Electric Current

Direct Current Circuits

A few, simple, direct current circuits

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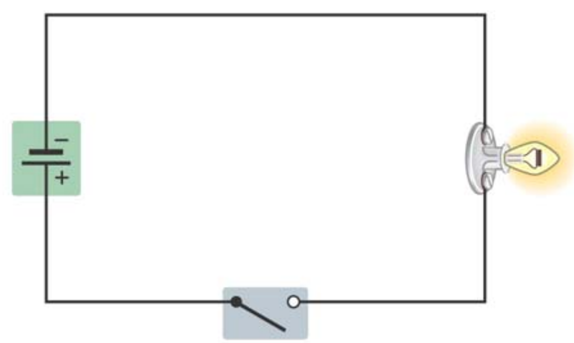

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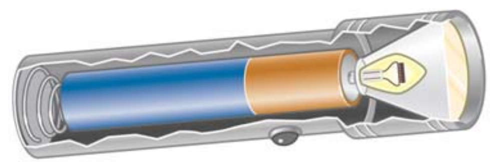
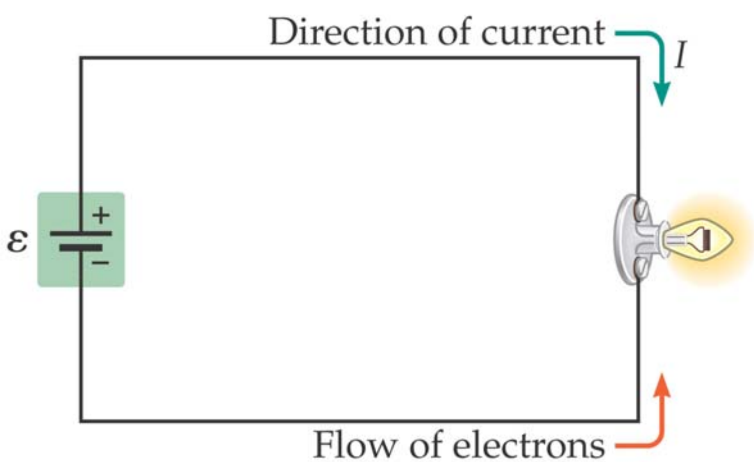
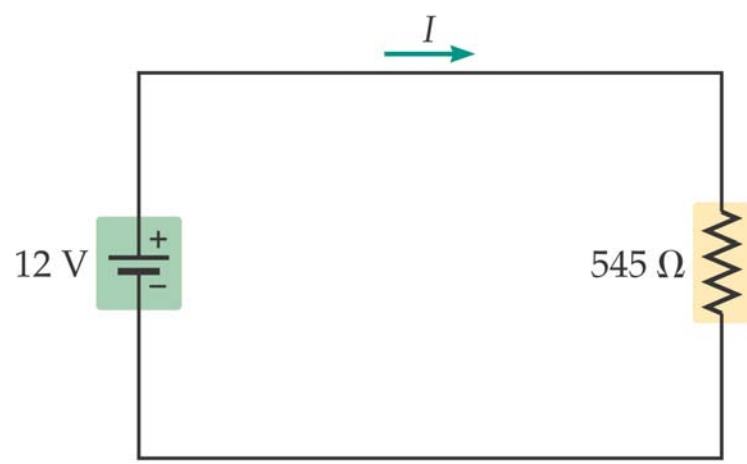
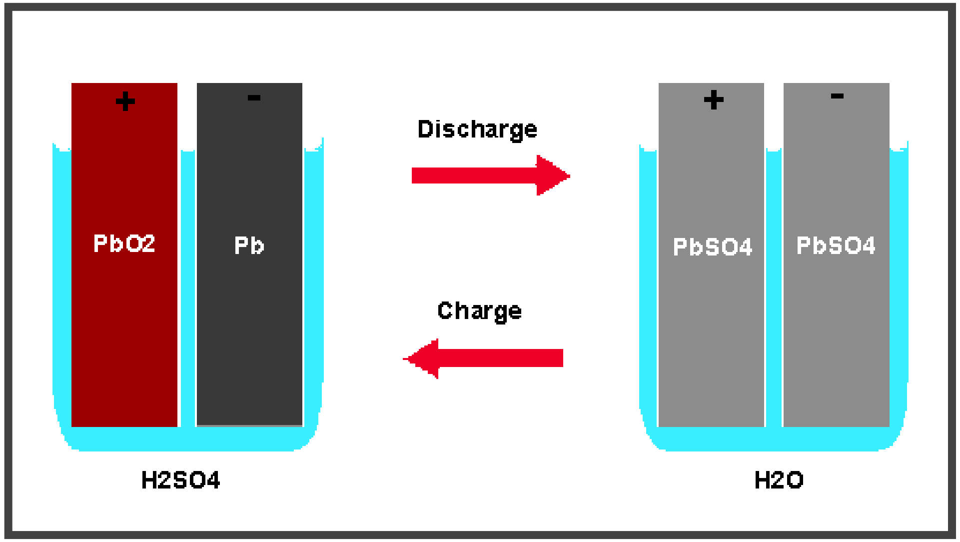
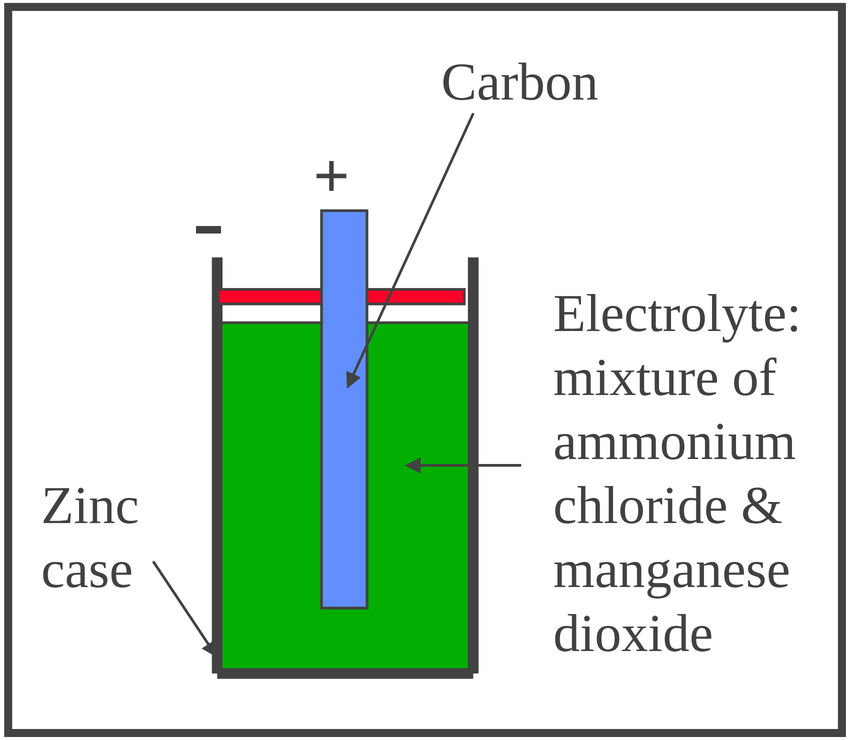




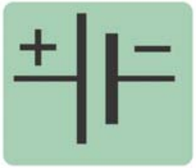


The Battery





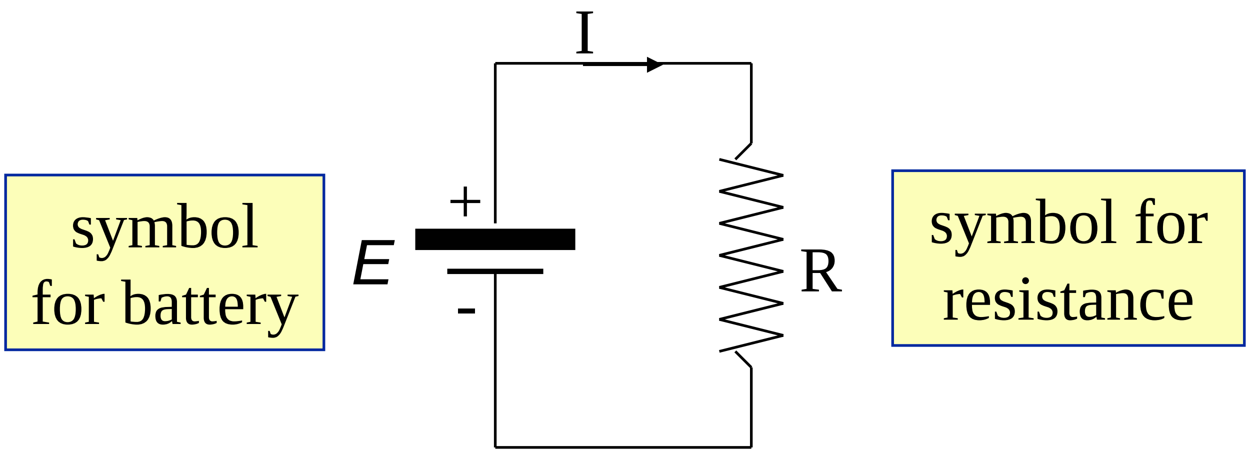
Battery symbol



electrical converter...

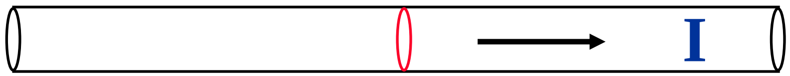
.....converts chemical energy to electrical energy

Electrical Description of a Battery



- A battery uses chemical reactions to produce a difference in electrical potential between its two ends
- The electromotive force (EMF) E is the difference in electrical potential between terminals when the battery is disconnected
- EMF is the work per unit charge exerted to move the charges "uphill" (to the + terminal, inside the battery) $E = W / \Delta Q$
- Current will flow, in the external circuit, from the + terminal, to the – terminal, of the battery (electrons move from – to +)

Electric Current



a wire

Δq passes through in time Δt

- We define the electric current as the movement of charge, across a given area, per unit time:

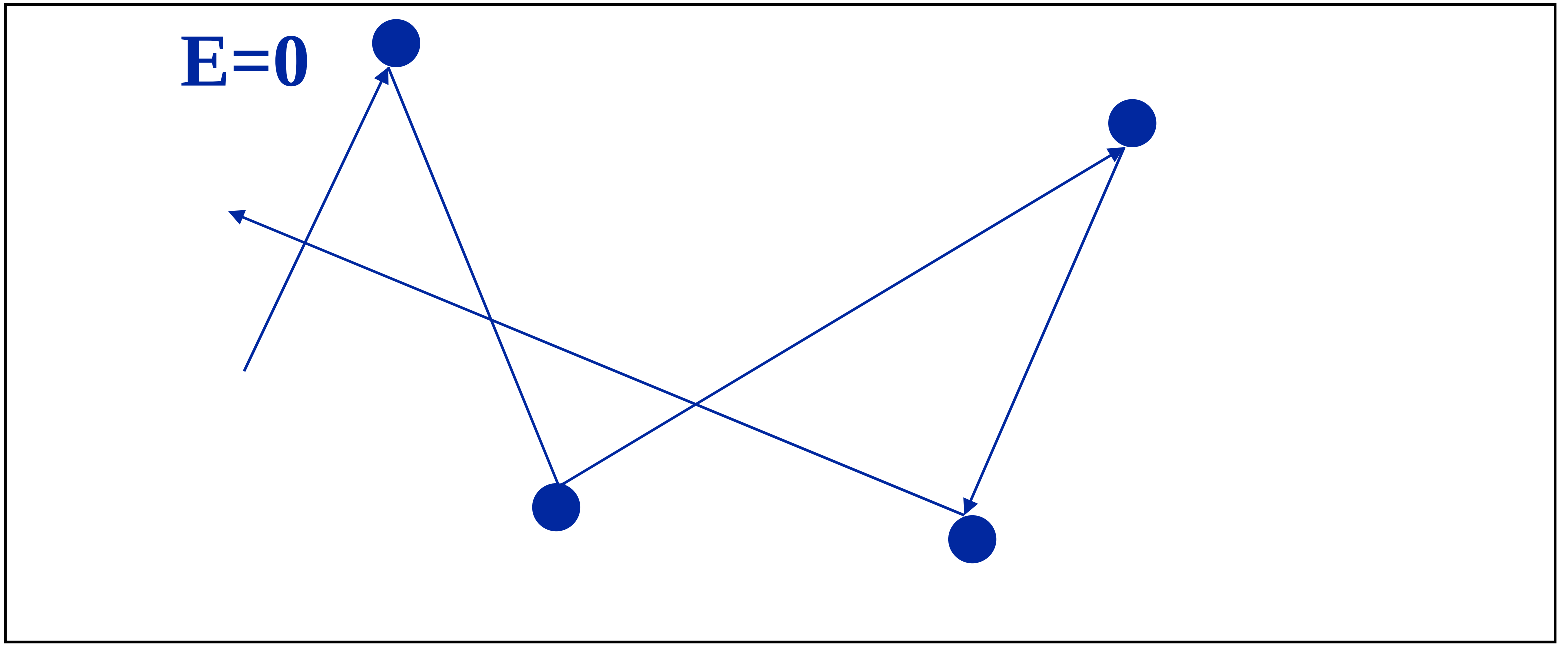
$$I = \Delta q / \Delta t$$

- SI unit of current: 1 C/s = 1 **Ampere** (Amp)
- The direction of the current is the direction in which positive charges would move.
- Electrons move opposite to the direction of the current.

Current Flow in a Conductor

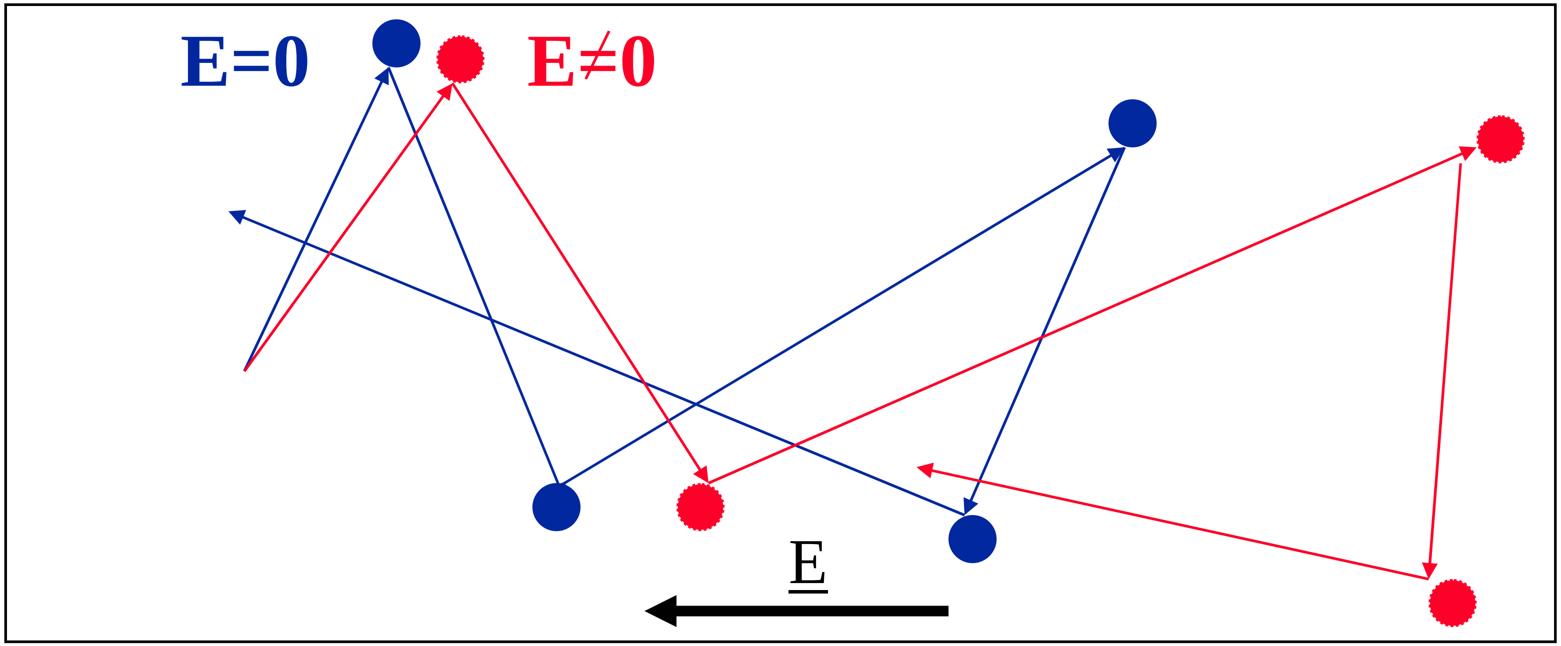
- Conductors are made of materials (usually metals) in which some of the electrons are free to move (not bound to the atoms). These are called conduction electrons.
- In normal state these free electrons have random, Brownian motion, in the material.
- However, a net average flow of charge (a current) is set up when an E field is applied (the individual motion of electrons is still quasi- random).
- Electrons move in a direction opposite to the E field.
- But remember: we describe current flow as the result of the motion of positive charge carriers

Influence of electric field on flow of electrons



When E = 0, the electrons move randomly in the conductor making frequent collisions with the atoms in the material.

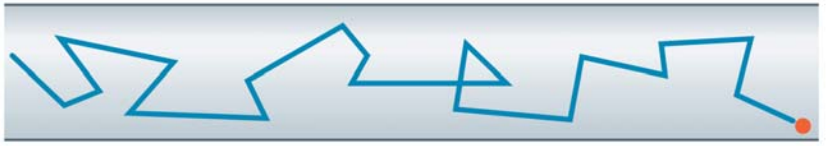
Influence of electric field on flow of electrons



- An electric field modifies the trajectories of electrons between collisions.
- When E is nonzero, the electrons move almost randomly after each bounce, but gradually they drift in the direction opposite to the electric field.

Movement of Charge Carriers

Inside a conductor



Inside a conductor negative electrons are the charge carriers

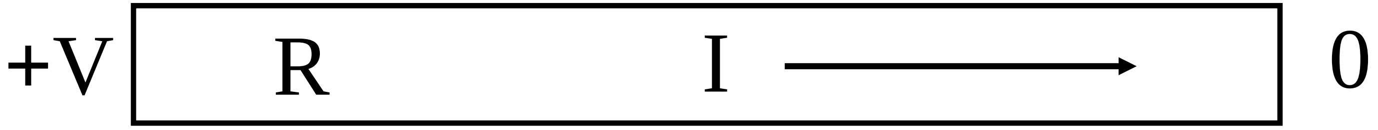
If an electric field is present, the electrons will start moving (in a direction opposite to the field).
However, the motion of the electrons will be disrupted by frequent collisions with the atoms in the material.
The net result is that the electrons acquire a slow average speed.
But remember: we describe current flow as the result of the motion of positive charge carriers

Ohm's Law

An electric field induces a current inside a conductor.
The electrons in the conductor do not move freely.
The frequent collisions with the atoms generate a RESISTANCE to the flow of current.

The relation between the applied voltage V, the resistance R of the conductor piece, and the current I that flows, is given by:

$$V = I R$$

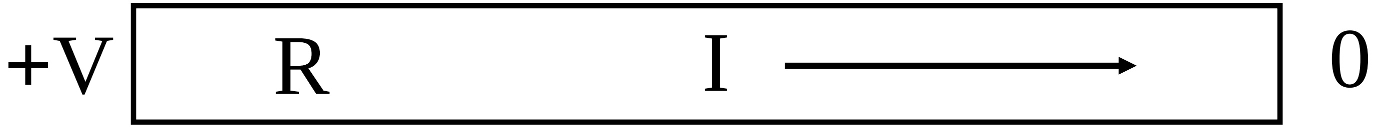


Ohm's Law

$$If \quad V = IR \quad then:$$

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

SI unit for R: Ω (Ohm) ⇒ Ω = V / A

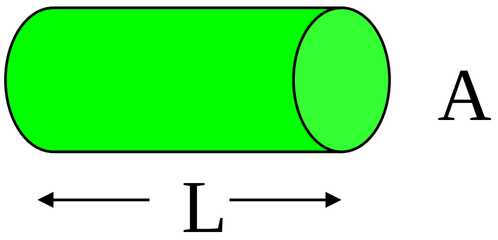


Ohm's Law

$$V = I\,R$$

The Resistance R depends on the material type and shape

The quantity that characterizes the resistance to current flow of a given material is the RESISTIVITY ρ (unit Ω m)



For a conductor of length L and section A

$$R = \rho\, L / A$$

Resistivities of Selected Materials

Material	Resistivity [Ω m]
Aluminum	2.65×10^{-8}
Cooper	1.68×10^{-8}
Iron	9.71×10^{-8}
Water (pure)	2.6×10^{5}
Sea Water	0.22
Blood (human)	0.70
Silicon	640
Glass	$10^{10} – 10^{14}$
Rubber	$10^{13} – 10^{16}$

Ohm's Law

$V = I\,R$ or $R = V/I$ or $I = V/R$

R is the **Resistance**

It depends on the material type and shape

$R = \rho\, L / A$ ***Unit: ohm (Ω)***

ρ is the **Resistivity**

It depends only on the material

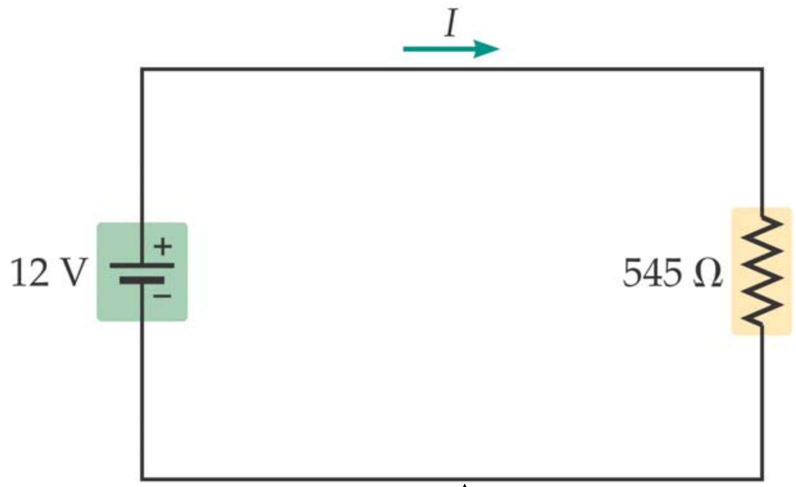
$\rho = R\, A / L$ ***Unit: Ohm-meter***

Sometimes we use

Conductivity $\sigma = 1 / \rho$ ***Unit: (Ohm m)$^{-1}$***

A note about circuits

The direction of the current is that of the flow of positive carriers



We concentrate the resistance at the resistor

We neglect the resistance in the wires (unless specified). The wires are equipotentials

Energy and Power in Electric Circuits

When a charge ΔQ, moves across a potential difference V, its electric potential energy U, changes by the amount:

$$\Delta U = \left(\Delta Q\right)V$$

Since power is rate of change of energy with time, the power dissipated as the charge ΔQ, moves across V, is:

$$P = \frac{\Delta U}{\Delta t} = \frac{\left(\Delta Q\right)V}{\Delta t} = IV$$

P = I V, unit ***W*** (Watt) ***W = A V or W = J / second***

Energy and Power in Electric Circuits

The expression $P = I V$ is general

When applied to a resistor that obeys Ohms Law $V = I R$ we have:

$P = IV$ or $P = V^2/R$ or $P = I^2R$

In a resistor power is dissipated as heat

What is the resistance of a Cu wire, 1.8 mm in diameter, and 1 m long ?.

$$R = \rho\, L / A \Rightarrow R = (1.68\text{x}10^{-8})\ \ 1 / \pi\ (0.0009)^2\ \Omega$$
$$R = 6.6\text{x}10^{-3}\ \Omega$$

What is the voltage difference between the extremes of a Cu wire, 1.8 mm in diameter, and 1 m long, when the current is 1.3 A ?.

$$V = I\, R = (1.3\ \text{A})\ 6.6\text{x}10^{-3}\ \Omega = 8.6\text{x}10^{-3}\ \text{V}$$

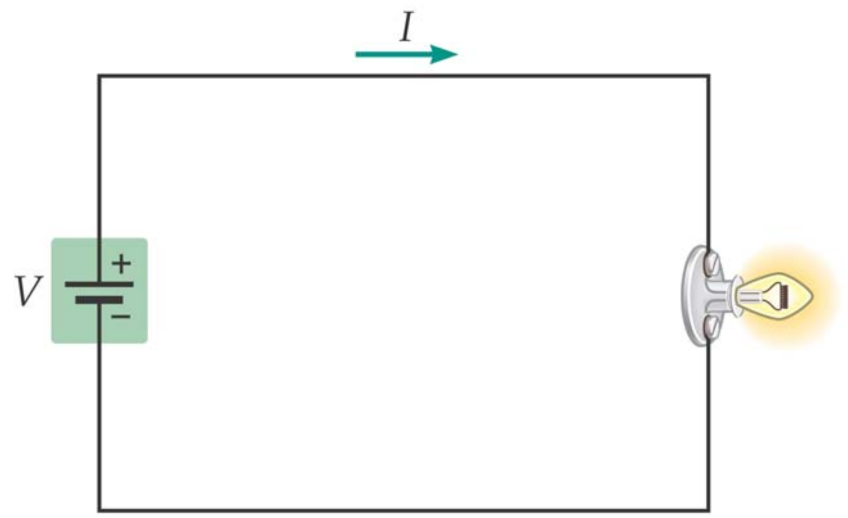
What is the power dissipated in a Cu wire, 1.8 mm in diameter, and 1 m long, when the current is 1.3 A ?.

$$P = I^2\, R = (1.3)^2\ 6.6\text{x}10^{-3}\ \text{W} = 1.12\text{x}10^{-2}\ \text{W}$$

A 1.5 V battery is connected to a 5 W bulb as shown.

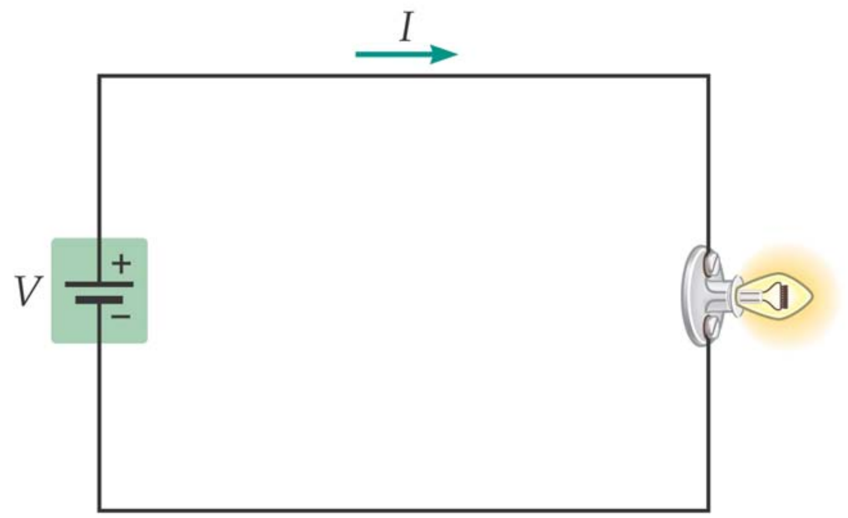
a) What is the current in the circuit

b) What is the resistance of the filament in the bulb



A 1.5 V battery is connected to a light bulb as shown. Which bulb lights brighter?

a) A 5 W bulb
b) A 10 W bulb



What determines the brightness of the bulb?

a) In terms of power
b) In terms of the properties of the filament