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Homogeneity Property

The homogeneity property states that if the input is multiplied by a constant, then the output(also called the response) is multiplied by the same constant.

For a resistor, Ohm's law relates the input *i* to the output *v*,

$$v = iR$$

If the current is increased by a constant *k*, then the voltage increases correspondingly by *k;* that is,

$$kv = kiR$$

Additivity Property

The additivity property requires that the response to a sum of inputs is the sum of the responses to each input applied separately.

If i_1 ampere current separately applied to the resister then output voltage is

$$v_1 = i_1 R$$

If i_2 ampere current separately applied to the resister then output voltage is

$$v_2 = i_2 R$$

Additivity Property

If (i_1+i_2) ampere current applied to the resister then output voltage is

$$v = (i_1 + i_2)R$$

$$v = i_1 R + i_2 R$$

$$v = v_1 + v_2$$

Linearity Property

The linearity property is a combination of both the homogeneity property and the additivity property.

A circuit is linear if it has both additive and homogeneous property.

A linear circuit consists of only linear elements, linear dependent sources, and independent sources.

A linear circuit is one whose output is linearly related (or directly proportional) to its input.

A resistor is a linear element because the voltage-current relationship satisfies both the homogeneity and the additivity properties.

Linearity Property

Relationship between power and voltage (or current) is nonlinear.

$$p_1 = i_1^2 R$$

$$p_2 = i_2^2 R$$

$$p = (i_1 + i_2)^2 R = i_1^2 R + i_2^2 R + 2 i_1 i_2 R$$

$$p \neq p_1 + p_2$$

Superposition Theorem

The superposition principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.

Superposition Theorem

The principle of superposition helps us to analyze a linear circuit with more than one independent source by calculating the contribution of each independent source separately.

we must keep two things in mind:

1. We consider one independent source at a time while all other independent sources are turned off. This implies that we replace every voltage source by 0 V (or a short circuit), and every current source by 0 A (or an open circuit). This way we obtain a simpler and more manageable circuit.

2. Dependent sources are left intact because they are controlled by circuit variables.

Superposition Theorem

Steps to Apply Superposition Principle:

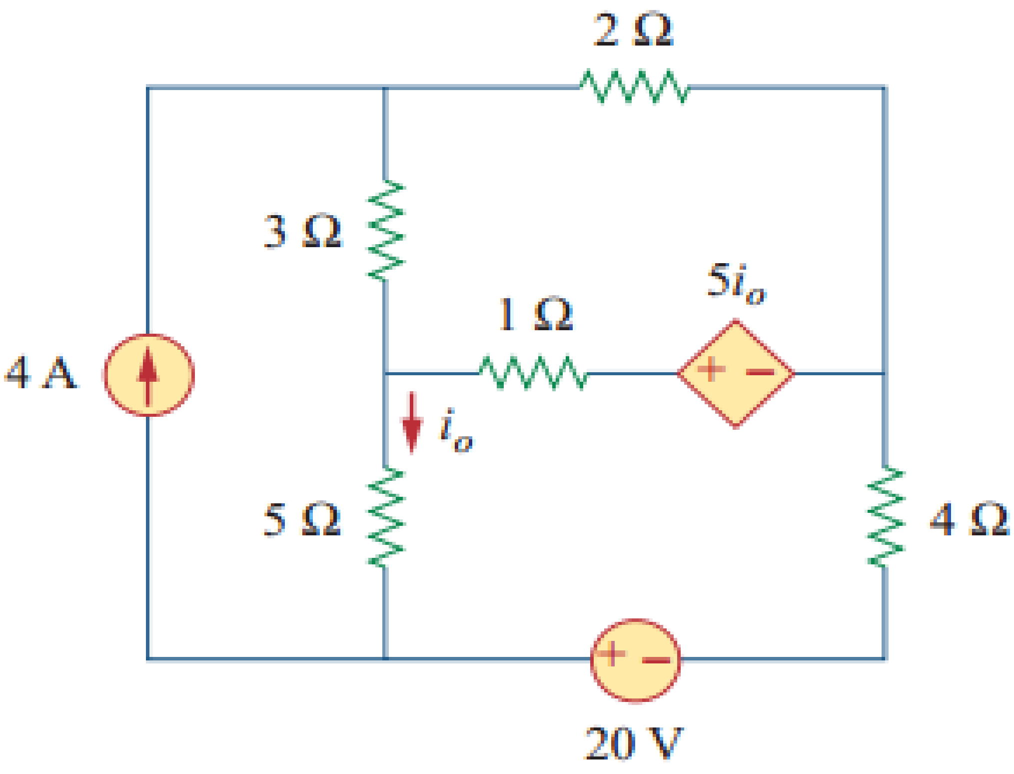
1. Turn off all independent sources except one source. Find the output (voltage or current) due to that active source using mesh analysis or nodal analysis

2. Repeat step 1 for each of the other independent sources.

3. Find the total contribution by adding algebraically all the contributions due to each the independent sources.

Superposition Theorem

Problem: Find i_o in the circuit using superposition.



Superposition Theorem

Solution: Let,

$$i_o = i'_o + i''_o$$

Where i'_o and i''_o are due to the 4 A current source and 20 V voltage source respectively.

Superposition Theorem

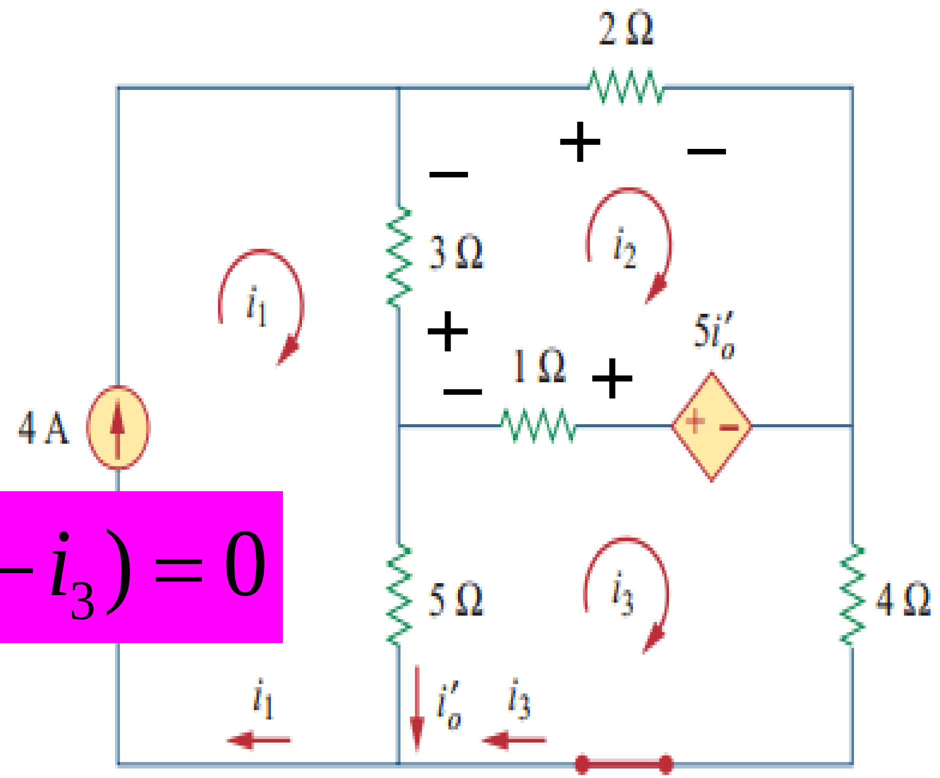
To obtain i'_o , we turn off the 20 V source

From mesh 1, we can write

$$i_1 = 4\,A$$

Apply KVL for mesh 2

$$3(i_2 - i_1) + 2i_2 - 5i_o' + 1(i_2 - i_3) = 0$$



But

$$i_o' = i_1 - i_3$$

$$6i_2 + 4i_3 = 32 \ldots\ldots (i)$$

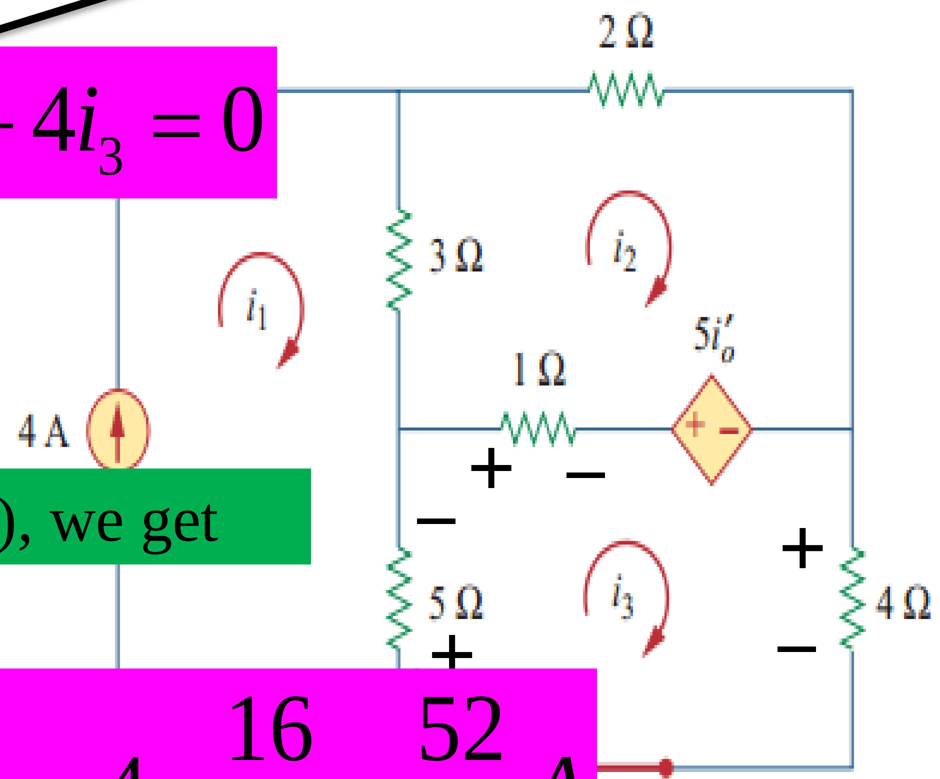
Superposition Theorem

Apply KVL for mesh 3

$$i_o^{'} = i_1 - i_3$$

$$5(i_3 - i_1) + 1(i_3 - i_2) + 5i_o^{'} + 4i_3 = 0$$

$$-i_2 + 5i_3 = 0......(ii)$$



After solving equation (i) and (ii), we get

$$i_3 = \frac{16}{17} A$$

$$i_o^{'} = i_1 - i_3 = 4 - \frac{16}{17} = \frac{52}{17} A$$

Superposition Theorem

To obtain i''_o , we turn off the 4 A source

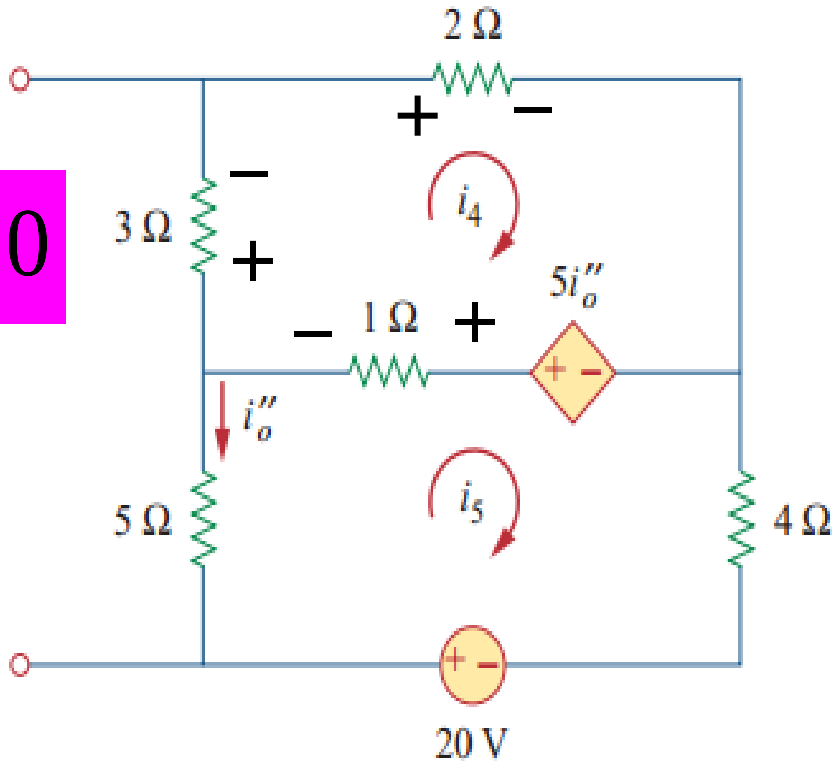
Apply KVL for mesh 4

$$3i_4 + 2i_4 - 5i_o'' + 1(i_4 - i_5) = 0$$

But

$$i_o'' = -i_5$$

$$6i_4 + 4i_5 = 0 \ldots\ldots(iii)$$



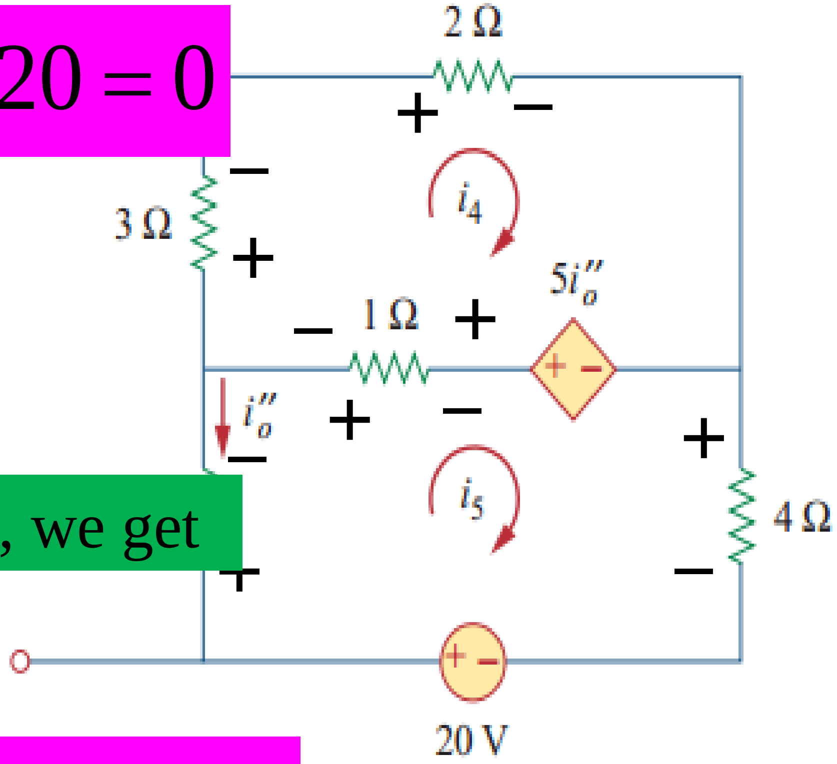
Superposition Theorem

Apply KVL for mesh 5

$$i_o'' = -i_5$$

$$5i_5 + 1(i_5 - i_4) + 5i_o'' + 4i_5 - 20 = 0$$

$$-i_4 + 5i_5 = 20......(iv)$$



After solving equation (iii) and (iv), we get

$$i_5 = \frac{60}{17} A$$

$$i_o'' = -i_5 = -\frac{60}{17} A$$

Superposition Theorem

I_o current is

$$\boldsymbol{i}_o = \boldsymbol{i}'_{\mathrm{o}} + \boldsymbol{i}''_{\mathrm{o}}$$

$$i_o = \frac{52}{17} - \frac{60}{17} = -\frac{8}{17}A$$

Home Work

Example: 4.3, 4.5

Practice Problem: 4.3, 4.4, 4.5

Thank You