

# Basics of Mechanical Engineering-3

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## Lecture 32: Virtual Lab Demonstration Thermodynamics 1

Welcome back to the course Basics of Mechanical Engineering 3. We have covered all the parts of thermodynamics in this course. We will start fluid mechanics next week. This is the last lecture in the thermodynamics part, where I will introduce you to the V-Lab (virtual lab) in thermodynamics. I will not cover all the experiments.

I will only discuss the heat transfer virtual laboratory, as we did in previous versions of the course, like Basics of Mechanical Engineering 1 and Basics of Mechanical Engineering 2. We talked about manufacturing processes, stress-strain diagrams, and virtual laboratories developed by Indian scientists or academicians here. Here, I will talk about the Virtual Laboratory on Heat Transfer. First, let us open the Google browser. I will type 'VLAB' and add 'heat transfer'.

The screenshot shows a web browser window displaying the 'Heat & Thermodynamics Virtual Lab' page. The page has a dark blue header and a light blue main content area. The title is 'Heat & Thermodynamics Virtual Lab'. Below the title, there is a brief description: 'Thermodynamics is the study of the conversion of energy into work and heat and its relation to macroscopic variables such as temperature, volume and pressure.' The page lists several experiments, each with a yellow folder icon and a brief description:

- Heat Transfer by Radiation**: Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero emits thermal radiation.
- Heat transfer by Conduction**: Heat conduction is a mode of transfer of energy within and between bodies of matter, due to a temperature gradient. Conduction takes place in all forms of ponderable matter, viz. solids, liquids, gases and plasmas.
- Heat Transfer by Natural Convection**: Convection is one of the major modes of heat transfer. Natural or free convection is caused because of density difference in solids or liquids or gases due to temperature differences under the influence of gravity.
- The Study of Phase Change**: Heat transfer with phase change is the phased transition of heat in the medium such as; water-to-ice and steam, steam-to-water, or ice-to-water and involves significant energy. This occurs through, boiling, condensation, freezing and melting, and sublimation.
- Black Body Radiation: Determination of Stefan's Constant**: Stefan-Boltzmann constant is a physical constant denoted by the Greek letter  $\sigma$ . This is the constant of proportionality in the Stefan-Boltzmann law. "The total energy radiated per unit surface area of a black body in unit time is proportional to the fourth power of its absolute temperature."
- Newton's Law of Cooling**: Newton's Law of Cooling states that the hotter an object is, the faster it cools. More precisely, the rate of cooling is proportional to the temperature difference between an object and its surroundings.
- Lee's Disc Apparatus**: Aim of this experiment is to determine the coefficient of thermal conductivity of a bad conductor using Lee's disc apparatus. Lee's disc apparatus consist of metallic disc (say D) and resting on it is a 5 cm deep hollow cylinder (Steam chamber).
- Thermo Couple-Seebeck Effect**: An interesting phenomenon applied in the field of instrumentation is the Seebeck effect, which is the production of a small voltage across the length of a wire due to a difference in temperature along that wire.

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Heat transfer by Conduction

Theoretical description of the experiment setup:

narrow air gap in between. Each heater is made up of electrical resistance wire sandwiched between two copper plates. Thermocouples are fixed to the plates to measure their surface temperatures.

Two identical circular slabs of the material to be tested are placed on either side of and in good thermal contact with the heater plates. On the outer sides of the two slabs, in good thermal contact, are two circular water-cooled slabs whose surface temperatures can also be monitored with thermocouples (Fig 1).

The purpose of the guard heater is to prevent heat loss from the edge of the main heater by maintaining the temperature outside the main heater at the same temperature as the main heater. This ensures that all heat lost from the main heater flows through the test slabs.



Figure 1

**Theory:**

The theory of heat transfer seeks to predict the energy transfer that may take place between material bodies as a result of temperature difference. This energy transfer is called heat. The heat is transferred from a body at a higher temperature to a body at a lower temperature.

Heat Transfer by Conduction



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It has appeared. I'll click it here. The first link you see here is the Heat and Thermodynamics Virtual Lab through Amrita Virtual Laboratory. I'm clicking it here. You can see the number of experiments here.

Heat transfer by radiation, heat transfer by conduction, heat transfer by natural convection, studying phase change, black body radiation, Newton's law of cooling, and so on. I will try to go through the conduction, convection, and radiation experiments where we will see the relationships that we observed in the tutorial program as well, where we attempt to calculate the values.

Here in the virtual laboratory, we will observe in the virtual environment the setup where heat transfer occurs. Through conduction, convection, or radiation, it is compared to the black body, and how the calculations are performed is shown here. These processes occur in the backend of the GUI of this laboratory setup, and we will find the final coefficient values here.

Let me first begin with heat transfer by conduction. I am clicking this link. You see, when I click this link, it opens this window where you have theory, procedure, self-evaluation, simulator, assignment, references, and feedback.

In the theory section, it generally discusses the aim, which is given as finding the thermal conductivity of a material by the two-slab guarded hot plate method and determining the thermal resistance of the sample. When they say two-slab guarded hot plate, you see this setup.

This is a test slab. The green color indicates a test slab. There are two test slabs. Between these two slabs, we have heaters. MH stands for Main Heater.

GH is the Guard Heater. The MS temperature would be higher. The GH temperature would be lower. To cool the slabs from the outer surfaces, there are water-cooled plates outside. That is, we have a heater at the center.

We have slabs across this heater. Above this slab, on both sides, we have the water-cooled plates. The temperature outside is minimum, and the inner layer temperature is maximum. This is the heat transfer through conduction experimental setup made here.

Here, you can see a circular main heater plate (MH) surrounded by an annular guard heater plate with a narrow air gap between. Each heater is made up of an electrical resistance wire sandwiched between two copper plates. It is GH, the guard heater plate, that guards the main heat to prevent it from going into the environment. So, this is the theory part that you can read just to recall the rate of conduction of heat.

$Q = \frac{kA\Delta T}{d}$ . It is  $Q/t$ , which is  $Q$  per unit time. It is also in the experiments given in the simulation part, where we will see the heat transfer happens for a specific amount of time. That is, for 10 minutes, 20 minutes, 30 minutes, or so. So, at that time, it calculates using this relationship. That is,  $Q = \frac{kA\Delta T}{d}$ . When  $Q$  is given,  $k = \frac{Qd}{A\Delta T}$ . Here, small  $t$  is time,  $A$  is area, and  $\Delta T$  is the temperature gradient.

And how is Q determined here? Q, we will have an electrical heating system here. So we have thermal resistance here, R is equal to  $d$  by  $k$ . And applications are given here, for example, heat exchangers, building construction works, thermal energy storage devices, heat transfer in the human body, thermopile and infrared thermometer, thermal resistance electronics like thermal diode and thermal rectifier, used in laser cooling, radiative cooling, magnetic cooling, etc. The heat transfer applications are there. There is a procedure given here.

They say choose material. I will come to the simulator and talk about this procedure while demonstrating the experiment. Number one is choose material. That is the combo box is chosen. Then we choose the diameter of the material, thickness of the material.

Cold water temperature. Cold water temperature because it is the colder part. It could be 0 degrees, 10 degrees, 20 degrees. Whatever we think through a contact of the human body is cooler. That temperature we will keep.

Then we have knobs of the simulator which we will select. MH and GH switch that is main heater and guard heater we will set. And here heating is done through electrical heating that is voltage and amperes is adjusted. VI that is Q is equal to VI through multiplication of V and I Q is calculated. Then we switch on the power button and temperature indicator is used to show the temperature positions for the different temperature thermocouples which are attached there.

Generally the timer goes for around 20 minutes. But this is a procedure for simulation. It shows go through all these steps and you will get through the simulation. I'll come to the simulation and go through these steps. Procedure for real lab, then we do the all these calculations voltmeter reading, ammeter reading. This is V, then VI is terms to the value of Q. Then all the main heater temperature T1, T2, T3, T4 are determined.

Average of these are taken. Cold plate temperatures T5, T6 are taken, and this average is also taken. Guard plate temperature T7 and T8 are taken. This average is also taken. And we get all these mean values, heat transfer,  $A = \frac{\pi d^2}{4}$ .

The diameter that we select here, we select a diameter here. Based upon this diameter, whatever diameter we put, this area would be calculated. And heat transfer  $Q = VI/2$ . So VI, as I said, is the heat transfer  $Q = VI/2$  is the heat transfer. Thermal conductivity is given in  $k = W/mK$  and we get the thermal conductivity value as our result value that will determine the simulation which is given in  $W/mK$ .

Now, certain questions that are self-evaluation questions before this simulation is taken. They say heat transfer by conduction is poorest in the medium that has maximum dispersion. Maximum dispersion is higher in gases than in liquids and solids. So, gases have the poorest conduction of heat transfer. In conduction, heat transfer is carried by means of collisions between molecules.

This seems to be surely true. Then it is transferred from one place to another by the actual motion of fluid. No, this is convection. Energy is carried by EM waves. No, this is radiation.

All of the above cannot be the answer. So, the right answer is it is carried through the collision between the molecules. Then, the rate of heat conduction is inversely proportional to the thickness of the material. This is the right answer. Then comes the question, which one has higher thermal conductivity?

We know among these, silver is very good at transferring heat through conduction. It has very high conductivity. I will submit the answers. So, let me see. It says, okay, this is not attempted.

All the answers I have submitted are correct. Now, let me move to the next part, which is the simulator. In the simulator, you see this interface. It is browsing. Yes, it has come now.

So, we have a voltmeter and an ammeter. We have a guard heater and main heater setting. And this is where we have the temperature display. And this is a timer that shows how long this experiment has been conducted. We have three dots or three lines here.

Here we can choose a material. For example, cardboard, glass, mica, a cement board, or ammonite solid. Let me just pick cardboard itself. Cardboard: the diameter of the material is 10 centimeters, thickness is 0.5 centimeters. Let me change the thickness to 0.6 centimeters. Cold water temperature is 0 degrees centigrade. Let me change this to maybe 10 degrees for the cold water temperature.

Now all these readings are set. We can now proceed. I am clicking here. These two small arrows that you can see. These two very small arrows. I am just enlarging the view. These arrows would set the voltmeter reading. For example, I have just set the main heater reading to 100 and 0.2, or maybe I change it to 110 and 0.31. So  $\frac{110 \times 0.31}{2}$  is the heat transferred that is calculated here.

For the guard heater, I have to set it to the same value, but I have selected here. If I do not do it and try to switch the power on, it will give an error. For example, power switcher: voltage of both heaters must be the same.

They say the guard heater and main heater both should have the same voltage. So through this itself, from the left pane here, I can also change or switch on the power. Power can be switched on through this MCB board, which is shown here. If I click here, or I click on this power-on button here, the power can also be switched on. I will just switch on the power. Okay, still it is not the same.

Okay, now I will set the guard heater to the same level. Yes, it is now on the same level. The same angle is there. I will switch on the power from here. Now you see the timer is running here. Here the timer is running; 10 minutes have elapsed, and the temperature is varying here. Now, once it has run for 20 minutes, I can also see the results here. I say, show results.

It has calculated the value of thermal conductivity as 0.21 watts per meter squared per Kelvin. We can also manually determine it. Manually, in a way, there is a table here in which we can input the values. The table, for example, for cardboard, glass, and mica, we can input these values here, and it will calculate based on the temperatures: T1, T2, T3, T4; it will calculate the mean here. Based on the average of T5 and T6, it will calculate the mean temperature of the cold plate.

Also, when you input the diameter here, it will determine the area by itself. Let me try to do this for another material. I will just reset everything. Click the reset button. So, let me select another material to input the values in the table.

Let me select, for example, mica. I set the diameter of the material as 15 centimeters, the thickness as 0.6 centimeters, and the cold water temperature to be set at 5 degrees. Now, I need to input the power. That is, I change my main heater reading. Similarly, I will change my guard heater reading. With this, everything is set.

Let me show the cross-section and try to run the experiment. Okay. It says both of them have to be the same value. Now it is right. I will switch on the power now. Now the temperature is varying, and the time is also running here.

Now see, after 20 minutes of running, it shows T1 as 23.91. And we can also see the values of T2, T3, and T4 from here. Now, I will quickly take the value of T1 and try to put it in the table. Putting all these values: diameter of material 15, thickness 0.6, cold

water 0.5. So, the diameter is 15, which is for mica. For a 15 diameter, it will show the area. The voltmeter reading is 110, and the ammeter is 0.31. The thickness I selected was 0.6.

Next is temperature  $T_1$ , which is given in this experiment as 23.9. It is not given; it is taken from this experiment, which is 23.91. And the other temperatures I will put as the same: 23.91. So, I get the average mean temperature as 23.91.

Now, the cold temperature, which is the temperature of the cold plate, is set at 5 degrees. I will put 5 degrees here and 5 degrees here. So, the mean is also 5. This is my coefficient of thermal conductivity, which is determined through this calculation. So, this was an experiment, and certain assignments are also given here. A mica sheet of 0.1-meter diameter and has a thickness subjected to the heater with a supply of 28-watt power. Cold water is circulated around the specimen with a temperature of 30 degrees or something. Calculate the thermal conductivity of the specimen.

Certain numerical problems are also given here. Just use these formulas, which are given in the theory part, and try to determine the coefficient of thermal conductivity. This was an experiment on heat transfer by conduction. Let me see another similar experiment, that is, heat transfer through convection, where there is a hollow pipe and air is flowing through that pipe. At certain points, thermocouples are there, and there is a heater that heats this pipe. Let us see how the temperature of air varies when it passes through this hollow pipe.

That is heat transfer through convection. So, I'll take this experiment: heat transfer by natural convection. In this experiment, you see this kind of setup is there. There is an apparatus which I just talked about. There is a hollow tube in which heaters are there inside. This is one heater that is shown here, and there are certain points where temperatures are determined.

$T_1$  and  $T_6$  are the temperatures outside the tube, that is, the air temperature.  $T_2$ ,  $T_3$ ,  $T_4$ , and  $T_5$  are the temperatures inside the tube. Air is flown through this hollow tube, which is a hollow metal cylinder. Outside, we have a wooden hollow rectangular tube so that no conduction happens here.

Now, the aim here is to determine the overall heat transfer coefficient or the surface of a given vertical metal cylinder by the natural convection method. Then, it is to determine

the Nusselt number. The apparatus that is given here can be seen here. The theory is also given on how we calculate the heat transfer. It is  $\frac{Q}{t} = \frac{kA\Delta T}{L}$ .

Where L is the thickness, and this small t is the time for which this heat transfer happens. And here, this is for conduction. Now, for convection, here is  $\frac{Q}{t} = hA\Delta T$  where h is the convective heat transfer coefficient, which is calculated in W/m<sup>2</sup>K.

Let me see the procedure that is given here. They say choose the material, side of the wooden box, which side we would like to take into account, height of the wooden box, diameter of the cylinder that we would like to determine, and length of the cylinder.

Thickness of the cylinder, white knob that could be rotated to set the voltage and current, like we did for the main heater and the guard heater in the conduction experiment. Then we switch on the power, and the temperature indicator shows the temperature variation. It runs for 20 minutes, and temperatures at different points from T1 to T6 are taken in degrees Celsius. So this procedure is also given. How do we go about it?

I will just go through it in the simulator. In certain calculations, we put in the kind of metal used, voltmeter reading, ammeter reading, temperature of the tube, and temperature of the air. T1 and T6 are the temperatures outside the cylinder. These are the temperatures of air, T1 and T6. Obviously, when T1 is the temperature of the entry of the air, that will be lower, then T6 when it passes through this hot tube; the T6 temperature of air would be higher than T1. What is this difference only?

That is to be determined here. Now, let me go through the self-evaluation questions. The first question is: Heat transfer by convection occurs only in liquids, only in gases, only in liquids and gases, or in solids, liquids, and gases. It does not occur in solids. Therefore, it occurs in liquids and gases.

The answer is: It occurs only in liquids and gases. The rate at which heat flows through the slab depends upon the thickness of the slab. Yes, it is. The area of the slab. Yes, it is proportional to it.

The temperature difference between the faces of the slab. That is the delta T gradient. Yes, all of the above are correct. Which of the following is not a method of heat transfer? Convection, conduction, insulation, or radiation.

Insulation is not a method. Outdoors in the winter, why does a piece of metal feel colder than a piece of wood? Humidity affects metal easily. The hardness of the wood. Metals are better conductors of heat than wood.

Yes, metals are good conductors of heat. That is why in winter, due to conduction, it feels colder than any other piece that is not metal, like wood. Why does hot air rise and cold air sink? This difference is due to density. Hot air is less dense. It rises up. So that is the right answer. Let me submit this. All of them are correct. This was self-evaluation.

That is, we are ready to start the simulation. Now, this is the simulation interface. This is similar to the conduction experiment interface. We have the voltmeter and ammeter here, which can be adjusted. We have the timer, the power knob, and the temperature display. This is the setup, where temperature T1 and T6 are of the air in between, while T2, T3, T4, and T5 are the temperatures in the cylinder.

Now, aluminium, copper, iron, and silver materials can be chosen. We can input voltmeter readings, ammeter readings, the diameter of the cylinder, and the length of the cylinder. This will calculate the area of the cylinder, temperatures T2, T3, T4, T5, and the mean of T1, T6, and T5.

It means that this will help us calculate the coefficient of heat transfer due to convection and also the Nusselt number. Now, let me see. What are the values given for aluminium? The width of the wooden box taken is 7.5 cm. The height of the wooden box taken is 75 cm.

The diameter of the cylinder is 7 cm. The length of the cylinder is 55 cm. The thickness is 0.2. Let these be the values which are by default taken here. And let me set these readings here. Let me switch on the power. The voltage is set to 100, and the ammeter reading is set to 0.2 amperes. It will run for 20 minutes.

You can see through the arrows that air is flowing through this. 60 minutes have passed. 20 minutes have passed. So, temperature T1 is 30 degrees. The temperature of the air is 30 degrees. Now, if I click here, temperature T2 is 29.86. Let me put all these values here.

The voltmeter reading is 100. That is given here. The ammeter reading is 0.2. Voltmeter: 100. Ammeter: 0.2. Voltmeter; let me put the value 100. Ammeter as 0.2. The diameter of the cylinder is 7 centimeters.

The length of the cylinder is 55 centimeters. The thickness is 0.2. The length is 55. This will calculate the area. Now comes the temperatures T2 and T3. The T2 temperature here is 29.86. Let me put this value here: 29.86. Temperature T3.

I will click this arrow to find T3. This is 31.86. See, it is heating. 31.86, then T4. This is 35.86. Then T5. This is 37.86. T2, T3, T4, and T5 are temperatures in the cylinder. You can see from T2 to T5, the temperature increases from 29, 31, 35 to 37. It is heating. Now, air comes out of the cylinder.

When it comes out of the cylinder, its temperature is T6. Let us see what the temperature T6 is here. T6 is outside the cylinder. The temperature is 36 degrees. It falls from 37 to 36 degrees now.

But this is the temperature outside the cylinder. T1 is—let me just see once again. T1 was 30, and T6 is 36. So, T1, I will put the value here as 30, and T6, the value is 36. So, the mean has come, and it has calculated.

You can see here the heat transfer coefficient, which is 192.37 watts per meter square per Kelvin, and also the Nusselt number value: 4408.517. Right. Let me take another material quickly and try to see the result that it calculates by itself. So, I will reset this experiment. And now, try to take another material.

For example, I'll take silver, which has higher coefficients of heat transfer. I will just change some values. For example, let me take the width of the wooden box as 10—that is, I keep it more safe from the outer environment. Height: let me reduce it to 70. Diameter of the cylinder: let it be 5. Length of the cylinder: let it be 55. Thickness: let it be 0.2. And if I switch on the power, it will run for 20 minutes.

Let it run for 20 minutes. And I can see the result here. Even before 20 minutes, they are showing what result would come. Heat transfer coefficient to be 4.51422 watts per meter square Kelvin and the Nusselt number to be 131.66476. So, this was heat transfer through convection. Certain assignments are there—just similar to those given in the conduction. These assignments, you can go through. For example, calculate the heat transfer coefficient and the Nusselt number of a copper cylinder which has a diameter of 0.6 meter, length of 0.8 meter, and is covered by a hollow rectangular box of size 0.6 meter and height 5 meter.

The input power given to the metal is 33 watts. Using the theory formulas, you can calculate the heat transfer that happens—that is, the heat transfer coefficient and the

Nusselt number. You can calculate here. There are reference books through which this experimental setup or virtual lab is developed, and certain feedback also you can give here.

Let me now come to the radiation part: heat transfer by radiation. When we talk about radiation, it will only calculate the emissivity. When we calculate the emissivity, it is calculated in comparison to the black body.

For which emissivity is 1 in radiation. They say to compare heat transferred between different material surfaces and black body surfaces by radiation to find the emissivity of the different material surfaces. You see there is a black plate here. There are three temperature points: T1, T2, T3, and there is a test plate here where the temperature points are T5, T6, and T7. There is an outside chamber in which the temperature is T4.

This is the setup for emissivity. So here you can see or read the theory part here on how the emissivity is calculated: incident radiation is there, reflective radiation is there, radiation is absorbed here, which leads to the heat transfer or heating of the material, then radiation is transmitted.

So this, as we have discussed in the theory part. This emissivity of the plate is calculated with respect to the black body emissivity, which is  $E_b$ . And the difference between the black body and the chamber temperature to the fourth degree, and the ratio of the differences is also there. So let me come to the procedure here.

They say to choose the material, diameter of the specimen, thickness of the specimen, and chamber temperature. Then we can set the black plate and test plate by adjusting the voltage. We can tune the switches and try to find the temperature from T1 to T7. To find the comparative emissivity point, this is the table or the observation that will be taken. Voltmeter readings would be given or taken, and we will set it.

Ammeter readings, blackbody temperatures T1, T2, T3 would be taken. The average temperature of the blackbody, that is  $T_b$ , and test plate temperatures T5, T6, T7. Its average is  $T_p$ , that is the temperature of the test plate. Then the temperature of the chamber, T4, all these will be taken.

Using these, we will calculate the heat emitted by the blackbody as  $\epsilon b = \sigma T_b^4 - T_c^4$  watts, and similarly for the test plate. We can determine the emissivity of the specimen plate by using this relation. Now let me come to the self-evaluation here.

It says radiation occurs only from liquids, only from solids, only from liquids and solids, from solids, liquids and gases, or from all the mediums radiation could occur. This should be the right answer. Heat energy reaches the earth from the sun by radiation. Which one of the following is the best surface for absorbing heat radiation? Shiny white, dull white, shiny black, dull black.

The best surface for heat radiation here would be dull black. That is what we call a black body. The emissivity of a black body is 1. Which one of the following is not correct in the case of radiation? Radiation travels in a straight line. Radiation can travel through a vacuum. Radiation requires particles to travel. Yes, this is not correct. Radiation travels at the speed of light. Radiation does not require any particles to travel. Let me submit it.

All of them are correct. We are ready for the simulation to play. This is the simulation setup. Let it render. Yeah, it has now come. You see, this is a black body. Three temperature zones here: T1, T2, and T3. This is the temperature T4 of the chamber, and their temperatures on the body that is to be compared—the plate material that is compared.

That is T5, T6, and T7. Here, you can see the selection of materials that this wheel hub has provided: aluminum, brass, iron, steel, and copper. Let me see one experiment and try to just see the results. So, let me take the aluminium material. Diameter of the plate, let me set it to 6 cm. Thickness as 2 cm. And let the chamber temperature be 20 degrees only. Now I can set the black plate or test plate voltages here.

For the test plate, if I move this lever to the test plate side, I can set this value. Let me say I have set this value to 100.2. A similar setup I have to make for the black plate. I will set it to 100.2. All these are now set.

Now I can switch on the power. When I switch on the power, you can see the temperature is varying here and also the time is being running here. This is slower than the previous experiments. Till now only four minutes have elapsed. This is going on and what values come, we will put those values here in this table.

Let it run. It is running, till seven or eight minutes it has gone. So, we'll put the values of voltmeter reading, ammeter reading, blackbody temperature, the test plate temperature. And chamber temperature here and we will find the emissivity value. So it is running till 12 minutes.

Let me at this time put the voltmeter and ammeter values here. The voltmeter value is 100 for the material aluminum. The voltmeter is 100. The ammeter value is 0.2. T1, let it come up for 20 minutes.

Yes, it is going to stop now in almost a few seconds. Yes, in 20 minutes, this T1 temperature is 191.31. I will record this temperature as 191.31. Now, to see the T2 temperature, I will click this button. T2 is 489.84.

Then, T3 is 489.84, exactly the same, 489.84. These were the black body temperatures. So, the average temperature has been given. The same temperature is given in Kelvin. That is why it seems to be higher.

273 is added to the average temperature. Now T5, T4. Let me say T4. T4 value is 253. That is chamber temperature. That I will put there where T4 value is required.

Chamber temperature here is 253.15. So this will be also noted here. T4 in Kelvin while adding 273 to 253 turns out to be 526.15. T5, T6, T7 are to be put here. T5 value is 520.76. T6 is also 520.76. I am putting the value T7. That is the temperature of the test plate is again 520.76. So average is this in Kelvin. This has now given me the emissivity value as this.

Let me try to see another experiment quickly and try to see the result only. For example, let me pick a material other than aluminium. Let me pick steel and let the diameter and thickness be same. Let the chamber temperature only vary to minus 5 degrees. Let me now set the black body and the test body settings to the same, and switch on the power. It will run, it will take 20 minutes.

So now it is going to be close to 20 minutes. So it has run for 20 minutes. So let me see the results here. I'll say, 'Show results,' and here I can see the results. The emissivity value is 0.85 for a test plate of material.

Steel; diameter: 5 centimeters, thickness: 1 centimeter, and the chamber temperature is minus 5 degrees. This was a quick virtual lab demonstration on heat transfer methods: conduction, convection, and radiation. With this, the thermodynamics part of the course is concluded. We will discuss fluid mechanics in the next part of the course.

Thank you.