Review of DC Circuit Analysis

EAS 199A Notes

Overview

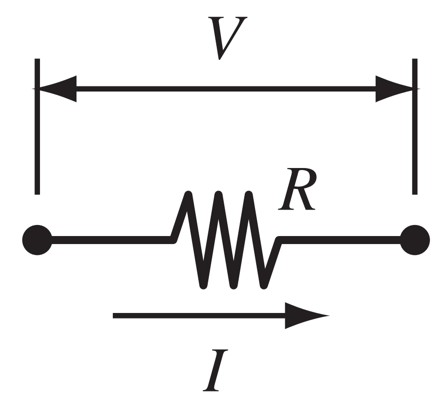
1. Ohm's Law
2. Power dissipation
3. Resisters in series
4. Resistors in parallel

Ohm's Law (1)

$$V = IR$$

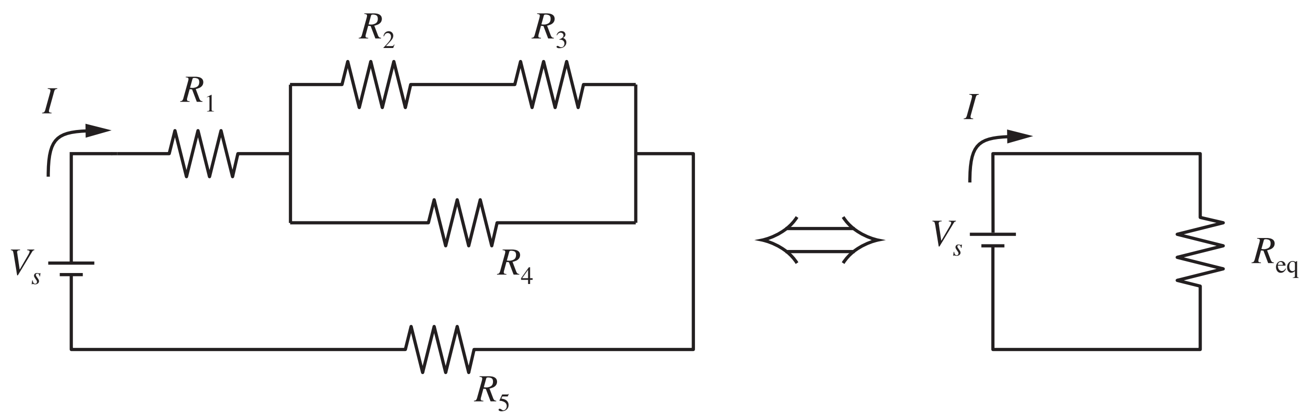
where

$$V = \text{voltage drop across the resistor (V)}$$
$$I = \text{current } \textit{through} \text{ the resistor (A)}$$
$$R = \text{resistance } (\Omega)$$



Ohm's Law (2)

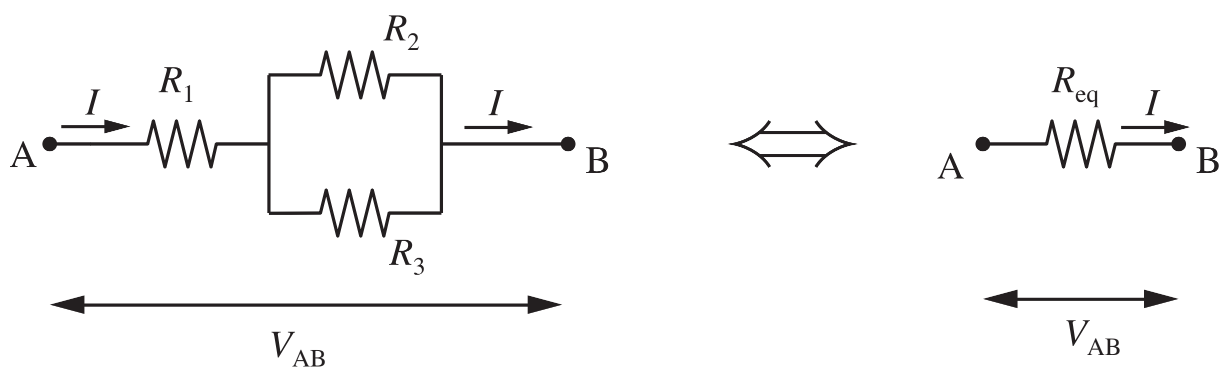
Complex arrangements of resistors can be reduced to an equivalent resistance, R_{eq}, and then Ohm's law can be applied to the equivalent circuit.



$$R_{\text{eq}} = R_1 + \frac{1}{\frac{1}{R_2+R_3} + \frac{1}{R_4}} + R_5 \qquad\qquad V_s = I R_{\text{eq}}$$

Ohm's Law (3)

Ohm's law can be applied to any continuous segment of a circuit.



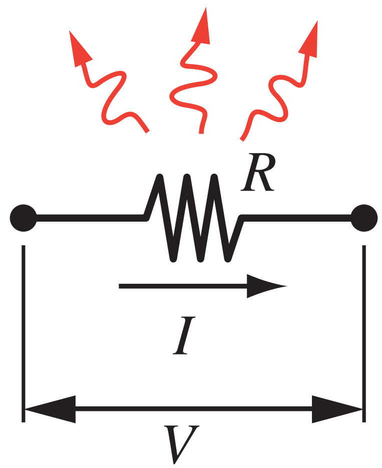
Ohm's law *cannot* be applied to LEDs, capacitors, inductors.

Ohm's law can only be applied to devices that act like simple resistors: e.g., simple resistors, incadenscent light bulbs, and long lengths of wire.

Power Dissipation (1)

When electrical current flows through resistor, electrical power is dissipated.

$$P = VI$$



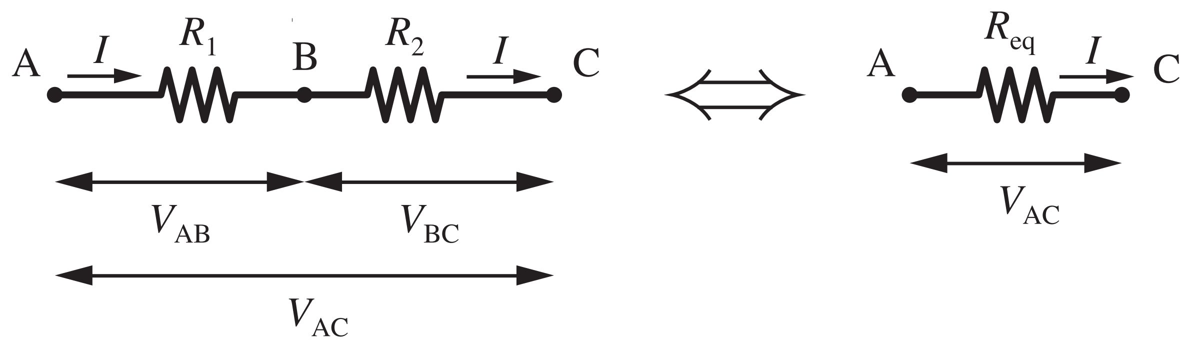
Power Dissipation (2)

Power dissipation can be computed from one of three formulas

$$P = VI \qquad P = I^2 R \qquad P = \frac{V^2}{R}$$

In each case, the V, I, and R refer to the values *for the circuit element under consideration*

Resistors in Series



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

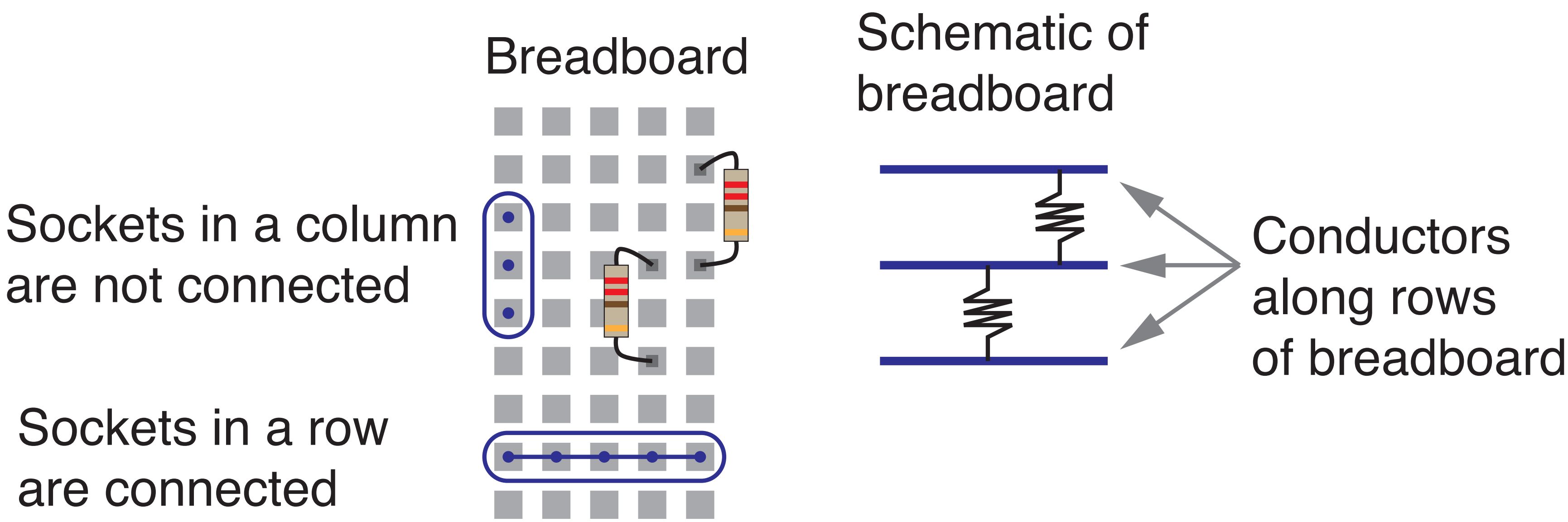
Kirchoff's voltage law tells us that the voltages across the resistors adds:

$$V_{\mathrm{AC}} = V_{\mathrm{AB}} + V_{\mathrm{BC}}$$

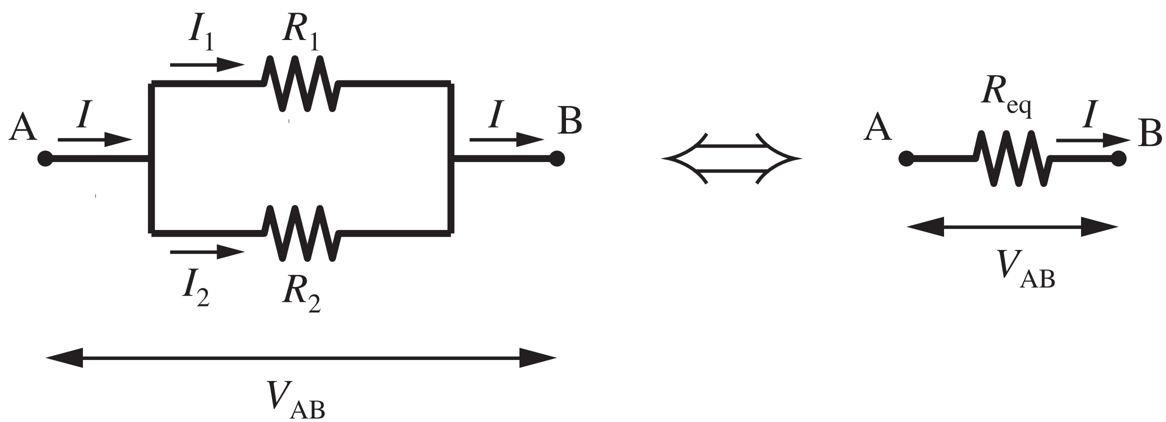
Kirchoff's current law tells us that the current through the resistors is the same:

$$I_1 = I_2$$

Resistors in Series on a Breadboard



Resistors in Parallel



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

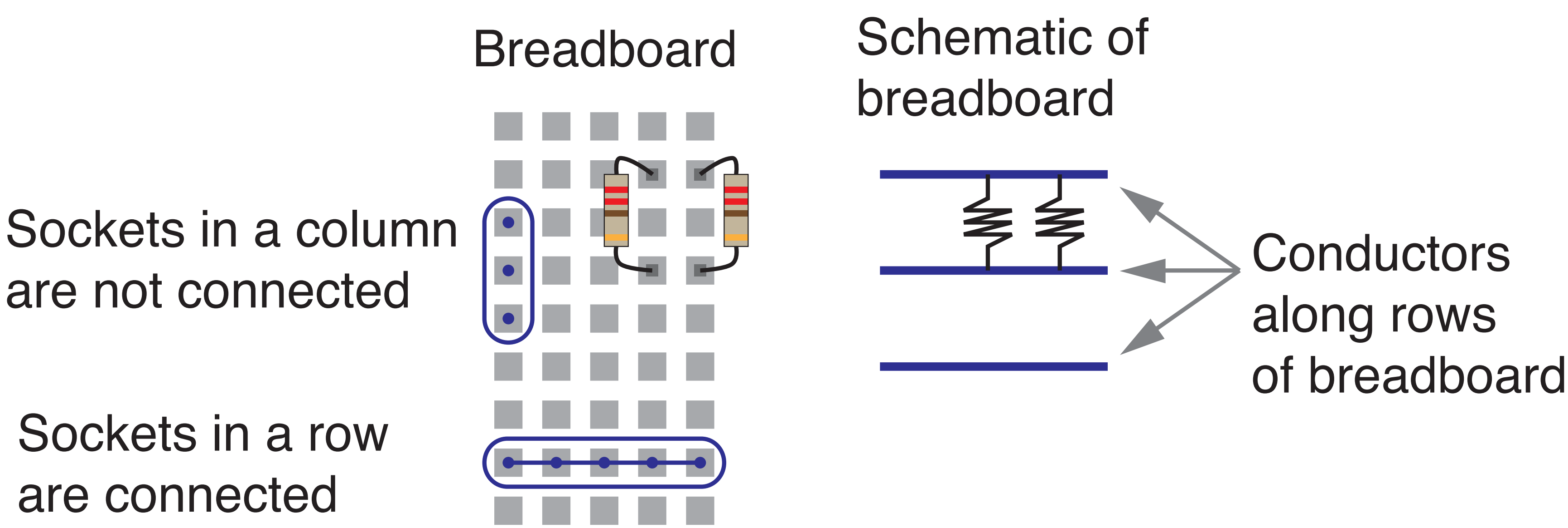
Kirchoff's voltage law tells us that the voltages across the resistors is the same

$$V_1 = V_2 = V_{\mathrm{AB}}$$

Kirchoff's current law tells us that the current through the resistors adds:

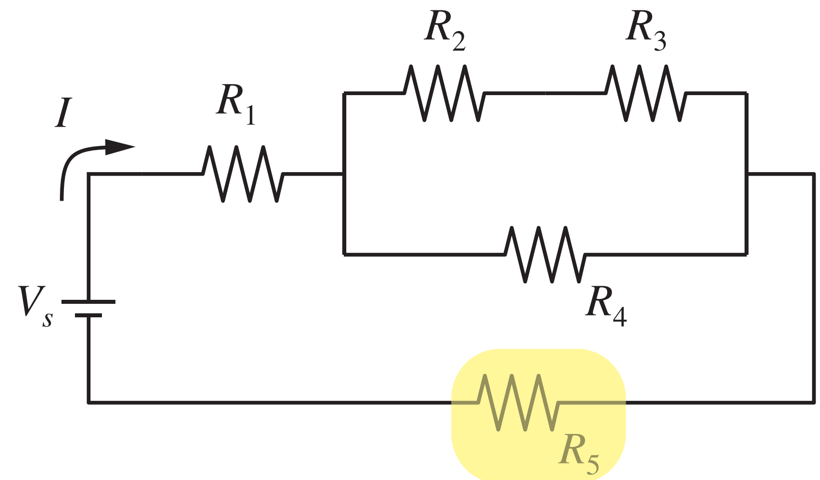
$$I = I_1 + I_2$$

Resistors in Parallel on a Breadboard



Example: Power dissipation for one resistor in a circuit (1)

What power is dissipated by R_5 in the circuit to the right? What is the *total* power dissipation of the circuit? Use the following system parameters.



$$V_s = 10\,\mathrm{V}$$

$$R_1 = R_4 = 470\,\Omega$$

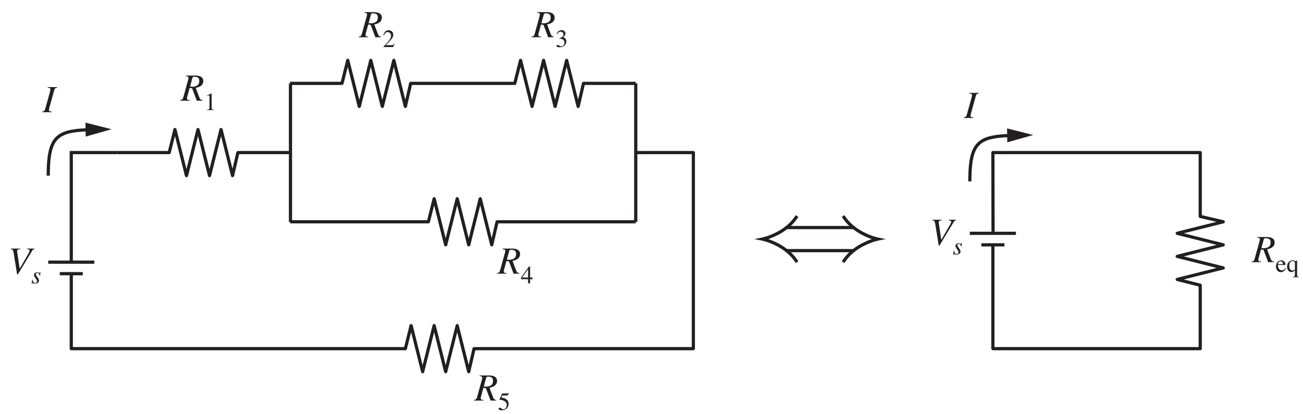
$$R_2 = R_3 = R_5 = 330\,\Omega$$

The power is $P_5 = V_5 I_5$, but neither V_5 nor I_5 is known.

Use the alterative formula $P_5 = I_5^2 R_5$. Since R_5 is known, the first step is to determine the current I_5. Note that the current through R_5 is the same as the total current leaving the battery, i.e., $I_5 = I$.

Example: Power dissipation for one resistor in a circuit (2)

Solution Step 1: Replace the resistor network with a single equivalent resistor.



$$R_{\mathrm{eq}} = R_1 + \frac{1}{\frac{1}{R_2+R_3} + \frac{1}{R_4}} + R_5 \qquad V_s = I R_{\mathrm{eq}}$$

Example: Power dissipation for one resistor in a circuit (3)

Solution Step 2: Substitute the known values to compute $R_{\rm eq}$.

$$R_{\rm eq} = R_1 + \frac{1}{\frac{1}{R_2+R_3} + \frac{1}{R_4}} + R_5$$

$$= 470\,\Omega + \frac{1}{\frac{1}{330+330\,\Omega} + \frac{1}{470\,\Omega}} + 330\,\Omega$$

$$= 1074.5\,\Omega$$

Solution Step 3: Apply Ohm's law to the equivalent circuit to compute the total current, I.

$$V_s = I R_{\rm eq} \implies I = \frac{V_s}{R_{\rm eq}} = \frac{10\,\mathrm{V}}{1074.5\,\Omega} = 0.00931\,\mathrm{A}$$

Example: Power dissipation for one resistor in a circuit (4)

Solution Step 4: Now that I is known, it is easy to calculate the power dissipated by R_5

$$P_5 = I_5^2 R_5 = (0.00931\,\mathrm{A})^2\,(330\,\Omega) = 0.0286\,\mathrm{W} = 28.6\,\mathrm{mW}$$

Solution Step 5: The total power dissipated in the entire circuit is

$$P_{\mathrm{total}} = V_s I = (10\,\mathrm{V})\,(0.00931\,\mathrm{A}) = 0.0931\,\mathrm{W} = 93.1\,\mathrm{mW}.$$

Of course, the power dissipated at R_5 must be less than the total power dissipated in the circuit.

$$P_5 = 28.6\,\mathrm{mW}, \quad P_{\mathrm{total}} = 93.1\,\mathrm{mW}, \quad \text{and} \quad P_5 < P_{\mathrm{total}} \quad \text{(as expected).}$$

Example: Power dissipation for one resistor in a circuit (5)

Practice: What is the power dissipated by R_2? *Answer:* 4.9 mW.