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CSE250 – Circuits and Electronics

SUPERPOSITION PRINCIPLE

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Linearity property

- *Linearity* is the property of an element describing a linear relationship between cause and effect. The property is a combination of both the *homogeneity* (scaling) property and the *additivity* property.
- Homogeneity property
  For a resistor, for example, Ohm's law relates the input i to the output v as $v = iR$. If the current is increased by a constant k, then the voltage increases correspondingly by k; that is, $kv = (ki)R$.
- Additivity property
  If applying v_1 & v_2 separately to a resistor gives rise to currents i_1 & i_2 respectively, then applying $(v_1 + v_2)$ should give rise to the current $(i_1 + i_2)$.
- A *linearity circuit* is one whose output is linearly related (or directly proportional) to its input

Circuit laws, methods of analysis, & theorems

Circuit Laws

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

Methods of analysis

- Nodal Analysis
- Mesh Analysis

Circuit Theorems

- **Superposition Theorem**
- Source Transformation
- Thevenin's Theorem
- Norton's Theorem
- Maximum Power Transfer Theorem

Superposition principle

- 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.
- Keep in mind that superposition is based on linearity. For this reason, it is not applicable to the effect on power due to each source.

$$P_{Total}^2 \neq P_1^2 + P_2^2 + \ldots + P_N^2$$

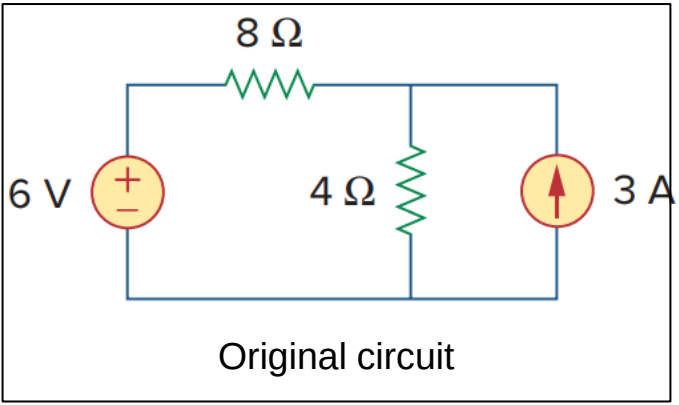
- If the power value is needed, the current through (or voltage across) the element must be calculated first using superposition.

Steps to Apply Superposition Principle:

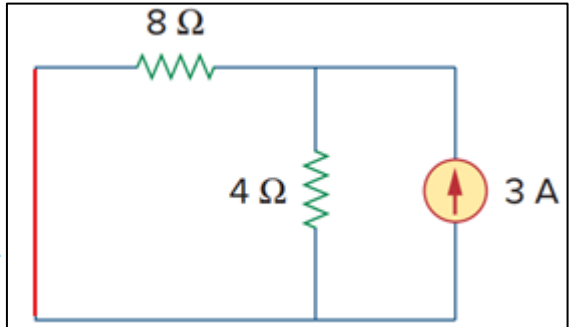
1. Turn off all independent sources e xcept one source. Find the output (voltage or current) due to that acti ve source using the techniques covered in Chapters 2 and 3.
2. Repeat step 1 for each of the other independent sources.
3. Find the total contribution by adding algebraically all the contributions due to the independent sources.

Equivalence with inactive I/V sources

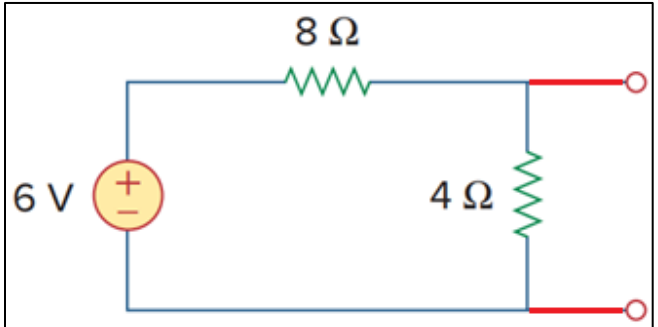
- In superposition principle, we consider one independent source at a time while all other independent sources are turned off. This implies that we replace every voltage source by 0 V (or a short circuit), and every current source by 0 A (or an open circuit).
- Dependent sources are left intact because they are controlled by circuit variables.



Original circuit



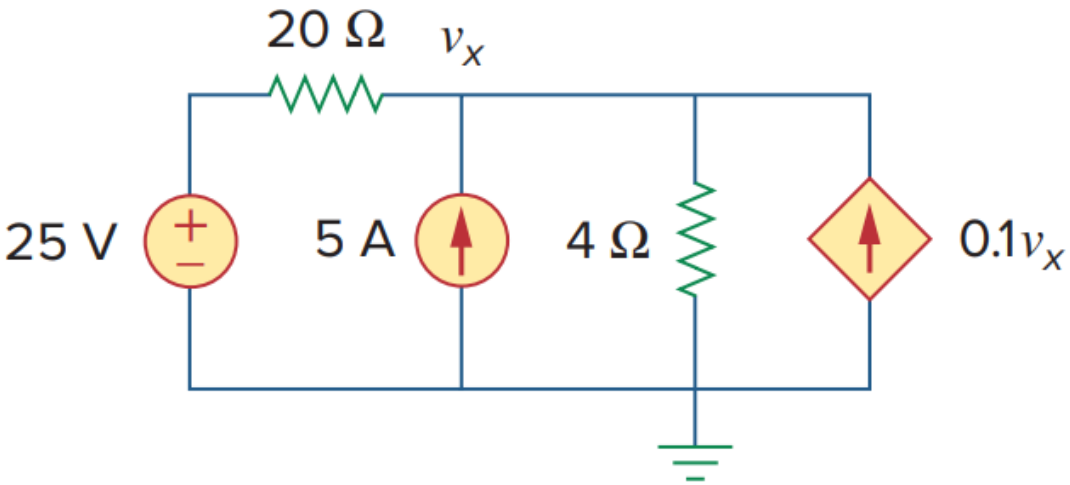
The voltage source has been replaced with a short circuit



The current source has been replaced with an open circuit

Example 1

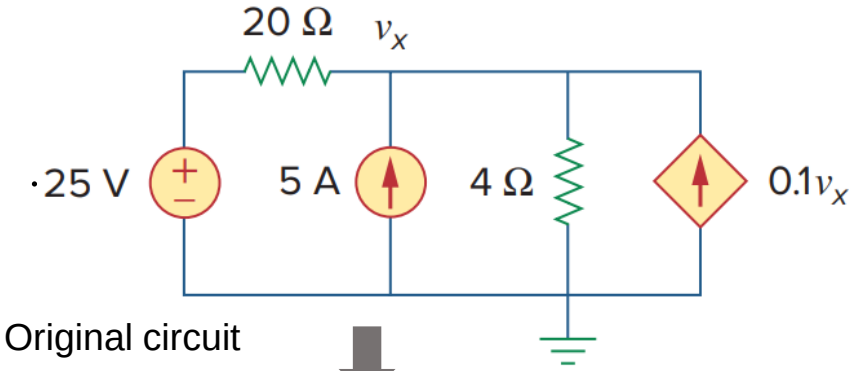
- Use superposition principle to find v_x.



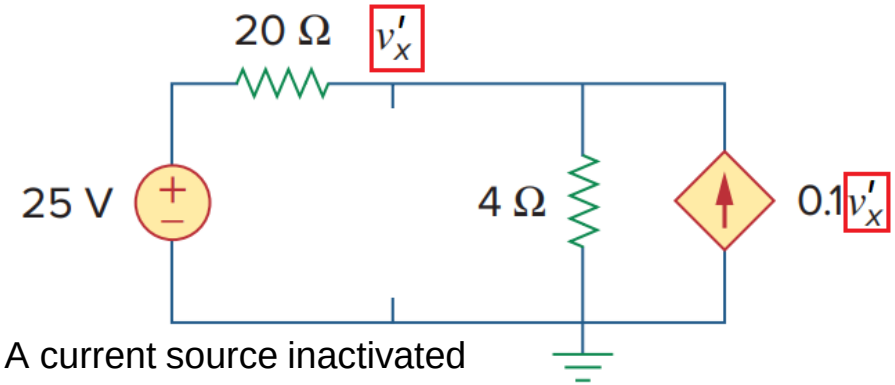
There are two independent and one dependent sources. The principle requires us to determine the individual contributions of the two independent sources to the node voltage v_x. If v_x' and v_x'' are the contributions from the 25 V voltage source and 5 A current source respectively, then

$$v_x = v_x' + v_x''.$$

Example 1: 25 V source is active



Original circuit



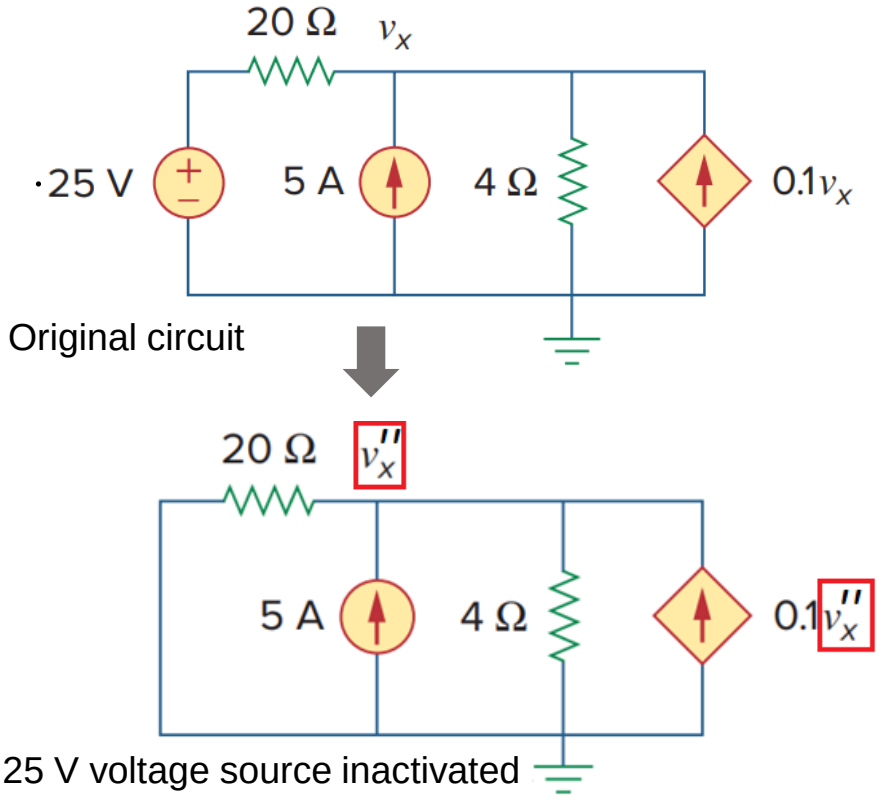
5 A current source inactivated

- The 5 A current source has been replaced by an open circuit. The notation v_x is replaced by v'_x.
- Different circuit solving techniques (nodal analysis or mesh analysis or source transformation or voltage division) can be applied to solve for v'_x. Nodal analysis may be the easiest one.
- KCL at the node v'_x,

$$\frac{v'_x - 25}{20} + \frac{v'_x}{4} = 0.1v'_x$$

Simplification yields, $v'_x = 6.25\ V$

Example 1: 5 A source is active



- The 25 V voltage source has been replaced by a short circuit. The notation v_x is replaced by v_x''.
- KCL at the node v_x'',

$$\frac{v_x''}{20} + \frac{v_x''}{4} = 5 + 0.1v_x''$$

Simplification yields, $v_x'' = 25\ V$

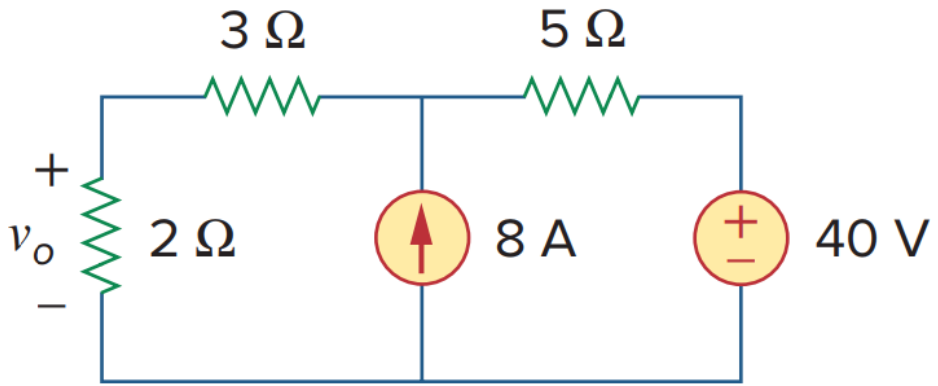
So, according to the superposition principle,

$$v_x = v_x' + v_x''$$

$$\Rightarrow \quad v_x = 6.25 + 25 = 31.25\ V$$

Problem 1

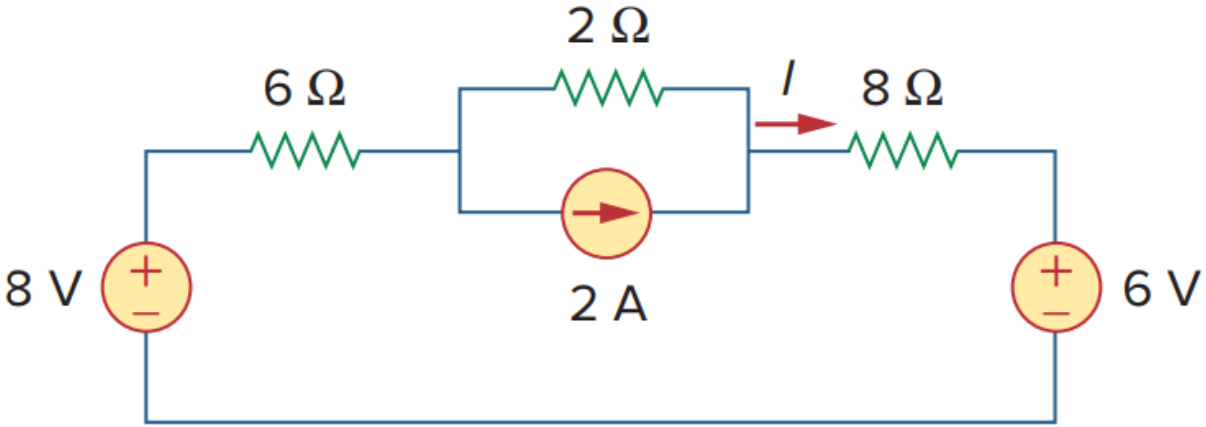
- Using the superposition theorem, find v_o.



Ans: $v_0 = 16\,V$

Problem 2

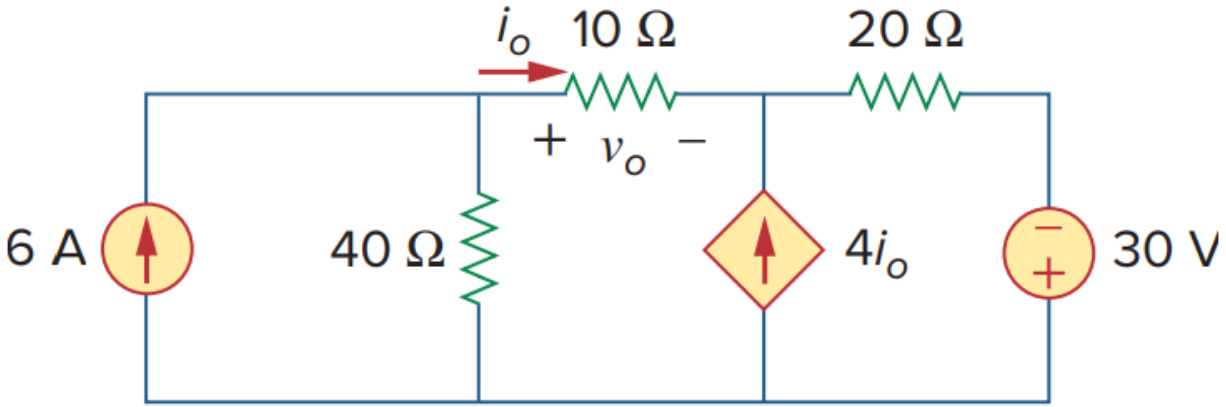
- Find I in the circuit using the superposition principle.



Ans: $i_0 = 0.375\ A$

Problem 4

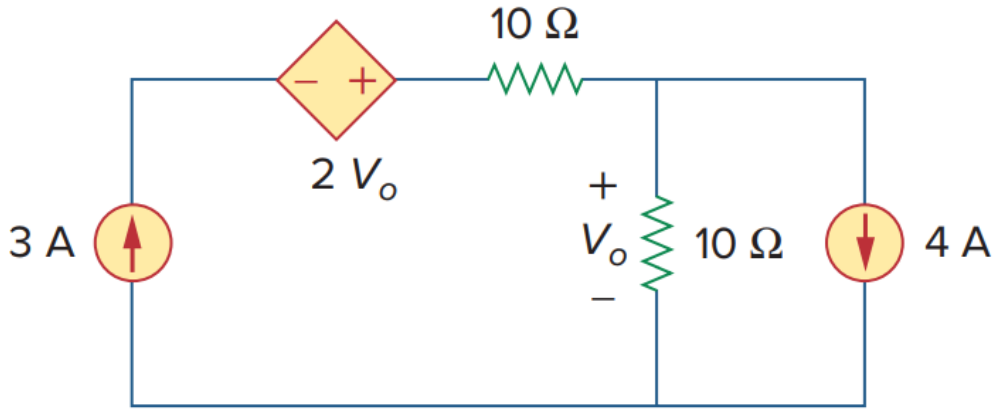
- Use the superposition principle to find i_o and v_o.



Ans: $\boldsymbol{i_0 = 1.8\,A;\ v_0 = 18\,V}$

Problem 5

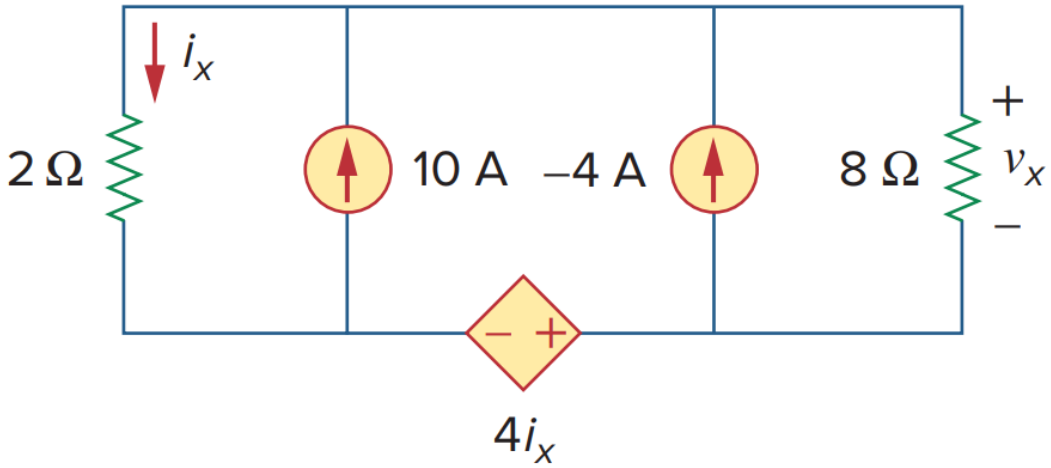
- Use superposition to solve for V_0.



Ans: $\boldsymbol{V_0 = -10\,V}$

Problem 6

- Use superposition to solve for v_x.



Ans: $\boldsymbol{v_x = -16\ V}$

Practice Problems

- Additional practice problems can be found here

Thank you for your attention