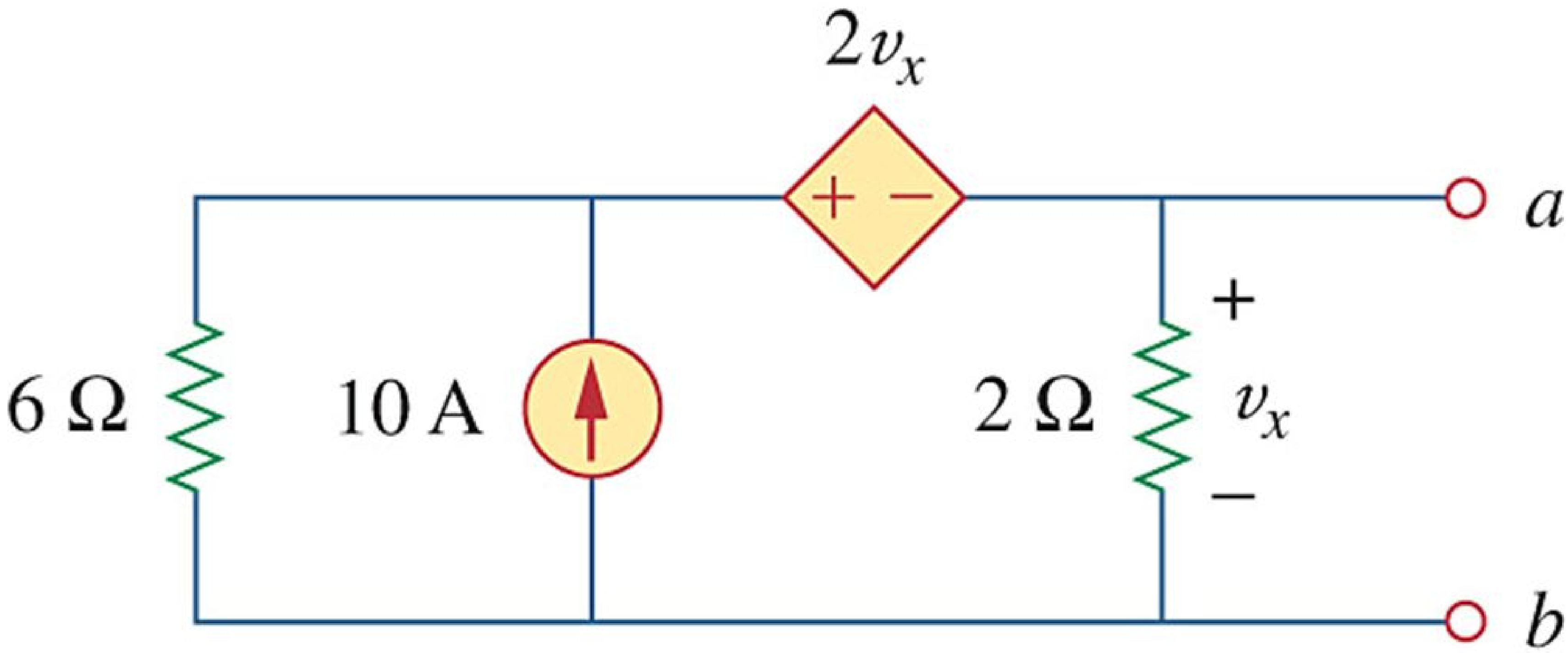


[R_N 찾기]



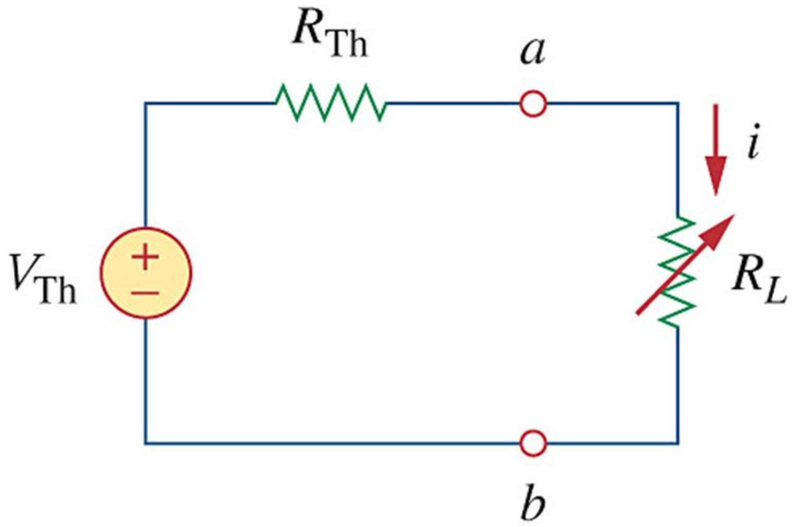
[I_N 찾기]

Practice 4.12



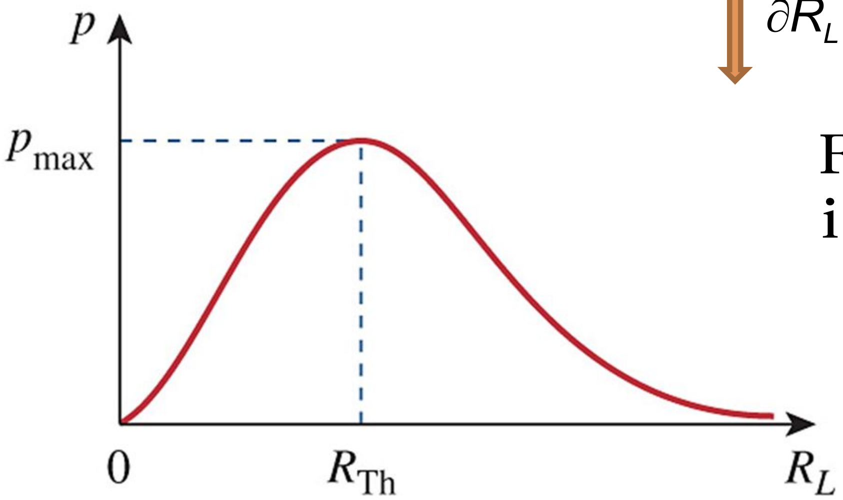
4.8 Maximum Power Transfer

If the entire circuit is replaced by its Thevenin equivalent except for the load, the power delivered to the load is:



$$P = i^2 R_L = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$

$$\frac{\partial P}{\partial R_L} = 0$$



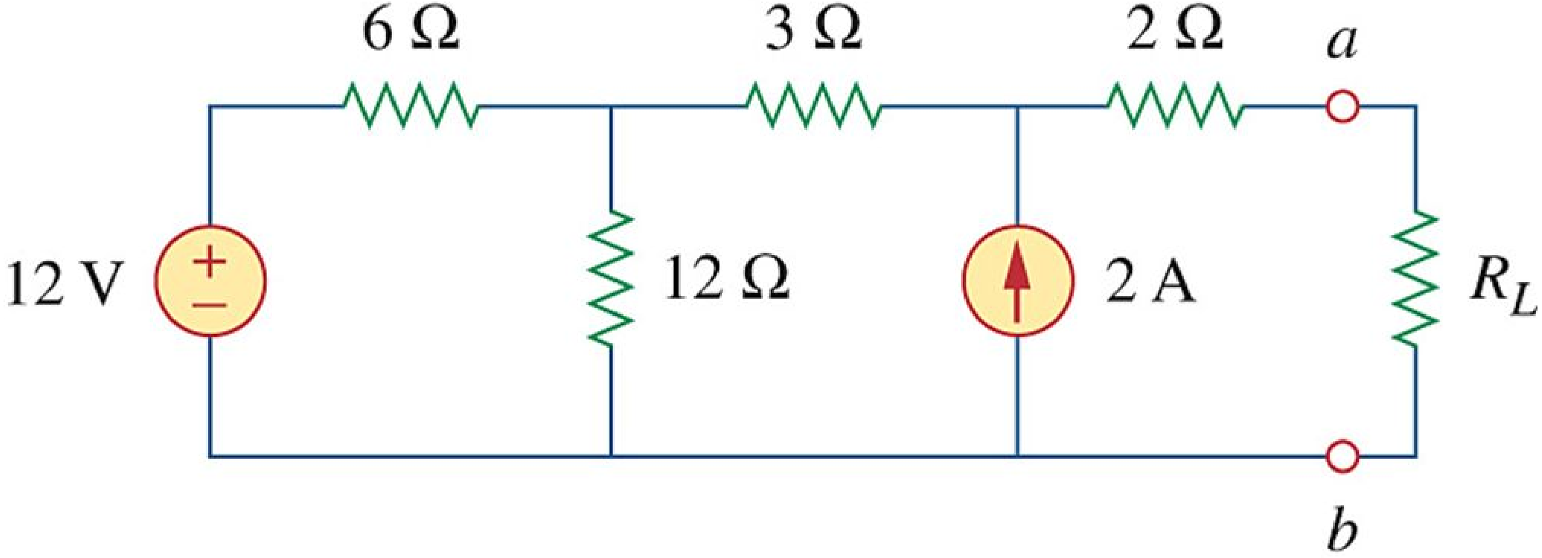
For maximum power dissipated in R_L:

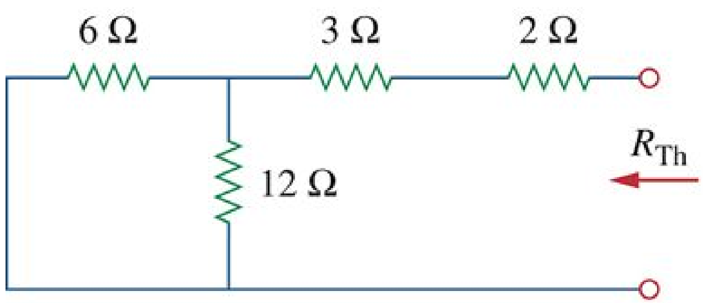
$$\boxed{R_L = R_{TH}} \Rightarrow P_{max} = \frac{V_{Th}^{\;2}}{4R_L}$$

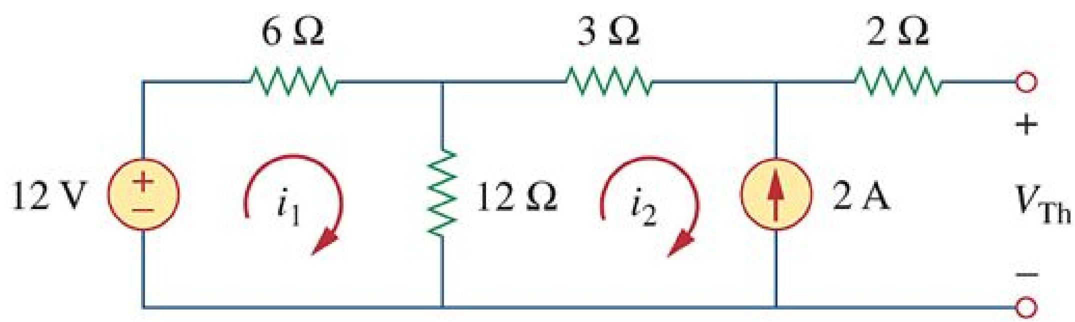
Two resistors are matched!!!

Example 4.13

- Find R_L for maximum power transfer!







Practice 4.13

최대 전력이 전달 되도록 R_L의 값을 구하라