Direct

Current

Circuits

(Chapter 18, Sections 1-4)

A New Term ---- emf ($\mathcal{E}$)

Historical Note – (see text footnote, p. 594)

emf **originally meant**
"electromotive force."

As it is now used, *emf* **in not a force, but the abbreviation** *emf* **has remained in use.**
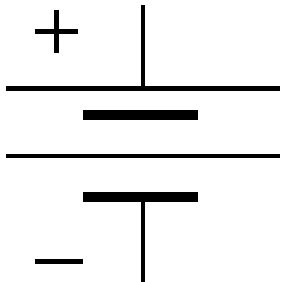
Sources of emf

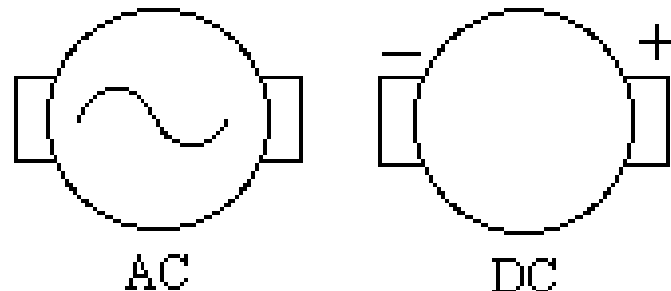A source that maintains the current in a closed circuit is called a source of *emf*. Devices that increase the potential energy of charges circulating in circuits are sources of emf.
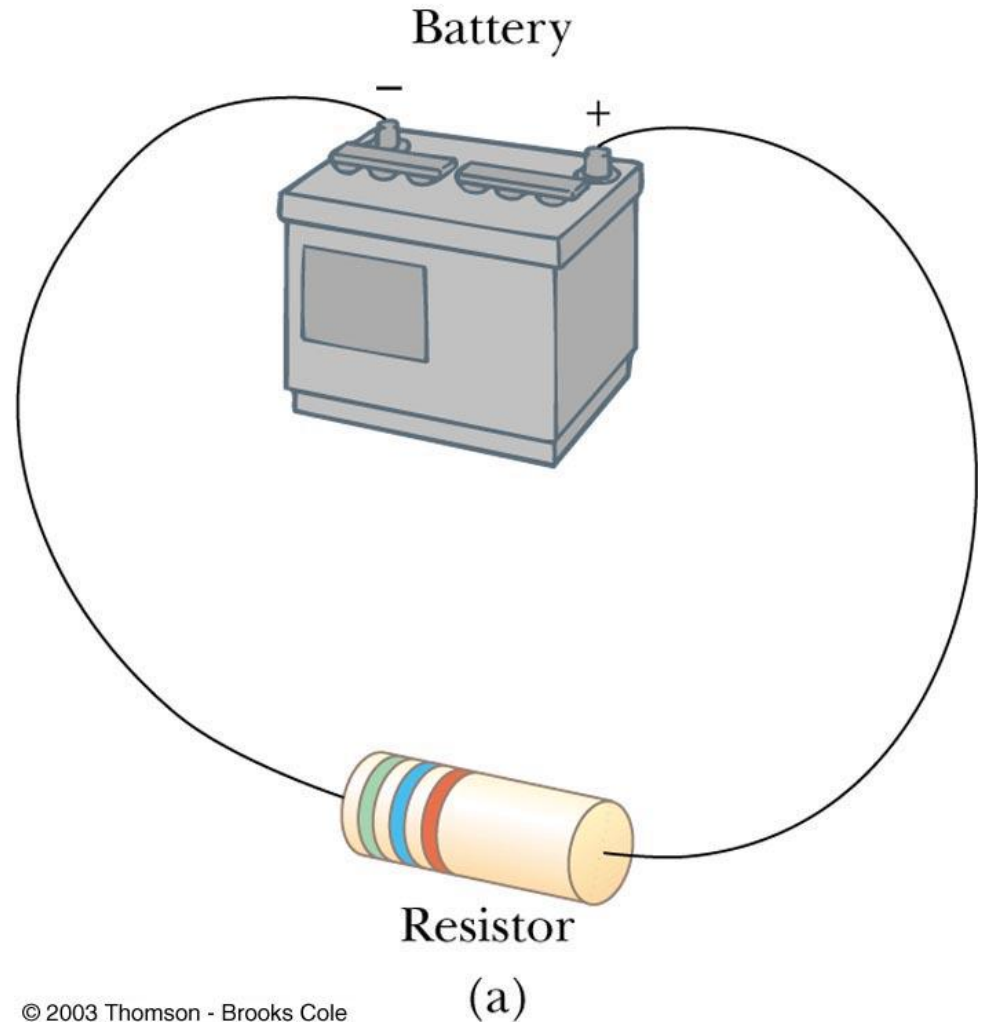
Examples include

Batteries

Generators

AC   DC

emf and Internal Resistance

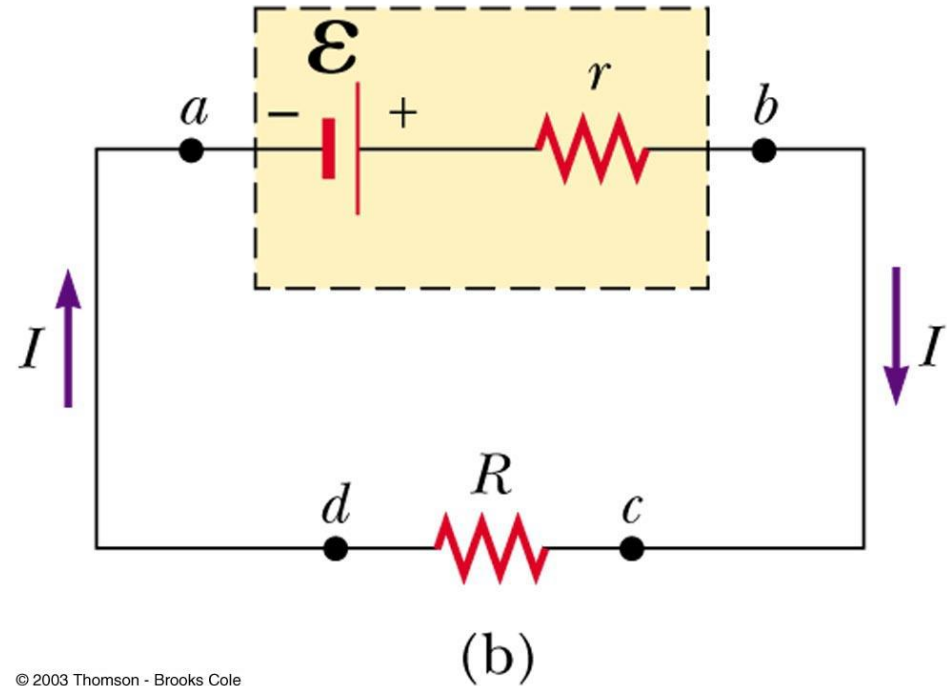A real battery has some internal resistance. Therefore, the "terminal voltage" is not equal to the emf.

Battery

−   +

Resistor

(a)

The schematic shows the internal resistance, *r*.
The terminal voltage is

$$\Delta V = V_b - V_a = \mathcal{E} - Ir$$

(b)

© 2003 Thomson - Brooks Cole

For the entire circuit,

$$\mathcal{E} = Ir + IR$$

$\mathcal{E}$ **is equal to the terminal voltage when the current is zero. It is also called the** *open-circuit voltage*.

R **is called the** *load resistance*.

The current depends on both the resistance external to the battery (load resistance) and the internal resistance

When $R >> r$, r can be ignored.
This is generally assumed in problems.

Power relationship:
$$I\mathcal{E} = I^2R + I^2r$$

When $R >> r$, most of the power delivered by the battery is transferred to the load resistor.

Resistors in Series

The current is the same in all resistors because any charge that flows through one resistor flows through the other.
The sum of the potential differences across the resistors is equal to the total potential difference across the combination.
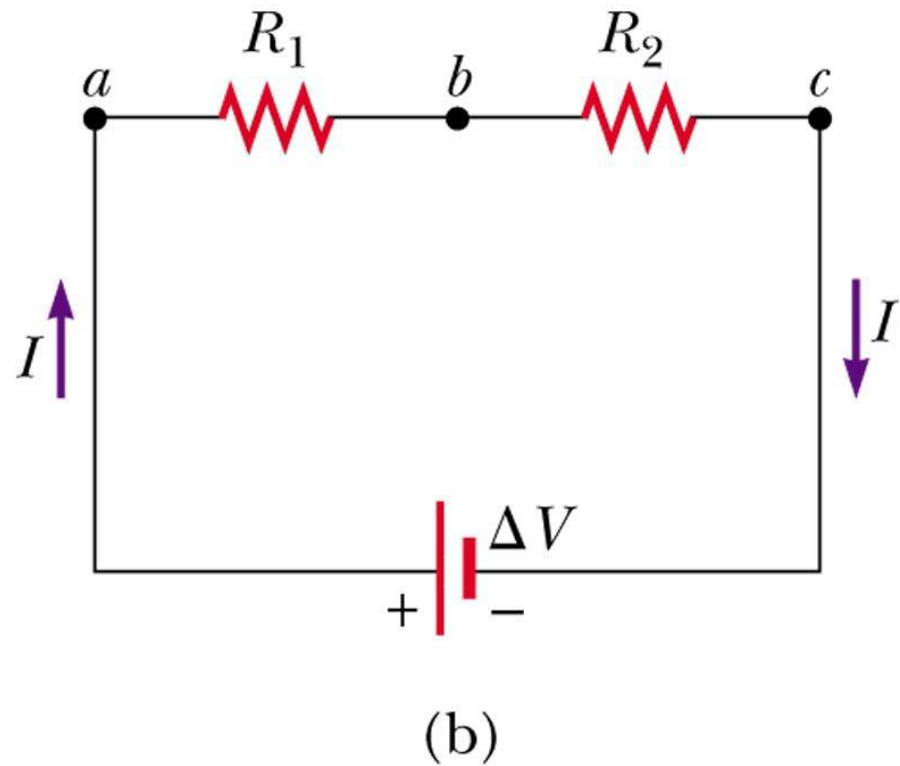
$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

The equivalent resistance of a series combination of resistors is the algebraic sum of the individual resistances and is always greater than any of the individual resistors.

Potentials add:

$$\Delta V = IR_1 + IR_2 = I(R_1 + R_2)$$

This is a consequence of *Conservation of Energy*.

(b)

© 2003 Thomson - Brooks Cole

The equivalent resistance has the same effect on the circuit as the original combination of resistors.

Resistors in Parallel

The potential difference across each resistor is the same because each is connected directly across the battery terminals.

The current, *I*, that enters a point must be equal to the total current leaving that point.

$$I = I_1 + I_2$$

This is a consequence of *Conservation of Charge*.

(The currents are generally not the same.)
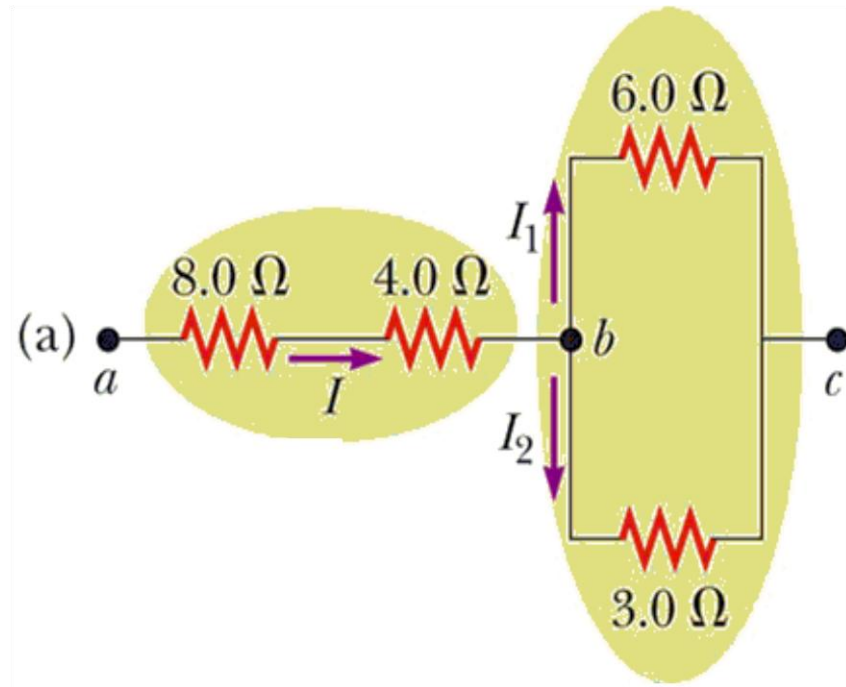
Equivalent Resistance – Parallel Resistors

Recall: The inverse of resistance is conductance.

$$G_{eq} = \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ... \qquad R_{eq} = \frac{1}{G_{eq}}$$

The equivalent is always _less than the smallest_ resistor in the group.

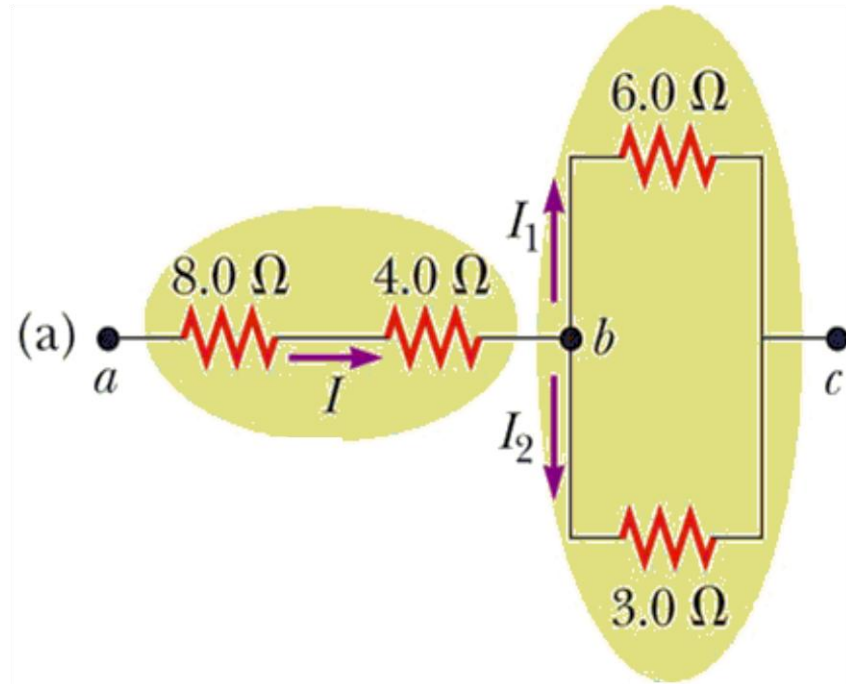# Example

Complex circuit reduction

Example

Complex circuit reduction

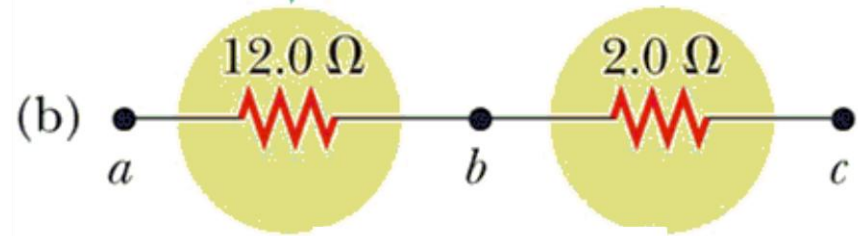Combine the resistors in series and parallel.

$$8 \; \Omega + 4 \; \Omega = 12 \; \Omega$$

$$\left(\frac{1}{6 \; \Omega} + \frac{1}{3 \; \Omega} \right)^{-1} = 2 \; \Omega$$

(a)

Example

Complex circuit reduction

Combine the resistors in series and parallel. Redraw the circuit with the equivalents of each set.

(b) 12.0 Ω   2.0 Ω

a   b   c

Example

Complex circuit reduction

Combine the resistors in series and parallel.

Redraw the circuit with the equivalents of each set.

Combine the resulting resistors in series to determine the final equivalent resistance.

(c)

14.0 Ω

a   c

© Brooks/Cole, Cengage Learning

Example

Complex circuit reduction

Combine the resistors in series and parallel. Redraw the circuit with the equivalents of each set.

Combine the resulting resistors in series to determine the final equivalent resistance.

(a)

a 8.0 Ω 4.0 Ω I b

I_1 6.0 Ω

I_2 3.0 Ω

(b)

a 12.0 Ω b 2.0 Ω

(c)

a 14.0 Ω c

© Brooks/Cole, Cengage Learning