Chapter 5

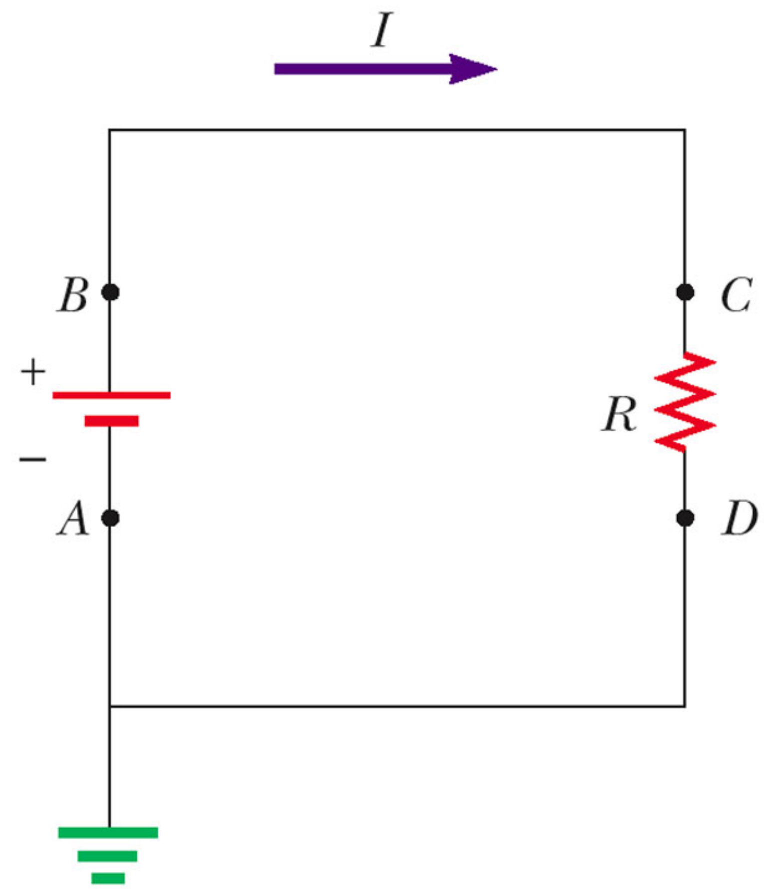
Direct Current Circuits

Electrical Energy and Power

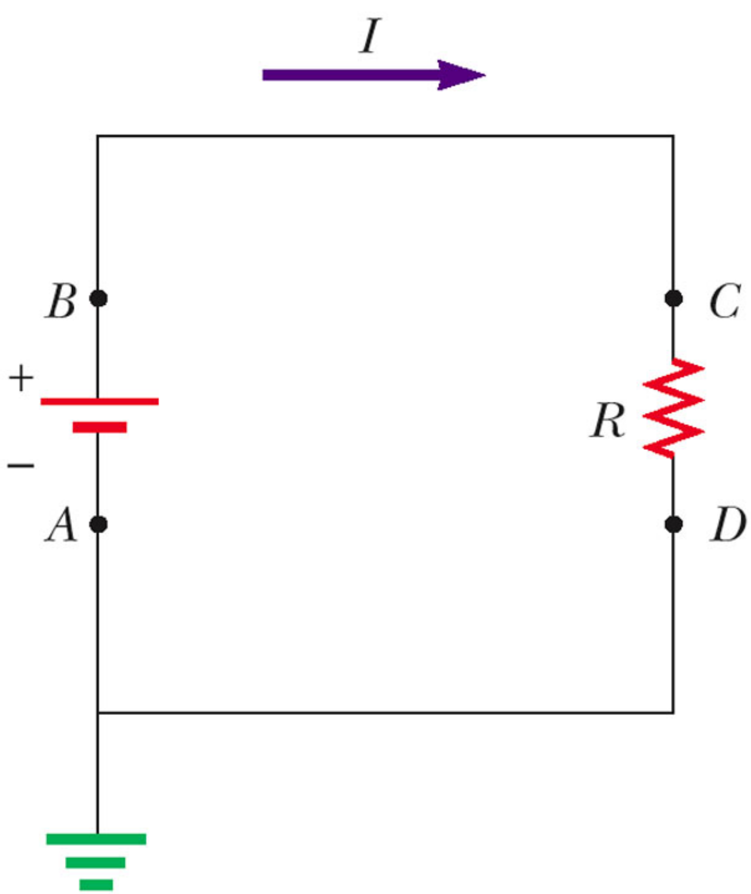
- In a circuit, as a charge moves through the battery, the electrical potential energy of the system is increased by $\Delta Q \Delta V$
  - The chemical potential energy of the battery decreases by the same amount
- As the charge moves through a resistor, it loses this potential energy during collisions with atoms in the resistor
  - The temperature of the resistor will increase

Energy Transfer in the Circuit

- Consider the circuit shown
- Imagine a quantity of positive charge, ΔQ, moving around the circuit from point A back to point A

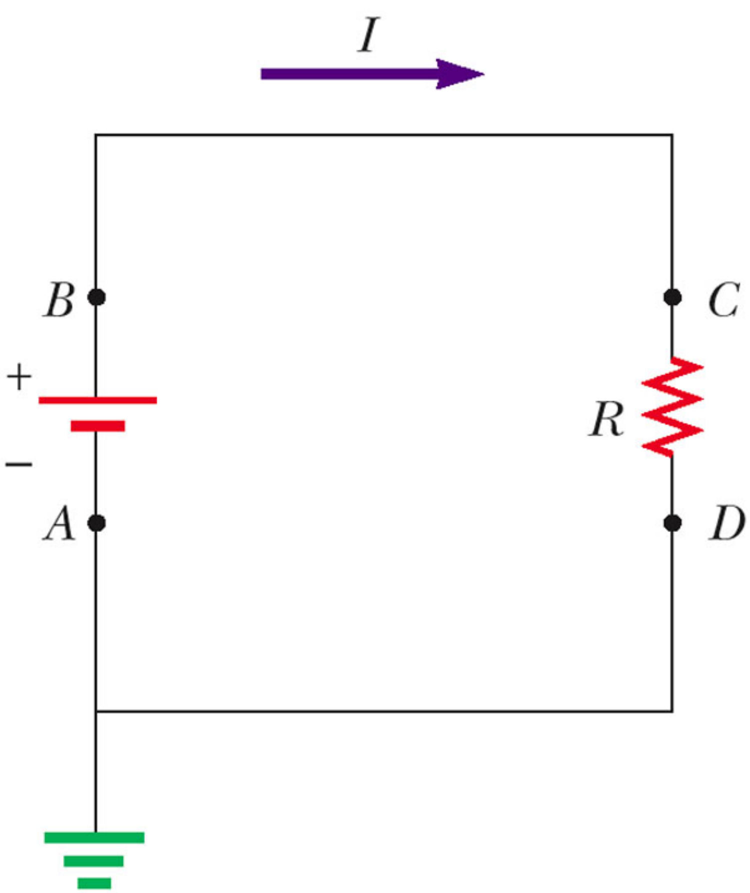


Energy Transfer in the Circuit, cont



- Point A is the reference point
  - It is grounded and its potential is taken to be zero
- As the charge moves through the battery from A to B, the potential energy of the system increases by $\Delta Q \Delta V$
  - The chemical energy of the battery decreases by the same amount

Energy Transfer in the Circuit, final



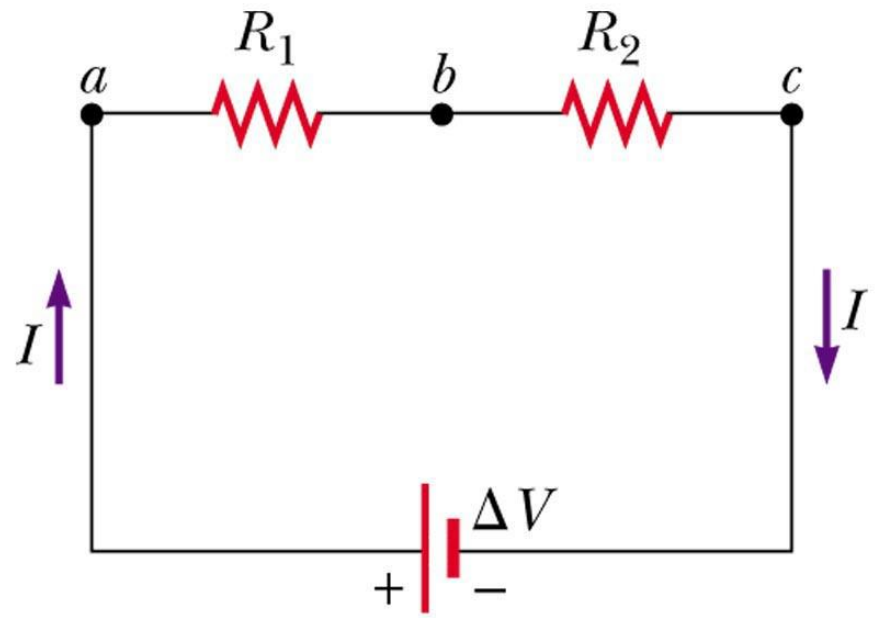
- As the charge moves through the resistor, from C to D, it loses energy in collisions with the atoms of the resistor
- The energy is transferred to internal energy
- When the charge returns to A, the net result is that some chemical energy of the battery has been delivered to the resistor and caused its temperature to rise

Resistors in Series

- When two or more resistors are connected end-to-end, they are said to be 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

Resistors in Series, cont

- Potentials add
  - $\Delta V = IR_1 + IR_2 = I\,(R_1+R_2)$
  - Consequence of Conservation of Energy
- The equivalent resistance has the effect on the circuit as the original combination of resistors

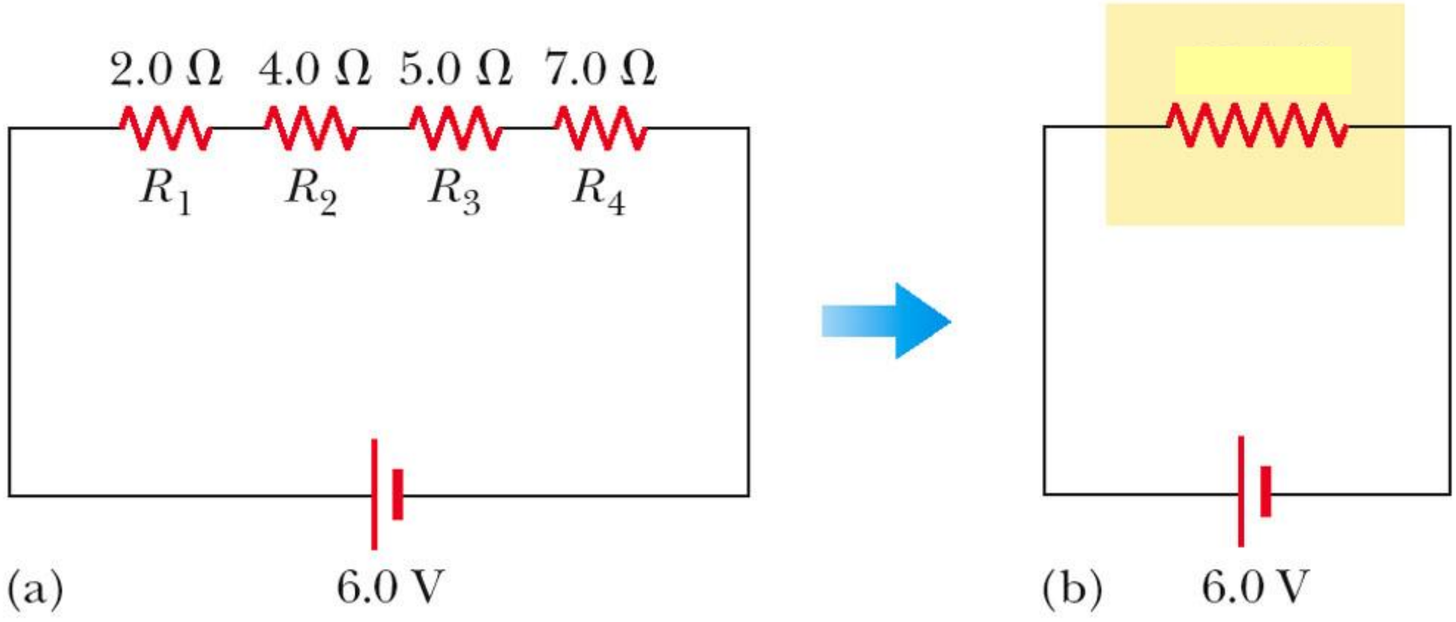


(b)

Equivalent Resistance – Series

- $R_{eq} = R_1 + R_2 + R_3 + \ldots$
- 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

Equivalent Resistance – Series: An Example

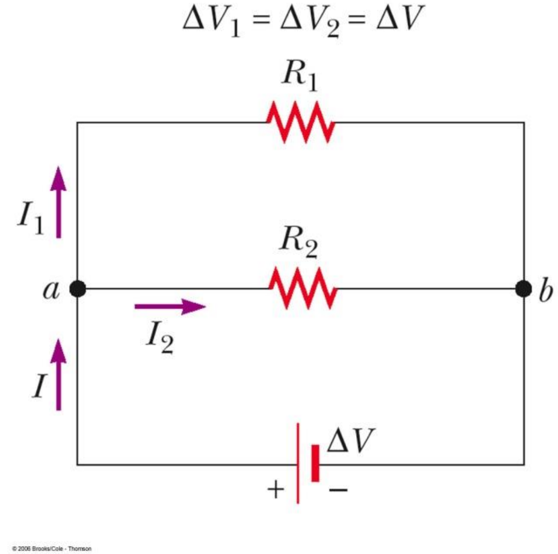


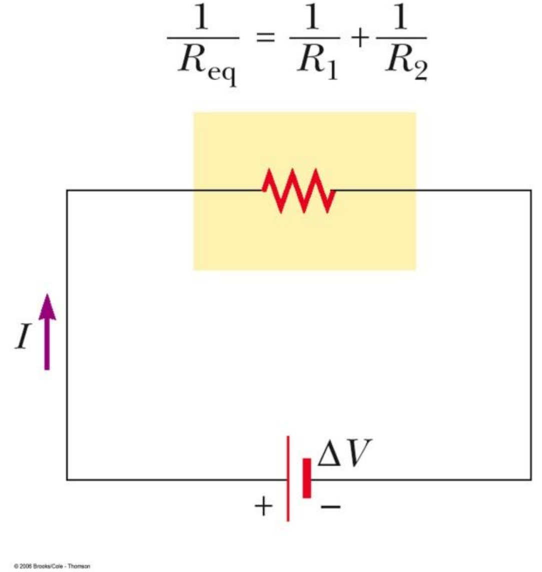
- What is the total current for this circuit?
- First, replace the 4 resistors with their equivalent resistance.

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
  - $I = I_1 + I_2$
  - The currents are generally not the same
  - Consequence of Conservation of Charge

Equivalent Resistance – Parallel, Example





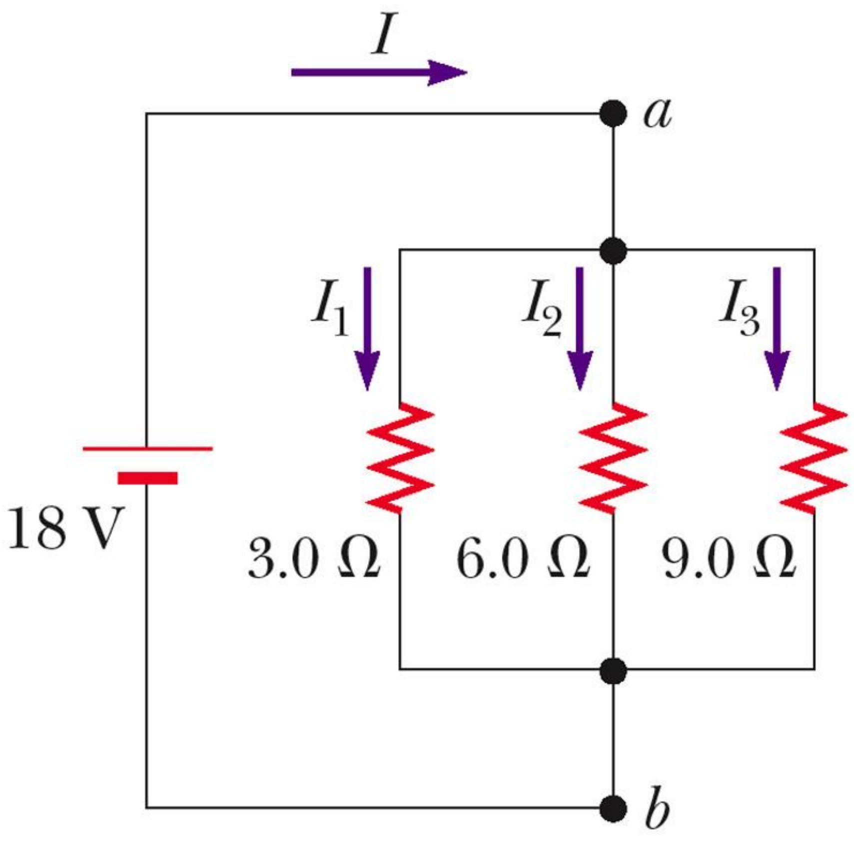
- Equivalent resistance replaces the two original resistances
- *Household circuits* are wired so the electrical devices are connected in parallel
    - Circuit breakers may be used in series with other circuit elements for safety purposes

Equivalent Resistance – Parallel

- Equivalent Resistance

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

- The inverse of the equivalent resistance of two or more resistors connected in parallel is the algebraic sum of the inverses of the individual resistance
  - The equivalent is always less than the smallest resistor in the group



Problem-Solving Strategy, 1

- Combine all resistors in series
  - They carry the same current
  - The potential differences across them are not the same
  - The resistors add directly to give the equivalent resistance of the series combination: $R_{eq} = R_1 + R_2 + \ldots$

Problem-Solving Strategy, 2

- Combine all resistors in parallel
  - The potential differences across them are the same
  - The currents through them are not the same
  - The equivalent resistance of a parallel combination is found through reciprocal addition:

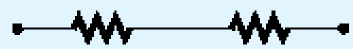
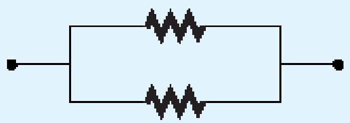
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

Problem-Solving Strategy, 3

- A complicated circuit consisting of several resistors and batteries can often be reduced to a simple circuit with only one resistor
  - Replace any resistors in series or in parallel using steps 1 or 2.
  - Sketch the new circuit after these changes have been made
  - Continue to replace any series or parallel combinations
  - Continue until one equivalent resistance is found

Problem-Solving Strategy, 4

- If the current in or the potential difference across a resistor in the complicated circuit is to be identified, start with the final circuit found in step 3 and gradually work back through the circuits
  - Use $\Delta V = I\,R$ and the procedures in steps 1 and 2

	Series	Parallel
schematic diagram		
current	$I = I_1 = I_2 = I_3 \ldots$ = same for each resistor	$I = I_1 + I_2 + I_3 \ldots$ = sum of currents
potential difference	$\Delta V = \Delta V_1 + \Delta V_2 + \Delta V_3 \ldots$ = sum of potential differences	$\Delta V = \Delta V_1 = \Delta V_2 = \Delta V_3 \ldots$ = same for each resistor
equivalent resistance	$R_{eq} = R_1 + R_2 + R_3 \ldots$ = sum of individual resistances	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$ = reciprocal sum of resistances

Equivalent Resistance – Complex Circuit