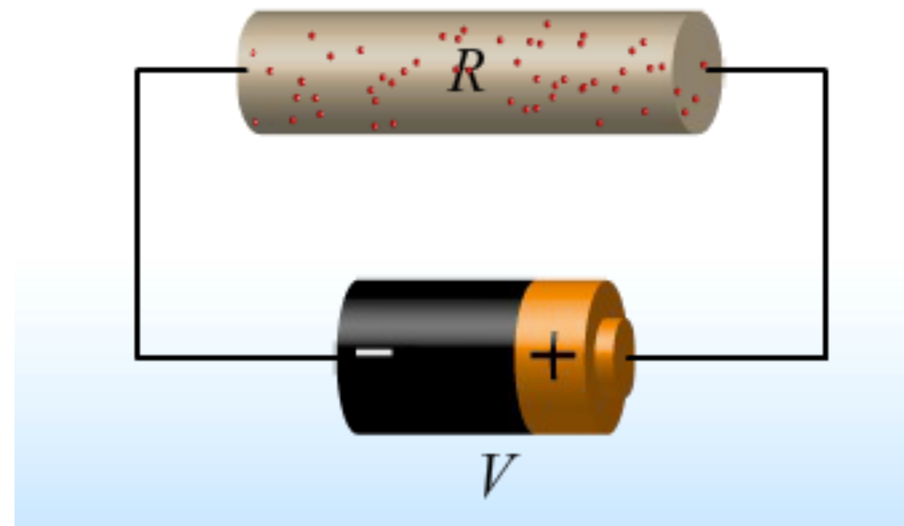
Introduction to electrodynamics: **Resistors**

Lecture 13

The microscopic picture…

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



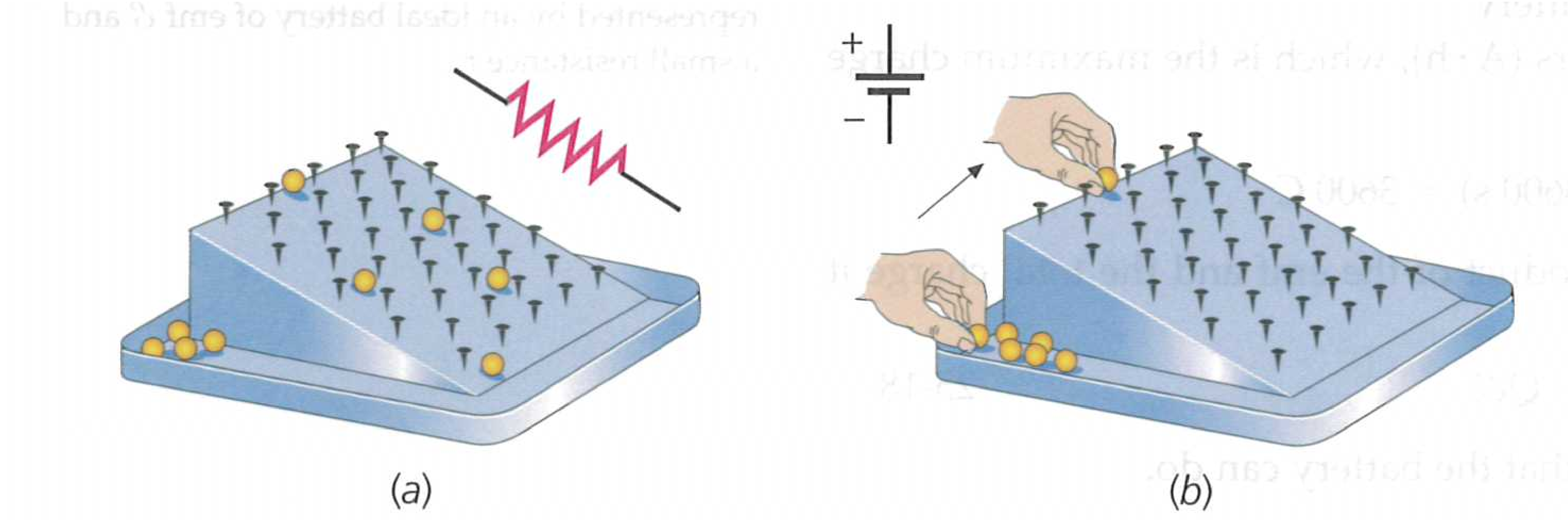
$$F = ma$$

$$F = \gamma v$$

Analogy to viscosity

- The Stokes Law: $F = \gamma v \qquad \gamma = 6\pi\mu R$
- ~ flow through a viscus medium

One more analogy…



The microscopic picture…

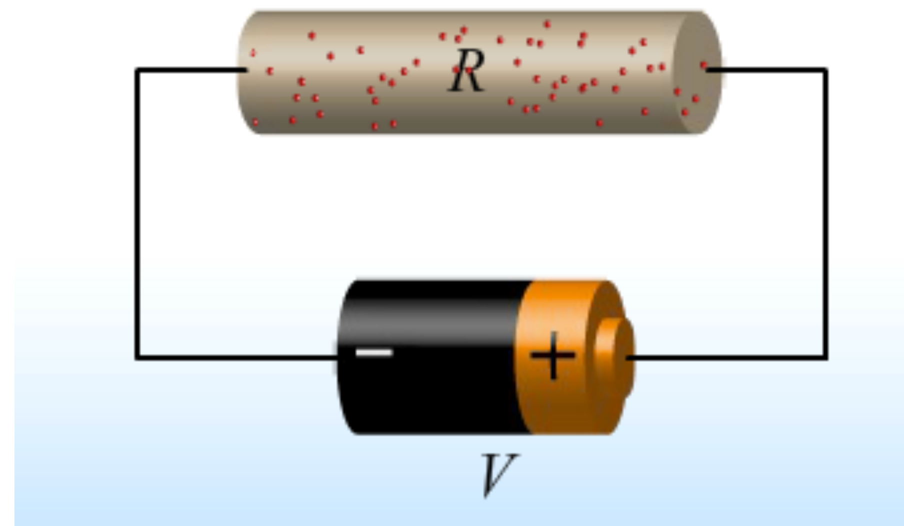
- Current density:

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

- 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:

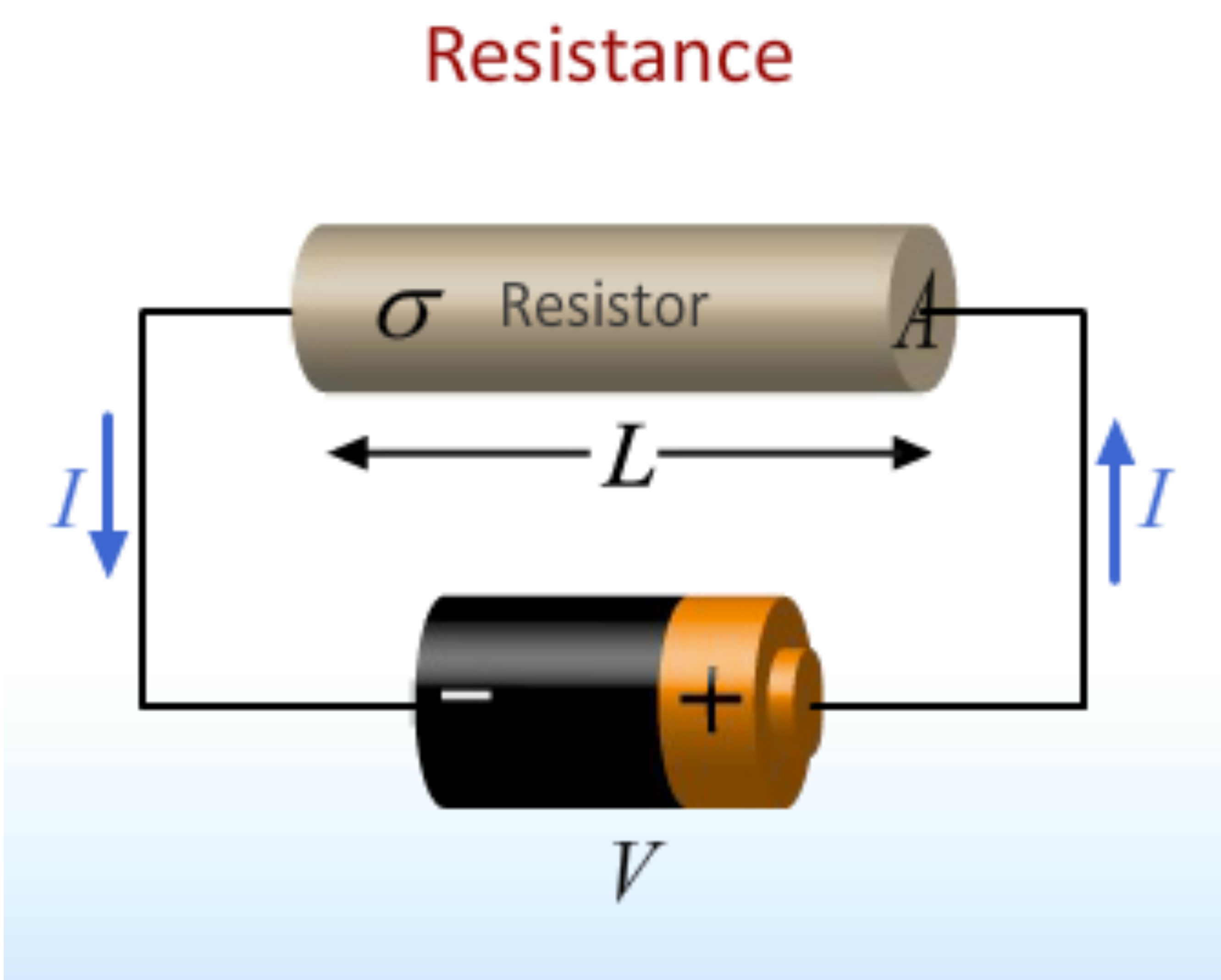
$$\vec{j} = \sigma \vec{E}$$

- σ is conductivity

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

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

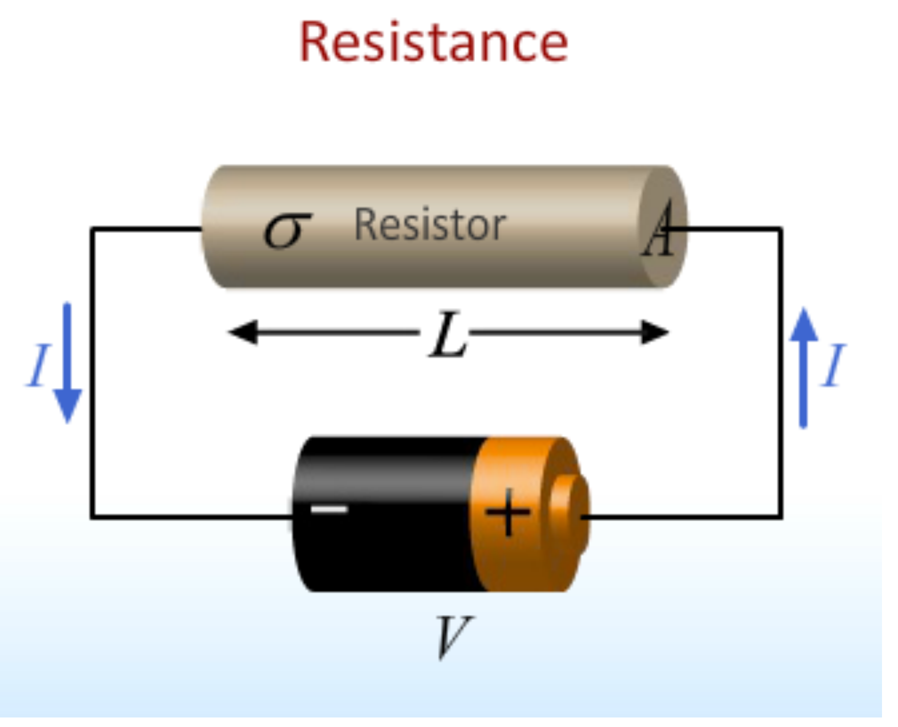
- ρ is resistivity



The macroscopic picture…

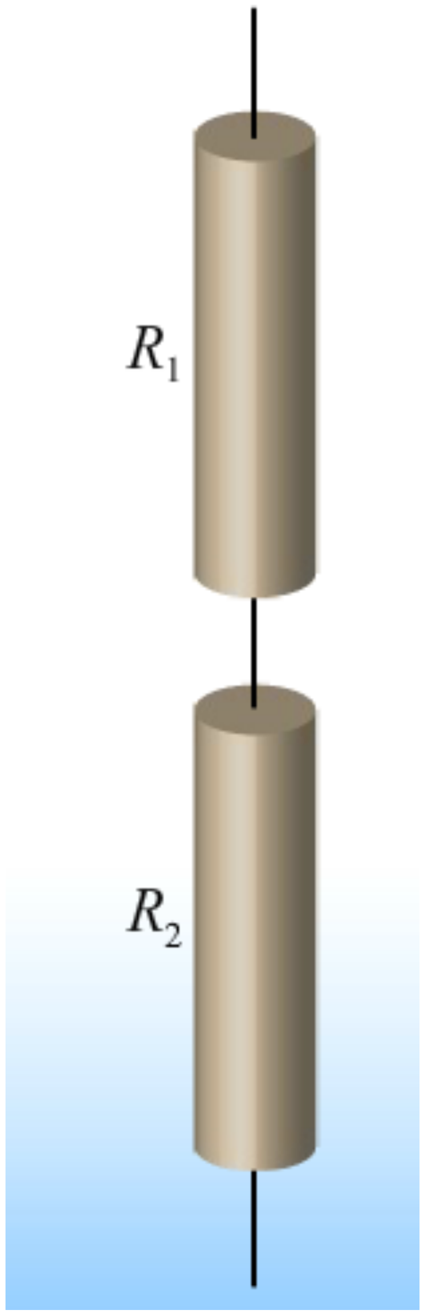
- **Current** is the **flux** of the current density through a surface

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



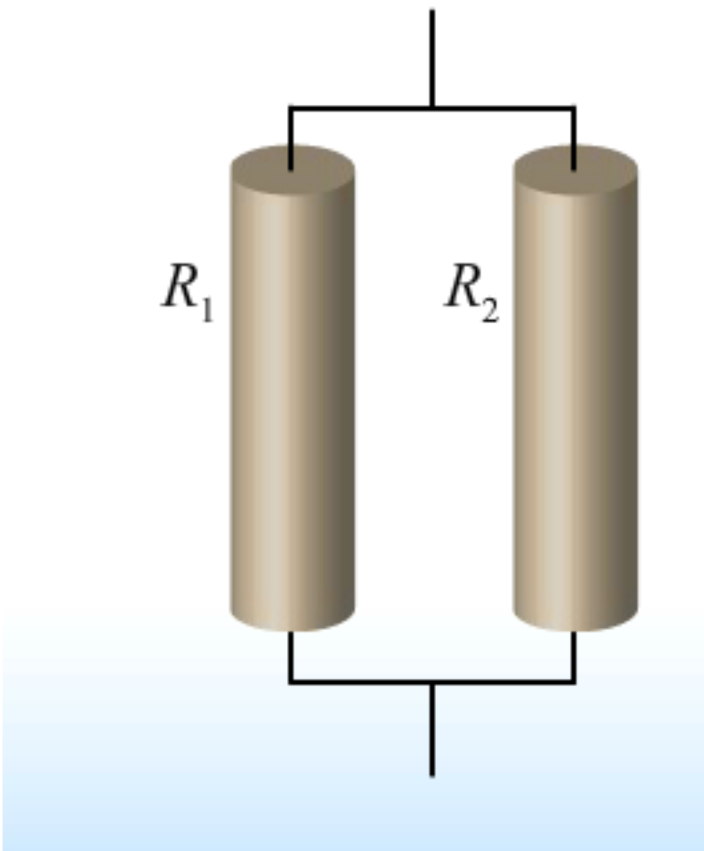
- Ohm Law:
  - Differential form: $\vec{j} = \sigma \vec{E}$
  - Integral form: $V = IR$ $\qquad R = L\rho/A$

Resistors in series



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

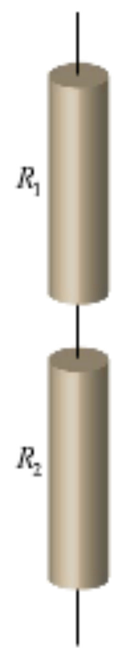
Resistors in parallel



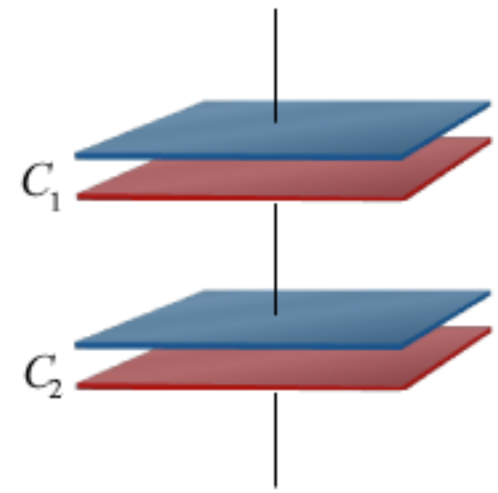
- Overhead derivation
- Result: $R_{\mathrm{Equiv}}^{-1} = R_1^{-1} + R_2^{-1}$
- Intuitive picture:

Capacitors vs Resistors

Series Combination

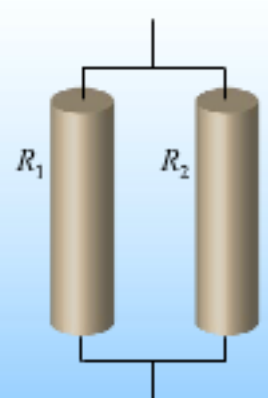


$$R_{equivalent} = R_1 + R_2$$

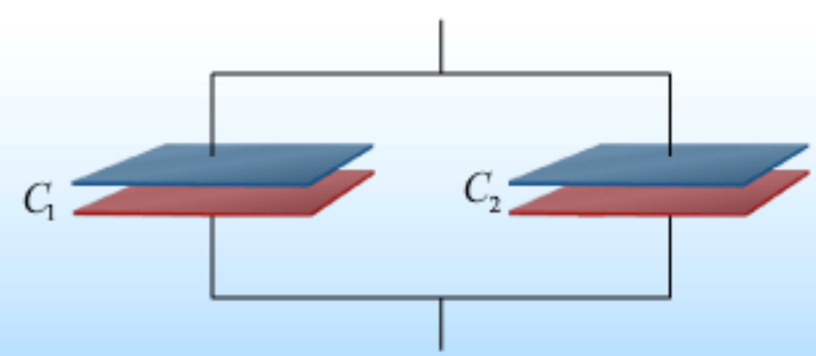


$$\frac{1}{C_{equivalent}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Parallel Combination



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



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

Units

- [I] = [Current] = [Charge / Time] = C/s
  Ampere = A = Amp

- [V] = [Energy/Charge] = J/C = Volts = V

- [R] = [Resistance] = V/A = Ohms = Ω

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