PHYSICS 3500/8800

Superposition Principle, Thevenin's Theorem, and Nodal Method

THE SUPERPOSITION PRINCIPLE

Basic Idea: The current through any element in a circuit containing many sources is the result of contributions from each source. The contribution from each source can be found by replacing ***all other sources*** with short circuits. Therefore, with this method, the total current in any circuit element is the sum:

$$I_{Ti} = I_{1i} + I_{2i} + \cdots + I_{Ni}$$

(1, 2, ... N represent the "partial currents" from the individual sources, and i represents circuit element "i".)

Important Point: When calculating the "partial currents", their directions must be taken into account, since some may be + and others may be −.

THEVENIN'S THEOREM

Basic Idea: If any two points of an electrical circuit are used as connections, the electrical effects detected at those connections are the same as if there were only a voltage source in series with a resistor causing the effect. (Of course, the "equivalent" voltage and resistance will be different for different pairs of connecting points.)

How This Can Be Used in Analyzing Electrical Circuits: Suppose the current through a particular resistor is of interest. Then, the complete circuit can be separated into the the "element of interest" (the resistor), and the "rest of the circuit". The effect of the "rest of the circuit" can then be summarized by its equivalent voltage and resistance (the "Thevenin" voltage and resistance). The result is that the current through the "element of interest" can be calculated from analysis of a simple circuit consisting of only one voltage source (the Thevenin voltage) and two resistances (the Thevenin resistance and the "element of interest"). (Note that in this case the "two connections" mentioned above are the points where the "element of interest" connects to the "rest of the circuit".)

Practical Considerations: The value of this approach is that a possibly complicated circuit (the "rest of the circuit") can be replaced by its equivalent, which is simply a voltage source in series with a resistance. However, this is useful only if the "Thevenin" voltage and resistance can be calculated with less difficulty than would arise from analyzing the complete circuit with more direct methods. As will be explained below, straightforward methods exist for calculating the "Thevenin" values; whether or not this is easier than more direct methods depends on the specific problem.

Calculating the "Thevenin" Voltage and Resistance: In both cases, only the "rest of the circuit" is to be considered; thus, the "Thevenin" equivalent values apply only to the fragment of the actual circuit which results from "disconnecting" the element of interest. Moreover, the two connecting points defined by the disconnection of the "element of interest" are important in the procedures explained below. These two points will be referred to as the "Thevenin terminals", or as "TT"; also, the "rest of the circuit" will be referred to as "ROC", and the "element of interest" as "EOI".

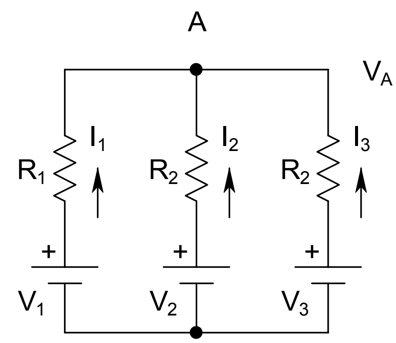
1. Calculating the "Thevenin" voltage: The Thevenin voltage is the voltage between the TT after the EOI has been disconnected (*i. e.*, the "open circuit" voltage between the terminals).

2. Calculating the "Thevenin Resistance": (Either of the following may be used.)

   a. The Thevenin resistance is the resistance between the TT when all voltage sources in the ROC are replaced by short circuits.

   b. The Thevenin resistance is the Thevenin voltage divided by the current when the TT are connected together ("short-circuited"). That is, the Thevenin resistance is the TT open-circuit voltage divided by the TT short-circuit current.

NODAL METHOD



Basic Idea: Uses Kirchoff's Voltage (KVL) and Current (KCL) Laws to shortcut the n-equation and n-unknown algebra of the straightforward approach. This is illustrated in the sketch where V_A indicates the voltage at the "node" (or junction) indicated by A. Use of KCL for A gives $I_1 + I_2 + I_3 = 0$; combining this with Ohm's law for the resistors gives:

$$\frac{(V_1 - V_A)}{R_1} + \frac{(V_2 - V_A)}{R_2} + \frac{(V_3 - V_A)}{R_3} = 0$$

The result is a single equation with a single unknown (V_A); the respective I's can then be easily calculated.