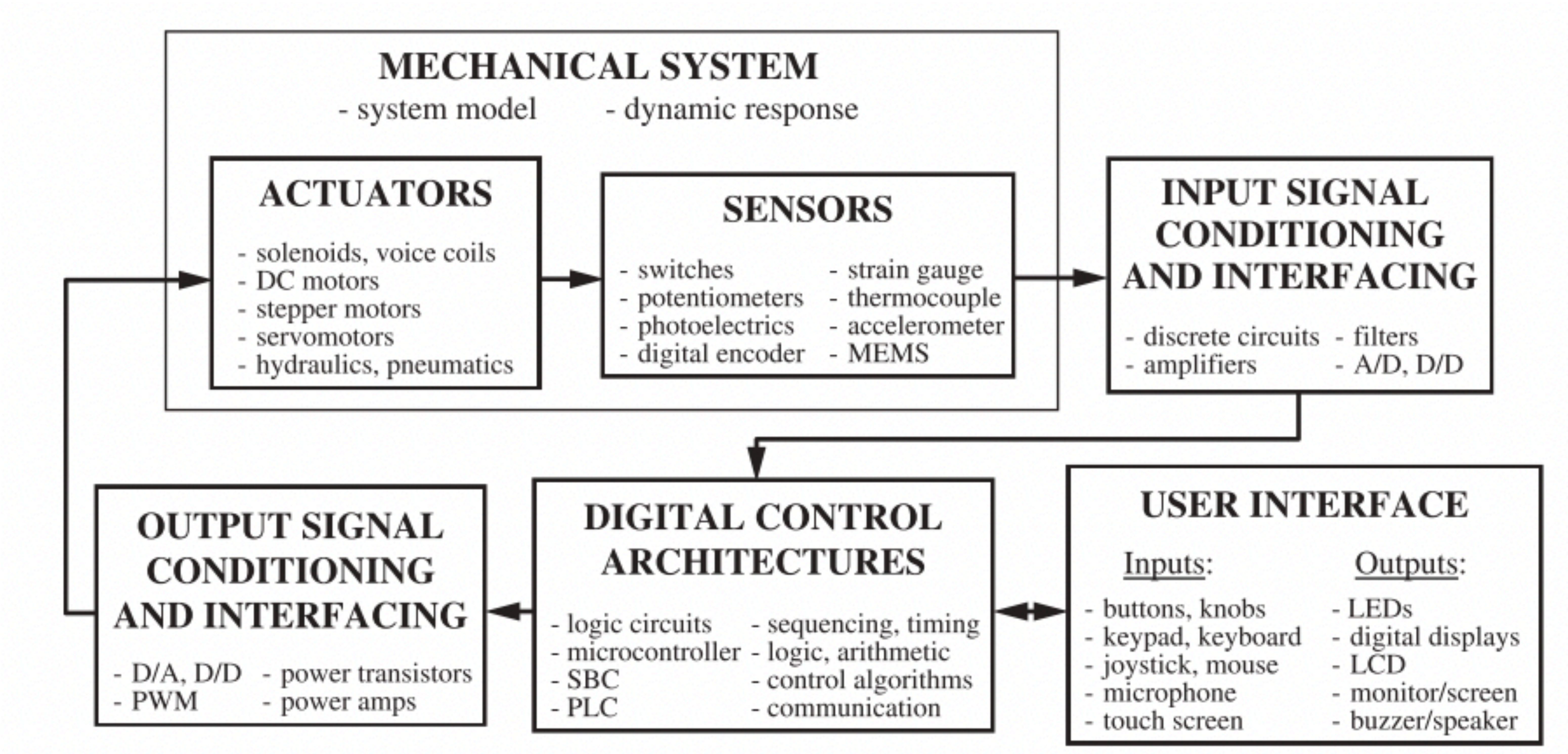
ME133 Lecture 2 1/12/23

Last time:

> What is mechatronics?



Quick Poll: How many have used ChatGPT? 5

Today:

- Basic electronic components
- Kirchoff's Laws
- Examples

All mechatronics systems contain electrical circuits

How do circuits work?

Today → Passive components?

↳ store or dissipate energy

↳ don't external power

Electricity Basics

Voltage: a measure of electric field potential.

→ relative

* analogous to potential energy in gravity field

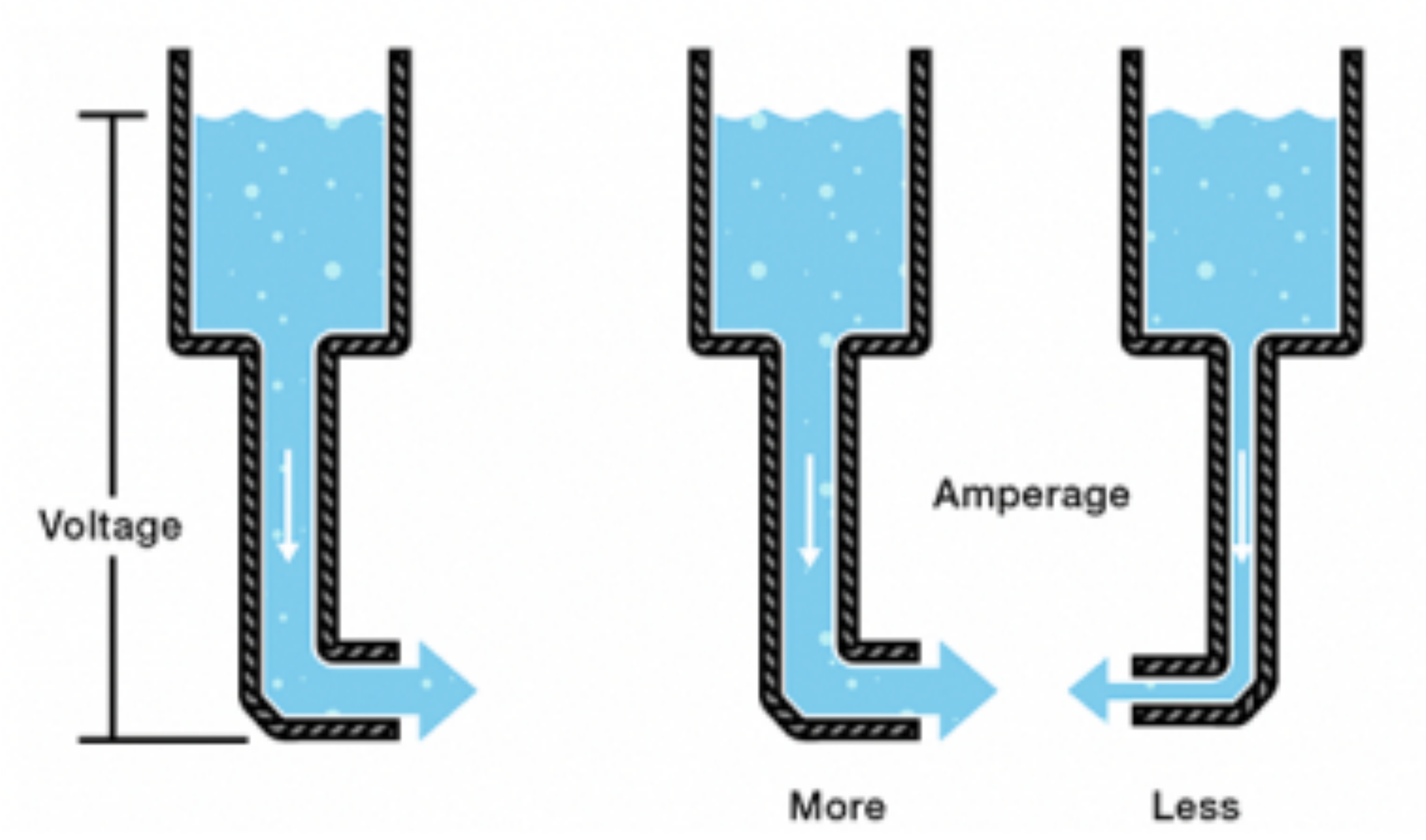
Current: time rate of "flow of charge"

$$I(t) = \frac{dq}{dt} \begin{array}{l} \rightarrow \text{charge} \\ \rightarrow \text{time} \end{array} \quad (A) \text{ amps}$$

Hydraulic Analogy

Voltage: a measure of <u>electric field potential</u>

Current: time rate of “flow of charge”



Direct vs Alternating Current

DC: $V = \text{constant}$

$I = \text{constant}$

Examples: Batteries, USB

solar cells, fuel cells

AC: $V = f(t)$

$I = f(t)$

function of time

(sinusoidal)

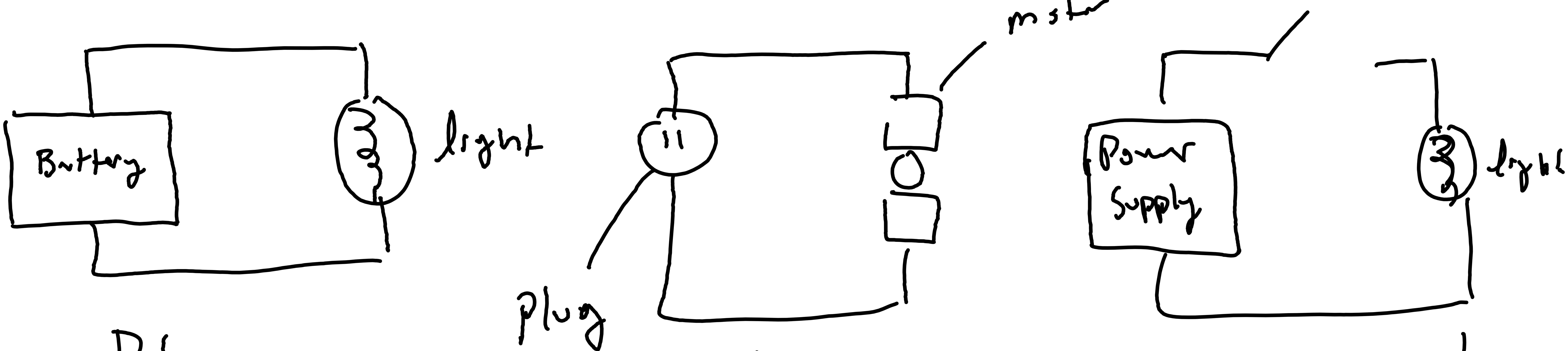
Examples: wall plug (outlet)

$\longrightarrow$ power lines

Electrical Circuit

allow current to flow

Close loop of **conductors** connecting electrical components

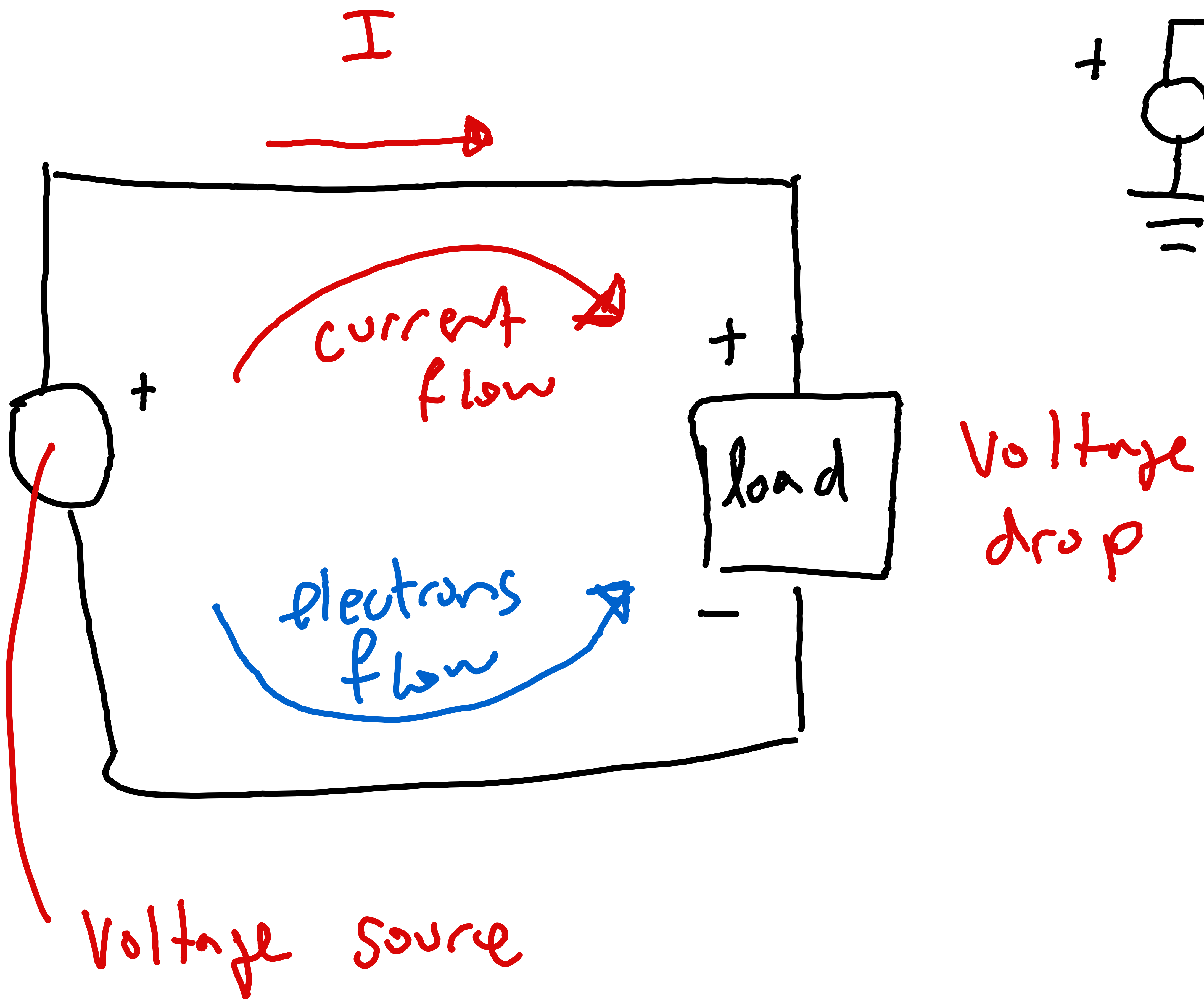


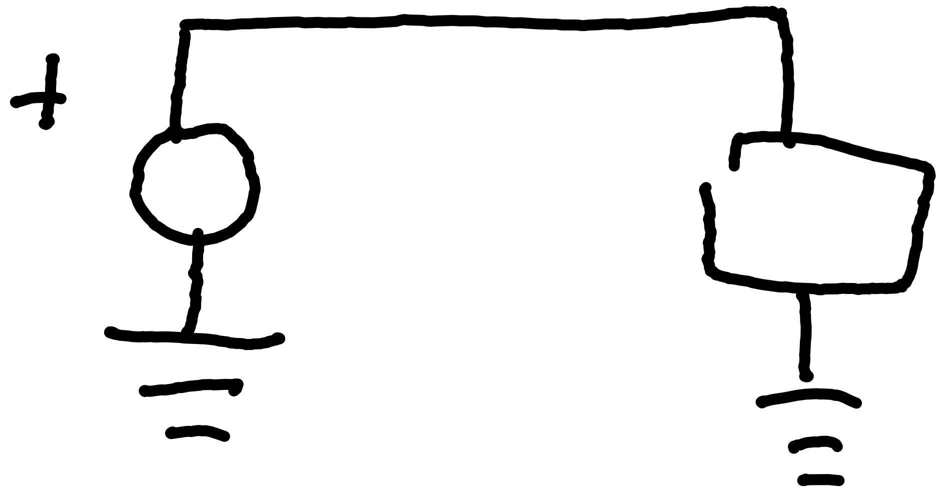
DC

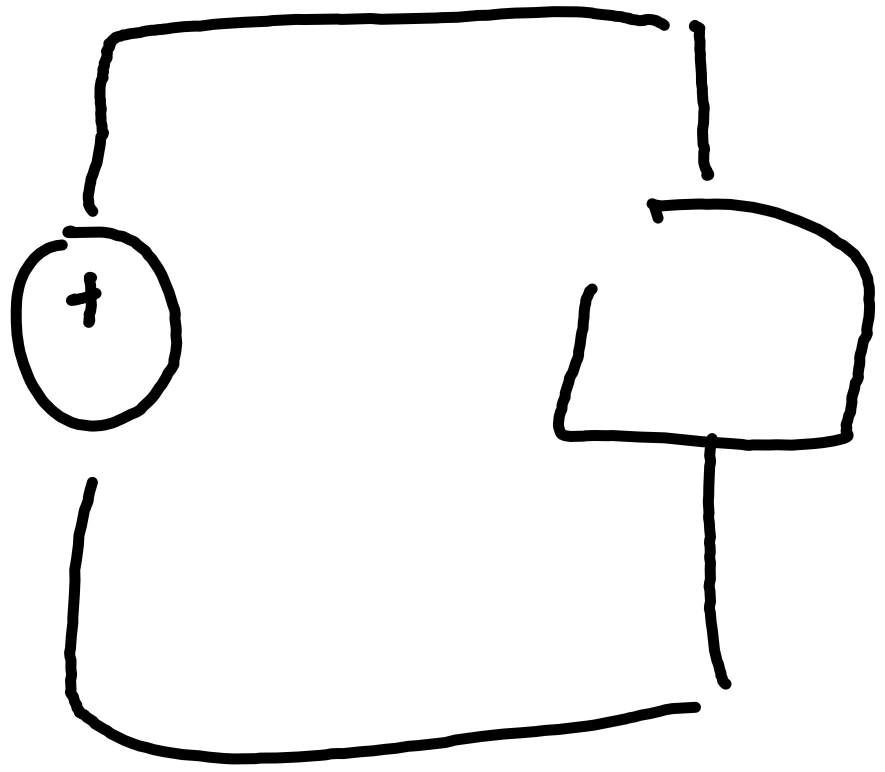
AC

open circuit until switch is closed

Terminology and Conventions







Current

flow of positive charge

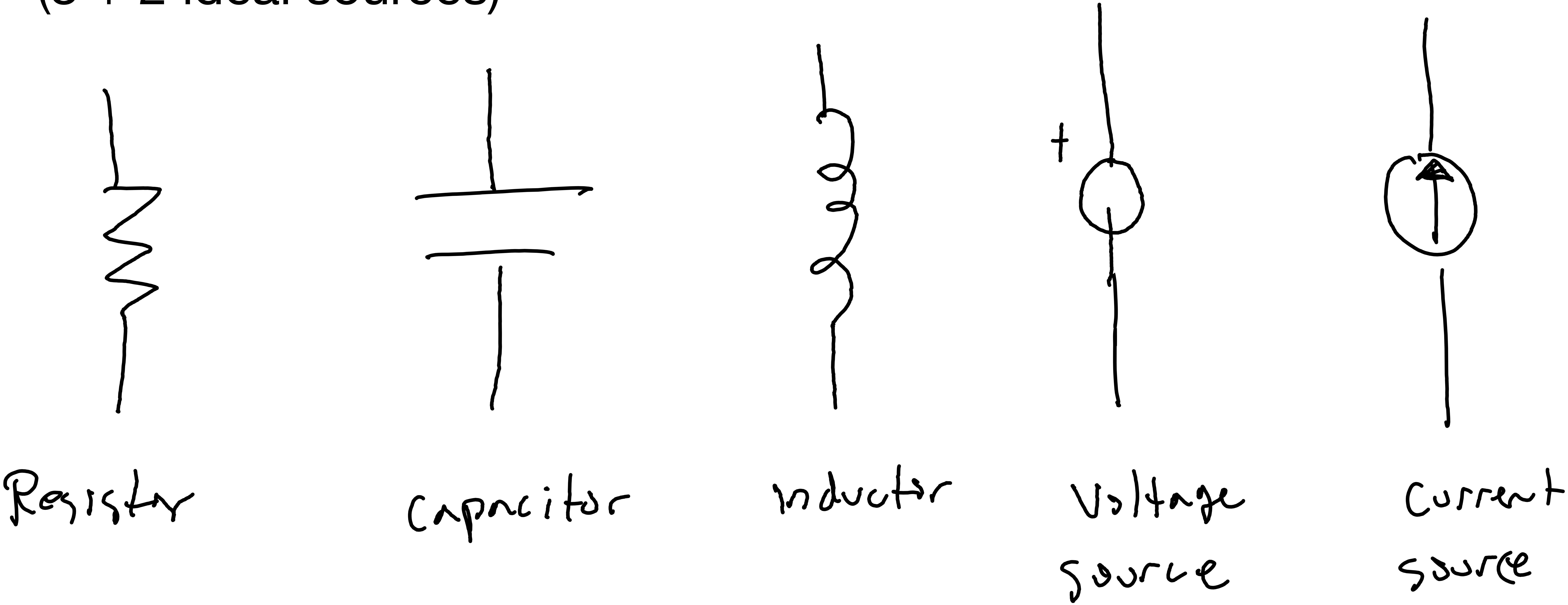
Load

network of electrical components that store/dissipate energy

Ground

reference point of circuit where voltage is zero

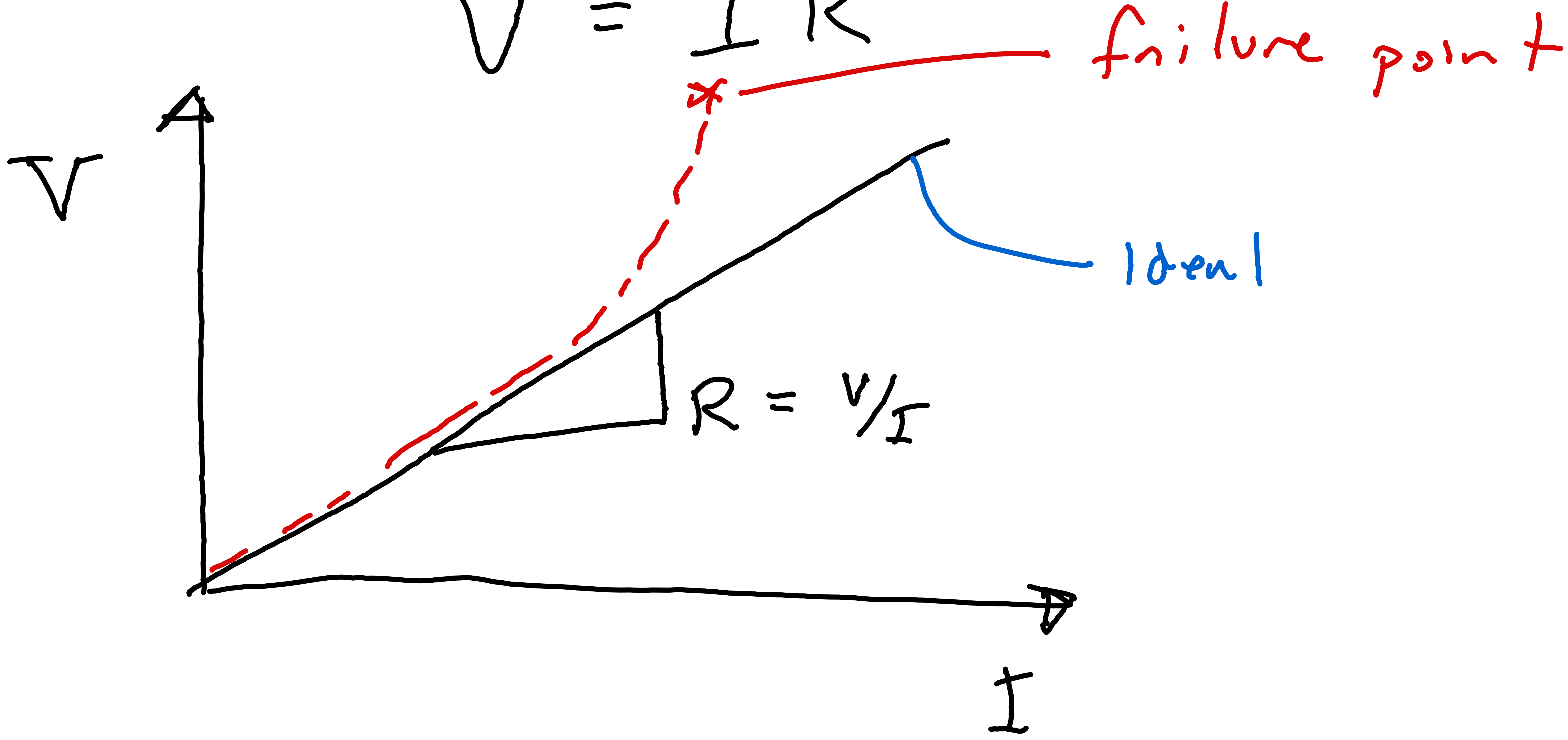
Basic Ideal Electrical Components
(3 + 2 ideal sources)



Resistor: converts electrical energy into heat
(dissipates energy)

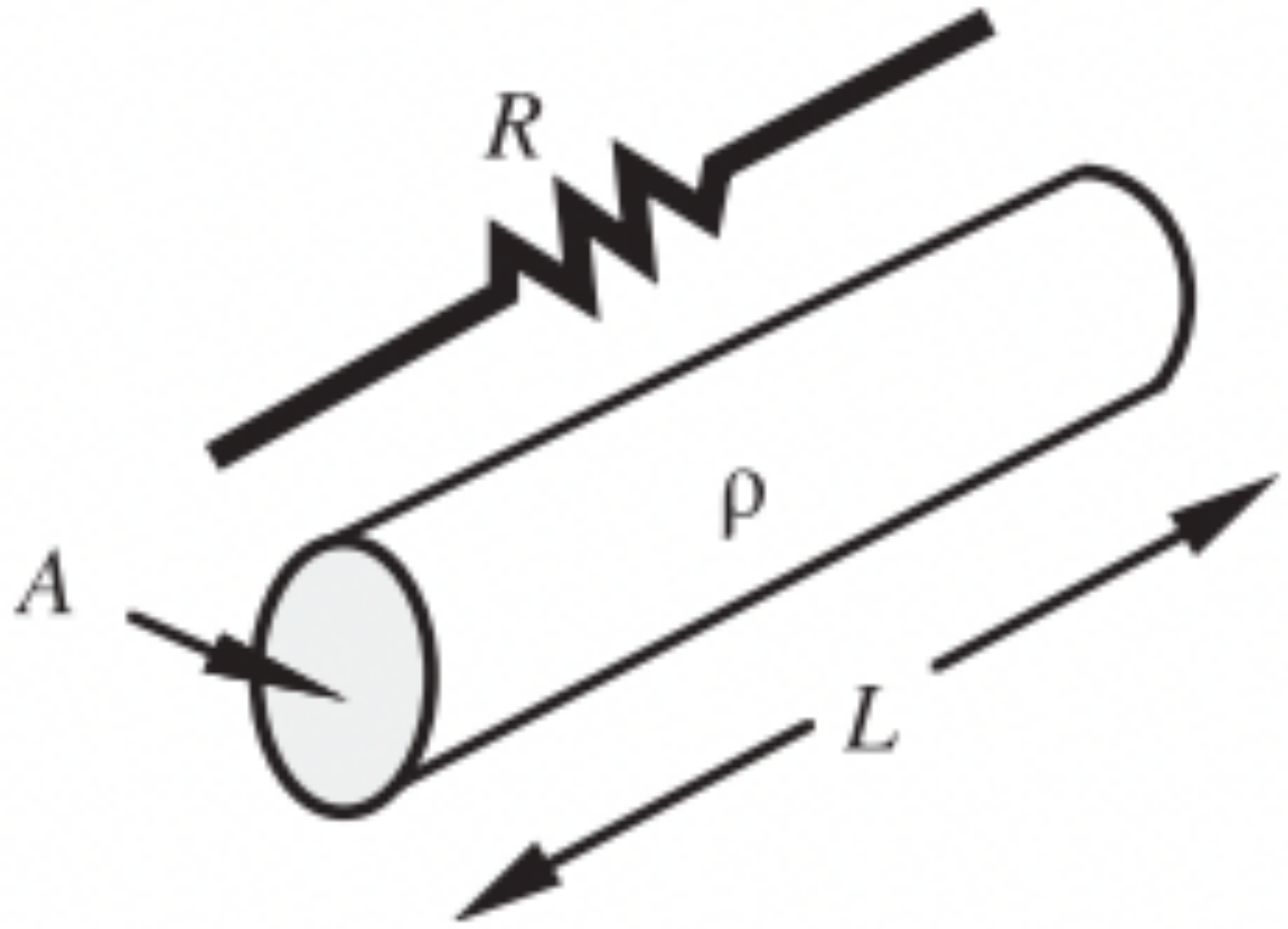
Ohms Law:

$$V = IR$$



For homogenous material with constant cross-sectional area

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

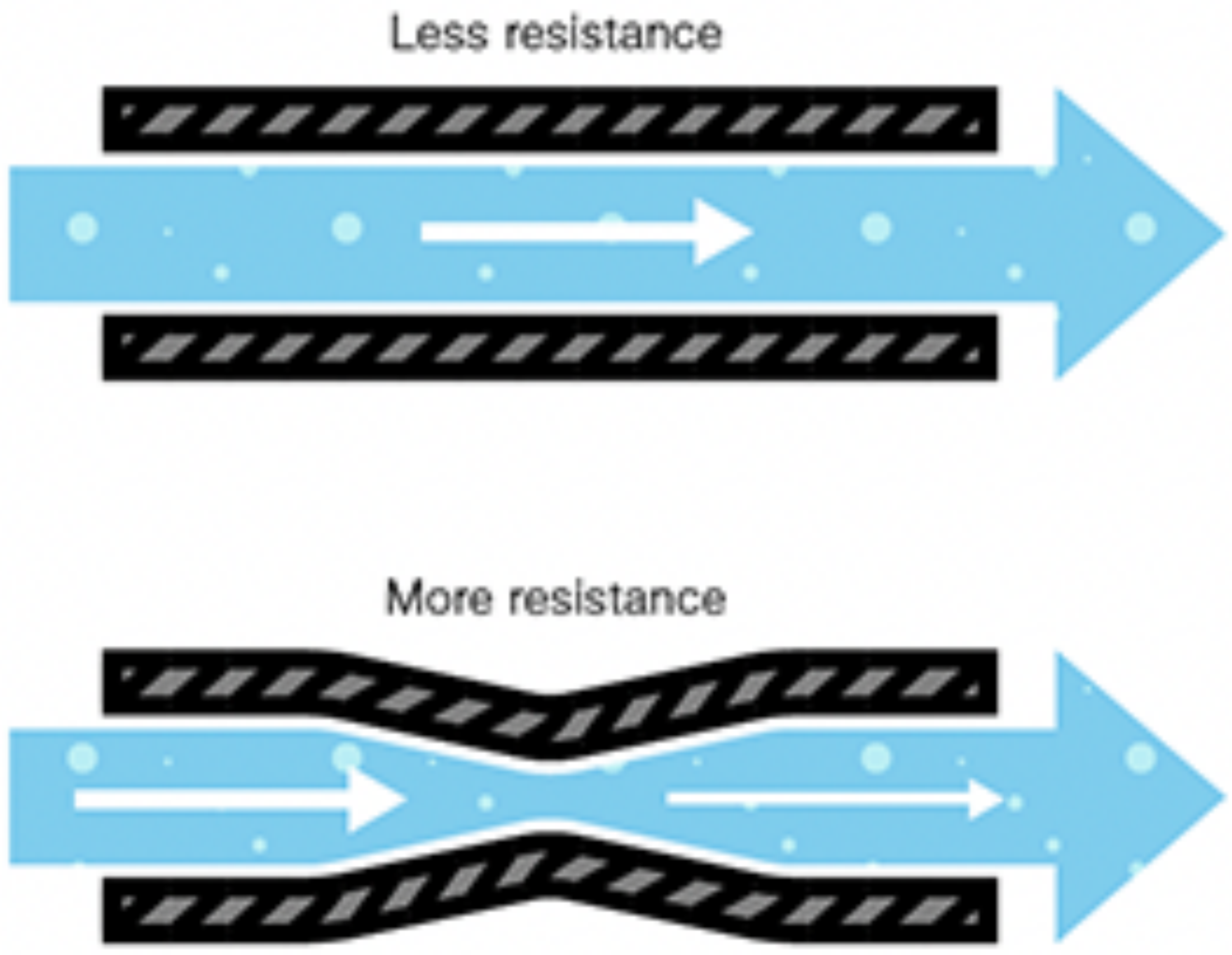


L: length
rho: resistivity
A: cross-sectional area

material property

Water Analogy for a resistor

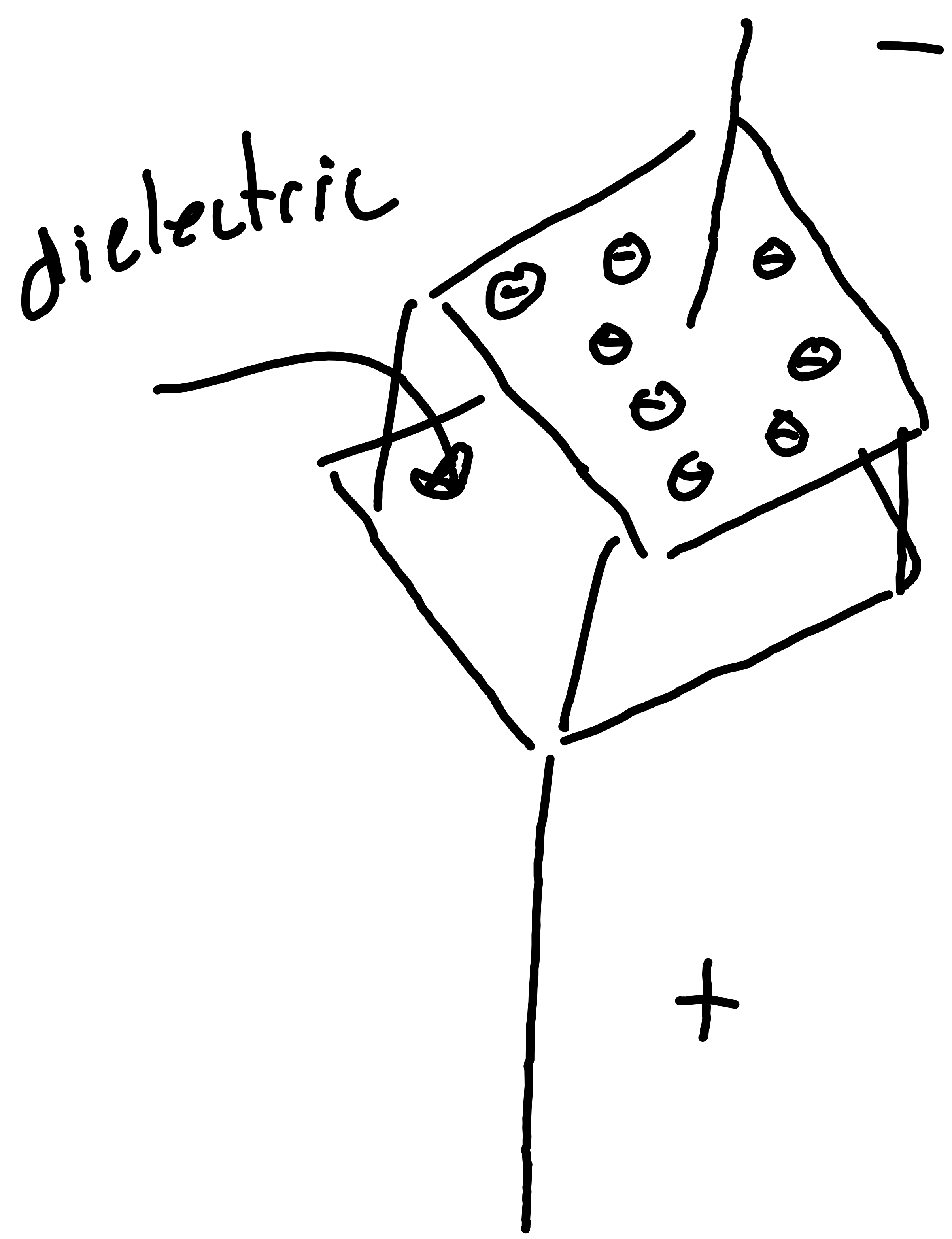
Water Analogy for a resistor



Potentiometer: variable resistor

Capacitor: Stores energy in the form of an electric field

simplest is made w/ parallel conductors seperated by dielectric material



$$V(t) = \frac{1}{C}\int_0^t I(\tau)\,d\tau$$

$$= \frac{q(t)}{C}$$

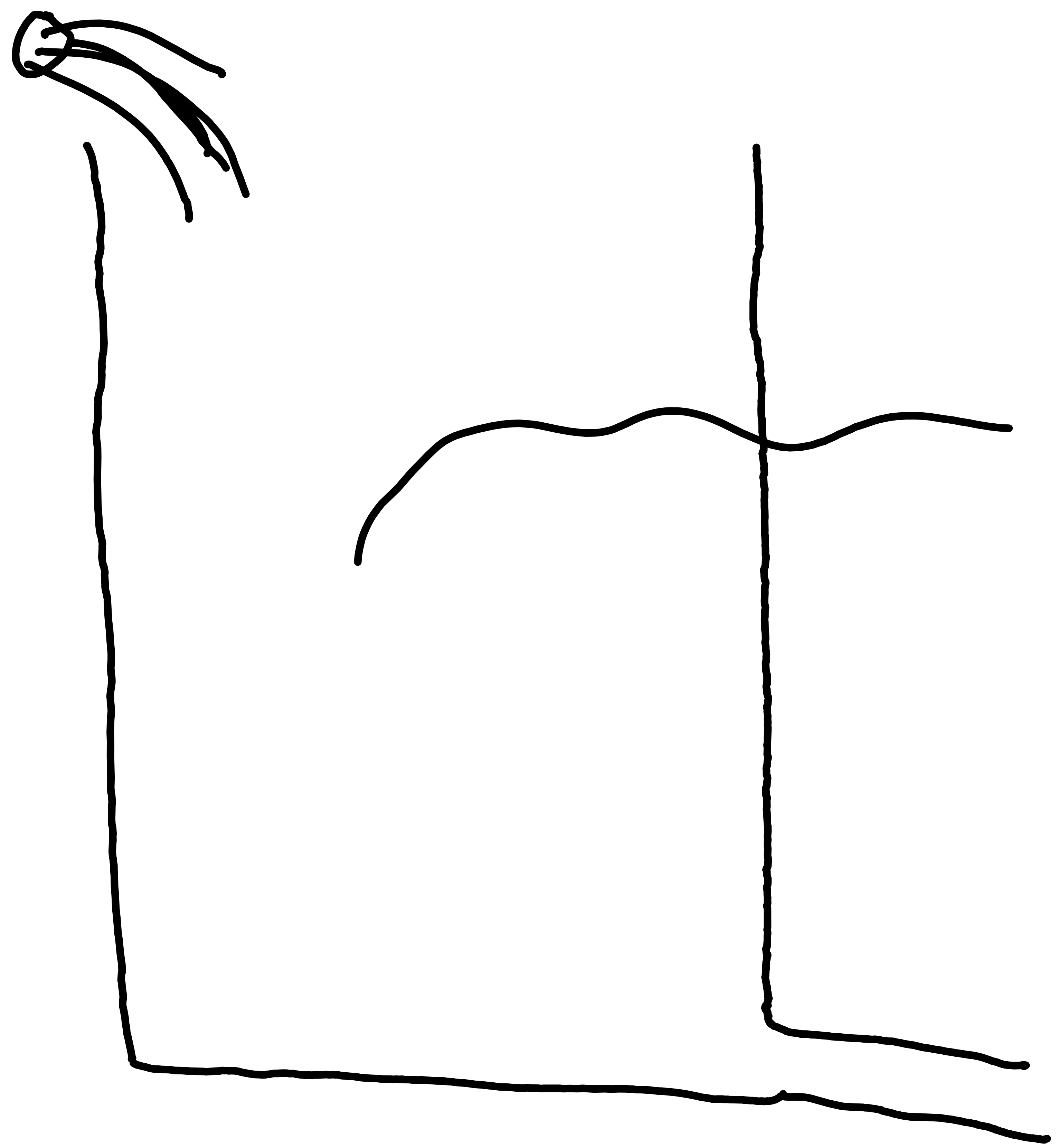
$$\frac{d}{dt}V(t) = \frac{1}{C}\frac{d}{dt}q(t) \Rightarrow I$$

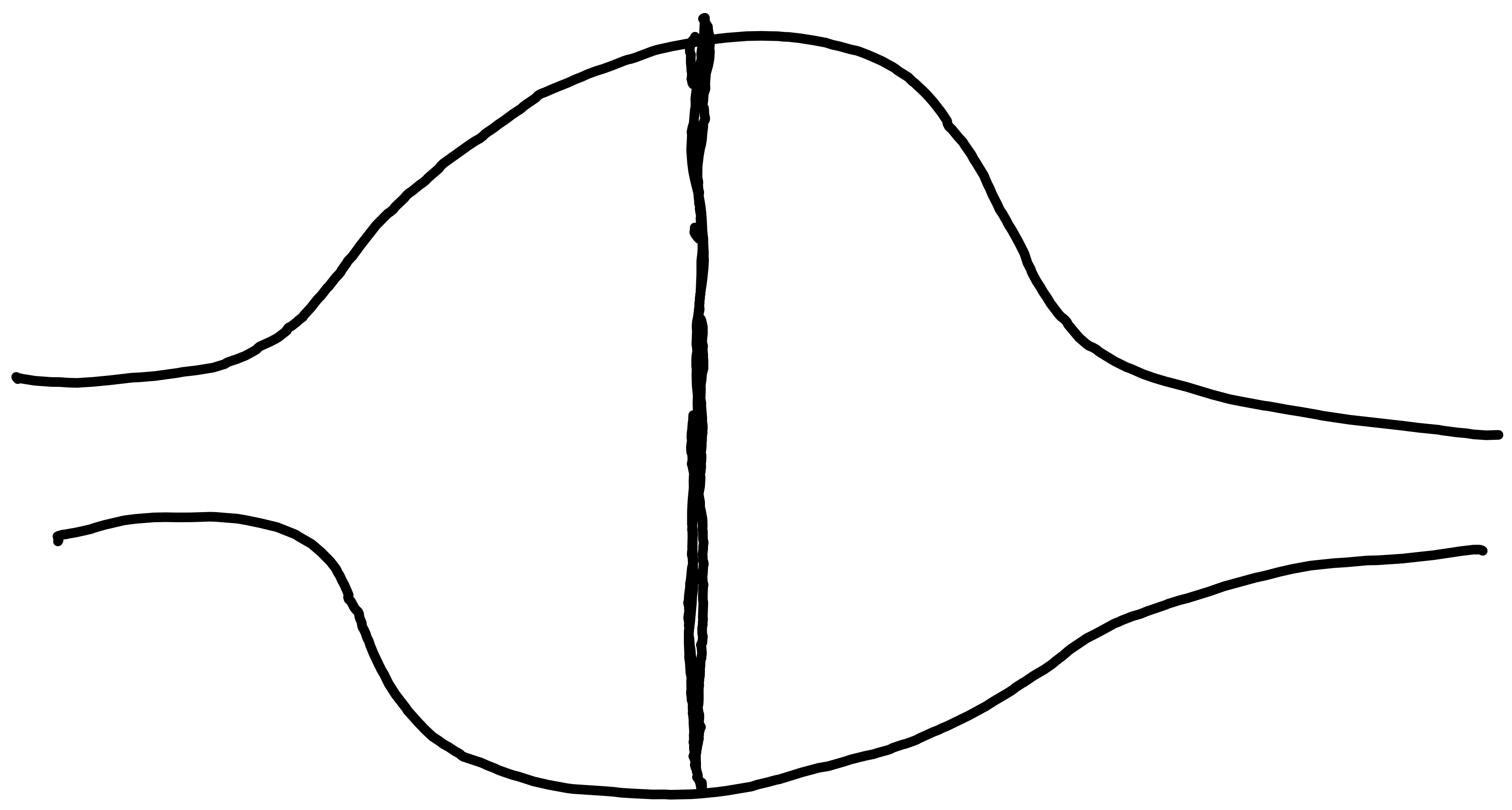
$$\Rightarrow I(t) = \frac{1}{C}\frac{dV}{dt} \Rightarrow \boxed{I = C\dot{V}}$$

C: capacitance

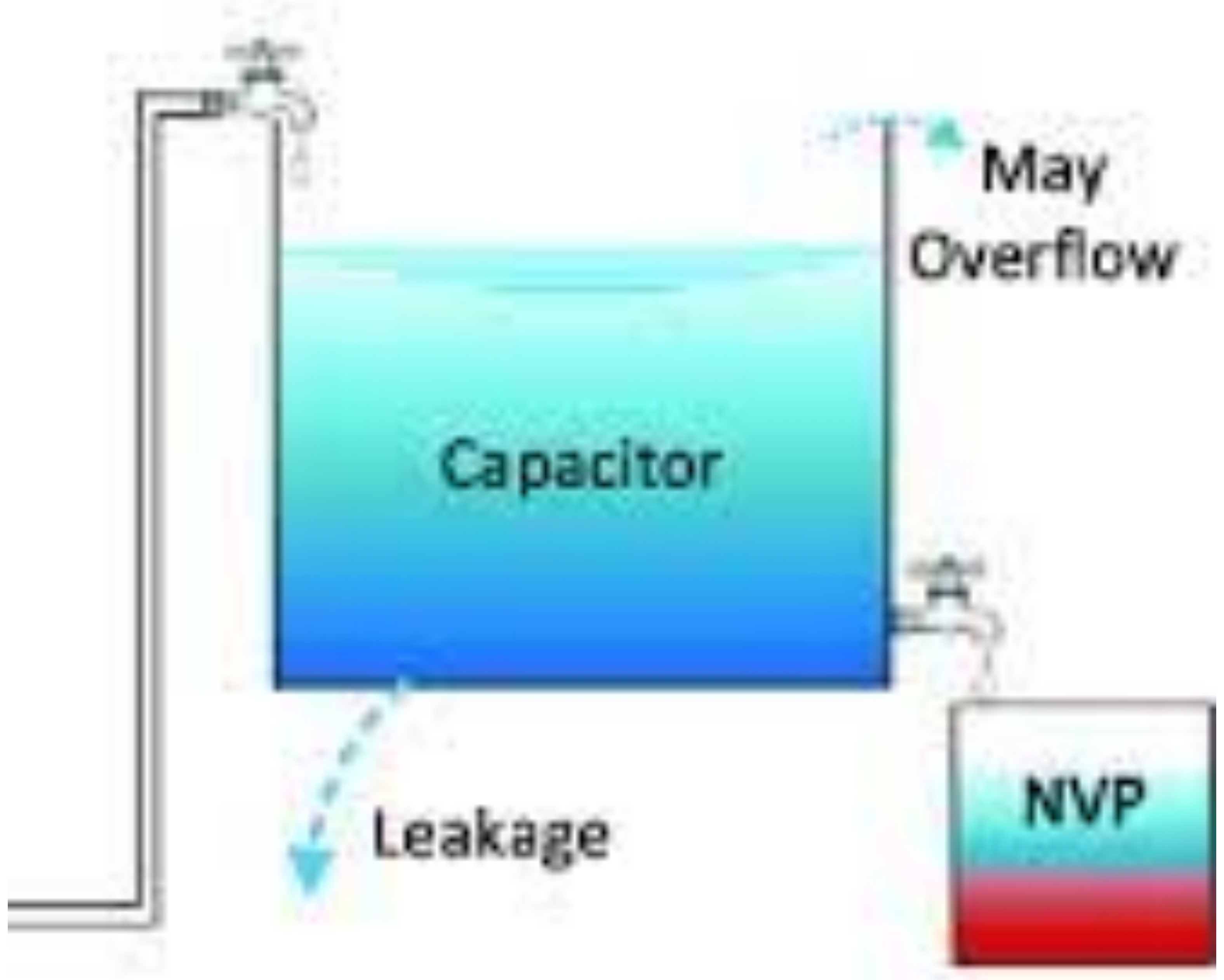
→ material & geometric property Farads

Water Analogy for a capacitor

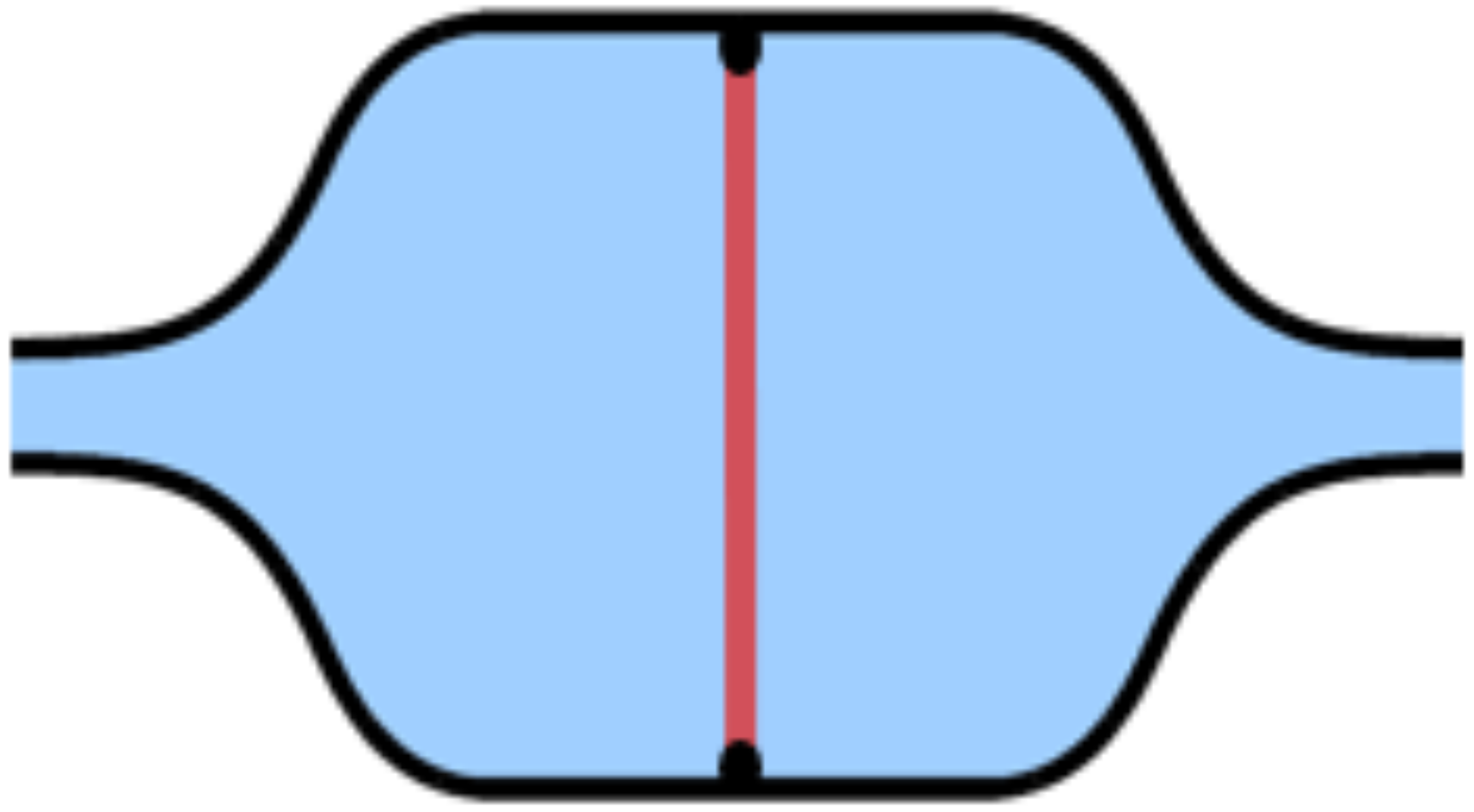




Water Analogy for a capacitor



tank analogy



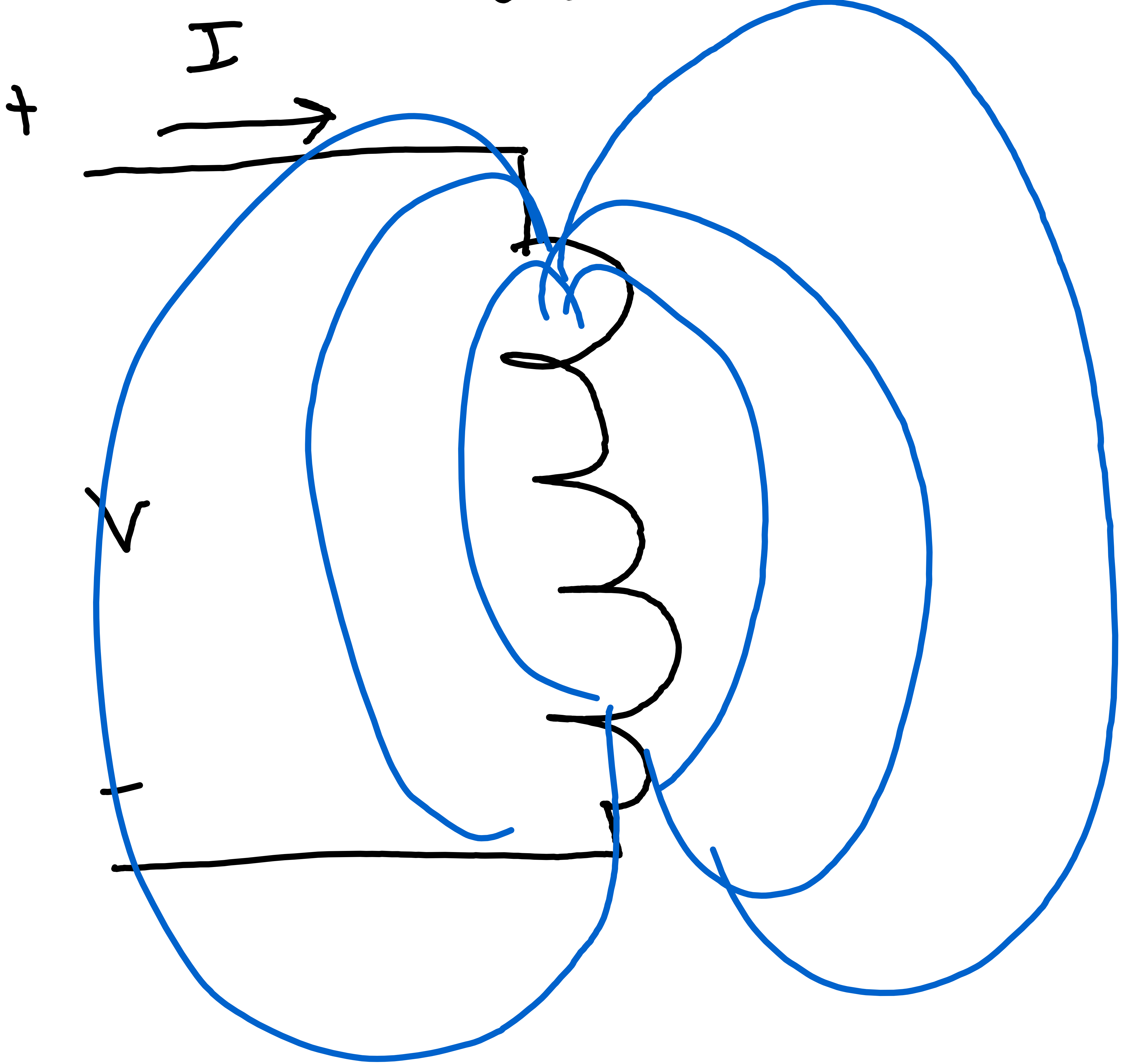
membrane analogy

Inductor: stores energy in the form of a magnetic field

→ coil windings which maintain magnetic field once established

$$V(t) = \frac{d\lambda}{dt}$$

Faraday's Law



λ : magnetic flux

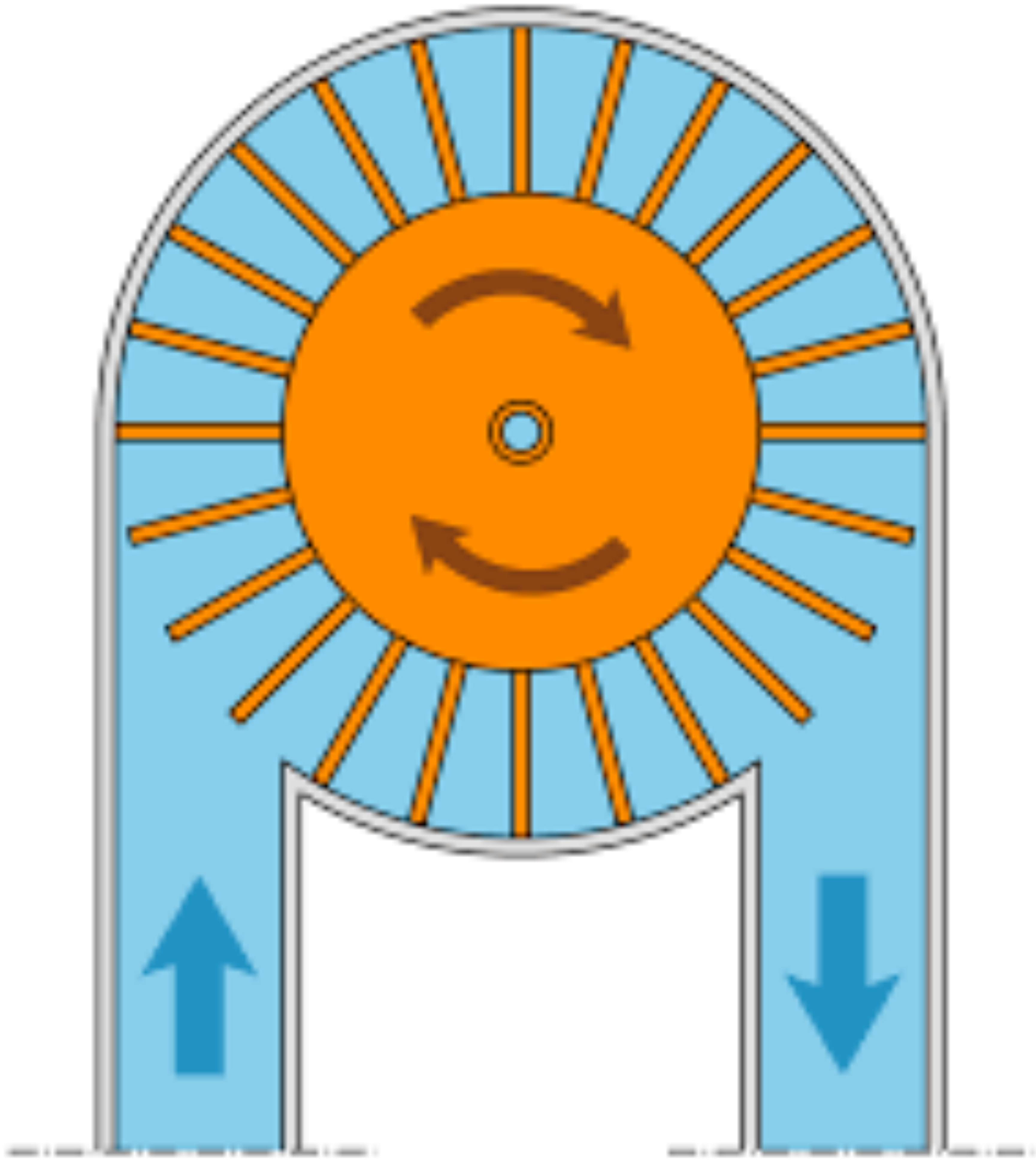
$$\lambda = L I$$

inductance

$$V(t) = L \frac{dI}{dt} = L \dot{I}$$

Water Analogy for a inductor

Water Analogy for a inductor

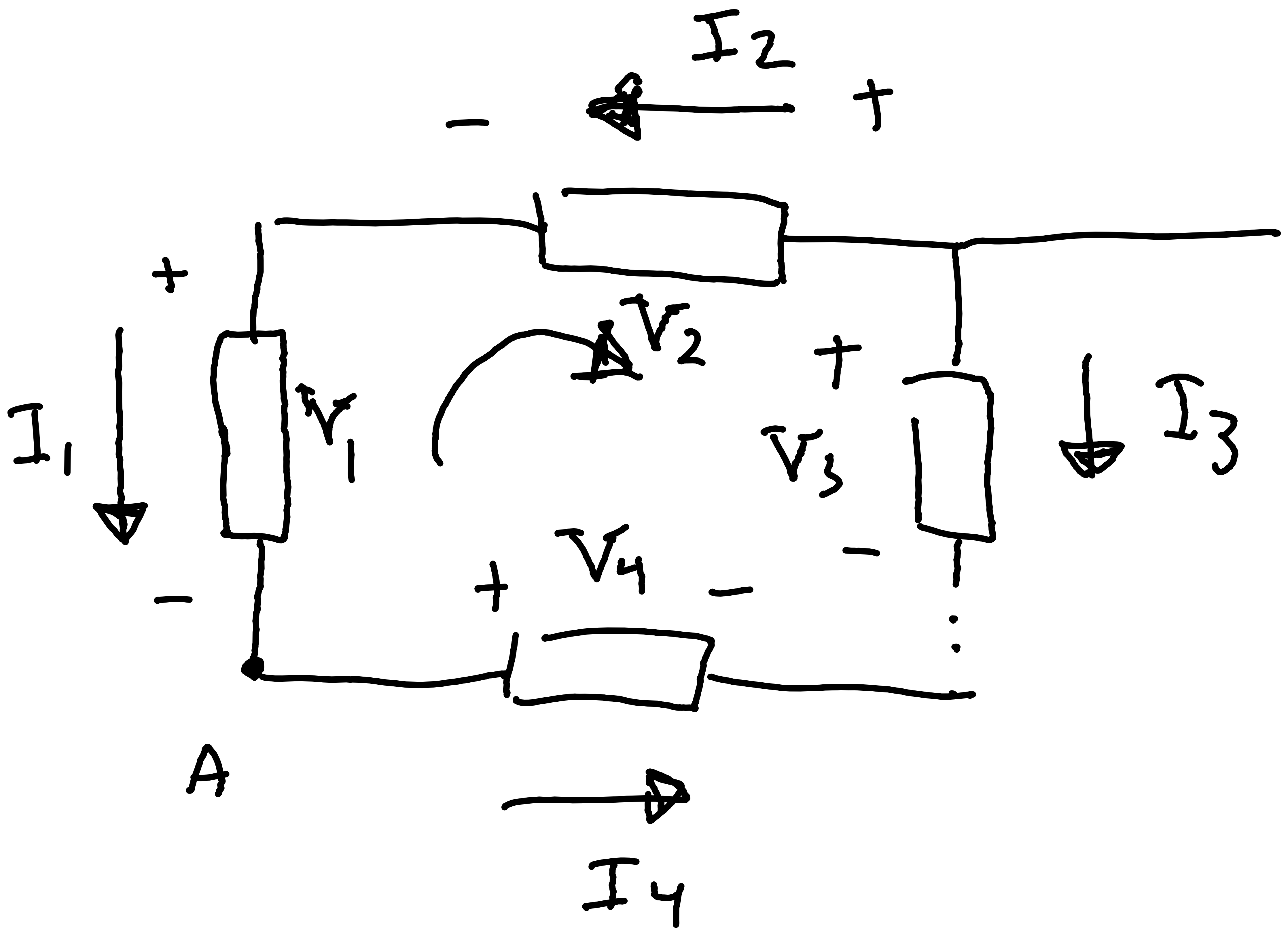


water wheels stores energy as inertia

Kirchhoff's voltage law (KVL)

sum of voltages around a closed path is zero.

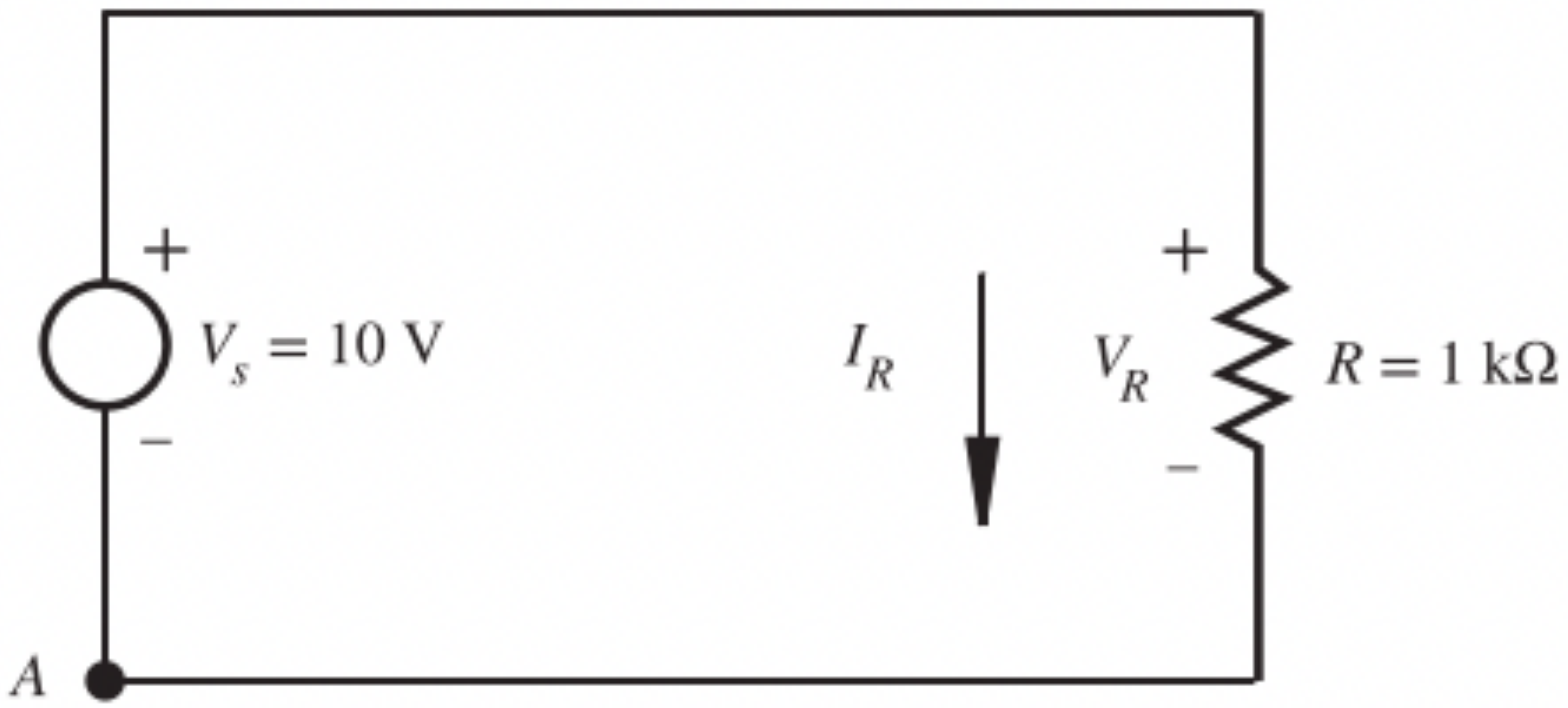
$$\sum_{i}^{N} V_i = 0$$



1. assume current direction
2. assign polarity
3. start loop from anywhere
4. sum all voltages

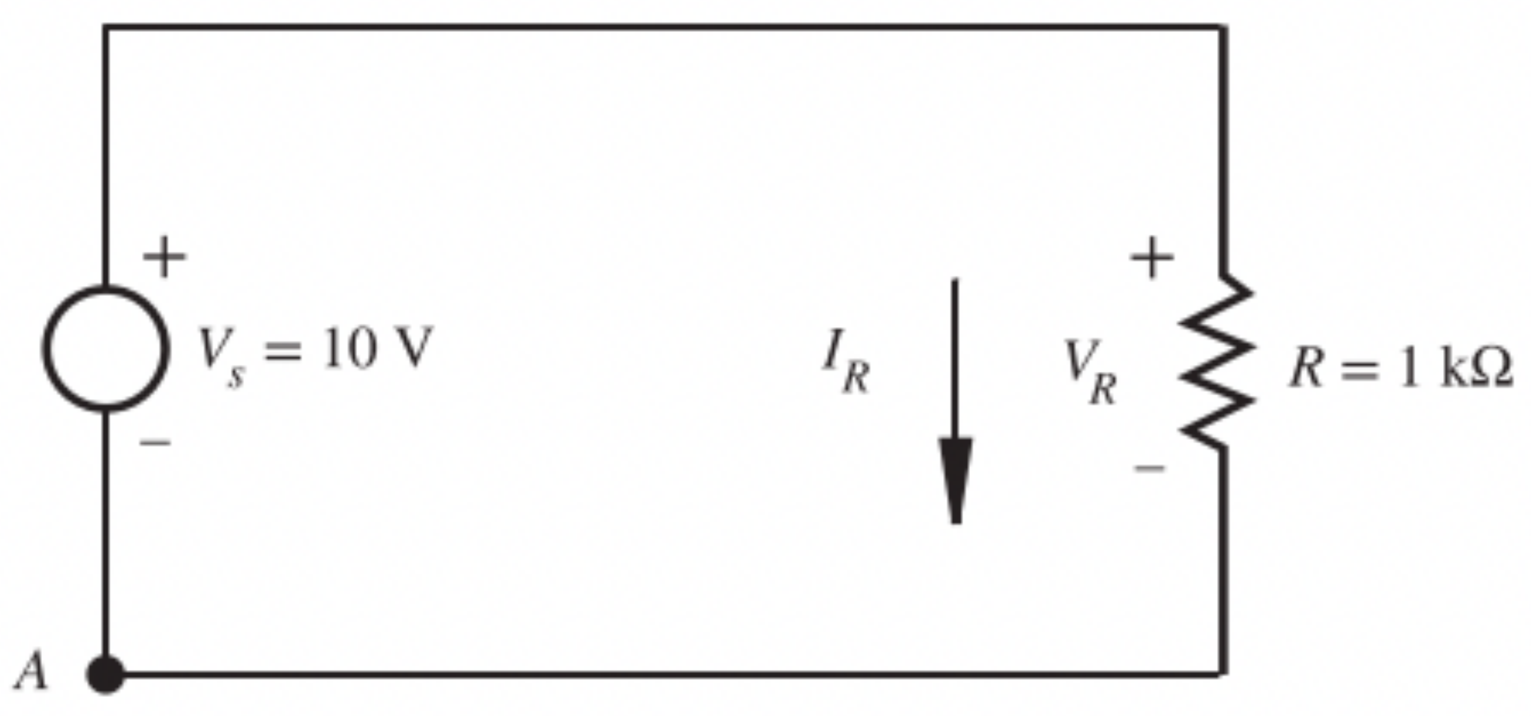
$$-V_1 - V_2 + V_3 + \cdots + -V_4 = 0$$

KVL Example (2.3 pg. 24)



Find the current through the resistor.

KVL Example (2.3 pg. 24)



Find the current through the resistor.

KVL: $-V_s + V_R = 0$

$$V_s = V_R$$

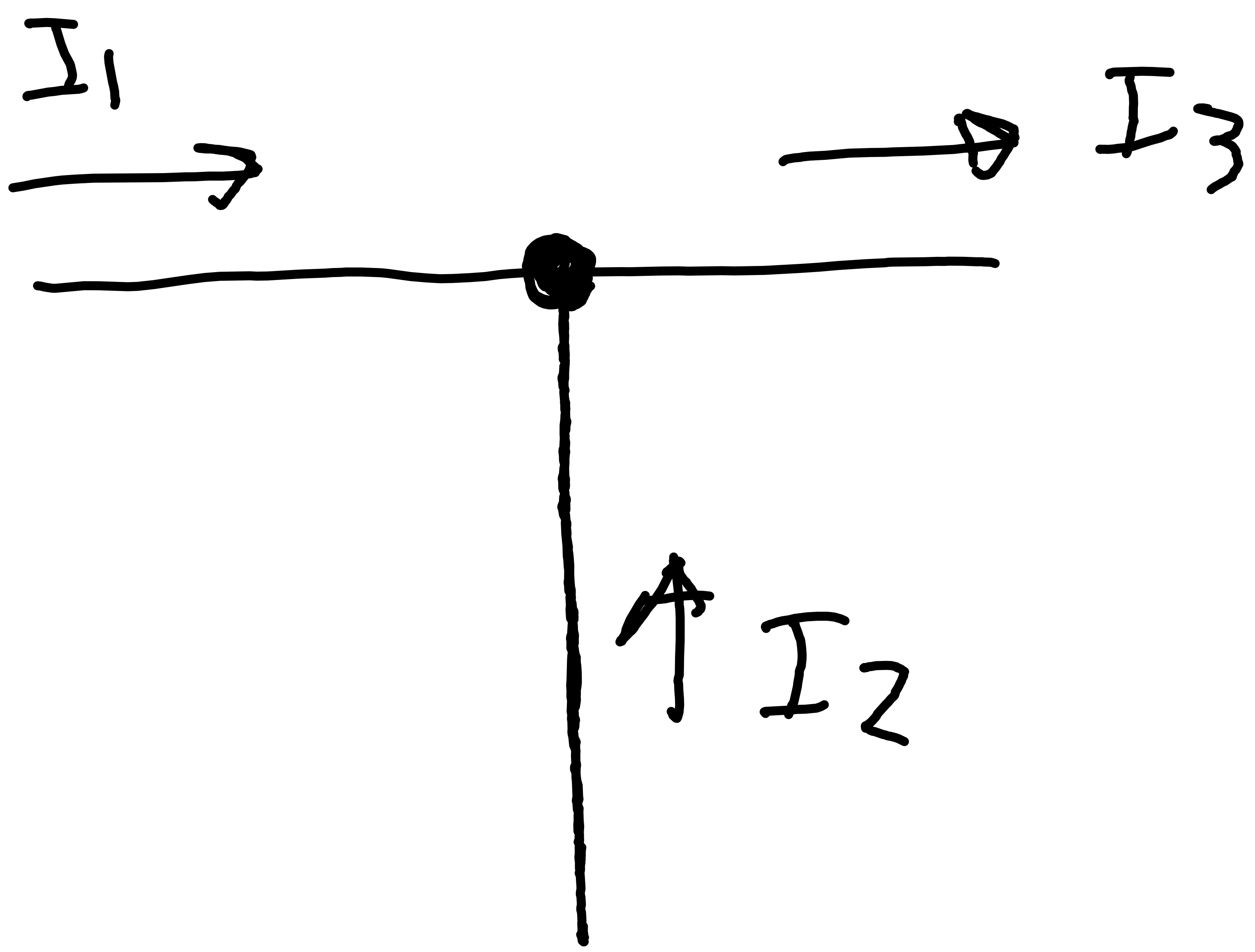
$$I_R = \frac{V_s}{R} = \frac{10V}{1k\Omega}$$

$$= \underline{10\,mA}$$

Kirchhoff's current law (KCL)

sum of currents flow in/out of a node is zero

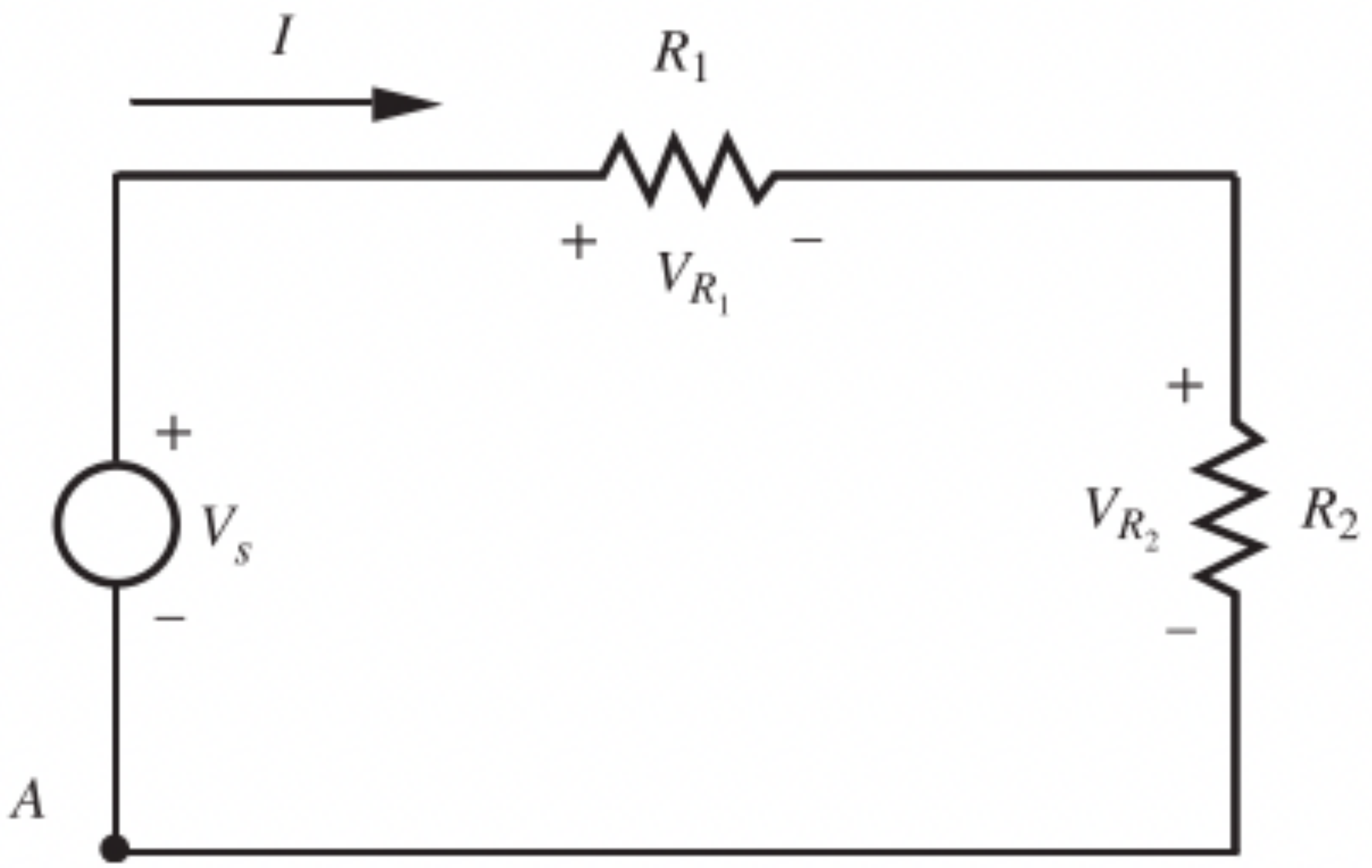
$$\sum_{i}^{N} I_i = 0$$



$$I_1 + I_2 = I_3$$

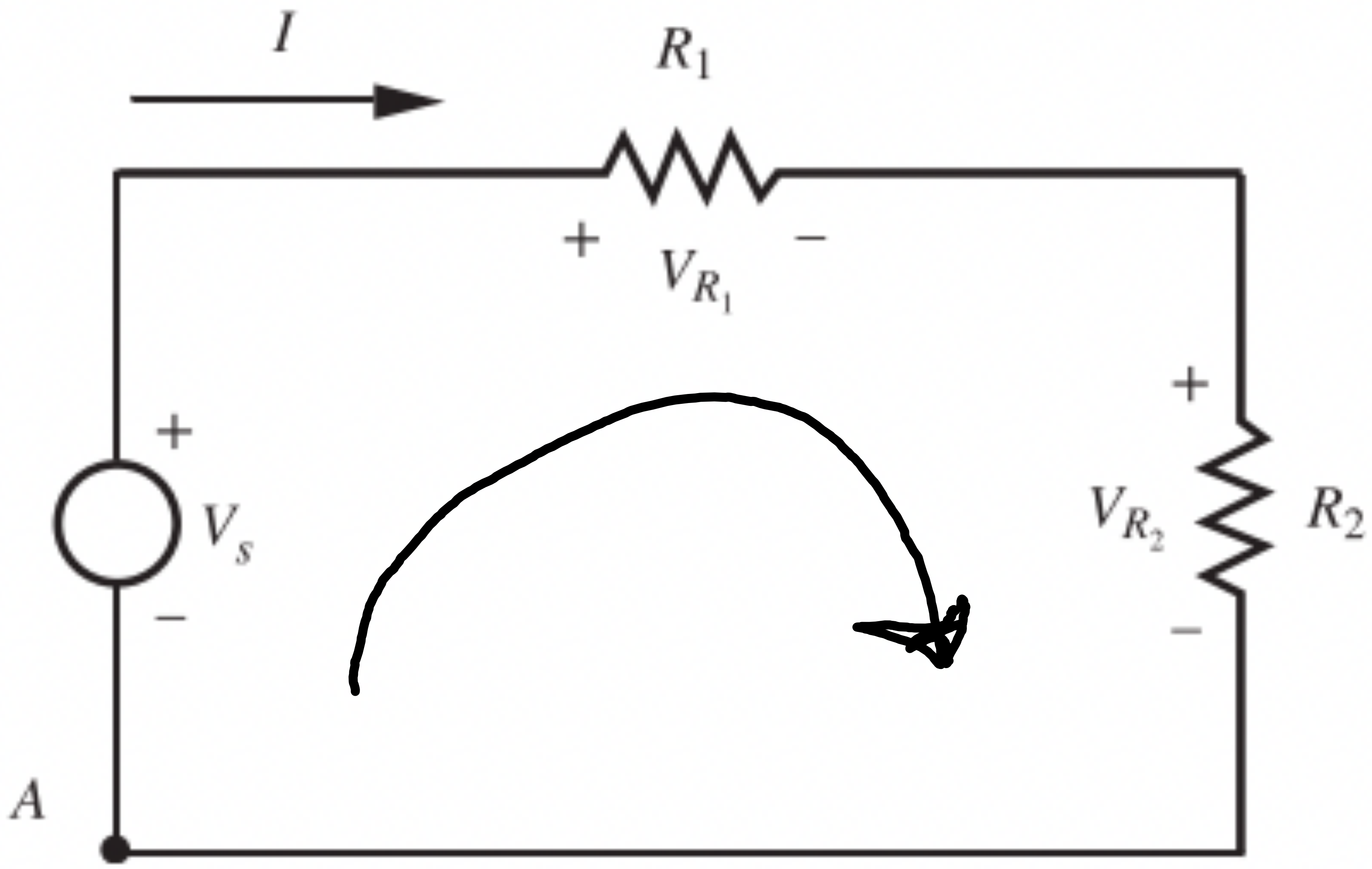
** often you must assume curret direction. You have assume voltage consistent with you current directions.! if after analysis the result are neg. that means the result is opposite of your assumption.

Series Resistance



Find Req?

Series Resistance



KCL: $I = I_{R_1} = I_{R_2}$

KVL: $-V_s + V_{R_1} + V_{R_2} = 0$

Ohm's Law

$V_{R_1} = I R_1$

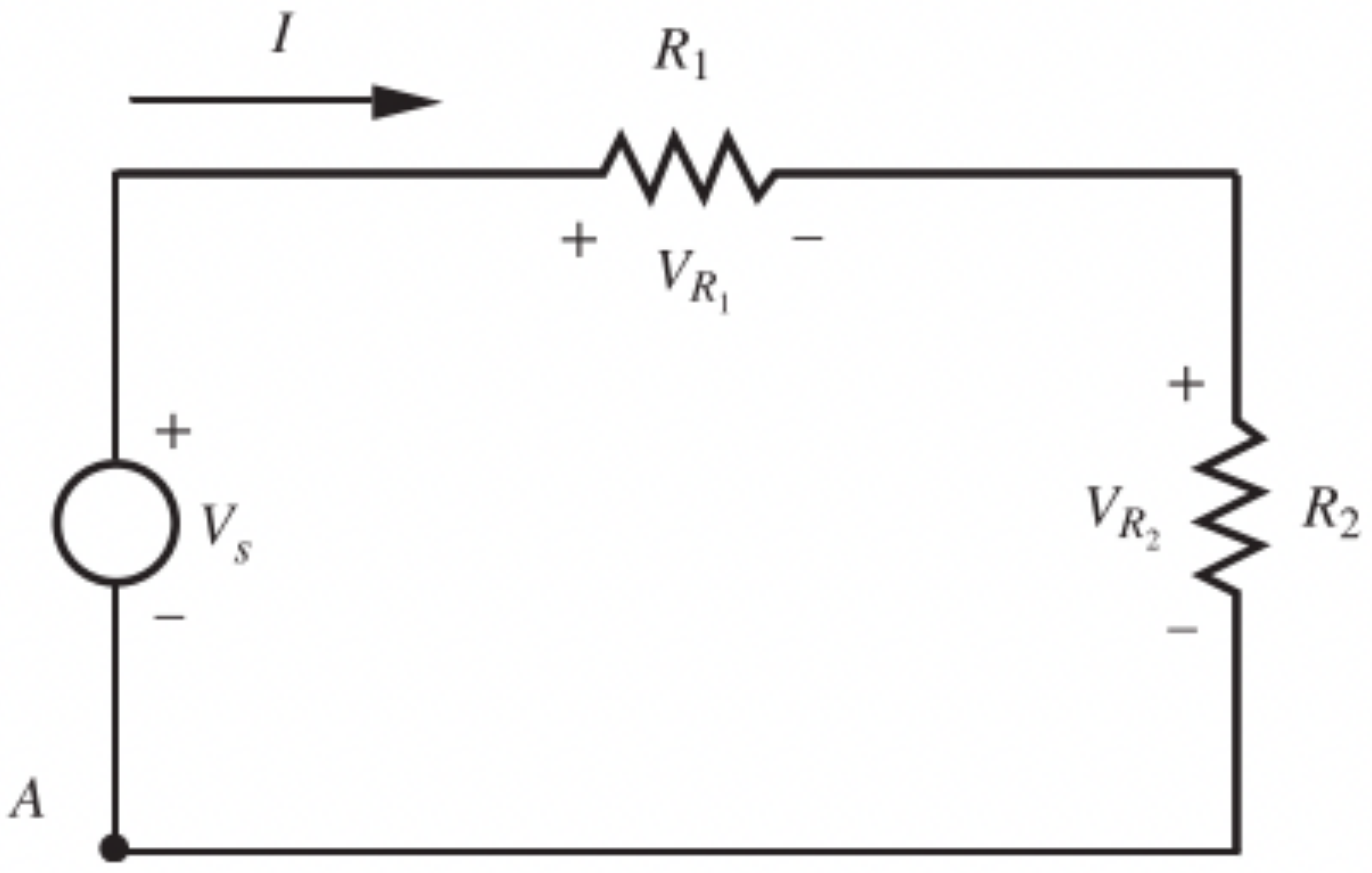
$V_{R_2} = I R_2$

$-V_s + I R_1 + I R_2 = 0$

$V_s = (R_1 + R_2) I$

Resistor in series add!

Voltage Divider Circuit



$$V_{R1} = \frac{R_1}{R_1 + R_2} V_s$$

$$V_{R2} = \frac{R_2}{R_1 + R_2} V_s$$

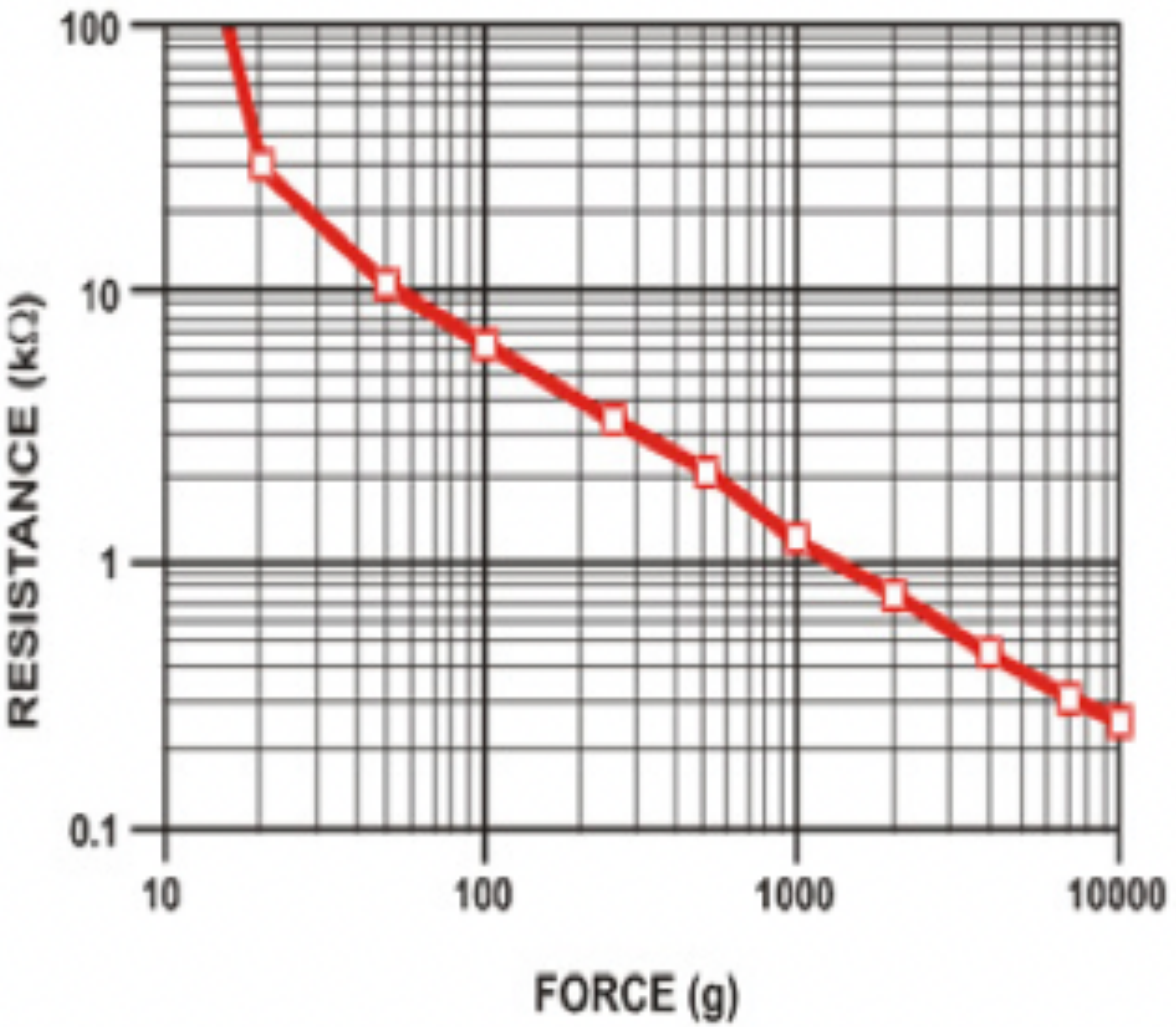
Why is this circuit useful?

> step down voltages

> simplest sensing circuit

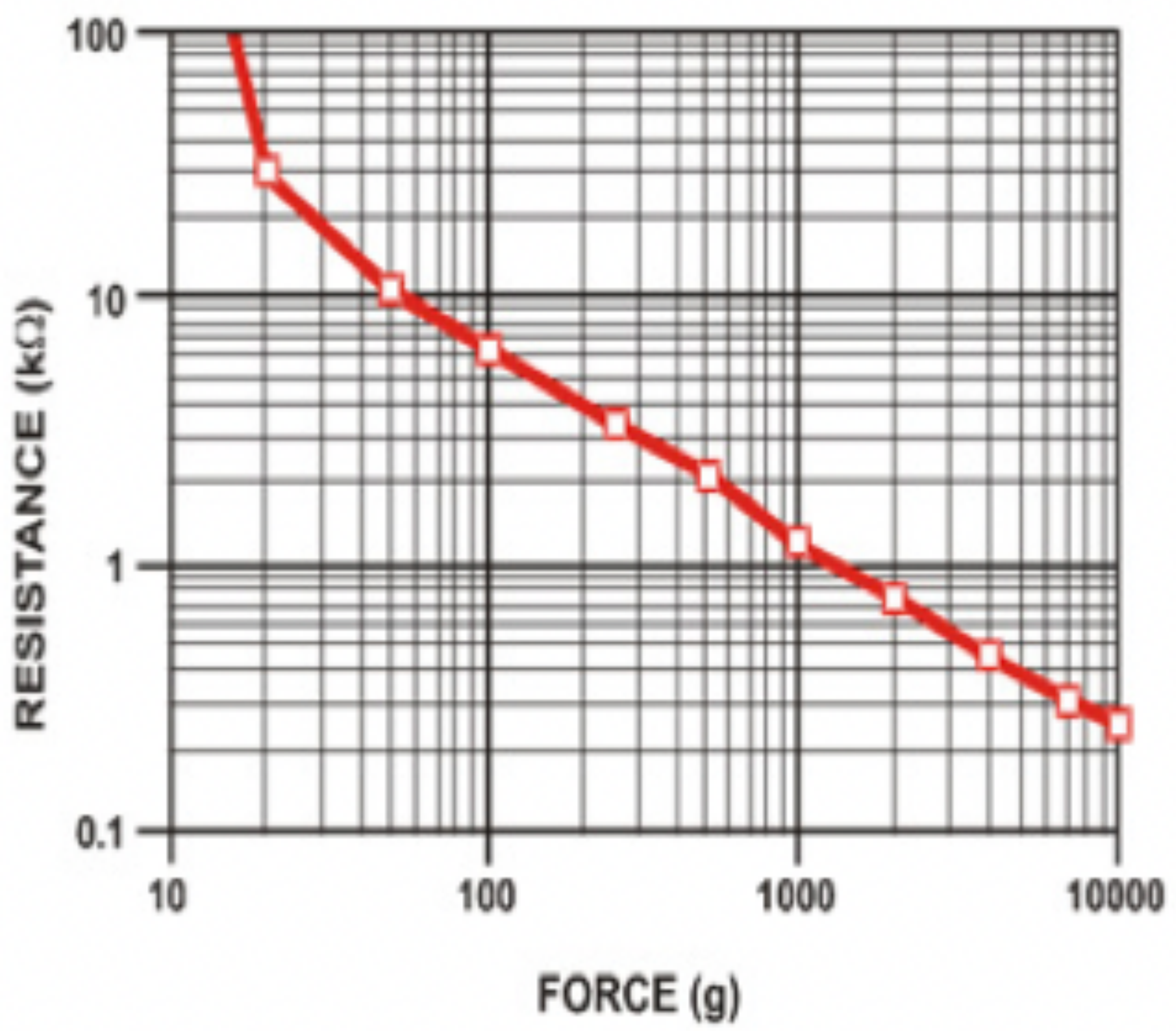
What if we have a sensor that changes a resistance with stimuli?

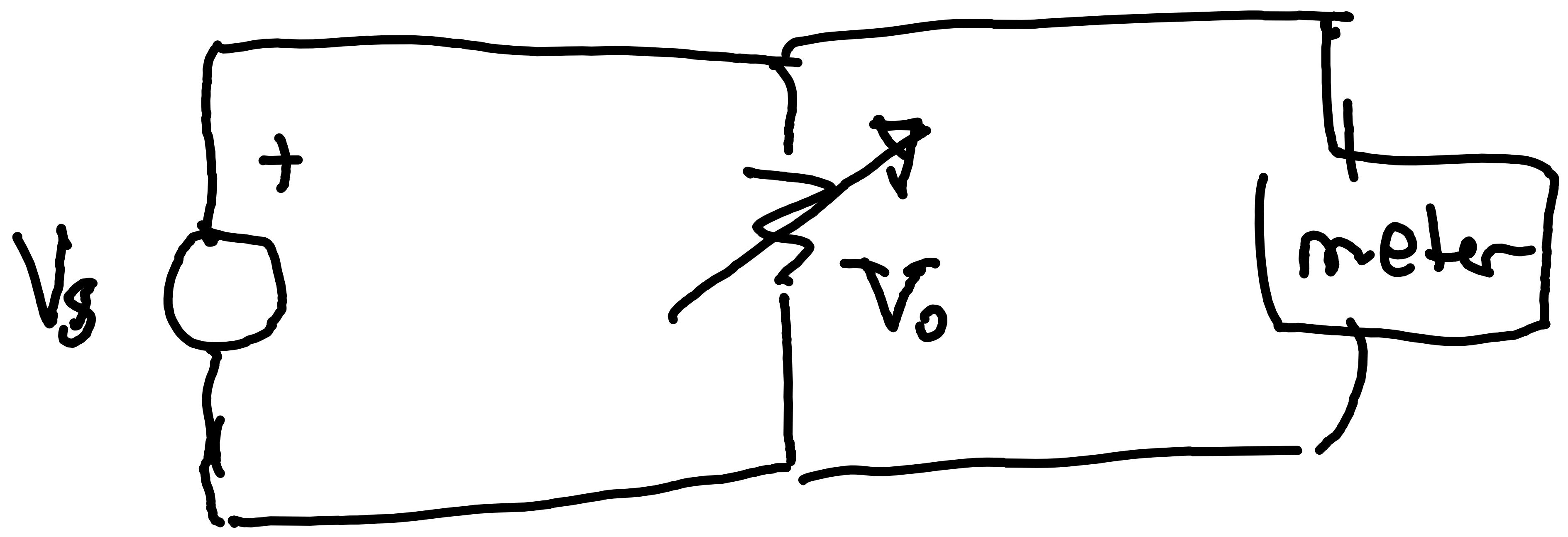
Force Sensitive Resistor



How can we convert resistance into something we can measure with a microcontrol (Voltage!?) ?

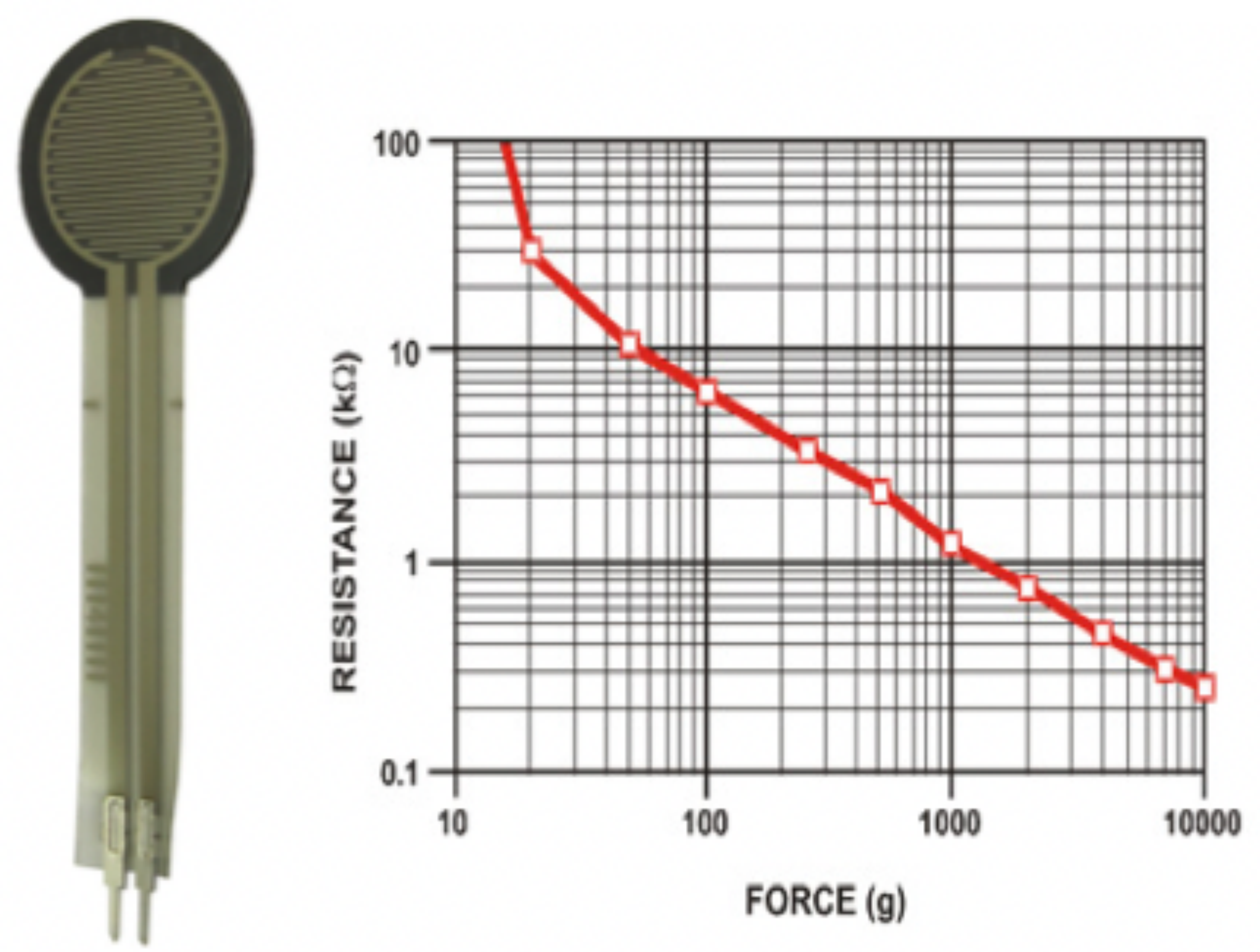
What if we have a sensor that changes a resistance with stimuli?

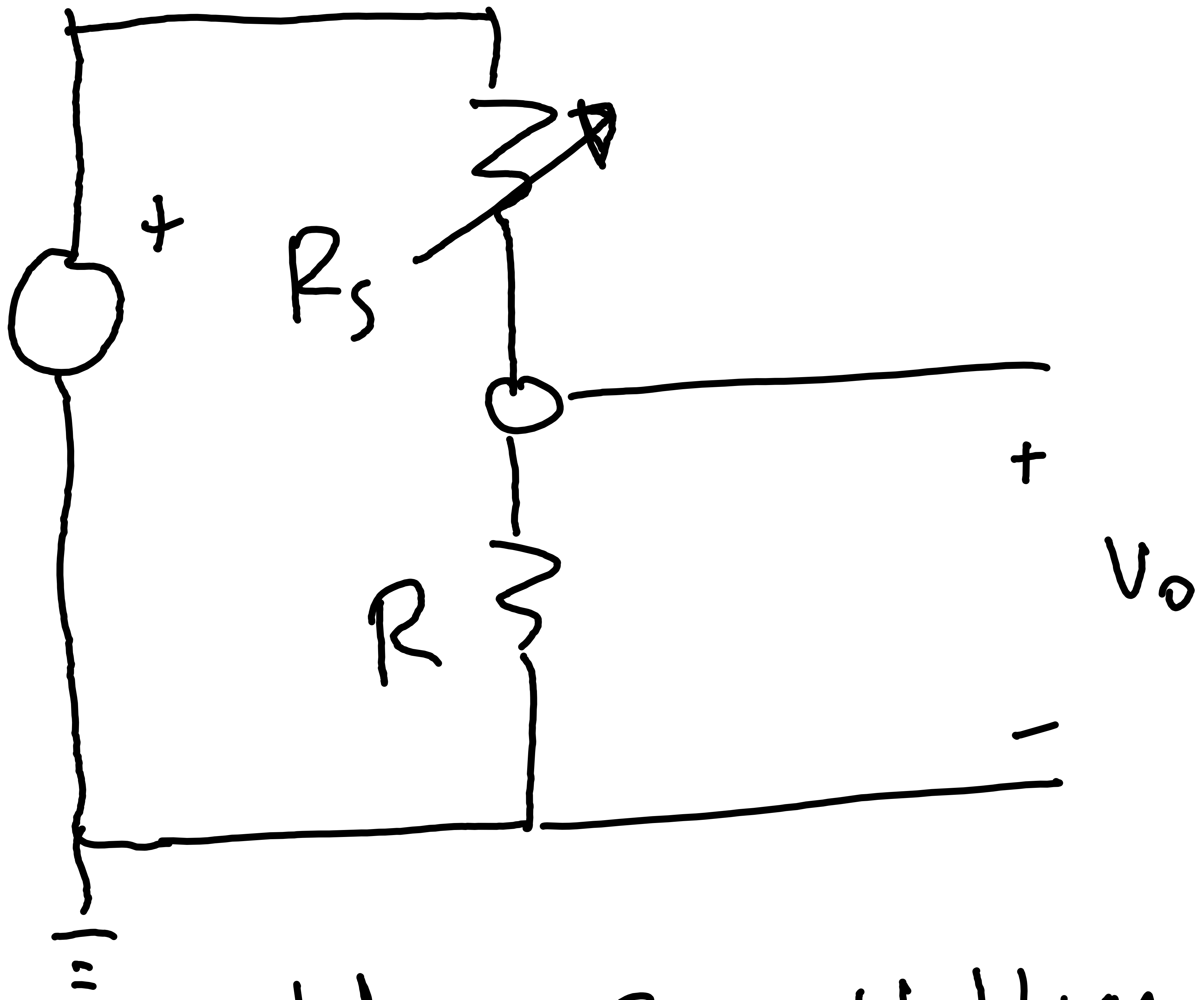




Idea 1: Would this work?

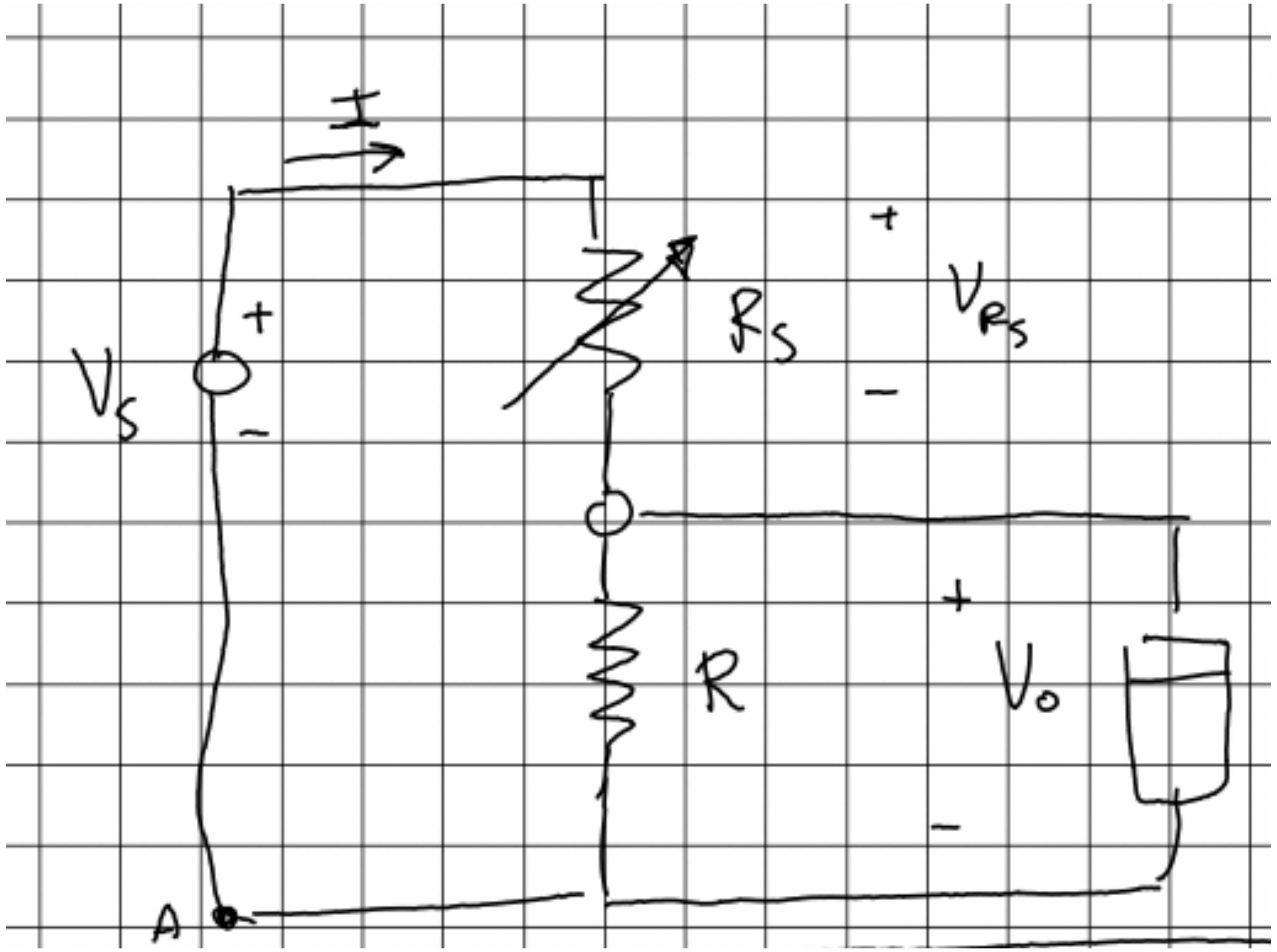
What if we have a sensor that changes a resistance with stimuli?





Idea 2: Voltage divider.

What if we have a sensor that changes a resistance with stimuli?



KCL: $I = I_{R_s} = I_R$

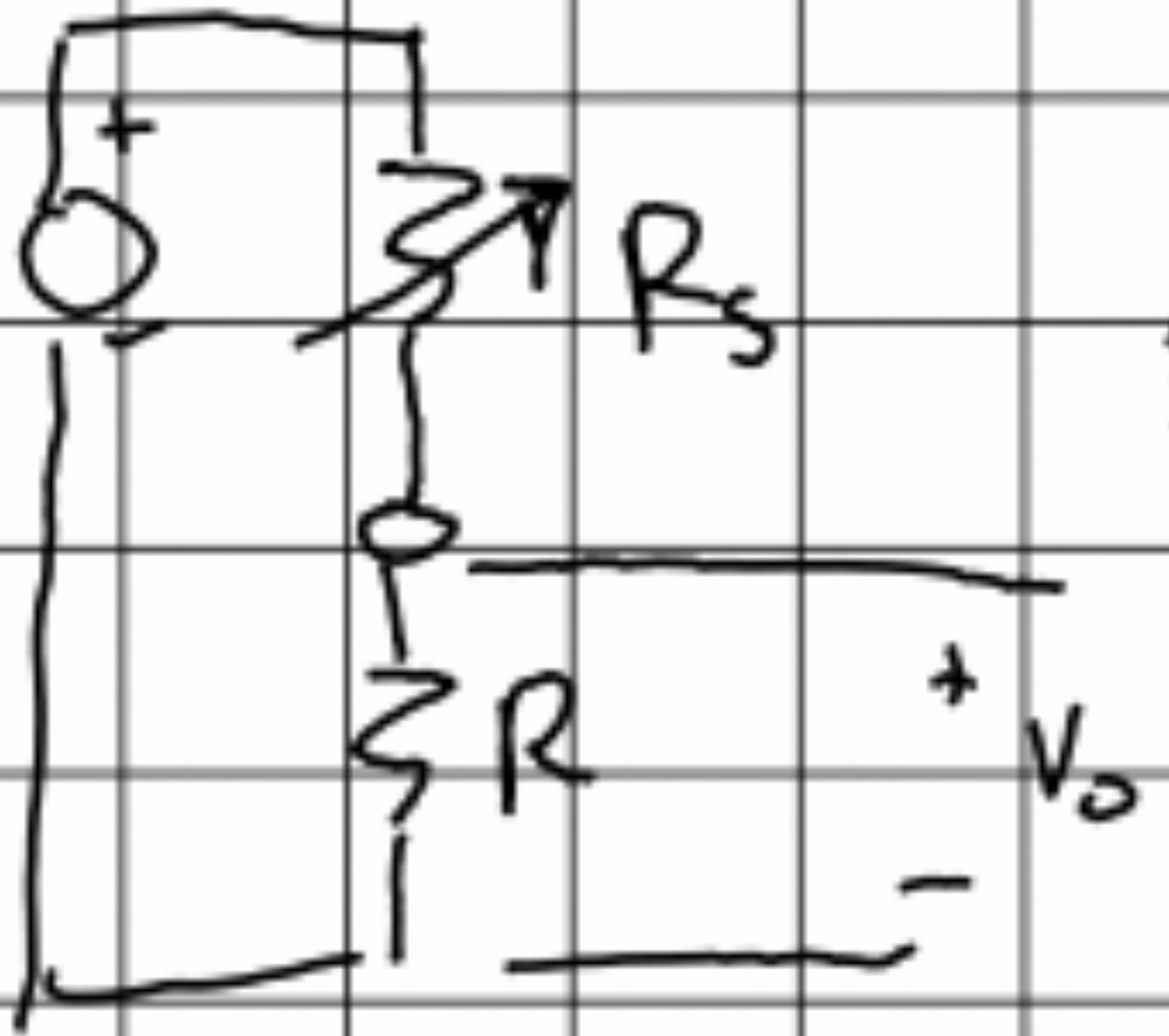
KVL: $-V_s + V_{R_s} + V_o = 0$

$$V_s = V_{R_s} + V_R$$

$$= IR_s + IR = I(R_s + R)$$

$$I = \frac{V_o}{R} \Rightarrow \boxed{\frac{R}{R_s + R} V_s = V_o}$$

Let’s look at the limits:



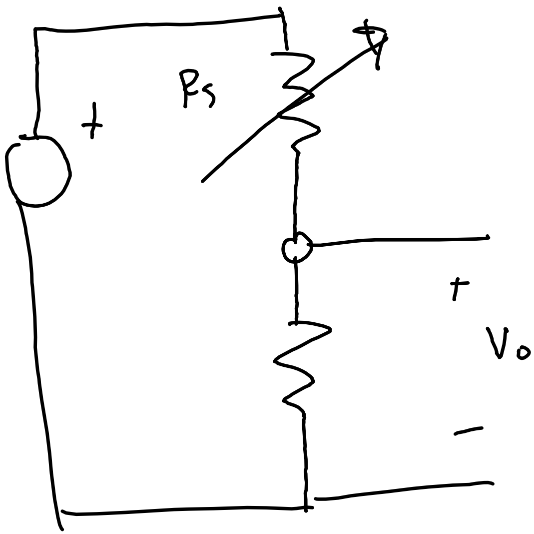
$$\lim_{\substack{R_s \to 0 \\ F \to \infty}} V_o = \left(\frac{R}{\cancel{R_s} + R}\right) V_s$$

$$\underset{0}{\downarrow}$$

$$= V_s$$

$$\lim_{\substack{R_s \to R_{s,max} \\ F \to 0}} V_o = \left(\frac{R}{R_{s,max} + R}\right) V_s$$

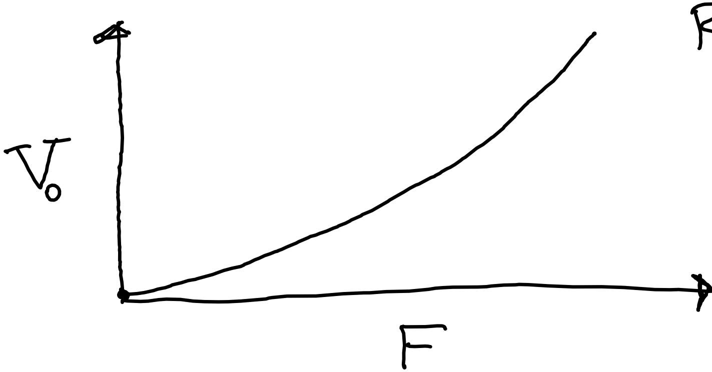
$$V_o = \left(\frac{R}{R_s + R}\right) V_s$$



$$\lim_{\substack{R_s \to 0 \\ F \to \infty}} \left(\frac{R}{R_s + R}\right) \bar{V}_s = V_s$$

$$\lim_{\substack{R_s \to R_{s,max} \\ F \to 0}} \left(\frac{R}{R_s + R}\right) \bar{V}_s = 0$$

$$R_{s,max} >> R$$



* multi meter tutorial

Now we can *sample* the voltage from the voltage divider, which is proportional to the force