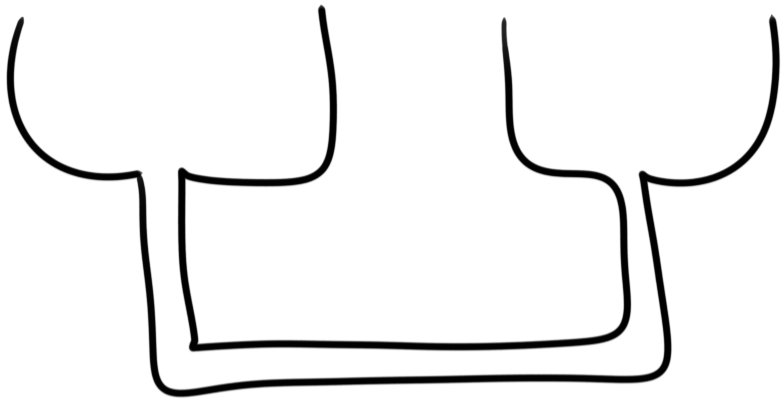
PAT 451/551 INTERACTIVE MEDIA DESIGN I

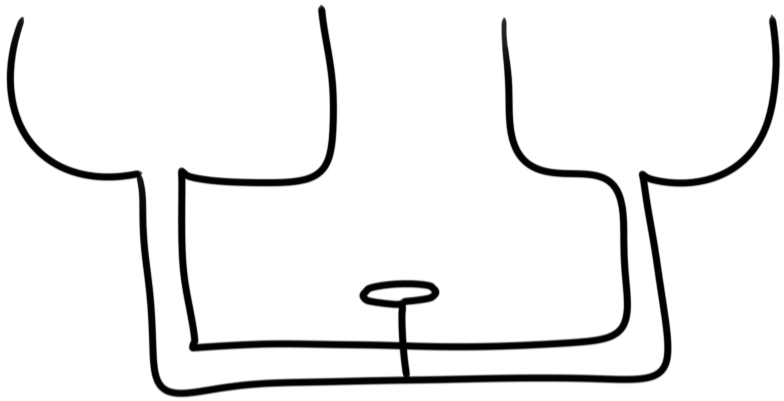
ELECTRONICS_PART1

PROF. MICHAEL GUREVICH
UNIVERSITY OF MICHIGAN
PERFORMING ARTS TECHNOLOGY

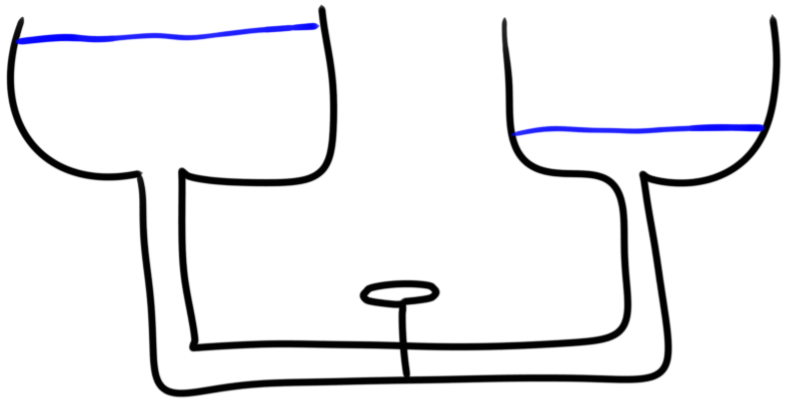
Hydraulic Analogy



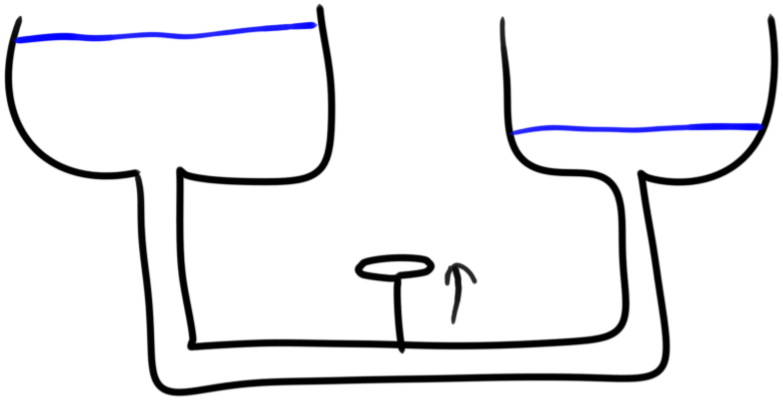
2 Empty water tanks



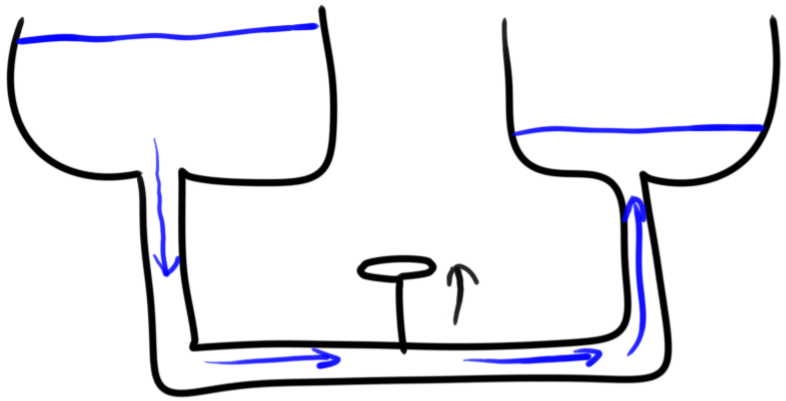
With a valve or stopper between them



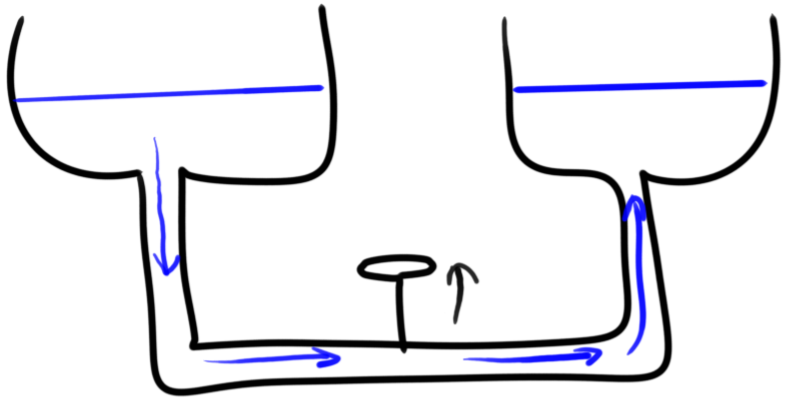
Fill them with water. More in the left tank than the right.



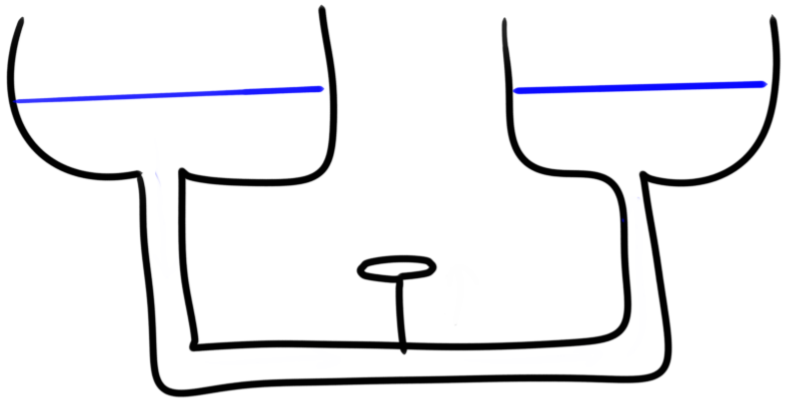
Open the valve.



Water flows from the left tank to the right.

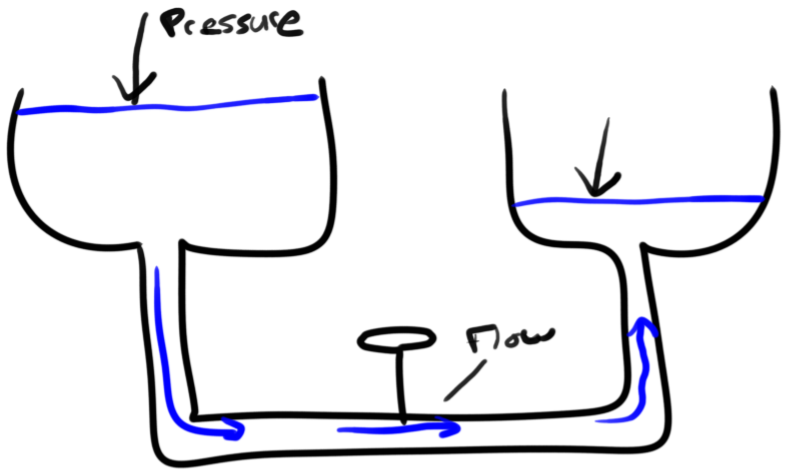


Until the water levels equalize.

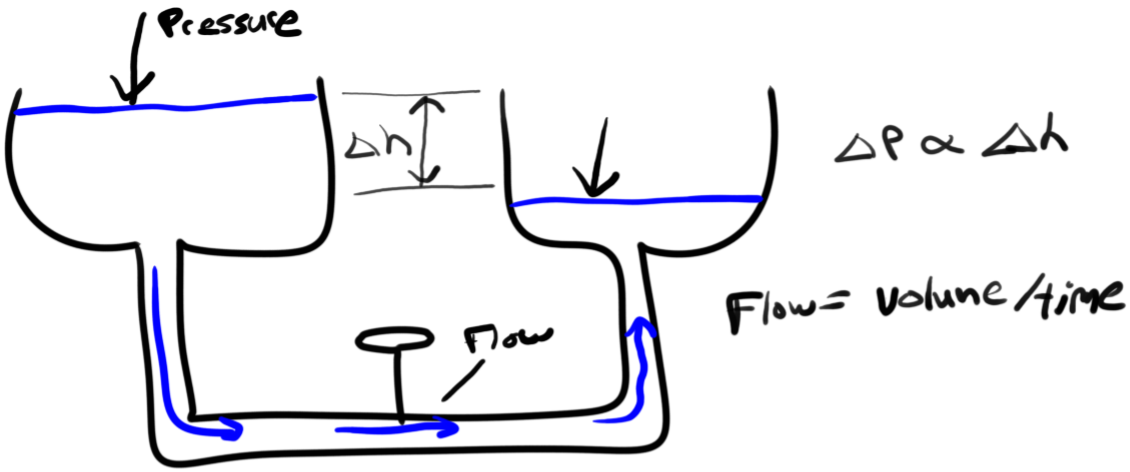


The flow stops.

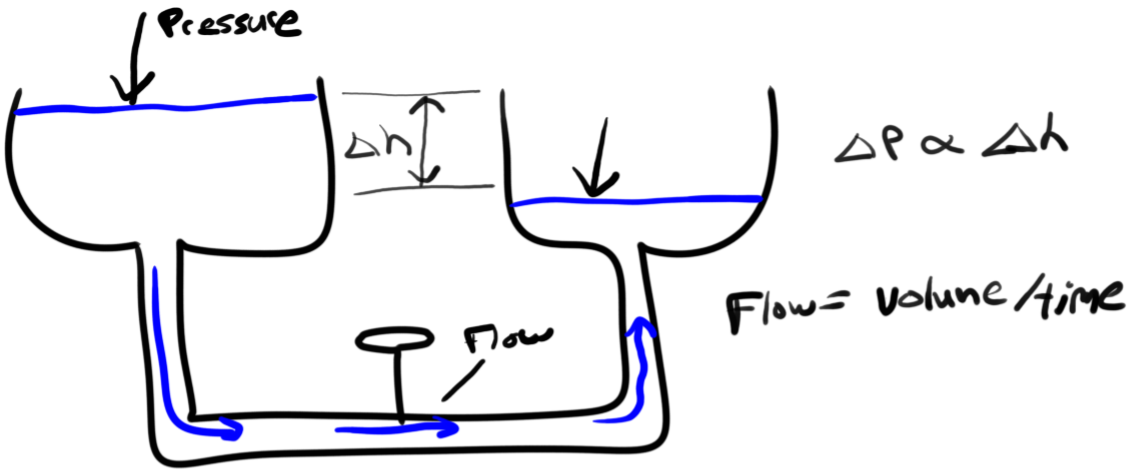
Why did the water flow?



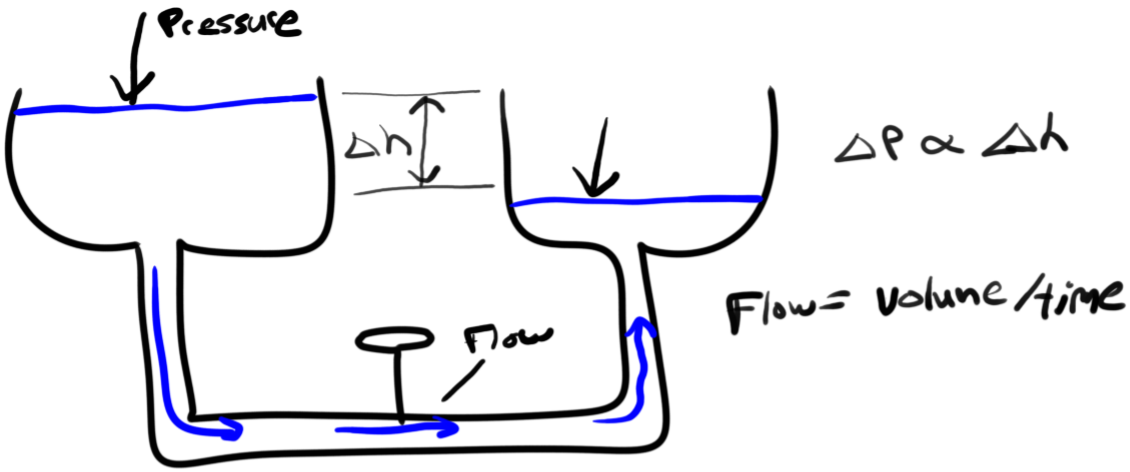
There is pressure (due to gravity) on both tanks.



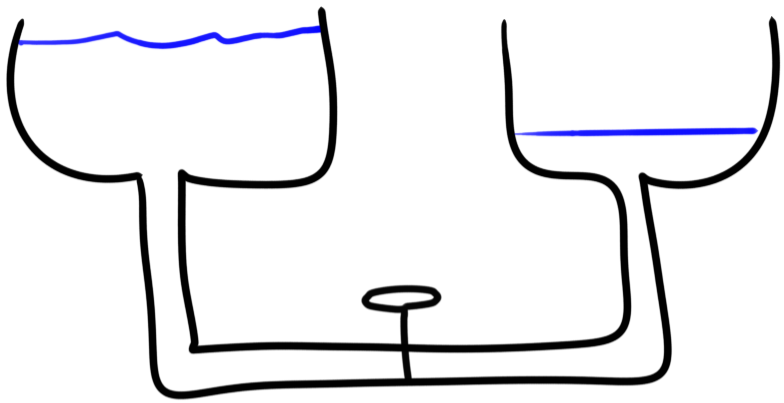
There is pressure (due to gravity) on both tanks.
But the pressure is greater on the left side than on the right.

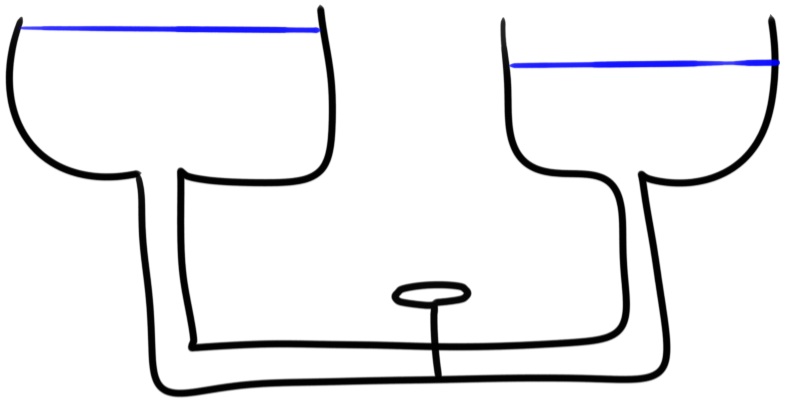


There is pressure (due to gravity) on both tanks.
But the pressure is greater on the left side than on the right.
So where there is a difference in pressure, which would be proportional to the difference in height, we have flow.

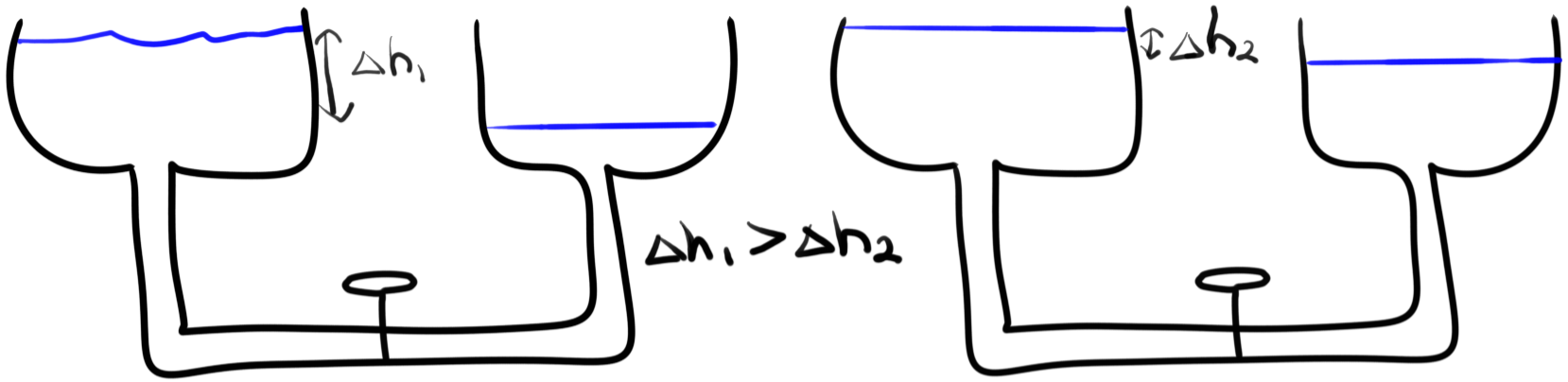


There is pressure (due to gravity) on both tanks.
But the pressure is greater on the left side than on the right.
So where there is a difference in pressure, which would be proportional to the difference in height, we have flow.
Flow is volume of water per unit time.

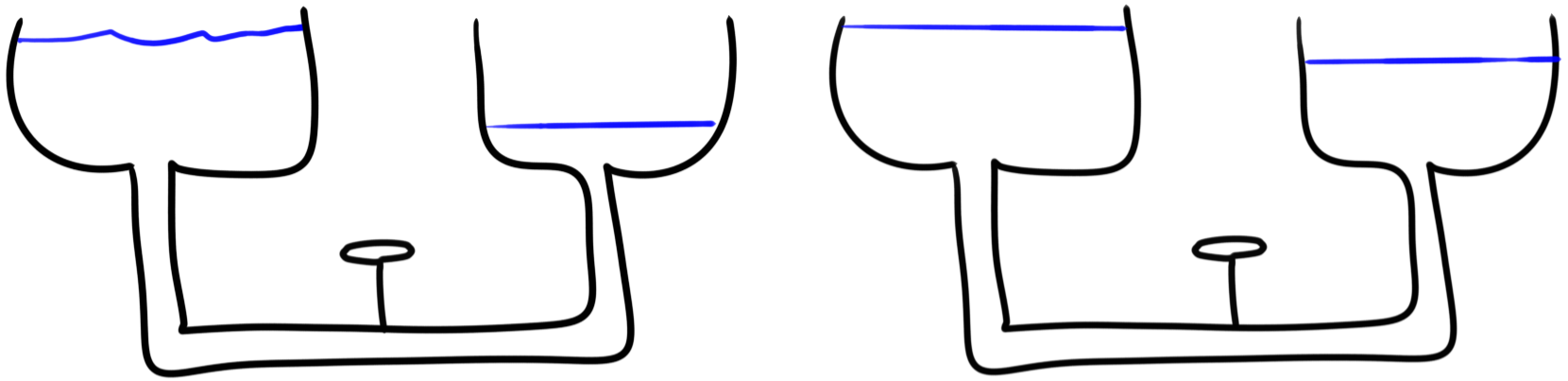




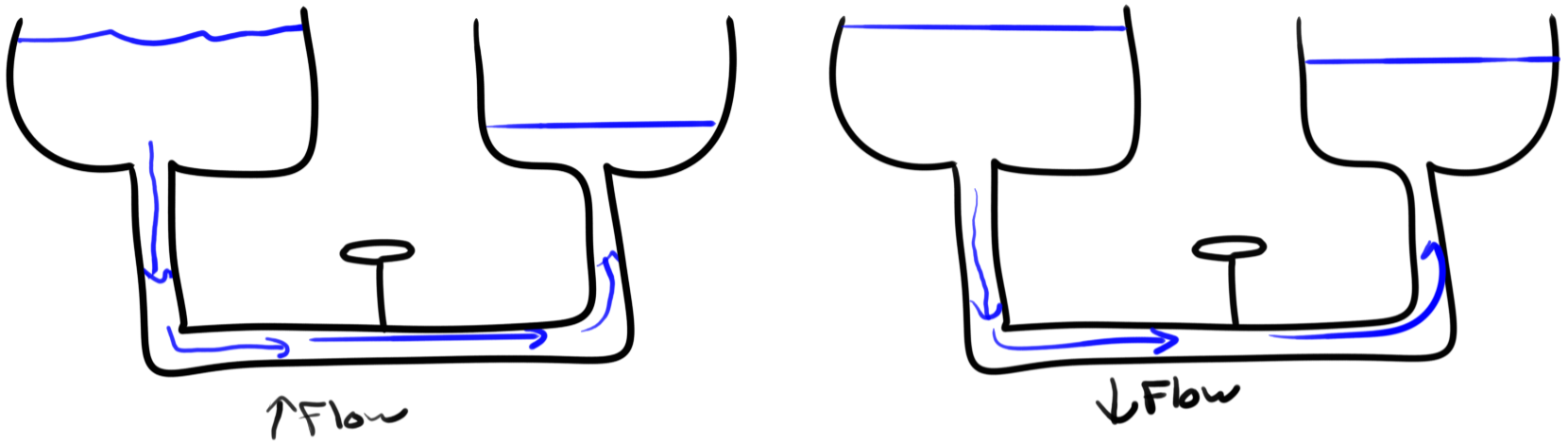
Add a second pair of tanks.



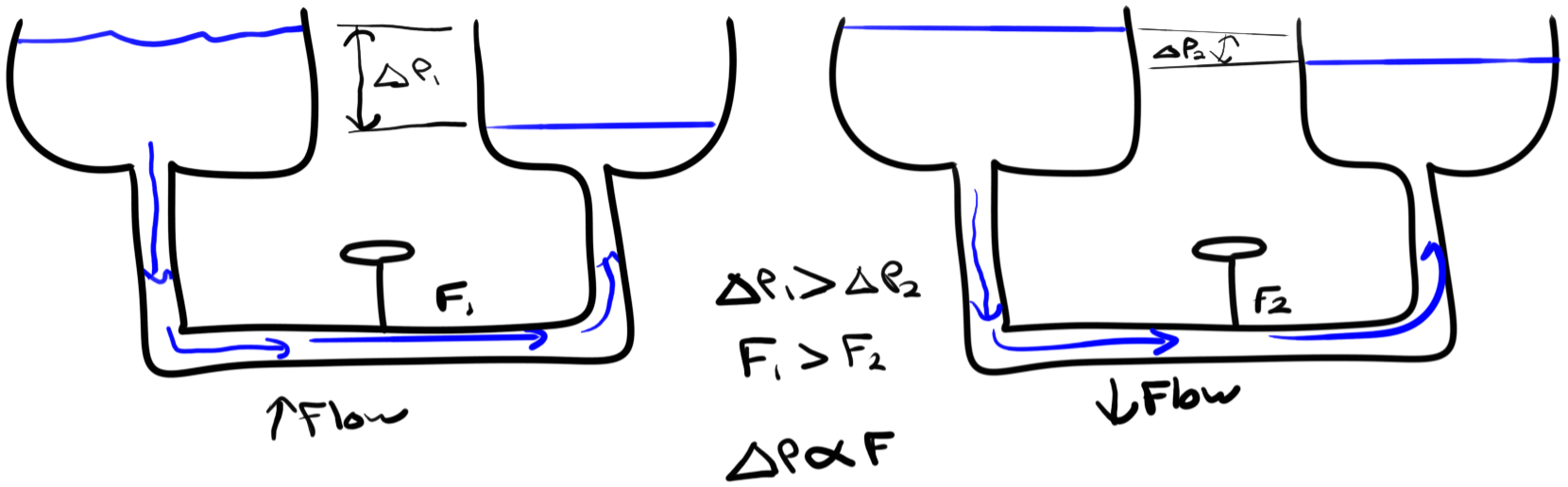
Add a second pair of tanks. But the left pair has a much greater difference in water level between the two than the right pair.



Open the two valves at exactly the same time. Will the flow (volume of water / time) be different?

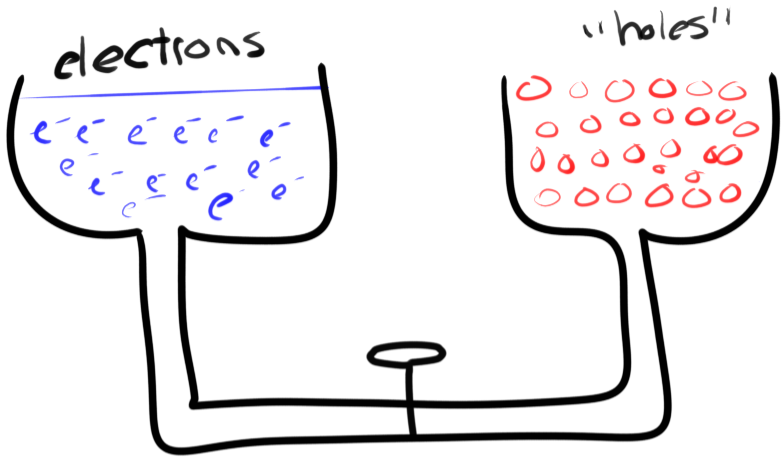


Greater flow where the difference in pressure was greater.

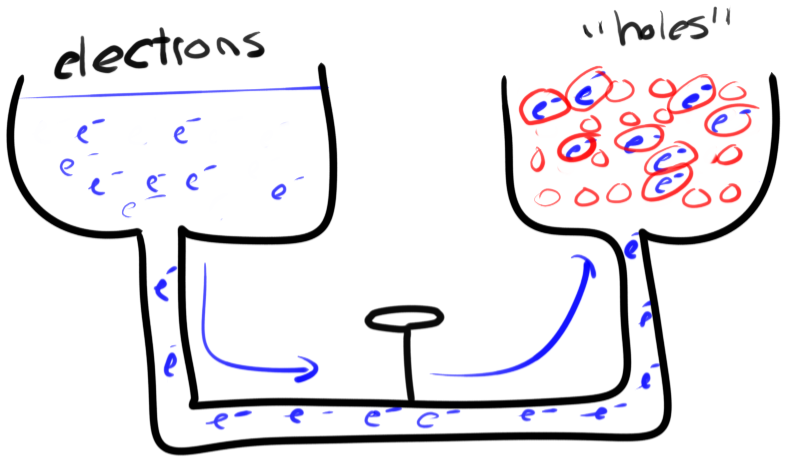


The difference in pressure is proportional to the flow.

What does this have to do with electronics?

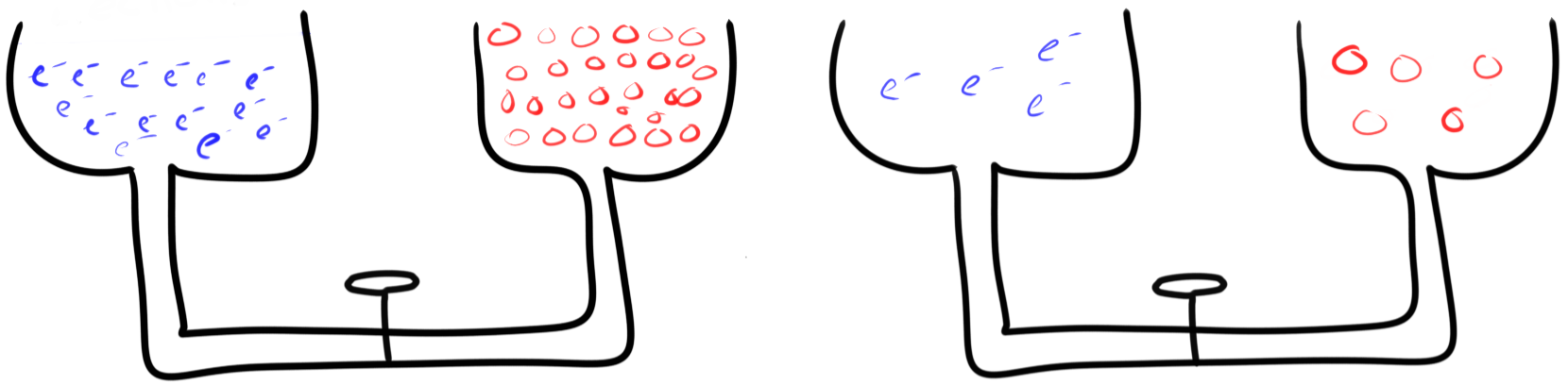


Back to the beginning. The water here is an analogy for electrons.
Electrons are charged particles.
An empty tank is an analogy for ”electron holes”.
An electron hole is a particle with an opposite charge of an electron, or simply ’a place an electron is attracted to.’

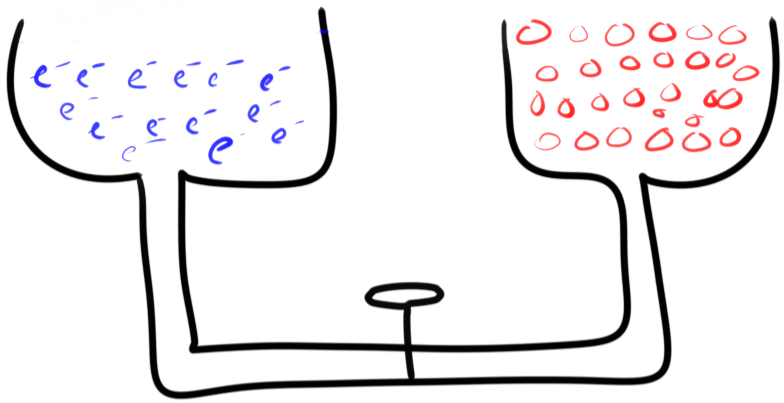


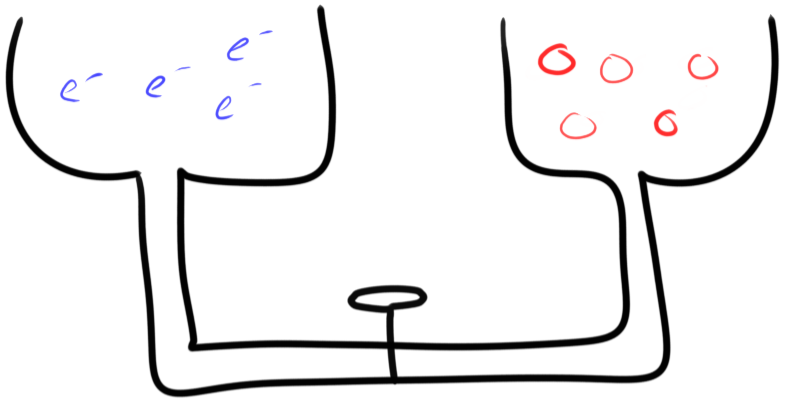
If we open the valve between the two tanks, electrons will flow — ‘ filling the holes’.

Like water, the electrons will flow until all of the available holes have been filled.



Two pairs of tanks.
On the left: lots of electrons on one side, lots of holes on the other.
On the right: fewer electrons and fewer holes.





e⁻ and ○ have opposite charge, so difference is

$n_{e^-} - -n_{\bigcirc}$

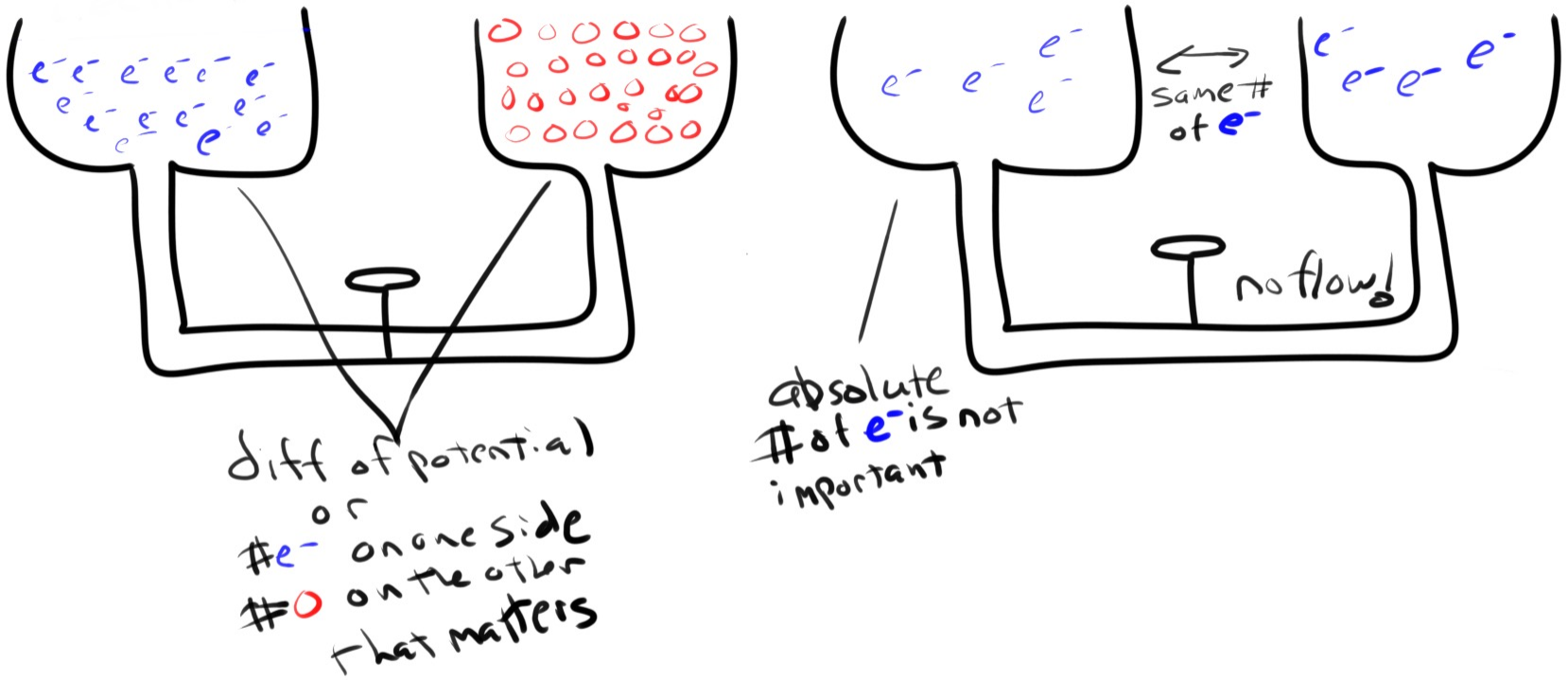
or

$n_{e^-} + n_{\bigcirc}$

As with water, we'd have higher flow on the left pair than on the right.

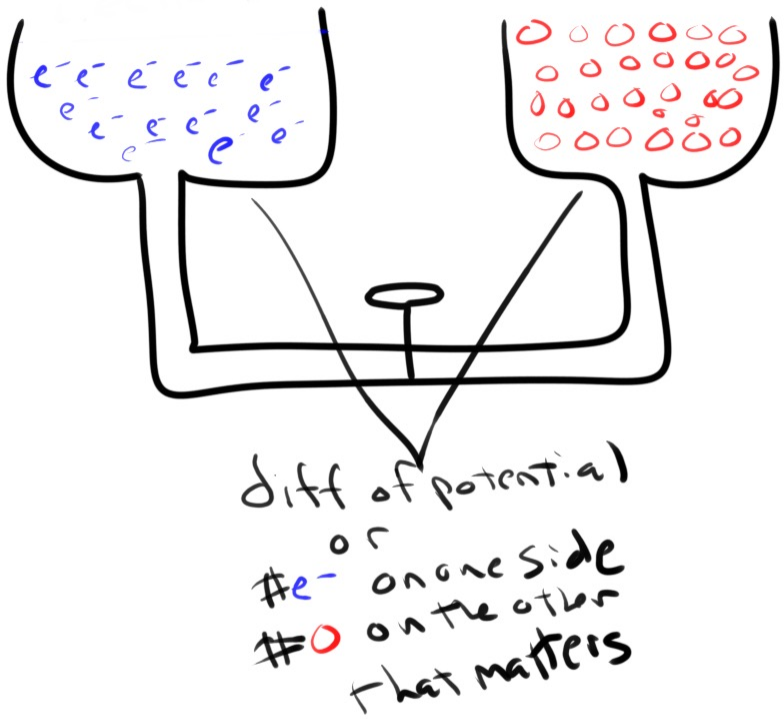
We're looking for the difference in charge between the two sides, or the number of electrons on one side, and the number of holes on the other.

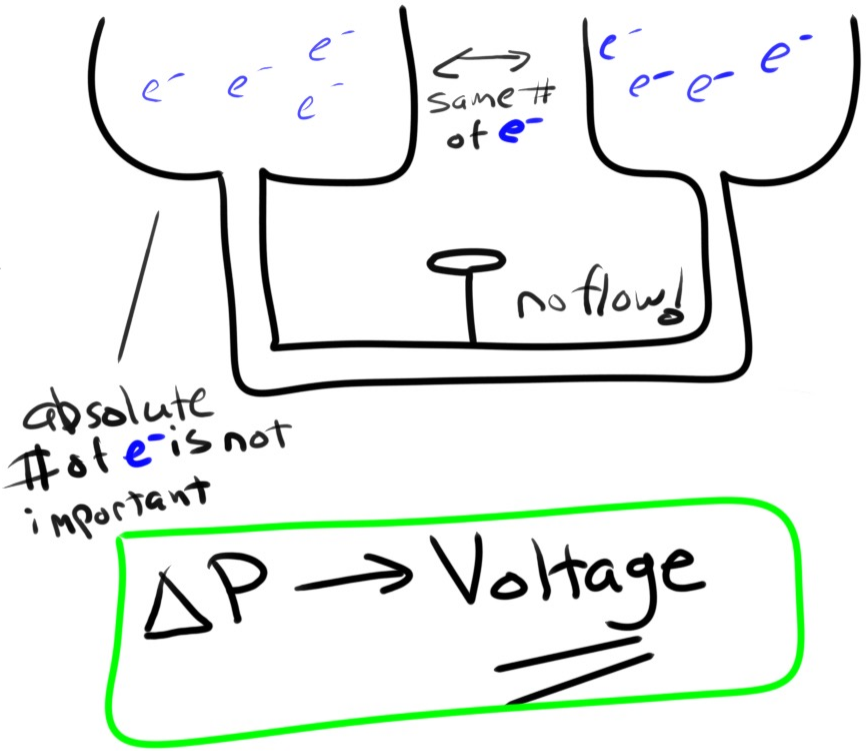
That is the analogy to the difference in pressure.



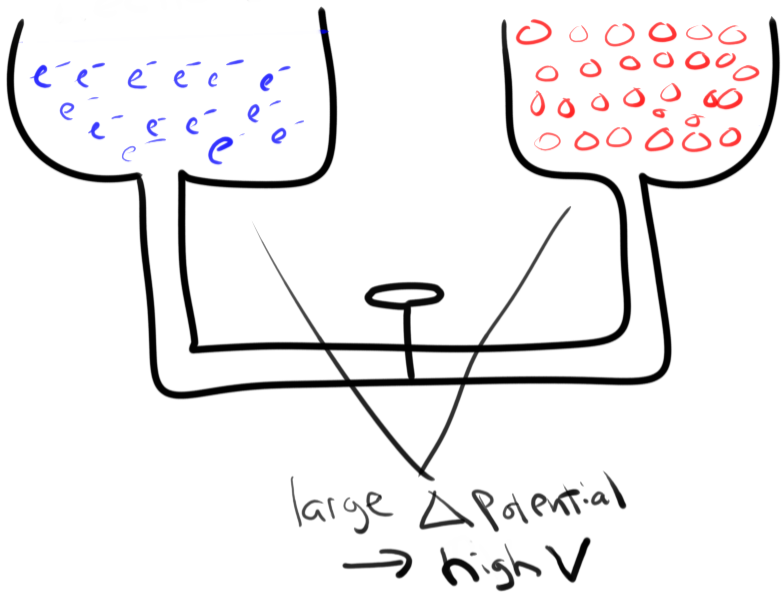
We call that a difference of *potential* – electrical potential refers to the ability of the electrons to do work for us.

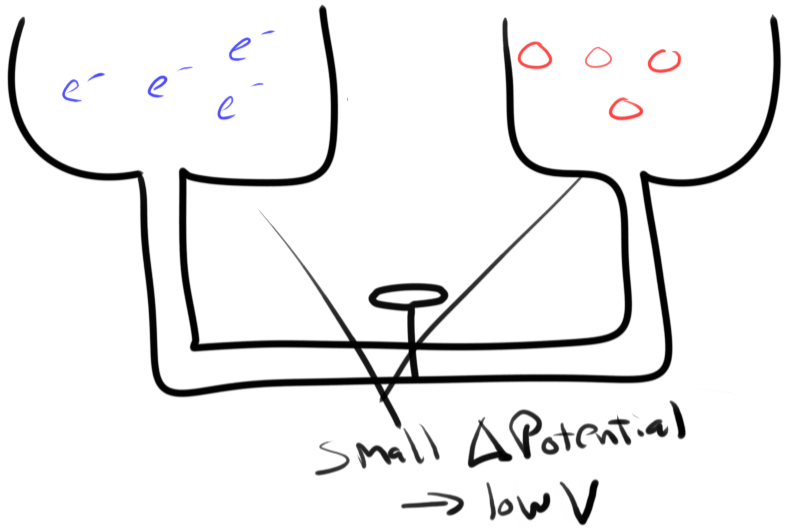
As with water pressure, it's the difference that allows the electrons to flow. If there is the same number of electrons in both connected tanks, there is no flow.



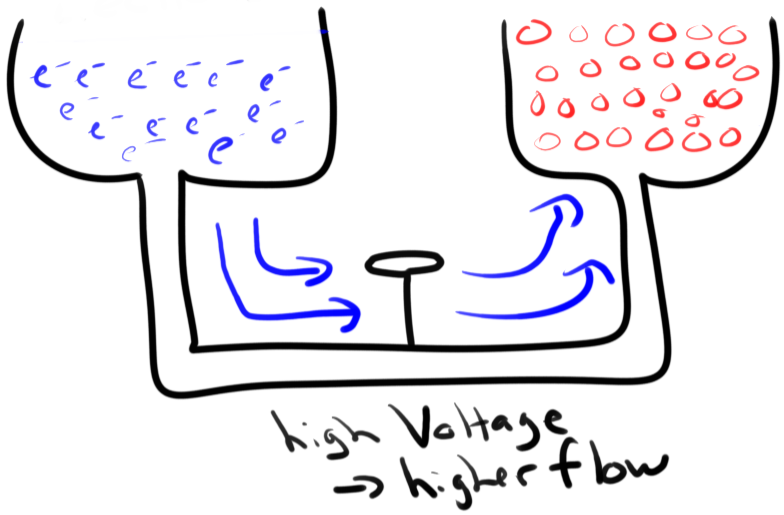


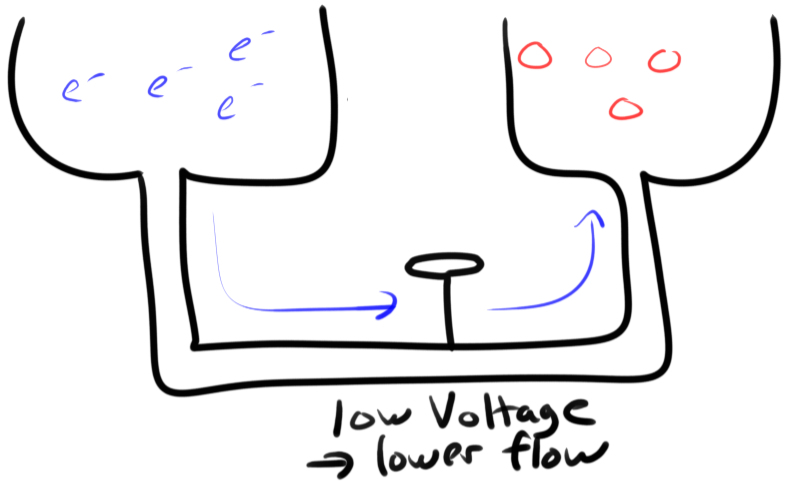
The analogy to the difference in pressure is what we call **VOLTAGE.**



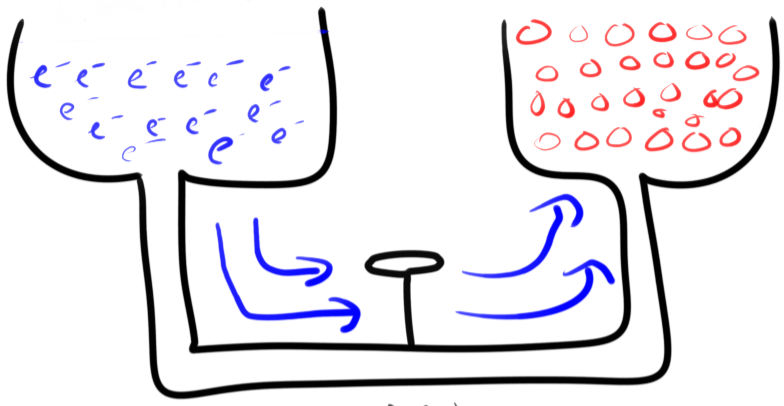


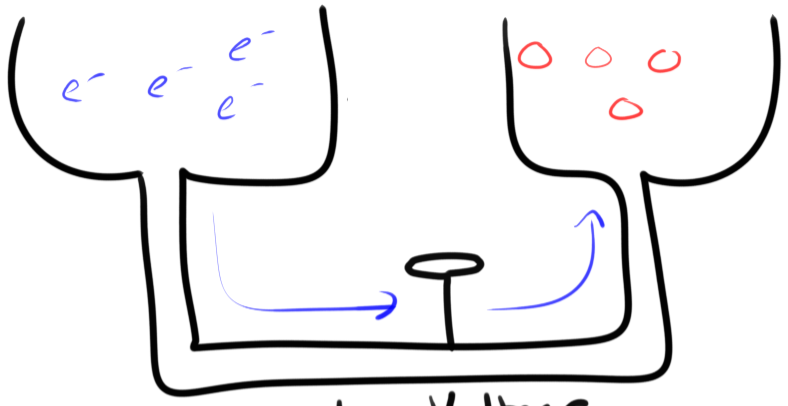
We call the difference in potential between adjacent tanks **VOLTAGE**.
Voltage is always a relative quantity.
It is the potential of one point in the circuit *RELATIVE* to another point.
In this case, it is the potential of the tank of electrons, relative to the attached tank of holes.





As with water, when we have higher voltage, we have greater flow.



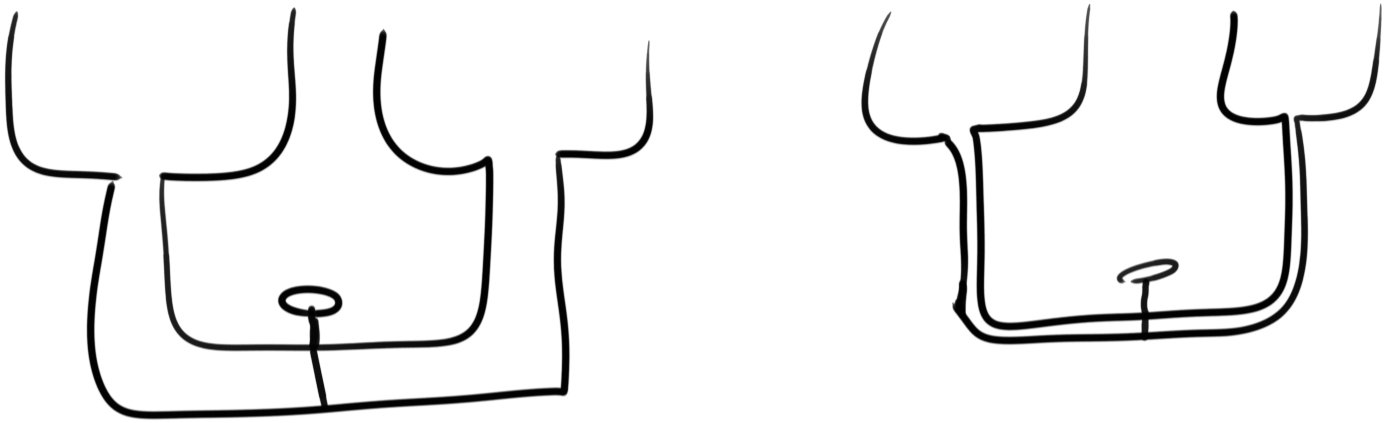


"Flow" → Current

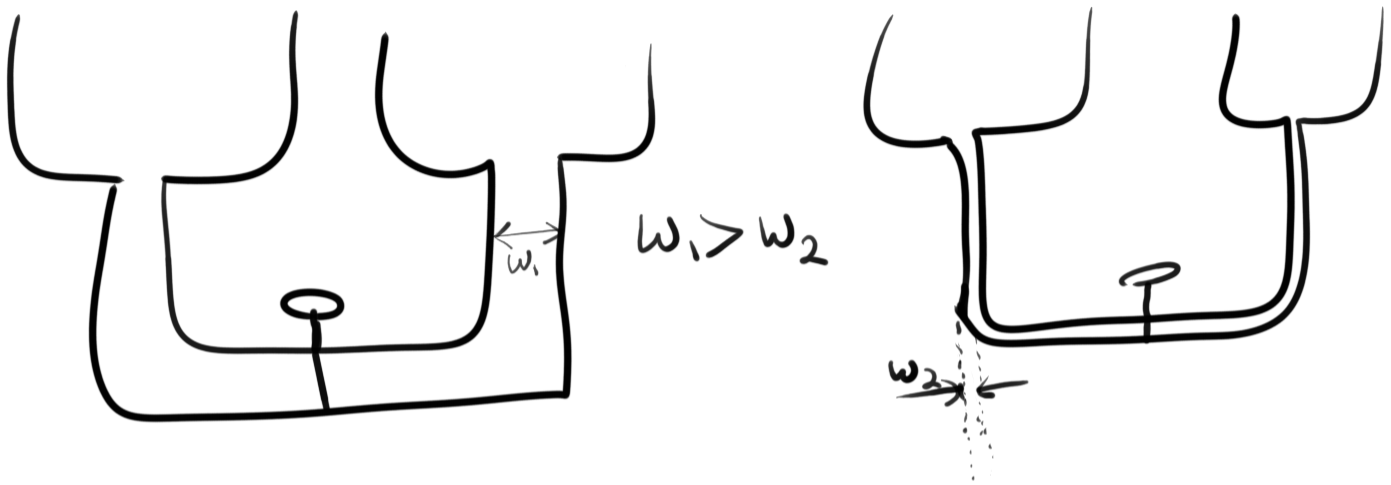
In electricity, what we've been calling flow, is called **Current**.
But we say "current flows" or "flow of current."

ELECTRICAL PROPERTIES

Property	Symbol	Units	Unit Symbol
Voltage	V	Volts	V
Current	I	Amperes	A

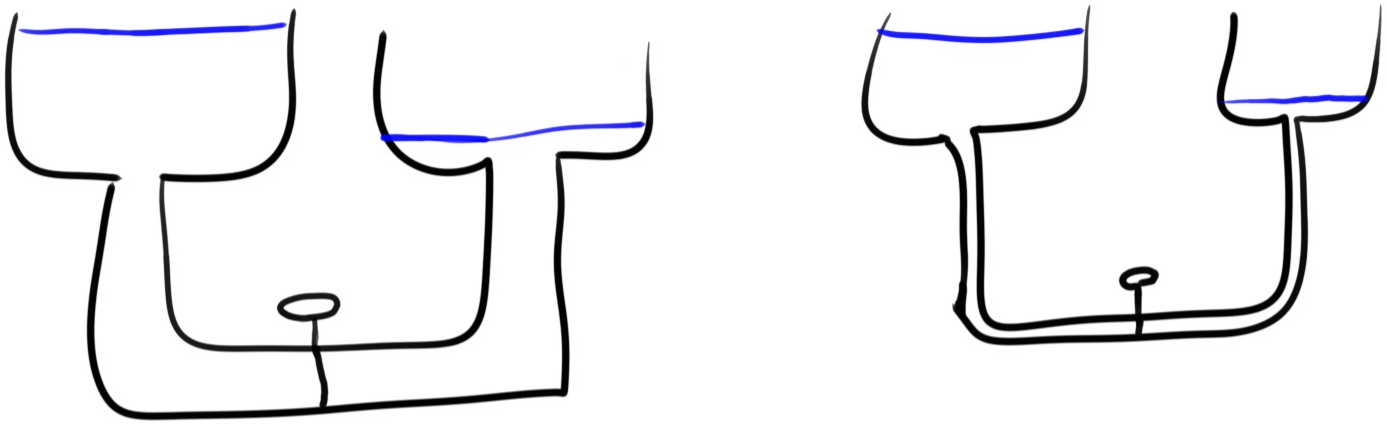


2 pairs of water tanks

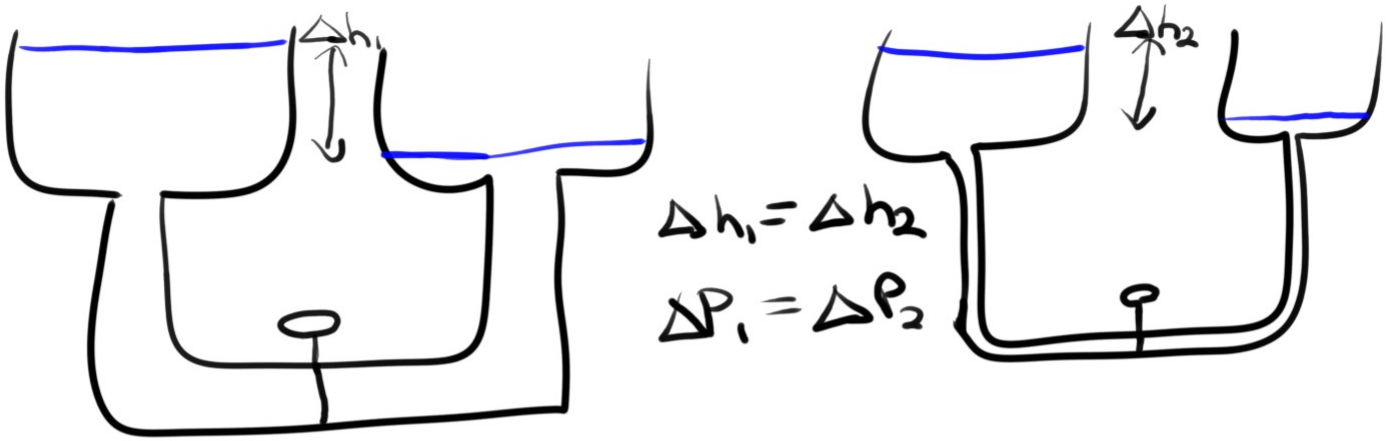


Assume the tanks hold the same volume, but the pipe connecting them is different.

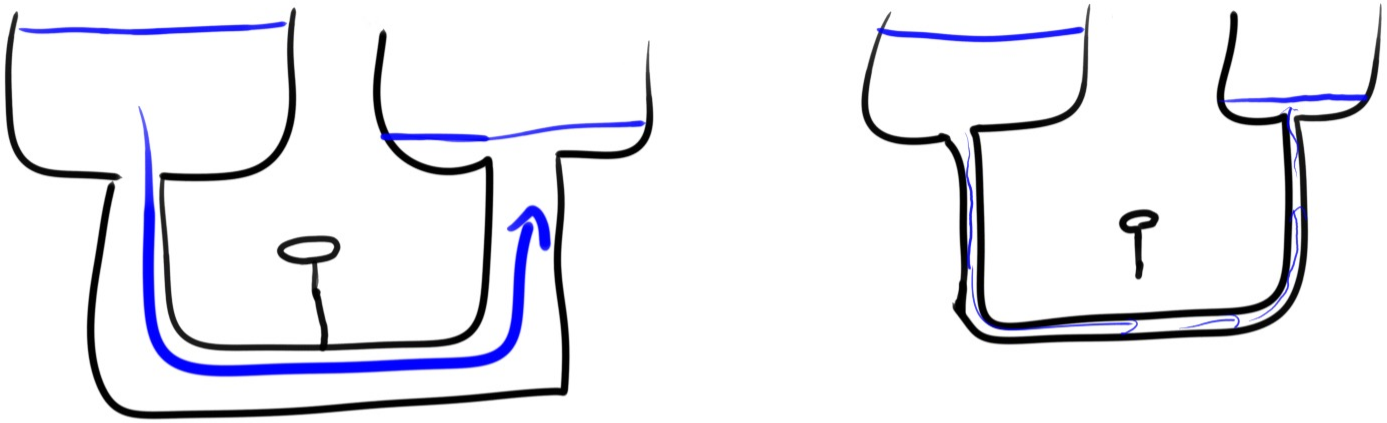
The pipe connecting the pair on the left is wide.
The pipe connecting the pair on the right is narrow.



Fill the two pairs so there is the same amount of water in the two lefthand tanks, and the same amount in the two righthand tanks.

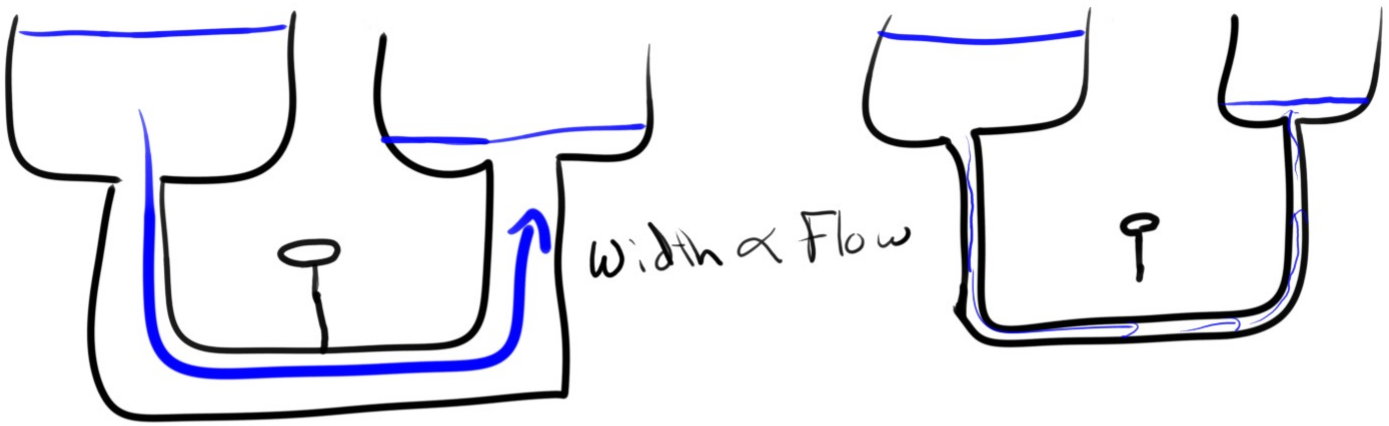


In other words, the pressure differential is the same in each pair.

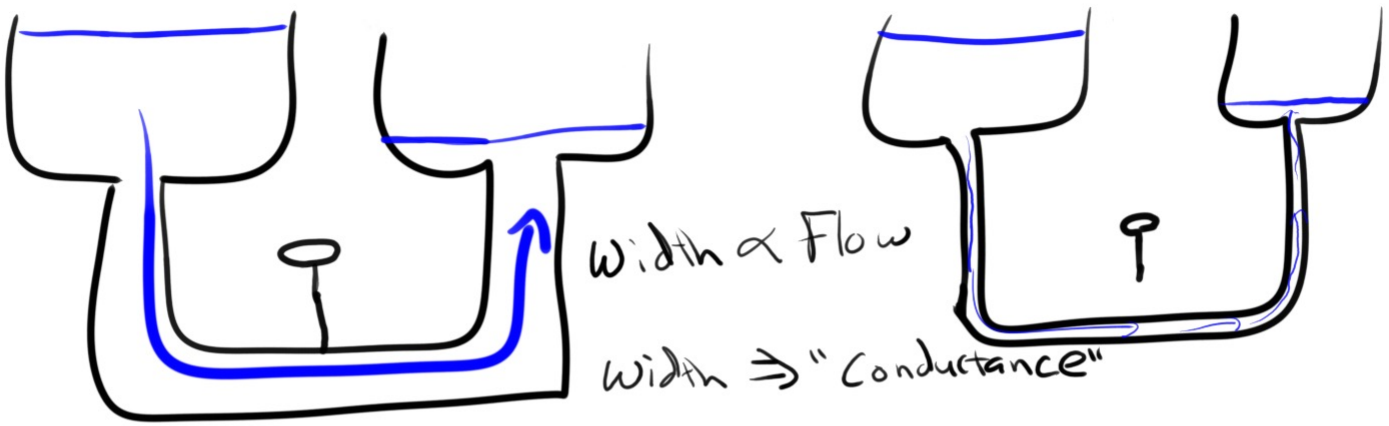


When we open the valves, we get greater flow in the pair with the bigger pipe.

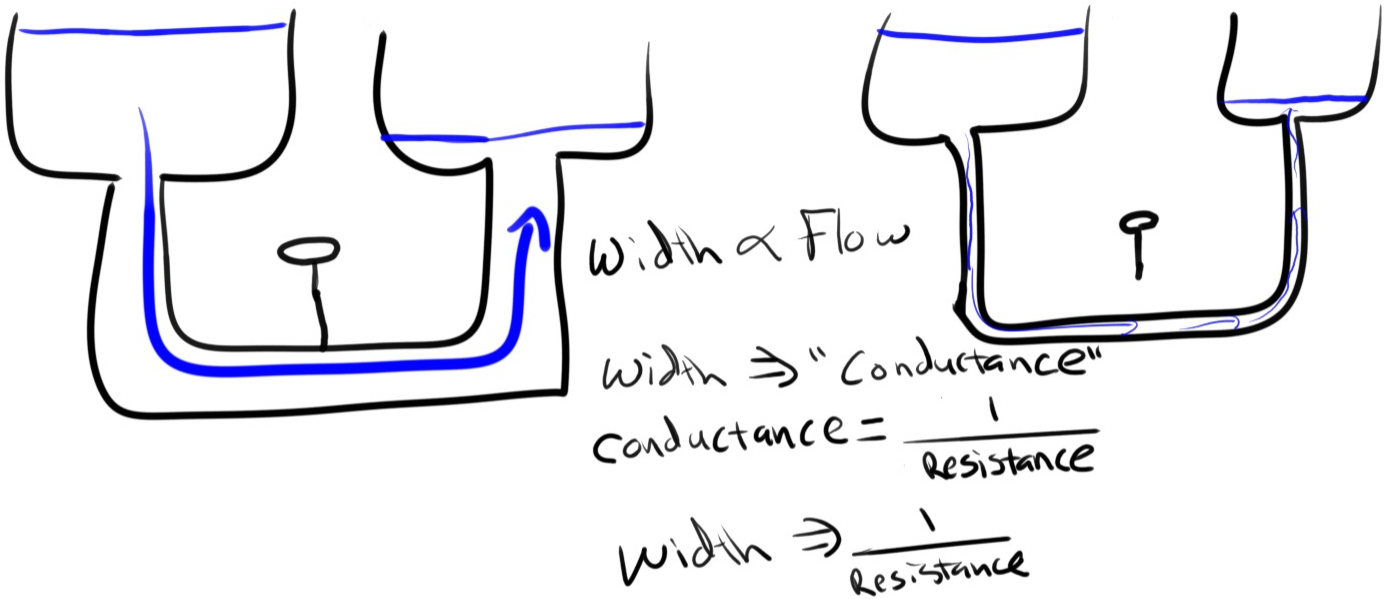
Less flow in the pair with the narrow pipe.



We can say that the width of the pipe is proportional to the flow.



In electrical terms, we can think of the pipe width as “conductance”: how easily the pipe will conduct electricity, or allow electrons to flow.



We don't usually talk about conductance in electricity though.

We talk about the inverse of conductance which is **Resistance:** how much the pipe impedes the flow.

ELECTRICAL PROPERTIES

Property	Symbol	Units	Unit Symbol
Voltage	V	Volts	V
Current	I	Amperes	A
Resistance	R	Ohms	Ω

Putting it all together, we get
Ohm's Law

"Ohm's Law"

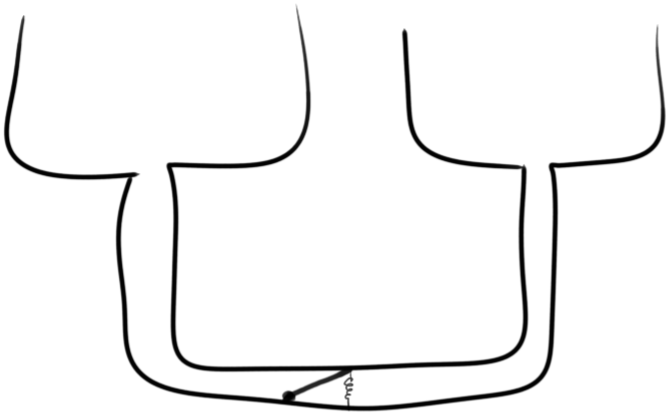
In practical terms:

For a given **Voltage:**
Higher resistance will mean lower current.

Lower resistance will mean higher current

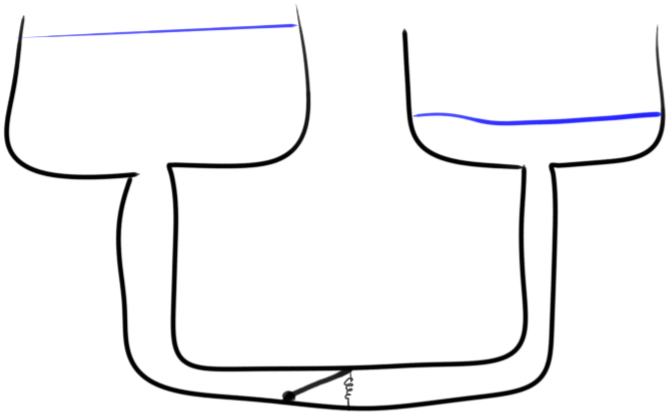
For a given **Resistance:**
Higher voltage would result in higher current.

Lower voltage would result in lower current.

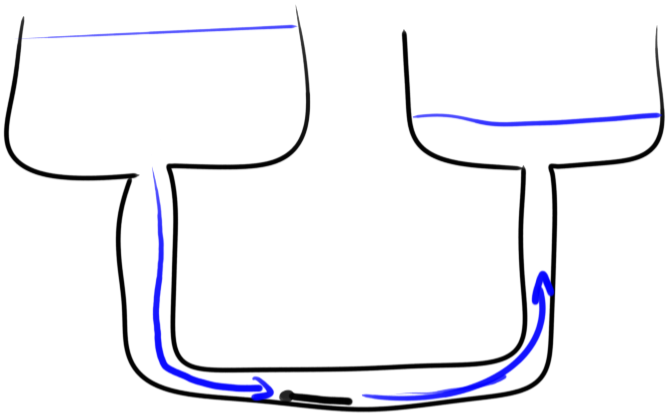


Imagine a component that looks like this:

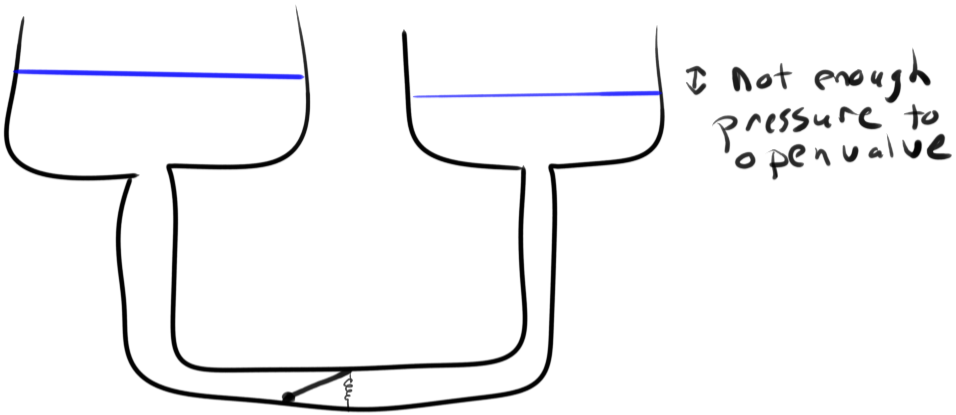
A directional valve in the pipe with a spring holding it shut.



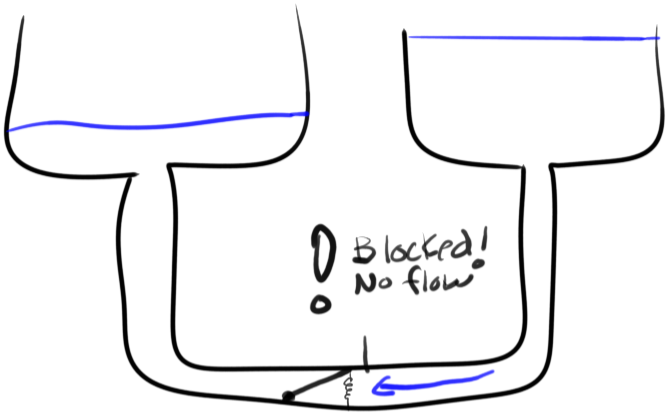
If we have sufficient pressure difference,



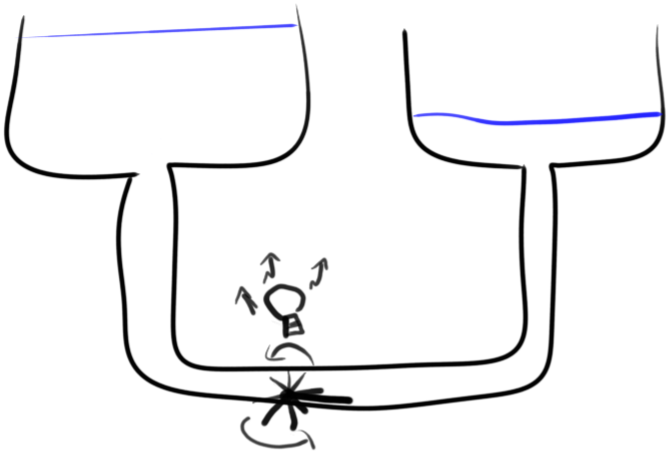
If we have sufficient pressure difference, the flow will push the valve all the way open, and water will flow through.



But if the pressure difference is too small, there isn't enough pressure to open the valve. So there is no flow.



The valve only allows the water to flow one way. If the pressure difference is reversed, the valve remains shut.



(this isn't a great sketch)

Now imagine a situation where there is a little water wheel attached to the valve. When opened, the water wheel powers a little light bulb.

The more flow there is, the more power to the light bulb, and the brighter it gets.

Components

Components

Resistors

Components

Resistors

Diodes

Components

Resistors

Diodes

Switches

Resistors

RESISTORS

Resistor

RESISTORS

Resistor

Not directional.
Think about the pipe. Water can flow either way just as easily.
(Flip the symbol over and it's the same)

RESISTORS

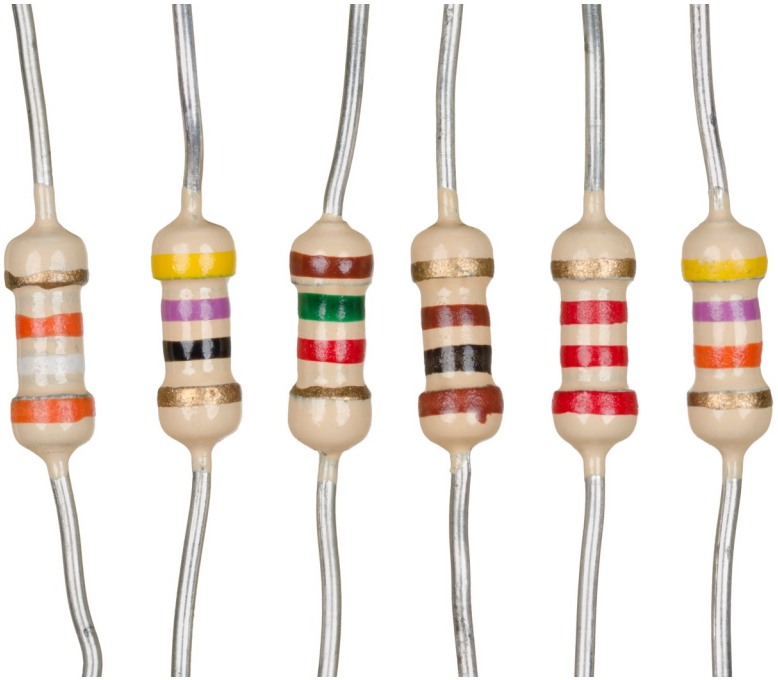
Resistor

Indicate resistance value above

Resistances 1000Ω and above are normally abbreviated:

2,200Ω = 2.2kΩ
22,000Ω = 22kΩ
222,000Ω = 222kΩ
2,200,000Ω = 2.2MΩ

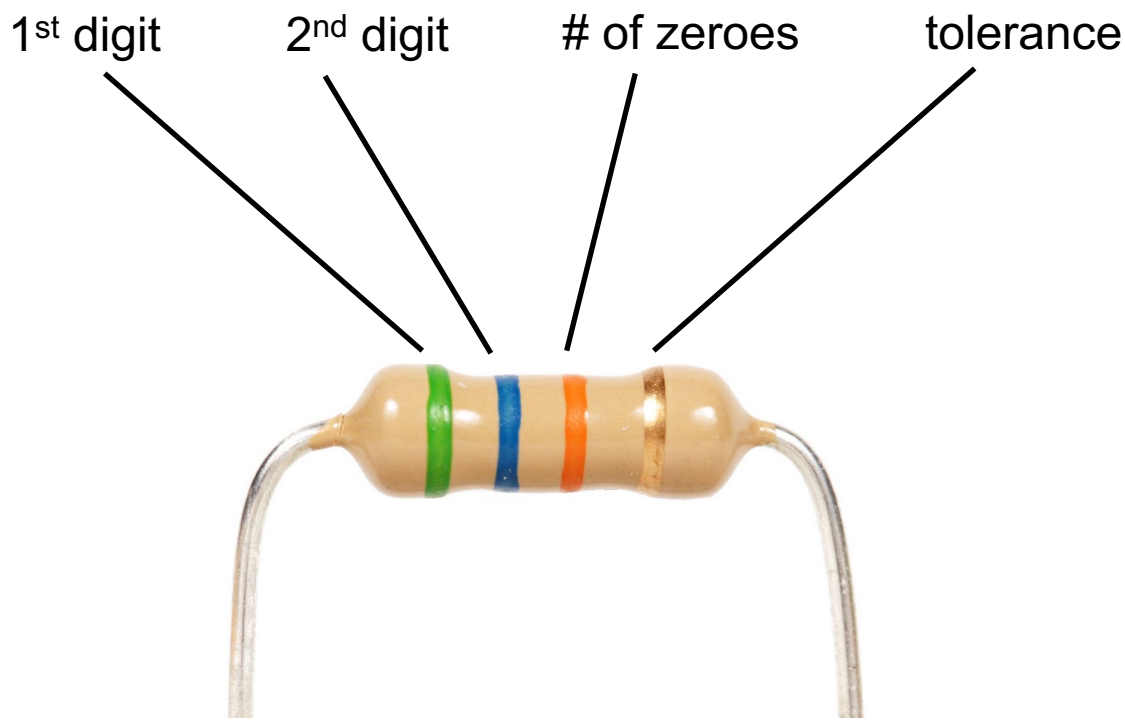
RESISTORS



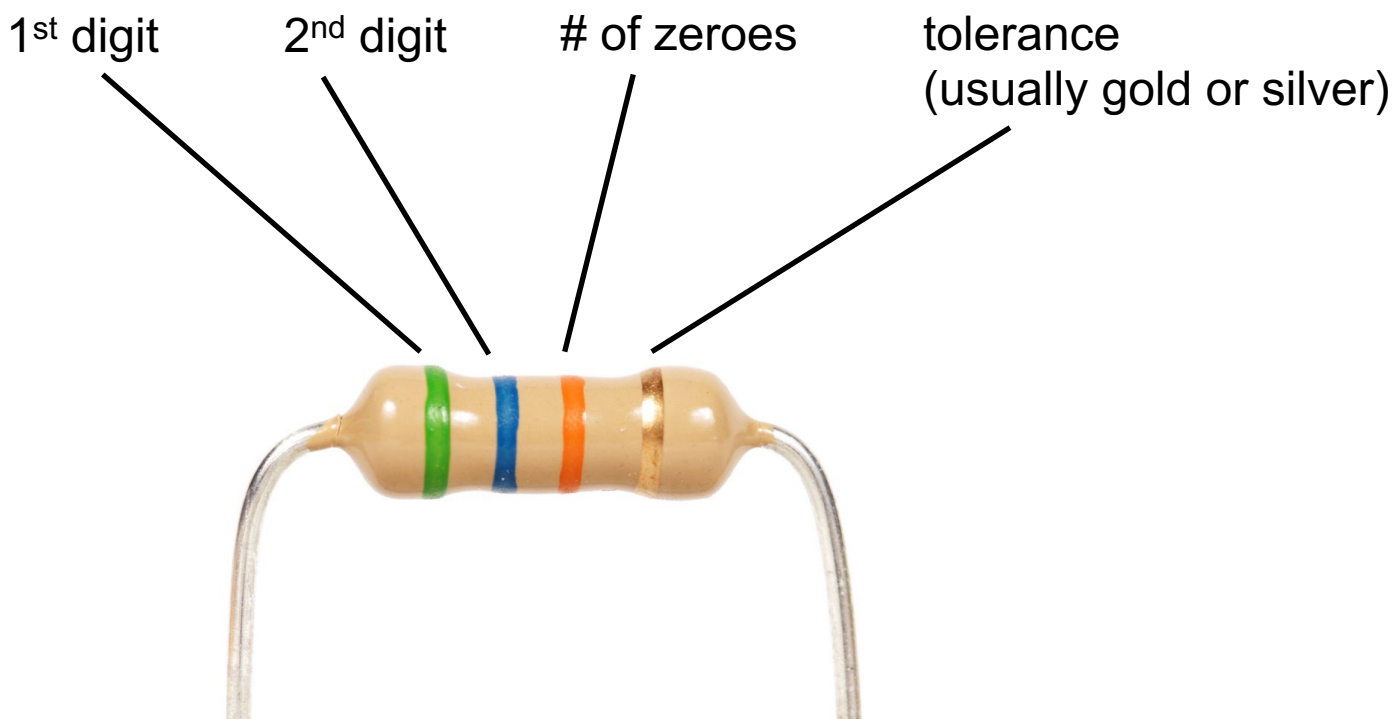
RESISTORS

Color code tells the resistance.
Most resistors we use have 4 bands.

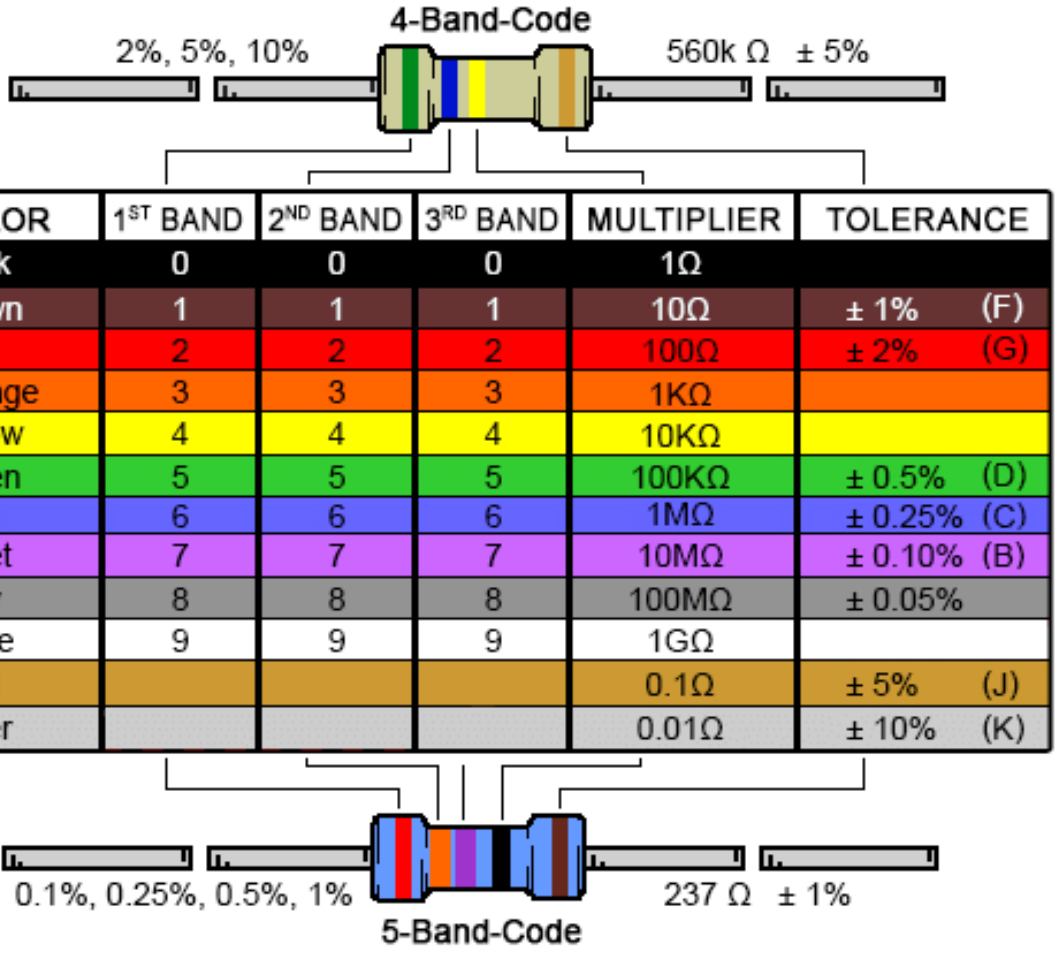
RESISTORS



RESISTORS


1st digit
2nd digit
# of zeroes
tolerance
(usually gold or silver)

RESISTORS



COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8	100MΩ	± 0.05%
White	9	9	9	1GΩ	
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code-4-band

DIODES

DIODES

Diode

Light emitting
Diode (LED)

DIODES

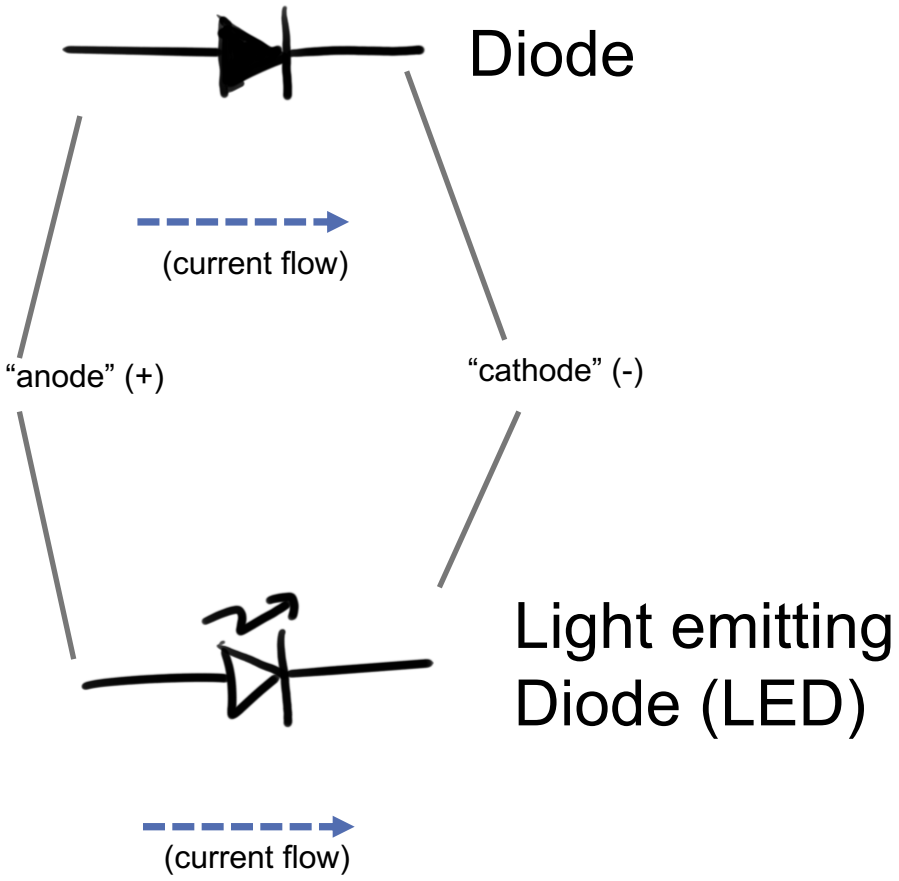
Diode

(current flow)

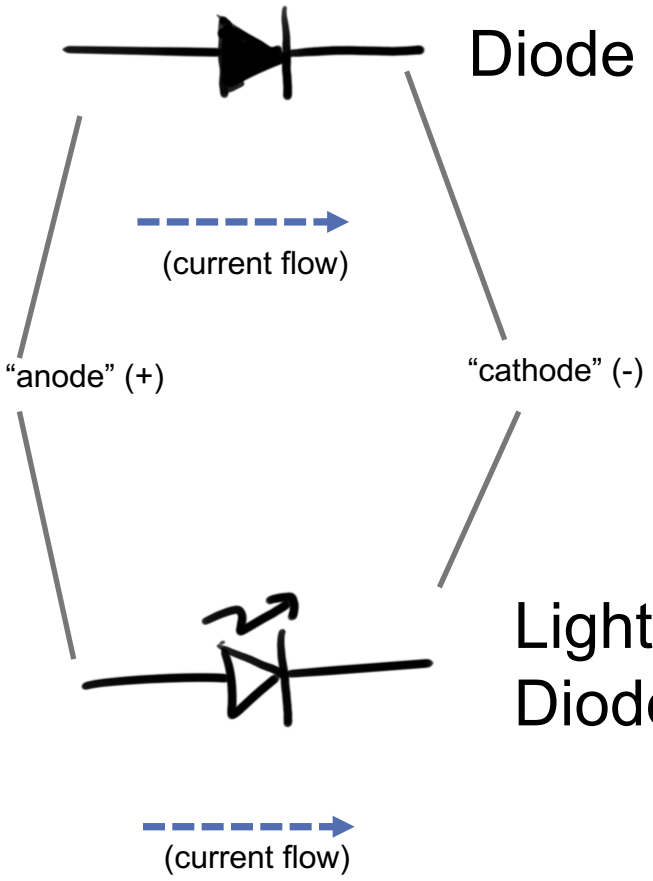
Light emitting Diode (LED)

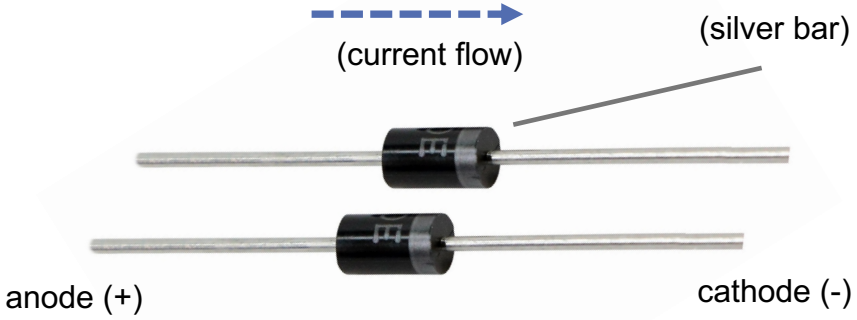
(current flow)

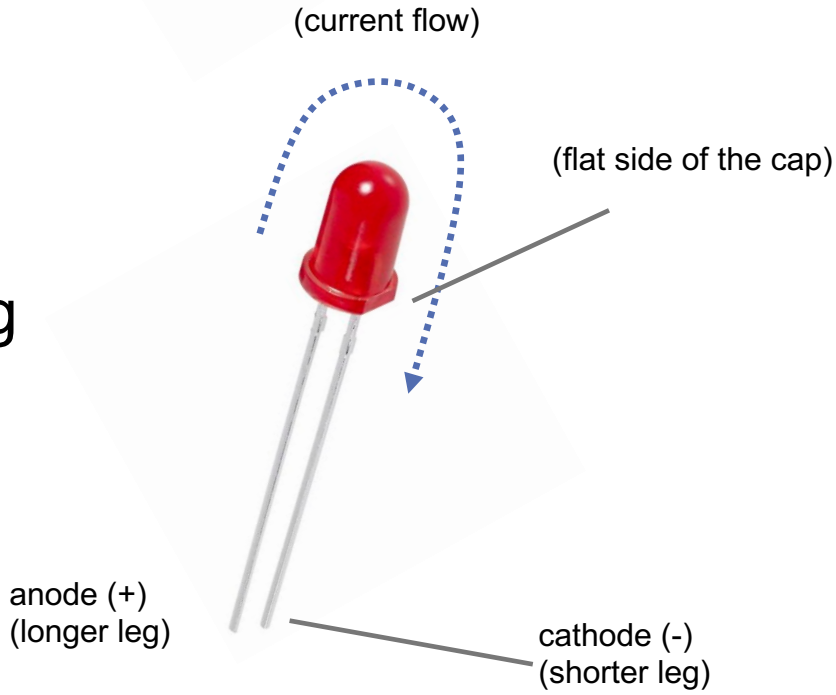
DIODES


Diode
(current flow)
“anode” (+)
“cathode” (-)
Light emitting
Diode (LED)
(current flow)

DIODES

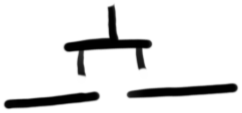

Diode
(current flow)
“anode” (+)
“cathode” (-)
Light emitting
Diode (LED)
(current flow)


(current flow)
(silver bar)
anode (+)
cathode (-)


(current flow)
(flat side of the cap)
anode (+)
(longer leg)
cathode (-)
(shorter leg)

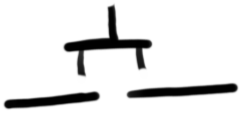
Switches

SWITCHES



Pushbutton Switch

SWITCHES



Pushbutton Switch

Technically:

Normally open, momentary switch

SWITCHES