L2 Basic Electronics

1. How do we do things?

In this course, we want to build a robot to complete some tasks. The logic is like Problem ⇒ Engineering ⇒ Science

So, we want the robot to "do sth". Then, how do we do things?

For example, how can I give the lecture?

Basically. Food ⇒ Energy ⇒ Do things.

How can your mobile phone make a call?

Battery ⇒ Energy ⇒ Call.

So, we need energy to do things. But, we can't create energy, right?

We can only change the form of energy.

In summary, we do things by changing the form of energy.

2. Types of Energy.

From physics, we know there are different types of energy.

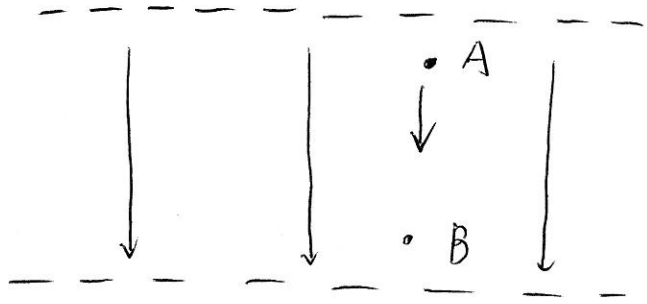
In fact, different engineering disciplines deal with different types of energy.

Then, what is electrical energy?

To answer this question, let's first look at "potential energy" (gravitational).

Who carries gravitational energy?

Mass: In gravitational field, any "mass" will experience a gravitational force.



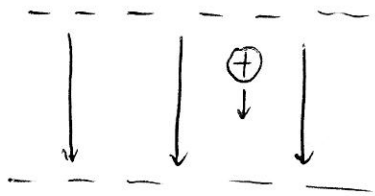
Any change of gravitational potential in the field, A→B, will lead to a transform of gravitational energy to another form.

Similar things happen for electrical energy.

3. What carries electrical energy?

Charge: carries electrical energy.

* Def: Charge is a physical property of matter that causes it to experience a force in the electrical field.

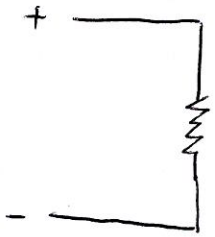


* Unit: Coulomb (C) A proton or electron has a charge of 1.6×10^{-19} C.

* Charges come from.
  - Metal: electrons
  - Semiconductor: electrons / holes
  - Polymers: organic
  - liquid electrolytes: ions.

※ Based on how easily charges flow through a material, we have

- Conductors
- Semi-conductor
- Insulator

4. Current : Charges experience force in electrical field. So, if we put a conductor in an electrical field, say  then, charges will move orderly.

※ Current is the orderly movement of charges. Its value is equal to the rate of charge flow.

※ symbol : I

unit : ampere (A)

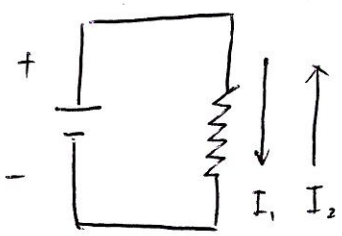
$I = \frac{\Delta Q}{\Delta t}$. If during time Δt, ΔQ charges flow through, then $I = \frac{\Delta Q}{\Delta t}$

※ Direction : defined as the direction of positive charges flow.

Note that the flow of negative charges in one direction is equivalent to the flow of positive charges on the other direction.

※ labelled direction : We can label the current by I_1 or I_2 in the following circuit.

$$I_1 = -I_2 > 0$$



Examples :

Q1 : 8.2×10^{21} electrons are provided in 10 seconds, what is I ?

$$I = \frac{\Delta Q}{\Delta t} = \frac{\#\text{ of electrons} \times \text{charges/electron}}{\Delta t} = \frac{8.2\times10^{21}\times1.6\times10^{-19}}{10} = 131.2\,A.$$

Q2 : We charge a Tesla with 50A current for 4 seconds. How many electrons flow into the battery ?

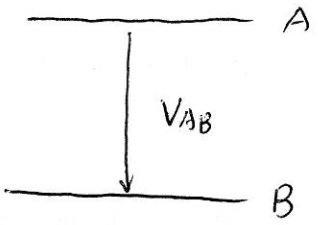
$$I = \frac{\Delta Q}{\Delta t} \Rightarrow \Delta Q = I\times\Delta t$$

$$\left.\begin{array}{l}\Delta Q = \#\text{ of electrons} \times \text{charges/electron}\end{array}\right\} \Rightarrow$$

$$\#\text{ of electrons} = \frac{\Delta Q}{\text{charges/electron}} = \frac{I\times\Delta t}{\text{charges/electron}} = \frac{50\times4}{1.6\times10^{-19}} = 1.25\times10^{21}$$

5. How to create electrical potential difference (voltage) in a circuit ? Battery.

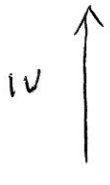
The potential difference between A and B is defined as $V_{AB} = V_A - V_B$, also called voltage.



※ symbol : V

unit : volt/v

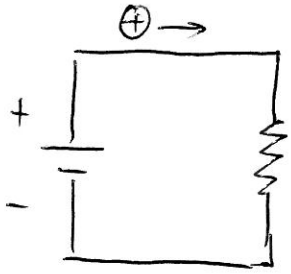
※ What does it mean if we say $V_{AB} = 1V$?



$V_{AB} = 1V$, indicates that we need 1 J of energy to push 1 C of charges from B to A.

$$E = VQ \Rightarrow V = \frac{E}{Q}$$

6. Resistance



When charges go from "+" to "−", they lose energy.

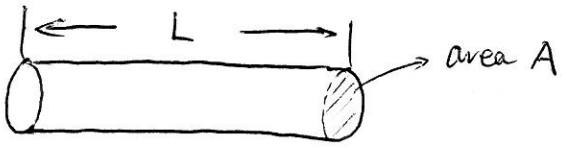
Then, who takes it? The load, for example a resistor.

※ Resistance : the ability of a material to resist the flow of charges.

※ Symbol : R

unit : ohm/Ω

※ For a wire,



$R = \rho \cdot \frac{L}{A}$, ρ is the resistivity, depending on the material.

※ Color code for resistor values.

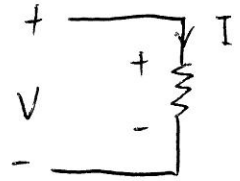
First digit, second digit, third digit | multiplier | Tolerance | Temperature Coefficient.

4-band : Yel, Brn, Brn, Gold ⇒ 410 ± 5%

5-band : G, Brn, Blk, Brn Brn ⇒ 5100 ± 1%

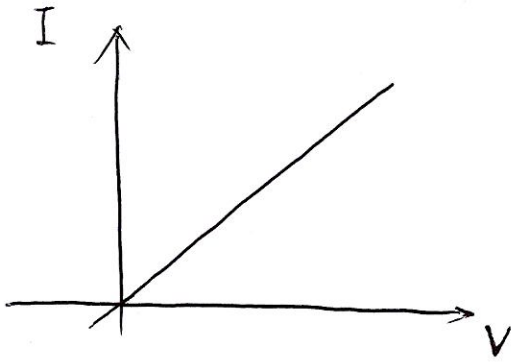
※ Metric prefix : for ease of expression.

7. Ohm's Law : How to describe the behavior of a resistor?



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

We can draw the I-V characteristics for resistor



It tells us how the current through a resistor changes if we change the voltage applied.

I-V characteristics can be regarded as the ID for a component.

I-V Characteristics $\Longrightarrow$ Resistor

Understanding Charge, Voltage, and Current by Analogy

Electric Field	Gravitational Field Analogy
Voltage: Electric potential difference Voltage measures the electric potential difference between two points. Such potential difference drives a positive charge to move from the higher potential point to the lower potential point. In a circuit, such potential difference is provided by a battery, which drives charges to flow within the circuit.	**Altitude or Height** Gravitational potential difference will drive an object (mass) to move from a higher altitude to a lower altitude. For example, without support, an airplane will fall.
Charge Any matter with charges will experience a force in an electric field. For example, in a circuit driven by a battery, positive charges will experience a force to drive them to flow from the higher potential point to the low potential point, which forms **current**. **(Question: Where does electric field come from?)**	**Mass** Any matter with mass will experience a force in the gravitational field. **(Question: Where does gravitational field come from?)**
Energy When charges move from a higher potential to a lower potential, they lose their potential energy and such energy will be used for other purposes. For example, in a circuit, a battery drives charges to flow and, at the same time, the energy stored in the battery is utilized by the circuit.	**Energy** When an object falls from a higher altitude to a lower altitude, its potential energy is changed to other kind of energy.

So, basically, we can understand **voltage as altitude** and **charge as mass.** Putting a battery to a circuit is just like giving an object a higher altitude. In this process, certain energy is provided to the circuit or the object. Why do we want to do this? Because, we want to drive charges to flow in the circuit so that certain **functions** can be achieved by the circuit. Note that, the flow of charges will form current and carry the energy from the battery to certain circuit element. So, we can image current as a train to carry energy to different elements of a circuit. Through such energy exchange between battery and circuit elements, circuits provide lots of interesting functions for us and make our life much easier.

This is just one way to understand charge/current/voltage. If you have any other ideas, let me know, ☺.