Electronics is cool

- Electronics has produced the most complex artificial systems in the known universe.
- Only biological systems are more complex, and among them, electrical (nervous) systems are the most complex and miraculous.
- You can build your own, cheap!
- You learn a lot of math by understanding circuits, and a lot about the scientific method building and debugging them.

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Physical Quantities & Units

physical quantity = numerical value × unit

normally shown in *italics*

Physical Quantity	Unit
"Q" charge	C coulomb
"I" current	A ampere (amp)

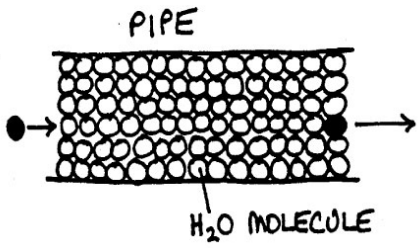
$6.241\times10^{18}\,\text{electrons} = -1\text{C}$

thank you Benjamin Franklin

$1\text{A} = \dfrac{1\text{C}}{1\text{sec}},\quad I = \dfrac{Q}{t}$

current, like gallons per second

Water Analogy



- Practically non-compressible; push one H_20 molecule in one end of steel pipe and one pops out the other end.
- Flow (current) limited by *viscosity* & *turbulence*.
- Pressure wave travels at ~ the speed of *sound*.
- Flow roughly proportional to *pressure*.

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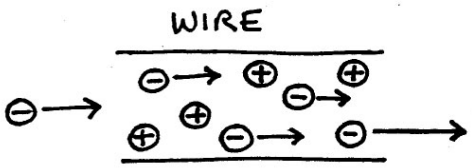
Electrons somewhat analogous



- Practically non-compressible - Nature really hates any buildup of *charge* in a small space.
- Flow (current) limited by *resistance* – bumping into atoms, not linear acceleration as in a vacuum, more like terminal velocity.
- Electric wave travels at ~ the speed of *light.*
- Flow roughly proportional to *voltage* – roughly equivalent to "electrical pressure".

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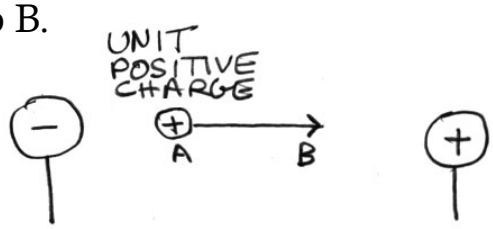
What is Voltage?

- Sometimes called *electromagnetic force* (EMF) (not really a force) or *potential* (but not potential energy, though it does have to do with energy)
- The voltage difference between points A and B is the energy required to move a unit positive charge from A to B.



- Moving from B to A produces the same voltage with an opposite sign.

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Physical Quantity	Unit
"*F*" force	N newton
"*E*" energy or "*W*" work	J joule
"*V*" voltage	V volt
"*P*" power	W watt

$$1\text{J (joule)} = 1\text{N (newton)} \times 1\text{M (meter)}$$

$$1\text{V (volt)} = 1\text{J (joule)} \;/\; 1\text{C (coulomb)}$$

$$1\text{W (watt)} = 1\text{V (volt)} \times 1\text{A (amp)} = \frac{1\text{J}}{1\text{C}} \times \frac{1\text{C}}{1\text{ sec}} = \frac{1\text{J}}{1\text{ sec}}$$

- Note confusion between *V* and V, as well as between *W* and W, especially when hand-written.

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- Voltage is energy per unit charge.
- For practical purposes, think about voltage as the pressure difference between two points, though this is not technically correct.
- A single point can only have a voltage relative to some reference point, often called the "circuit ground".
- Power is the brightness of the light bulb; energy is how much gas is in the tank of the generator.
- Power is energy per unit time.

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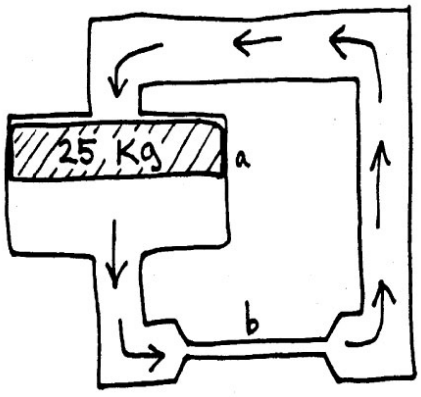
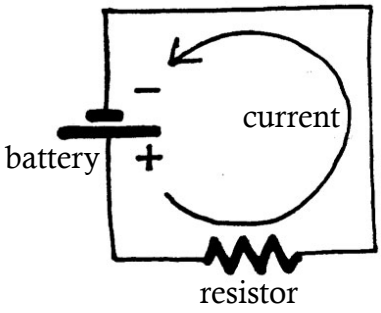
Ohm's Law





- Any good plumber understands it intuitively.
- Pressure source *a* pushes water through skinny pipe *b*.
- Pressure "drops" across skinny pipe (resistor).
- Note completed circle or "circuit", with big pipe (wire).

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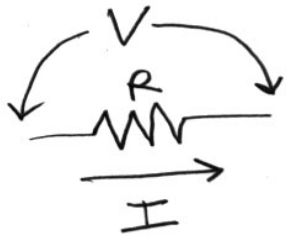
Ohm's Law



voltage *across* resistor
current *through* resistor

$\frac{V}{R} = I$ ⟵ more intuitive, given a voltage and a resistance, you get a current.

$V = IR$ ⟵ also true; "forcing" a certain current through the pipe generates a "pressure drop".

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