

## ELEN 50 Class 02 – Voltage and Current Sources, Resistance

S. Hudgens

Okay, we have reviewed the SI system of units and we defined basic circuit elements and discussed the passive sign convention:

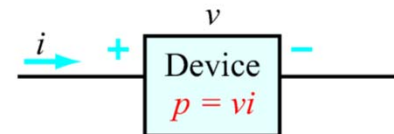
- Ideal basic circuit element:
  - Has only two terminals
  - Is described mathematically in terms of current and voltage
  - Cannot be subdivided further into other elements

- Passive sign convention:

..and we defined power:

$$P = VI$$

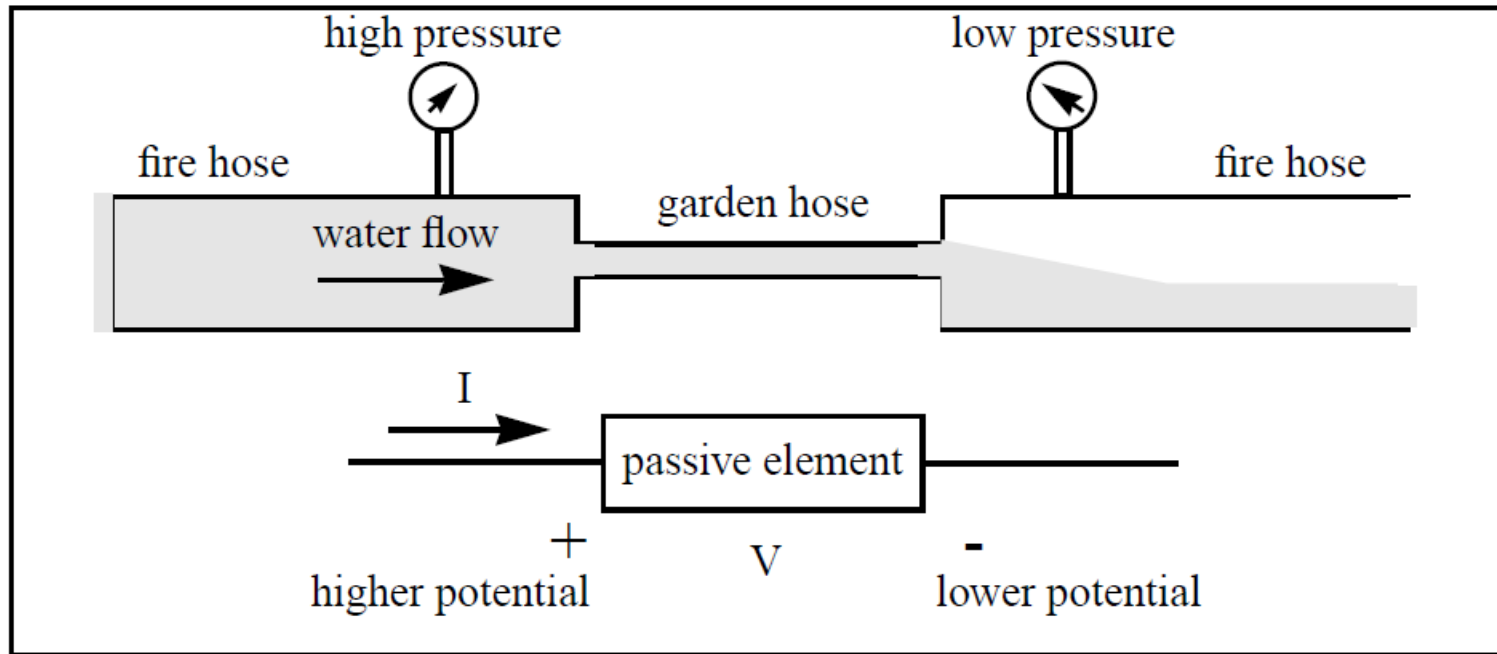
### Passive Sign Convention



$p > 0$  power delivered to device  
 $p < 0$  power supplied by device

\*Note that  $i$  direction is defined as entering (+) side of  $v$ .

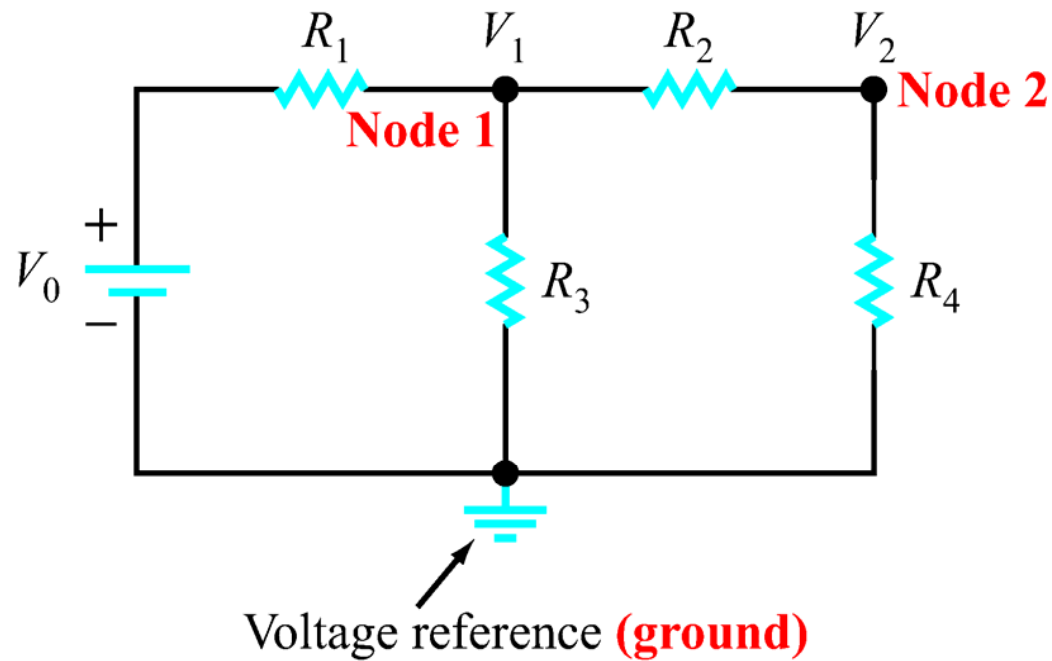
Here's the water analogy again

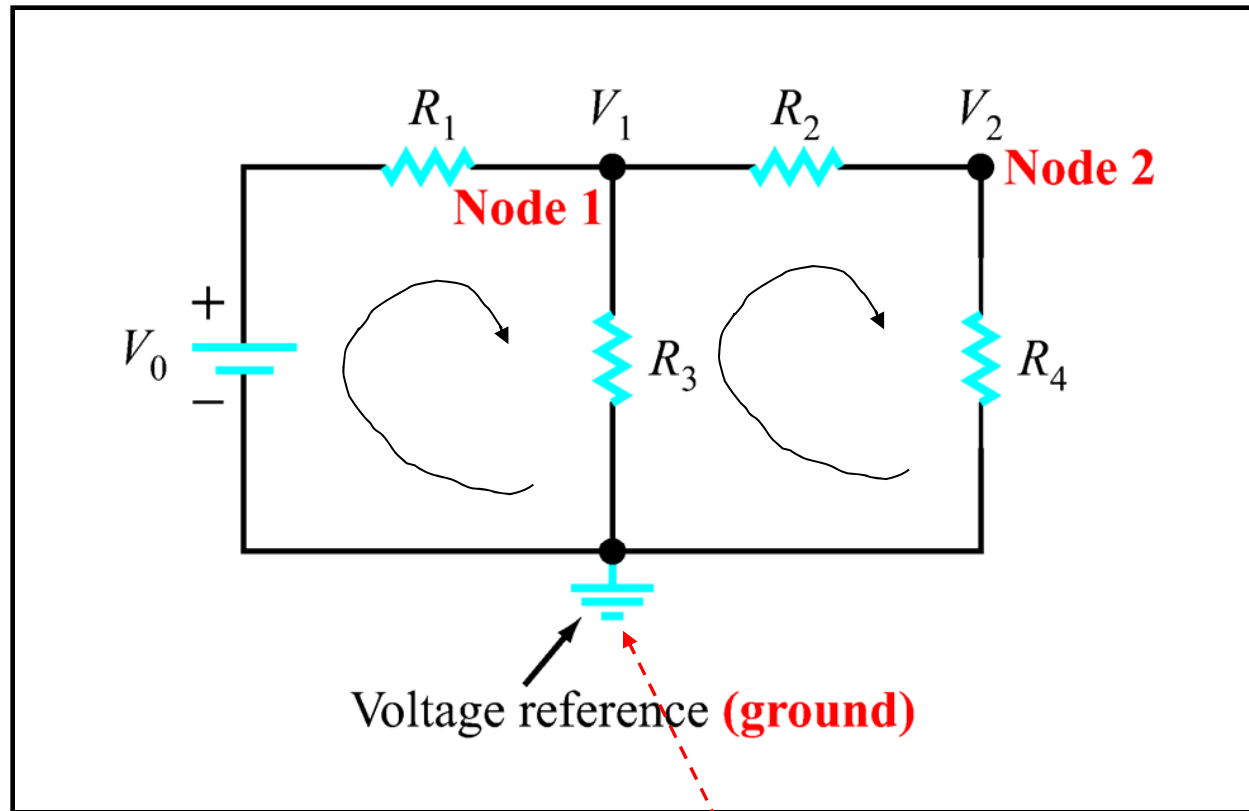


Here's another way you might think about the passive sign convention:

another way of saying it is that conventional (positive) current flows “downhill” from the higher (positive) potential to the lower one.

How would you add arrows to this circuit to indicate current flow- using the passive sign convention? Which direction is current flowing in all the branches?



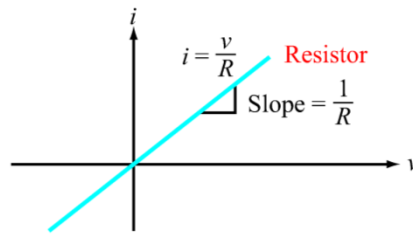


Why did I draw the current loops this way?

Could I pick another node to be the ground node? Would this cause the current loops to change?

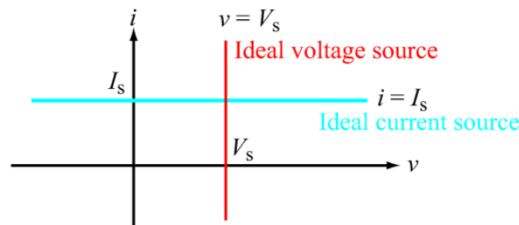
## I-V Relationships

- **Ohms Law [  $I = V/R$  ]** describes the I-V relationship for a perfect resistor. It seems intuitive ....and we'll talk more about it later.
- Since this is a linear I-V relationship, circuits composed of ideal resistors are “linear circuits.”



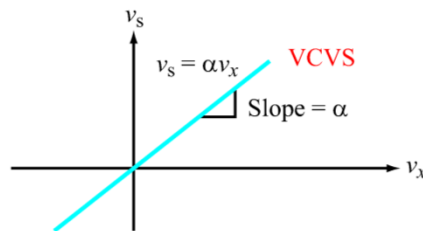
(a)

Resistor



(b)

Current and  
Voltage Sources

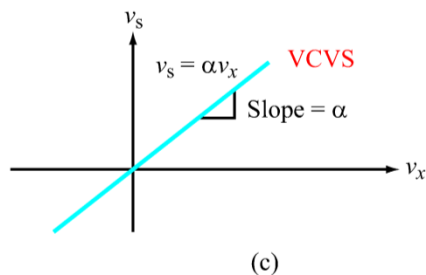
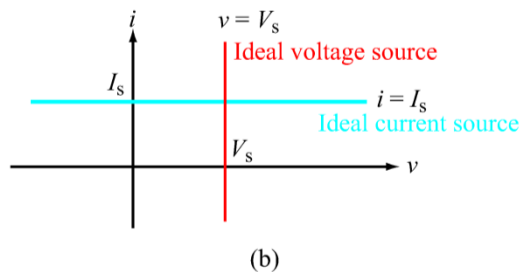
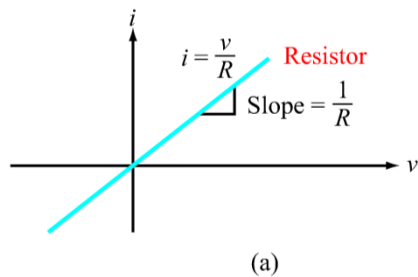


(c)

Voltage Controlled  
Voltage Source, etc.

Remember:

From the perspective of circuit theory, circuits are networks of two-terminal circuit elements that are completely defined by their current-voltage (I –V) relationships.



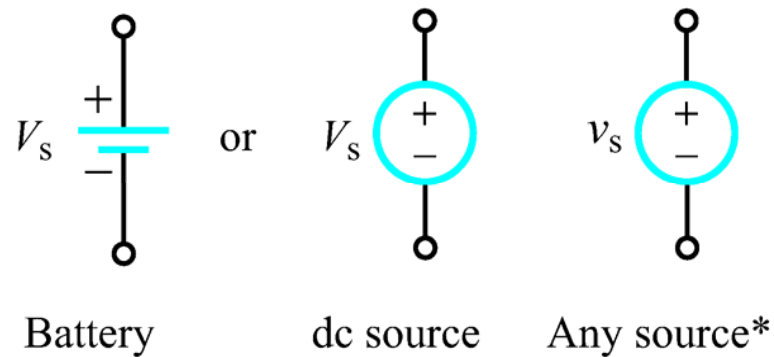
Circuit elements with these I-V relationships will occupy us for the next 6 weeks or so.

What is the I-V relationship for an open circuit?

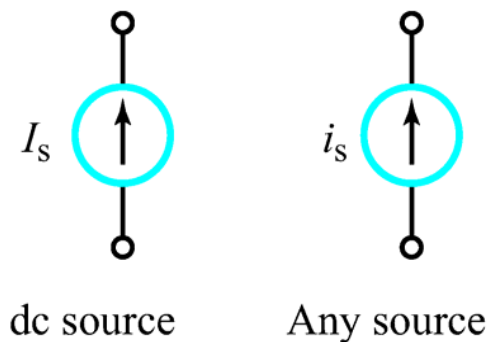
What is the I-V plot for a short circuit (aka a wire)?

## Independent Sources

- An ideal independent voltage source provides a specified voltage across its terminals regardless of the load or type of circuit connected to it.



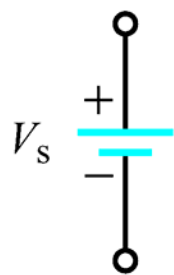
- An ideal independent current source provides a specified current flowing through it regardless of the voltage across it.



However .....

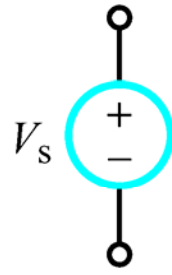
- No short circuit is allowed across an ideal voltage source – this would require an infinite current to flow in the circuit.
- No open circuit is allowed across an ideal current source – this would result in an infinite voltage drop across the source.
- In general ...not all circuits containing ideal current and voltage sources (independent or otherwise) are valid! Look closely and be sure that a circuit is valid before you begin to analyze it! Invalid circuits have no solutions!

## Ideal and Realistic Current and Voltage Sources

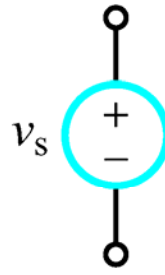


Battery

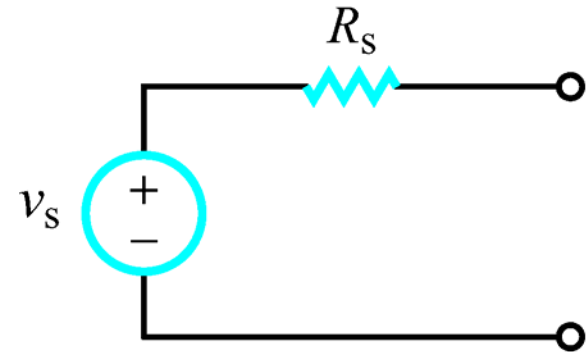
or



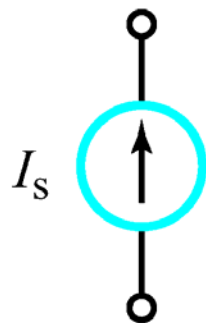
dc source



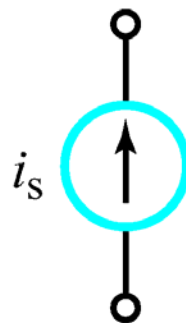
Any source\*



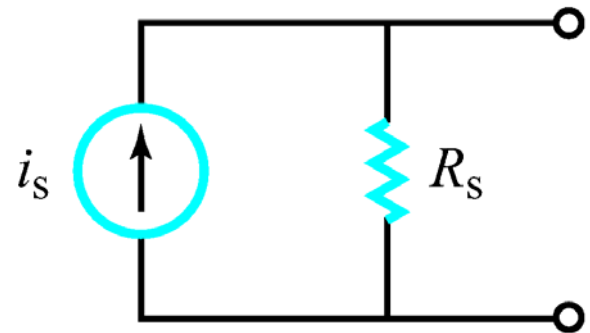
Any source



dc source



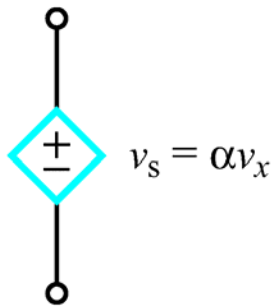
Any source



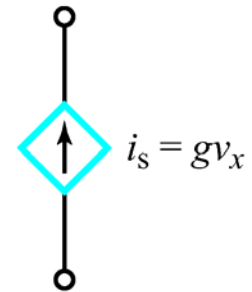
Any source

## Dependent Sources

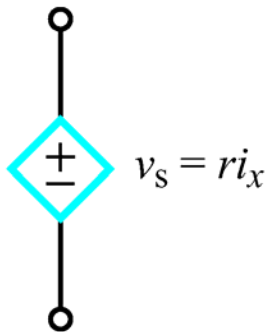
Voltage-Controlled Voltage Source (VCVS)



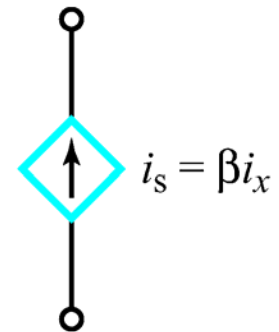
Voltage-Controlled Current Source (VCCS)

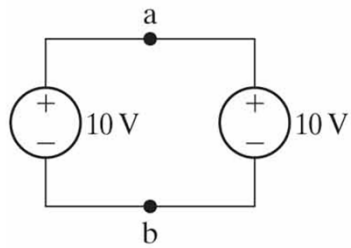


Current-Controlled Voltage Source (CCVS)

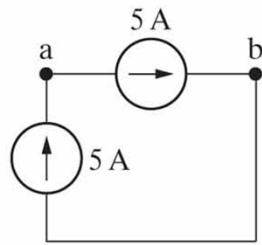


Current-Controlled Current Source (CCCS)

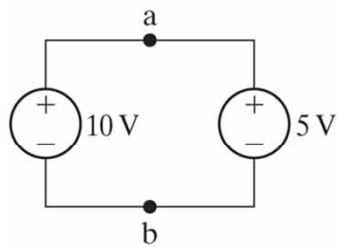




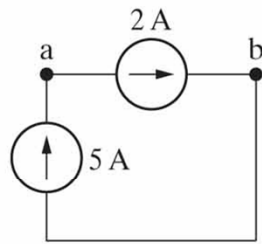
(a)



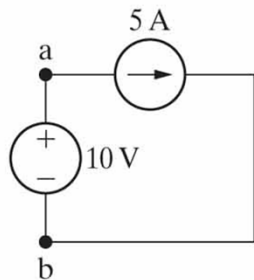
(b)



(c)



(d)



(e)

Which of these circuits are valid given the properties of ideal sources?

As a general rule, voltage sources in parallel are either invalid or pointless (redundant)!

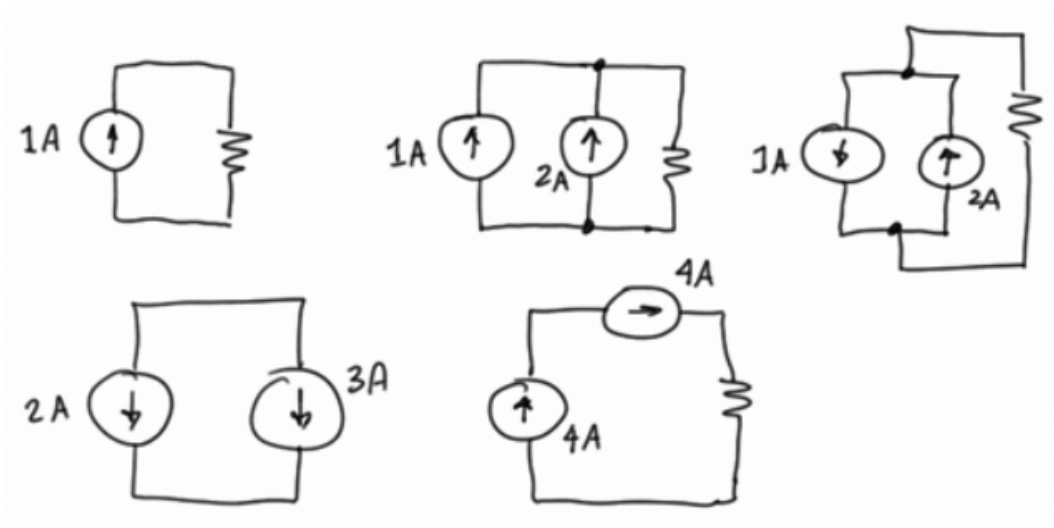
Similarly, as a general rule, current sources in series are either invalid or pointless!

Open circuits across current sources are always invalid as are short circuits across voltage sources.

The inverse situation (shorts across current sources and open circuits on voltage sources) are OK.

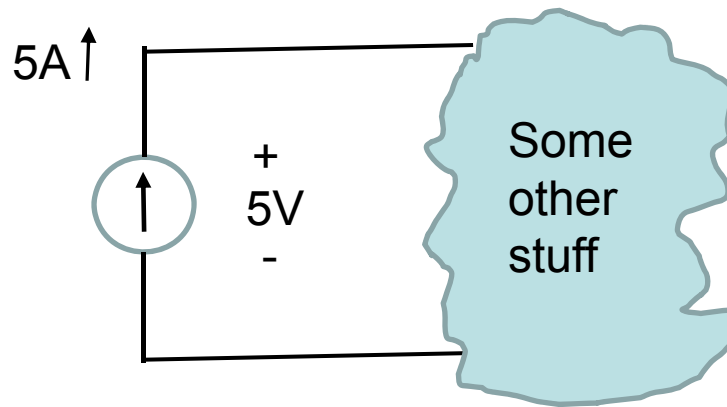
If you are uncertain, you can always draw the I-V characteristics of the source(s) and see if the circuit makes sense.

Are these circuits valid or invalid – and why?



From Ed Doering and Xiaoyan Mu – Circuits Learned Online

Here's a current source. It is connected to some other parts of a circuit – that are not shown. A current magnitude and direction and a voltage difference across the current source (voltage drop) are indicated.



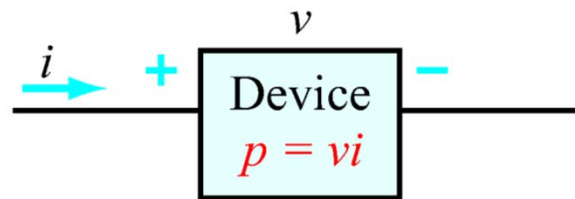
First, is this a valid circuit – i.e. does it lead to contradictions or infinite current or voltage?

Does this labelling obey the passive sign convention?

Is this current source delivering or absorbing power?

Remember – here's the rule

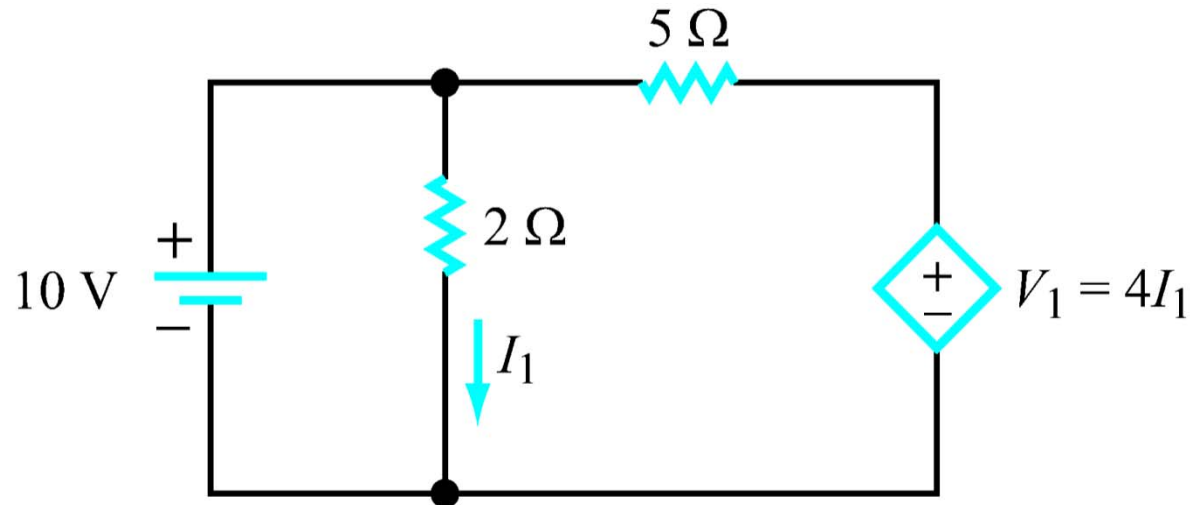
## Passive Sign Convention



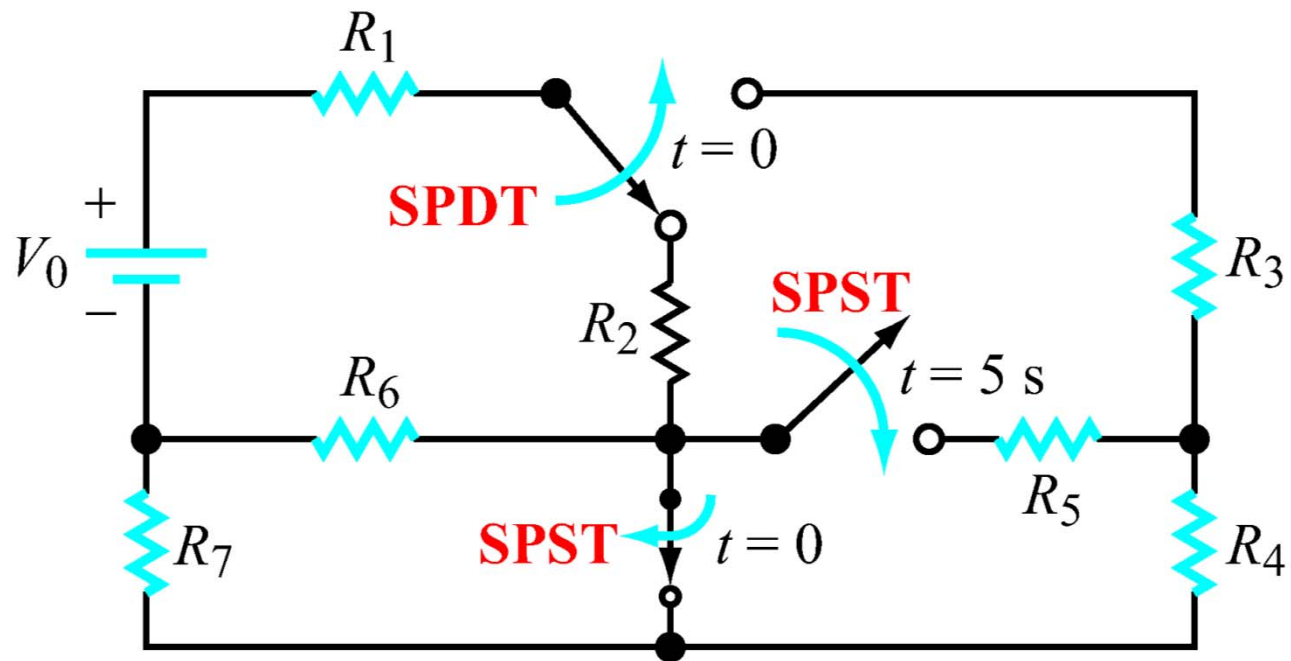
$p > 0$  power delivered to device

$p < 0$  power supplied by device

\*Note that  $i$  direction is defined as entering (+) side of  $v$ .



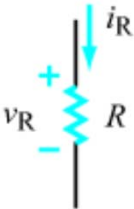

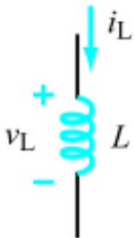
Can you solve this circuit? We haven't talked about any systematic procedures for circuit analysis yet ...but, knowing what you know about sources and Ohms law, you should be able to figure this out. Where would you start?



What are the equivalent circuits for this circuit with the switches in different positions?

## Passive Circuit Elements

**Table 1-4:** Passive circuit elements and their symbols.

Element	Symbol	$i$ - $v$ Relationship
Resistor		$v_R = Ri_R$
Capacitor		$i_C = C \frac{dv_C}{dt}$
Inductor		$v_L = L \frac{di_L}{dt}$

We've  
discussed  
only this  
one so far

# Voltage-Pressure Analogy

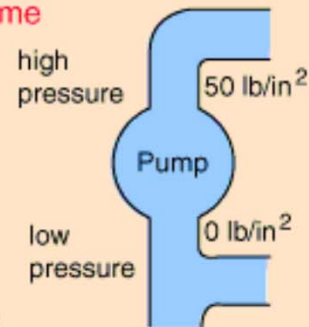
A battery is analogous to a pump in a water circuit. A pump takes in water at low pressure and does work on it, ejecting it at high pressure. A battery takes in charge at low voltage, does work on it and ejects it at high voltage.

$$\text{pressure} = \frac{\text{energy}}{\text{volume}}$$

$$\text{pressure} = \frac{F}{A}$$

$$\frac{F}{A} = \frac{F d}{A d} = \frac{W}{V}$$

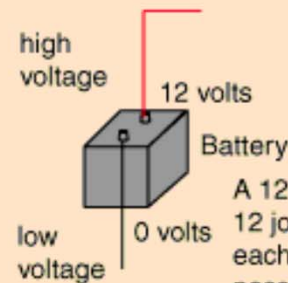
$$= \frac{\text{energy}}{\text{volume}} = \frac{\text{joule}}{\text{m}^3}$$



A closed faucet has pressure behind it, but no flow.  
(resistance  $\rightarrow \infty$ )

$$\text{voltage} = \frac{\text{energy}}{\text{charge}}$$

$$\text{volt} = \frac{\text{joule}}{\text{coulomb}}$$



A 12 volt battery does 12 joules of work on each unit of charge which passes through it.



A receptacle has voltage behind it, but no current if nothing is plugged in.  
(resistance  $\rightarrow \infty$ )

[Water analogy to DC circuits](#)

[Index](#)

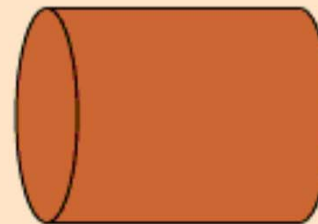
[DC Circuits](#)

# Current-Flowrate Analogy

Volume  
flowrate in  
liters/min,  
 $\text{cm}^3/\text{sec}$ ,  
 $\text{m}^3/\text{sec}$ , etc.



A large pipe offers very little resistance to flow, as shown by Poiseuille's law.



A wire offers very little resistance to charge flow according to Ohm's law.

Electric current  
flow in  
 $\text{coulombs/sec}$   
= amperes.

Connecting a battery to an appliance through a wire is like using a large pipe for water flow. Very little voltage drop occurs along the wire because of its small resistance. You can operate most appliances at the end of an extension cord without noticeable effects on performance.

[Water analogy to DC circuits](#)

[HyperPhysics](#)\*\*\*\*\*[Electricity and Magnetism](#)

R  
Nave

[Index](#)

[DC  
Circuits](#)

[Go Back](#)

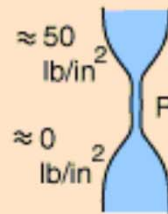
From  
Hyperphysics

<http://hyperphysics.cs.phy-astr.gsu.edu/hbase/hframe.html>

# Resistance to Flow

The [resistance to flow](#) represented by a severe constriction in a water pipe is analogous to the [resistance to electric current](#) represented by a common electric "resistor".

The resistance of a constriction in a large pipe is so great that essentially all the pressure drop will appear across the resistance.



$\approx 12 \text{ volts}$   
 $R$   
 $\approx 0 \text{ volts}$

The resistance of a copper wire is so small that essentially all the voltage drop will appear across the resistor (or an appliance).

The severe constriction will have more resistance than the remainder of the pipe system. Likewise a resistor in an electric circuit will generally have much more resistance than the wire of the circuit. If the single elements represented are the only resistances in the circuit, then essentially all the pressure or voltage will drop across these single elements. The fact that essentially all the voltage drop appears across a resistor or an ordinary electrical appliance makes possible the operation of such appliances from an extension cord, or the operation of several appliances in parallel on a single circuit in your home.

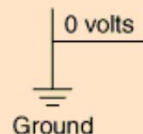
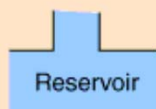
[Water analogy to DC circuits](#)

From  
Hyperphysics  
<http://hyperphysics.cs.phy-astr.gsu.edu/hbase/hframe.html>

## Ground-Reservoir Analogy

The function of a ground wire in an electric circuit is in many ways analogous to the reservoir attached to the water circuit. Once the pipe is filled with water, the pump can circulate the water without further use of the reservoir, and if it were removed it would have no apparent effect on the water flow in the circuit.

The reservoir can supply water to the circuit, and holds the pressure of the adjacent pipes at the pressure of the reservoir.



The ground can supply charge to the circuit, but its main function is to hold the voltage of nearby wires at the voltage of the earth.

The reservoir provides a pressure reference, but is not part of the functional circuit. Likewise, the battery can circulate electric current without the ground wire. The ground provides a reference voltage for the circuit, but if it were broken, there would be no obvious change in the functioning of the circuit. The [ground wire](#) protects against electric shock and in many cases provides shielding from outside electrical interference.

This view of a ground is not adequate to explain the function of an [appliance ground wire](#) because just a connection to the earth is not sufficient to trip a circuit breaker in case of an electrical fault. To be effective in preventing shock hazards, an appliance ground must connect back to the supply through the [neutral wire](#).

Nevertheless, the image of the earth as a charge reservoir is helpful in understanding the energetics of the entire electrical supply system. At a power plant, charge can be drawn from the earth and the generation process does work on the charge to give it energy. This energy is described by stating its [voltage](#) ( $1 \text{ volt} = 1 \text{ joule/coulomb} = \text{energy/charge}$ ). The energy can be transported cross-country at high voltages and then supplied to end users at lower voltages with the use of step-down [transformers](#). The energy can then be used and the charge discharged to the earth. The charge upon which the work is done at the power plant does not have to be transported cross-country, and the "spent" charges do not have to be transported back to the power plant, but just dumped into the "reservoir".

[Water analogy to DC circuits](#)

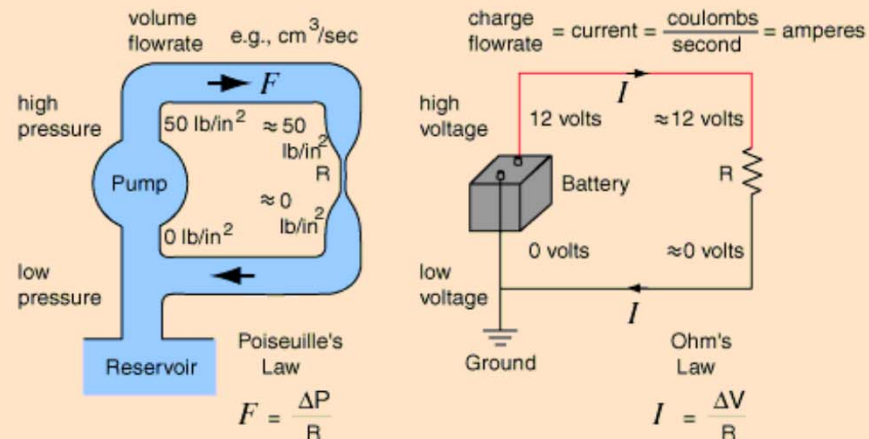
[Index](#)

[DC  
Circuits](#)

From  
Hyperphysics  
<http://hyperphysics.cs.phy-astr.gsu.edu/hbase/hframe.html>

## DC Circuit Water Analogy

This is an active graphic. Click any part of it for further details.



In a direct current (DC) electrical circuit, the voltage ( $V$  in volts) is an expression of the available energy per unit charge which drives the electric current ( $I$  in amperes) around a closed circuit. Increasing the resistance ( $R$  in ohms) will proportionately decrease the current which may be driven through the circuit by the voltage.

Each quantity and each operational relationship in a battery-operated DC circuit has a direct analog in the water circuit. The nature of the analogies can help develop an understanding of the quantities in basic electric circuits. In the water circuit, the pressure  $P$  drives the water around the closed loop of pipe at a certain volume flowrate  $F$ . If the resistance to flow  $R$  is increased, then the volume flowrate decreases proportionately. You may click any component or any relationship to explore the details of the analogy with a DC electric circuit.

[Ohm's law](#) [Voltage law](#) [Current law](#) [Power relationship](#)

[Basic DC circuit relationships](#)

[Index](#)

[DC  
Circuits](#)