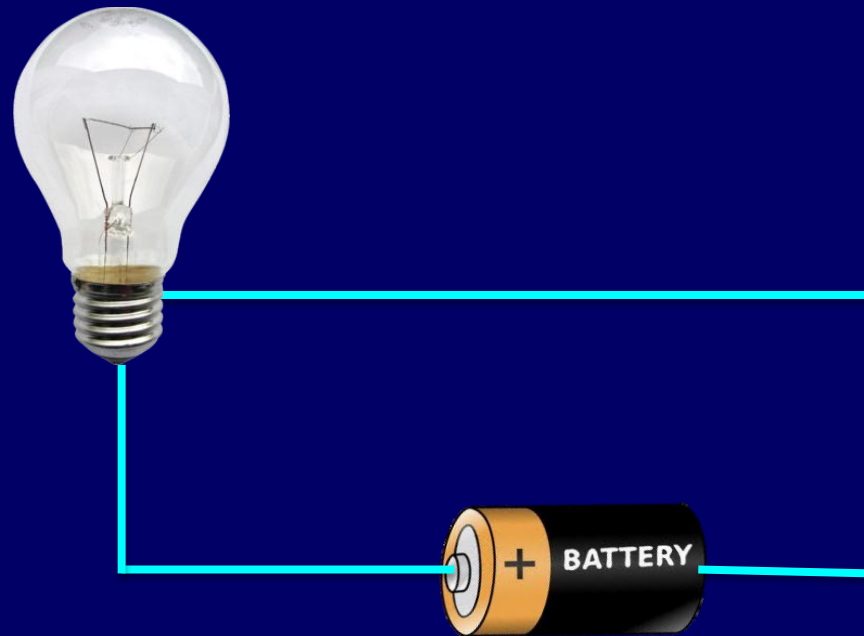


Physics 102: Lecture 05

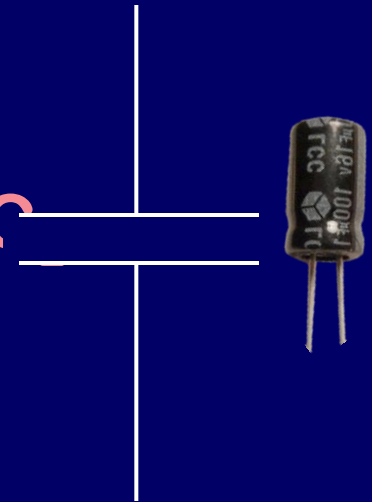
Circuits and Ohm's Law



Summary of Last Time

- **Capacitors**

- Physical $C = \kappa \epsilon_0 A/d$ $C=Q/V$
- Series $1/C_{eq} = 1/C_1 + 1/C_2$
- Parallel $C_{eq} = C_1 + C_2$
- Energy $U = 1/2 QV$



Summary of Today

- **Resistors**

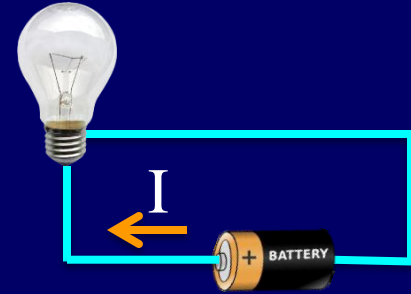
- Physical $R = \rho L/A$ $V=IR$
- Series $R_{eq} = R_1 + R_2$
- Parallel $1/R_{eq} = 1/R_1 + 1/R_2$
- Power $P = IV$



Electric Terminology

- **Current: Moving Charges**

- Symbol: **I**
- Unit: **Amp** \equiv Coulomb/second
- Count number of charges which pass point/sec
- Direction of current is direction that + charge flows



- **Power: Energy/Time**

- Symbol: **P**
- Unit: **Watt** \equiv Joule/second =
Volt Coulomb/sec
- $P = VI$



60 W = 60 J/s

Physical Resistor



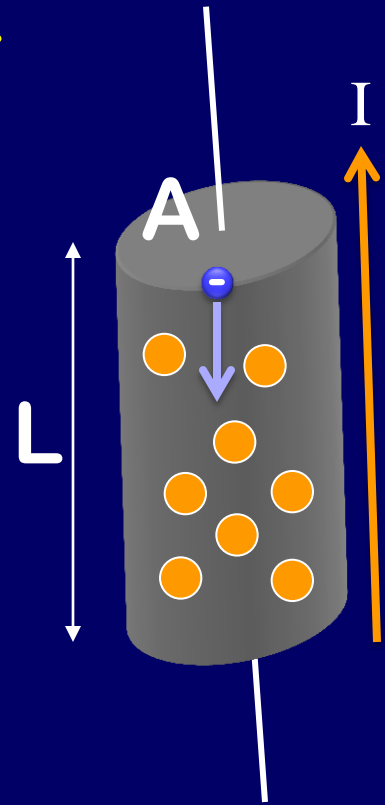
- Resistance: Traveling through a resistor, electrons bump into things which slows them down.

$$R = \rho L / A$$

- ρ : Resistivity: Density of bumps
- L : Length of resistor
- A : Cross sectional area of resistor

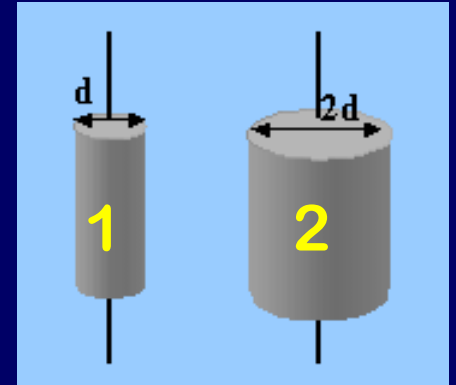
- Ohms Law $I = V/R$

- Cause and effect (sort of like $a=F/m$)
 - potential difference cause current to flow
 - resistance regulate the amount of flow
- Double potential difference \Rightarrow double current
- $I = (VA) / (\rho L)$



CheckPoint 1.1

Two cylindrical resistors are made from the same material. They are of equal length but one has twice the diameter of the other.

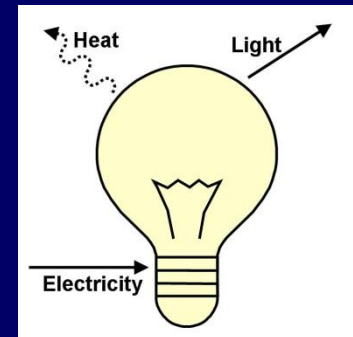
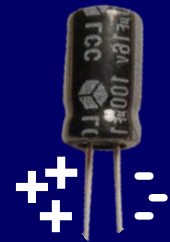


1. $R_1 > R_2$
2. $R_1 = R_2$
3. $R_1 < R_2$

Comparison:

Capacitors vs. Resistors

- Capacitors *store* energy as separated charge: $U=QV/2$
 - Capacitance: ability to store separated charge:
 $C = \kappa \epsilon_0 A/d$
 - Voltage drop determines *charge*: $V=Q/C$
- Resistors *dissipate* energy as power: $P=VI$
 - Resistance: how difficult it is for charges to get through:
 $R = \rho L / A$
 - Voltage drop determines *current*: $V=IR$
- Don't mix capacitor and resistor equations!

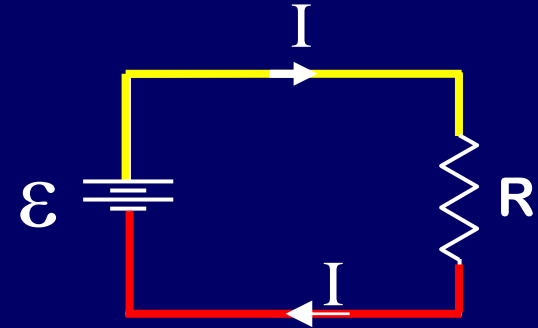
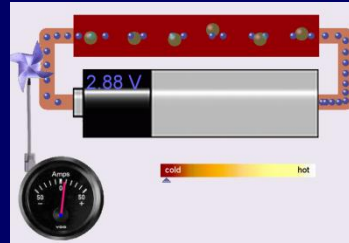


Example



Simple Circuit

- Phet Visualization
- Practice...



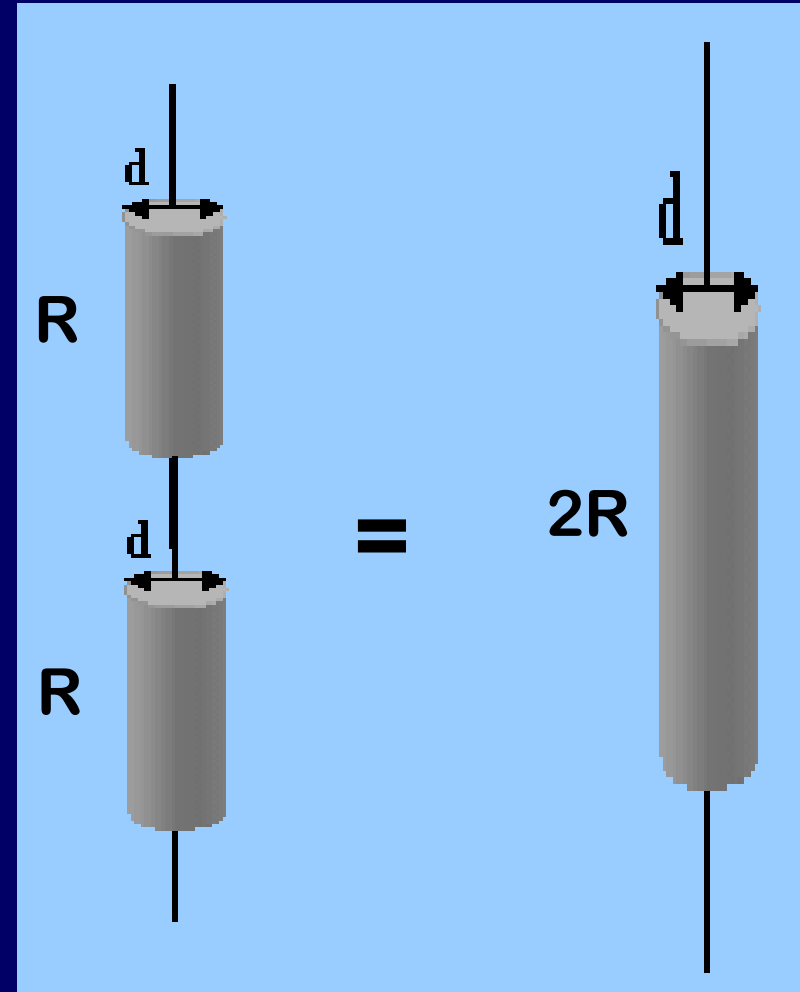
- Calculate I when $\mathcal{E}=24$ Volts and $R = 8 \Omega$
- Ohm's Law: $V = IR$

$$I = V/R = 3 \text{ Amps}$$

Resistors in Series

- One wire:
 - Effectively adding lengths:
 - $R_{eq} = \rho(L_1 + L_2)/A$
 - Since $R \propto L$ add resistance:

$$R_{eq} = R_1 + R_2$$



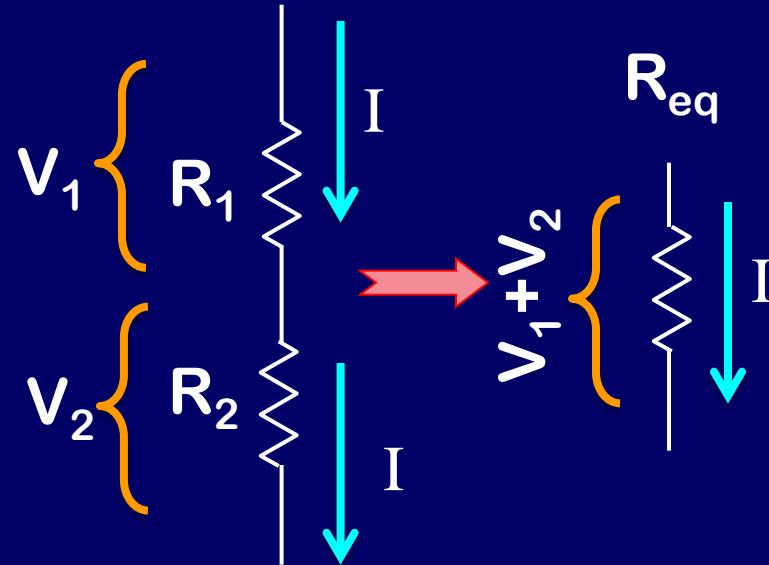
Resistors in Series

- Resistors connected end-to-end:
 - If charge goes through one resistor, it must go through other.

$$I_1 = I_2 = I_{eq}$$

- Both have voltage drops:

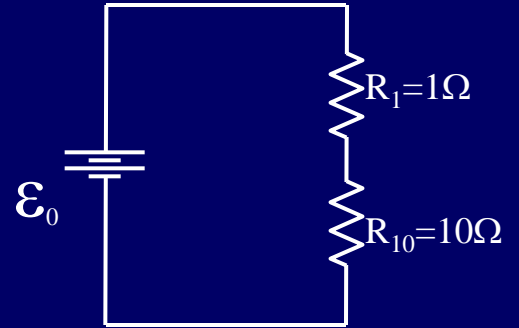
$$V_1 + V_2 = V_{eq}$$



CheckPoint 2.1

Compare I_1 the current through R_1 , with I_{10} the current through R_{10} .

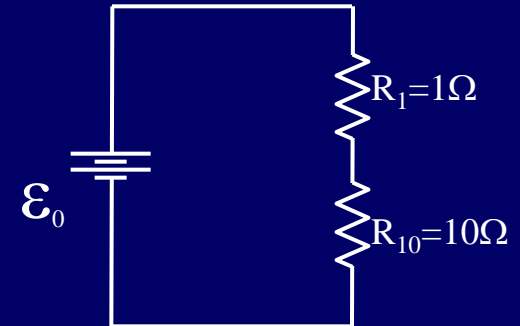
1. $I_1 < I_{10}$
2. $I_1 = I_{10}$
3. $I_1 > I_{10}$





ACT: Series Circuit

Compare V_1 the voltage across R_1 , with V_{10} the voltage across R_{10} .



1. $V_1 > V_{10}$
2. $V_1 = V_{10}$
3. $V_1 < V_{10}$

Example

Practice: Resistors in Series

Calculate the voltage across each resistor if the battery has potential $\varepsilon_0 = 22$ volts.

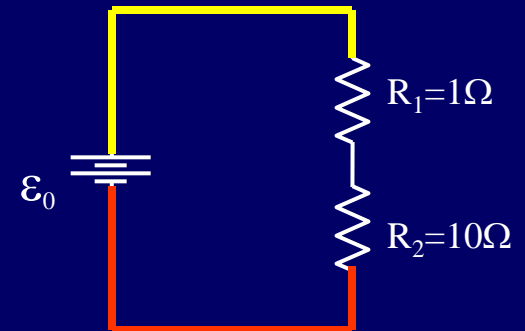
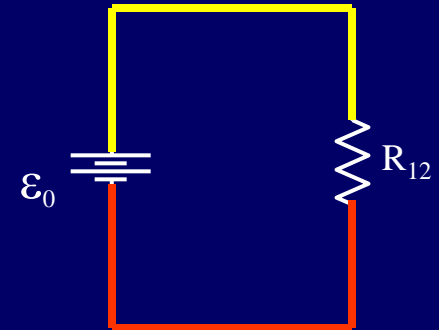
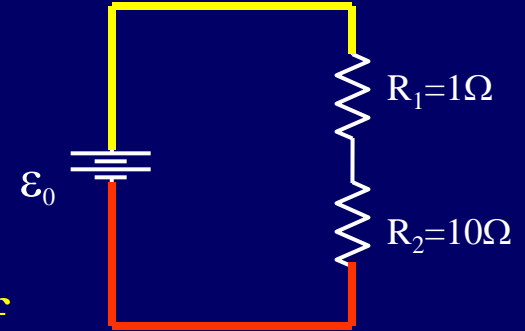
Simplify (R_1 and R_2 in series):

- $R_{12} = R_1 + R_2 = 11 \Omega$
- $V_{12} = V_1 + V_2 = \varepsilon_0 = 22 \text{ Volts}$
- $I_{12} = I_1 = I_2 = V_{12}/R_{12} = 2 \text{ Amps}$

Expand:

- $V_1 = I_1 R_1 = 2 \times 1 = 2 \text{ Volts}$
- $V_2 = I_2 R_2 = 2 \times 10 = 20 \text{ Volts}$

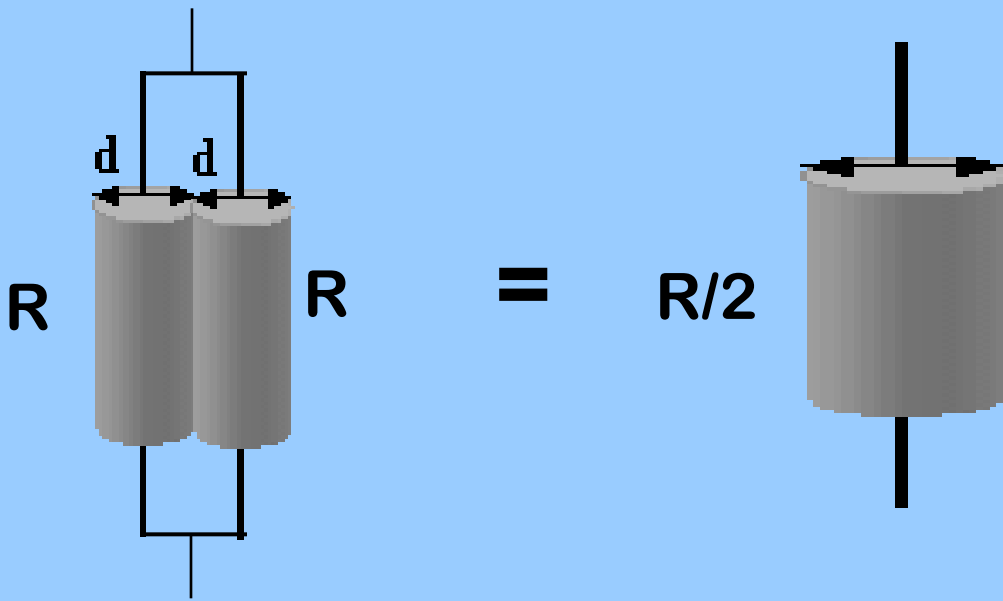
Check: $V_1 + V_2 = V_{12} ?$



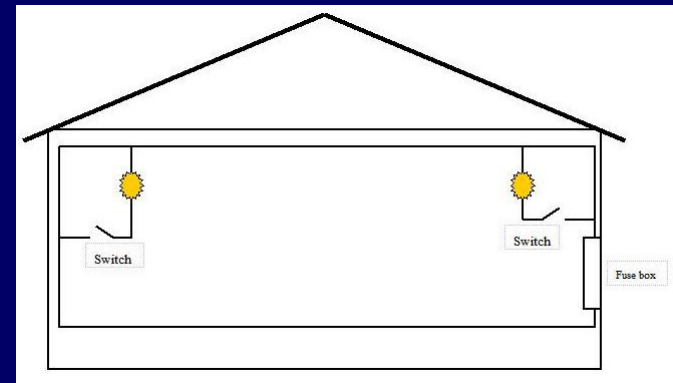
Resistors in Parallel

- Two wires:
 - Effectively adding the Area
 - Since $R \propto 1/A$ add $1/R$:

$$1/R_{eq} = 1/R_1 + 1/R_2$$



Used in your house!



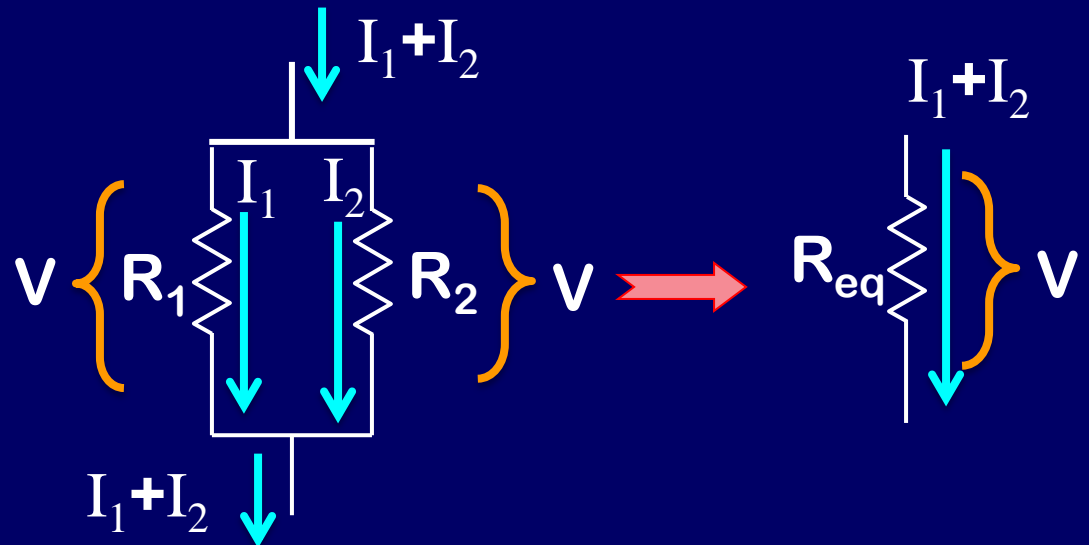
Resistors in Parallel

- Both ends of resistor are connected:
 - Current is split between two wires:

$$I_1 + I_2 = I_{eq}$$

- Voltage is same across each:

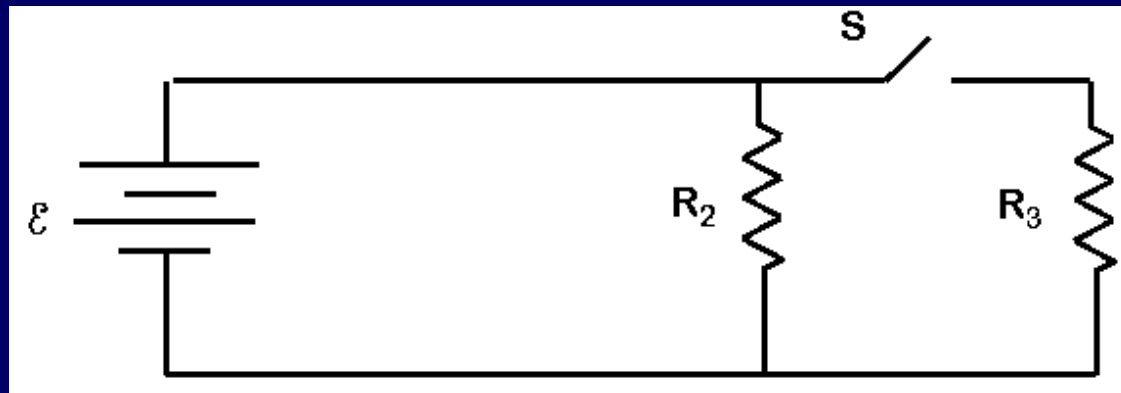
$$V_1 = V_2 = V_{eq}$$



CheckPoint 3.1

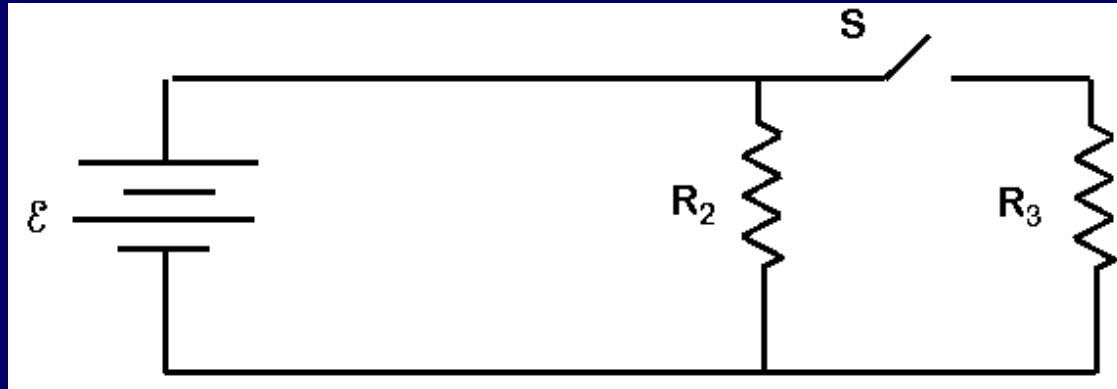
What happens to the current through R_2 when the switch is closed?

- Increases
- Remains Same
- Decreases





ACT: Parallel Circuit



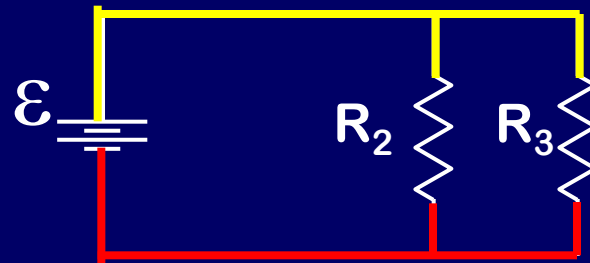
What happens to the current through the battery when the switch is closed?

- (A) Increases
- (B) Remains Same
- (C) Decreases

Example



Practice: Resistors in Parallel



Determine the current through the battery.

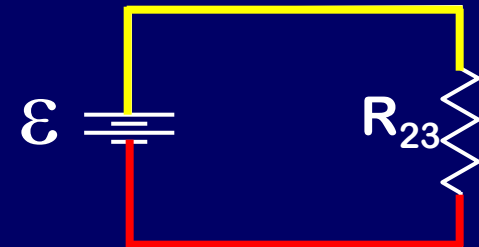
Let $\mathcal{E} = 60$ Volts, $R_2 = 20\ \Omega$ and $R_3 = 30\ \Omega$.

Simplify: R_2 and R_3 are in parallel

$$1/R_{23} = 1/R_2 + 1/R_3 \quad R_{23} = 12\ \Omega$$

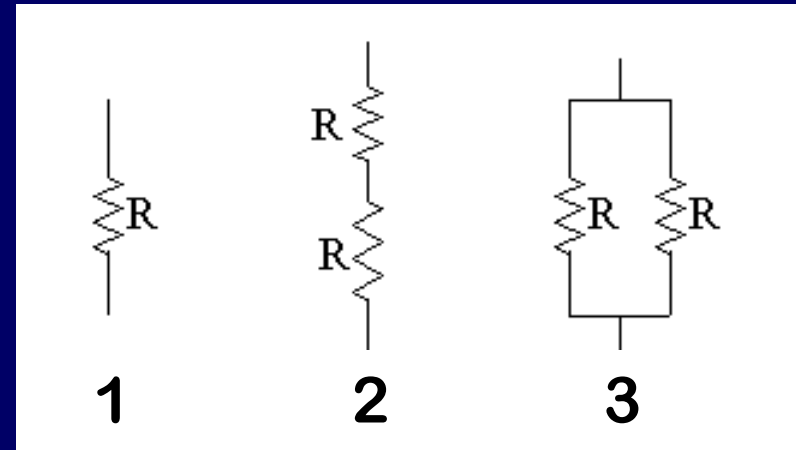
$$V_{23} = V_2 = V_3 = 60\text{ Volts}$$

$$I_{23} = I_2 + I_3 = V_{23} / R_{23} = 5\text{ Amps}$$





ACT / CheckPoint 4.1,4.2



Which configuration has the **smallest** resistance?

- A. 1
- B. 2
- C. 3

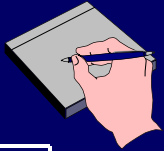
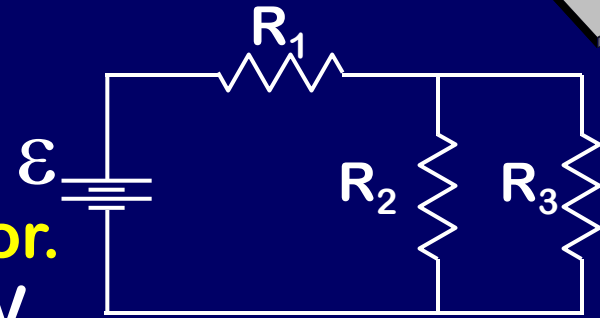
Which configuration has the **largest** resistance?

Example

Try it!

Calculate current through each resistor.

$$R_1 = 10 \, \Omega, R_2 = 20 \, \Omega, R_3 = 30 \, \Omega, \mathcal{E} = 44 \, \text{V}$$

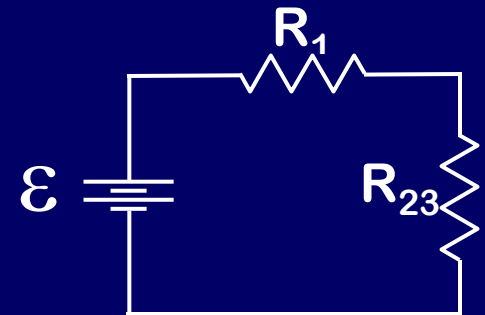


Simplify: R_2 and R_3 are in parallel

$$1/R_{23} = 1/R_2 + 1/R_3 \quad : R_{23} = 12 \, \Omega$$

$$V_{23} = V_2 = V_3$$

$$I_{23} = I_2 + I_3$$

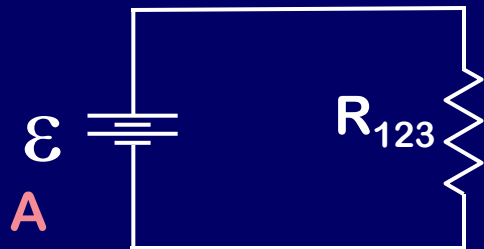


Simplify: R_1 and R_{23} are in series

$$R_{123} = R_1 + R_{23} \quad : R_{123} = 22 \, \Omega$$

$$V_{123} = V_1 + V_{23} = \mathcal{E}$$

$$I_{123} = I_1 = I_{23} = I_{\text{battery}} \quad : I_{123} = 44 \, \text{V} / 22 \, \Omega = 2 \, \text{A}$$



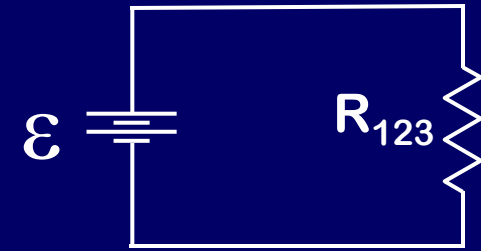
Power delivered by battery? $P = IV = 2 \times 44 = 88 \text{ W}$

Example

Try it! (cont.)

Calculate current through each resistor.

$$R_1 = 10 \, \Omega, R_2 = 20 \, \Omega, R_3 = 30 \, \Omega, \mathcal{E} = 44 \, \text{V}$$



Expand: R_1 and R_{23} are in series

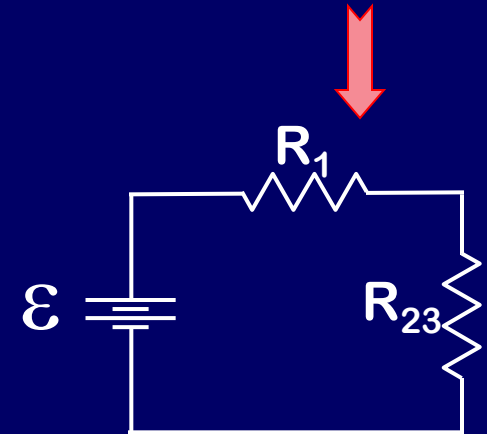
$$R_{123} = R_1 + R_{23}$$

$$: I_{23} = 2 \, \text{A}$$

$$V_{123} = V_1 + V_{23} = \mathcal{E}$$

$$: V_{23} = I_{23} R_{23} = 24 \, \text{V}$$

$$I_{123} = I_1 = I_{23} = I_{\text{battery}}$$



Expand: R_2 and R_3 are in parallel

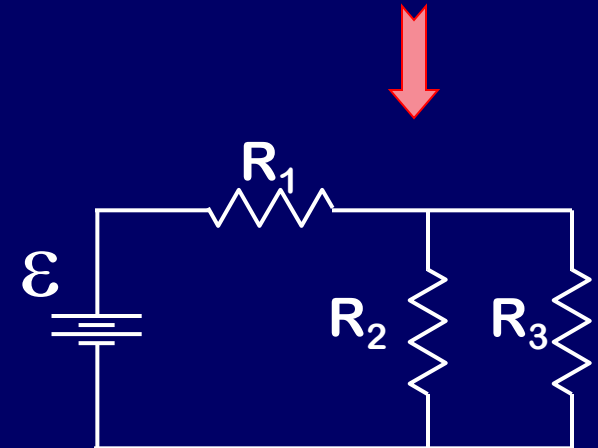
$$1/R_{23} = 1/R_2 + 1/R_3$$

$$V_{23} = V_2 = V_3$$

$$I_{23} = I_2 + I_3$$

$$I_2 = V_2/R_2 = 24/20 = 1.2 \, \text{A}$$

$$I_3 = V_3/R_3 = 24/30 = 0.8 \, \text{A}$$

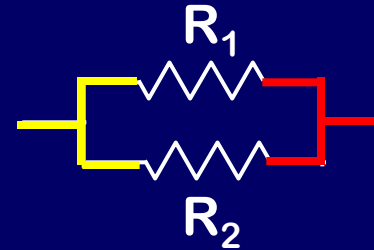


Summary

Series



Parallel



Wiring

Each resistor on the same wire.

Each resistor on a different wire.

Voltage

Different for each resistor.

$$V_{\text{total}} = V_1 + V_2$$

Same for each resistor.

$$V_{\text{total}} = V_1 = V_2$$

Current

Same for each resistor

$$I_{\text{total}} = I_1 = I_2$$

Different for each resistor

$$I_{\text{total}} = I_1 + I_2$$

Resistance

Increases

$$R_{\text{eq}} = R_1 + R_2$$

Decreases

$$1/R_{\text{eq}} = 1/R_1 + 1/R_2$$