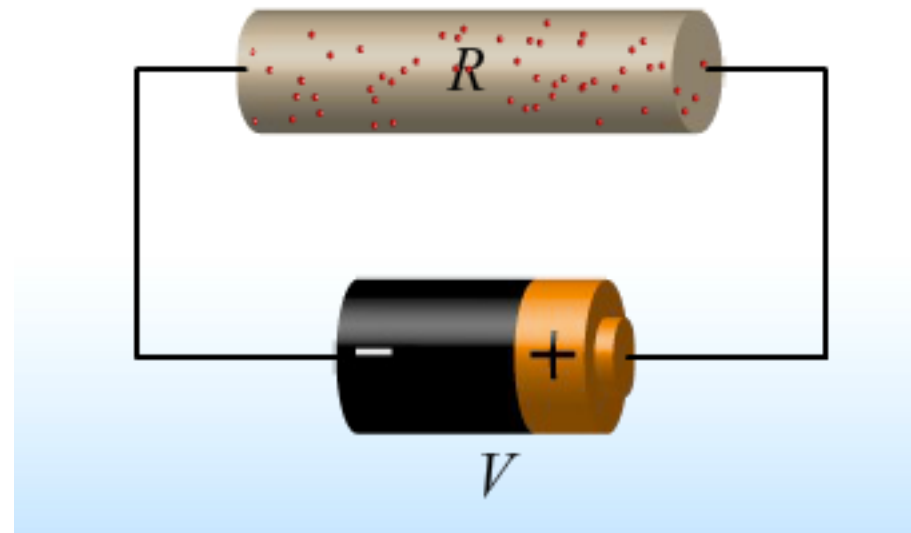


Introduction to electrodynamics: **Resistors**

Lecture 13

The microscopic picture...

- Gas of charge carriers (usually electrons)
- Electric field accelerates charges
- Random collisions with the lattice leads to **resistance**

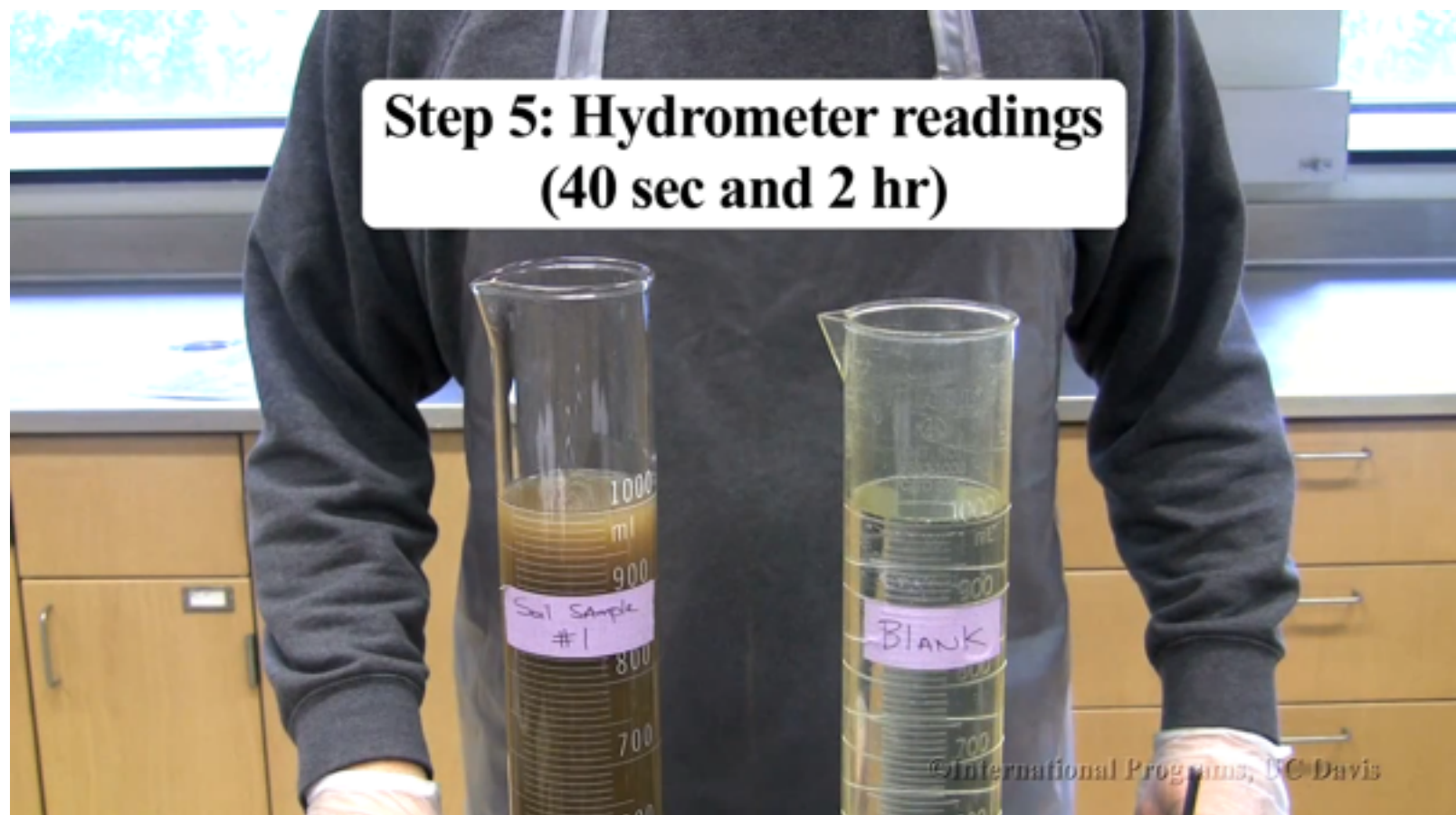


$$F = ma$$

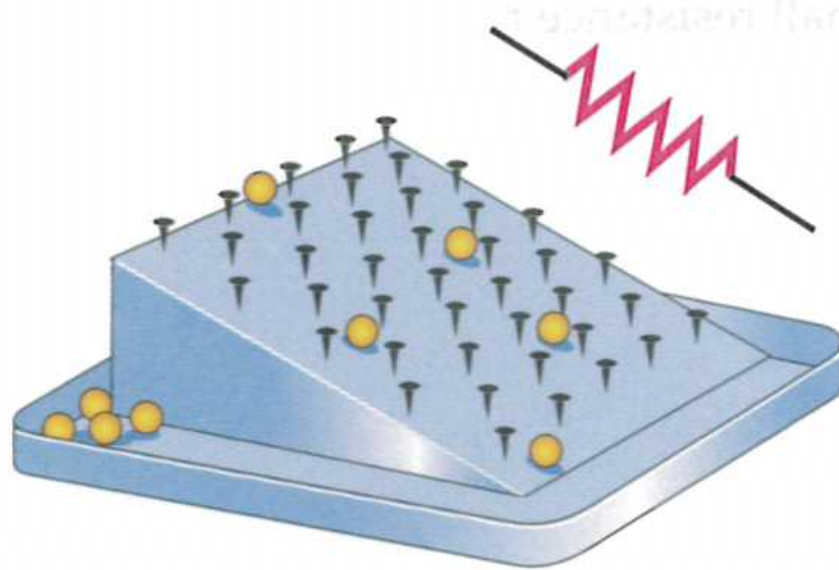
$$F = \gamma v$$

Analogy to viscosity

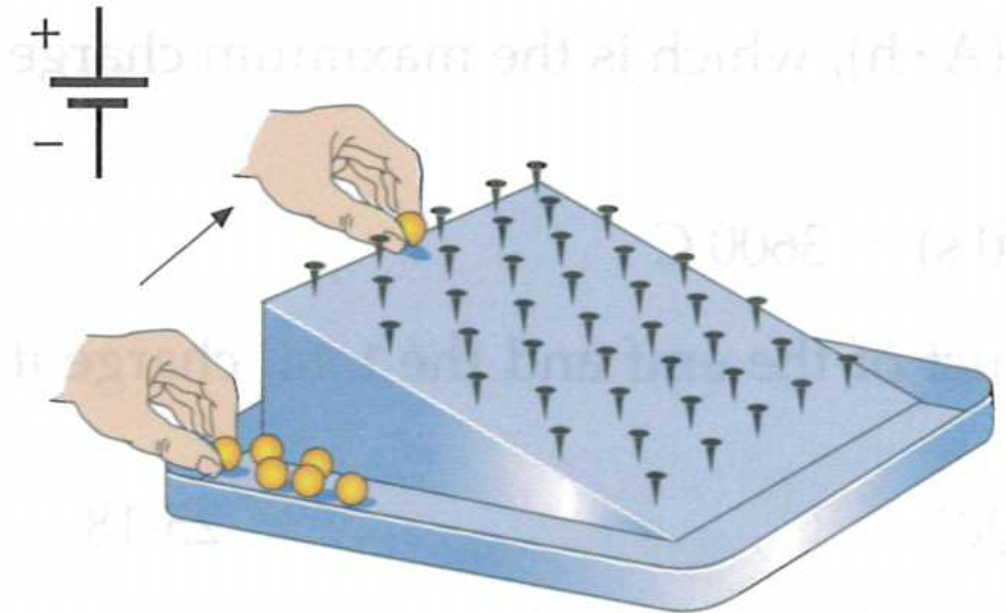
- The Stokes Law: $F = \gamma v$ $\gamma = 6\pi\mu R$
- \sim flow through a viscous medium



One more analogy...



(a)



(b)

The microscopic picture...

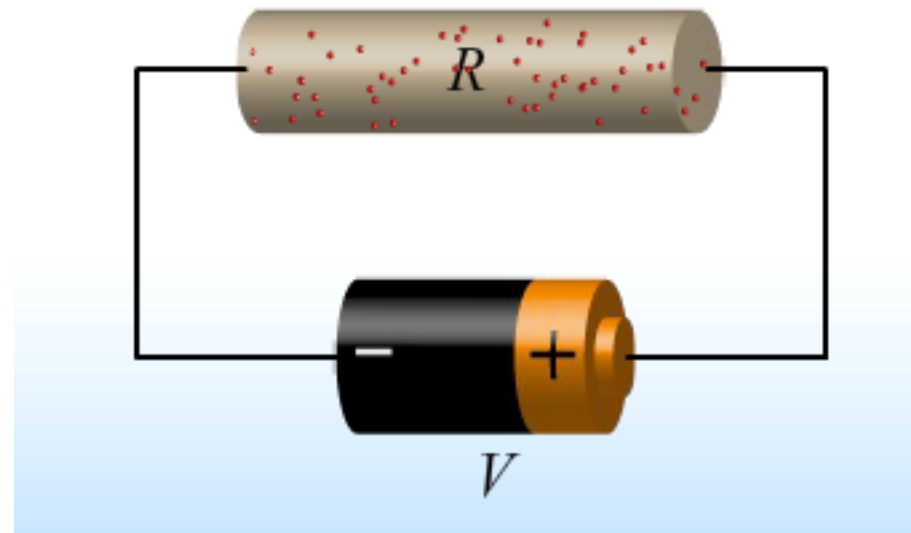
- Current density:

$$\vec{j} = nq\vec{v}$$

- Random collisions with the lattice leads to **resistance**

$$\vec{j} = nq\vec{F}/\gamma$$

$$\vec{j} = nq^2\vec{E}/\gamma = \sigma\vec{E}$$



The microscopic picture...

- Ohm Law:

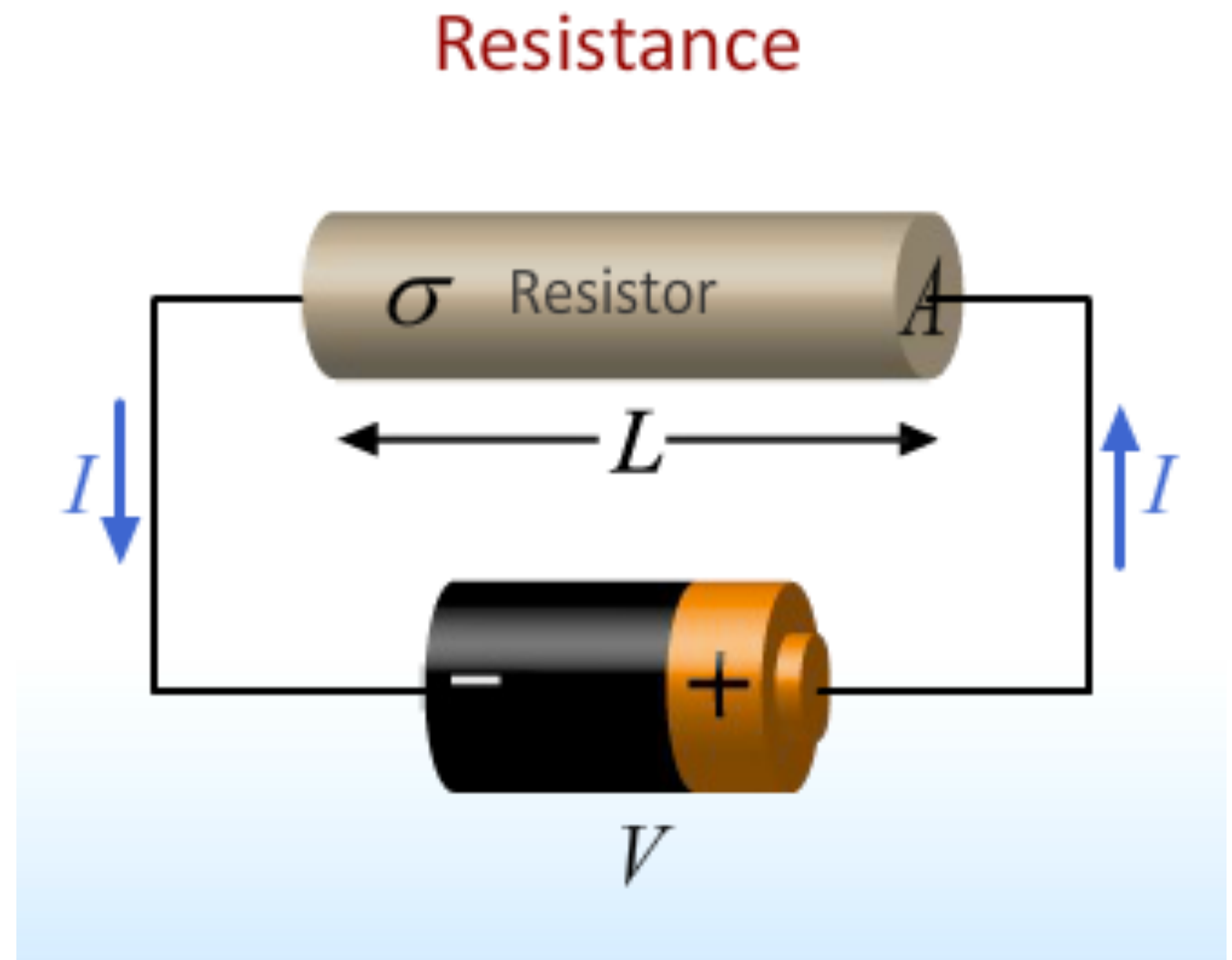
$$\vec{j} = \sigma \vec{E}$$

- σ is conductivity

$$\rho \vec{j} = \vec{E}$$

$$\rho = \sigma^{-1}$$

- ρ is resistivity



The macroscopic picture...

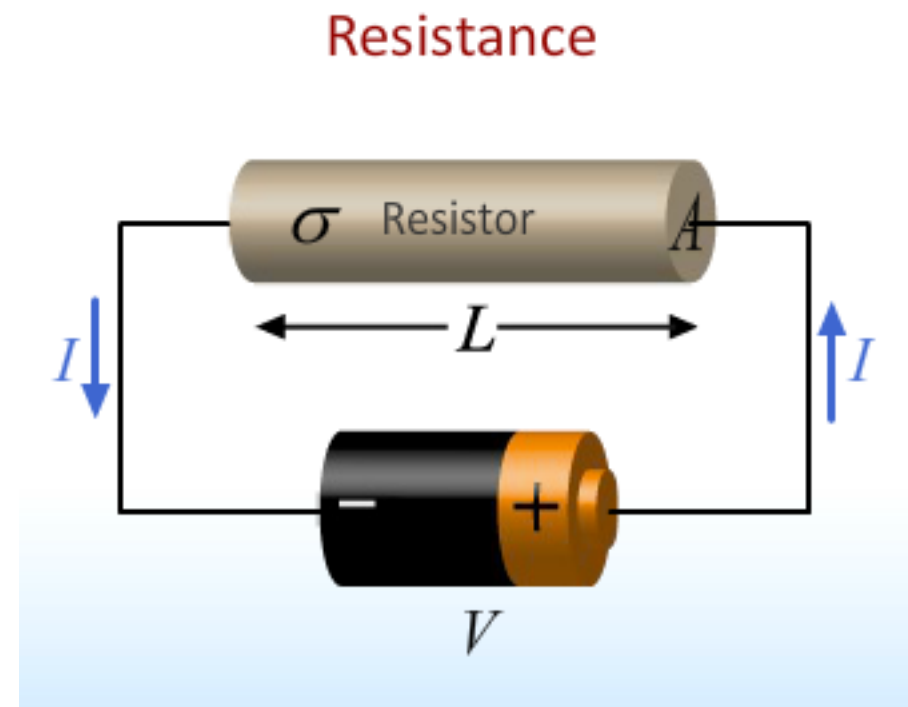
- **Current** is the **flux** of the current density through a surface

$$I = \int d^2A \, \hat{n} \cdot \vec{j} = dq/dt$$

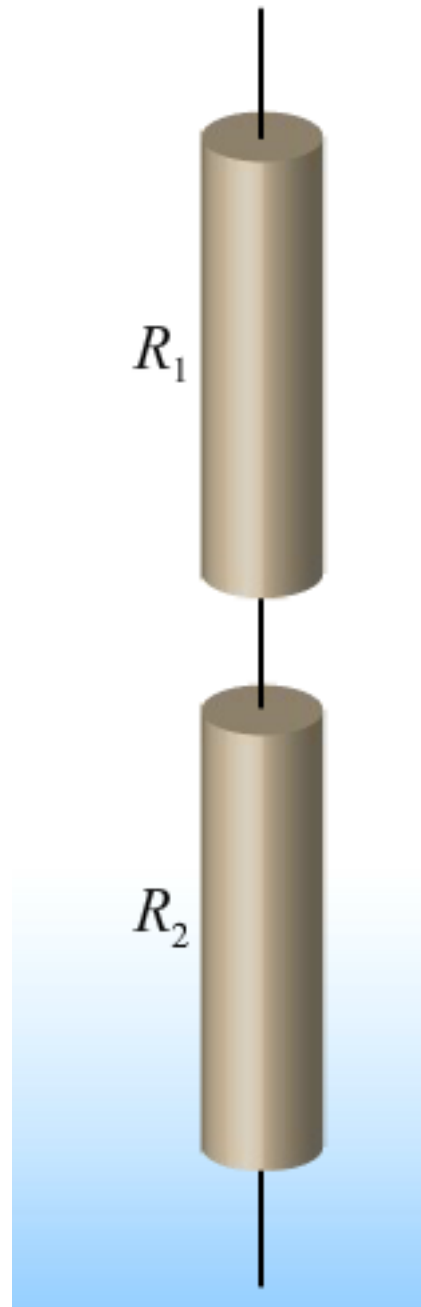
- Ohm Law:

- Differential form: $\vec{j} = \sigma \vec{E}$

- Integral form: $V = IR$ $R = L\rho/A$



Resistors in series



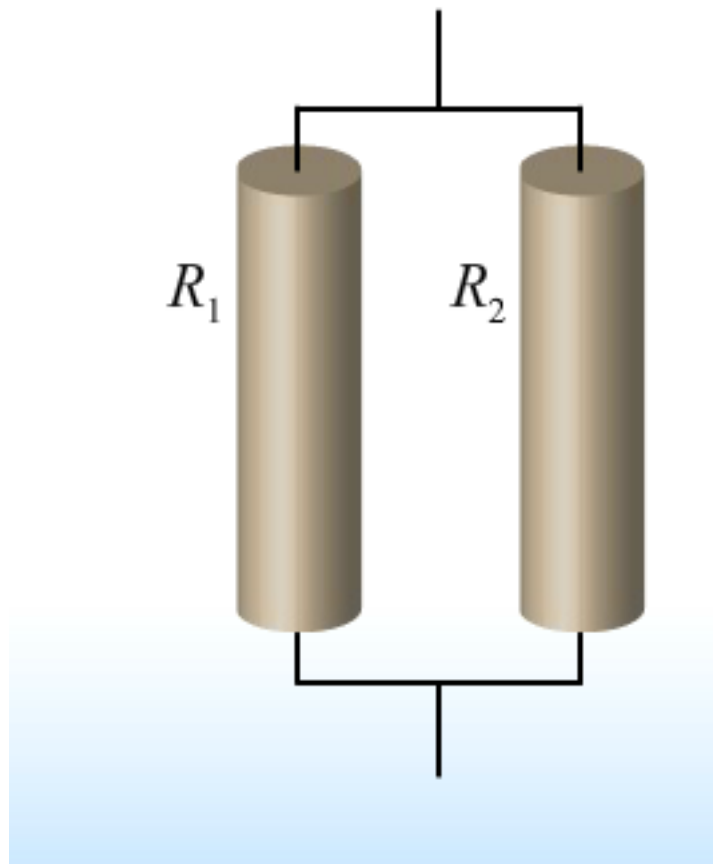
- Overhead derivation
- Result: $R_{\text{Equiv}} = R_1 + R_2$
- Intuitive picture:

Resistors in parallel

- Overhead derivation

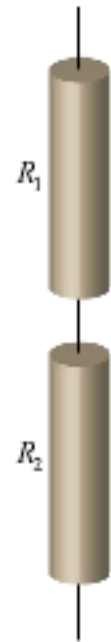
- Result: $R_{\text{Equiv}}^{-1} = R_1^{-1} + R_2^{-1}$

- Intuitive picture:

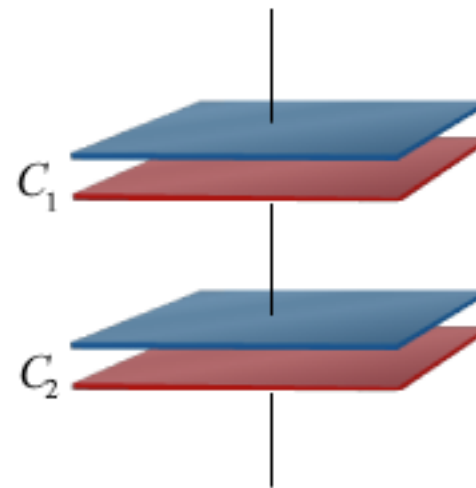


Capacitors vs Resistors

Series Combination

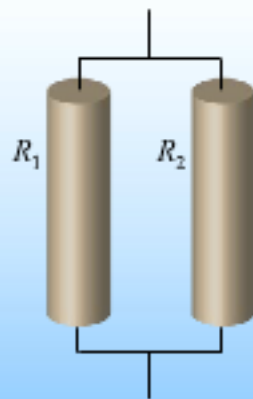


$$R_{\text{equivalent}} = R_1 + R_2$$

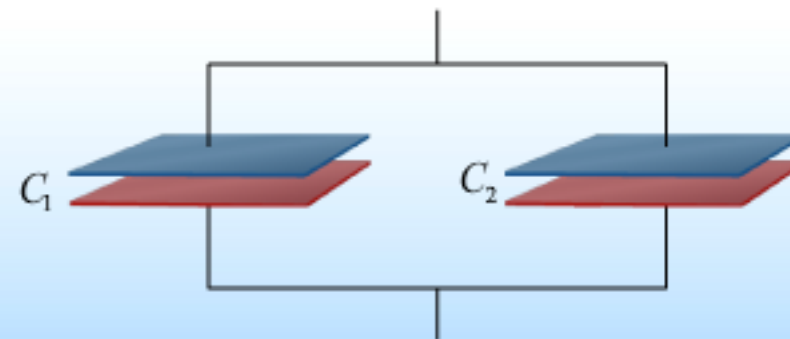


$$\frac{1}{C_{\text{equivalent}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Parallel Combination



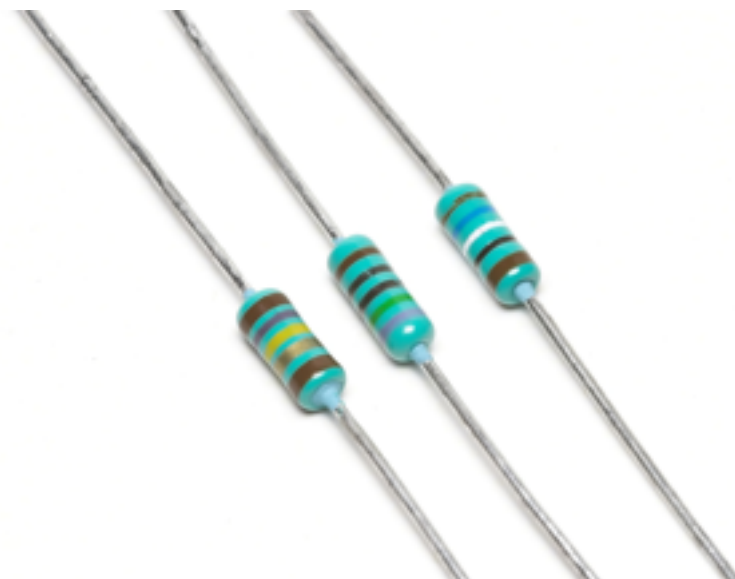
$$\frac{1}{R_{\text{equivalent}}} = \frac{1}{R_1} + \frac{1}{R_2}$$



$$C_{\text{equivalent}} = C_1 + C_2$$

Units

- $[I] = [\text{Current}] = [\text{Charge} / \text{Time}] = \text{C/s}$
Ampere = A = Amp
- $[V] = [\text{Energy/Charge}] = \text{J/C} = \text{Volts} = \text{V}$
- $[R] = [\text{Resistance}] = \text{V/A} = \text{Ohms} = \Omega$



Electromotive force

- **EMF**: Historical name for **voltage gain** in a battery
- Work done per unit charge to increase/decrease its potential

$$[\mathcal{E}] = \mathcal{V}$$

Power:

Supplied and Dissipated

- Power supplied by a source of emf (voltage supply)

$$P = IV$$

- Power dissipated by a ohmic resistor (to heat):

$$P = IV = RI^2 = V^2/R$$

- Units: [Power] = J/s = Watts = W