ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

LOIS FONDAMENTALES DE L'ÉLECTRICITÉ

INTRODUCTION

LEÇON 3

Électrotechnique I
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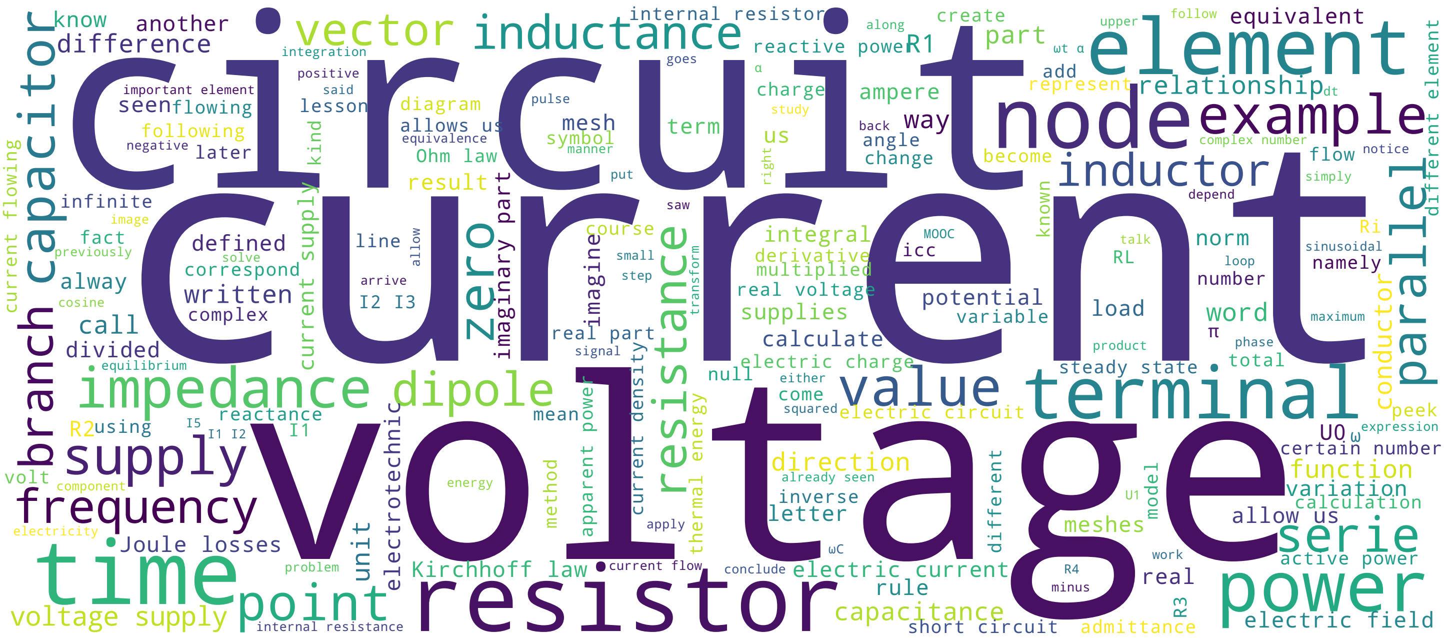
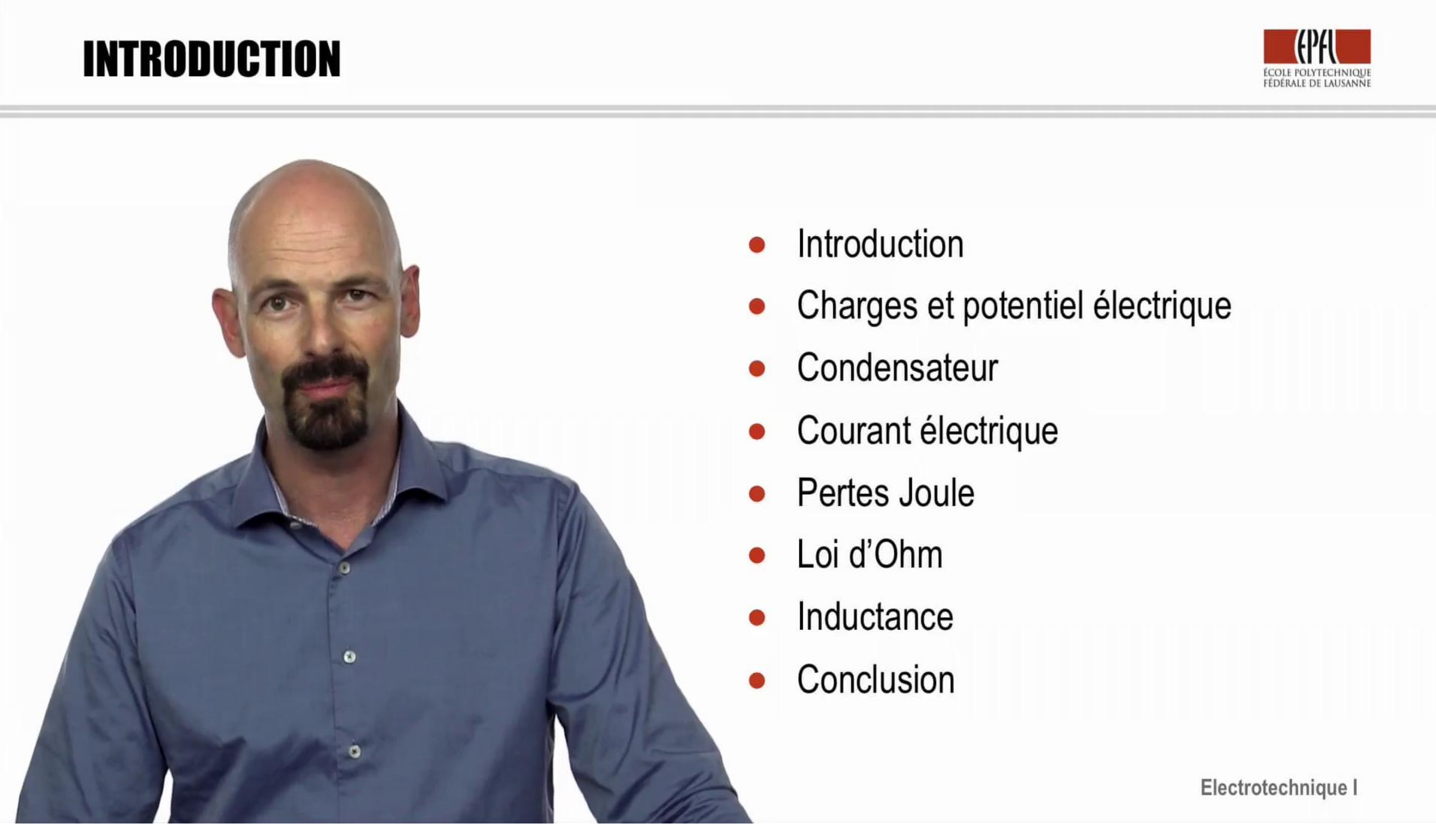


Video

EPFL



Hello and welcome to this third lesson of Electrotechnics 1 dedicated to the fundamental laws of electricity. After an introduction, we will see what are electric charges and electric potentials, followed by the capacitor, the electric current, the associated Joule losses, we will discover Ohm's law, Kirchhoff's laws and finally, the inductance which will conclude this chapter on the fundamental laws along with a small conclusion.

Notes

Summary

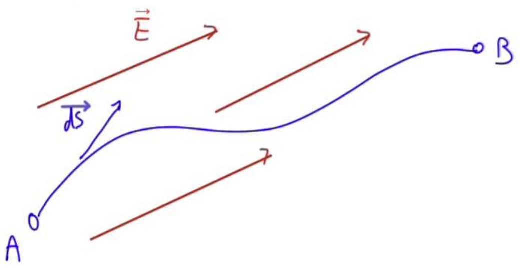
0m 03s

CHARGES ET POTENTIEL ÉLECTRIQUE

Q ← charge électrostatique

$1\ C = 1\ As$

$V_A - V_B$



$$V_A - B_B = -\int_B^A \vec{E} \cdot d\vec{s}$$

$$= \int_A^B \vec{E}\, d\vec{s} = U_{AB}$$

= Tension électrique

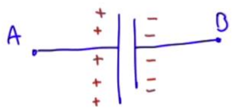
Electrotechnique I

The electrostatic charge is a quantity of static electricity, The representative symbol, It's the letter Q the unit of measurement is the coulomb, whose symbol is C, So we have one coulomb is equal to one ampere second and this, the letter Q, is the electrostatic charge. We can also define a very important element in the laws of electricity, it's the difference of electric potential. We will write here the difference of potential between two points Va and Vb that we imagine in a system like this, bathed in a uniform electric field, that we write like this, and we have our electric field here and our conductor, A and B bathed in this uniform electric field. We also define a distance vector ds here on this conductor between A and B. We can then write, I'll continue here, the difference of potential Va - Vb, as being the circulation of the electric field along the edge linking A to B which becomes the integration from B to A of this electric field by this element of distance ds or also, by reversing from A to B, the minus sign disapears and by definition this is the difference of potential between A and B that we also call voltage. it is this voltage that will keep us busy all along these Electrotechnics 1 and 2 MOOCs, and we will progressively start saying only voltage and by extension, no longer the difference in potential.

Notes

Summary

0m 32s



Propriété C capacité

$$C = \frac{Q}{U_{AB}}$$

Unité : Farad F $1\,F = 1\,As/V$

Electrotechnique I

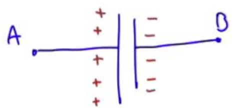
The condenser is a very important element in electrical engineering, one of the three passive elements that we will study all along this MOOC. Its symbol is represented by two vertical plates upon which will in fact accumulate, electric charges that will characterize the properties of the capacitor. We can say that this property of the capacitor, also known as capacitance, this capacitance C is defined as the number of accumulated charges between the plates of the capacitor, these plus and minus that are in front of each other, divided by the voltage between A and B, we will thus also define here an A and B potential. The symbol, the unit of the capacitance is the farad, written F, and one farad is worth one ampere second per volt in the units of the MKSA international system. We can now go one step further and define the relationship between voltage and current for this capacitor which will be very useful later on, we've seen with Ohm's law, we will see it for the inductor, we need this relationship between voltage and current to later on solve electric circuits.

Notes

Summary

2m 56s

CONDENSATEUR



propriété C capacité

$$C = \frac{Q}{U_{AB}}$$

Unité : Farad F $1\,F = 1\,As/V$

$$Q = \int i \, dt$$

$$u = \frac{1}{C} \int i \, dt \quad \text{ou} \quad i = C \frac{du}{dt}$$

Electrotechnique I

We've already seen the electric charge, this electric charge we know, is an accumulation of charges, in other words it's the integration of the current over time, since current is in fact this progression of charges in a circuit, we can define here, by substitution, the voltage which is equal to 1/C integral of of idt, by replacing with the equation seen here. Or, also write that the current is the capacitance times the variation of the voltage, one or the other. As we can see here the relationship is nonlinear and the voltage in a capacitor is proportional to the integral of the current over time.

Notes

Summary

4m 38s

$$I = \frac{dQ}{dt}$$ Variation de charge par unité de temps

→ courant [A]

courant

$$J = \frac{I}{S}$$ = Densité de courant A/m^2

Surface du conducteur

Let us now see the electric current and the associated Joule losses. The electric current, as we've briefly mentioned it previously, is an element that enables the quantification of the number of electrons or charges that or moving or flowing through a conductor, that we will write using the letter I, here, an I that I'm purposefully writing in upper-case, dQ over dt, in other words, it's the variation of charges over a unit of time that defines the electric current. Perhaps one more very important thing to mention this electric current will be written, or the symbol of current; this unit of current is the ampere, that is written as A, in upper-case. We can also define by the letter J the current density as being this electric current over an area, so we have here the area of the conductor through which this current is flowing, here we have the current we've just defined and here, by definition, we have the current density whose unit is then ampere per meter square. This notation of current density will be very useful for us later on to also define from the point of view of power, what we are permitted or not in a system defined by the cross-section of the conductor.

Notes

Summary

5m 30s

$$I = \frac{dQ}{dt}$$ Variation de charge par unité de temps → courant [A]

$$J = \frac{I}{S}$$ = Densité de courant A/m^2

(I : courant ; S : Surface du conducteur)

Pertes Joule : $P = R \cdot I^2$

Energie thermique : $W_{th} = \int_t R I^2 \, dt$

Electrotechnique I

We can finally define the Joule losses associated to a current that is flowing through a resistor and that will transform this electric energy into thermal energy. A phenomena analogous to friction is occurring which creates a heating. The losses that result from it are called Joule losses, or heating losses. And these Joule losses, written P, are equal to the resistance multiplied by the current flowing through, squared.

Notes

Summary

7m 28s

LOI D'OHM

$$U_{AB} = R_{AB}\, I \quad \longrightarrow \quad R_{AB} = \frac{U}{I}$$

Electrotechnique I

Thermal energy which is dissipated by this power can be characterized in the following manner : we have the thermal energy which is the integral over time of this power : integral (RI^2dt) Here is the definition of Ohm's law, certainly very well known to a few amongst you, but it is always good to be reminded in the basis of this law and also later on in Kirchhoff's laws that will follow and which will allow us to apply the conventions seen during the second lesson. By definition, Ohm's law is so : We have a voltage between two terminals A and B that is equal to this resistor between terminals A and B and the current flowing through. In other words, the resistance R AB is the relationship between the voltage and the current, thus we have a linear relationship for the resistance which will be very pleasant for all the next steps in electrotechnic theory, this resistor, or instead everything that flows through the resistance and comes out as the same image, in other words, whatever may be the voltage at the entrance, we will have this same image on the current which flows through this same resistor. I arrive now at the definition of meshes (or loops) and nodes (or junctions), in general so as to later on apply Kirchhoff's laws.

Notes

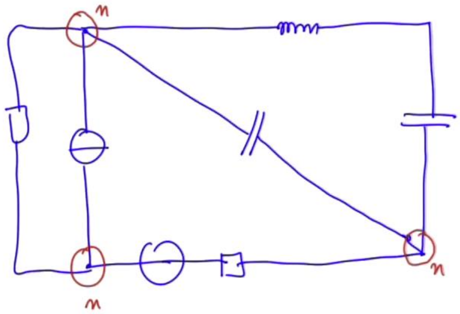
Summary

8m 04s

LOI D'OHM

$$U_{AB} = R_{AB} \, I \longrightarrow R_{AB} = \frac{U}{I}$$

Mailles et Noeuds :



Noeud : n, point de convergence de 3 conducteurs ou plus

Branche : b, éléments situés entre 2 noeuds parcouru par le même courant

Electrotechnique I

We will thus define here what are meshes and nodes and to do so, we will take an example which will enable us to properly understand what a node, a mesh and also a branch is. So let's take an example in which we have different elements, that we haven't necessarily completely seen yet but which will allow us, especially here to define these meshes and nodes problems. So here is a first element, I'm putting several random elements to define here a circuit. So we have here a random circuit, we will first try to define what are nodes, or junctions. Well, nodes, which we will write n a node is the point of convergence of three or more conductors. So, where are the nodes in my circuit ? We've said three conductors or more, so our first node is here, the second one here and the third node is here. This is not node, this is not a node, there are no other nodes in this circuit. Second definition : a branch, which we will write as b. A branch includes the elements located between 2 nodes and through which the same current flows. So it's the elements located between 2 nodes through which the same current flows. So let us try here as well to indicate where our branches are.

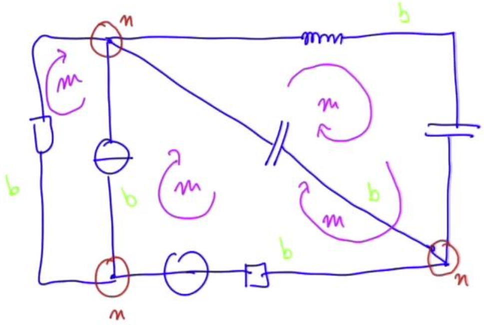
Notes

Summary

9m 49s

$$U_{AB} = R_{AB} \, I \longrightarrow R_{AB} = \frac{U}{I}$$

Mailles et Noeuds :



Noeud : n, point de convergence de 3 conducteurs ou plus

Branche : b, éléments situés entre 2 noeuds parcourus par le même courant

Maille : m, ensemble de branches parcourues en partant d'un noeud pour y revenir

So between two nodes we have here a branch, we have here a branch, here a branch, and also here, and finally here. Last element : the mesh, or loop, which we will write as m. It is formed by several branches, branches through which we go through from one node and loop back to it By starting from a node to go back to it. Naturally, without passing twice through the same branch. So we can define here a first mesh m, we define here a second mesh m, a third mesh m and eventually we can go from this, come back here and make the entire loop, so we would still have one big mesh m, that I will write here. Here is by definition the node, the branch and the meshes which will allow us to tackle as we've mentioned, Kirchhoff's law.

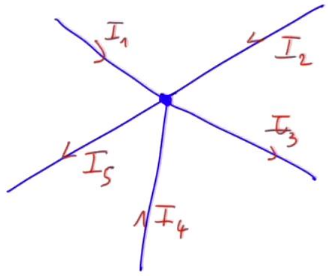
Notes

Summary

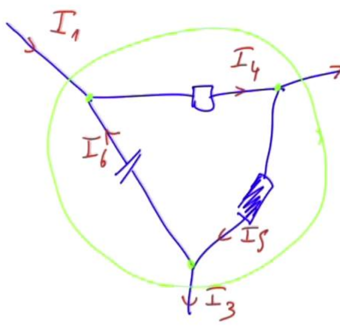
11m 58s

Loi de Kirchhoff pour les noeuds :

$$\sum_j I_j = 0$$



$$I_1 + I_2 - I_3 + I_4 - I_5 = 0$$



$$I_1 - I_2 - I_3 = 0$$

Electrotechnique I

So, first of all, Kirchhoff's nodal rule. The expression of this rule, or law, is quite simple, universal and absolutely fantastic; it says that the sum of the currents at every node is equal to zero. An example. We take here various currents that all converge on a node, So we will write here I1, we will write I2, I3, I4, and finally I5. What Kirchhoff tells us, is that if we look at the sum of all these currents at this point it must be equal to zero. so we write, first of all we have I1 + I2 - I3, which exits the node, +I4 and -I5 equal to zero. Absolutely fantastic and which allows us to systematically know that in every node, everything that goes in is equal to everything that comes out, and thus, allows us to write this kind of relationship. We can, more generally speaking, I will draw you another diagram; let's imagine a diagram in which you have this kind of circuit with an I1 here, an I2 here and an I3 here, but with an I5, I6, and here an I4, of course, we a first node, a second node, a third node on which we can write many relationships as I've written them earlier; but what we can notice is that we can imagine here this like a generalized node and we will be able to write in the relationship that I1 - I2 - I3 is equal to zero without worrying about what is inside this green circle. We call this a generalized node.

Notes

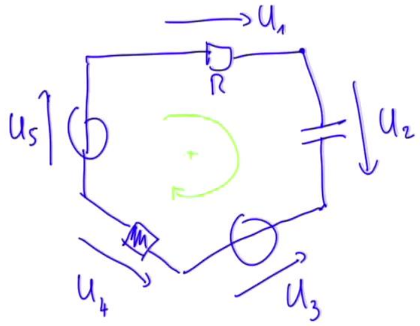
Summary

13m 18s

LOI D'OHM

Loi de Kirchhoff sur les mailles :

$$\sum_j U_j = 0$$



$$U_1 + U_2 - U_3 - U_4 + U_5 = 0$$

Electrotechnique I

We will now see Kirchhoff's second law, or rule, which is Kirchhoff's mesh rule. What does this rule say ? It tells us that here as well the sum of voltages in a mesh are always equal to zero. In other words, a sum of voltages on the mesh is always equal to zero. So we can here also make an example by taking here a voltage U5, a voltage U1 at the terminals of the resistor here, and a voltage U2 at the terminals of a capacitor, so I imagine here a random circuit, a voltage U3 on a supply and also an element with a voltage U4 finally, on this inductor. Well, through Kirchhoff, since I have here a mesh going from this point and returning to this other point, In my case, I systematically choose the clockwise direction to always make my mesh calculations in the same direction, all that is needed is to define once and for all a direction for each of us, we then arrive at the following equation : U1 + U2 - U3 - U4 + U5 = 0 and you can see that using extremely simple methods, we can write equations either on nodes or on meshes, which allow us to solve a certain number of things in an electric circuit in an already very simplistic and very evident way.

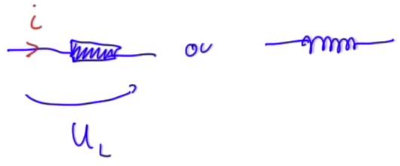
Notes

Summary

15m 50s

INDUCTANCE

Symbole :



$$u_L = L \frac{di}{dt}$$

L unité en H

Electrotechnique I

To finish this lesson, we will talk about the inductor or the manner in which we write and model an inductor and its physical relationship. The inductor is symbolized in electrical engineering by a filled-in square or sometimes also as a kind of spring like this since the reality of an inductor is in fact a coil or or a grouping of copper wire coils within which will happen a certain number of magnetic phenomena which we will go into detail for now but that very clearly link the electric world with the magnetic world. We can, by definition, say that the voltage at an inductor's terminals UL is this definition of the inductance L times the derivative or variation of the current over time flowing through this inductance. In effect, the inductance acts like a brake to the current, or to any current variations, it will thus create a difference of potential at its terminals the higher the variation of the current is big. The inductance is written in, or the unit of the inductance, in henry, symbolized by the letter H.

Notes

Summary

17m 47s

This concludes our lesson, we have thus seen the different basic elements that in the end constitute our different elements in our study of electrotechnics, in other words the resistor, the capacitance, the inductor, the supplies, and the way that they will interact with each other, the physical aspects of every element, the nodal rule and the mesh rule in Kirchhoff's laws which will allow us to solve electric circuits and finally, an application of the conventions already seen in previous lessons. Good bye and see you in the next lesson.

Notes

Summary

19m 22s