Circuit Analysis: Analysis of a circuit means determining the complete distribution of voltages and currents.

In many resistive circuits, series-parallel reductions suffice. For example, determine $V_1$, $V_3$, $I_y$.

With this reduced circuit, $I_y$ can be written as:

$$I_y = -\frac{V_3}{R_y(R_1 + R_2)||R_3}$$

$V_3$ must then be:

$$V_3 = -V_5 - I_y R_4 \quad \text{(KVL)}$$

This technique fails when the circuit is not "ladder-like."

Representing any two-terminal lumped circuit element, i.e., a resistor.

The eight elements in this circuit represent 16 electrical variables: 8 currents and 8 voltages.

The circuit has 5 nodes on any 4 of which KCL statements can be written. The KCL statement for the 5th node is derivable from the others and is not independent.

The circuit has four simple loops or meshes (think fishnet). There are many other more complex closed loops, none of which are independent.

Each element has a constituent relationship. That is, $L_m = f(2\alpha)$

or $V_m = g(\theta)$. 
Summing up, 4 KVL equations plus 4 KCL equations plus 8 constituent relationships amounts to 16 equations, which are sufficient to solve for the unknown currents and voltages, of which there are 16 Q.E.D.

A better approach to systematic circuit analysis:
Employ node-to-reference voltages

Steps:
1) Pick a reference node ("ground")
2) Define the unknown node-to-reference voltages: \( E_1, E_2, E_3 \)

Note that the voltage at the top node is not unknown; it is constrained by the voltage source because of my choice of reference node.

3) Write KCL statements at the nodes where \( E_1, E_2, E_3 \) are defined using conductances.

Summing currents out yields:

At \( E_1 \):
\[
(e_1 - v) g_1 + (e_1 - 0) g_2 + I = 0
\]

At \( E_2 \):
\[
I + (e_2 - 0) g_3 + (e_2 - E_3) g_4 = 0
\]

At \( E_3 \):
\[
(e_3 - E_2) g_4 + (e_3 - 0) g_5 + (e_3 - v) g_6 = 0
\]

These three KCL equations can be solved for the three node-to-reference voltages. The currents are obtained from the voltage differences and Ohm's law.

A note on choices:
Add together the three KCL statements:

(Slightly rearranged)

\[
(e_1 - v) g_1 + (e_2 - v) g_6 + (e_2 - 0) g_2 + (e_2 - 0) g_3 + (e_3 - 0) g_5 = 0
\]

Currents into the central node

KCL, of course, applies there too!
Second Example

1) How many nodes?
2) How many independent nodes?
3) Where to put the reference node?
4) How many node-to-reference voltages?

The labeling shows one possible choice - there are five more.

Node equations (summing currents out of the nodes)

At \( V_1 \): \((V_1 - V_A)g_1 + V_1g_2 + (V_1 - V_2)g_3 = 0\)

At \( V_2 \): \((V_2 - V_1)g_3 + (V_2 - V_3)g_5 + V_2 - (V_3 - V_B)g_4 = 0\)

Voltage at the node marked *

At \( V_3 \): \((V_3 - V_2)g_5 + [V_3 - V_B - 0]g_6 = -I + [V_3 - V_B - V_2]g_4 = 0\)

Components of current flowing out of *

Which added together equal the current down through \( V_B \).

This reach to the next node (*) is necessary because the current out through \( V_B \) cannot be specified a priori; it is known only when the analysis is finished.

Another way of thinking about current components at \( V_3 \) is to link the nodes * and at which \( V_3 \) is defined.

Sometimes called a "super node"

The four components of current out of the node at \( V_6 \) are marked with arrows.