MORGAN BINGGELI: Hi, everyone. My name is Morgan Binggeli. I'm a first year masters student at EPFL in material science and engineering, and I'm going to present to you this video about heat transfer in a material. This video start with a little introduction where I will give you some definitions which will be useful for heat transfer, and where I will talk a bit about heat equations. Then I'm going to present to you some concrete examples that you can meet in your everyday life.

In order to be able to see the next example in a proper way, we need to give some definitions. In this video we're going to say that heat is a form of energy. The temperature is a measurable manifestation of the stored heat Instabilities in which different temperatures are in contact-- a heat transfer occurs, transferring the heat from the warmer to the colder body.

Several heat transfer modes exists. Through heat conduction, which corresponds to the heat exchanged between two points of a motionless and opaque solid, liquid, or gas. Through convention, which corresponds to a heat exchange between the wall and a fluid, with a heat transfer done by the moving fluid. Finally, the radiation corresponds to a heat exchange between two walls, separated by a transparent environment.

As we're going to talk about heat transfer in this video, it's important to understand our heat equations in this kind of phenomena. First, the heat conduction law, which defines the diffusive thermal flux and function of the temperature gradient. And this relation is linearly governed by the thermal conduction coefficient created here.

Then, the heat equation, which has a time-dependent term, a speed-dependent term-- which correspond to the advection phenomena. A divergence term, here, of the diffusive thermal flux. And finally, a heat system which corresponds often to chemical reactions which are either esoteric or endothermic. Combining both equations, we get this final relation, which defines heat transfer and heat phenomena.

We're now going to apply these relations to some concrete examples. As a first example, a simple wall of a house with thickness, e, is chosen. Its thermal state is stable, and there is no [INAUDIBLE]. A thin wall is considered, with an unidirectional heat flux along x-axis. The temperatures on both sides of the wall are different. T1, here, is lower than T2, here. The temperature profile in the wall is researched.

To solve this problem, it is adept to use the Cartesian system. The temperature only changes along x-axis, and the nonhomogenous distribution of the temperature is weighted in the other directions. The conditions of this problem allow to simplify the heat equations presented before, which becomes such an equation.

As boundary conditions, we define the temperature in x equals 0 to T1, here. And in x equal e to T2, here. We then defined the system and try to solve it.

You can see here that the solution is dependent on e, the thickness. To be able to have a general solution, nondependent of this thickness, a variable change is done. The temperature is not in function of x, anymore-- as it is here-- but in function of the ratio x over e, which varies between 0 and 1.

The differential system of equations and the solution are as follows. Here, we define the system. And here, we try to solve it. The solutions look like this. Changing the disposition of the equation, it's possible to get this kind of solution. It's then possible to generalize this equation to every case, doing the following transformation, here.

So we can now see that our solution is only dependent on an extra e variable. Thus, it's possible to plot the temperature profile for this case. It looks like this.

So we have a linear behavior between T1, here, and T2, here, along the x-axis. It may be easier to see the temperature distribution in the wall. Here we can clearly see that, if it's our wall, we have a linear gradient of the temperature, with the minimum at T1, and, here, our maximum at T2. That's all for this first example.

As a second example, a concrete wall with a thickness, e, is chosen. This concrete wall is hardening due to an exothermic chemical reaction, like a direction, for the concrete. The temperature is the same at both sides of the wall, and is equal to Tw. This case is shown as a stable and motionless case.

To solve this problem, it is adept to use the Cartesian system. The temperature only changes along the x-axis, and an homogeneous distribution of the temperature is weighted in the other directions. The conditions of this problem allow to simplify the heat equation presented before, which becomes this kind of equation.

At the boundary conditions, we have the temperature defined in x equals 0 and x equal Te, as Tw. Again, we define the differential equation system and it's boundary conditions, and try to solve it. To get the general solution, usable for a large amount of cases, it's much likely to be easier to [INAUDIBLE] results.

Thus, a variable change is done. The temperature is not in function of x anymore, as before, but in function of the ratio x over e-- which varies between 0 and 1, as it was explained before. The differential system of equations and the solution are as following. So the differential system of equations is this one, and its solution looks like this.

Furthermore, all temps that are independent of x over e are placed to the left side of the equals sign. Thus, the temperature profile looks like this. We can clearly see a symmetrical behavior in this solution, with a maximum in the center of the piece, where the temperature is higher due to the exothermic phenomena. The minimum are at the faces, where the temperature is equal to Tw.

We can also see the temperature distribution in the wall as following. We can clearly see this maximum in the center of the piece, and the minima at the side of the wall.

As a last example, a thin steel bar is considered during a continuous thermal treatment process. The bar is extracted from an oven, heated at a temperature of T0, and then quenched after L, distance, in a water bath, which is at a TL temperature. The temperature profile of the bar, between the exit of the oven and the entrance of the water bath is researched when a steady state is established.

To solve this problem, it is adept to use the Cartesian system. As the bar is still, a uniform temperature is assumed in its translucent section. Which means, the temperature will only depend on the exposition.

The conditions of this problem allow to simplify the heat equation presented before, which becomes this equation. As boundary conditions, we have that the temperature in x equals 0, here, is equal to T0. And the temperature in x equal L is equal to TL.

The differential equation system is the following, and its solution is as follows. This looks quite complicated, but we can simplify a bit knowing the factor rho times Cp over K, is one of alpha-- where alpha is the thermal diffusivity coefficient of the material.

We still have this solution. This solution also looks complicated. However, it appears simpler rewriting it in the following way. As for the previous example, a general solution is researched. In this case, this solution looks like this. We can only add that.

We still have this solution, here. And knowing the ratio vL over alpha corresponds to the adimensional Péclet number-- which defines the ratio between advection and diffusion phenomena for our process-- it's possible to simplify a bit. Here, the Péclet number is put at the denometer, and here, at the numerator. Finally, in the same way as the previous cases, a variable change is done from replacing x over L with the variable x to L.

It's possible to try to understand how the Péclet number works, varying the temperature profile in function of it. Here, we have the temperature profile with a low Péclet number. We see that it has a mostly linear behavior as we have for the first example. However, when we increase the Péclet number, we see that it has increased the curvature of our curve.

And when we arrive at a big Péclet number, we almost have a vertical line-- here. That's due to the speed of the bar. It's possible to show this result with the graphical solution of the temperature profile for a different Péclet number. We define a list of Péclet numbers, apply the solution on it. The graphical solution looks like this.

We can see that the solution for the low Péclet numbers are quite linear, and that it has a bigger more and more curve as the Péclet number increases-- the number you end with, here. Finally, it's also possible to present a solution in a wall allowing a variable Péclet number. Here, we can clearly see that the gradient is linear when the Péclet number is low. But if we increase it, we see that the differential of the temperature is almost on the side of the bar. So that's all for this video about heat transfer in the material. Here are my references. Thank you for watching.