Electric Circuit, Ohm's Law

by

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In circuits, the relationship between electric current, I, electric potential difference, V, and resistance, R, is quantified by $V = I R$ (Ohm's Law). Work is the amount of energy transferred during an interaction. In electrical systems, work is done when charges are moved through the circuit. Electric power is the amount of work done by an electric current in a unit of time, which can be calculated using $P = I V$.

P4.10A Describe the energy transformations when electrical energy is produced and transferred to homes and businesses.

P4.10e Explain energy transfer in a circuit, using an electrical charge model.

P4.10j Explain the difference between electric power and electric energy as used in bills from an electric company.

Items;

1- Electric Circuit

2- Capacitor

3- Ohm's Law

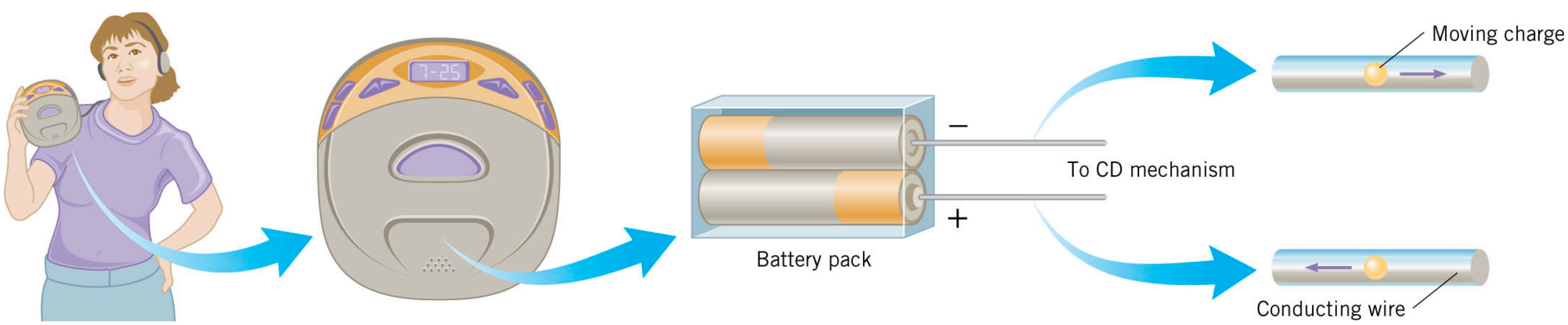
4- Power in Electric Circuit

5- Electric Energy

Electric Circuit

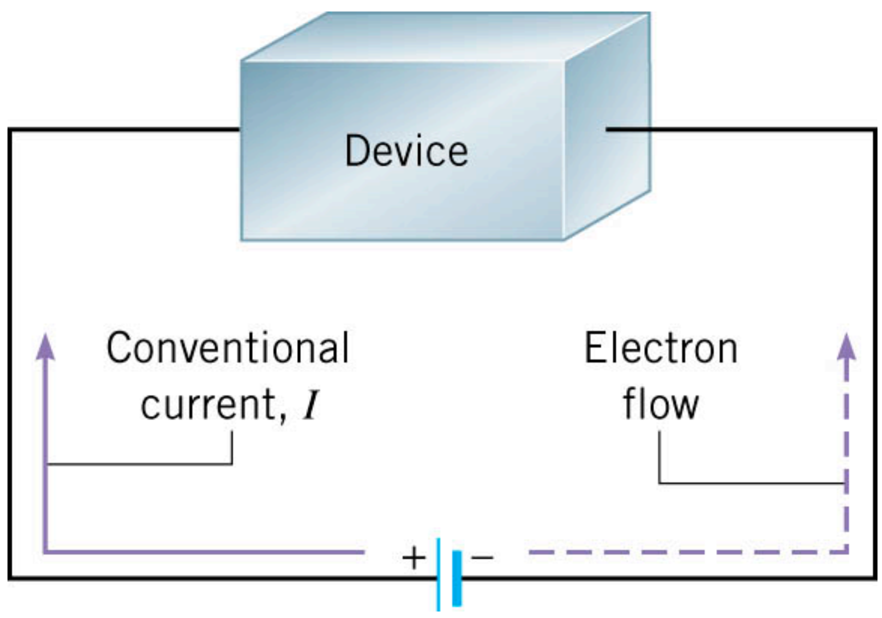
Electrons move in the presence of an electric field to a region of lower electric potential. As a result of the work done on them, the electrons possess electric potential energy that they can use to produce heat, light, and motion as they pass through various loads. This reduces their electric potential. To make it possible for the electrons to do this, we connect sources of electric potential energy to electric loads by means of circuits.

In an electric circuit, an energy source and an energy consuming device are connected by conducting wires through which electric charges move.



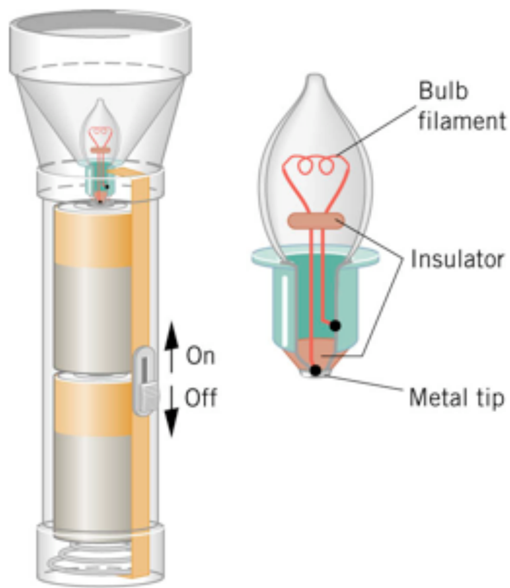
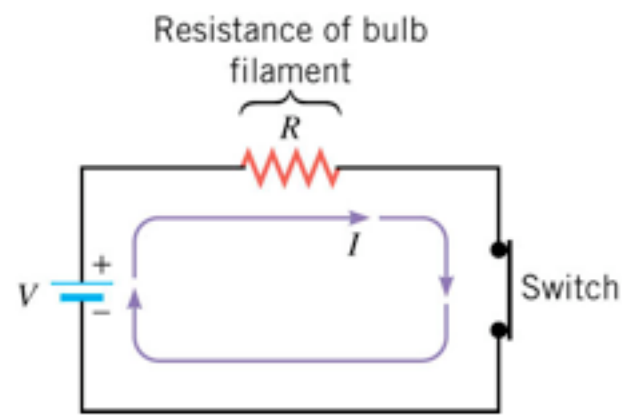
“Electron Flow” current is what constitutes an electric current in a solid conductor (such as wire). It is the flow of negatively charged electrons from the negative terminal to the positive terminal of the source of electric potential.

“Conventional” current is the hypothetical flow of positive charges that would have the same effect in the circuit as the movement of negative charges that actually does occur.



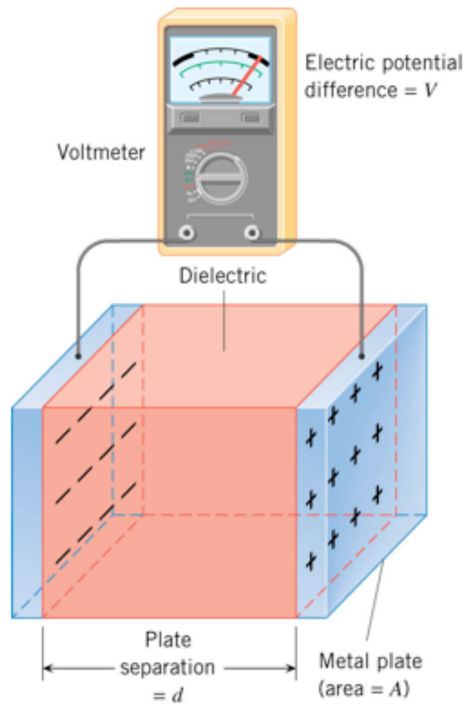
Example 1: *Flashlight;*

The filament in a light bulb is a resistor in the form of a thin piece of wire. The wire becomes hot enough to emit light because of the current in it. The flashlight uses two of electric potential V batteries to provide a current (I) in the filament. R is the resistance of the glowing filament.

Flashlight	**Circuit Schematic** **Electric Circuit Drawing of the Flashlight**
	

Storing Charges: The Capacitor

Capacitor is used to store electric charge. A parallel plate capacitor consists of two metal plates, one carrying charge +q and the other carrying charge –q. The region between the plates is filled with an electrically insulating substance called a dielectric.



THE RELATION BETWEEN CHARGE AND POTENTIAL DIFFERENCE FOR A CAPACITOR

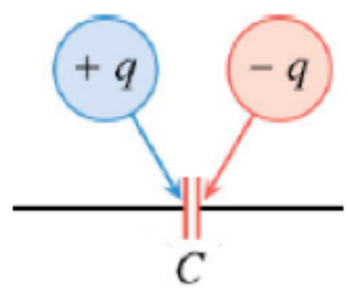
$$\boxed{q = C\,V}$$

C : The capacitance. It is the proportionality constant.

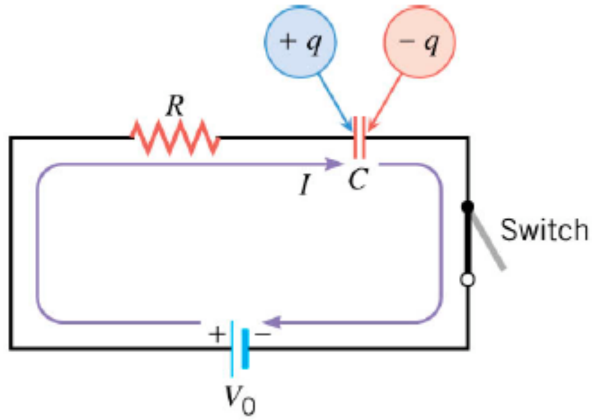
SI Unit of Capacitance: coulomb/volt = farad (F)

The larger C is, the more charge the capacitor can hold for a given V.

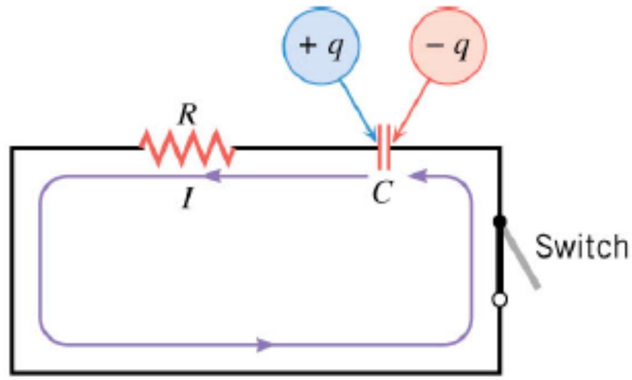
The symbol for capacitor in an electric circuit is



Example 2; *Capacitor Charging: Circuit Schematic;*



Example 3; *Capacitor Discharging: Circuit Schematic;*



Ohm's Law

George Simon Ohm (1787-1854), a German physicist, found that for a given conductor, the ration *V/I* is a constant. *V* is the voltage applied across a piece of material and *I* is the current through the material. The resistance (*R*) is defined as the ratio of the voltage *V* applied across a piece of material to the current I through the material.

Ohm's Law

$$\frac{V}{I} = \underbrace{R}_{\text{Resistance}} = \text{constant} \qquad \text{or} \qquad V = IR$$

SI Unit of Resistance: volt/ampere (V/A) = ohm (**Ω**)

V is the voltage applied across a piece of material.

I is the current through the material.

Power in Electric Circuits

The rate at which a load uses energy is defined as Power . When there is current (I) in a circuit as a result of a voltage (V), the electric power (P) delivered to the circuit is:

Electric Power	
$P = IV$	$P = I(IR) = I^2R$ $P = \left(\frac{V}{R}\right)V = \frac{V^2}{R}$

SI Unit of Power: watt (W)

Electric Energy

When electrons move through a circuit, they disperse the energy they receive from the source to the various loads they encounter. The amount to energy lost during a period of time t, is given by:

Electric Energy
$E = Pt$

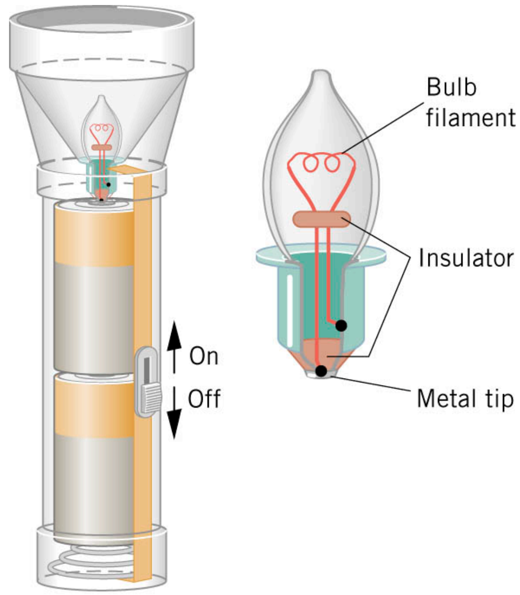
SI Unit of Power: watt (W)

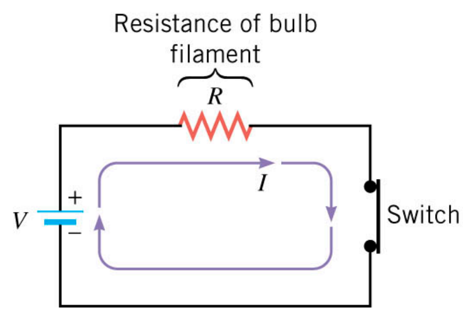
SI Unit of Energy is Joules (J)

Time (t) has to be in seconds.

Example 4: *Flashlight*

The filament in a light bulb is a resistor in the form of a thin piece of wire. The wire becomes hot enough to emit light because of the current in it.


Bulb filament
Insulator
Metal tip
On
Off


Resistance of bulb filament
R
I
V
+
−
Switch

The flashlight uses two 1.5-V batteries to provide a current (I) of 0.40 A in the filament. Find the resistance (R) of the glowing filament.

Data Table		
V	I	R
1.5 V	0.40 A	?

$$R = \frac{V}{I} = \frac{3.0\ \text{V}}{0.40\ \text{A}} = 7.5\ \Omega$$

Furthermore, determine:

(a) the power (P) delivered to the bulb and

(b) the energy (E) dissipated in the bulb in 5.5 minutes (or 5.5 x 60 = 330 seconds) of operation of the flashlight.

Data Table				
V	I	t	P	E
1.5 V	0.40 A	330 s	?	?

(a) $$P = IV = (0.40\ \text{A})(3.0\ \text{V}) = 1.2\ \text{W}$$

(b) $$E = Pt = (1.2\ \text{W})(330\ \text{s}) = 4.0 \times 10^{2}\ \text{J}$$

References:

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Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current.* *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

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