Circuit elements (devices)

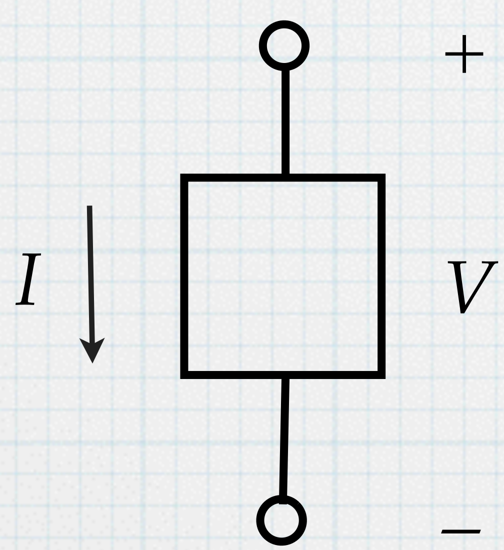
We build circuits by connecting together various types of circuit elements. (Devices, in semiconductor parlance.)

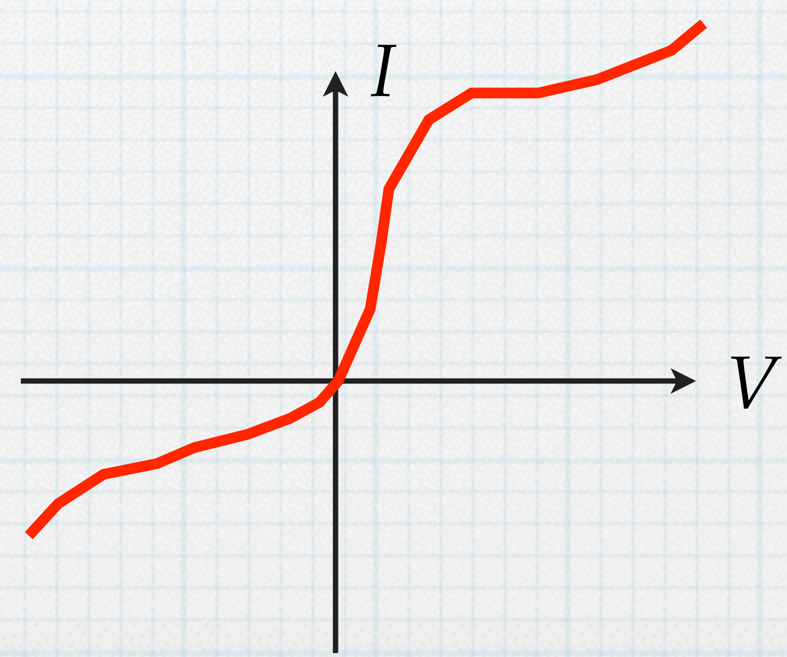
We start with the three most basic circuit elements: voltage sources, current sources, and resistors.

Later in 201, we will add others: dependent sources, capacitors, inductors, amplifiers, and diodes.

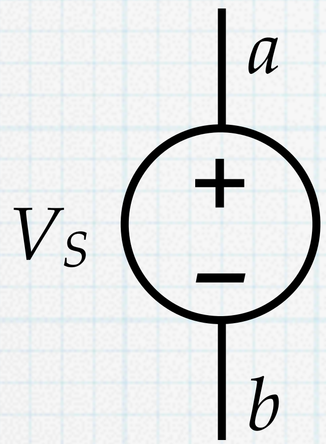
In electronics (EE 230), you will add a transistors. Then things get really interesting.

A circuit element is defined by how its current and voltage are related.





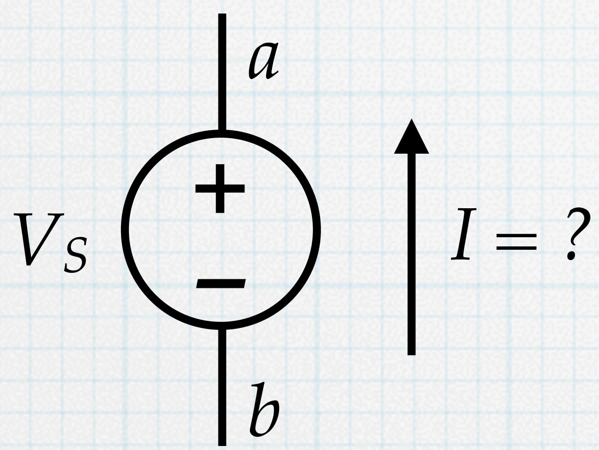
Independent voltage source



Point a is higher in voltage than point b.

$v_a - v_b = V_S$

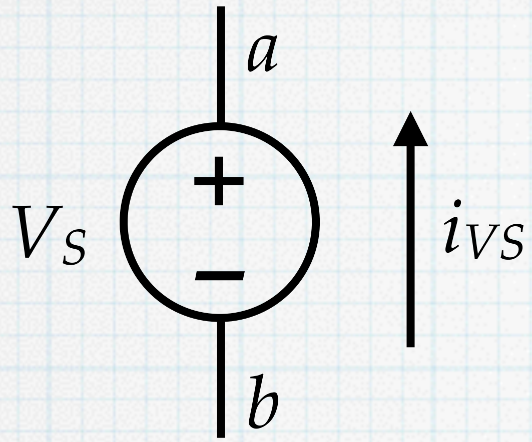
The +/– symbols define the *polarity* of the source.



However, we cannot know the current in an ideal source.

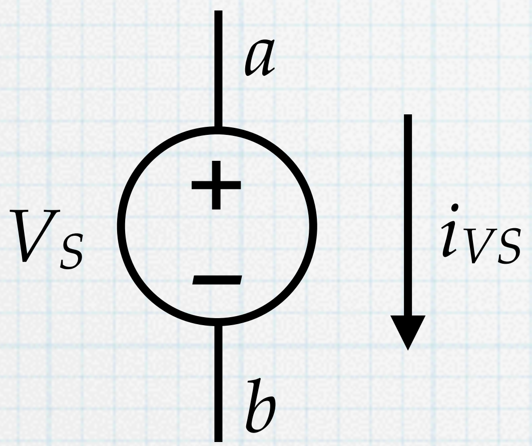
Must be measured in the lab or calculated from the currents in the rest of the circuit.

- Alkaline battery (AAA, AA, C, D) =1.5 V
- car battery = 12 V
- lithium-ion batteries for your gadgets – various voltages
- wall outlet = 120 V (AC).



Typically a voltage source produces electrical power which is delivered to the rest of a circuit.

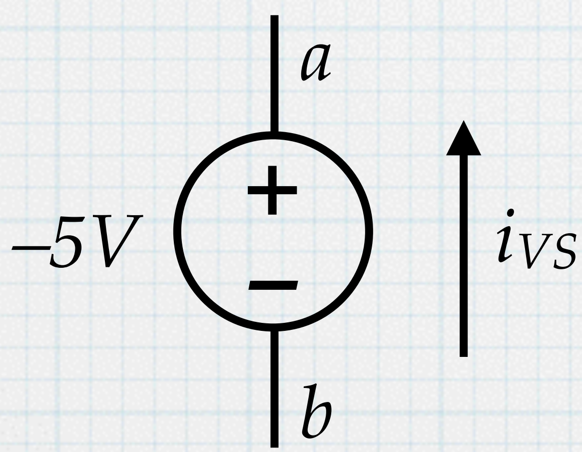
The current direction at left is consistent with producing power, $P_S = V_S \cdot i_{VS}$.



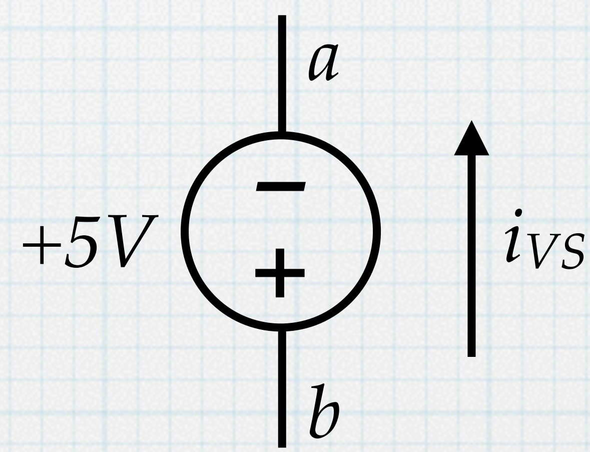
However, a source can *absorb* power as well – current can flow *into* the positive terminal.

Example: charging a battery.

$P_{absorbed} = V_S \cdot i_{VS}$.

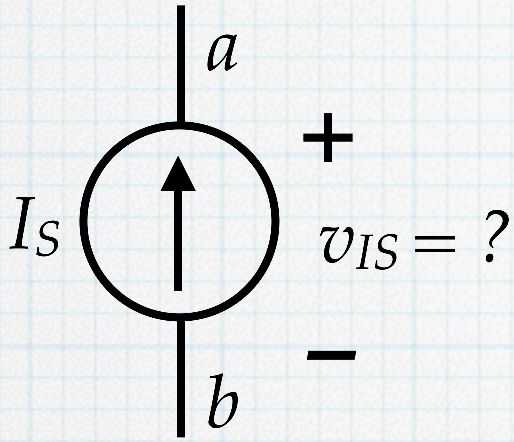


same as



In either representation, the source is absorbing power.

Independent current source



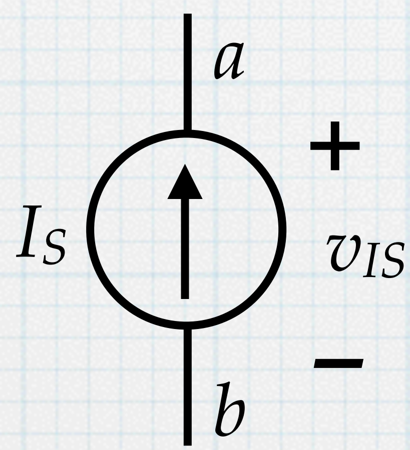
Introduces a fixed current in a branch of a circuit.

However, we do not know the voltage across an ideal current source.

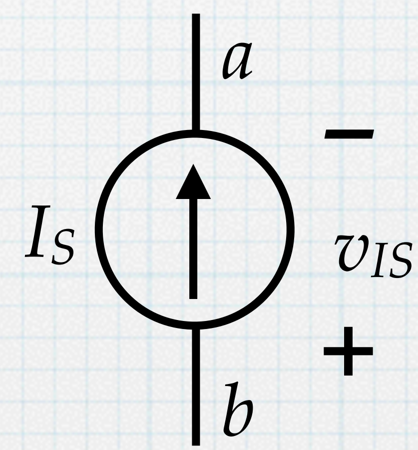
This behavior makes it the d*ual* of the independent voltage source.

Less common than voltage sources.

Typically, the current source is used to deliver power to an attached circuit. However, if the voltage is reversed, it can absorb power, too.

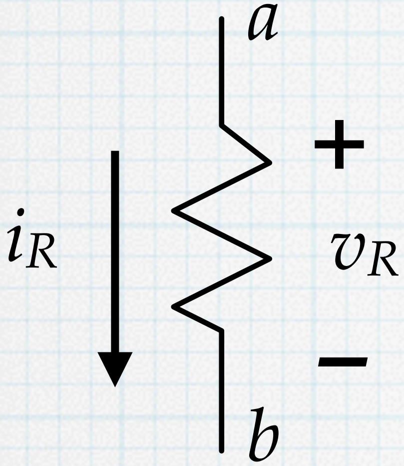


generating power



absorbing power

Resistor



A purely passive circuit element (only absorbs energy)

Turns electrical energy into heat (and maybe light).

Current flows from higher voltage to lower voltage – the current direction and voltage polarity must always have this relationship.

Ohm's law: $v_R = i_R \cdot R$

R → resistance.

Units: V/A = Ω (ohms)

Values can range from 0 to ∞.
(never negative)

In 201 lab, 10 Ω < R < 100,000 Ω (100 kΩ).

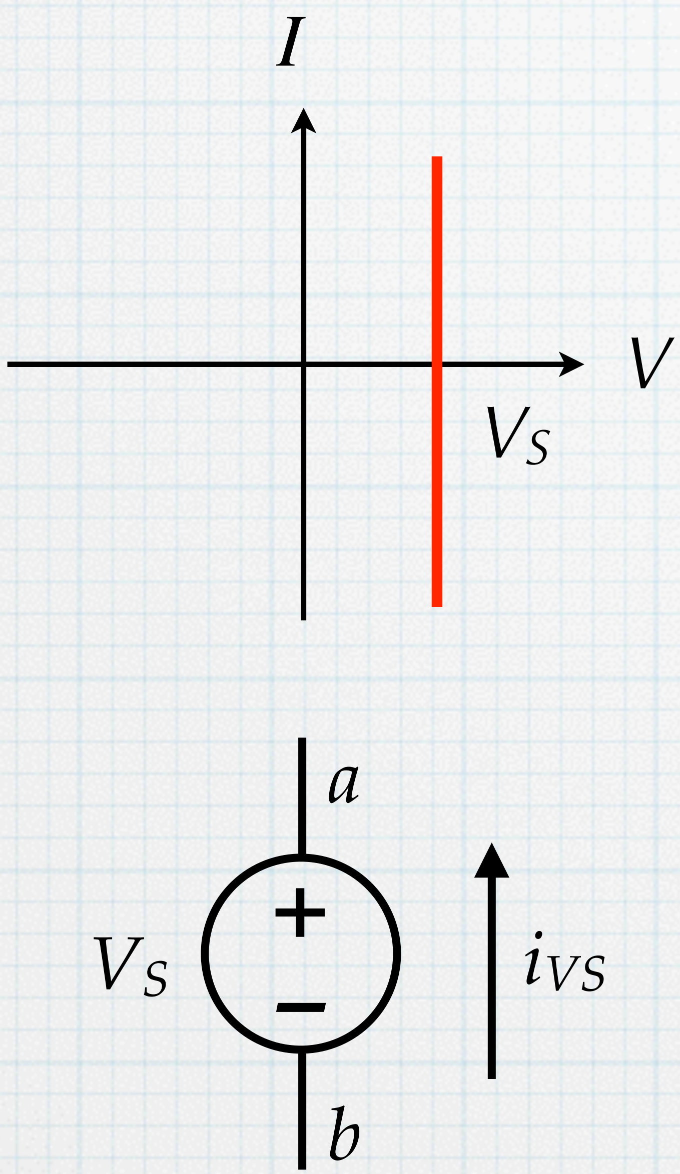
Power dissipation:

$$P_R = v_R i_R$$

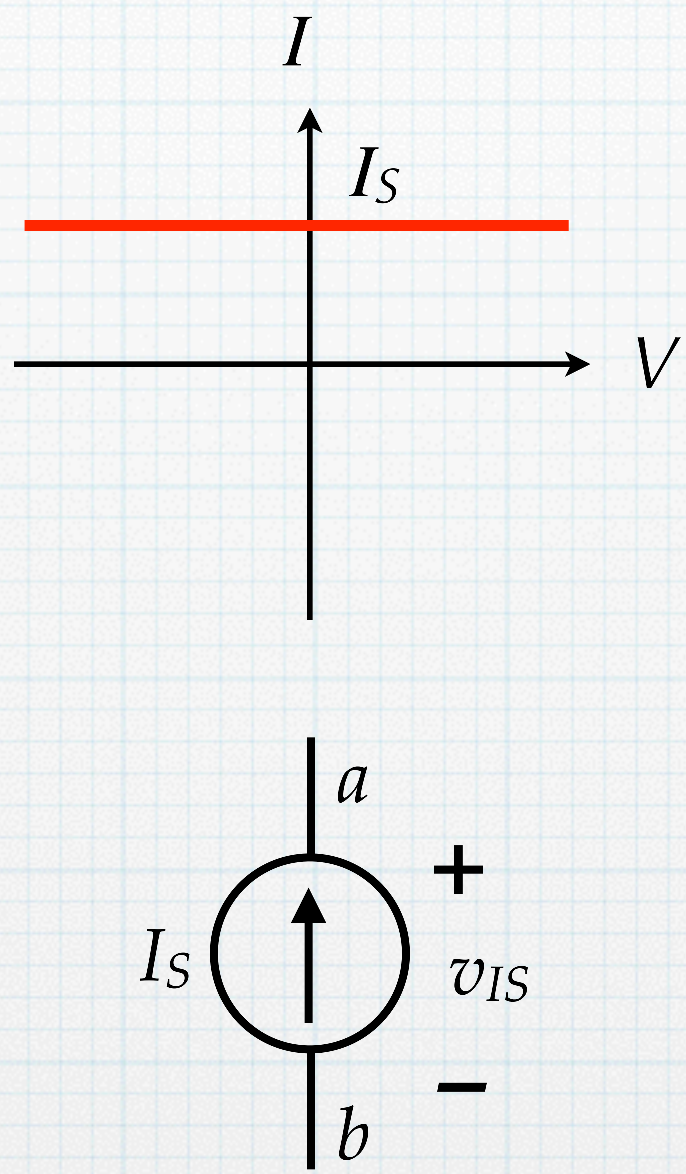
$$\boxed{P_R = \frac{v_R^2}{R} \qquad P_R = i_R^2 R}$$

A graphical view

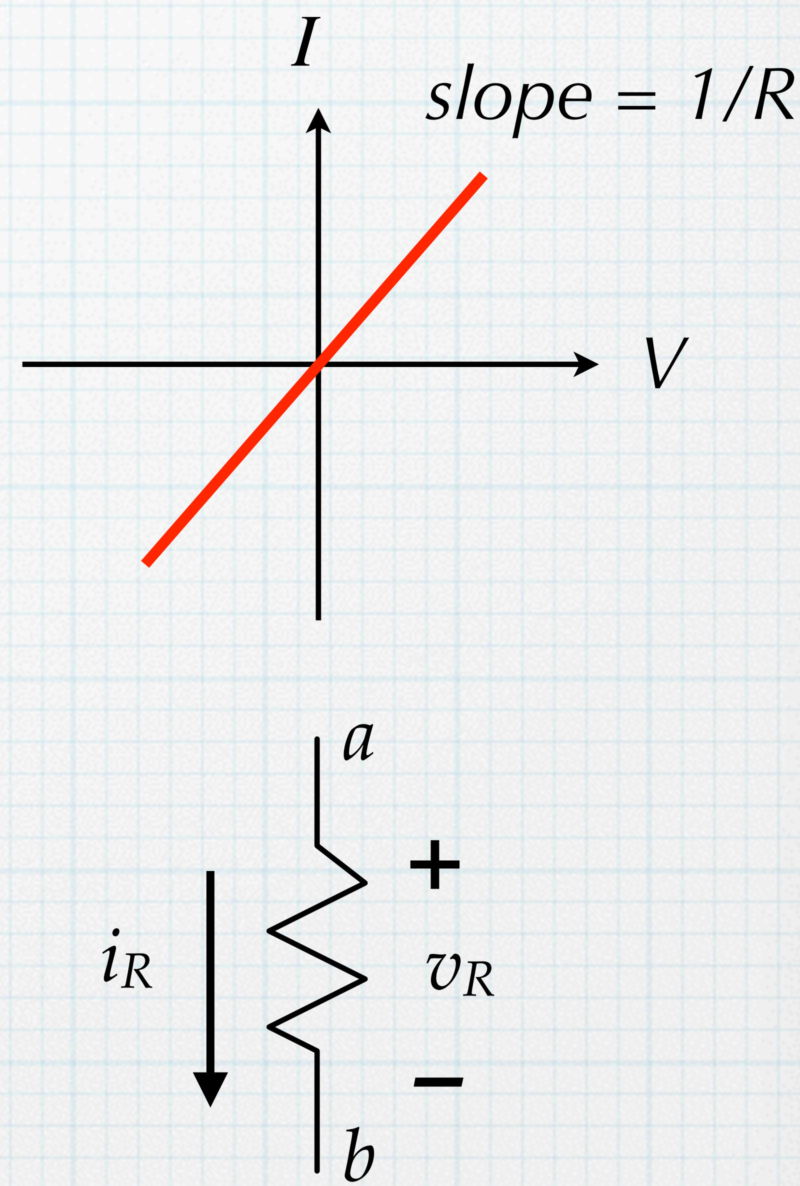
voltage source



current source

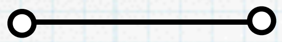


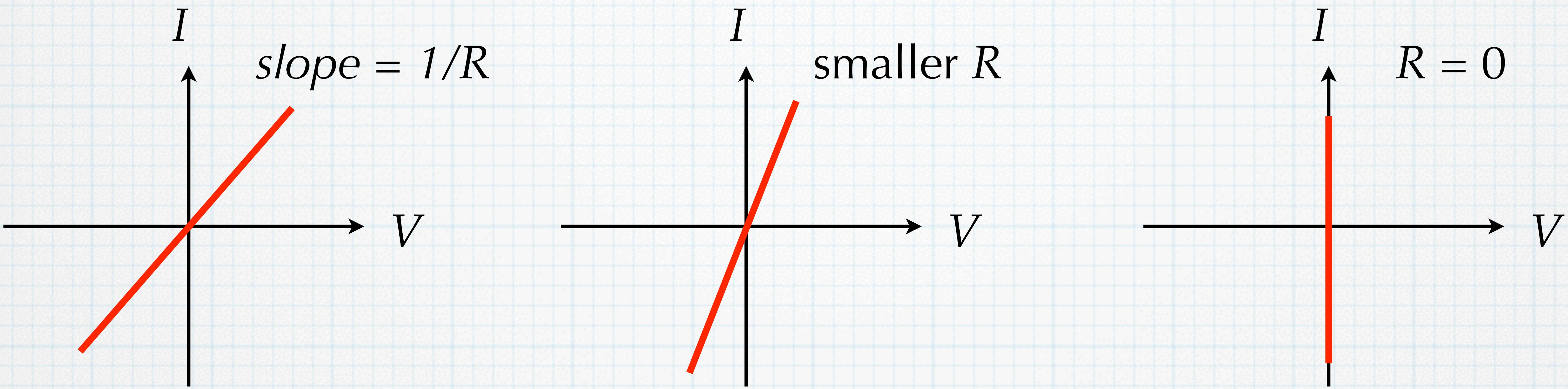
resistor

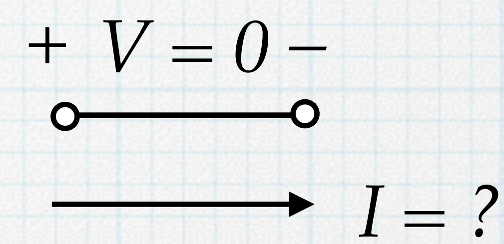


Note that all are *linear.*

Wire



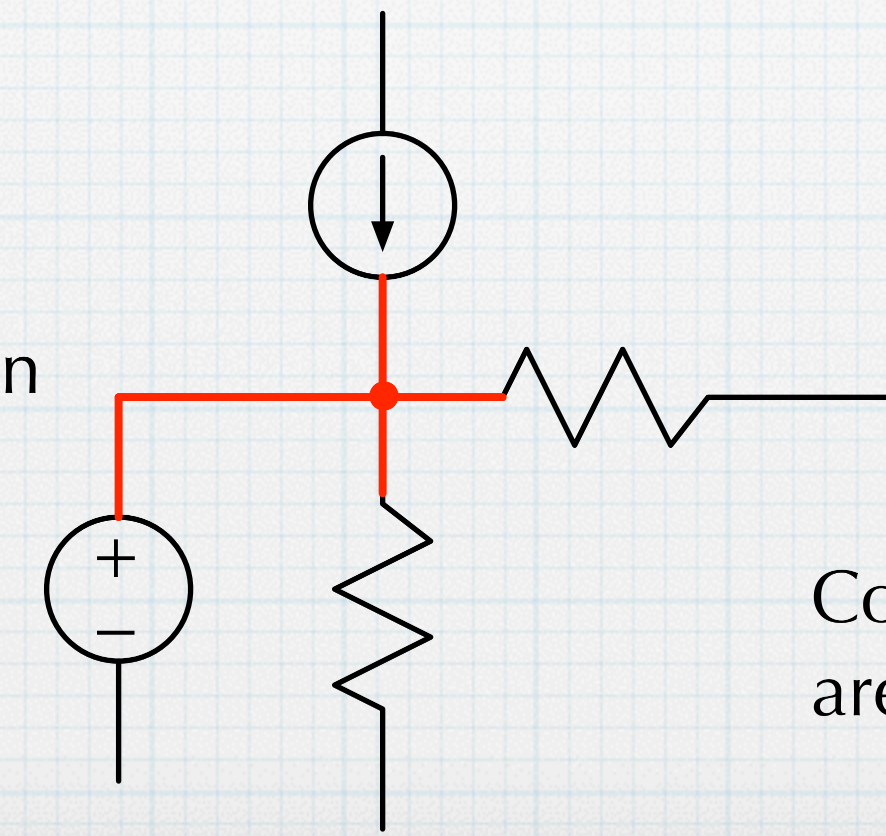




Use wires to connect together circuit elements. No voltage drop. Any amount of current.

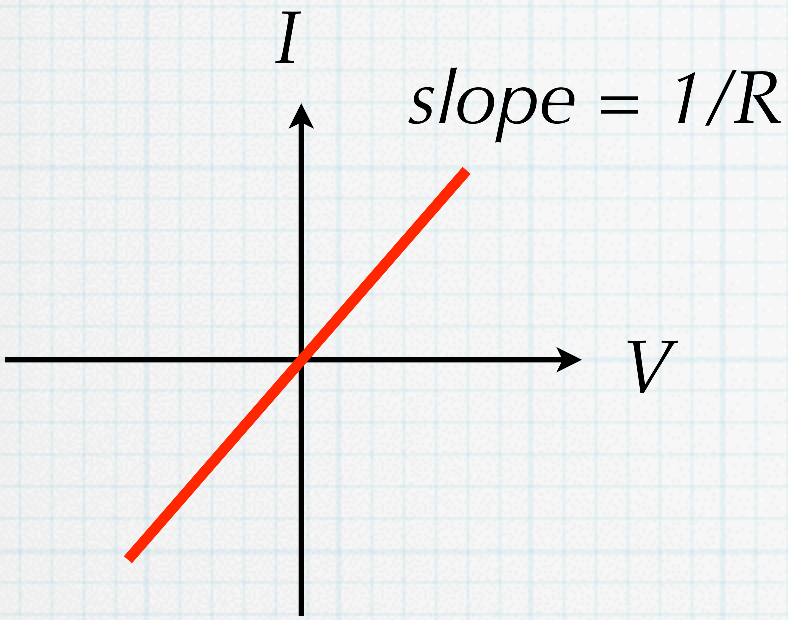
$R = 0$ has the same properties as voltage source with $V_S = 0$.

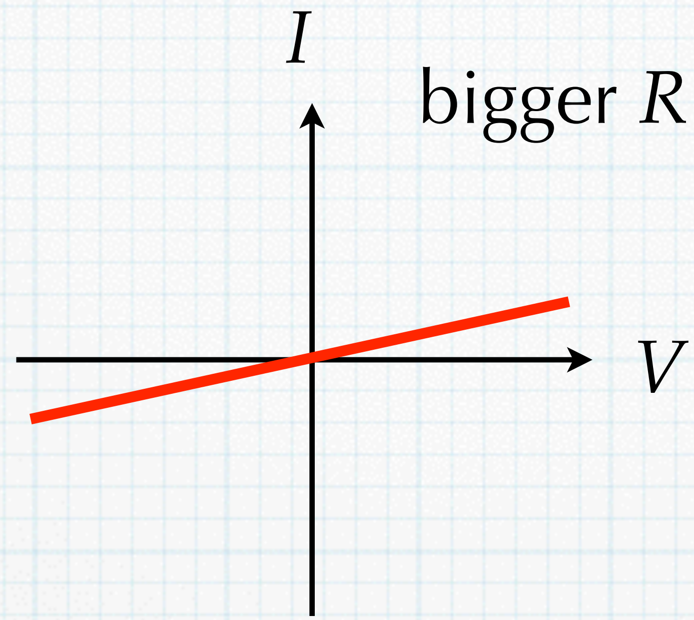
Red wires connect 4 elements. Everything in red is at the same voltage.

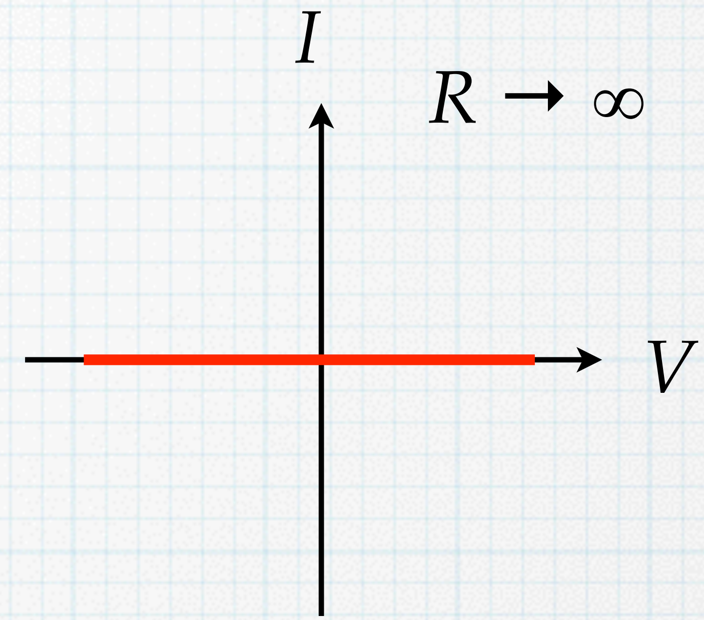


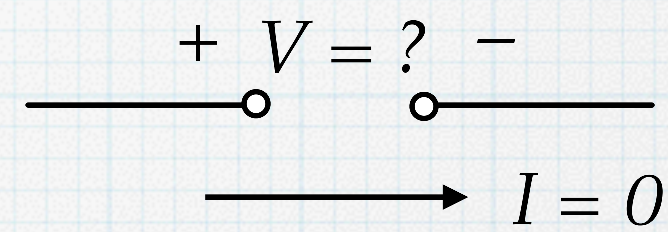
Copper and aluminum are good wire materials.

Open-circuit







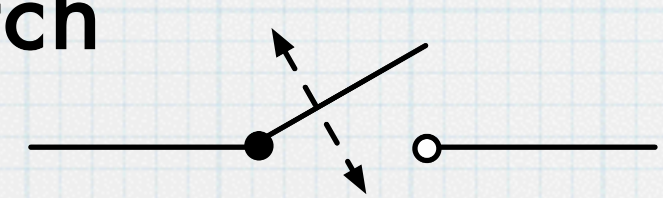


No current through open circuit. (Current requires a continuous path to flow.)

Voltage across open circuit can be anything.

$R \rightarrow \infty$ has the same properties as current source with $I_S = 0$.

switch



Changes between two extremes.