Electronics Enclosures Thermal Issues
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Lecture – 05
CEDT worked examples 2

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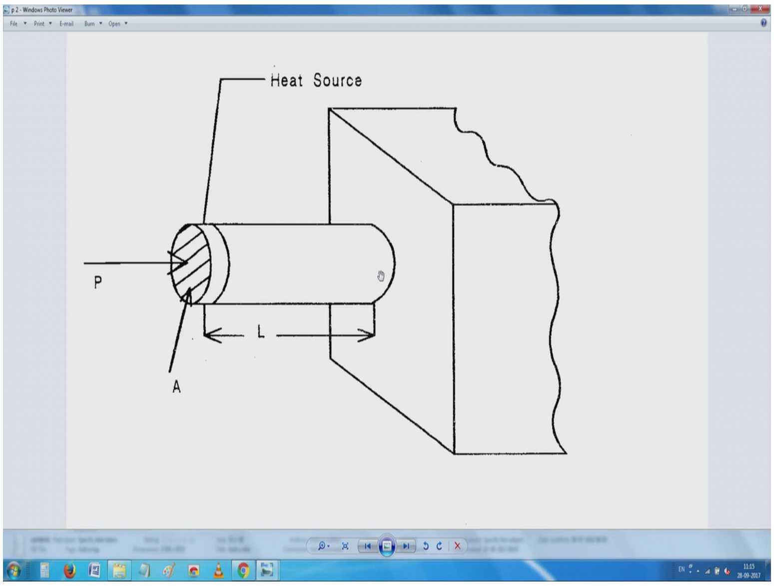

Where heat source and then for purposes of simplification they have taken it circular. So, that you know the effects are not there. So, we have so much of P there is A and length of contact and this is exactly what is trying to tell you when I pointed out this; experiment with the thermal conductivity flask which we have all done once upon a time long long ago.

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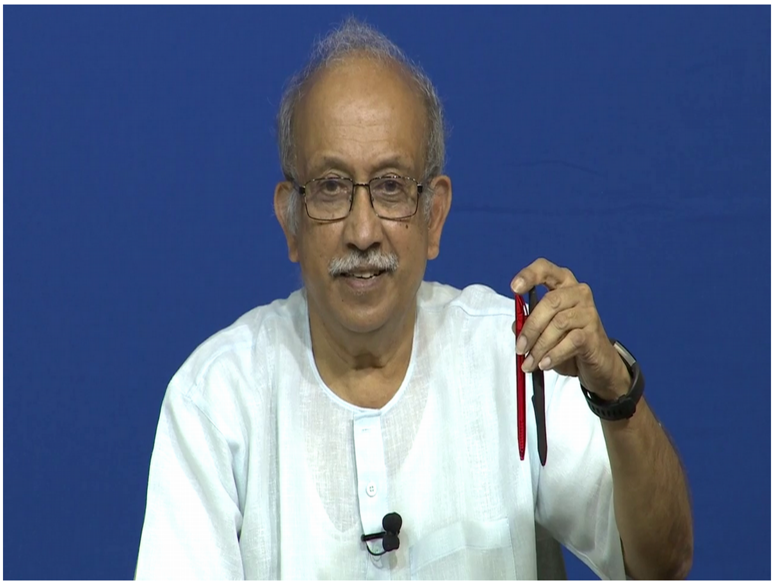

I have done it in 1960 that shows how young I am, but physics has not changed physics says the remains same our understanding and modeling has changed.

Now, you probably do not even need to make the experiment, you have an animation and all the things are modeled and the model is fairly accurate. Somebody has tried it and then what you call the come to the conclusion, there is nothing wrong in the modeling because the model is based on actual experimentation.

They also know similar to what I have seen there I have shown you there they know the conductivity they know the cross section. And most of them are made typically to make it very convenient now to be visible in a class usually they are on 4 millimeters diameter. Earlier it was you know somewhere between, what you call? Probably it is between one-eighth and you know quarter inch and one-eighth probably, it was a three-eighth of an inch or something like that; I am sorry three-sixteenth of an inch.

So, that can be easily checked. So, you if you are curious enough now go back to the internet and may be in YouTube you can find it; though I have it with me I want you to search; go onto the internet find out is experiment about how to find out comparative thermal conductivity of 3 materials which is usually done when you are around 11 years or 12 years old. So, they are all simplified things like this here yes in this homogeneous heat conduction.

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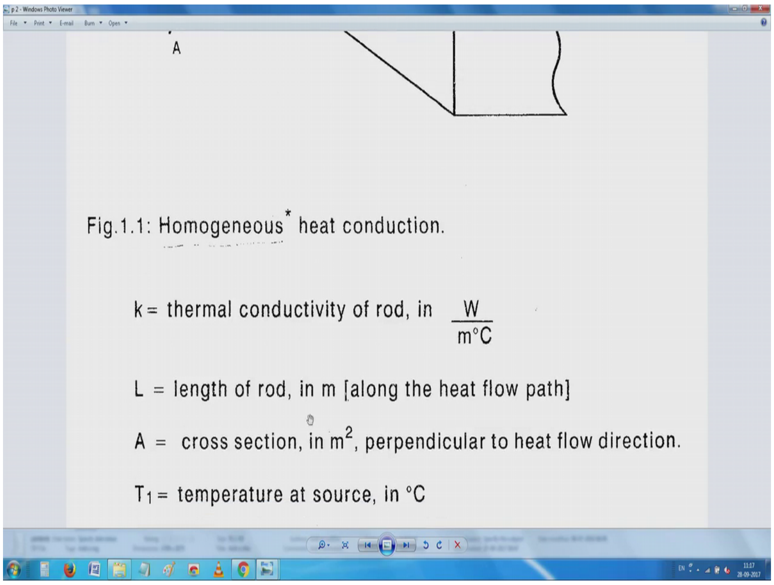

As star there I will read the star about it later. It just generally it says that star refers to area of cross section is uniform throughout the heat flow you understood know area of cross section is very, very critical about it. And coming back that Fourier's laws about it know saying, thermal conductivity as we know has been defined in the table as what per the meter degrees centigrade. And then length of rod in meters along the heat flow path.

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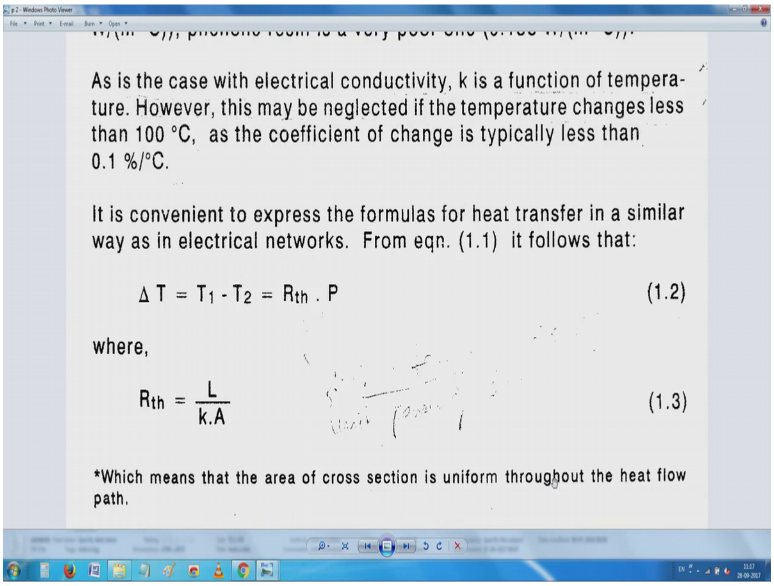

Cross section in meter square perpendicular to heat flow path, temperature of source and temperature root ceasing; that is how the other thing has been done. It will be same whether T 1 T 2 are expressed in degree or Kelvin because you know 273 gets canceled. Thermal conductivity depends on the material that metals are generally good conductors, insulators are not certain similarity to electrical conductance.

So, copper is an excellent heat conductor and resin is a very poor one. As in the case of electrical conductivity k one more time is a function of temperature. You understood know? Rather I hope when you I started with the example of the incandescent bulb. So, a lot depends on the where the thermal conductivity and the where the current flows through and as it goes what happens? You too would have noticed if you are one of those you know people who were before bend the bulb hesitations I used in the Sydney opera house they had the bend the bulb, what you call?

Launch around 2 or 3 years back; I understood it is a big event they even switched off the lights and every year know we have this how to save energy switching of the lights, lot of incandescent lamps surprisingly when you switch on they fail as a very iterative very rarely they fail when it is already working except there is a voltage fluctuation.

The moment you switch on suddenly enriched current comes in case there is any already some deterioration of the material or anything it fails automatically; which is a little related to this k the thermal conductivity is also a function of temperature, but; however, it is very, very low because typically it is you know less than know 0.1 percent per degree is centigrade.

So, we are saved and those things.

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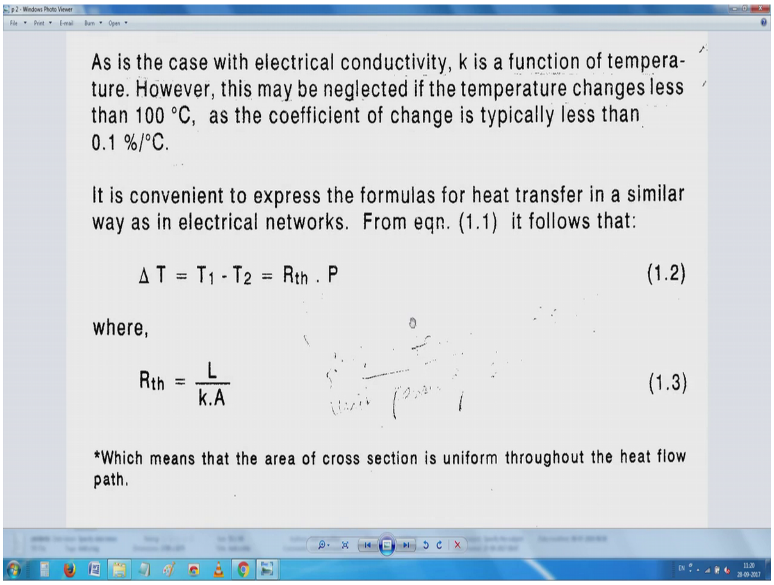

It is convenient to express the formulas for heat transfer in a similar way as electrical networks. So, in the case of electrical network we have a delta v saying, is it not possible for us saying this thermal resistance into the power will give you the temperature difference; sorry for the interruption we will edit it out.

So, we see here that; it is possible for us to define a thermal resistance just like we have conductance and good old ohms formula or ohms relationship can be used just like you know resistance is equal into voltage by, what you call? Current vi and similarly an ir drop, saying we have a thermal resistance and then we have the total flow for this thing and then what will be the temperature thing.

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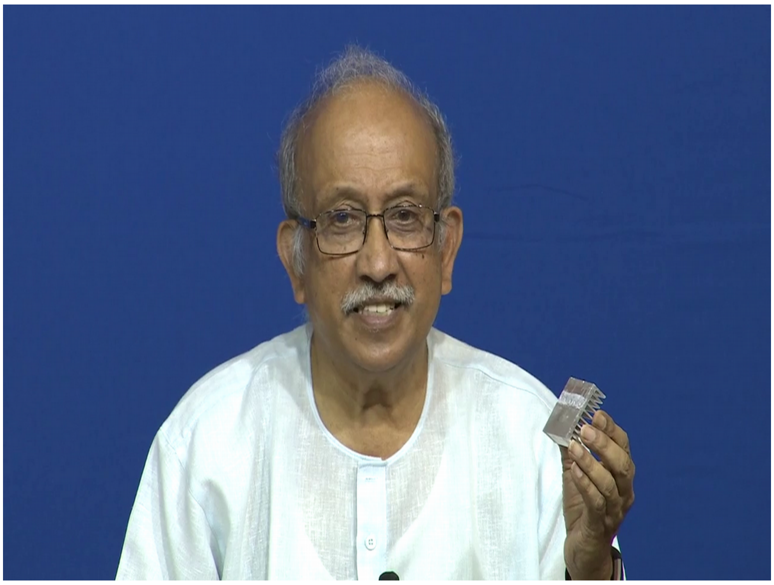

So, once you do the things like degree centigrade for what for a device like this can easily be defined. Now comes the next level of thing which I thought now I should leave it you for saying how to, what do you call? Model this next expression you seen then.

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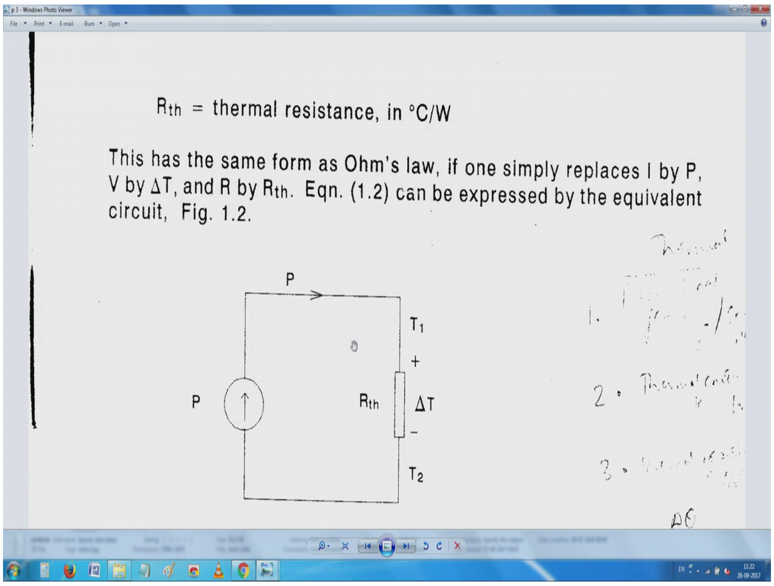

This what is telling you reading it out, same form as ohms law one simply replaces power by voltage and I am sorry they. If you are replace current by the power then the voltage by the temperature difference then the thermal resistance is equivalent to, what you call? The thing which is shown by the l by k into which is shown there can be expressed by the equivalent circuit like this.

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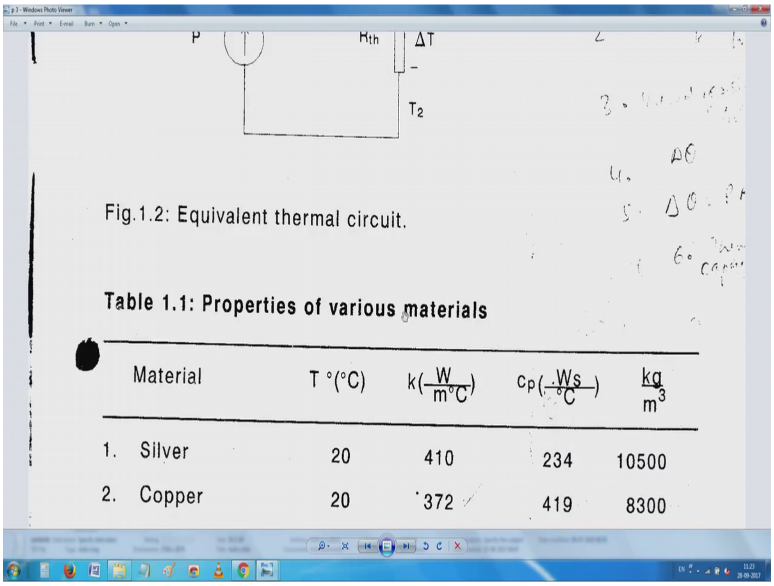

Fig.1.2: Equivalent thermal circuit.

Table 1.1: Properties of various materials

	Material	T °(°C)	$k(\frac{W}{m°C})$	$Cp(\frac{Ws}{°C})$	$\frac{kg}{m^3}$
1.	Silver	20	410	234	10500
2.	Copper	20	372	419	8300

So, it is possible for us to now start working on this example now I sort of jumped through and then I showed you.

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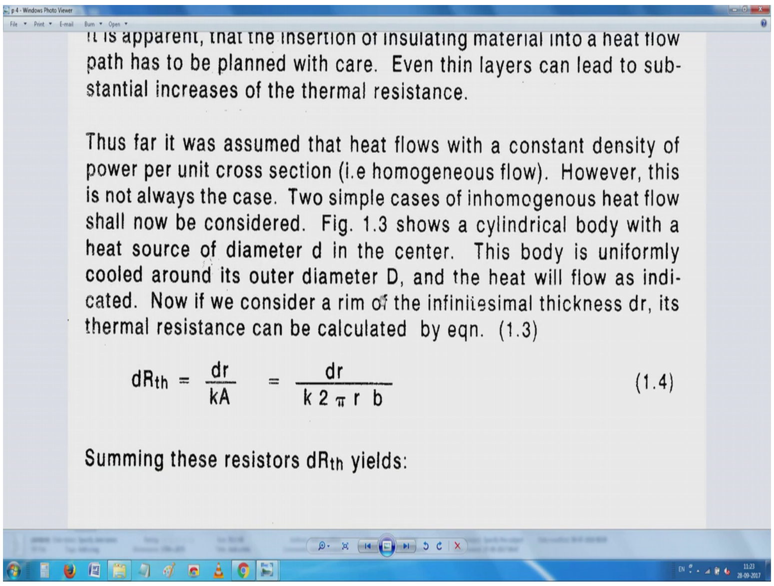

It is apparent, that the insertion of insulating material into a heat flow path has to be planned with care. Even thin layers can lead to substantial increases of the thermal resistance.

Thus far it was assumed that heat flows with a constant density of power per unit cross section (i.e homogeneous flow). However, this is not always the case. Two simple cases of inhomogenous heat flow shall now be considered. Fig. 1.3 shows a cylindrical body with a heat source of diameter d in the center. This body is uniformly cooled around its outer diameter D, and the heat will flow as indicated. Now if we consider a rim of the infinitesimal thickness dr, its thermal resistance can be calculated by eqn. (1.3)

$$dR_{th} = \frac{dr}{kA} = \frac{dr}{k\,2\,\pi\,r\,b} \qquad (1.4)$$

Summing these resistors dR_{th} yields:

The analysis is now extended to can we have radial and can we have a spherical heat flow. So, if you see this heat sink my suggestion is kindly take whatever heat sink is there with you and then you take the area here.

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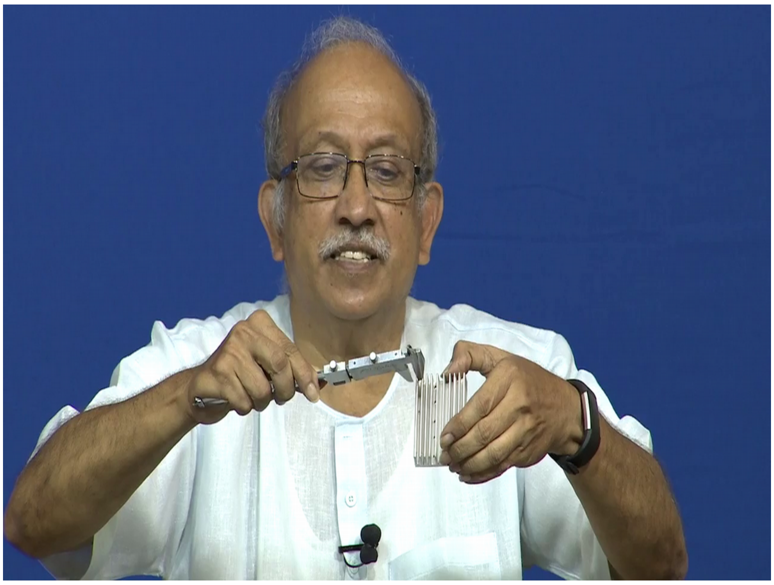

and you take the area of cross section of this, so in this case this is a 2 mm by 70 mm. Understand now we have one 40 square millimeters and we have 1 2 3 4 5 10 fins on this 10 into 140. That is the area available for us for an applet over conduction though this is very, very high. Understand know this is 17 into 50 this is very high compared to that 2 into 70 140 into 10 that is only 1400 here we have 50 into 70 which is 3500.

So, that is typically about 2 and half times of this, now we comes come to the next thing to enable conduction why cannot we make this wider, but then we will end up with the problem of not having enough space for the air to pass. This is where the complications or the modeling becomes effective, understood know?

So, take this some typical heat sink what you have and imagine if something were to be mounted here directly it is attached to power device typically it could be a heat bridge; in this case we had direct access to these power devices a lot of times may not have access to these devices.

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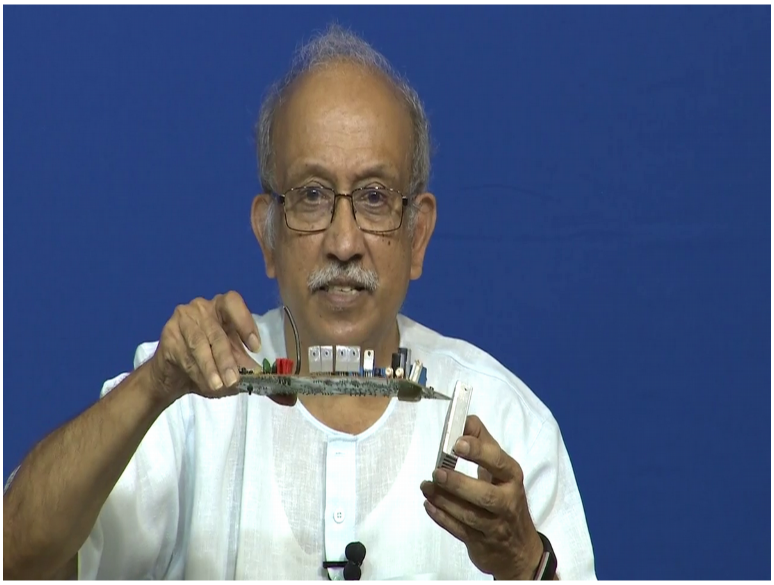

So, you may need to pack it up with some other material imagine the whole thing is covered and this is the case itself imagine this is the case itself ok. It is a corrugated case like this and then you need to pass that thing. So, we need to find the conduction usually because of the large aluminum conduction and all that it comes here and comes here one more time is still having this problem only.

A small area is available out of the 70 into what you call? 50 3500 square millimeters we still have only a small area which typically represents this only; this is where conduction calculations are very, very critical.

Now, the next picture shows; saying in the case of a radial heat flow.

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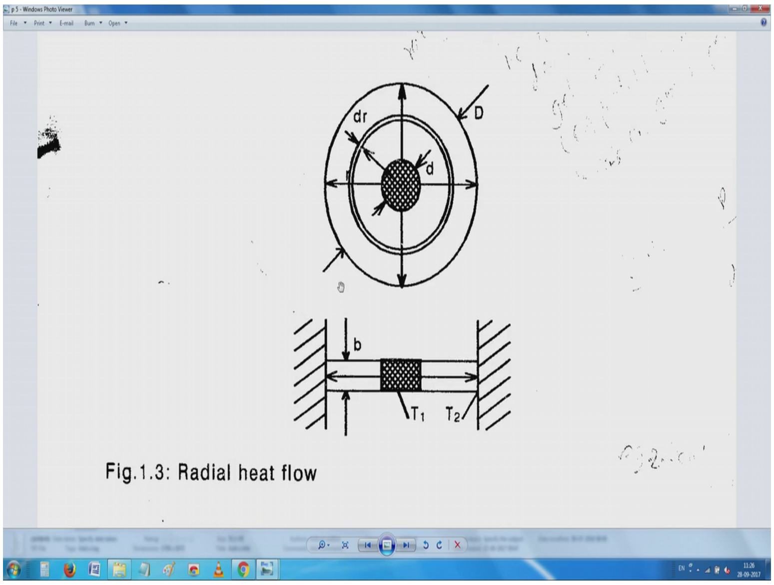

You will notice that area is continuously increasing, but we have known small d we know and then if you know small d and this thickness b d into b at this area as it goes out. We know the typically you know you can have a definite integral between you know what you call? Internal radius to external radius.

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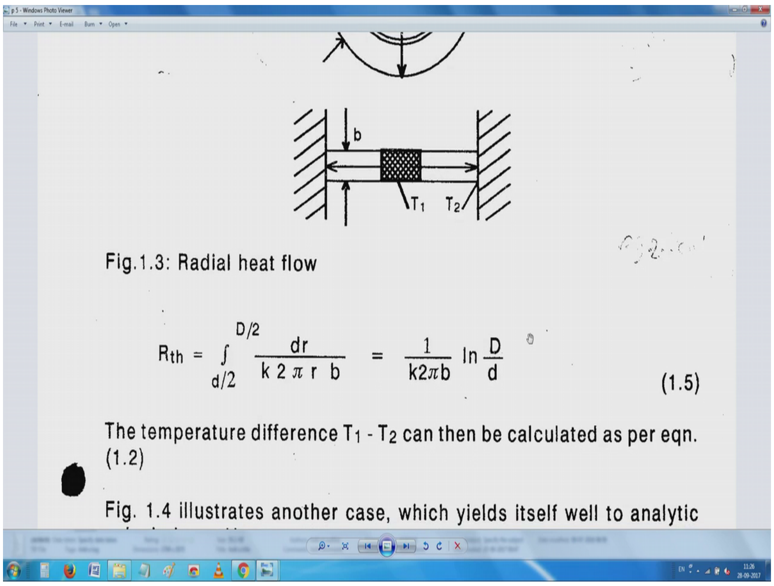

And then by integrating the whole thing we end up with a beautiful expression which can read what you call readily be used. This follows that Pentium cooler which I have shown you if you see that radial modeling their base of it is, if we see that earlier first picture I showed you there is a, what you call circular ? Heat sink and then at the base of it the square pad is mounted and then from there radially we have heat sinks at those point now when you are calculating the heat sink, what you call ? The way the heat reaches the end point you will be able to use these expressions easily.

And this is already what is built into most of the CFD or packages. They use these known correlations, but 2 things very important is your geometric model, what you present has to be accurate. You cannot I have just you know just like that I have try to this only is slightly better than my filling with my finger not that fingers are bad, see I can by practice if you take it in the work shop you will fill it like this and says. So, this must be probably you know what you call? 1.6 millimeters because he knows typically such devices there the practical thing is 1.6 and if you measure it will exactly be 1.6.

So, things like 1 by the k contains you know the same thing which has seen their into 2 pi by b you know this natural logarithm of d by d can be calculated as per equation.

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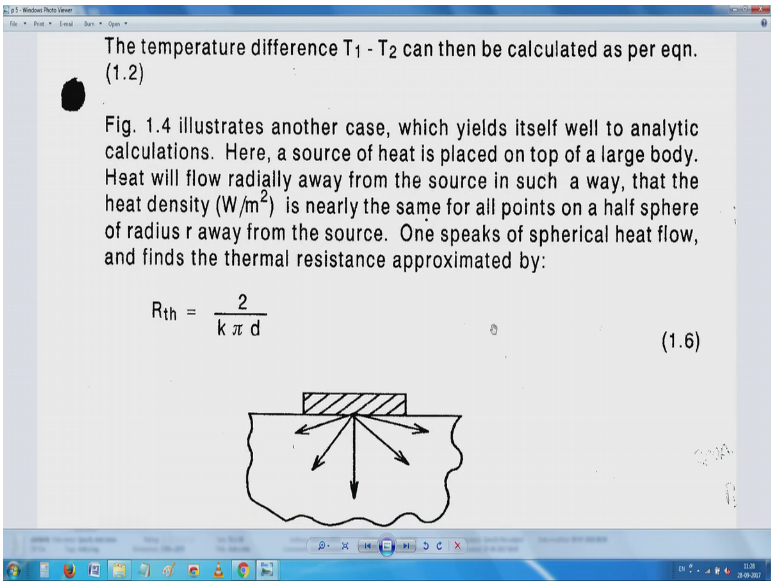

These analytical methods can be easily used for known geometries ok, but I am not very sure where you will get while I have shown you a rod like a typically a pin fin. I am not very sure where then I have shown you what you call if you have a component mounted at the middle, how it can go away radially and then after that it can go to a pin fin. So, I have a pin fins then we have a circular base and or even if you have a square base you can approximate it.

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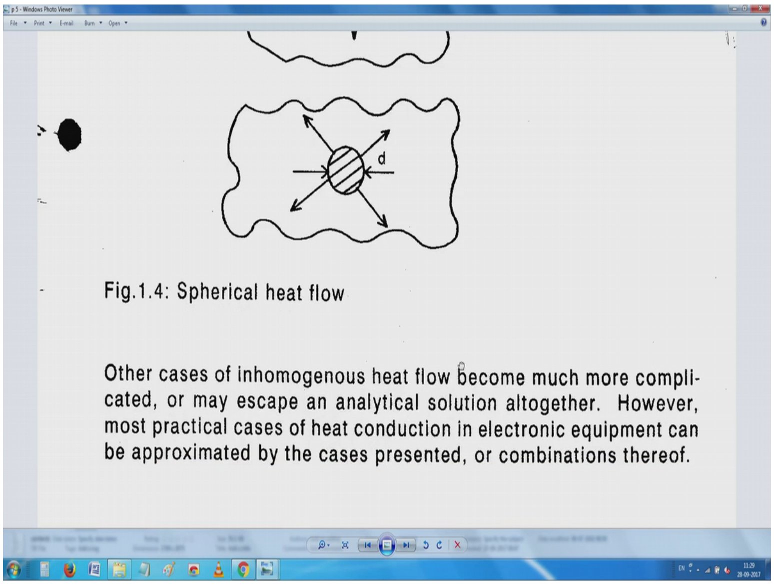

This comes much more important for you see the beautiful note that is given here in homogeneous heat flow becomes much more complicated may escape an analytical solution. Practical case of heat conduction in electronic equipment can be approximately given by using these combinations. A source of heat is placed on a top of a large body heat will flow radially away; that the heat density is nearly the same for all points in a half sphere of radius away from the source.

So, then uniformly at the same rate it is going so we have a spherical heat flow where they have already approximated and given this 2 or 3 things can happen. The temperature gradient may change and it may be other losses directly at various points; even in the case of heat sink, even a simple parallel heat sink.

We have assume this is cross section is constant, but we have forgotten that the ambient temperature varies at the tip the ambient temperatures different at the base it is different. And as it goes further the behavior of it; obviously, know it is valid only in the case of a pin fin which is insulated outside. So, no heat loss is there by any other means including convection to the ambient.

So, we have this what do you call things about how to model these things the next picture in that notes takes us to yeah maybe I will start here and repeat it away .

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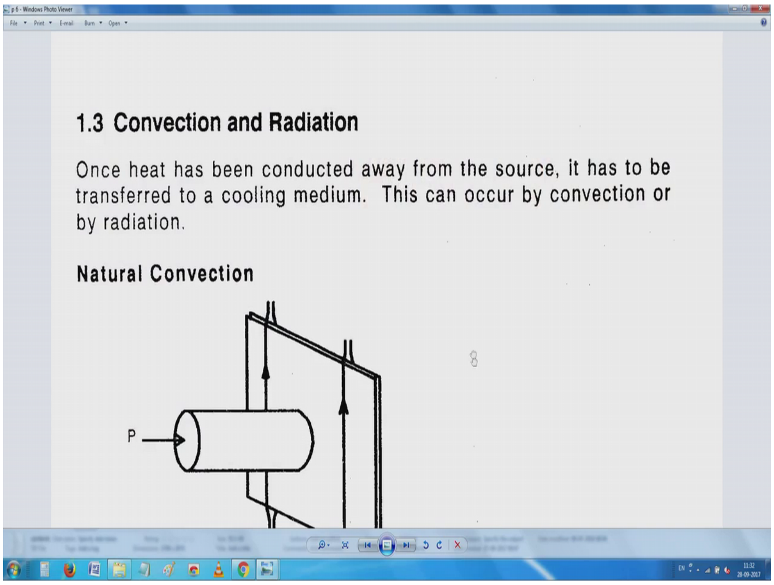

We have noticed that the so called heat sink is nothing but a, what do you call? A bridge or a heat what you call? conductor away from the source. Now you need to pass it on to the cooling medium I have given you an example of the circular tubes which are used in air conditioning and other things where you can have radial fins inside and you can have radial fins outside.

So, when you have this radial fins inside and outside that behavior is can be module easily. Now in the case of heat sinks that similar modeling has been done here because these are also having that like this saying you need to take away heat by convection.

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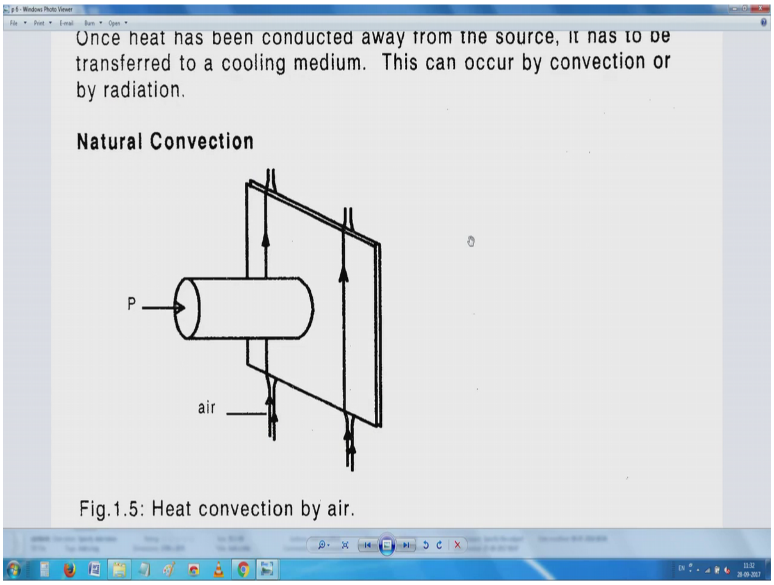

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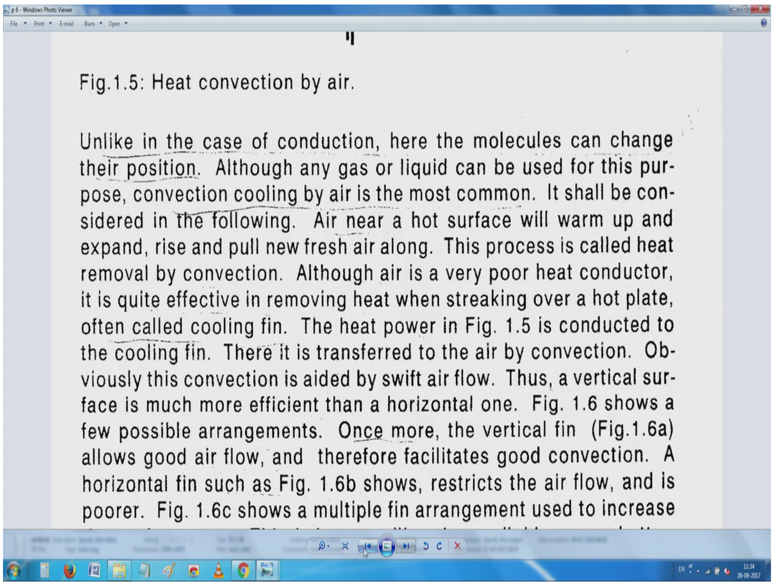

By definition convection depends heavily on position change. Understood know? The molecules change their position; that is why heat and mass transfer are related somehow and then as if you know things are not what you call good or bad enough the moment you heat some portions of a fluid it expands and buoyancy is created; that is what creates natural conviction cycles or thermal cycles inside; which you can see in the thing on a hot day you can see.

So, called mirages on the street; you do not see all that what is shown in the comic characters know saying somebody is you know is crawling in the desert and in the distance, he sees lot of entertainment going on, that is not what happens what happens is due to total internal reflection you see something which seems to be reflecting the top surface.

So, if you have trees you see something you have any objects rocks use your object. So, you are likely to mistake it for water. So, this is all exclusively created by thermals and the variation of refractive index depending on the nearest refractive index. So, something called the total index total internal reflection what you see in the case of your prisms and all will take place without actually there being 2 medium 2 media, total internal reflection typically will have 2 media on one side; we are all familiar will have water another side air are we are familiar we have a glass and we have air.

But in this case is air versus air still one that causes is the small temperature difference, which causes all that you know various types of phenomena. What happens is air near a hot surface warms up expands rises and pulls new fresh air along this process called removal by convection air is a very poor heat conductor. I have shown you there it is not very great actually in the table when we went back air is a very poor this thing and in fact, all insulation all insulating materials depend heavily on air you have seen this know still air.

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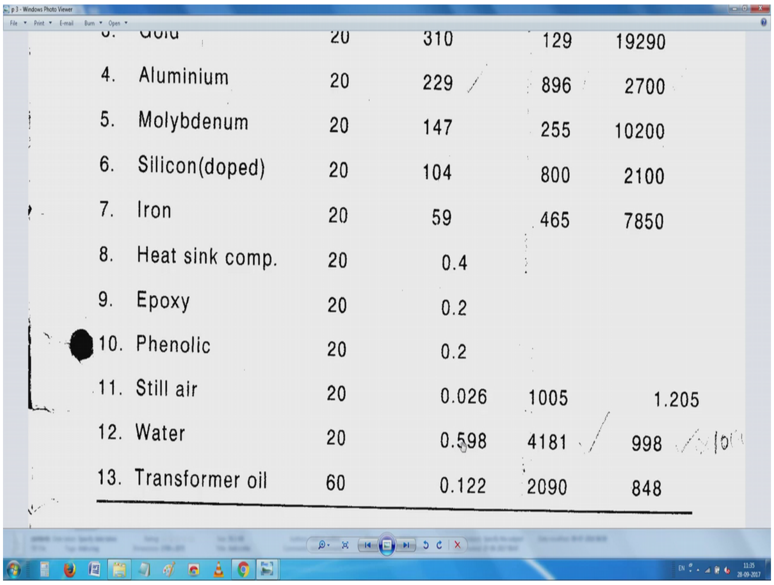

3.	Gold	20	310	129	19290
4.	Aluminium	20	229	896	2700
5.	Molybdenum	20	147	255	10200
6.	Silicon(doped)	20	104	800	2100
7.	Iron	20	59	465	7850
8.	Heat sink comp.	20	0.4		
9.	Epoxy	20	0.2		
10.	Phenolic	20	0.2		
11.	Still air	20	0.026	1005	1.205
12.	Water	20	0.598	4181	998
13.	Transformer oil	60	0.122	2090	848

Even water also it is does not seem to be very great it is only 0.6 what you call this?

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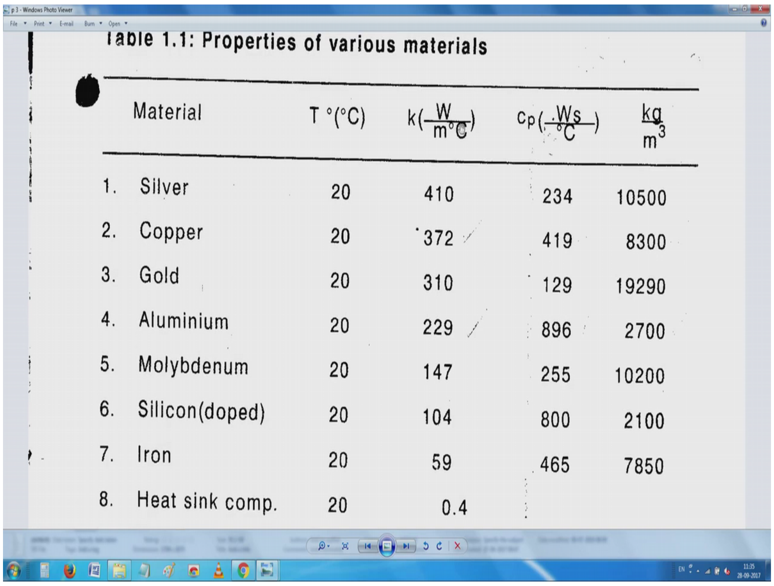

Table 1.1: Properties of various materials

	Material	T °(°C)	k($\frac{W}{m°C}$)	Cp($\frac{Ws}{°C}$)	$\frac{kg}{m^3}$
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6.	Silicon(doped)	20	104	800	2100
7.	Iron	20	59	465	7850
8.	Heat sink comp.	20	0.4		

Watts per meter degree centigrade, not very what you call encouraging, is you know compared to aluminum; that is if you divide this by that you will get a were really horribly you know some 300 or 400 times less conductive then. Air is a very poor heat conductor and then all your insulation depends on trapping air in closed cells.

So, typically if you take expanded polystyrene, polystyrene, polystyrene form or poly you, what you call? Pu form your cells inside, if it is closed it is very good because it will prevent ingress or condensation of moisture and air is the one that creates the insulation by themselves know there know insulating materials as such. All insulating materials depend on air as insulator same thing with your jacket.

And I am sure you have noticed when it gets waterlogged it becomes ridiculously cold any insulation including mineral rule which is used in your boilers or even which is used in now called the electrical gazers and all then, once water gets into their 0.02 suddenly becomes 0.5 and then we are lost from there onwards it is a very short jump towards problems.

Heat is transferred to the air by convection, this convection is a aided by swift air flow, a vertical surface is more efficient than a horizontal one.

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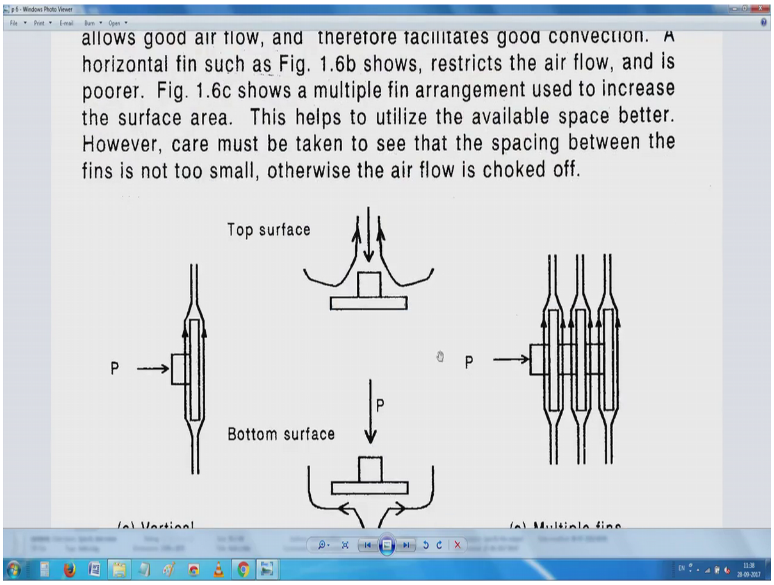

The vertical fin allows good air flow and therefore, facilitates good convection. A horizontal fin restricts the air flow and is poorer a multiple fin arrangement by which you can increase the total surface area that is available, I just pointed out to you in a practical example.

You cannot really you know keep them close very, very close and again in that statement you will notice that ; a lot of it depends on the speed of the air flow, swift air flow you have seen that now air flow should be fast enough that is the already little what you call? Warm air I mean warm molecule should be replaced by colder one. So, that directly on the surface you have all these effects.

So, people have worked on it and even today that modeling is critical and as I said the corporate who manufacture this heat sink and all. Employee people trained by us and then to make the model clearer and better and better and all that. So, then if somebody were to sell you a heat sink all they need to do is try is just make one model.

If they increase the depth they have the answer, and if the increase the length the answer is there and if they increase the spacing or increase the width the answer is there, which is all based on use of the electro what you call? That modeling the things which I have shown you earlier as we go down all the 3 conditions are shown here.

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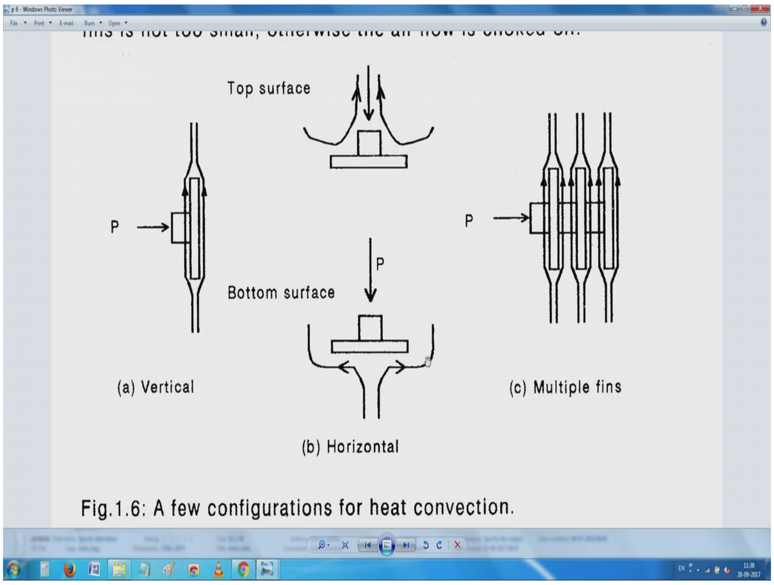

So, the next what you call? Slide points us to the as air moves upwards along the fins it gets heated.

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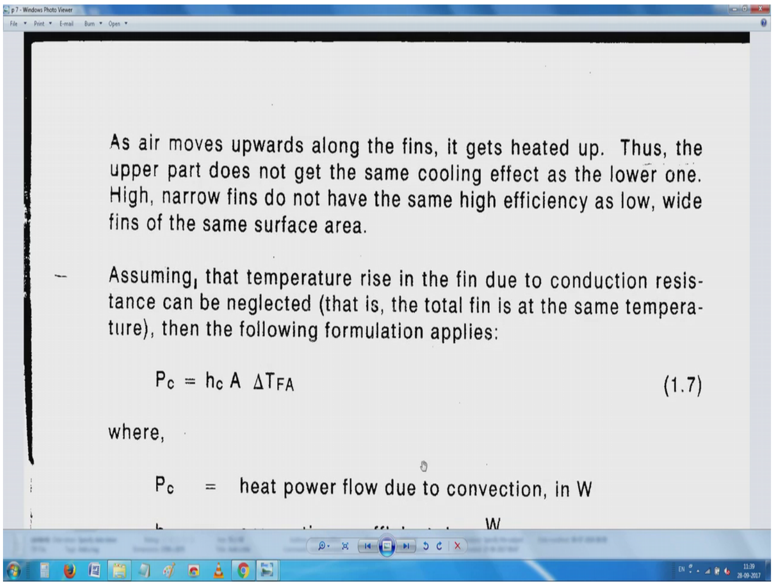

The upper part does not get the same cooling as a lower one, high narrow fins do not have the same high efficiency as low wide fins of the same surface area. Temperature in the fin due to conduction resistance can be neglected that is total fin is there.

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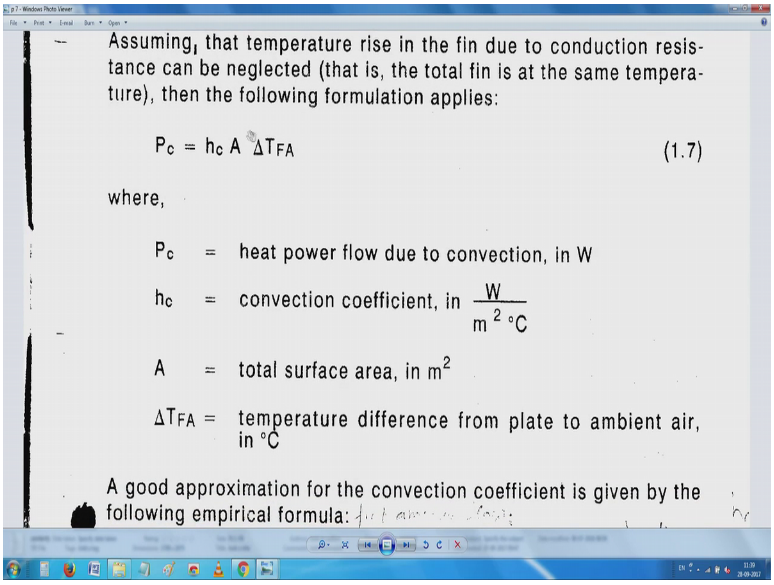

And then we end up with one more time know hc here just like as we had heat transfer coefficient in conduction, we have a heat transfer coefficient in convection. Our whole problem is, how do we get that hc; heat transfer coefficient in convection. It is not yet it is not that easy as it looks like a good approximation can be given by the following formula understood know?

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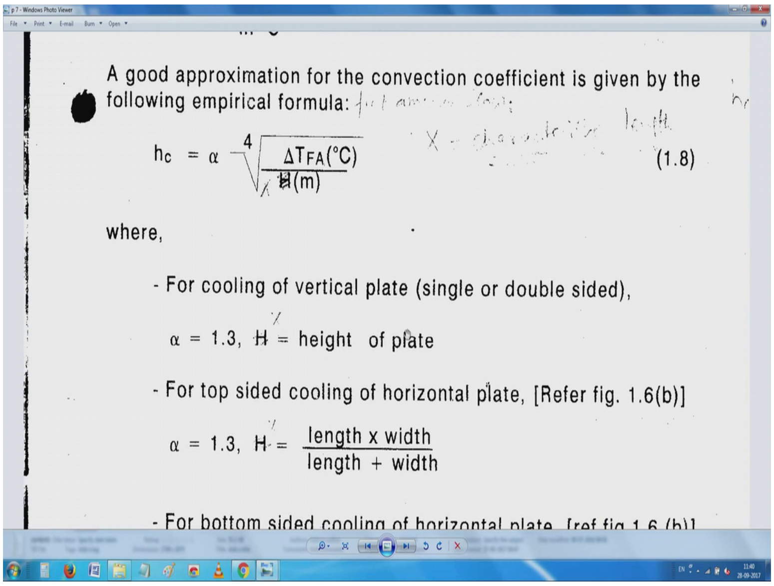

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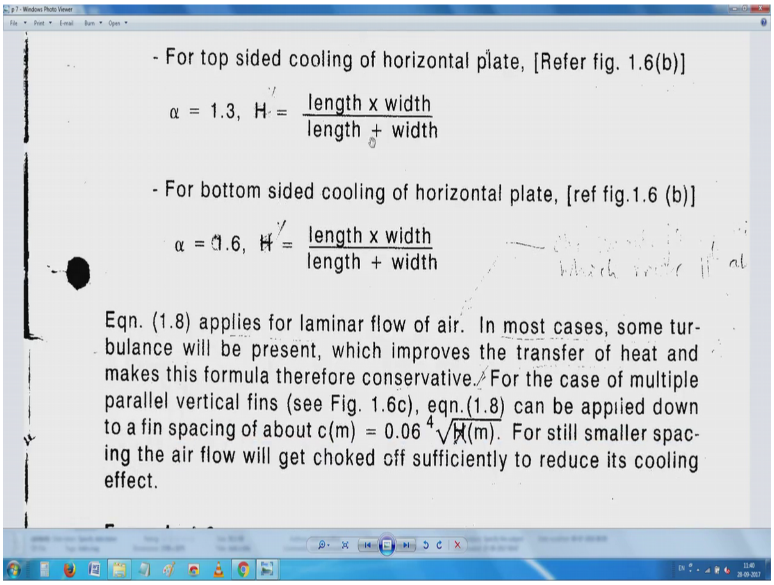

They have given here alpha is equal to in the case of a vertical plate and then they should be of course, what I am sided cooling how much should it be and top sided cooling and how much it should be 0.6 there is a mistake. These things partly due to understanding of the physics, partly out of experimentation they have got into these beautiful figures ok. At this point I will try to probably what you call? Stop here and then in the next lecture I will get back here again and then try to see how this whether we can solve it and we can try to apply it for a small heat sink like this.

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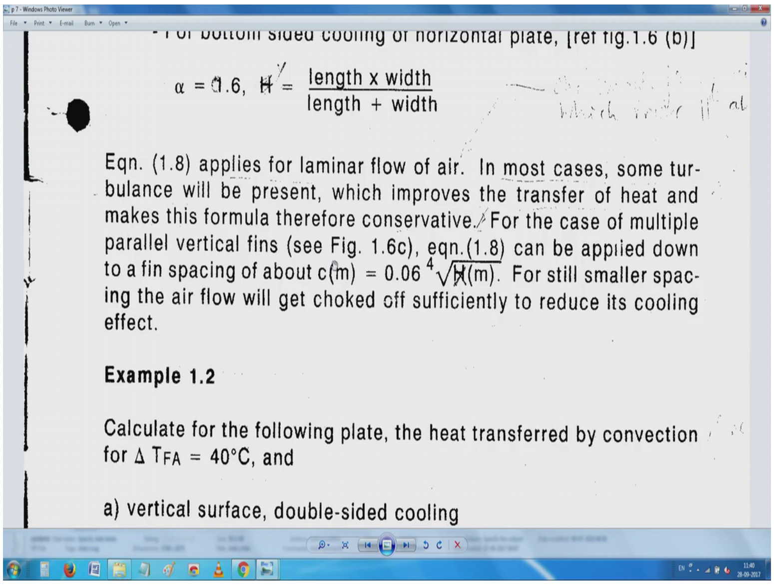

So, thank you and see you again next time.