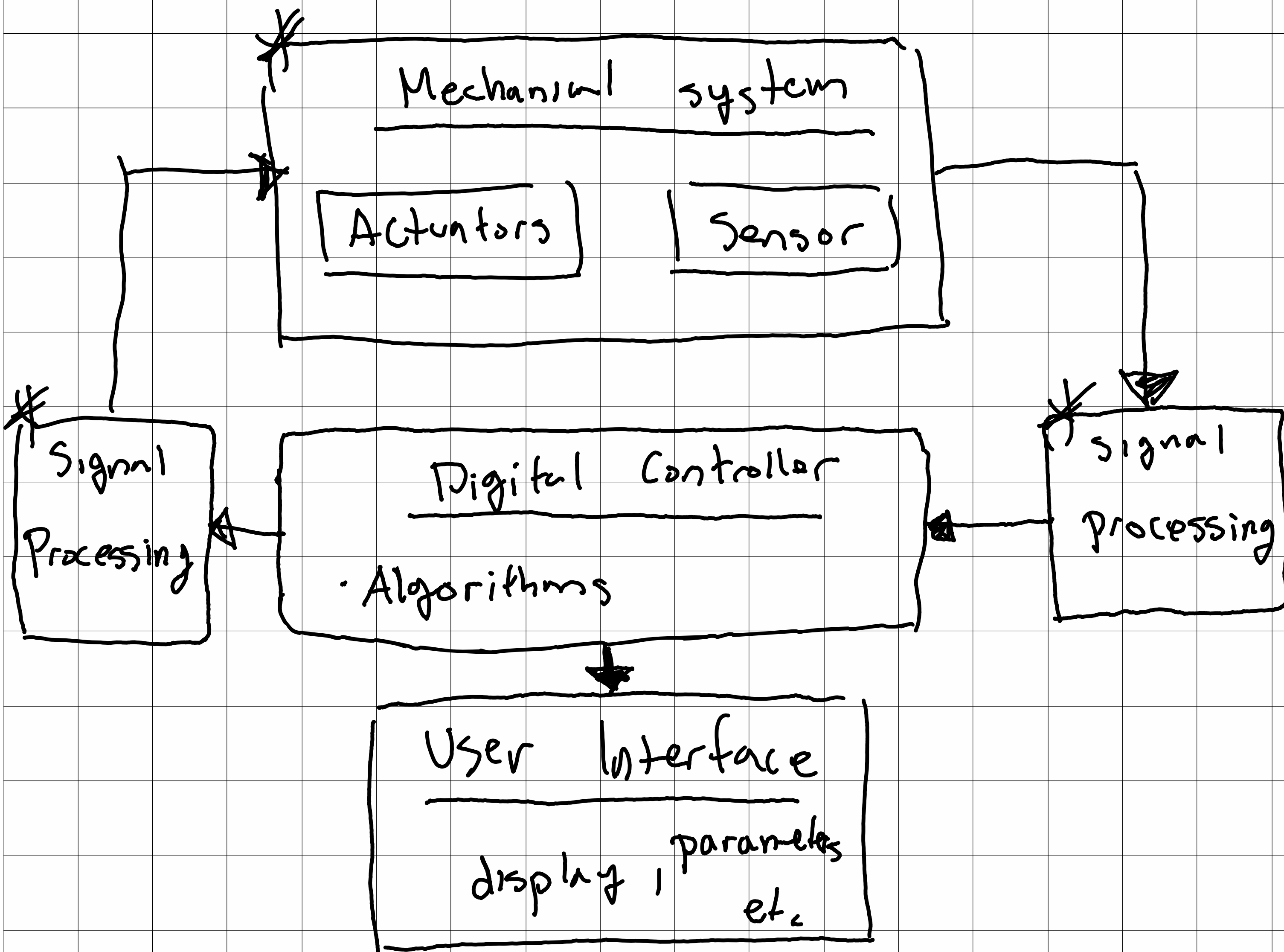
Lecture 2 1/6/2022

last time: "What is mechatronics?"



Basic electronic components

Today:

1. Basic elements of electrical systems

2. Kirchoff's Laws

3. Examples

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all mechatronic systems contain electrical circuits

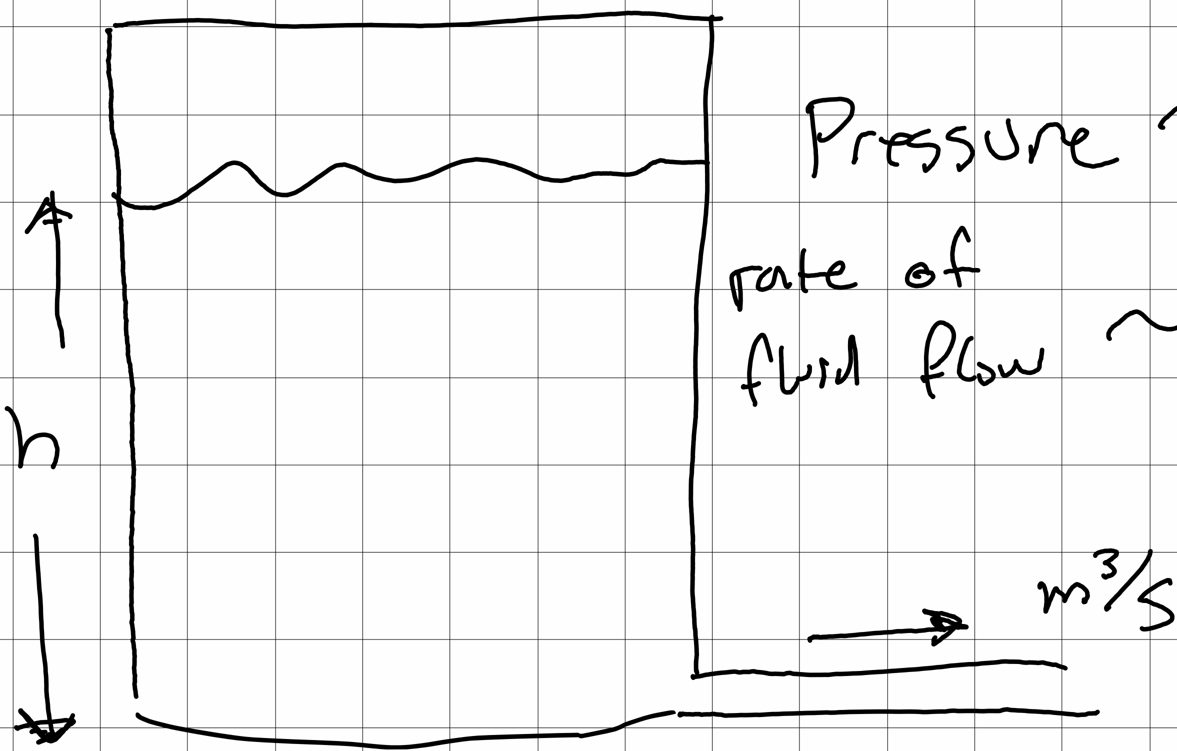
How do circuits work?

Voltage: a measure of the electric field potential

* analogous to potential energy in a gravitational field

Current: time rate of "flow of charge"

→ water through a pipe.



Pressure ~ Voltage

rate of fluid flow ~ current

$$I(t) = \frac{dq}{dt}$$

$dq \rightarrow$ charge

$dt \rightarrow$ time

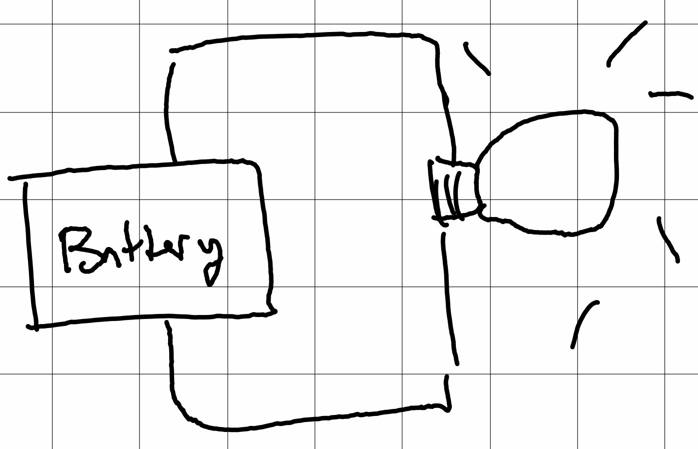
Amperes (A)

* Charge is from negatively charged electrons

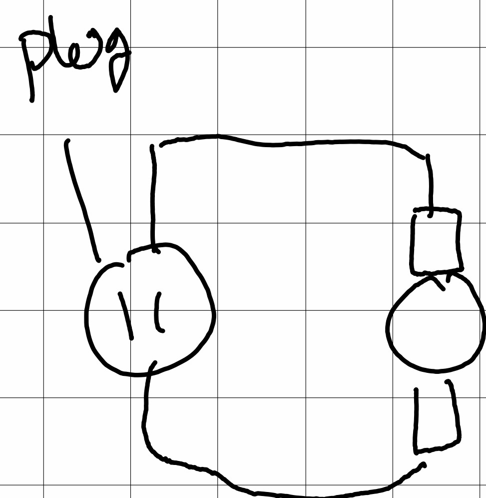
$$\left.\begin{array}{l} V = \text{constant} \\ I = \text{constant} \end{array}\right\} \begin{array}{l} \text{DC} \\ \text{direct current} \end{array}$$

if
$$\left.\begin{array}{l} V = f_1(t) \\ I = f_2(t) \end{array}\right\} \begin{array}{l} \text{AC} \\ \text{alternating current.} \end{array}$$

<u>Electrical circuit:</u> closed loop of conductors

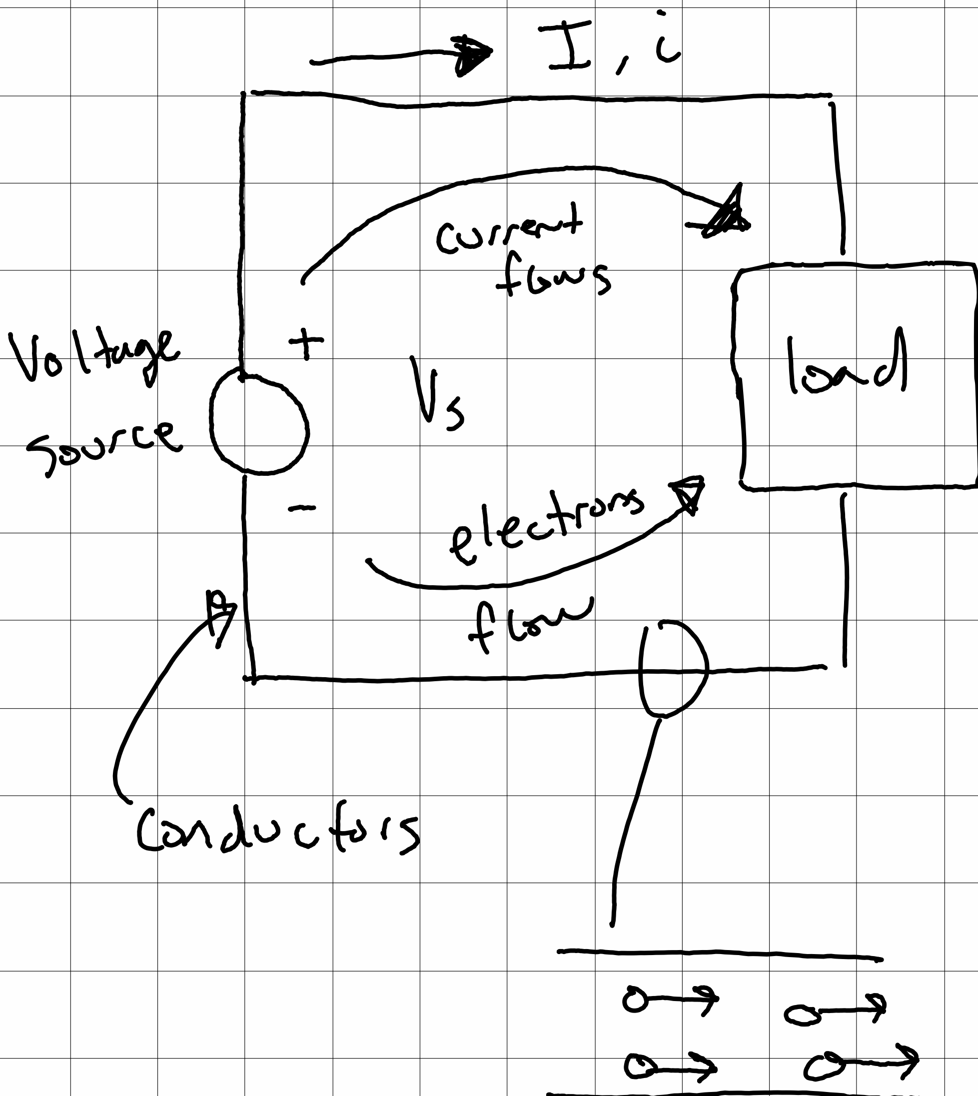


DC



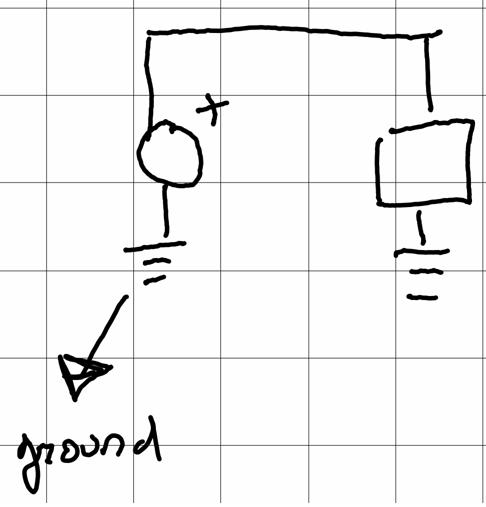
AC

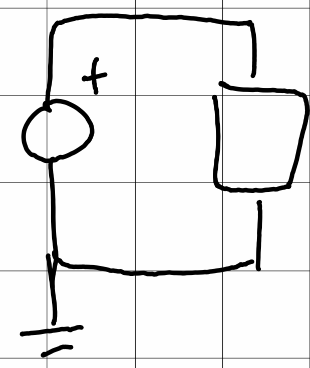
Terminology & Conventions



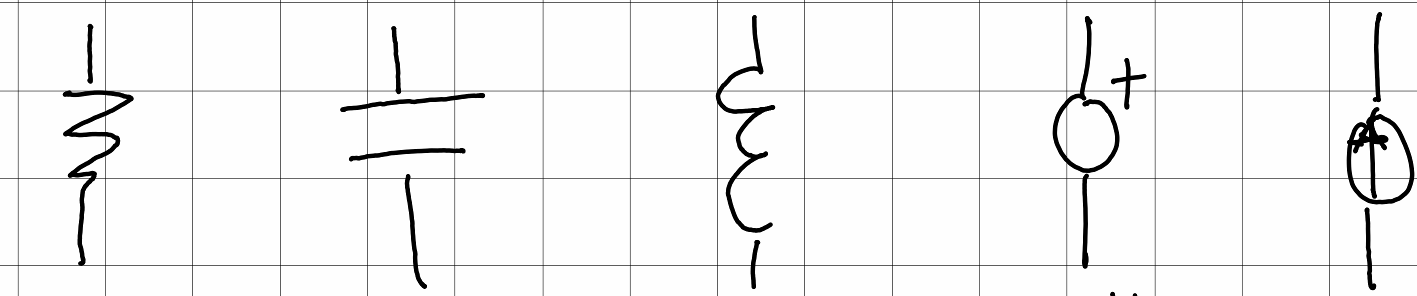
load: network of circuit elements that store/dissipate electrical energy

*** current is the flow of positive charge**





Basic electrical Elements



resistor capacitor inductor Voltage source Current source

(ideal)

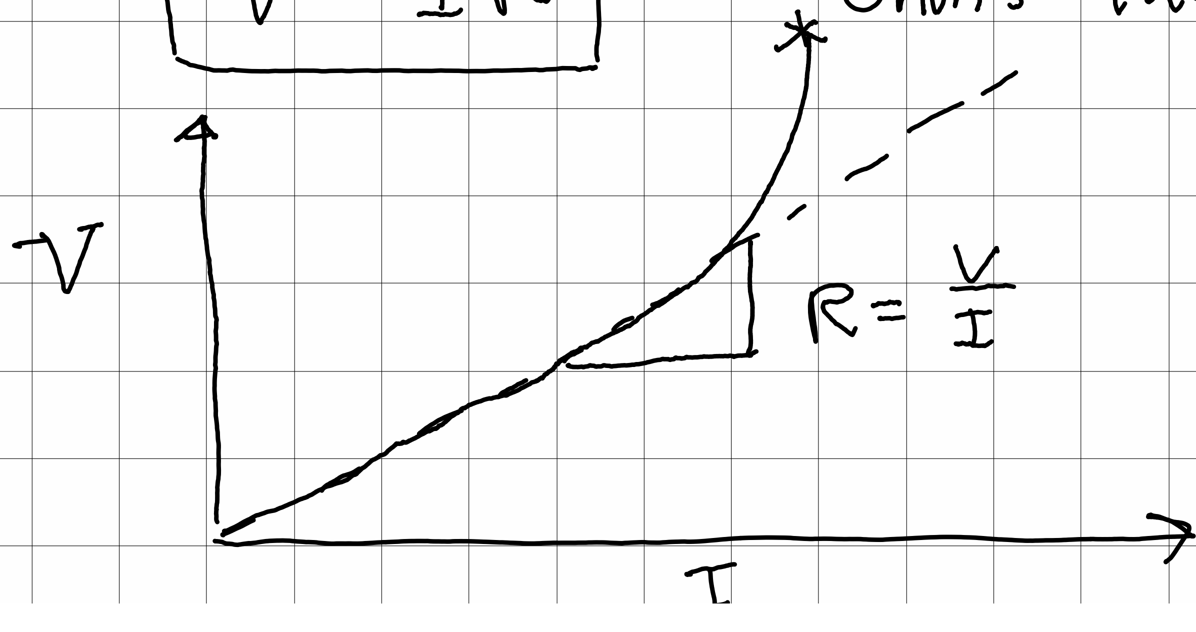
Resistor: converts electrical energy into heat

dissipates energy.

Voltage - current characteristics:

$$\boxed{V = IR}$$

Ohm's law

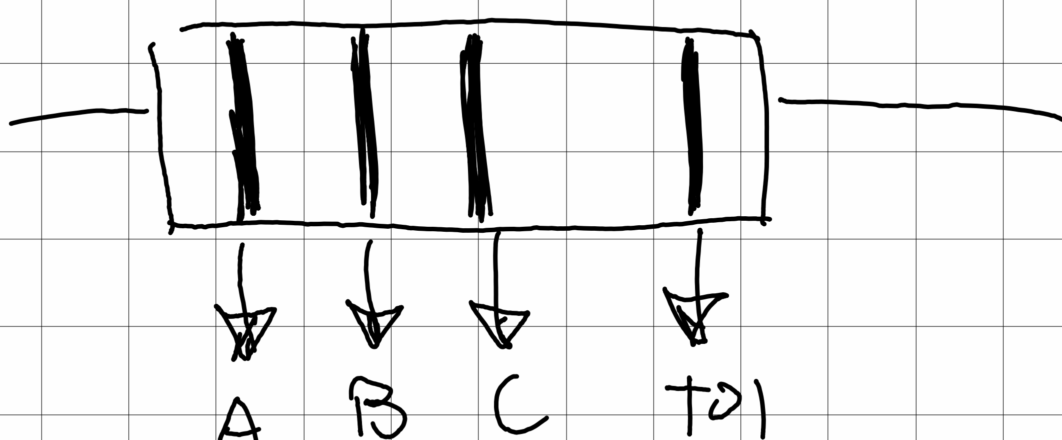


For homogenous material w/ constant cross-sectional area:

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

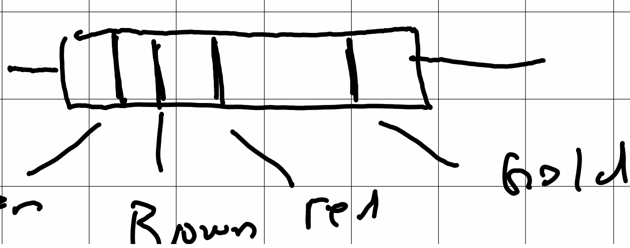
L: Length
ρ: resistivity
A: cross-sectional area

Resistor Color Codes:



$$R = A \cdot B \times 10^{C} \pm \text{Tol}\ \% \ (\Omega)$$

EX.



$R = 51 \times 10^2$
$\pm 5\%$

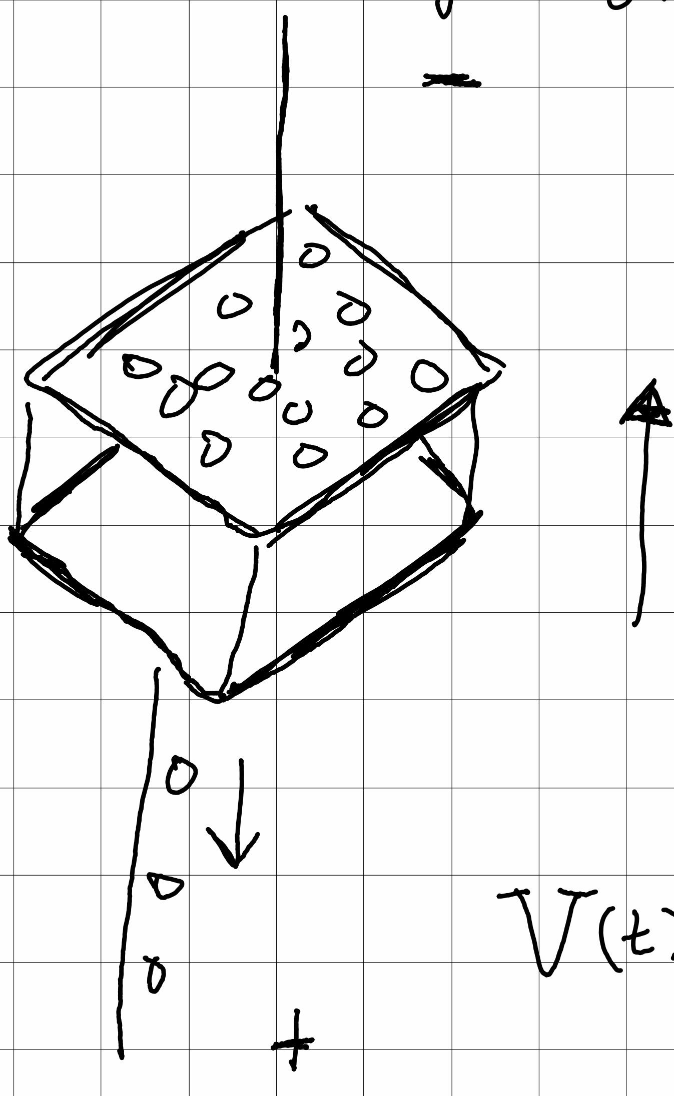
Water Analogy

R ~ D

Potentrometer : variable resistor

Capacitor: stores energy in the form of an electric field

simplest: parallel conductors separated by dialectric material



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

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

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

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

$$\boxed{I(t) = C \frac{dV}{dt}}$$

$$I = C\dot{V}$$

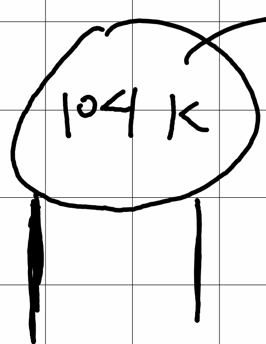
C: capacitance

- material & geometric property
- unit farad (F)

Water analogy

membrane analogy.

Capacitor Values



first two digits is value

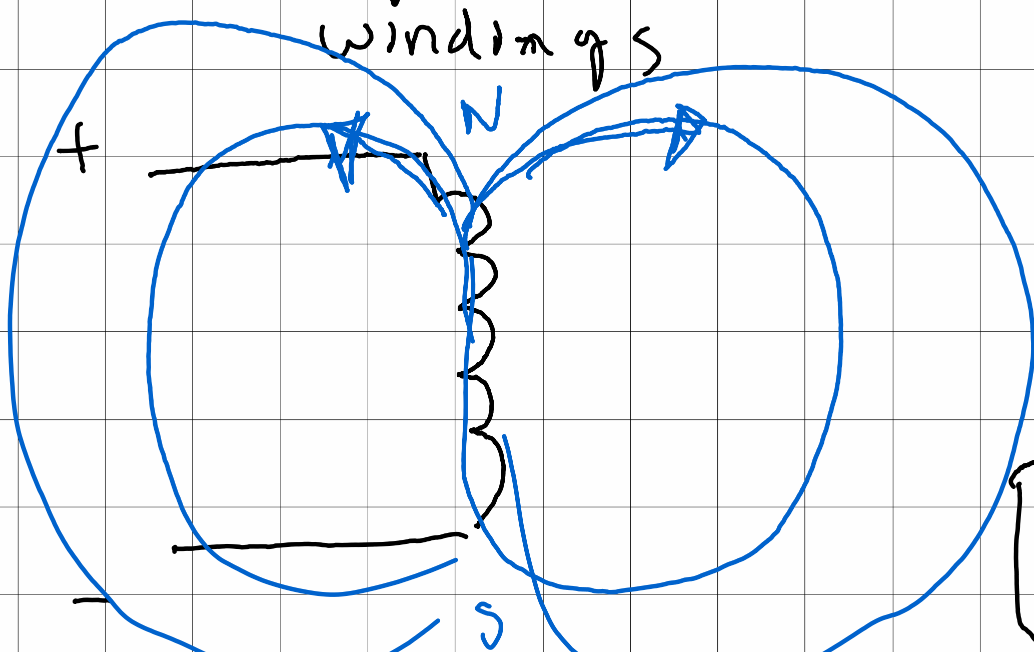
third power

$10 \times 10^{4} \pm 10\%$ pF

Inductor: stores energy in the form of a magnetic field

Faraday's law: $V(t) = \dfrac{d\lambda}{dt}$

λ: magnetic flux through coil windings

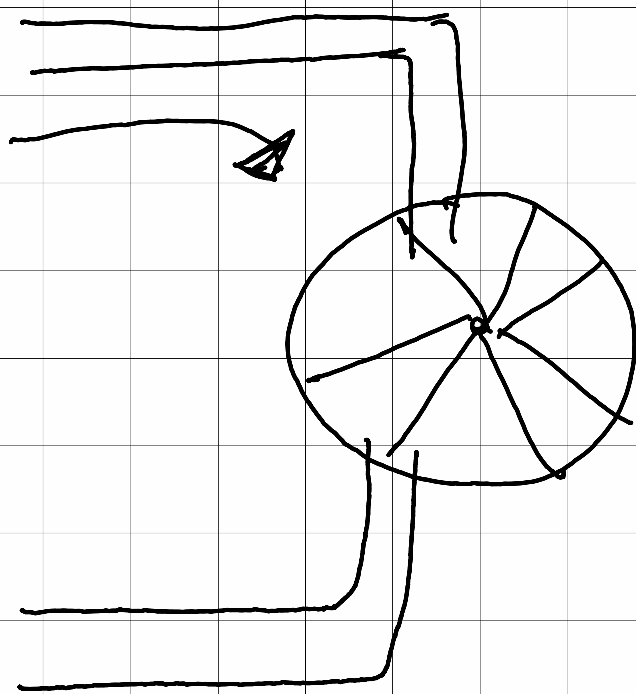


$\lambda = LI$

L: inductance (H)

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

Water Analogy



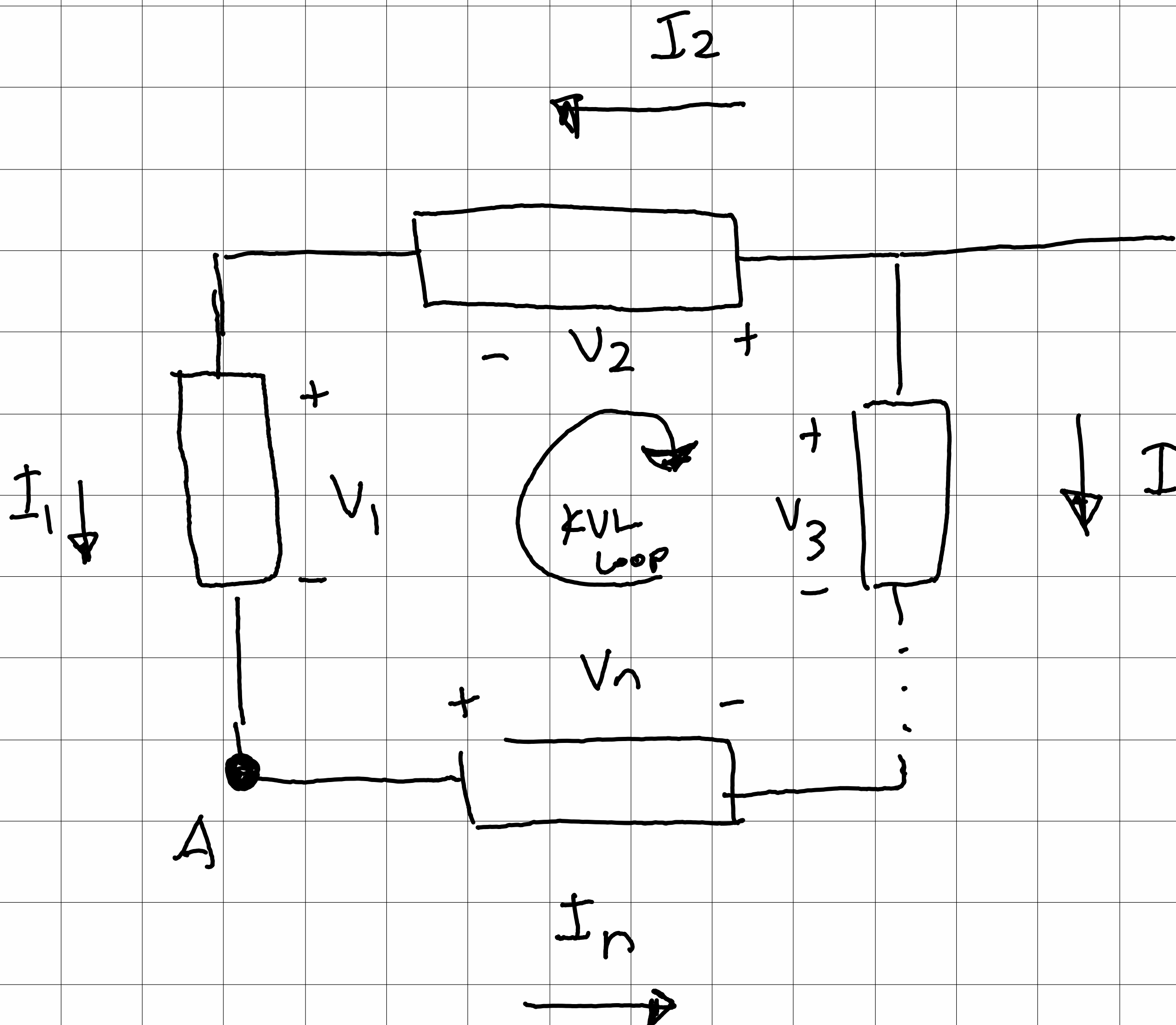
Water wheel stores energy

Kirchhoff's Laws :

KVL : Voltage Law :

$$\sum_{i=1}^{N} V_i = 0$$

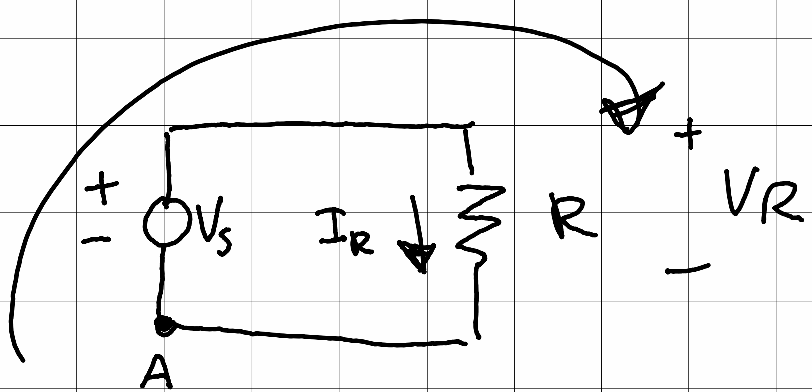
the sum of voltages around closed loop is zero!



$$\sum_{i=1}^{N} V_i = 0$$

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

Ex. 2-3 : Use KVL to find current I_R :



$$-V_s + V_R = 0$$

$$V_R = I_R R$$

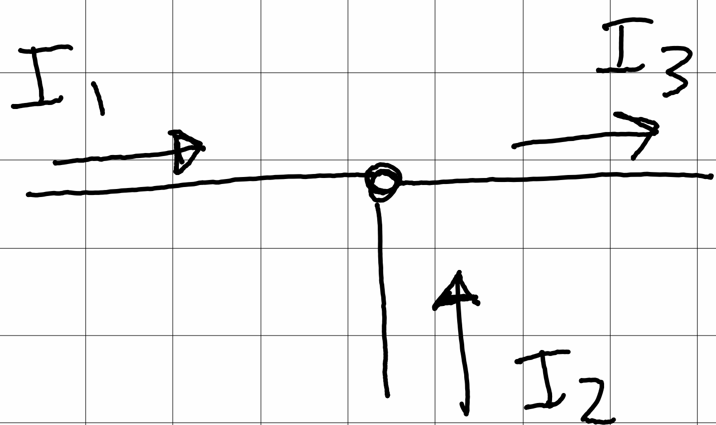
$$-V_s + I_R R = 0$$

$$\boxed{I_R = \frac{V_s}{R}}$$

Current law (KCL):

Sum of currents flowing <u>into</u> a node is 0:

$$\sum_{i=1}^{N} I_i = 0$$



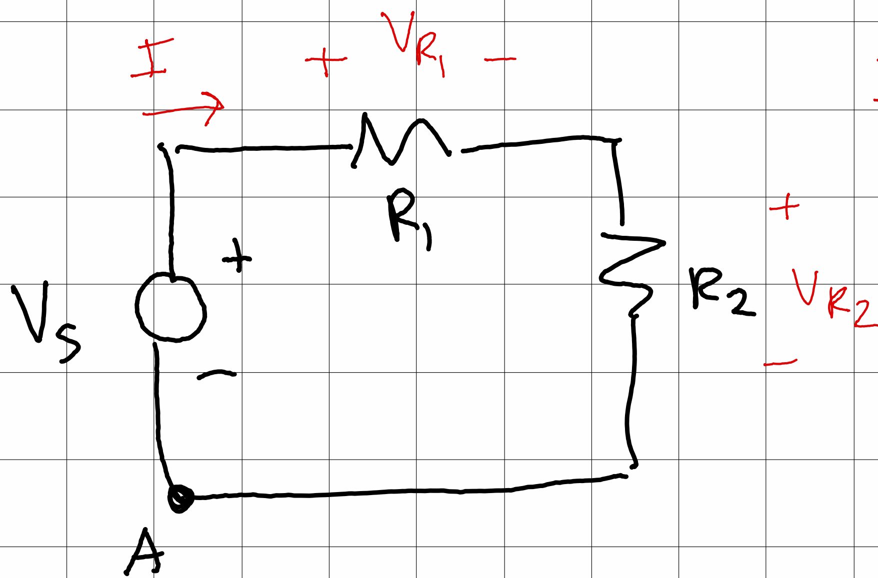
$$\boxed{I_1 + I_2 = I_3}$$

* Very Important*

often you must arbitrarily assume current direction (denote w/ arrow).
assume voltages <u>consistent</u> with current.

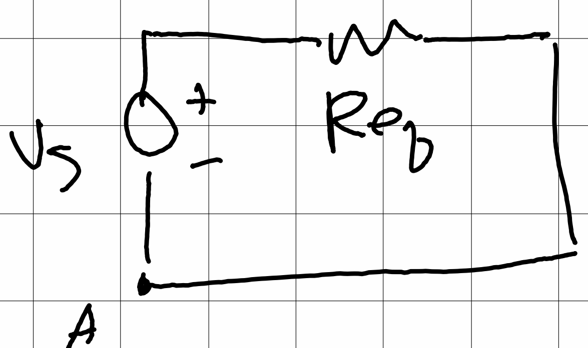
If the results are negative, the current (voltage) flow <u>opposite</u> to Assumed

Series Resistance



$$I_{R_1} = I_{R_2}$$

$$||$$



$$R_{eq} = ?$$

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

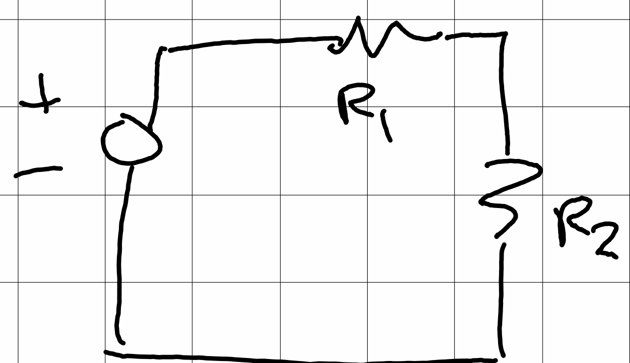
$$V_{R_1} = IR_1$$
$$V_{R_2} = IR_2$$

$$-V_s + IR_1 + IR_2 = 0$$

$$I = \frac{V_s}{R_1 + R_2}$$

$$\boxed{\begin{aligned} V_s &= (R_1 + R_2) I \\ V_s &= R_{eq} I \end{aligned}}$$

Resistor is series add!



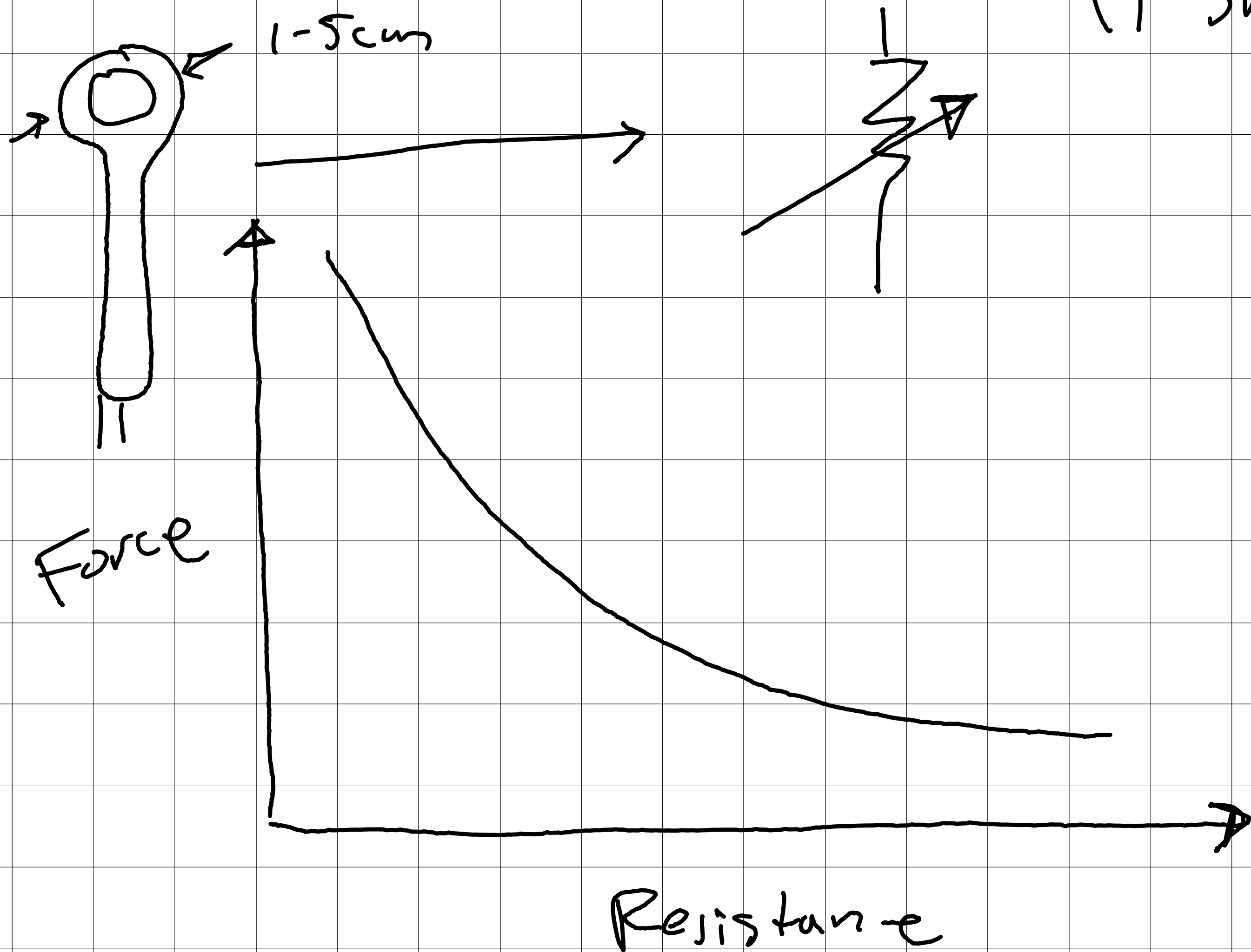
Voltage divider

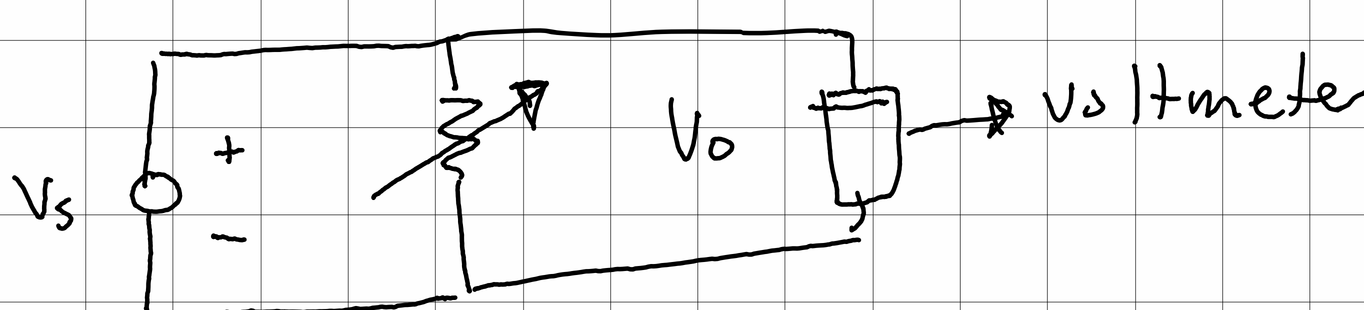
Why is a voltage divider useful?

- step down voltages
- sensing circuits

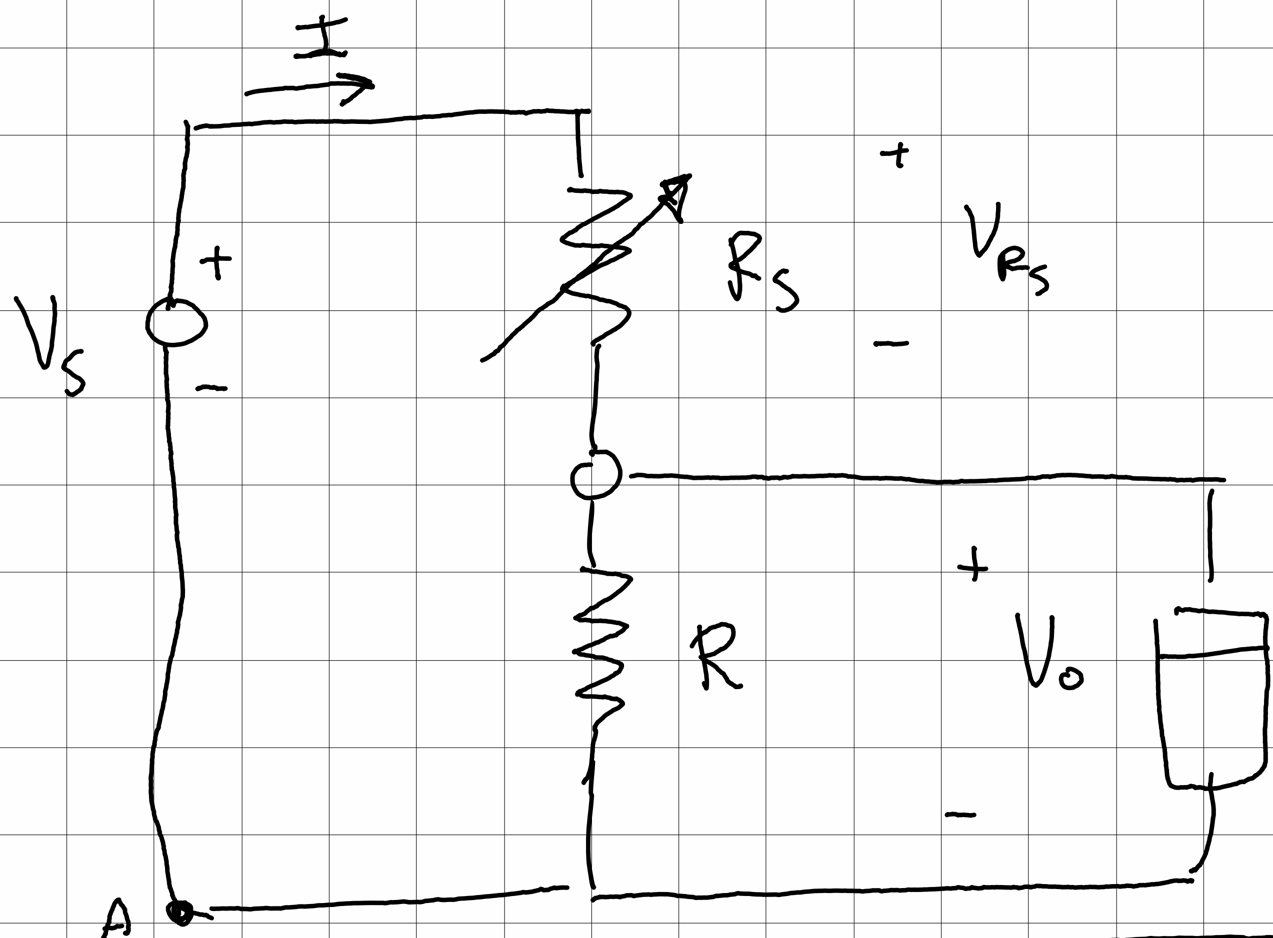
Force Sensitive resistors

(FSR)





$V_s = V_o$



We want $V_o = ?$

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

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

$$V_s = V_{R_s} + V_o \Rightarrow V_s = I(R_s + R)$$

$$I = \frac{V_o}{R}$$

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

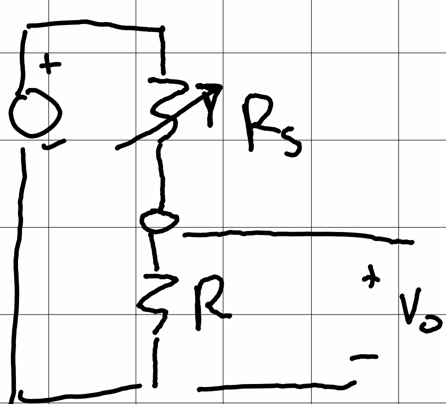
KCL: $I_{R_s} = I_R = I$

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

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

$$I = \frac{V_o}{R}$$

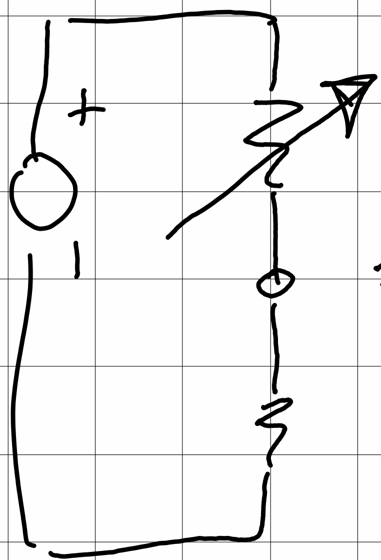
$$\boxed{V_o = \left(\frac{R}{R_s + R}\right) V_s}$$

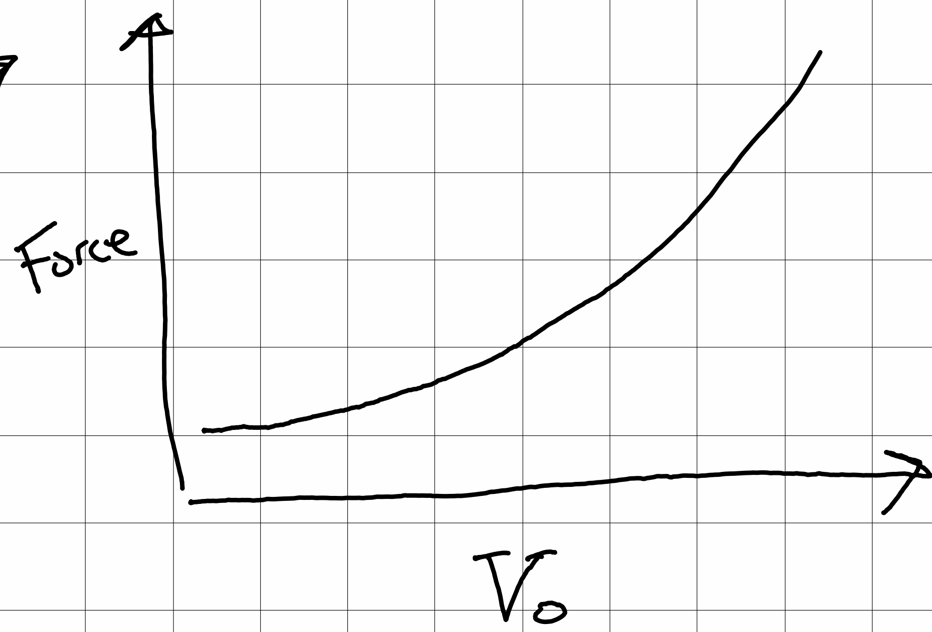


$$\lim_{\substack{R_s \to 0 \\ F \to \infty}} V_o = \left(\frac{R}{\underset{0}{\cancel{R_s}} + R}\right) V_s$$

$$= V_s$$

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





This just one example of voltage divider application.

Kits pick up today

A325 2:30 - 4:30