Chapter 2.3
Resistive Circuits
Kirchhoff’s Law

Section 2.3 Objective

• Learn to apply Kirchhoff's laws.
Ohm’s Law

- The relationship between voltage, current, and resistance is defined by *Ohm’s law* which states that

\[ V = IR \]

where

- \( V \) = the voltage in volts;
- \( I \) = the current in amps;
- \( R \) = the resistance in ohms.
Ohm’s Law Illustrated

Series Connections

• Elements connected head-to-tail and carrying the same current are said to be connected in **series**.
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 \textit{parallel}.

Nodes, Paths, Loops, Branches

- These two circuits are equivalent.
- There are three \textit{nodes} and five \textit{branches}:
  - \textit{Node}: a point at which two or more elements have a common connection;
  - \textit{Path}: a sequence of nodes;
  - \textit{Branch}: a single path in a circuit composed of one simple element and the node at each end of that element;
  - \textit{Loop}: a closed path.
Kirchhoff’s Current Law

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

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

KCL: Alternative Forms

- Current IN is positive:
  \[ i_A + i_B + (-i_C) + (-i_D) = 0 \]

- Current OUT is positive:
  \[ (-i_A) + (-i_B) + i_C + i_D = 0 \]

- Current IN = Current OUT:
  \[ i_A + i_B = i_C + i_D \]
KCL Application

Find the current through resistor $R_3$ if it is known that the voltage source supplies a current of 3 A.

![Circuit Diagram]

*Answer: $i = 6 \, A$*

Kirchhoff’s Voltage Law

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

$$ -v_1 + v_2 - v_3 = 0 $$
KVL: Alternative Forms

- Sum of RISES is zero (clockwise from B):
  \[ v_1 + (-v_2) + v_3 = 0 \]
- Sum of DROPS is zero (clockwise from B):
  \[ (-v_1) + v_2 + (-v_3) = 0 \]
- Sum of RISES is equal to sum of DROPS (clockwise from B):
  \[ v_1 + v_2 = v_3 \]

KVL Application

Find the current \( i_x \) and the voltage \( v_x \)

\[ \begin{align*}
  7 \text{ V} & \quad \text{+} \\
  5 \text{ V} & \quad \text{+} \\
  100 \Omega & \quad \text{+} \\
  i_x & \quad \text{+} \\
  v_x & \quad \text{+} \\
\end{align*} \]

Answer: \( v_x = 12 \text{ V} \) and \( i_x = 120 \text{ mA} \)
**Circuit Analysis with Dependent Sources**

- Circuits that contain dependent sources can be analyzed using Ohm’s and Kirchhoff’s laws.
- A dependent source generally adds another equation to the solution process.

**Textbook Problem 2.22 (Nilsson 10E)**

The current $i_0$ is 1 A.

A) Find $i_1$.

B) Find the power dissipated in each resistor.

C) Verify that the power developed = power absorbed.

\[ A) \quad i_1 = 2A \]

\[ B) \quad P_4 = 100W \quad P_{50} = 50W \quad P_{10} = 90W \quad P_{65} = 260W \quad P_{25} = 400W \]

\[ C) \quad P_{150V} = 900W = \text{sum of powers dissipated in the 5 resistors.} \]
Zybook Exercise 2.3.13

(a) Given that in the circuit above, $I_1 = 4\, \text{A}$, $I_2 = 1\, \text{A}$, and $I_3 = 1\, \text{A}$, determine node voltages $V_1$, $V_2$, and $V_3$.

Measuring Voltage and Current

- An **ammeter** is an instrument designed to measure current; it is placed in *series* with the circuit element whose current is being measured.
- A **voltmeter** is an instrument designed to measure voltage; it is placed in *parallel* with the element whose voltage is being measured.
Measuring Resistance

- An **ohmmeter** is an instrument designed to measure resistance; it is placed in **parallel** with the resistive circuit whose resistance is being measured. Note that accurate measurements of resistance require that the resistive circuit have no energy present (no voltage or current).
- Often, one instrument – called a **multimeter** – is used to measure all three parameters, but not all at once.

![Circuit Diagram]

Fluke Multimeters

![Fluke Multimeters Image]
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 $0 \, \Omega$.
- That means when an ideal voltmeter is placed in parallel to measure the voltage across an element, it should have an equivalent resistance of $\infty \, \Omega$.

Textbook Problem 3.39 (Nilsson 11th)

An ammeter with an internal resistance of $0.1 \, \Omega$ is used in the circuit below. Find the percentage error in the measured value using the following formula:

$$\%\text{Error} = \frac{(\text{Measured value} - \text{True value})}{\text{True value}} \times 100\%$$

**Answer:** $\%\text{error} = -0.347\%$
Section 2.3 Summary

• Section 2.3: You learned to apply Kirchhoff's laws.