Physics 202, Lecture 10

Today’s Topics

- Direct Current Circuits (Ch. 25)
- Basic circuit components (E, R, …)
- Kirchhoff’s Rules
- Circuits Analysis (For circuits of R’s and e’s)
- Exam scores posted tomorrow

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>$\Delta V$</td>
<td>$V_+ - V_- = \varepsilon$</td>
</tr>
<tr>
<td>Resistor</td>
<td>$R$</td>
<td>$\Delta V = -IR$</td>
</tr>
<tr>
<td>Realistic Battery</td>
<td>$\approx$</td>
<td>$\Delta V = 0$ ($\rightarrow R=0, L=0, C=0$)</td>
</tr>
<tr>
<td>Capacitor</td>
<td>$Q$</td>
<td>$\Delta V = V_+ - V_- = -Q/C, \frac{dQ}{dt} = I$</td>
</tr>
<tr>
<td>Inductor</td>
<td>$L$</td>
<td>$\Delta V = -L\frac{dI}{dt}$</td>
</tr>
<tr>
<td>(Ideal) Switch</td>
<td>$\approx$</td>
<td>$L=0, C=0, R=0$ (on), $R=\infty$ (off)</td>
</tr>
</tbody>
</table>

Future Topics

- Diodes, Transistors, …

Exercise: Equivalent Resistance of a Combined Parallel and Serial Circuit

- What is the $R_{eq}$ for the combination shown? $R_1 = R_2 = 1\ \Omega$, $R_3 = 2\ \Omega$, $R_4 = 4\ \Omega$.
  
  1. 8Ω
  2. 6Ω
  3. 5Ω
  4. None of above

A Complicated Circuit

A complicated circuit:
- May contain more than one emf
- May not be simplified as “in series” or “in parallel”
- May contain multi loops and junctions.
**Kirchhoff’s Rules: Junction Rule**

- **Junction Rule (Charge conservation):**
  The sum of currents entering any junction equals the sum of currents leaving that junction.
  \[ \Sigma I_{in} = \Sigma I_{out} \]
  - In practice, the classifications of "in" and "out" are determined by assigned direction for each current.

**Quick Quiz: Junction Rule**

1. \( I_1 + I_2 = I_3 \)
2. \( I_1 - I_2 = I_3 \) (Note: The sign is changed to follow the template form)
3. \( I_1 - I_2 = -I_3 \)

Although equation 2 and 3 are equivalent, equation 3 does not follow template form \( \Sigma I_{in} = \Sigma I_{out} \).

**Kirchhoff’s Rules: Loop Rule**

- **Loop Rule (Energy Conservation):**
  \[ PE = QV \] (if no new energy is introduced)
  The sum of potential drops across components along any closed circuit loop must be zero.
  \[ \Sigma \Delta V = 0 \]
  - The potential "drop" across a component is always defined as \( V_{down\_stream\_end} - V_{up\_stream\_end} \) where, the stream direction is the loop direction.
  - 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**

- \( \Delta V = V_b - V_a = -\epsilon \) if the loop is clockwise and \( \epsilon \) is positive.
- \( \Delta V = V_b - V_a = +\epsilon \) if the loop is counter clockwise and \( \epsilon \) is positive.

**Steps to Apply Kirchhoff’s Rules**

1. Assign a directional current for each branch (segment) of a circuit. The assigned direction for each current can be arbitrarily chosen but, once assigned, need to be observed.
2. Set up junction rules at certain (any) junctions. (Typically you need one less than you have junctions)
3. Select a number of closed loops to apply loop rule.
   - For each closed loop, assign a loop direction (clockwise or counter clockwise). Follow that assigned direction, find \( \Delta V \) drop across each component, and apply loop rule.
4. Solve for unknowns. (If you don’t have enough equations to solve for the unknowns you probably missed some loops)
5. If a current is found to be negative, it means its actual direction is opposite to the originally chosen one. (A little thought in step 1 will lead you to more often identify the direction correctly)

**Example 1: Multi-Loop**

- (Text example 28.7)
- Find out \( I_1, I_2, I_3 \)
- **Kirchhoff’s Rules:**
  - Junction c:
    \( I_1 + I_2 = I_3 \)
  - Loop abcda:
    \( \epsilon_1 - I_1 R_1 - I_3 R_3 = 0 \)
  - Loop befcb:
    \( -\epsilon_2 + I_1 R_1 - I_2 R_2 = 0 \)
- Solving three equations:
  \( I_1 = 2.0A, I_2 = -3.0A, I_3 = -1.0A \)
- What does the – sign mean?

- (Very) Quick Quiz: Junction Rule
  - What is the junction rule for the current assignment shown?
### Example 1: Interpretation of Results

<table>
<thead>
<tr>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_1 = 2.0A$</td>
</tr>
<tr>
<td>$I_2 = -3.0A$</td>
</tr>
<tr>
<td>$I_3 = -1.0A$</td>
</tr>
</tbody>
</table>

**Actual situation**
Note how the positive current typically is pushed away from the positive terminal of the emf.

### Example 1 Again: Different Initial Directions

Different initial direction for $I_1$, $I_2$

- Apply Kirchhoff's Rules:
  - Junction c:
    \[ 0 = I_1 + I_2 \]
  - Loop abcd:
    \[ \epsilon_1 + I_1R_1 - I_3R_3 = 0 \]
  - Loop befcb:
    \[ -\epsilon_2 - I_1R_1 - \epsilon_1 + I_2R_2 = 0 \]

Solving three equations:
- $I_1 = -2.0A$, $I_2 = +3.0A$, $I_3 = -1.0A$,

Same effective result as in previous slide.