# NOTES FOR SEPTEMBER 10

## Series and Parallel Resistors

First, let's have a **summary** of the types of quantities so far introduced, and then we will derive two new results.

| Quantity | Usual Variable Name | Standard Unit | Unit Abbreviation |
|---|---|---|---|
| Charge | $Q$ | Coulomb | C |
| Current | $I$ | Ampere | A |
| Energy | $E$ | Joule | J |
| Power | $P$ | Watt | W |
| Electrical Potential | $V$ | Volt | V |
| Resistance | $R$ | Ohm | $\Omega$ |

Charge, like mass, cannot be created or destroyed. Because like charges repel, charge never piles up. In other words, all almost circuit elements are neutral, even batteries.

Resistors have a linear I-V curve. The resistance of a resistor, R, is the slope of the line, so

$$V = IR$$

Before leaving the summary, let's also get all the jargon on the table:

| Term | Synonyms or Jargon |
|---|---|
| Current | Sometimes called "amperage" |
| Electrical Potential | Usually just "potential"<br>Very often called "voltage" |
| Power | often called "wattage" |
| Ampere | often shortened to "Amp" |

## Fundamental formulas

definitions are written with $\equiv$

$$V \equiv \frac{E}{Q}$$ ($E$ ← energy, $Q$ ← charge)

Definition of electrical potential

$$P \equiv \frac{E}{t}$$ ($E$ ← Energy, $t$ ← time)

Definition of power

$$I \equiv \frac{Q}{t}$$ ($Q$ ← charge, $t$ ← time)

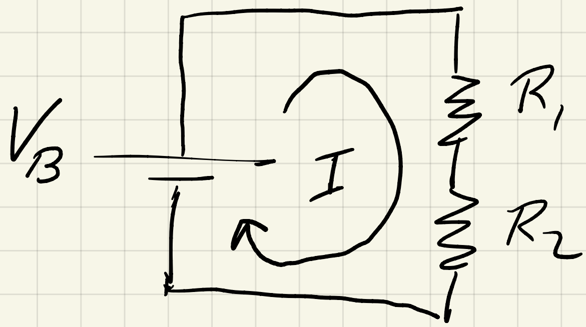
Definition of current

The formula $V = IR$ is extremely important, but it is a property of an ideal resistor. Real resistors are so close to ideal, this formula is known as "Ohm's Law."

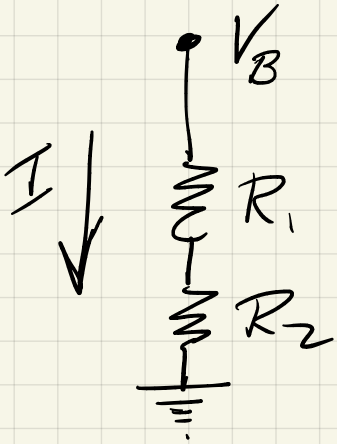
That's the summary. Onward to two new results....

# 1. Resistors in Series

Consider this circuit:

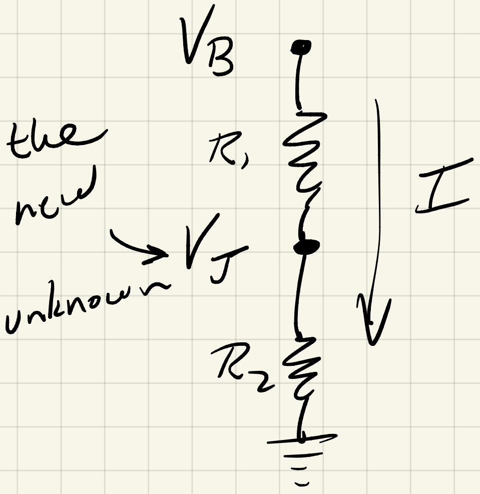



Or equivalently:




If $V_B$ (the voltage of the battery) and $R_1$ and $R_2$ are known, what is $I$?

The trick is to label one more unknown:




$V_J$ is the voltage on the wire connecting the two resistors. The voltage drop across $R_1$ is $V_B - V_J$ and this must be $IR_1$ by Ohm's Law

The voltage drop across $R_2$ is $V_J - 0 = V_J$ and this must be $IR_2$ (again by Ohm's Law)

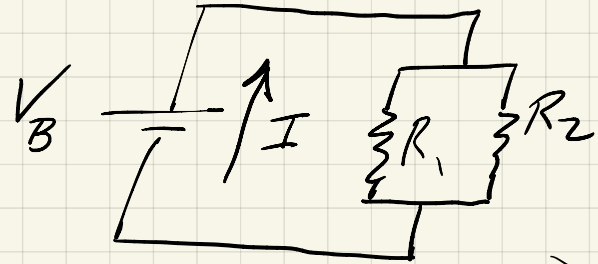
$$\left.\begin{aligned} V_B - V_J &= IR_1 \\ V_J &= IR_2 \end{aligned}\right\} \text{ ADD THESE EQUATIONS TO GET } V_B - \cancel{V_J} + \cancel{V_J} = IR_1 + IR_2$$

$$V_B = I(R_1 + R_2)$$ ← Resistors in series add

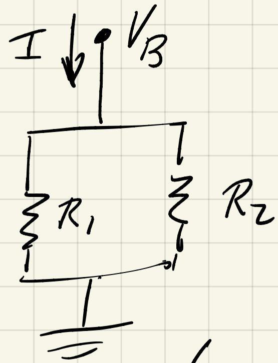
$V = IR_{Series}$ $\quad R_{Series} = R_1 + R_2$

# 2. Resistors in Parallel

Consider this circuit:

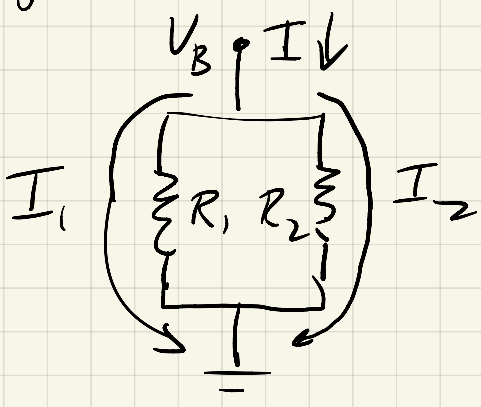



Or equivalently:




If $V_B$, $R_1$, and $R_2$ are known, what is $I$?

Again the trick is to label some unknowns:




$I_1$ is the current flowing through $R_1$

$I_2$ is the current flowing through $R_2$

The total current going from the battery to ground divides up and goes through the two resistors:

$$I = I_1 + I_2$$

By Ohm's Law for $R_1$: $V_B = I_1 R_1$ or $I_1 = \frac{V_B}{R_1}$

By Ohm's Law for $R_2$: $V_B = I_2 R_2$ or $I_2 = \frac{V_B}{R_2}$

So $$I = \frac{V_B}{R_1} + \frac{V_B}{R_2} = V_B\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Or $V_B = I R_{Parallel}$ where $R_{Parallel} = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$ ← The weird result for resistors <u>in</u> <u>parallel</u>