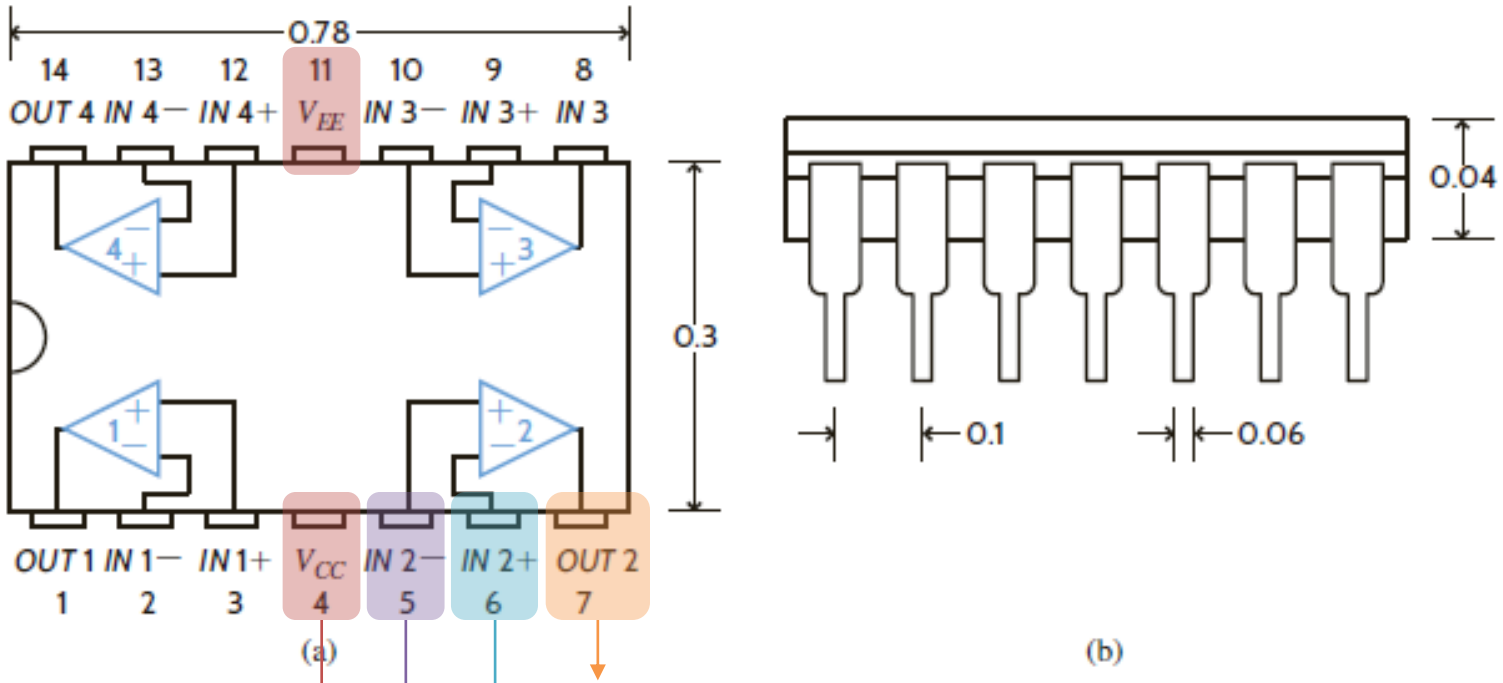
Last Lecture → Op-Amp

- **LM324 – Dip Package - Pinout**



Output

Non-inverting Input

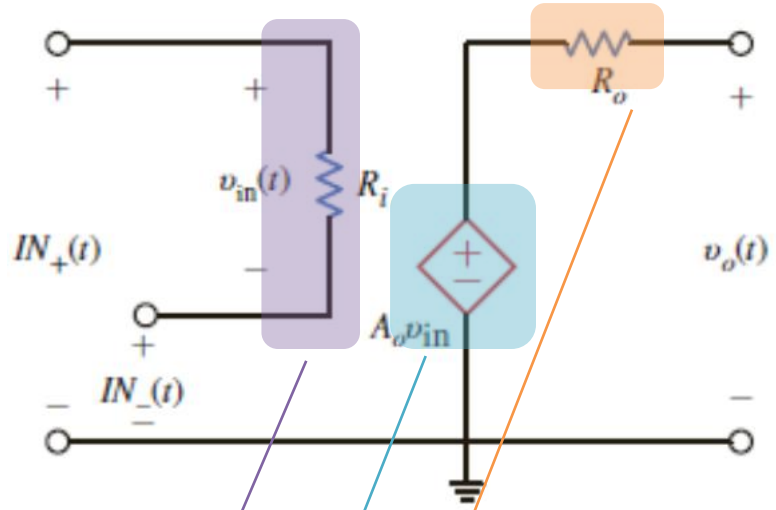
Inverting Input

Negative / Positive Supply

$$V_0 = A_0(IN_+ - IN_-)$$

Gain of op-amp ~ (10,000 – 1,000,000)

- **Circuit Model**



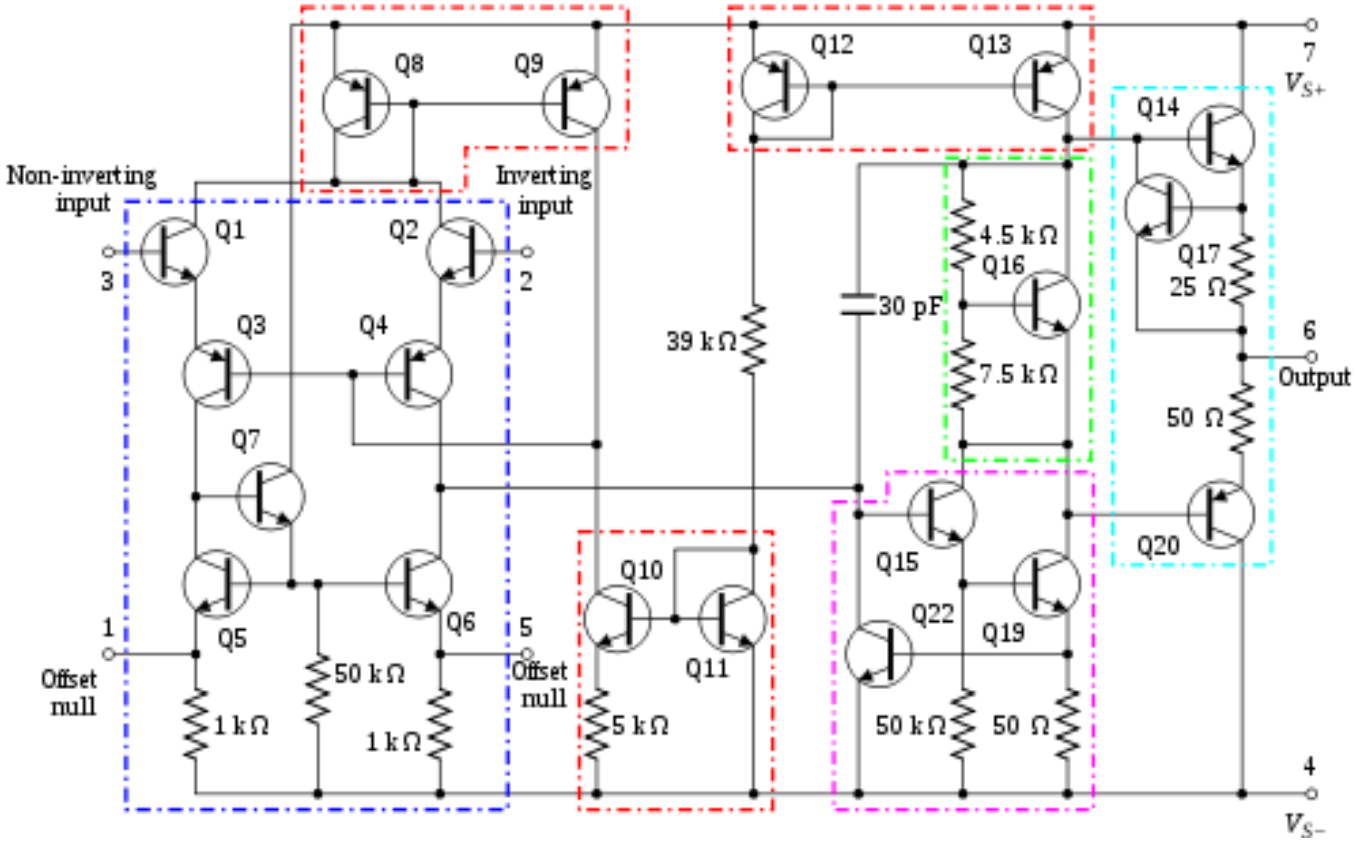
Models I-V relationship at output

Models op-amp gain

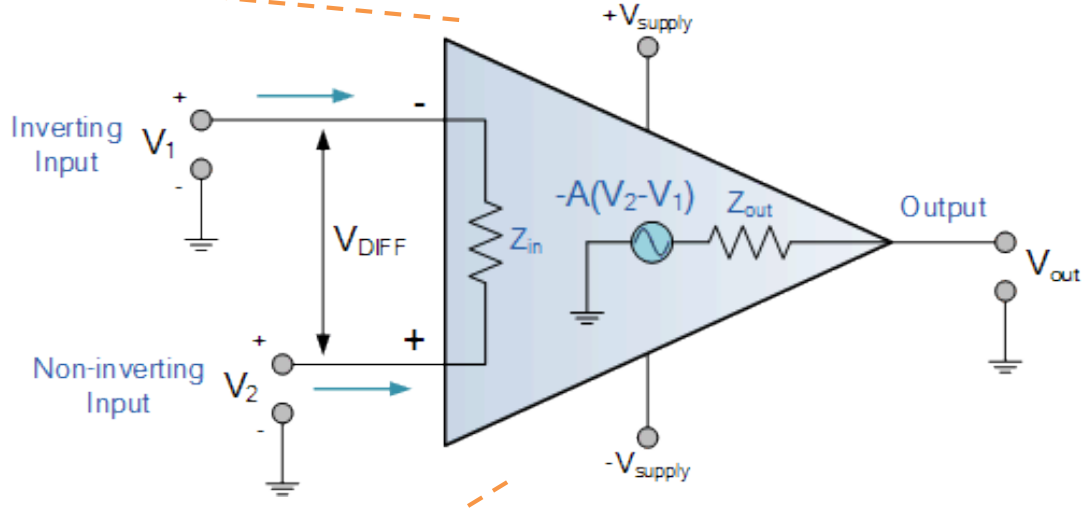
Models I-V relationship at input

Operational Amplifier

- **Internal Circuit Diagram**



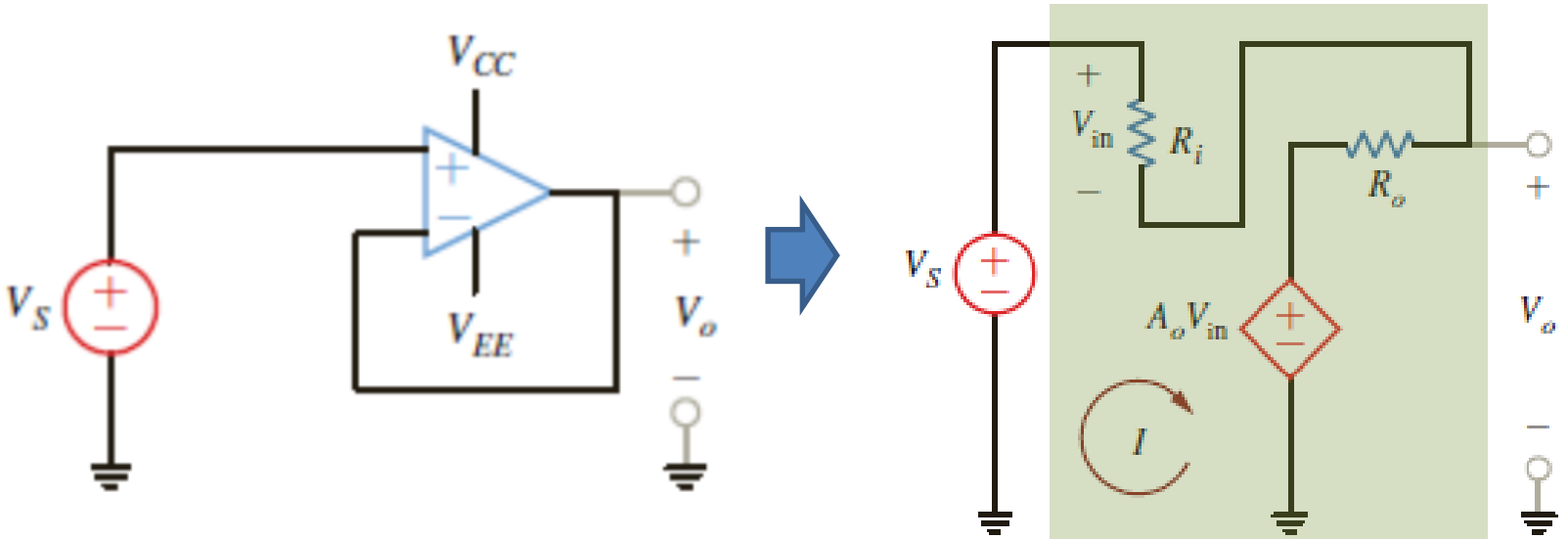
- **Symbol / Equivalent Circuit**



$$V_0 = A_0(IN_+ - IN_-)$$

Unity Gain Buffer

Using the op-amp model find the expression for the transfer function V_o/V_s.



Op-Amp Ideal Behavior

- $R_i = \infty$
- $A_0 = \infty$
- $R_o = 0$

$$i_{R_i} = \frac{V_{in}}{R_i} = 0$$

$$\therefore i_+ = i_- = 0$$

$$\frac{V_0}{V_s} = \frac{1}{1 + \frac{1}{A_0 + \frac{R_0}{R_i}}} \approx \frac{1}{1 + \frac{1}{A_0}} \approx 1$$

$A_0=\infty$

$R_i=\infty$, $R_0=0$

$$V_0 = A_0(V_+ - V_-)$$

$$\hookrightarrow (V_+ - V_-) = \frac{V_0}{A_0} = 0 \qquad \therefore V_+ = V_-$$

Ideal Op-Amp Circuit Analysis

- **Stablish ideal op-amp conditions on the circuit schematic**
  1) $i_+ = i_- = 0$
  2) $v_+ = v_-$
- **Write nodal equations at the op-amp input terminals**
- **Solve for the input/output relationship**

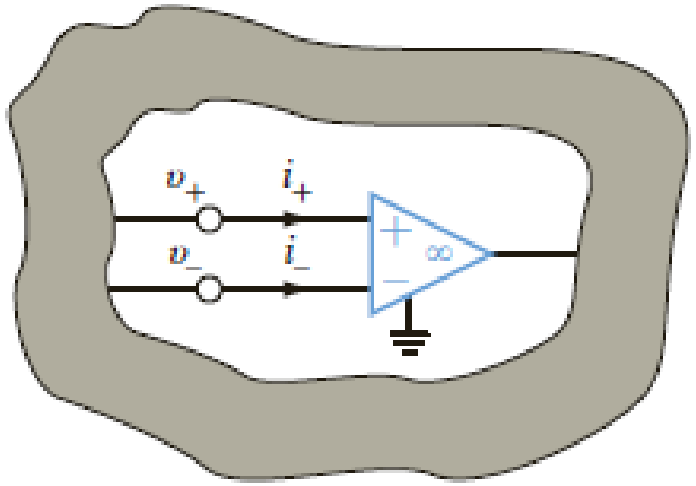
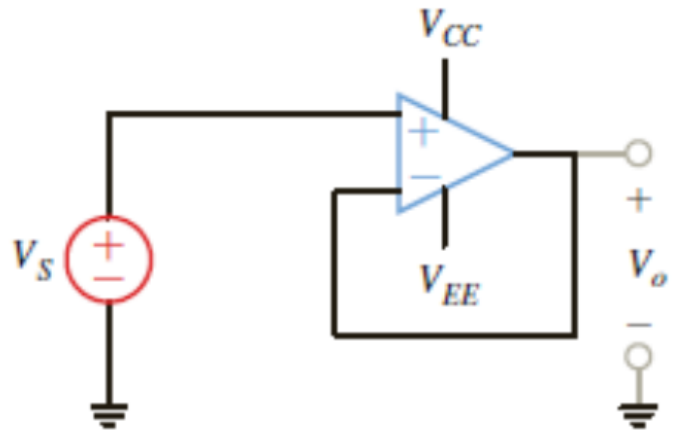


Figure 4.9

Ideal model for an operational amplifier. Model parameters: $i_+ = i_- = 0$, $v_+ = v_-$.

Unity Gain Buffer - Revisited



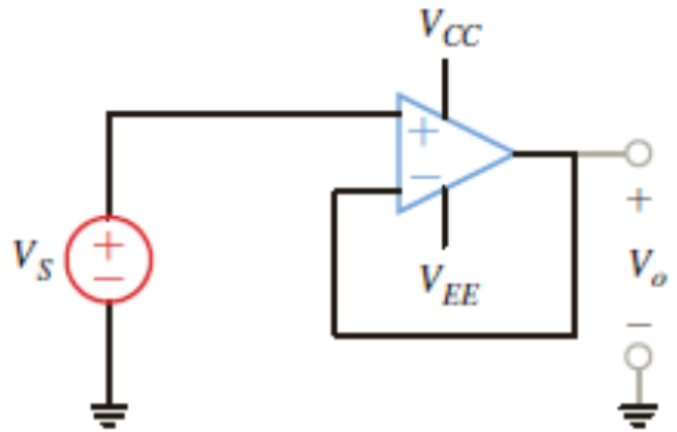
MODEL ASSUMPTION	TERMINAL RESULT
$A_0 \to \infty$	input voltage $\to$ 0 V
$R_i \to \infty$	input current $\to$ 0 A

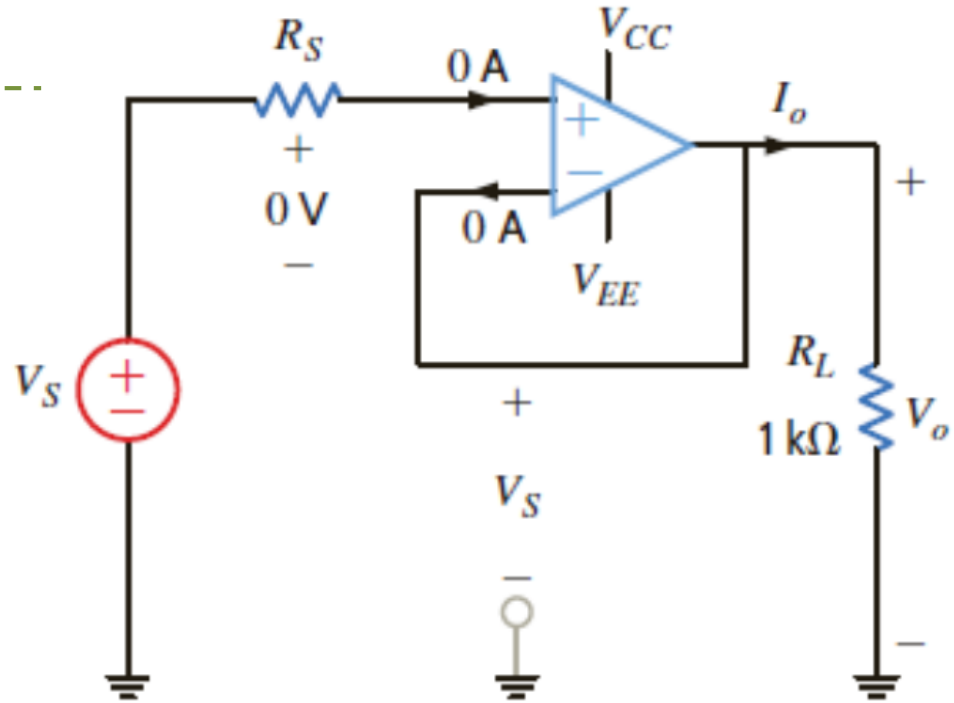
Ideal Op-Amp Circuit Analysis

- **Stablish ideal op-amp conditions on the circuit schematic**
  1) $i_+ = i_- = 0$
  2) $v_+ = v_-$
- **Write nodal equations at the op-amp input terminals**
- **Solve for the input/output relationship**

$$\therefore V_0 = V_s$$

Unity Gain Buffer - Revisited





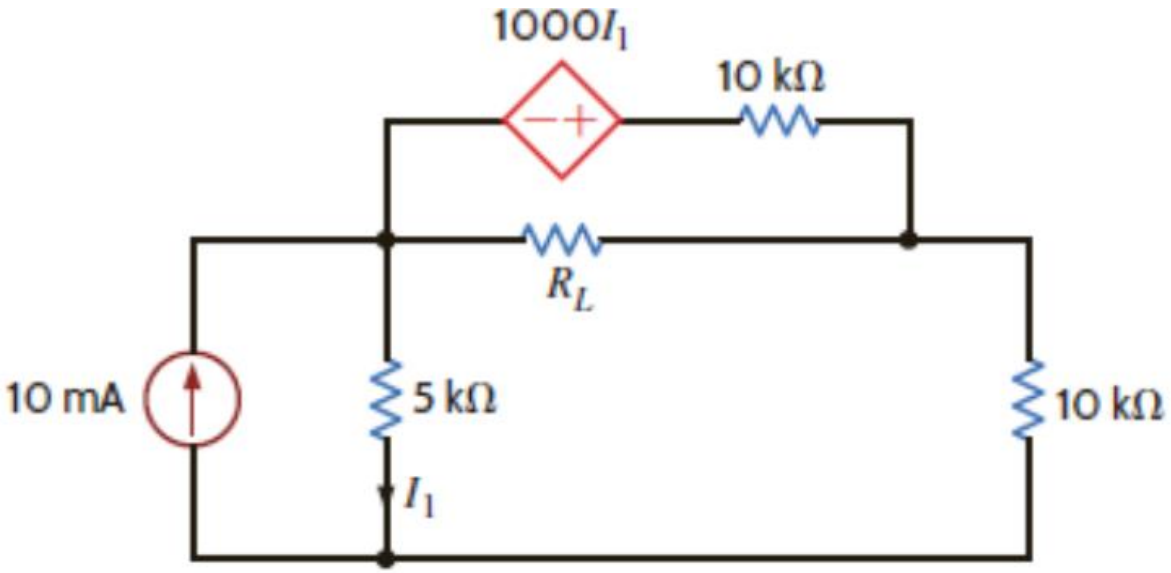
Exam #3 → Tuesday, March 12

Concepts Chapter #5:

1) Superposition
2) The venin's & Norton's Theorem
3) Source Transformation
4) Maximum Power Transfer

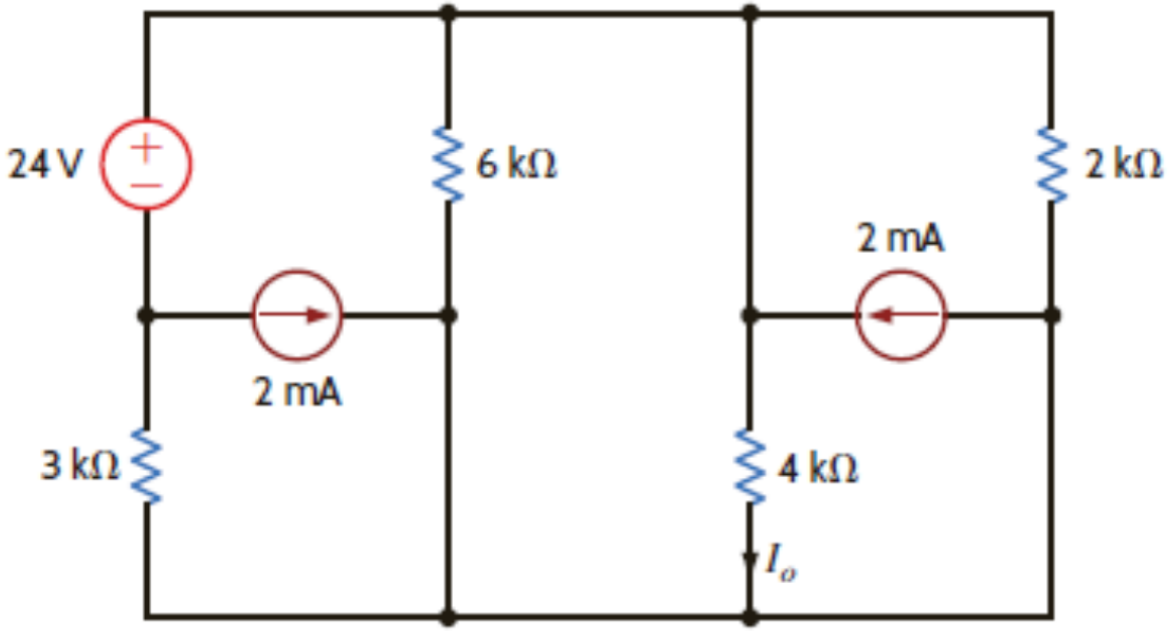
Problem → P5.124

For the given network find the value of R_L for maximum power transfer and the maximum power that can be transferred to this load.



Problem → P5.106

Using source transformation, find I_0 in the circuit provided.



Problem → P5.87

Find the Thevenin equivalent circuit of the provided network at terminals A-B.