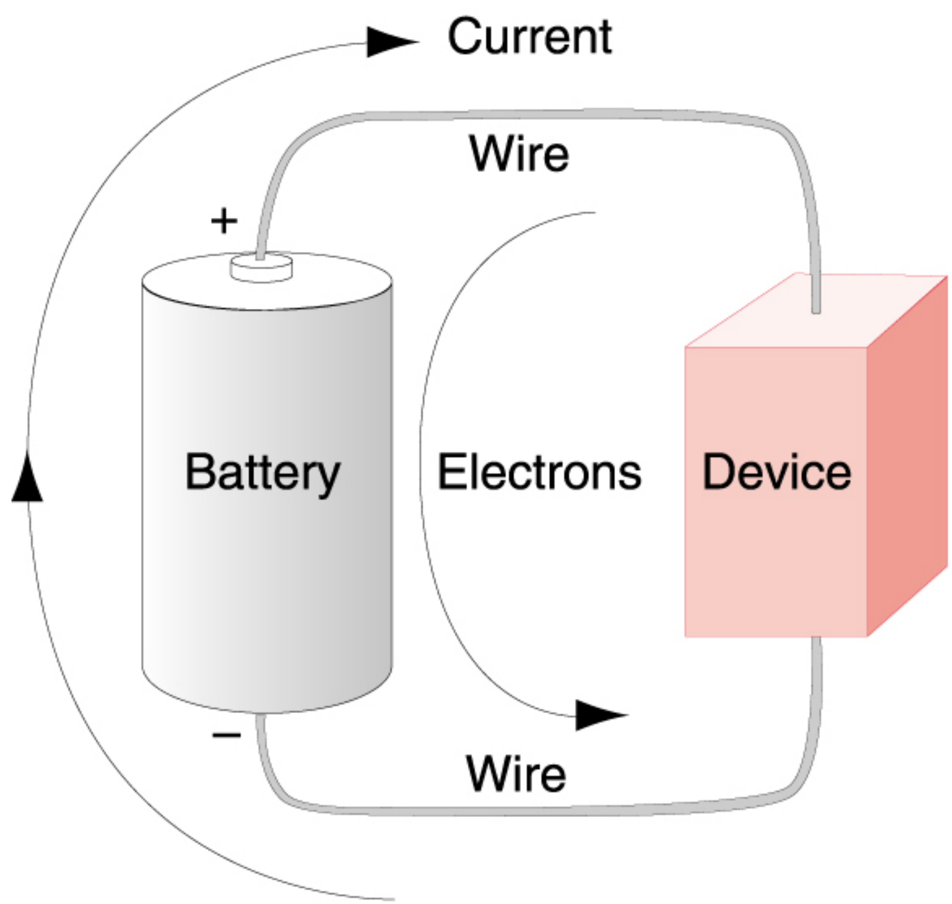
Chapters 25: Circuit theory
Tuesday October 4th

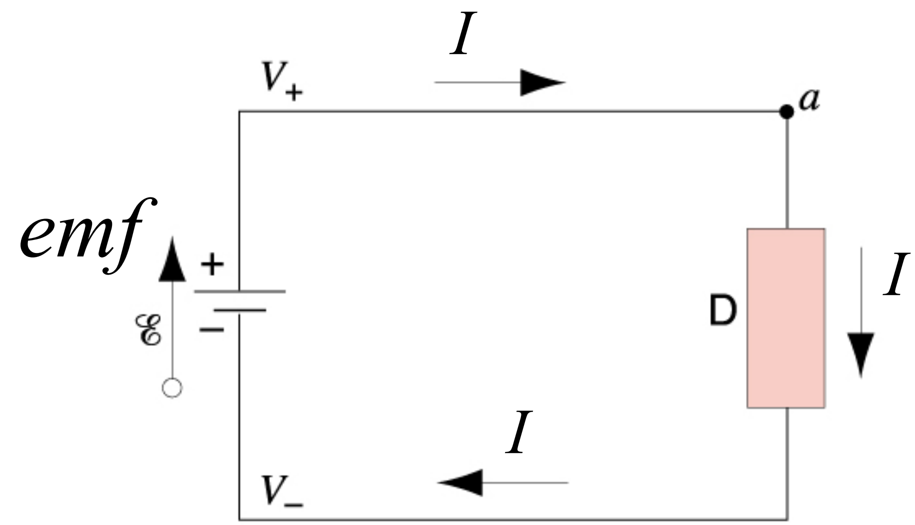
Mini Exam 3 on Thursday

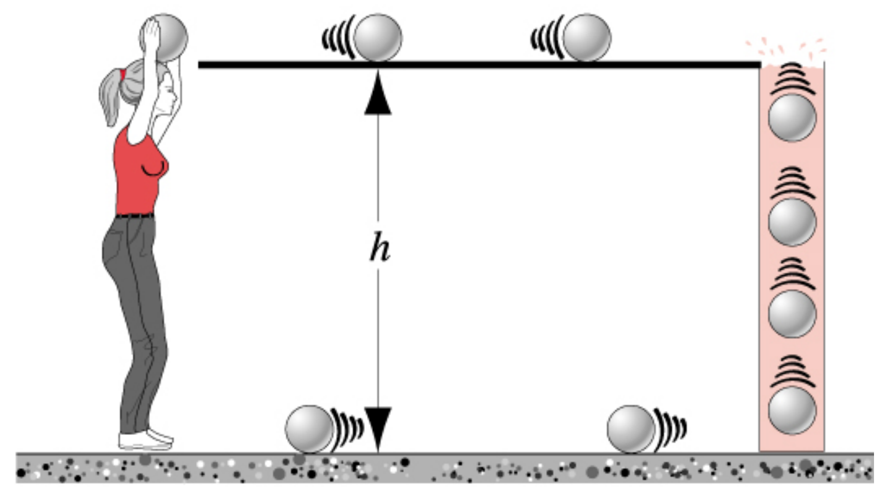
- DC circuits
  - Kirchoff's 2nd law (loop law)
  - Energy transfer in DC circuits
  - Internal resistance of a battery
  - Kirchoff's 1st law (node law)
- Examples
  - Network circuit with 1 battery
  - Parallel batteries
  - Complex circuit
- Thursday will involve capacitors

Reading: up to page 426 in the text book (Ch. 25)

DC Circuits







EMF = electromotive force

Electromotive force (emf)

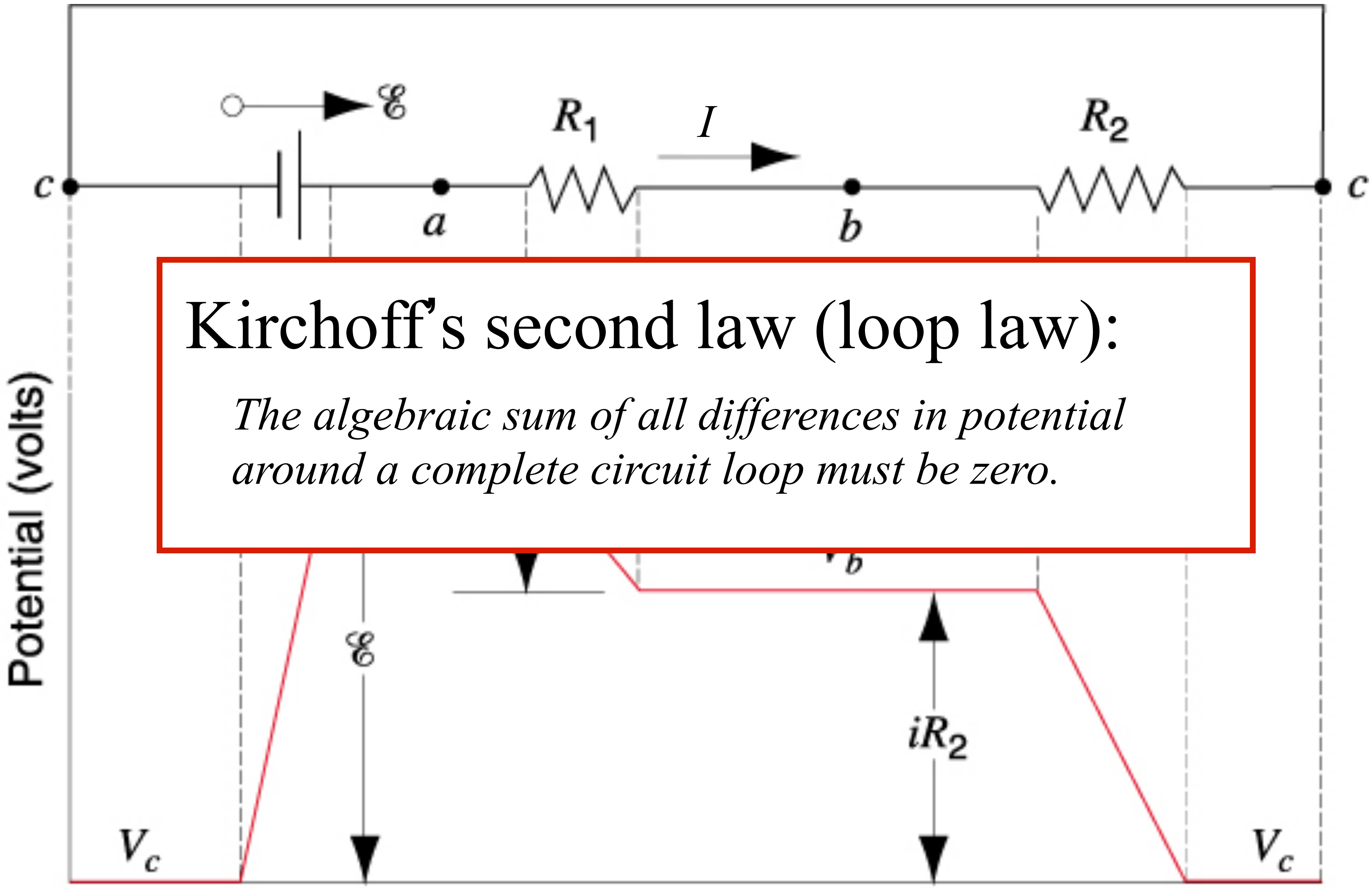
- **Source of electrical energy in a circuit.**

$$\varepsilon = dW \,/\, dQ$$

SI unit: joule/Coulomb

- Represents the potential energy provided to each coulomb of charge that passes through the device.
- IT IS NOT A FORCE!!!
- Most often, emf is provided by a battery (a chemical cell).
- The emf is the same as the potential difference between the negative and positive terminals of a battery **WHEN NO CURRENT FLOWS**.
- In general, when a current flows, the potential difference at the terminals of a battery is lower than the emf.
- An emf can also store energy.

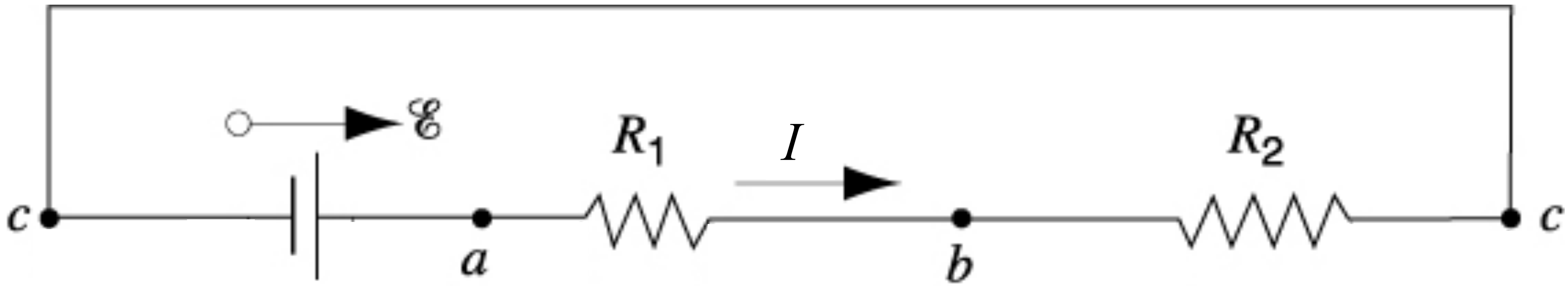
Circuit analysis – series circuits



Kirchoff's second law (loop law):

The algebraic sum of all differences in potential around a complete circuit loop must be zero.

Circuit analysis – series circuits



Kirchoff's second law:

The algebraic sum of all differences in potential around a complete circuit loop must be zero.

$$\Rightarrow \varepsilon - IR_1 - IR_2 = 0$$

$$\varepsilon = I\left(R_1 + R_2\right) = IR_{eq}$$

$$R_{eq} = R_1 + R_2,\ \text{in general } R_{eq} = \sum_i R_i$$

Energy transfer in electric circuits

- A 1V battery does work by providing each coulomb of charge that leaves its positive terminal 1 joule of energy.
- If charge flows at a rate of 1 coulomb per second, then the battery does work at a rate of 1 joule per second, i.e.

$$\text{Power}=\frac{\text{joule}}{\text{coulomb}}\times\frac{\text{coulomb}}{\text{second}}=\frac{\text{joule}}{\text{second}}=\text{watt}$$

$$P=\varepsilon I=dW/dt$$

- In a resistor, energy is lost in an amount *iR* per coulomb.

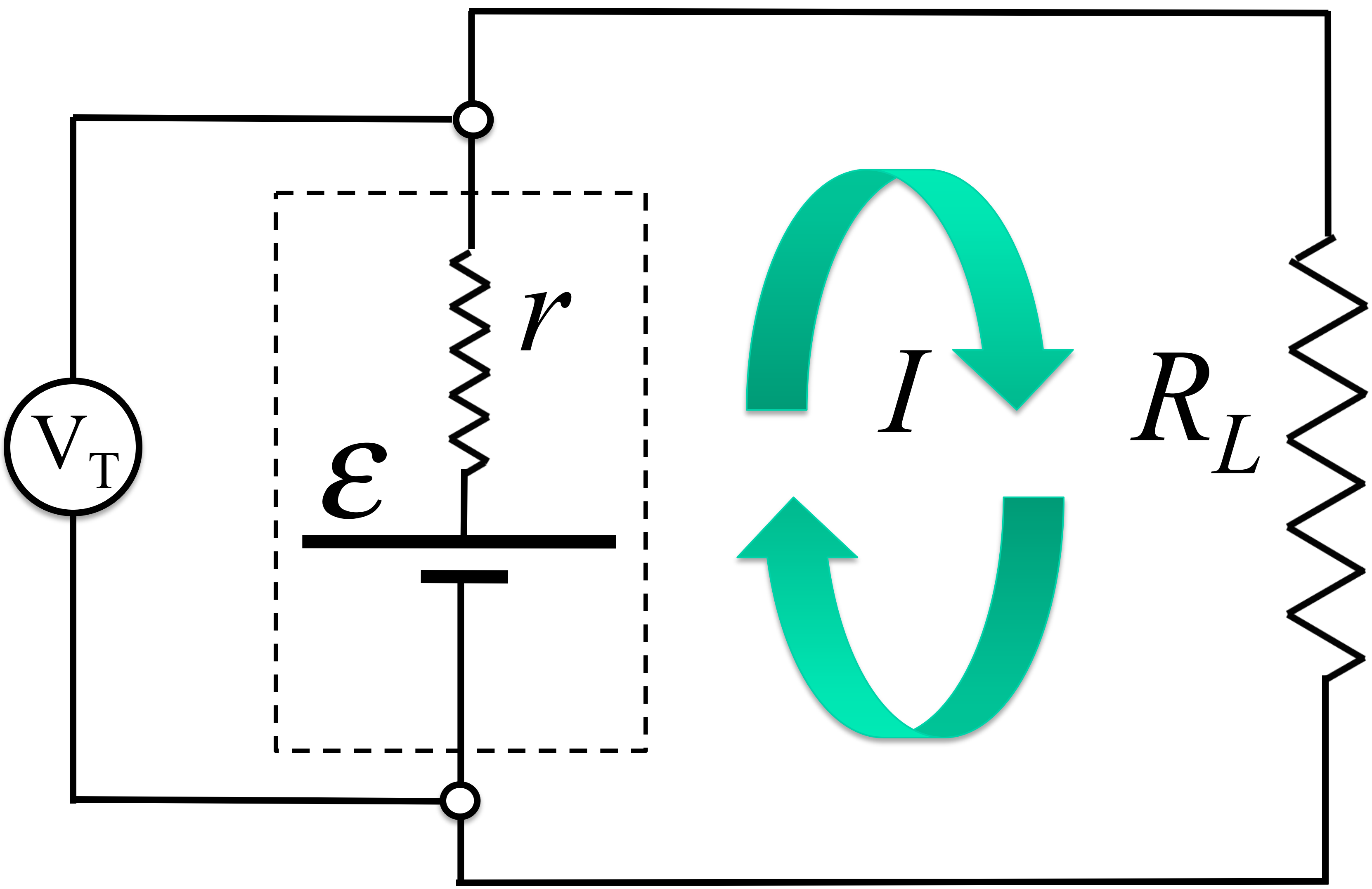
$$\Rightarrow P_{charge}=I\times\Delta V=I\left(-IR\right)=-I^2R$$

$$P_{heat}=I^2R=\left(V/R\right)^2R=V^2/R$$

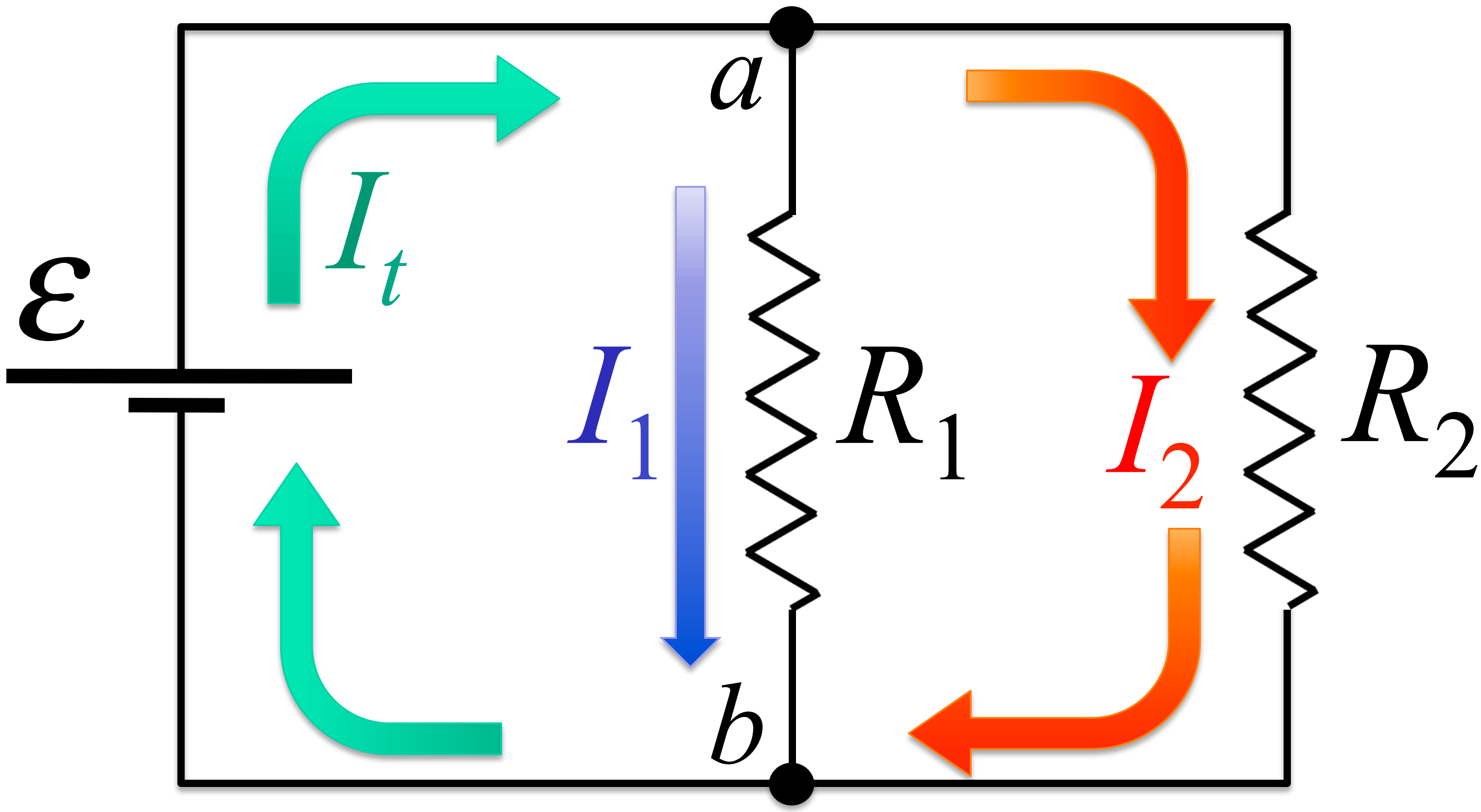
- This process is irreversible.

Example: Battery with internal resistance

R_L = load resistance; r = internal resistance; ε = battery *e.m.f.*



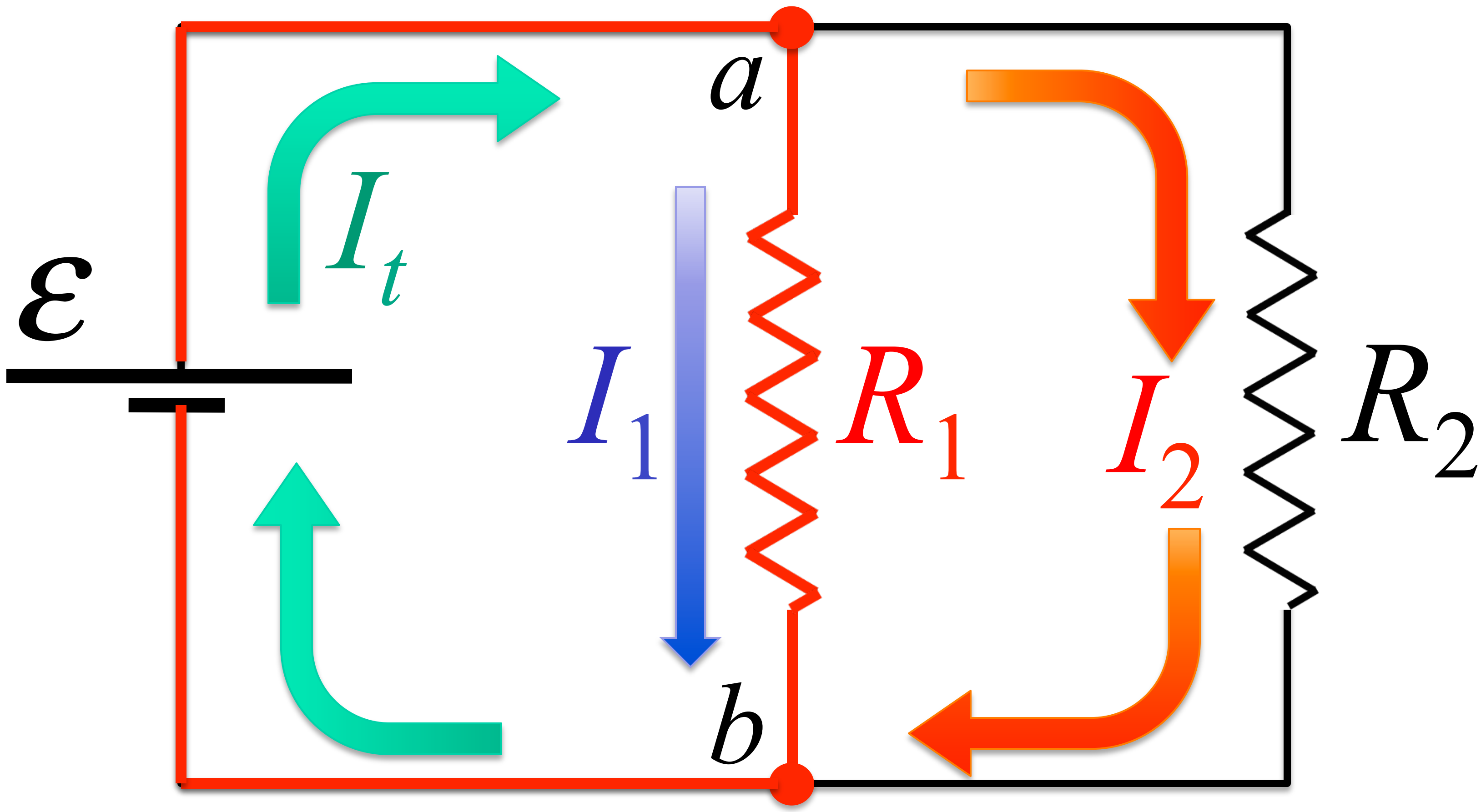
Example: parallel resistances



Kirchoff's first law (node law):

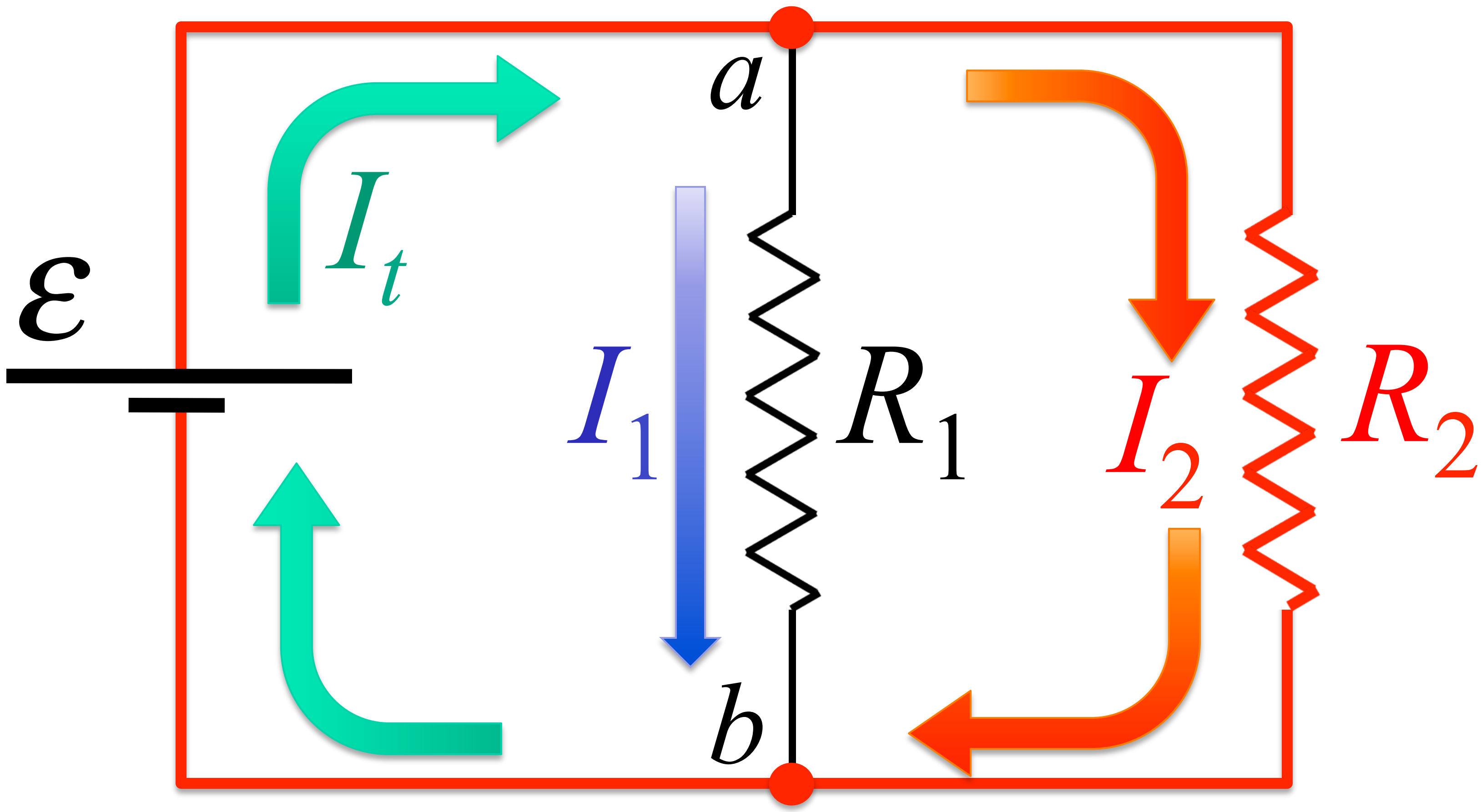
Algebraic sum of currents at any node is zero: $I_t - I_1 - I_2 = 0$

Example: parallel resistances



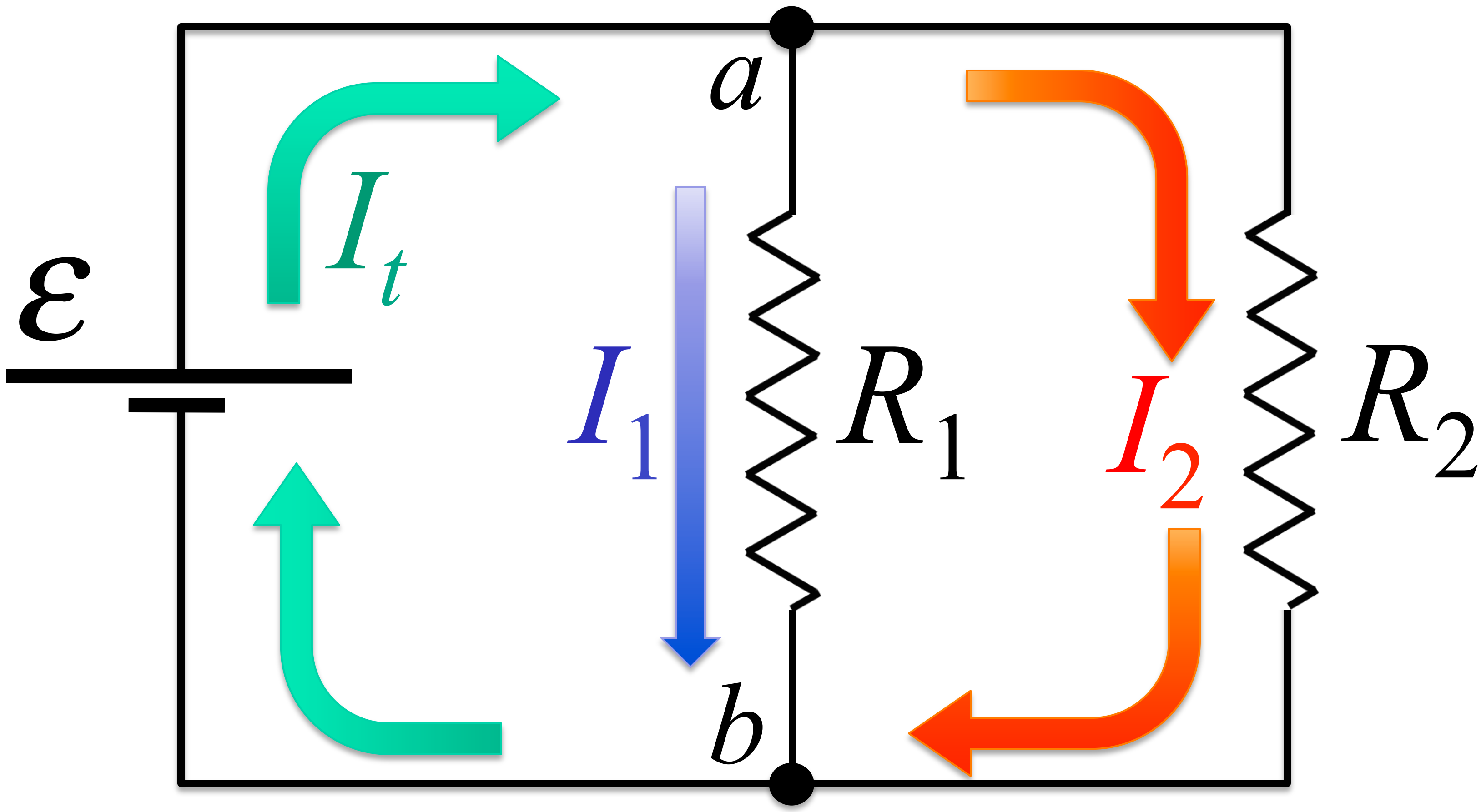
Loop 1

Example: parallel resistances



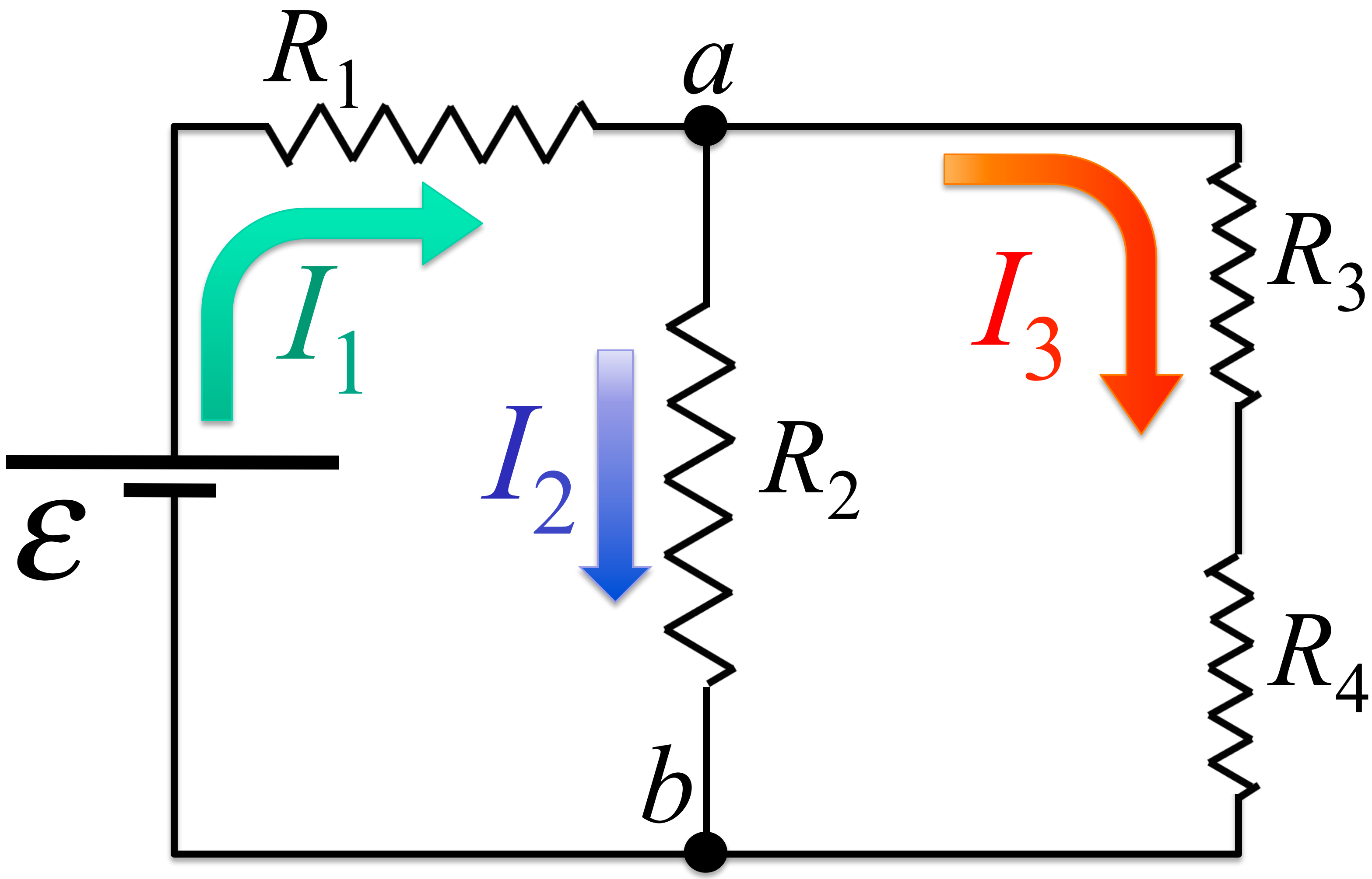
Loop 2

Example: parallel resistances



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}, \text{ in general } \frac{1}{R_{eq}} = \sum_i \frac{1}{R_i}$$

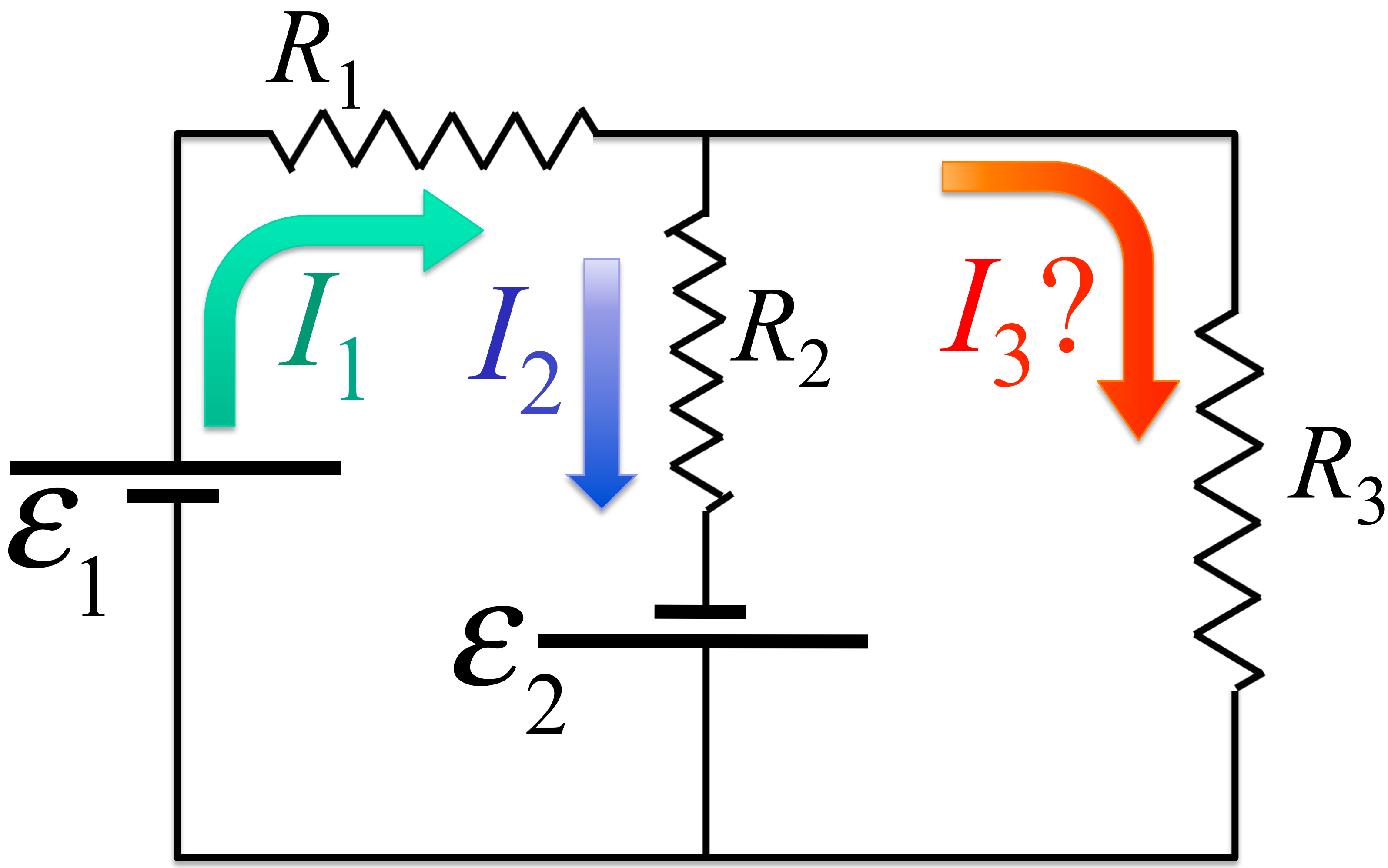
Example: parallel/series resistors



Deduce: (a) current through R_2; (b) power dissipation in R_4; and voltage across R_3.

$$\varepsilon = 10\ \text{V};\ R_1 = 5\ \Omega;\ R_2 = 16\ \Omega;\ R_3 = 7\ \Omega;\ R_4 = 12\ \Omega$$

Example: multiple batteries



Find current I_3

$\varepsilon_1 = 10$ V; $\varepsilon_2 = 20$ V; $R_1 = 15\ \Omega$; $R_2 = 6\ \Omega$; $R_3 = 7\ \Omega$.

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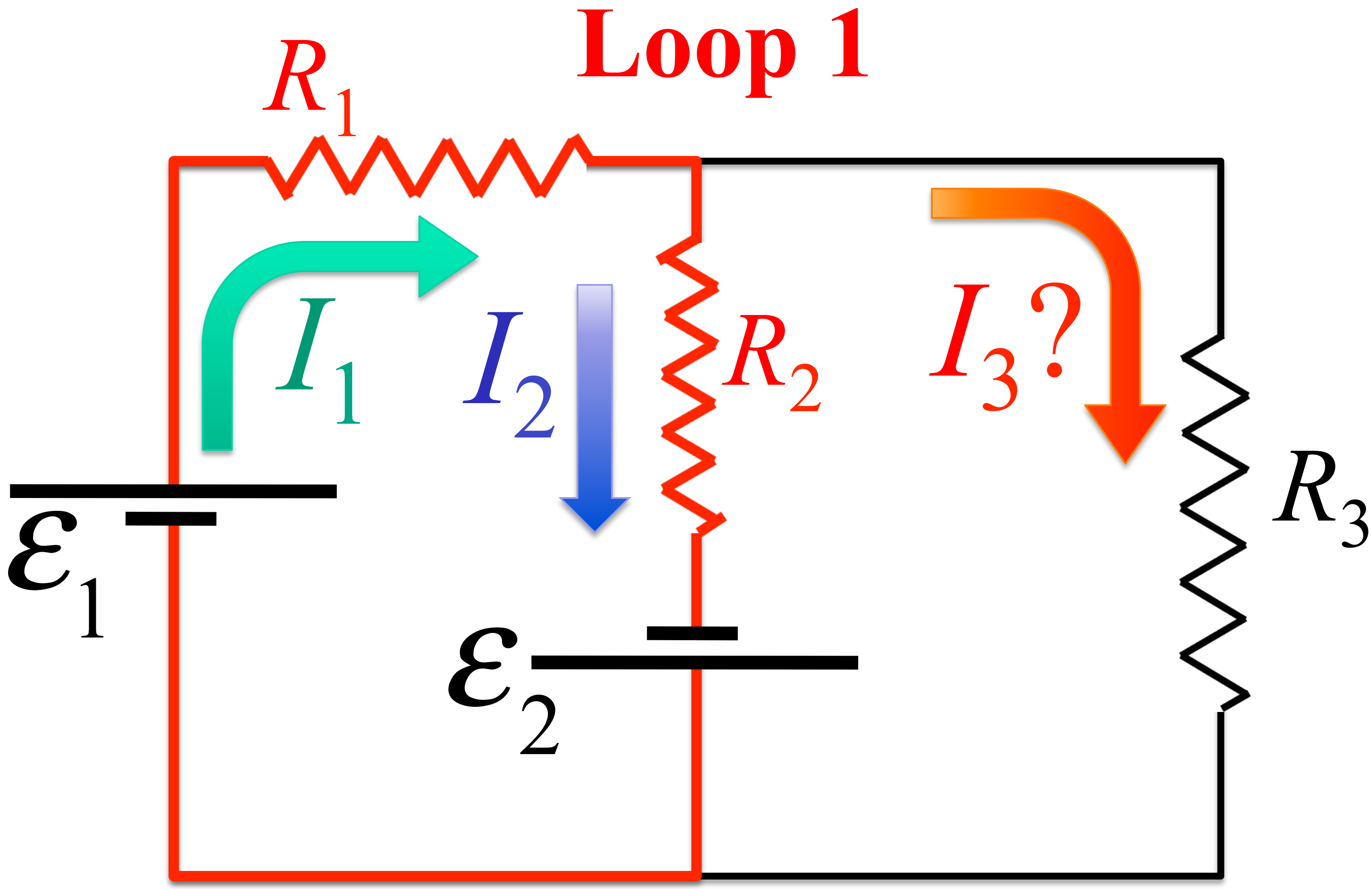

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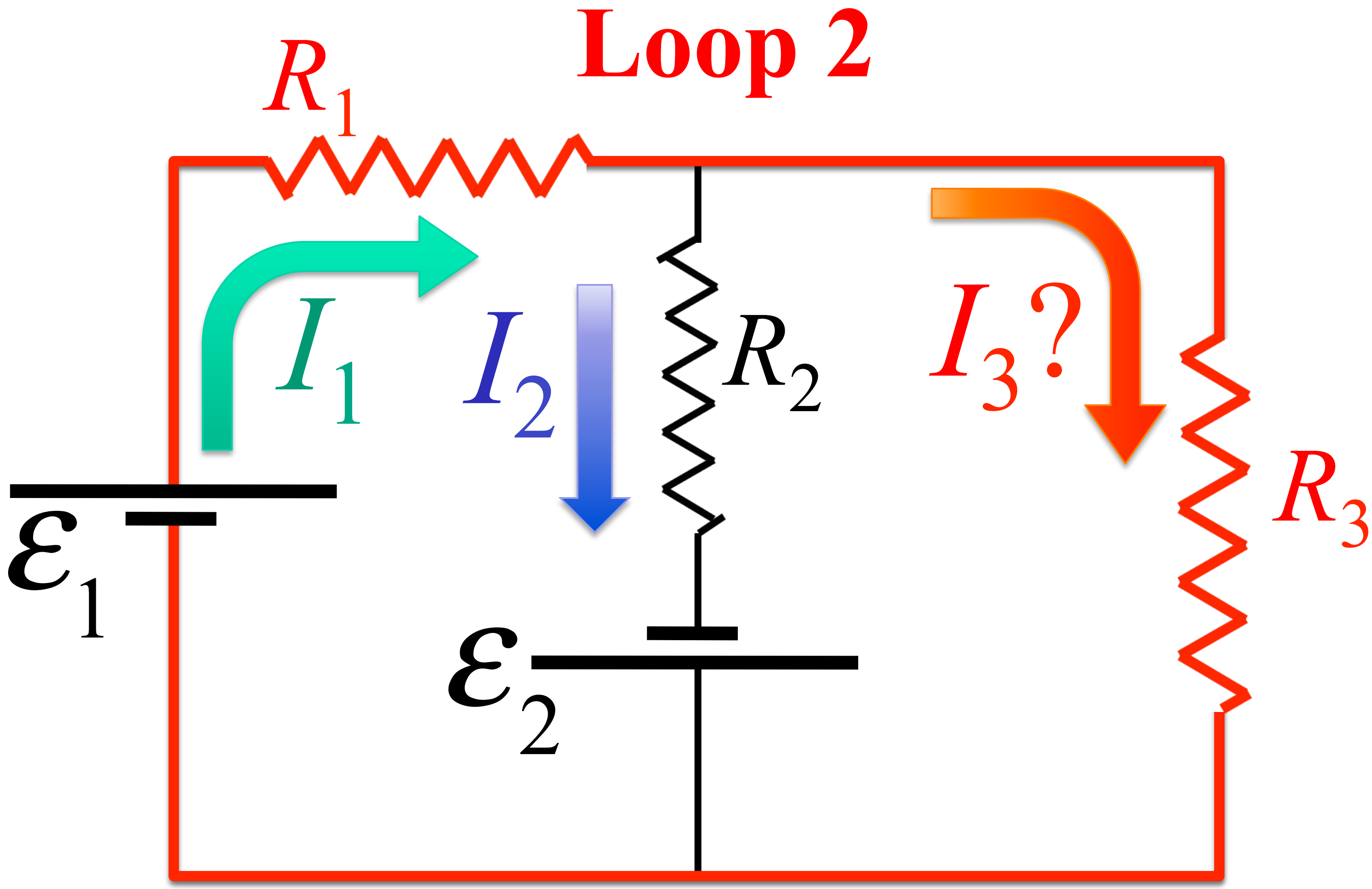

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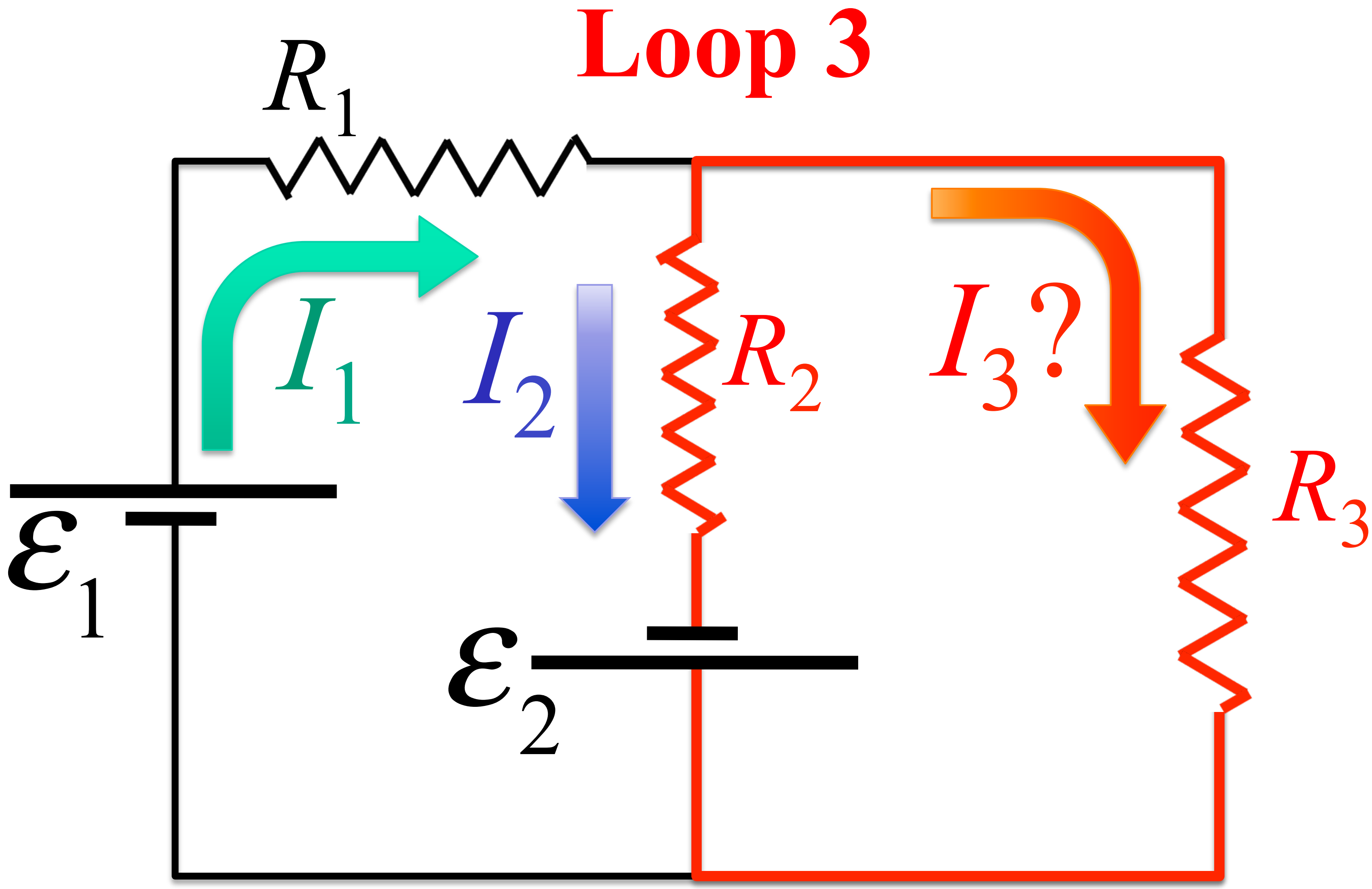

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