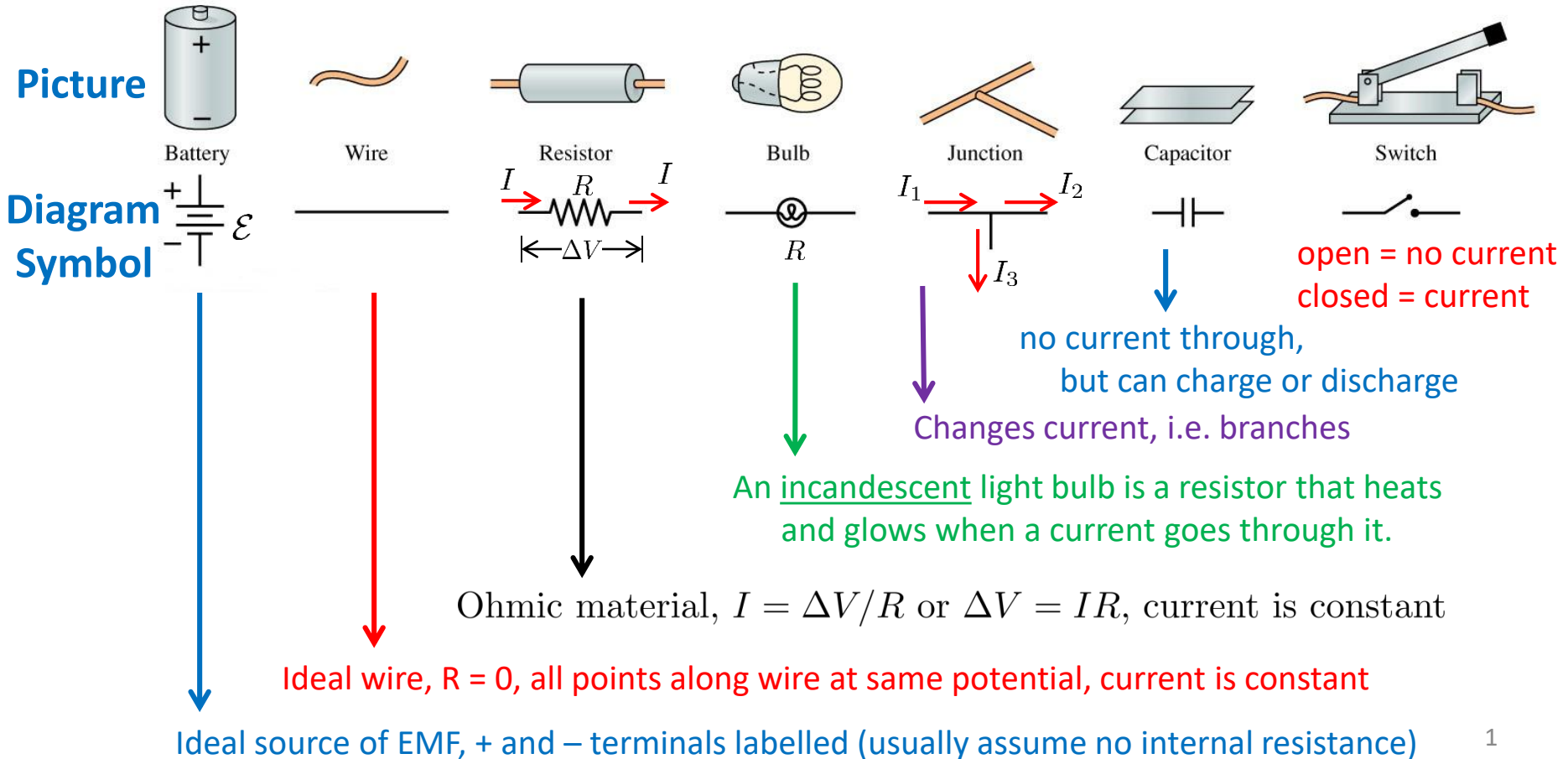


# 28-1: The Fundamentals of Circuits

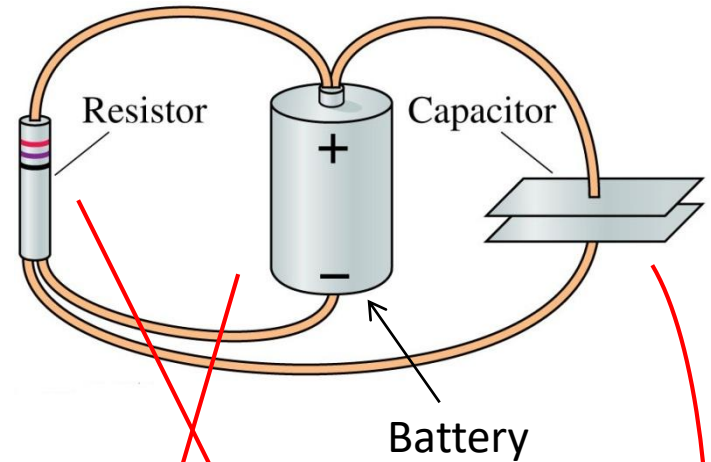
Now that we have an understanding of **current and resistance**, we're ready to start studying basic **Direct Current (DC) Circuits**. We'll start with resistor circuits, and then move on to resistor-capacitor (RC) circuits. *Note: many engineering majors will return to this topic in ECE205; physics majors in PHY292/294.*

## Common Circuit Elements:



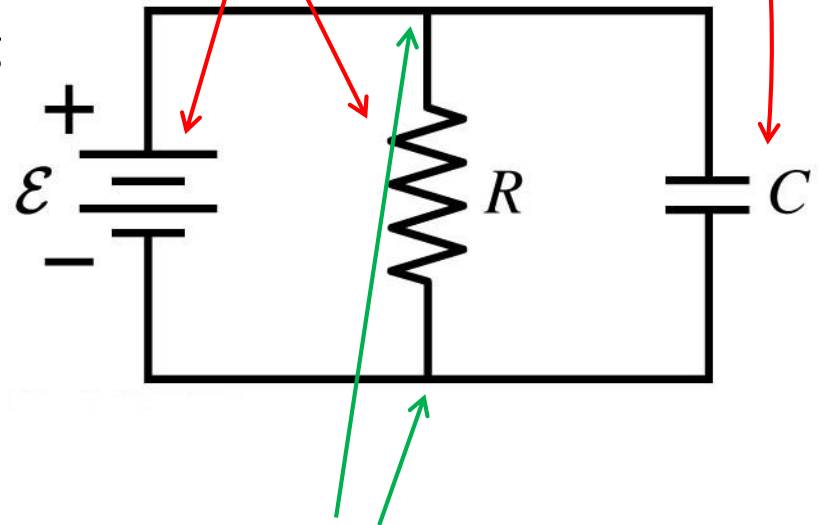
# Circuit Diagrams

A pictorial representation of a circuit with batteries, resistors, etc. can be very confusing to follow. Where are the junctions? ***What elements are in series or parallel (more on this later)?***



It is important that you learn to follow and draw accurate circuit diagrams using the circuit element symbols on the previous slide.

**For example, the above circuit with a battery, resistor, and capacitor looks like this when properly diagrammed.**



**Drawn this way, we can easily see that there are two junctions and that the Resistor and Capacitor are in parallel.**

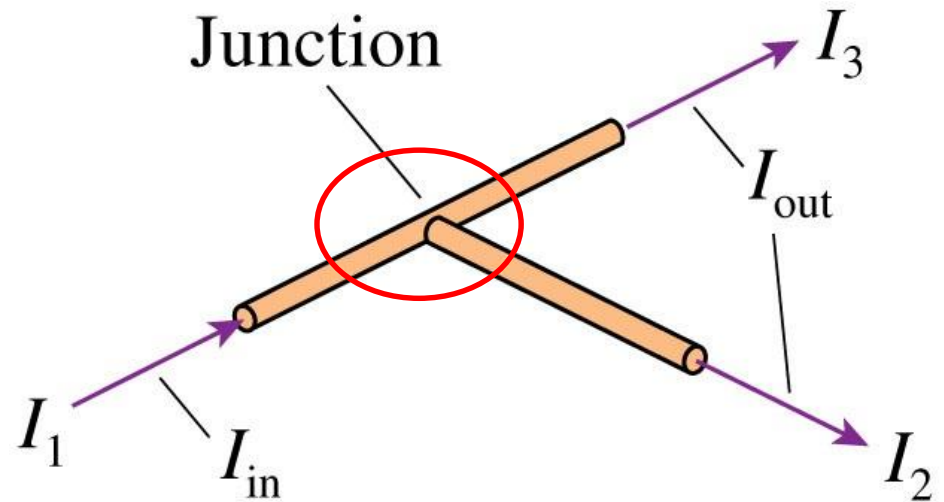
# The Basic Laws: Kirchoff's Laws

To solve any circuit, we need only two basic laws – which we already know: the **Kirchoff Loop and Junction Laws**. (Note that in all that we do in Chapter 28, we will use the Conventional Current, I)

## Kirchoff Junction Law\*:

At any junction:

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$



$$\text{Junction law: } I_1 = I_2 + I_3$$

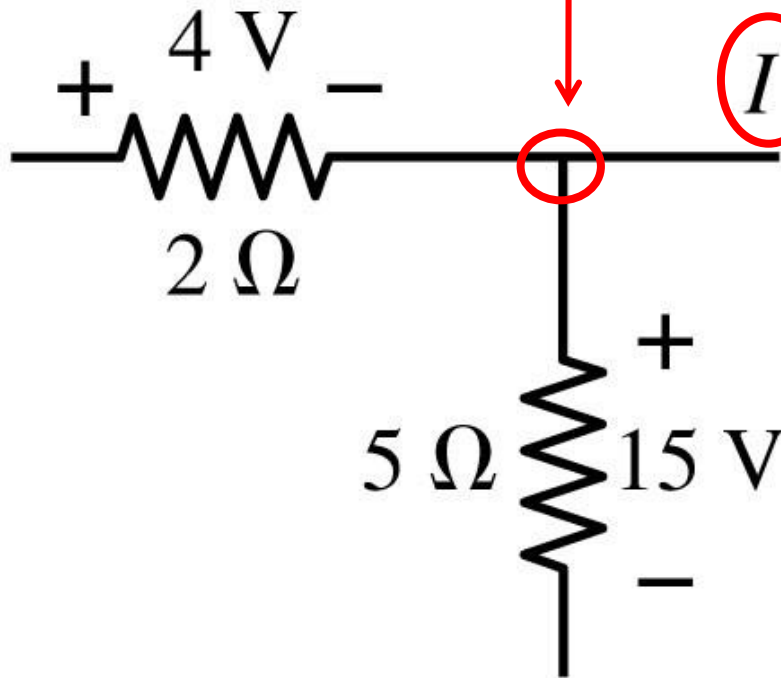
\*This is just really just the Conservation of Current

# Whiteboard Problem: 28-1

In the figure below, a piece of a circuit is shown.

(a) what is the magnitude of the current,  $I$ , in the wire to the right of the junction (LC)?

(b) Does the current,  $I$ , flow to the right or to the left (LC)?



Hint: current flows from high to low potential across a resistor, so we know the directions of those currents. But what about the unknown current,  $I$ ?

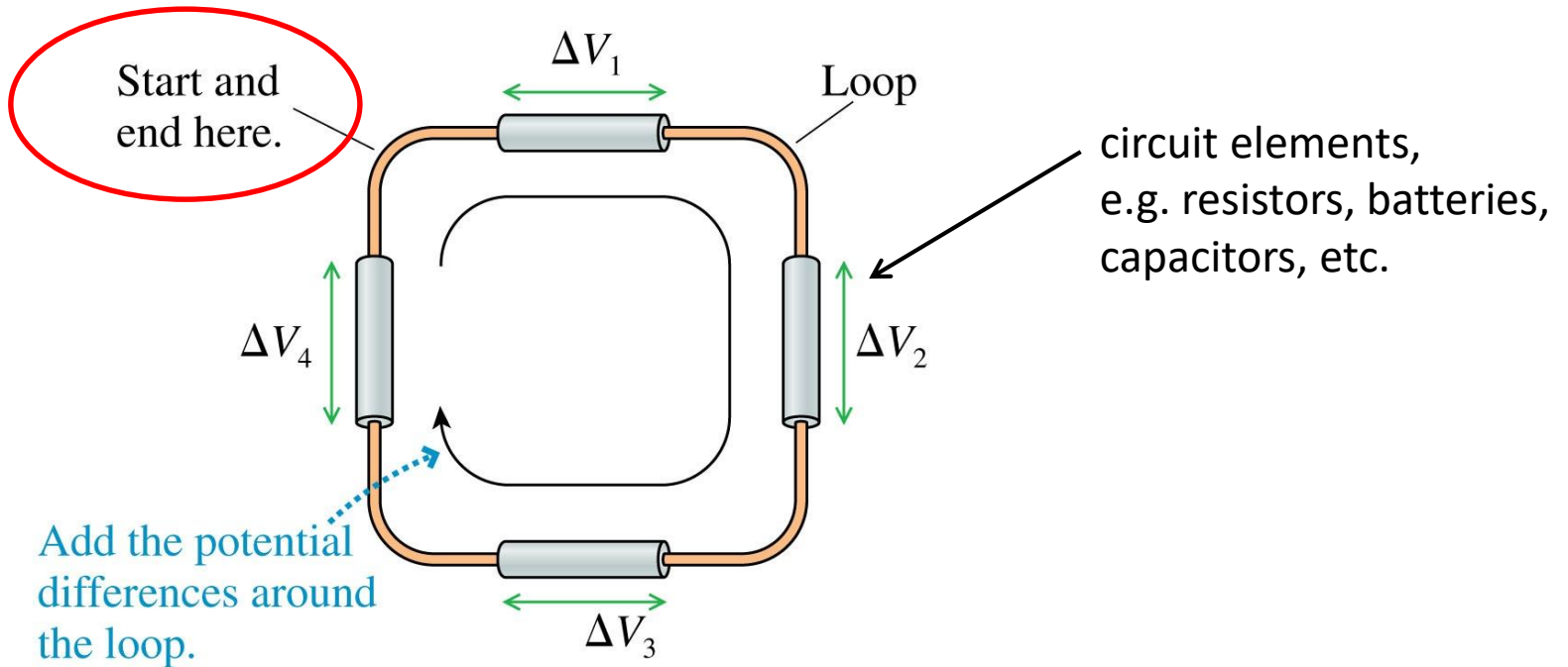
Hint: assume whatever direction you want for the current  $I$ , and calculate it with the Junction Law.

If your answer is positive, you chose the correct direction; if your answer is negative, the magnitude is correct, but the direction is opposite of your choice.

# The Basic Laws: Kirchoff's Laws

**Kirchoff Loop Law\***: For any closed circuit loop:

$$\sum_{\text{around loop}} (\text{changes in potential}) = 0$$



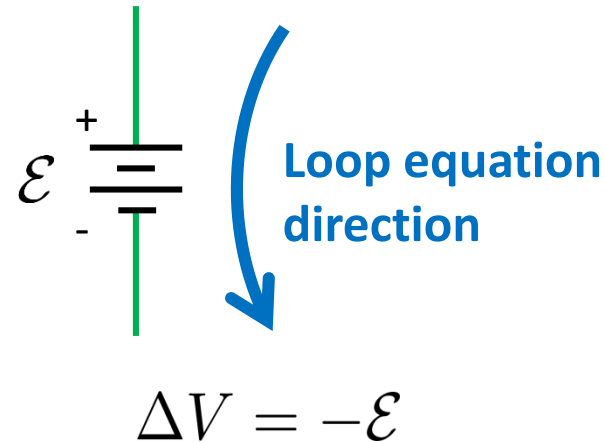
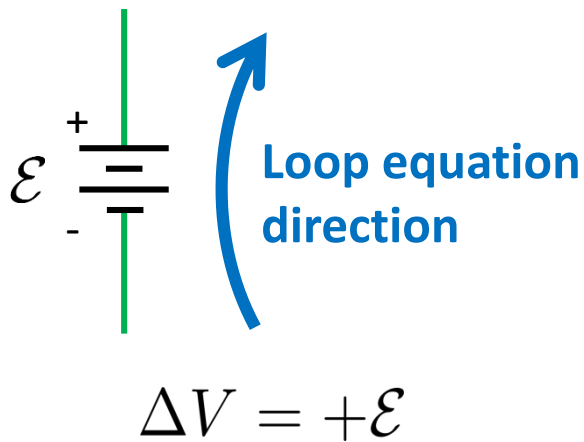
$$\text{Loop law: } \Delta V_1 + \Delta V_2 + \Delta V_3 + \Delta V_4 = 0$$

\*this is a consequence of energy conservation

# Sign Conventions with the Loop Law

When writing loop equations for a circuit, it is **very important** to follow the the proper sign conventions for potential changes:

## Across a Battery or Source of EMF:

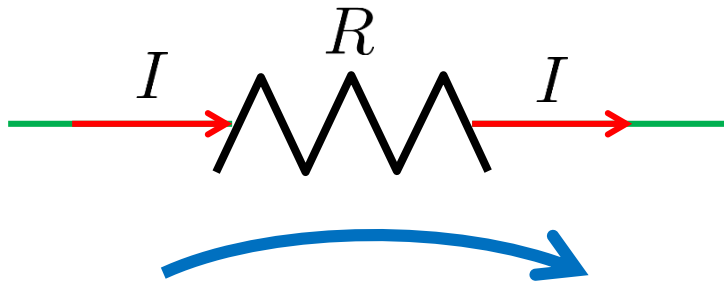


Here's what's on your equation sheet:

$$\Delta V = \pm \mathcal{E} \left( \begin{array}{l} \text{from } - \rightarrow + \\ \text{from } + \rightarrow - \end{array} \right)$$

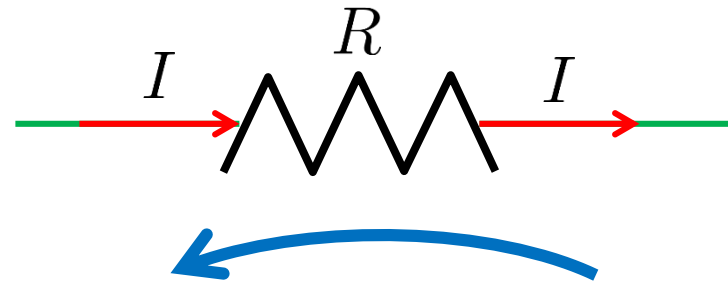
# Sign Conventions with the Loop Law

## Across a Resistor:



loop equation direction  
with the current

$$\Delta V = -IR$$



loop equation direction  
against the current

$$\Delta V = +IR$$

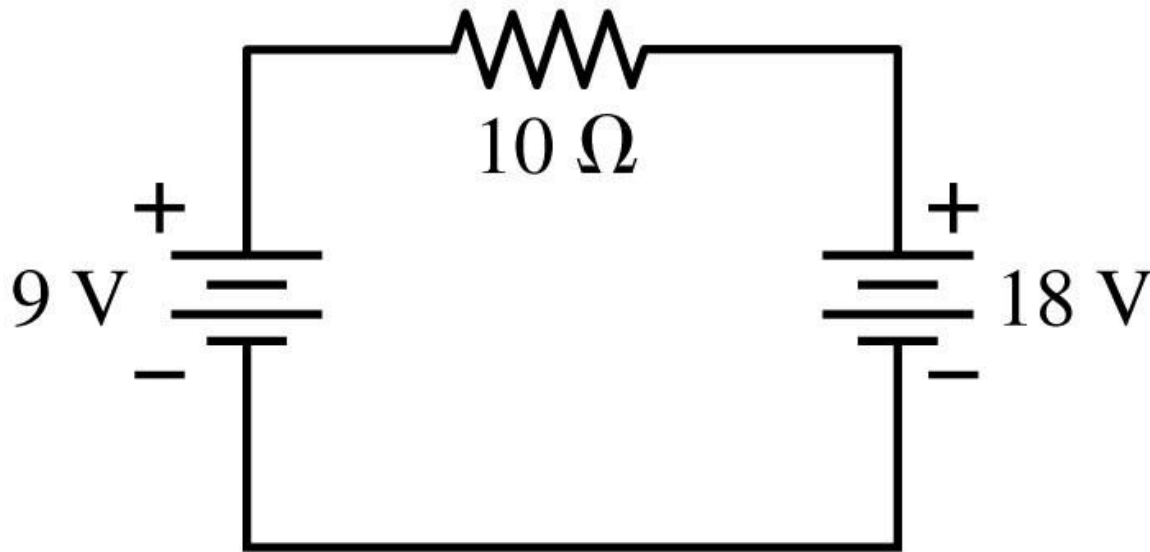
Here's what's on your equation sheet:

$$\Delta V = \mp IR \left( \begin{array}{l} \text{with } I \\ \text{against } I \end{array} \right)$$

## Whiteboard Problem 28-2

What is the magnitude (part a LC) and direction (part b, CW or CCW) of the current in the 10 Ohm resistor?

CW = ClockWise; CCW = CounterClockWise

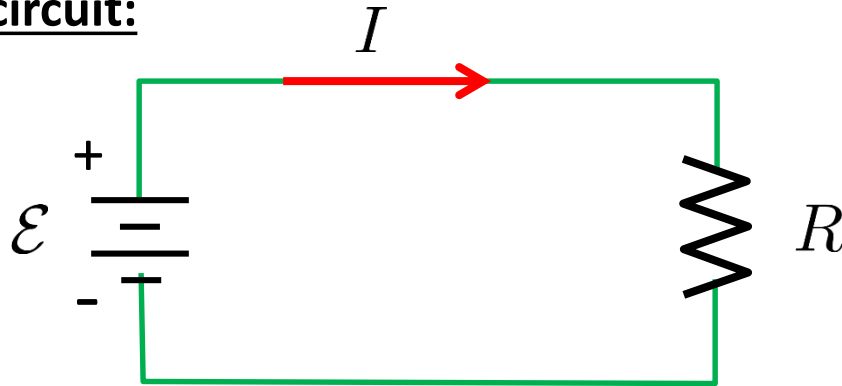


**Hint:** *assume whatever direction you want for the current, and calculate it.*

*If your answer is positive, you chose the correct direction; if your answer is negative, the magnitude is correct, but the direction is opposite of your choice.*

# Power in Circuits

For a simple circuit:



**Your author shows:**

Power supplied by the battery:

$$P_{\text{bat}} = I\mathcal{E}$$

Units = Watts

This energy is dissipated in the resistor into thermal energy:

$$P_R = I^2 R$$

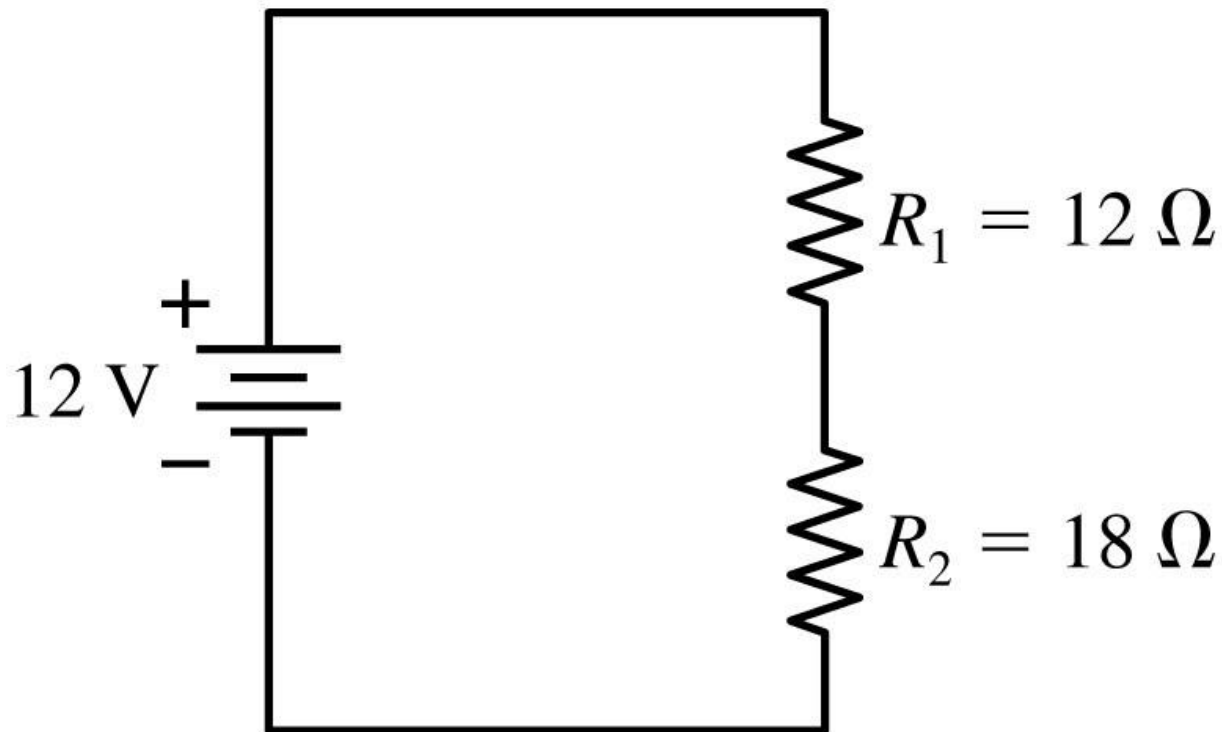
or using Ohm's Law:  $I = \Delta V/R$ :

$$P_R = \frac{(\Delta V)^2}{R} = I\Delta V$$

**Note:** for the resistor, the potential difference must be the potential across the resistor and the current is the current through the resistor.

## Whiteboard Problem: 28-3

For the circuit below, how much power is dissipated by each resistor? (LC, enter the power dissipated in  $R_2$ )



# Combinations of Resistors

Sometimes in a circuit, combinations of resistors can be combined into a **single equivalent resistor**.

**Resistors in Series** (*series means the same current*), e.g. for three resistors:



As shown in your text, these three resistors can be replaced by a **single equivalent resistor** where:



Where:

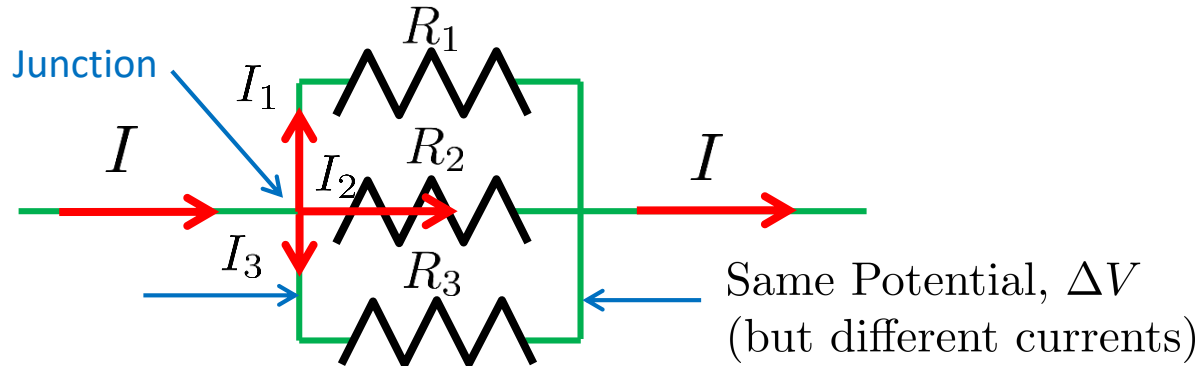
$$R = R_1 + R_2 + R_3$$

Note: for series, the equivalent resistance is always greater than any of the individual resistors *i.e.*  $R > \text{any } R_i$

**Also note:** we illustrated this for three resistors, but the formula holds for any number of resistors in series.

# Combinations of Resistors

**Resistors in Parallel** (*parallel means the same potential*), e.g. for three resistors:



As shown in your text, these three resistors can be replaced by a **single equivalent resistor** where:



Where:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

*be careful with this equation:*

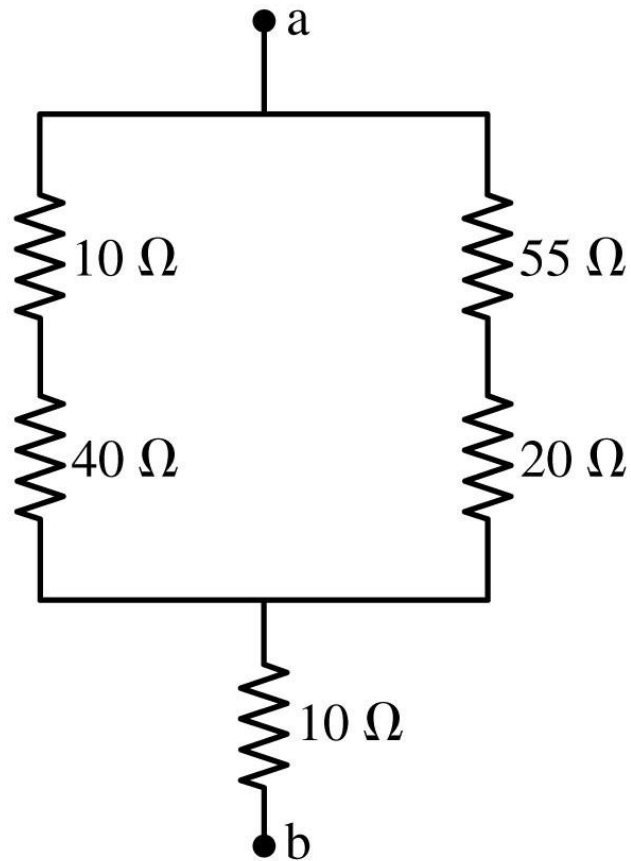
$$\text{e.g. } \frac{1}{2} + \frac{1}{3} \neq \frac{2}{5} !$$

Note: for parallel, the equivalent resistance is always less than any of the individual resistors *i.e.*  $R < \text{any } R_i$

**Also note:** we illustrated this for three resistors, but the formula holds for any number of resistors in parallel.

## Whiteboard Problem: 28-4

What is the equivalent resistance between points a and b in the segment of circuit shown below? (LC)



# Whiteboard Demo Problem: 28-5

Incandescent light bulbs are just resistors that heat and emit light when a current runs through them. The emitted power is  $P = I^2R$ , where  $I$  is the current through the bulb with resistance  $R$ .

Here, we will observe the brightness of a single bulb connected to a battery. Then we will predict and observe the brightness of the bulb when connected in series with an identical bulb. Then, we will do the same for parallel.

## Part 1: Prediction and Observation:

- Observe brightness of a single bulb.
- Predict (LC) the brightness of a single bulb in series. Observe (LC).
- Predict (LC) the brightness of a single bulb in parallel. Observe (LC).

## Part 2: Show what the actual brightness change is by analyzing the circuits:

- Watch, I'll show that for a single bulb, the emitted power is  $P_1 = \mathcal{E}^2/R$ .
- Find an expression, in terms of  $P_1$ , for the power emitted by one bulb connected in series with an identical bulb.(LC)
- Find an expression, in terms of  $P_1$ , for the power emitted by one bulb connected in parallel with an identical bulb.(LC)