Kirchhoff's voltage law (KVL): Cont.

The sum of voltages around a closed loop is zero.

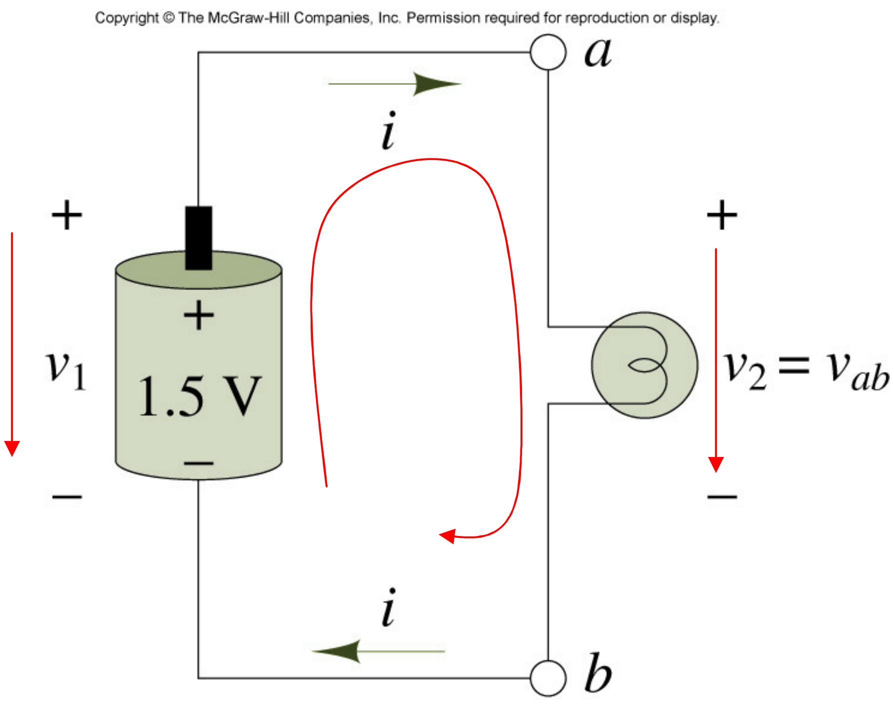


Illustration of Kirchhoff's voltage law: $v_1 = v_2$

$$-v_1 + v_2 = 0$$

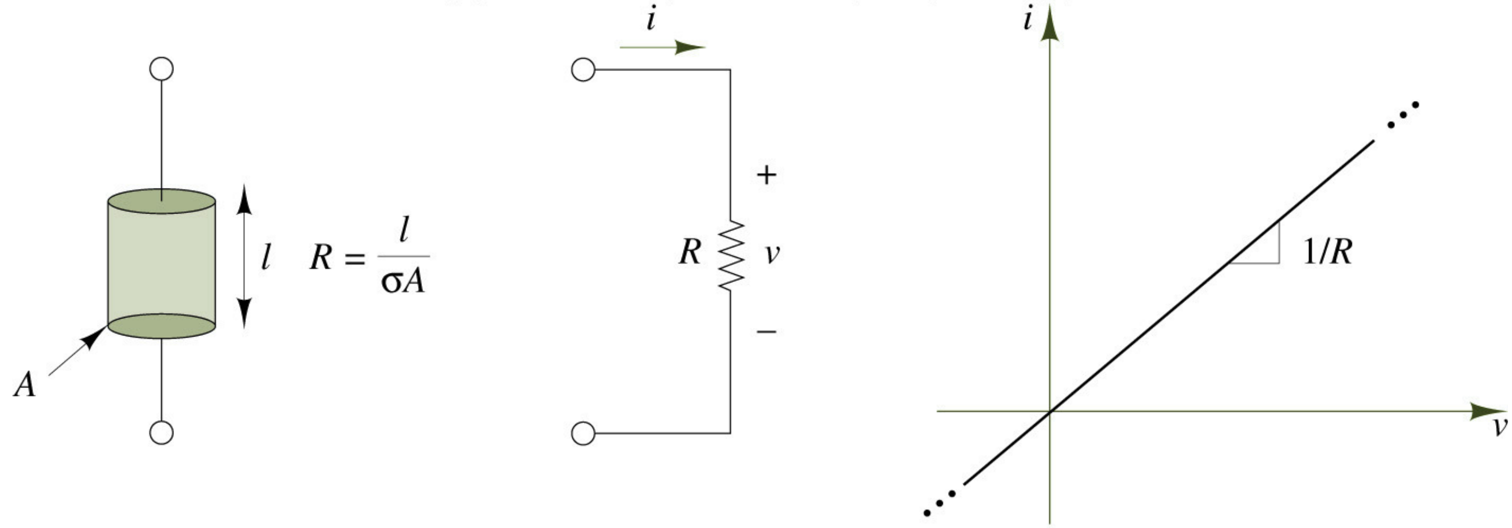
Voltage difference (V) vs. Voltage (V)

Voltage: at each node, v_a, v_b
Voltage difference: $v_2 = v_a - v_b$

Ground (point of zero voltage):
- true ground (earth)
- chassis ground (enclosure)

Class 2 (2/15F) Circuit Elements and Their *i*-*v* Characterisitcs

Resistance and Ohm's Law:



Physical resistors with resistance *R*. Typical materials are carbon, metal film.

Circuit symbol

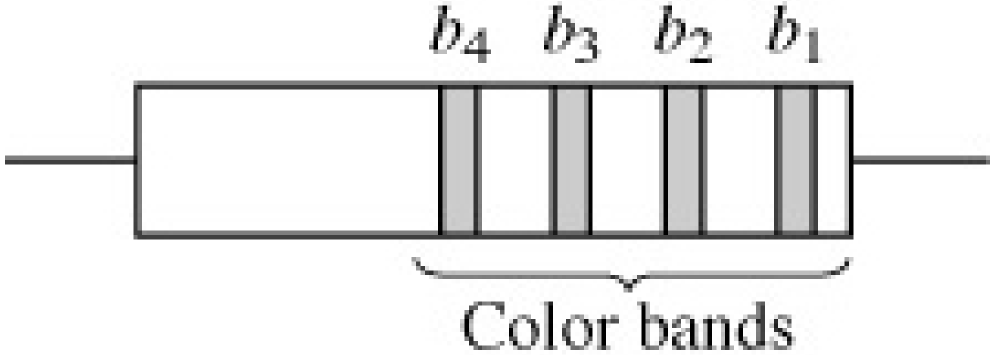
i-*v* characteristic

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

$$R = \rho \frac{L}{A} = \#\,\Omega \bullet \mathrm{m} \times \frac{\mathrm{m}}{\mathrm{m}^2} = \#\,\Omega$$

$$\sigma = \frac{1}{\rho}$$

Resistance (R) depends on materials and geometry, and resistivity (ρ) only depends on materials.



black	0	blue	6
brown	1	violet	7
red	2	gray	8
orange	3	white	9
yellow	4	silver	10%
green	5	gold	5%

Resistor value = $(b_1\, b_2) \times 10^{b_3}$;
b_4 = % tolerance in actual value

Table 2.3 Resistance of copper wire

AWG size	Number of strands	Diameter per strand (in)	Resistance per 1,000 ft (Ω)
24	Solid	0.0201	28.4
24	7	0.0080	28.4
22	Solid	0.0254	18.0
22	7	0.0100	19.0
20	Solid	0.0320	11.3
20	7	0.0126	11.9
18	Solid	0.0403	7.2
18	7	0.0159	7.5
16	Solid	0.0508	4.5
16	19	0.0113	4.7
14	Solid	0.0641	2.52
12	Solid	0.0808	1.62
10	Solid	0.1019	1.02
8	Solid	0.1285	0.64
6	Solid	0.1620	0.4
4	Solid	0.2043	0.25
2	Solid	0.2576	0.16

Electric Power

Electric power: moving charge → doing work (energy)

Power (P) = Work / time = work / charge x charge / time = V I

P = Joules / sec = Watts (W)

What are we paying for electricity bill ?

kW H = energy

More on Resistance

Home electric appliances: what does a 1000 W hair dryer tell you?

- Always assume 120V if the voltage is not specified.

$$P = iV \Rightarrow i = \frac{P}{V} = \frac{1000}{120} = 8.33\,(A)$$

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{120^2}{1000} = 14.4\,(\Omega)$$

- Never exceed the rated power.

- Can you use these appliances in 220 V lines.

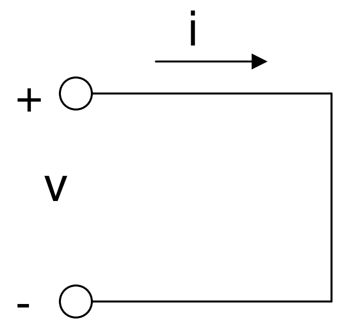
You destroy the appliance!

$$P = \frac{V^2}{R} = \frac{220^2}{14.4} = 3661\,(W)$$

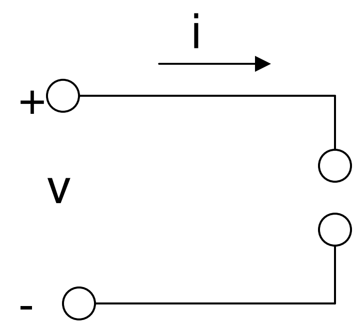
You can use appliances rated with 220V in 110 V, but with much lower power than rated. (Exercise)

Open and Short Circuits

- Short Circuit: R=0, v=0 for any i.
  - Particularly bad for voltage source.



- Open Circuit: $R \to \infty$, i=0 for any v.
  - Particularly bad for current source.



Series Resistors and the Voltage Divider Rule

- Series Circuit: One branch → same current through each resistor.

$$1.5V = v_1 + v_2 + v_3$$
$$= i_1R_1 + i_2R_2 + i_3R_3$$
$$= i(R_1 + R_2 + R_3)$$
$$i_1 = i_2 = i_3 = i$$

$$1.5V = iR_{EQ}$$
$$R_{EQ} = R_1 + R_2 + R_3$$

In general for N resistors in series :

$$R_{EQ} = \sum_{n=1}^{N} R_n, \quad i = i_1 = ... = \mathrm{i_N} \;, v = \sum_{n=1}^{N} v_n$$

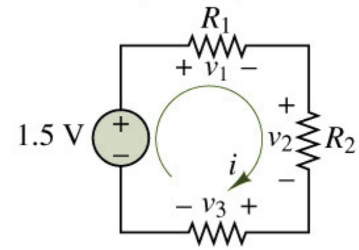
For a series resistors : $R_{\mathrm{EQ}} > (R_1, R_2, ...R_N)$

Voltage Divider:

$$v_1 = \frac{R_1}{R_{EQ}}(1.5V)$$

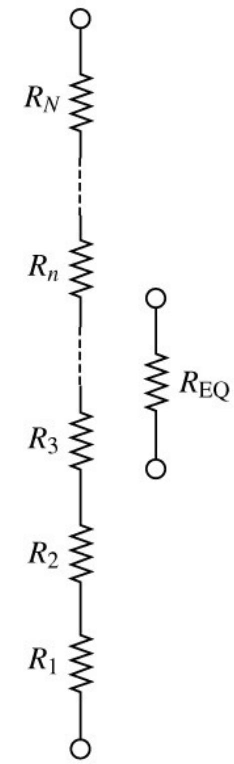
$$v_2 = \frac{R_2}{R_{EQ}}(1.5V)$$

$$v_3 = \frac{R_3}{R_{EQ}}(1.5V)$$



The current i flows through each of the four series elements. Thus, by KVL,

$$1.5 = v_1 + v_2 + v_3$$



N series resistors are equivalent to a single resistor equal to the sum of the individual resistances.