Electronics Enclosures Thermal Issues
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Lecture - 01
Electronic Equipment Thermal issues

Hello, I hope you have followed the other course which I have done, which is about how to make a an enclosure. Now if you remember contrary to normal engineering analytical approach to any design, the word design in our context means integrating or synthesizing available knowledge and technology to come out with products.

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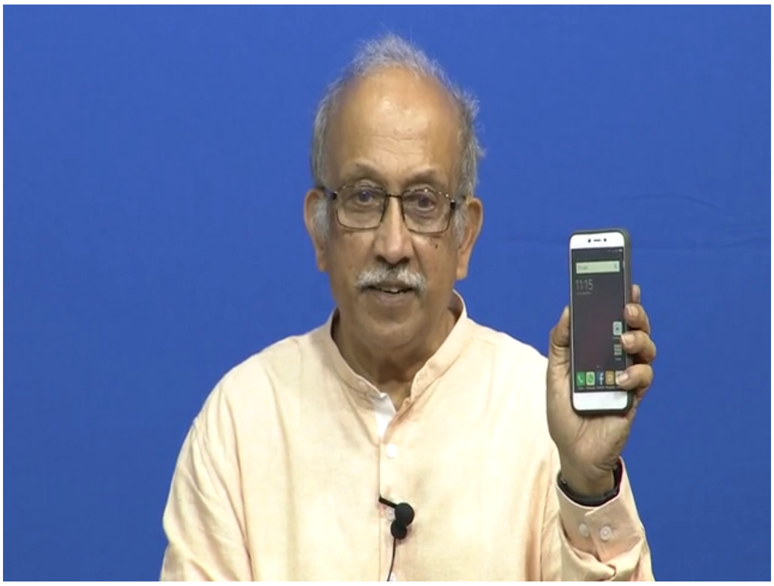

So, typically if you were to take a thing like our mobile phone which I keep using right now, this is a clone; clone of a well known thing. Suddenly things have exploded it is like you see at the back can you see? Front there is nothing. Now if I touch it at the back, it will go on automatically; so, there is the sensor here.

It is not as if this fingerprint sensor is older nobody has invented or anything like that; same thing is about when you want to switch off, I just need to touch another thing and it gets it; goes off; good known things. So, I have a user interface and then you have a sensor and then add it to that in this small size; it is between 4 to 6 radios, antennas and all of them are nicely packed inside.

The only disadvantage or something which is followed is heat; it gets hot. So, putting any protective case like this seems to beat all the whole thing; only makes it hotter seen this know. These things keep getting hotter and hotter; so suddenly that whole back is hot. We do not know that the original designer wanted it this way with this attached or he wanted it raw. this is where the problem of heating starts.

So, we have here while this is a not a very critical application; we will end up with certain applications like this I think I showed you this.

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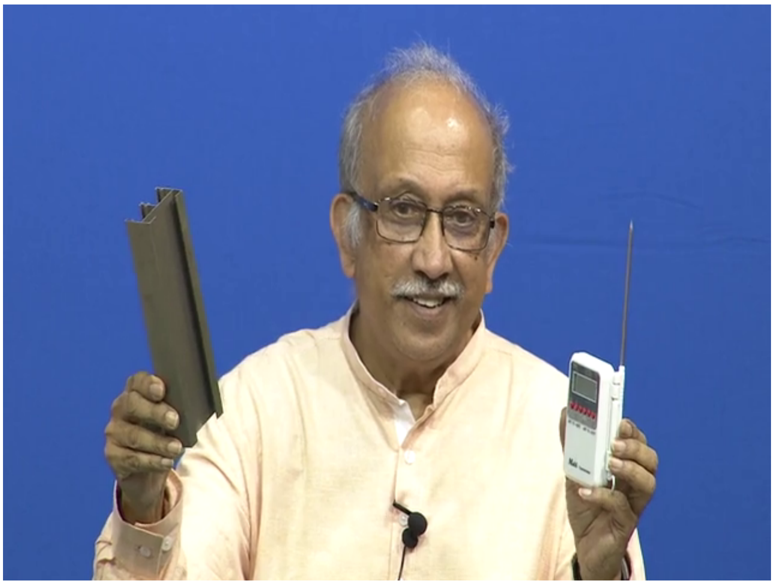

I got thanks to another colleague of mine this time I got a new piece which is no; it even works not damaged and all that. You see this is the temperature measuring device, you have a tip and in case I want to see where it is I just need to touch it and it shows a number.

Now, when we come to more and more understanding of the physics as well as how to use the knowledge in developing new things; we need to be a little more what you call proficient or professional about these things. One of the first things is it is not as if heat sink and design; have not invented the heat sink or design.

This in my view; is an (Refer Time: 03:38) something I do not know what it is; it is aluminium and it is a nice gray color, can also be probably used as heat something. And to start with let me start with a well known device.

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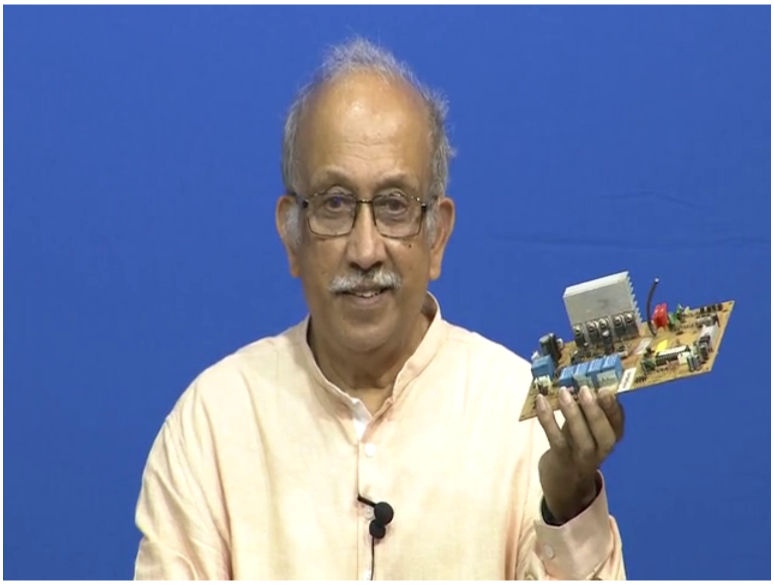

I strictly do not know what this devices; it has been taken out from I had not know something one of the first thing you will notice is there are heat generating components; I do not know there are some transistors or linear or switching devices or anything I expect that there are so many of them and then we have again 1, 2, 3, 4, 5, 6 relays here..

Advantage of a relay is it has only two nice states; in the open condition there is no current, there is an voltage across it; no current. In the closed condition of the contacts there is no voltage, but current is only passing through. As such this is an ideal switch; in contrast with that any of our active devices which see here are not ideal; even though you can have low forward drop something, you still have a lower drop means there is a voltage.

And similarly there is the current the moment you know multiply it; obviously, you get the issue of heat loss and heating up. How to get over it? Is still a lot of what you call science and engineering and little bit of one because the alternatives you need to generate the alternatives. And one of the things again meant here is you see this whitish thing which is here, I think all of us know we know what it is; we loosely call it a heat sink and we also understand you know it is not an infinite heat sink it is just a heat spreader a heat exchanger.

Whatever is picked up from here it is passed on to this block, which in turn tries to passed on to any medium in this any fluid medium; in this case we have air. It is not what you call; it is a common knowledge, it is just like a car. Car has a radiator inside; the radiator does not radiate it we are in deep soup if it radiates it does not radiate at all; what it does is all the time it tries to use a convective cooling; sometimes natural when the car is moving; obviously, another thing which we do not have in the car is a fan built the fan is run not in belt.

But we all understand when we mean what a fan built its used for other things; for running other things. What it has instead is an electrical fan; this electrical fan tries to force air through the heat exchanger. Basically it is a heat exchanger from a liquid inside typically water mixed with probably propylene glycol with a ambient cold air.

In some conditions, it is needed and generally when the vehicle is moving at a particular speed; often we do not need to have the fan switched on. This is a definitely a jump over the maybe cars made about 50 years 60 years back, where to the crankshaft there used to be yes a fan built which connects the what you call; dynamo or loosely they use the word dynamo alternate or anything interchangeable, but we know basically it is a generator of some sort it could be AC or DC. And then you also have a water pump and then you have the fan belt and then the fan belt has a fan which throws the air on the radiator. So, radiator is wrong fan is wrong; we still have that heat exchanger no more fan belt

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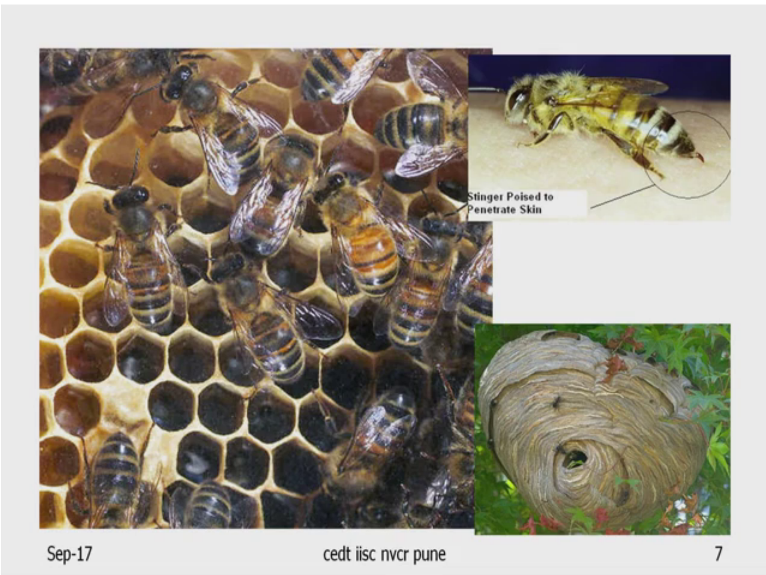

Now, coming back to this thing now if my friend can show me the monitor; any design if you have already seen this it is been there included in the other lecture of mine; about equipment design. Equipment involves tremendous amount of various other people which need to work in it together.

In this case fortunately; obviously, it is a social creature and so, on. So, at the thing you have a beautiful what you call I mean beehive; these hives are common among the animal kingdom, you also have it for hornets nest, you also have it for various other thing. The common purpose we know is to probably make store food and also know use it for various other thing and then probably a little bit of socializing; I will not talk about it, I am just going to talk about the allegorical representation about this thing.

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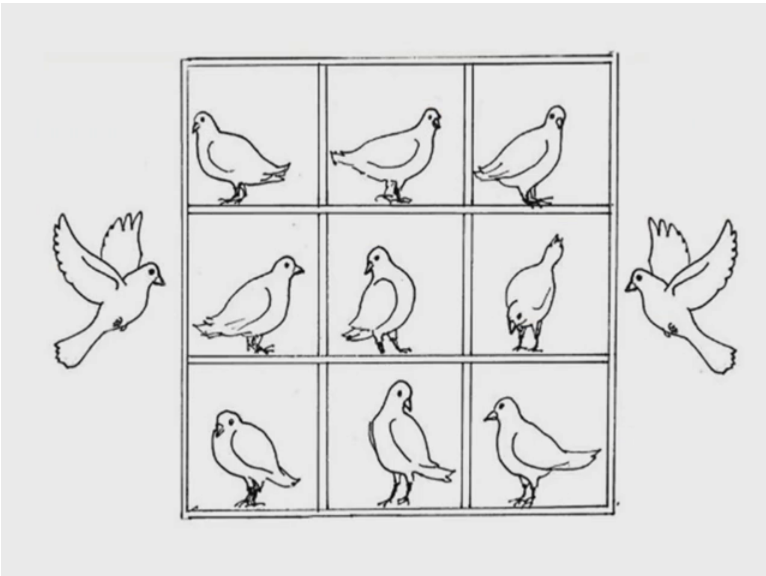

Contrary to what we think; it is not pigeonhole; the activity is not pigeon holed everything is to work together.

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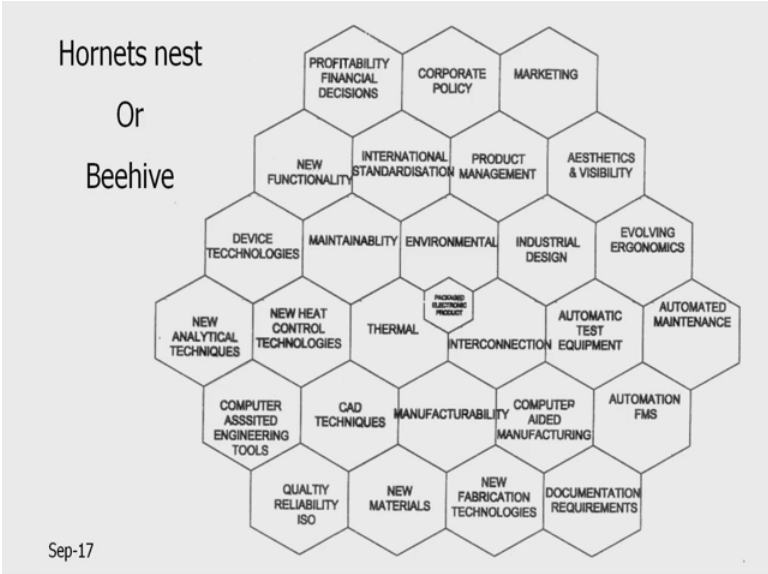

Probably the next slide will try to explain what is it I was trying to do about it. All these are needed; so in this corner we have only this; what you call thermal heat technology slightly related to is the interconnection.

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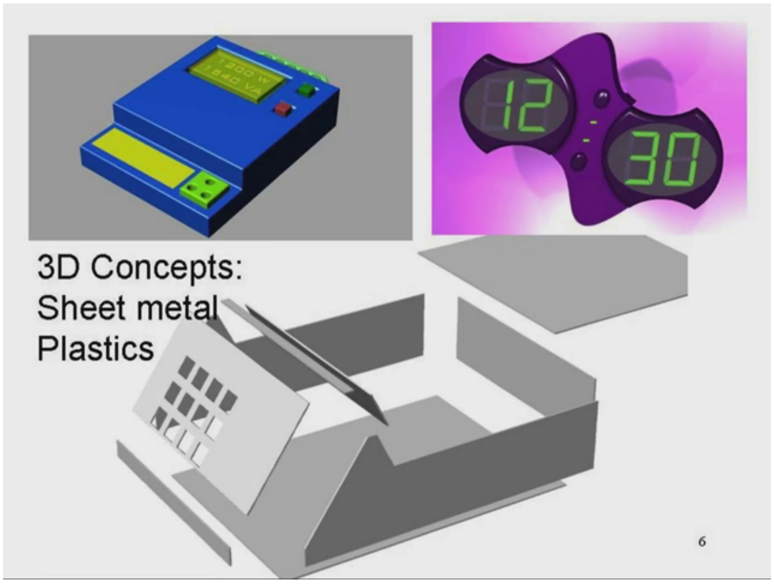

So, if you remember I have mentioned this earlier saying in our case normally as far as possible with right only.

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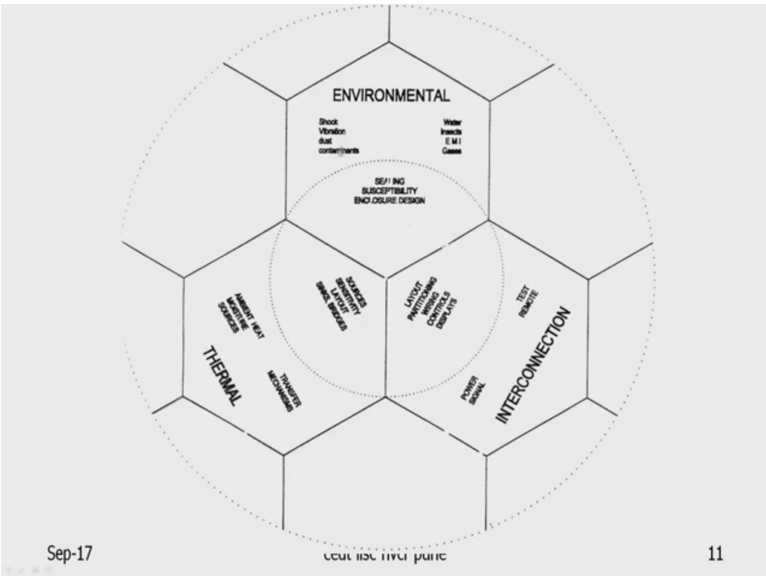

Work about the enclosure and then how to treat heat with this; I have mentioned it in passing earlier that we have this dotted line probably represents the external enclosure. And then we have this thermal aspects by which inside the device; how do you bring the heat out, what we have here is a breadboard.

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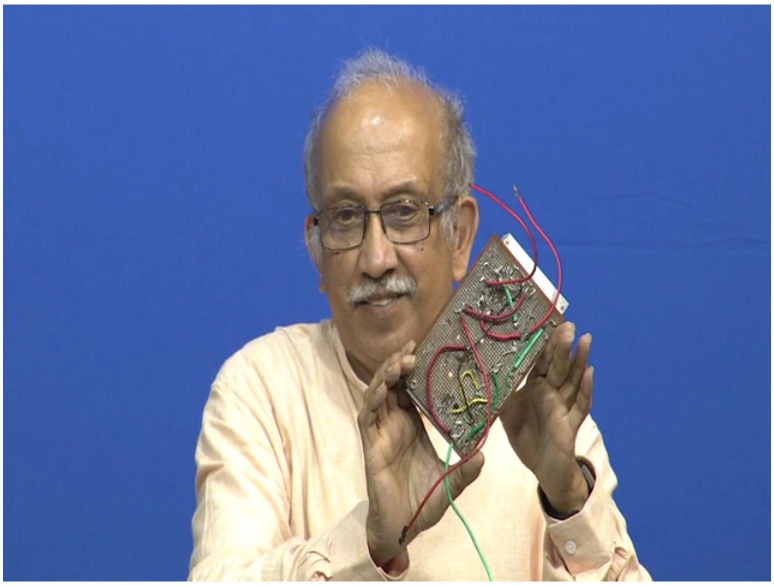

It is made with a on a what you call I think you would have seen these things; board which has a lot of things and all that. And then we have this aluminium plate here and aluminium plate here, they have tried a circuit. And in this case; it is easy nicely you know things it here and there is no problem, this is a starting point but eventually when you end up with a complicated thing like this.

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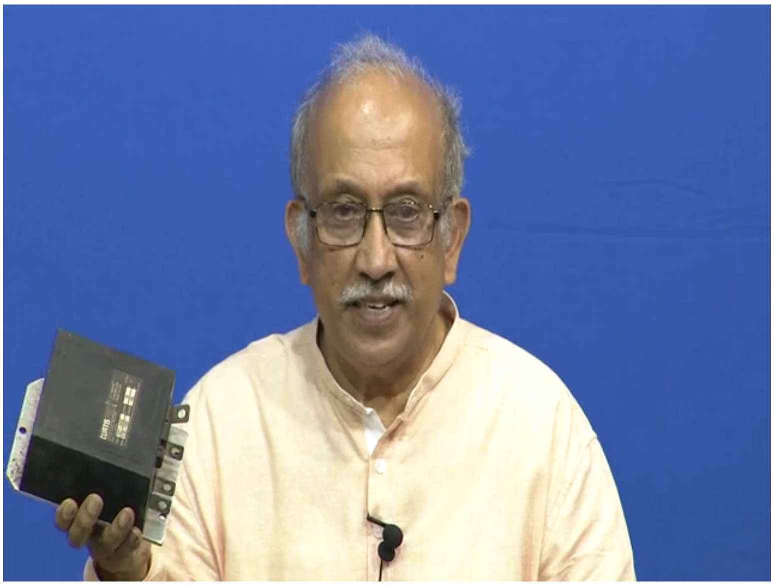

This is a full IP 67 sealed drive from a commercial manufacturer; it is a DC motor controller, the voltage is 36 volts in the current is 150 amps that is a lot of current.

So, even if we assume 90 percent; what you call efficiency it means 10 percent loss and its 10 percent loss; this 160 amps comes to 16 amps into 36; that is a lot of power; is it not? 16 into 36 something like I think 500 watts; 500 watts of losses are associated with it, but the magic is it is not continuous, not continuous neither is the current continues. Obviously, you know it goes in peak side the back the manufacturer has taken care to give us a flat plate. In fact, all drives like this unless you ask the manufacturer to fit the heat spreader on the trend give, they all come with its.

Now, they give all the specifications here saying it works with an ambient up to 65 degrees centigrade provided you can maintain this at something. It is fashionable to use the word 25 degrees centigrade, but impossible to maintain anywhere like this. So, typically if we can maintain this around 50 degree centigrade and the ambient is around 25; we still have 25 degrees to play.

So, we need to make a device or make a method know by which that 25 degree centigrade for a given wattage of these 500 watts, will give you the thermal resistance of it. So, you have seen that we ended up with the beautiful 25 by 500 which will come to a very small number; typically all power heat sinks are all designed with these numbers like that. So, if you take normally 50 by what you call 500 it will come to a 0.1; if you take 25 by 500 it will come to a 0.5. So, if you have something which can be made at 0.5 centigrade per watt, it can be used safely in continuous running conditions; alternatively you need to deride the drive which is typically what is done.

Where are early full 160 amperes passes and then 360 thing is there because 160 and 360 comes to 5 kilowatt; this is not intended for a motor like that. Typically, this is used in wheelchairs, it is used in a little type of high power electrical mobility devices and the peak currents are never used; this is only for this thing. So, typically they use it for motors up to around you know 200, 300 watts. So, if I take it I get only 30 watts; so, 30 watts I can design the heat sink for it..

You will notice that most of the thing inside is how sensitive are the components; this is where electronics has been improving and in fact, if you can look up the internet; you will discover things like high temperature what you call electronics. There are electronic device which will work it I believe 200 degrees centigrade; I will show you the link afterwards.

Another is how will you make a layout and then important thing is heat bridges; how do you bring the heat from inside to the outside? So, typically the plate I have shown you had something make sure that everything is brought and the plate uniformly has to be at a very high temperature; it is a very very interesting thing. If you have a heat sink, when you put your hand on it if it feels cold something must be wrong.

Either it is really working very efficiently with 0 this thing and or inside the device is already failed or it is not switched on. And all and a heat sink which is at the ambient temperature or a heat spread at ambient temperature, it can really not take any this thing across; you seen this show you it cannot really take anything across.

So, we have the problems about it; my lecture is going to be a little about basics of thermal aspects. And then little bit of how to select a little heat sink and all it and then how to manage this; what you call what are the heat transfer mechanisms.

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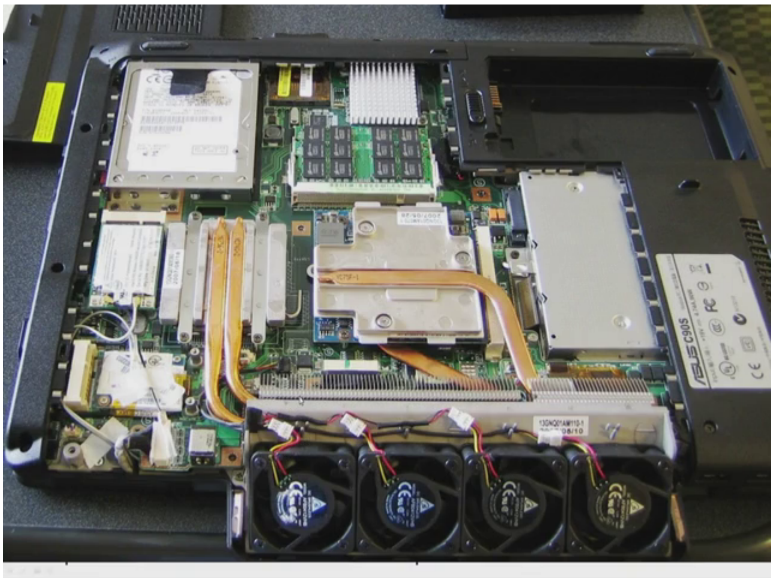

If any of you recollect this; this about sums up all that is there in modern thing including face change; you will see you know. We have this beautiful face change devices and even see here it is not as if its everything is you know cut and dry, you have a heat pipe; flatten such that the what you call actually evaporation of the working flow it takes place; from there and then it comes and circulates. And then in this case you know probably by definition heat pipes do not have a internal circulator. And then we have a heat spreader; one thing have you noticed; the color, heat spreader is not black.

Some reason we have all been told heat sinks better be black; have a look at this is actually inside an equipment.

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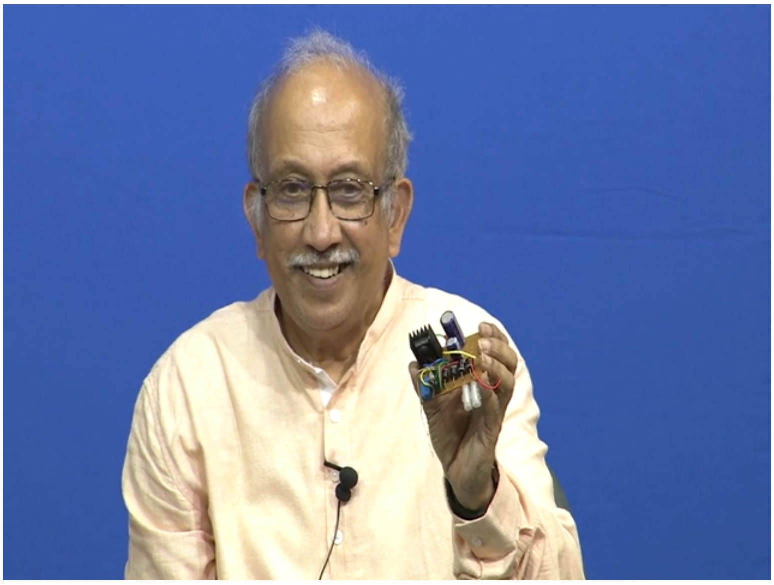

And it is coated black does it make sense to make it black? In due course; so, you will you know you can probably take a call on that saying whether you agree with me or not..

And just look around any of the new equipment you know instantly they have discovered that if you coated with black; contrary to whatever theory you have been taught, they tend to fail. Because black absorbs heat as much as it can radiate heat; so, to say I mean in one of the lectures; I have heard know there three modes of thing and then one of them is conduction another is you know convection, third is? Radiation and they take equal thing maybe that equal is only a simplified way of explaining to a common man. They never take an equal thing; in fact, in the normal thing wherever you see it is unlikely that radiation ever is used to lose heat.

Again like all rules, I have give an exception if we take a break toaster; it best works with radiation. And if you ever wondered about it, we have a beautiful toaster inside you can see the hot coils, but outside even its a plastic; it does not melt and then you do not have any what you call insulator like a polyurethane foam and all that; you instead have a simple heat shield which is a what you call polished aluminum foil; which will reflect away all the heat that can come inside plus there is a small air gap. Air gap plus this reflective shield is sufficient to make the walls warm not hot, otherwise the plastic will melt.

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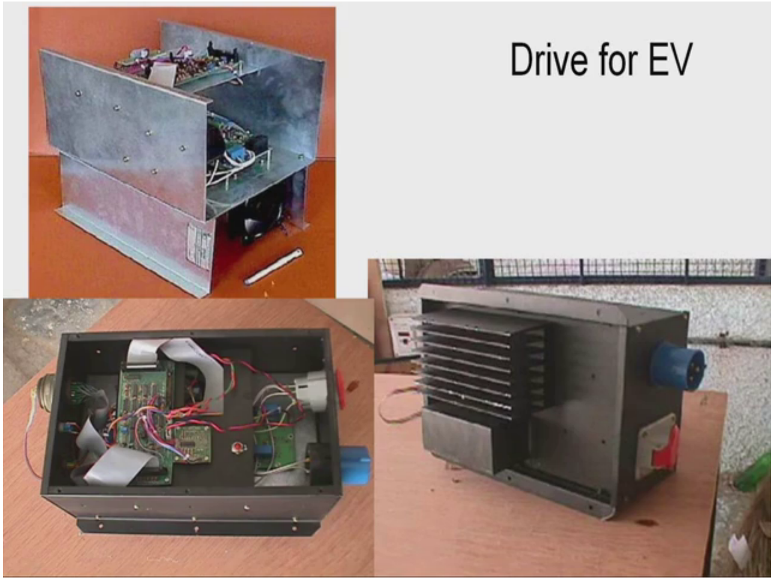

Now, while coming back to this again you see here you see this beautiful what you call EV drive for the electric vehicle, which is typically characteristic of most of these things here; do not ask me, sir then why is it painted black? Pass the question. It has been made for a replacement mechanism hence it is even big and that was made for a; I think 20 kilowatts or something probably it is much smaller than this you do not need to make and then this environmentally and all I have shown.

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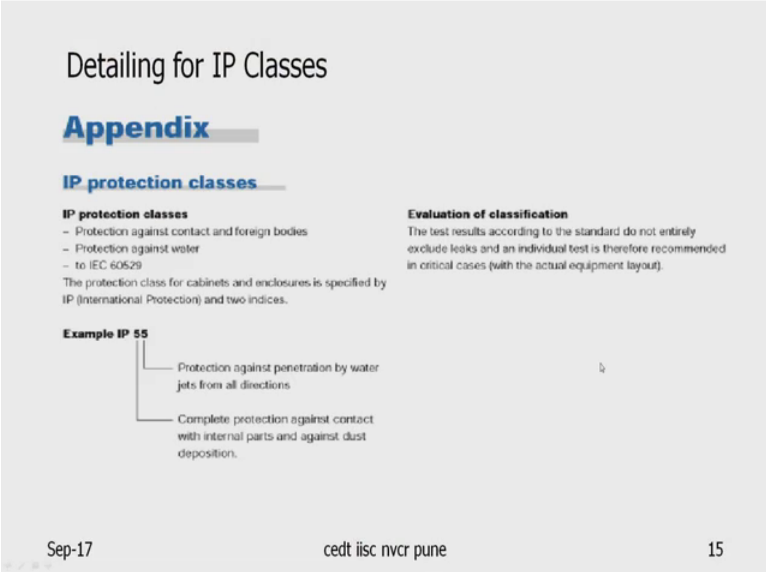

So, I will now skip go back demonstrations; today I have shown you this; this is a drive we make our best interest to see that we put a heat spreader to make sure that this is maintained around 50 degrees centigrade. Only when around 50 or 60 degree centigrade, we can take away the heat to the spreader.

So, typically this heat spreaders will be like this; no problem about it, I have here a small experiment you know that one you show me this.

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I have an experiment which I wanted to zoom it out; which I wanted to conduct to see how do things reach a steady state; this is a thermocol box which was you know actually it has come from some biological thing. At the bottom inside, what you have is a plate and this plate uses a heating element; a PTC what you call thermistor element, mounted on a some; one type of an aluminum sheet with spacers and all that.

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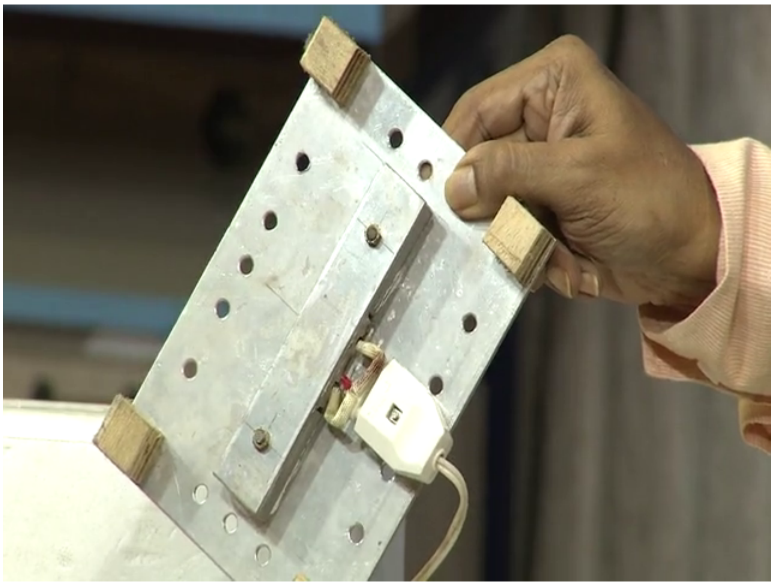

This is the same thing which is used in our mosquito coils; you have that small mosquito pad, there its written 7 watts. And then I am sure you would have seen it also; if we take a that mosquito pad and put it on that it feels a little hot. But then by using a insulating mechanism; in this case it is a an expanded PS form polystyrene expanded polystyrene form; otherwise we know it is thermocol.

And then insulating it and leaving it here after around 1 or 2 hours, you will notice that it gets hot really hot; you cannot touch its 70 or 80 degrees. So, I will get back to you later when the time comes and then part of this is; this small instrumentation, this instrumentation typically is something which we will show you the temperature at a contact point.

If the word subjective makes some sense probably; they should this is a huge thermal mass; there by the time I touch something already the temperature would have changed. Which I am sure in your physics and or anything if you are the curious, you would have found out how come a block of steel feels cold and a block of wood does not feel cold.

We are at the same temperature that both the steel and the wood also feels its ambient; let us say the ambient has a reduced to 15 degree centigrade and our body is normally skin temperature around 35 degrees; inside is 37; this thing a 15 degree steel block feels cold and a 15 degree wood block no looks not cold or anything. I am sure you like guess the answer, it is a lot to do heat about the very very local heat. The moment you touch the what you call wood thing; it is already attained the temperature of pure thing; on the surface it will be 35 only..

And if you touch the steel thing; steel continues to be at 15 and if you touch it this strip becomes maybe 20 or 25 degrees your thing; there is a small error which is exactly why instead of just depending on this usually in very critical applications, they build the sensors also in to be other things.

Now, as we go on this let me show you this device which we have made.

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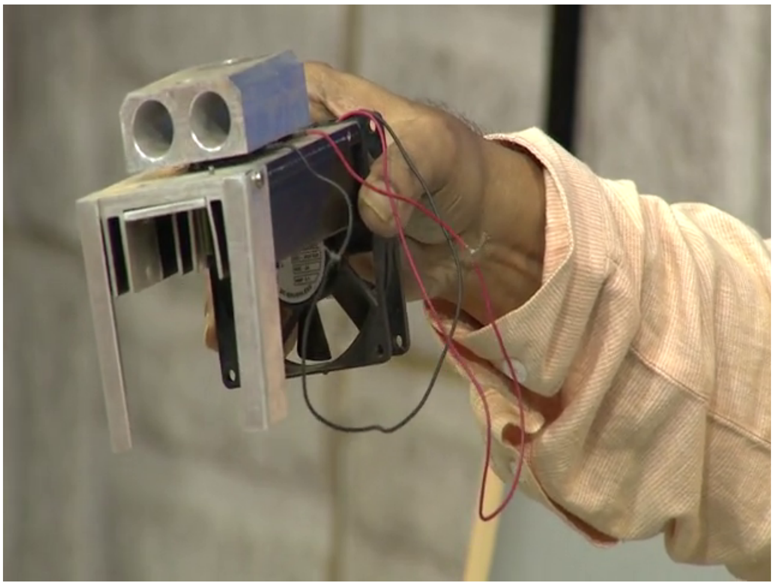

I am sure somebody would I went right to play with it; this uses the now suddenly you know once in a while suddenly people discover that we have a peltier cooler like that it has a peltier cooler. Something which they forget or I am sorry something which needs a due attention is peltier cooler is not an absolute cooler, it just maintains attempts to maintain a temperature between two surfaces.

In this case, we have an aluminum heat spreader and here we have a contact block. It was made specifically for a biomedical application; in this we keep two what you call ampules of some sample and we need to maintain the sample like various temperatures; it was part of some what you call sensor instrumentation for biomedical applications, typically the effect of various types of biological things typically antibiotics on curing some sample.

So, the sample is kept there it is collected from a human body some scientifically urine sample, which when it comes out as I said know it may be some 36 degrees centigrade; quickly it is shield and kept back in a temperature, we want to see the rate of activity. And then afterwards, it is again incubated back at 37 degrees and then one is a control thing, the other is not a control the actual thing, we add the concentration of medicine in it and then we are able to find out the action specifically.

If I have a urinary tract infection and if I give a sample and if you can put it in that; you can easily find out what is the ideal concentration and what is the frequency; where I need slow releaser what you say dosage and all that which is there; which instantly saves lives. The focus of it is the peltier cooler; peltier cooler has advantage the we can heat, it as well as cool it and rapidly.

But everything depends on the rate of heating and secondly, which most of us will tend to forget; this surface here is expected to be cooled, this surface here is expected to be warm. And you cannot afford to have a short circuit, the moment you have a short circuit any amount of putting your current here will not help at all. So, this whole thing has been made so, should it as a cap which we close the cap or in critical applications; we also use polyurethane forming arrangement.

The moment you cool it and then we have a small opening and then if you put a sample and this mass has been calculated critically; saying quickly within given mass of the what you call liquid; typically which has specific it a one and we have this aluminium block and all that; the moment you keep all this we know the rate at which we can heat or cool the device; the issue is you need to insulate it. It works only when it is insulated, these are all well known things as to how to mount something and how to attach it to this and all that which is used for temperature things.

So, what starts as a reasonably simple; what you call calculation we need to again remember two or three things. One is physical process have not changed, we do not know creation or what you call by evolution it exists natures vacuum exists, natures rules exists; we have absolute 0, then we have 5000-6000 degree (Refer Time: 27:06) and then we have flux; all these that natural things. Our understanding of it you know seems to be moving a little up and down and all the more that is why when I point out; I suggest you check I am sure several people say may call heat sinks black; first of all its not a heat sink, secondly, making it black will not make any difference.

And in fact, the issue is that epsilon or heat transfer coefficient in radiation that does not depend on the color. Especially in the case of aluminum whether you use what you call white or gold or black, it is typically around 0.88 no changing over it. Now we can go and check on the internet; what is the epsilon for various types of materials; very very carefully they have tried to formulate certain materials slightly. But it is not a ordinary application, you need to what you call it is a surface make everything and then slightly you know you can improve another thing..

But whether a naturally anodized and sealed gray color aluminum material or if you anodize it black; color of the paint which is to the human eye does not make any difference. This understanding is new means maybe lasts around 50 years back; so, we have physical process just allow me to go here and you know do a little bit of let me take it here.

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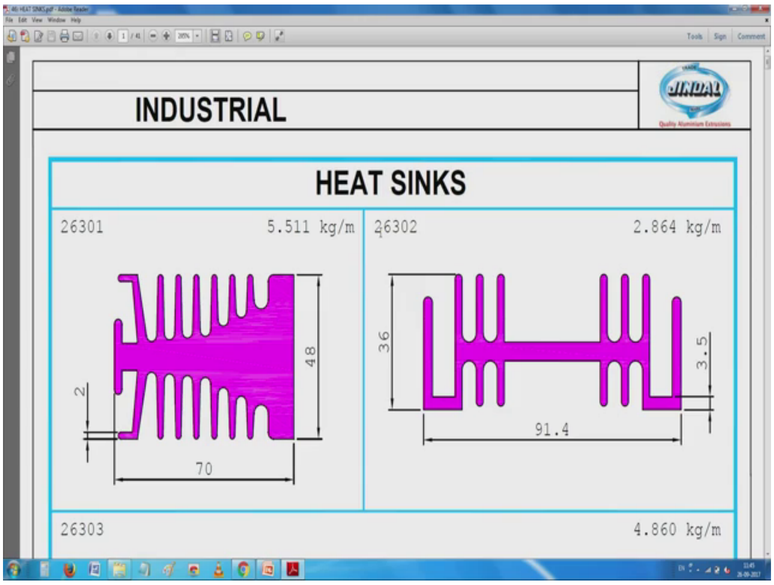

We have several commercial you know these heat sinks and things nonstop, you will see something very peculiar about it. You see the device which is on the left side this is a 26301; this is supposed to be a diode heat sink. One of the two things you will notice is at the base where is attached a thick. So, does the mass help or not yes it does help here; in the case to the best way, this heat spreader works is if the fins; all the surfaces are maintained at the highest possible temperature, which depends a lot on how well the heat is conducted to this and how well the heat is taken away from this..

If you are to take this right side one mounted small device here; you will see that towards the end in the end they already; it has become very cold. And then if we go to the fin tip, you will notice that a not much of temperature differential exists between the tip and the ambient; as such it will not be able to maintain the heat transfer rate which we are looking for.

Typically, things like this are meant for one type of thing where one side you have a device to be mounted like the drive what I have shown you; it comes in long lengths. And this time this thing is slightly different these two limbs are used for mounting and this is cooled by natural convection on both the directions you have seen that know.

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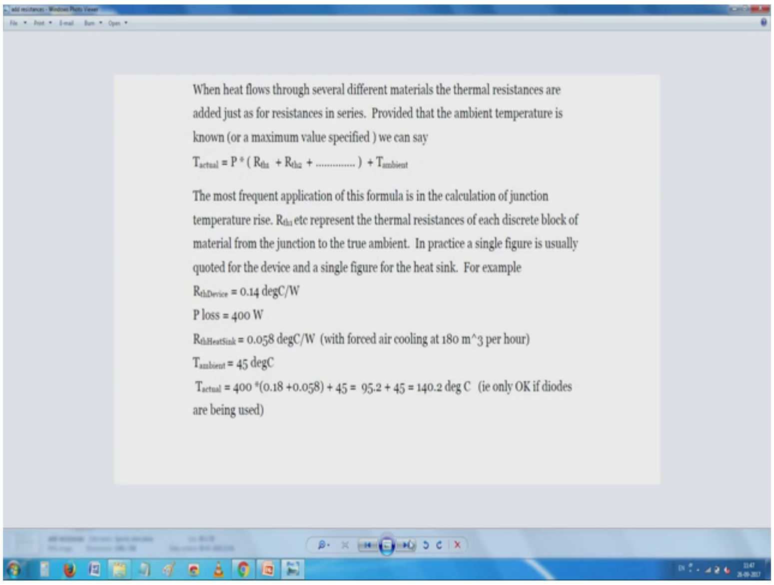

We slowly get into this idea of how to calculate or how to work on a gross thermal resistance which we need to have.

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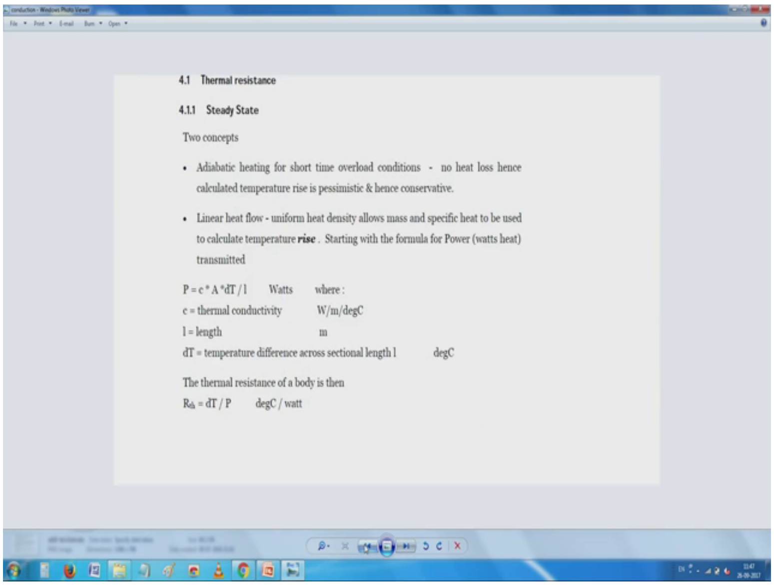

So, right now my suggestion is right now I will take a small break here. So, far we have started please go to your what you call if you have a browser and if you have a reasonably first connection; I am not saying you need the type of connection we have here which is 300 or 400 mbps, even we have something around 2 mbps and just give a search go to YouTube; give a search on heat and mass transfer. I will see whether I can get a YouTube heat and mass transfer; first of all I need to check whether I have YouTube; I have they have not disconnected it.

It even works then I go here and say NPTEL heat transfer.

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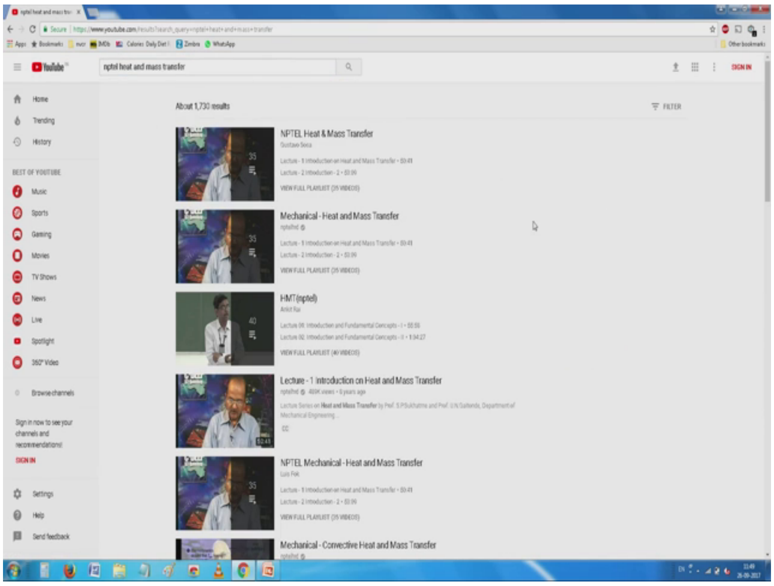

Have you noticed it gives 1730 results; so, I am not the first one even on our courses several of them there. I feel you should go back and at your leisure try to see which one of them is likely to make sense to you.

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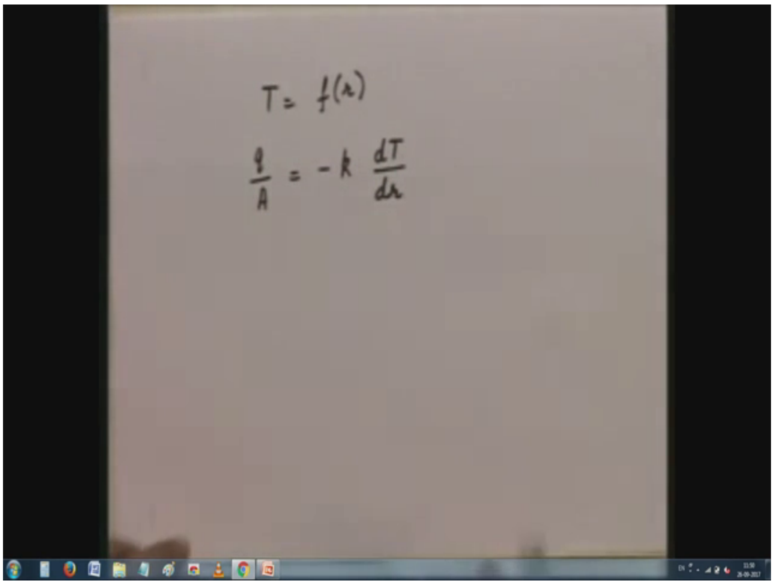

So, it your leisure kindly go through any one of these things which you know they you fancy. And whatever I wanted to talk as I said this is not the first time that has been done; it has been done, done and again and again like this. The only difference being their analytical methods and then there are tools for you given a configuration, very much possible for us to estimate actually in a very very complicated case like this; we have a small conviction here, we have a mass and then this is likely to lose heat. So, on this you know we have a cap which is probably made with polyurethane foam.

The other side, we have this heat spreader which it goes to the heat spreader again you know this the surface is hot; without it being hot, it cannot it transfer anything and then we expect the surface to be cold. So, this whole thing it is possible for us to very much to model it; as if this complication is not sufficient here; for good effect we have added a fan also here. So, first cooling then we have something which people dread at the Renaults number. And I am sure Renaults friends like Prandtl and all that you know 4 of them Nusselt and all the people also joined and you have more numbers then what you want to deal with.

So, you see a complex model like this we have heat what you call a mass transfer on top of it. Then we have a heat spreader in which you see these fins are thin; by definition they are not ideally suited for this site of mass transferred like thing; how does it matter? Yes in this case it make sense because it is cheap; this is available for nothing.

If you want to make an optimized thing you do not; you know you cannot do it with it its used in the case of space and all that you know this big heavy thing probably if you optimize it; probably can be made in my guesses one third to one sixth of the weight for the given flux here. For the given flux even this is over designed, all you need is probably a small tube like thing and a small really tiny fan and this is where all the theory helps alert which goes on here.

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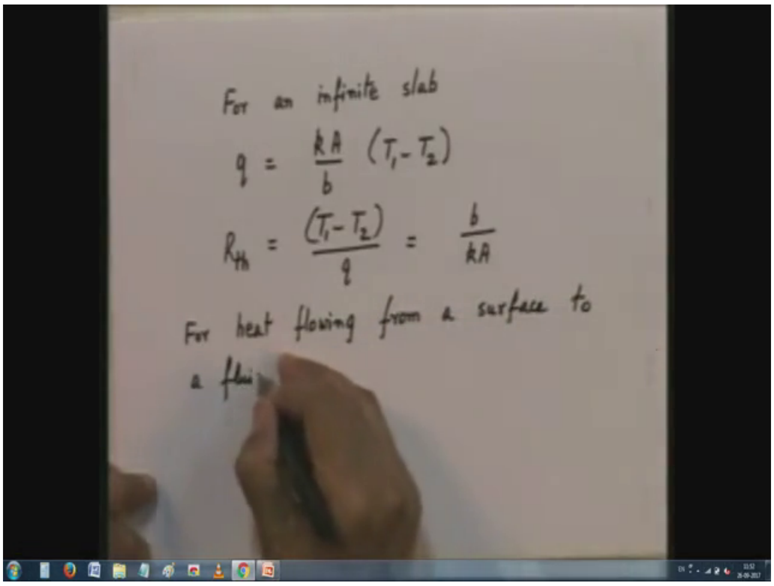

So, you see here that if you go here; you have seen this; I will be probably repeating a few of these things here, but at your leisure know I suggest you kindly also now read up these things upfront and come back and then you will not be disappointed about it.

You see here nice, beautiful, very threatening equations are there.

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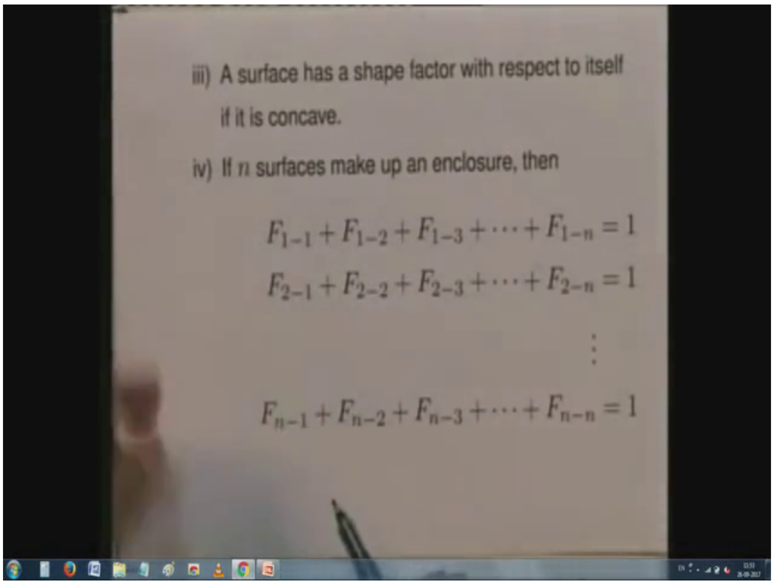

However, the radiation constrained epsilon is only one of the things here; you see here a surfaces the shape factors because it is concave..

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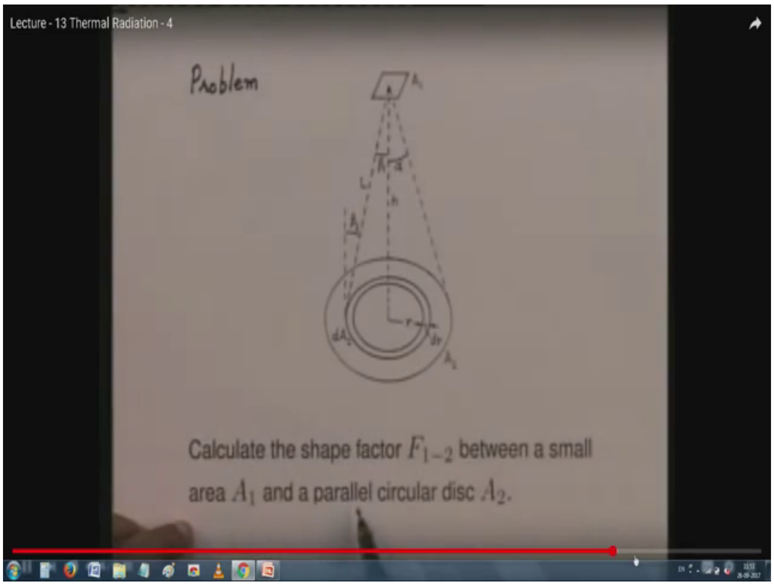

Then we have all this you know beautiful what you call a non threatening I am sure where the people are there in a small area, in the parallel circular disk right from various things like this are have all been dealt already.

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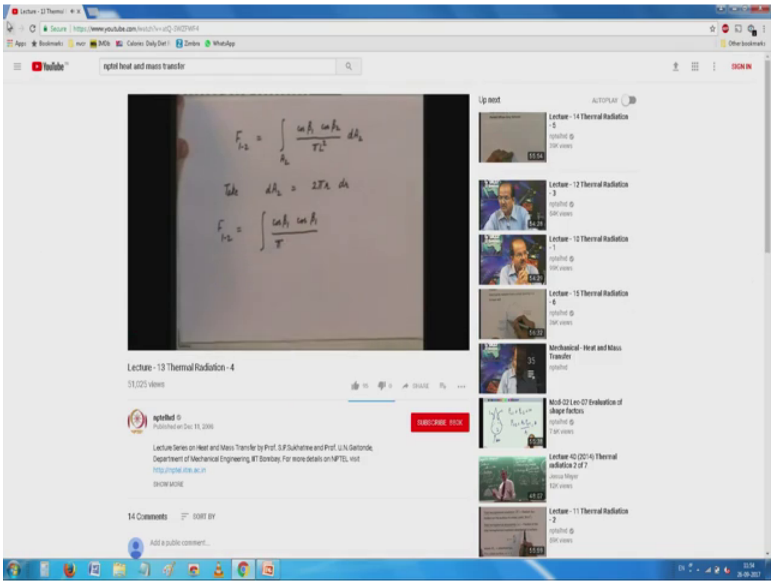

So, I am not the first and one thing have you noticed here everything has been simplified such that the very complicated problem can be made into a smaller problem; in spite of the best software that you have and all these things, still every instance is a unique instance. So, I have shown you that what you call covered thing which I wanted to do; kindly go through these links and see what best will help you.

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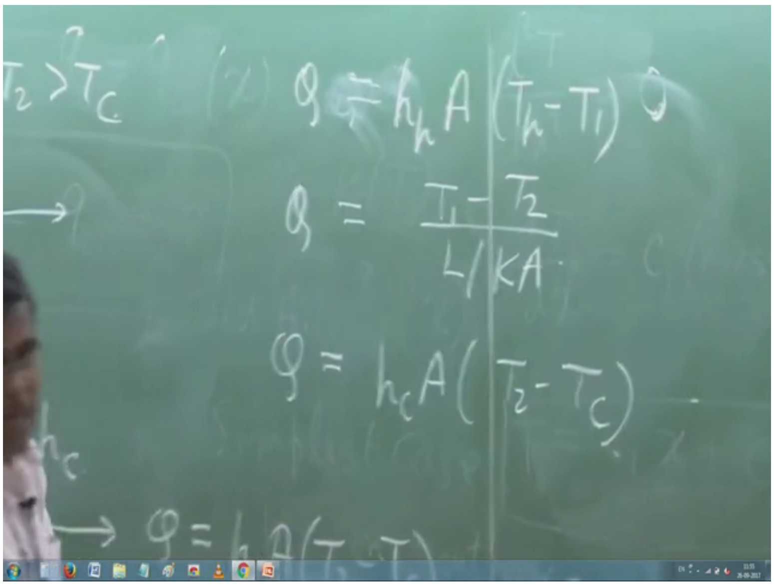

I have seen that very very critical things have been put L by K and Q and all are constant that is about the same; there is no variation at all. And then the thermal gradient also is constant; there is no problem about it at all. The problem is our if you take a gross problem, how do you simplify it such that in case you have a surface which is generating heat, in case a surface does not generate heat; these are all this symbol. Then have you seen in the small thing this; one h c coefficient in conduction or in that case you know in the thing.

How well let you deal with it and then you also have a transfer coefficient in convection; how do you deal with these things? This is where mix of both theory and then a mix of practical things and then finally, a gross combined thermal resistance. We usually use the word thetas; so when you buy a commercial heat sink directly that the sales person gives you or the manufacturer know they already give you.

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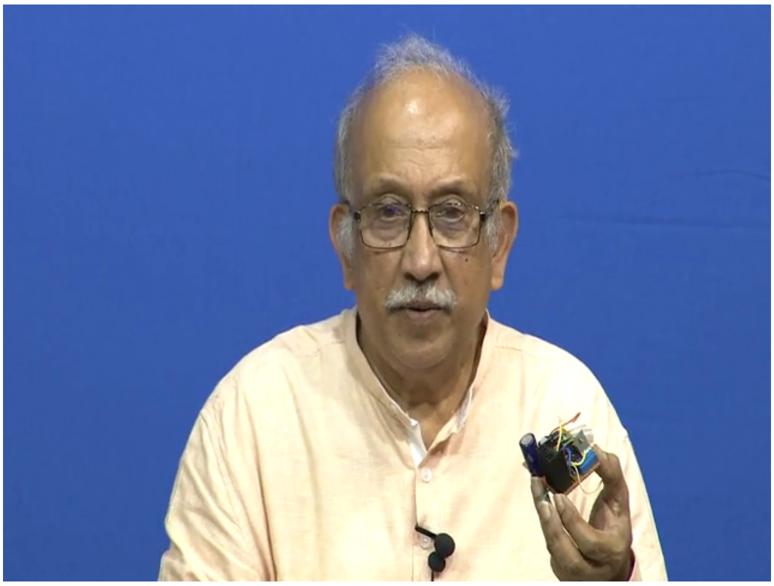

Given these conditions the ambient to the heat sink; what you call heat transfer coefficient is typically in this case you know it may be around 20 degree centigrade per watt; small heat sink total mass is small area is available and then you need to decide now you take a device and then you mount it how well it works here.

This is invariably you know the starting point of most design. So, you have a physical model which you need to do and then you can use simple instrumentation like this. And then we want to further improve on this you know maybe you can put a sleeve and all that, touch it wherever you want I have done this; right now it is a little bit dirty, but I can even take the sublingual temperature with this; it is initially very accurate.

And generally they have made sufficient accuracy such that this tip know; can take I mean there is in fact, a dam like thing inside it dammed ensures that this heat is not transferred to the tip and the tip is really accurate. I think at this point; I will take a break and then so, that the whole lecture can be condensed into a manageable thing so.

Thank you.