Review: In last lecture, we came to one conclusion:

Anything we do on the earth, we do it by changing the form of energy.

In the ECE field, we do that by building a circuit, where we put a battery to create an electrical potential difference (voltage).

Since charges will experience a force in an electrical field, the voltage “V” will push positive charges to go through the resistor R from A \Rightarrow B.

During this process, charges move from a high electrical potential to a low potential (A \Rightarrow B), and thus lose their electrical energy.

When the positive charges come back to the negative terminal of the battery, the chemical mechanism inside the battery will pull the positive charges up to the positive terminal.

During this process, charges obtain electrical energy and battery loses chemical energy. Then, charges carry electrical energy to the resistor again.

The whole process is about “chemical energy” \Rightarrow “electrical energy”.
1. Energy:

- Energy is a property of objects and systems.
  
  Symbol: E
  
  Unit: Joule or J
  
  Forms of Energy: Mechanical (Kinetic & Potential), Thermal, Electrical, Chemical.

- Energy Conservation:
  
  Exercise: Mass = 2 Tons, Velocity = 100 km/h
  
  \[ E_k = \frac{1}{2} m v^2 \]

- Energy in ECE:
  
  Pushing an object to a higher position gives potential energy to the object ⇒
  
  Pushing a charge from a lower electric potential B to a higher electric potential A gives electric energy to the charge.

In fact, the energy \( E = q \times V_{AB} \) where \( V_{AB} = V_A - V_B \)

The formal definition of voltage is \( V_{AB} = \frac{E}{q} \). The potential difference between A & B = Energy (work) needed to move a unit charge against the static electric field between A & B.
2. **Power**

If energy is the ability to do work, power is the rate of doing work. Power is defined as the rate at which energy is produced/consumed/dissipated.

- **Symbol:** $P$
- **Unit:** $\text{Watt} / \text{W} / \frac{1}{\text{s}}$

$$ P = \frac{E}{t} $$

- **Electrical Power:**

  Assuming $\alpha$ changes go through the resistor in $t$ seconds, what is the power (consumed) of the $R$.

  $$ P = \frac{E}{t} = \frac{V \cdot \alpha}{t} = V \cdot \frac{\alpha}{t} = V \cdot I \rightarrow \text{Rate of moving changes} $$

  Energy to move one Coulomb of charge

  $$ P = VI = I^2R = \frac{V^2}{R} $$

- **Power rating of a speaker = maximum power that can be delivered without damage.**

  **Example:** The power rating of a speaker = 100 W. Internal resistance = 10Ω.

  What is maximum safe current?

  $$ P = I^2R \Rightarrow I^2 = \frac{P}{R} \Rightarrow I = \sqrt{\frac{P}{R}} = \sqrt{\frac{100}{10}} = \frac{10}{\sqrt{10}} = 2.5 \text{ A}. $$
Example:

What is the power consumed by \( R \) and the battery?

\[ I = \frac{V}{R} = \frac{5}{200} \, \text{A} \]

\[ P_R = VI = \frac{V^2}{R} = \frac{25}{200} = \frac{1}{8} \, \text{W} \]

How about \( P_B \), power consumed by the battery? \( P_B = VI \) then \( P_B = P_R > 0 \)

Reference direction: Current enters the component from the positive terminal.

\[ I_R = I \text{ but } I_B = -I \] Thus, \[ P_R = V_R I_R = VI \]

\[ P_B = V_B I_B = -VI \]

Consumed = Produced.

Resistor Network:

What is the power for the load \( R_L \)?

Method 1:

\[ I = \frac{V_{AB}}{R_{AB}} = \frac{5}{4.8 \, \text{k} \Omega} = 1.04 \, \text{mA} \]

\[ P_L = I^2 R_L = (1.04 \, \text{mA})^2 \times 2.4 \, \text{k} \Omega = 2.6 \, \text{mW} \]

Method 2:

\[ P = \frac{V^2}{R} = \frac{5^2}{R + R_L} = 5.2 \, \text{mW} \] (total power)

\[ P_L = \frac{P}{2} = 2.6 \, \text{mW} \]


For the above network, \( V_{AB} = R_L \cdot I = R_L \cdot \frac{V_{AB}}{R_{AB}} = \frac{R_L}{R_{AB}} \cdot V_{AB} \)

Voltage is divided according to the ratio of the resistance.
4. Resistors in parallel

[Diagram of a parallel circuit with labels R1, R2, I1, I2, and current V]

What is the equivalent resistance for the boxed resistive network?

\[
\begin{align*}
I_1 &= \frac{V}{R_1} \\
I_2 &= \frac{V}{R_2}
\end{align*}
\]

\[
I = I_1 + I_2 = \frac{V}{R_1} + \frac{V}{R_2}
\]

\[
\text{Req} = \frac{V}{I} = \frac{1}{R_1 + R_2}
\]

\[
\text{Req} = \frac{V}{R_1 + R_2} = \frac{1}{R_1 + R_2} = \frac{R_1 R_2}{R_1 + R_2}
\]

Similarly, we can prove that \(\text{Req}\) for \(n\) resistors in parallel is given by

\[
\frac{1}{\text{Req}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}
\]

\[
\text{Req} = \frac{R_1}{R_1 + R_2 + \ldots + R_n}
\]

Obviously, for such a case, it is easier to work with \(\frac{1}{R}\).

\(\frac{1}{R}\) is called conductance having the unit Siemens (S) or \(\Omega^{-1}\), mho, \(\text{M\Omega}\), etc.

\(\times\) Energy Sources: DC + AC.
Exercise: On the battery of iPhone 6, you can see some parameters
3.8V, 2915 mAh.

Question: If we charge this iPhone everyday (fully), how much do we need to pay assuming the electricity price at 1 HKD/kWh.

So:
\[ E = V \cdot Q = 3.8V \times 2915 \times 10^{-3} \times \frac{C}{3} \times 3600 \text{J} = 3.8 \times 2915 \times 10^{-3} \times 3600 \text{J} \rightarrow \text{one charging} \]

One day \[ $ = \frac{E}{\text{kWh}} = \frac{3.8 \times 2915 \times 10^{-3} \times 3600}{10^3 \times 3600} = 0.011077 \text{ HKD} \]

1 year \[ $ = $ \times 365 = 4 \text{ HKD} \]