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National programme on technology enhanced learning
Video lectures on convictive heat transfer

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Lecture 10
Couette flow- part 3

A sparkler cut by 2 y / l x 1 - y by that is what we have now if you plot y by L as the ABS ordinate t - T 0/ T 1 - T 0 as the abscissa pant layer cut becomes a parameter so if you currently occur to equal to 0 means there is no velocity of the plate so it is a static thing and then the heat transfer process is purely conduction and please at this point assume T 1 <T 0 for our discussion purposes T 1 < T 0.

So you will find when you plot this when plant will occurred apparently the fluid occurred equal to 0 there is heat transfer from top plate to the bottom plate because T 1 is higher than T 0 that you can easily make on that profile will tell you now as you now put in some value for pant leg cut starting greater than 0.5 1 point 5 2 3 4 5 6 something interesting is happening that is why I take up this problem I will just do my bit an go.

At promptly I cut equal to 2 rather I would say Brantley occurred greater than 2 there is something very interesting happening to the temperature profile now when you draw this temperature profile you will take the abscissas θ from 0 to 1 and of course Y / 0 to 1 so one would like to think that all the profiles would be within this 0 to 1 0 to 1 thing but when you go beyond partly cut equal to 2 suddenly you will see the temperature profile extending outside θ equal to 1 number 1.

Number 2 not only that when we say the top plate is at t 1 you know what it means it is held at T 1 it is artificially deliberately held so if there is some heat transfer into that you are taking away that heat to hold it that is what it means it would not go beyond that so T 1 is held constant the temperature profile is extended beyond 1 that means the temperature there is now higher than the temperature of the plate T1.

What it means is although you are holding the temperature T 1 greater than T 0 you are holding it at certain plant like heart number being at certain u 1 u 1 value the profile extends temperature profile extends beyond the θ 1 but you have to bring that profile back to that one point now you see the gradient has changed its direction originally the gradient was like this for partly account equal to zero gradually when you increase the Planck liquor did become a 2 it became vertical at y = L and when you went beyond pant leg cut equal to 2 the profile is changing that means the direction of the heat flow is changing.

So what does what does it mean although you are holding T 1 and T 2 constant deliberately T 1 being greater than T 0 and a value apparently cut equal to just beyond to heat has now started flowing into the top plate rather than from the top plate to the fluid that means there is a heat reversal has happened heat flow reversal has happened this is something now which is coming out because coming out of work flow because we took the viscous dissipation time into consideration do by DY^2.

We did not neglect it we said here do BI do BI divine may be important d by DX may be neglected D by DZ we all those we neglected when we have taken in situation the problem where DU by DY was PI is finite and it should be considered you find now a beyond certain value of u 1 heat is started flowing into the upper plate question or not this only if you plot you will understand.

Then you think what is happening to the physics of the problem now the answer is that some of this increasing velocity increasing a cart number in velocity has created has generated heat in the system that heat has caused the fluid temperature to rise that rise in fluid temperature beyond the t1 value is what is the cause of heat transfer into the t1 therefore increasing velocities are finally the root of this phenomenon of heat generation within the fluid and therefore heat transfer to the top plate this is happening this phenomenon of heat generation within the flow because of u1 is viscous dissipation.

Actually it is viscous heat dissipation viscous energy dissipation now this viscous disappear not simply kinetic energy was not simply u1 squared it's actually μ if you look at the inner energy term energy equation μ DU by DY^2 μ is always present so it is a combination of the viscosity and the velocity gradient so it depends upon what are the values of these two μ can be extremely high do by D Y can be very small viscous dissipation is important when is μ very high for oils so when there is an oil involved even small D u by D s can generate enough viscous dissipation on the other hand if you go to low viscosity fluid typically here is extremely small.

But your under those conditions if DU by DY is very large DU by DY^2 will be considerable so for low viscosity fluids high velocity gradients will cause viscous I mean there is heat generation and therefore heat transfer for high viscosity fluids even small Bay diems will lead to the same effect I am trying to make an important point here it is not simply viscosity that counts it is not simply to the velocity gradient it is a combination of these two which brings in a very important physical phenomenon into the system where heat has been generated.

When heat is generated it has to escape somewhere it tries to go towards the plates and that can happen only when the temperature of the fluid itself is very high higher than these two plates that is what you see when you plot this temperature profiles you can go up to 4 6 & 8 even time so viscous heat generation has now caused heat flow reversal at the top work no more if there is a heat the temperature prefer reversal there should be a maximum for that profile.

Please find out what the maximum temperature is this is all a case T 1 greater than T not only we are talking about what is the maximum temperature and at what location it occurs please find out no this is purely by plotting the profiles you can make on how else can you find out that there is a DT by DY equal to 0 at the top wall please look at the file can you find out by analysis what is the value of frankly I cut to equal to 2.

If you plot it you will know that but derive an expression for the value of prattler cut T equal to 2 when DT by DY is 0 at the 1 that is when the change of direction takes place so the temperature profile temperature profile is there TY differentiate that DT by DY at Y equal to L you put 0 and obtain Brantley occurred equal to 2 that is what I am telling you to do you can get it to the profile if you plot which you are not plotted but at least analytically find out from the T equation at what value apparently occurred is DT by DY equal to 0 3 or 4 steps.

Please obtain Brantley occurred equal to 2 as this critical number beyond which heat gets transferred into the top one although T 1 is greater than T 0 we emphasize this point simply because there is a mindset amongst all of us generally that as long as T 1 is greater than T 0 you should always flow the heat should always flow from T one to T 0 but what this problem tells you is no that is not right your mindset is not right there is what is called as a viscous dissipation it is possible it is possible for low viscosity fluids at high velocity gradients and high viscosity fluids at low velocity gradients heat is generated because of this viscous shear.

That shear Force which is depends upon the kinetic energy is converted into heat that heat is now trying to escape the if the temperature of the fluid goes beyond the T1 temperature of the top plate there is heat transfer them to the team and do not always look at the physical model and say T1 I mean heat transfer will be always from T1 to T0 that is what it says this is the effect of viscous dissipation importance of μ and DU by DY we always look at μ DU by DY not μ alone but DU / DU alone .

Please obtain that partly equal to 2r and look at equal to 2 also well does the Y maximum occur T maximum occur this again DT by DY at y 0 you have to find out where DT by DY becomes 0 and please obtain this I am really not going to write anything on the board I am a little unhappy with nothing being done by you, you are all intelligent people please do this yourself I will give the final.

Y max this is where the T max occurs in this case of T 1 greater than T 0 so take the temperature equation differentiated DT by DY and find out where this is equal to 0 that is the maximum point please obtain this following expression y maximum is equal to I am going to dictate wrote down if you are interested .

Y maximum is equal to K by μ UN^2 again and again this μ UN^2 K combination comes in all this problem u squared by 2 KK 2 KL μ UN^2 you can look at the term μ viscosity human spare kinetic energy Y max equal to K by μ UN^2 into T 1 - T 0 is the positive temperature difference plus y is this half plus half not plus half it should be plus L by 2 Y max equal to K by μ 1 square into T 1 - T 0 plus L by 2 I think L you should get and one thing we can check here.

If T 1 equal to T not equal temperatures where will the maximum occur so check that here from the solution if T 1 equal to t 0 my maximum will be L by 2 and find out what that temperature is okay do that now I will ask a question if T 1 equal to T 0 equal temperatures occur to equal to 0 there is no heat transfer at all it is the entire fluid body is at you know whatever equal template is at T 0 T 0 the moment you introduce the plate velocity and depending upon that now heat transfer comes into picture a non heat transfer problem in adiabatic problem you are converting into it is converting itself into a heat transfer problem simply because of the imposed flow that you have created or not use any pump an impulse flow because of the movement of the plate that you .

Have imposed actually so now there is a viscous generation that heats up the fluid only thing is it is doing it symmetrically because both the plates are at the same temperature the heat that is generated has to go in these two directions you will find a nice symmetric temperature profile y equal to 0 T equal to T 0 y equal to L also T equal to T not you can call it RTL but both of them are equal and there is a parabolic temperature profile with a maximum at L /2 find out what that maximum .

In I asked you to do this also for oils you will find this temperatures could be very high but area does not matter but this is taken for our lubrication problems T max is the most important physically significant thing coming towards from quiet flow in the case of lubrication films what would be the temperature of the oil film that will attain at various you 1 why is it important higher the temperature for liquids what happens with viscosity for liquids will it increase or decrease for a higher temperature.

Decrease that will destroy the lubrication characteristic of that particular so we want to keep the maximum temperatures within a certain limit therefore this comes in so you will find by looking at physical situations you should be able to formulate your own problem when you look at a heat transfer problem you should be able to identify whether it is conduction convection radiation what are therefore the important parameters coming into picture what is the physical model all that you have to do it is not simply that this is given as something very specific what it tells you what you should understand is you look at the heat transfer situation think about it write down the physical model and find out what are the parameters find out how heat is transferred and what variables control the heat transfer.

Now I have also asked you to look at to calculate heat transfer at the lower one what lower world upper one you have a temperature profile okay how do you write down a small expression for heat transfer at the lower world how do you calculate it from the temperature profile QW = - K at have you done that by = to zero now can you tell me therefore what is the final expression for Q at y = to zero is very important after all temperature differences are there thermal conductivity is L is there this I will give you three minutes to do this please.

I will just give you a hint QW or whatever is equal to K by L into you may what is there in the brackets K by n it should we have that of K DT by DX so K by L you take give me what you get in the brackets in terms of prandtl number Q at the bottom wall equal to K by L multiply by something in the brackets in terms of Branham yeah tell me K by L I have taken it outside the bracket in the brackets you tell me what is this simplified here there is no moral if I you have taken yell outside the bracket there will be no more L K by L has come out .Give me the thing in the bracket anybody else what is it okay.

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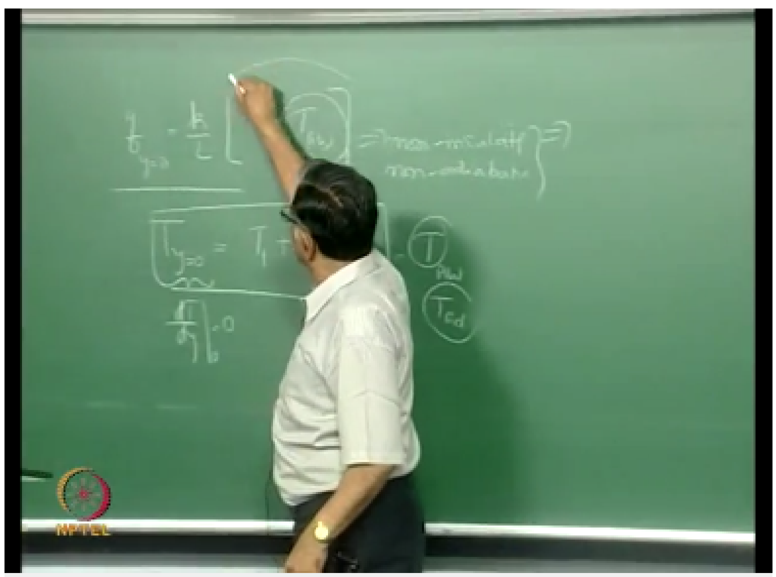

There are several ways of how you can put it can you please do this see whether you can put it in this form can you tell me here now what I can write then this is a simple conduction equation as you can see K by L T0 - T1 please see whether you can get this into this form side manipulation K by L you got it anybody has got it K by L now I hope you have got it .

Now look at this expression this is the QR bottom wall so there is usually one would think K by L into T 0 - T one but now we know that is possible only when a card number equal to zero so fine and if T 1 is greater than T 0 you will get a that directions you will get you know - and all that but you see from this expression the driving temperature difference when viscous dissipation exists is not simply T 0 - T 1 but it is T 0 - you take this together T 1 plus parentally 1 square by 2 C look at parentally u 1 square by 2 CP.

Obviously the units of that term must be temperature it has to be temperature so this is the heat flow at the bottom one mark it leave it we will go to the next step we will come back to this equation later so when T 1 is greater than T 0 both the plates are at some temperature control the heat flow at the bottom wall = K by L into T 0 - (T1 +) now take up the next problem now you have a quiet flow you have done this hopefully you have done is in your exam.

You have a quiet flow the bottom plate is insulated get me get me the temperature of the bottom one the insulated wall it has some temperature there is some temperature attained by the insulated wall what is the temperature again go to the same temperature equation is the same that this is now another thing you will learn here is temperature equation is the same different boundary conditions T 1 greater than T 0 T 1 equal to T 0 T 0 greater than T 1 DT by DX 0 at wall all these give will give you different information and of course answers but more than that information that you can call out of it.

One we have now seen that viscous dissipation is important beyond a certain partly cut and it has a tendency to make the heat reverse even though the temperature is high we have said that now it turns out the bottom wall you get you got it as K by L into T 0 - of T 1 plus Brantley 1 square by 2 CP keep it aside take a new case where the same quiet flow bottom proof bottom plate is insulated get me a simple expression for the temperature of the bottom.

Y = 0 DT by DY is 0 y equal to L T equal to t1 same the two boundary conditions two constants get me the temperature for the bottom one which is actually DT by DY at Y equal to C a very simple expression you got it tell me T at Y = zero is what yeah can you give it in terms of prattle number yes little man whenever you find μ and K you put a CP there make it into prime to divide the other thing by multiply divided by CP this is okay no problem it is permitted.

That should be easier for them yeah the temperature profile Y = 0 DT by DY is 0 Y equal to L T equal to T tell me if you are completed if you have made a mistake it does not a matter tell me this is okay tell me now anyone of you know start with the temperature term here T1 plus frontal not row now what is the problem you have taken a flow with y equal to 0 DT by DY = Z when I say DT by DY = 0 what is can you use a world to describe that surface it is a needed by Dy equal to 0 means what it is a adiabatic it is a insulated surface it is an adiabatic surface that means the temperature T y equal to what you have got is actually T adiabatic wall R T whatever.

So in an insulated condition you are know the temperature now please see it is always higher than t1 we did not specify the temperature as T 0 we specified insulated boundary condition then when you got it actually in terms of the other variables you found the way at y equal to 0 which we now call the adiabatic wall temperature not anybody can play anybody go wall temperature or insulated wall temperature you found T 1 + something which depends upon u 1 of course the fluid also very important leave it.

Now go to the previous case where you form the heat transfer at the bottom one look at that heat transfer at the bottom wall QW equal to K by L multiplied by T 0 - you are getting this but that was not adiabatic wall that was the equal to 0 T equal to T0 so for the case of an non adiabatic situation here so actually what now I can write I can actually write it as periodic for the non adiabatic case I can still know the adiabatic wall temperature concept no although it is not adiabatic our communicating here the T 1 not equal to T 0 K has is not adiabatic but when you calculate the rate of heat transfer at the bottom one you are getting a combination of parameters which happen to be give you the anybody wall temperature.

How do I know it is an adiabatic wall temperature that is what you did just know putting DT by DY at y equal to 0 equal to 0 you said the temperature that is a 10 by the insulated wall is this but this happens to be same as this that means ladies and gentlemen even in a non insulating or non adiabatic wall condition now what is this is a equation for heat transfer the driving force driving temperature difference is not simply the impose T0 - T1 but it is a imaginary temperature difference the driving potential which has no adiabatic wall temperature into it if you say said there is no aromatic wall this is my aromatic wall so this is a concept of the adiabatic wall he is coming into the non aromatic thing.

Meaning the first thing that now when you when we got this expression we did not use the term anyway that is a high velocity flow we have not used it we did not set the high velocity flow we said we went on saying plan taker what is the value plan taker meaning the effect of the prandtl number and the velocity is coming into picture with simply did not say high velocity flow because you have done high velocity flow and force conversion if you listen to you by do a cut number you said no I did not say high velocity I simply said we will take μ by DU^2 into consideration let us see what happens.

Now in that situation the actual analysis is telling me the heat transferred the lower wall for a certain prattle number for a second do you buy D right he is not simply K by L into T 0 - T 1 but it is K by L into T 0 - a new temperature which is t1 plus partly 1 square by 2 CP then you holds everybody so what it means is in all such situations and it is true for normal convective situations the there is always a velocity of the flow either the flow is there is a velocity of the flow or in this case it is the velocity of the plane because convection is relative velocity whenever there is a relative velocity therefore that is in convection the current driving temperature potential is this and not simply the temperature difference that you see on paper.

Therefore for all convection cases the first thing that you have to do is calculate T AW even if it is not a adiabatic case that is the right temperature the moment there is u1 there the question is u 1 square by 2 CP is there it may be small large very large there is a different matter but it is there u1 is not 0 the moment u NS come into the picture it is a quit flow and then you go to the boundary layer flow they reach the kinetic energy there is a viscosity therefore there is a viscous dissipation the question is it important how important know.

When you do not know what it is what you should do is take this expression for calculation if that you have understood the next question is how do I get the T adiabatic wall temperature go one step ahead now look at this T adiabatic norm is equal to what is it frontal U1 T1 + T1 will make a small again manipulation here bring T 1 to the left hand side so TAW- T 1 divided by u 1 square by 2 CP can you tell me what it was now that you have done the high velocity flow you have done a velocity plate aravind yeah what is this term in high velocity flow now what is it called I will I put a symbol for this tell me.

In high velocity flow you got a very similar expression you already knew about anybody well temperature earlier actually TW - T 1 divided by U1 square by 2 CP I will give you a hint before I left in the last class I said can you compare the quilt floor to something else which you are which you know that is a mountain air flow is not it now what is T 1 corresponding to them in boundary layer flow what is T 1 correspond to and u 1 corresponds to so suppose you put TW - T infinity here u infinity to CP now do you recollect what it was.

No, tent is a tomorrow in pretty CP yeah look into the notes if you have I want you to give me the name of this term may be you are more familiar with that flatbed problem therefore in this I am replacing T 1 by T infinity 1 by u infinity that is about where problem it is that the way of looking at it is right but the what you get on the right hand side will be different but what is this term called TW - T infinity divided by u infinity square by 2 CP please find out you refer to CP is a temperature term therefore is non-dimensional.

Do you want me to give you a hint beyond that you don't have the notes earlier notes high velocity boundary airflow with air what is it called now you thought recording factor was only in a high velocity boundary layer flow now I'm giving a recording factor in a simple quiet flow which you have solved by hand complete set of nervier stokes equations is not a boundary airflow it is a parallel flow you took the governing energy equation including a term which you did not know what it was but do by D whole squared you did not cancel out.

So you took that into consideration then when you take the temperature profile and put the various boundary conditions you are getting so much of information first thing what was a cut number then we know now there is a heat reversal at the wall you wonder T1 is greater than the bottom temperature that is because of viscous generation and there is therefore some critical value where viscous heat comes into picture that you formed out you should find out partly cut to equal to 2 by DT by DY = to 0.

Now you go one step beyond you find that the non adiabatic case the bottom wall temperature is something which is very similar for which you need a temperature from a insulated boundary condition which is the insulated or adiabatic wall temperature so you take the adiabatic wall temperature term put it into the non adiabatic thing that is the right driving equation for convection is what I am now trying to tell you and now go you go for that now yeah I ask you T infinity now I will come back to t aw - T 1 because it is a quote flow situation there is infinite here this is called a recurring factor and what is the recovery factor in this case this is equal to from this expression .

So much comes out of this problem you know why is it called record fact record affair is recording something, something is being recorded what is being recovered you can guess do not say heat loss the heat that is generated by viscous dissipation that is being recorded in the case of the adiabatic wall where is it being required if you see it is going to the by the way what is the max.

I will just go back what is the maximum temperature in the adiabatic case and where does it occur I think I have asked you this question people where is the adiabatic temperature maximum temperature does it occur you know the T 1 T 0 profile you have drawn so max T 1 T 0 is held constant so nothing can happen the maximum temperature occurred in the fluid T 1 equal to T not the same thing T max occurs in the fluid at y equal to L by 2 in the adiabatic case which is the maximum temperature where yeah at the volatility yeah.

So draw the profile at 20 equal to sit there is a maximum temperature how it has come about some of the hint that is generated is being recorded at the plate this may or may not be the very right physical interpretation but this use of an idea the heat that was generated by friction has been recovered by the system itself he does not let it go as a loss it would be the loss well still the insulated surface would have some temperature maybe it is slightly lower but it has record taken the heat and supplied part of it in insulated case there is no heat loss from the plate DT by divisor but at that point whatever it has absorbed it has raised its temperature so an insulated boundary conditions case the insulated plate temperature is the highest and therefore you can draw the profile.

I want all of you to draw the quite flow draw the profiles for T 1 greater than T 0 case T1 equal to T0 case and the area where you can see the temperature proposed how they change okay no you go beyond that so we are saying here the frictional heat is being recovered therefore it is any recovery factor now we will go to the next step so what is the record in fact weak can you tell me from your notes what was the required factor for that particular case that you so what is a valuable recording factor for the high velocity laminar boundary layer flow whatever you have done.

Turbulent laminated that R value what is it you got the R somewhere there in your notes so are R should be a relationship R equal to what suppose I want to calculate he what TW - T infinity divided by you've induced by two CP equal to R that are equal to what for that particular situation I am sure you have that value there notes what will in terms of what you will find the value of R at least no you must have you got the definition of our in your class notes .

Come on I should be asking so many questions here you send a query factor fine so there is an expression for the query factor I am asking you what is the value of that in that particular case the laminar flow flat plate case find out it should be get will go further I wanted to bring to the point here that R is a function of prandtl number only in terms of number but it changes from situation to situation in terms of the geometry and the flow so a flat plate laminar problem has a certain recovery factor is a function of Prandtl number in laminar I sorry a flat plate turbulent flow has its own recovery factor which is a function of Prandtl number a quiet flow we did not specify the fluid here but fluid is the Prandtl number so for the quiet flow the recurring factor it doesn't matter whether it is adiabatic around that's not the point at all the coding factor value is equal to prandtl.

So if you know the Prandtl number half the solution is now I do not know whether your mist for laminar boundary layer it should be a pan to the power half or something laminar high velocity no you a mistake it you should be there somewhere there should be square root of prandtl number this is very important for us to know that the recovery factor has a value which is some factor I do not want a function yeah okay function of prandtl number title power 1/2 root one-third or whatever in the case of queer flow it is equal to prandtl number.

That is all for high velocity lamina an order for with air it is I think planted power hope you please check for turbulent fluid will part he is very important two aspects one you should know that recording factor is a function of prandtl number and also how much it is because hmm one is a physical signal we are recording now so tell me when you want to solve a problem for your how does this help you this expression what is it that you know what is it that you do not know in this expression this is expression to calculate the area body water temperature.

Because you always know the fluid is a rarer for so a royal it could be water it does not matter at all so the moment you know what is the fluid of course you know the plate velocity is given plate velocity plate temperature T AW is known the moment T AW is known to go to the heat transfer equation do not simply put T 0 - T1 that is what I am trying to convey to you same thing in the case of laminar boundary layer flow usually what is the Newton's law of cooling Q is equal to H a delta T delta T is TW - T infinity I am saying do not do that take KW - T adiabatic do not worry now T adiabatic has you and square all it simply means is if we one is small business.

If we one is considerable that will be important it could be a razor point 0 1 degree centigrade when you 1 is small but it is there you may you may neglect it but it can never be 0 viscous dissipation is zero only when u 1 equal to 0 but then we do not talk about convection at all so the moment there is au one that is coming into picture fluid velocity there is kinetic energy there is a viscosity there is a velocity gradient therefore μ DU by DY whole squared becomes important that comes from tau W Coulomb you do by DY so viscous shear leads to heat generation heal generation heats up the fluid and the temperatures in the fluid will be slightly higher than what actually the T infinity.

But it may be negligible if T infinity is 150 degree centigrade and the viscous dissipation has increased at 0.1 degree you don't care but if T 1 is 150 degree centigrade and viscous this was included by 40 degrees centigrade now and what does that mat depend either 0.1 or 40 two things Prandtl number the fluid and the velocity gradient how Eckert number prandtl occur so when we want to calculate the rate of heat transfer in convection in any situation this is an example the same thing you can do in the laminar they hear it very clearly says do not worry about what u 1 and T 1 are there get the aromatic wall temperature use this expression T 0 is actually TW in a way our old thing and immediately we have the heat transfer coming into.

So we do this squirt flow generally and in the beginning of the laminar flows we never said lamina we did not say turbulent because it was all for lamina we wrote the expressions for lamina we do this therefore to come to first of all understand the procedure of solution of a convective heat transfer problem starting from the physical model I will never I say this very often you have to start with the physical model at Nazi is a physical model mathematical model simplification of the equations if they are very complex and neither Stokes equations are complex.

Then take the simplified version so in a boundary layer fluid can be planted equations but in this case they have no name given to those four equations you know DW this call you idea what name there is no name how do you please look at them it is like in conduction what is the simplest expression for conduction this for T by $DR^2 = 0$ you can not get anything simpler than that with two boundary conditions similarly we have here d square u by DY square equal to 0

DW by D Y square equal to 0 Y momentum has taken care of taken care energy equation if we wrote everything we said there is no heat generation so we did not say there is no viscous dissipation purposely so that we wanted to study because it has do bed you know.

In this after that you have to solve you do not have to rush to the computer big fluent core you can do it by hand this is the only problem and the corresponding positive for ZOA problem which you can do by hand with three different boundary conditions T 1 greater than 0 T 1 equal to T0 , I want you to do that and a boundary condition are they in selective boundary condition these are different temperature profiles but importantly you find lot of physics the effect of viscous dissipation the possibility that the heat transfer can go to a temperature which is higher than the other temperature in the system.

Simply because the fluid has increases temperature a practical application in lubrications or anywhere oil is involved as a lubricant it loses its viscosity at this higher temporal there is the important things so you got to find out what is it that is why the gaps are given as 3 mm 4 mm you know otherwise you know it is not a duck kind of a thing and then you come the new non-dimensional term which is a card number which you never thought you do that you did not say it is a high velocity problem but it came in a card number then we knew temperature profiles were drawn you got the heat reversal then you go to the anybody wall temperature there you find you can get the area magic wall temperature expression but that is exactly is what appears in a non adiabatic case.

Therefore in the non adiabatic case even for you to calculate to answer first calculate the adiabatic wall temperature that can be obtained to the definition of rickrack factor which is nothing but TW - T1 by towards cover 2 CP which is a recording factor in this particular case it has a different value which is equal to the Prandtl number it would is oil it is thousand it would say at this point seven two and immediately you know the effects will not be very high in the case of air.

But you do extremely high in the case of oil there itself the pendulum effect is simply hitting you in the eye actually and therefore when you want to find out the rate of heat transfer in any conduction problem you say right thing to do fundamental calculate the area of attic wall temperature which is non-existent which is a imaginary thing it is as if there is a anybody call temperature there is no everybody what temperature never normal our cases.

This is very important for you to understand because the students will always says sir why do we calculate the area matic wall temperature there is no it is simply so happens the physics tells you when you have this non adiabatic equation there is a term which is nothing but the area of attic wall temperature so you say there is a imaginary adiabatic wall temperature imaginary temperature which is equal to anybody call once you put that in that is the right equation heat transfer and that is a function of plant lumber which comes to a recovery factor record simply means the frictional heat that is being generated is being recorded as much as possible within the system.

That is all it means so for you to solve this problem for rate heat transfer in all convection system get the aromatic wall temperature through the query factor which is simply a function of prandtl number we can actually plot all this you know as a function of parental and R for various flows go back and calculate very difficult all these new ideas physics of the problem how to solve the convection equation how to put in the boundary conditions actually song now if you take a complex narrow Stokes equation you would not do this you will go to a code that you would not know how it is done.

You are now integrated in every equation the temperature equation twice every time to get the two constants depending about the two boundary conditions so the whole thing about convection is encapsulated in a square problem if you know this problem completely you can play with any equation even if you go to the code you at least you know what is happening how did this come up how did the unit of heat transfer calculated Q is equal to - K DT by DY that is why in the beginning stage I said physics wise I want for my heat transfer DT by DY atY = 0.

For me to get that I have to have the entire temperature profile for you to have the temperature profile you out of the energy equation all will be boundary conditions and that comes from nature which is the first off thermal so from nature to rate of heat transfer in an adiabatic or a non adiabatic situation you can understand provided you actually do the calculations by hand not by a computer.

Put Brantley at various values plot it and there used to have these graph sheets and which we use to plot and as the plot we are putting the whole thing comes usually do not you have to accept what I say about the computer says you do it by hand there is only problem which you can do my hand and see the solution as I say coming out because of you are churning all the information mathematical information physics information you integrate these together to calculate the rate of fitness.

Coutte flow – Part 3
End of Lecture 10
Next: Boundary layer approximation

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IIT MADRAS PRODUCTION
Funded by
Department of Higher Education
Ministry of Human Resource Development
Government of India