Today’s Topics

- DC Circuits (Chapter 28)
- Circuit components
- Kirchhoff’s Rules
### Basic Circuit Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Symbol</th>
<th>Behavior in circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal battery, emf</td>
<td>![Battery Symbol]</td>
<td>$\Delta V = V_+ - V_- = \epsilon$</td>
</tr>
<tr>
<td>Resistor</td>
<td>![Resistor Symbol]</td>
<td>$\Delta V = -IR$</td>
</tr>
<tr>
<td>Realistic Battery</td>
<td>![Realistic Battery Symbol]</td>
<td>$\Delta V = 0$ ($\rightarrow R = 0, C = 0$)</td>
</tr>
<tr>
<td>(Ideal) wire</td>
<td>![Wire Symbol]</td>
<td>$\Delta V = 0$ ($\rightarrow R = 0, C = 0$)</td>
</tr>
<tr>
<td>Capacitor</td>
<td>![Capacitor Symbol]</td>
<td>$\Delta V = V_- - V_+ = -\frac{q}{C}$</td>
</tr>
<tr>
<td>Inductor</td>
<td>![Inductor Symbol]</td>
<td>We’ll see this later</td>
</tr>
<tr>
<td>(Ideal) Switch</td>
<td>![Switch Symbol]</td>
<td>C=0, R=0 (on), R=\infty (off)</td>
</tr>
<tr>
<td>Transformer</td>
<td>![Transformer Symbol]</td>
<td>Future Topics</td>
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<tr>
<td>Diodes, Transistors,…</td>
<td></td>
<td></td>
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</tbody>
</table>
Resistors in Circuits

In series
Share current, V add up

$R = R_1 + R_2 + R_3 \ldots$

In parallel
Share V, currents add up

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$
Kirchoff’s Laws

#1 Conservation of electric charge

All the charge that flows into a junction of conductors per unit time, the same amount must leave in the same time interval.

#2 Conservation of energy

A complete trip around the circuit (the end point is the same as the beginning point) must result in zero net energy change.
Kirchhoff’s Rules: Junction Rule

Rule #1: Junction Rule

The net current entering any junction equals the net current leaving that junction.

\[ \sum I_{\text{in}} = \sum I_{\text{out}} \]

Determined by assigned direction for each current:

- “in” : current with assigned direction towards junction
- “out” : current with assigned direction off junction

\[ I_1 = I_2 + I_3 \]
(Very) Quick Quiz: Junction Rule

What is the junction rule for the current assignment shown?

\[ I_1 + I_2 = I_3 \]
\[ I_1 = I_2 + I_3 \]
\[ I_1 - I_2 = I_3 \]

Although equation 2 and 3 are equivalent, equation 3 does not follow template form \( I_{\text{in}} = I_{\text{out}} \).
Quick Quiz: Junction Rule

- What is the junction rule for the current assignment shown?
  - $I_1 + I_2 = I_3$
  - $I_1 + I_2 + I_3 = 0$
  - Neither

While the actual currents can not all go into a junction, the assigned currents can.
Kirchhoff’s Rules: Loop Rule

Loop Rule (Energy Conservation):
The sum of potential drops across components along any closed circuit loop must be zero.

\[ \sum \Delta V = 0 \]

The exact expression of the potential drop is determined by the type of component and the assigned current direction (see next slides)
Determine Potential Difference(1)

Choose a direction for the current, and move around the loop in that direction.

\[ \Delta V = V_b - V_a = -\varepsilon \]

When a battery is traversed from the positive terminal to the negative terminal, the voltage drops (- sign).

When a battery is traversed from the negative terminal to the positive terminal, the voltage increases (+ sign).
Determine Potential Differences (2)

Choose a direction for the current, and move around the loop in that direction.

\[ \Delta V = V_b - V_a = -IR \]

When moving across a resistor in the direction of the assigned current, the voltage drops (- sign).

When moving across a resistor in a direction opposite to the assigned current, the voltage increases (+ sign).
Steps to Apply Kirchhoff’s Rules

1. Assign directional currents for each branch of the circuit.

2. Set up junction rules at certain (any) junctions. Normally:
   \[ \text{# of junctions} = \text{# of currents} - 1. \]

3. Select a number of closed loops to apply loop rule.
   For each, follow a clockwise (or counterclockwise) direction, find $\Delta V$ across each component, apply loop rule.
   \[ \text{# of loops determined by # of unknowns.} \]

4. Solve for unknowns. (A negative current indicates its direction is opposite to the assigned direction.)
Example: Multi-Loop

Question: find $I_1$, $I_2$, $I_3$

Kirchhoff’s Rules:

Junction c: $I_1 + I_2 = I_3$

Loop 1: $-\varepsilon_2 + I_1R_1 - \varepsilon_1 - I_2R_2 = 0$

Loop 2: $\varepsilon_1 - I_1R_1 - I_3R_3 = 0$

Solve:
$I_1 = 2.0\text{A}$, $I_2 = -3.0\text{A}$, $I_3 = -1.0\text{A}$

(What do the – signs mean?)
Example: Interpretation of Results

$I_1 = 2.0A$, $I_2 = -3.0A$, $I_3 = -1.0A$,
Example Again: Different Initial Directions

Different initial directions for $I_1$, $I_2$

Apply Kirchhoff’s Rules:

Junction c: $0 = I_3 + I_1 + I_2$

Loop 1: $-\varepsilon_2 - I_1 R_1 - \varepsilon_1 + I_2 R_2 = 0$

Loop 2: $\varepsilon_1 + I_1 R_1 - I_3 R_3 = 0$

Solve:

$I_1 = -2.0A$, $I_2 = +3.0A$, $I_3 = -1.0A$

Same result as previous slide