Solving Circuit Problems

PHY 114-01

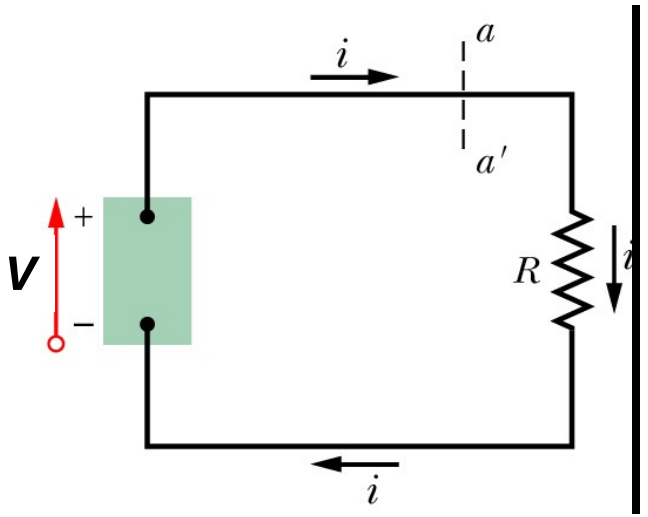
Fall 2026

Agenda

- Last time:
  - Electric Current
  - Batteries
  - Resistors
  - Ohm’s Law

- This time:
  - Electric power
  - Kirchoff’s laws

Work, Power and Electric Current



- **Imagine some charge *dq* moving through a resistor**
  - **change of potential across the resistor = –V**
  - **the change in potential energy of *dq* is**

$$dU = -Vdq$$

- **since the potential energy has changed (it has decreased), work must have been done by the battery**

$$dW = -dU = Vdq$$

Electric Power

- **The rate at which electric energy is transformed is given by the electric power:**

$$P = \frac{dW}{dt} \qquad dW = Vdq$$

$$\Rightarrow P = V\frac{dq}{dt} = VI \qquad \text{since} \qquad \frac{dq}{dt} = I$$

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

Unit of power is the Watt (W):

1 Watt = 1 J/s

Electric Power

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

- **Electric energy can be converted into many forms of energy**
  - ***thermal energy*** **(heaters, ACs)**
  - ***mechanical energy*** **(motors, speakers)**
  - ***light*** **(light bulbs, lasers)**

ConceptCheck Electric power

Two light bulbs operate at 120 V. One has a power rating of 25 W while the other has a power rating of 100 W.

Which one has the greater resistance?

A. the 25 W bulb

B. the 100 W bulb

C. both have the same current

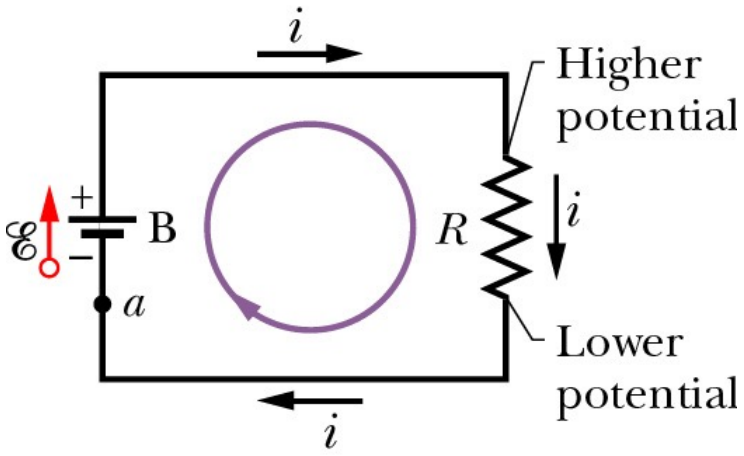
D. this has nothing to do with resistance

E. need more information

Since V is same, use $P=V^2/R$, or $R = V^2/P$.
A smaller P means a greater R.

Simple Circuits

- A battery supplies a constant voltage (EMF)
- The EMF pushes current through the circuit
- Current flows through the resistor
  - As a result, voltage “drops” across the resistor



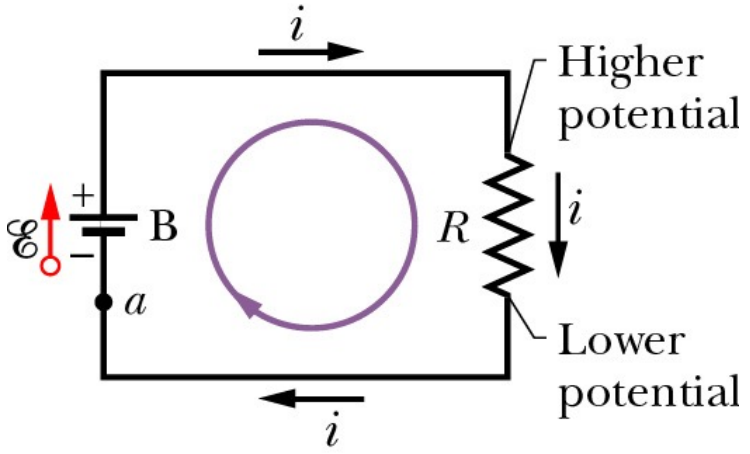
Two important rules govern circuit behavior:

- Conservation of energy → Kirchoff’s loop rule
- Continuity of charge → Kirchoff’s junction rule

Loop rule

- Imagine walking around a loop of current flow in your circuit
- Every time you pass a device, add its potential drop
  - (careful with sign!)
- If you start and end in the same place, the total voltage change should be zero
  - (conservation of energy)

Loop rule



- Start at point (a)
- As you pass the battery, add $\Delta V = \mathcal{E}$
- No voltage drop in wires (equipotential)
- As you go over the resistor, add $\Delta V = -iR$
  - (moving from high to low potential when we follow current direction)
- End up back at (a), so total voltage change is zero

$$\mathcal{E} - iR = 0$$

$$i = \mathcal{E}/R$$ Solve for current!

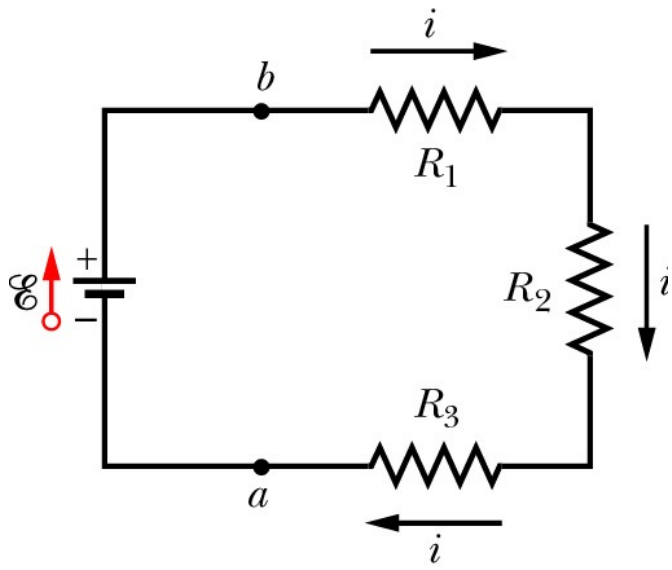
Loop rule: try it!

What is the current in this circuit?

Write your answer in terms of R1, R2, R3, and EMF.

$$\mathcal{E} - iR_1 - iR_2 - iR_3 = 0$$

$$i = \frac{\mathcal{E}}{R_1 + R_2 + R_3}$$



Rules for potential in circuits

Resistance Rule

moving through a resistor in the direction of the current flow the change in potential is $V = -iR$

EMF Rule

moving through an ideal emf source in the direction of the (external) current flow then the change in potential is $V = +\varepsilon$

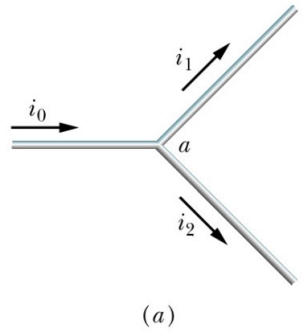
* These rules are not arbitrary! They are backed up by physical principles. If you know the principles, it will help you use the rules correctly.

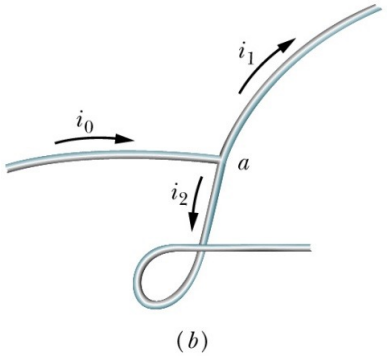
Junction Rule

- When a circuit splits into two paths, charge must be conserved between all the paths

- The sum of all currents entering a junction must be equal to the sum of all currents leaving the junction.

$$i_{in} = i_{out}$$





$$i_0 = i_1 + i_2$$

Simplification: resistors in series

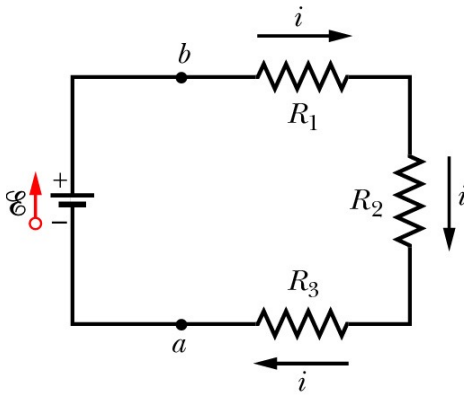
- Goal: create an equivalent resistor that describes the circuit behavior
  - All the resistors share the same current
  - What equivalent resistance is needed to get that current?

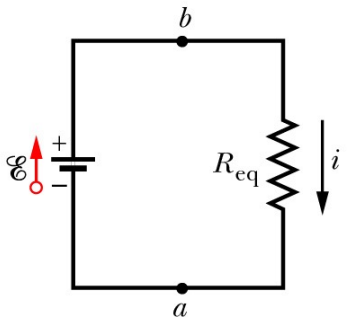
$$i_1 = i_2 = i_3 = i$$

$$\mathcal{E} - iR_1 - iR_2 - iR_3 = 0$$

$$\mathcal{E} = i(R_1 + R_2 + R_3) = iR_{\text{eq}}$$

Resistors in series add directly!

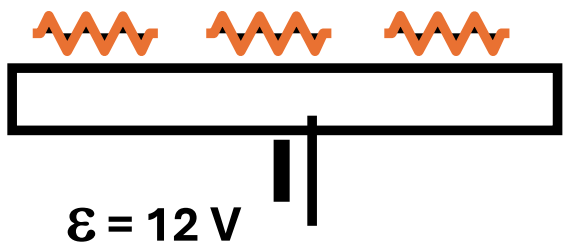




ConceptCheck Resistors in series

Assume that the voltage of the battery is 12 V and that the three resistors are identical. What is the potential difference across each resistor?

A. 12 V
B. 4 V
C. 3 V
D. zero
E. not enough info, need R



Since the resistors in series are all equal, the voltage will drop equally across each of them, ε /3

ConceptCheck Resistors in series

In this circuit, what is the voltage drop across R_2?

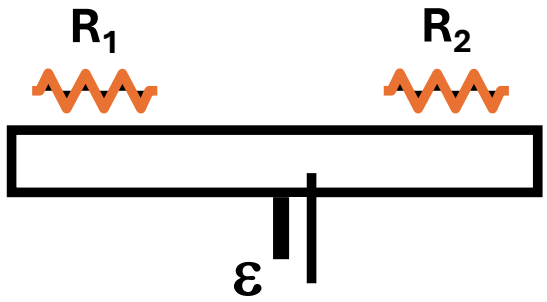
A. ε

B. ε / R_1

C. ε / R_2

D. $\varepsilon R_1/(R_1+R_2)$

E. $\varepsilon R_2/(R_1+R_2)$



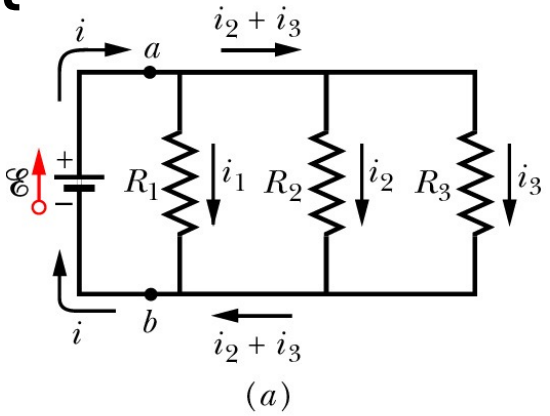
net resistance is R_1+R_2,
current is $i = \varepsilon/(R_1+R_2)$,
so voltage on R_2 is iR_2

*** Daily quiz!**

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Simplification: resistors in parallel

- Goal: create an equivalent resistor that describes the circuit behavior
  - All the resistors share the same voltage
  - What equivalent resistance is needed to get current draw i ?



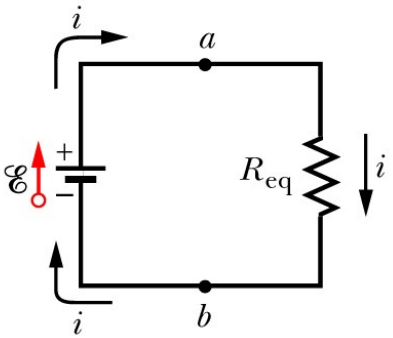
(a)

$$V = i_1R_1 = i_2R_2 = i_3R_3$$

$$i = i_1 + i_2 + i_3$$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \longrightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Parallel resistors add in inverse!



(b)