Chapter 28

Direct Current Circuits

Outline

- 28.1 Electromotive Force
- 28.2 Resistors in Series and Parallel
- 28.3 Kirchhoff's Rules

28.1 Electromotive Force (emf)

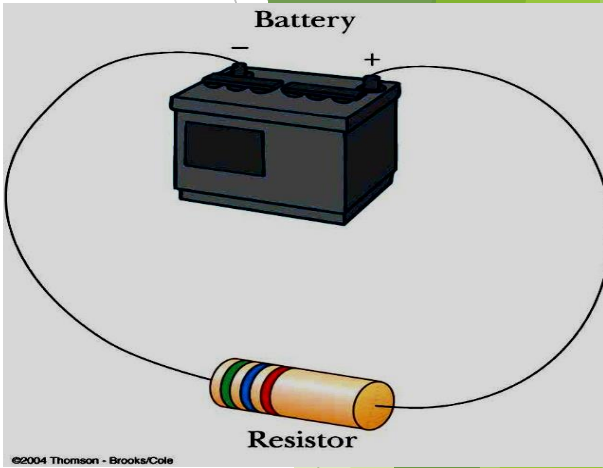
- **Because the potential difference at the battery terminals is constant in a particular circuit, the current in the circuit is constant in magnitude and direction and is called *Direct Current***

- ***A battery is called a source of emf***

- ***The emf of a battery is the maximum possible voltage that the battery can provide between its terminals***

28.1 Electromotive Force (emf)

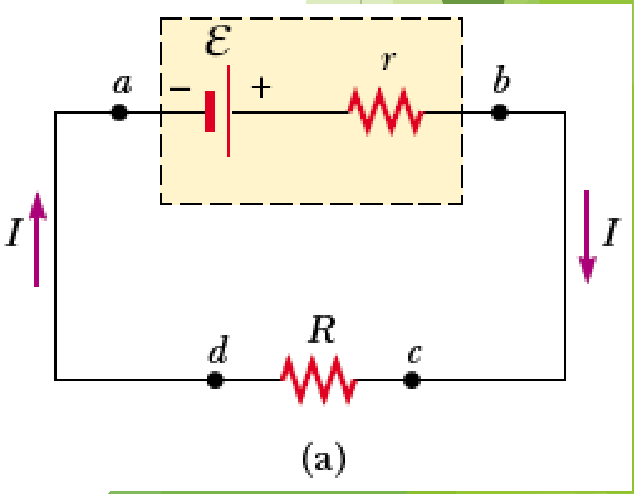
- The positive terminal of the battery is at a higher potential than the negative terminal. Because a real battery is made of matter, there is resistance to the flow of charge within the battery. This resistance is called **internal resistance *r***



- Imagine moving through the battery from a to b and measuring the electric potential at various locations

- As we pass from the negative terminal to the positive terminal, the potential increases by an amount ε

- As we move through the resistance r, the potential decreases by an amount ***Ir***.

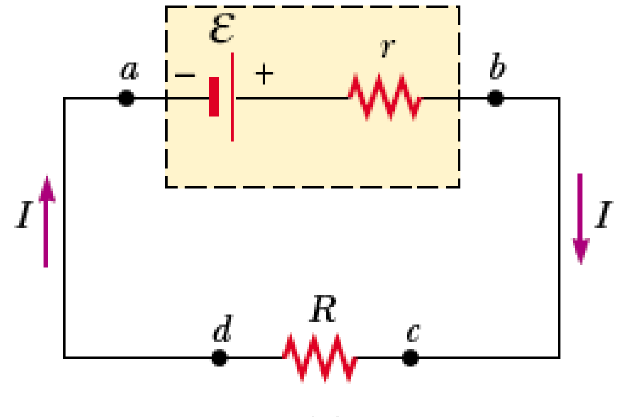


$$\Delta V = \varepsilon - Ir$$

28.1 Electromotive Force (emf)

- **ε is equivalent to the open-circuit voltage—that is, the terminal voltage when the current is zero. The emf is the voltage labeled on a battery**

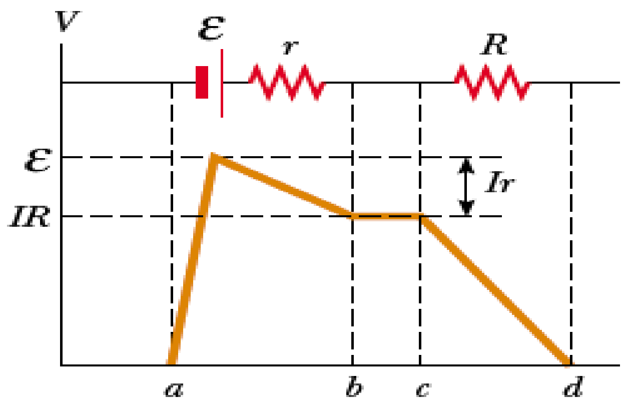
- **The terminal voltage "V must equal the potential difference across the external resistance R, often called *the load resistance***



(a)

$$\varepsilon = IR + Ir$$

$$I = \frac{\varepsilon}{R + r}$$



(b)

- **In many real-world circuits, *R is much greater than r and thus r can be neglected***

28.1 Electromotive Force (emf)

- **Total power by battery:**

$$I\varepsilon = I^2R + I^2r$$

- **The total power output $I\varepsilon$ of the battery is delivered to the external load resistance in the amount $I^2 R$ and to the internal resistance in the amount $I^2 r$.**

28.1 Electromotive Force (emf)

- ***Quick Quiz 28.1***

In order to maximize the percentage of the power that is delivered from a battery to a device, the internal resistance of the battery should be

(a) as low as possible

(b) as high as possible

(c) The percentage does not depend on the internal resistance.

28.1 Electromotive Force (emf)

➢*Example 28.1*

A battery has an emf of 12.0V and an internal resistance of0.05 Ω. Its terminals are connected to a load resistance of 3.00 Ω.

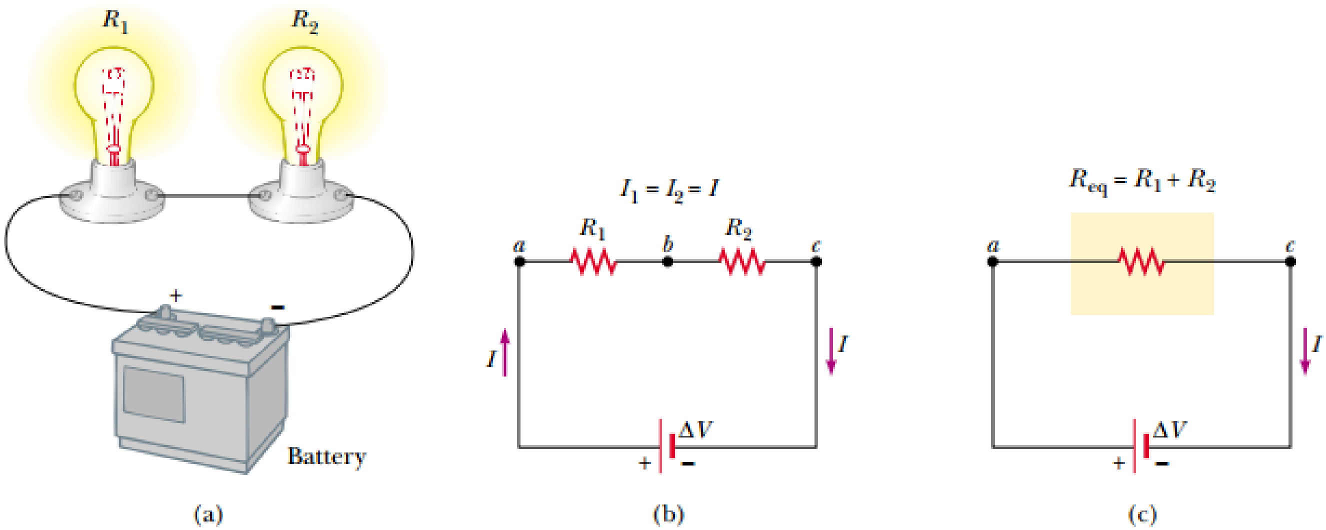
(A) Find the current in the circuit and the terminal voltage of the battery

(b*) Calculate the power delivered to the load resistor, the power delivered to the internal resistance of the battery, and the power delivered by the battery***

As a battery ages, its internal resistance increases. Suppose the internal resistance of this battery rises to 2.00Ω toward the end of its useful life. How does this alter the ability of the battery to deliver energy?

28.2 Resistors in Series and Parallel

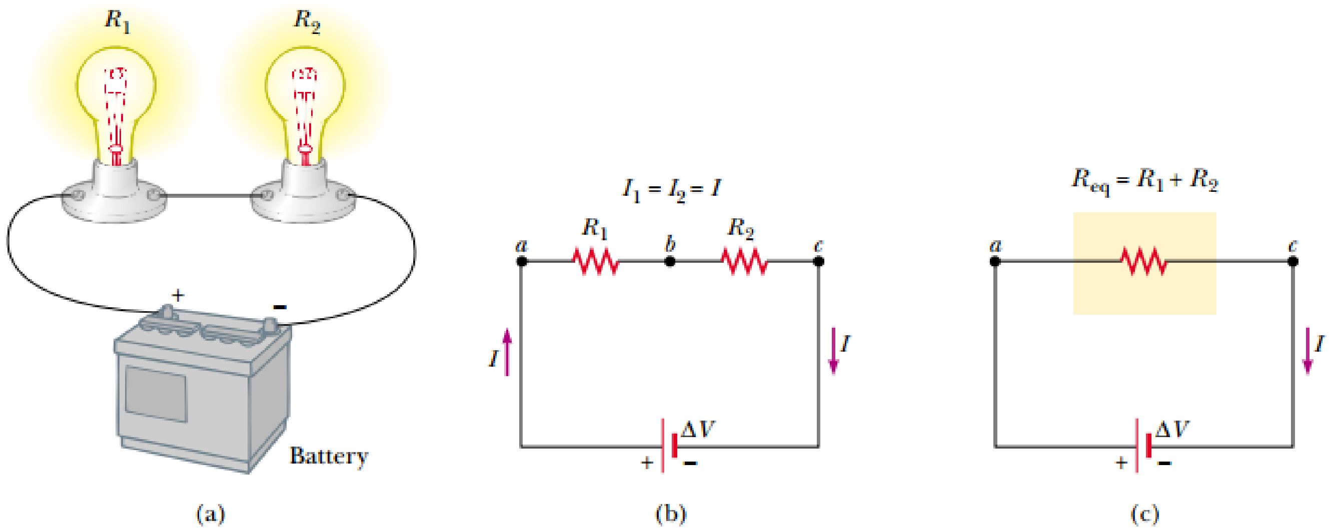
➢ **Resistors in Series**



➢ ***For a series combination of two resistors, the currents are the same in both resistors because the amount of charge that passes through R1 must also pass through R2 in the same time interval.***

28.2 Resistors in Series and Parallel

➢ **Resistors in Series**



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

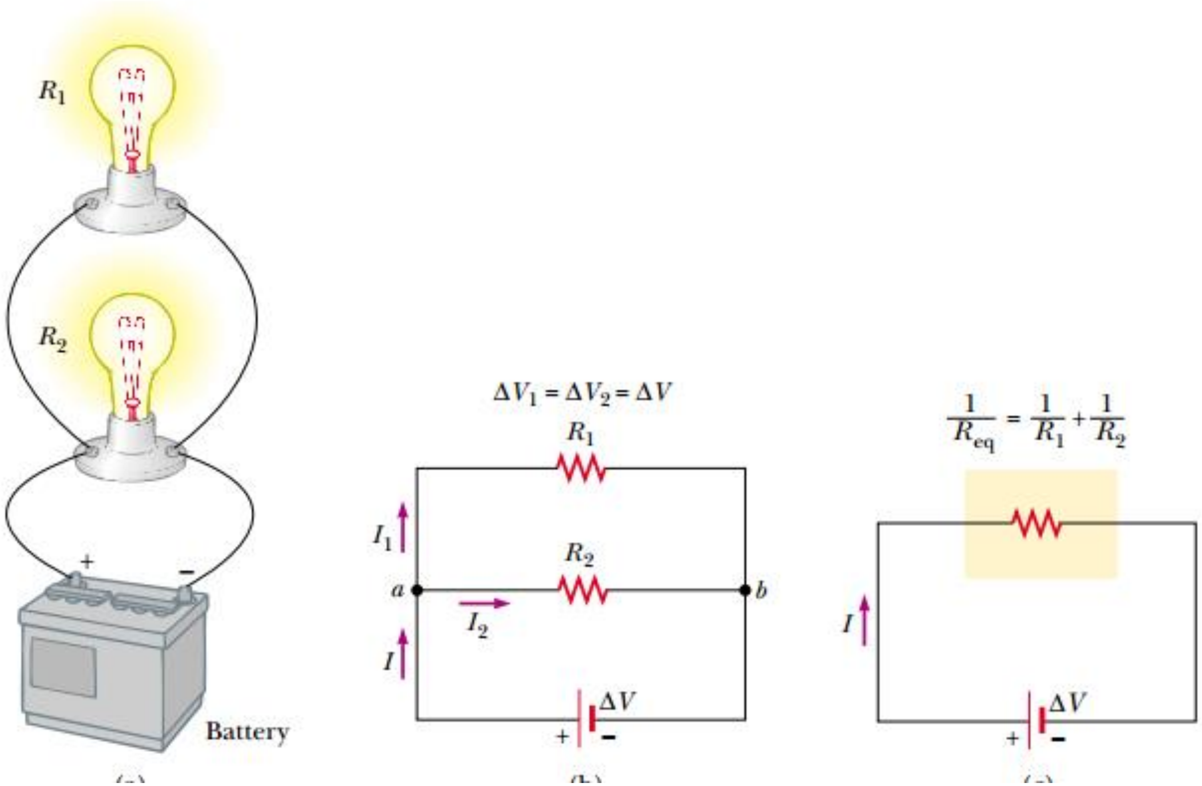
$$\Delta V = IR_{eq}$$

Equivalent Resistance

$$R_{eq} = R_1 + R_2 + R_3 + \cdots$$

28.2 Resistors in Series and Parallel

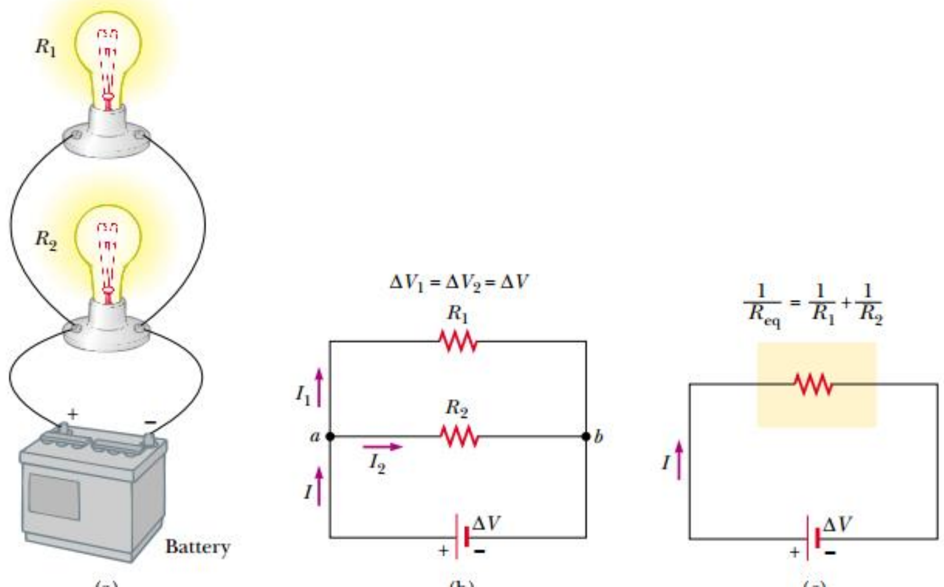
- **Resistors in Parallel**



- ***When resistors are connected in parallel, the potential differences across the resistors is the same.***

28.2 Resistors in Series and Parallel

➢ Resistors in Parallel



$$I = I_1 + I_2 = \frac{\Delta V}{R_1} + \frac{\Delta V}{R_2} = \Delta V\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{\Delta V}{R_{eq}}$$

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

Equivalent Resistance

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

28.2 Resistors in Series and Parallel

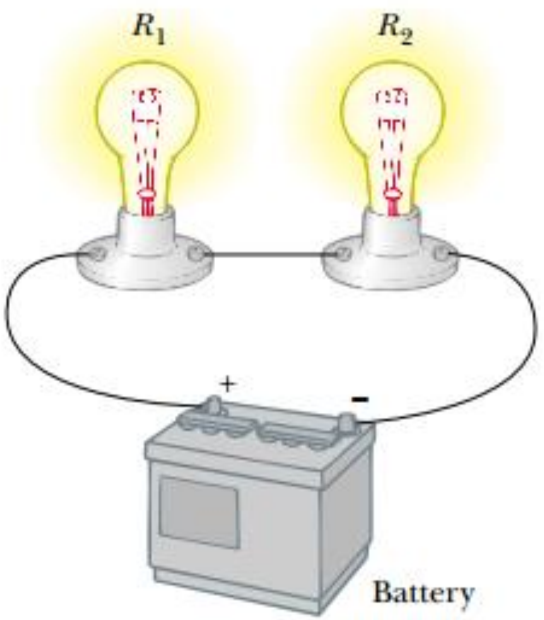
➢ ***Quick Quiz 28.5***

In this figure, imagine that we add a third resistor in series with the first two. The current in the battery will:

(a) **Increase**

(b) **decrease**

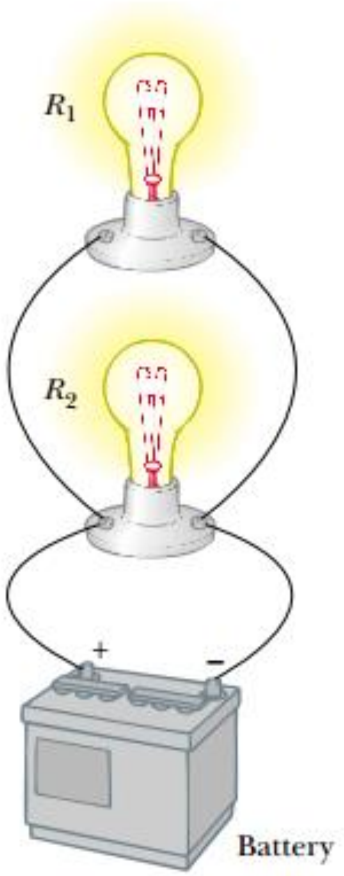
(c) **remain the same**



28.2 Resistors in Series and Parallel

➢ ***Quick Quiz 28.6***

In this figure, imagine that we add a third resistor in series with the first two. The current in the battery will:



(a) Increase

(b) decrease

(c) remain the same

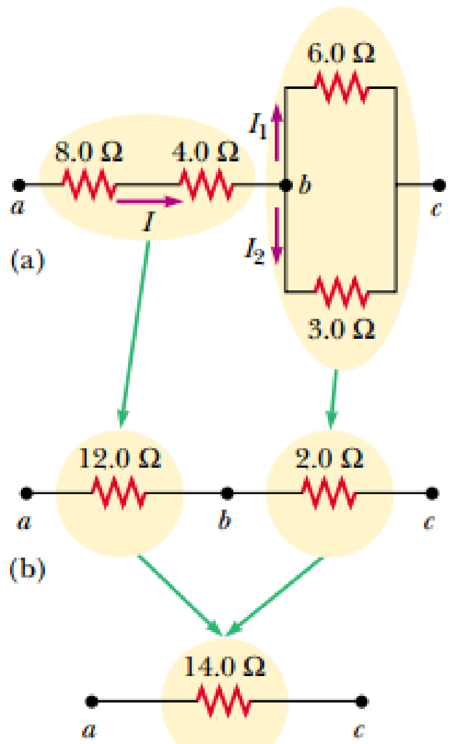
28.2 Resistors in Series and Parallel

➢***Example 28.4***

Four resistors are connected as shown in the Figure

(A) Find the equivalent resistance between points a and c

(B) What is the current in each resistor if a potential difference of 42V is maintained between a and c



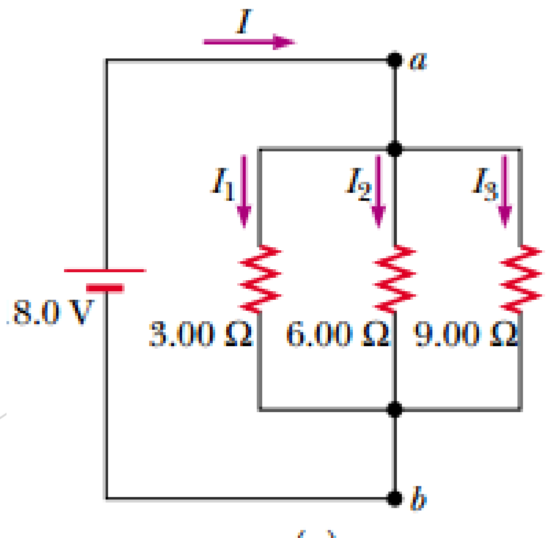
28.2 Resistors in Series and Parallel

➢***Example 28.6***

Three resistors are connected in parallel as shown in the Figure A potential difference of 18.0V is maintained between points a and b

(A) Find the current in each resistor.

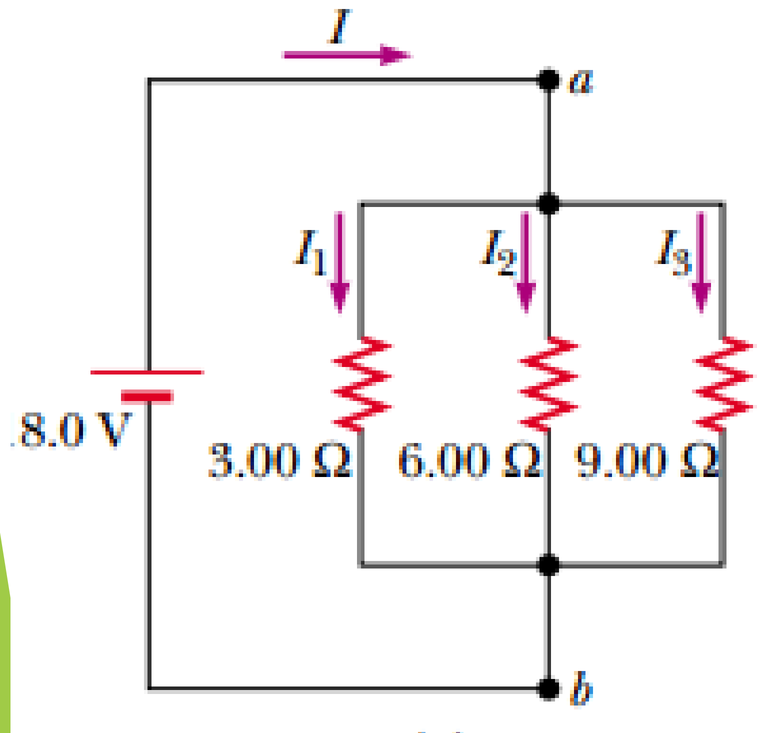
(B) Calculate the power delivered to each resistor and the total power delivered to the combination of resistors

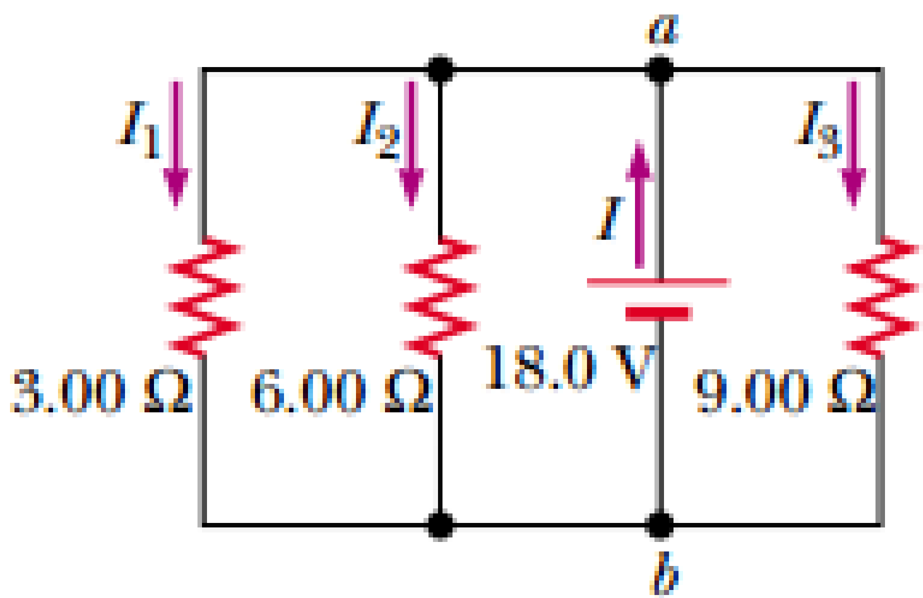


28.2 Resistors in Series and Parallel

- ***Example 28.6***

What if the circuit is as shown in the right instead of that in the left?? How does this affect the calculation?





28.3 Kirchhoff’s Rules

- ***Because it is not often possible to reduce a circuit to a single loop, we use Kirchhoff’s rules for analyzing more complex circuits.***

1. **Junction rule.** The sum of the currents entering any junction in a circuit must equal the sum of the currents leaving that junction:

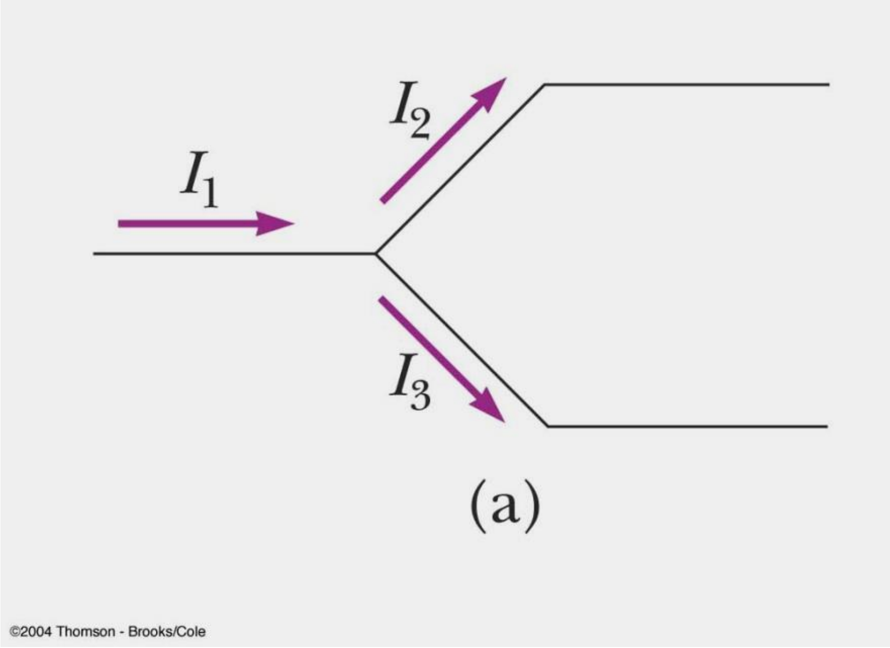
$$\sum I_{in} = \sum I_{out} \quad (28.9)$$

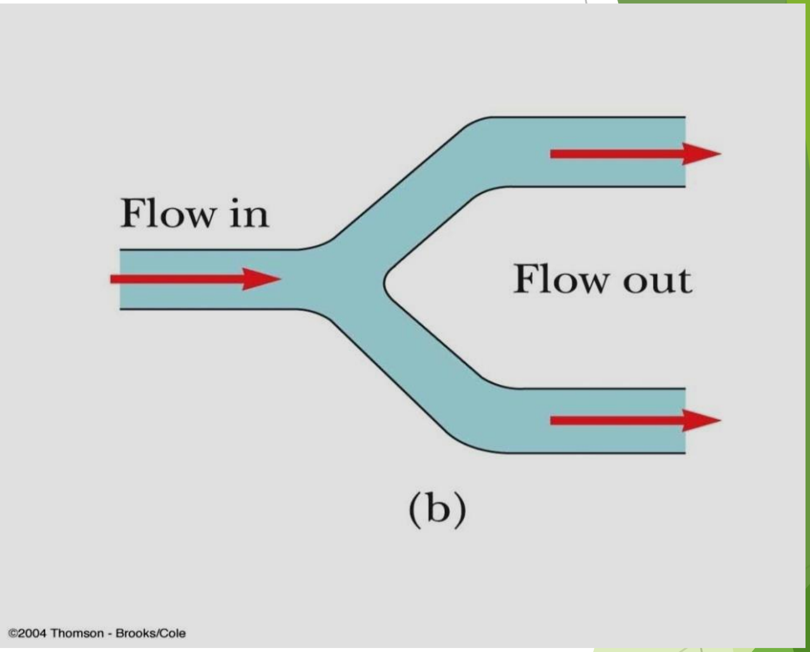
2. **Loop rule.** The sum of the potential differences across all elements around any closed circuit loop must be zero:

$$\sum_{\substack{\text{closed}\\ \text{loop}}} \Delta V = 0 \quad (28.10)$$

28.3 Kirchhoff’s Rules

➤ ***Junction Rule***





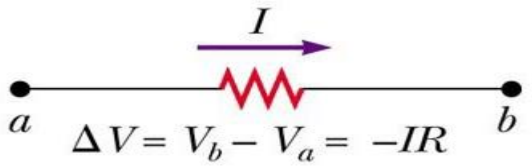
$$I_1 = I_2 + I_3$$

28.3 Kirchhoff’s Rules

➢ **Loop Rule**

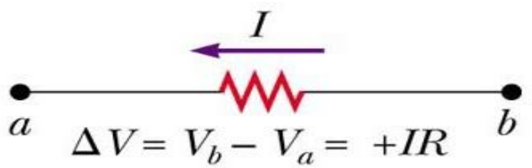
(a) If a resistor is traversed in the direction of the current, the potential difference ΔV across the resistor is -IR

(a)



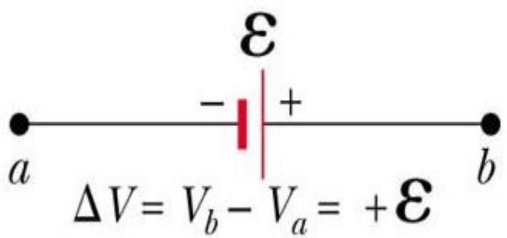
(b) If a resistor is traversed in the direction opposite the current, the potential difference ΔV across the resistor is +IR

(b)



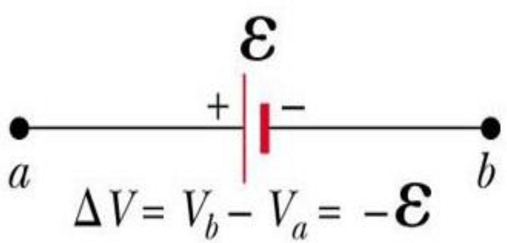
(C) If a source of emf (r=0)) is traversed in the direction of the emf (from – to +), the potential difference ΔV is +ℇ

(c)



D) If a source of emf (r=0)) is traversed in the direction opposite of the emf (from + to -), the potential difference ΔV is -ℇ

(d)



28.3 Kirchhoff's Rules

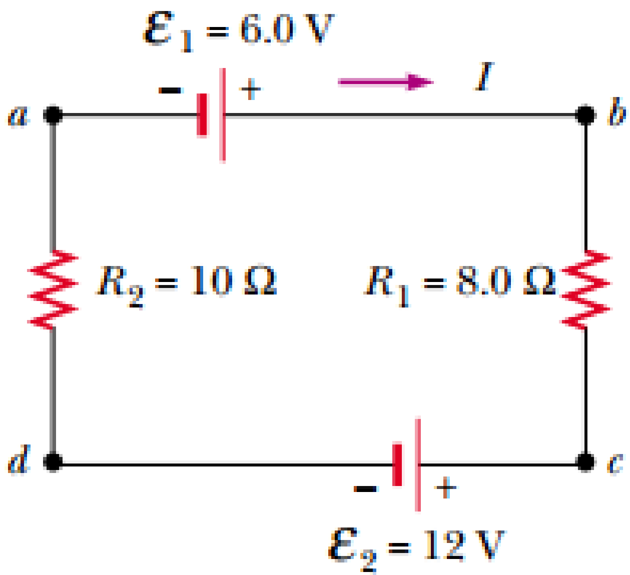
- ***Example 28.8***

A single-loop circuit contains two resistors and two batteries, as shown in the Figure. (Neglect the internal resistances of the batteries.)

(A) Find the current in the circuit.

(B) What power is delivered to each resistor? What power is delivered by the 12-V battery?

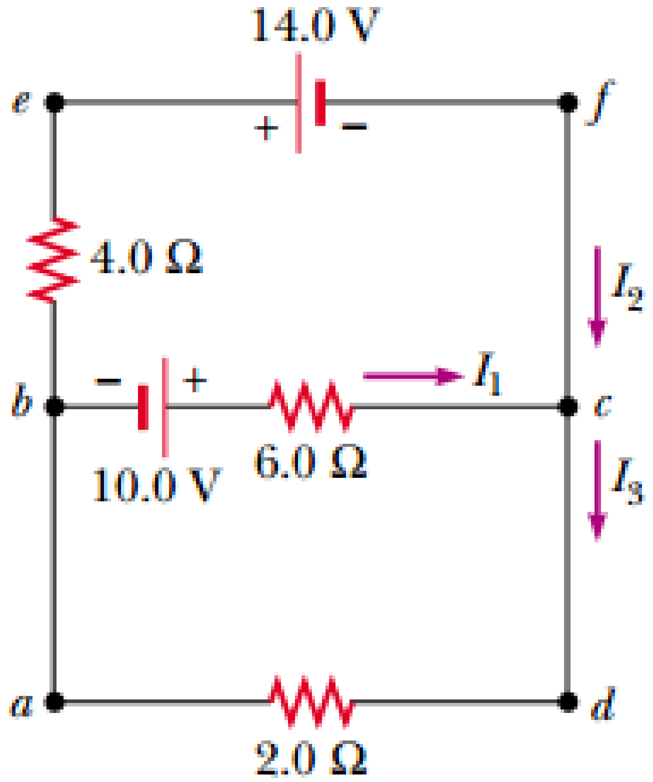
What if the polarity of the 12.0-V battery were reversed? How would this affect the circuit?



28.3 Kirchhoff's Rules

➢ ***Example 28.9***

Find the currents I_1, I_2, and I_3 in the circuit



28.3 Kirchhoff’s Rules

س9) في الدائرة المرفقة إذا كان التيار المار بالمقاومة Ω 3 يساوي 2A فان التيار المار بالمقاومة Ω 5 يساوي:

Q9) In the given circuit, if the electric current passes through the resistance 3 Ω is 2A, the electric current passes through the resistance 5 Ω equals:

A. 6 A B. 3 A C. 2 A D. 1 A