Kirchhoff's Current Law

Sum of currents entering a node is zero
Also holds for closed boundary

\[ \sum_{n=1}^{N} i_n = 0 \] (KCL),

\[ i_1 - i_2 - i_3 + i_4 = 0 \]

or

\[ i_1 + i_4 = i_2 + i_3 \]

Pay attention to the signs

All current enter the node
All current leave the node
Kirchhoff’s Voltage Law (KVL)

**Sum of voltages around a closed path is zero**
**Sum of voltage drops = sum of voltage rises**

\[ \sum_{n=1}^{N} V_n = 0 \quad \text{(KVL)} \]

**Sign Convention**
- Add up the voltages in a systematic clockwise movement around the loop.
- Assign a positive sign to the voltage across an element if the (+) side of that voltage is encountered first, and assign a negative sign if the (−) side is encountered first.

\[ -4 + V_1 - V_2 - 6 + V_3 - V_4 = 0 \]
Example 2-3 KCL Equations

Write the KCL equations at nodes 1 through 5 in the circuit of Fig. 2-10.

**Solution:**

At node 1: \[-I_1 - I_3 + I_5 = 0\]
At node 2: \[I_1 - I_2 + 2 = 0\]
At node 3: \[-2 - I_4 + I_6 = 0\]
At node 4: \[-5 - I_5 - I_6 = 0\]
At node 5: \[I_3 + I_4 + I_2 + 5 = 0\]
Example 2-4 Applying KCL

If \( V_4 \), the voltage across the 4-\( \Omega \) resistor in Fig. 2-12, is 8 V, determine \( I_1 \) and \( I_2 \).

\[
10 - I_2 - I_1 = 0
\]

\[
+10 + 2 - I_1 = 0
\]

\[
I_1 = 12 \text{ A}
\]

\[
10 - I_1 + I_2 = 0
\]

\[
\Rightarrow I_1 = I_2 + 10
\]

\[
= 2 + 10
\]

\[
= 12 \text{ A}
\]
Example 2-4

If \( V_4 \), the voltage across the 4-\( \Omega \) resistor in Fig. 2-12, is 8 V, determine \( I_1 \) and \( I_2 \).

\[
10 - I_1 - I_2 = 0
\]

\[
I_2 = I_{4R} = 2 \, A
\]

\[
I_{RA} = \frac{V_4}{4R} = \frac{8}{4 \cdot 2} = 2 \, A.
\]

\[
I_1 = 10 - I_2 = 10 - 2 = 8 \, A.
\]

Figure 2-12: Circuit for Example 2-3.

Solution: Applying Ohm’s law,

\[
I_2 = \frac{V_4}{4} = \frac{8}{4} = 2 \, A.
\]

At the node:

\[
10 - I_1 - I_2 = 0.
\]

Hence,

\[
I_1 = 10 - I_2 = 10 - 2 = 8 \, A.
\]
Example 2-5 Applying KVL

(a) Circuit for Example 2-5

-12 + \(v_1\) + \(v_2\) + \(v_3\) = 0  \(\Rightarrow\)  60 \(I\) = 12 \(\Rightarrow\)  \(I\) = 0.2 A

To determine \(I\) using KVL

\[-12 + 10 \cdot I + 20 \cdot I + 30 \cdot I = 0\]

\[60 I = 12\]

\[I = 0.2 A\]

(b) After labeling voltages across resistors

\[V_1 = 10I\]
\[V_2 = 20I\]
\[V_3 = 30I\]

KVL

\[-12 + 10I + 20I + 30I = 0\]

\[I = 0.2 A\]
**Example: KCL/KVL**

**Solution:**

- **Loop 1**
  
  \[-50 + I_1 + 5I_2 + 4I_1 = 0,\]

- **Loop 2**
  \[-5I_2 + V_c - (10 \times 2) = 0.\]

Next, we apply KCL at node 1 which gives

\[I_1 - I_2 + 2 = 0.\]

**Three equations w/three unknowns:**

- \[I_1 = 4 \text{ A}, \quad \checkmark\]
- \[I_2 = 6 \text{ A}, \quad \checkmark\]
- \[V_c = 50 \text{ V}. \quad \checkmark\]
Exercise 2-4  If $I_1 = 3$ A in Fig. E2-4, what is $I_2$?

Solution: KCL at the top center node requires that

$$I_1 + I_2 - 2 \text{ A} = 0.$$ 

Hence,

$$I_2 = 2 - I_1 = 2 - 3 = -1 \text{ A}.$$ 

Fawwaz T. Ulaby, Michel M. Maharbiz and Cynthia M. Furse *Circuit Analysis and Design*
**Exercise 2-5** Apply KCL and KVL to find $I_1$ and $I_2$ in Fig. E2-5.

**Solution:**

KCL at node 1 requires that

$$I_1 = I_2 + 4.$$  

Also, KVL for the left loop is

$$-20 + 4I_2 + 2I_1 = 0.$$  

Simultaneous solution leads to

$$I_1 = 6 \, \text{A}, \quad I_2 = 2 \, \text{A}. $$  

$$3I_2 = 6 \Rightarrow I_2 = 2 \, \text{A}.$$  

$$I_1 = 2 + 4 = 6 \, \text{A}.$$