Electric Circuits
Spring 2020

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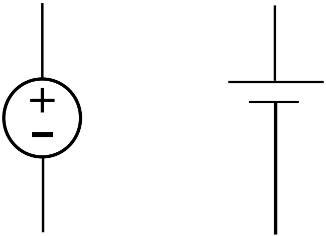
January 10, 2020

Ideal Voltage Source

- Prescribes a preset voltage value regardless of (valid) circuit connection or drawn current
- Prescribed voltage could be constant or a function of time/frequency
- A valid connection means (in the ideal sense):
  - Voltage source is not short-circuited, unless its voltage value is zero. In this case you can replace it with a wire
  - Multiple voltage sources are not connected in a manner that violates Kirchhoff's circuit laws (more on that next lecture)
- A valid connection means (in the practical sense):
  - Connecting wires must be thick enough to handle amount of passing current
  - Voltage range should match ratings of connected devices

Ideal Voltage Source

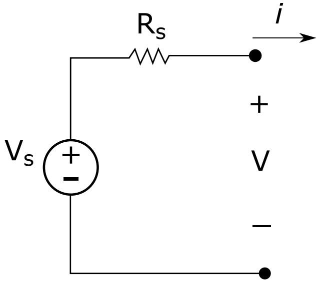
- Most common circuit symbols:



- Right symbol is strictly used for DC (or constant) voltage sources. Long dash signifies positive voltage polarity
- The Mains outlet in your room may reasonably be assumed an ideal voltage source
- Your AA battery, phone battery or car battery may not

Non-Ideal Voltage Source

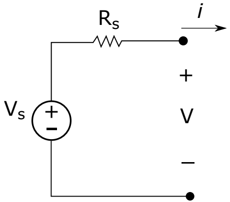
- Its construction results in internal ohmic losses that could be modeled as



- V_s is called the nominal voltage. That is the 1.5 V of your AA battery or 12 V of your car battery
- V_s is what you measure under no-load condition
- R_s represents the ohmic losses and is called the source resistance
- $R_s \to 0 \Rightarrow$ Ideal voltage source

Non-Ideal Voltage Source

- Once loaded (connected to a load that draws current), R_s hogs a portion of V_s which causes the measured voltage V to drop



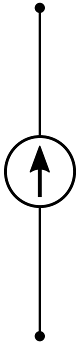
- When you start your car engine, current drawn from the battery measures in the hundreds of amps for a split-second. [In comparison, your home current draw, on average, is approximately 5 - 10 A]
- Due to the high current demand from them, car batteries should always be tested under load

Ideal Current Source

- Prescribes a preset current value regardless of (valid) circuit connection or developed voltage drop
- Prescribed current could be constant or a function of time/frequency
- A valid connection means (in the ideal sense):
  - Current source is not left open-circuited, unless its current value is zero. In this case you can disconnect it from circuit with no interference. The current source's output current has to go somewhere and eventually circulate back, even if just through a short wire
  - Multiple current sources are not connected in a manner that violates Kirchhoff's circuit laws (more on that next lecture)
- A valid connection means (in the practical sense):
  - Connecting wires must be thick enough to handle amount of passing current
  - Max voltage is limited by the capacity of its constituent electronics (more on than when we study Operational Amplifiers)

Ideal Current Source

- Most common circuit symbol:



- Current Source Uses:
  - Powering LED lights
  - Charging batteries
  - Electronic Circuits design

Non-Ideal Current Source

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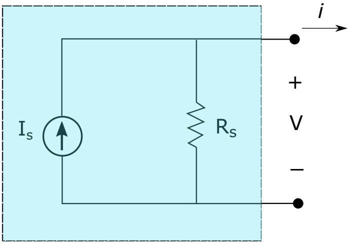
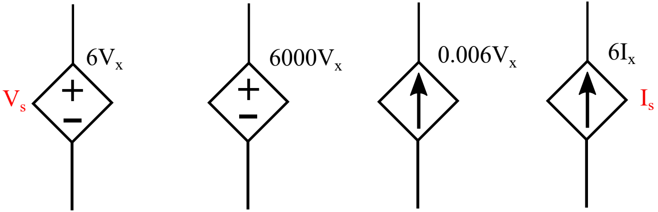


- i_s is called the nominal source current
- A finite R_s wicks away some of the produced current from being delivered to the externally connected circuit
- It also wastes energy as heat
- $R_s \to \infty \Rightarrow$ Ideal current source

Dependent Sources

- Their current or voltage values depend some nearby voltage and/or current:
  - Voltage-controlled voltage source
  - Current-controlled voltage source
  - Voltage-controlled current source
  - Current-controlled current source
- Circuit symbols:



- Do not confuse the controlling variable with the source's unit. For example, the second source's value is $6000I_x$ Volts! This means the 6000 constant has a unit of V/A or Ohms

Dependent Sources

- A bicycle example: Think of your bike as a dependent source
  - Controlling variable: your pedaling speed
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  - Multiplier: gear setting

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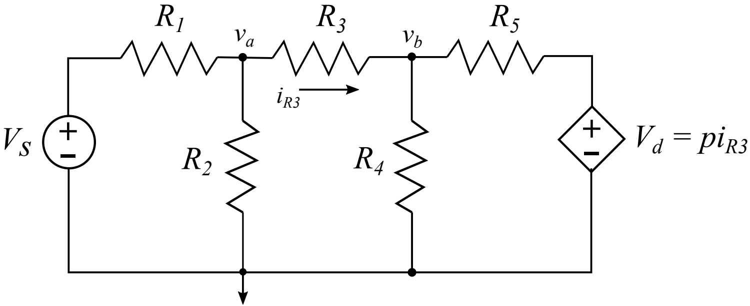
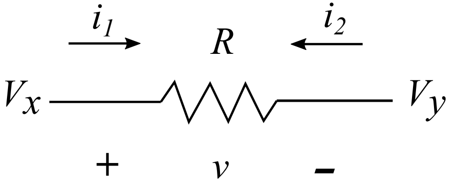


Ohm's Law

- From your Physics class, you learned that Ohm's Law is $v(t) = Ri(t)$
- However, this formula is incomplete
- There is a specific relation between current direction and voltage polarity for this formula to be correct
- Missing this point is the source of the most common mistake in Circuits exams

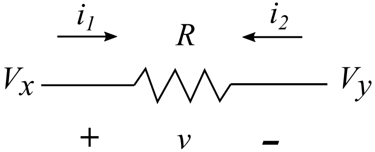
Ohm's Law

- The complete statement is: $v(t) = Ri(t)$, provided that $i(t)$ enters the resistor through the positive voltage polarity
- Otherwise, a negative sign must be introduced
- Depending on which voltage or current you choose, you may need to negate the expression to get it right



Ohm's Law

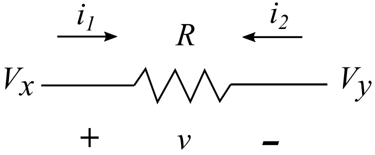
- The following are <u>correct</u> Ohm's Law statements as per the defined variables on the circuit



  - $v = i_1 R$
  - $v = -i_2 R$
  - $i_1 = \frac{V_x - V_y}{R}$ $\leftarrow$ We implicitly assume a positive polarity related to the first variable of a voltage difference
  - $R = -\frac{V_x - V_y}{i_2}$

Ohm's Law

- Examples of <u>incorrect</u> Ohm's Law statements



  - $i_2 = v/R$
  - $R = vi_1$
  - $V_x - v = V_y$
  - $R = V_x - V_y$
  - $R = \frac{V_x - V_y}{i_2}$

Ohm's Law: Conductance vs Resistance

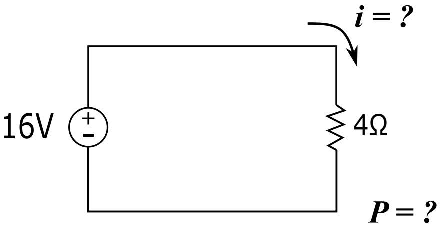
- Conductance $G = \frac{1}{R}$ [SI unit: Siemens or S, Informal unit: ℧]
- Ohm's Law: $v = Ri$ or $i = Gv$
- Current direction/Voltage polarity relation remains intact
- Short wire $\rightarrow R = 0$ or $G = \infty \rightarrow v = 0$ for any current through the wire
- Broken connection $\rightarrow R = \infty$ or $G = 0 \rightarrow i = 0$ for any voltage drop across the gap

Special Power Equation for Resistors

- Remember that $p = +vi$ for any circuit element when i enters the element through the positive voltage polarity
- For a resistor, we can use Ohm's Law to specify power in multiple ways
  - $p = vi$
  - $p = v(v/R) = v^2/R$
  - $p = (iR)i = i^2R$
- These special power relations tolerate a sign mistake since v or i gets squared anyway. DO NOT get complacent! Maintain consistency!

Example 1

- Find the current and power for the load resistance



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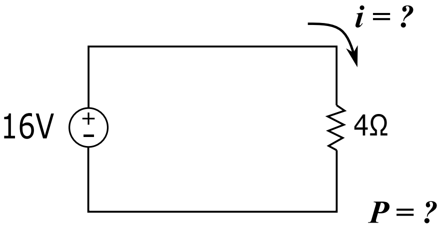

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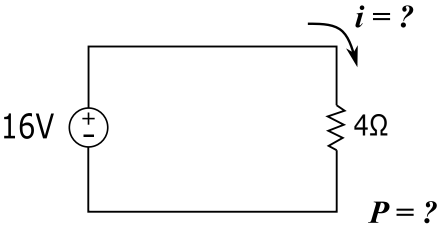

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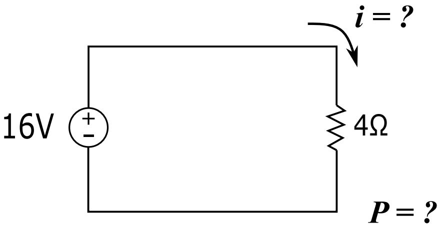
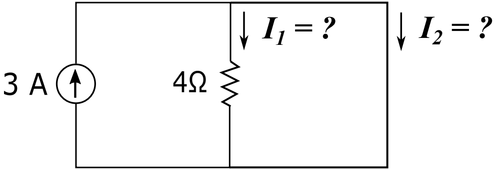


- $i = +16/4 = 4$ A
- $P = (16)(4) = 64$ W, or $P = 16^2/4$, or $P = (4^2)(4)$
- You need to anchor your power calculation to a specific element or circuit block

Example 2

- Find both currents



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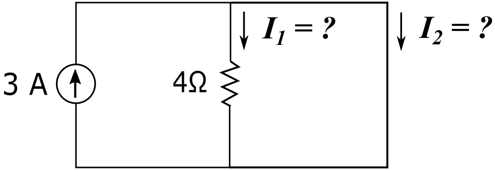

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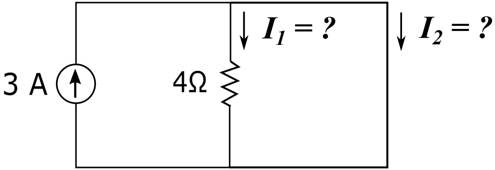

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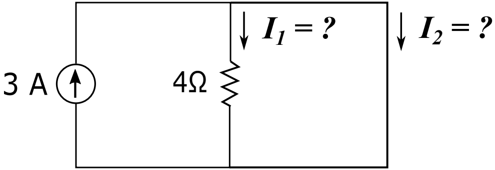

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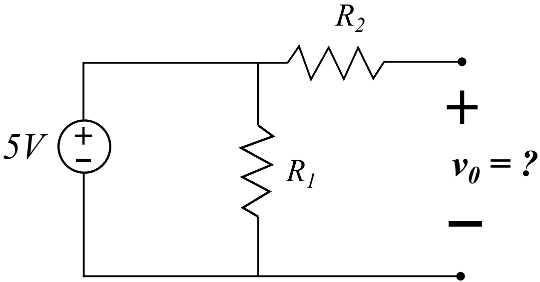
- $I_1 = 0$ and $I_2 = 3$ A

Example 3

- Find the output voltage



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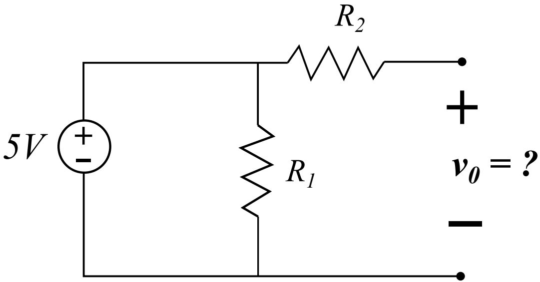

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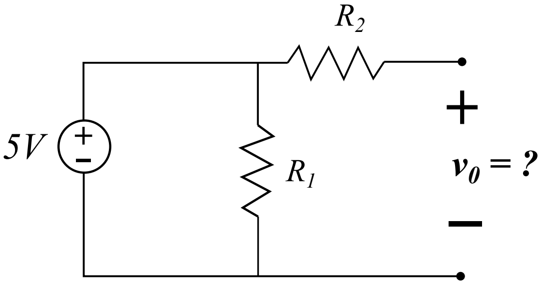

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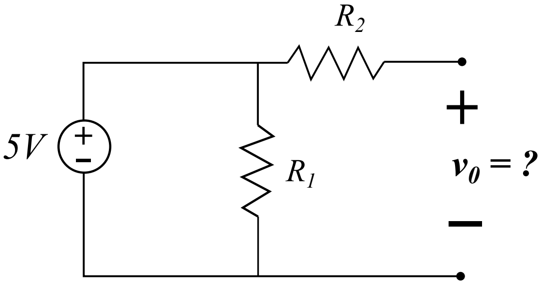

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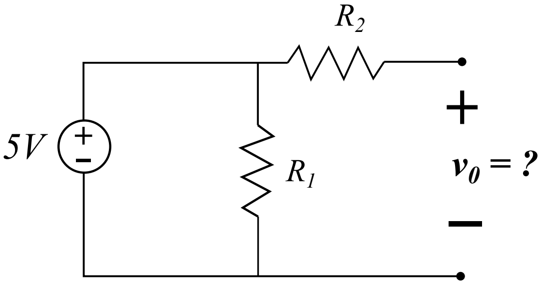

- Since the output port is unloaded, there is no possibility for any current to flow through R_2
- Therefore, no voltage will develop across R_2
- Voltage drop across R_1 is v_o
- $v_o = 5$ V