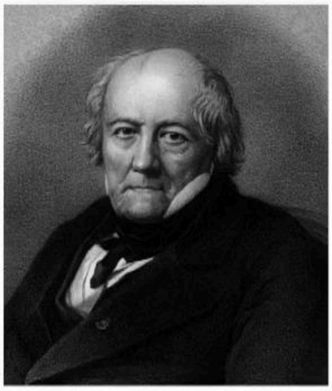
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

RESCIF
Réseau d'excellence des sciences de l'ingénieur de la Francophonie

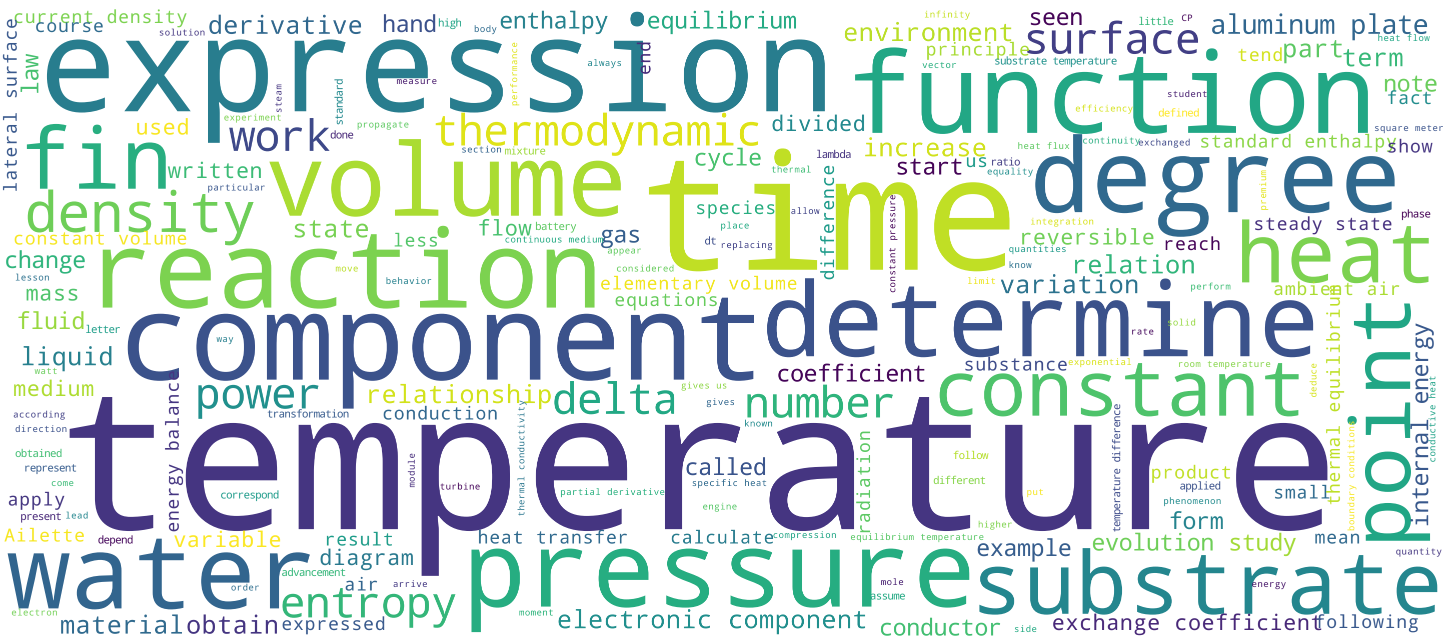
Thermodynamique

Transfert conductif en régime non stationnaire : Application



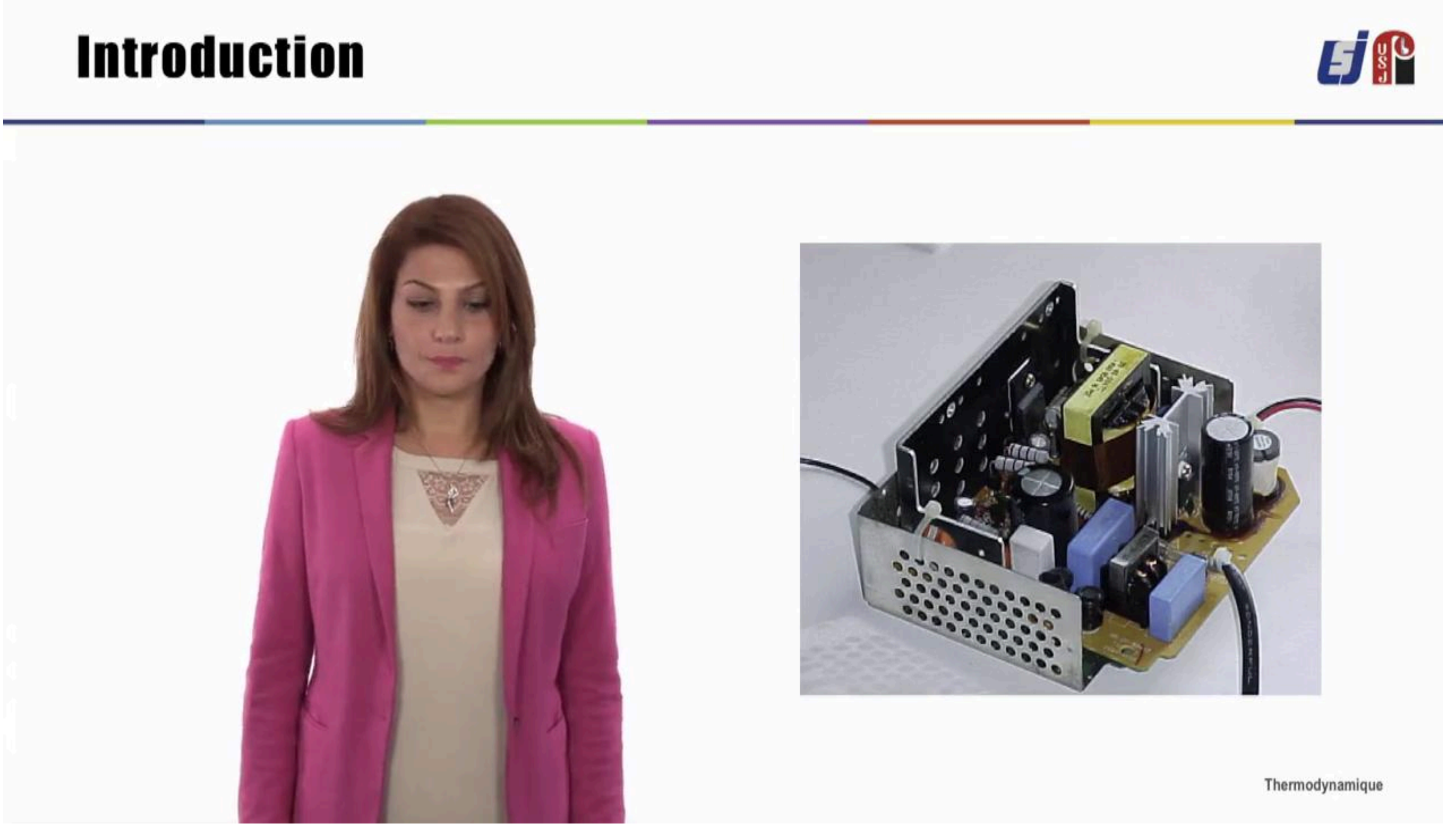
Jean-Baptiste Biot, 1774-1862

Dr. Chantal Maatouk



Video

EPFL

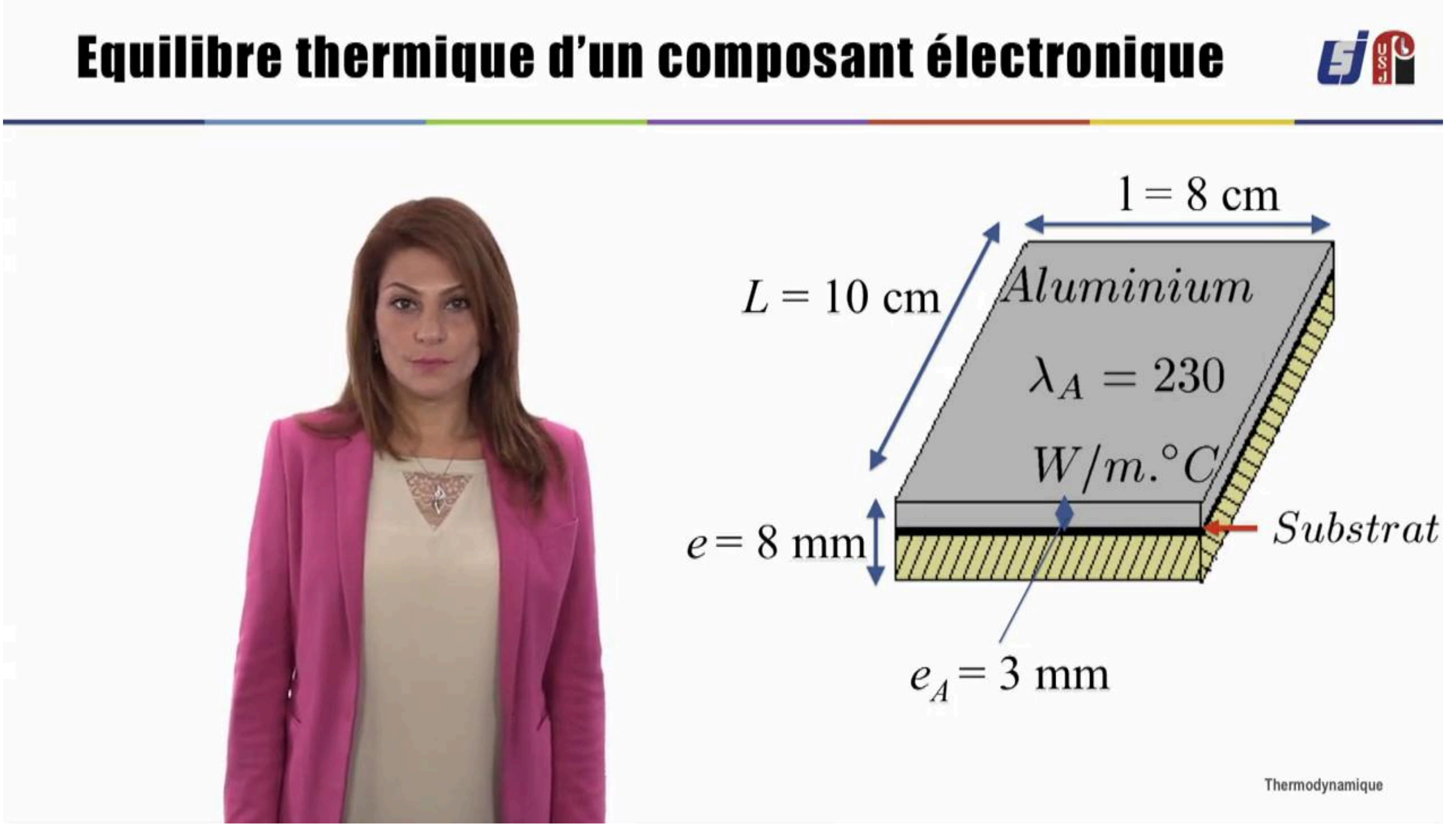


As you know, some electrical components work when they are active, releases a power which, by Joule effect, causes the overheating of this component. The objective of this exercise is to study the thermal equilibrium of an electrical component and to see the solutions that we can be used to remedy this overheating. For this, we will apply the heat equation, Fourier's law, Ohm's law and so we will integrate cooling by means of cooling fins.

Notes

Summary

0m 03s

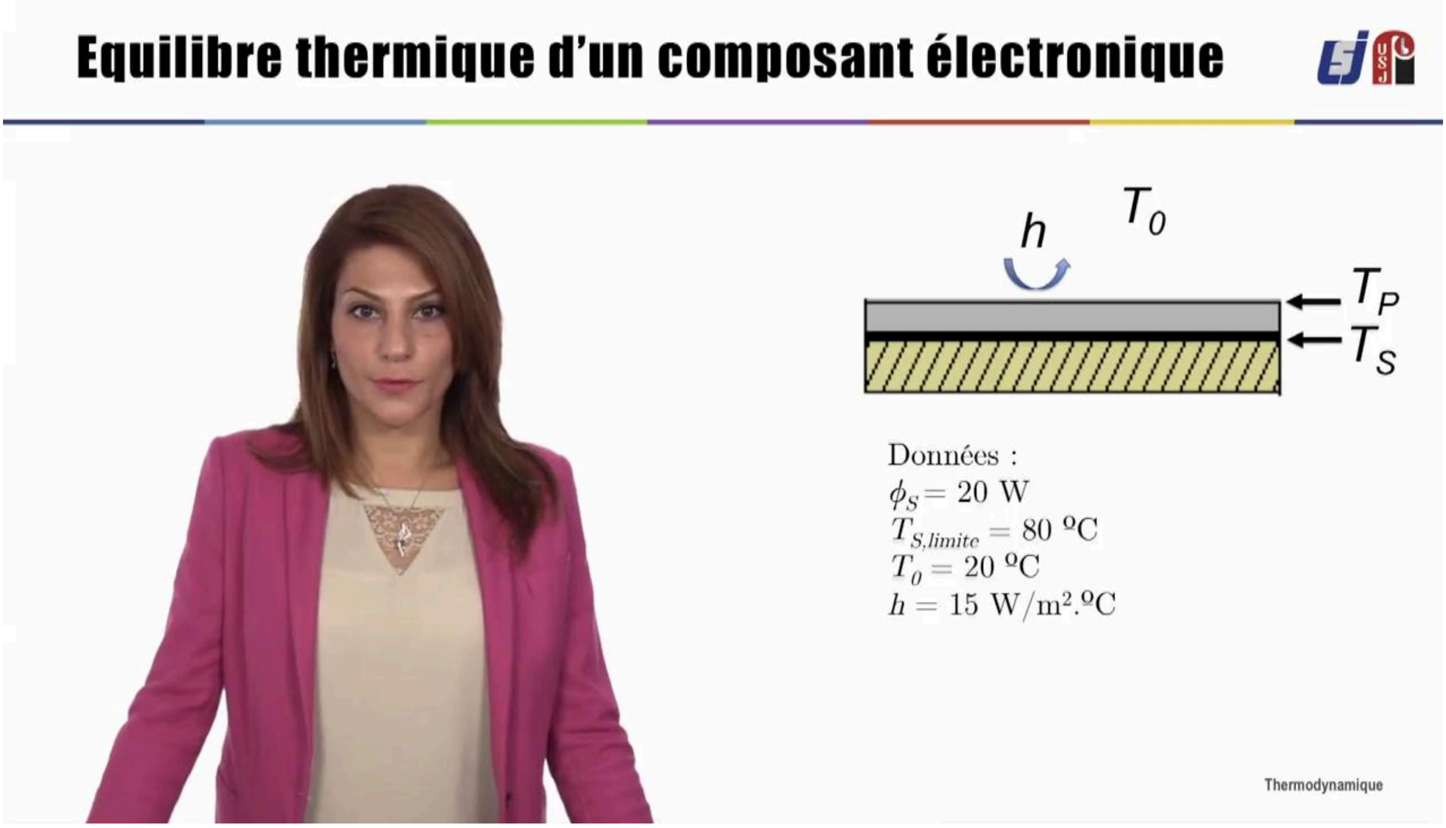


We propose to study a component electronic parallel form, the peaks of the ten centimetre disks of length, eight cm wide and has a thickness of eight mm. In general, electronic components are composed of an insulating layer. In this case, it is five mm. On the insulating layer, a substrate of thickness negligible in which we will drown a conductor. On the substrate, we will place an aluminum plate. In this case, it is three mm with a thermal conductivity of which will serve to evacuate the heat released by the driver towards the environment.

Notes

Summary

0m 42s

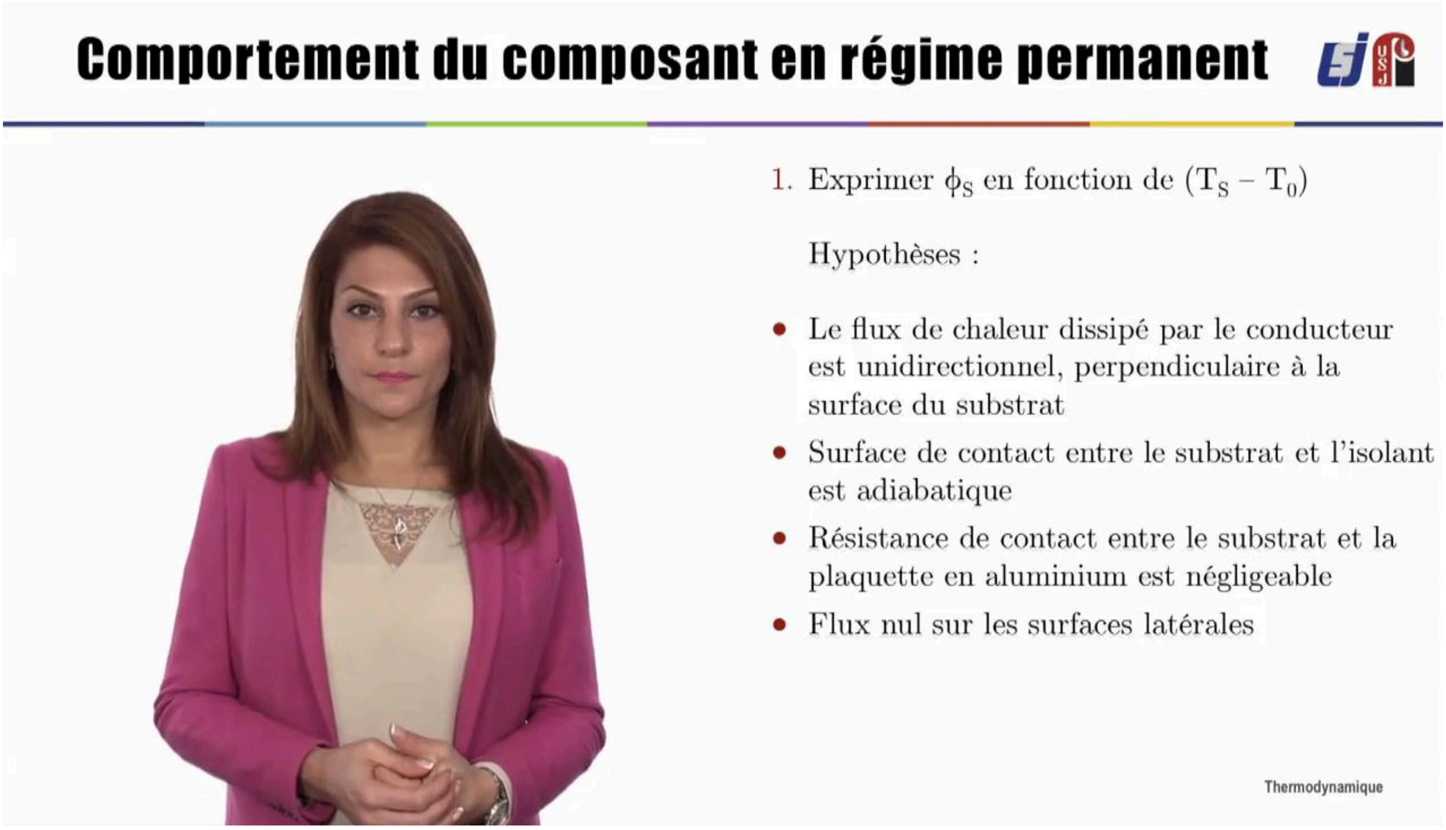


When the component is active, the conductor embedded in the substrate gives off a power forced to be distributed uniformly over the surface of the component and we note t2 s the temperature of this substrate. This temperature of S is limited to 80 degrees to avoid damage to this electronic component, the power thus released is propagated in the aluminum by conduction. It is then evacuated to the atmosphere by a conductive heat transfer convective governed by the convective exchange coefficient H. In this case H, it is fifteen and it is equal to fifteen watts per degree per square meter. The temperature of the upper surface of the aluminum plate is noted TP.

Notes

Summary

1m 25s

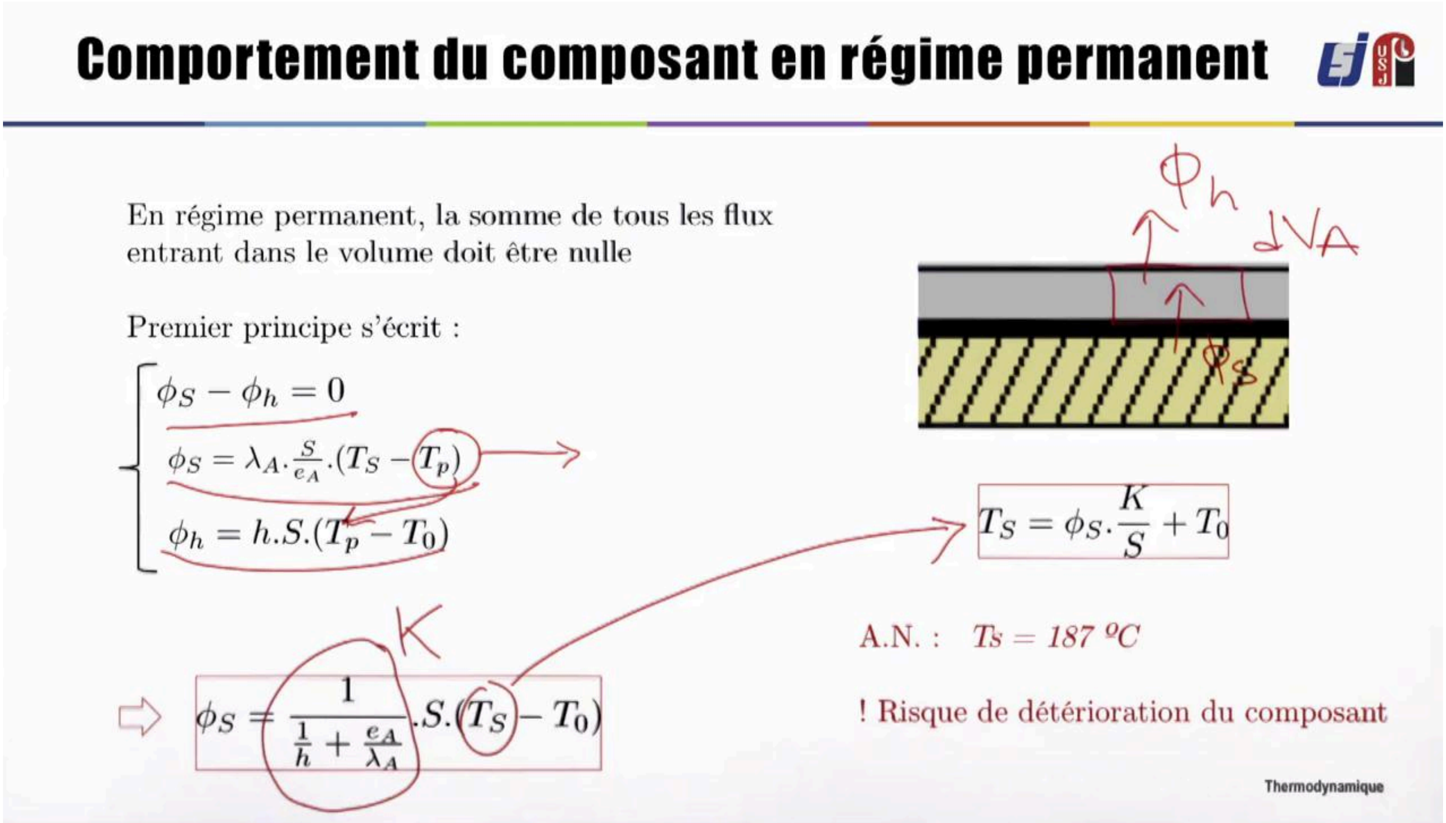


In a first step, we will study the behavior of this electronic component in stationary regime. To do this, we will start by determining the expression of the flux fi s as a function of the temperature difference T of S. Substrate was zero from the ambient air. In order to solve this problem, we will first assume some assumptions that apply to our case study. First, we will consider that the flow of heat dissipated by the substrate is unidirectional and propagates in a direction perpendicular to this substrate. Then, we will consider that the surface which separates the substrate and the insulator is an adiabatic surface, so we have no heat flow exchanged at this interface. Then, we will consider that the contact resistance between the aluminum material and the substrate itself is negligible. And finally, we will neglect the heat fluxes exchanged by the lateral surfaces of this component, given its geometric characteristics.

Notes

Summary

2m 20s

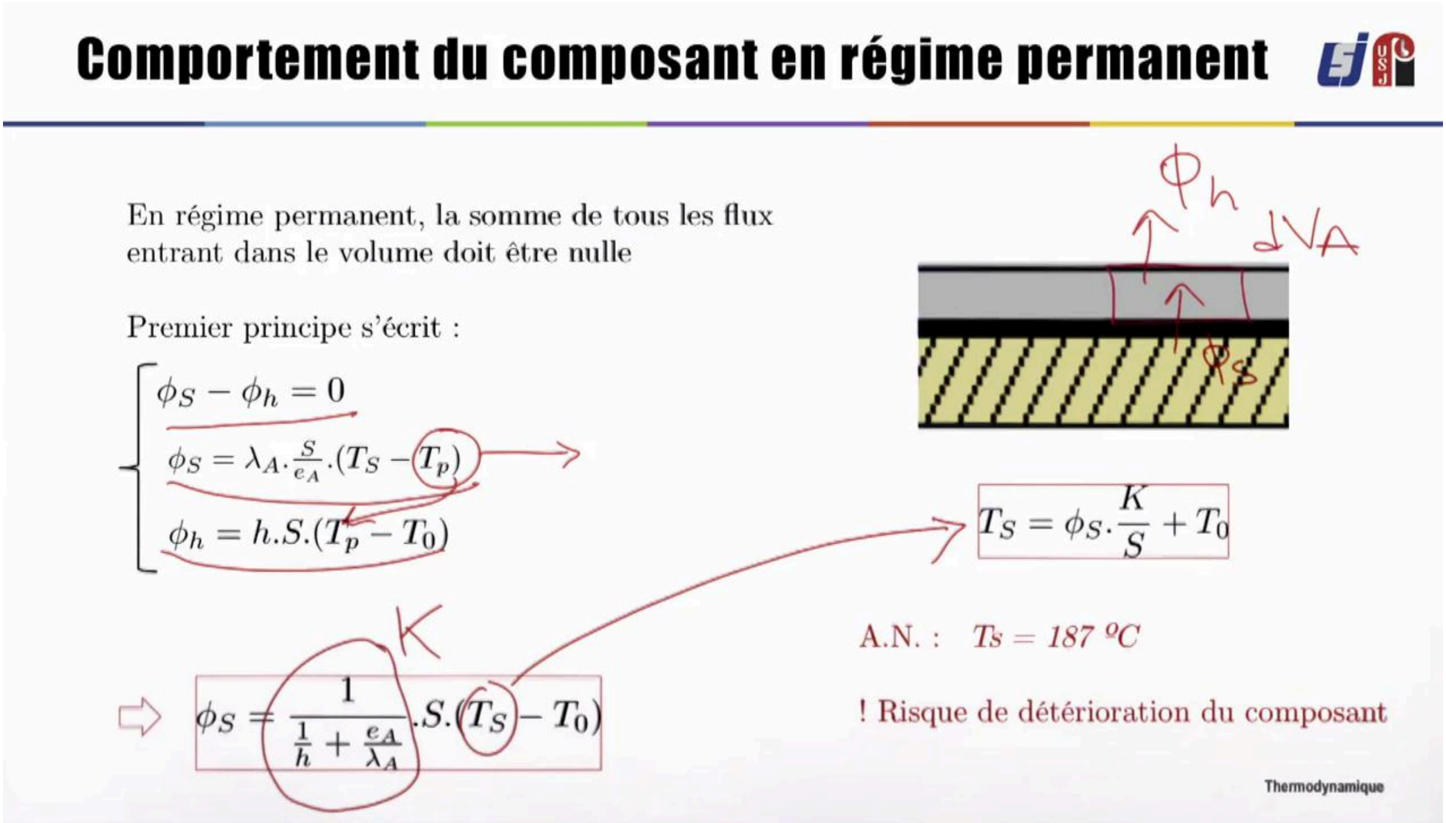


On the following figure, we see a part of the electronic component. We will consider an elementary volume in the aluminum plate that we will note of hevea, of hevea. The substrate receives a flux fi s and evacuates through the upper surface of the aluminum plate a flux noted fi h exchanged with the air by convection conductor. If we apply the first principle to this elementary volume in steady state, the sum of all flows entering this volume must be equal to zero. Thus, if f h is equal to zero, if s is the heat flux that propagates by conduction to the plate is in aluminum, so l is expressed according to the law of Fourier and if h is the evacuated flux by convection conductor and is governed by Newton's law. By combining these three expressions, we can determine the expression of TP from this equation, by replacing the expression of TP in this expression and thus considering the first equation which is if h equal to s, we can then determine if s, according to an exchange coefficient containing the case of s and the temperature difference between TS and T0. From this expression. We can then deduce the expression of ts and calculate its value, since the different parameters of the expression are well known.

Notes

Summary

3m 31s

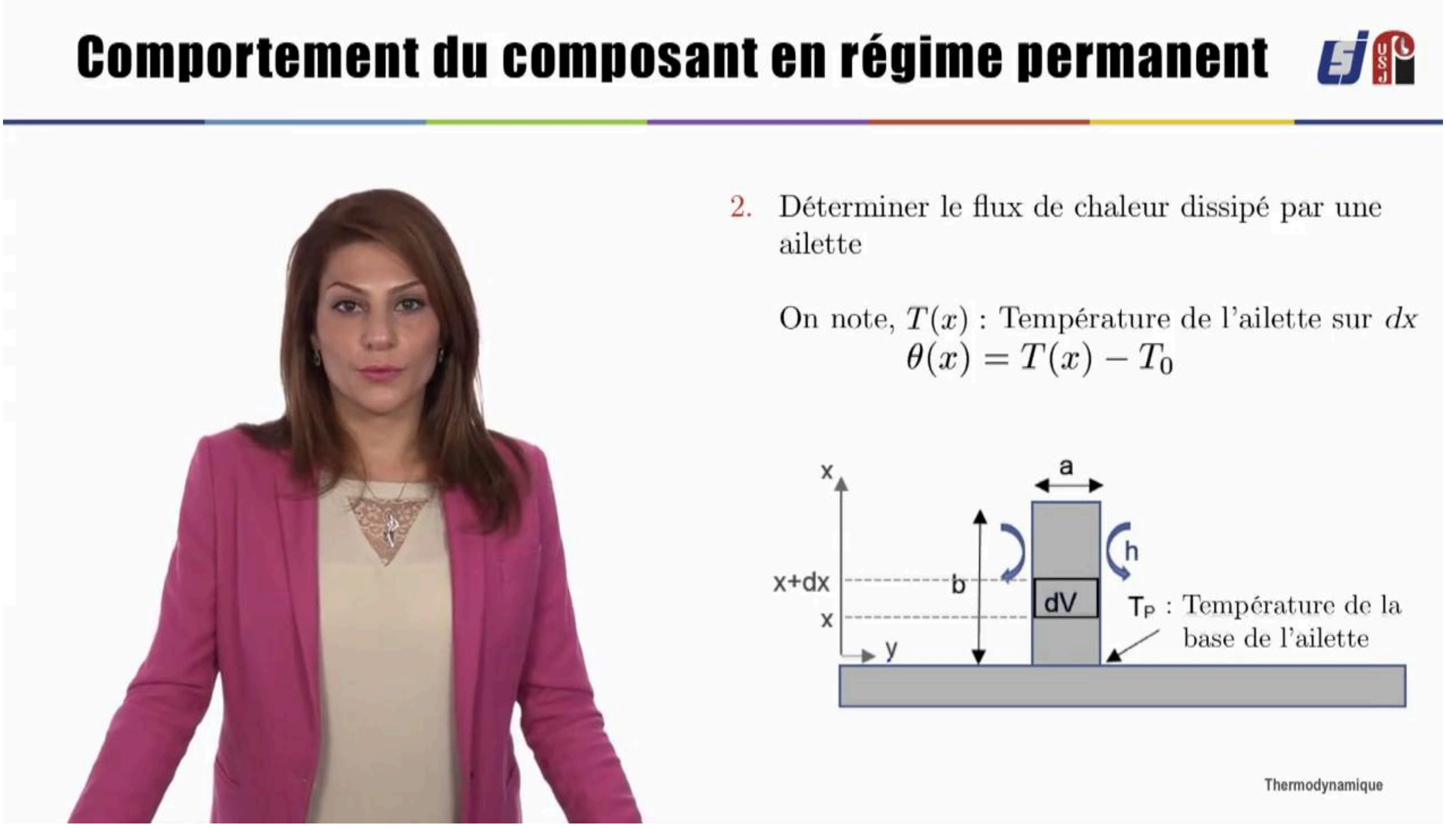


In the case of a simple component. As can be seen, the substrate temperature reached is 187 degrees. This temperature is above the acceptable limit temperature by the component, which may damage the component given a body that we even cooling times.

Notes

Summary

5m 17s

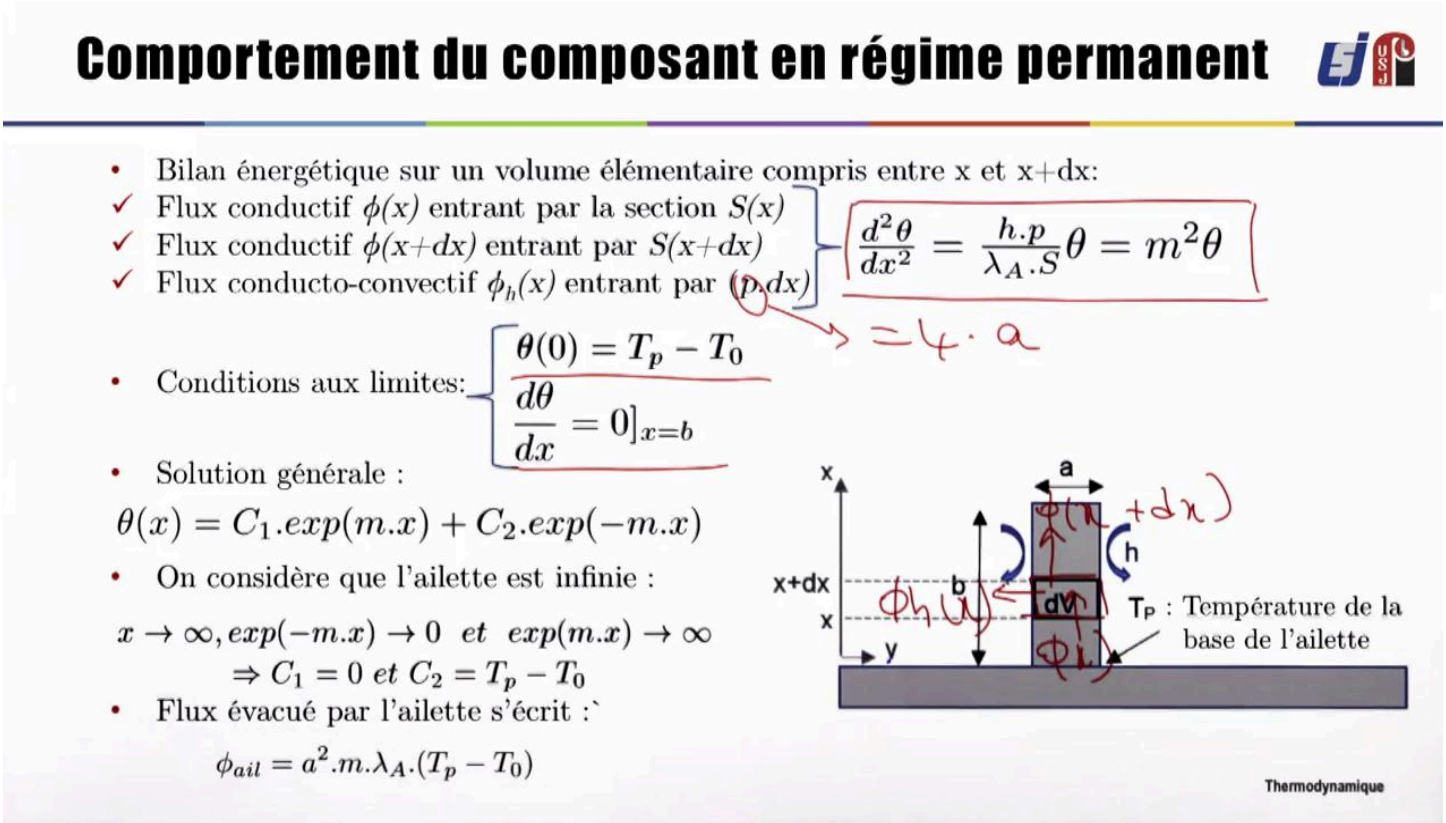


The question of sizing can be asked in different ways. In the case studied, we decide to define well the geometrical characteristics of the Ailette and to choose the material. And so the question would be to determine the number of fins needed to reach the objective and to have the proper functioning of this electronic component. For the selected letters, we have considered a height B which is equal to two cm. A square section of the fin equal to A being two mm. This student will exchange with the ambient air a convective conductive heat flow governed by the exchange coefficient convective H which is equal to fifteen watts per square meter. We will first try to determine the heat flux evacuated by a fin to be able to determine the number of of fins required for proper operation of this component. For this, we will note de X as the temperature of a slice of this fin between an abscissa x and x more than x. Hicks was also reported as being equal to the difference between the temperature of the slice of the student and Hicks and the ambient temperature carried out by maintaining the balance energy on an elementary volume between x and x dx of satellite.

Notes

Summary

5m 38s



On this elementary volume, we have a conductive flow fi of x which crosses the student through the X section, another conductive flow that crosses the section one s of X and more than x and y is denoted fi of x plus x. Through its lateral surface, the student exchanges with the environment a convective heat flux noted son h of X. The lateral surface of the Ailette and it is equal to P. The perimeter of this x p fin is equal to four one. In steady state, the sum of the inflows in an elementary volume is equal to zero. This allows us to determine the general letter equation. Now it remains to determine the boundary conditions. An x is equal to zero. The temperature of the student's base T of X is equal to the temperature of the upper surface of. The aluminum plate TP at their head at zero is equal to tp t0. Via this student's geometry, it is. The height B is much larger than the section A. If we can say that the flux exchanged by the top of this fin is negligible and can be assimilated to zero, which brings us to a second boundary condition at x equal to B which is equal to detecta on tx equal to zero.

Notes

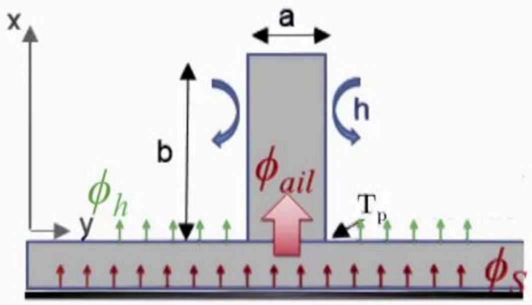
Summary

7m 17s

Comportement du composant en régime permanent

Nombre d'ailettes minimal ?

Exprimons $\phi_S = f(T_S\text{-}T_0)$



- Conduction dans la plaquette

$$\phi_S = \lambda_A.\frac{S}{e_A}.(T_S - T_p) \implies T_p = T_S - \frac{\phi_S.e_A}{\lambda_A.L.l}$$

- Convection ''plaquette et ailettes'' et ambiance

$$\phi_S = \phi_{h'} = h.(L.l - n.a^2).(T_p - T_0) + n.\phi_{ail}$$

$$\phi_S = h'.L.l.(T_S - T_0)$$

$$h' = \left(\frac{e_A}{\lambda_A} + \frac{L\ l}{hLl - nha^2 + na^2m\lambda_A}\right)^{-1}$$

A.N. : $T_{s,limite} = 80$ ºC
$h' = 41{,}6$ W/m².K
$n_{min} = 20{,}2$

Thermodynamique

The general solution of the equation of the Ailette is written as heap of x equal to C1 exponential m2 x plus d2 exponential m2 x C1 and C2 being the integration constants. We will determine if we consider that letters and infinite. In this case, when X tends to infinity, the exponential of X or of m of x tends to zero and the exponential of m of x tends to infinity, which is impossible. Thus, we can say that the constant C1 is equal to zero and C2 is equal to tp t0. The flow through the letters in X is equal to zero and cleared by the lateral surfaces of the fin by conductors. Convection. By making this equality and replacing in the general equation of the Ailette, we can determine the evacuated flux by a fin which is written in this form and which depends on A2. The Linette M section which has a constant lambda is the thermal conductivity of the aluminum plate and the temperature difference between the base of the Ailette and the ambient air. Now we have to determine the number of fins needed for a good operation of this electronic component. We will first express fi of s as a function of ts t0.

Notes

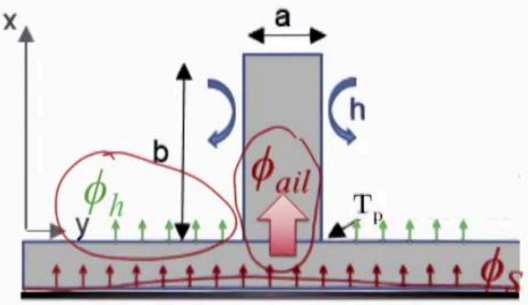
Summary

8m 55s

Comportement du composant en régime permanent

Nombre d'ailettes minimal ?

Exprimons $\phi_S = f(T_S - T_0)$



- Conduction dans la plaquette

$$\phi_S = \lambda_A . \frac{S}{e_A} . (T_S - T_p) \Longrightarrow \boxed{T_p = T_S - \frac{\phi_S . e_A}{\lambda_A . L . l}}$$

- Convection ''plaquette et ailettes'' et ambiance

$$\phi_S = \phi_{h'} = h.(L.l - n.a^2).(T_p - T_0) + n \phi_{ail}$$

$$\phi_S = h'.L.l.(T_S - T_0)$$

$$h' = \left(\frac{e_A}{\lambda_A} + \frac{L\, l}{hLl - nha^2 + na^2 m \lambda_A} \right)^{-1}$$

A.N. : $T_{s,limite} = 80$ ºC

$h' = 41{,}6$ W/m².K

$n_{min} = 20{,}2$

Thermodynamique

It is well known that the flux fi s that comes from the conductor in the substrate that we see here propagates into the aluminum wafer by conduction and it is governed, according to this expression of son of S. From this girl's expression of S, we will determine the expression of the temperature. This flux coming out of the Fraser aluminum plate will evacuate on the one hand by a convective conductive exchange through the surfaces of the aluminum plate not covered by the fins. On the other hand, it will be evacuated in the letters, first by conduction inside the Ailette. And then this flow will be. Will be released by a conductive exchange convective through the lateral surfaces of the fin. If we write the energy balance of this system, we have that fi s equals fi hp. If h premium is the convective conductive heat flow and exchanged on the one hand of a through the uncovered aluminum plate by the fins and on the other hand by the fins themselves. And here is defined the number of fins to achieve the desired objective. By simplifying this expression, the flux fide s is expressed as a function of h takes the new global exchange coefficient of the platelet assembly aluminum, skeleton of the surface, l times L of the electronic component and the temperature difference between the substrate and the ambient air t0.

Notes

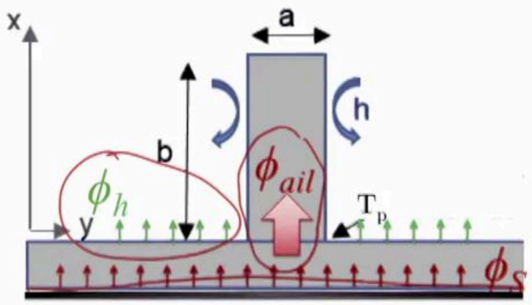
Summary

10m 34s

Comportement du composant en régime permanent

Nombre d'ailettes minimal ?

Exprimons $\phi_S = f(T_S - T_0)$



- Conduction dans la plaquette

$$\phi_S = \lambda_A . \frac{S}{e_A} . (T_S - T_p) \Longrightarrow \boxed{T_p = T_S - \frac{\phi_S . e_A}{\lambda_A . L . l}}$$

- Convection "plaquette et ailettes" et ambiance

$$\phi_S = \phi_{h'} = h.(L.l - n.a^2).(T_p - T_0) + n\phi_{ail}$$

$$\phi_S = h'.L.l.(T_S - T_0)$$

$$h' = \left(\frac{e_A}{\lambda_A} + \frac{L\, l}{hLl - nha^2 + na^2 m \lambda_A} \right)^{-1}$$

A.N. : $T_{s,limite} = 80$ ºC

$h' = 41{,}6$ W/m².K

$n_{min} = 20{,}2$

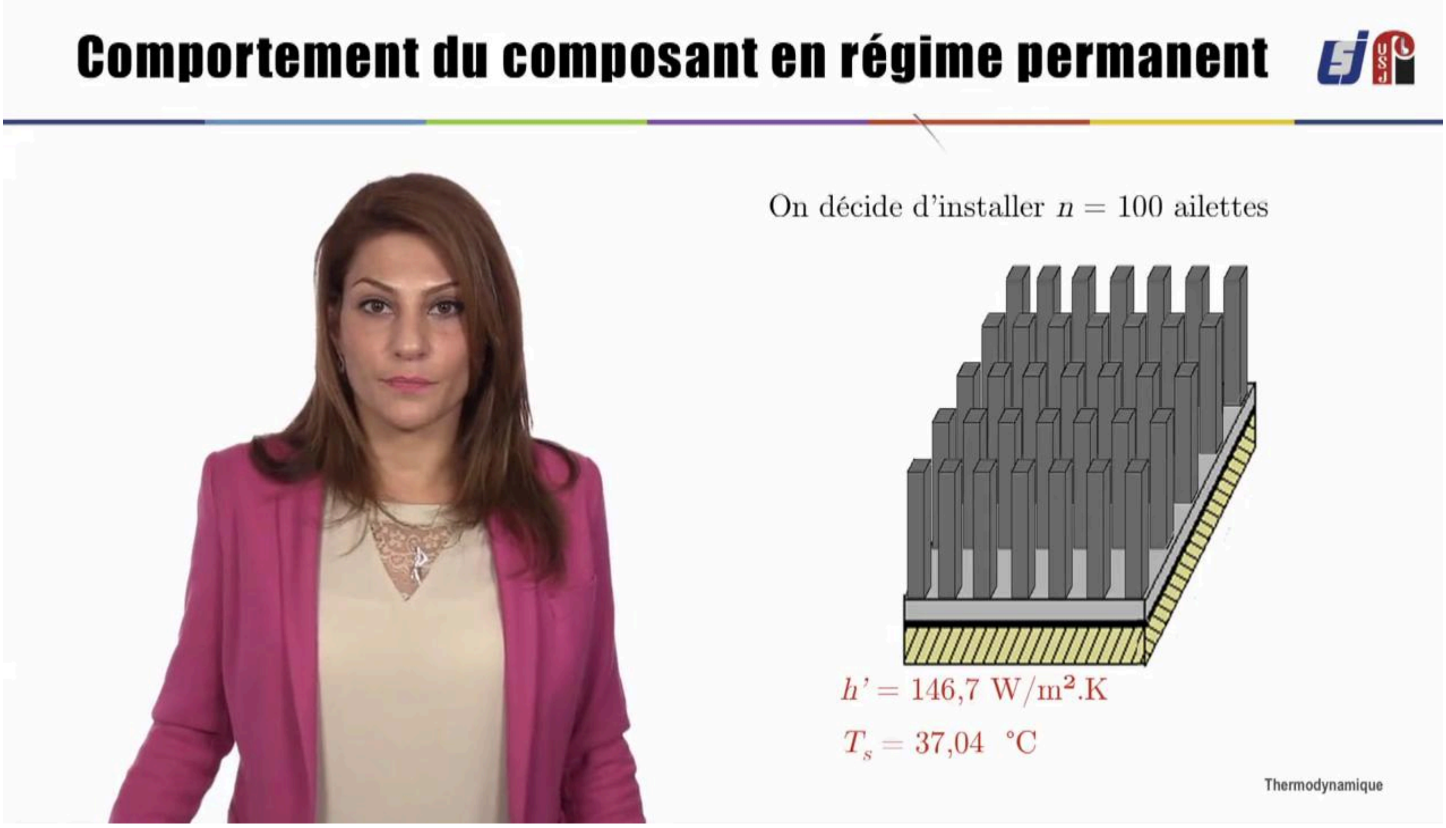
Thermodynamique

If we set c s, the temperature is limit of the substrate as equal to 80. A new global exchange coefficient H equal to 41.6 compared to the exchange coefficient that we had in absence of the letters on the aluminum plate. We can see that we have improved the heat transfer between the substrate and filling it by adding fins and to reach the limit temperature, or to avoid overheating of this component and to be able to limit to a substrate temperature of 80 degrees. The number of letters required is 21.

Notes

Summary

12m 27s

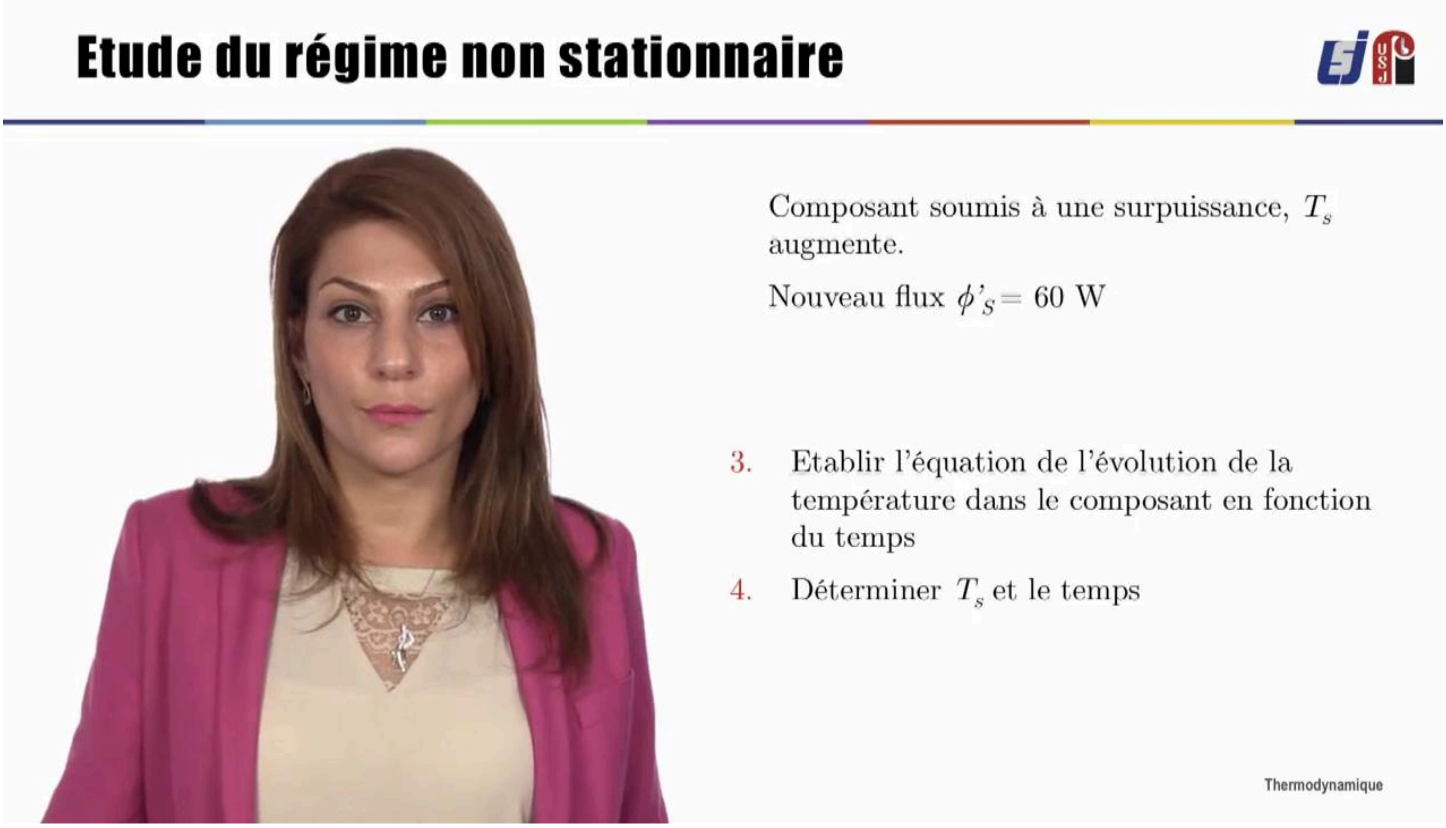


For security reasons, we decide to place on the aluminum plate without fins. With this new number of fins, the exchange surface between the component and the ambient air is further increased, which leads to an increase of the global exchange coefficient H which increases to 147 Watt per square meter and two grease and temperature of the substrate obtained for this number of fins is equal to 37 degrees.

Notes

Summary

13m 11s

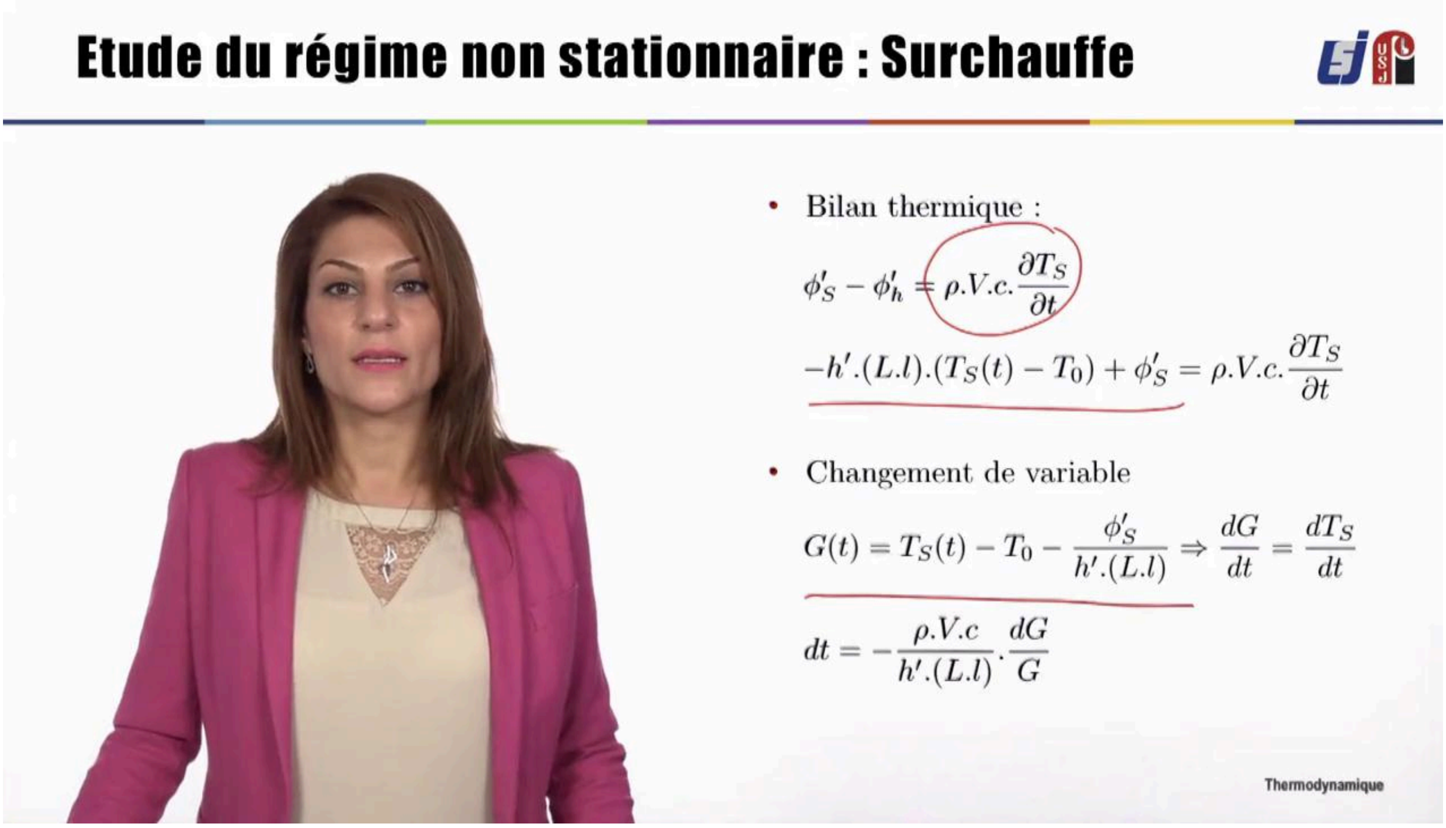


Now we will study the behavior of of this electronic component when it undergoes a change of thermal equilibrium, i.e. we will study its non-stationary state. For this, we assume that the electronic component is subjected to an overpower and that the flux of electricity from the conductor is increased from 20 to 60 watts. With this increase in power, there is necessarily an increase in of the substrate temperature in this part of the exercise. We will see how this behavior reacts, towards what temperature it will evolve and what would be the temperature and the minutes that it and the time it takes to reach this temperature. To do this, we will start by establishing the equation of the evolution of the temperature as a function of time.

Notes

Summary

13m 42s

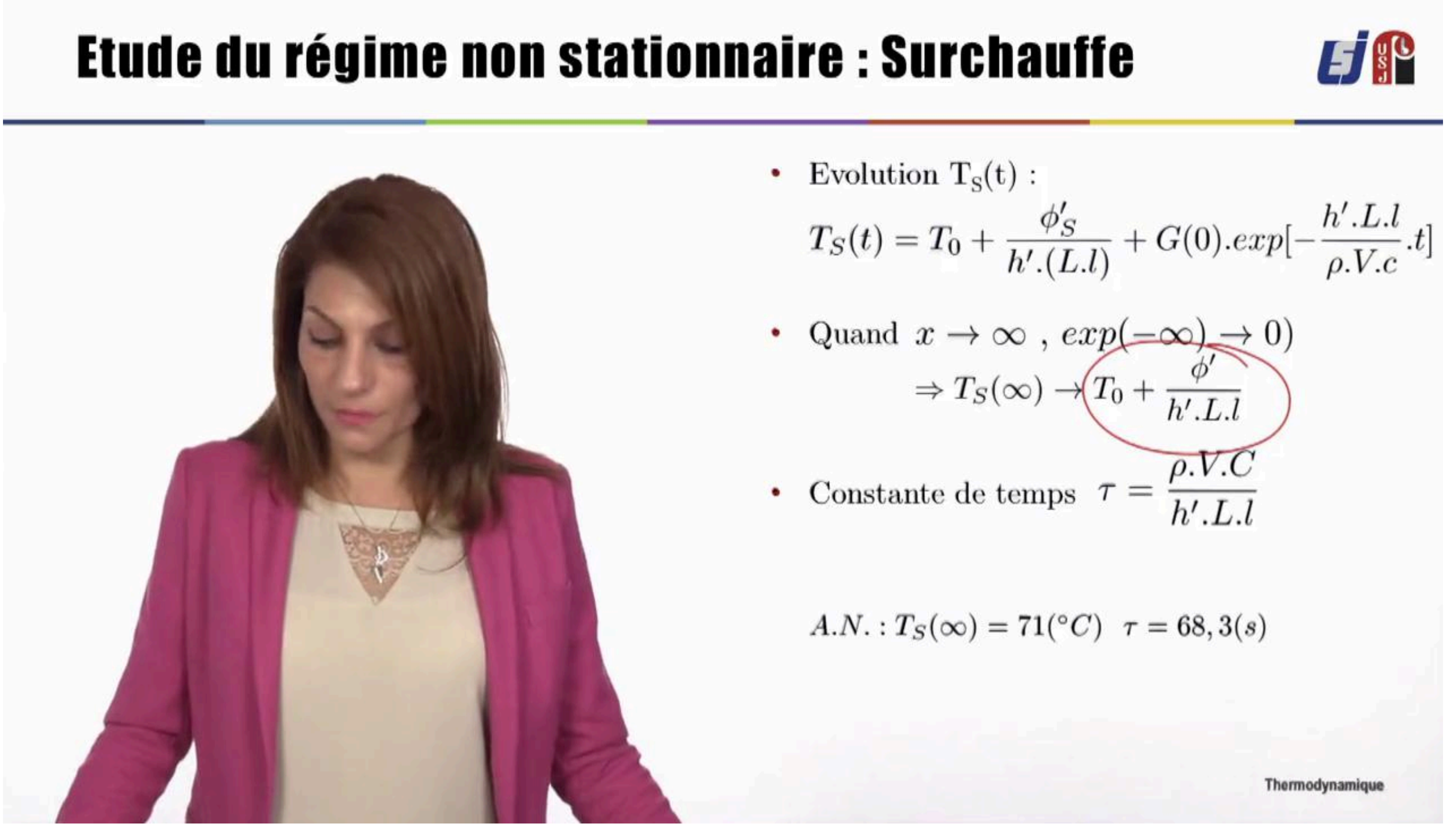


In the non-steady state, the temperature of the component varies with time. If we perform the energy balance applied to this component, we can say that the sum of the flows entering this component is equal to the variation of its internal energy expressed by this term, and depends mainly on the properties of the material constituting this component which are here ROS and the density of aluminum V, its volume and mass heat capacity and the partial derivative of the temperature divided by the partial derivative of time. If we replace of s which is the flux dissipated by the substrate through the conductor and which is propagates by conduction in the aluminum wafer and the expression of fibers of H which is which corresponds to the heat flux exchanged by conductors convection between the component and the outside. We obtain this first term of the equality if in which we have only at the temperature T of S which depends on the time. We're going to divide the whole thing up. The two members of the expression per h premium per month h premium l times L and we will perform a change of variable as follows. The derivative of g with respect to time is equal to the derivative of the temperature of S of the substrate with respect to time.

Notes

Summary

14m 38s

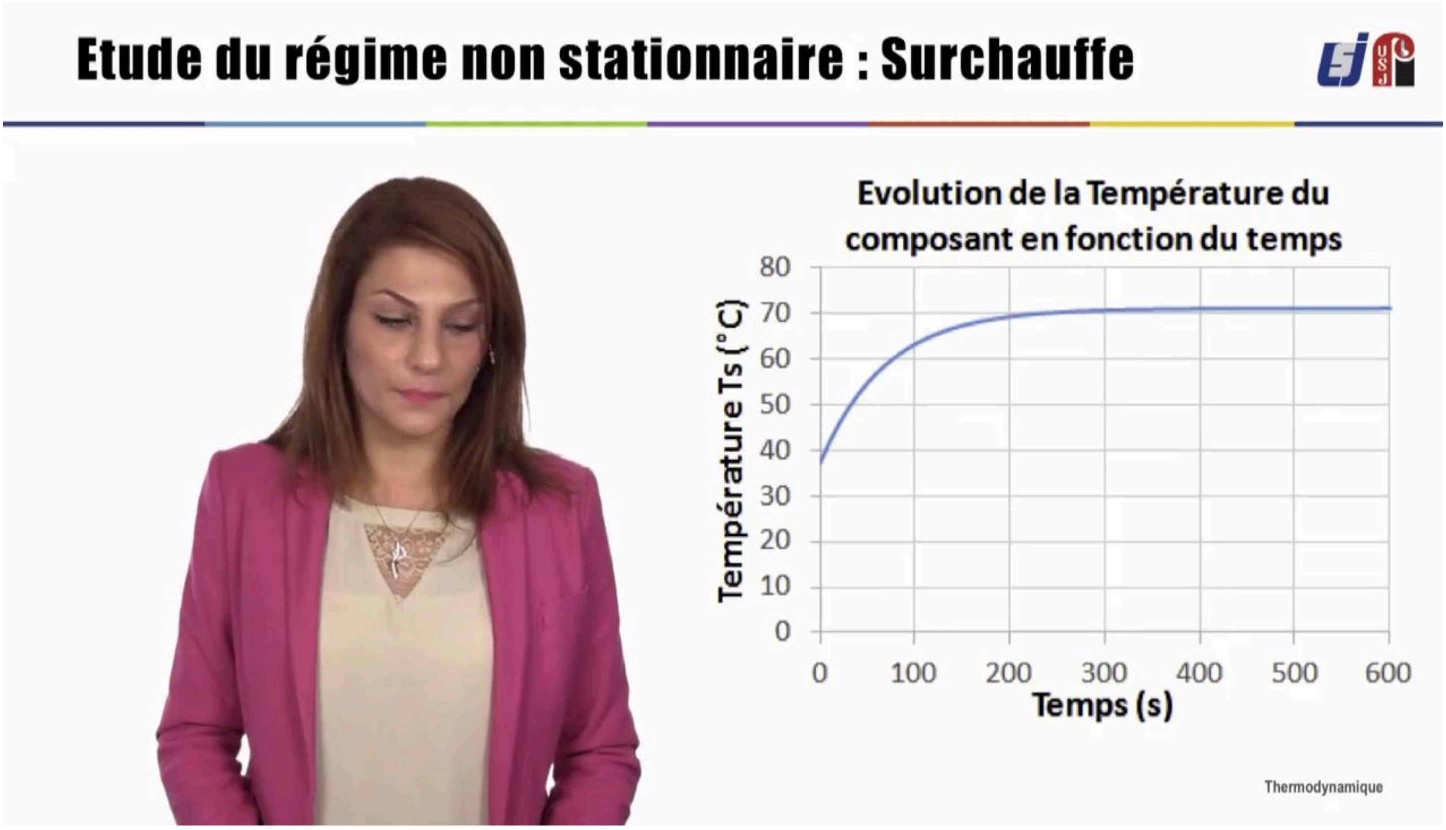


If we replace these two expressions in the previous expression, we can then determine the expression of DT as a function of DG on the following system of equations. A compound by the expression obtained from the energy balance and boundary conditions at time T equal to zero was equal to finite. These are as follows. We will consider that, at time t equal to zero, the temperature of the substrate is equal to 37 degrees, i.e. at the nominal operating temperature of this component. And then, we will perform an integration between the time T equal to zero and another time T. The solution of this integration is obtained and it is equal. So as you can see, at g from zero times the exponential of l times l divided by o vc multiplied by the time T. From the result of the integration, we obtain the evolution of the temperature of the substrate to be tested as a function of T and G0. The boundary condition at time T is equal to zero when T time tends to infinity. We see that the exponential of minus infinity tends to zero. Thus, we can determine the infinite temperature T which is equal to t0 plus a constant term. This temperature is equal to 71 degrees. We can also define a constant of tantot that we calculate equal to 68 seconds.

Notes

Summary

16m 13s

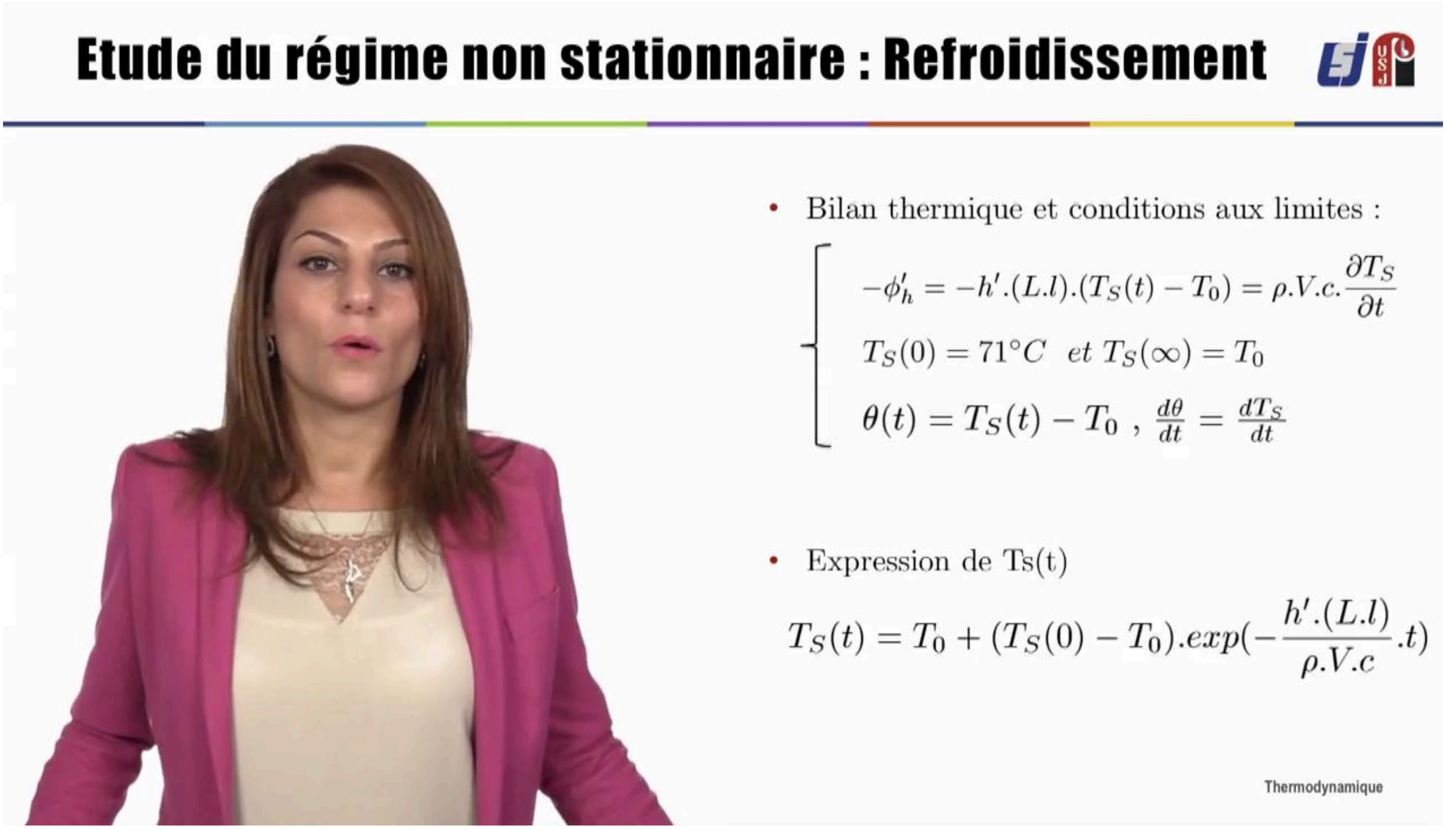


On this slide, you can see the evolution of the substrate temperature as a function of time. It is clear that the temperature is limit on which tends. The new thermal balance of the component is equal to 71 degrees.

Notes

Summary

18m 03s

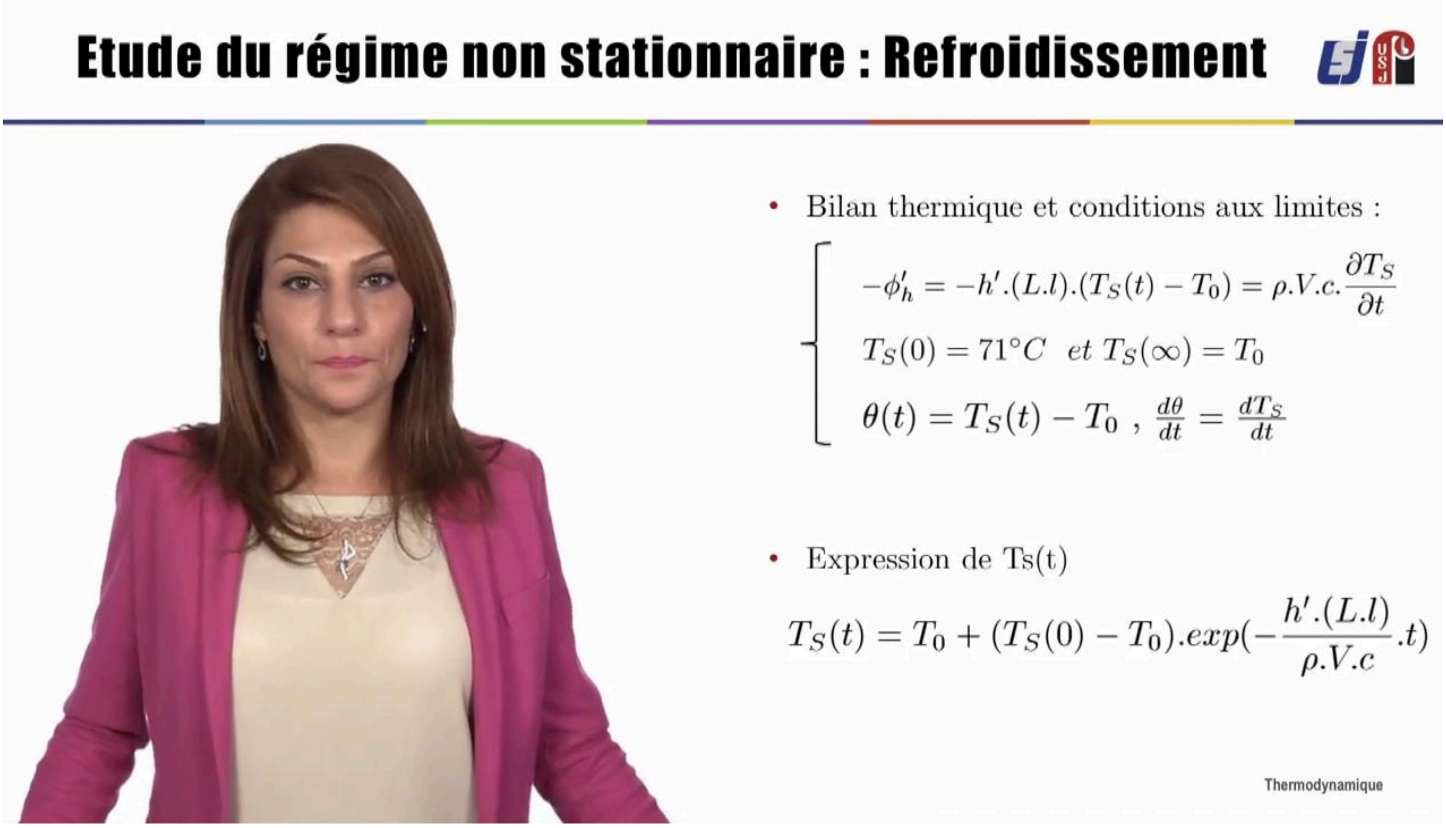


It is now. If we consider that the component is at 71 degrees and at this moment, we cut the power supply of this conductor. So we have a full flow of s equal to zero. In this case, we will see how the temperature has varied of this component and how the temperature evolves with time, at which time this component reaches the normal operating temperature which is 37 degrees, and when it reaches an equilibrium temperature, i.e. a constant temperature which in this case is equal to the room temperature. We will start by establishing the balance sheet energy applied to this component which operates in a non-steady state. The sum of the flows entering this system is equal to the variation of its internal energy. In the present case, in the absence of power dissipation by the conductor, the only flow exchanged by the conductor is of h and it is an outgoing flow of water the sign minus it is equal to the variation the temperature of the divided substrate or as a function of time. The boundary conditions applied therefore at this case study correspond to the time T is equal to zero. It is the moment or there that the power was cut and a moment T which corresponds to the new thermal equilibrium that the component will reach.

Notes

Summary

18m 20s

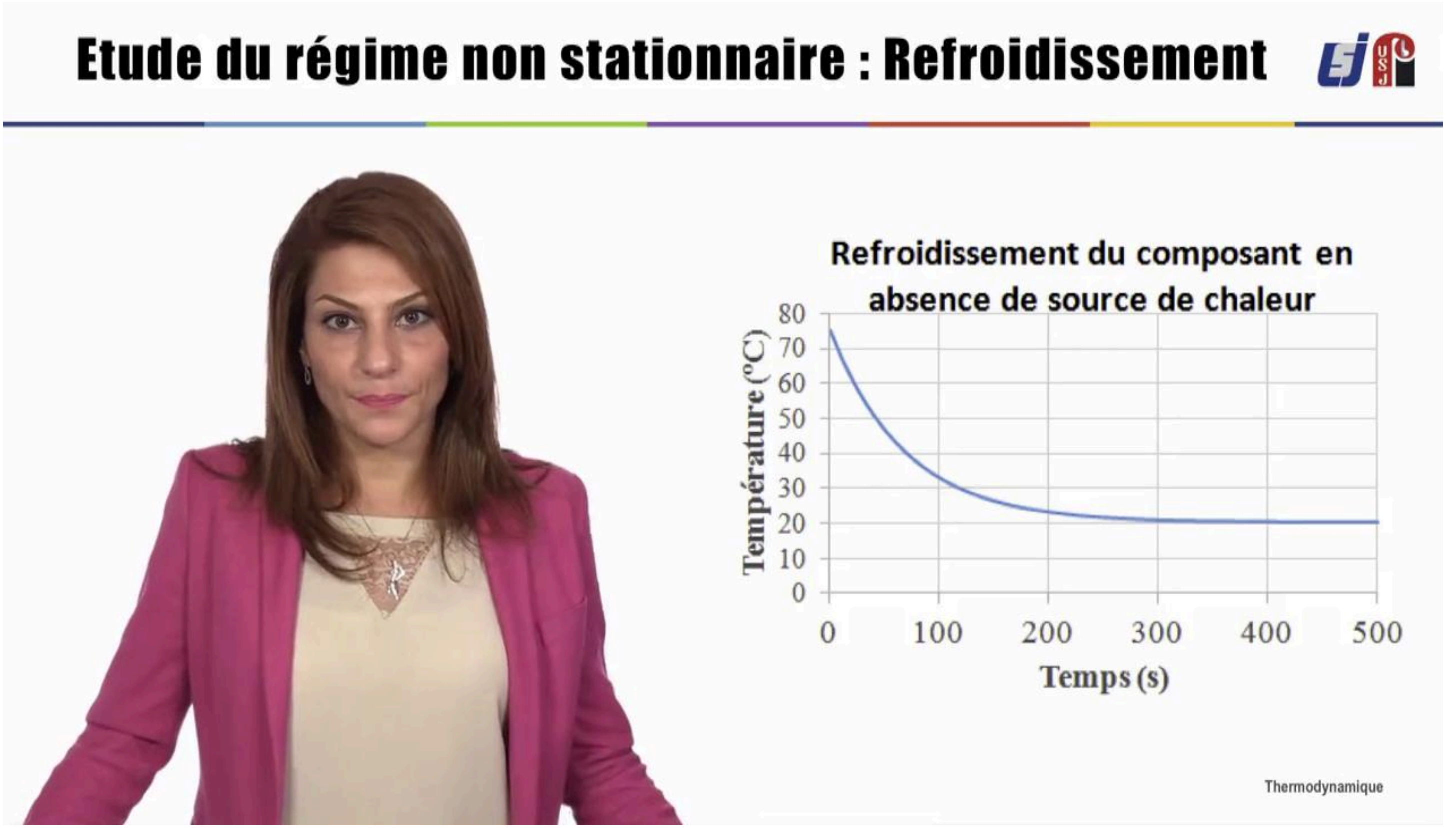


First, we will make a change of variable by putting a pile of earth which is equal to tst t0. The derivative of A with respect to time is equal to the derivative of the substrate temperature with respect to time. By replacing the expression of Tata and Tata in the previous expression. By integrating this one between the time T equal to zero and the time T, we obtain the new distribution. The new evolution of the temperature as a function of time that we see expressed as a function of T0, TS, zero and the different parameters H Prime and the geometric characteristics of the aluminum insert and Rover on the evolution of the temperature thus obtained is reproduced on this graph.

Notes

Summary

19m 54s

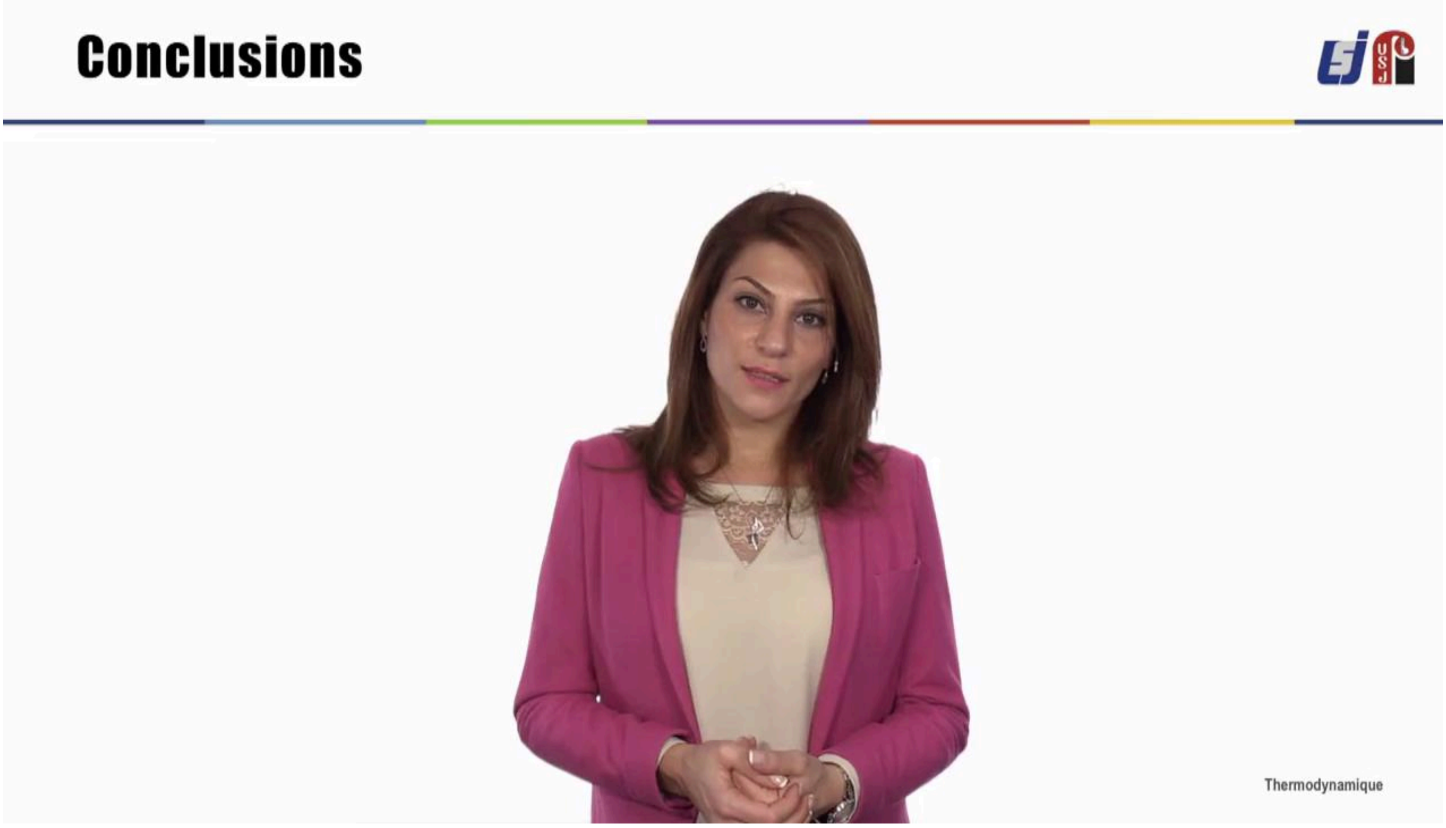


We can see that, at time t equal to zero, the temperature is 71 degrees. It goes down to 37 degrees at the time 70 seconds, it reaches the equilibrium temperature after 480 seconds, the equilibrium temperature being at room temperature, which is equal to 20 degrees C.

Notes

Summary

20m 53s



In conclusion, we have treated during this session the steady state conductive heat transfer and non-stationary in an electronic component. We have seen that when the exchange surfaces are insufficient for the proper functioning of a component The only thing that needs to be done is to add cooling fins to the electronic system. The role of these fins is to increase the exchange surface between the component and the ambient air and therefore to intensify the thermal exchanges between this system and the environment. We have applied the different physical laws and we have studied the behavior of this system, thus in a non-stationary regime. Or we have seen that when this electronic component is subjected to that the thermal equilibrium of this component varies and tends towards a new equilibrium temperature. Also, we have seen how this component when the power is off, i.e. when it is at a temperature above room temperature. What would be the dynamics of evolution of its temperature and when does it reach a new thermal equilibrium? Thank you for your attention.

Notes

Summary

21m 16s