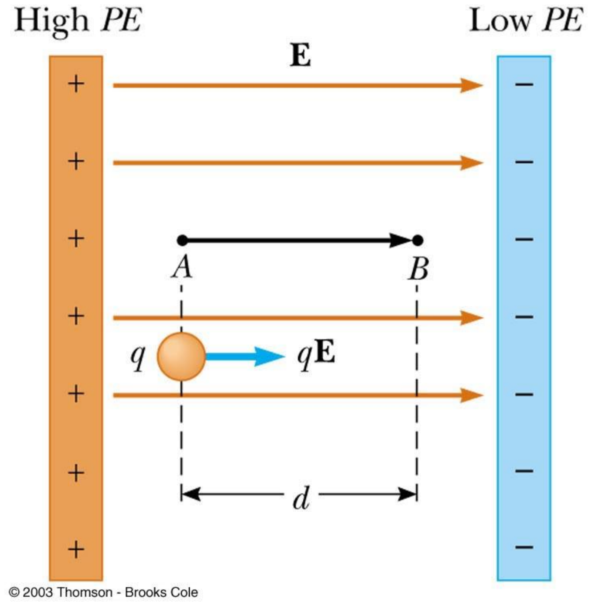
Chapter 2 Dynamic Electricity

Electric Potential Difference



- There is a uniform field between the two plates
- As the positive charge moves from A to B, work is done
- $W_{AB}=F\ d=q\ E\ d$
- $\Delta PE = -W_{AB} = -q\ E\ d$
- only for a uniform field
- The potential difference between points A and B is defined as the change in the potential energy (final value minus initial value) of a charge *q* moved from A to B divided by the size of the charge

  $$\mathbf{\Delta V = V_B - V_A = \Delta PE / q}$$
- Potential difference is not the same as potential energy
- Another way to relate the energy and the potential difference:

  $$\Delta PE = q\ \Delta V$$
- Both electric potential energy and potential difference are *scalar* quantities
- Units of potential difference

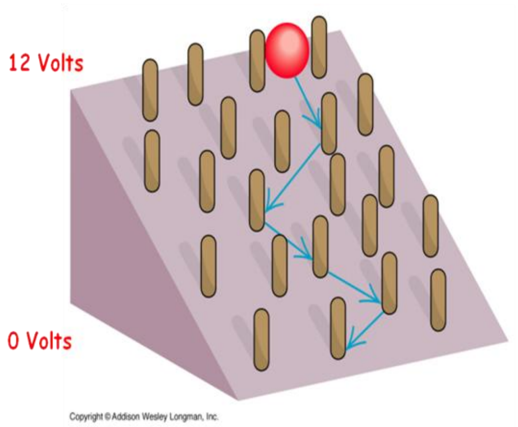
  V = J/C
- A special case occurs when there is a *uniform electric field*

  $$V_B - V_A = -Ed$$
- Gives more information about units: N/C = V/m

- Physical quantity which state electrons are able to flow through materials → goes to the earth
- The earth has zero for potential difference
- Potential difference or voltage difference: potential magnitude between two points in circuit
- The important word is potential **difference** and it is not potential.
- If potential difference between two points are zero or have same potential, then electric current will not flow through the circuit
- Which one the dangerous: electric current or potential difference?
  - Electric current and it is not electric potential or voltage or potential difference
  - Problem:
    - Birds are on the non insulated wire with high voltage, but why we don't get burned birds?

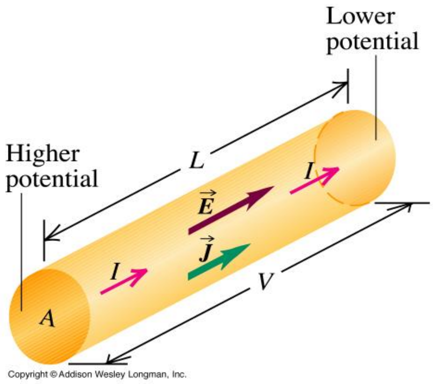
Concept of Electric Current

- Electrons keep on the surface of material or stay on the place permanently → static electricity
- Electric charges moves around through the conductor → called electric current → dynamic electricity
- Electric current concepts:
  - There is potential difference (*level*) between two points or plates
  - From high potential to the lower potential
  - Convention of Scientist about electric current (Conventional Current):
    - ✓ 19^{th} Century: positively charged particles, electron haven't invented yet at this period.
    - ✓ From high potential to the lower potential
    - ✓ After 19^{th} Century, electrons was invented by J.J. Thompson

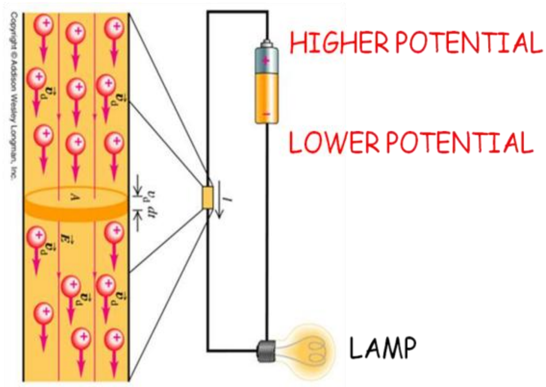


Analogy of charge moving in conductor

- Actually, now, it is not positively charged particles which flows through the circuit (conventional current), but electrons (negatively charged particles) flows through the conductors.
- Still use conventional current?
  - Conventional current direction is opposite to the direction of electric charges.
  - Quantitatively: the amount of electrons flows through conductor have the same amount with positively charges when positively charges flows in the opposite way through the electrons
- Two condition when electric current flows through the circuit:
  1. Closed circuit
  2. Potential difference between two points in the circuit



Conductor with conventional current moving from high potential to the lower potential

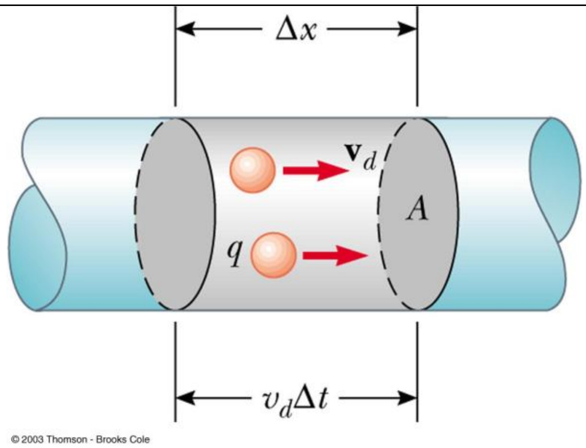


Conventional charges drifting in conductor

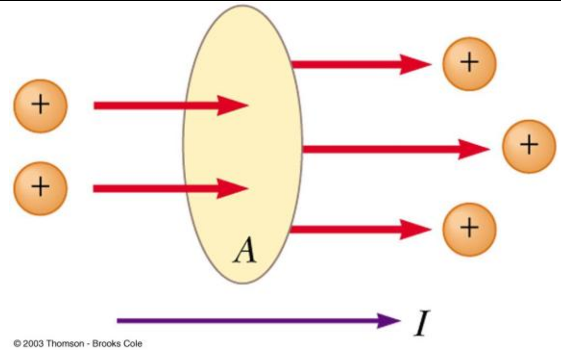
Other Opinion of Concept Electric current

- Metals or Conductor have less electrons → positively charged materials → ***hole***
- Need some of electrons to fill the empty hole
- It can't be happened because it is not reacted with the other atom which has more electrons
- By using electromotive force from electric source (for example: battery, accumulator, solar cell, etc) to push electrons through the conductor
- But the empty hole can't be filled → electrons flows through the conductor with opposite direction with the empty hole
- Empty hole flows also in opposite direction through the electrons
- Empty hole which flows is named the positively charges or electric current

Electric Current (*I*)



1. Charged particles moves through a conductor of cross sectional area *A*.
2. *n* is the number of charge carriers per unit volume *V* (=concentration)
3. $nA\Delta x = nV$ is the total number of charge carriers in *V*.
4. The total charge is the number of carriers times the charge per carrier, *q* (elementary charge)
   $\Delta Q = (nA\Delta x)q$ [unit: $(1/m^3)(m^2\,m)As$=C]
5. The drift speed, v_d, is the speed at which the carriers move
   $v_d = \Delta x/\Delta t$
6. Rewritten: $\Delta Q = (nAv_d\Delta t)q$
7. Finally, current, $I = \Delta Q/\Delta t = nqv_dA$

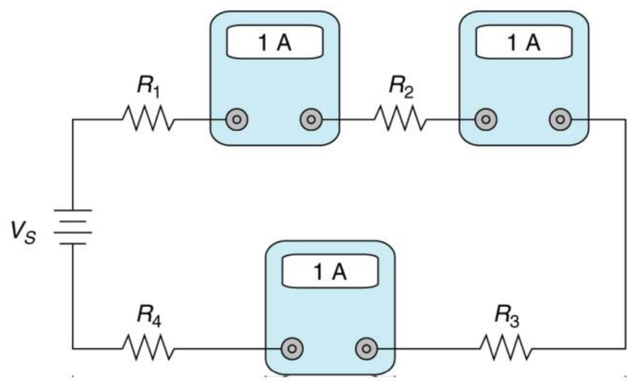
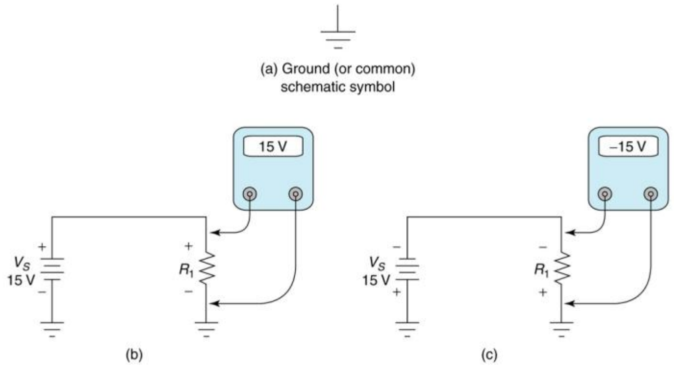


- Positively charges moving but actually electrons moving through the conductor
- More positively charges moves through cross sectional area of wire per time → electric current will be strength.
- Definition:
  1. Rate between positively charges (*Q*) which flows through cross sectional area through the time (*t*).
  2. The rate at which the charges flows through a certain cross section

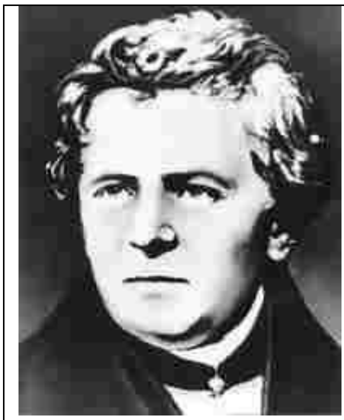
$$I = \frac{Q}{t} \text{ or } Q = It$$

  3. *Q* = electric charge (C or coulomb), *t* = time (s), *I* = electric current (ampere, A)
  4. 1 coulomb = 1 A s
  5. One coulomb is electric charges which flow in any points through the circuit when constant current for one ampere is flowing in one second.

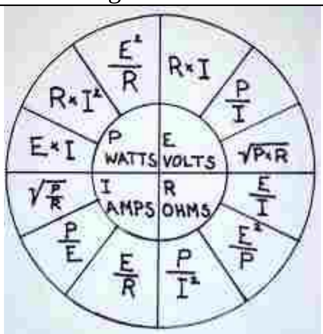
Device to Measure Electric Current and Voltage

Electric Current	Potential Difference or Voltage
Ψ By using ammeter Ψ It should be connected by series connection to the circuit 	ϒ By using voltmeter ϒ It should be connected by parallel to the circuit 

Ohm's Law



George Simon Ohm

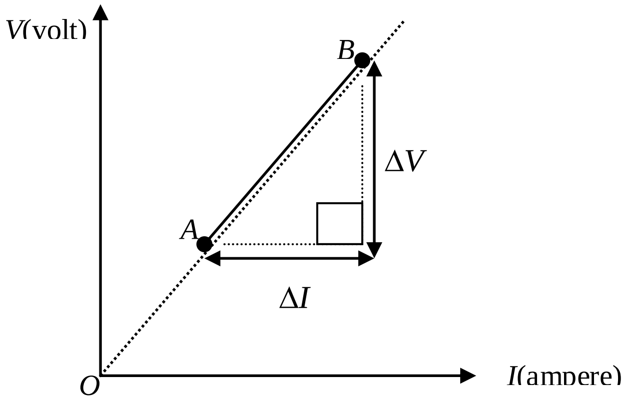


- ✓ The magnitude of the electric current that flows through a closed circuit depends directly on the voltage between the battery terminals and inversely to the circuit resistance. The relationship that connects current, voltage and resistance is known as OHM'S LAW and is written as follows:

$$V = IR$$

  - The current is measured in amperes (A)
  - The voltage in volts or J/C
  - The resistance in ohms (Ω).

- ✓ Mathematical Relation between electric current and potential difference (*V* versus *I*)



  - ✓ From the graph *V* versus *I*, remember that graph of $y = mx$, *m* is a gradient and $m = \frac{\Delta y}{\Delta x}$, then based on the graph *V* versus *I*, $m = \frac{\Delta V}{\Delta I}$.
  - ✓ The equation related to the Ohm's Law would be $V = mI$, *m* is a constant
  - ✓ Since *m* is constant, named as a electric resistance (*R*)
  - ✓ The unit for electric resistance is ohm (Ω), the equation can be written as:

$$V = IR$$

Non-ohmic Conductor:	Ohmic Conductor
1. disobey the Ohm's Law 2. Graph *V* versus *I* is not straight line 3. The value of resistance is influenced by temperature 4. The component: Bulb	1. Obey the ohm's law 2. Resistance value is constant 3. Nothing temperature variable into resistance value 4. The component: constant wire

Application of Ohm's Law

- ✓ Why electricity circuit needs load?-read electric current-
- ✓ Ohm's Law and Electric Shock
- ✓ Fuse: wire-cut off-high load-uncontrolled-house safety-electricity

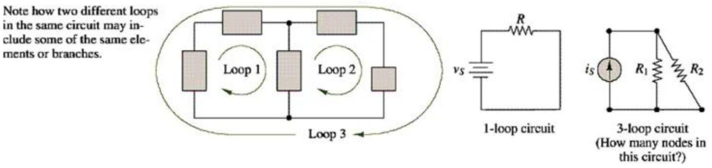
KIRCHHOFF'S LAW

1st Rule (Kirchhoff Voltage Law)
Loop Rule

- When any closed circuit loop is traversed (moved across area), the algebraic sum of the changes in potential must equal zero.
- $\sum_{loop} V_n = 0$
- **potential difference is independent of path**
- Rules of the road:

We will follow the convention that voltage drops enter with a + sign and voltage gains enter with a - sign in this equation.

➢ **Move clockwise around circuit:**

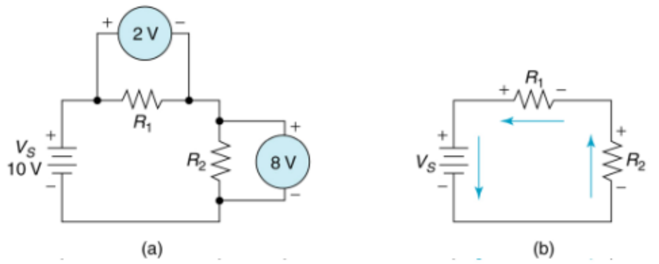


- The sum of the component voltages in a series circuit must equal the source voltage

  $V_s = V_1 + V_2 + V_3 + ... + V_n$

  1840 – German Physicist, Gustav Kirchhoff
- Actual wording – The algebraic sum of the voltages around a closed loop is zero
- The following equation takes polarity into account

  $V_s + V_1 + V_2 + V_3 + ... + V_n = 0\,\text{V}$
- Example:

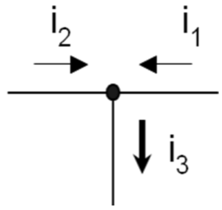


V_S = +10V, V_1 = +2V, V_2 = +8V

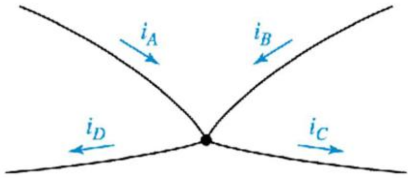
$$-V_S + V_1 + V_2 = -10\,\text{V} + 2\,\text{V} + 8\,\text{V} = 0\,\text{V}$$

2nd Rule (Kirchhoff Current Law)
Junction Rule

- In deriving the formula for the equivalent resistance of 2 resistors in parallel, we applied Kirchhoff's Second Rule (the junction rule).
- At any junction point in a circuit where the current can divide (also called a node), the sum of the currents into the node must equal the sum of the currents out of the node.
- $\sum I_{in} = \sum I_{out}$
- **The conservation of charge at any given node.**
- The algebraic sum of the currents entering and leaving a point must equal zero
- In other words, the total current leaving a point must equal the total current entering that point



$$\sum_{k=1}^{n} i_k = 0$$



➢ The algebraic sum of the currents entering the node must be zero:

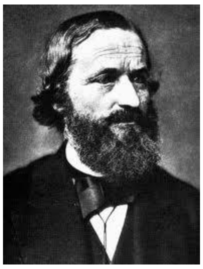
$i_A + i_B + (-i_C) + (-i_D) = 0$

➢ It is evident that the law could be equally well applied to the algebraic sum of the currents leaving the node:

$(-i_A) + (-i_B) + i_C + i_D = 0$

➢ We might also wish to equate the sum of the currents having reference arrows directed into the node to the sum of those directed out of the node:

$i_A + i_B = i_C + i_D$



Gustav Kirchhoff

Series and Parallel Circuit

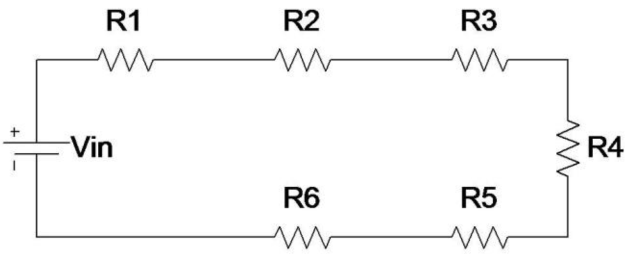
Series Circuit

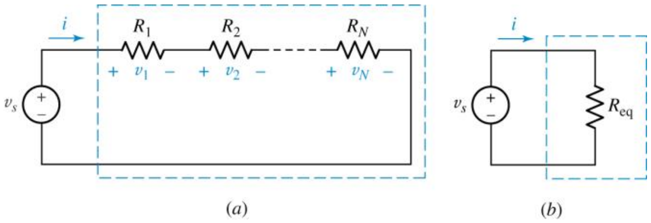
- Series Circuit – a circuit that contains only one current path.
- The current at any point in the circuit equals to the current at all others points in the circuit.

$$I_t = I_1 = I_2 = I_3 = ... = I_n$$

- The value of the currents depends on the source voltage and the total circuit resistance. By formula

$$I_t = \frac{V_s}{R_t}$$





$$V_{total} = V_1 + V_2 + V_3 + ... + V_n$$

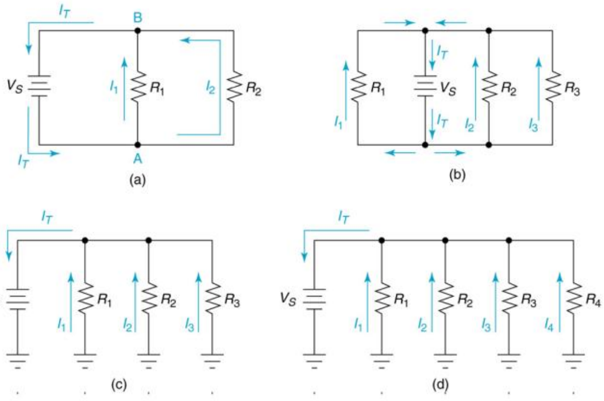
$$R_{eq} = R_1 + R_2 + R_3 + ... + R_n$$

$$V_s = R_{eq} I_t$$

$$P_{total} = P_1 + P_2 + P_3 + ... + P_n$$

Parallel Circuit

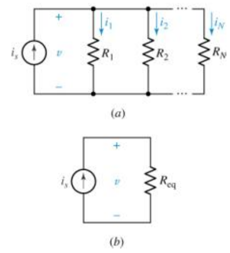
- Parallel Circuit – a circuit that provides more than one current path between any two points



- Current characteristic: $I_t = I_1 + I_2 + I_3 + ... + I_n$
- I_n = the current through the highest-numbered branch in the circuit
- Voltage across each component is equal.

$$V_t = V_1 = V_2 = V_3 = ... = V_n$$

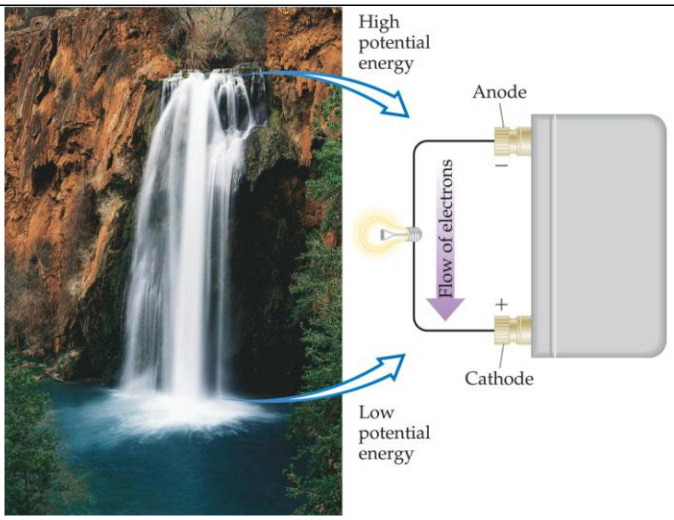
- Current through each branch is determined by the source voltage and the resistance of the branch. $I_n = \frac{V_s}{R_n}$
- Resistance Characteristics – the total circuit resistance is always lower than any of the branch resistance values



$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... + \frac{1}{R_n}$$

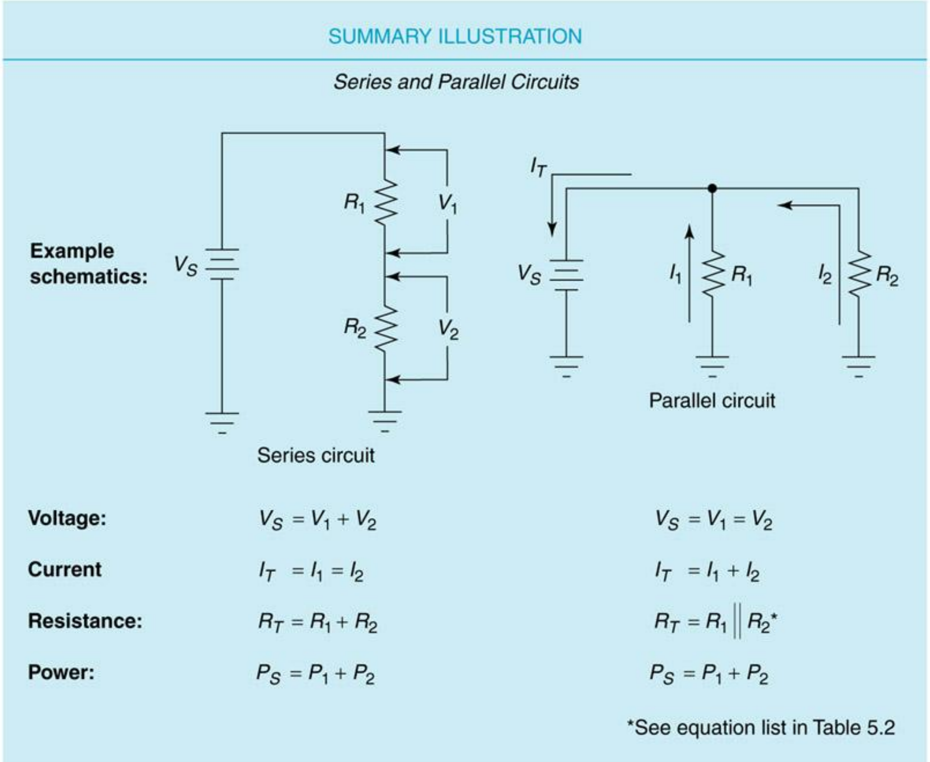
- Total Power – sum of the power dissipation values for the individual components
- The lower value of the branch resistance, the higher percentage of the total power it dissipates (opposite that of series circuits)

Internal Resistance and Electromotive Force



- Water only spontaneously flows one way in a waterfall.
- Likewise, electrons only spontaneously flow one way in a redox reaction—from higher to lower potential energy.
- The potential difference between the anode and cathode in a cell is called the electromotive force (emf).
- It is also called the cell potential, and is designated E_{cell}.
- Cell potential is measured in volts (V).
- 1 V = 1 J/C

- Internal resistance:
  - Particle needs energy to move from one point to the other point
  - Battery or the other electric source:
    - need energy to push the energy inside the battery
    - will take a small energy to push the energy inside the battery
    - Battery itself: has resistance inside the battery to resist small energy to push energy inside the battery
    - 9V battery will resist 0.1V for battery itself to push 8.9V into electricity circuit.

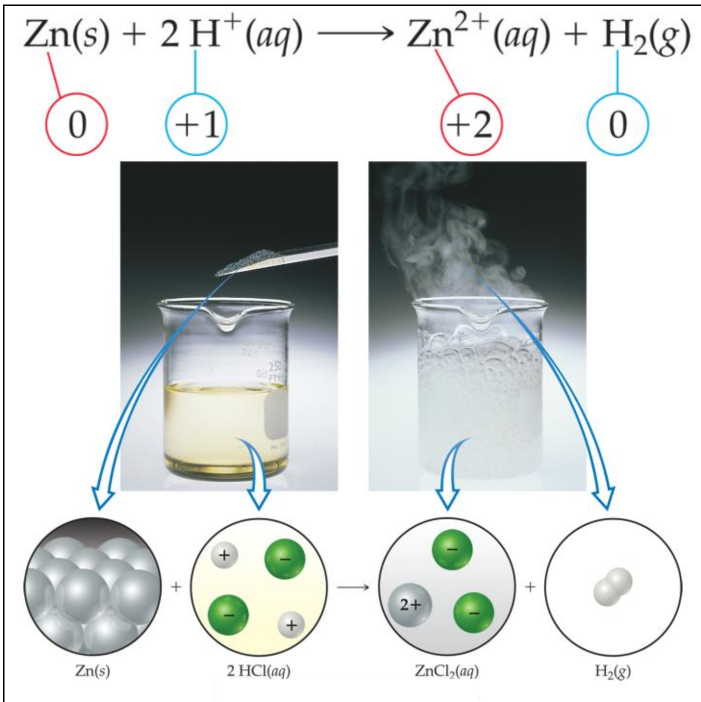


Resistivity

- The value of resistance depends on the:
  - Resistivity of materials it self
  - Length of materials
  - Cross sectional area
- The formula can be written:
  - $R = \rho \frac{l}{A}$

A Brief History of Electrochemistry

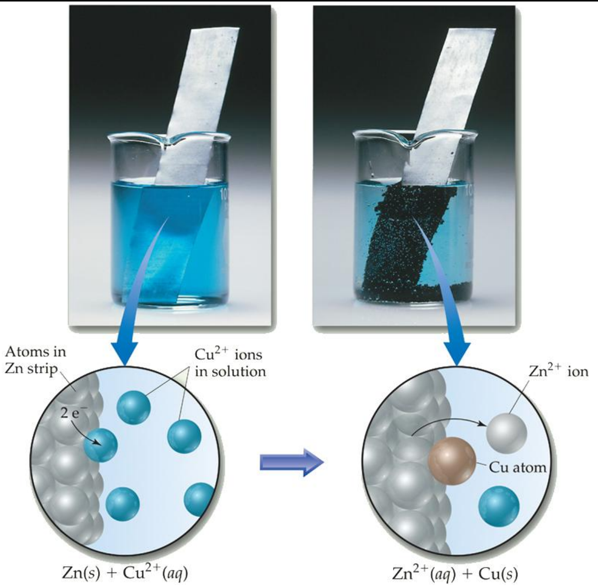
Ψ In electrochemical reactions, electrons are transferred from one species to another.



- In order to keep track of what loses electrons and what gains them, we assign oxidation numbers.
- A species is oxidized when it loses electrons.
  - Here, zinc loses two electrons to go from neutral zinc metal to the Zn^{2+} ion.
- A species is reduced when it gains electrons.
  - Here, each of the H^+ gains an electron and they combine to form H_2.
- What is reduced is the oxidizing agent.
  - H^+ oxidizes Zn by taking electrons from it.
- What is oxidized is the reducing agent.
  - Zn reduces H^+ by giving it electrons.

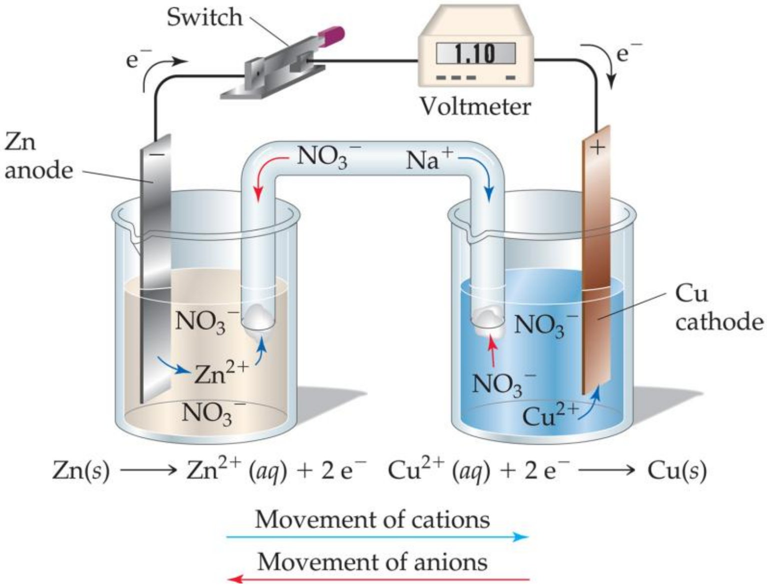
ELECTRIC SOURCES

Voltaic Cells

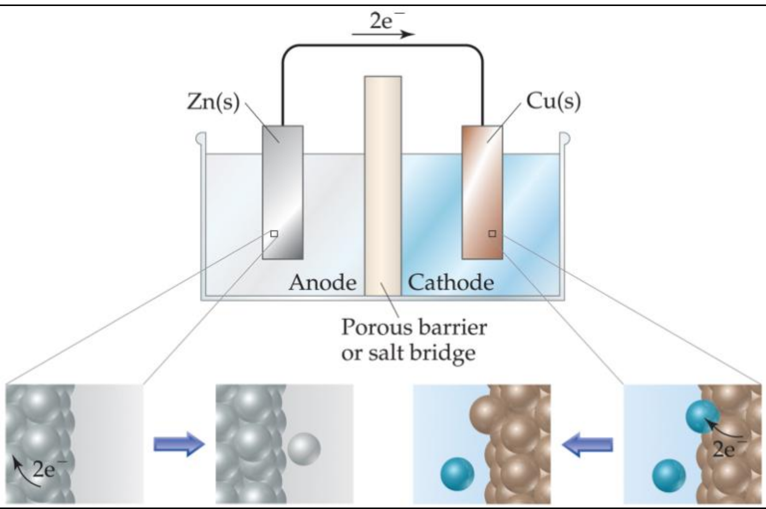


In spontaneous oxidation-reduction (redox) reactions, electrons are transferred and energy is released.

We can use that energy to do work if we make the electrons flow through an external device.
We call such a setup a voltaic cell.



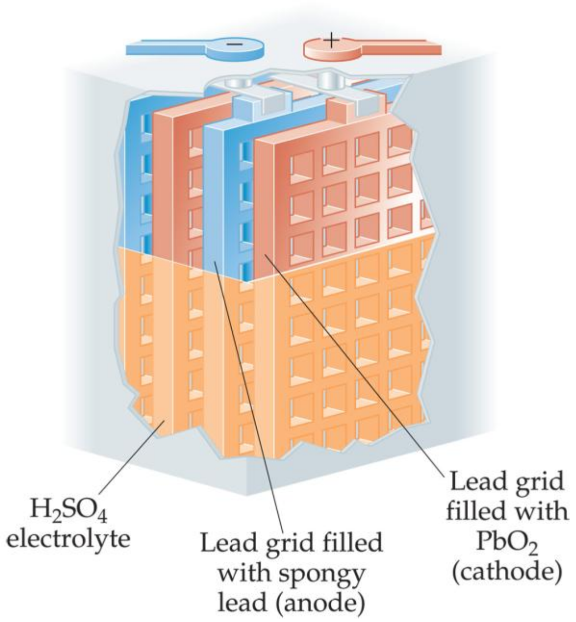
- A typical cell looks like this.
- The oxidation occurs at the anode.
- The reduction occurs at the cathode.
- Once even one electron flows from the anode to the cathode, the charges in each beaker would not be balanced and the flow of electrons would stop.
- Therefore, we use a salt bridge, usually a U-shaped tube that contains a salt solution, to keep the charges balanced.
  - Cations move toward the cathode.
  - Anions move toward the anode.

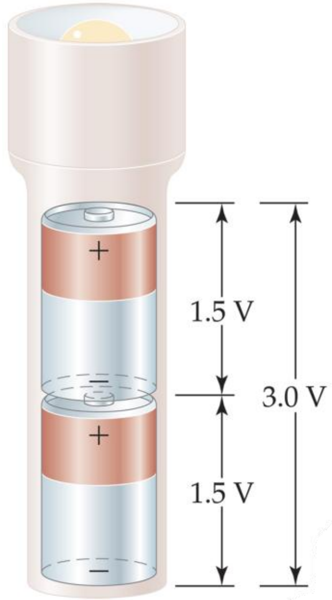


- In the cell, then, electrons leave the anode and flow through the wire to the cathode.
- As the electrons leave the anode, the cations formed dissolve into the solution in the anode compartment.
- As the electrons reach the cathode, cations in the cathode are attracted to the now negative cathode.
- The electrons are taken by the cation, and the neutral metal is deposited on the cathode.

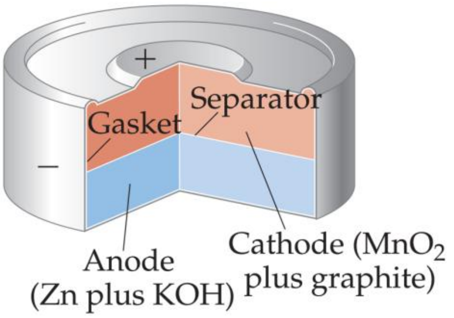
Batteries

Accumulator

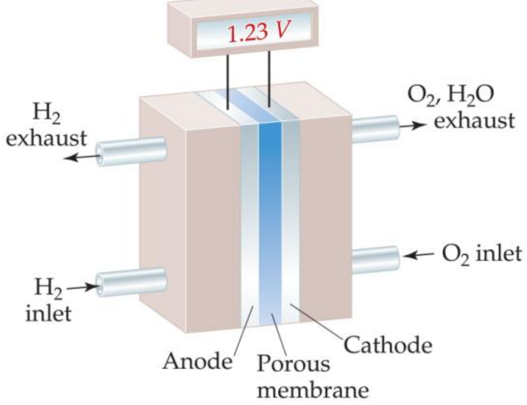




Alkaline Battery



Hidrogen Fuel Cells

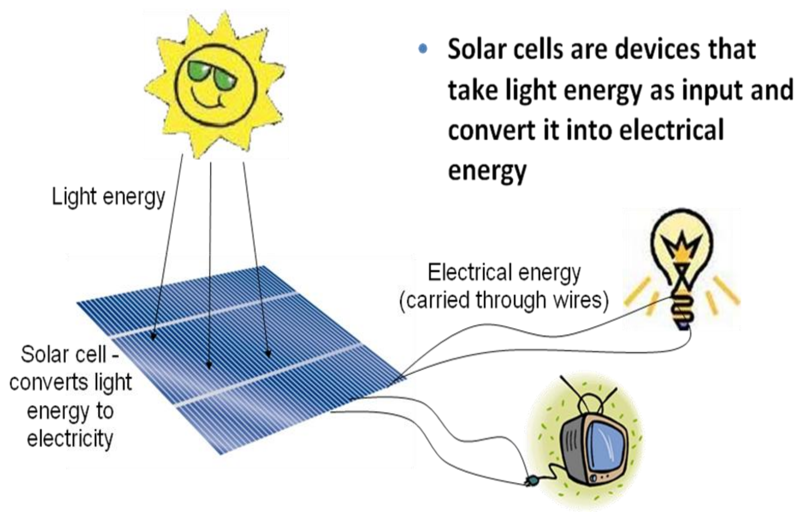


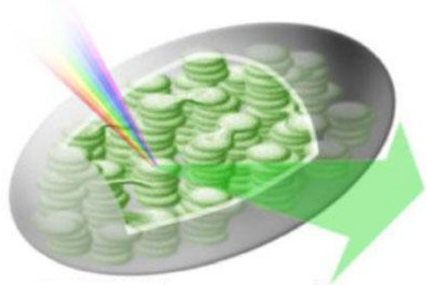
Nano Sense in Photovoltaic Cells

Silicon-based solar cell

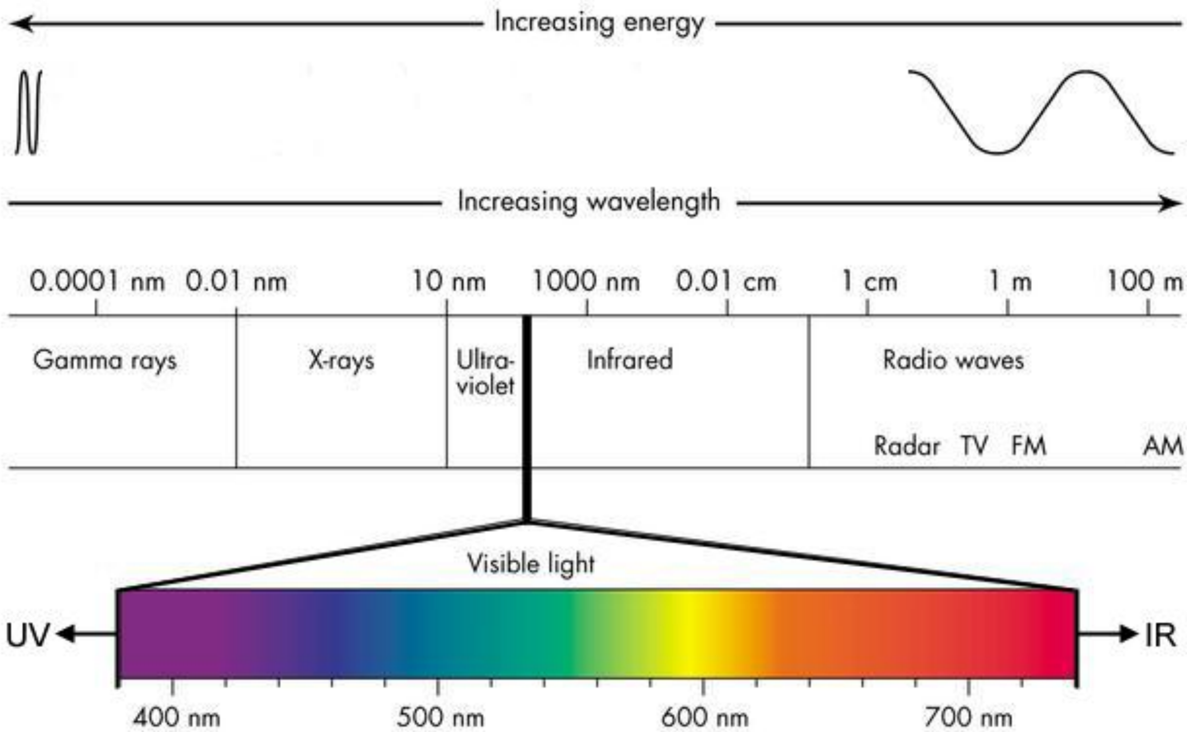
- o Single-crystal silicon (traditional)
- ▪ Widespread
- ➢ Expensive to manufacture

➢ Solar cells are converter of energy ….but not all of energy are converted



 Dye sensitized solar cell • Dye-sensitized (“nano”) • Newer, less proven • Inexpensive to manufacture • Flexible	➢ Like chloroplasts in plants, solar cells can only absorb specific wavelengths of light. ➢ In both, light that isn’t absorbed is either transmitted through or reflected back. ➢ Whether a certain wavelength of lights gets absorbed depends on its energy. ➢ Chlorophyll molecules absorb blue and red light, but reflect green light 

A Little Background on Light



Ψ Different colors of light have different wavelengths and different energies

References
Many resources (Book, Internet, Physics and Chemistry Journal, and many more)

Made in Yogyakarta, 13 September 2010
Jogjakarta is Never Ending Asia