Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Notes for today:

1) Brief review of Quiz 2 (→ take home) due now
2) Assignment 4 (Mastering Physics) online and separate, written problems due now
3) Complete Chapter 25 this week (review all of Chap 21-24 for Midterm next week)
4) Schedule for next week:
    1) Monday: holiday
    2) Wednesday: review
    3) Friday: Midterm #1

Resistance R

We define resistance, R as $$R = \rho \frac{L}{A}$$

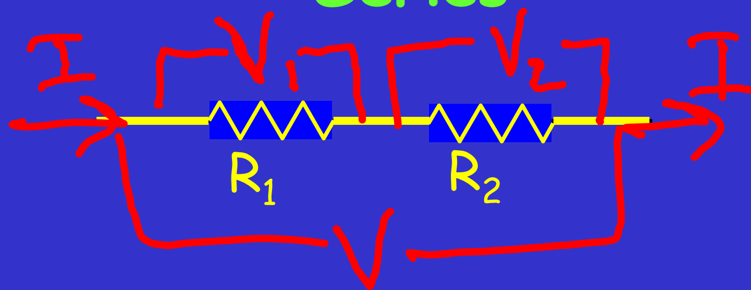
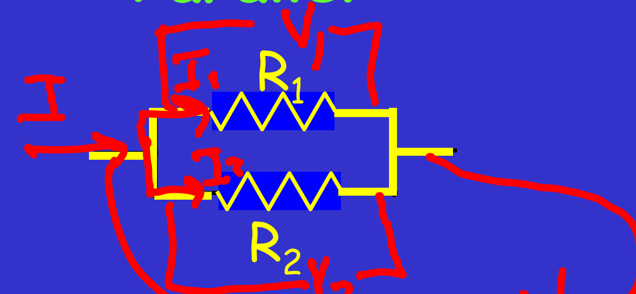
Units of R: Ω

And we have for ohmic materials Ohm's Law: $$V = I\ R$$

Temperature dependence (ohmic materials):

$$R(T) = R_0[1 + \alpha(T - T_0)]$$

Resistor Rules

	Series	Parallel
		
Wiring	Each resistor on the <u>same</u> wire.	Each resistor on a <u>different</u> wire.
Voltage	<u>Different</u> for each resistor. $V_{total} = V_1 + V_2$	<u>Same</u> for each resistor. $V_{total} = V_1 = V_2$
Current	<u>Same</u> for each resistor $I_{total} = I_1 = I_2$	<u>Different</u> for each resistor $I_{total} = I_1 + I_2$
Resistance	<u>Increases</u> $R_{eq} = R_1 + R_2$	<u>Decreases</u> $1/R_{eq} = 1/R_1 + 1/R_2$

Example: A 80.0 m Cu wire 1.0 mm in diameter is joined to a 49.0 m iron wire of the same diameter. The current in each is 2.0 A.

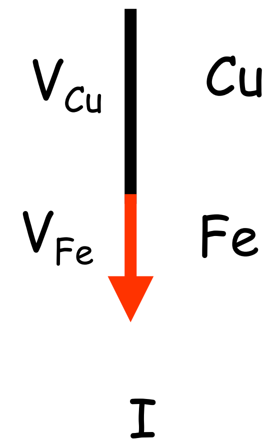
a.) Find V in each wire.

$$R_{Cu} = \frac{\rho_{Cu} L_{Cu}}{A} = \frac{(1.7\times10^{-8}\,\Omega\, m)(80.0\, m)}{\pi(0.5\times10^{-3}\, m)^2} = 1.73\ \Omega$$

$$R_{Fe} = \frac{\rho_{Fe} L_{Fe}}{A} = \frac{(10\times10^{-8}\,\Omega\, m)(49.0\, m)}{\pi(0.5\times10^{-3}\, m)^2} = 6.24\Omega$$

$$V_{Cu} = IR_{Cu} = (2.0A)(1.73\Omega) = 3.46V$$

$$V_{Fe} = IR_{Fe} = 12.5V$$



b.) Find E in each wire.

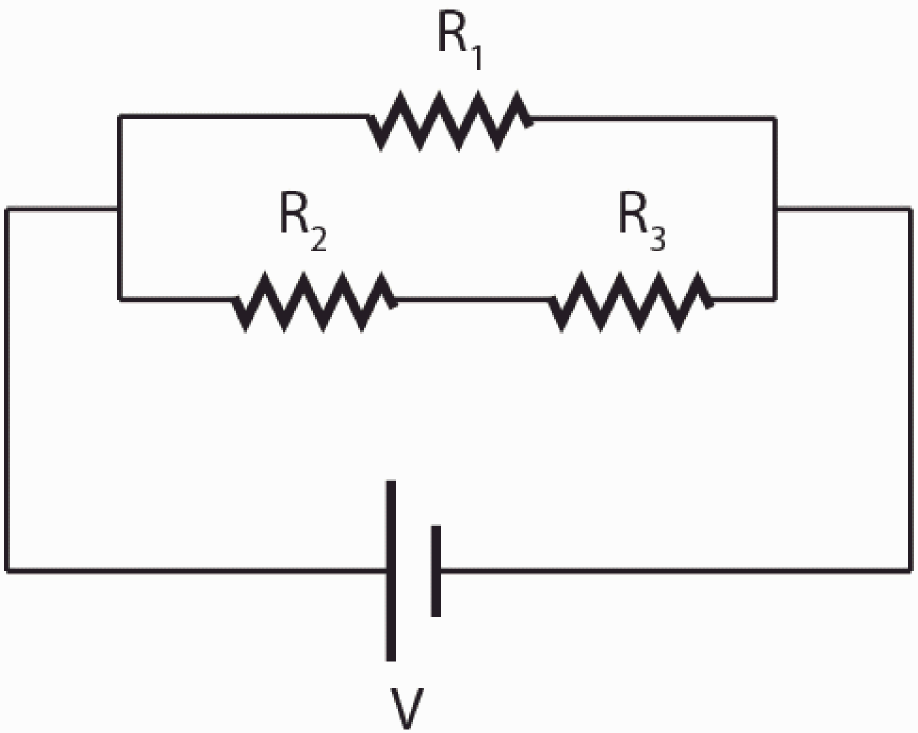
$$V = EL$$

$$E_{Cu} = \frac{V_{Cu}}{L_{Cu}} = 0.43\frac{V}{m}$$

$$E_{Fe} = \frac{V_{Fe}}{L_{Fe}} = 0.255\frac{V}{m}$$

Example 1

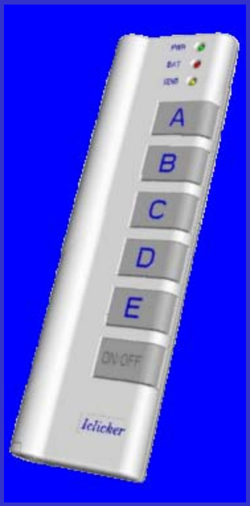
6) Three resistors are connected to a battery with emf V as shown. The resistances of the resistors are all the same, i.e. $R_1 = R_2 = R_3 = R$.



Compare the current through R_2 with the current through R_3:

○ $I_2 > I_3$ ○ $I_2 = I_3$ ○ $I_2 < I_3$

A B C



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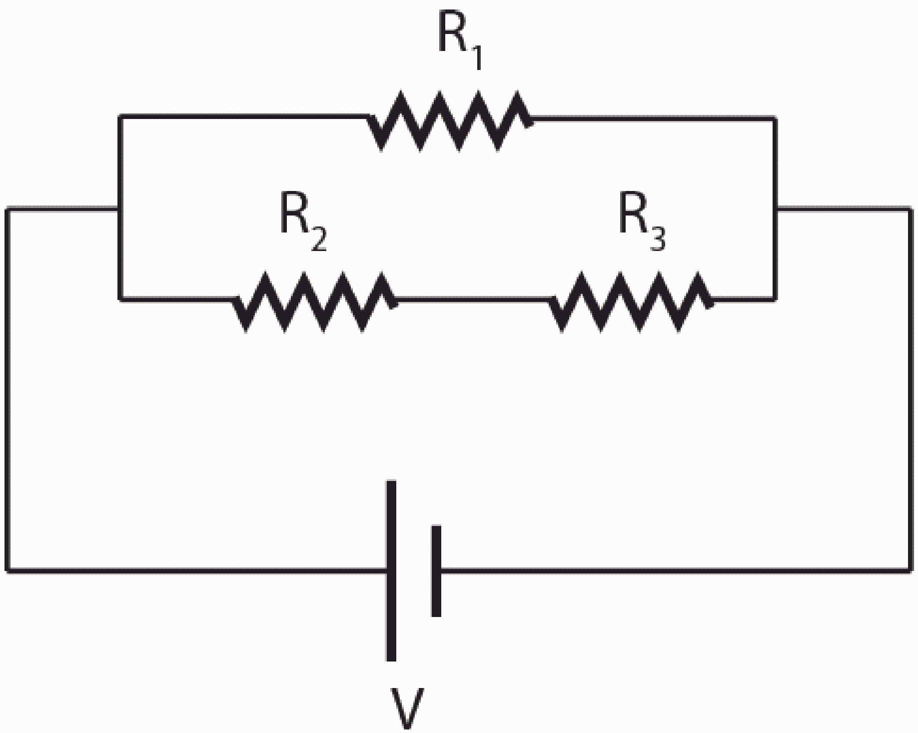

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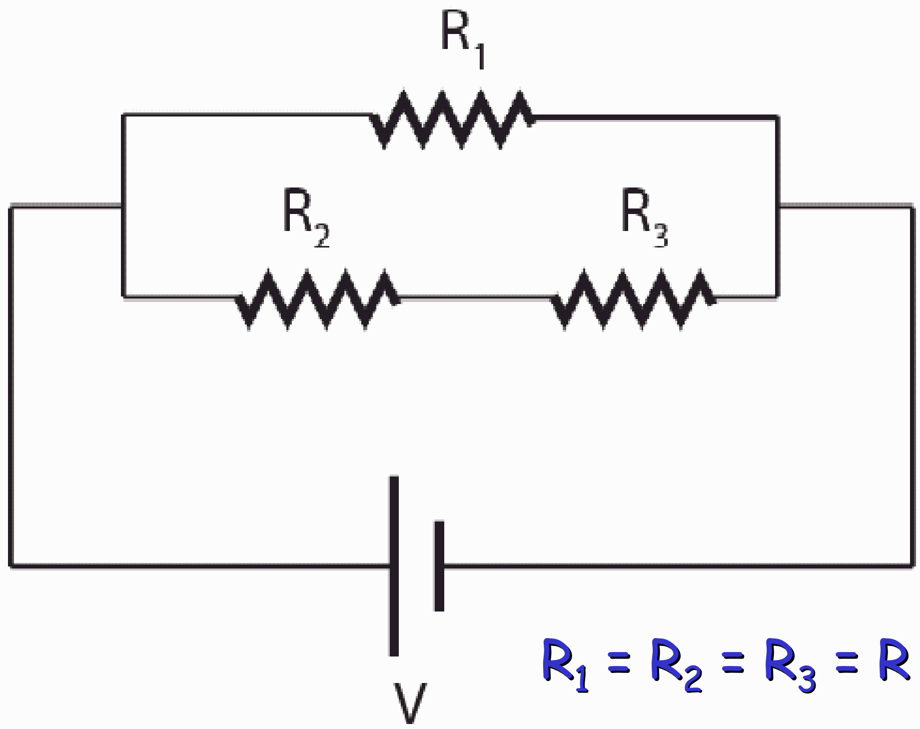
Compare the current through R_2 with the current through R_3:

○ $I_2 > I_3$ ○ $I_2 = I_3$ ○ $I_2 < I_3$

A B C

$$I_{23} = \frac{V}{R_2 + R_3}$$

R_2 in series with R_3 → Current through R_2 and R_3 is the same



$R_1 = R_2 = R_3 = R$

Example 2

Compare the current through R_1 with the current through R_2

A $I_1/I_2 = 1/2$

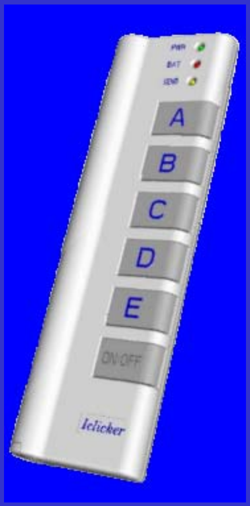
B $I_1/I_2 = 1/3$

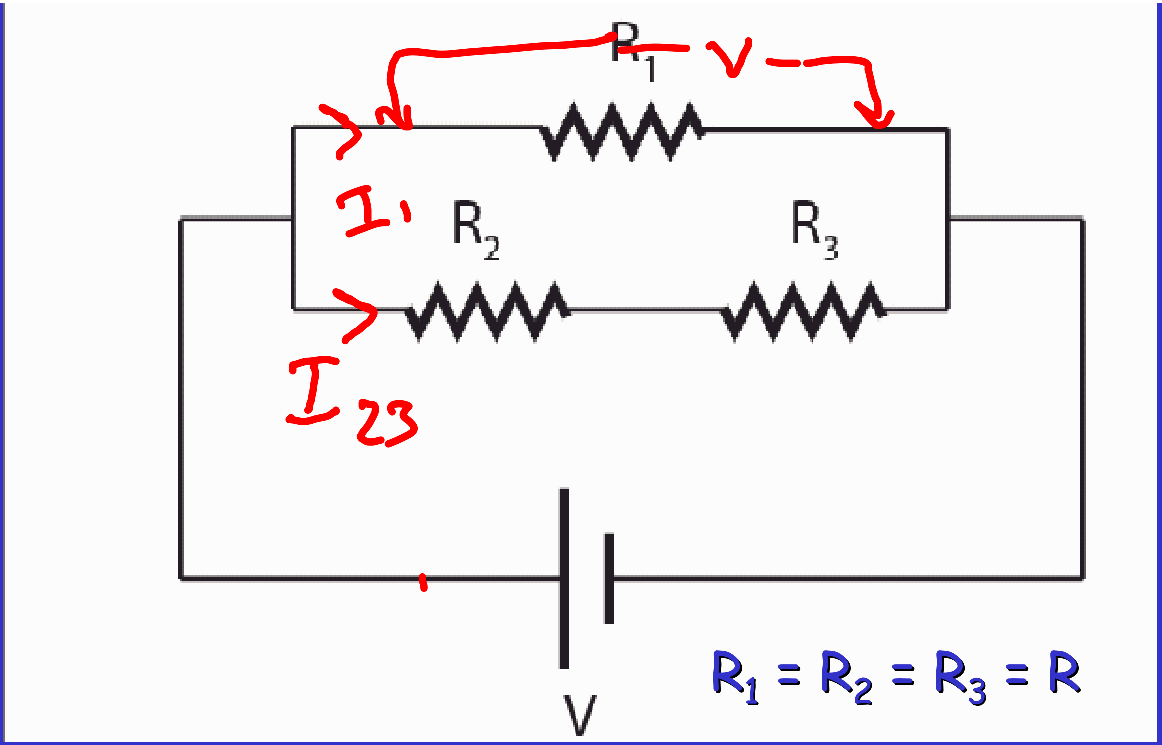
C $I_1/I_2 = 1$

D $I_1/I_2 = 2$

E $I_1/I_2 = 3$

Where to start?





Example 2

Compare the current through R_1 with the current through R_2

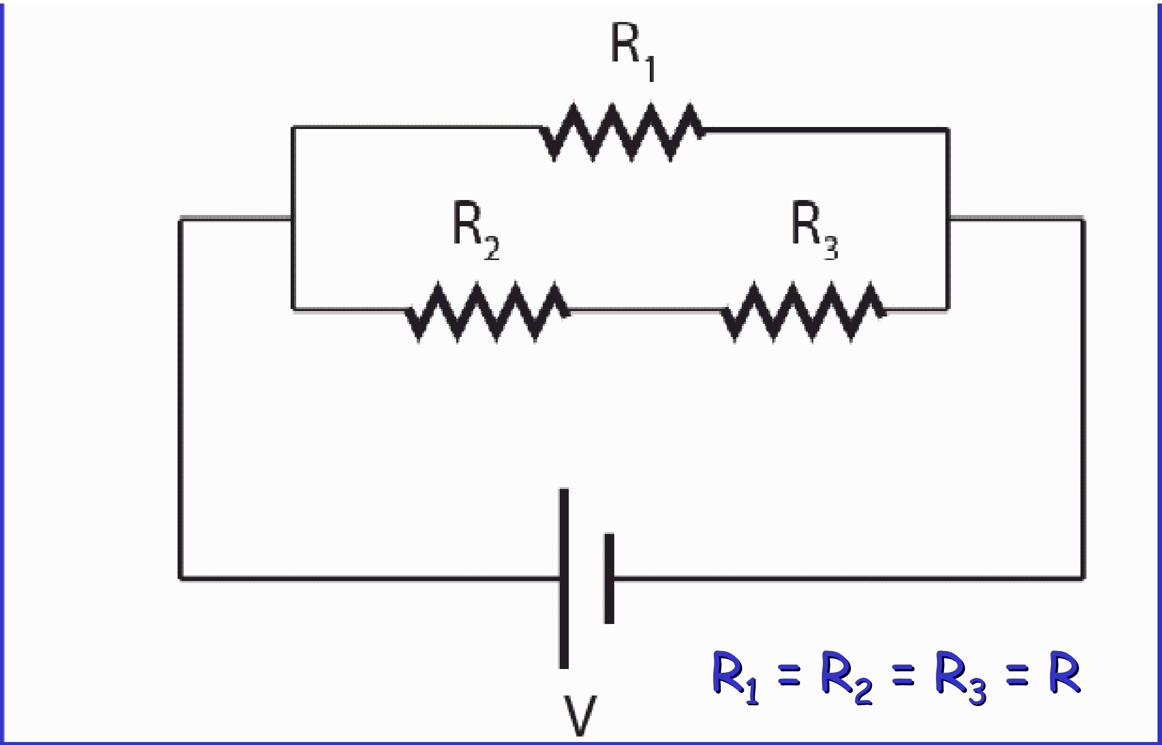
- A $I_1/I_2 = 1/2$
- B $I_1/I_2 = 1/3$
- C $I_1/I_2 = 1$
- D $I_1/I_2 = 2$
- E $I_1/I_2 = 3$

We know: $I_{23} = \frac{V}{R_2 + R_3}$

Similarly: $I_1 = \frac{V}{R_1}$

$$I_1 = I_{23}\frac{R_2 + R_3}{R_1}$$

$$\frac{I_1}{I_{23}} = \frac{R_2 + R_3}{R_1} = 2$$



Example 3

Compare the voltage across R_2 with the voltage across R_3

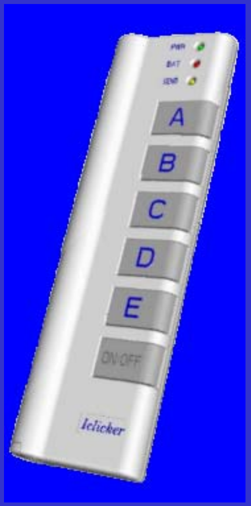
Where to start?

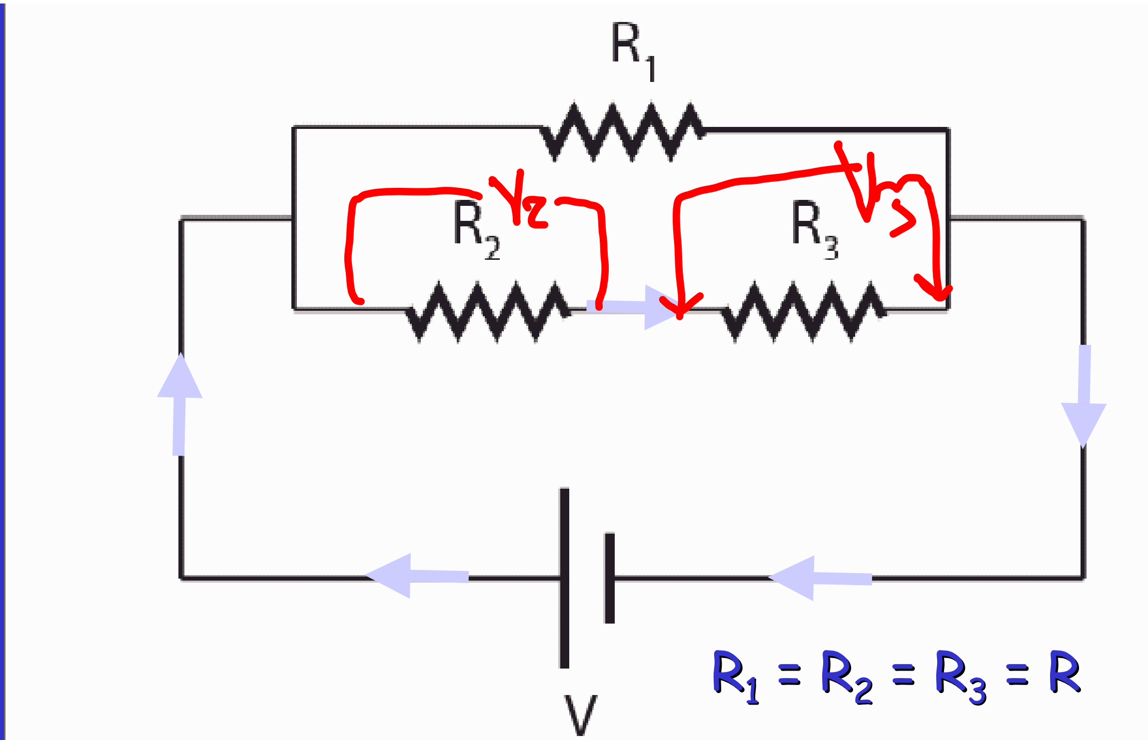
A $V_2 > V_3$

B $V_2 = V_3 = V$

C $V_2 = V_3 < V$

D $V_2 < V_3$





Example 3

Compare the voltage across R_2 with the voltage across R_3

A $V_2 > V_3$

B $V_2 = V_3 = V$

C $V_2 = V_3 < V$

D $V_2 < V_3$

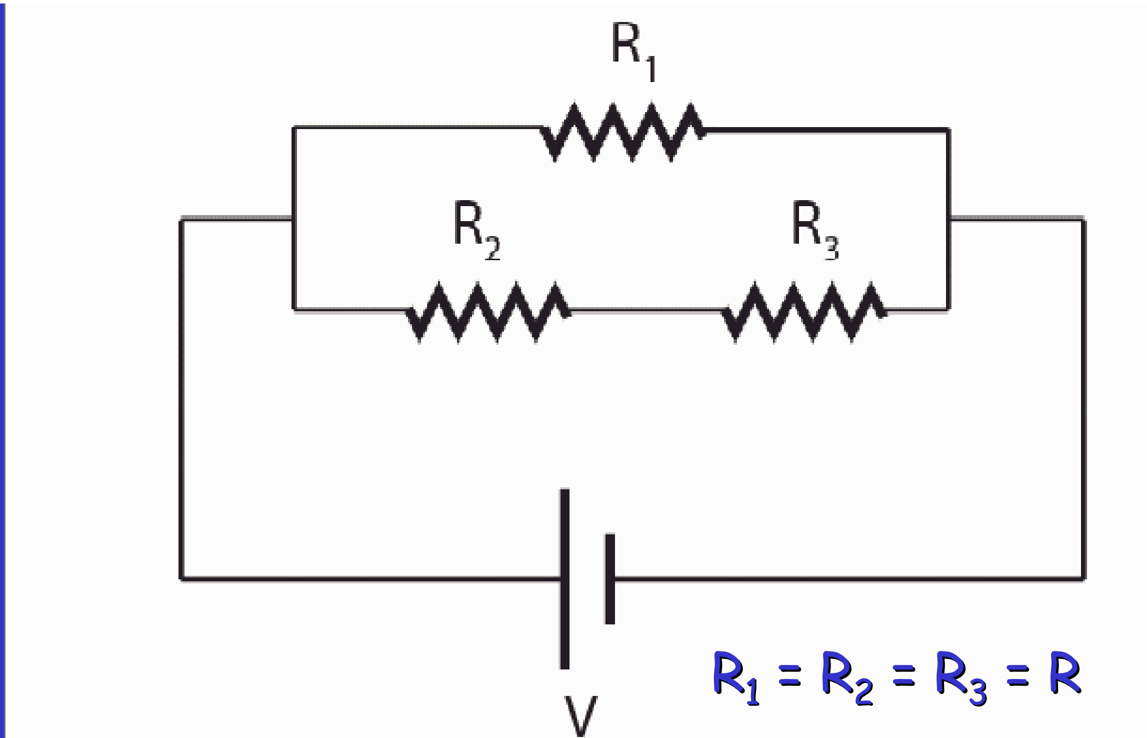
Consider loop

$$V_{23} = V$$

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

$$R_2 = R_3 \Rightarrow V_2 = V_3$$

$$V_2 = V_3 = \frac{V}{2}$$



Example 4

Compare the voltage across R_1 with the voltage across R_2

A $V_1 = V_2 = V$

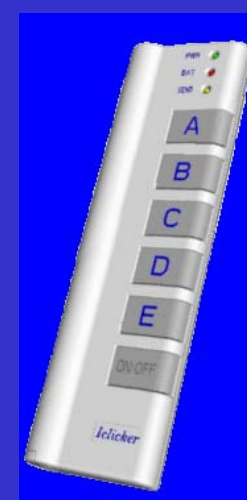
B $V_1 = \frac{1}{2} V_2 = V$

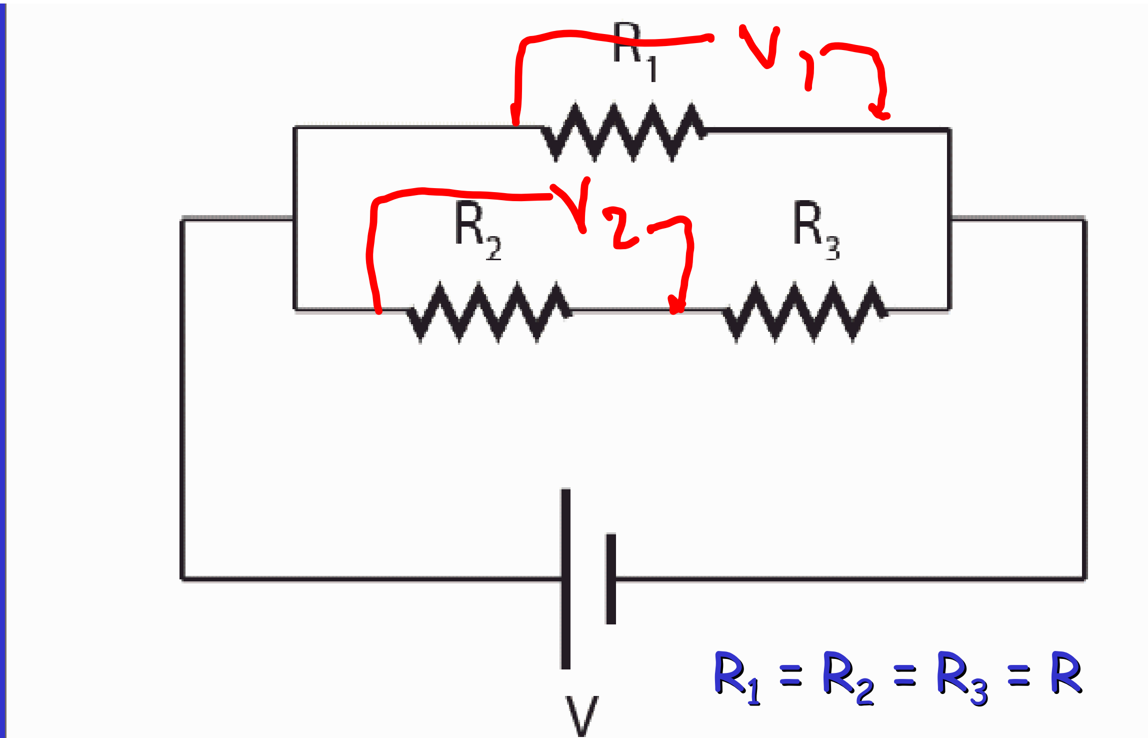
C $V_1 = 2V_2 = V$

D $V_1 = \frac{1}{2} V_2 = 1/5\ V$

E $V_1 = \frac{1}{2} V_2 = \frac{1}{2}\ V$

Where to start?





Example 4

Compare the voltage across R_1 with the voltage across R_2

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B $V_1 = \frac{1}{2} V_2 = V$

C $V_1 = 2V_2 = V$

D $V_1 = \frac{1}{2} V_2 = 1/5\ V$

E $V_1 = \frac{1}{2} V_2 = \frac{1}{2}\ V$

R_1 in parallel with series combination of R_2 and R_3

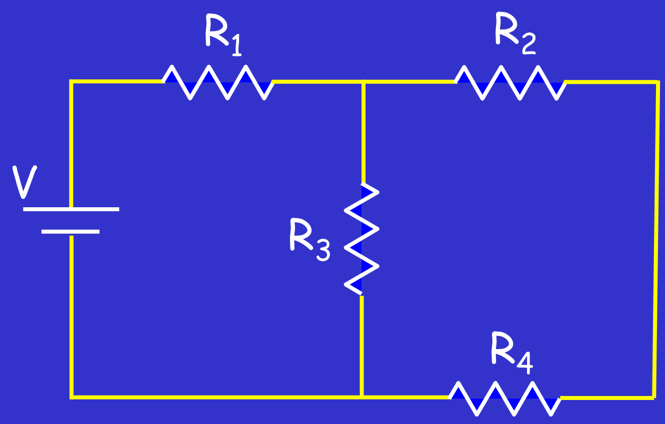
$$V_1 = V_{23}$$

$$R_2 = R_3 \Rightarrow V_2 = V_3$$

$$V_{23} = V_2 + V_3 = 2V_2$$

$$\Rightarrow \quad V_1 = 2V_2 = V$$

Calculation

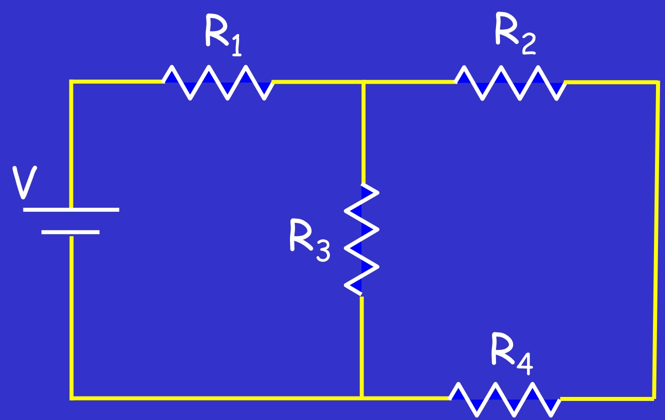


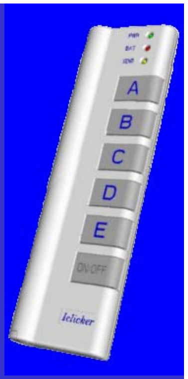
In the circuit shown: V = 18V, R_1 = 1Ω, R_2 = 2Ω, R_3 = 3Ω, and R_4 = 4Ω.

What is V_2, the voltage across R_2?

- Conceptual Analysis:
  - Ohm's Law: when current *I* flows through resistance *R*, the potential drop *V* is given by: $V = IR$.
  - Resistances are combined in series and parallel combinations
    - $R_{series} = R_a + R_b$
    - $(1/R_{parallel}) = (1/R_a) + (1/R_b)$
- Strategic Analysis
  - Combine resistances to form equivalent resistances
  - Evaluate voltages or currents from Ohm's Law
  - Expand circuit back using knowledge of voltages and currents

Calculation 1





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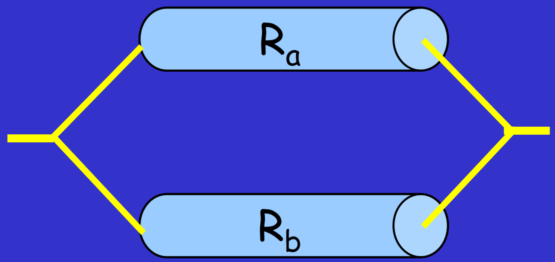
What is V_2, the voltage across R_2?

- Combine Resistances:

R_1 and R_2 are connected:

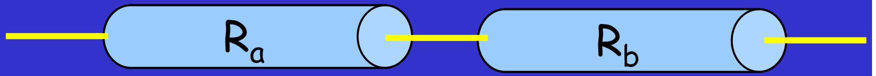
(A) in series (B) in parallel (C) neither in series nor in parallel

Parallel Combination



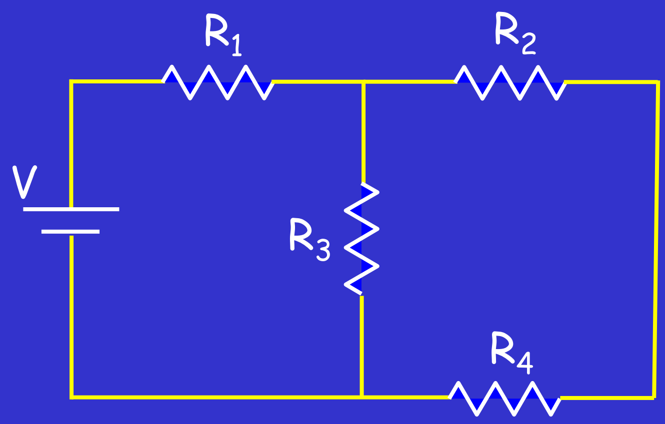
Parallel: Can make a loop that contains only those two resistors

Series Combination



Series : Every loop with resistor 1 also has resistor 2.

Calculation 1



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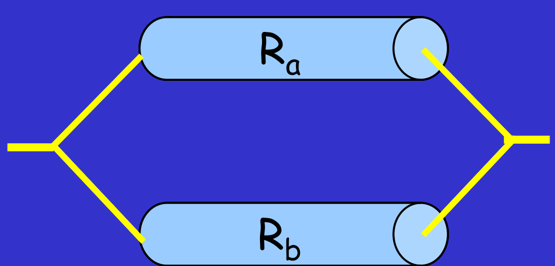

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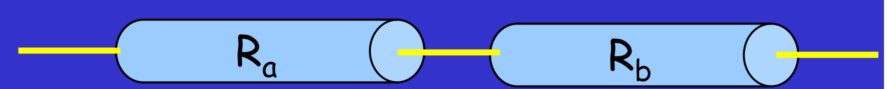

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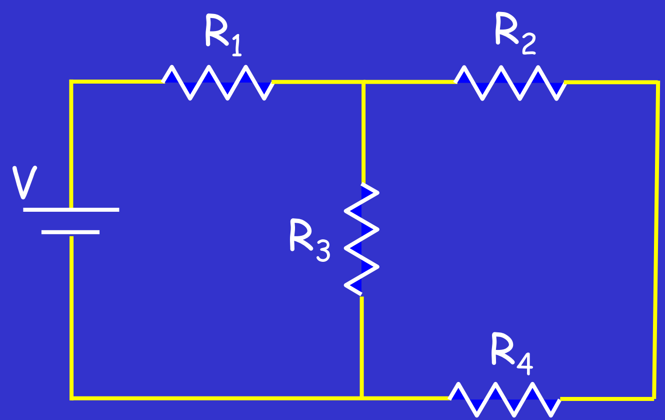
Calculation 2



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What is V_2, the voltage across R_2?

- Combine Resistances:

R_2 and R_4 are connected:

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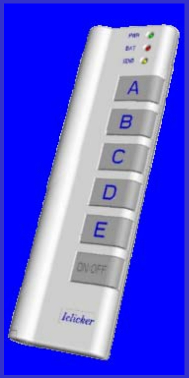

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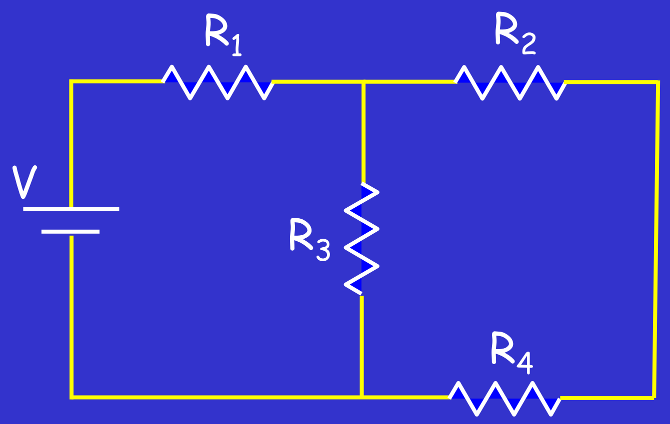

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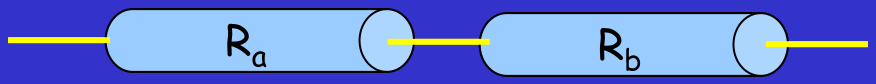

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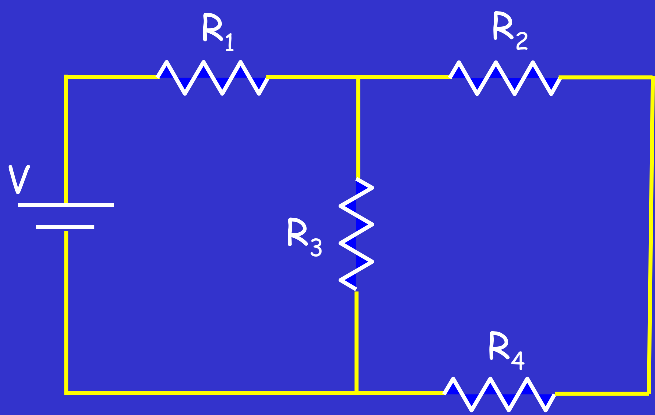
Calculation 3



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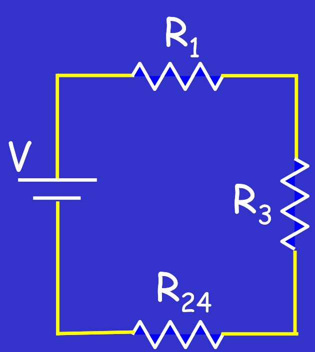
What is V_2, the voltage across R_2?

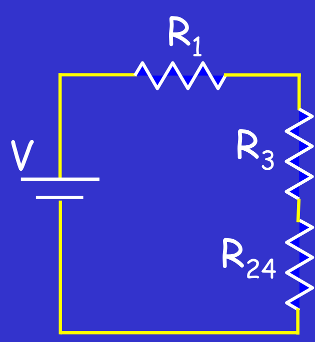
- Combine Resistances:

R_2 and R_4 are connected in series = R_{24} = 2 + 4 = 6 Ω

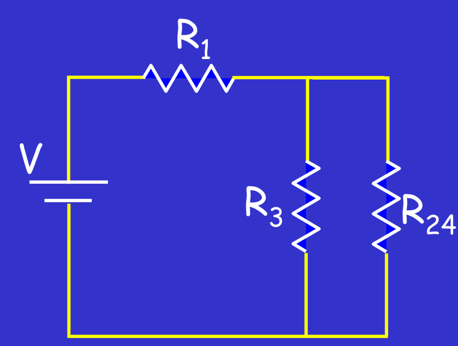
Redraw the circuit using the equivalent resistor R_{24} = series combination of R_2 and R_4.



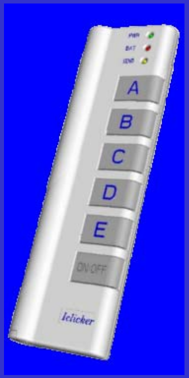
(A)



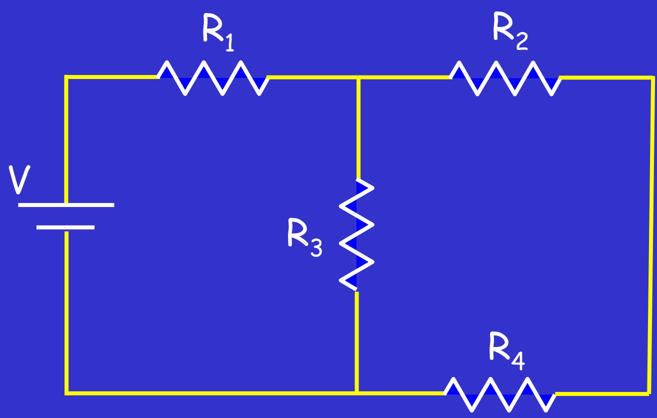
(B)



(C)



Calculation 3



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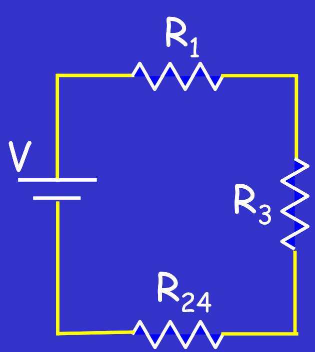
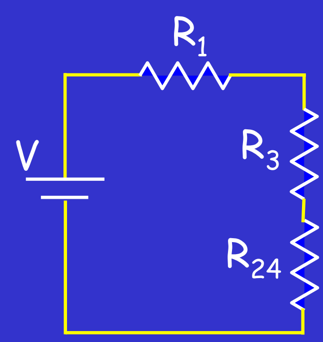
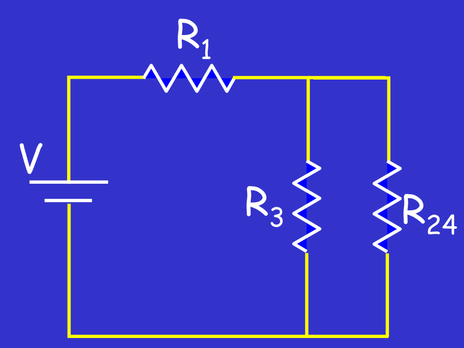


(A)



(B)



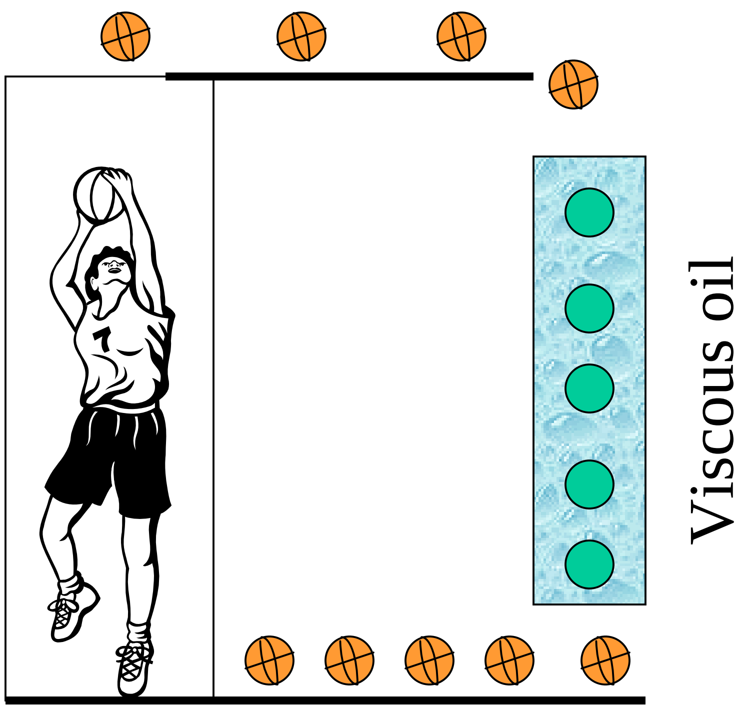
(C)

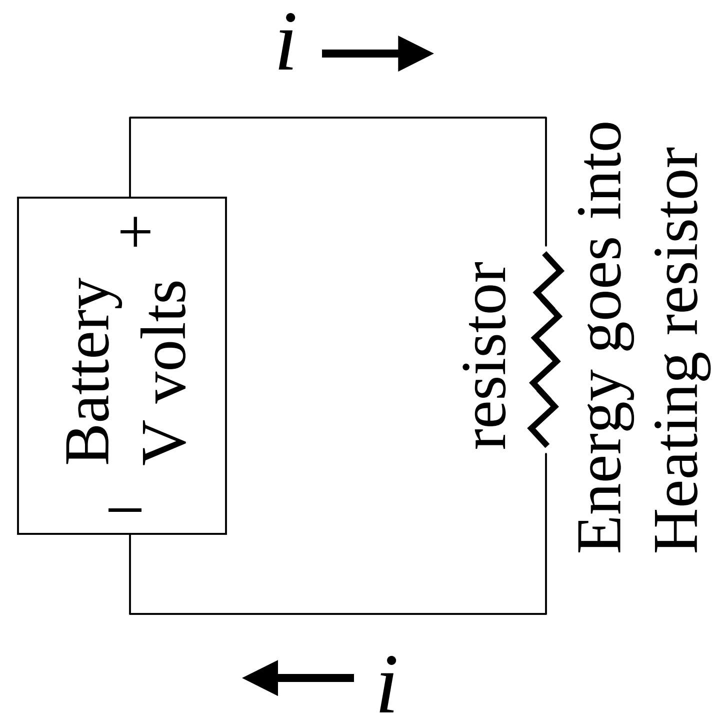
Electromotive Force and Circuits

"sources of electromotive force" are batteries, electric generators and solar cells

→consider how they behave in a closed circuit.

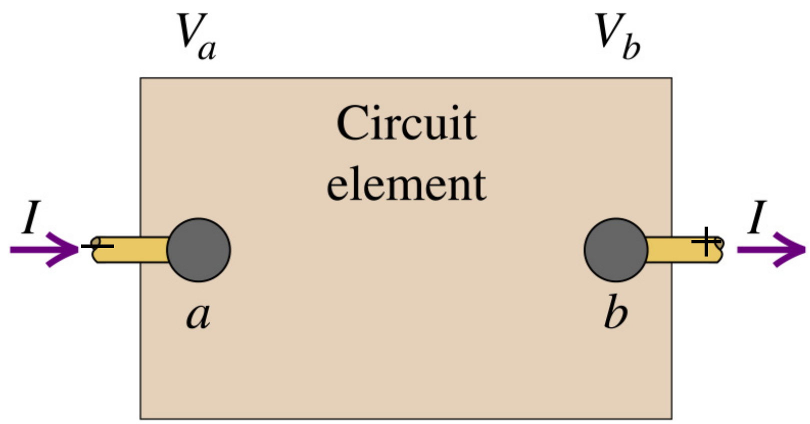
→Below is an analogy between basketball and current in a closed circuit. The player does work to move the ball up and the ball loses energy in the viscous oil giving off heat. The battery does work to move q from – to + terminals, gaining energy qV. The charge q moves through wire to resistor and loses energy in the resistor and goes to the – terminal.



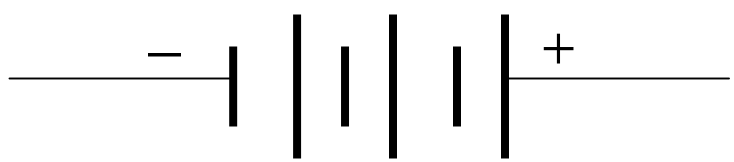


Electromotive Force (EMF)

A battery is a device that keeps a & b terminals at a fixed potential difference and will move a positive charge or current from the a to the b terminals by some process such as electrolysis (storage battery) or the photoelectric effect (solar cells). This "force" is called the *electromotive force* or EMF or script $\mathcal{E}$.



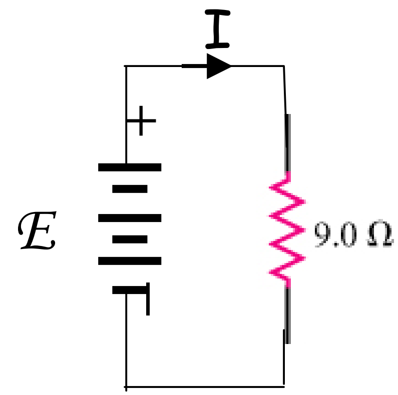
The battery circuit diagram is given by perpendicular lines, with + terminal with the bigger line.



Idealized Battery

The ideal battery with potential ℰ has no internal resistance and is represented by

V across battery is ε no matter what current is drawn! Not very physical.



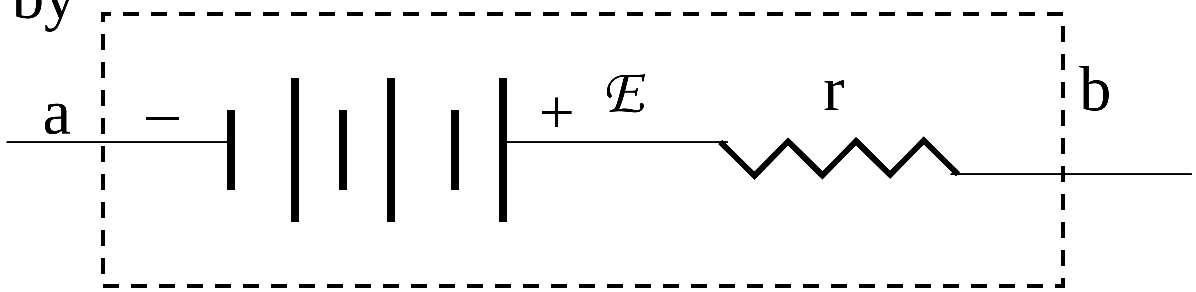
$$V_B = V_R$$

$$\varepsilon = IR$$

$$I = \frac{\varepsilon}{R}$$

"Real Battery"

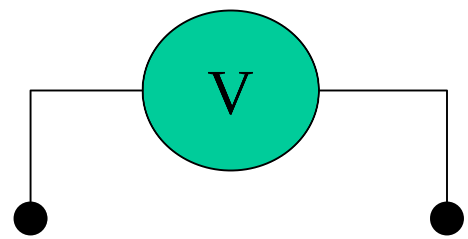
The real battery with potential □ has a small internal resistance r and is represented by



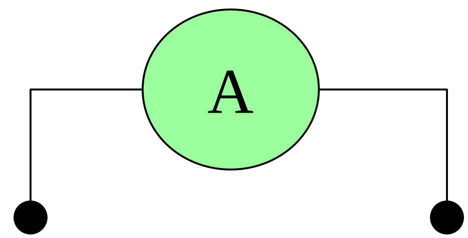
Voltage, between a & b, is slightly different than ℰ

Electrical Meters

Voltmeter, measures voltage and has large internal resistance. An ideal voltmeter has infinite resistance and does not conduct any current.



Ammeter, measures current and has very small internal resistance. An ideal ammeter has zero resistance and behaves like a conducting wire.



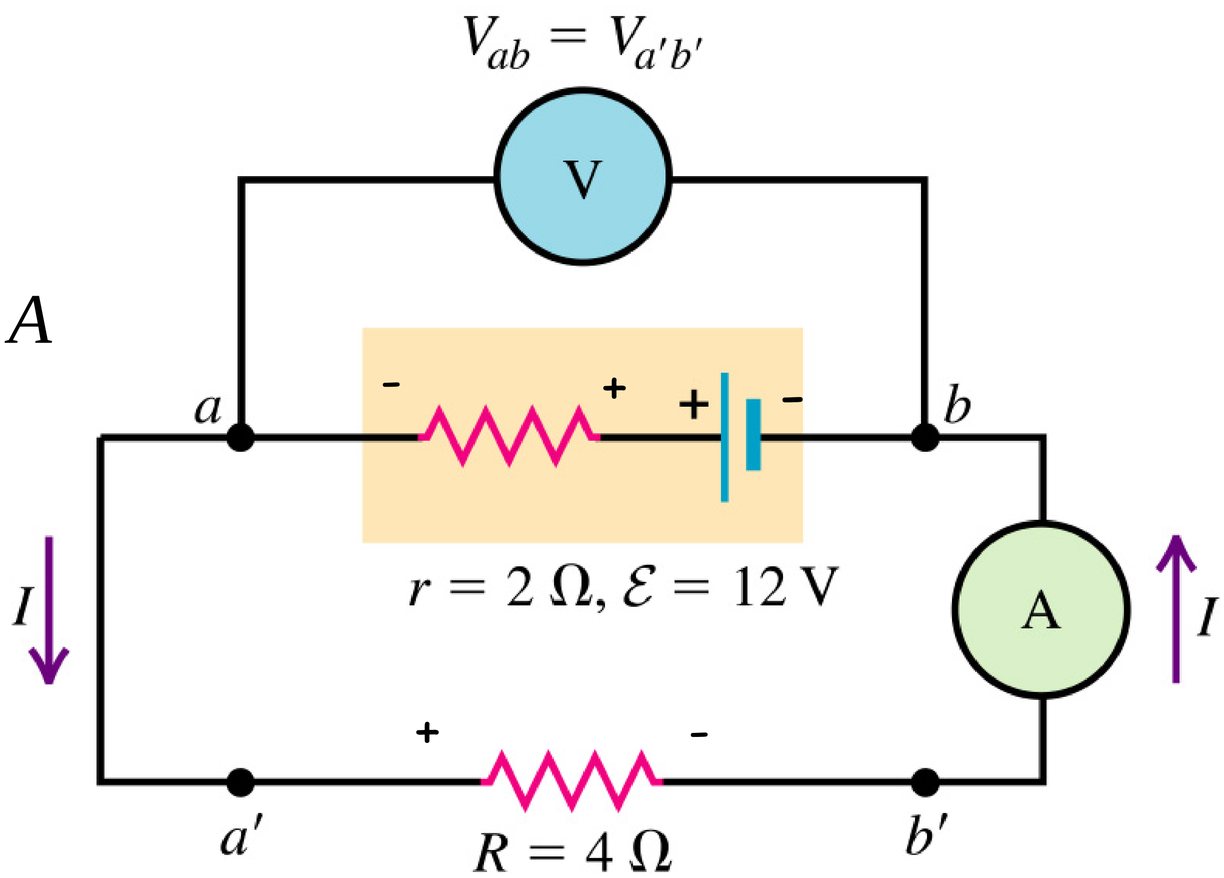
Real Battery with 12volts and an internal resistance of 2 ohms in a circuit with a resistor of 4 ohms

$$V_{AB} = V_{A'B'}$$

$$\varepsilon - Ir = IR$$

$$I(R + r) = \varepsilon$$

$$I = \frac{\varepsilon}{R + r} = \frac{12V}{6\Omega} = 2A$$



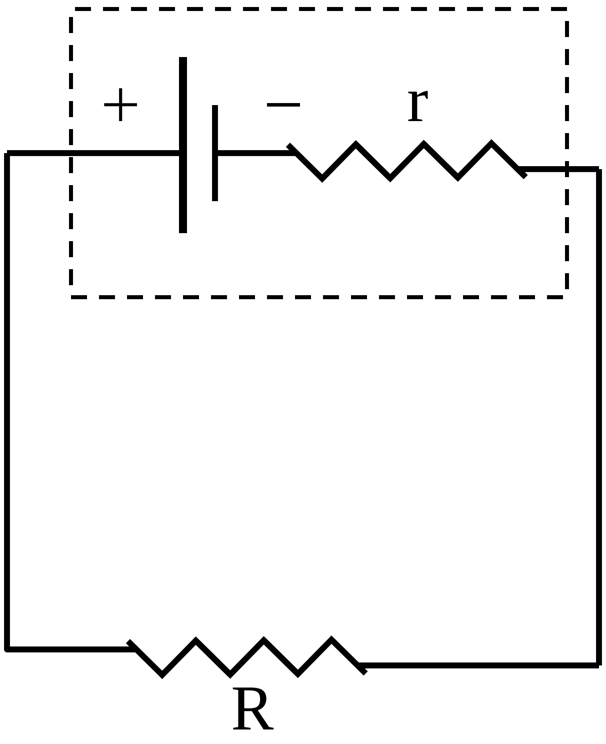
Voltage drop across 2 Ohms is 4 volts

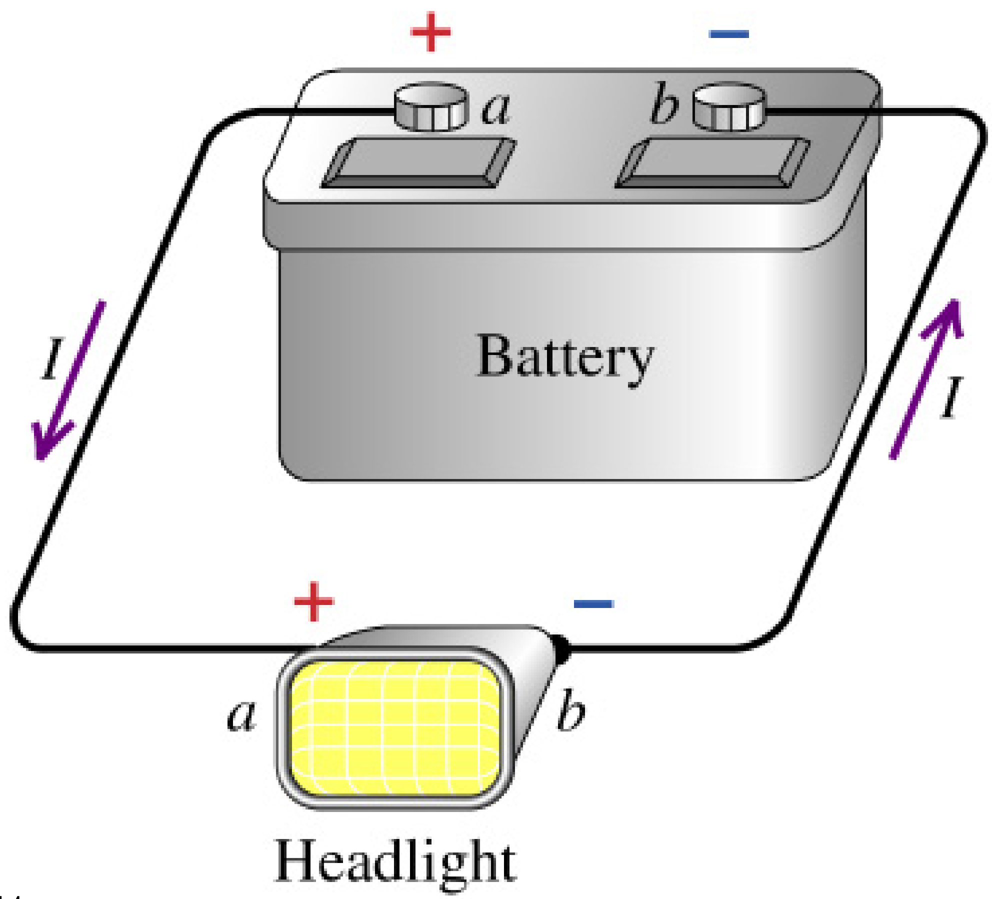
Voltage drop across 4 Ohms is 8 volts

$V_{ab} = V_{a'b'} = 8$ volts

Terminal potential difference $V_{AB} = 12 - 4 = 8$ V

Real life example of previous circuit is a car battery and a headlamp





R = resistance in headlight

r = internal resistance in battery

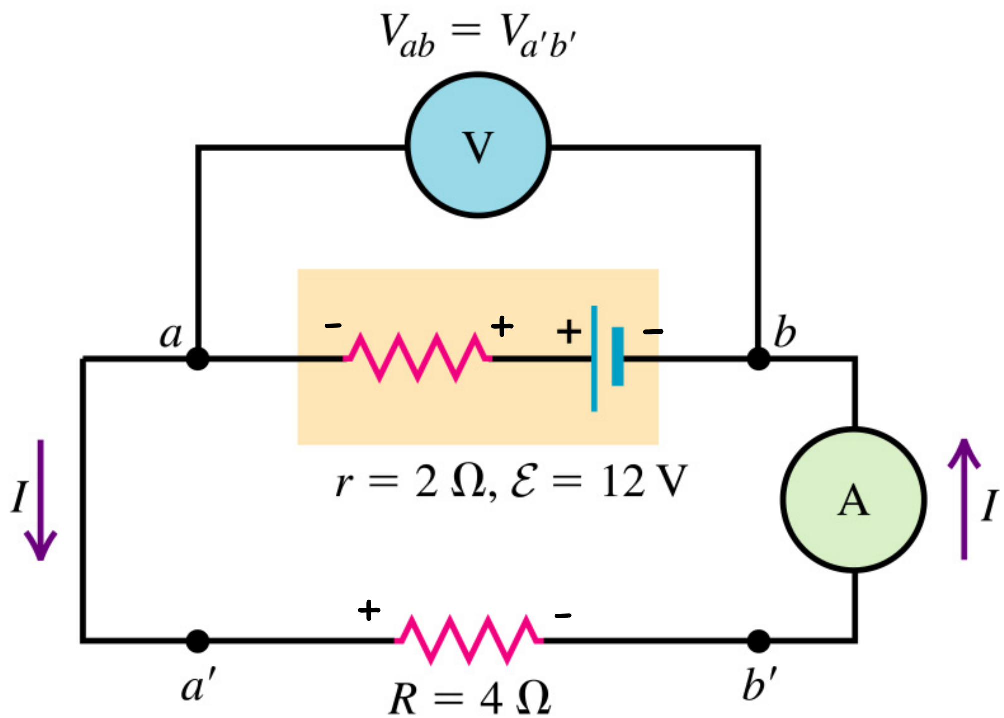
Real Battery with 12volts and an internal resistance of 2 ohms in a circuit with a resistor of 4 ohms

$$\varepsilon - Ir = IR$$

Rearranging:

$$\varepsilon - Ir - IR = 0$$

Can interpret this as the sum of all potential differences around a closed loop must add to zero.



Kirchoff's voltage law or loop rule.

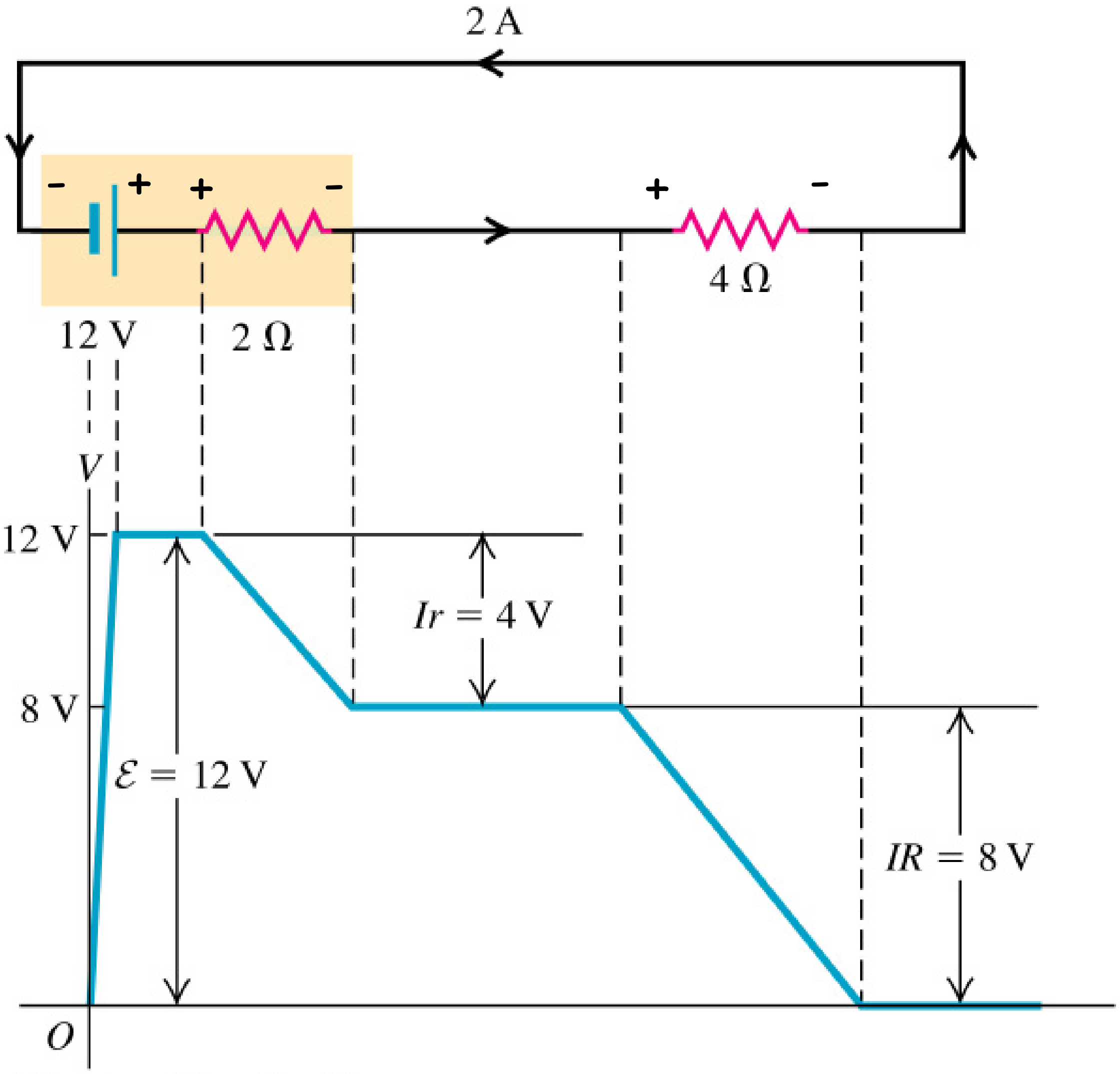
Can define a voltage rise as positive OR a voltage fall as positive.

Electric Potential/Voltage Diagram of the circuit

Voltage drop across 2 Ohms is 4 volts

Voltage drop across 4 Ohms is 8 volts

NOTE 4Ω resistor has only 8 of the 12 volts.

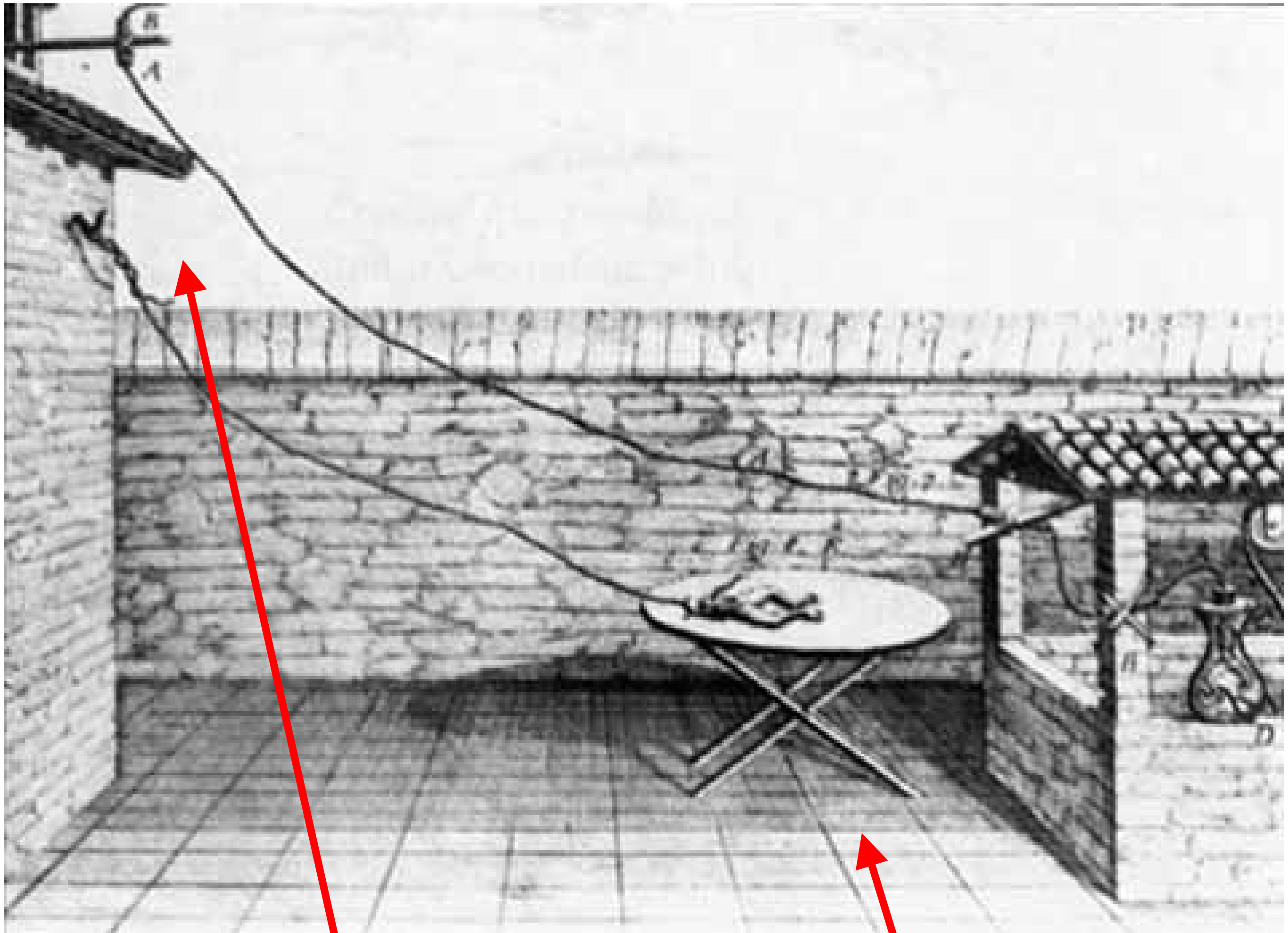


Early History of Current and Batteries

The development of the battery has a curious history. Henry Cavendish studied sting rays (called Torpedoes) to investigate how they created electricity around 1776. Around ~1790, Luigi Galvani applied current to frog's legs and observed them twitching. He believed there was an "animal electricity" stored in the frog's brain. About 1800, Allesandro Volta, invented the "pile", a series of silver and zinc disks in salt water. Volta tested his electricity by attaching electrodes to his tongue and eventually demonstrated his pile before Napoleon.

In 1803, George Forster, a convicted murdered was hanged at Newgate prison, and Galvani's nephew, Giovanni Aldini, applied current from a Volta pile to the corpse causing the jaws, eyes, hands and legs to move. This process of resuscitation was eventually applied to drowning victims. This created philosophical and religious controversy about life, death and electricity. This gave Mary Shelley the idea for the 1818 novel, Frankenstein, about a corpse brought to life by electricity.

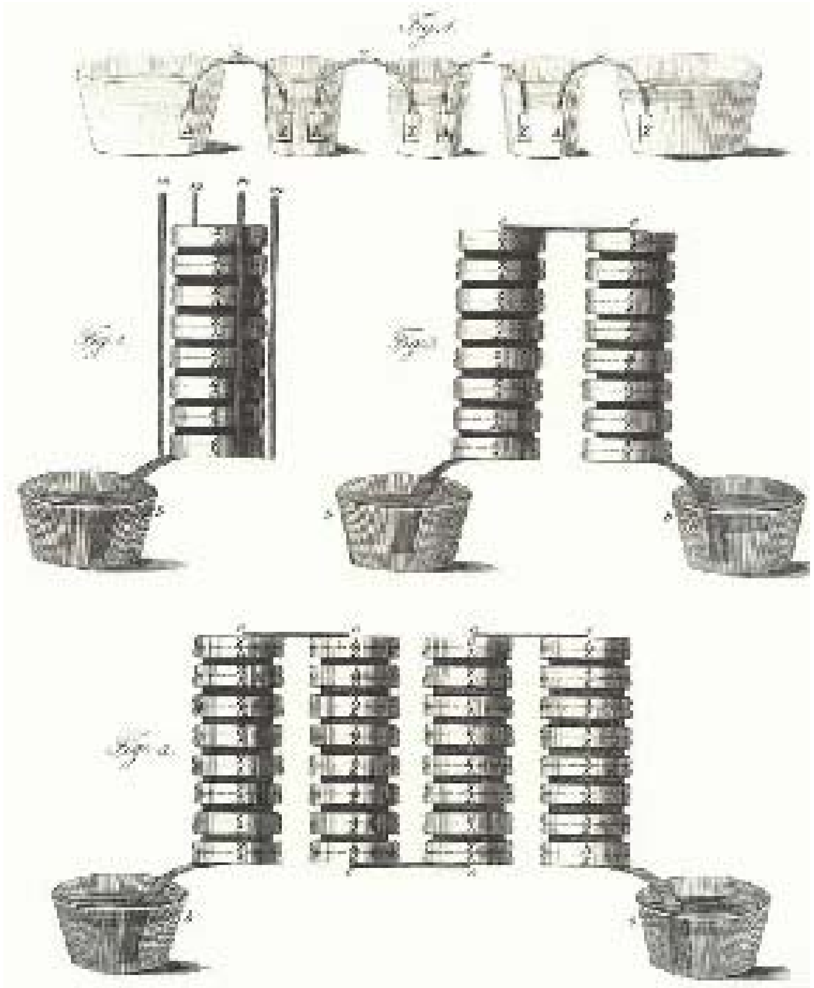
Drawing of one of Luigi Galvani's experiments



Leyden
Jar

lightning rod attached to froggy!!

Drawing of Volta's Pile or Battery

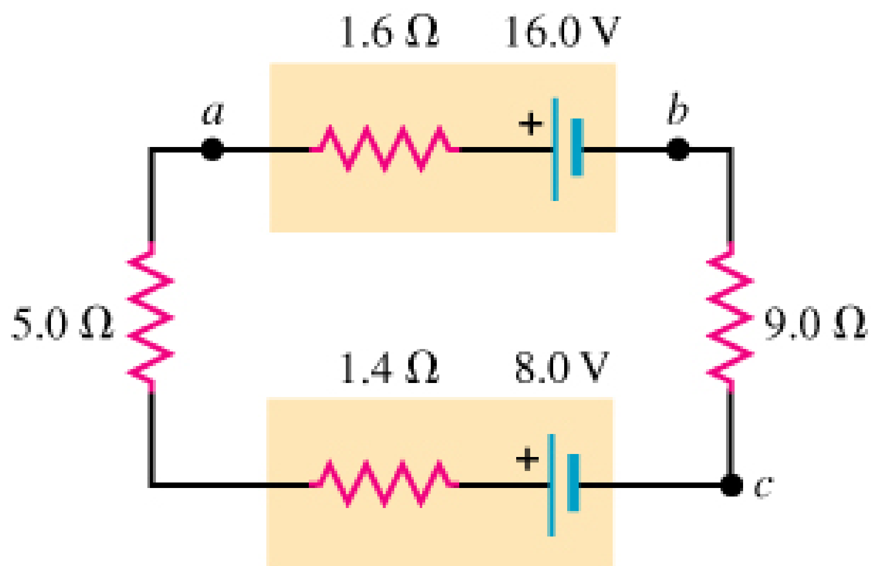


Demonstrating before Napoleon

Manuscript on the invention of the battery sent to the Royal Society of London. Cardboard soaked in salt water was placed in between the zinc and silver disks.

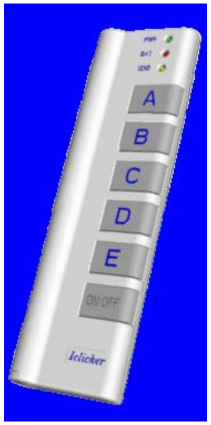
Y&F 25.36

The circuit shown in the figure contains two batteries, each with an emf and an internal resistance, and two resistors.



For this circuit estimate the direction of the current:

A) Clockwise
B) Counterclockwise
C) Neither – there is no net current flow



Y&F 25.36

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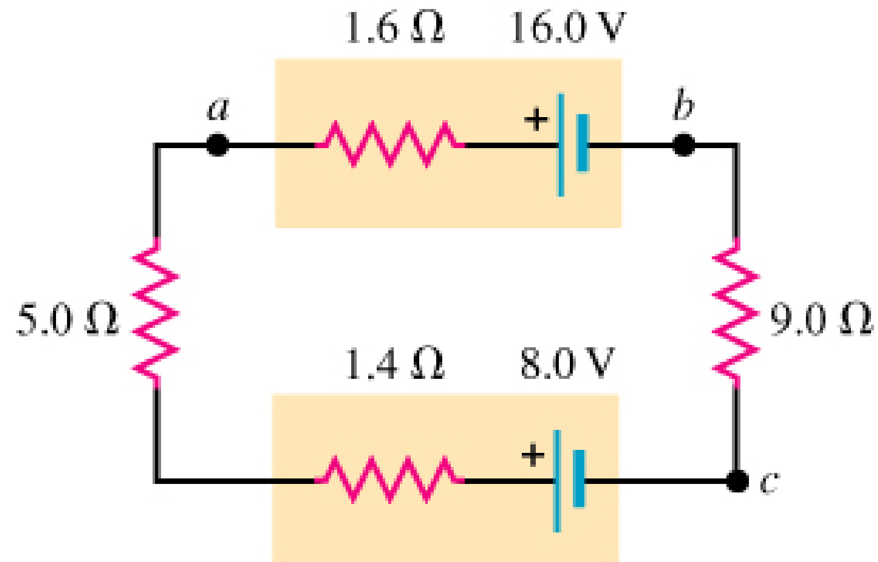
How could we get Case C ?



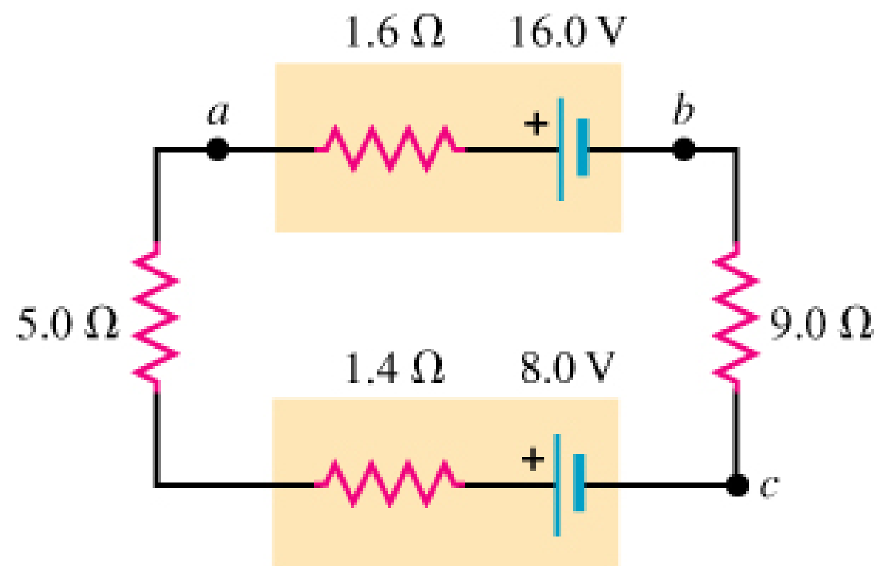
For this circuit estimate the direction of the current:

A) Clockwise
B) Counterclockwise
C) Neither – there is no net current flow

Y&F 25.36

The circuit shown in the figure contains two batteries, each with an emf and an internal resistance, and two resistors.

A) Find the direction and magnitude of the current in the circuit
B) Find the terminal voltage Vab of the 16.0-V battery.
C) Find the potential difference Vbc of point b with respect to point c .



Y&F 25.36

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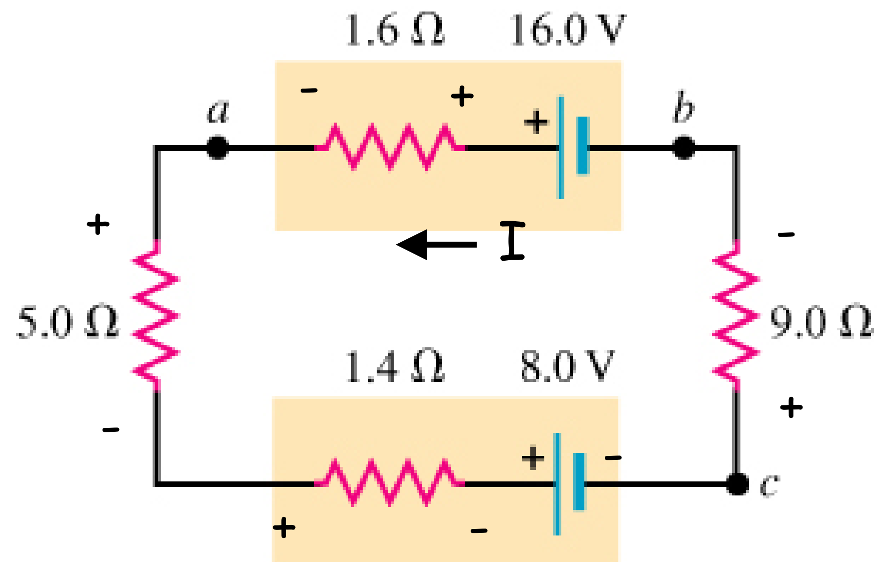

A.) Use Kirchoff's loop law:

$$16V - 1.6\Omega I - 5.0\Omega I - 1.4\Omega I - 8V - 9.0\Omega I = 0$$

$$8V - 17\Omega I = 0$$

$$I = \frac{8}{17} A = 0.471A$$

B.) V_{ab} = 16V – I(1.6 Ω) = 16V – (0.471 A)(1.6 Ω) = 15.2 V

C.) V_{bc} = – I(9.0 Ω) = – (0.471 A)(9.0 Ω) = -4.24 V

For next time

- HW #5 assigned → due next Wednesday

- Now is time to resolve any questions you may have about previous HW, Quiz

- Office Hours usually after this class (9:30 – 10:00) in WAT214 – today (1-1:30pm)