Electric Potential, Current, Resistance

by

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P4.10D Discriminate between voltage, resistance, and current as they apply to an electric circuit.

P4.10f Calculate the amount of work done when a charge moves through a potential difference, V.

Items;

1- Electric Potential Energy.

2- Work and Electric Potential.

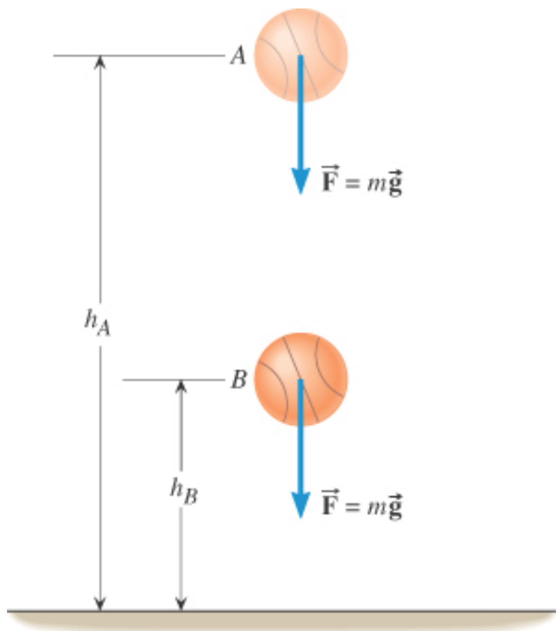
3- Electric Current.

4- Resistance in Electric Circuit.

5- Electric Circuit.

Gravitational Potential Energy and Electric Potential Energy

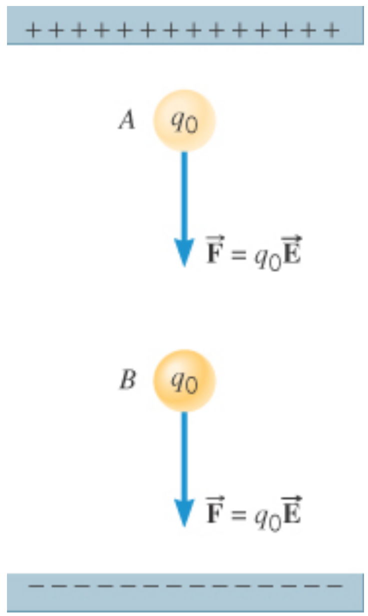
A basketball of mass m, accelerates downward from an initial point A of height (h_A) to a final point B of height (h_B).



Using the work-energy theorem, the work done by the gravitational field ($W_{gravity}$) going from A to B is equal to the difference in gravitational potential energy (GPE) between A and B. It is independent of the path taken.

$$(W_{gravity})_{AB} = GPE_A - GPE_B = mg\,(h_A - h_B)$$

Analogous situations exist between: the work done by the gravitational field (G) on the ball and the work done by the electric field (E) on the charge. The electric force (F) is conservative.



The work done by the electric field on the charge ($W_{electric}$) going from A to B is equal to the difference in electric potential energy (EPE) between A and B. It is independent of the path taken.

$$(W_{electric})_{AB} = EPE_A - EPE_B$$

Electric Potential (V) and Electric Potential Difference (ΔV)

The electric potential at a given point is the electric potential energy of a small test charge divided by the charge itself.

$$V = \frac{\text{EPE}}{q_o}$$

SI Unit of Electric Potential: joule/coulomb = volt (V)

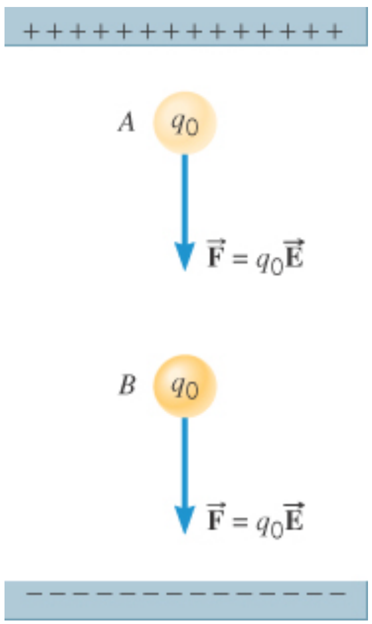
The potential difference (ΔV) between two points A and B in an electric field is the work done per unit charge as a charge is moved between these points:

$$\Delta V = V_B - V_A$$

$$V_B - V_A = \frac{\text{EPE}_B}{q_o} - \frac{\text{EPE}_A}{q_o} = \frac{-W_{AB}}{q_o}$$

Example 1: *Work, Potential Energy and Electric Potential*

A test charge of $+2.0\times10^{-6}$ C moves from A to B. The work done by the electric field on the charge ($W_{electric}$) going from A to B is $+5.0\times10^{-5}$ J.



a) Find the difference in EPE between these points.

b) Determine the potential difference between these points.

Data Table			
$(W_{electric})_{AB}$	q_o	$EPE_B - EPE_A$	$\Delta V = V_B - V_A$
$+5.0\text{x}10^{-5}$ J	$+2.0\text{x}10^{-6}$ C	?	?

a) $EPE_A - EPE_B = (W_{electric})_{AB}$

$$EPE_B - EPE_A = -(W_{electric})_{AB} = -5.0\text{x}10^{-5} \text{ J}$$

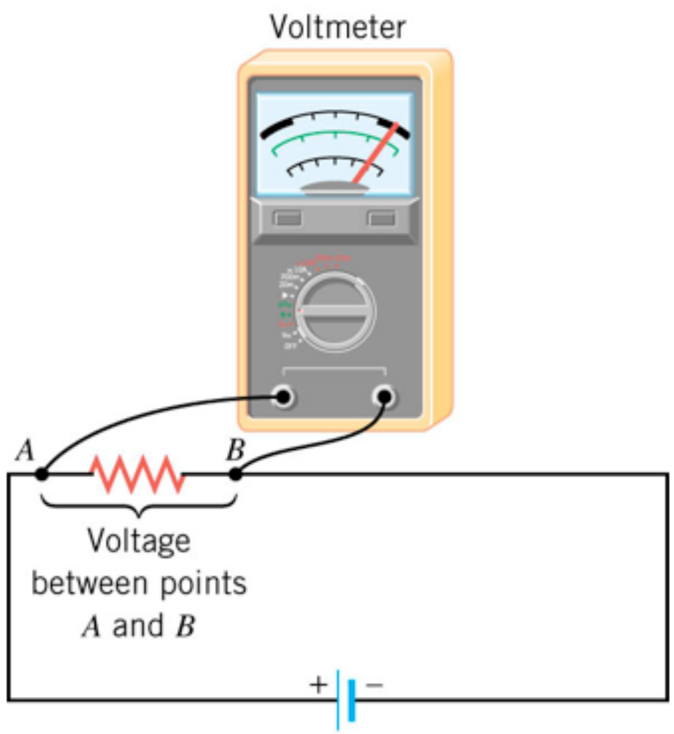
b) $\Delta V = V_B - V_A$

$= -(W_{electric})_{AB} / q_o$

$= -5.0\text{x}10^{-5} / 2.0\text{x}10^{-6}$

$= -25$ Volt

Voltmeter: measures voltage across some device in the circuit



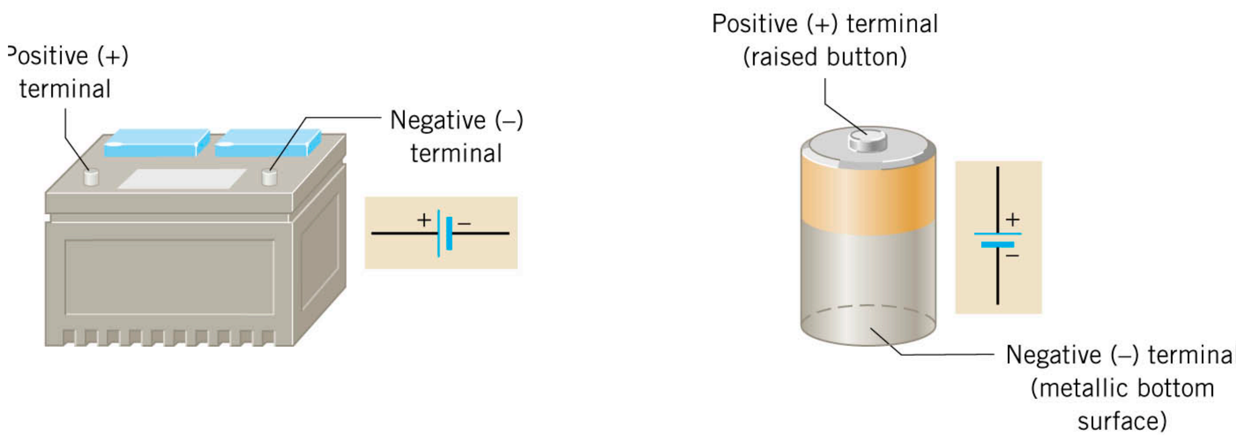
Electric Current (I)

When electrons move through a conductor, they constitute an electric current.

Within a battery, a chemical reaction occurs that transfers electrons from one terminal to another terminal.

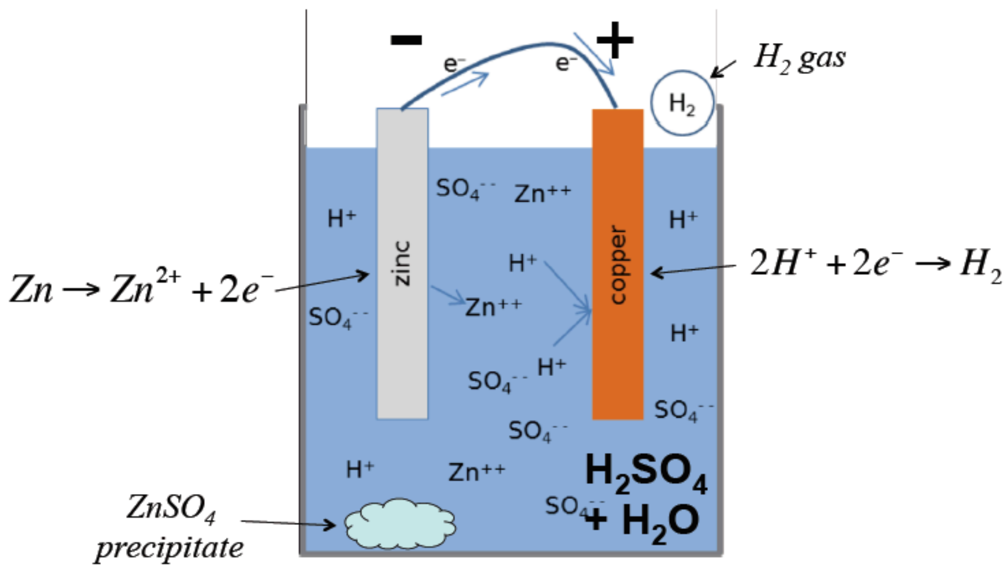
Example 2: *Batteries;*

The drawing below shows the terminals of a car battery and of a flashlight battery. The drawing also illustrate the symbol  used to represent a battery in circuit drawing.



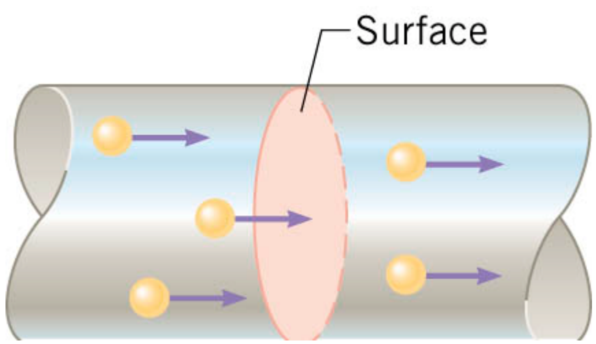
Voltaic Cell

Voltaic cell is a source of continuous electric potential. Two electrical conducting materials with different electrical potential are connected together via a conducting wire. Electric current travels from the conductor with higher potential to the conductor with lower potential and this process consumes energy. The electrical current will continue until a potential equilibrium is achieved.



Zn – Cu cell in dilute acid (H2SO4) electrolyte

When electrons move through a conductor, they constitute an electric current. The electric current (I) is the amount of charge (q) per unit time (t) that passes through a surface that is perpendicular to the motion of the charges.

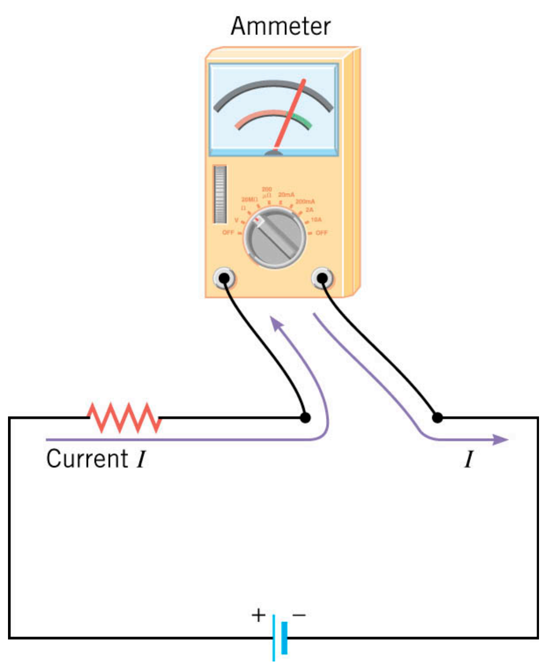


$$I = \frac{\Delta q}{\Delta t}$$

SI unit for electric current is: One coulomb per second equals one ampere (A).

By definition, the direction of the current *I* in a circuit is the direction in which the positive charges would move. The actual charge carriers, however, are generally electrons; hence, the move in the opposite direction to *I*.

If the charges move around the circuit in the same direction at all times,the current is said to be direct current (dc) --> e.g. simple circuits with batteries are normally dc. Ammeter- measures current flowing in the circuit



Example 3: *Electric Toaster;*

Calculate the amount of current through an electric toaster if it takes 900 C of charge to toast two slices of bread in 1.5 min.

Data Table		
q	t	I
900 C	1.5 min = 90 second	?

$$I = q / t = 900 / 90 = 10 \text{ A}$$

Example 4: *Electroscope;*

A gold-leaf electroscope with 1.25×10^{10} excess electrons is grounded and discharges completely in 0.5 s. Calculate the average current through the grounding wire.

Data Table				
N	e	t	q	I
1.25×10^{10}	1.6×10^{-19} C	0.5 s	?	?

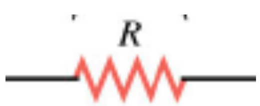
$q = N\,e = (1.25 \times 10^{10})\,(1.6 \times 10^{-19}) = 2 \times 10^{-9}$ C

$I = q / t = 2 \times 10^{-9}\;\; 0.5 = 4.0 \times 10^{-9}$ A

Resistance in Electric Circuits (R)

When electrons pass through a device that uses their electrical energy, they experience an opposition or resistance (R), to their flow. As a result they loose energy to the molecules and atoms of the conductor as they move through it.

So, resistance represents to what extent the current can flow freely in the circuit. The larger resistance slows down electrons and transfers energy as heat to the material. A larger current arises from a smaller resistance.

To the extent that a wire or an electrical device offers resistance to electrical flow, it is called a resistor. The symbol of a resistor is 

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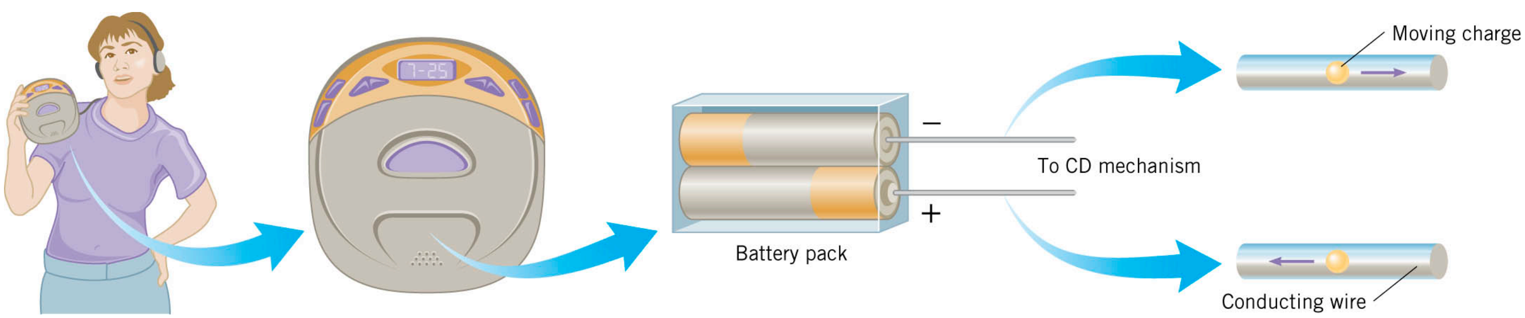
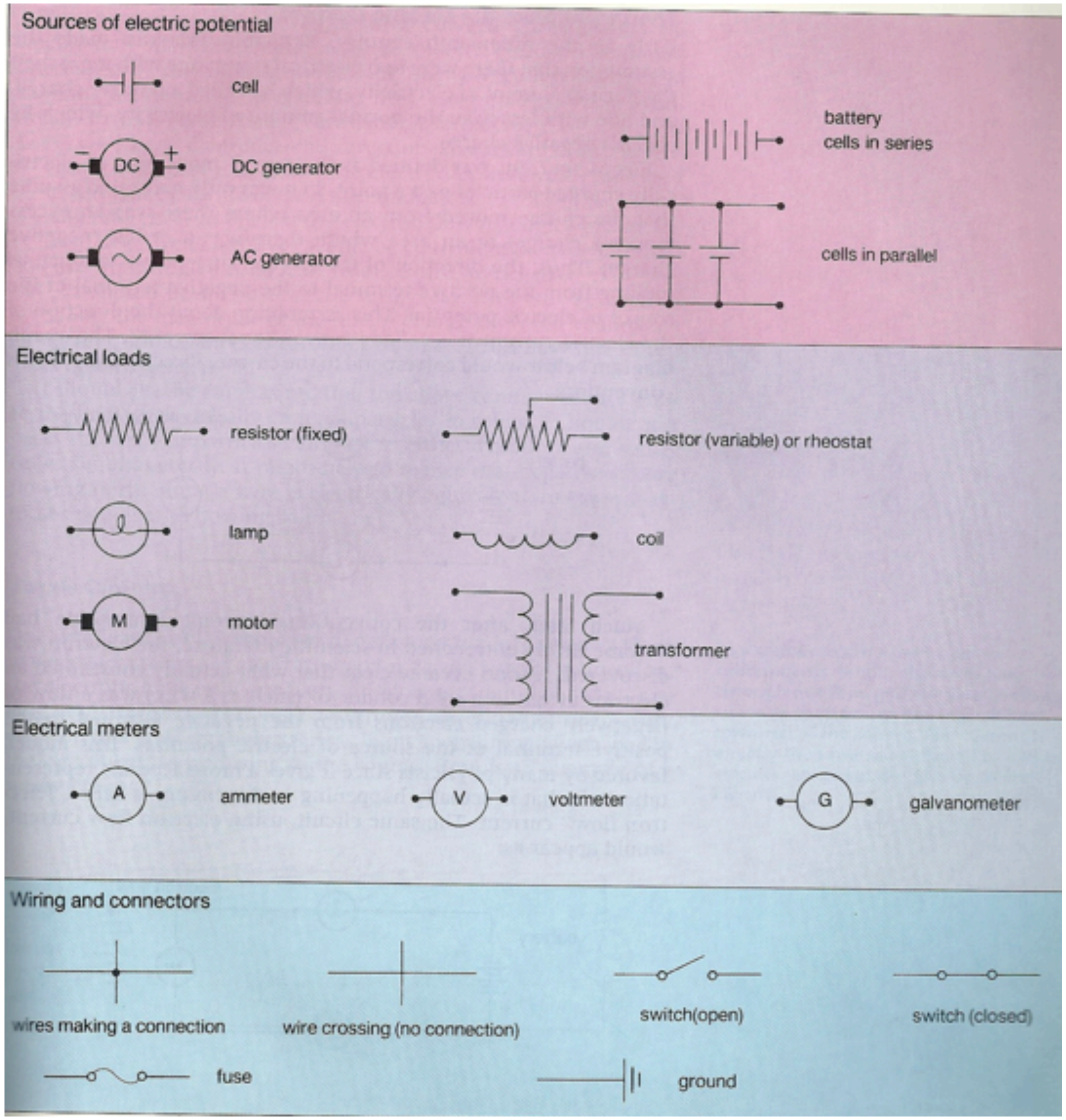
Electric Circuit

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

Example 5: *CD player*

In a electric circuit, energy is transferred from a source (the battery pack) to a device (the CD player) by charges that move through a conducting wire.




Sources of electric potential
cell
DC generator
DC
− +
AC generator
battery
cells in series
cells in parallel
Electrical loads
resistor (fixed)
resistor (variable) or rheostat
lamp
coil
motor
M
transformer
Electrical meters
A
ammeter
V
voltmeter
G
galvanometer
Wiring and connectors
wires making a connection
wire crossing (no connection)
switch(open)
switch (closed)
fuse
ground

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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