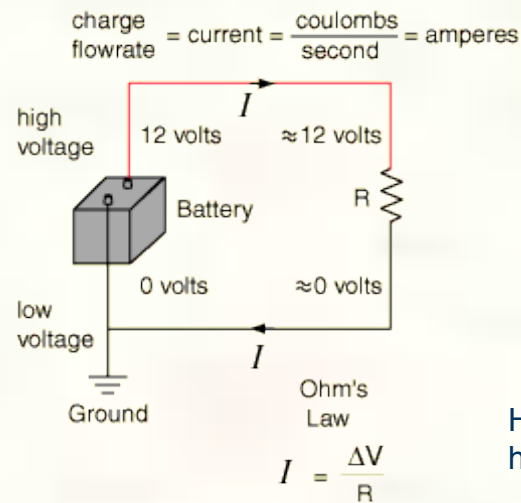
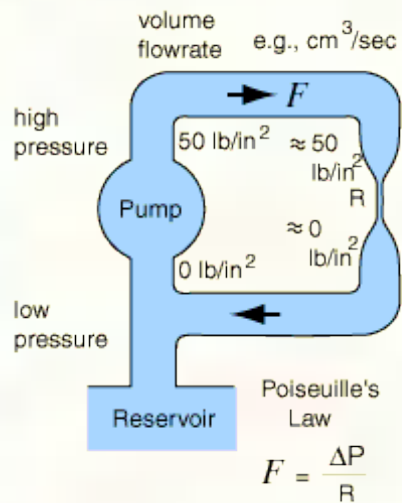


Ohm's Law and CMOS Transistors



Simple electronics

- Ohm's Law - $V = IR$
 - voltage (V) equals current (I) times resistance (R)
- Hydraulic Analogy
 - Charge \Rightarrow liquid
 - Current \Rightarrow flow rate
 - Voltage \Rightarrow water pressure
 - Resistance \Rightarrow related to length and radius of pipe (kL/r^4)



Hydraulic pictures from
<http://hyperphysics.phy-astr.gsu.edu>

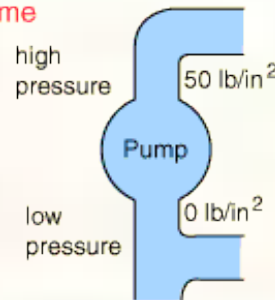



Hydraulic analogy

■ Voltage \Rightarrow water pressure

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

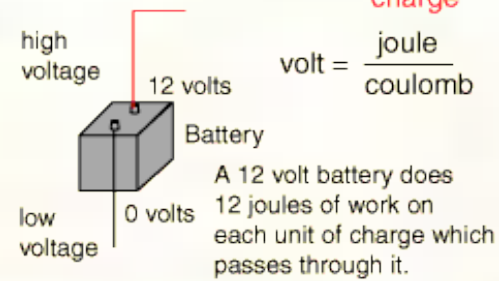
$$\begin{aligned} \text{pressure} &= \frac{F}{A} \\ \frac{F}{A} &= \frac{F d}{A d} = \frac{W}{V} \\ &= \frac{\text{energy}}{\text{volume}} = \frac{\text{joule}}{\text{m}^3} \end{aligned}$$




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

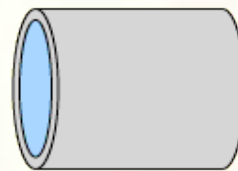
$$\text{voltage} = \frac{\text{energy}}{\text{charge}}$$

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

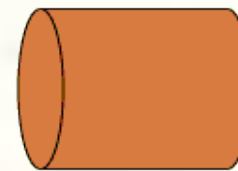


 A receptacle has voltage behind it, but no current if nothing is plugged in. (resistance $\rightarrow \infty$)

■ Current \Rightarrow flow rate



Volume flow rate in m^3/sec , etc.



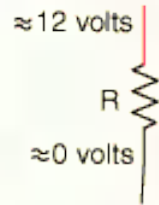
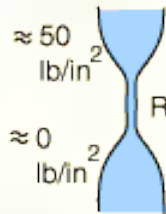
Current flow rate in coulombs/sec = amps



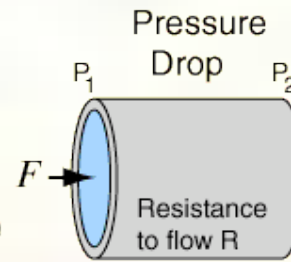
Hydraulic analogy

■ Resistance \Rightarrow related to length and radius of pipe (kL/r^4)

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

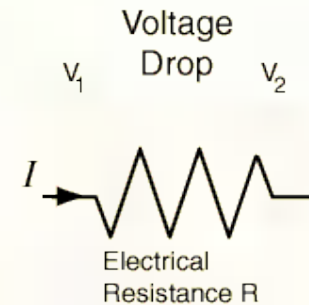


The resistance of a copper wire is so small that essentially all the voltage drop will appear across the resistor (or an appliance).



$$F = \frac{P_1 - P_2}{R}$$

Poiseuille's law for fluids

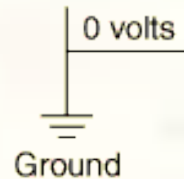
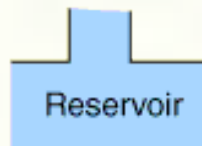


$$I = \frac{V_1 - V_2}{R}$$

Ohm's law for electric circuits

■ Ground \Rightarrow reservoir

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

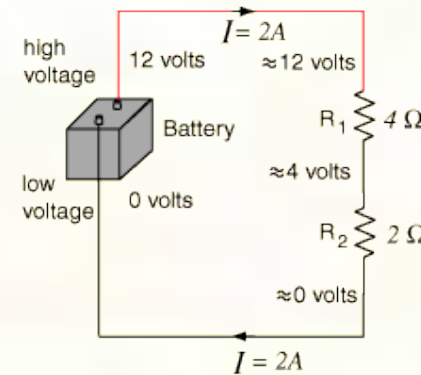
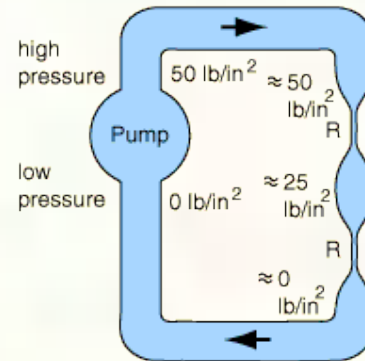


The ground can supply charge to the circuit, but its main function is to hold the voltage of nearby wires at the voltage of the earth.

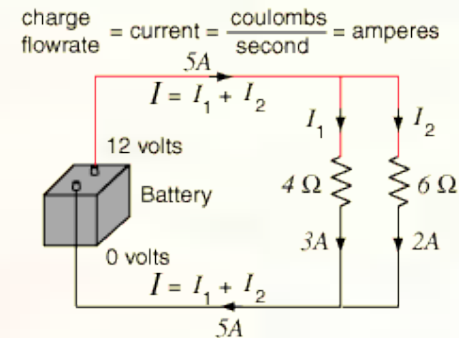
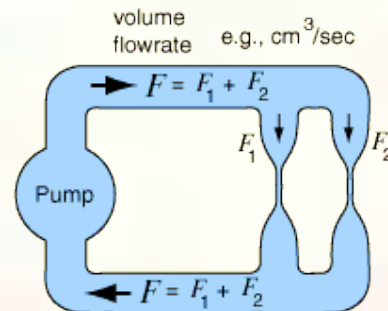


Hydraulic analogy

■ Resistances in series



■ Resistances in parallel





CMOS Transistors

- Need circuits to represent 2 discrete values
 - 1,0 for binary representations
 - True, False for Boolean logic
- Let high voltage (V_{dd}) represent 1, or true
- Let low voltage (0 volts or gnd) represent 0, or false
- If we have some switches to control whether or not these voltages can propagate through a circuit, we can build a computer with them
 - Note, the earliest digital computers were electromechanical, made out of relays, so this is hardly a new idea
- Our switches will be CMOS transistors