Thermodynamique

Rayonnement thermique: Application

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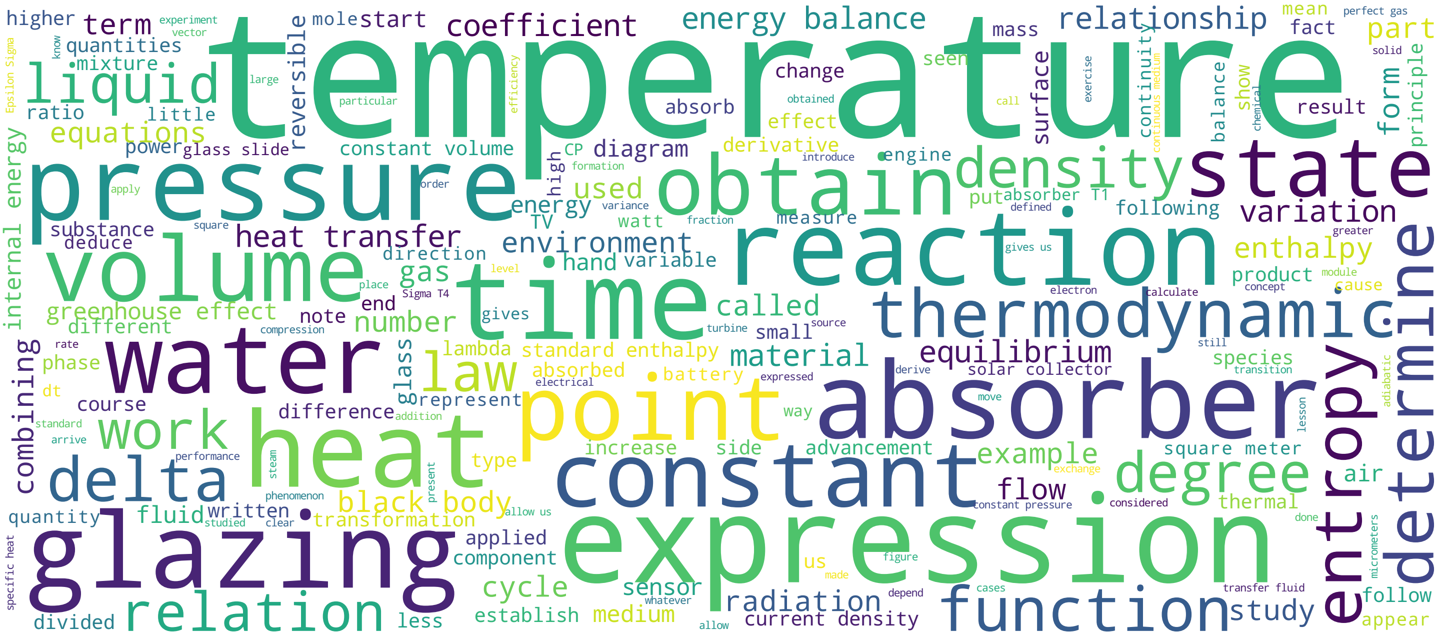
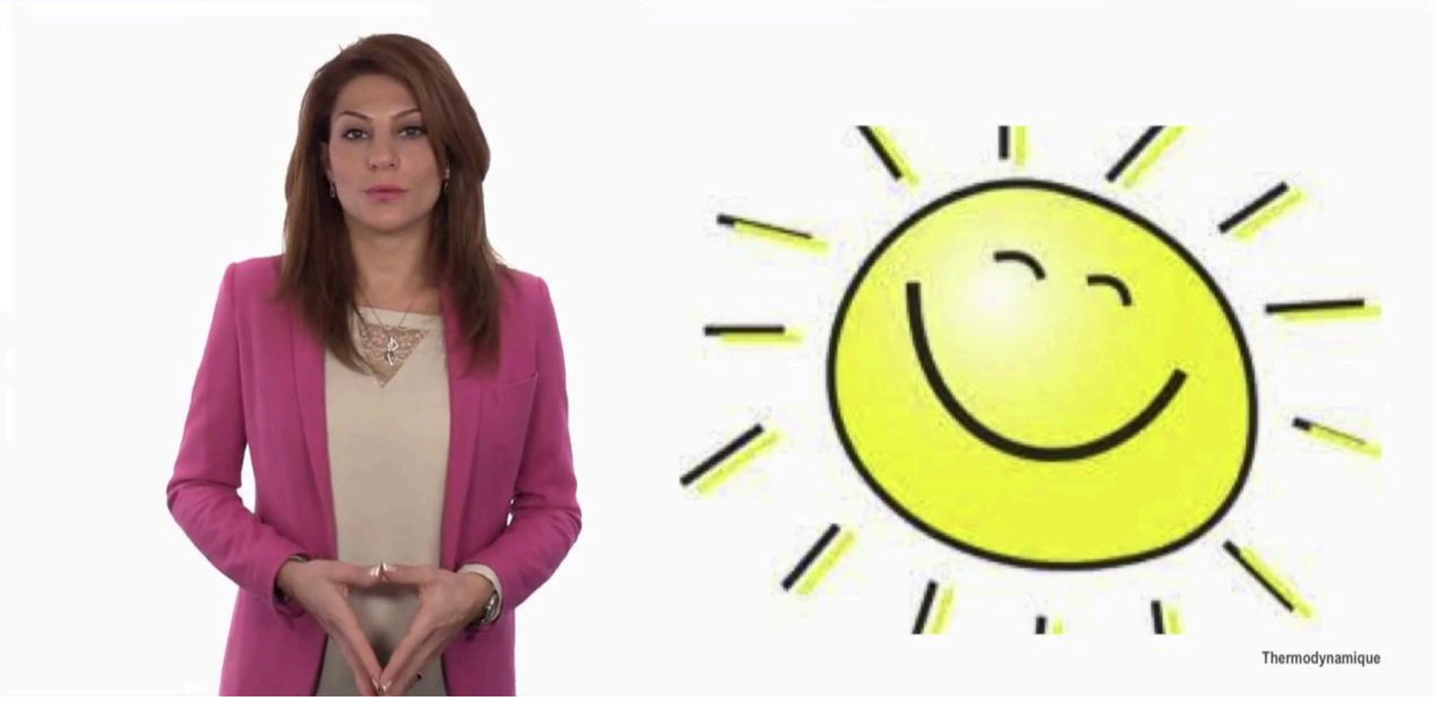
Max Planck, 1858 -1947



Video

Bienvenue

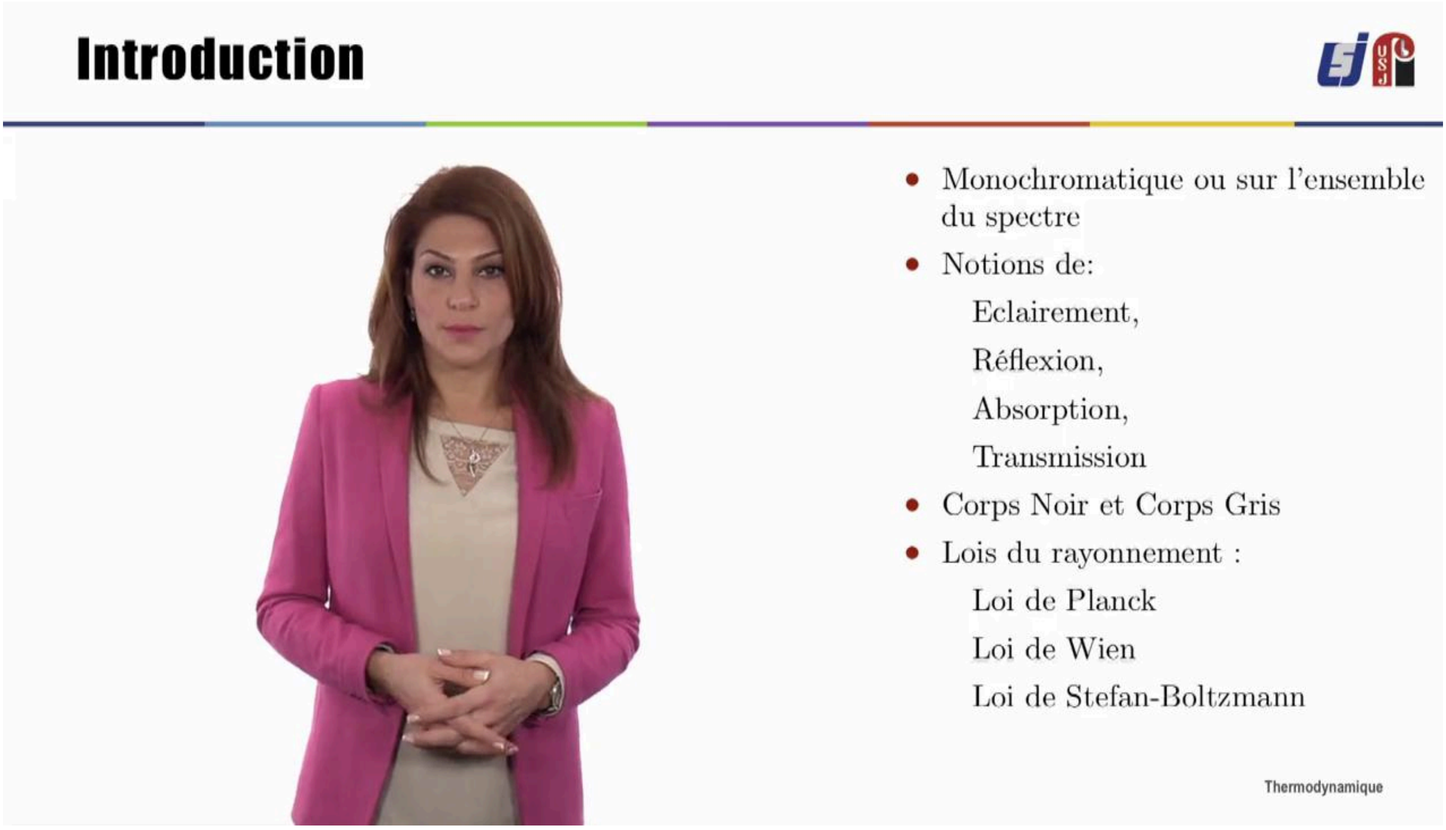


Welcome to the online heat transfer courses. During this session, we will deal with heat transfer by radiation. During this session we will study the functioning of a solar collector for heating and hot water production.

Notes

Summary

0m 04s



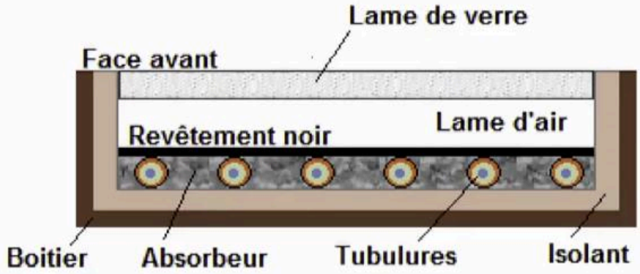
In this type of system, the heat transfer is mainly done by radiation. The study of this mode of heat transfer will allow us to discover that thermal energy is only a small part of the much larger whole of the electromagnetic radiation. In this exercise, we will characterize the sources of radiation on the whole spectrum. We will have to introduce the concepts of illumination, reflection, absorption and transmission, which will lead us to consider a thermally ideal body called black body. The grey body is used for the most common applications. We will also be required to state and enforce the laws of radiation which are Planck's law, the law of life and Boltzmann's law.

Notes

Summary

0m 18s

Application : Capteur Solaire Plan



Coupe d'un capteur solaire plan

Thermodynamique

There are different technologies of solar thermal collectors. We mention the vacuum tube collectors, unglazed flat plate collectors and glazed flat plate collectors. In this exercise, we will study the operation of a glazed flat plate solar collector. This type of sensor is composed of mainly of a black coating called absorber. This absorber is installed on a circuit of pipes in which a heat transfer fluid circulates. The role of this fluid is to evacuate heat to the device and use of the installation on the front side. We put a glass slide whose role is to reduce the energy or radiation lost towards the outside by the greenhouse effect that it causes. The lathe is installed in a box G heat exchanger to reduce losses from the back and sides of the system.

Notes

Summary

1m 07s

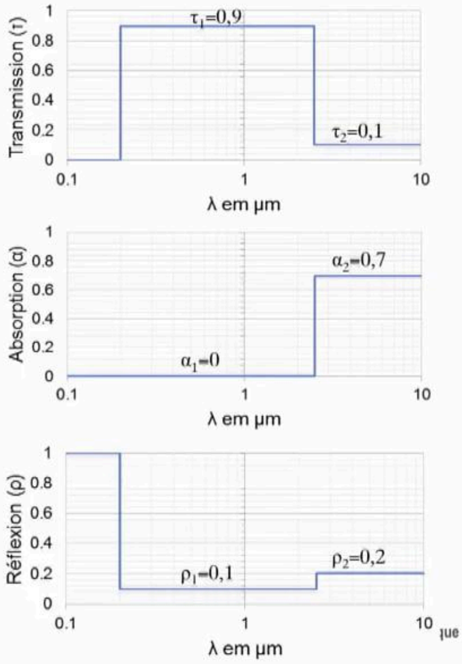
Hypothèses et données

Hypothèses

- Les échanges par conduction sont négligées
- Les pertes thermiques générées au fond du boitier sont négligées

Données

- L'éclairement solaire $E = 1000\ W/m^2$
- Le fluide caloporteur est de l'eau, ayant un capacité calorifique $C = 4{,}18\ kJ/kg.K$
- Les propriétés radiatives moyennes du vitrage présentées sur les graphes ci-contre:
- Emissivité du vitrage $\varepsilon = 0{,}9$
- Constante de Stefan-Boltzmann : $\sigma = 5{,}6704\ .10^{-8}\ W.m^{-2}.K^{-4}$



We propose to evaluate the temperatures that will reach the absorber and the glazing when the circulation of the heat transfer fluid is interrupted. To solve the problem, the following assumptions are made. First, we will neglect all the exchanges by conduction to consider only the radiative exchanges. Then, it is assumed that there is no heat loss through the bottom and side of the housing. Physical data needed to the resolution of the problem are the following. Solar illumination radiation on the glazing is 1000 watts per square meter. This stop party lighting is considered for standardized testing of solar collectors. The heat transfer fluid circulating in the pipes is water. Its average mass calorific capacity is 4.18 kilo joules per kilogram per case. We know the average radiative properties of the glazing in two spectral bands for AM between zero and 2.5 micrometers and that of thermal radiation called of low temperature, i.e. when the MDA is higher than 2.5 micrometers. These data are shown in the figure below. The properties of the glass transmission curve show that this material is practically transparent to solar radiation with a factor of one equal to 0.9, but transmits little radiation beyond that of 2.5 micrometers or the transmission factor to both is equal to 0.1.

Notes

Summary

2m 06s

Hypothèses et données

Hypothèses

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- Les pertes thermiques générées au fond du boitier sont négligées

Données

- L'éclairement solaire E = 1000 W/m^2
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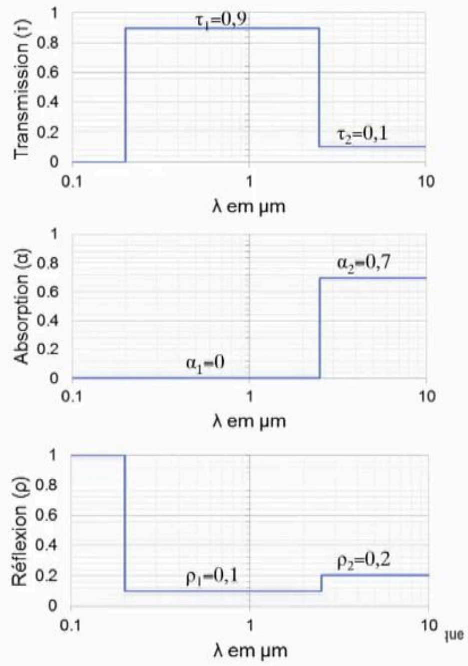
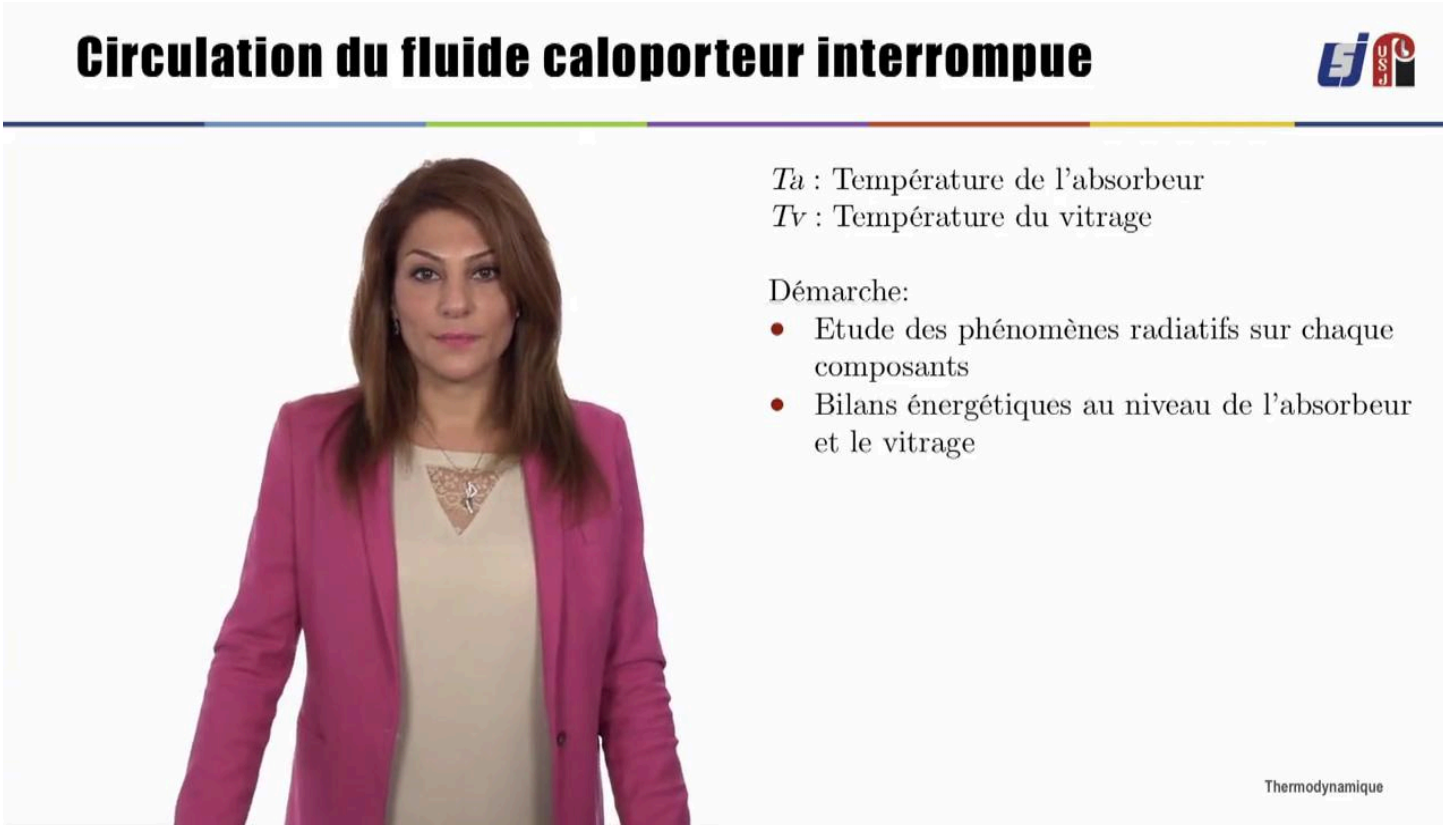


In addition, it absorbs all ambient temperature radiation, whose maximum is around ten micrometers of wavelength, with an alpha three attractiveness factor equal to one. The speed emission of Epsilon glazing is equal to 0.9.

Notes

Summary

3m 44s

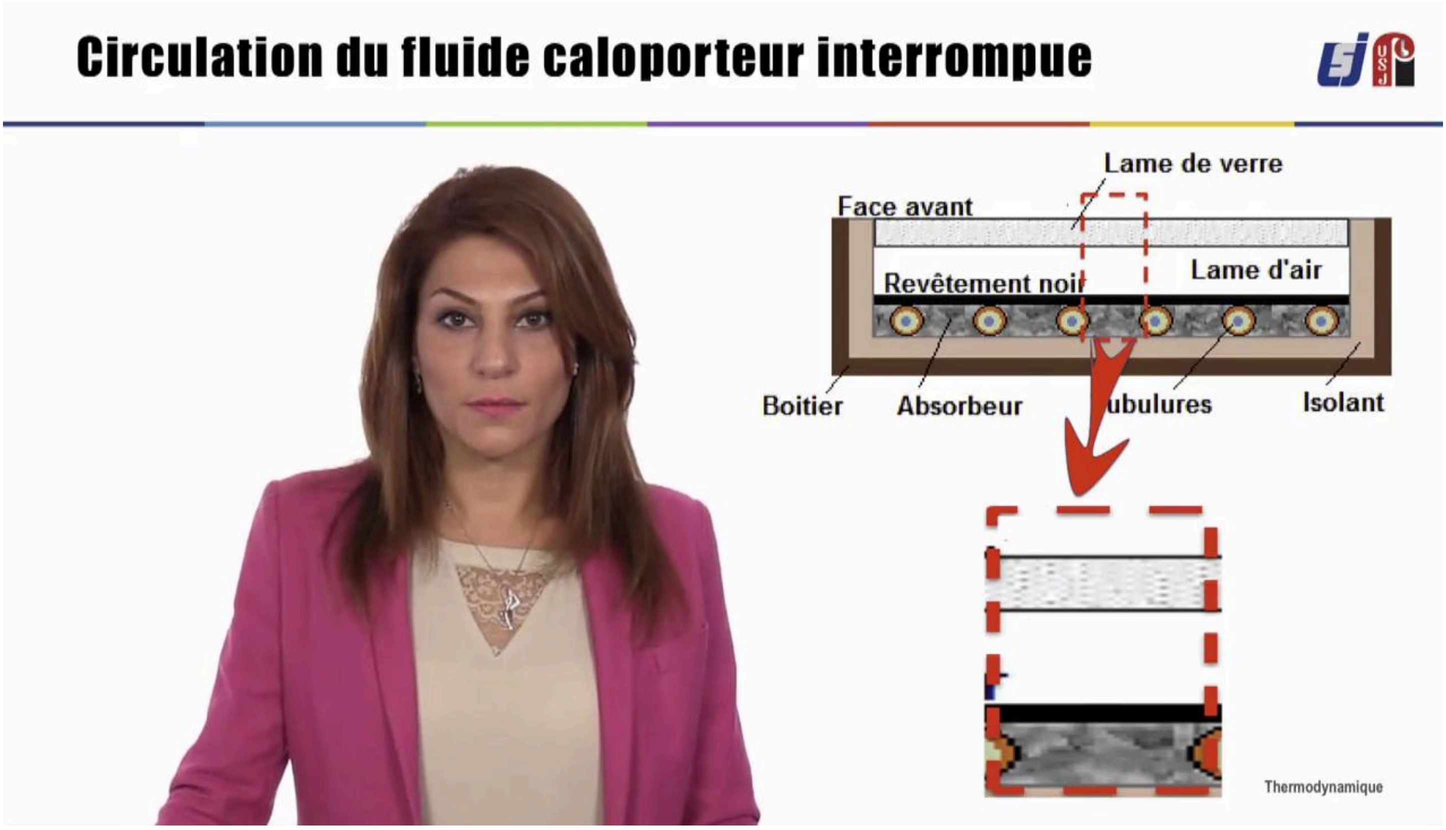


We designate by and at the temperature of the absorber and TV the temperature of the glazing. The procedure to follow is as follows. First, we will study the radiative phenomena on the absorber on the one hand and the glazing on the other hand. Then, we will establish the energy balances on each of these components. We will then obtain a system of equations which will allow us to determine on the one hand A and on the other hand TV.

Notes

Summary

4m 02s



For the study, we will consider a collector surface equal to one square meter on which we will establish the energy balance.

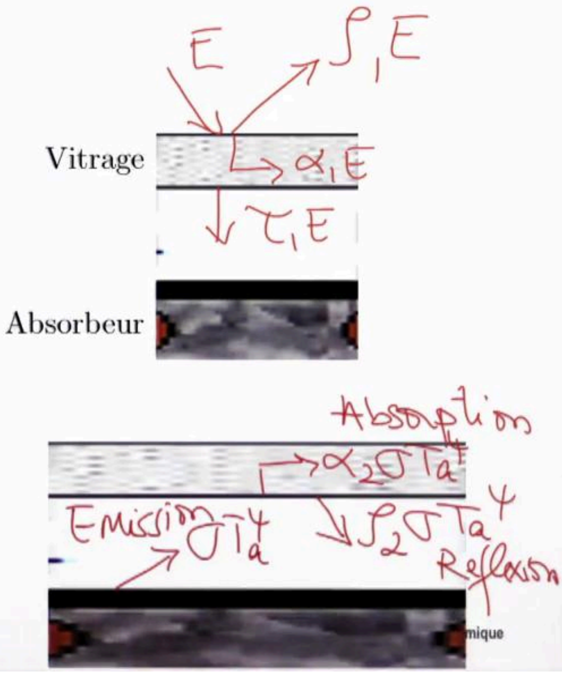
Notes

Summary

4m 30s

Phénomènes radiatifs

- E éclairement solaire incident :
  - (ρ_1 E) réfléchie,
  - (α_1 E) absorbée,
  - (τ_1 E) transmise par le verre et absorbée par la surface noir de l'absorbeur.
- L'absorbeur réagit comme un corps noir : (Loi de Stefan Boltzmann)
  - (σT_a^4) émise vers le vitrage
  - ($\alpha_2 \sigma T_a^4$) absorbée par le vitrage
  - ($\rho_2 \sigma T_a^4$) réfléchie vers l'absorbeur



Incident solar radiation strikes the glazing. A fraction of this radiation is reflected back to the atmosphere. It is equal to one. Another fraction alpha one. Eux is absorbed by the worm, while the remaining fraction of the flow incident passes through the glass and is equal to a little. All the radiation transmitted by the glass is absorbed by the black surface of the absorber. The absorber reacting as a black body emits a radiation whose existence is provided by Boltzmann's Stephen's law. So Sigma T4. The radiation from the absorber hits the glass. A horo two sigma fraction T4 is reflected from the glass and therefore returns to the absorber. Another alpha fraction of Sigma T4 is absorbed by the glazing.

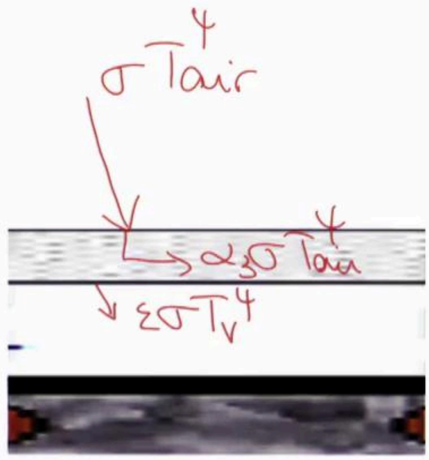
Notes

Summary

4m 37s

Phénomènes radiatifs

- A l'équilibre thermique, le vitrage à la température T_v :
  - $(\varepsilon\sigma T_v^4)$ émise par le vitrage
  - $(\alpha_3 \sigma T_{air}^4)$ absorbée par le vitrage
- Rayonnement ambiant : σT_{air}^4



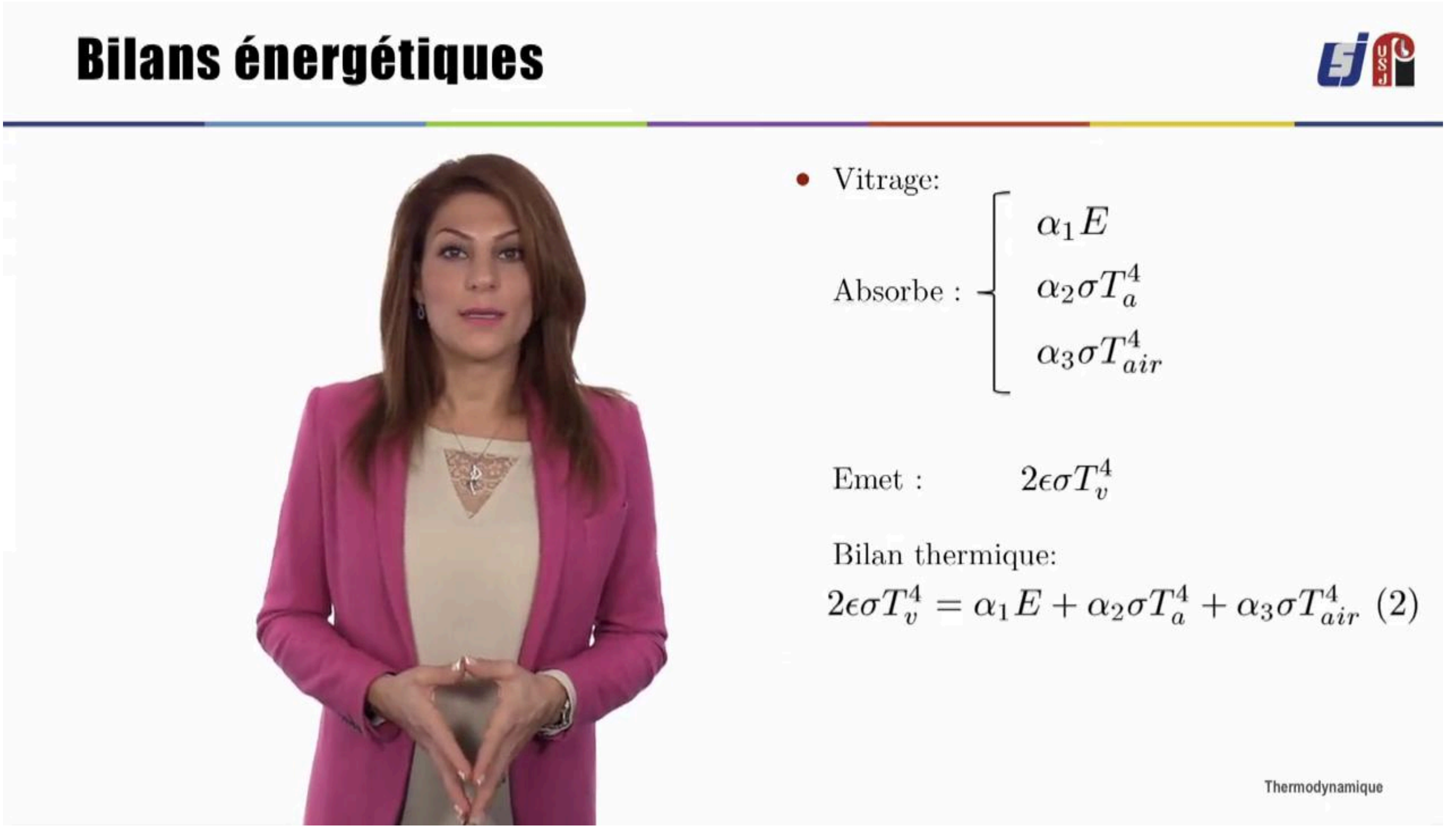
Thermodynamique

The glazing in thermal balance at TV temperature emits Epsilon Sigma TV radiation which will be absorbed by the black body opposite. At the same time, it absorbs a three sigma alpha fraction T4 of the ambient radiation emanating from the environment at temperature tr do. We note Sigma. TR. Exhibitors four. As being the ambient radiation and alpha three. Sigma T4. The fraction of ambient radiation absorbed by the glazing.

Notes

Summary

6m 13s

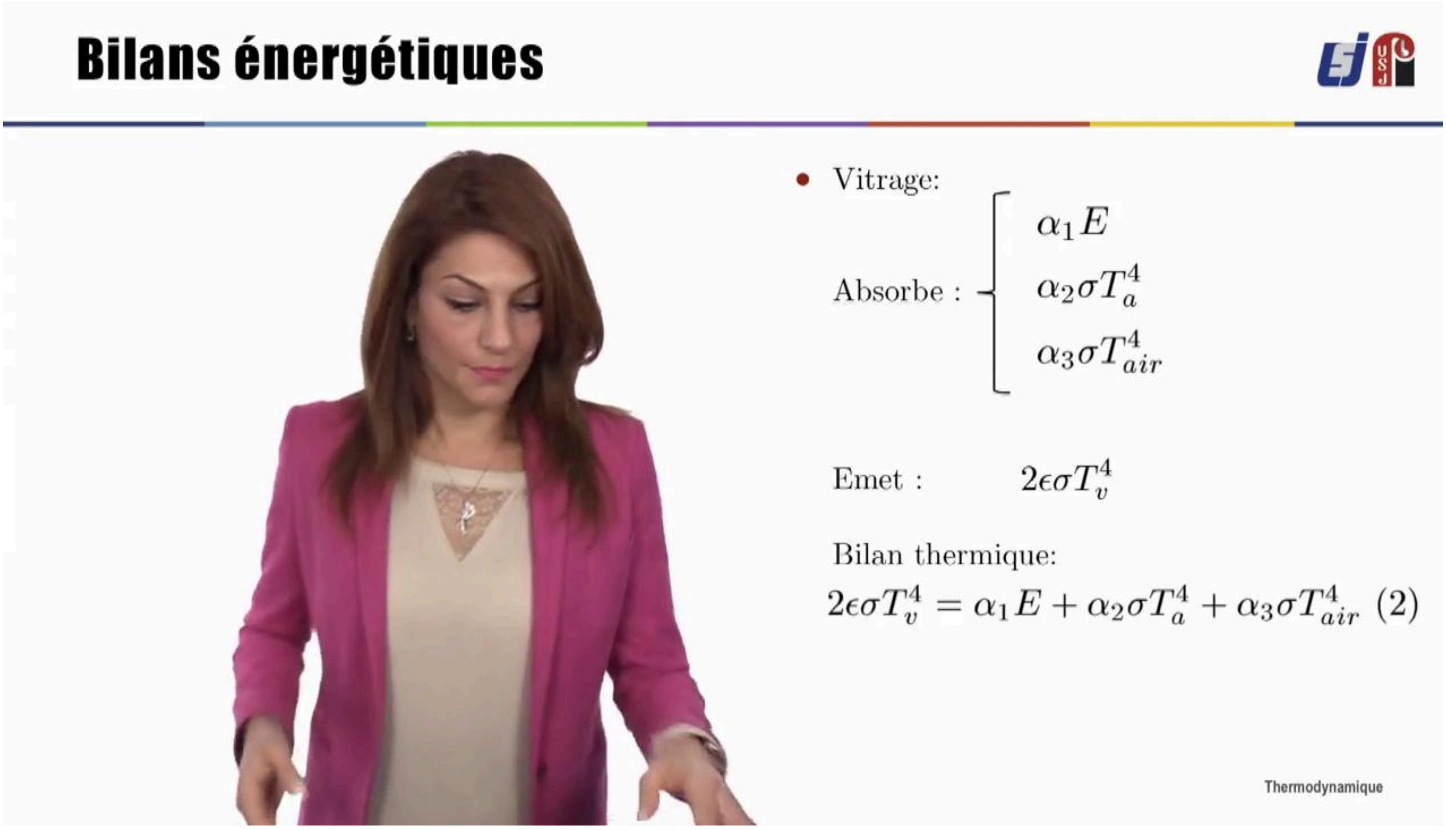


We have determined the quantities of heat exchanged in the glazing and the absorber. We will now establish the energy balances on each of these components. At the level of the absorber, that there absorbs a fraction of the solar radiation noted to them. It also absorbs part of the black body radiation, which is reflected by the glazing, noted two sigma CH4. It also absorbs a quantity of of a fraction of the radiation emitted by the glazing, noted Epsilon Sigma TV4. This absorber emits radiation equal to Sigma T at four. A steady state and thermal equilibrium of this absorber. The sum of the flows entering the absorber is equal to the sum of of the radiations that are emitted from this absorber. By writing the energy balance, we obtain the equation that we see on the screen noted T1. The same goes for the glazing. If we want to establish the energy balance, we will start by determining the quantities of heat absorbed by this one. Then the glazing absorbs alpha one radiation. Uh, it is a fraction of the incident radiation from the sun. It will also absorb a radiation alpha of Sigma 3 to 4 emitted by the black body. And finally, it will absorb a fraction of the radiation from the environment, noted Alpha Three.

Notes

Summary

7m 03s



Sigma TR. Exhibitors four. Earth being the air temperature ambient, that one will emit by these two facets a radiation equal to two. Epsilon Sigma TV4 Epsilon being the glass outlet at thermal equilibrium, the sum of the incoming flows is equal to the sum of the outgoing flows, which leads us to the expression shown in the figure and noted two.

Notes

Summary

8m 45s

Résultats

$$\begin{cases} \sigma T_a^4 = \tau_1 E + \rho_2 \sigma T_a^4 + \epsilon \sigma T_v^4 \quad (1) \\ 2\epsilon\sigma T_v^4 = \alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4 \quad (2) \Rightarrow T_v^4 \end{cases}$$

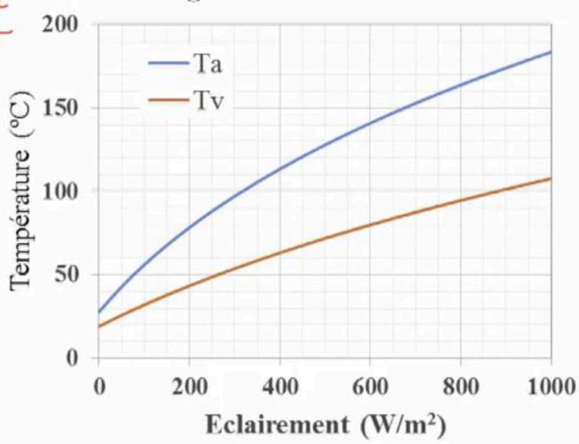
$$T_a = \sqrt[4]{\frac{(\alpha_1 + 2\tau_1)E + \alpha_3 \sigma T_{air}^4}{(2 - \alpha_2 - 2\rho_2)\sigma}}$$

$$T_v = \sqrt[4]{\frac{(\alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4)}{2\epsilon\sigma}}$$

$A.N.: \quad T_a = 457K = 184°C$

$\qquad\quad T_v = 380K = 107°C$

Effet de la variation de l'éclairement E sur la température de l'absorbeur et du vitrage



Thermodynamique

By combining the two balances. By combining the two energy balance thus obtained, we get this system of equations. If we isolate the expression TV4. And we write it from equation two. It can be replaced in the equation as follows one and determine the expression for the temperature of the absorber T1. As a replacement. The expression for t a. In the equation two numbers. We can then determine. Decreasing. The tv equation. We repeat. Stay. By combining the two energy balance. By combining the two energy balance, we obtain the system of equations composed by the equation one and two. Vicious extract. By combining the two energy balances, we can, from the balance equation energy established on the glazing, draw the VAT expression of four. If we replace the expression for TV4 in equation one, we can then determine the expression of T at the temperature of the absorber. Now, if we replace the expression of t a in equation two, we can then determine the expression that allows us to calculate TV the temperature of the glazing for the properties characterizing the glazing. As well as for a radiation equal to 1000 watts per square meter.

Notes

Summary

9m 23s

Résultats

$$\begin{cases} \sigma T_a^4 = \tau_1 E + \rho_2 \sigma T_a^4 + \epsilon \sigma T_v^4 \ (1) \\ 2\epsilon\sigma T_v^4 = \alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4 \ (2) \end{cases}$$

$$T_a = \sqrt[4]{\frac{(\alpha_1 + 2\tau_1)E + \alpha_3 \sigma T_{air}^4}{(2 - \alpha_2 - 2\rho_2)\sigma}}$$

$$T_v = \sqrt[4]{\frac{(\alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4)}{2\epsilon\sigma}}$$

$$A.N.: \quad T_a = 457K = 184°C$$

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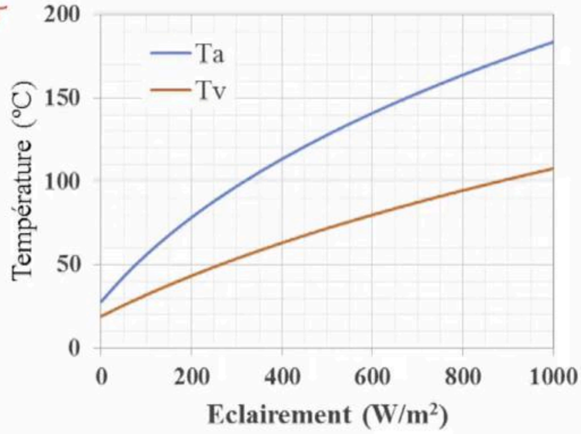
Effet de la variation de l'éclairement E sur la température de l'absorbeur et du vitrage



Thermodynamique

We can determine a TH value of the absorber equal to 184 degrees C and a TV glazing temperature of 107 degrees. It is. We can see the greenhouse effect caused by the glazing in this installation, since we can see that the temperature of the absorber is much greater than that of the glazing. The effect of the variation of the illumination on the temperature of the absorber and the glazing. We're coming. It is clear that whatever the illumination received by the sensor, the temperature of the absorber is always higher than the temperature of the glass. Even at low temperatures or in the absence of light, we still have a greenhouse effect that is caused by the glass slide placed on this sensor. All in. Well, I will repeat to be precise, but we repeat without any. By combining the two heat balances, we obtain this system of equations. From equation two, we can derive the expression for TV4 that can be replaced in equation one and determine the expression of the temperature of the absorber T1. By replacing the expression for t a. In equation two, we can derive the expression of TV the temperature of the glazing. The application of the numerical application leads to a temperature T1 to equal 184 degrees is raised equal to 107 degrees.

Notes

Summary

11m 31s

Résultats

$$\begin{cases} \sigma T_a^4 = \tau_1 E + \rho_2 \sigma T_a^4 + \epsilon \sigma T_v^4 \ (1) \\ 2\epsilon\sigma T_v^4 = \alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4 \ (2) \end{cases}$$

$$T_a = \sqrt[4]{\frac{(\alpha_1 + 2\tau_1)E + \alpha_3 \sigma T_{air}^4}{(2 - \alpha_2 - 2\rho_2)\sigma}}$$

$$T_v = \sqrt[4]{\frac{(\alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4)}{2\epsilon\sigma}}$$

$A.N.: \quad T_a = 457K = 184°C$

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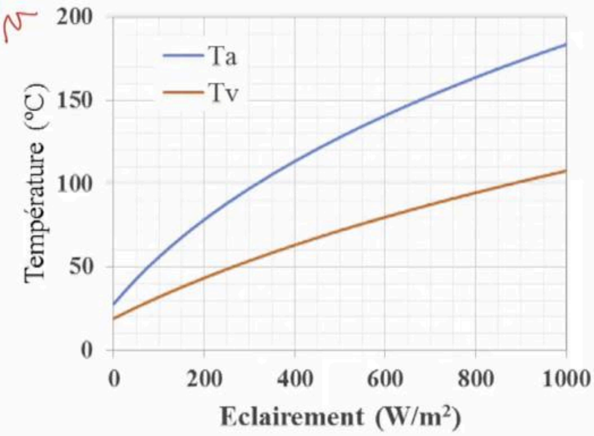
Effet de la variation de l'éclairement E sur la température de l'absorbeur et du vitrage



Thermodynamique

From these results, we can see the greenhouse effect caused by the glazing since its temperature remains lower than the temperature of the absorber. Then, the effect of the variation of the illumination was studied on the temperature of the absorber and the glazing. It is clear that whatever the illumination received by the sensor, the temperature of the absorber is always higher than the temperature of the glazing due to the greenhouse effect between the air space and the new standard. Moreover to repeat this myth elsewhere. By combining the two heat balances, we obtain the following system of equations. From expression two, we can deduce the temperature TV4 that we can replace in equation one. This will allow us to determine the expression of the temperature of the absorber T1. If we replace the expression of T to in equation two, we can then deduce the temperature TV glazing for a solar illumination of 1000 watts per square meter. And if we do the numerical application, we obtain a temperature of the absorber T1 equal to 184 degrees and TV the temperature of the glass equal to 107 degrees C. It is clear, since the temperature of the absorber is higher than that of the glass slide, the greenhouse effect that it causes.

Notes

Summary

13m 38s

Résultats

$$\begin{cases} \sigma T_a^4 = \tau_1 E + \rho_2 \sigma T_a^4 + \epsilon \sigma T_v^4 & (1) \\ 2\epsilon\sigma T_v^4 = \alpha_1 E + \alpha_2 \sigma T_a^4 + \alpha_3 \sigma T_{air}^4 & (2) \end{cases}$$

$$T_a = \sqrt[4]{\frac{(\alpha_1 + 2\tau_1)E + \alpha_3 \sigma T_{air}^4}{(2 - \alpha_2 - 2\rho_2)\sigma}}$$

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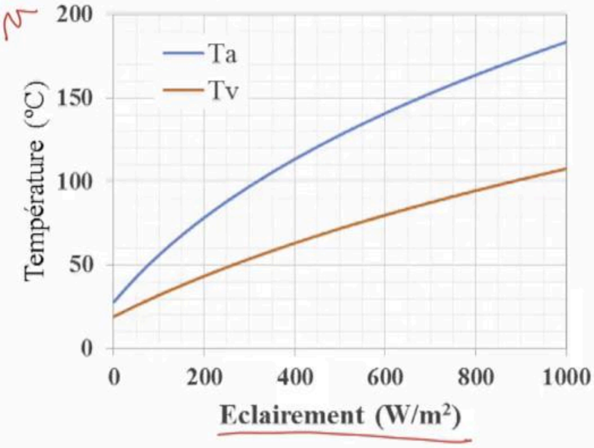
Effet de la variation de l'éclairement E sur la température de l'absorbeur et du vitrage



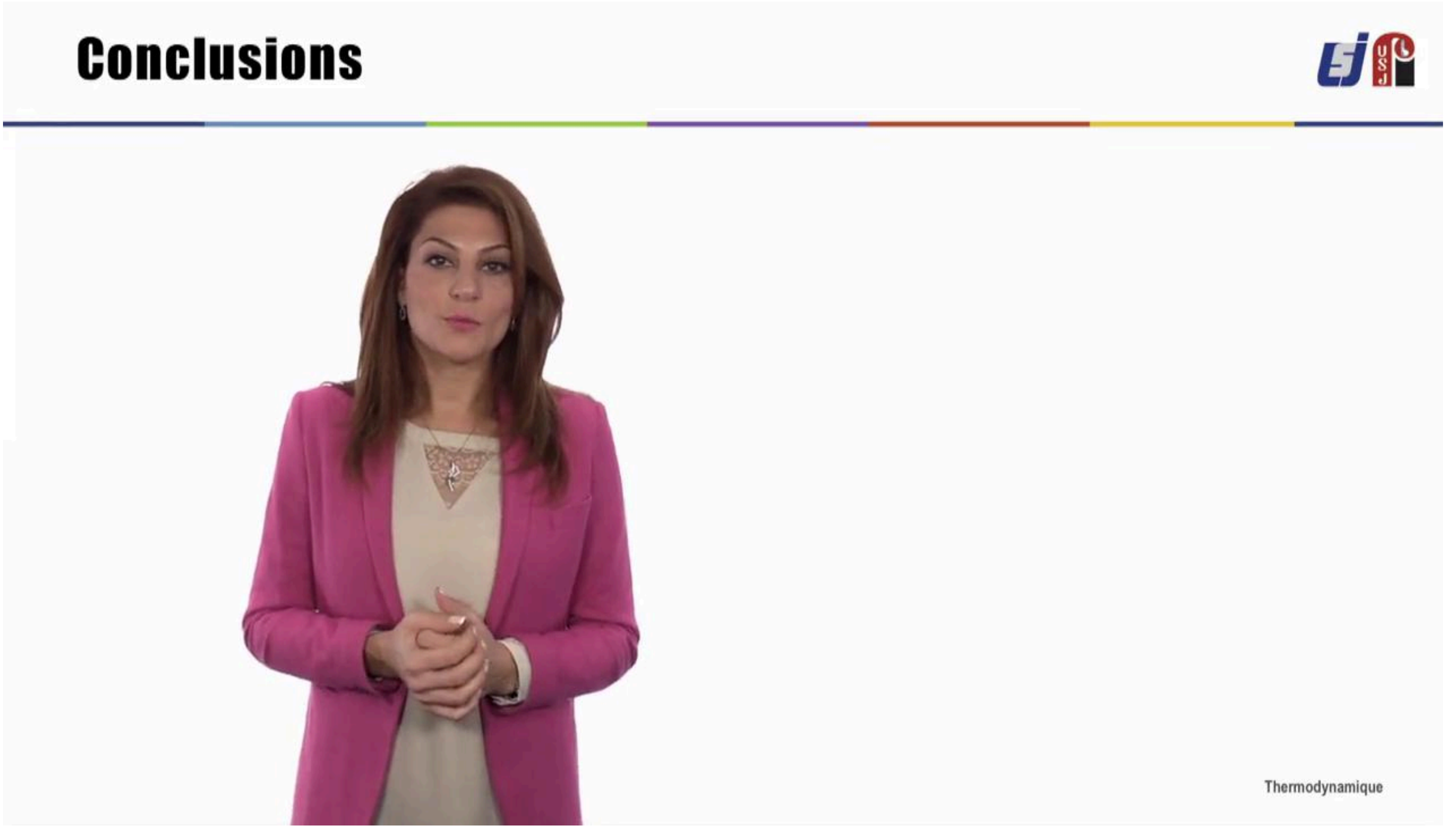
Thermodynamique

We also studied the effect of of the variation of the illumination on the temperature of the absorber and the glazing. We see that whatever the illumination received by the sensor, the temperature of the absorber remains higher than that of the glass. This is well related to the greenhouse effect that the glass blade causes on this system.

Notes

Summary

15m 14s



To conclude, during this exercise, we studied the radiative phenomena that take place in a solar collector. To solve the problem, the laws of radiation were used and applied. For this type of system, the following effect has been identified of greenhouse caused by the presence of the glass slide on the sensor. This is directly related to its of transmission which is weak for these wavelengths. Thank you for your attention.

Notes

Summary

15m 36s