# Electric circuit elements

## Resistor

$$Z_R = R$$

Power $= P = IV = I^2R = V^2/R$

Notation:


$$R = R_1 \parallel R_2 = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$

## Capacitor

$$Z_C = \frac{1}{j\omega C}$$

Charge $Q = CV \Rightarrow \dot{Q} = I = C\dot{V}$

Energy stored: $E = \frac{1}{2}CV^2$

$\Rightarrow$ Capacitor resists voltage changes. Why?

## Inductor

$$Z_L = j\omega L$$

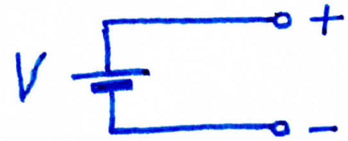
Magnetic flux $\Phi_m = LI \qquad \dot{\Phi}_m = V_{ind} = L\dot{I}$

Energy stored: $E = \frac{1}{2}LI^2$

$\Rightarrow$ Inductor resists current changes. Why?

# Sources (voltage and current)

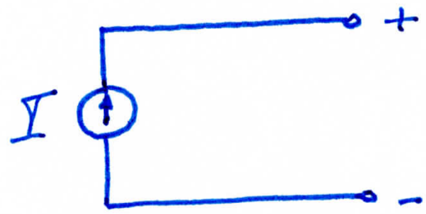
Ideal voltage source



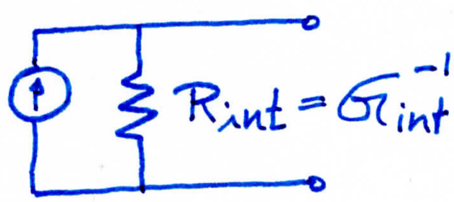

Real voltage source


Typically small, e.g. $3\Omega$. Why?

Ideal current source




Real current source




Typically large, e.g. $100k\Omega$

Why?

Resistance of ideal voltage source

$V$  $$R = \frac{dV}{dI} = \frac{\Delta V}{\Delta I} = \frac{0}{\Delta I} = 0$$

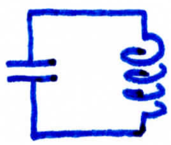
Question: Why is $\Delta V = 0$ ?

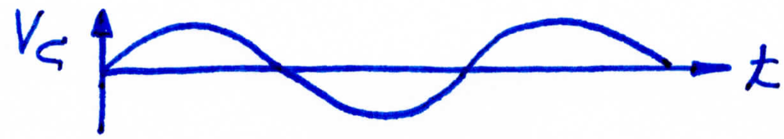
Resistance of ideal current source

$I$  $$R = \frac{dV}{dI} = \frac{\Delta V}{\Delta I} = \frac{\Delta V}{0} = \infty$$

Question: Why is $\Delta I = 0$ ?

## LC circuit

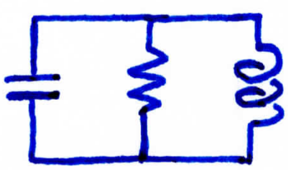


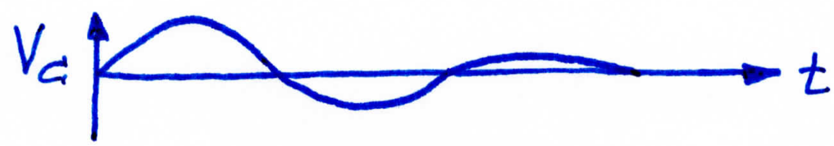



$$\omega_{Resonance} = 2\pi f_{Resonance} = 1/\sqrt{LC}$$

Mechanical analog: ① Pendulum
② Spring and mass

## LCR circuit






$$\omega_{Resonance} \approx 1/\sqrt{LC}$$

Strong damping $\Rightarrow$ $R = ?$

Weak damping $\Rightarrow$ $R = ?$