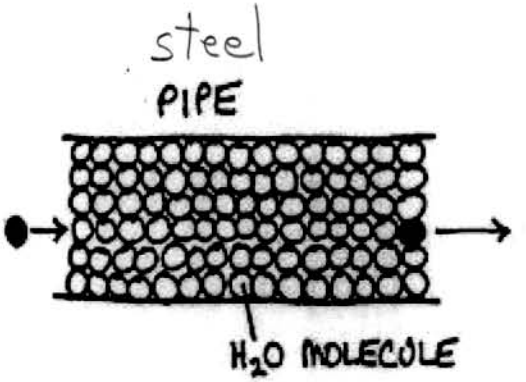
Engineers must be smarter than scientists, they need to invent what they study.

Electronics has produced the most complex artificial systems in the known universe

Only biological systems are more complex, and there, the electrical systems (nervous) are by far the most complex and miraculous.

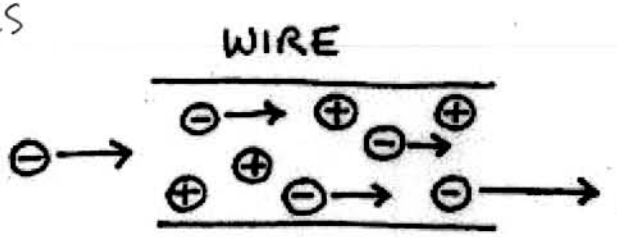
Practical Electronics requires the scientific method - debugging.

a physical quantity = a numerical value x a unit



usually written in italics

physical quantity
charge "Q"
current "I"



unit ← positive current

6.241×10^{18} electrons = -1 C (coulomb)

1A (ampere) or "amp" = $\frac{1\,C}{1\,sec}$

we have Benjamin Franklin to thank for the negative sign.

Water analogy

water – practically non compressible
wave travels at speed of sound
flow limited by (viscosity/turbulence)
flow roughly proportional to pressure

electrons– practically non-compressible
wave travels at ~ speed of light
flow limited by resistance, (bumping into atoms, not linear accelleration, more like terminal velocity)
flow roughly proportional to voltage (electrical "pressure")

no appreciable build-up of water or electrons anywhere.
practically non-compressible.

What is Voltage?

Luigi Galvani
Alessandro Volta
invented battery 1800
also frog's leg experiment
BioEngineer!
coins in mouth

Voltage is sometimes called
"electromagnetic force" (EMF)
or
"potential" (but not potential energy!!)

Voltage does have to do with energy...

physical quantity	unit
Energy, Work "W" * "E"	1 J (joule) = 1 N (Newton) × 1 M (meter) (like foot·pound)
Voltage "V"	1 V (volt) = 1 J / 1 C
Power "P"	1 W (watt) = 1 V × 1 A = $\frac{1\,J}{1\,C} \times \frac{1\,C}{1\,sec} = \frac{1\,J}{1\,sec}$

The voltage between 2 points is the energy required to move a certain amount of charge between them.

For practical electrical engineering, think about it as a pressure difference.

A single point can only have a voltage relative to some other point called "ground"

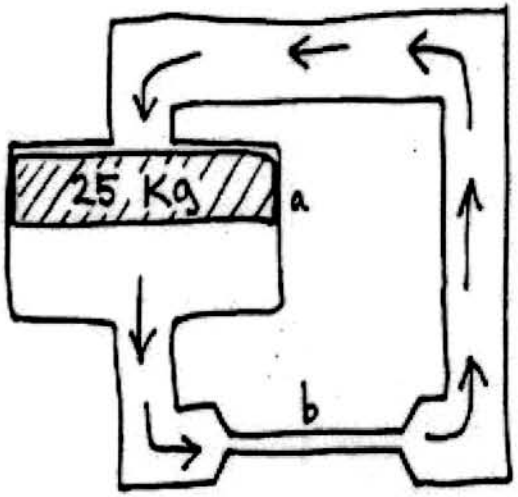
* confusion arises from letters used for physical quantities ("W" for work) and for units, ("W" for watts). "V" is used for both voltage and volts

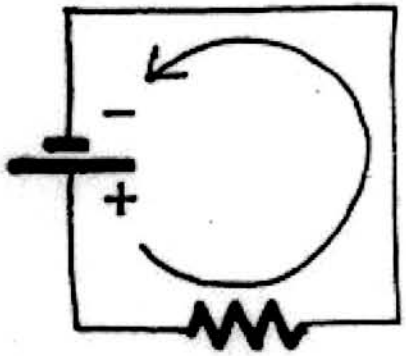
Ohm's Law

$$\frac{V}{R} = I \quad \leftarrow \text{more intuitive}$$

$$V = IR \quad \leftarrow \text{also true; "forcing" a certain current through the pipe}$$

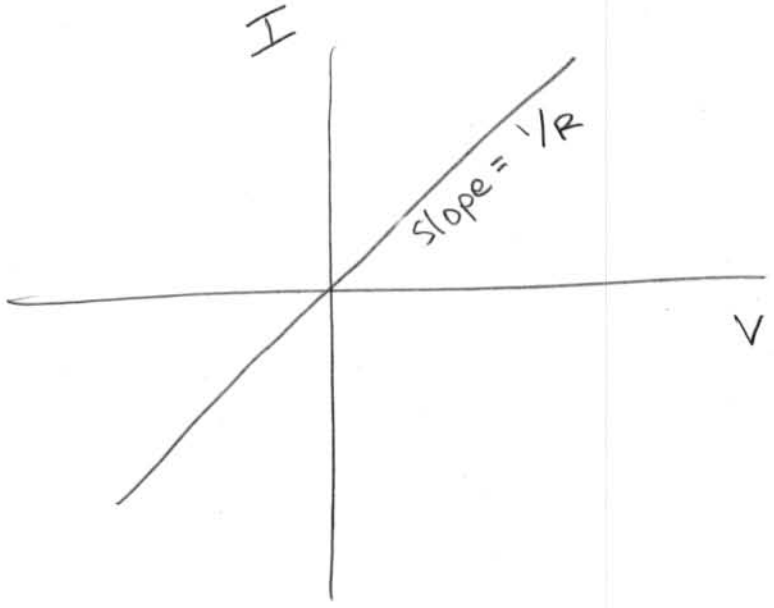
Ohm's Law is only an appoximation, and only for certain components, called "resistors." (but for them it is a very good approximation.)

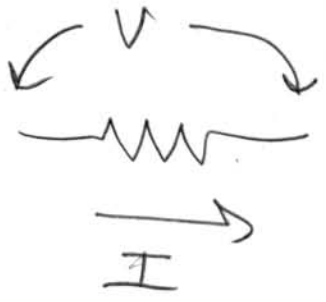




physical quantity	unit
resistance "R"	$1\,\Omega$ (ohm) $= 1\,V / 1\,A$
conductance "G"	$\frac{1}{1\,\Omega}$ (mho) $= 1\,A / 1\,V$

Ohm's Law assume a linear relationship.





Voltage can be constant, V
or it can vary with time, V(t)