PHYSICS 1B – Fall 2007

Electricity
&
Magnetism

Professor Brian Keating

SERF Building. Room 333

UCSD

UCSD

Schedule

- Today: Current, resistance
- Wednesday: Resistance and Power
- Friday: Circuits with Resistors/Capacitors
- Monday 11/12: NO CLASS
- Wednesday 11/14: Magnetism Ch 18
- Friday 11/16: QUIZ 3 (Ch 17 and 18)

- New Syllabus due to the fires: Posted Soon

Quiz results – posted soon

17.1 Electric Current

Electric current

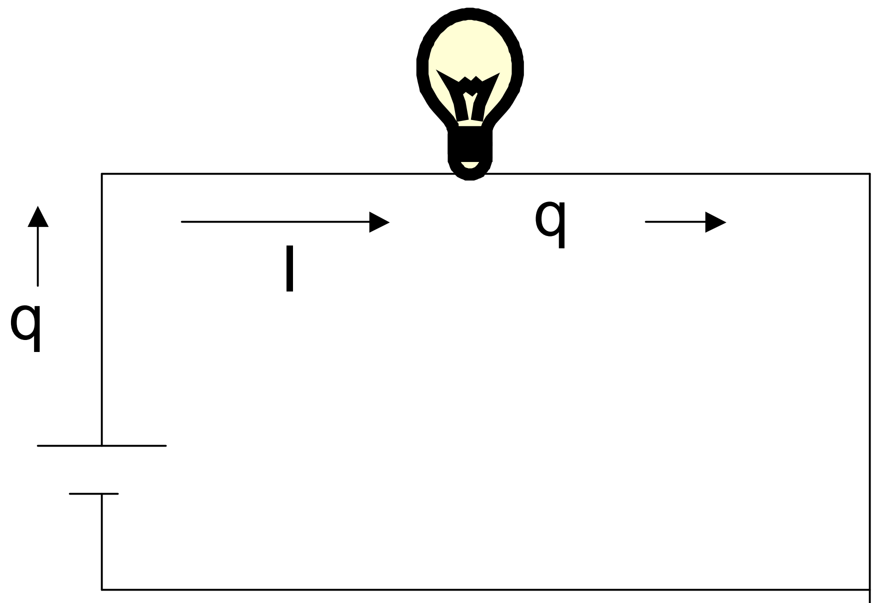
Drift speed

Current sources: Batteries

Charge flow slowly in a wire

Carry kinetic energy like water in a pipe

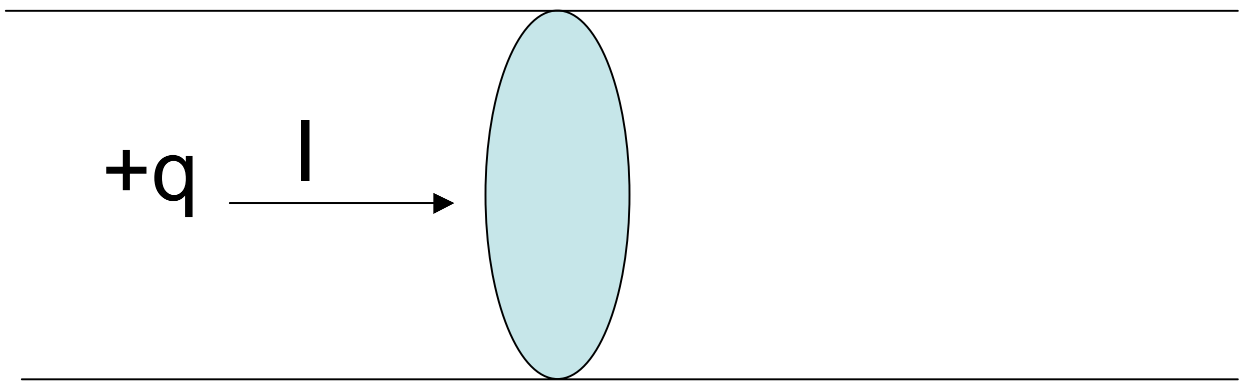
The energy can be released eg. Lightbulb



There is an electric field in the conductor.
Non-Equilibrium System. – Charges move

Electric Current, I

rate of +charge flow through a surface



$$I = \frac{\Delta q}{\Delta t}$$

Units Coulombs/sec –
Ampere (A)

A flashlight bulb carries a current of 0.1 A. (a) Find the charge passed in 10 s. (b) How many electrons does this correspond to?

(a)

$$I = \frac{\Delta q}{\Delta t}$$

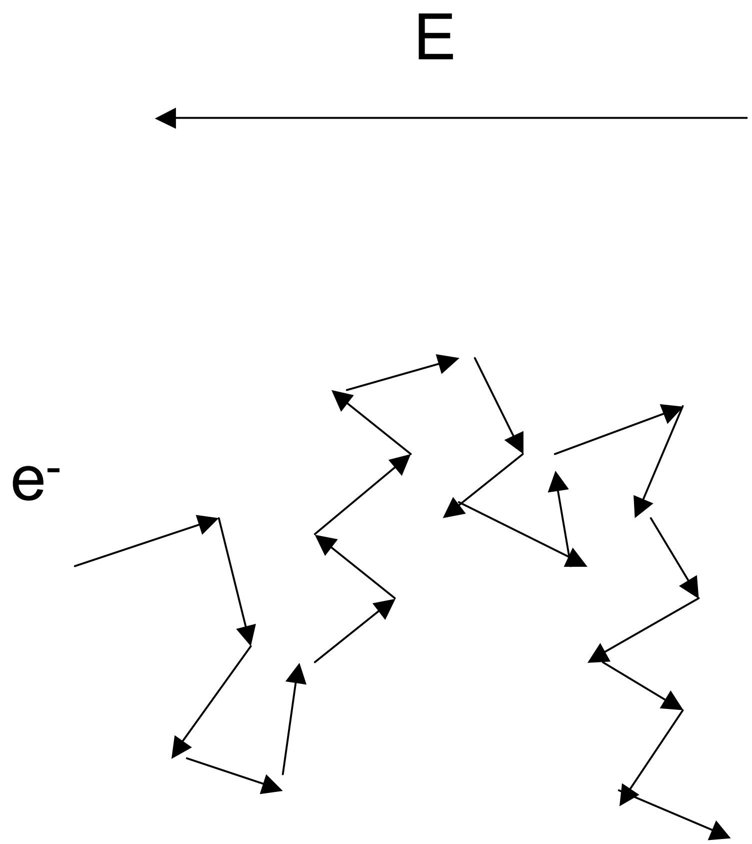
$$\Delta q = I\Delta t = 0.1(10) = 1C$$

(b)

$$q = Ne$$

$$N = \frac{q}{e} = \frac{1}{1.6x10^{-19}} = 6.2x10^{18} electrons$$

Drift Velocity

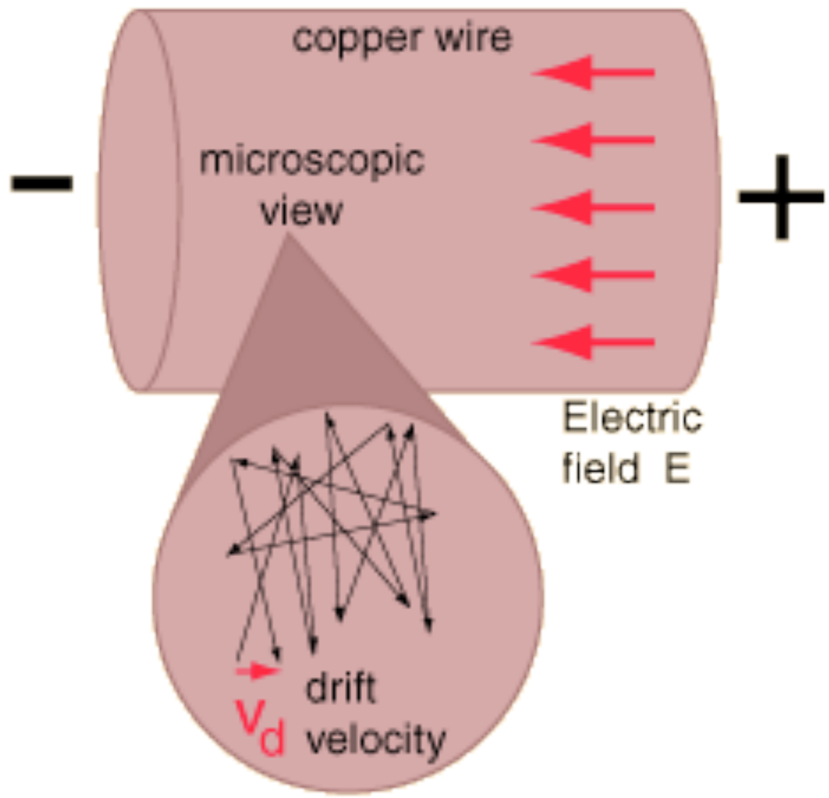


$$\tau \approx 10^{-14} s$$

Collisions of electron with the lattice (a.k.a resistance) slows down the velocity.

Drift velocity- Average velocity in the direction of the flow.

The electron moves at the
Fermi speed, and has only
a tiny drift velocity superimposed
by the applied electric field.



Avogadro's number   Density

$$n = \frac{(N_A\,atoms\,/\,mole)(\rho\ \ kg\,/\,m^3)}{A(kg\,/\,mole)}$$

Atomic mass

$$V_d = \frac{\Delta x}{\Delta t}$$

Current – like a fluid through a pipe.

Rate of flow is

$$\frac{charge}{time} = \left(\frac{charge}{volume}\right)\left(\frac{volume}{time}\right) = (qn)\left(\frac{A\Delta x}{\Delta t}\right) = qnAv_d$$

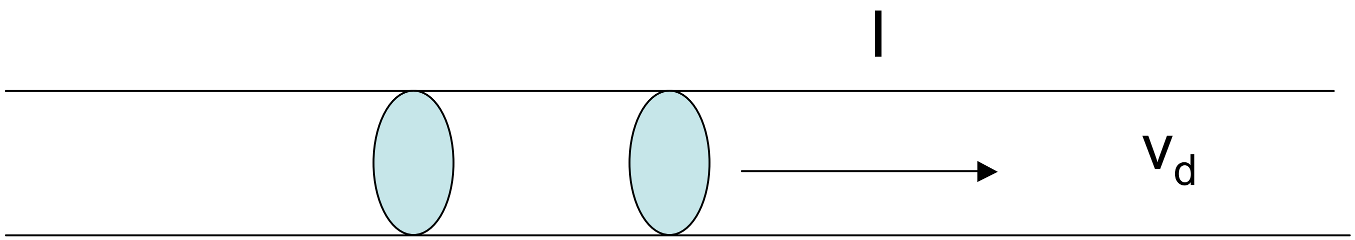
$$I = \frac{\Delta q}{\Delta t} = qnAv_d$$

V_d –Drift velocity

n – no. of charge carriers/volume

q- charge per charge carrier

17.2 Find the drift velocity of electrons in Cu. For I=10 A, A=3x10^{-6} m^2. Use density of Cu, ρ=8.95 g/cm^3(each atom of Cu contributes 1 carrier electron) M_A=63.5g/mole



$$I = qnAv_d \qquad q = e$$

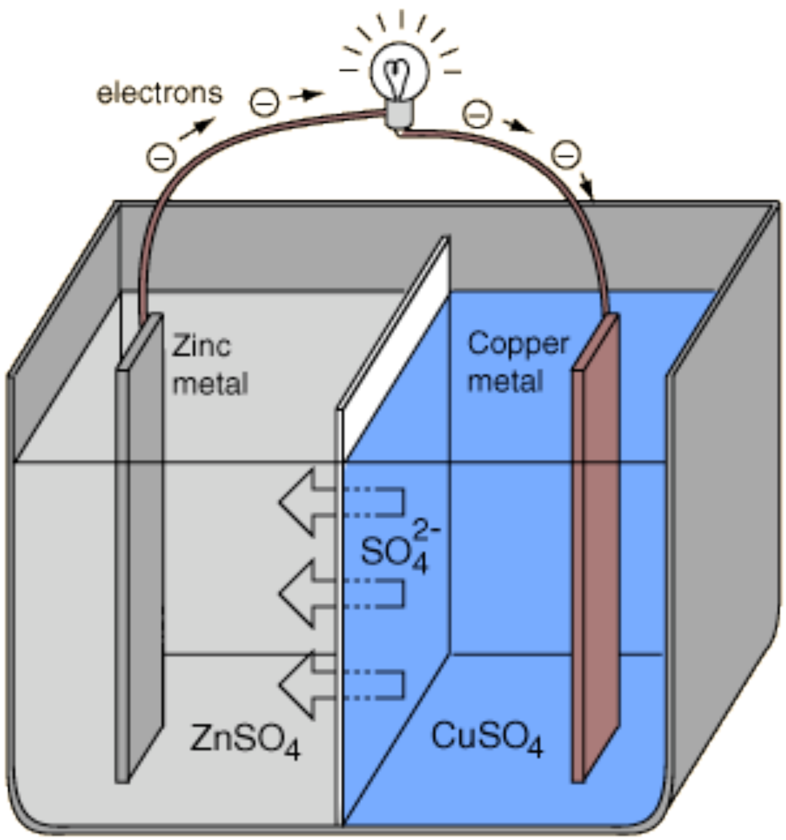
$$n = \frac{atoms}{m^3} = \frac{grams}{cm^3}\frac{10^6\,cm^3}{m^3}\frac{atoms}{gram}$$

The drift velocity is very low.

The current is large because of the large number of charge carriers.

The electrical signal travels fast, because electrons interact and “push” other electrons in the conductor

Voltage sources
Batteries



- Chemical Energy->Electrical Energy

Cu has a higher *affinity* for electrons than Zn, produces ΔV: Zinc more readily loses electrons than copper, so placing zinc and copper metal in solutions of their salts can cause electrons to flow through an external wire which leads from the zinc to the copper.

Amp hour (unit of charge)

How much charge is equal to 2100 mAh (milliamp hours)

charge=(current)(time)

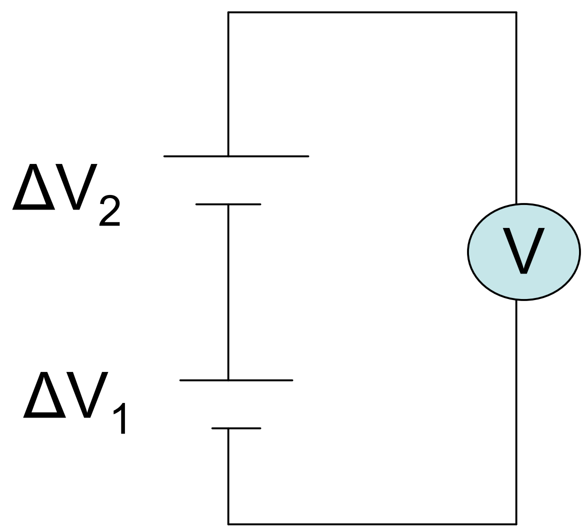
Ni-MH Nickel metal hydride battery

A battery with a 2 amp hr rating is used to power a flashlight that draws 5 A of current. How long will the battery last

$$Q = I\Delta t$$

$$\Delta t = \frac{Q}{I} = \frac{2amp.hr}{5amp} = 0.4hr$$

Voltages in series

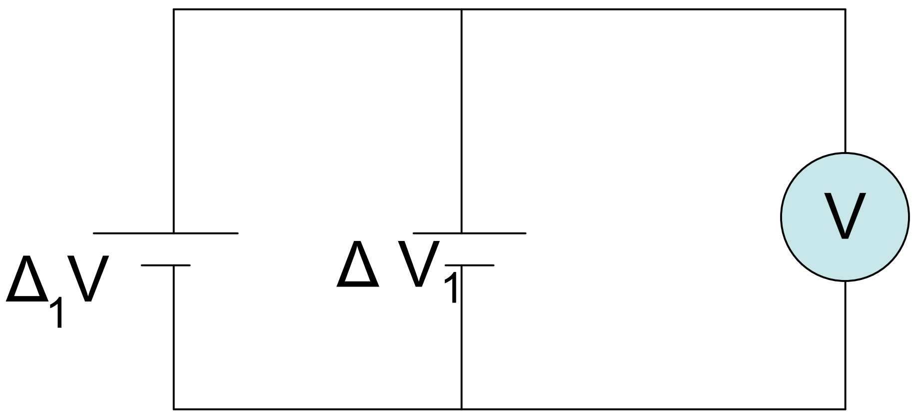


$\Delta V = \Delta V_1 + \Delta V_2$

Voltmeter- acts as the load

Ideal voltmeter draws no current

Voltages in parallel



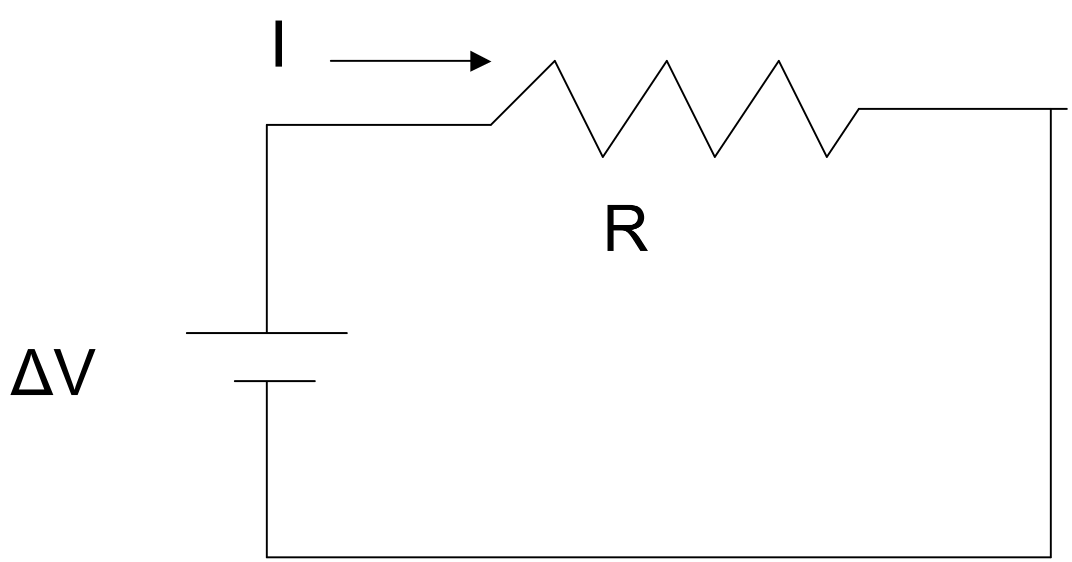
$\Delta V = \Delta V_1$

The current is
increased 2 fold

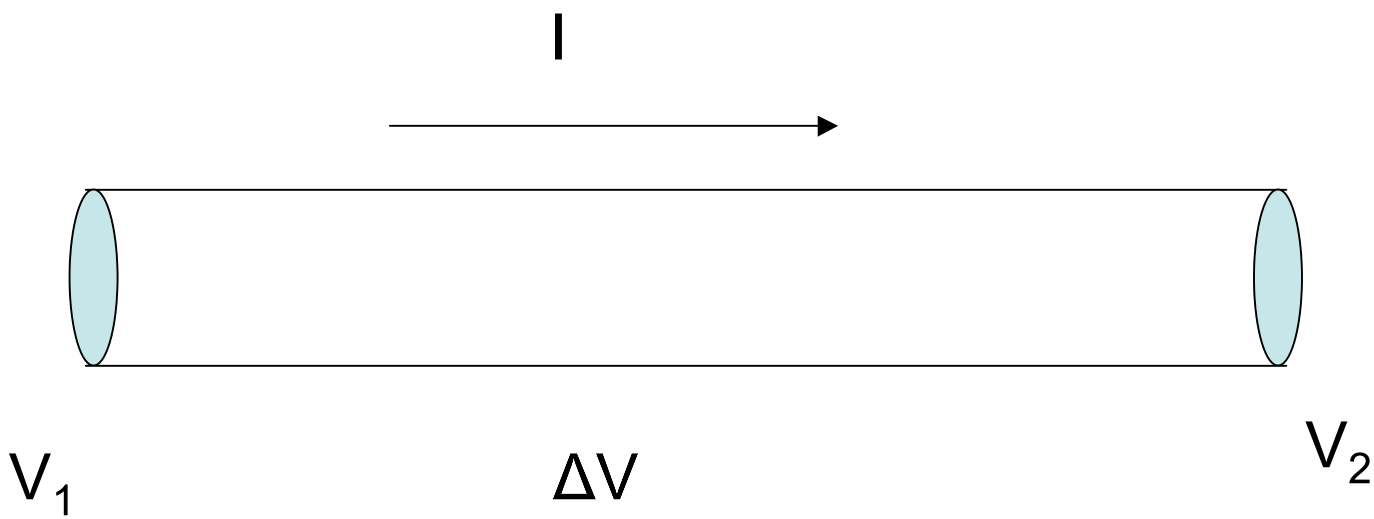
Resistance Chapter 17.4

Resistance

R units Volts/Ampere , Ohms (Ω)



Resistance

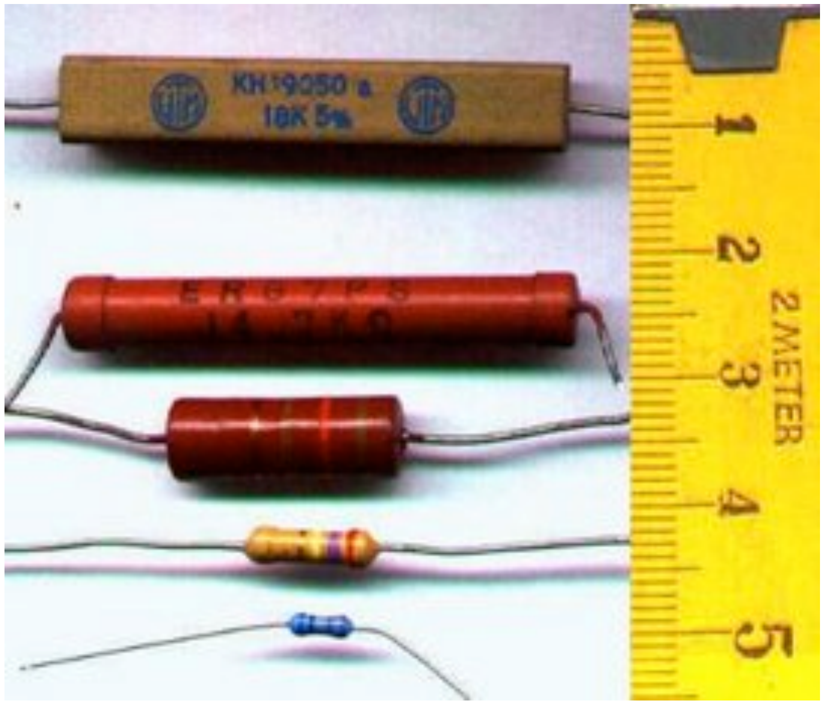


$$R = \frac{\Delta V}{I}$$

Resistance, units Volts/Ampere = Ohm (Ω)

Resistance causes conversion of potential energy to heat.

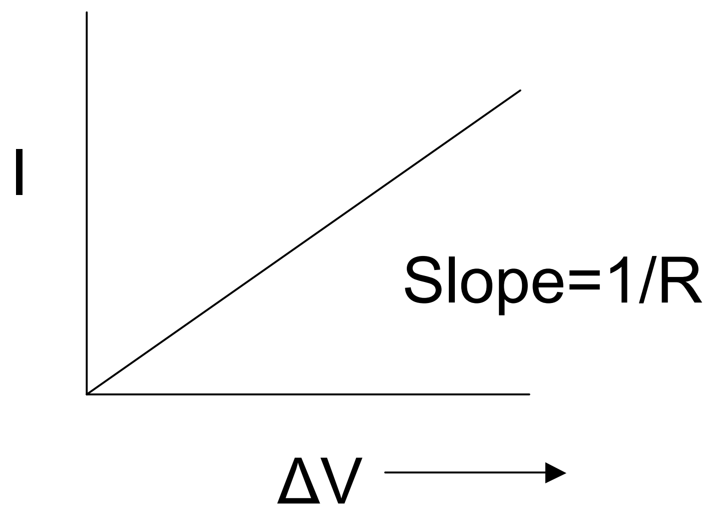
Resistors



carbon resistors
wire wound resistors
thin metal film resistors

Ohm's Law

For many conductors I is linear with ΔV,



$$I \propto \Delta V$$

$$I = \frac{1}{R}\Delta V$$

$$\Delta V = IR$$

R is a constant

Gravitational analogy to $\Delta V = IR$

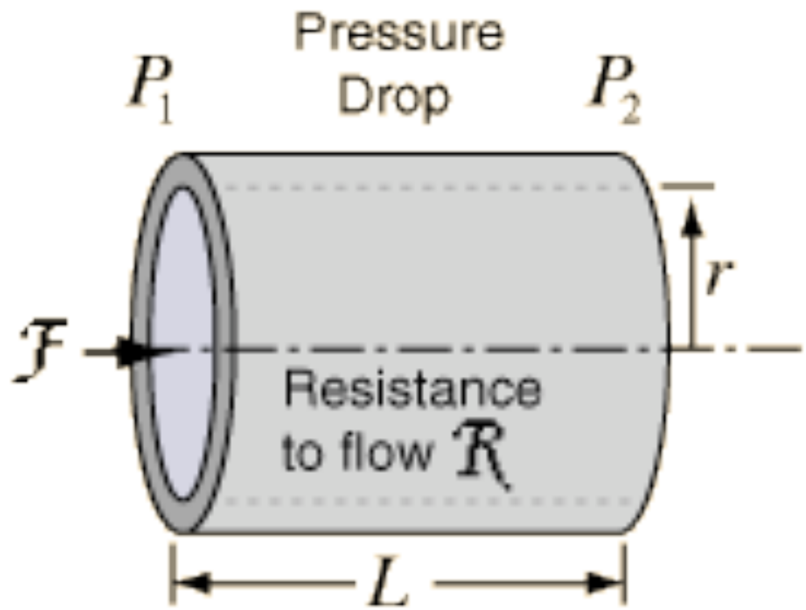
Water flow in a river

Water flow is fast where the slope is steep (large potential drop).

H_2O resistor

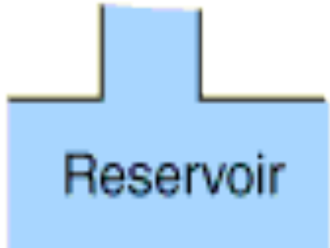
Volume Flowrate $= \mathcal{F} = \dfrac{P_1 - P_2}{\mathcal{R}} = \dfrac{\pi(\text{Pressure difference})(\text{radius})^4}{8(\text{viscosity})(\text{length})}$

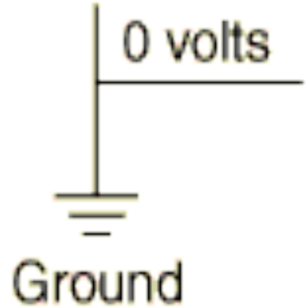
Resistance to Flow $\mathcal{R} = \dfrac{8\eta L}{\pi r^4}$



E&M & H_2O

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





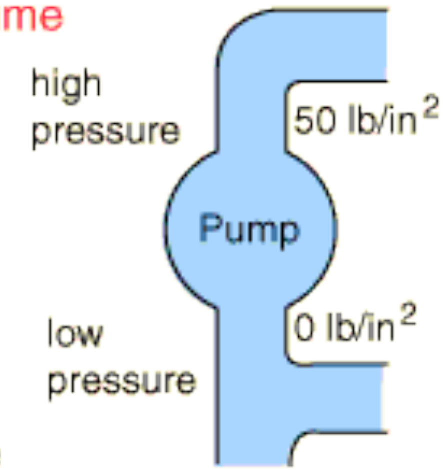
The ground can supply charge to the circuit, but its main function is to hold the voltage of nearby wires at the voltage of the earth.

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

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

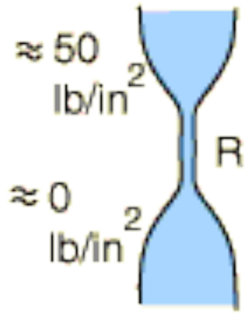
$$\frac{F}{A} = \frac{F\,d}{A\,d} = \frac{W}{V}$$

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



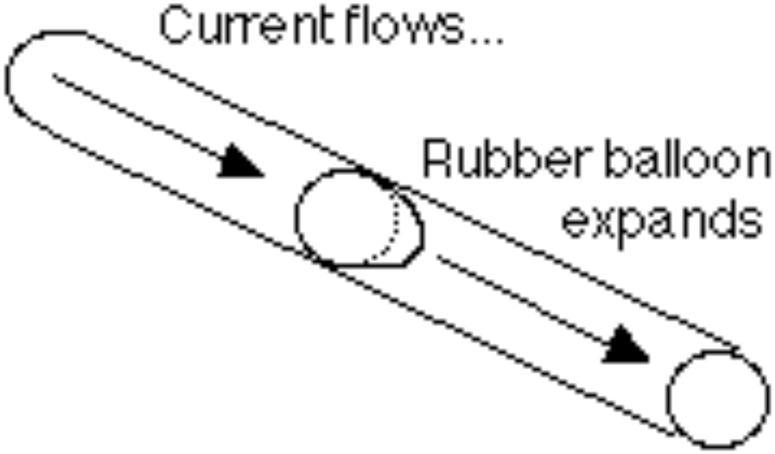
E&M & H_2O

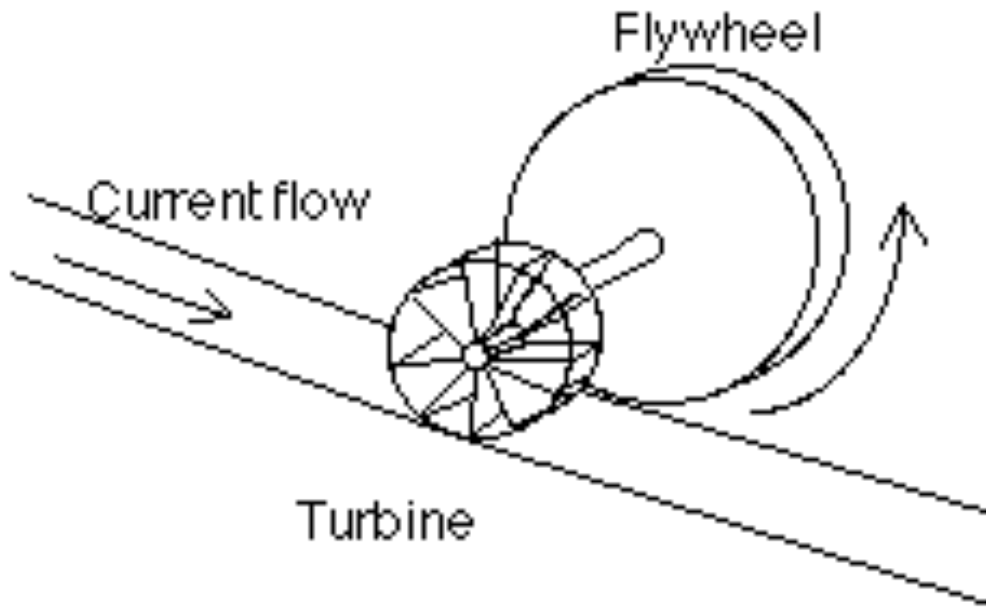
The resistance of a constriction in a large pipe is so great that essentially all the pressure drop will appear across the resistance.



Capacitor

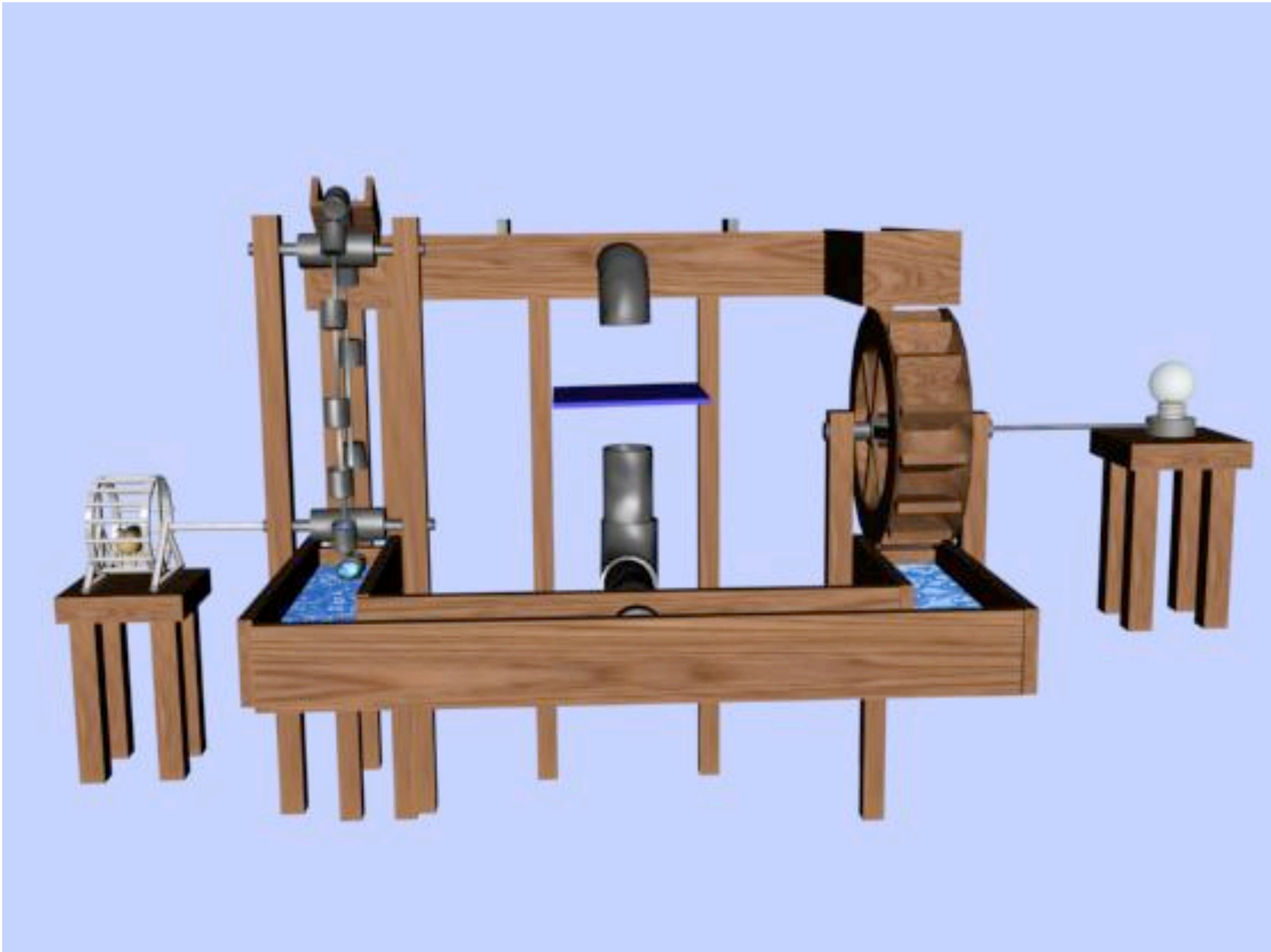
Inductors

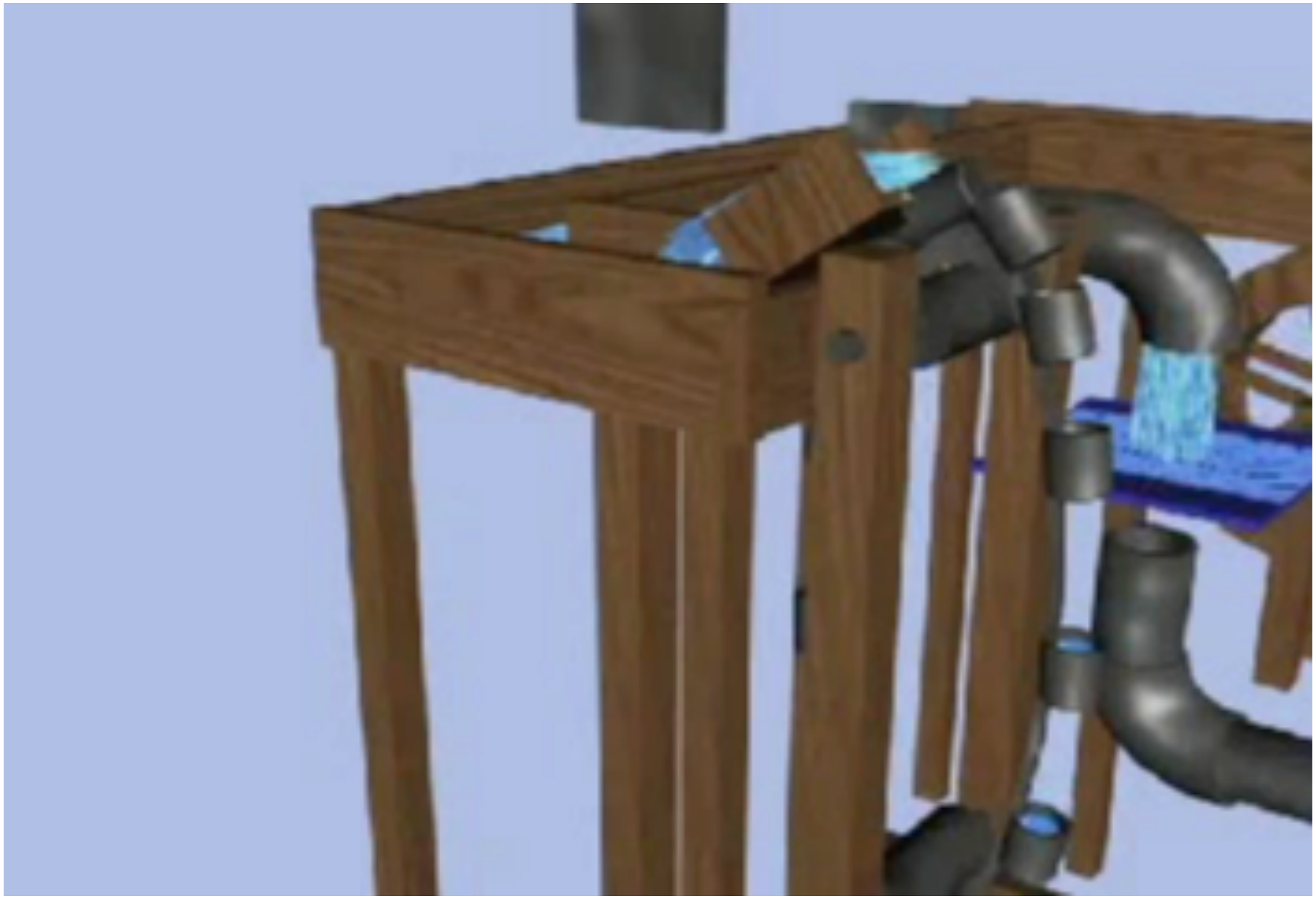


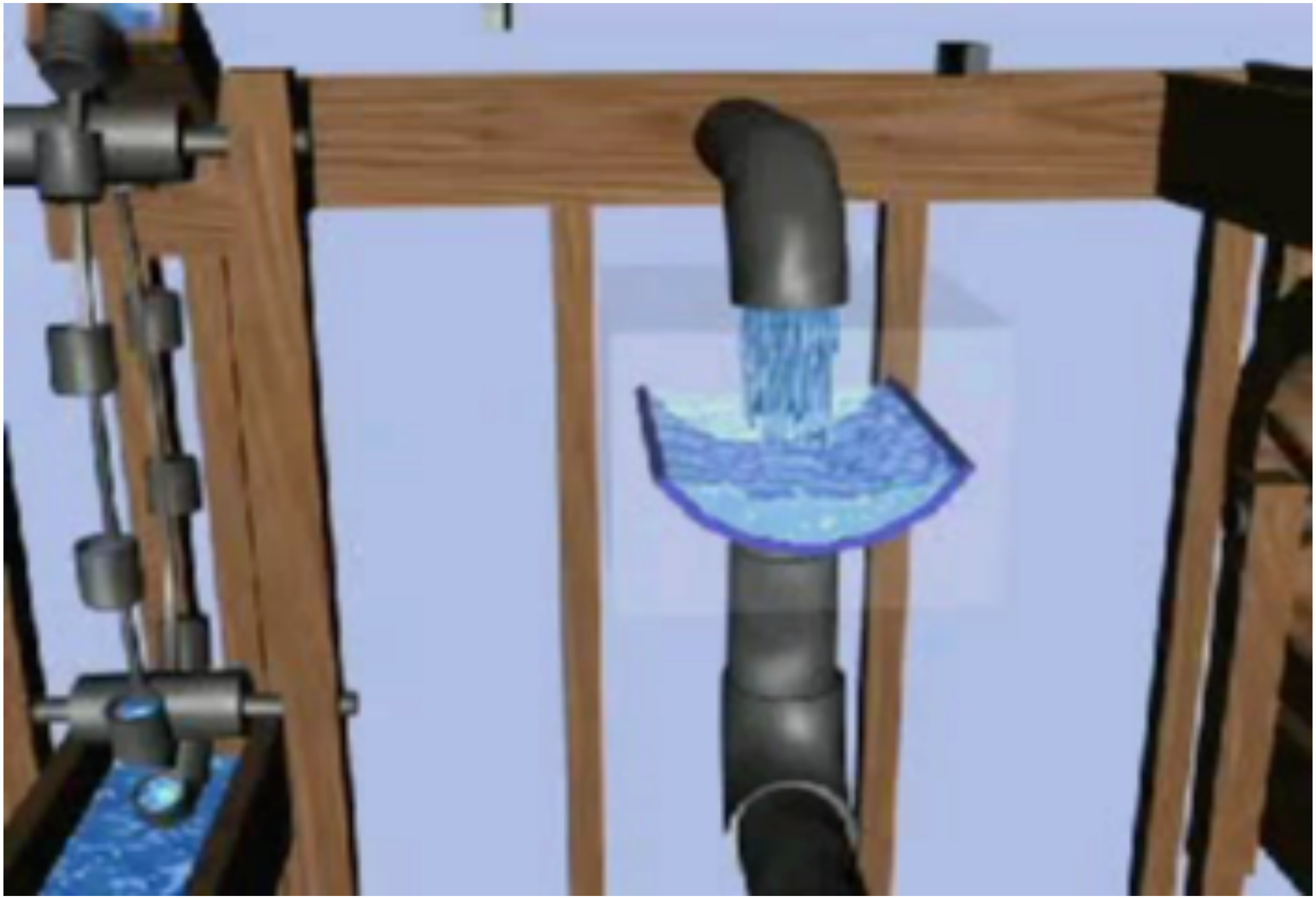


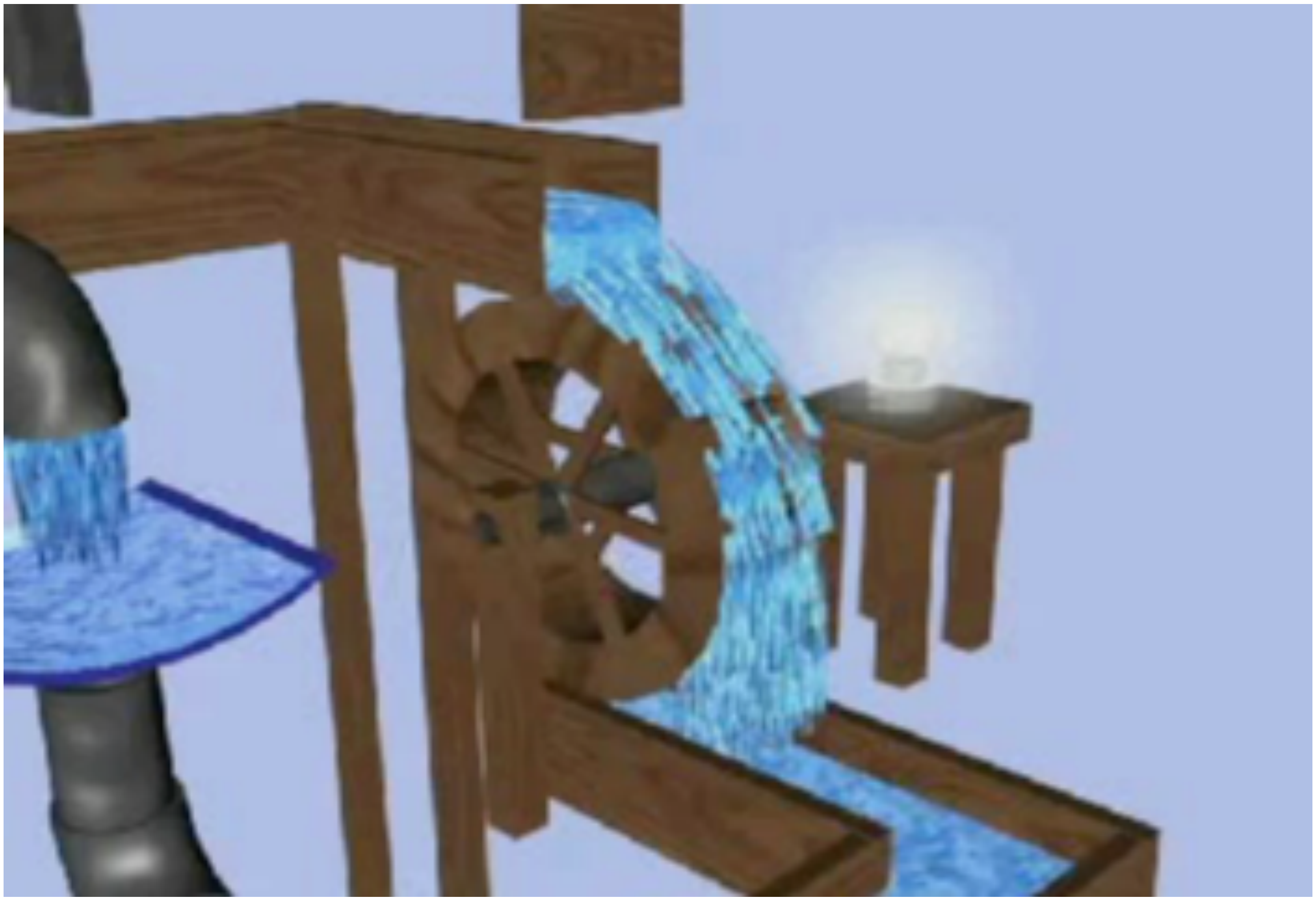
Movies

- Water/Circuit Analogies



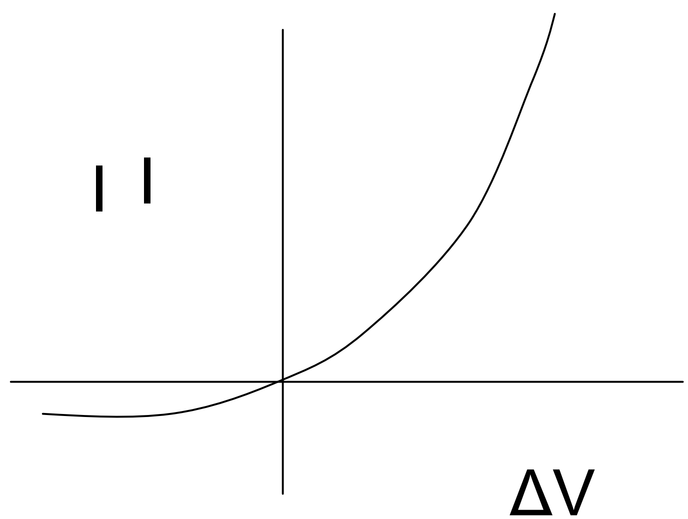






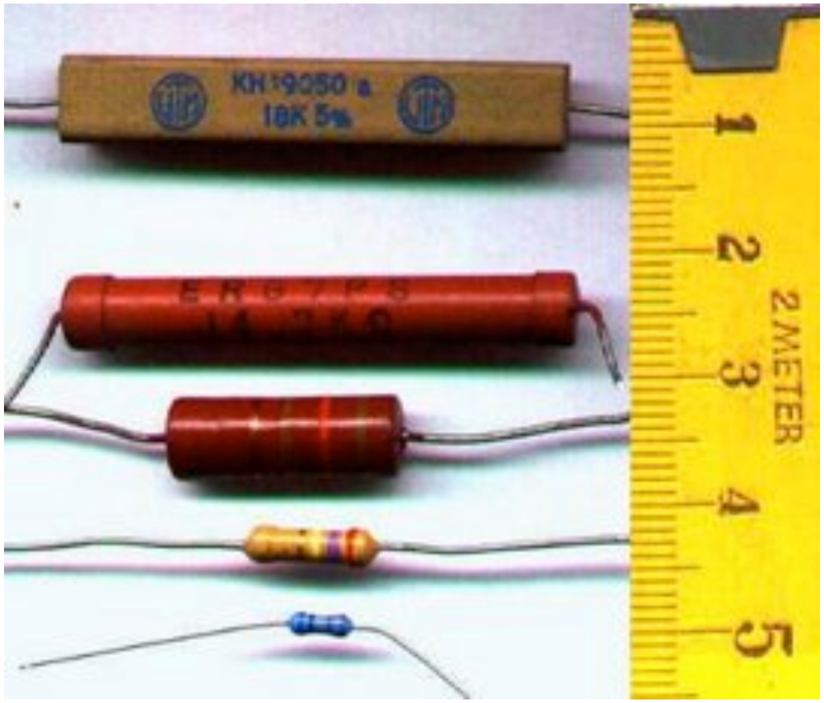
Some materials show non-ohmic resistance

Semiconductor diode



Does the resistance of the diode increase or decrease as ΔV increases?

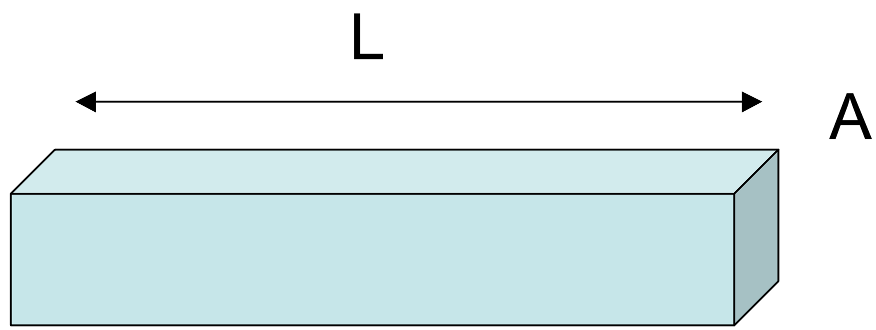
Resistors



carbon resistors
wire wound resistors
thin metal film resistors

Resistance of a resistor is determined by the geometry of the resistor and the resistivity.

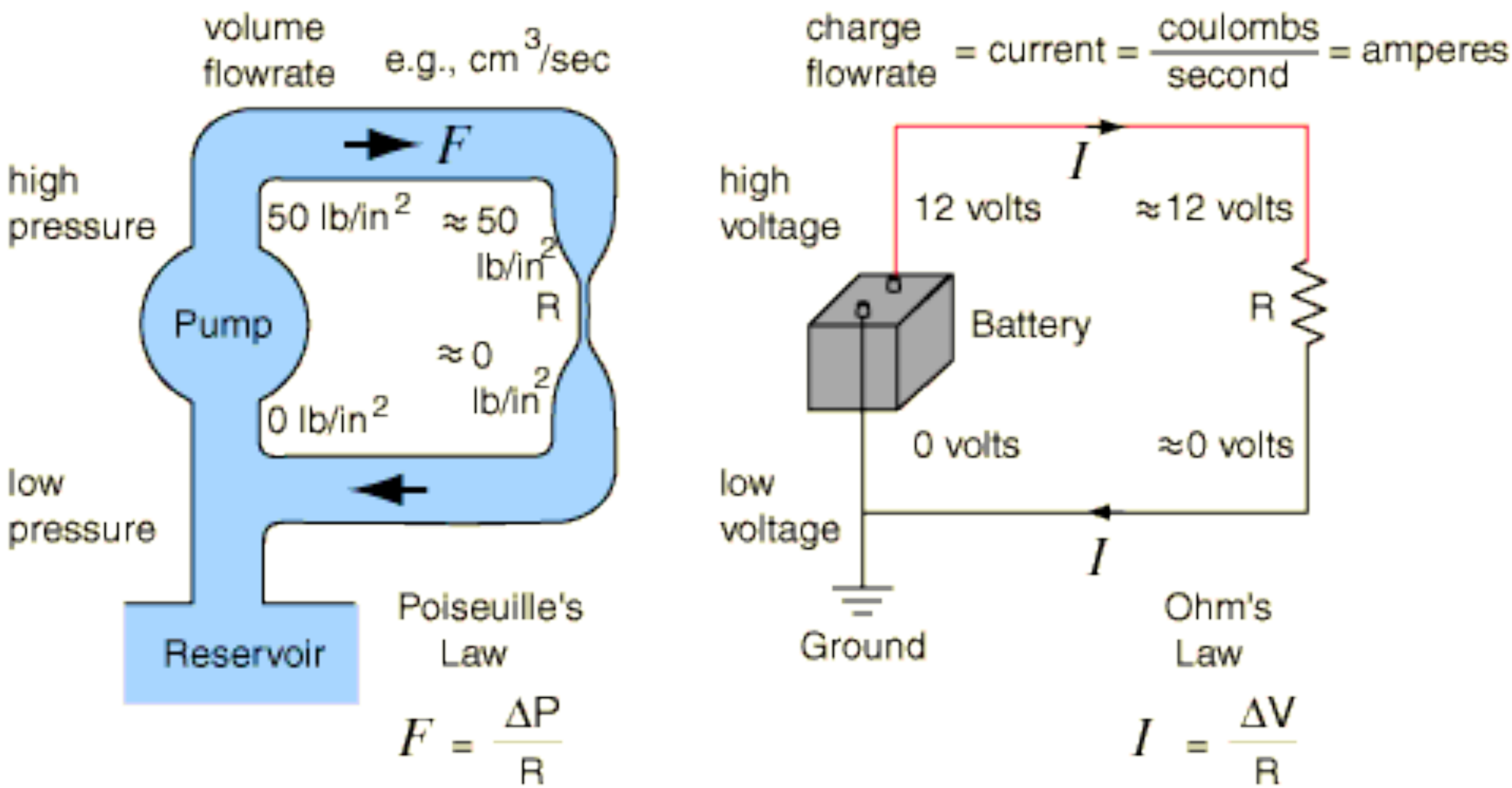
Resistivity, ρ
Property of conducting material



$$R = \rho \frac{L}{A}$$

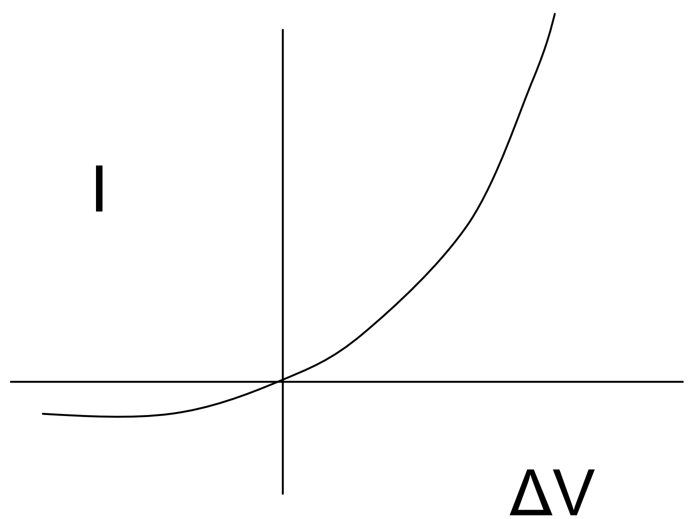
ρ Resistivity, ohms meter (Ω·m)

Voltage – Pressure Analogy



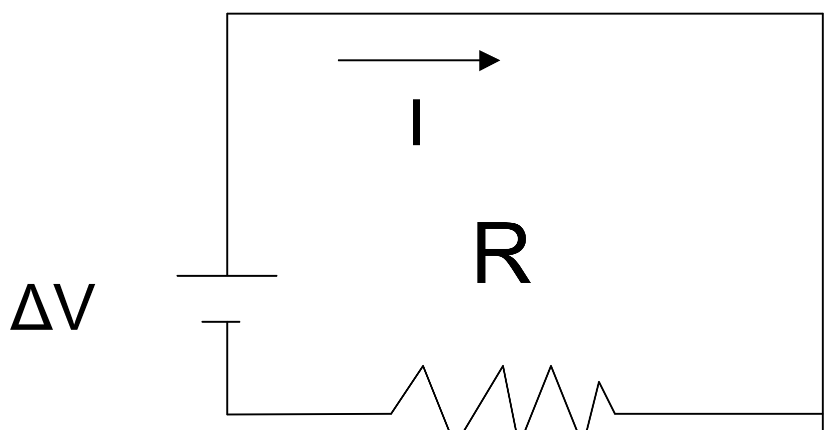
Some materials show non-ohmic resistance

Semiconductor diode



Does the resistance of the diode increase or decrease as ΔV increases?

A light bulb connected to a 3.0 V battery draws a current of 0.2 A. Find the resistance of the light bulb.

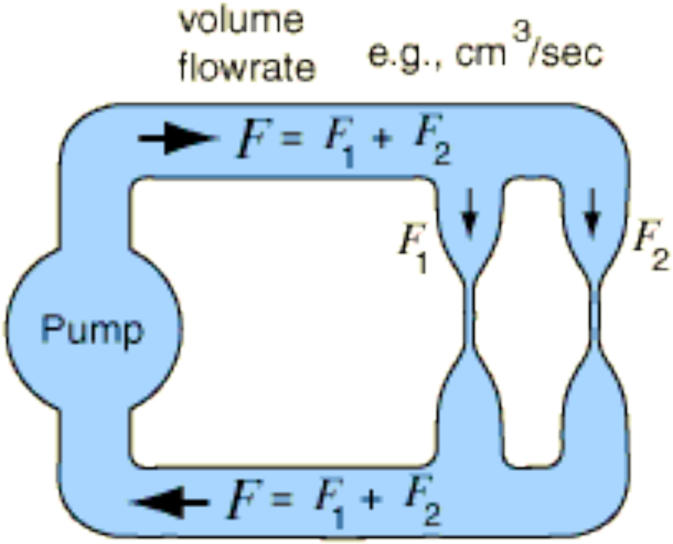


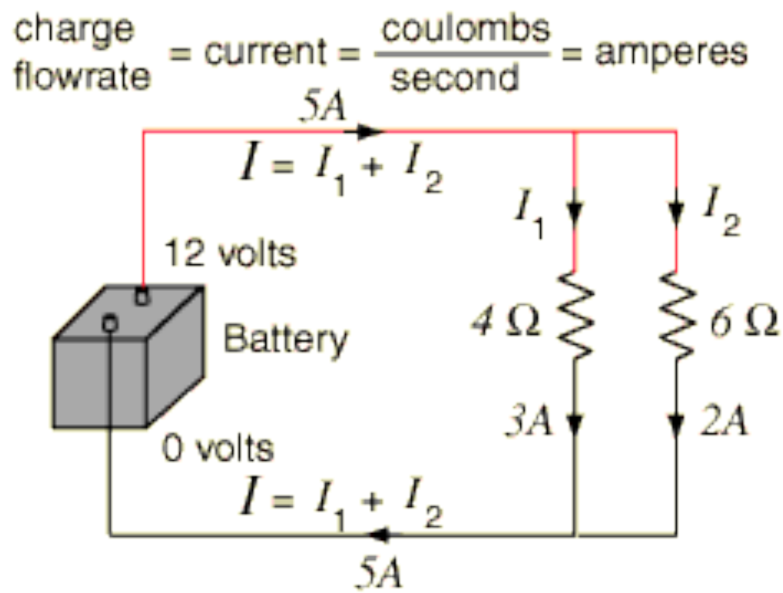
$$V = IR$$

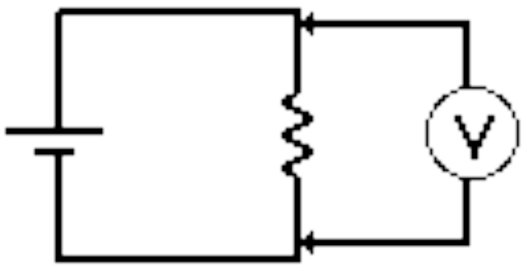
$$R = \frac{V}{I} = \frac{3.0}{0.2} = 13\Omega$$

We assume that the resistance of the wires is negligible compared to the resistance of the light bulb.

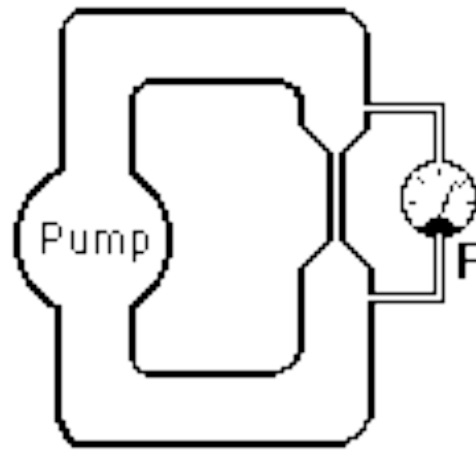
Voltages in Parallel







A voltmeter is connected in parallel to measure the voltage change across a circuit element



A pressure gauge is connected in parallel to measure the pressure drop across the resistance.

Circuits with Resistors