Thermal Operations in Food Process Engineering: Theory and Applications

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Lecture - 36
Heat Transfer by Convection (Contd.)

Good morning. You remember that in few classes before when we were doing convective heat transfer and we had been given, we have been given here that lot of non-dimensional parameters. So, those non-dimensional parameters on that basis I had given you a problem. And, I told that you try and may be after some time we will come back to that and solve so that you can also make it whether things are all, ‘‘right’’ or not according to your solution, ‘‘right’’.

So, today also we will do that and again and again I repeat that once you are going through the class then obviously, the class material you have to go through thoroughly along with that try to solve as my problems other than those which are solved in the classes. If you can do that yourself then you can come to know that yes you have understood and you are able to solve unknown problems, ‘‘right’’.

So, these unknown unseen problems because we had given you lot many relations and it is not possible in classes to solve these problems differently. Otherwise that would itself, will become a tutorial of the whole semester or of the whole course which perhaps will not be permitted by the authority.

So, and I fully agree with you that if such kind of courses are also plotted that becomes very helpful for you, but unfortunately it is not feasible. What we need to do is that we will definitely do this and in now in this class in the heat transfer by convection may continued class number or lecture number 36 will come back to that problem and solve, ‘‘right’’, but again we are managing the time because solution I have been doing it in advance and not using the calculator over it.

So, that that calculation will take itself a whole class, but yes at times it may be required, but I am not sure where from I will get this calculator here. So, that is why I am not utilizing, ‘‘right’’.

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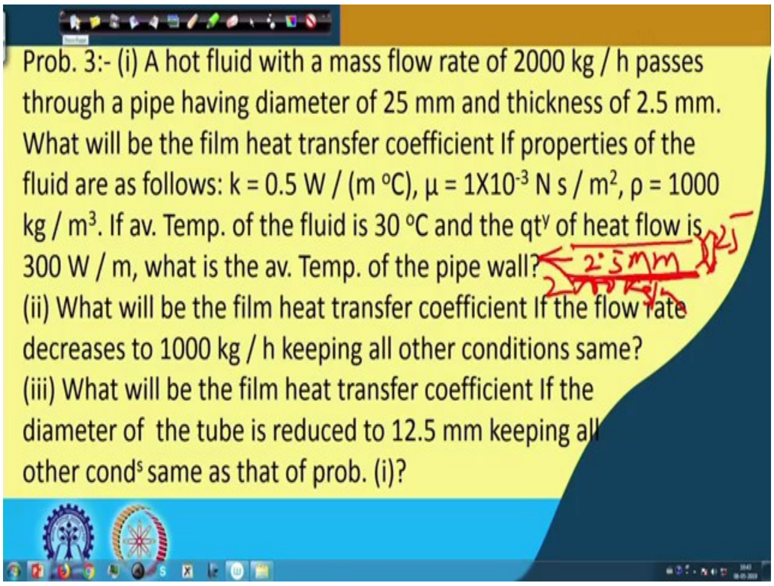

So, let us go into that solution. We go to lecture number 36 and the problem is like this a hot fluid with a mass flow rate of it was given to you. A hot fluid with a mass flow rate a 2,000 kg/h passes through. Let me yeah it is going off passes through a pipe having diameter of 25 mm and thickness of 2.5 mm, ‘‘right’’.

So, hot fluid of mass flow rate of 2,000 kg/h passes through a pipe having diameter of 25 mm and thickness of 2.5 mm. What will be the film heat transfer co-efficient, if properties of the fluids are as follows given. Conductivity is 0.5 W/m.°C viscosity 1×10^{-3} Ns/m^2, density ρ 1000 per kg 1,000 kg/m^3. If average temperature of the fluid is 30 °C and the quantity of heat flow is 300 W/m, 300 Watt per unit length or per meter what is the average temperature of the pipe wall? ‘‘right’’.

This is number1. Number 2 what will be the film heat transfer co-efficient if the flow rate decreases to 1,000 kg/h keeping all other conditions same. Third one what will be the film heat transfer co-efficient if the diameter of the tube is reduced to 12.5 mm keeping all other conditions same as that of the problem 1, ‘‘right’’. So, let us quickly look into a again a hot fluid with a mass flow rate of 2,000 kg/h passes through a pipe having diameter of 25 mm and thickness of 2.5 mm.

What will be the film heat transfer co-efficient, if property values of the fluid are given as thermal conductivity is 0.5 W/m.°C, viscosity μ 1×10^{-3} Ns/m^2, ρ density 1,000 kg/m^3. If average temperature of the fluid is 30 °C and the quantity of heat flow is 300 W/m.

What is the average temperature of the pipe wall and second what will be the film heat transfer co-efficient if the flow rate decreases to 1,000 kg/h. It was 2,000 kg/h and now it is brought to brought down to 1,000 kg/h, ‘‘right’’. Keeping all other conditions same only the flow rate is changed.

Another one; what will be the film heat transfer co-efficient if the diameter of the tube is reduced to 12.5 mm keeping all other conditions same as that of the problem one, ‘‘right’’. So, if we look at the first problem we had this pipe whose diameter D is given as 25 mm, ‘‘right’’, 25 mm and the thickness of this tube is 2.5 mm, ‘‘right’’ and a flow rate which is flowing is 2,000 kg/h, ‘‘right’’ and all other fluid properties are given.

This is problem number 1. For problem number 2 again it is same that same d same thickness, but the flow rate is instead of 2,000 it has been brought down to 1,000 kg/h, ‘‘right’’.

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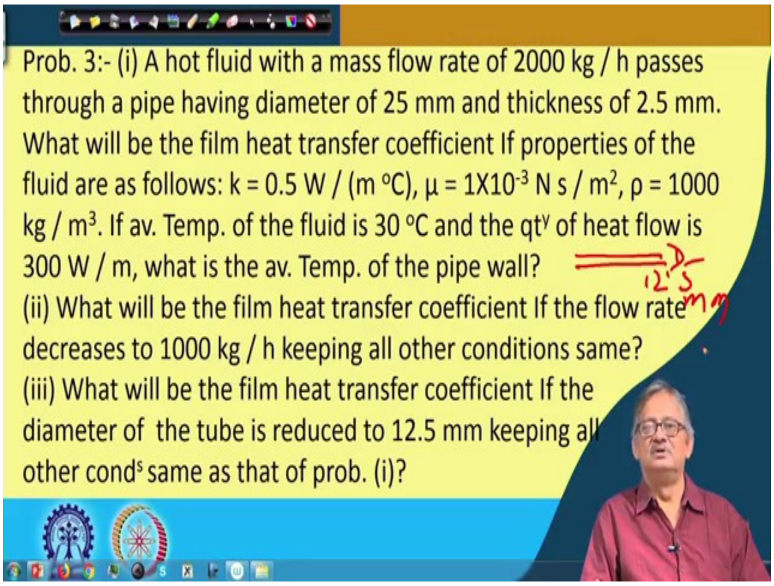

And in the third case it is said that instead of all other things now you reduce the pipe diameter, ‘‘right’’ and this new diameter is 12.5 mm, ‘‘right’’. So, what is the heat transfer co-efficient? So, you see in 3 different situations you are finding out heat transfer co-efficient and as you said in the earlier class that heat transfer co-efficient is function of many parameters many ways the heat transfer co-efficient will vary and that is why there is no general equation as for all the things, ‘‘right’’ because it is dependent on many parameters which we have already said, ‘‘right’’.

Now, to solve it as we know that we have to find out the different property values, we have to find out different non-dimensional parameters and these non-dimensional parameters; obviously, will be Reynolds number, Prandtl number, Nusselt number these numbers and by this time we have more or less memorized the non-dimensional numbers, ‘‘right’’.

So, if you have any doubt about the non-dimensional numbers. So, before solving it again have a brushing of these non-dimensional parameters which we had given and then come to the solution, then it will be easy for you to understand, ‘‘right’’.

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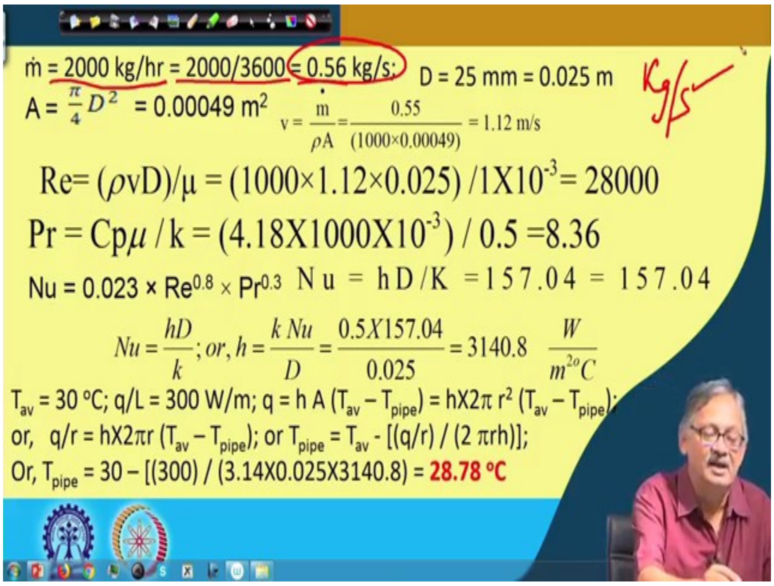

So, let us look into that. First thing is that we have been given mass flow rate 2,000 kg/h, ‘‘right’’ and in SI units mass flow rate is kg/s, ‘‘right’’. So, kg per hour to be transformed into kg per second, ‘‘right’’ so, that we have done 2,000 kg/h, ‘‘right’’. So, 2,000/3,600 is 0.56 kg/s. So, mass flow rate we have got in kg/s.

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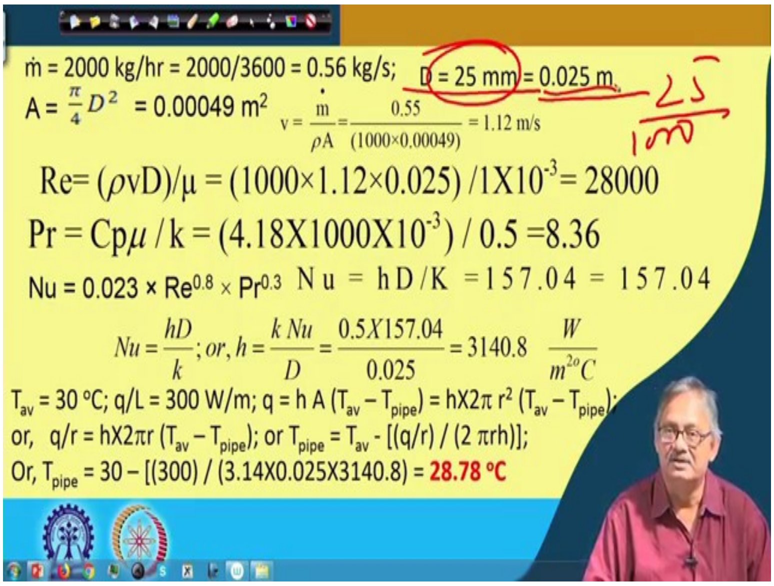

Next the diameter of the pipe was given 25 mm, ''right'' and mm is not the SI unit directly because all other units are in meter. So, that has to be converted into meter. So, it is 0.02 pipe meter 25 mm /1,000, ''right'' 25/1,000 it is nothing, but 0.025 mm, ''right''.

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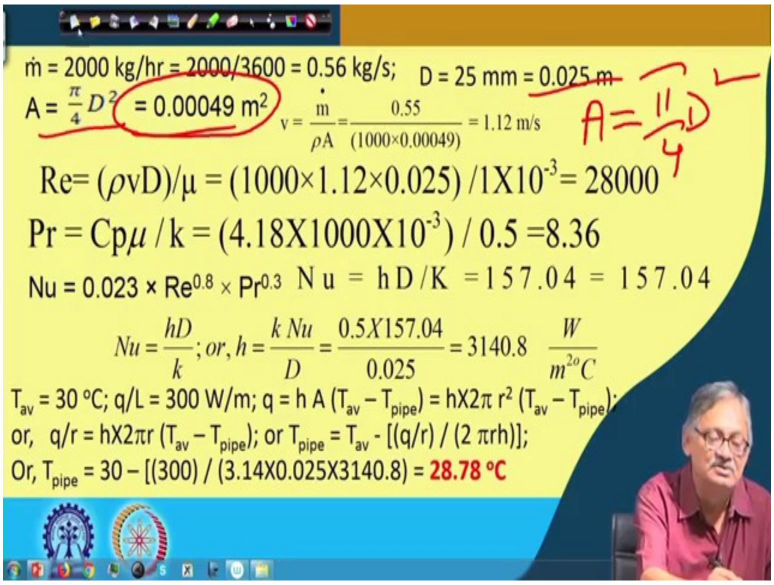

So, we got the diameter then we need to know the heat transfer area, ''right''. So, area of heat transfer is this is for pipe. It is $\pi/4$ D^2, ''right'' D is given D is already 0.025. So, $\pi/4$ D^2 if we put the value of D as 0.025^2 and multiply that with $\pi/4$ it comes to 3 not point 3 not 49 or 0.00049 m^2, ‘‘right’’. So, area also we got. Next comes flow rate has been given, ‘‘right’’ and area we have found out density we know.

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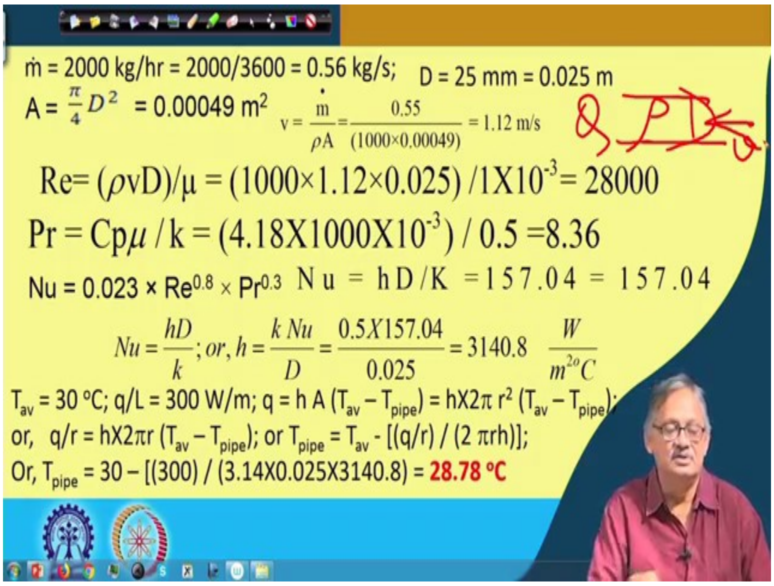

So, what is the velocity because this pipe when you have a flow rate of Q, ‘‘right’’ or $\dot{Q}$ rather this is the flow rate when you have a flow rate of $\dot{Q}$ through a diameter D and the density of the material is known, then velocity through this you can find out by knowing the flow rate area and density, ‘‘right’’.

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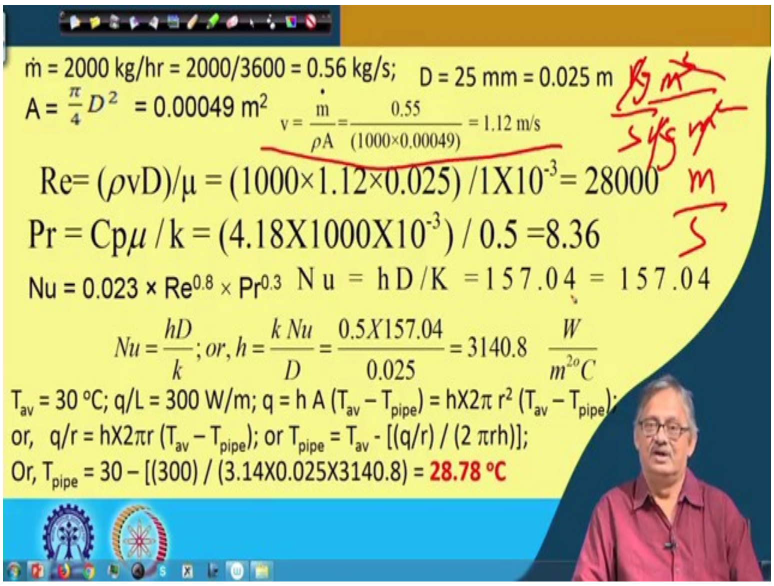

So, this is possible as $v = \frac{\dot{m}}{\rho A}$. $\dot{m}$ is the mass flow rate, ''right''. $\dot{m}$ is in the mass flow rate. So, you see it is mass flow rate. So, it is kg per second, density over density. Density is kg/m^3 and area is m^2, ''right''. So, this $m^2$and m^3 goes out 1 m remains and this kg, this kg goes out. So, the unit remains is meter per second that is the unit of the velocity, ''right''.

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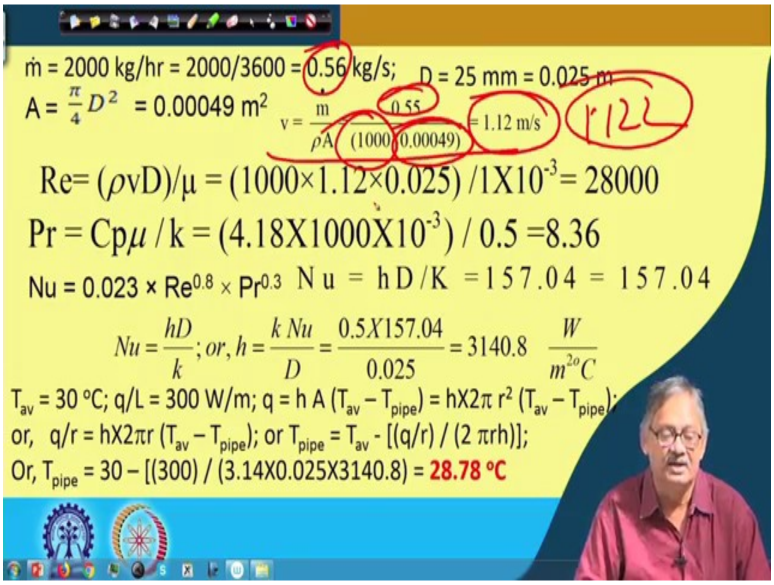

So, we can find out the velocity as $\dot{m}/\rho A$ that is 0.5 either 55 or 56 rounded off ok. So, 55 is written here by 1,000 into 0.0049 and this comes to 1.12 perhaps it will be 1.122 like that. So, that is why if it is not rounded that 0.56 taken may be it is 1.122 like that it will come. However, so it does not matter whether it is 1.12 or 1.122 our objective is the method or procedure by which we are able to find out, ''right''.

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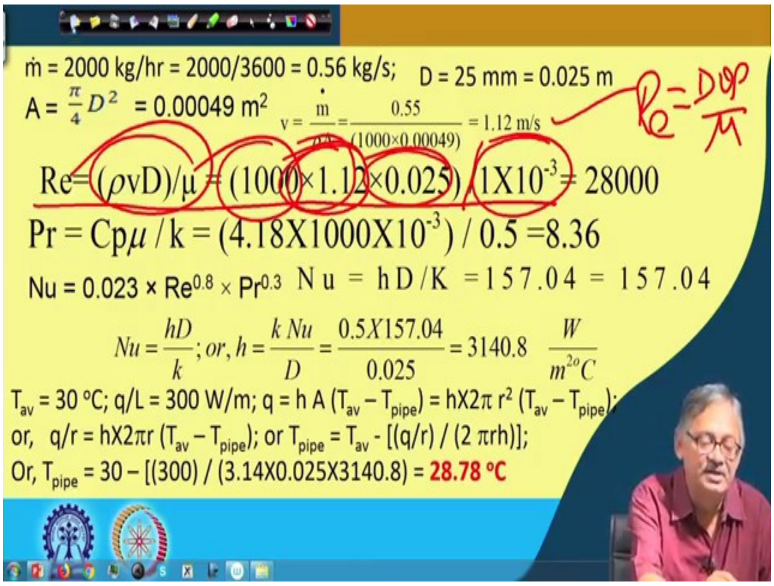

So, we have obtained that velocity through the pipe. Next comes what is the Reynolds number Re. So, Re we know is Dvρ/μ all the values are given D given v we have found out ρ given μ also given. So, substituting them into this equation Dvρ/μ by substituting the value of ρ 1000, D as 1.12 and 1 point sorry v as 1.12 D as 0.025 and D sorry D as 1 yeah 125 over 1 μ1 × 10^{-3}, ‘‘right’’.

So, this leads to 28,000. So, (Refer time: 17:06) is highly turbulent. Whether turbulent or not that is not our look out at this moment, but we have to find out the value and the value is 28,000, ‘‘right’’.

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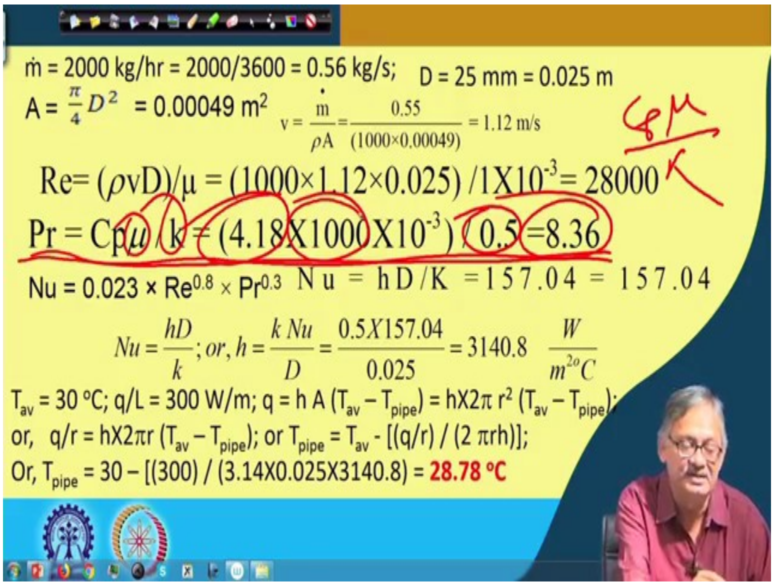

So, if that be true then we find out next the Prandtl number. Prandtl number we know is $C_p\mu/k$, ‘‘right’’; so, the value of C_p given value of mu given value of k given. So, Prandtl number once the fluid is fixed then the Prandtl number will remain unchanged, ‘‘right’’ if the property values does not change then only, ‘‘right’’.

So, we are finding out Prandtl number as $C_p\mu/k$ C_p given is 4.18 ‘‘right’’; μ a 4.18 perhaps kilojoules. So, into 1,000, ‘‘right’’ into 10^{-3} that is μ 1 $\times 10^{-3}$ 1 I have not written over k k given is 0.05, ‘‘right’’. This comes to 8.36, ‘‘right’’. This comes to 8.36. For a check let us look that really this is 4.18 kJ, ‘‘right’’.

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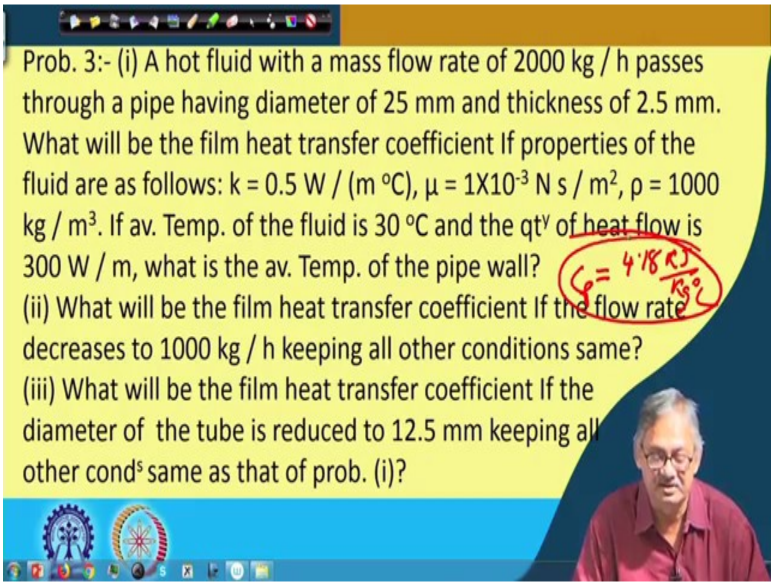

That is C_p specific heat which was given temperature fluid 30 °C, heat flow is 300. What is the fluid temperature, ''right'' yeah 4.18. Perhaps this was not given here. So, that is why suddenly it struck me that I did not read out the value of C_p while telling the problem. So, the value of C_p is 4.18 kJ/kg.°C.

So, C_p value is equal to 4.18 kJ/kg.°C, ''right'' for that fluid, ''right''. So, that this value was not given. So, incorporate into it. So, while doing the problem perhaps we have seen that it was not given and perhaps we have taken it, ''right''. So, here that is what we have taken it 4.18 into 1,000.

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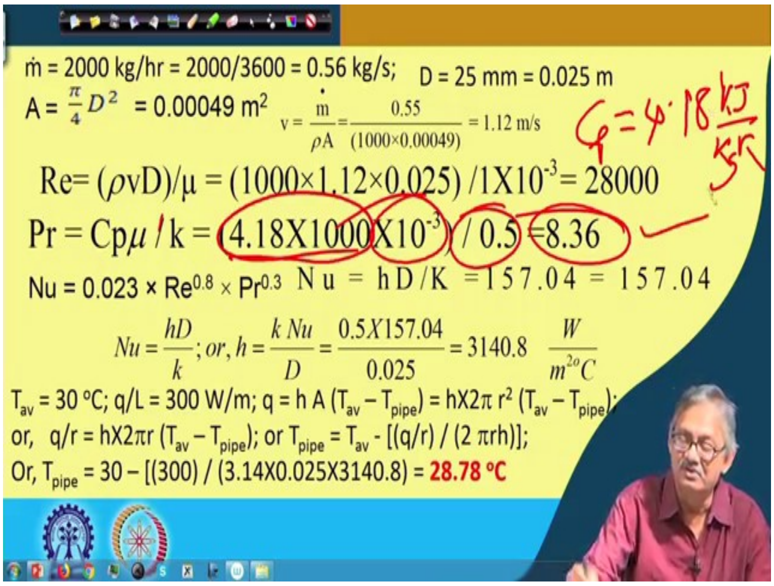

So, that is in J/kg.°C μ is 1× 10^{-3} and k 0.5. So, this comes to 8.36. I repeat that the value of C_p we have assumed is 4.18 kJ/kg.K, ‘‘right’’ or per /kg.°C, ‘‘right’’. So, once we know C through a Prandtl number, once we know Reynolds number then we can use the earlier relations given, ‘‘right’’.

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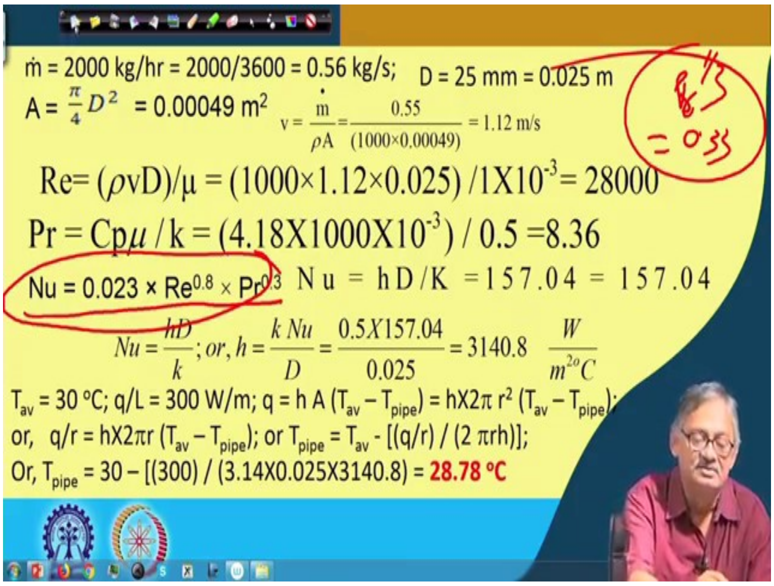

So, one of the relation was Nusselt number is equal to 0.023 $Re^{0.8}$ × $Pr^{0.3}$, ‘‘right’’. So, this Nusselt number is 0.023 × $Pr^{0.3}$ or it was $Pr^{1/3}$ that is that is equal to 0.33, but we have taken the parse decimal here, ‘‘right’’.

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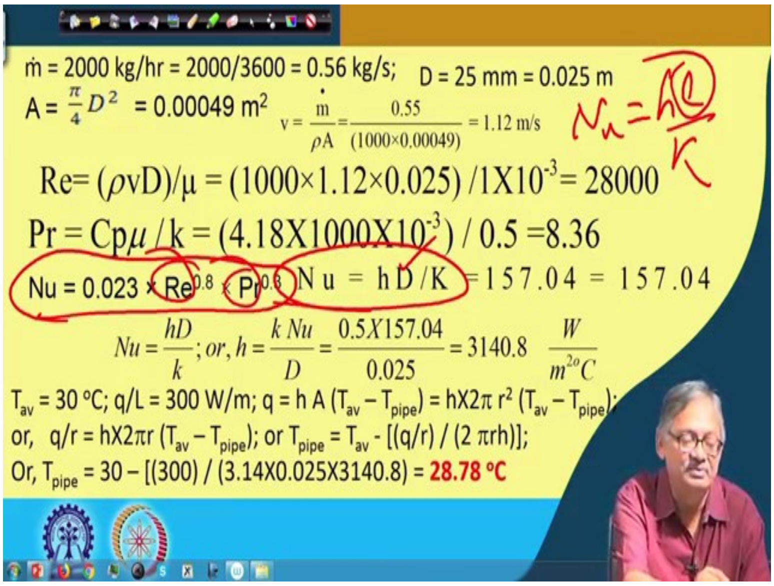

So, if that be true then from this value already Reynolds number is known Prandtl number is known. So, we can write Nu= hD/K hD/K is Nusselt number, ''right'' which we had said earlier also that Nusselt number is hl/k where l was the characteristic length, ''right''. So, in this case we can write that the value of this is this D is of course, in terms of your 0.025 ''right'' and this value has come to h is not known, ''right''. So, from the given relation that 0.023 $Re^{0.8} \times Pr^{0.3}$.

So, if you put this and the value of Reynolds number is 28,000 value of Prandtl number is 8.36 to the power of this. So, this value comes to 157.04, ''right''. So, this value comes to 157.04 which is nothing, but equal to Reynolds number and that reynold number is we know hD/K, ''right''. So, from this we can say that Nusselt number being hD/k h is (k ×Nu)/D or is (0.5 × 157.04)/ 0.025, ''right''. So, that comes to 3140.8 W/ m^2.°C ''right''.

So, here we have seen that the value of heat transfer co-efficient has come very high as to the tune of 3140.8 W/m^2.°C.

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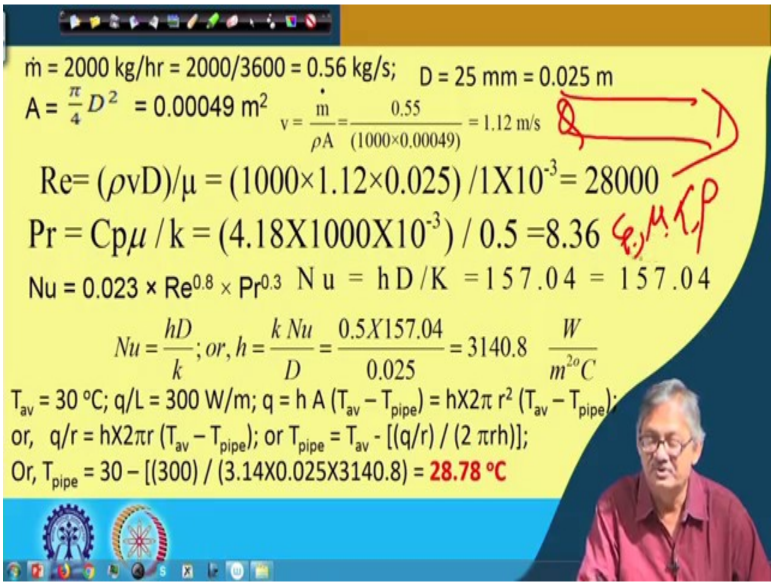

Where if you just keep in mind the situation we had that π whose diameter was given 0.025, ‘‘right’’ and whose another thing was given flow rate was given as a 2,000 kg/h. And, it was given that diameter was there and other property values were given that is C_p that is we have introduced C_p then μ then k then ρ this values were given.

So, from those given values we found out Reynolds number Prandtl number use the relation $Nu=0.023\ Re^{0.8} \times Pr^{0.3}$. So, this is not having any correction that viscosity correction if you remember there was another equation, but this is a simpler equation. So, that would have been μ/μ_w. So, you need to know μ_w also μ is given here 1×10^{-3}, but not given at the wall also.

So, there we have found out what is the value of h ‘‘right’’ 3140.8, ‘‘right’’. So, the other equation other second one which we have to find out that average temperature was 30 °C q/ L given was 300 W/m q then becomes equal to h A $(T_{average} - T_{pipe}) = h \times 2\ \pi\ r^2 \times (T_{average} - T_{pipe})$, ‘‘right’’.

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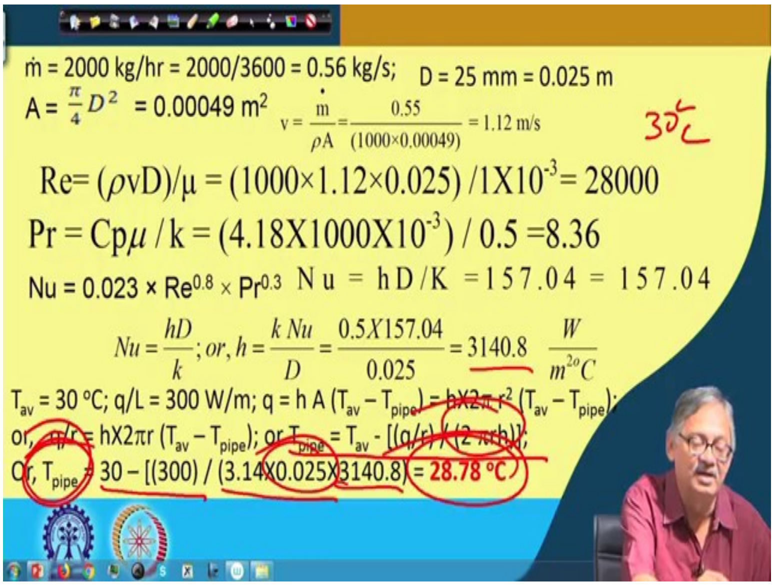

From where we can write q over r into 2 π r h $T_{average}$ T_{pipe} ''right'' or (T_{pipe} – T) T_{pipe} = $T_{average}$ – [(q/r)/(2πrh)], ''right'' and this comes to equal to T_{pipe} = 30 - [300/(π)] there is 3.14 × D because 2 r so, D. So, 0.025 into this h 3140.8 and that came to be 28.78 °C. So, the pipe temperature average temperature of the fluid was 30 degree. So, pipe temperature came to 28.78 °C, ''right''.

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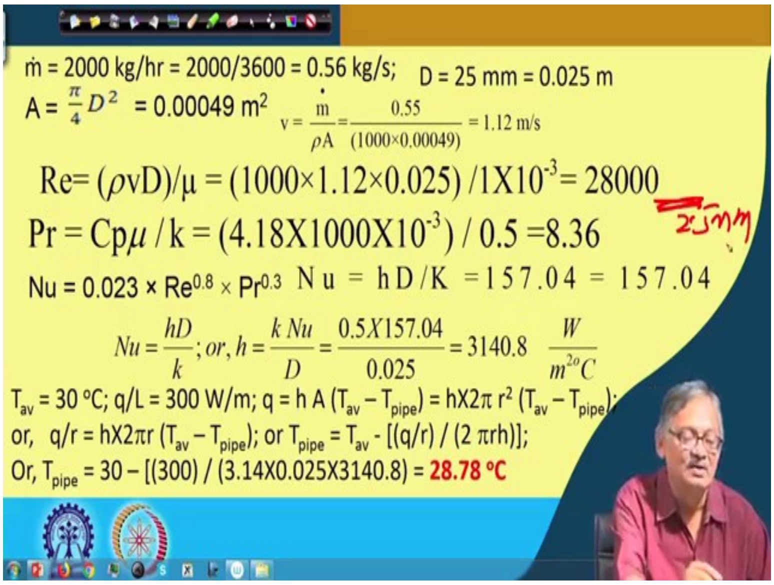

And, the pipe had a thickness of 2.5 mm, ''right'' this you keep in mind.

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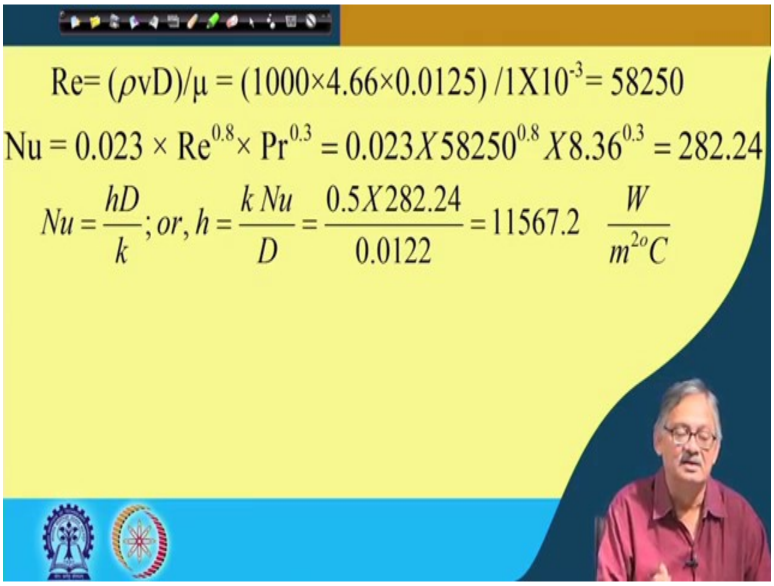

So, for the last solution for the last problem if we look at this was again we will find out first the Reynolds number. Now, what has been done now the diameter has been reduced, ‘‘right’’ diameter has been reduced to from 25 mm to 12.5 mm, ‘‘right’’ keeping all other things at identical.

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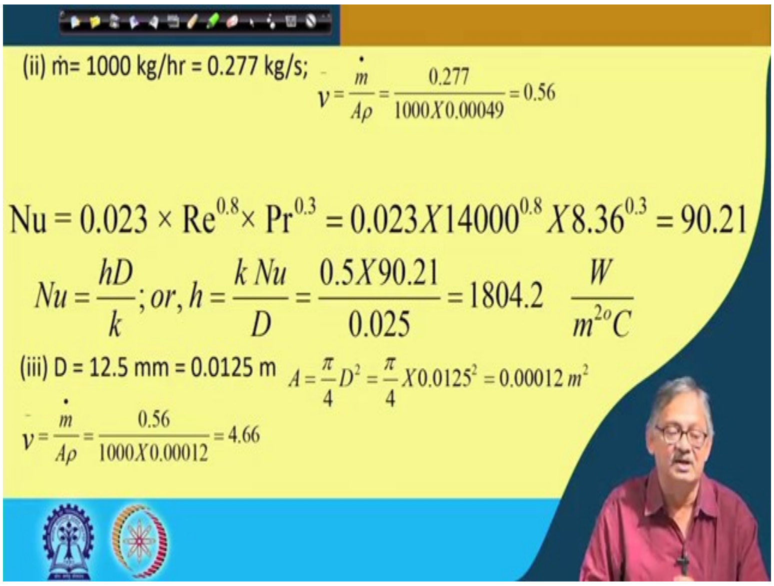

In the previous one what we did. It was if you remember it was given that yeah this is second this was given this was $T_{average}$ T_{pipe} we have found out that was to be found out. In this that m dot is 1,000 kg/h, ‘‘right’’ 1,000 kg/h is 0.277 kg/s. So, we found out the average velocity which is 0.56, ‘‘right’’ from this relation then from $Nu = Re^{0.8} \times Pr^{0.3}$ we found out that Nusselt number to be 90.21 then from the relation of Nusselt number is hD/K we found out the value of h which came to be 1804.2 $W/m^2.°C$ and that is the h which you were asked to find out.

For number 3 problem we had been given diameter 12.5. So, area we got by $\pi/4\ d^2$, ‘‘right’’. So, it was 0.0012 m^2 velocity we found out is 4.66 and then we found out the heat transfer co-efficient from this, ‘‘right’’. So, Reynolds number was $\rho Dv/\mu$ which was 58,250 from this relation and Nusselt number is $0.023\times Re^{0.8} \times Pr^{0.3}$.

So, these times this makes 282.24 as Nusselt number. So, if Nusselt number is 282.24 from the relation Nusselt number is D / k h is found out to be 11,567.2 W/m^2, ‘‘right’’. So, this way you try to solve problems and then get into the subject more and more, ok. So, next we will go back to what we were doing that radiation heat transfer, ok.

Thank you.