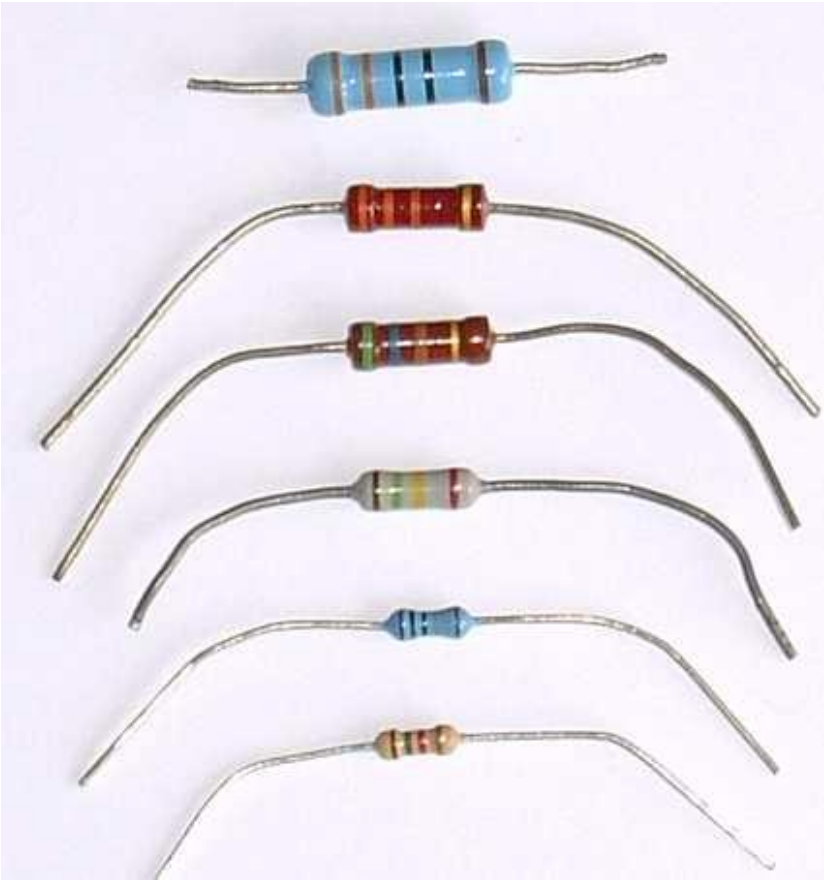
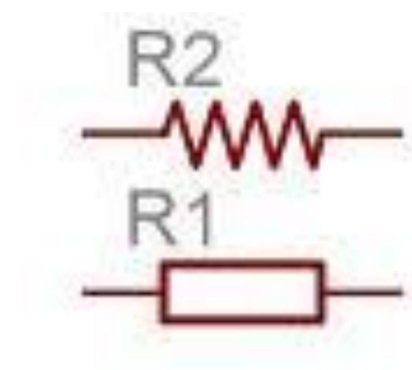
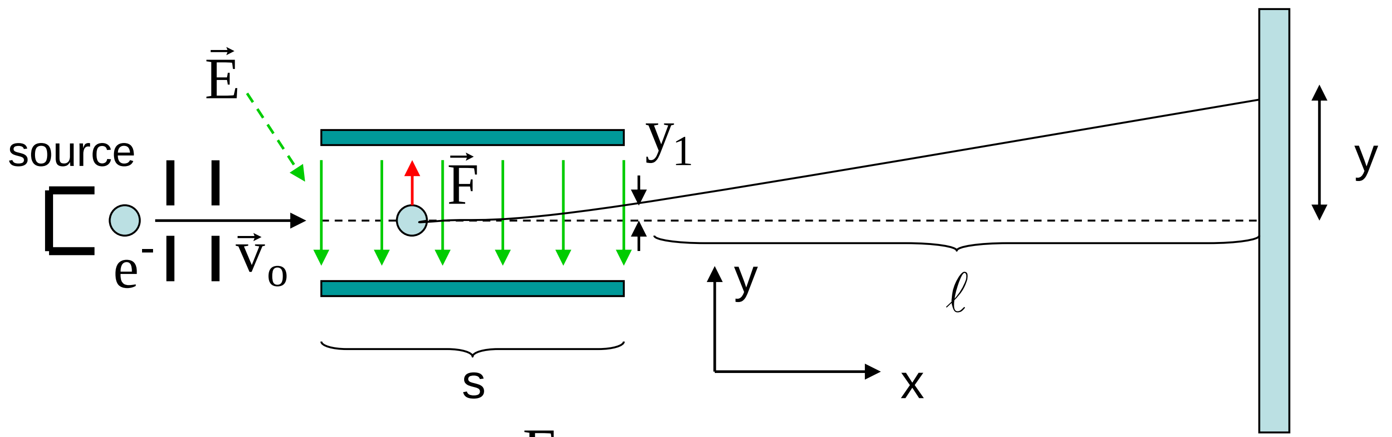
7. lecture Part I.





Direct current, resistors, conductivity, etc.

The CRT monitor



$$F = qE = ma \rightarrow a_y = \frac{qE}{m}$$

$$t_1 = \frac{s}{v_o} \rightarrow y_1 = \frac{1}{2} a_y t_1^2 = \frac{1}{2}\frac{qE}{m}\frac{s^2}{v_o^2} \quad \text{és} \quad v_y = a_y t_1 = \frac{qE}{m}\frac{s}{v_o}$$

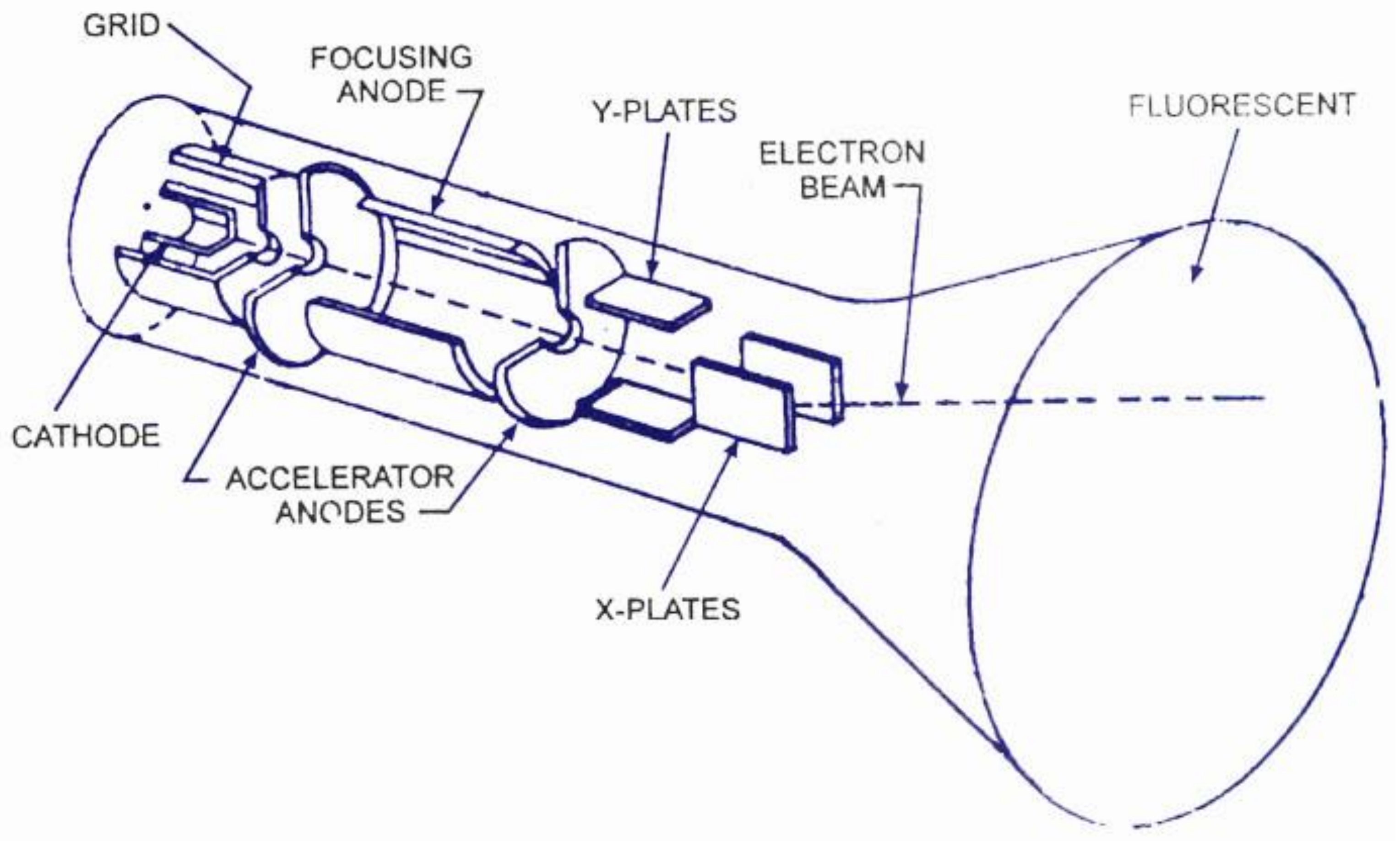
$$t_2 = \frac{\ell}{v_o} \rightarrow y_2 = v_y t_2 = \frac{qE}{m}\frac{s}{v_o}\frac{\ell}{v_o}$$

így $y = y_1 + y_2 \rightarrow y \propto E$

$$V = Ed \rightarrow \boxed{y \propto V}$$

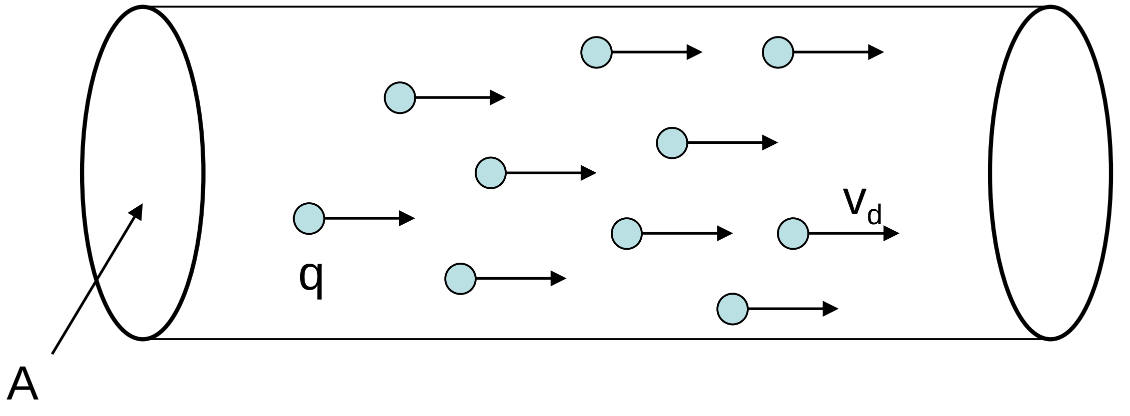
V: electric potential
d: separation of plates (of capacitor)

CRT monitor



Cathode Ray Tube

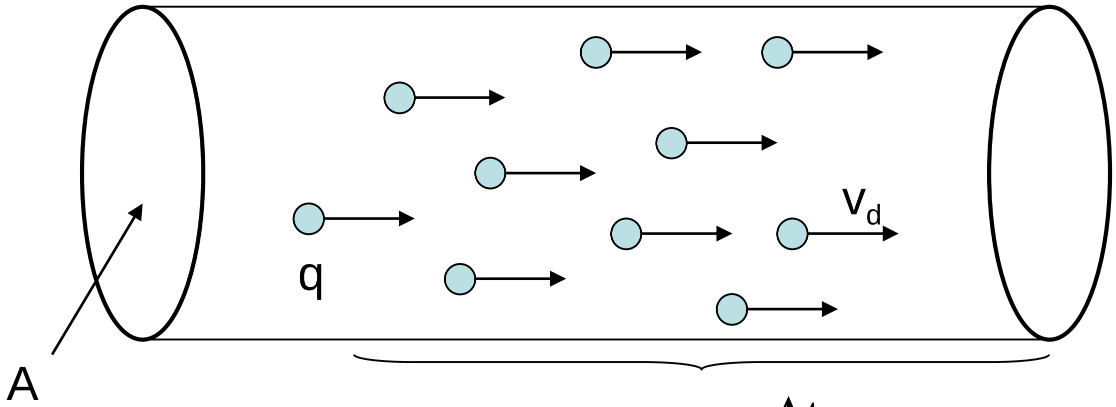
Direct current, current density



Current: $$I = \frac{\Delta Q}{\Delta t} \qquad \left[\frac{C}{s} = A\right]$$

Current density: $$J = \frac{I}{A} \qquad \left[\frac{A}{m^2}\right]$$

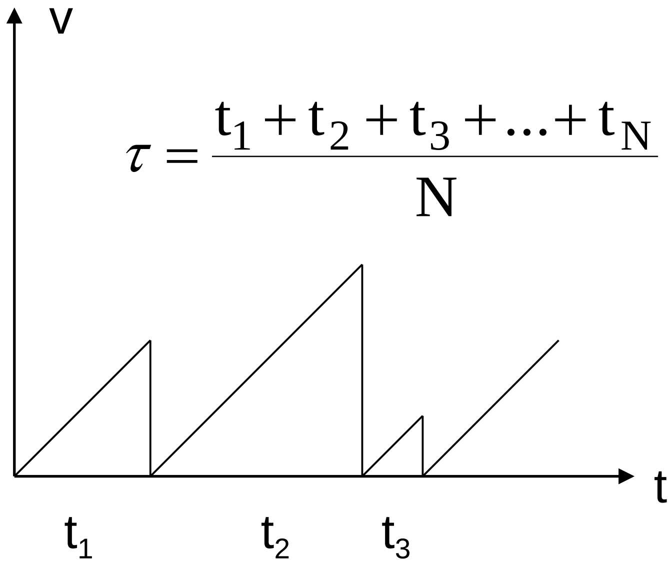
Direct current



$$s = v_d \cdot \Delta t$$

The charge of electron: q

Density of particles: n



$$\tau = \frac{t_1 + t_2 + t_3 + \ldots + t_N}{N}$$

Drift speed: $v_d = \frac{qE}{m}\tau$

$$\Delta Q = A v_d \Delta t q n$$

Current: $I = \frac{\Delta Q}{\Delta t} = A v_d q n$

Current density: $J = \frac{I}{A} = v_d q n$

Direct current

$$I = \frac{\Delta Q}{\Delta t} = A v_d q n \qquad v_d = \frac{qE}{m}\tau \qquad V = E\ell \;\rightarrow\; E = \frac{V}{\ell}$$

$$I = Aqn\frac{qE}{m}\tau \;\rightarrow\; I = \frac{Aq^2 n\tau}{m}\frac{V}{\ell}$$

Current density: $J = \sigma E$

$$\frac{V}{I} = \frac{m}{qn^2\tau}\frac{\ell}{A} \;\rightarrow\; \boxed{\frac{V}{I} = R} \;\rightarrow\; R = \rho\frac{\ell}{A} \text{ ahol } \rho = \frac{m_e}{q_e n^2 \tau}$$

Ohm’s law

$$\left[\frac{V}{A} = \Omega\right]$$

Resistance: ρ

Conductivity: $\sigma = \frac{1}{\rho}$

Insulators, semiconductors & metals

Substance	Resistance [Ωm]
Insulators	
Mika	$2*10^{15}$
Glass	$2*10^{11}$
Semiconductors	
Si (silicon)	640
Ge (germanium)	0,46
Conductors	
Aluminum	$2.8*10^{-8}$
Copper	$1.7*10^{-8}$
Gold	$2.4*10^{-8}$
Iron	$10*10^{-8}$

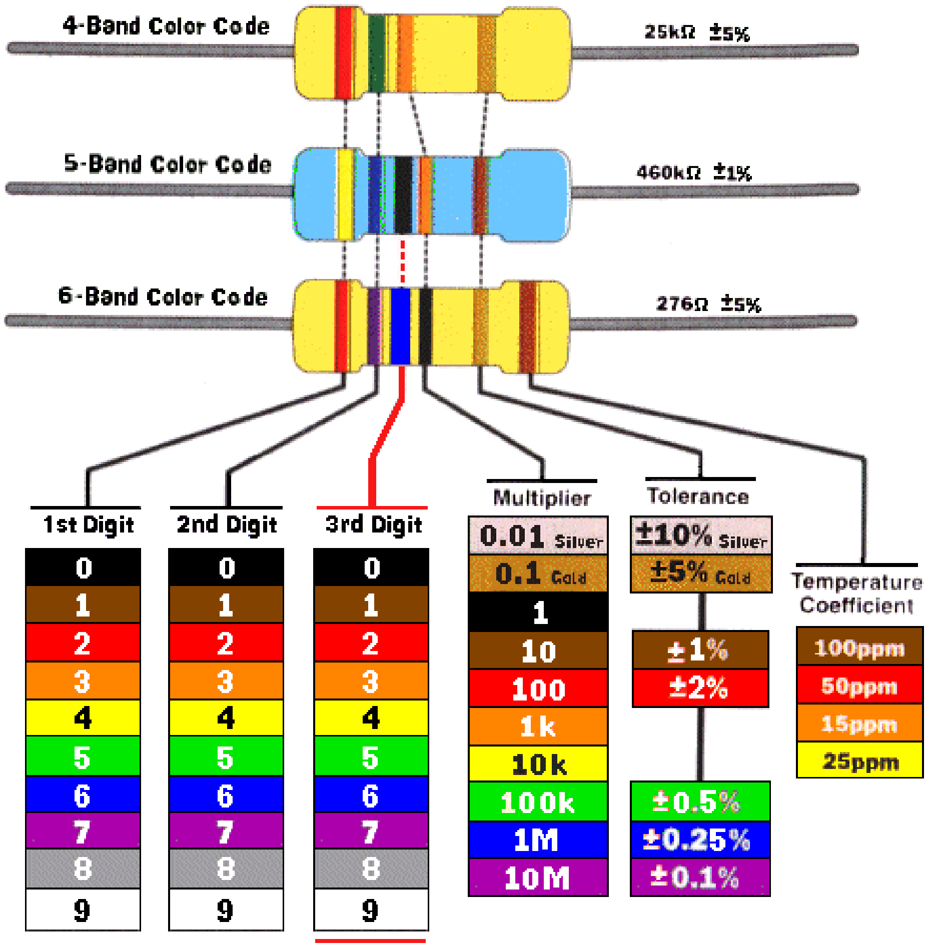
Resistance depends on temperature

$$\rho = \rho_o\left(1 + \alpha(T - T_o)\right)$$

(electric thermometer)

$$\alpha \propto 10^{-3}\frac{1}{^{o}C}$$

Colour code:

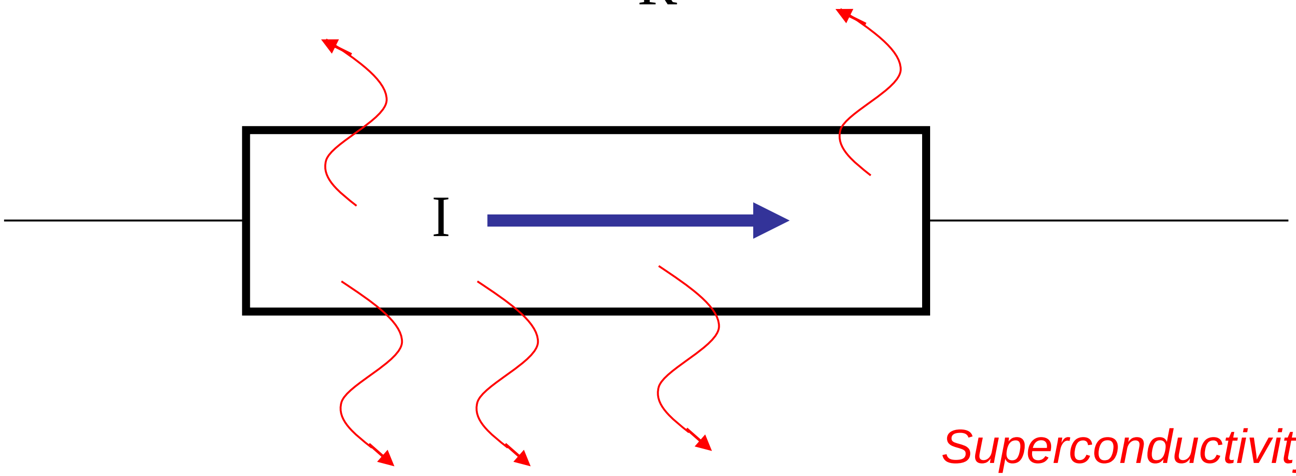


Joule's law

$$dW = Vdq$$

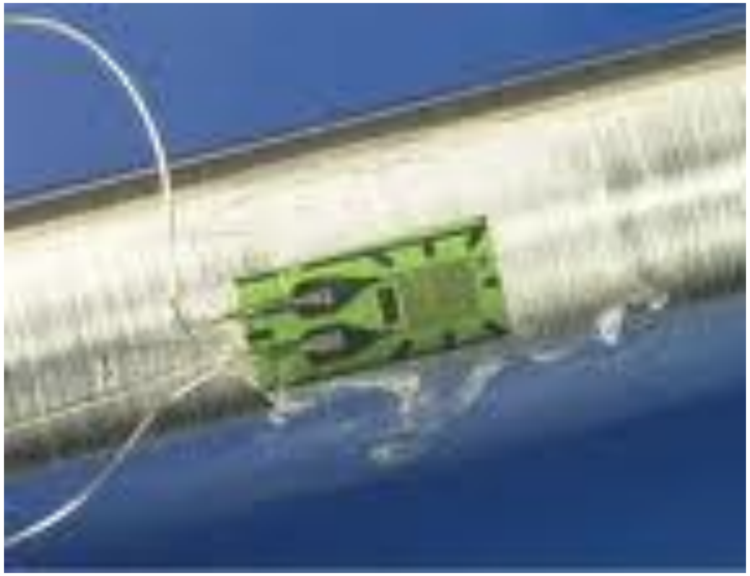
$$P = \frac{dW}{dt} = V\frac{dq}{dt} = VI$$

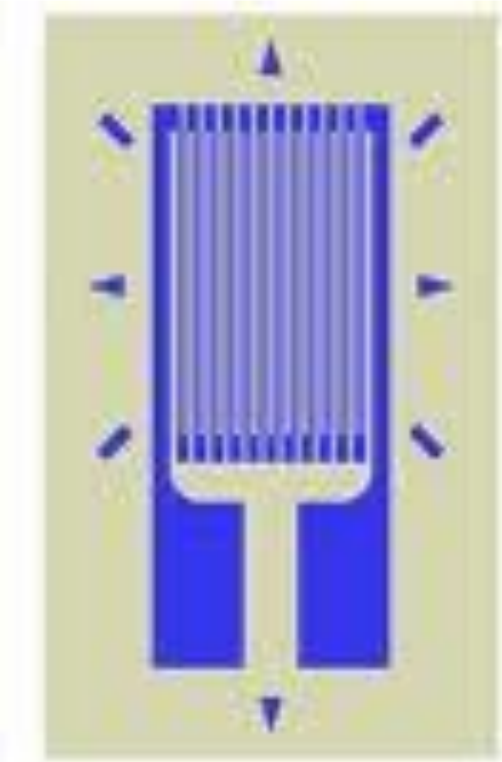
$$V = IR \quad \rightarrow \quad P = VI = RI^2 = \frac{V^2}{R}$$



Superconductivity???

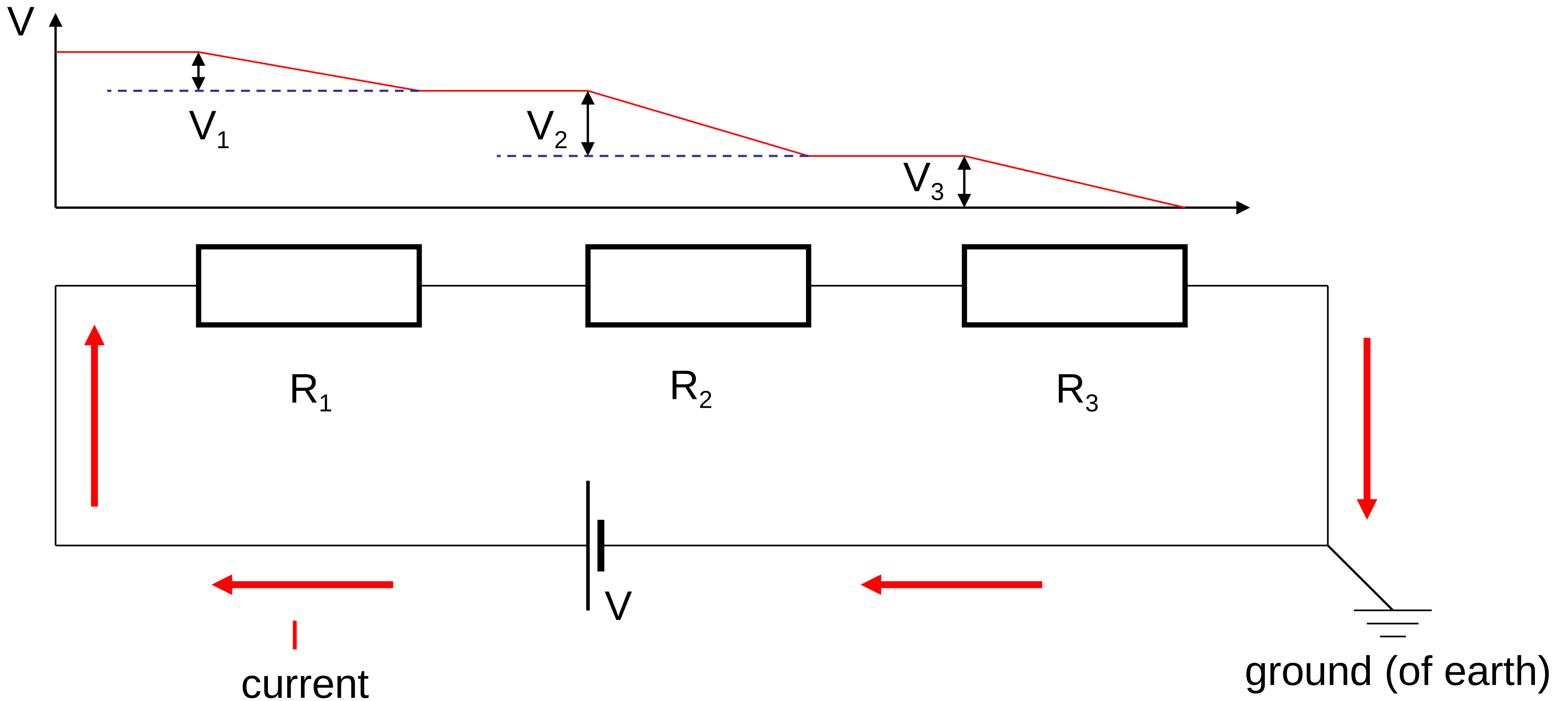
Part II.





Direct current circuits

Series combination of resistors:



$$V = V_1 + V_2 + V_3$$
$$V_1 = IR_1$$
$$V_2 = IR_2$$
$$V_3 = IR_3$$

$$V = IR_e \qquad IR_e = IR_1 + IR_2 + IR_3$$

$$R_e = R_1 + R_2 + R_3$$

$$R_e = \sum_i R_i$$

Parallel combination of resistors:

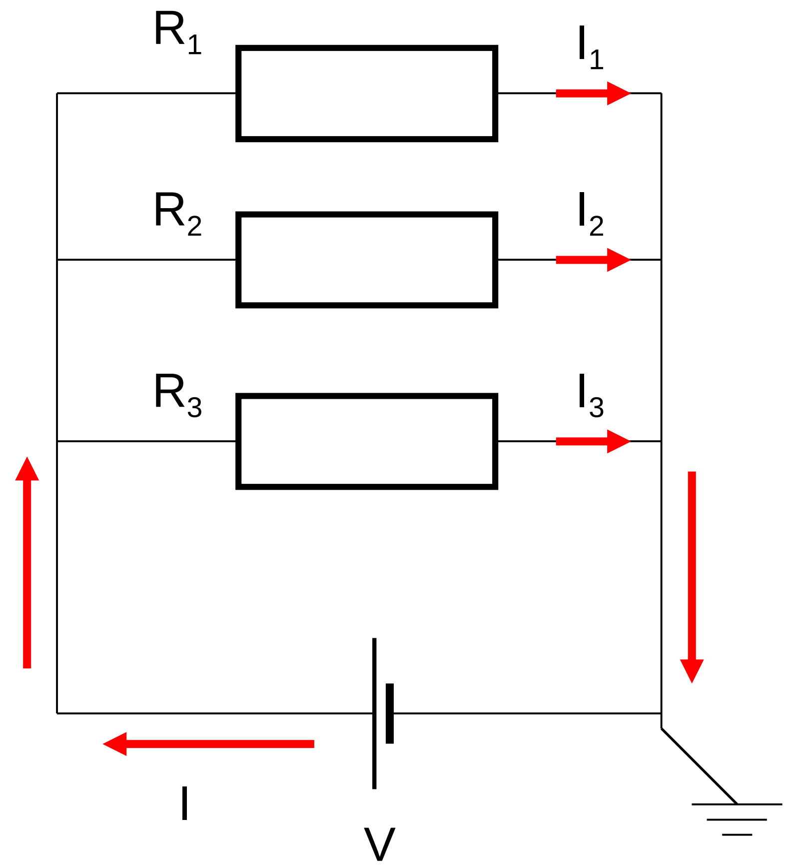
$$I = I_1 + I_2 + I_3$$

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

$$I = \frac{V}{R_e}$$

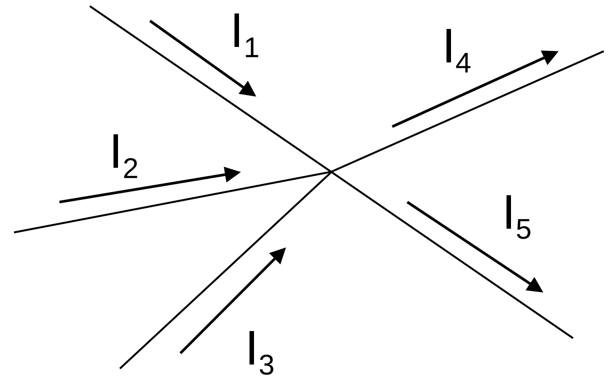


$$\frac{V}{R_e} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \Rightarrow \frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\boxed{\frac{1}{R_e} = \sum_i \frac{1}{R_i}}$$

Kirchoff's rules

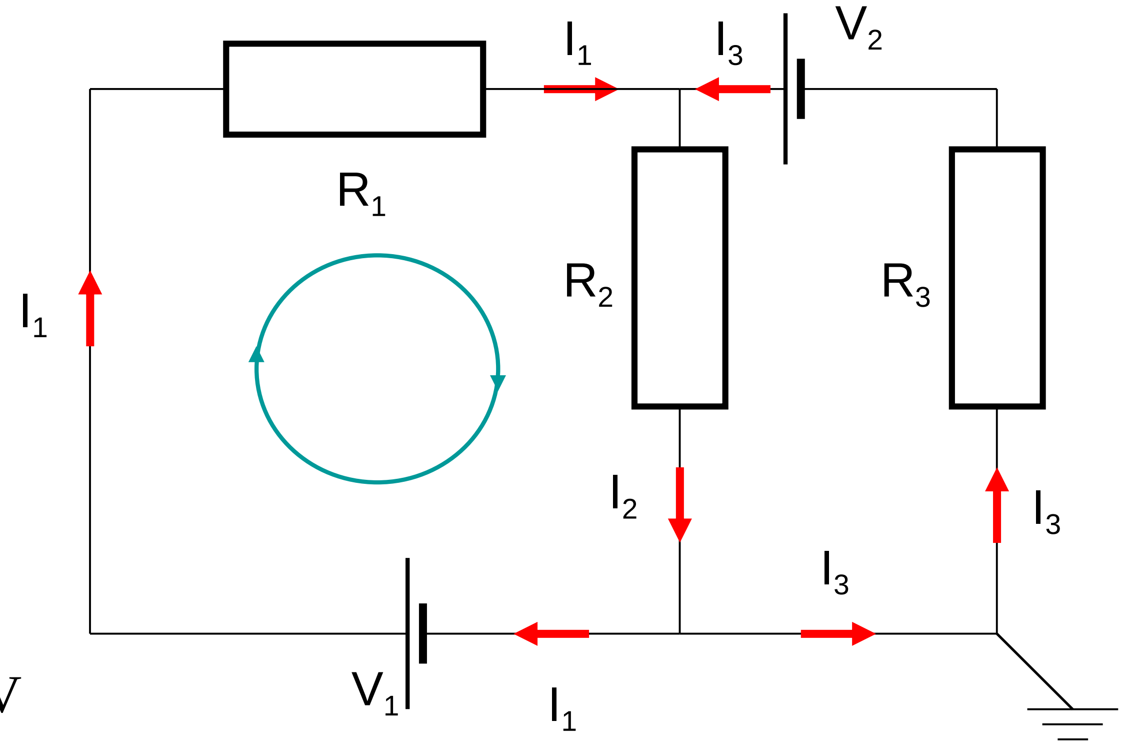
1. Junction rule

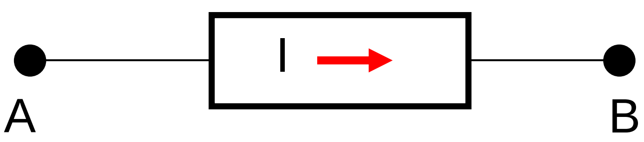


$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

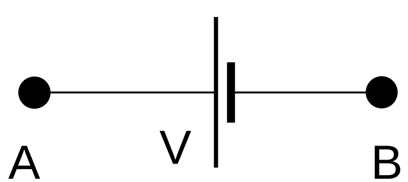
2. Loop rule

$$V_1 - I_1R_1 - I_2R_2 = 0$$



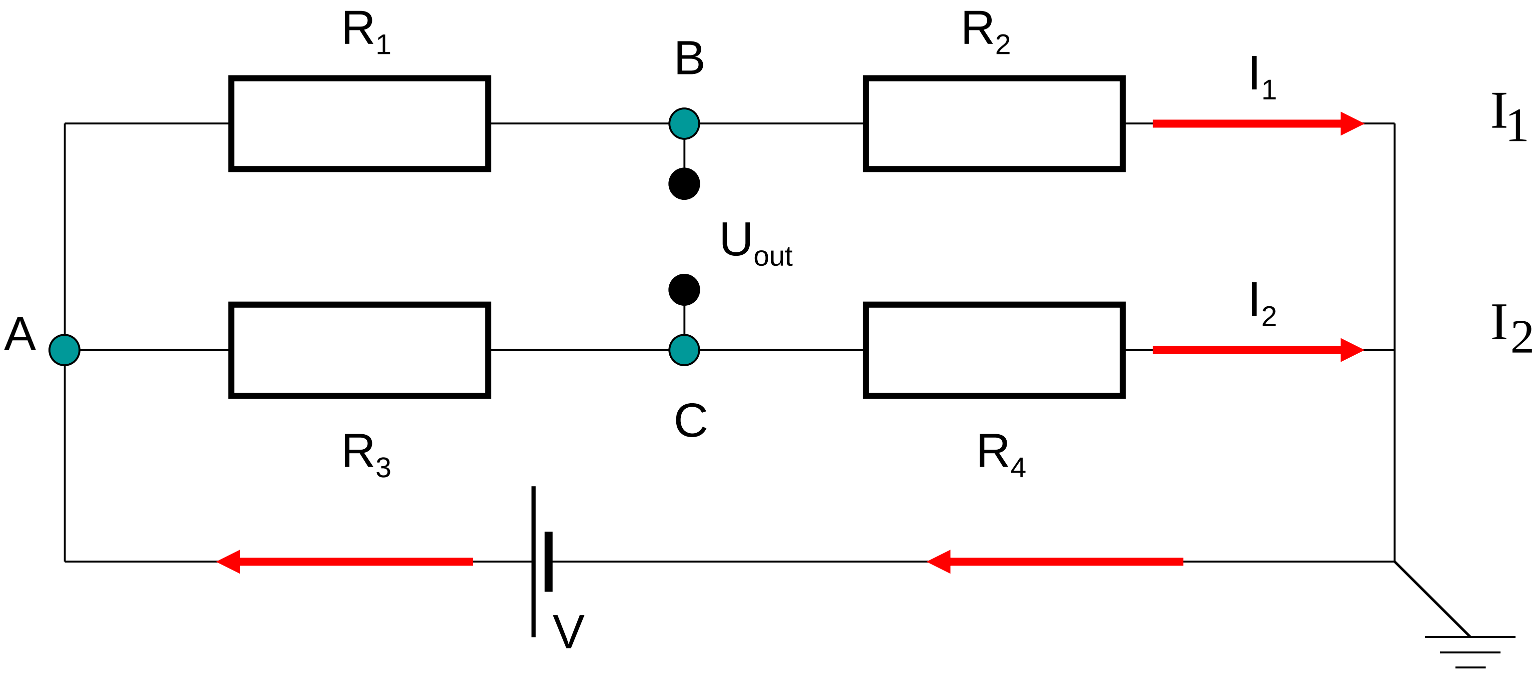


$$V_{AB} = -IR$$
$$V_{BA} = +IR$$



$$V_{AB} = -V$$
$$V_{BA} = +V$$

Wheaston-bridge



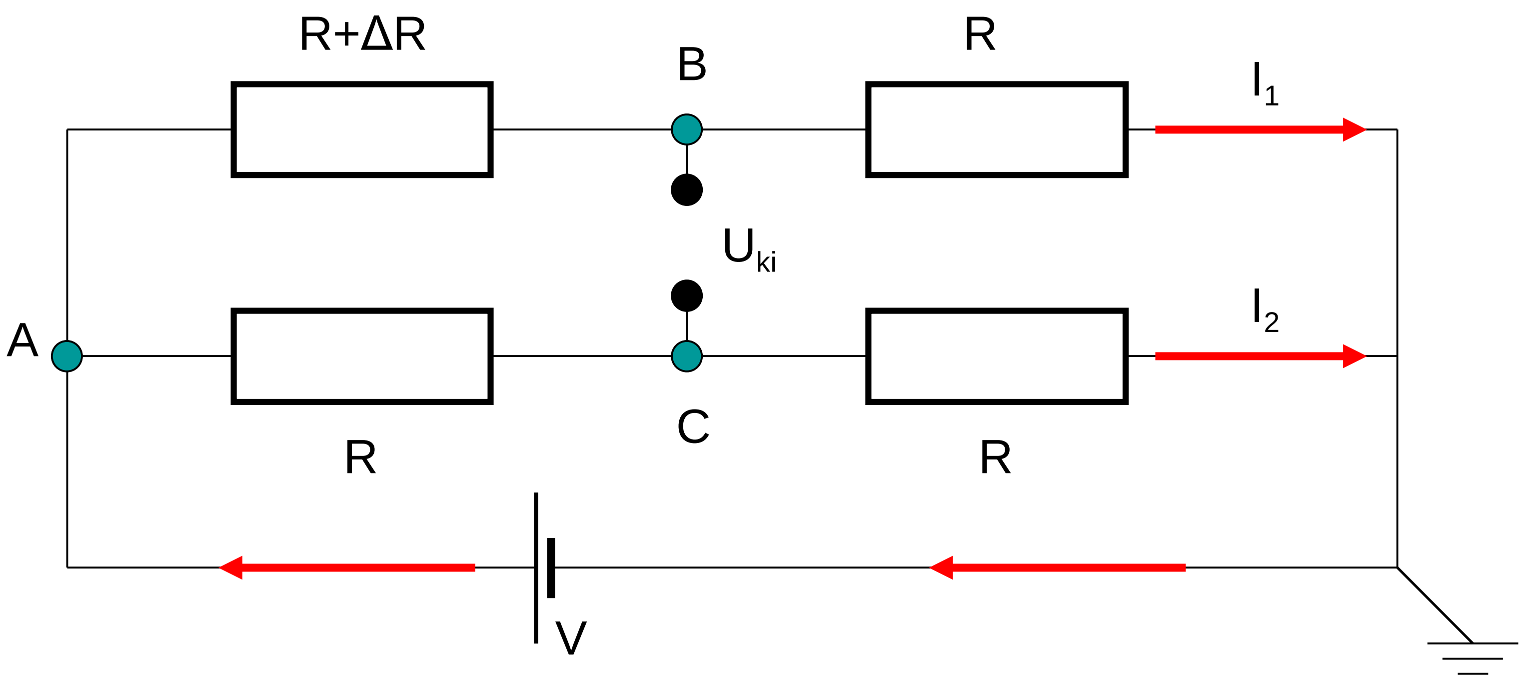
$$I_1 = \frac{V}{R_1 + R_2}$$

$$I_2 = \frac{V}{R_3 + R_4}$$

$$V_{BA} = I_1 R_1 = \frac{V}{R_1 + R_2} R_1 \qquad V_{CA} = I_2 R_3 = \frac{V}{R_3 + R_4} R_3 \qquad U_{out} = V_{BA} - V_{CA}$$

$$U_{out} = \frac{V}{R_1 + R_2} R_1 - \frac{V}{R_3 + R_4} R_3 = V \frac{R_1(R_3 + R_4) - R_3(R_1 + R_2)}{(R_1 + R_2)(R_3 + R_4)} = V \frac{R_1 R_4 - R_3 R_2}{(R_1 + R_2)(R_3 + R_4)}$$

The measurement of change in resistance with Wheaston-bridge



$$U_{ki} = V\frac{(R+\Delta R)R - RR}{(2R+\Delta R)(2R)} = \frac{V}{4}\frac{\Delta R}{R}$$