INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Convective Heat Transfer

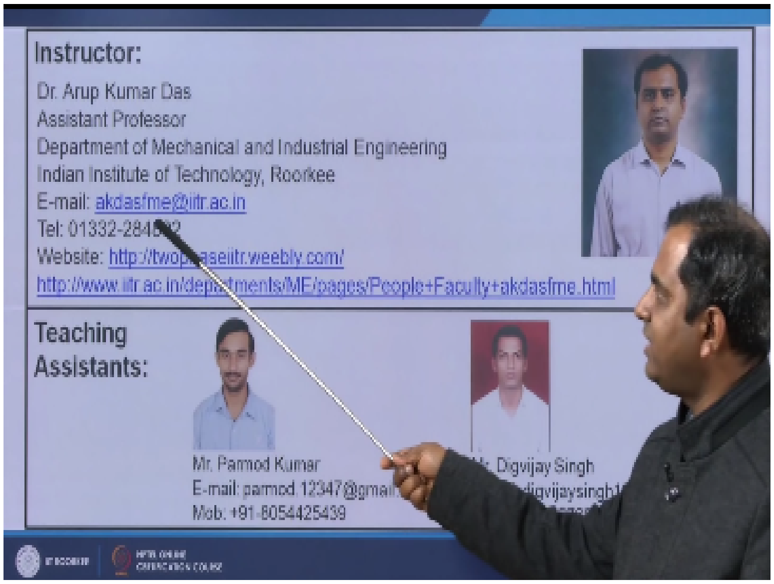
Lec-01
Introduction

Dr. Arup Kumar Das
Department of Mechanical and Industrial Engineering
Indian Institute of technology Roorkee

Hello welcoming the first lecture of my course convective heat transfer, in this course basically we will be discussing about what things we are going to study okay, and what different or terminologies we are going to use throughout this course. Obviously at the beginning I will tell you that, what is the necessary books okay for understanding this course okay. So to begin with I have named this lecture as introduction lecture okay.

So in this lecture first I will be introducing myself, so I am actually Dr. Arup Kumar Das okay, I am assistant professor in the department of mechanical and industrial engineering of Indian Institute of technology Roorkee okay.

(Refer Slide Time: 01:11)

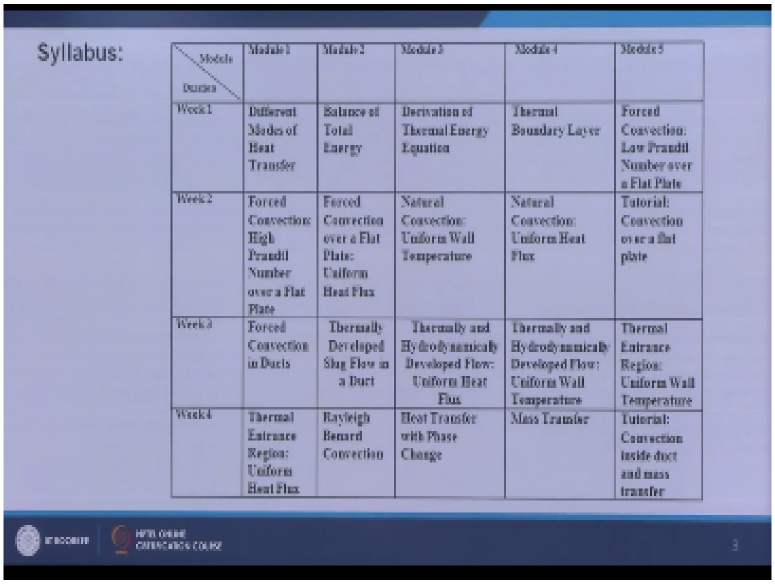


So you can note down my E-mail id: akdasfme@iitr.ac.in and you can also note down my telephone number, if you have any query or doubt you can always post me E-mail or you can contact me by this telephone number okay. You can also go through my web pages for better knowing that what type of research work at present time doing, this is a very nice and interactive web page what I am having to face iitr in weebly.com okay.

As well as you can also visit my iitr official web page, so this goes like this okay. In this course I will be having two teaching assistants, they will be basically communicating with you Mr. Parmod Kumar okay, and Mr. Digvijay Singh. So you may please note down their E-mail ids okay and their telephone numbers okay respectively okay. So if you have any query or any doubt definitely there is discussion forum for this course, but in a certain cases you may also contact them okay.

So with this introduction little brief introduction let me first tell you that what things we are targeting in the course. So I will be showing you the syllabus what we will be covering. As you know this course is for 10 actually hours, so we have distributed this 10 hours in 20 lectures okay, more or less all the lectures are having length of 30 minutes okay +- 30 minutes. So you see we are having actually 10 hours that means 4 week course, so the week I have distributed like this.

(Refer Slide Time: 02:57)



So week 1, week 2, week 3 and week 4 and each week I will be giving you 5 modules okay module 1 to module 5, so all together we will be having 20 modules okay so as I am doing over here in the first module we will be discussing about introduction and then I will be giving you idea of different modes of heat transfer okay. Then immediately in the next lecture I will be discussing that how energy can be balanced as it is convective heat transfer, so energy is very important.

So I will be showing you how energy balance can be done and what is the governing equation for energy conservation okay. Then in the next lecture that means week 1 module 3, I will be showing you that how energy equation can be written in different form especially Cp form, CV form all these specific heat forms we will be showing you okay. Then in this week only we will be giving you idea of thermal boundary layer okay.

So this is nothing but flow over a flat plate if it happens and the plate if it is having higher temperature compared to or some other temperature compared to frosting temperature whatever flow is coming, then we will be having a concept of boundary layer development just like your hydro economic boundary layer, this boundary layer will be calling from the boundary here and this we will be discussing in module 4.

In this week last module we will be keeping for force convection okay, so we will be having some predominant flow over the flat plate, so we will be having forced conviction and in this case, in this lecture we will be discussing about extreme limit of low prandtl number okay.

Immediately in the next lecture that means week 2, module 1 we will be discussing about high prandtl number extent. So these two will be more or less discussing same phenomenon, but discussing two different extents okay.

Then we will be going for another analogous case which is uniform heat flocks of the plate. In these two cases we will be actually having constant temperature, but here we will be having uniform heat flux, okay supplied by the plate okay so this case will be reversing over here than in second week we will be briefly seeing that what is natural convection and we will be seeing two different extends of natural convection uniform wall temperature and uniform heat flux okay at the end of this week we will be doing some tutorials on convection over a flat plat okay we will be going for some science.

In medical science okay which will be covering all this lectures over her okay then in week 3 we will be moving towards few inside a channel okay so internal flow situation so if pervious things works flow on a flat met external flow here we will be seeing forced convection inside ducts internal flow okay.

Then in that week only we will continuing thermally developed slug flow so we will be discussing what is slug flow and what is thermal development okay so thermally developed slug flow will seen okay in second module of 3rd week in 3rd module we will be seeing thermally and hydro dynamically both developed flow okay but we will be considering first uniform heat flux case in module 3 and in module 4 we will seeing uniform wall temperature case.

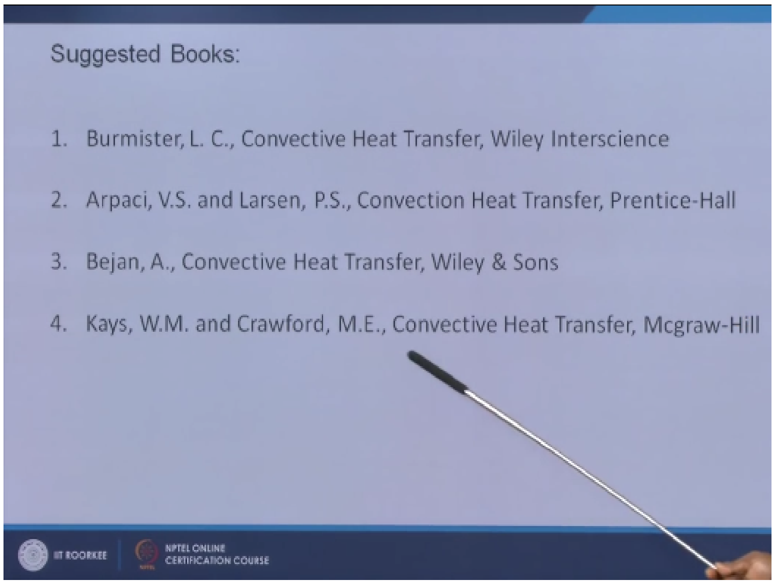
So at the end of this week that means week 3 in module 5 we will see another extend which is called thermal entrance region, so this actually the beginning section of the duct okay for convective heat transfer so we will defining what is n terms region and then we will be knowing that what will be the governing equations and different non dimensional numbers for uniform wall temperature case okay.

Last week at the beginning we will be continuing and we will be seeing the same case thermal entrance region for uniform heat flux case okay, in this week in the second module we will be seeing a special type of combination called Rayleigh Benard convection in this we will be seeing that whenever we are having two parallel plate in between that how convection sales from and then how that can be seen using governing equation okay and boundary condition susceptive and then we will be seeing 2 special cases related 2 convection only 1st is heat transfer with phases change.

So I will be showing how phase change can be linked up convection phases change means it will be only boiling and convection in other cases convection will be not be that much involved okay so we will be seeing boiling and convection cases over here and then we will be seeing the mass transfer which is more or less over convective heat transfer and this will be very much related to your chemical engineering students okay and then at the end of this lecture we will be doing once again some tutorials and in this tutorial will be specially concentrating on convection inside a duct and some problem on mass transfer okay.

So with this I will be ending up this course okay every week we will getting some assignments okay which we need to submit towards and at the end of 4th week we will having one examination if you want to get certificate you have to appear for the examination okay so let me go inside so before going to the topic let me tell you what are the book you can follow.

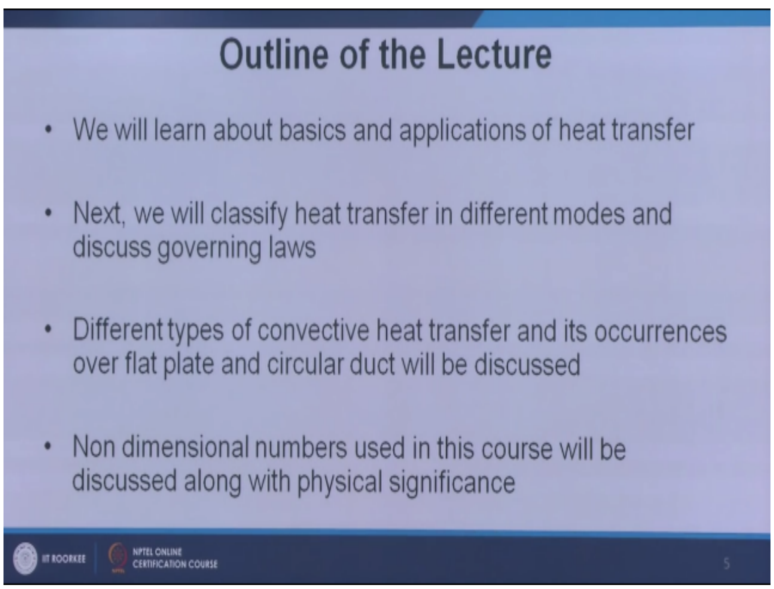
(Refer Slide Time: 08:44)



If necessary so very good they are called Burmister or L.C Burmister the title of the book is convective heat transfer published by Wiley interscience publisher we are having some more books this is also very good by Arpaci and Larsen okay V.S Arpaci and P.S Larsen the title of the book is once again convective heat transfer this is available with Prentice and Hall okay Prentice Hall publisher then this book is also very good by Bejan, the convective heat transfer publisher is Wiley & Sons okay.

Even you can refer Kays, and Crawford, W.M Kays and M.E Crawford once again the title is convective heat transfer and this is available with Mcgraw hill okay Mcgraw Hill publisher so all these books are very nice if you want you can suggest these books also along with this course okay.

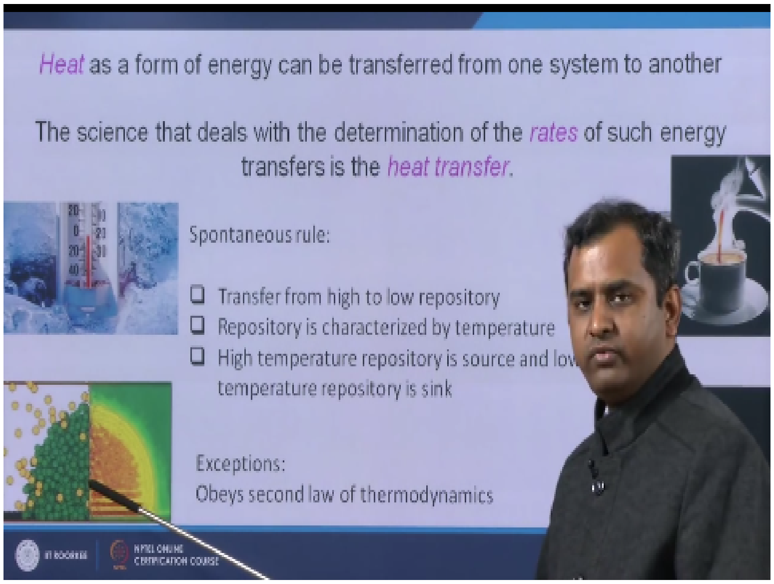
(Refer Slide Time: 09:30)



Let me go to outline what we are going to discuss in this lecture we will learn about basics and applications of heat transfer and as we are beginning the course so we have to learn the very preliminary basics and applications then we will be going for classification of heat transfer and no different modes okay as well as we will discuss about the governing laws.

Okay then we will be seeing what are the different types of convective heat transfer available and its occurrence over flat plate and circular duct okay because first 9 lectures will be having this flat and then rest lectures will be having one circular duct so this two cases we understand in this lecture and then finally I would getting you non dimensional numbers which will be important for convective heat transfer I will also telling the physical significance of those numbers right.

(Refer Slide Time: 10:30)



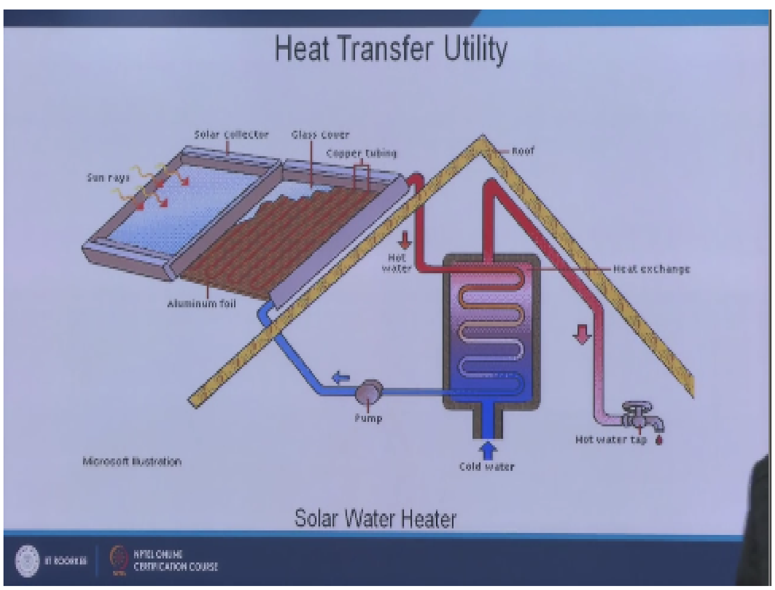
So let us go inside so first let me tell you what is heat. Heat is nothing but it is actually for morph energy which can be transferred from system to another system okay so this is actually energy nothing but energy okay now the science which deals with the intermediation of rates of such energy be transferred is called actually heat transfer okay so if you are having energy transfer to cater that one or two more that energy be transferred we are having the subject called heat transfer here I have shown to extends of you know heat so here you can see very hot objects of fire or a cup of tea.

You can see the vapor coming out I mean the other side you can see the ice okay having certain less than 0^0 centigrade temperature okay so we are having some spontaneous rule for transfer of heat from one side to another side so that rule is always heat transfers spontaneously from high to low repository where your having high hest repository to loading heat repository heat will be transferring spontaneously then repository is actually characterized what called temperature which is coming in thermodynamics.

We have learned already and then high temperature repository is called source and low temperature repository it is called actually sink so it is our spontaneously what heat transfer follows now there are exceptions also so if you are having exceptions those who called different heat transfer devices so in both devices you have to obey certain law of thermodynamics so in your thermodynamics knowledge you know what is second law of thermodynamics and you have already learned.

That how heat transfer can be revaluated using second law of thermodynamics here I have shown some molecular structure of vapor and you know liquid over here you can see these molecules are very much compact but here molecules are flying here so here you can have higher temperature okay to have this adaptations and here we are having low temperature to I have the compactness okay so temperature difference or convection actually determines whatever features will be there so this subject we will also discussing about phase same solution be important in now whatever we have shown over here these are related to single phase things only okay so phase change cal also come with convection right.

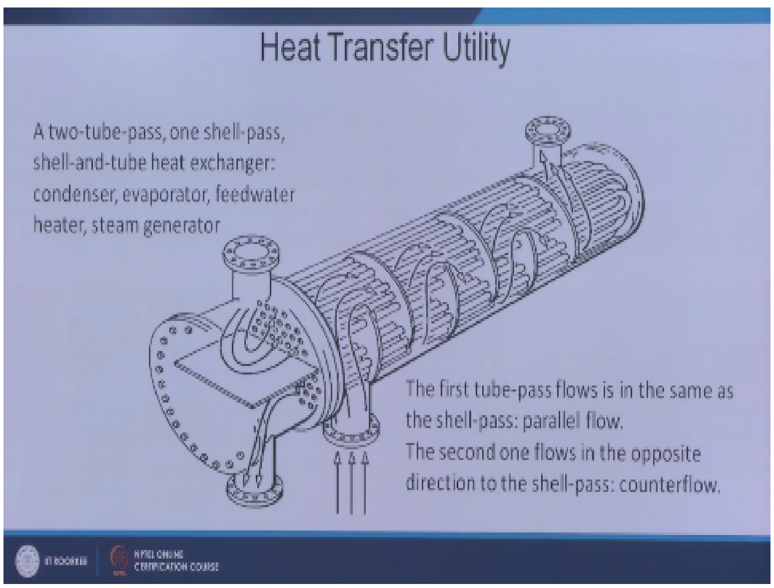
(Refer Slide Time: 12:52)



Next will be shoeing some utility there are multiple utility but here I have named few to said my time so first utility what I am saying is solar water heater so you have seen let say this is the roof of a house and the roof you can have this type of solar connector and from there solar ray whenever it comes over here so heat actually comes in this in the copper tube carrying hot water and this is the manifold which actually gather solid water and then it can supply hot water for different purposes for example you know hot water pot can be there, there can be hot water heat exchanger.

Through heat the room will become hot and finally this pump can one second give back the cold water after heat transfer give back that cold water to the solar chamber one second so here you see the whole phenomenon is given by heat transfer here also heat is being transferred here also if the heat is being transferred and one second when your heat has gone back it is one second really for and new heat transfer stages okay so solar water heater vapor for example for heat transfer utility.

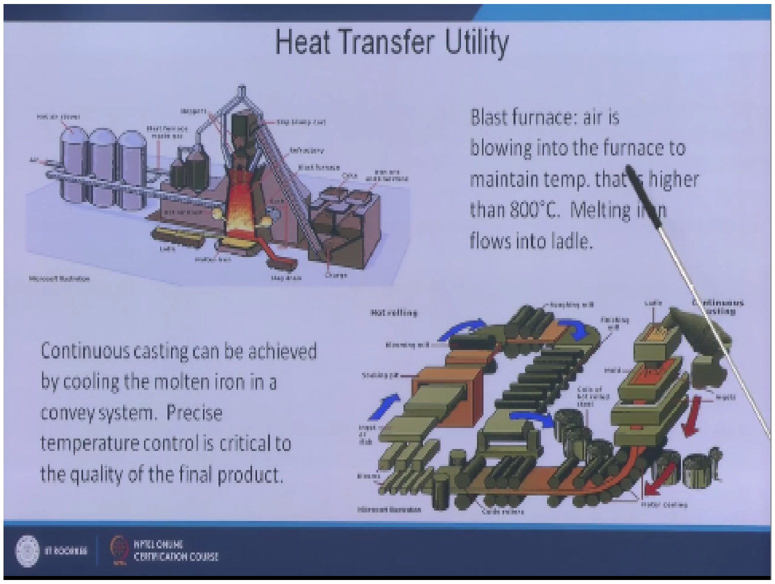
(Refer Slide Time: 14:06)



Next a tube a two tube pass one shell pass shell and tube heat exchanger so heat exchangers are devices where exchange of heat from one phase to another phase we deal so there obviously heat transfer will be important some devices we call condenser evaporator and these are they are in air-conditioning refrigeration units even you can find out condenser in your power plants in power plant we can also have feed water heater and steam generators of boilers so all these are actually heat transfer utility okay.

So here I have shown a schematic of schematic of measure to heat exchanger you can see all these tubes and we are having flow of another feed wire this inlet and exit over here to have some short of heat exchange between the fluids so okay.

(Refer Slide Time: 14:55)

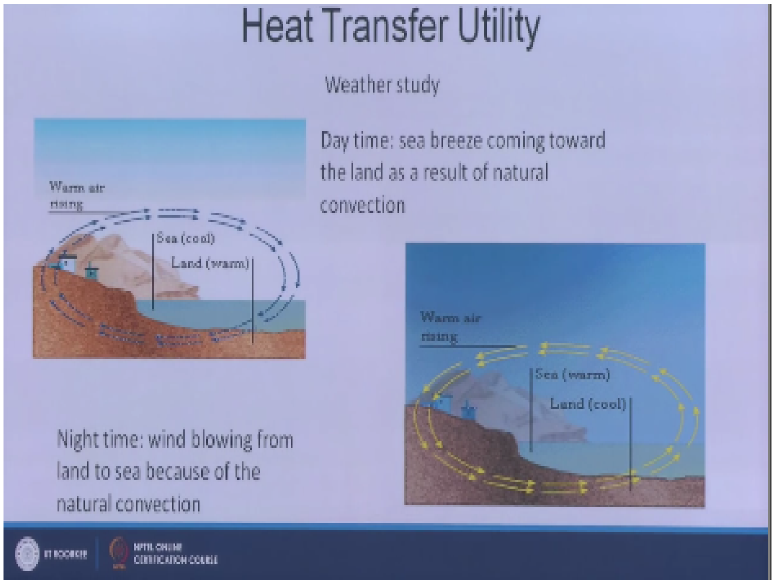


Next another one I can say is these this figures you can see this is nothing but a blast furnace okay where air is blowing into the furnace to maintain temperature that is higher than 800^0C okay so it is actually required for melting iron okay so here you can see iron is being melted and it is flowing into the ladle okay so it is flowing into the ladle for you know casting somewhere else okay.

So this blast furnace is perfect example of heat transfer utility, now as we have talked about this ladle which is being carried out and that will be used for actually casting later on so casting is nothing but giving form of your desired shape okay in manufacturing it will be very, very important so this is actually example of a continuous casting machine, so continuous casting can be achieved by cooling the molten metal.

Whatever you have melted over here that you cool and give some desired shape okay in a conveyor system okay so précised temperature contrail is critical for the quality of the final product, so here also heat transfers takes a major role okay.

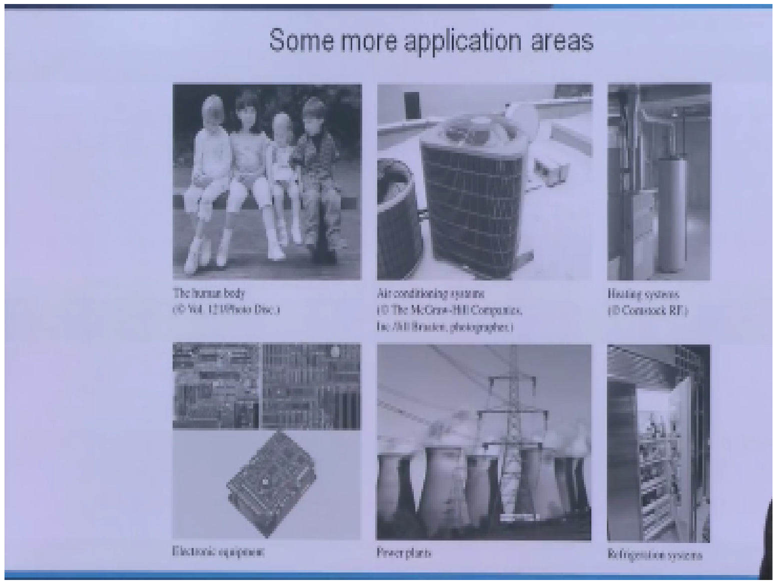
(Refer Slide Time: 16:03)



Apart from this in our art we can have weather study so you see all of your aware that during day time sea breeze comes okay towards the land okay so sea breeze whatever you are having that comes toward the land and as a result this is actually result of natural conviction okay so this happens between natural conviction and at night time the wind blows from the land to sea okay so this just reverses from the land to sea, it actually blows okay.

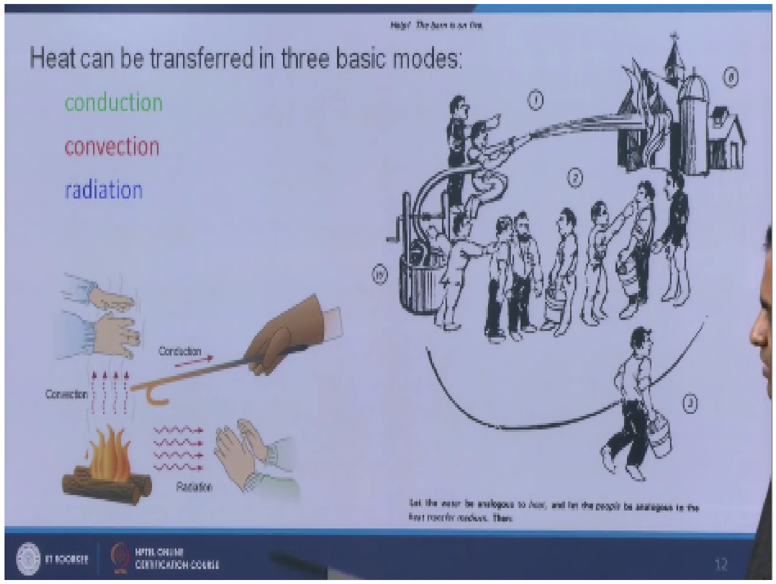
That is also sue to natural conviction so here also you can see our weather changes by the virtue of the heat transfers so this is also a perfected example of heat transfer utility, apart from this there are various other examples I am not mentioning all even our human body is having you know.

(Refer Slide Time: 16:57)



May heat transfer utility air conditioning system definitely heating system whatever we use in cold countries electronic component cooling so all this laptops and PC’s and cameras and smart phones all are having this heat transfer in equipments over like this we are having power generations so power plants and refrigerator systems definitely is having concept of heat transfer okay. Apart from this there are many more.

(Refer Slide Time: 17:26)



So it is very interesting subject to learn heat transfer so first let me show you that what are the modes of heat transfer basically we are having three different modes, modes are conduction, conviction and radiation okay, first I have given small example of a heat transfer let us say this is fire if heat or heat source if you try to take the heat via A iron rod okay and you touch the rod over here then you can see that this side of the rod is very having very high temperature and it is very low temperature.

Through the solid the heat will transfer which is nothing but actually conduction and if the heat is being transferred via air okay so there is predominant motion of the medium okay to transfer the heat from the high temperature to low temperature size so that is conviction, on the other hands if heat come is significant amount of this times without disturbing the medium that is actually called radiation.

For radiation medium will not be involved okay so this heat can be observed from a very distance but here for conviction you have to keep a certain distance so that heat can be taken from high temperature to low temperature, to explain this one I have given a small story over here that here let us say here we are having a house which is burning okay so it is burning so we have to extinguish the fire so here we are having some water well let us say okay so in this well we are having water so my task is to throw the water or take the water to extinguish the fire in the house okay so you can call that this is actually high temperature source this is low temperature source so we need a transfer of water or heat okay analogs to heat from high temperature to low temperature.

Now let us see different modes over here so what the invades of this house can do they can take a bucket first they can take a bucket and then they need the bucket they can pick up water from the well and they can run okay like this person how he is doing he can run and then go to the house and then throw the water to extinguish the fire so this is the first mode where the person is running okay.

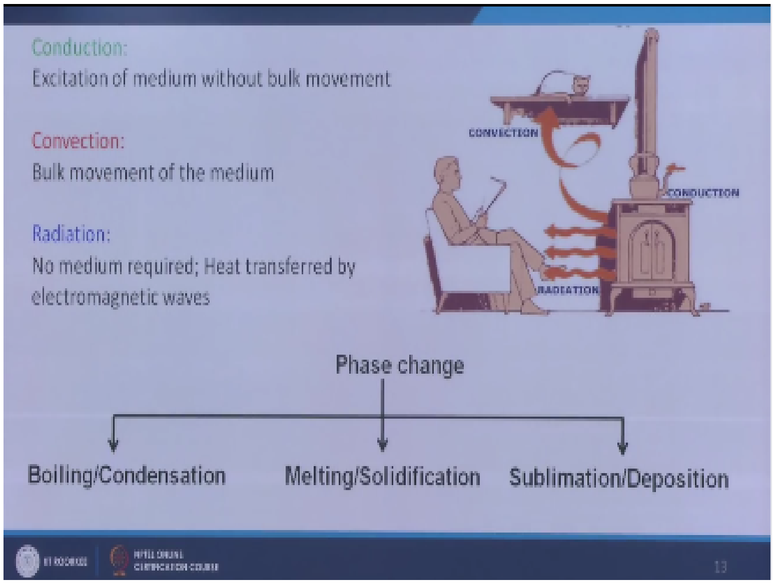
The distance between the wall and the house okay and then here another well is there let us say all the next they form an invention like this okay starting from the well to the house and the bucket is being filled up by the nearest person to the well and he is after filling the bucket he is actually transferring to the next person, next person is transferring to the next person like this the bucket is reaching.

So the human chain to the person nearest to the house and he is actually responsible for throwing the water to the house, so here you can see the persons are not moving the bucket is actually shifting from one person to another person, okay so though predominant motion of the persons are note there, okay.

And third one you see they have actually you take in hose okay, let us say they are fire extinguisher company they have take any hose and without movement what they have done they use some mechanism pumps or something like that they have thrown the water to the house, okay taking water from the well, and now if you consider this three cases of no transfer of water from the well to house you can find out this is having predominant motion the person is actually doing some predominant motion.

So this is actually comparable to your convection which we are going to study in this course, okay. Here you can see only the persons are taking the bucket and passing to the next person which is along goes to your conduction so there is no predominant motion of the medium and here the medium is no longer required okay, but choose of some other mechanism which is pumping the water they are actually trying to extinguish the fire so this is analogous to your radiation, okay. So all three modes I have shown you using this example, okay.

(Refer Slide Time: 21:24)

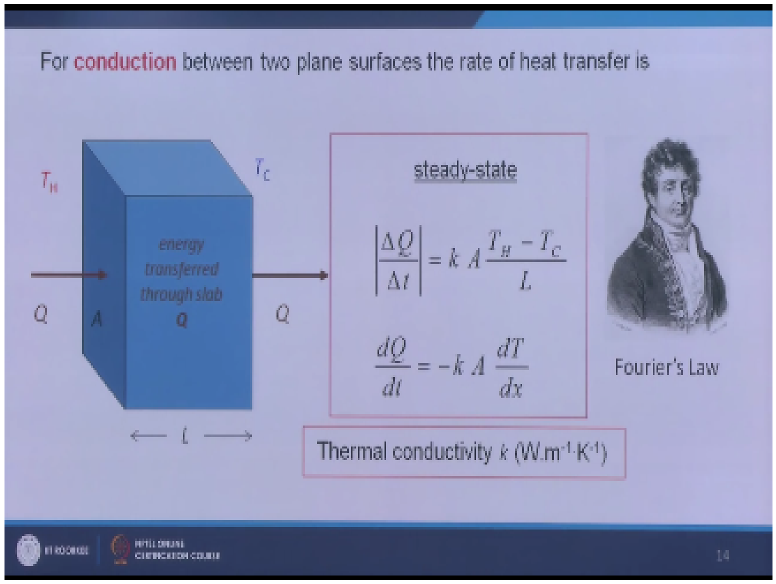


Next as I have to tell definitely about conduction, convection and radiation so conduction is excitation of medium without bulb movement, okay so here you can see it is actually fire pot over that you are having a kittle so heat is being transferred from a fire pot to the kittle via solid okay, without the bulb movement so this is actually perfect example of conduction. Convection bulb movement of medium will be necessary this is actually via convection this person is getting via convection, okay so air is moving like this and the cat is getting via convection.

It cannot see the fire but via the air it is getting the convection, okay. On the other hand no medium is required for heat transfer via radiation if they can see each other no, medium is required the person can directly take the heat from the fire, okay. So these three modes once again can be explained from this small fire pot example. Apart from this three mediums of heat transfer we are having phase change also.

These are all single phase heat transfer modes in phase change we can have boiling condensation for gas liquid domain, melting solidification for liquid solid domain and sublimation deposition for gas solid domain, okay. So convection our interest is actually lying in this zone where gas and liquid is being involve so boiling and condensation, some convection you can also see in this two moments but I mean duty of the times the convections are in the lighter phase so we will not be study this thing in detail we will be concentrating on this one, okay.

(Refer Slide Time: 23:02)



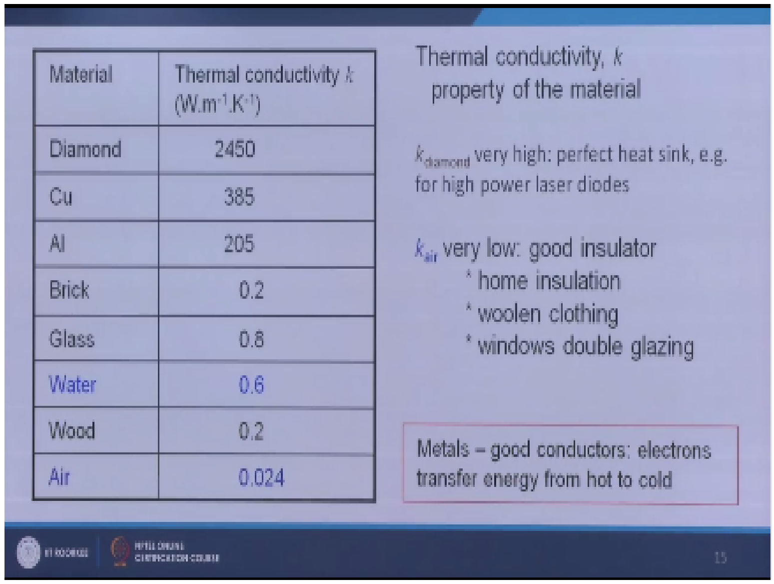
Next let us go one by one in different modes, first mode is conduction so in conduction what happens let us say we are having two planes okay, so let us say this is one plane and on the opposite side there is another plane having temperature T_H and T_C now as it is high temperature this is low temperature so spontaneously heat will transfer from high temperature side to low temperature side.

So we can write down this Q or heat transfer Q though this slab is actually proportional to T_H-T_C so which is nothing but actually my temperature change between the planes T_H-T_C so if T_H-T_C increases then definitely heat transfer will be increasing. We have also found out that if this length of gap between the, if the gap between the plates decreases then definitely heat transfer rate will be increasing so L is actually inversely proportional to $\Delta Q/\Delta t$ heat transfer rate.

As soon as if the area increases, now this is the surface area of the plates okay, both the plates are having same surface are in this example. If this A increases then definitely we will be finding out it transfer rate increases so we get that $\Delta Q/\Delta t$ heat transfer with respect to time is proportional to A proportional T_H-T_C and proportional to 1/L and we give the constant here over here as k, k we call as thermal conductivity.

The unit of thermal conductivity is W/mK okay, so this famous law has been given by Fourier so that is why we call this law as Fourier's Law, okay.

(Refer Slide Time: 24:42)

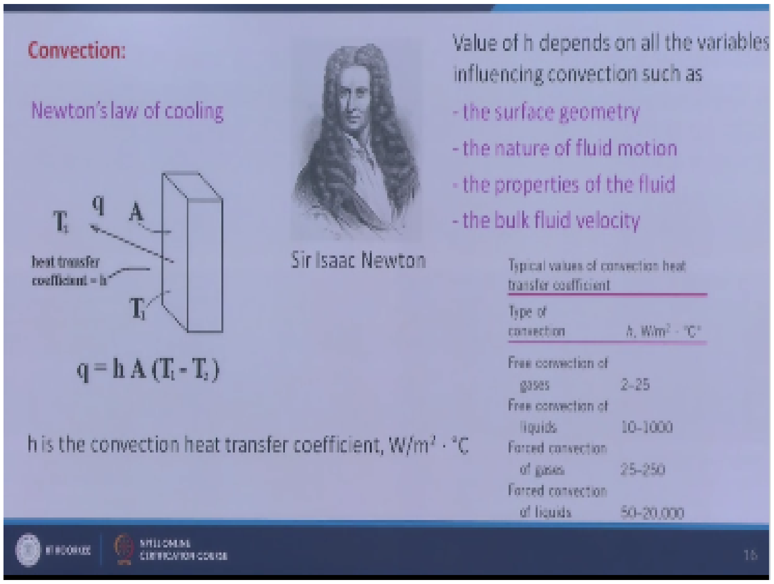


Material	Thermal conductivity k ($W.m^{-1}.K^{-1}$)
Diamond	2450
Cu	385
Al	205
Brick	0.2
Glass	0.8
Water	0.6
Wood	0.2
Air	0.024

Next if we try to find out what is the thermal conductivity so this is actually a property of material diamond is having very high thermal conductivity whereas k is having very low thermal conductivity, so air can be used for different insulation purpose okay, as well as we can have different woolen clothing which is having low thermal conductivities okay for windows glazing we can use air for having low thermal conductivity and it can act as very good insulator some values of thermal conductivities I have mention in this table you can see air is having very low 0.024 thermal conductivity okay.

Whereas diamond is having very high 2450 okay so metals are actually good conductors and electron transfer energy from hot to cold okay so actually the in conduction the electrons actually become cogitated and transfer from one molecule to another molecule, so this becomes important electron transfer become important for conduction mode.

(Refer Slide Time: 25:45)



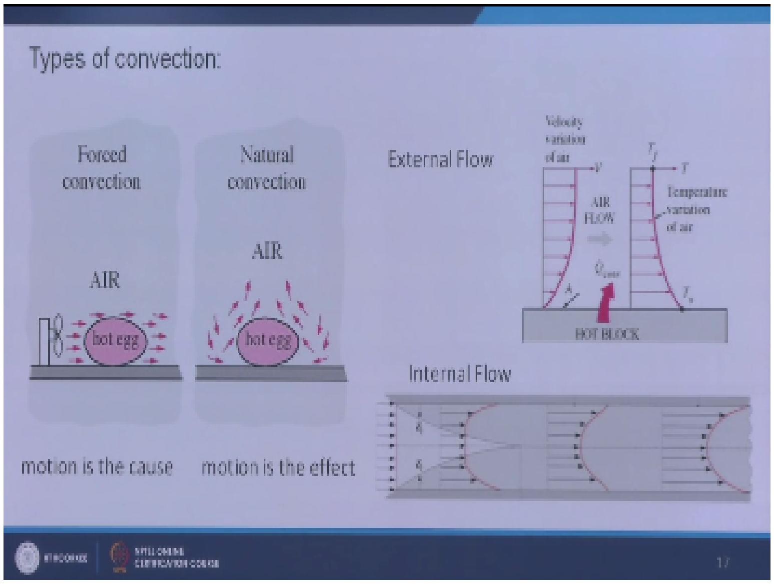
Let us see the next version which is very important for us convection so for this we will understand Newton's law of cooling, so Sir Isaac Newton has given this law so what he saying that if we are having a hot let say a block of temperature T1 and it is being open to fisting here of temperature T2 so he said that there the heat transfer from this hot block to the air so there which is having temperature T2 and that heat transfer will be actually propositional to T1 –T2 the temperature change between the block and the neighboring air okay.

So and also he has say the area would be very important if area increased then it transfer increases so he said q is propositional to a and q is propositional to T1 – T2 okay, and if you give the constant so that is that can be called as h and now we call this constant as convict heat transfer coefficient okay. So we will be doing detail discussion about convict heat transfer coefficient in this course.

The unit of convict heat transfer course heat transfer coefficient will be w/m^2 Kelvin or $w/m^{2\ 0}$ C some example of convict heat transfer coefficient I have given over here quickly I have introducing what is free convection what is forced convection so you can see for gases and for liquids convict heat transfer varies okay. Free convection for gases is having very low convict heat transfer coefficient whereas force convection for liquids is having very high convict heat transfer coefficient okay.

Force convection heat transfer coefficient definitely depends on the velocity of the fluid okay, so Reynolds number will be important okay. Now value of h is actually depends on what is the geometry of the surface what is nature of the fluid what is the property of the fluid and what is the velocity definitely okay, as I said velocity is important.

(Refer Slide Time: 27:41)



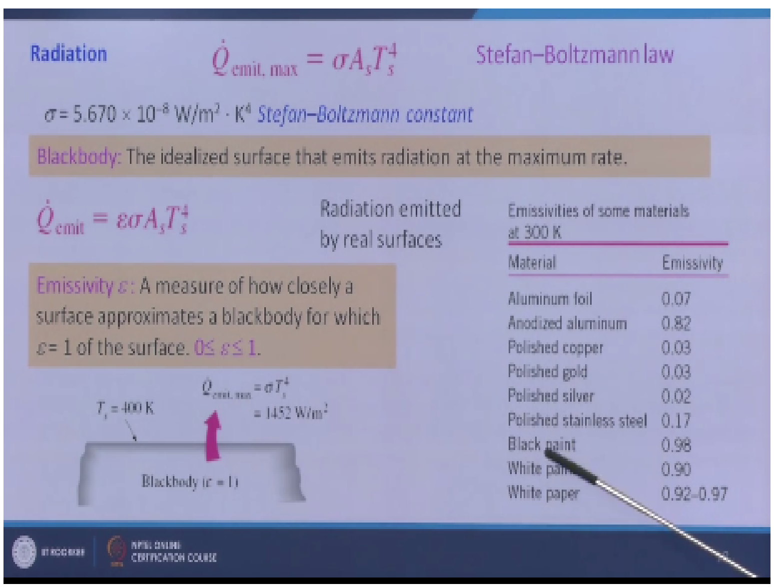
Next let us see what are the different types of the convection have a level I have sais this towards I have used forced convection and free convection or natural convection okay free or natural both are same so her you see if this is hot egg okay which we want to cool down by air flow so first case what we have done we have use the small fan to blow here on the hot egg, so here you can see the air is having some predominant motion which actually is being generated by the fan okay.

So this you can see motion is the cause over here which is cause in the convection so this is actually forced convection situation on the other hand if you just keep the hot water in normal air then you can find out the air will be taking the heat of the egg and it will move up and subsequently higher density here will be coming in the contact with the hot egg. So this type of cells convection cells will be generated always this type of convection cells will be always generated which will be taking the heat and this mode is actually called natural convection okay.

Here the motion of this air is actually the effect okay effect of heat transfer here the motion is actually causing the heat transfer okay so this is basic difference between forced convection and natural convection and in this course we will be also seeing internal flow and external flow internal flow is nothing but flow inside a duct the duct can be a pipe the duct can be a rectangular pipe or something like that some other cross section and in external flow is whenever there is some flow over air open plat so let us say this is a plat fixed like this on the fresh steam and here you have some velocity okay.

From fluid mechanics you know there will be one velocity boundary a velocity boundary and velocity profile will be like this only here also you can see in case of internal flow there will be parabolic velocity profile in case of energy thermal energy or in case of convection you will be finding out to have temperature profile like this we will be detailed I will be having detailed discussion of this one in new due of time and here internal flow will be having the temperature profile like this and finally the temperature profile will come like that okay.

So some terminal these are involved call thermal in terms length and so on with internal flow we will be discussing in this course okay, so after introduction of these different types of convection
(Refer Slide Time: 30:10)



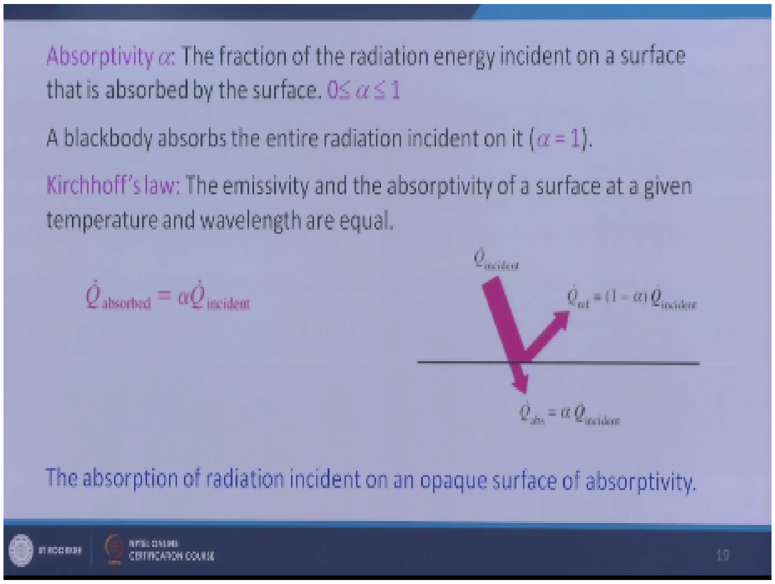
Let us see what radiation of third mode is. In case of radiation actually it has been proposed by Stefan Boltzmann that is why it is called Stefan Boltzmann law. They proposed that emit heat transfer from a hot body is nothing but proportional to surface area of the body and portioned to the forth power of the temperature of the body.

Okay he has proposed the Q is proportional to A and Q is portioned to T^4. So once you give the constant that is called actually Stefan Boltzmann constant the value of σ can be found out has

5.670 x 10^{-8} W/m^2. Okay usually we call black body in case it is the idealized surface. Okay this emits radiation at the maximum rate.

So if we think about black body there are some blackbody sun is the perfect example for that it emits the maximum. Okay so the real surfaces which are not the blackbody we can find out some fraction of this maximum possible emission will be obtain. So keep this coefficient which is nothing but the emissivity. The value Emissivity is in-between 0 and 1. If it is 1 then it becomes the black body. So if we get then it becomes 1 and this equation converts into this one. Okay here I have given some example if the body is having 400 K temperature becomes σ value from here it becomes 1452 W/m^2.
So here you see that Q. and Q. so this actually par unit area. Okay so area I have considered 1 over here. Okay here you have to temperature in K so next some emissivity is 0 and 1. I have mentioned different material starting from aluminum foil and white paper. White paper is having very good emissivity. Okay so almost near to black body. So we can see this way that paint is also having very good emissivity.

(Refer Slide Time: 32:42)

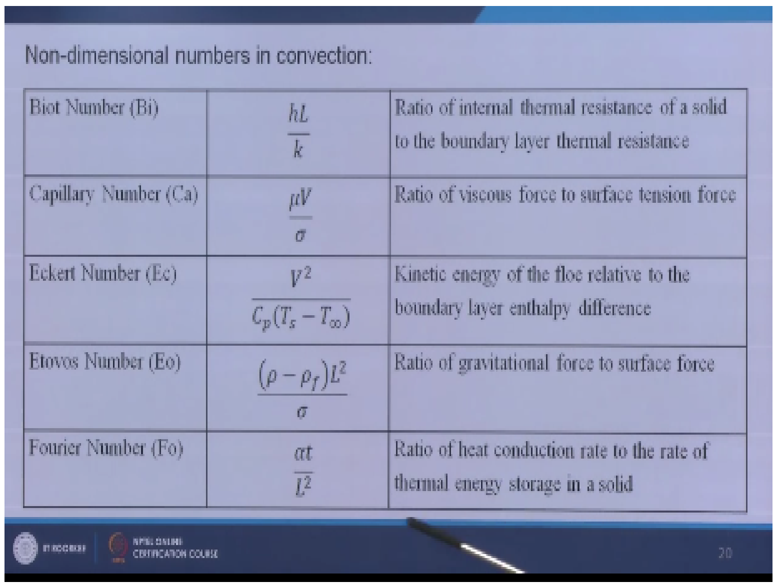


Then another factor is also there which is called absorptivity it can absorb also emissions. So the fraction of the radiation energy incident on a surface that is absorbed by the surface. So whatever is coming on the surface how much fraction is occurred by the surface is called the absorptive.

The value will be once again between 0 and 1. Perfect black body actually absorbs everything so it is having the Absorptivity = 1.

Okay so these two are the absorptivity which is given by the Kirchhoff law. So the law is the emissivity and the absorptive of a given surface at a given temperature and they are wavelength is equal. So here I have given you some idea that how emission has been absorbed and rest has been reflected. So similarly there is reflective is nothing but α.

(Refer Slide Time: 33:59)

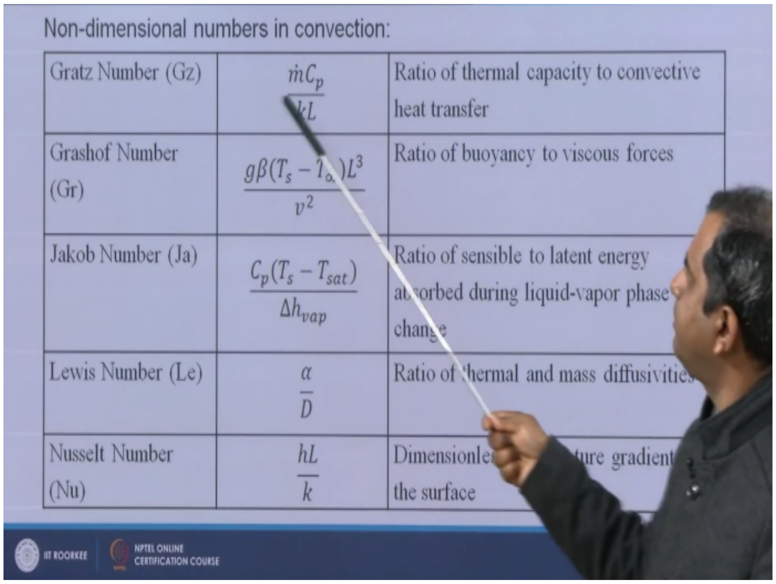


Biot Number (Bi)	$\frac{hL}{k}$	Ratio of internal thermal resistance of a solid to the boundary layer thermal resistance
Capillary Number (Ca)	$\frac{\mu V}{\sigma}$	Ratio of viscous force to surface tension force
Eckert Number (Ec)	$\frac{V^2}{C_p(T_s - T_\infty)}$	Kinetic energy of the floe relative to the boundary layer enthalpy difference
Etovos Number (Eo)	$\frac{(\rho - \rho_f)L^2}{\sigma}$	Ratio of gravitational force to surface force
Fourier Number (Fo)	$\frac{\alpha t}{L^2}$	Ratio of heat conduction rate to the rate of thermal energy storage in a solid

So let us see number which we will be reading in this course in our conviction coarse. First one is bio number this is nothing but ratio of internal thermal resistance of a solid to the boundary layer thermal resistance. Then the capillary number ratio of viscous force to surface tension force. Eckert number is nothing but v^2/cp(ts-t) kinetic energy of the flow.

The flow energy is relative to the boundary layer enthalpy difference. Etovos number is nothing but gravitational force to surface force. Fourier number is nothing but ratio of conduction heat rate of thermal energy storage in a solid that is Fourier number.

(Refer Slide Time: 34:54)

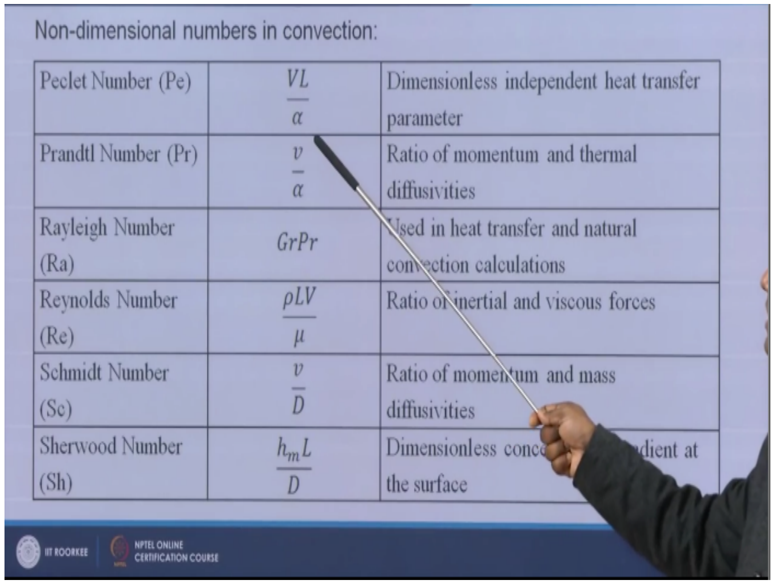


Next we are having Gratz number is nothing but the thermal capacity to convective heat transfer m.Cp/kL Gratz of number are important Gratz number will be important for the national convection gabs the infinite is the a temperature gradient in to the hot surface and the ambient in the delta LQ/D^2 ok the ratio between, the and the discuss force and the number cp x delta P and the dig so the latent in the which vapor in to the latent heat.

So thaw sensible in the it absorb the liquid face change so that face change processes so the use number will be the mass transfer by the d and the mass diffused ratio ability and the normal diffuse ability there assent number will be the very important and the convection hl /k dimension and the temperature and the gradient the surface okay this is having similarly with the bio number and the following here and for the fluid we are having the parley number.

.

(Refer Slide Time: 36:59)



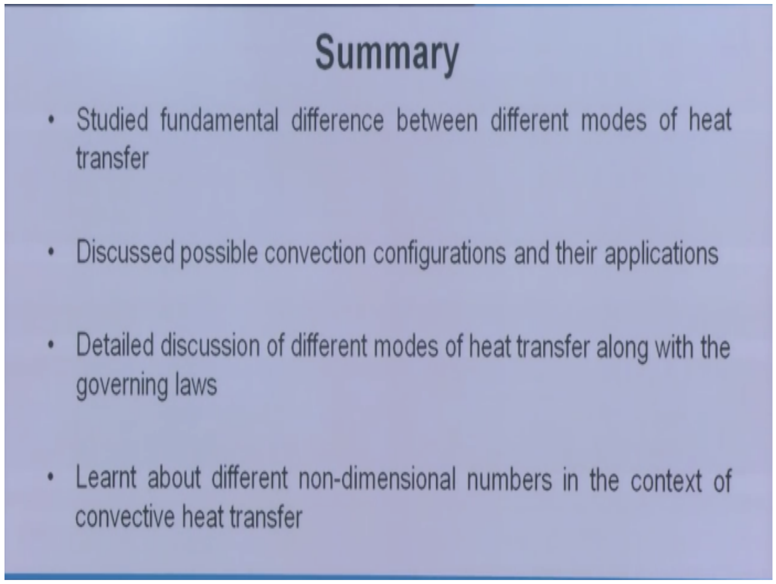
Non-dimensional numbers in convection:

Peclet Number (Pe)	$\frac{VL}{\alpha}$	Dimensionless independent heat transfer parameter
Prandtl Number (Pr)	$\frac{\nu}{\alpha}$	Ratio of momentum and thermal diffusivities
Rayleigh Number (Ra)	$GrPr$	Used in heat transfer and natural convection calculations
Reynolds Number (Re)	$\frac{\rho LV}{\mu}$	Ratio of inertial and viscous forces
Schmidt Number (Sc)	$\frac{\nu}{D}$	Ratio of momentum and mass diffusivities
Sherwood Number (Sh)	$\frac{h_m L}{D}$	Dimensionless conc… dient at the surface

And the ά and the independent and the heat transfer parameter so okay and then we are having partial number and the paternal number will be the ratio of thermal diffusebility and the rally number is an important for a your natural convection and the partial number so this is once again used for natural convection and the remolds number is already is soon fluid mechanism.

So this is moment of inertia and the ratio the speed number will be the important and the∑ for the initially number for the mass transfer v/d is the mass transfer the ratio between the moment of ratio and the mass diffuseblities and the schedule number is nothing but and the mass transfer and the l/d and the dimension constant and the gradient and the surface that is end this lecture and then summaries in this we are understood.

(Refer Slide Time: 36:51)



So are studied in the fundamental dependence for the most of its transfers we discussed possible convection configurations and their applications we have detailed this discussion different discussion the most heat transfers and the allover the laws and we have learned different knowledge the fundamental number in the context of configure in the heat transfer let me now try to taste to your understanding we have learned in this lecture so first we have three questions so we have here so first question .

So the following is not single phase mode of its heat transfer so you have to figure it the two phase heat for over hear so face treatment heat transfer for over here and the convection and the radiation and boiling so you know the boiling and the boiling is not applicable heat transfer so fill hears law of cooling intense law of motion and the stiffen law of motion that Newton laws of motion is written to the transfer the mechanics.

So it is the correct answer which one is not and the non dimensional number and the, but 8 g is the symbol of number so this is the correct number 8 g okay we will keep this we ending this lecture in our next lecture we will disusing about balance of total energy if you have the first lecture and the centralize lecture heat transfer and the posting in our discussion is thank you very much.

For Further Details Contact

Coordinator, Educational Technology Cell
Indian Institute of Technology Roorkee

Roorkee-247 667
E Mail: etcell.iitrke@gmail.com, etcell@iitr.ernet.in
Website: www.iitr.ac.in/centers/ETC, www.nptel.ac.in

Production Team
Sarath. K. V
Jithin. K
Pankaj Saini
Arun. S
Mohan Raj. S

Camera, Graphics, Online Editing & Post Production
Binoy. V. P

NPTEL Coordinator
Prof. B. K. Gandhi

An Eductaional Technology Cell
IIT Roorkee Production