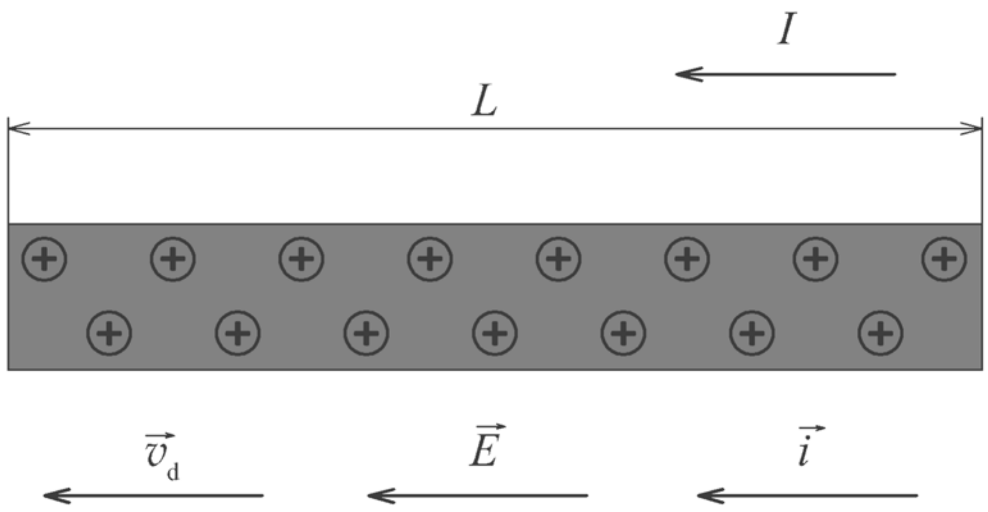
Electric current

Electric current

$$I = \frac{dQ}{dt}$$



drift velocity $\vec{v}_d$

current density $dI = \vec{i} \cdot d\vec{S}$

$$I = \frac{Q}{\tau} = \frac{nSLe}{\frac{L}{v_d}} = nSev_d \qquad i = nev_d \qquad \vec{i} = ne\vec{v}_d$$

$$Q = Ne = nSLe \qquad N = nSL$$

Ohm's law

$$U = RI$$

$$R = \rho \frac{l}{S} \qquad \rho = \frac{1}{\gamma} \qquad \Delta U = \varphi_1 - \varphi_2 = \vec{E} \cdot \Delta \vec{l}$$

$$\vec{i} = \gamma \vec{E}$$

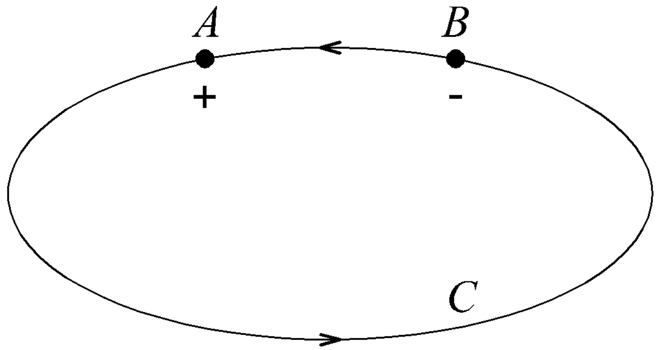
conductors	$10^{-7} - 10^{-8}\ \Omega \cdot m$
non-conductors	$10^{6} - 10^{16}\ \Omega \cdot m$
semiconductors	$10^{-6} - 10^{7}\ \Omega \cdot m$
linear temperature function	$R = R_0\left[1 + \alpha\left(t - t_0\right)\right]$

"emf" and "emf device"

$$\vec{E}^* = \frac{\vec{F}^*}{Q}$$

electromotive force

emf device



$$U_{AB} = \int_A^B \vec{E}_s \cdot d\vec{l}$$

$$\oint_C \vec{E} \cdot d\vec{l} = \int_{AB} \vec{E}_s \cdot d\vec{l} + \int_{BA} \left(\vec{E}_s + \vec{E}^*\right) \cdot d\vec{l} = \int_{AB} \vec{E}_s \cdot d\vec{l} + \int_{BA} \vec{E}_s \cdot d\vec{l} + \int_{BA} \vec{E}^* \cdot d\vec{l}$$

$$\int_{AB} \vec{E}_s \cdot d\vec{l} + \int_{BA} \vec{E}_s \cdot d\vec{l} = \oint_C \vec{E}_s \cdot d\vec{l} = 0$$

$$\int_{AB} \vec{E}_s \cdot d\vec{l} = -\int_{BA} \vec{E}_s \cdot d\vec{l} = U_{AB}$$

$$\mathcal{E} = \int_{BA} \vec{E}^* \cdot d\vec{l}$$

$$\oint_C \vec{E} \cdot d\vec{l} = \int_{BA} \vec{E}^* \cdot d\vec{l}$$

energy per unit charge = **emf**

= potential (≈ voltage)

$$I = \frac{U_{AB}}{R} = \frac{1}{R}\int_{AB} \vec{E}_s \cdot d\vec{l}$$

$$I = \frac{1}{R_i}\int_{BA} \left(\vec{E}_s + \vec{E}^*\right)\cdot d\vec{l} = \frac{1}{R_i}\int_{BA} \vec{E}_s \cdot d\vec{l} + \frac{1}{R_i}\int_{BA} \vec{E}^* \cdot d\vec{l} = -\frac{RI}{R_i} + \frac{\mathcal{E}}{R_i}$$

$$\int_{AB} \vec{E}_s \cdot d\vec{l} = RI$$

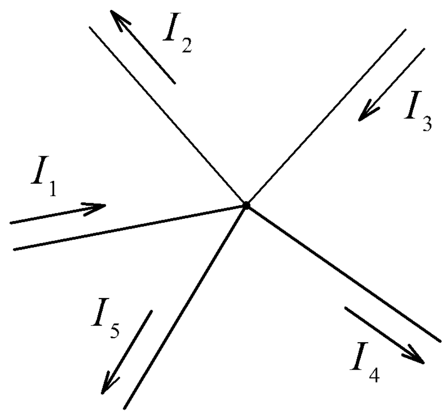
$$\mathcal{E} = \left(R + R_i\right) I$$

$$\mathcal{E} = U_{AB} + R_i I$$ terminal voltage

Kirchhoff's laws

1st Kirchhoff's law (current rule)

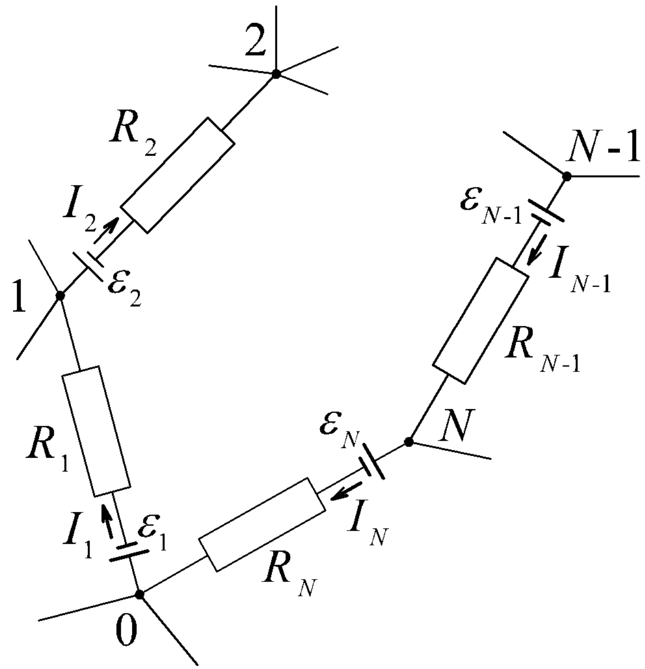
The algebraic sum of currents in a network of conductors meeting at a point is zero.



$$\sum_{k=1}^{N} I_k = 0$$

2nd Kirchhoff's law (voltage rule)

The directed sum of the potential differences (voltages) around any closed loop is zero.



$$\sum_{k=1}^{N} \varepsilon_k = \sum_{k=1}^{N} R_k I_k$$

Energy and power in circuits

$$dW_p = dQ\,U = I\,dt\,U$$

Joule's law (Joule heating):
the heat power that develops in a wire carrying a current is proportional to the wire resistance the square of the current.

$$P = UI \qquad P = \frac{U^2}{R}, \qquad P = RI^2$$

$$p = \vec{E} \cdot \vec{i}$$ differential Joule's law

$$p = \frac{dP}{dV}$$ heat power density

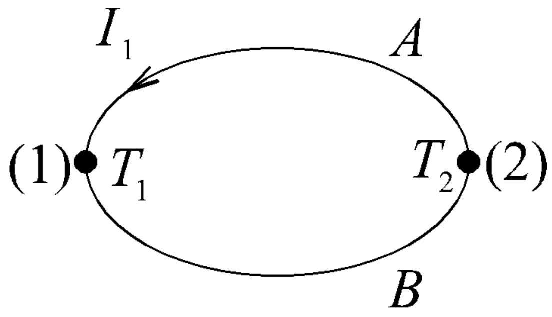
energy per unit time τ

$$W = \int_0^t P\,d\tau = \int_0^t UI\,d\tau = \int_0^t U\,dQ$$

Thermoelectric effect

- Intrinsic connection of charge and heat transport phenomena
- A matter subjected to temperature gradient = diffusion of carriers

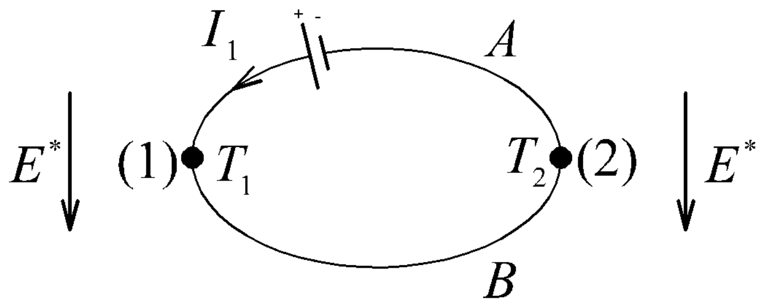
Seebeck effect $T_1 \neq T_2$



$$I = \frac{U_{AB}(T_1) - U_{AB}(T_2)}{R}$$

$$\varepsilon_k = U_{AB}(T_1) - U_{AB}(T_2)$$

thermocouple principle



Peltier effect $T_2 > T_1$

inverse to Seebeck effect – thermoelectric pumps (cooling, heating)