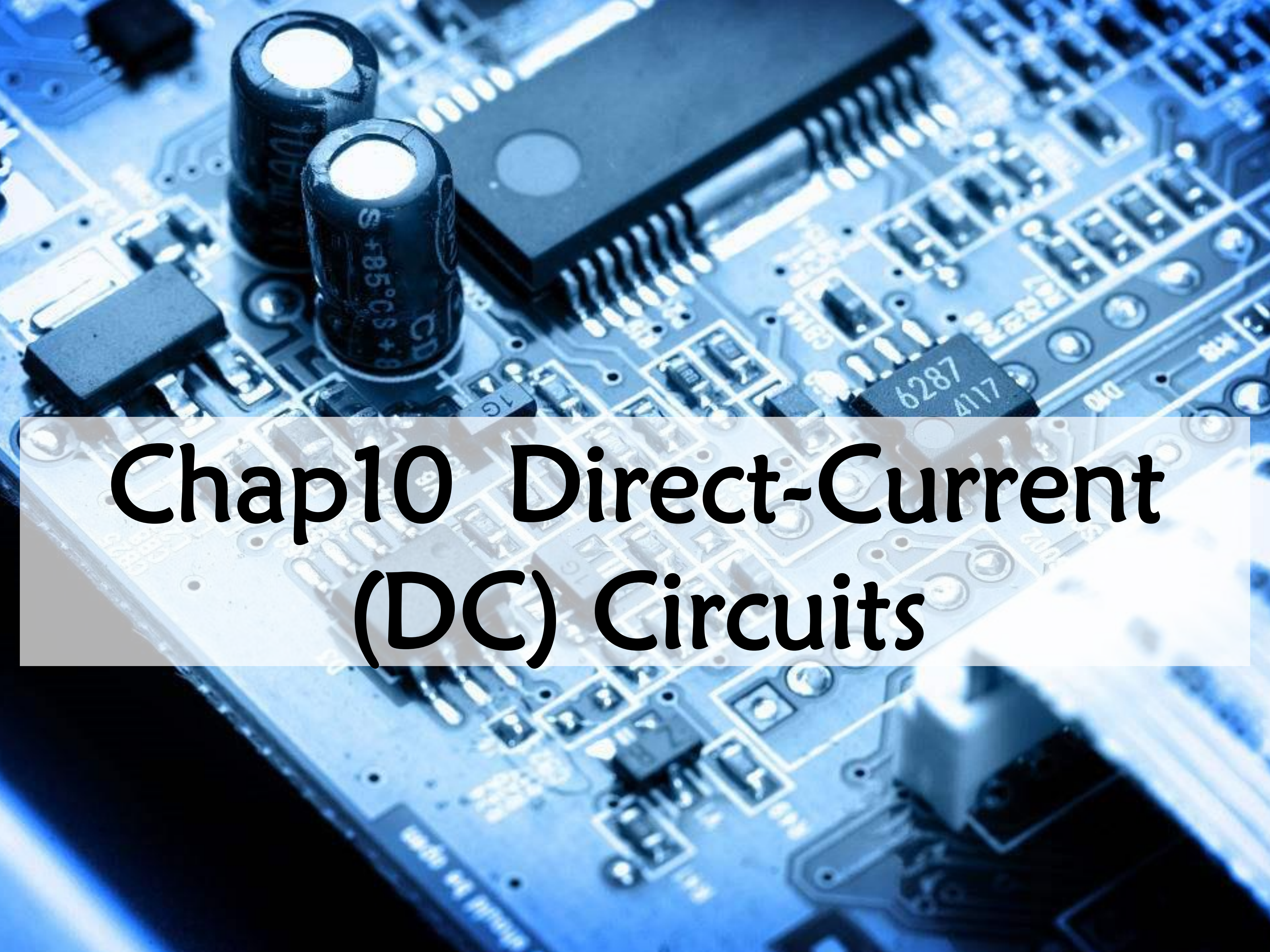
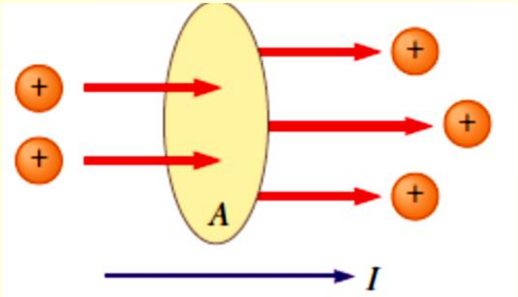


Chap10 Direct-Current (DC) Circuits

Electric Current ••• *scalar*

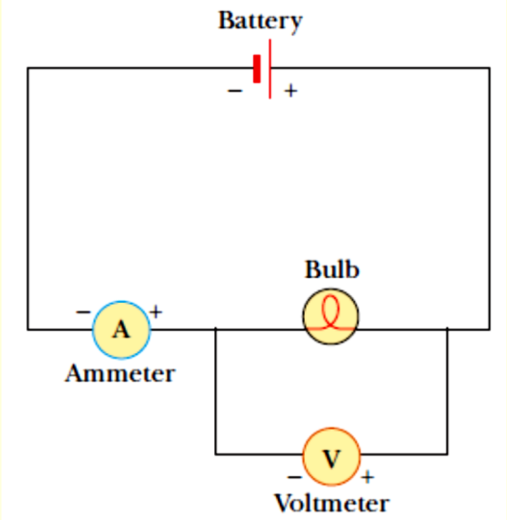
- the rate at which charge flows through a surface.



- Magnitude: $I = \dfrac{\Delta Q}{\Delta t}$
- SI unit: A [1 A = 1 C/s]
- Direction: the direction in which *positive charges* flow.

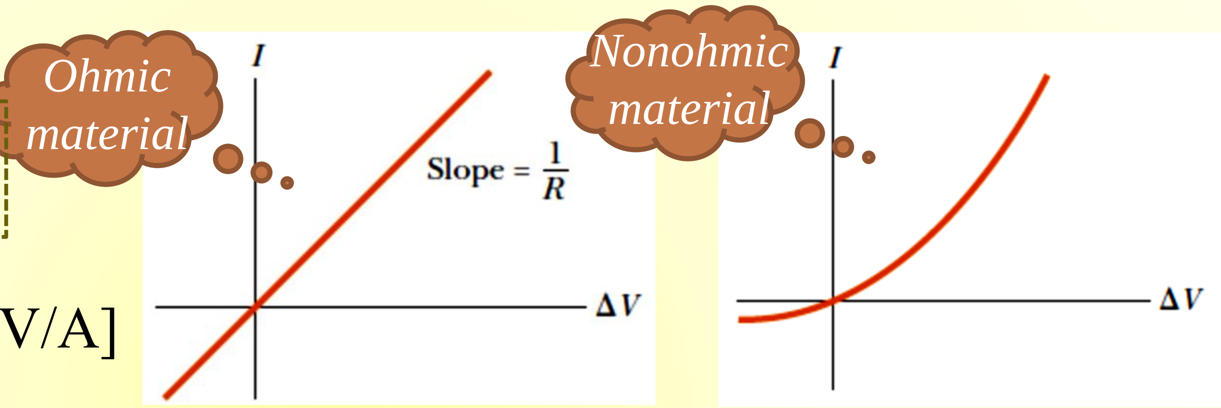
Voltage ••• *scalar*

- The difference in electric potential between two points, which creates a current in a closed circuit.
- SI unit: V



Resistance ∘∘∘ *scalar*

- The resistance of an object depends on the material it is made of and its shape.
- Definition: $R \equiv \dfrac{\Delta V}{I}$



- SI unit: Ω [1 Ω = 1 V/A]
- Ohm's law: $\Delta V = IR$
- Resistance of an ohmic conductor:

$$R = \rho \frac{l}{A}$$

  ρ: the resistivity of the material
  l: the conductor's length
  A: the conductor's cross-sectional area

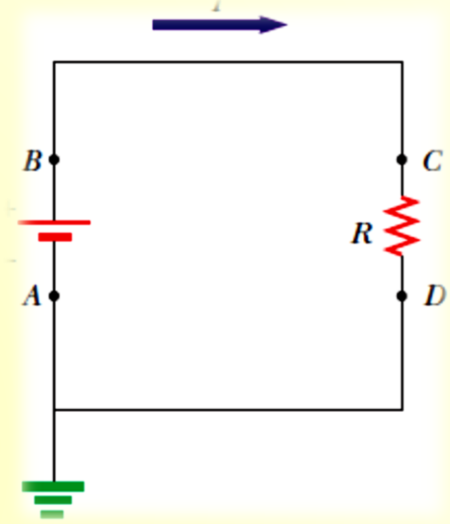
- Resistivity of a material depends on its molecular & atomic structure and on temperature.

Electric Energy & Power

- **Electric power:** *scalar*
  - Magnitude: $P = I\Delta V$
  - SI unit: W [1 W = 1V·A]
  - As for ohmic resistors:

$$P = I^2R = \frac{\Delta V^2}{R}$$

  - The light intensity of a light bulb is related to its power.



- **Electric energy:** *scalar*
  - Magnitude: $E = Pt$
  - SI unit: J [1 J = 1 W·s], Common unit: kWh [1kWh = 3.6×10^6 J]

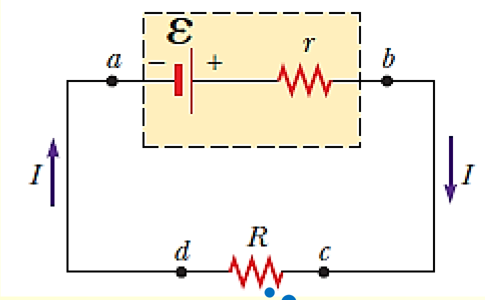
Sources of EMF

➢ EMF:

- EMF (ε) stands for "*Electromotive Force*", but it is not a force, it is the work done (increase of electric potential energy) per unit charge.
- SI unit: volt (V)

➢ Internal Resistance:

- Internal resistance (r) is the resistance of a battery or a generator.
- Internal resistance subtracts voltage from the EMF, and the residual voltage is called the terminal voltage.
- The terminal voltage of the battery: $\Delta V = \varepsilon - Ir$



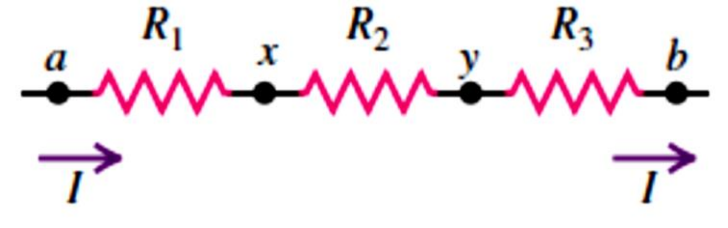
load resistance

$$\left.\begin{aligned}\varepsilon &= \Delta V + Ir \\ \Delta V &= IR\end{aligned}\right\} \Rightarrow \varepsilon = IR + Ir \Rightarrow \varepsilon I = I^2 R + I^2 r$$

Power output of emf source

Combinations of Resistors

In series:



- Resistance adds:

$$R_s = R_1 + R_2 + R_3 + \cdots$$

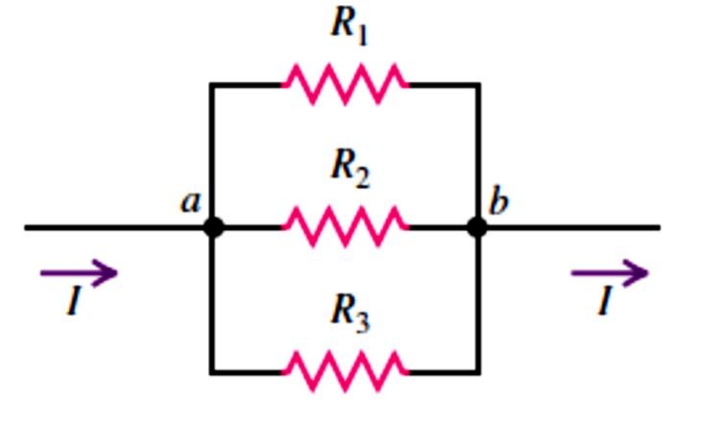
- Current remains the same:

$$I_s = I_1 = I_2 = I_3 = \cdots$$

- Voltage adds:

$$V_s = V_1 + V_2 + V_3 + \cdots$$

In parallel:



- The reciprocal of resistance adds:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

- Current adds:

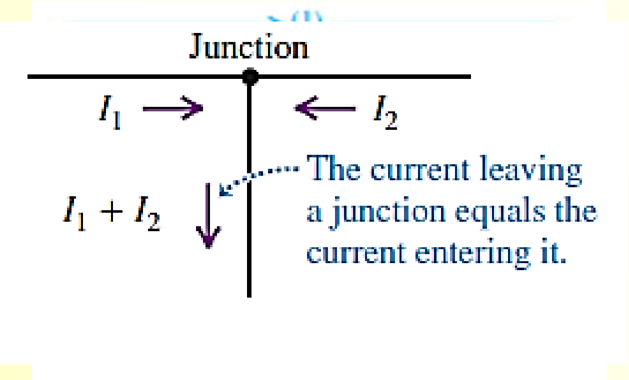
$$I_p = I_1 + I_2 + I_3 + \cdots$$

- Voltage remains the same:

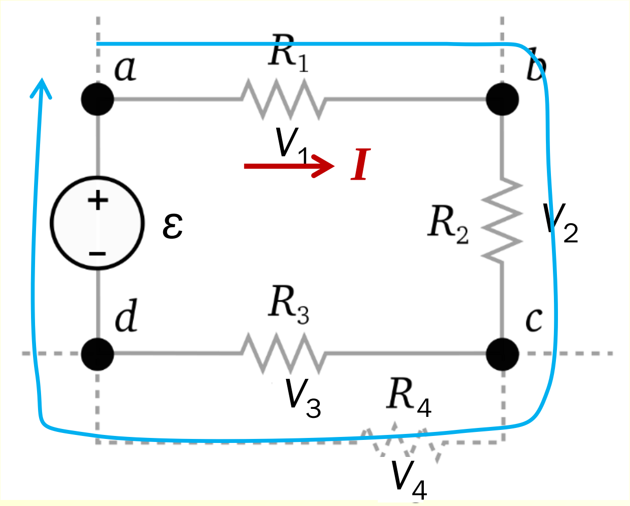
$$V_p = V_1 = V_2 = V_3 = \cdots$$

Complex Circuits & Kirchhoff's Rules

- **Junction rule:** *Conservation of charge*
  - The sum of the currents entering any junction must equal the sum of the currents leaving that junction.

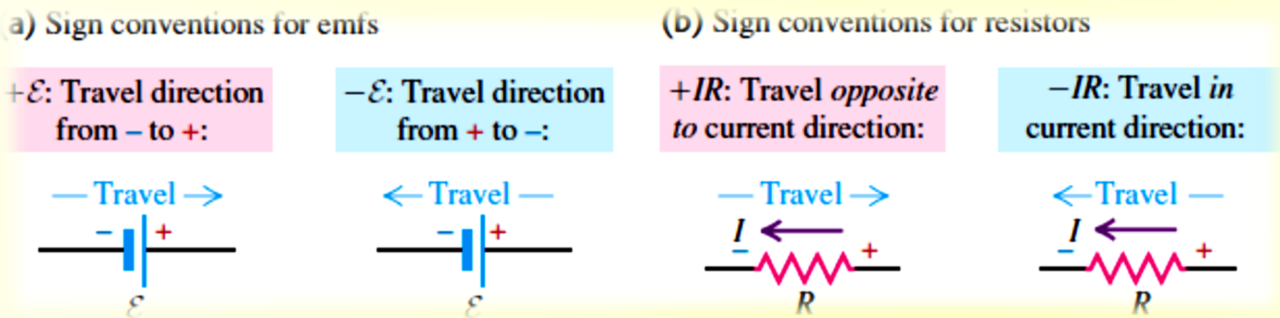


- **Loop rule:** *Conservation of energy*
  - The sum of the potential differences across all the elements around any closed circuit loop must be zero.
  - Loop *abcda*: $-V_1-V_2-V_3+\varepsilon=0$



- Sign Conventions for the Loop Rule:

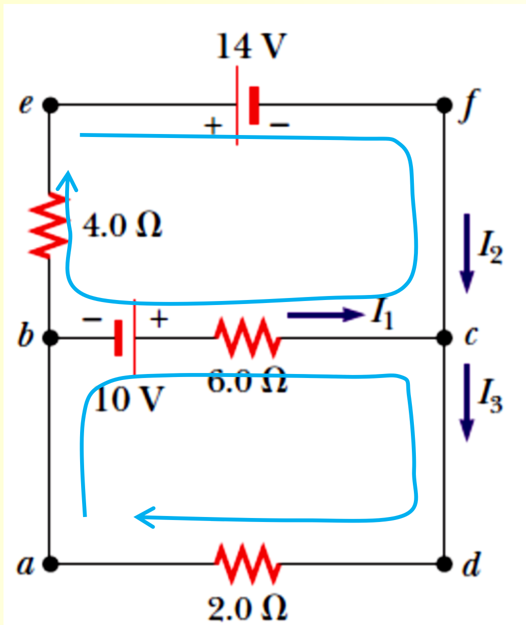
Potential drops "-"
Potential increases "+"



In each part of the figure "Travel" is the direction that we imagine going around the loop, which is not necessarily the direction of the current.

【Exercise】

Find I_1, I_2, and I_3 in the right Figure.



Junction *c*: $I_3 = I_1 + I_2$

Loop *abcda*:

$$10\text{V} - (6.0\Omega)I_1 - (2.0\Omega)I_3 = 0$$

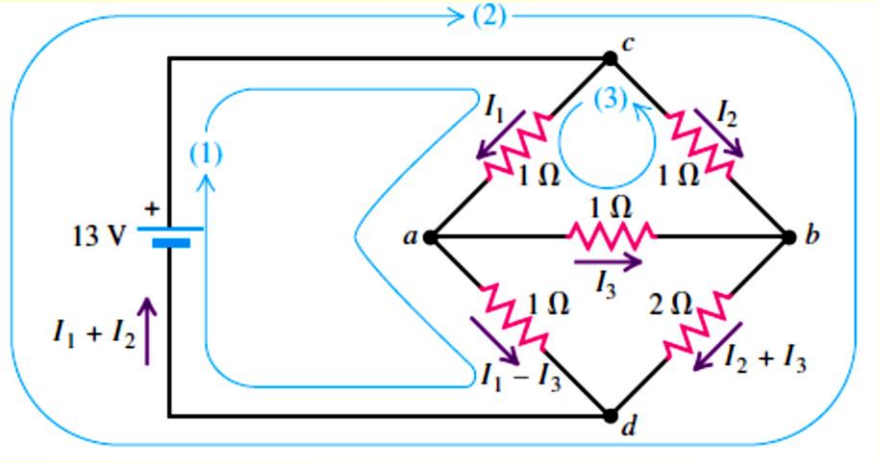
Loop *efcbe*:

$$-14\text{V} + (6.0\Omega)I_1 - 10\text{V} - (4.0\Omega)I_2 = 0$$

$$\Rightarrow \begin{cases} I_1 = 2.0\text{A} \\ I_2 = -3.0\text{A} \\ I_3 = -1.0\text{A} \end{cases}$$

【Exercise】 A complex network

The right figure shows a "bridge" circuit. Find the currents I_1, I_2, and I_3 and the equivalent resistance of the network of five resistors.



Loop (1):

$$-(1\Omega)I_1-(1\Omega)(I_1-I_3)+13\text{V}=0$$

Loop (2):

$$-(1\Omega)I_2-(2\Omega)(I_2+I_3)+13\text{V}=0$$

Loop (3):

$$-(1\Omega)I_1-(1\Omega)I_3+(1\Omega)I_2=0$$

$$\Rightarrow \begin{cases} I_1=6\text{A} \\ I_2=5\text{A} \\ I_3=-1\text{ A} \end{cases}$$

Equivalent resistance of the network: $R_{eq}=\dfrac{13\text{V}}{I_1+I_2}=\dfrac{13\text{V}}{11\text{A}}\approx 1.2\Omega$