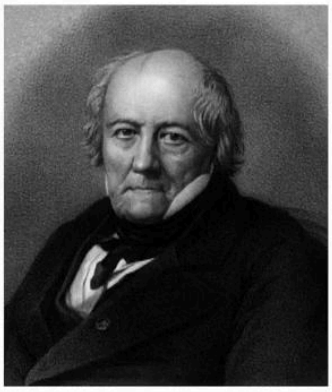
RESCIF
Réseau d'excellence des sciences de l'ingénieur de la Francophonie

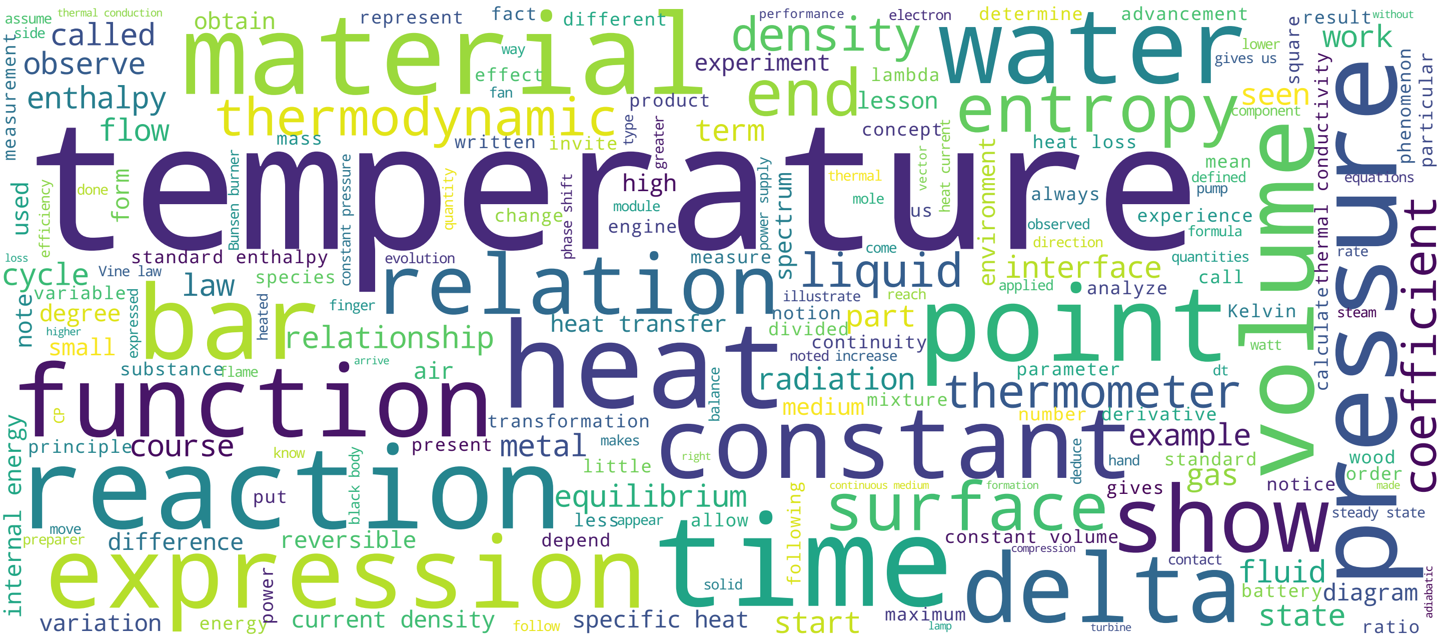
Thermodynamique

Expériences : Transferts thermiques



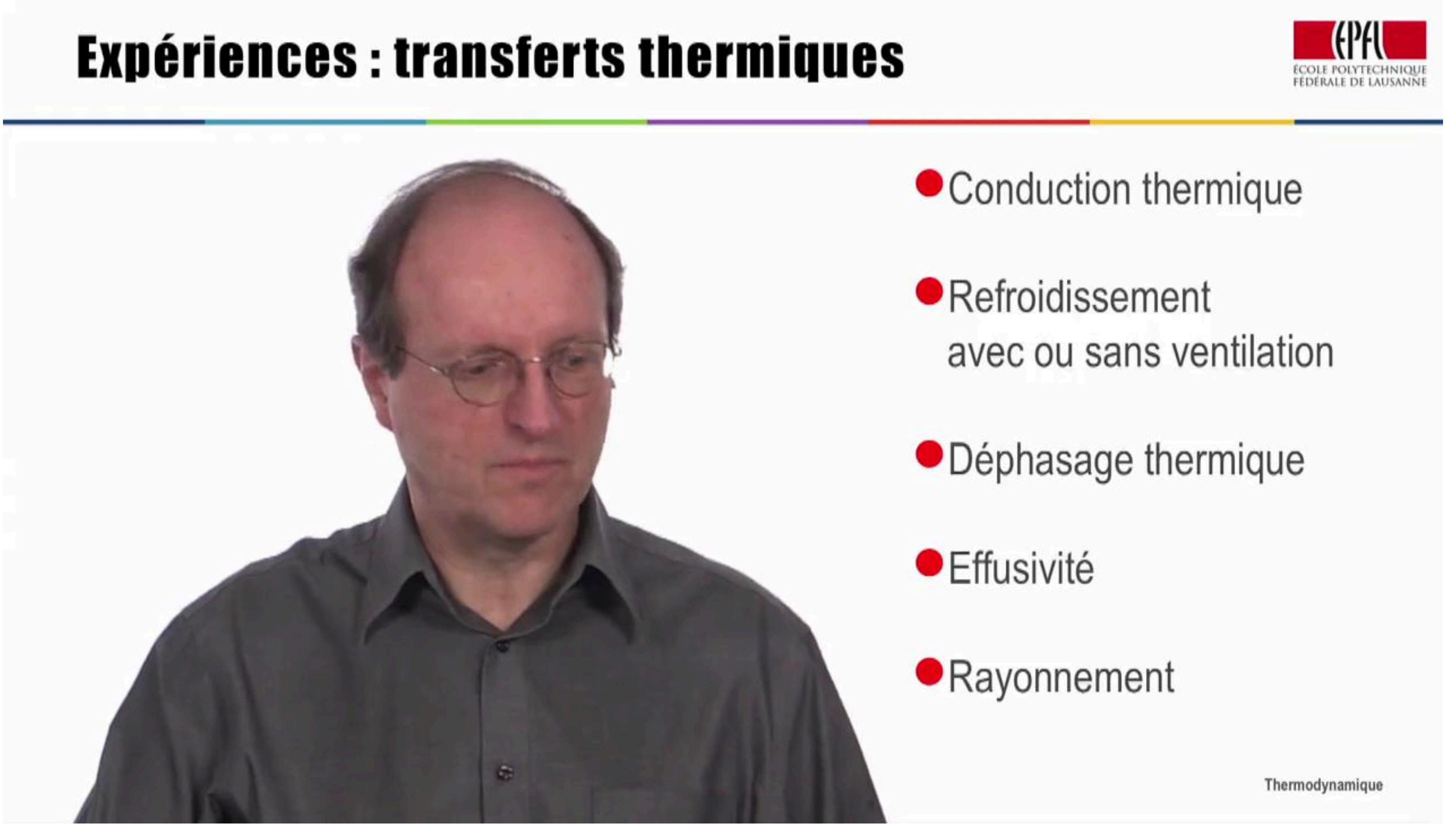
Jean-Baptiste Biot, 1774-1862

Prof. Jean-Philippe Ansermet



EPFL

Video

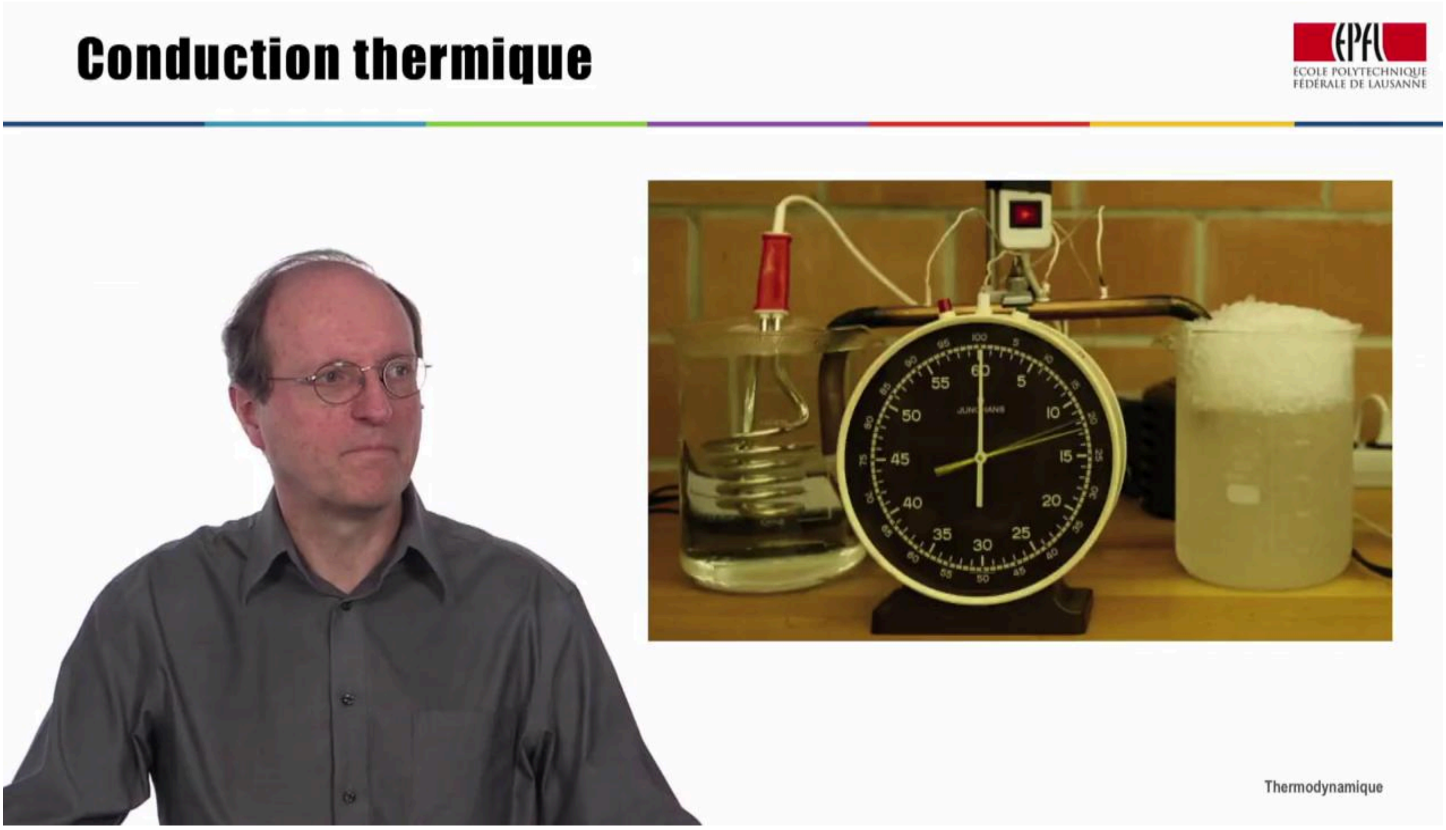


Here I am again to present you some experiences. Chantal Matteau and Martin Brochu give you a lesson on heat transfers in stationary and transient regimes. Here. I would like to illustrate their lesson by first showing them the conduction in a copper rod in steady state. Next, I would like to address the issue of heat loss of a metal in contact with air. Next, I would like to illustrate the concept of thermal phase shift. And then I would like to show you an experiment for which the notion of diffusivity intervenes. And I will end with two experiences on heat transfer by radiation starting with thermal conduction.

Notes

Summary

0m 04s



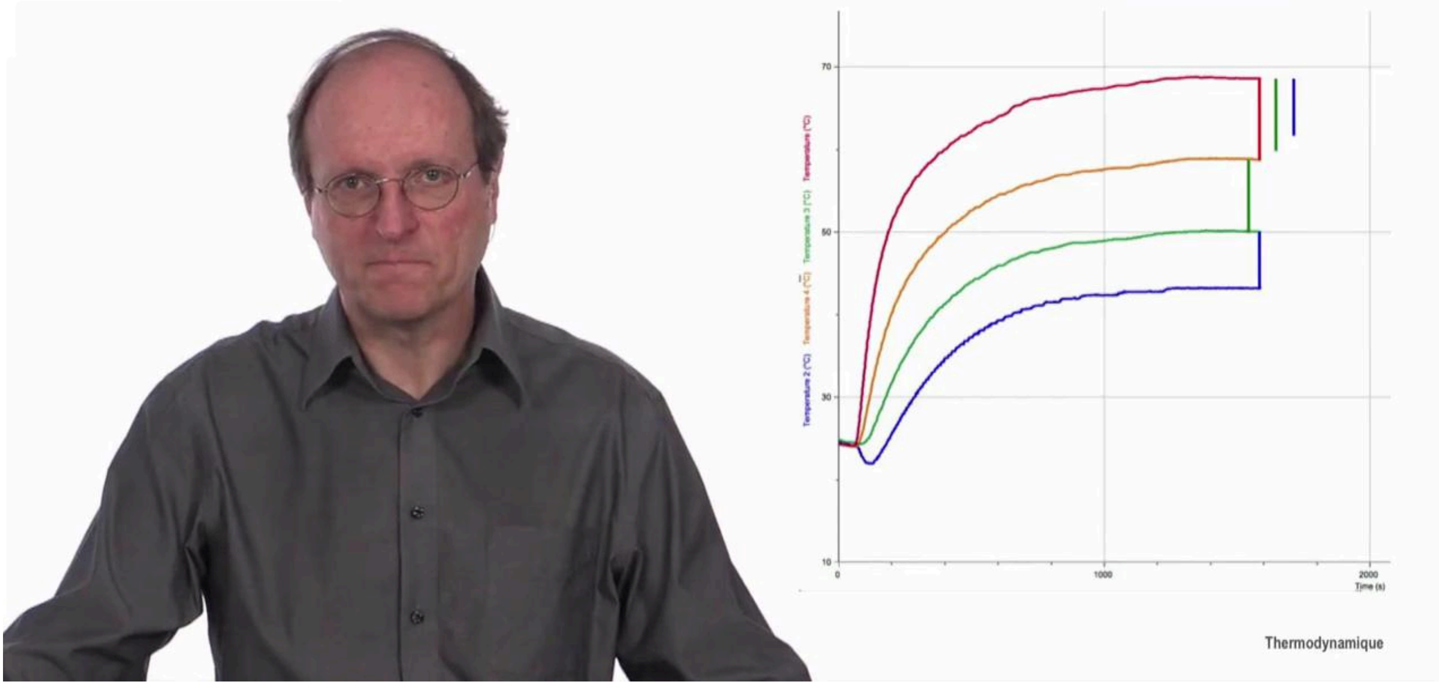
I suggest you look at the temperature along a copper rod. That you can see right behind that big timer. Four thermocouples were mounted at equal distances along the bar. We will record these temperatures while the bar is held at one end in boiling water and at the other end in crushed ice. Melting. So at zero degrees.

Notes

Summary

1m 03s

Conduction thermique

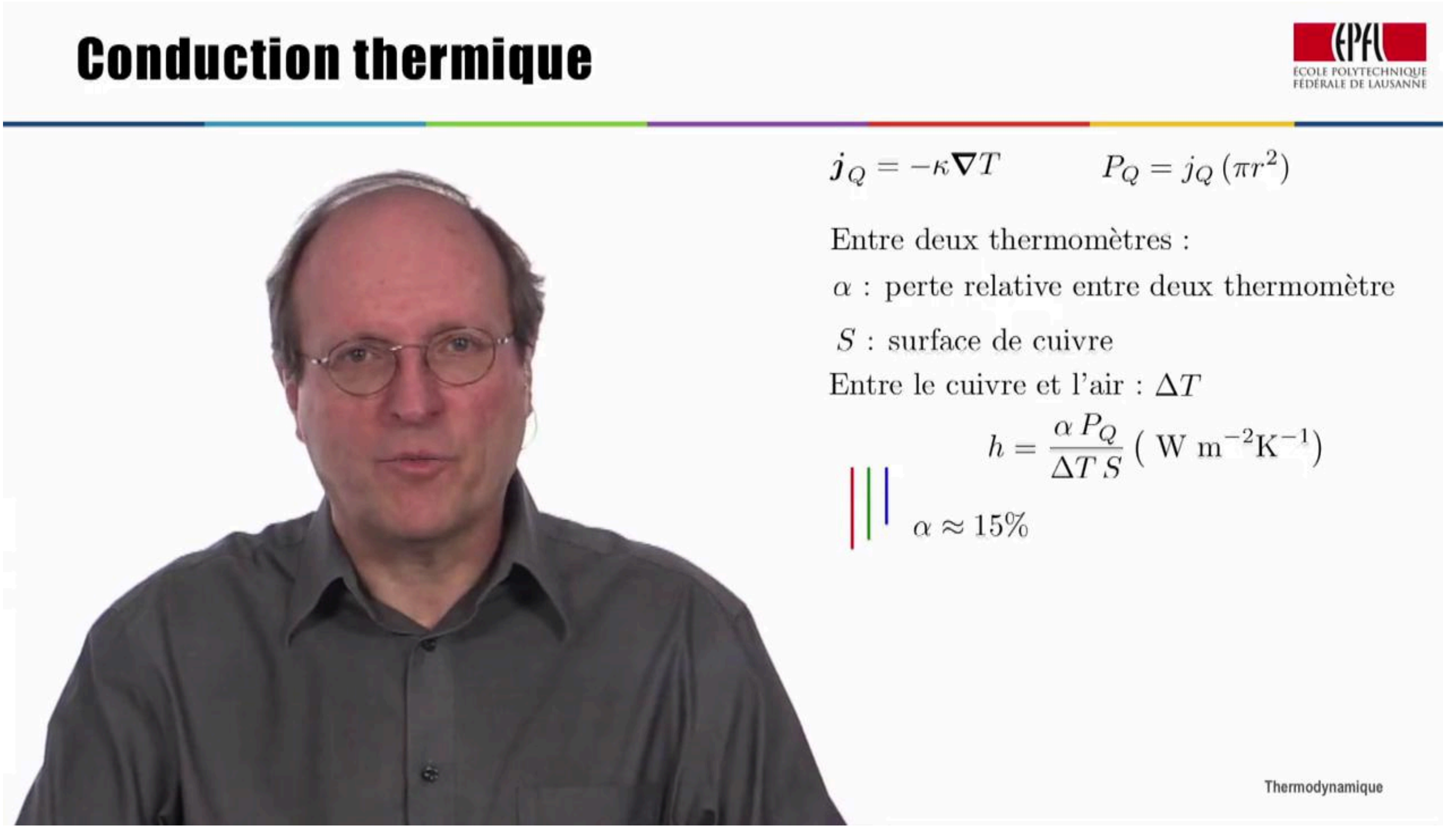


I show you on this graph. The result of the experiment. You have. On the ordinate the temperature in degrees Celsius. On the x-axis the time in seconds. We are not interested here in to the temporal evolution, but you see that we have after 1000 seconds, a stationary regime is reached. What I observe is that the temperature differences do not are not exactly what I had planned for the ideal case. If you want, I can plot the difference between two reported temperatures here. These gaps? You can see that with this little montage graph, we don't always have the same gap of temperature while the four thermometers are acquired distant.

Notes

Summary

1m 34s

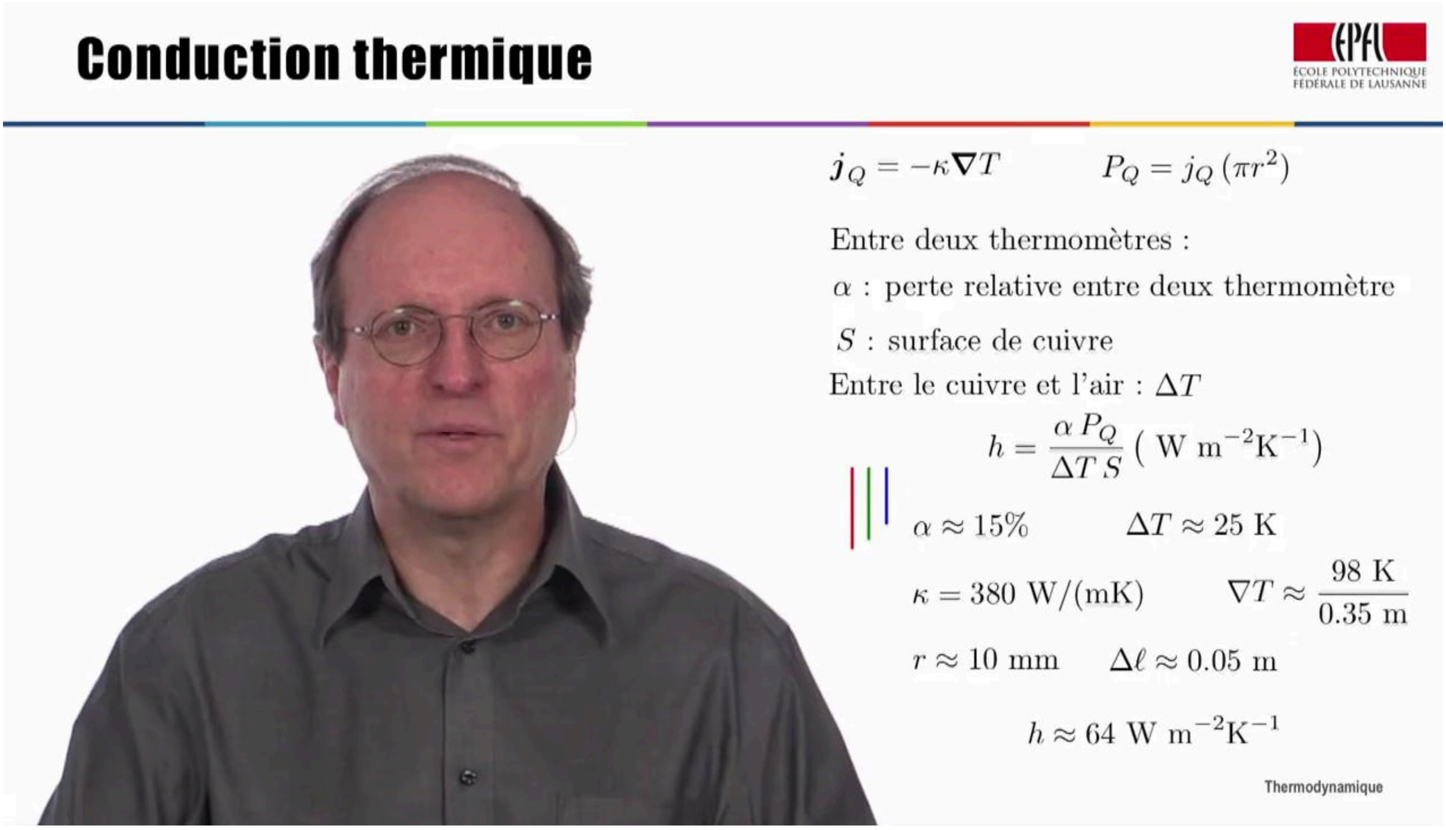


How to analyze this experience? So I'm talking about Fourier's law. I don't call it thermal conductivity. If there is no heat loss, this law can be applied everywhere. We have the same thermal power PQ. Which depends on the heat current, the heat current density GQ and the cross-sectional area of the bar, then r square which gives us the power. We would have the same power everywhere. Obviously, this is not the case. Otherwise we would have the same delta t between every three thermometers, every four thermometers. So I'm going to assume that in two thermometers, I have a relative loss of power, but I will call this relative loss alpha. I call the surface of the copper between two thermometers ESS. I'm going to guess, that's the parameter I'm least comfortable with. I'm going to assume that I have a difference of temperature delta T1 between the surface of the metal and the air in its vicinity. And so I'll calculate a heat loss coefficient like this. Per unit area. I have a loss in watts per square meter per Kelvin. If I take my digital data, I have my little geometric construction that reappears here. Roughly speaking, I have a loss of about 15% between two thermometers.

Notes

Summary

2m 29s

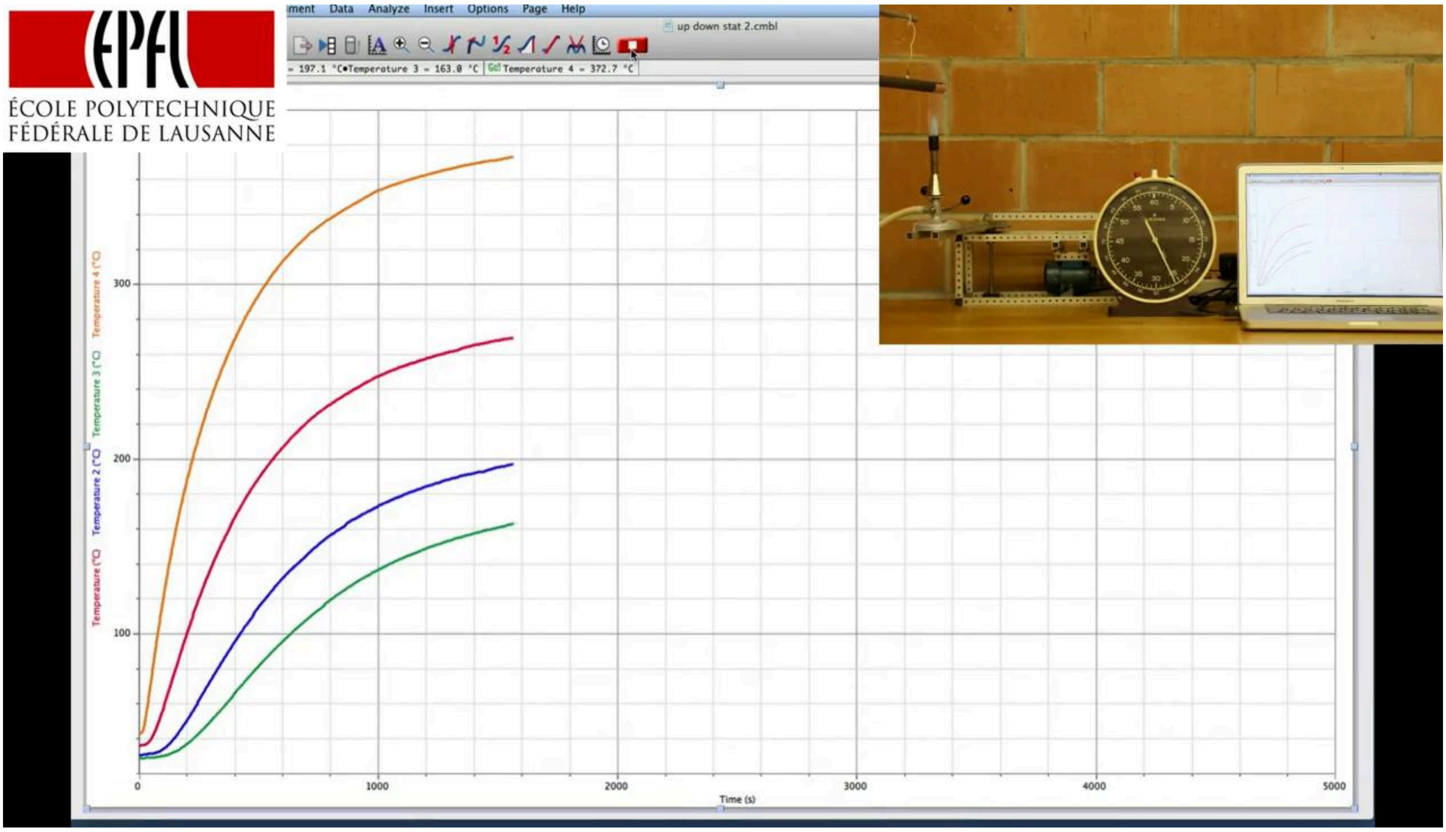


Of course, the loss is continuous along the bar. Here, I simply try to estimate this coefficient h. So look for an order of magnitude. So I simplify things for myself assuming there is a loss, just one location per segment. The Delta t. As I said earlier, I'm not sure of its value. I'll take 25, Kevin. I will look up the thermal conductivity of copper in a table. I have water boiling at ninety-eight degrees. And then the length of the bar is about 35 cm. It gives me the temperature gradient. So I can deduce the thermal power. PQ. I know the diameter of the tube. Finally, the copper bar. The distance between two thermometers is five cm. And so I deduce a loss of 64 watts per square meter per Kelvin. It may be a bit much compared to the tabular values, but at least we have an order of magnitude.

Notes

Summary

4m 11s



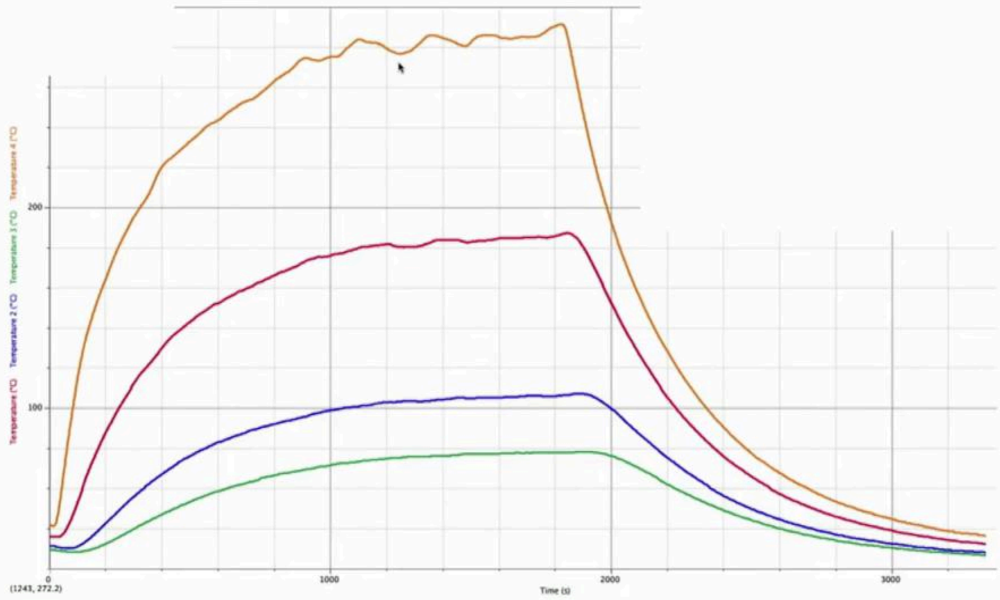
I am now passing another experience that you can analyze, that will allow you to better quantify this heat loss at the surface of a metal. We will consider a copper bar, again with four thermometers and this time we will observe. The evolution of the temperature. At the four measuring points. So the temperature as a function of time, with or without a fan that blows on the bar. Let's start with the static case. See here, you could see the Bunsen burner which heats the end of the bar and you have here now, as a function of time, the temperature of the four thermocouples. And you can see that we're getting close. A stationary state.

Notes

Summary

5m 20s

Refroidissement avec ventilation



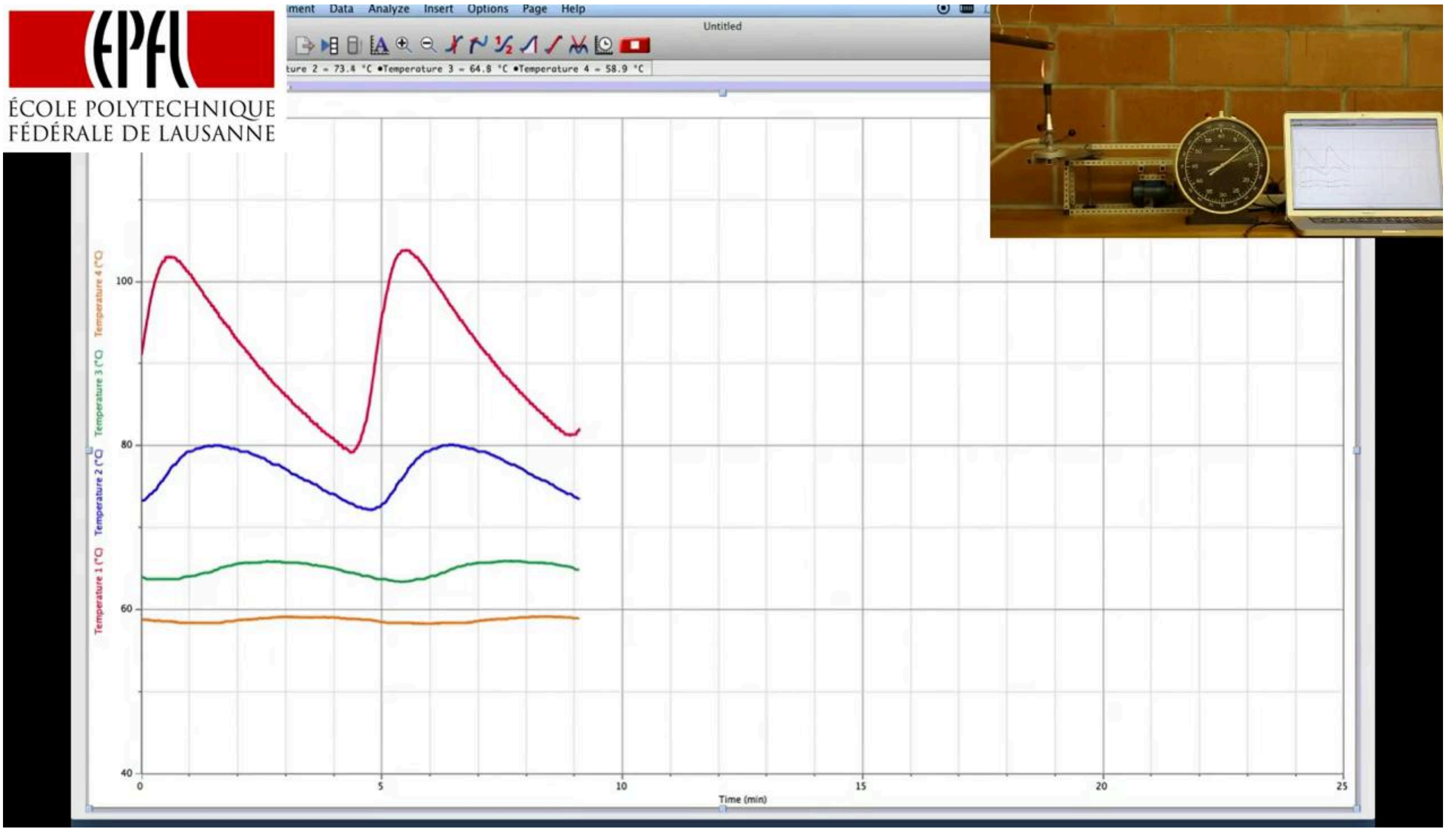
Thermodynamique

I show you here. The whole of the measurements. Of course, halfway through, we stopped the flame. That's why the baron gets cold. And I invite you to use the equation of heat to account for these data. I would now like to see how these data change experimentally when the fan blows on the bar. Do you see the fan in operation here? And the temperature is measured again as a function of time. Mostly we observe, for the first thermometer closest to the flame, fluctuations that come from the fact that the fan disturbs the flame. I now show you the set of measures for this same bar. But with the fan on, you immediately notice that you reach a steady state, but temperatures are lower and I invite you to analyze the graph to observe that the speed cooling capacity is also greater.

Notes

Summary

6m 22s



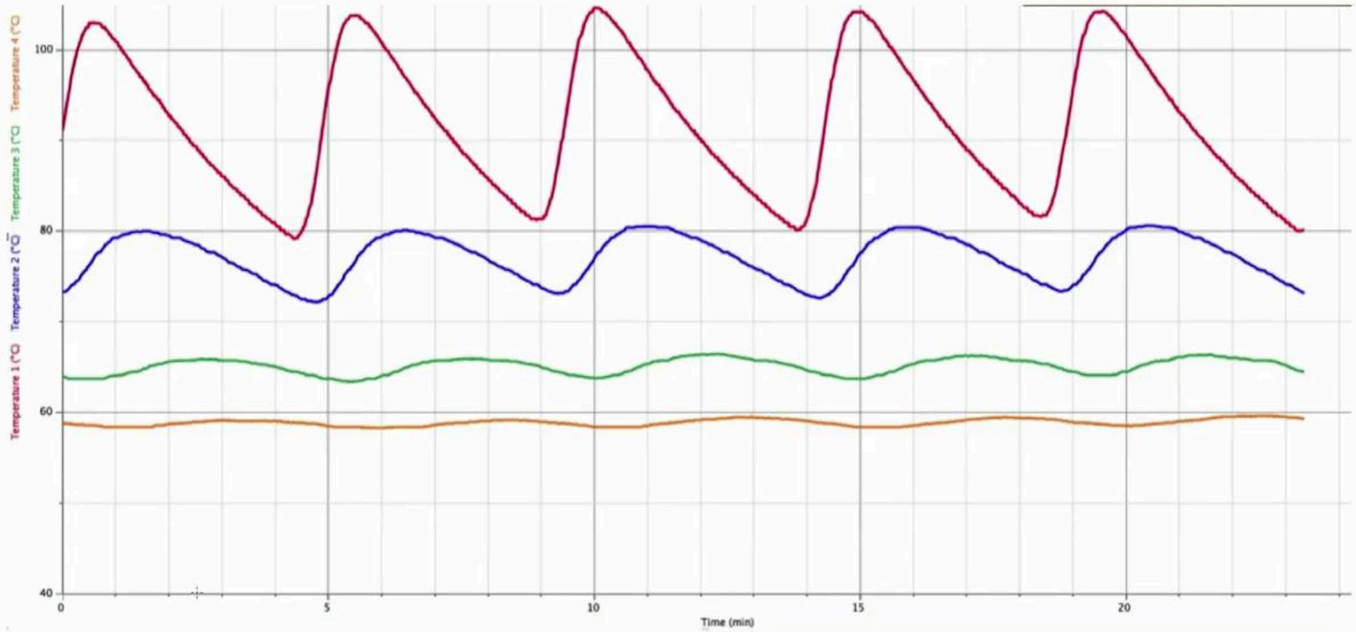
I would now like to illustrate the concept of thermal phase shift. To do this, I propose to examine this brass bar once again. But this time, the Bunsen burner is mounted on an arm. Who also, what makes him periodically pass under the bar. The Bunsen burner that is far from the bar and here it is under the bar. And that he is once again stepping away from the bar.

Notes

Summary

7m 36s

Déphasage thermique



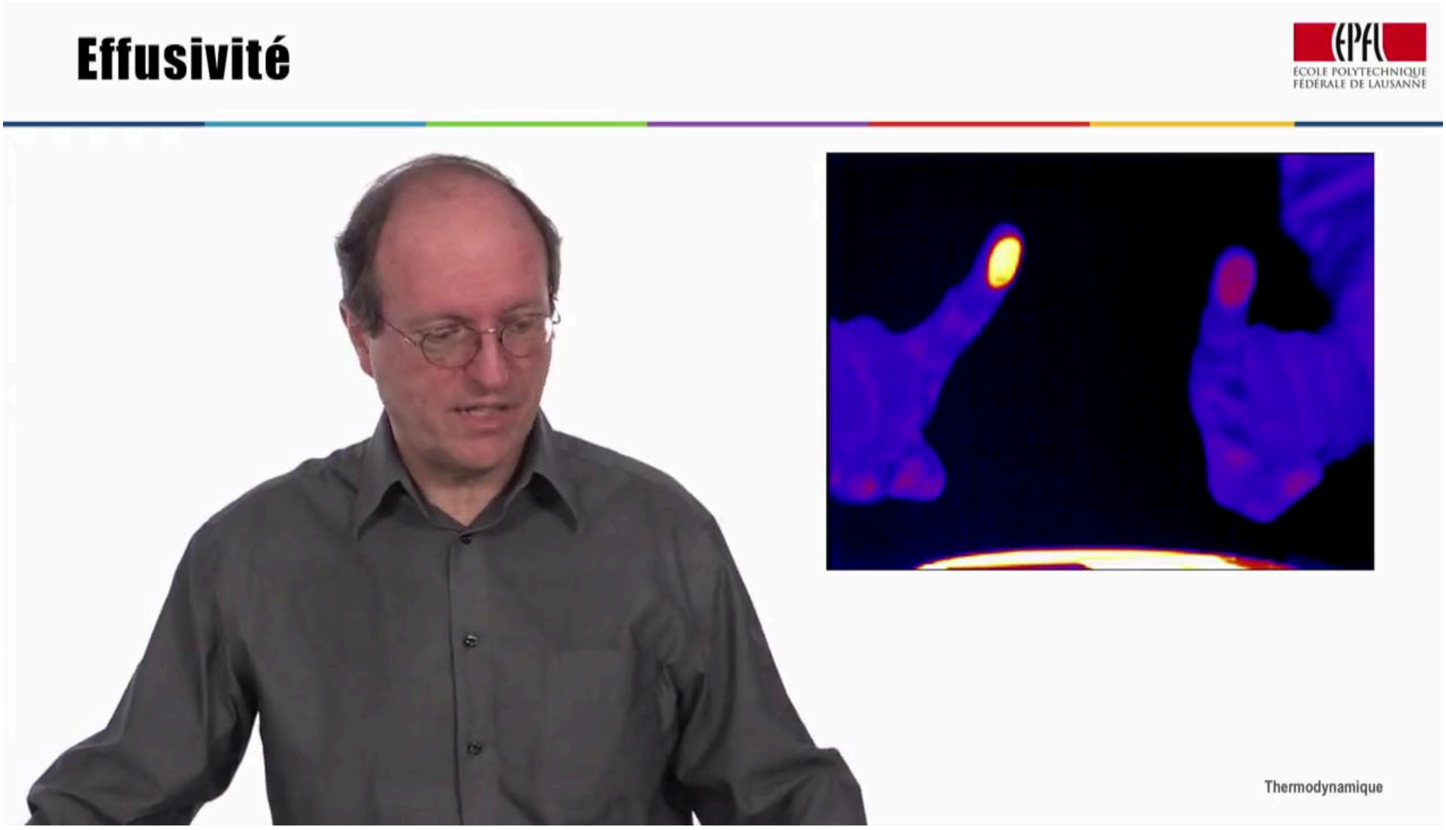
Thermodynamique

I will show you the whole measure here. Note that the recording was made after several passes of the flame of the Bunsen burner under the bar to reach this periodic regime. What I invite to notice, is that obviously the highest temperature is that of the thermometer which is closest to the hot spring. And you notice that the further away we get of this hot spot, the more the maximum takes place by themselves. On the fourth curve, one can hardly distinguish an oscillation. But if you take the time to look at it carefully, you can see that there are always this phase shift which is more and more important. The further away from the hot spring.

Notes

Summary

8m 15s

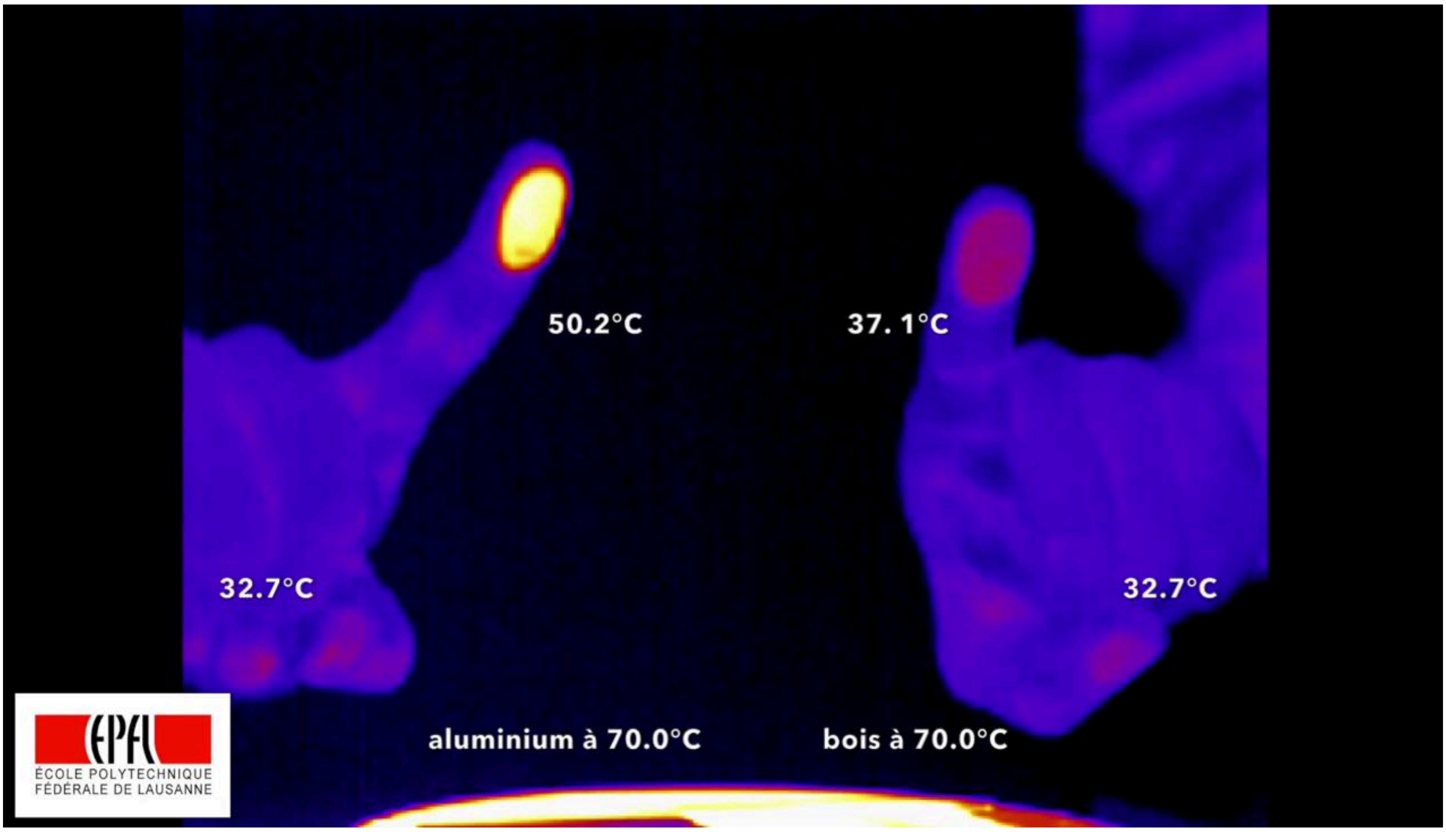


I would like to show you now an experiment for which the notion of diffusivity intervenes. Like this image. This image is an infrared camera image showing two fingers. It's two fingers that have been pressed on surfaces of different nature but which are at the same temperature.

Notes

Summary

9m 09s

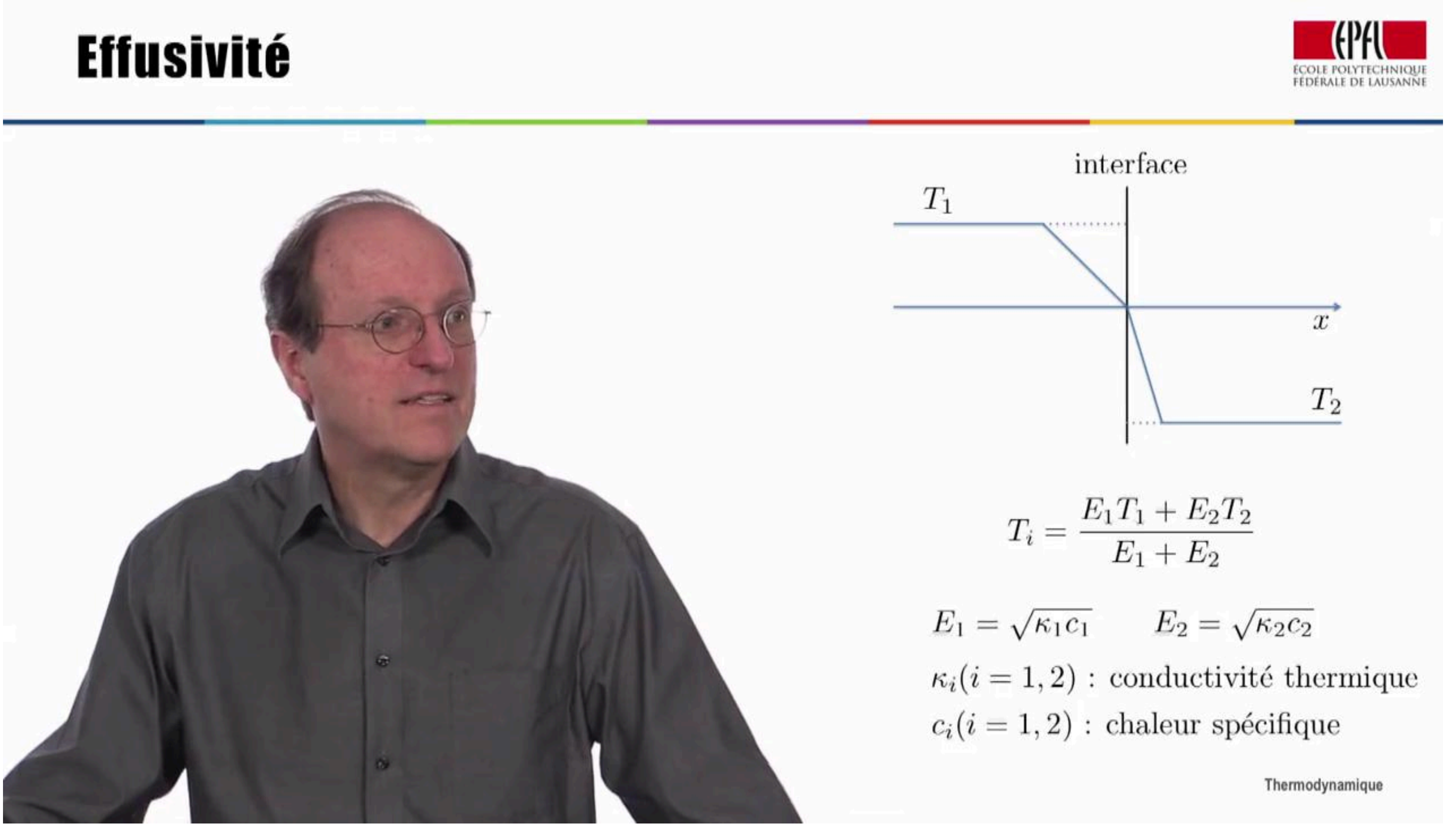


I invite you to watch the video. Here we see a block that is heated to seventy degrees Celsius on it. For a long time, a square of wood and a square of metal were arranged. The preparer will press his fingers on both materials. And then present them to the infrared camera. Here we see the detail. You notice that the temperature is decreasing, but slowly enough so that the initial measurement is representative of the temperature at the interface between the finger and the metal or wood. This temperature is used in the calibration of the camera. We see that on the wood, we have a much lower temperature than what we get on the metal.

Notes

Summary

9m 30s

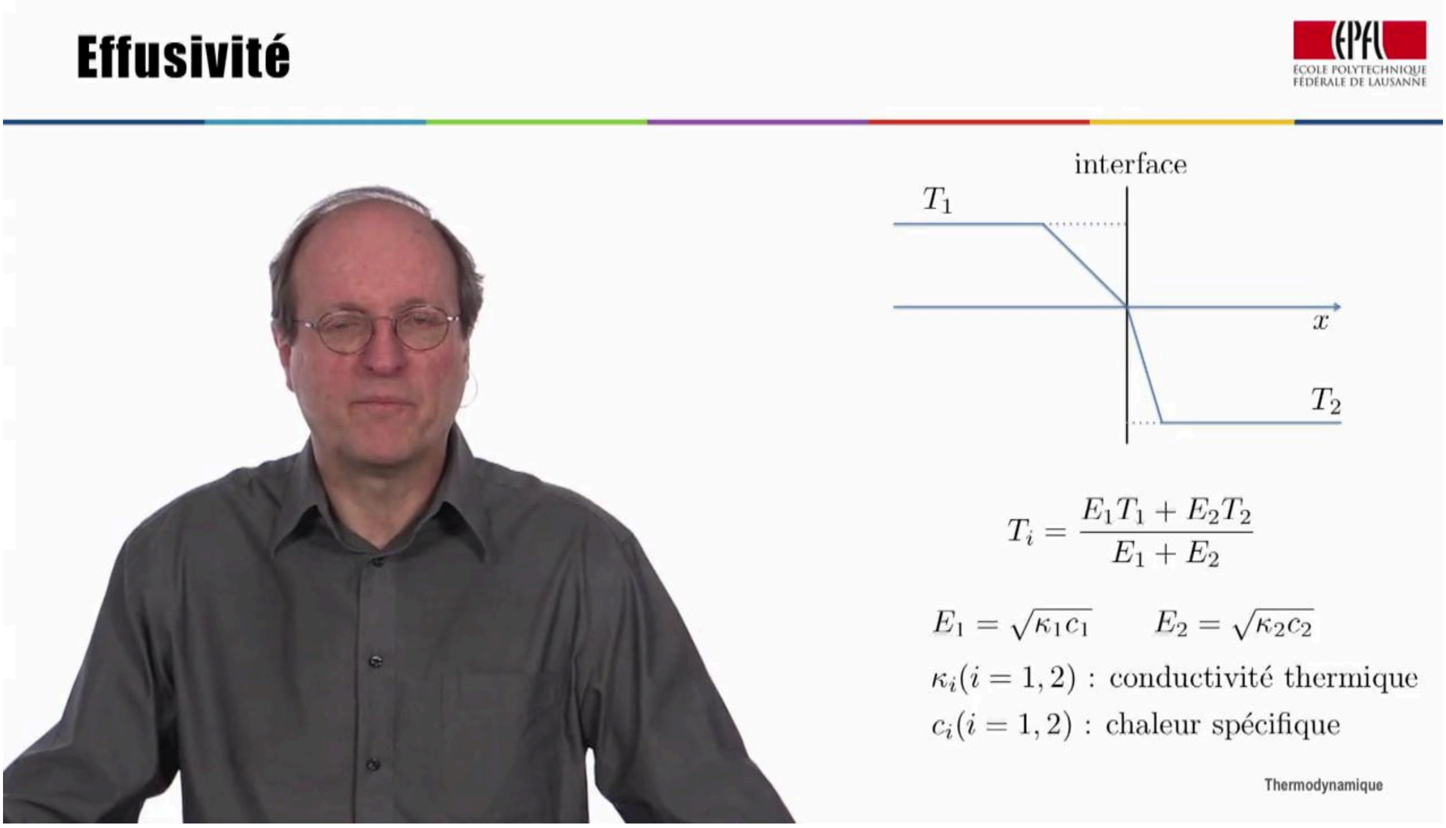


How do you do it? Describe the phenomenon. I propose the following description. I represent here the interface between the two materials. Initially, one material has a temperature T1, the other has a temperature T2, so T1. It is for example the wood and T2 is the must very quickly. When these two materials are in contact with each other, they will not stay at different temperatures due to the effect of the of thermal conduction, even on a very thin layer around the interface. The interface will take a temperature. This is what I have represented in the drawing. There will of course be a gradient of temperature corresponding to a heat flow between the two materials. Now both materials are assumed to have different thermal conductivities. We have a continuity of the heat current at the interface, so we have slopes corresponding to different thermal conductivity. If we do the analysis from the heat equation, we will see that the parameter that intervenes is the flows. It is noted here them an index one or two which depends on the conductivity of the material and the specific heat of the material and a volumetric specific heat. The formula we get when we do short time analysis at a very small distance from the interface.

Notes

Summary

10m 27s

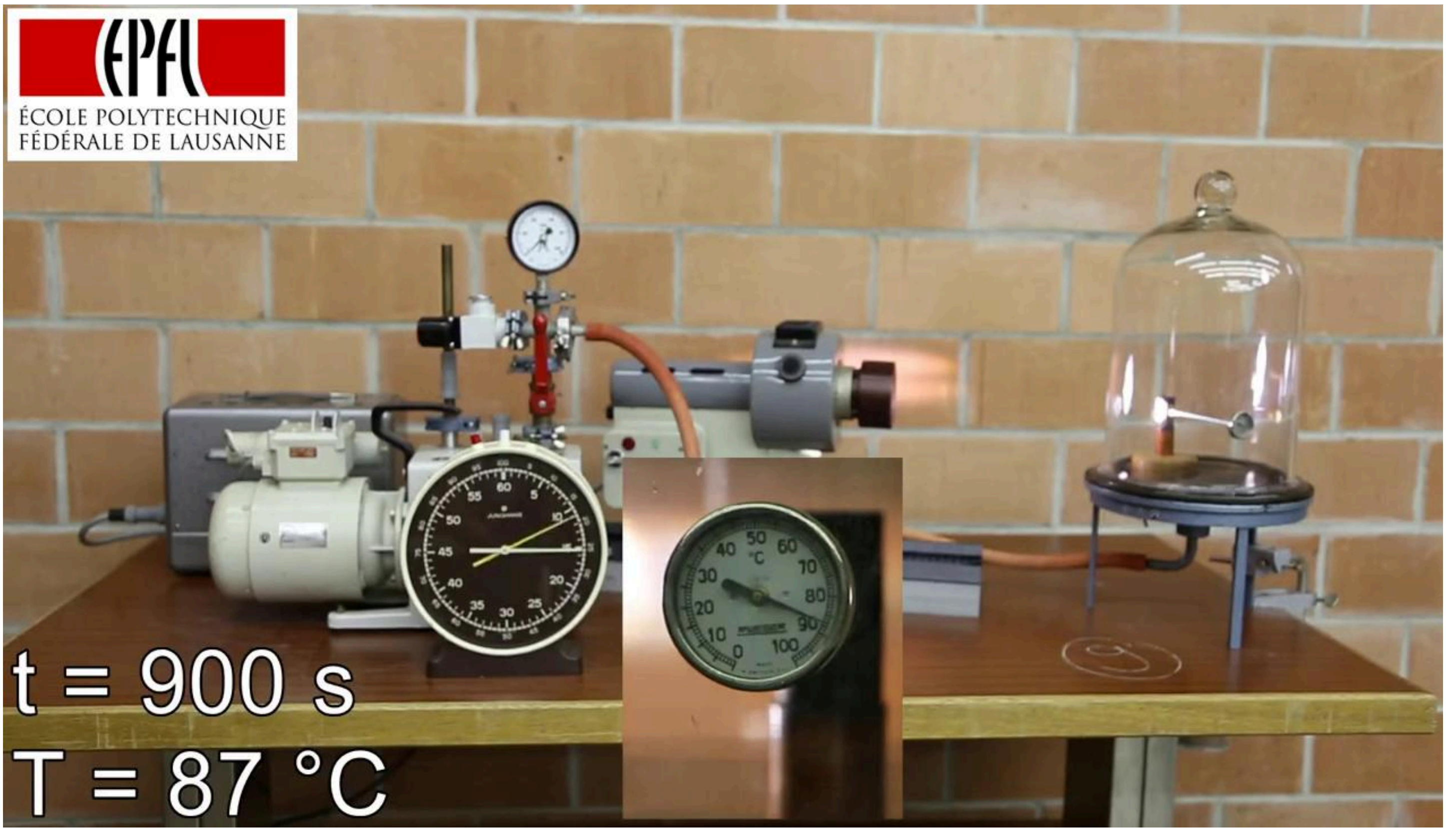


That's the formula you see right now. Therefore, if a material has an influence, it is very small because it has a small specific heat and a small thermal conductivity. It can be very hot, but given to an interface temperature that is not very high. The other way around, if the material has a very good thermal conductivity and a high specific heat, then the temperature of the interface can be be very high, very close to the temperature of the material itself.

Notes

Summary

12m 07s

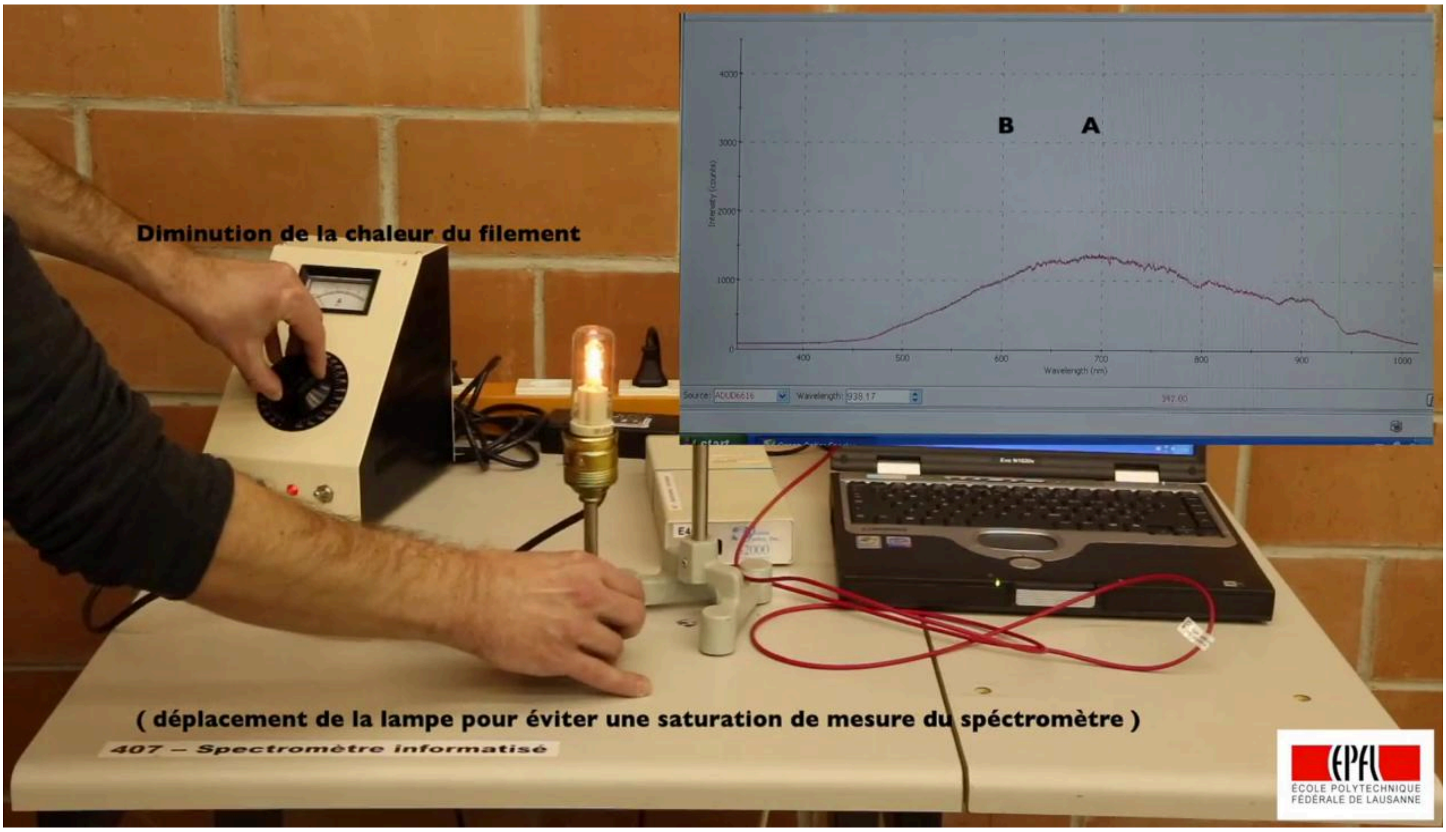


I end with two experiences in relation to the heat transfer by radiation. In this first experience. We will put a thermometer under a vacuum bell. And we're going to light up that thermometer. As there is a vacuum around the thermometer and the support, I ask you to believe it, is a material that conducts heat very badly. We are forced to realize that it is by the radiation that we have a heating of the thermometer. The preparer switches on the pump. And. We start with a room temperature thermometer. Little by little, we observe that the temperature of the thermometer increases.

Notes

Summary

12m 43s

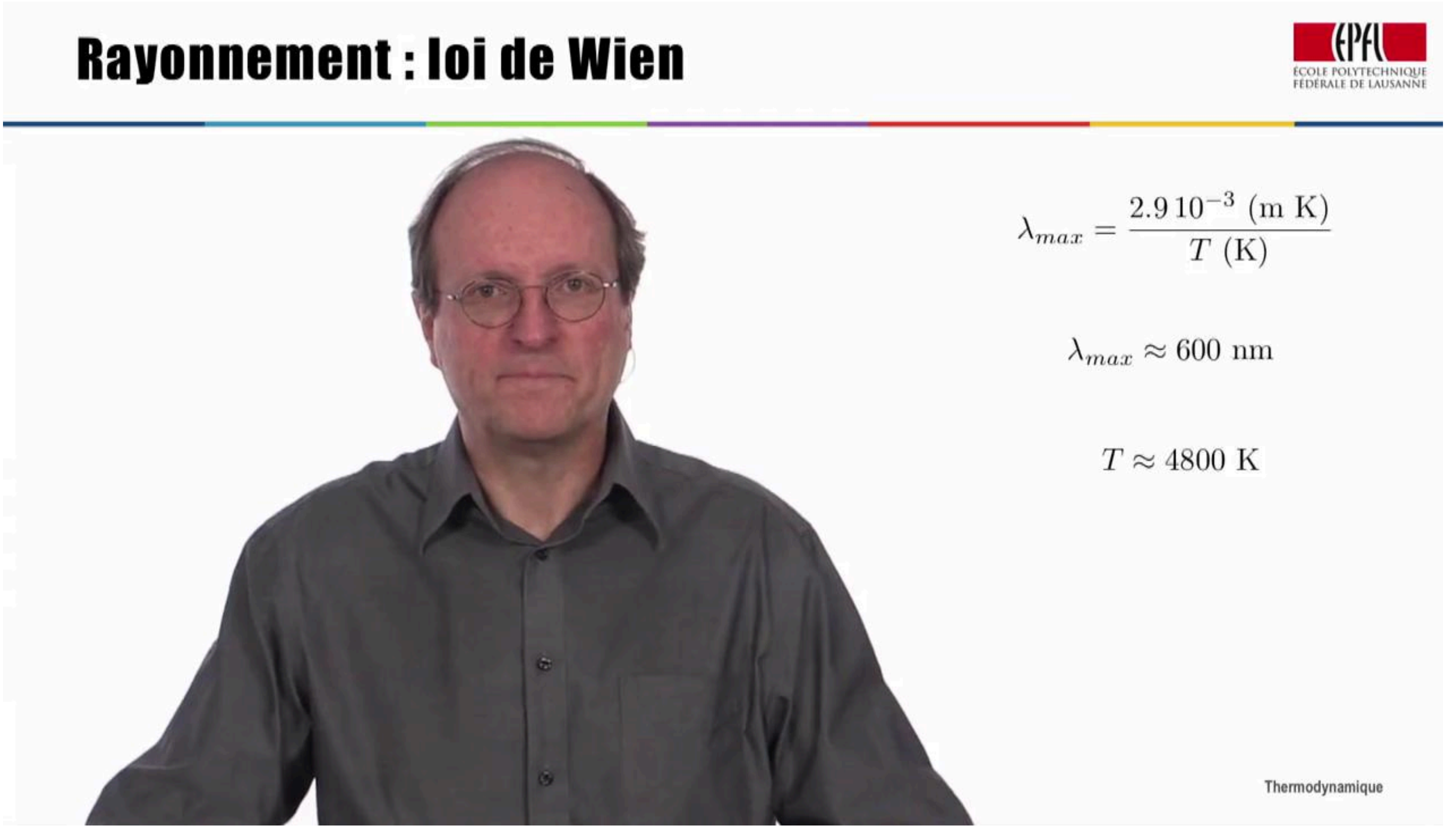


Marwan Brush mentions Vine's law in his lesson. I would like to show you a small experiment here that illustrates Vine's law. You have a halogen lamp whose power supply can be varied. An optical fiber. Points to the halogen lamp and is connected to a spectrometer linked to a computer. We can thus measure the spectrum of this lamp and we will do it for different values of the power supply, of the power with which this halogen lamp is supplied. The spectrum can already be seen on the computer screen. And the preparer noted a letter A. The maximum spectrum for a low power supply. Then, the preparer increases the power, which makes the light intensity greater. It moves the lamp away to keep the detected intensity about the same. And you should observe that the maximum of the spectrum moves. To point B. This is the measurement has no artifact. We can go back the other way. Decrease the power supply of the lamp and observe that we return to a spectrum maximum at the point at.

Notes

Summary

13m 50s

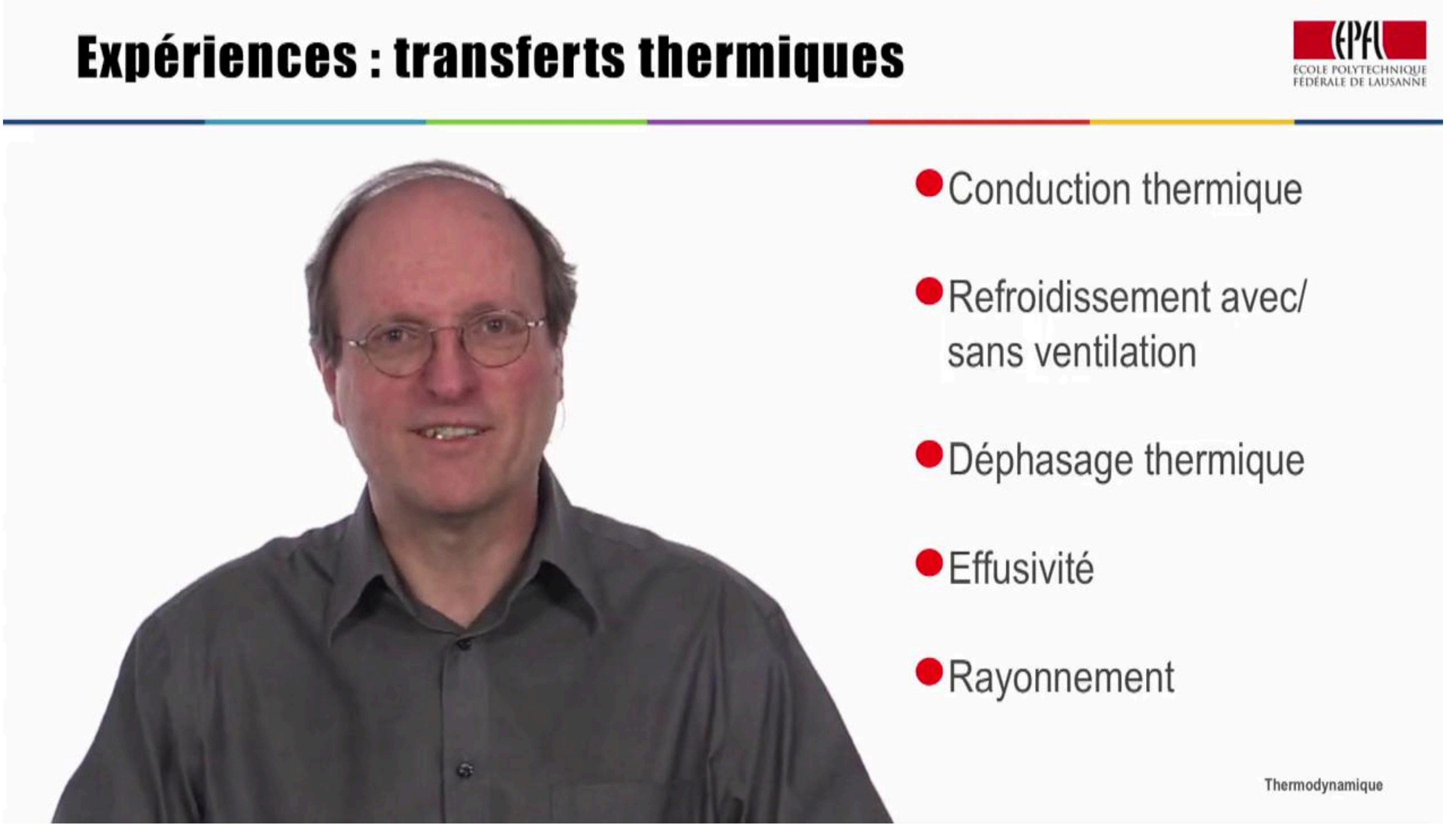


We can. Analyze what the position means of this maximum with Vine's law that I recall here. In particular, a maximum was observed at 600 nanometers and with Vine's law, this means that the temperature is 4800 degrees. This should be interpreted as follows. If we had an oven. Equipped with a small hole so that one can observe the radiation in the oven and this oven was heated to 4800 degrees. The same spectrum would be observed that the spectrum of this lamp, as far as we can admit that the spectrum of this lamp has the spectrum of the so-called black body radiation.

Notes

Summary

15m 33s



I summarize. We have seen some experiments concerning the thermal transfer. We have seen a steady state heat transfer. This led us to ask the question heat loss at the surface of a metal with or without forced air. We then illustrated the concept of thermal phase shift by measuring temperature versus time on a bar with heated at one end. Then I showed an experiment of contact between two objects that can be described with the notion of diffusivity. And finally, we observed. A thermal transfer by radiation. Thank you for your attention.

Notes

Summary

16m 23s