Announcements

1. First hour exam – Monday, February 10, 2003 – covering Chapters 23-28.

   May bring 1 8½" x 11" sheet of paper to the exam (to be turned in with your exam papers).

   The exam will be proctored by Professor Salsbury.

   Practice exam available on website.

   Extra review session Friday afternoon (2/7/03)?

2. Today's topic

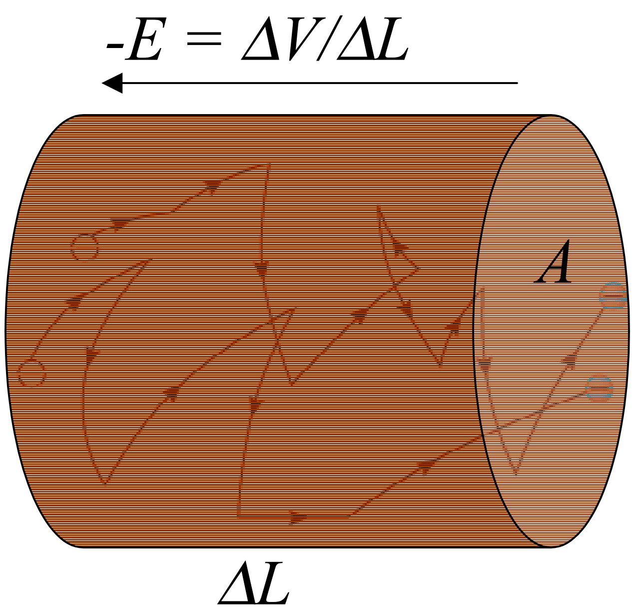
   Current, power, circuits

Electrical current in a wire

Approximately follows Ohm's law: $\Delta V = IR$

The resistance R depends on properties of the materials

$$R = \frac{m\Delta L}{q^2 n\tau A} \equiv \rho \frac{\Delta L}{A}$$



m electron mass

q electron charge

n number of electrons/volume

τ time between collisions

In general R depends on temperature T.

Electrical power associated with current in a wire

$$dU = dq\Delta V$$

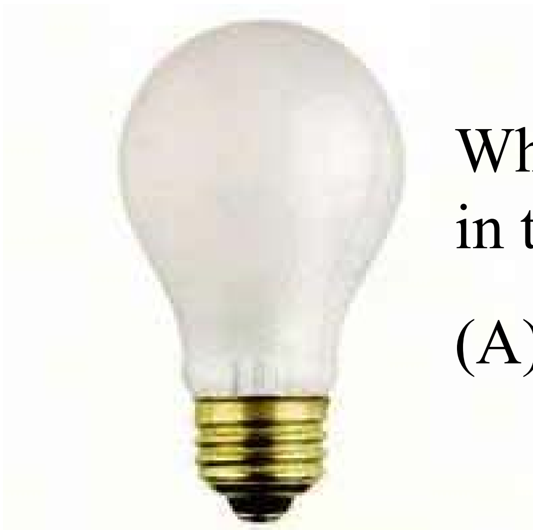
$$\Rightarrow \underbrace{\frac{dU}{dt}}_{\mathcal{P}} = \frac{dq}{dt}\Delta V \equiv I\Delta V$$

$\mathcal{P}$ (electrical power)

unit: 1 J/s = 1 Watt

$$\mathcal{P} = I\Delta V = I^2 R = \frac{(\Delta V)^2}{R}$$

Consider a 60 W light bulb, connected to a 120 V voltage source.



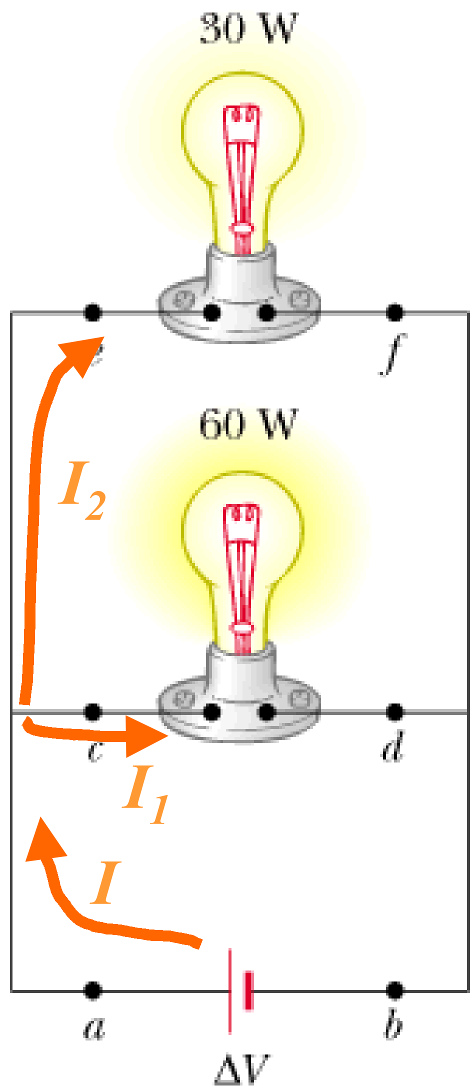
What is the current passing through the wire in the bulb?

(A) 0.5 A (B) 1.0 A (C) 30 A (D) 240 A

What is the resistance of the wire in the bulb?

(A) 0.5 Ω (B) 1.0 Ω (C) 30 Ω (D) 240 Ω

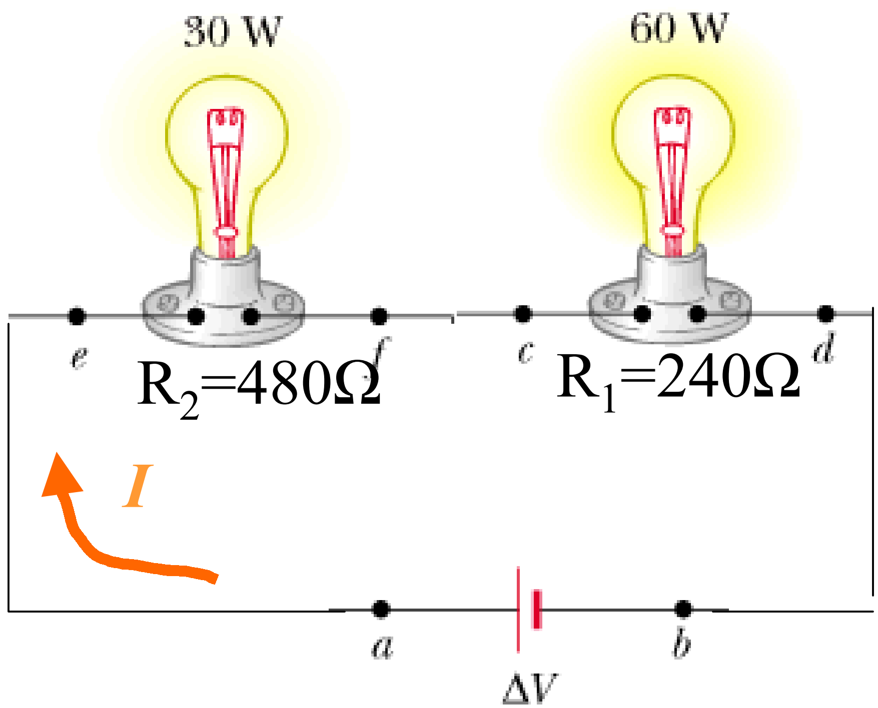
Consider the circuit shown on the left. How much current is running in each light bulb when $\Delta V = 120$ V? (Note: the power rating of each bulb is valid only when they are connected to a 120 V voltage source.)



$$I_2 = \frac{\mathcal{P}_2}{\Delta V} = 0.25A \qquad R_2 = \frac{(\Delta V)^2}{\mathcal{P}_2} = 480\Omega$$

$$I_1 = \frac{\mathcal{P}_1}{\Delta V} = 0.5A \qquad R_1 = \frac{(\Delta V)^2}{\mathcal{P}_1} = 240\Omega$$

$$I = I_1 + I_2 = 0.75A$$



$$\Delta V = I\,(R_1 + R_2)$$

$$I = 0.167\ \text{A}$$

$$\mathcal{P}_2 = 13.33\ \text{W}$$

$$\mathcal{P}_1 = 6.67\ \text{W}$$

Peer instruction question

Suppose you connect two devices, each with a resistance of $100\ \Omega$ in ***parallel*** to a 120 V voltage source. What is the total current in the circuit?

(A) 0.6 A (B) 1.2 A (C) 2.4 A (D) 4.8 A

Suppose you connect two devices, each with a resistance of $100\ \Omega$ in ***series*** to a 120 V voltage source. What is the total current in the circuit?

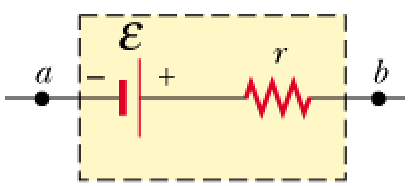
(A) 0.6 A (B) 1.2 A (C) 2.4 A (D) 4.8 A

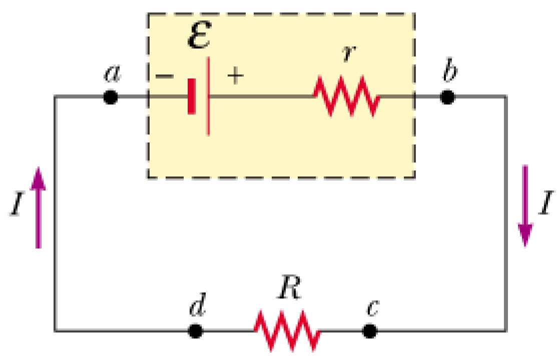
Voltage sources

- •Batteries (chemical reactions)
- •Solar cells (conversion of solar energy to voltage output)
- •Generators (conversion of mechanical energy to voltage output)

General terminology – "electromotive force" – emf, $\mathcal{E}$

Real emf's often have energy losses during operation so that the ideal voltage $\mathcal{E}$ is reduced. This energy loss can be modeled by an internal resistance *r* represented by the equivalent circuit:





In this case the current is then determined by

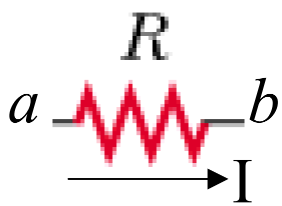
$$\mathcal{E} = (r + R)I$$

$$I = \frac{\mathcal{E}}{r + R}$$

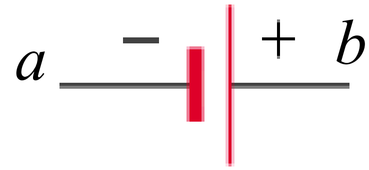
Analysis of DC circuits:

Elements:

wire – $V_{ab} \approx 0$



resistor – $V_{ab} = -IR$



emf – $V_{ab} = \mathcal{E}$

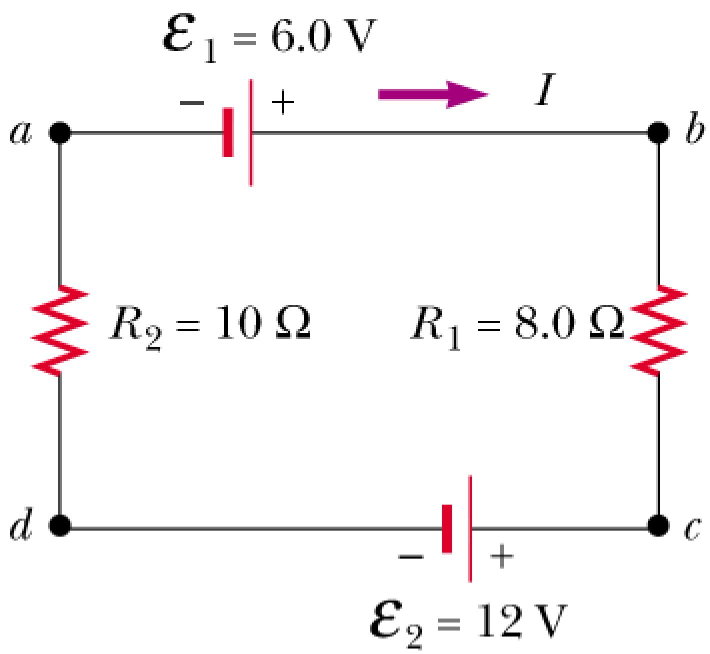
The principles:

Kirchhoff's rules

At any wire function: $\sum I_{in} = \sum I_{out}$

For any closed wire loop: $\sum \Delta V = 0$

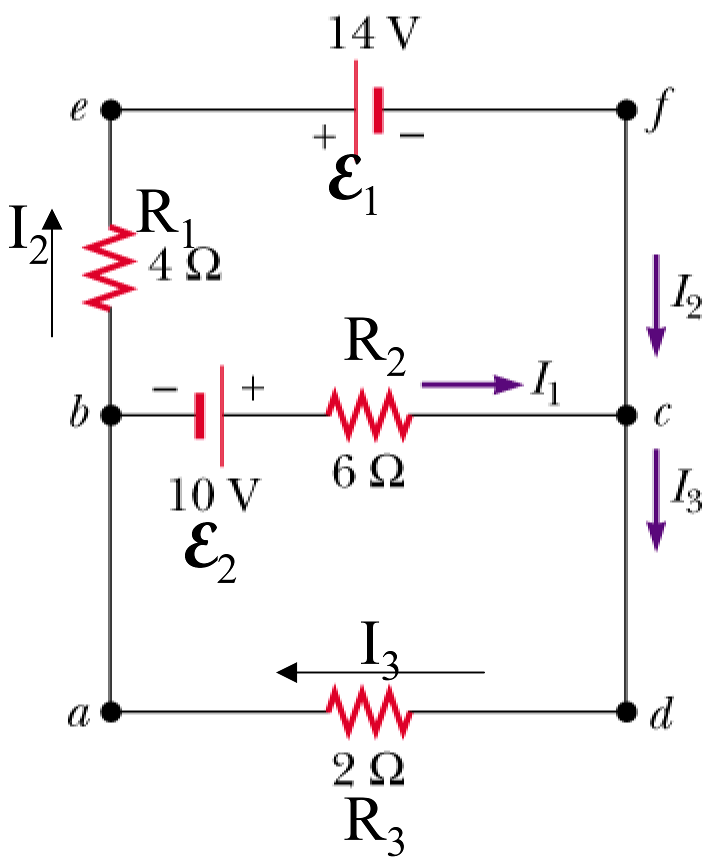
Example:



$$\mathcal{E}_1 - IR_1 + (-\mathcal{E}_2) - IR_2 = 0$$

$$I = \frac{\mathcal{E}_1 - \mathcal{E}_2}{R_1 + R_2} = -0.33A$$

Example:



$$-\mathcal{E}_1 + I_1R_2 - \mathcal{E}_2 - I_2R_1 = 0$$

$$\mathcal{E}_2 - I_1R_2 - I_3R_3 = 0$$

$$I_1 + I_2 = I_3$$

$$I_1 = 2\ A$$

$$I_2 = -3A$$

$$I_3 = -\ 1\ A$$