EECS2200 Electric Circuits

Chapter 2

Circuit Elements

Objectives

- Understand independent and dependent sources
- Understand resistors
- Know and be able to use Ohm's Law
- Know and be able to use Kirchhoff Laws
- Be able to calculate the power of a circuit

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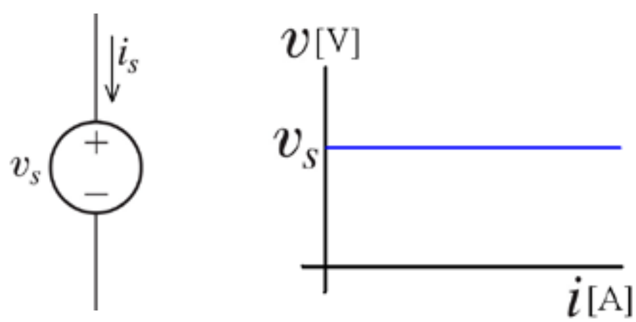
Voltage and Current Sources

Independent & Dependent

Ideal independent voltage source

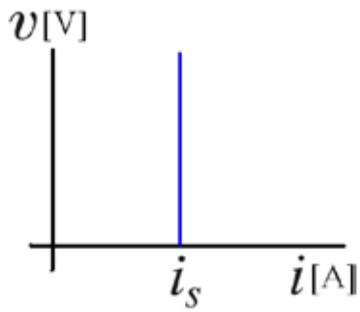
- Constant voltage across its terminals regardless of the current flowing in theses terminals



Observation – if all we have is the voltage drop across an ideal voltage source, there is no formula we can use to calculate the current through that source!

Ideal independent current source

- Constant current through its terminals regardless of the voltage across theses terminals



Observation – if all we have is the current flowing through an ideal current source, there is no formula we can use to calculate the voltage drop across that source!

Independent Sources

- The sources just presented are “independent” because the voltage or current supplied by the source does not depend on any other quantity in the circuit to which it is attached.
- As you might already have guessed, there are other sources that supply a voltage (or current) whose value depends on the voltage (or current) found elsewhere in the circuit.

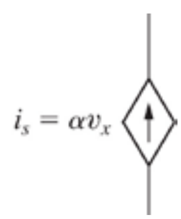
Dependent voltage sources

- Voltage-controlled voltage source (VCVS), where v_s is the voltage supplied, v_x is the controlling voltage, and μ is the gain, whose units are V/V

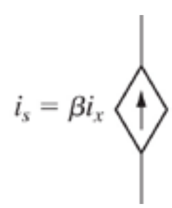
- Current-controlled voltage source (CCVS), where v_s is the voltage supplied, i_x is the controlling current, and ρ is the gain, whose units are V/A

Dependent current sources

- Voltage-controlled current source (VCCS), where i_s is the current supplied, v_x is the controlling voltage, and α is the gain, whose units are A/V



- Current-controlled current source (CCCS), where i_s is the current supplied, i_x is the controlling current, and β is the gain, whose units are A/A

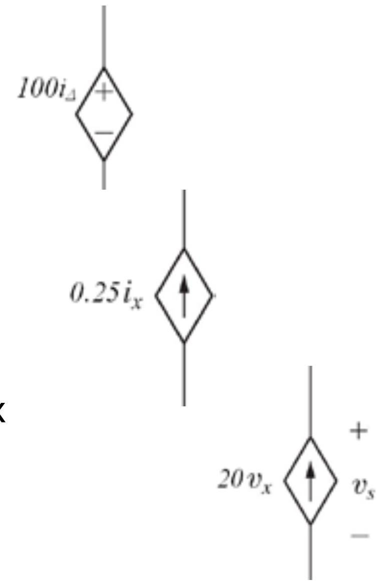


Activity 1

(a) If i_Δ is 15 mA, how much voltage does this dependent source supply?

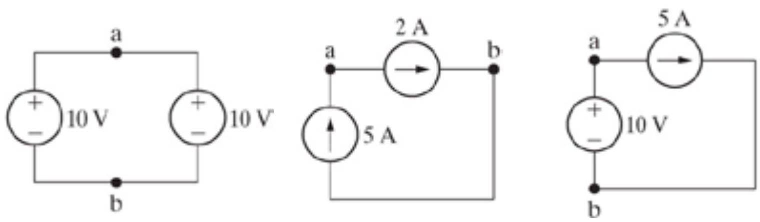
(b) What units are associated with the gain 0.25 for this dependent source?

(c) Suppose the value of vx is 4 V. What is the value of vs?



Interconnected sources

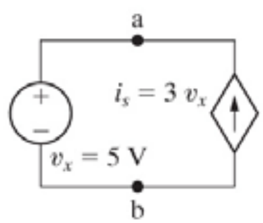
- When ideal sources are connected together to form a circuit, the connection is valid only if the constraints imposed by the ideal sources are not violated.
- Which of following connections are valid?

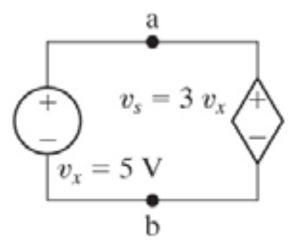


(a) (b) (c)

Activity 2

- Which of the circuits below is valid?





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Resistance(Ohm's Law)

Resistance

- Resistance is the capacity of the material to impede the flow of current (charges).
- R is measured in ohm Ω.
- The reciprocal of the resistance is **conductance**, G measured in siemens (S)
- The resistance of a wire is

$$R = \rho \frac{l}{A}$$

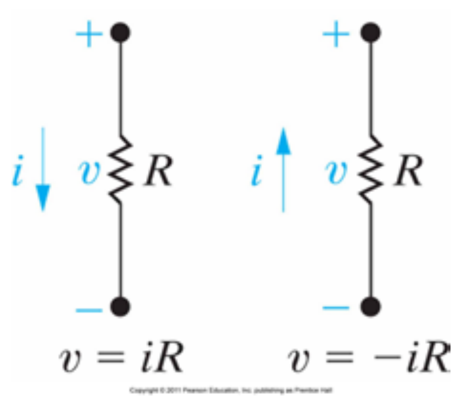
where R is the resistance, l is the length in meters, A is the cross-sectional area in square meters, ρ is the resistivity of the material in ohm meter

Resistance

- Typical values for resistivity in Ω.m
- Silver 1.59 × 10^{-8} Ω.m at 20 C
- Copper 1.68 × 10^{-8} Ω.m
- Germanium 4.6 × 10^{-1} Ω.m
- Sea water 2 × 10^{-1} Ω.m
- Hard rubber 1 × 10^{+13} Ω.m

Ohm's Law

- Ohm's Law describes the relationship between voltage and current in a resistor

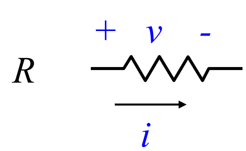


Calculate power in a resistor

$$p = vi$$

$$p = i^2 R$$

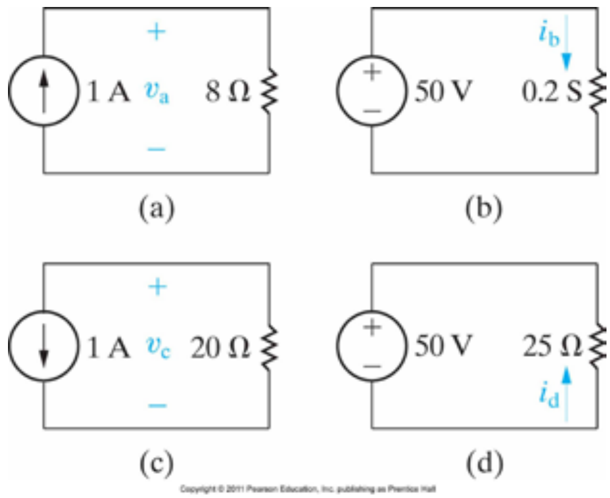
$$p = \frac{v^2}{R}$$



Note: the power associated with a resistor is always positive. Therefore, resistor always absorb power.

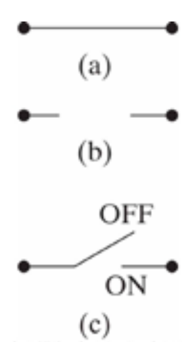
Activity 3

find *v* or *i* in every circuit



Short Circuit and Open Circuit

- Short Circuit
  - Wire
  - R = 0
  - No resistance
  - No voltage
- Open Circuit
  - Air (or insulator)
  - R=∞
  - No current flowing



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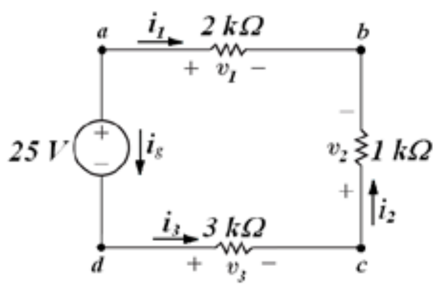
Kirchhoff's Laws

Kirchhoff' s Laws

Consider the circuit shown below. We wish to "solve" this circuit. To solve a circuit, we must find all of the unknown voltages and currents.



How many unknowns are in this circuit?

Kirchhoff's Laws

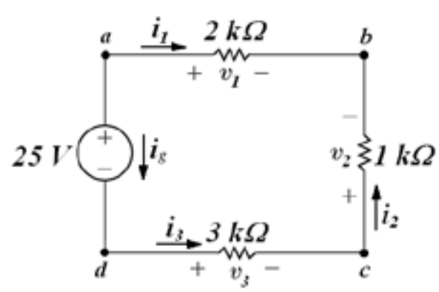
To solve for 3 unknown voltages and 4 unknown currents, how many independent equations do we need?

A. 3
B. 4
C. 7
D. 8
E. We need more information

Kirchhoff's Laws

The only equations we know how to write at this point come from Ohm's law. Let's write them.

$$v_1 = 2000 i_1$$
$$v_2 = 1000 i_2$$
$$v_3 = 3000 i_3$$

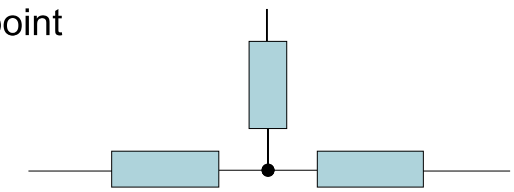


Kirchhoff' s Laws

We need more equations – they will come from Kirchhoff' s laws.

Kirchhoff' s Current Law (KCL)
The algebraic sum of all the currents at any node in a circuit equals zero.

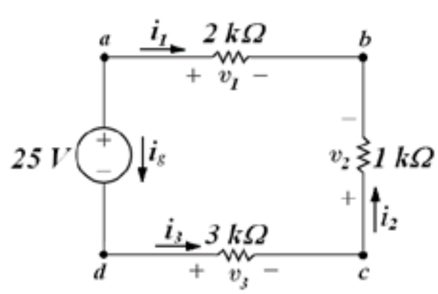
Note – a **node** is a point where two or more circuit elements are connected.



Kirchhoff' s Laws

How many nodes are in this circuit?

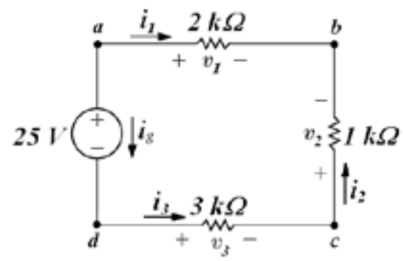
A. 4
B. 3
C. 2
D. None of the above



Kirchhoff' s Laws

Let' s write the KCL equations at each node.
Are they all independent?

a (leaving):	$i_g + i_1 = 0$
b (entering):	$i_1 + i_2 = 0$
c (enter = leave):	$i_2 = i_3$
d (leaving):	$-i_g + i_3 = 0$



Note that only 3 of the 4 are independent – the 4th equation can be derived from the other 3.

Kirchhoff' s Laws

If a circuit has 6 nodes, how many independent KCL equations can you write?

A. 7
B. 6
C. 5
D. None of the above

Kirchhoff's Laws

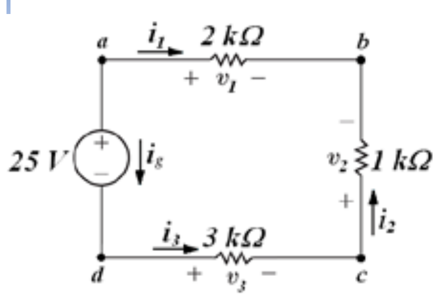
We have 3 equations from Ohm's law and 3 (independent) KCL equations – we need one more equation, because we have 7 unknowns. That equation will come from Kirchhoff's Voltage Law

Kirchhoff's Voltage Law (KVL)
The algebraic sum of all the voltages around any closed path in a circuit equals zero.

Note – a closed path starts at any node, travels through selected circuit elements, and returns back to the starting node without including any intermediate nodes more than once.

Kirchhoff's Laws

Let's write the KVL equation around the closed path formed by this circuit.



Start at node a and go clockwise:

$$+v_1 - v_2 - v_3 - 25 = 0$$

Or start at node d and go counter-clockwise:

$$+v_3 + v_2 - v_1 + 25 = 0$$

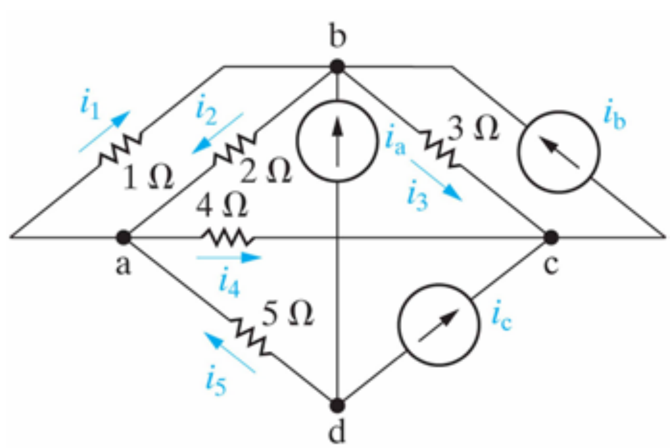
Kirchhoff's Laws

Now we have 7 equations and 7 unknowns, so we can solve the 7 equations and find unknown voltages and currents.

Analysis of circuits with resistors and constant sources is based on the use of Ohm's Law, KCL and KVL. However, we will develop some useful analysis techniques that will NOT require us to solve 7 equations for the simple example circuit we've been studying. Actually, we can solve this circuit with just 1 equation!

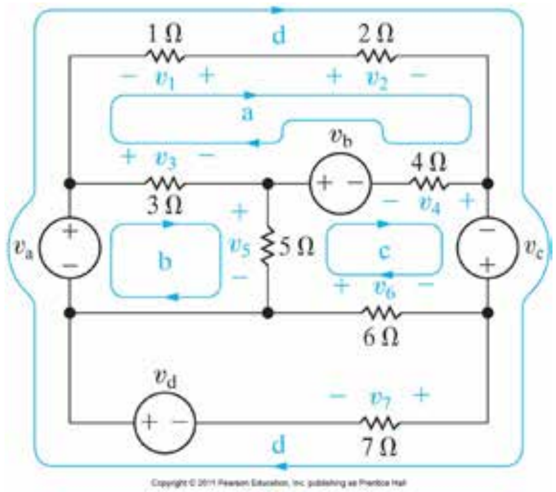
Activity 4

Sum the currents at each node in the circuit.



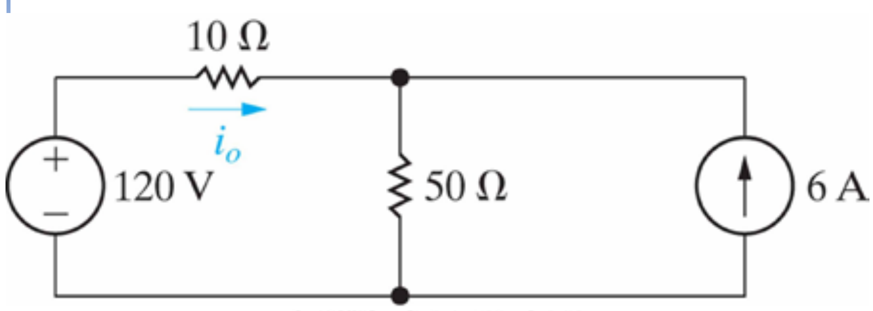
Activity 5

Sum the voltage around each designated path in the circuit.



Activity 6

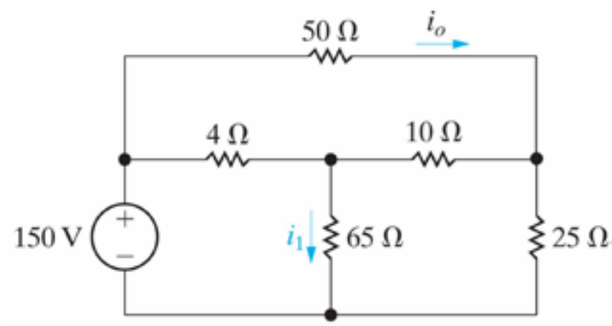
Use Kirchhoff's Law and Ohm's Law to find i_0 in the circuit.



Activity 7

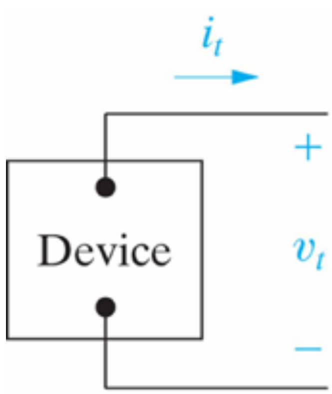
(1) If i_0=1A, find i_1

(2) Find the power dissipated in every register



Activity 8

Construct a circuit model for a device



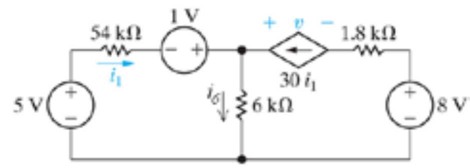
(a)

v_t (V)	i_t (A)
30	0
15	3
0	6

(b)

A circuit with a dependent source

Find i_1 and v.

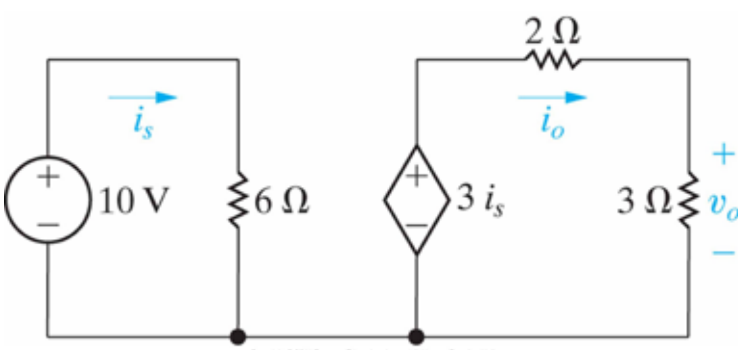


$$\text{KVL left}: -5 + 54{,}000i_1 - 1 + 6000i_6 = 0$$
$$\text{KCL top}: i_1 + 30i_1 = i_6 = 31i_1$$
$$\Rightarrow \quad -5 + 54{,}000i_1 - 1 + 6000(31i_1) = 0$$
$$\Rightarrow \quad [54{,}000 + (6000)(31)]i_1 = 6 \quad \therefore \quad i_1 = 25\mu\text{A}$$
$$\text{KVL right}: -v + (6000)(31i_1) - 8 + 1800(30i_1) = 0$$
$$\Rightarrow \quad v = (6000)(31)(25\mu) - 8 + (1800)(30)(25\mu) = -2\text{ V}$$

Activity 9

(a) Use Kirchhoff's Law and Ohm's Law to find the voltage v_0.

(b) Show that the solution is consistent with the constraint that the total power developed in the circuit equals the total power dissipated.



Activity 10

The circuit represents a common configuration encountered in the analysis and design of transistor amplifiers. Assume that the values of R_1, R_2, R_C, R_E, V_{cc} and V_0 are known.

Find i_B in terms of the circuit element values.