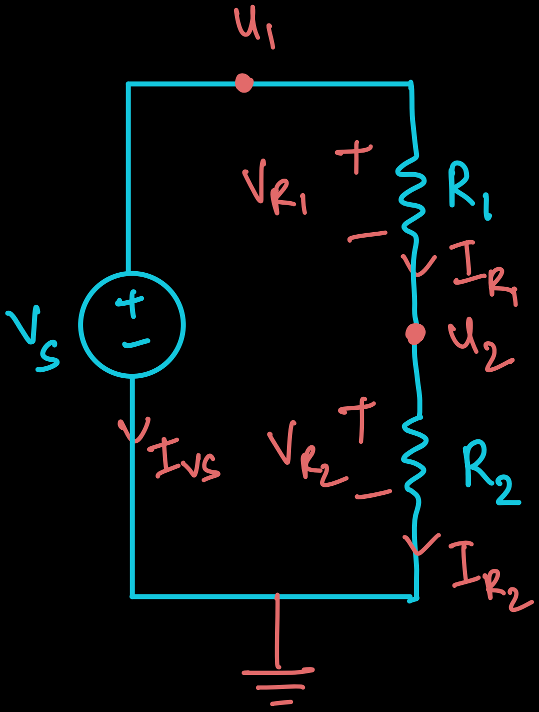
EECS 16A
Power and Voltage/Current Measurement

Previously on 16A......

NVA –
1. Identify nodes
2. Choose a ground
3. Label all elements (currents + voltages) & node potentials
4. KCL
5. Ohm's law
6. Current / Voltage sources
7. Set up $A\vec{x} = \vec{b}$ and solve

Previously on 16A......

{Voltage Divider}



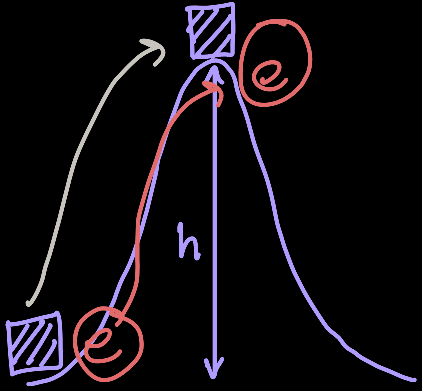
$$\rightarrow u_2 = \frac{R_2}{R_1+R_2} V_s$$

$$u_2 = \frac{1}{\frac{R_1}{R_2} + 1} V_s \quad \left\{ \frac{R_1}{R_2} = \alpha \right.$$

$$u_2 = \frac{1}{\alpha + 1} V_s$$

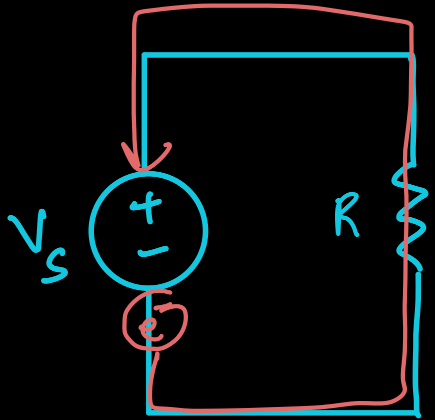
Energy and Power

Current - Rate of flow of charge



$E \propto h$

$E \propto m$



$E \propto V$

$E \propto q$

q, V

$E = qV$

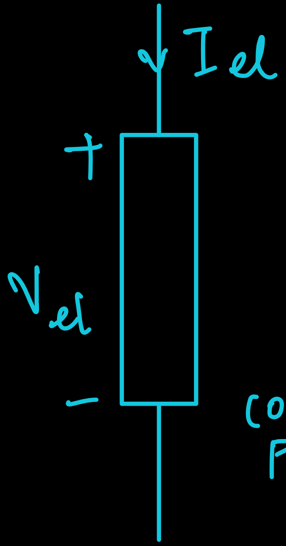
↳ charge

DC analysis

$$P = \frac{dE}{dt} = \frac{d}{dt}(q \cdot V) = V \cdot \frac{dq}{dt} = VI$$

How to think about Energy and Power in circuits?

$P \rightarrow$ Watt (W)



$P = I_{el} V_{el}$

$V = IR$

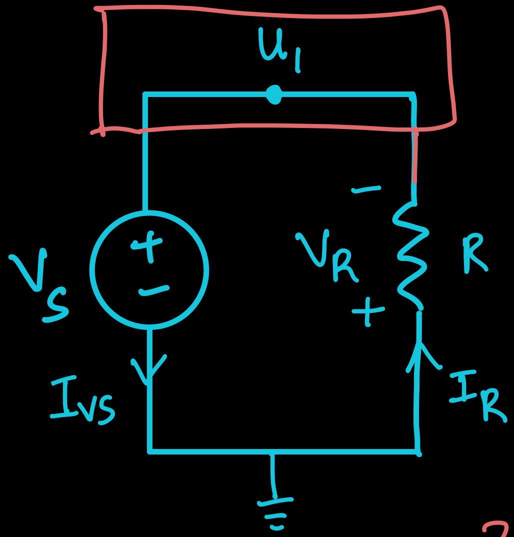
$P = VI = I^2R = \frac{V^2}{R}$ } → For a resistor only

$I^2R \geq 0$

consumes power ← any passive element $P \geq 0$ is the passive sign convention

supplies power ← active element $P < 0$

Power in Circuits Example



KCL: $I_{VS} = I_R$

Ohm's law: $V_R = I_R \cdot R = 0 - u_1$

VS: $u_1 - 0 = V_S$

$I_{VS} = I_R$

$u_1 = V_S$

$R \cdot I_R = -u_1$

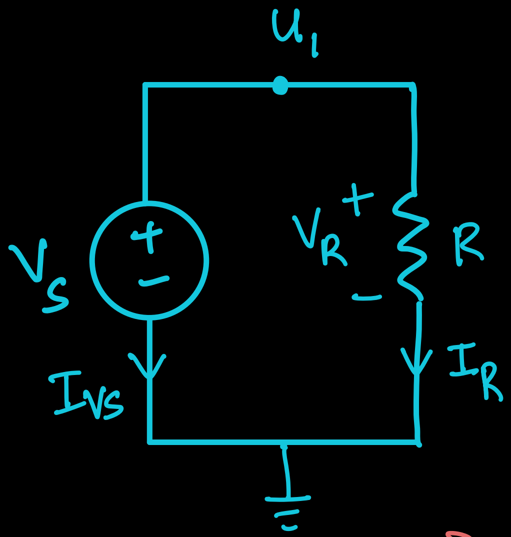
$$I_R = \frac{-V_S}{R}$$

$$P_{VS} = \frac{-V_S^2}{R}$$

$$P_R = I_R^2 R = \left(\frac{V_S}{R}\right)^2 R = \frac{V_S^2}{R}$$

$$P_{VS} = I_{VS} V_S = \frac{-V_S^2}{R}$$

Power in Circuits Example



KCL — $0 = I_{VS} + I_R$

OL — $V_R = I_R \cdot R = u_1$

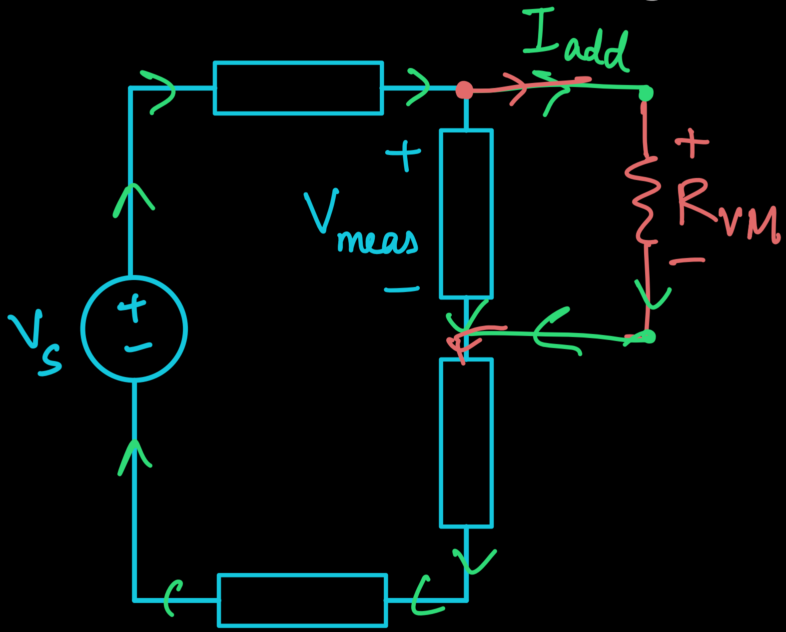
VS — $u_1 - 0 = V_S$

$$I_R = \frac{V_S}{R} \qquad I_{VS} = -I_R = -\frac{V_S}{R}$$

$$P_R = I_R^2 R = \frac{V_S^2}{R}$$

$$P_{VS} = V_S \cdot I_{VS} = -\frac{V_S^2}{R}$$

How to measure voltage? with a Voltmeter

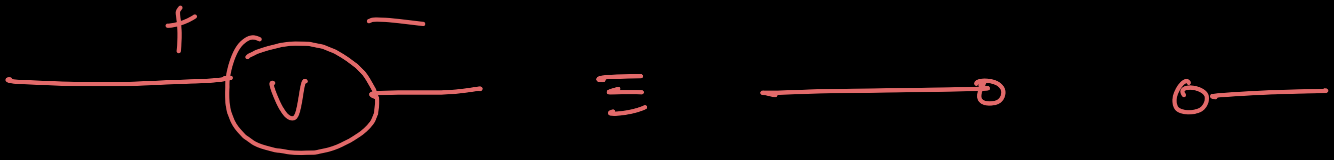


$I_{add} = 0$

$R_{VM} \to \infty$

Ideal

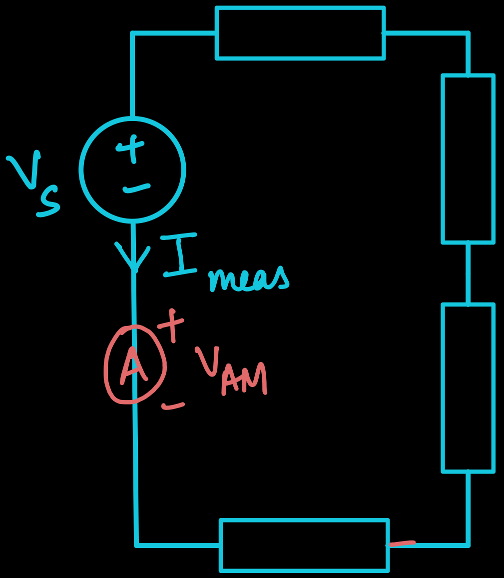
$R_{VM} \to \infty$



Ideal

$R = 200\,M\Omega$

How to measure current? with an Ammeter



I_{Meas} ✗

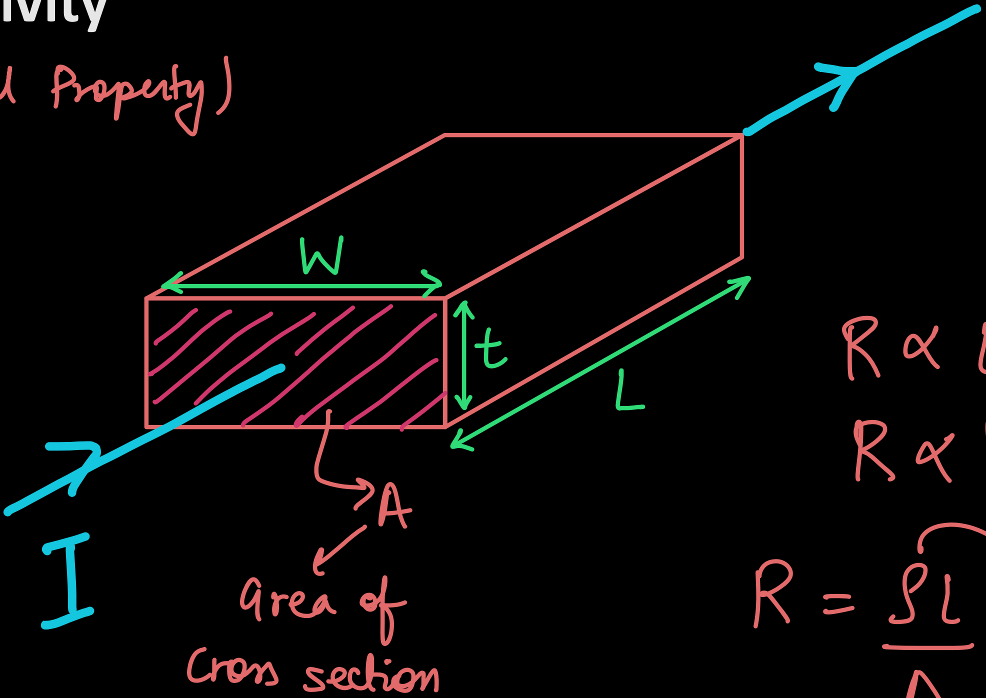
$R_{AM} = 0$

$(V_{AM} = 0)$

Ideal

Resistivity

(Material Property)



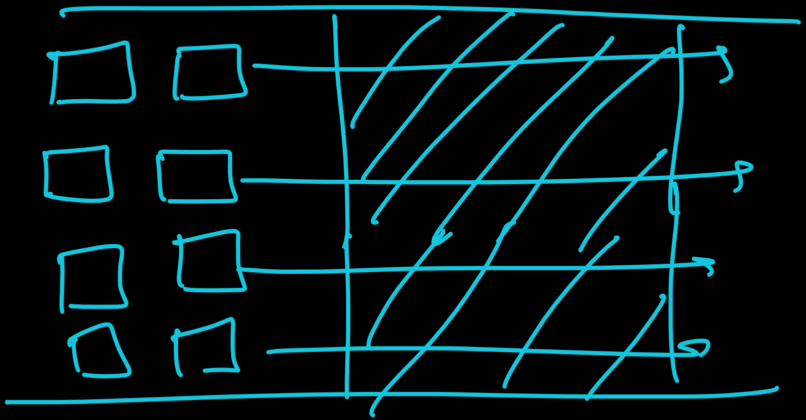
$$R \propto L$$

$$R \propto 1/A$$

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

ρ → resistivity (rho)

Analogy



Resistivity (Example)

$\rho_{Cu} = 1.7 \times 10^{-8}\,\Omega m$

(rho)

$\rho_{wood} = 10^{14}\,\Omega m$

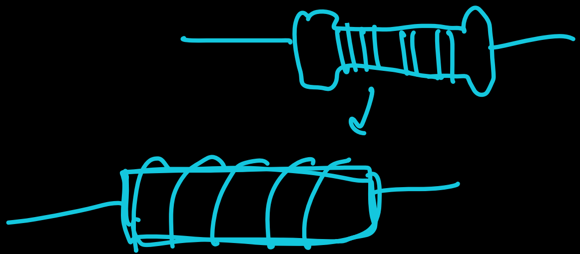
∞

$l = 50\,cm$ $A = 5\,cm^2$

$R = \frac{\rho l}{A} = \frac{1.7 \times 10^{-8} \times 50 \times 10^{-2}}{5 \times 10^{-4}}$ (10, 10^2)

$= 1.7 \times 10^{-5}\,\Omega$

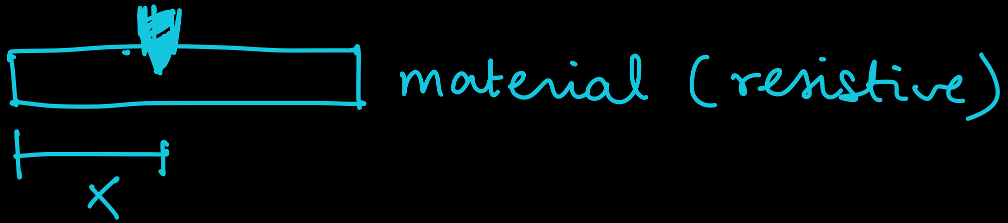
$l = 50 \times 10^{5}$ $= 1.7\,\Omega$



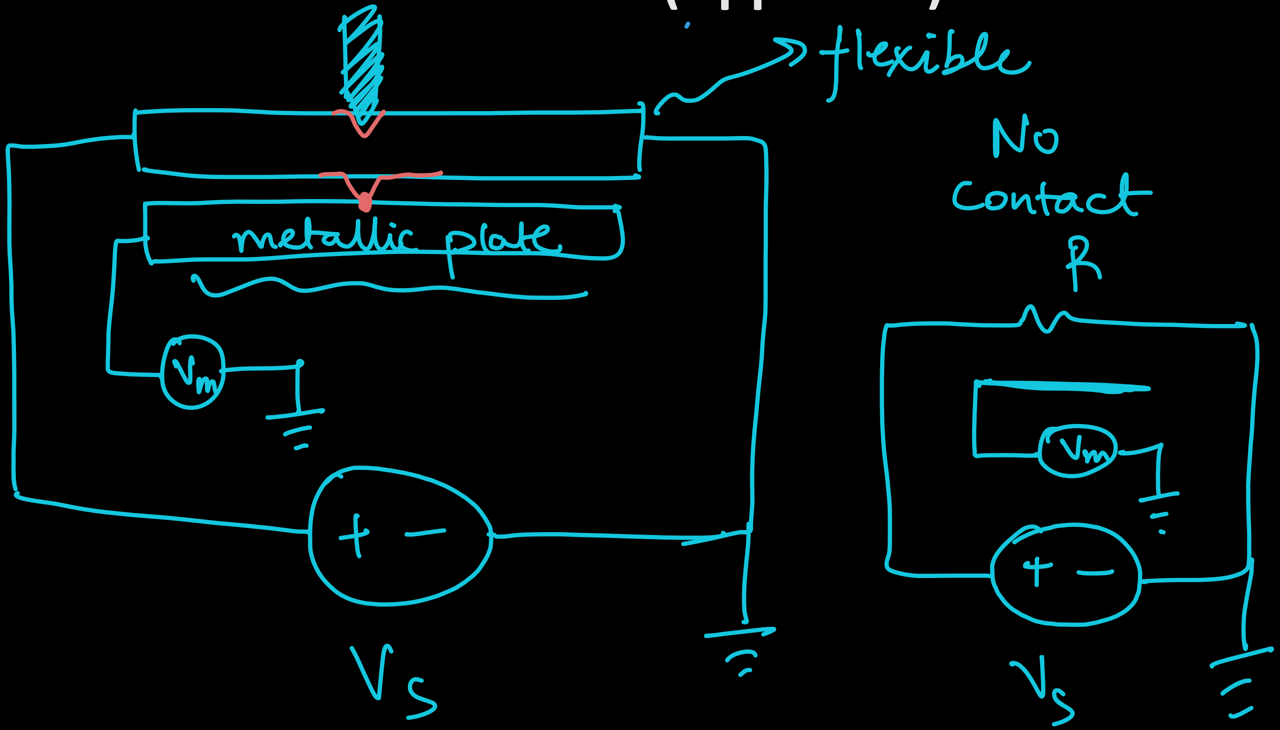
Resistive Touchscreen Design

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

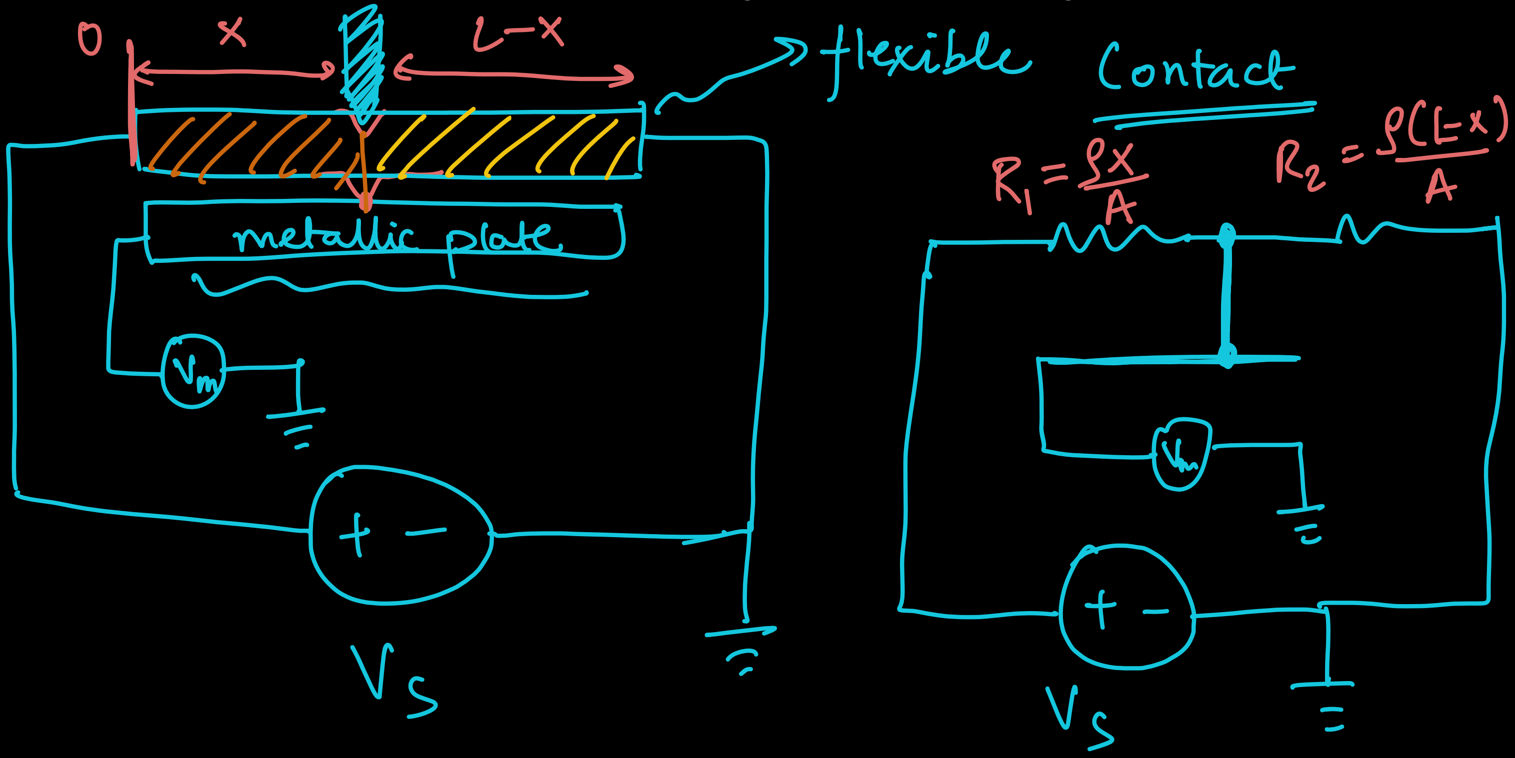
1D touchscreen

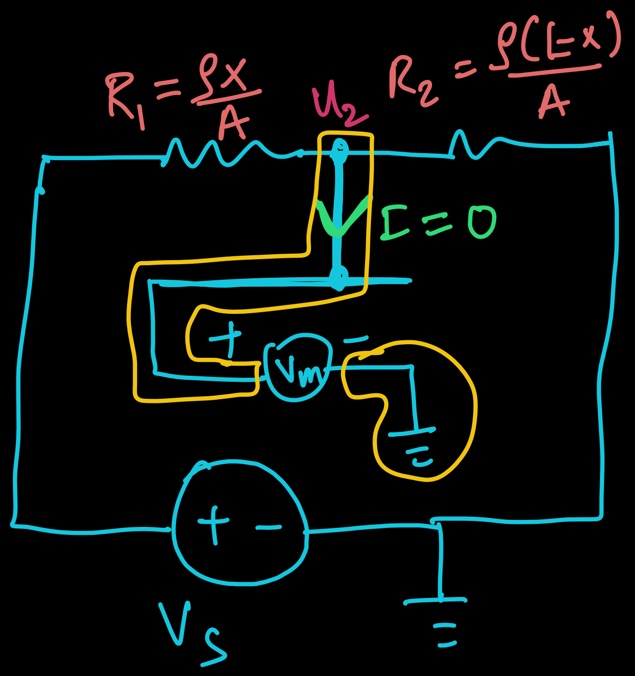


1D Resistive Touchscreen (Approach)



1D Resistive Touchscreen (Basic Model)





$$V_m = u_2 - 0$$

$$u_2 = \frac{R_2}{R_1 + R_2} V_s$$

$$u_2 = \frac{\frac{\rho(L-x)}{A}}{\frac{\rho L}{A}} V_s = \frac{L-x}{L} V_s$$

$$u_2 = \left(1 - \frac{x}{L}\right) V_s$$