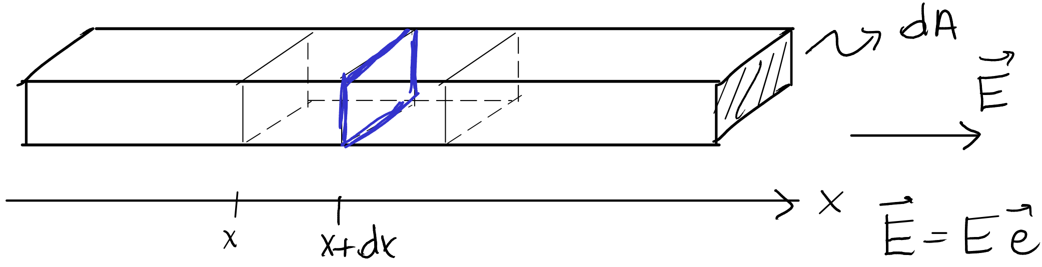
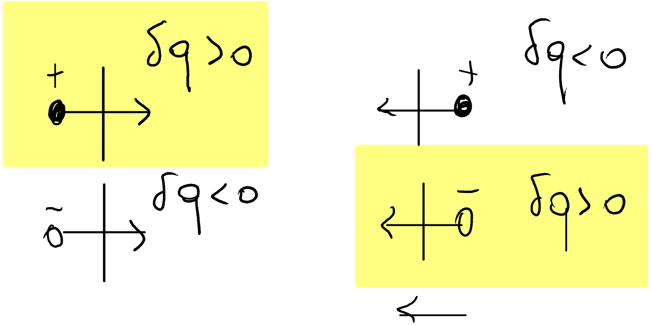
CONDUZIONE ELETTRICA

campo $\vec{E}$ ⟶ differenza di potenziale ΔV → corrente elettrica I_e

Corrente attraverso una superficie



$\vec{E} = E\vec{e}_x$



$\delta q \equiv$ variazione carica sottosistema in x+dx dovuto al trasporto di carica attraverso dA durante l'intervallo di tempo dt

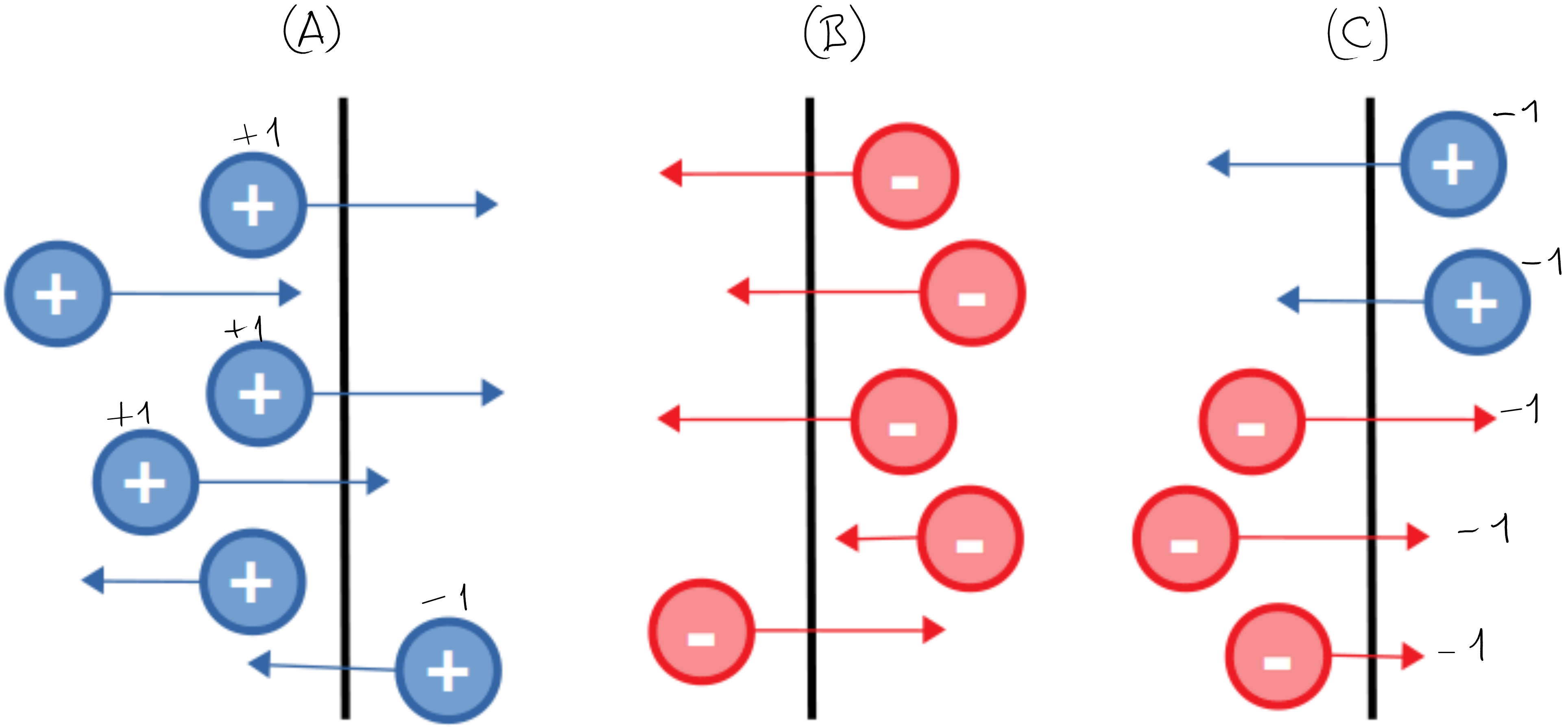
$$\delta q \sim dA\, dt\, E \longrightarrow E = -\frac{dV}{dx}$$

$I_e \equiv \frac{\delta q}{dt}$ <u>corrente elettrica</u> SI: $\frac{C}{s} \equiv A$ Ampère

$J_e \equiv \frac{\delta q}{dt\, dA}$ <u>densità di corrente elettrica</u> SI: $\frac{A}{m^2}$

Es: intervallo di tempo $dt = 10^{-14} s$, cariche elementari $\pm e = \pm 1.6 \times 10^{-19} C$

Calcola la corrente elettrica I_e in A .



$$I_e = \frac{2e}{dt} = \frac{3{,}2 \times 10^{-19}}{10^{-14}} A$$
$$= 3{,}2 \times 10^{-5} A$$

$$I_e = \frac{2e}{dt}$$
$$= 3{,}2 \times 10^{-5} A$$

$$I_e = -\frac{5e}{dt}$$
$$= -8 \times 10^{-5} A$$

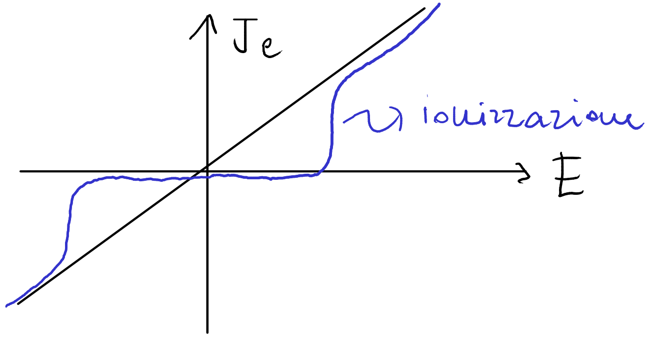
$$J_e \sim E \sim -\frac{dV}{dx} \Rightarrow J_e = \sigma E = -\sigma \frac{dV}{dx}$$

$\sigma \equiv$ conducibilità elettrica

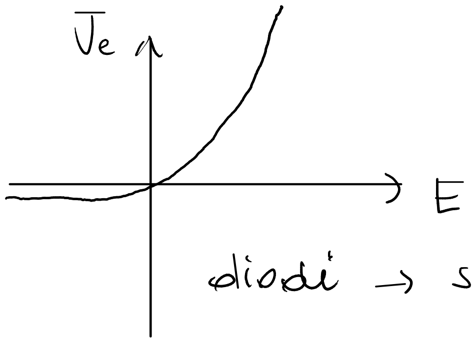
SI: $\frac{A}{m^2}\frac{m}{V} = \frac{A}{Vm}$

legge di ohm

empirica



conduttori ohmici



diodi → semiconduttori

3d: $\vec{J}_e \rightarrow \vec{J}_e = \sigma \vec{E} = -\sigma \vec{\nabla} V$ (ohm)

Analogia con la conduzione termica

legge di ohm $\quad J_e = -\sigma \frac{dV}{dx}$ $\quad$ resistenza elettrica $\quad R \equiv \frac{\Delta V}{I_e}$

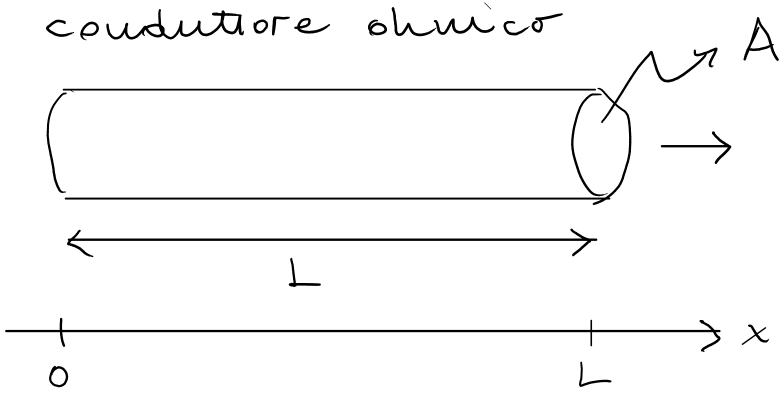
legge di Fourier $\quad J_u = -\lambda \frac{dT}{dx}$ $\quad$ resistenza termica $\quad R \equiv \frac{\Delta T}{I_u}$

↑

conducibilità

Stato stazionario : $J_e = \text{cost}$ (continua)

conduttore ohmico



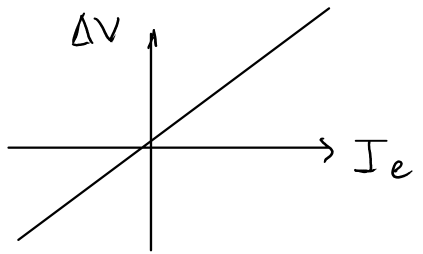
$$I_e = J_e A = -\sigma A \frac{dV}{dx}$$

$$I_e \, dx = -\sigma A \, dV$$

$$\int_0^L I_e \, dx = -\int_{V_i}^{V_f} \sigma A \, dV \qquad \Delta V = V_i - V_f$$

$$I_e L = -\sigma A (V_f - V_i) = \sigma A \Delta V$$

$$\Delta V = \frac{L}{\sigma A} I_e \longrightarrow \Delta V \sim I_e$$



$$R \equiv \frac{L}{\sigma A}$$ resistenza elettrica $\Rightarrow$ $\Delta V = R I_e$

$$\Delta V = I_e R \leadsto \Delta V = IR$$

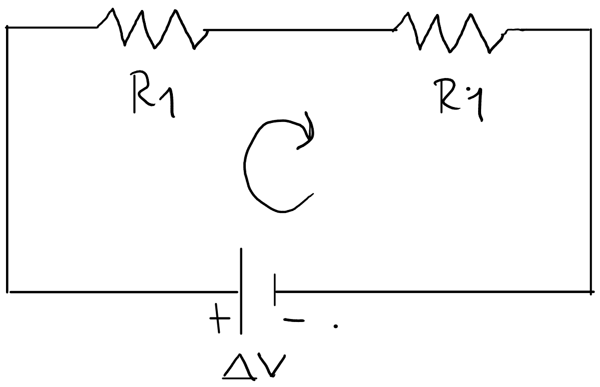
SI : $\frac{V}{A} \equiv \Omega$ Ohm

$\sigma \rightarrow \frac{A}{Vm} = \frac{1}{\Omega m} = (\Omega m)^{-1}$ conducibilità elettrica

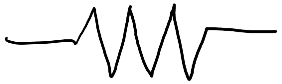
$\rho_e \equiv \frac{1}{\sigma}$ resistività elettrica

SI : Ωm

1) Resistenze in serie



conduttori di resistenza $R \neq 0$ → resistenze



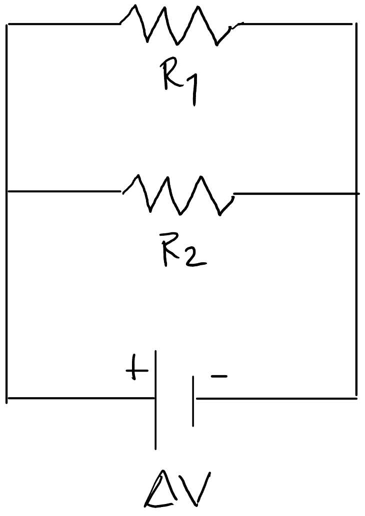
filo $R=0$

$$I_{tot} = I_1 = I_2$$

$$\Delta V = \Delta V_1 + \Delta V_2$$

$$I_{tot} R_{tot} = I_1 R_1 + I_2 R_2 = I\,(R_1 + R_2) \Rightarrow R_{tot} = R_1 + R_2$$

2) Resistenze in parallelo



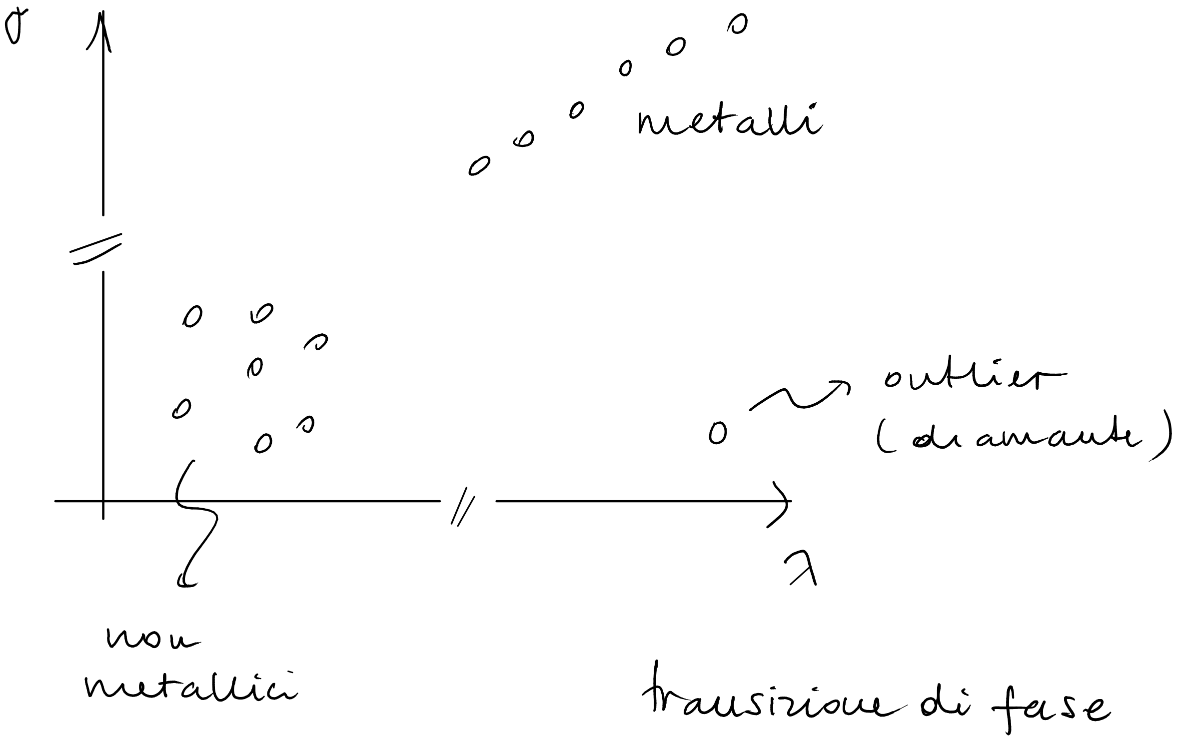
$$\Delta V = \Delta V_1 = \Delta V_2$$

$$I_{tot} = I_1 + I_2$$

$$\frac{\Delta V}{R_{tot}} = \frac{\Delta V_1}{R_1} + \frac{\Delta V_2}{R_2} = \Delta V \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \Rightarrow \frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\left[\begin{array}{l} \Delta V = R I \\ Q = C \Delta V \Rightarrow \Delta V = \frac{1}{C} Q \end{array} \right]$$

Conducibilità elettrica / termica

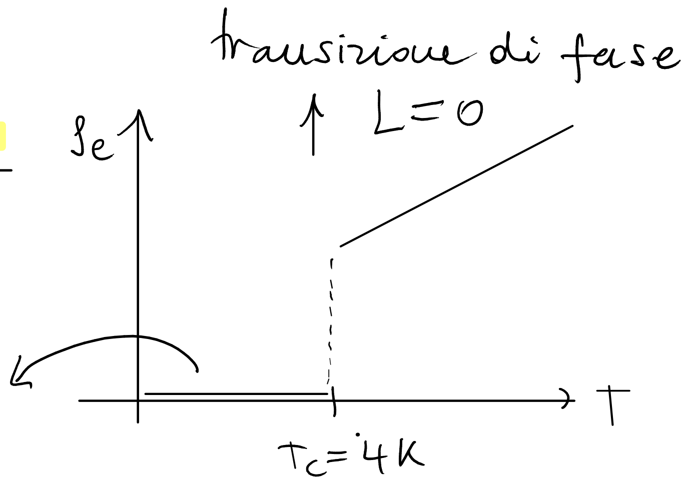


Superconduttività

1911 Onnes Hg

meccanica quant.

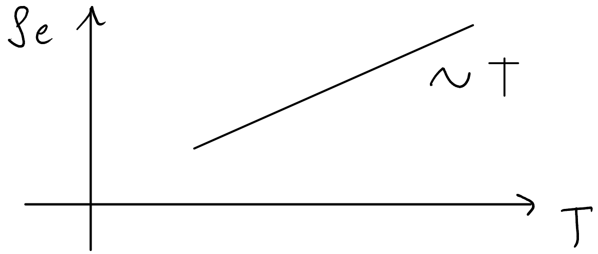
$R \approx 10^{-25}\ \Omega m$



Dipendenza da T di ρ_e

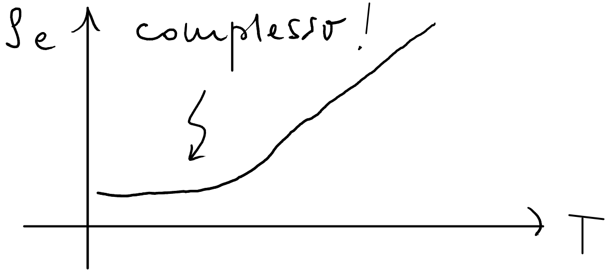
Resistività $\rho_e = 1/\sigma$

- alta temperatura



$\rho_e \sim T$

- bassa temperatura



- Ag, Cu, Au non sono superconduttori
- ceramici → $T_c \sim 100\ K - 200\ k$