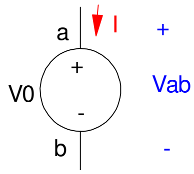
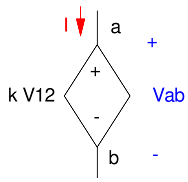
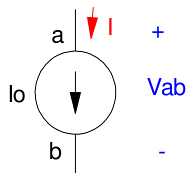
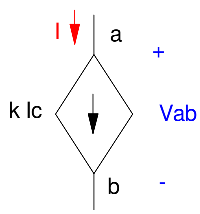
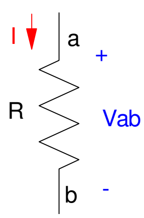
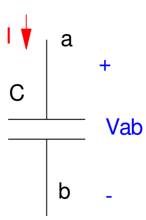
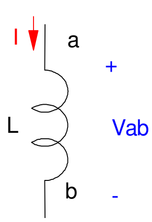
Circuit Elements and Kirchoff's Laws

Element	Symbol	VI Relationship
Voltage Source (battery)		$V_{ab} = V_0$ $I = \text{any}$
Voltage Controlled Voltage Source (amplifier)		$V_{ab} = kV_{12}$ $I = any$
Current Source (LED driver)		$I = I_0$ $V_{ab} = any$
Current Controlled Current Source (transistor)		$I = kI_c$ $V_{ab} = any$
Resistor (basic circuit element)		$V_{ab} = IR$
Capacitor (basis circuit element)		$I = C\frac{dV_{ab}}{dt}$
Inductor (basic cicuit element)		$V_{ab} = L\frac{dI}{dt}$

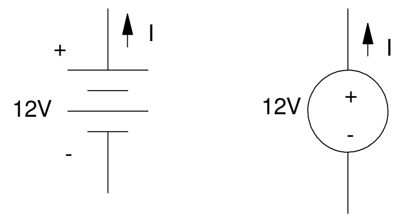
Independent Sources

Voltage: Voltage sources are like batteries. The voltage is fixed. The current is whatever it takes to hold the voltage (and depends upon what you're connecting the battery to.) If there is no load, the current is zero.

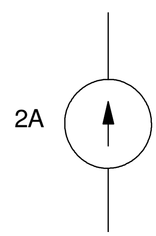
Note that with voltage sources you cannot short the + and - terminals. This creates a conflict:

- The voltage source tries to hold the voltage at +12V
- The wire shorting out the source tries to hold the voltage at zero.

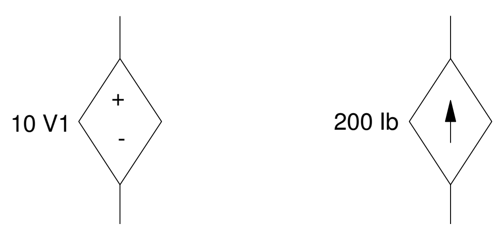
Whichever one has the higher current capacity wins.



Current: Current sources are transistors (and covered in ECE 320 Electronics). For this class, they are just a device which forces the current to be a constant.



Controlled Current and Voltage Sources: A diamond indicates a controlled voltage source or a controlled current source.



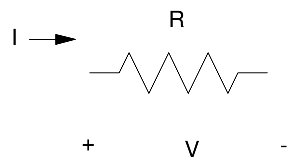
Controlled sources arise from various components covered in ECE 320 Electronics

- Operational Amplifiers (voltage controlled voltage source)
- Transistors (current controlled current source)
- MOSFET (voltage controlled current source)

For this class, just treat them as a device.

Ohm's Law

The symbol for a resistor is as follows. The passive-sign convention defines the current going from the + voltage to the - voltage:



Symbol for a resistor: Note that the current goes into the + terminal.

With this notation, the voltage-current relationship is

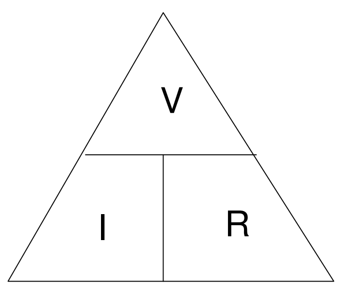
$$V = I \cdot R$$ Volts

This also leads to the equations

$$I = \frac{V}{R}$$ Amps

$$R = \frac{V}{I}$$ Ohms

One way to remember this is with the following figure:



Using the passive sign-convention, V = IR, I = V/R, R = V/I

The power dissipated by a resistor is

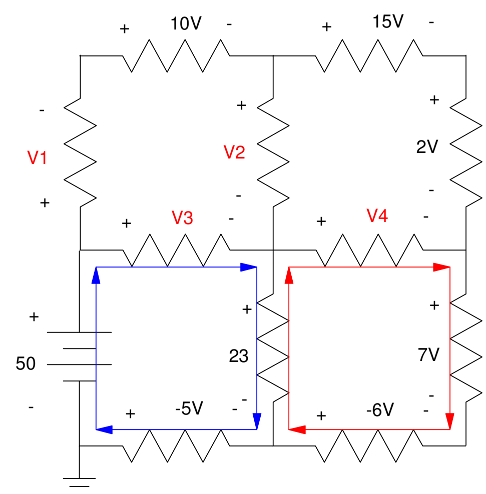
$$P = V \cdot I$$ Watts

From V = IR, you also have

$$P = \frac{V^2}{R}$$

$$P = I^2 R$$

All three forms are correct: the one you use depends upon which parameters are easiest to obtain.



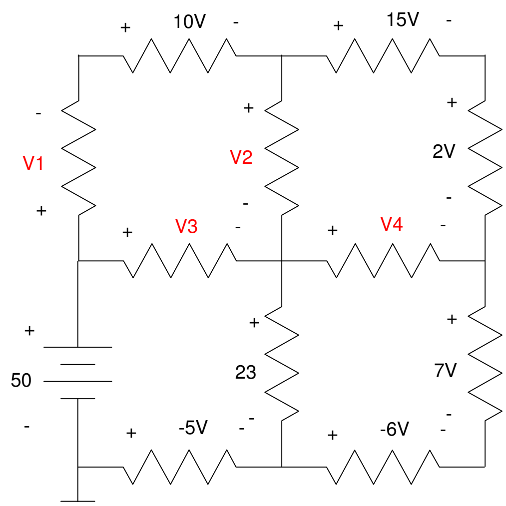
Kirchoff's Laws

Kirchoff's laws simply restate the conservation of voltage and current:

- If you sum the voltages around any closed path, the sum must be zero.
- If you sum the current flowing away from a point, the sum must be zero.

Conservation of Voltage:

Around any closed path, the voltages must add to zero. You can use this to find unknown voltages. For example, determine the voltages V1..V4 for the following circuit:



Around any closed-path, the voltages must sum to zero. Since there are five unknown voltages, if you write 4 equations you can solve for the 4 unknowns.

Sometimes you can do this by inspection. If you can identify a closed-path with only one unknown voltage, you have one equation to solve for 1 unknown. One such path is the lower left corner (shown in blue):

To be consistent, as you go around this path, add the voltage if you hit the + sign first, subtract if you hit the - sigh first:

$$-50 + V_3 + 23 - (-5) = 0$$

$$V_3 = 22V$$

The lower right corner (shown in red) gives

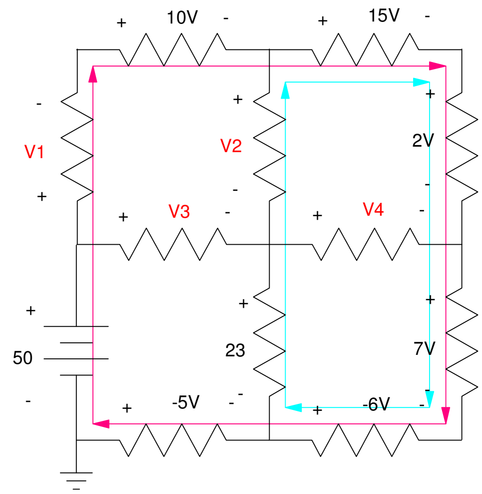
$$-23 + V_4 + 7 - (-6) = 0$$

$$V_4 = 10V$$

Another two loops are shown to the right. The outer loop (in red) gives

$$-50 + V_1 + 10 + 15 + 2 - 8 - (-6) - (-5) = 0$$

$$V_1 = 5V$$



The loop to the right (blue) gives

$$-23 - V_2 + 15 + 2 + 7 - (-6) = 0$$

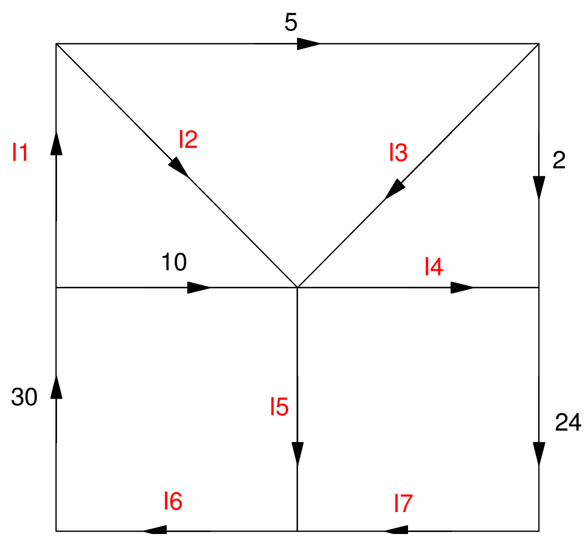
$$V_2 = 10V$$

There are many other paths you could take For each closed path, the voltages must add to zero.

Conservation of Current

Current is the flow of electrons. Unless you are creating matter, the sum of the current from (or to) a given node must be zero. You can use this to find unknown currents.

For example, determine the currents I1..I7



To solve for the unknown currents, find a point where there is one unknown current flowing to (or from) that node:

A: 30 = 10 + I1

I1 = 20

B: I6 = 30

C: 24 = I7

D: 5 = I3 + 2

I3 = 3

E: 2 + I4 = 24

I4 = 22

This lets you solve for I2 and I5:

F: 20 = I2 + 5

I2 = 15

G: I5 + 24 = 30

I5 = 6