

Network Theory - Kirchhoff's Laws

Network elements can be either of **active** or **passive** type. Any electrical circuit or network contains one of these two types of network elements or a combination of both.

Now, let us discuss about the following two laws, which are popularly known as **Kirchhoff's laws**.

- Kirchhoff's Current Law
- Kirchhoff's Voltage Law

Kirchhoff's Current Law

Kirchhoff's Current Law (KCL) states that the algebraic sum of currents leaving (or entering) a node is equal to zero.

A **Node** is a point where two or more circuit elements are connected to it. If only two circuit elements are connected to a node, then it is said to be simple node. If three or more circuit elements are connected to a node, then it is said to be **Principal Node**.

Mathematically, KCL can be represented as

$$\sum_{m=1}^M I_m = 0$$

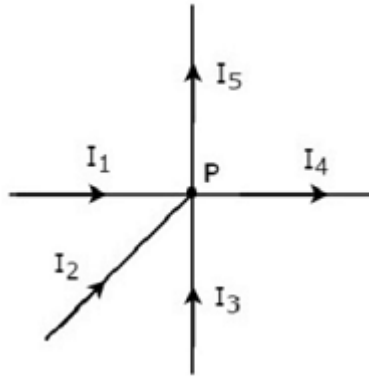
Where,

- I_m is the m^{th} branch current leaving the node.
- M is the number of branches that are connected to a node.

The above statement of **KCL** can also be expressed as "the algebraic sum of currents entering a node is equal to the algebraic sum of currents leaving a node". Let us verify this statement through the following example.

Example

Write **KCL equation** at node **P** of the following figure.



- In the above figure, the branch currents I_1 , I_2 and I_3 are **entering** at node P. So, consider negative signs for these three currents.
- In the above figure, the branch currents I_4 and I_5 are **leaving** from node P. So, consider positive signs for these two currents.

The **KCL equation** at node P will be

$$-I_1 - I_2 - I_3 + I_4 + I_5 = 0$$

$$\Rightarrow I_1 + I_2 + I_3 = I_4 + I_5$$

In the above equation, the left-hand side represents the sum of entering currents, whereas the right-hand side represents the sum of leaving currents.

In this tutorial, we will consider positive sign when the current leaves a node and negative sign when it enters a node. Similarly, you can consider negative sign when the current leaves a node and positive sign when it enters a node. In both cases, the **result will be same**.

Note – KCL is independent of the nature of network elements that are connected to a node.

Kirchhoff's Voltage Law

Kirchhoff's Voltage Law (KVL) states that the algebraic sum of voltages around a loop or mesh is equal to zero.

A **Loop** is a path that terminates at the same node where it started from. In contrast, a **Mesh** is a loop that doesn't contain any other loops inside it.

Mathematically, KVL can be represented as

$$\sum_{n=1}^N V_n = 0$$

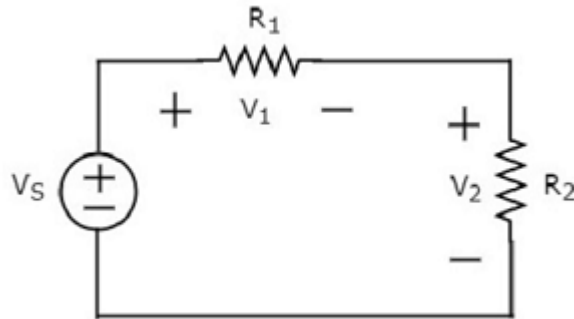
Where,

- V_n is the n^{th} element's voltage in a loop (mesh).
- N is the number of network elements in the loop (mesh).

The above statement of **KVL** can also be expressed as "the algebraic sum of voltage sources is equal to the algebraic sum of voltage drops that are present in a loop." Let us verify this statement with the help of the following example.

Example

Write **KVL equation** around the loop of the following circuit.



The above circuit diagram consists of a voltage source, V_S in series with two resistors R_1 and R_2 . The voltage drops across the resistors R_1 and R_2 are V_1 and V_2 respectively.

Apply **KVL** around the loop.

$$V_S - V_1 - V_2 = 0$$

$$\Rightarrow V_S = V_1 + V_2$$

In the above equation, the left-hand side term represents single voltage source V_S . Whereas, the right-hand side represents the **sum of voltage drops**. In this example, we considered only one voltage source. That's why the left-hand side contains only one term. If we consider multiple voltage sources, then the left side contains sum of voltage sources.

In this tutorial, we consider the sign of each element's voltage as the polarity of the second terminal that is present while travelling around the loop. Similarly, you can consider the sign of each voltage as the polarity of the first terminal that is present while travelling around the loop. In both cases, the **result will be same**.

Note – KVL is independent of the nature of network elements that are present in a loop.