Section 2.4 Objective

- Understand voltage and current division.
**Kirchhoff’s Current Law**

- Kirchhoff’s Current Law (KCL) states that the algebraic sum of all currents entering a node is zero.

\[ i_A + i_B + (-i_C) + (-i_D) = 0 \]

**Kirchhoff’s Voltage Law**

- Kirchhoff’s Voltage Law (KVL) states that the algebraic sum of the voltages around any closed path is zero.

\[ -v_1 + v_2 + -v_3 = 0 \]
Measuring Voltage, Current, and Resistance

• An ideal meter has no effect on the circuit variable being measured.
• That means when an ideal ammeter is placed in series to measure the current through an element, it should have an equivalent resistance of 0 Ω.
• That means when an ideal voltmeter is placed in parallel to measure the voltage across an element, it should have an equivalent resistance of ∞ Ω.

Series Connections

• Elements connected head-to-tail and carrying the same current are said to be connected in series.
**Resistors in Series**

Resistors in series “share” the voltage applied to them.

\[
v_i = v_1 + v_2 + \cdots + v_N
\]

\[
v_i = R_1i + R_2i + \cdots + R_Ni
\]

\[
= (R_1 + R_2 + \cdots + R_N)i
\]

\[
v_s = R_{eq}i
\]

\[
R_{eq} = R_1 + R_2 + \cdots + R_N
\]

**Voltage Division**

Resistors in series “share” the voltage applied to them.

\[
i = \frac{v}{R_1 + R_2}
\]

\[
v_2 = i R_2 = \left(\frac{v}{R_1 + R_2}\right) R_2
\]

\[
v_2 = \frac{R_2}{R_1 + R_2}v
\]
Voltage Divider Example

Calculate $V_1$ using the voltage divider equation.

$V_f = 4.00V$

Textbook Problem 3.12 (Nilsson 10th)

Find the voltage $v_0$ and the power dissipated in both resistors.

$v_0 = 66V$

$P_{R1} = 1.88W$

$P_{R2} = 1.32W$
Parallel Connections

- Elements in a circuit connected head-to-head and tail-to-tail have a common voltage across them and are said to be connected in *parallel*.

Resistors in Parallel

\[ i_S = i_1 + i_2 + \cdots + i_N \]
\[ i_S = \frac{V}{R_1} + \frac{V}{R_2} + \cdots + \frac{V}{R_N} = \frac{V}{R_{eq}} \]

\[ \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N} \]
Two Resistors in Parallel

\[ R_{\text{eq}} = R_1 \parallel R_2 \]
\[ = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \]
\[ R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2} \]

Connecting resistors in parallel makes the equivalent resistance smaller. Always.

Current Division

Resistors in parallel “share” the current through them.

\[ i_2 = \frac{v}{R_2} \]
\[ = \frac{i (R_1 \parallel R_2)}{R_2} \]
\[ = \frac{i}{R_2} \frac{R_1 R_2}{R_1 + R_2} \]
\[ i_2 = i \frac{R_1}{R_1 + R_2} \]
Current Divider Example

Calculate the current in the two resistors below using the current divider equation.

\[ i_{2K} = 0.667 \text{mA} \]
\[ i_{4K} = 0.333 \text{mA} \]

Textbook Problem 3.2d (Nilsson 11th)

Compute the equivalent resistance seen by the 30 mA source.

Answer: \( R = 120 \Omega \)
Textbook Problem 3.19 (Nilsson 11\textsuperscript{th})

For the current divider shown below, calculate $i_0$ and $v_0$.

\[ i_0 = 0.16A \text{ and } v_0 = 16V \]

Section 2.4 Summary

- You learned how to recognize and apply the laws of voltage and current division.