Potential Difference

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ define the potential difference across a component as the energy transferred per unit charge
- ☐ understand the terms *potential difference*[1], e.m.f. and the volt
- ☐ use energy considerations to distinguish between p.d. and e.m.f. ($\mathscr{E}$)
- ☐ recall and use $\Delta V = {}^{W}/_{Q}$
- ☐ recall and use $P = VI$

[1] def:

Leadin

Alessandro Volta has invented the "*voltaic pile*" from the oberservation of twitching frogs, and even showed that device to the conquerer-Napoleon Bonaparte. And that earns him the right to record any potential differnece as volt, V. And with the invention of such batteries could *electrolysis*[2] of water can be carried out. Science is combined with history, how amazing!

[2] exp:

Figure 1: Volta showing his voltaic pile to Napoleon

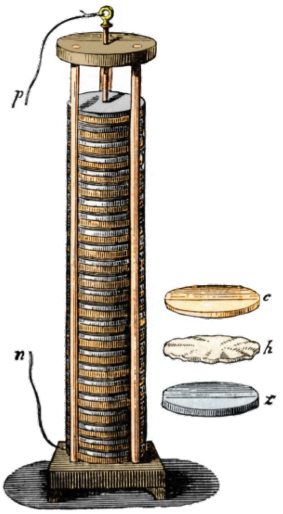


Figure 2: Votaic Pile is consist of zinc and copper and saltwater

Voltage

Now can you see the connection between Volta and Voltage? When the voltaic pile(battery) was invented, the voltage is around 1.1 V. What is voltage in describing the batteries? Let's dig into that.

Lemon Battery

Let's make our own Lemon battery, and do not be shocked, that's a home-made version of voltaic battery, because we are still using zinc and copper, but the saltwater is replaced by the lemonade, serving as the *electrolyte*[3].

[3] exp:

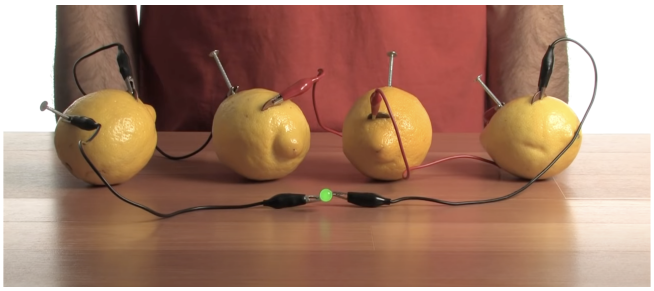


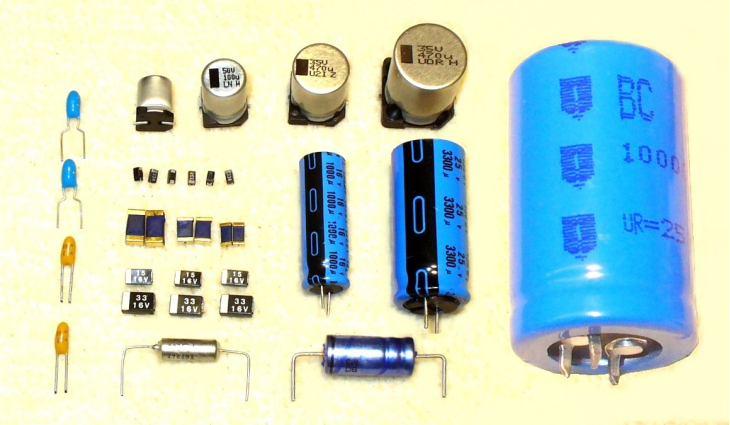
Figure 3: lemon battery

Task

Why in the youtube video, four lemons are used?

Let's blow up the Capacitor!

A *capacitor* is a quite common electric components which is used to store and release charges. And every capacitors has it voltage tolerance, Let's see



what's happening if I rise the voltage across the capacitor.

Meaning of p.d.

The voltage, a.k.a potential difference, across an electric components seems related with energy. It is used when charge transfers energy to the component or the surroundings.

Summary

Potential Difference, V, between two points A and B, is the transferred per unit _____ as it moves from point A to point B.

$V =$ /

The unit for voltage(p.d.s) is _____. And thus the SI base unit is _____.

And very obviously, if a component has larger potential difference, charges can do more work (transfer more energy) just as illustrated in Fig.4

Figure 4: two identical lamps but with different luminosity

Task

- Why four lemon batteries are used?
- Why the voltage should exceed the *threshold* or maximum voltage to explode the capacitors?
- Which lamp has higer potential difference?

e.m.f.

ElectroMotive Force[4] is abbreviated into e.m.f., the symbol for it is $\mathscr{E}$. Such term is used when we are describing the power supply or battery, galvanic cells[5], etc.

[4] It has nothing at all to do with force, it is actually a kind of voltage

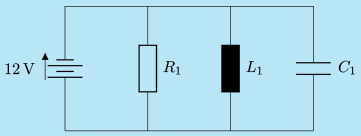
[5] You shall see this chemistry terms quite frequently in chapter ElectroChemistry

Summary

The electromotive force (e.m.f.), $\mathscr{E}$, of the supply is also defined as the energy transferred per unit charge in driving charge round a complete circuit.

Task

Compare p.d. and e.m.f. using the following circuits diagram



Analogy p.d. to gravity

If an object lies in higer place, the object has higher gravitational potential energy. Similarily, if a **postive** charge is located at higher electical potential, it does have higher energy. Just as illustrated in Fig.5, when the water

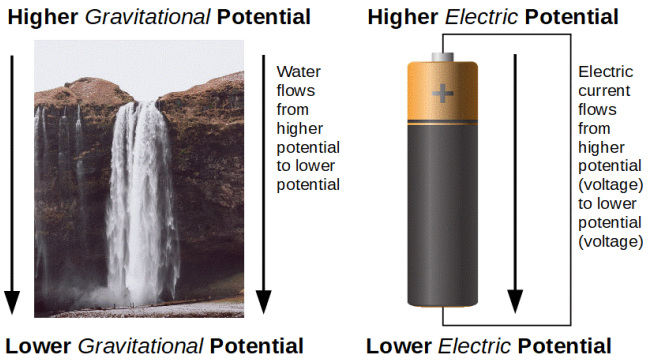


Figure 5: higher to lower

molecules goes from higher places to lower places,the change in gravitational potential energy will converted to other forms of eneryg. Now let's look how this process be applied into calculating the energy in electric circuits.

- electrons carries positive/negative charge, and are free to move if e.m.f. are applied
- the positive terminal of a battery has a larger/smaller potential than the negative terminal, thus the difference is defined as the e.m.f.
- when one single electron starts its journey from the positive/negative terminal, it has larger energy, But when it arrives at the positive/negative terminal, the energy is reduced just as the water molecules in waterfall
- change in the energy is equal to the amount of charge multiplied by the e.m.f.

That's How a battery can supply energy to any electric components. and why e.m.f. or p.d. is used to describe energy related with electricity.

Electric Power

Now, the Power in electric circuits can be deduced:

$$
\begin{aligned}
W &= Q \cdot V \\
P &= \qquad\qquad\qquad / \\
&= V \cdot \text{———————} \\
&= VI
\end{aligned}
$$

Actually, differentiation should be employed. But now, we can assume the current is constant.

Summary

The instaneous power of a components in the circuits is the product of the potential difference across the component and the current through the component.

According to the Fig.6, what is the power from the powerbank?

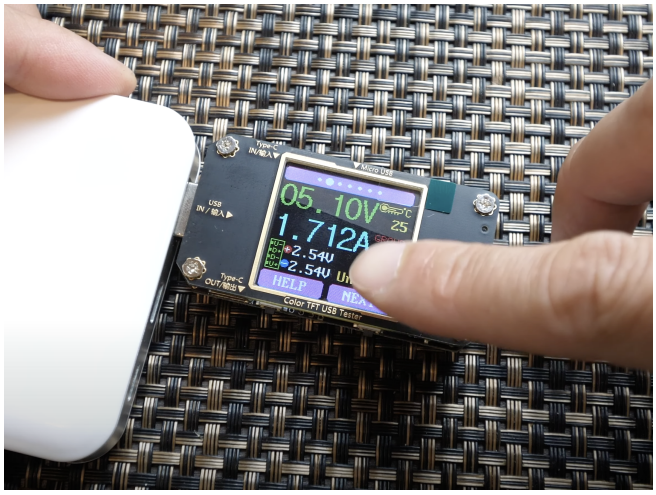


Figure 6: A USB power tester connected in a powerbank