Intro. to Circuits

- Charges create electric fields. (E)
  - Can be represented as field lines.

Come out of the (+) — Go into the (−)

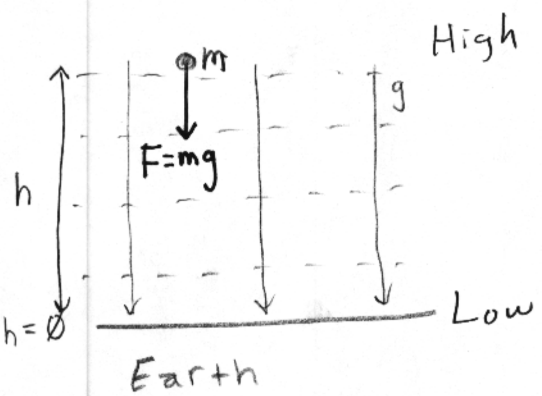
  - These fields represent the force a charge would experience if it was in the E-field.

These E-fields can form inside <u>wires</u> when a <u>potential difference</u> is applied.

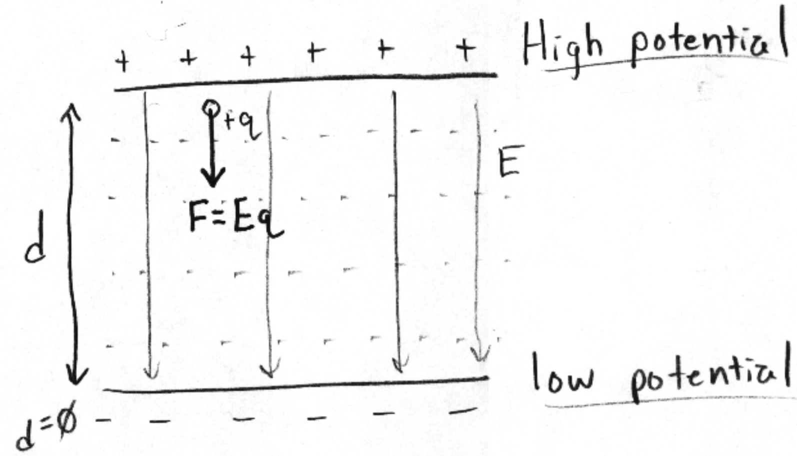
What is this?

<u>Analogy to height in a gravity field!</u>

$W = F \cdot d = -\Delta U_g$



$\Rightarrow$



$U_g = \cancel{mg}\, h$

$U_e = E\cancel{q}\, d$

$\Delta V = E \cdot d$

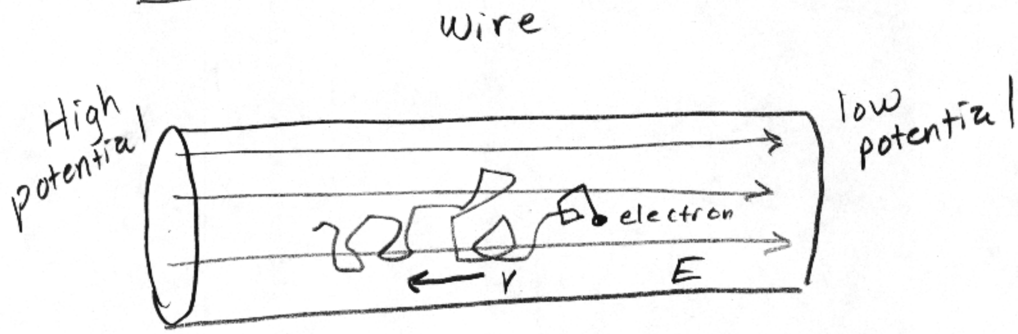
ΔV = potential difference also called <u>voltage</u>!

(ΔV) potential difference is provided by a voltage source. (batteries, generators, cells)

The potential difference causes an EMF, electromotive force, which drives the flow of charge.

EMF - is not really a force, it's the work done per unit charge.

Electric Current



When a potential difference is applied to a conductive wire, an E-field forms inside at the speed of light.

- The charges (electrons) do not move this fast.
- They simply have a net movement through the E-field.

Current

- The amount of charge passing a cross-sectional area in a given amount of time.

$$\boxed{I_{avg} = \frac{\Delta Q}{\Delta t}}$$

I = current

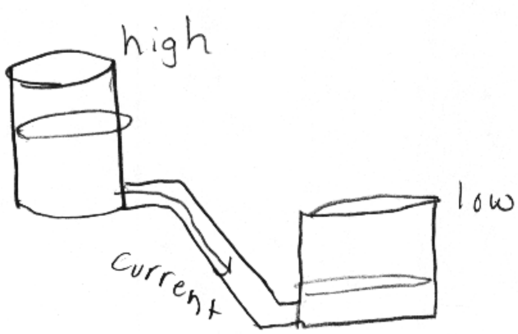
units: $\frac{C}{s}$ = Ampere (Amps)

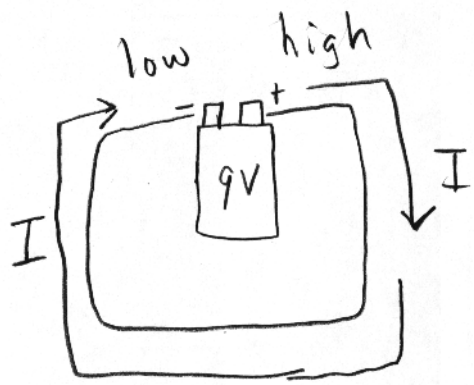
- So why do we say current flows from positive (high V) to negative (low V) terminals of a battery?
- Electrons really go from (low V) to (high V)
- However, <u>conventional current</u>, was established prior to the discovery of electrons!

★ We will use <u>conventional current</u>

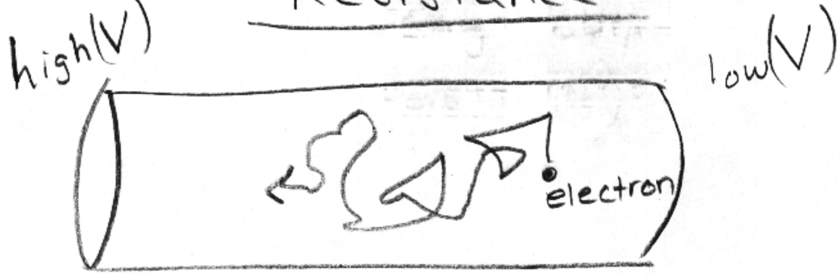
- Current (I) will flow from (+) high to (−) low

Current is like flowing water.





Resistance



Why does the electron move so eratically?

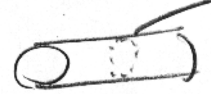
All material have some resistance. It is determined by the wire.

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

ρ = resistivity constant (varies based on material)

l = length

A = cross-sectional area $A = \pi r^2$



- units of resistance are based on Ohm's Law

Ohm's Law

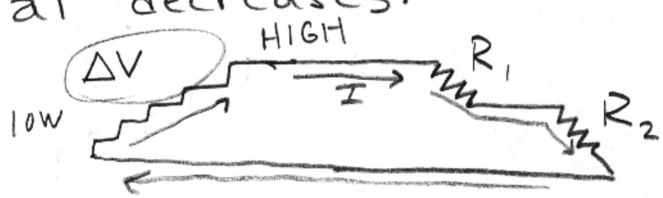
$$I = \frac{\Delta V}{R}$$

unit for resistance

$$R = \frac{\Delta V}{I} = \frac{\text{Volts}}{A} = \Omega \text{ (ohm's)}$$

☆ Resistors are appliances that often do work.

- When work is done by the resistor the potential decreases.



Power and Energy

- Many electrical devices are rated by the amount of power they use.

Power (Watts)

$\boxed{P = I\Delta V}$ = Amps • Volts = Watts

Apply Ohm's law to derive...

$I = \frac{\Delta V}{R}$

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

$\Delta V = I \cdot R$

$$P = I \cdot IR = I^2 R$$

3 ways to find Power

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

★ Energy dissapated by appliance

$P = \frac{W}{t}$ W = Energy in action

$P = \frac{E}{t}$ $\boxed{E = Pt = I\Delta V \cdot t}$

Circuit Analysis

- We use circuit analysis to find information about a circuits components.

Ohm's Law is our key

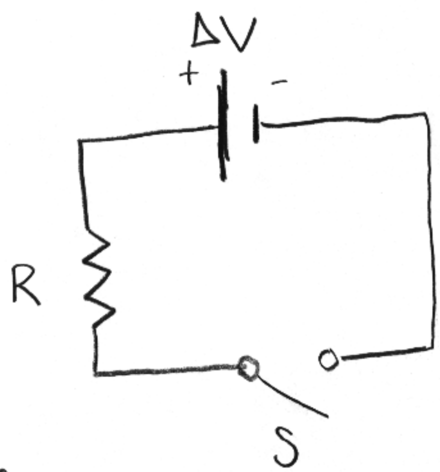
$$I = \frac{\Delta V}{R}$$

Schematic symbols for circuits

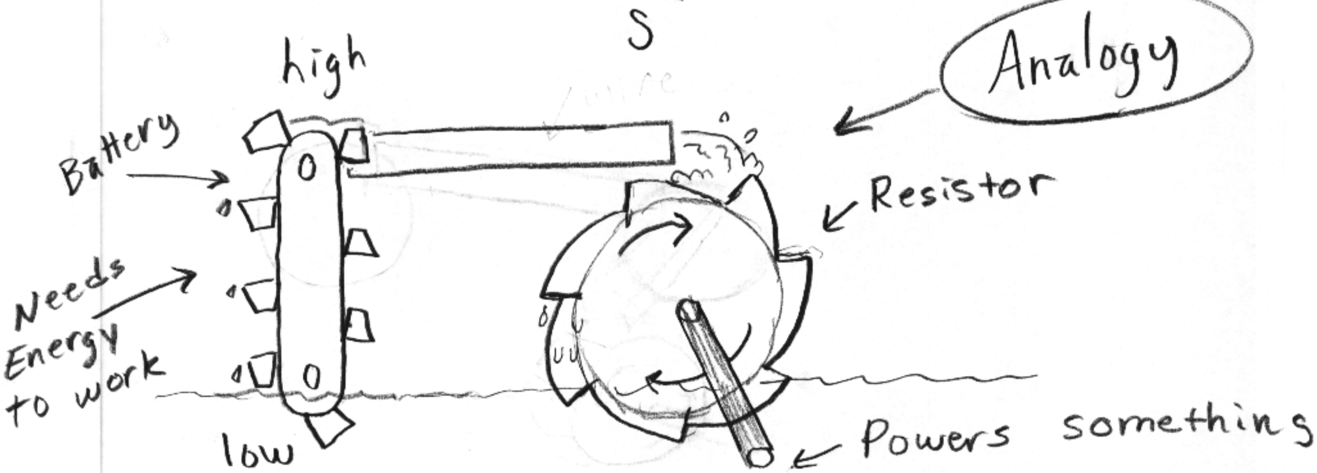
Battery 

Resistor  . Lightbulb 

Switch 



Basic circuit

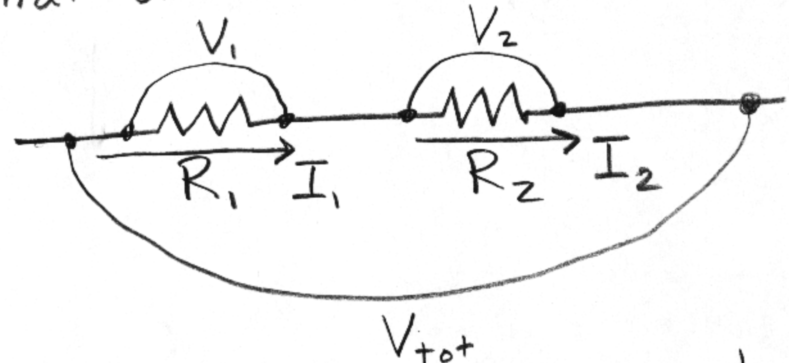


Combining Resistors

2 ways to combine

Series

- wired one after another
- same current must go through every resistor
- Potential difference is different across each resistor



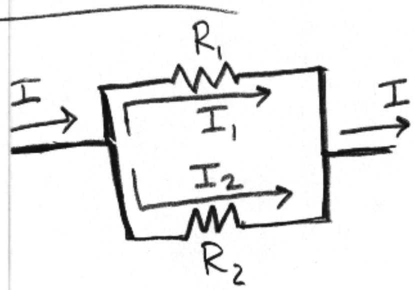
$$I_1 = I_2$$

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

- The combined resistance, equivalent resistance, is...

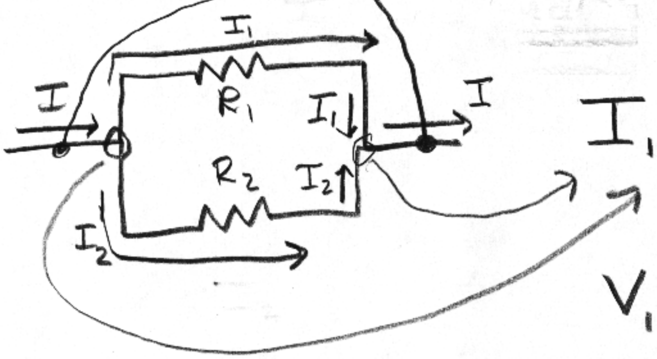
$$R_{eq} = R_1 + R_2 \ldots \qquad \boxed{R_{eq} = \sum R_i}$$

Parallel



- wired on different paths
- current is different across each resistor
- Potential difference is same across both resistors

Parallel V



$$I_1 + I_2 = I$$

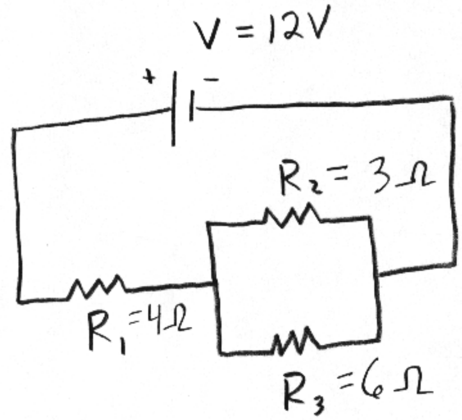
$$V_1 = V_2$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \cdots$$

$$\boxed{\frac{1}{R_{eq}} = \sum \frac{1}{R_i}}$$

So lets use this.

Ex 1:

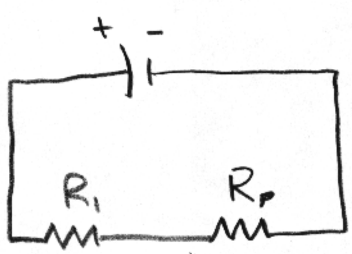


a) Find equivalent resistance of circuit.

- First, find R_{eq} of the resistors in parallel

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6} = \frac{1}{2}$$

$$\frac{1}{R_p} = \frac{1}{2} \qquad \underline{R_p = 2\Omega}$$



- Now, find the R_{eq} of them in series.

$$R_{eq} = R_1 + R_p = 4 + 2$$

$$\boxed{R_{eq} = 6\,\Omega}$$ ← This is for the total circuit

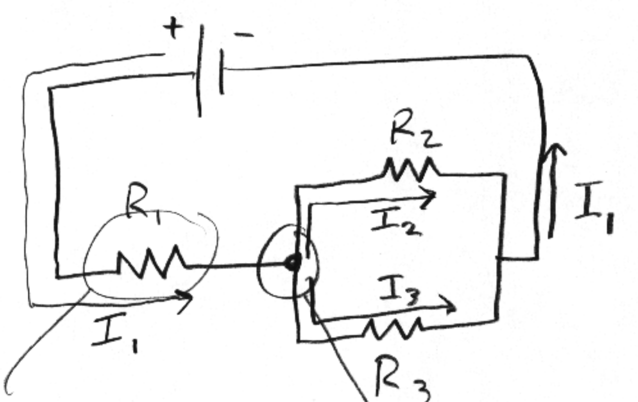
b) Find the total current.

$R_{eq} = 6\,\Omega$ $\qquad \Delta V = 12\,V$

Ohm's Law

$$I = \frac{\Delta V}{R} = \frac{12\,V}{6\,\Omega} = \boxed{2A}$$

c) Find the current flowing through each resistor.



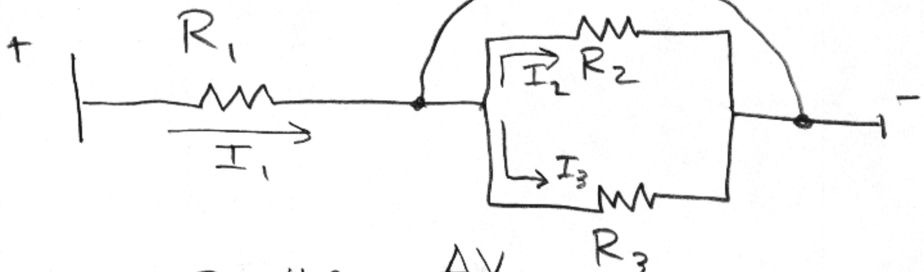
total current must pass through R_1

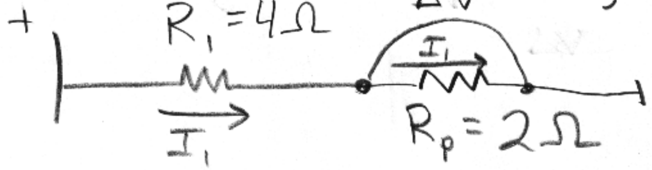
$$\boxed{I_1 = 2A}$$

Current splits at the junction (need ohm's law)

$$I_2 = \frac{\Delta V}{R_2}$$ ← we need the voltage

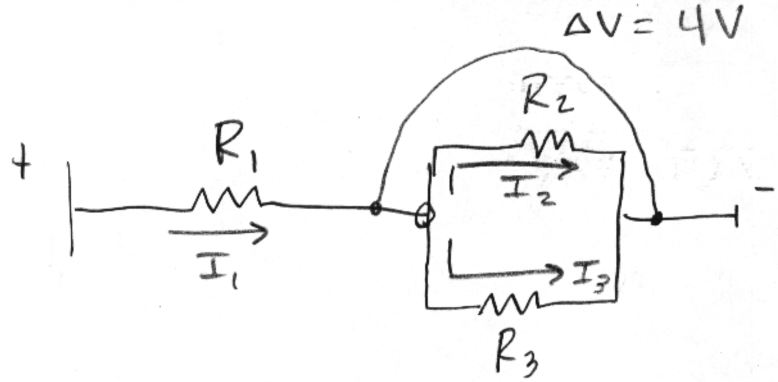
ΔV - the drop can only be found with R_p





← since the current through is now just I_1

$$\Delta V = I_1 R_p = 2A \cdot 2\,\Omega = 4V$$



Resistors in parallel share potential difference

$$I_2 = \frac{\Delta V}{R_2} = \frac{4V}{3\Omega} = \boxed{1.33A}$$

For I_3 we could use $I_3 = \frac{\Delta V}{R_3} = \frac{4V}{6\Omega} = \boxed{0.66A}$

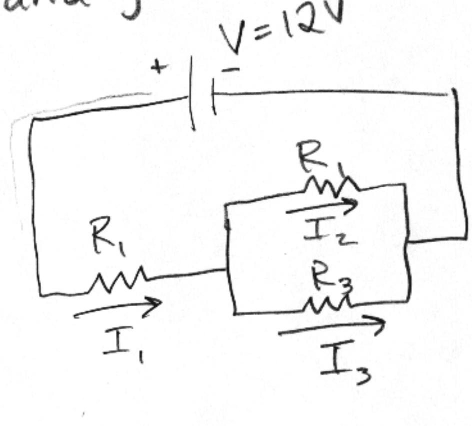
★ or we could use the junction rule

$$I_1 = I_2 + I_3$$

$$I_3 = I_1 - I_2 = 2A - 1.33A = \boxed{0.66A}$$

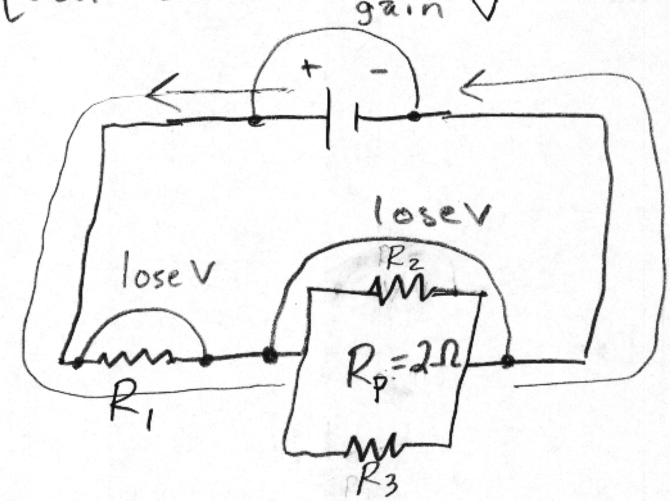
- The Junction Rule states that the current going into a junction will equal the current coming out.

Finally, lets analyze the entire situation,



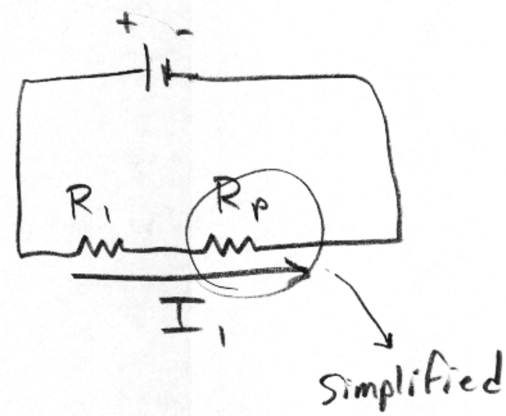
Kirchhoff's loop rule will help us check our work.

- It states that the sum of potential drops and gains around any circuit loop will equal zero.



Ohm's Law

$\Delta V = IR$



$$V - I_1 R_1 - I_1 R_p = \emptyset$$

$$12\,V - (2A \cdot 4\Omega) - (2A \cdot 2\Omega) = \emptyset$$

$$12 - 8 - 4 = \emptyset$$

✓ Nice