Course on Momentum Transfer in Process Engineering
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Lecture 09
Module 2
Problems and Solution of Compressible Flow

We have done that compressible fluid we have studied with compressible fluid and we have found out the relation how the pressure can be found out if one pressure is known how the other pressure can be found out with the relation for that was for isothermal fluid, right those fluid which are under isothermal conditions so they can be they can be predicted the pressure drop or if one pressure is known the other pressure can be also found out, right. So we said that we will do some problem so that the understanding of the use of the equation can be more effective, right.

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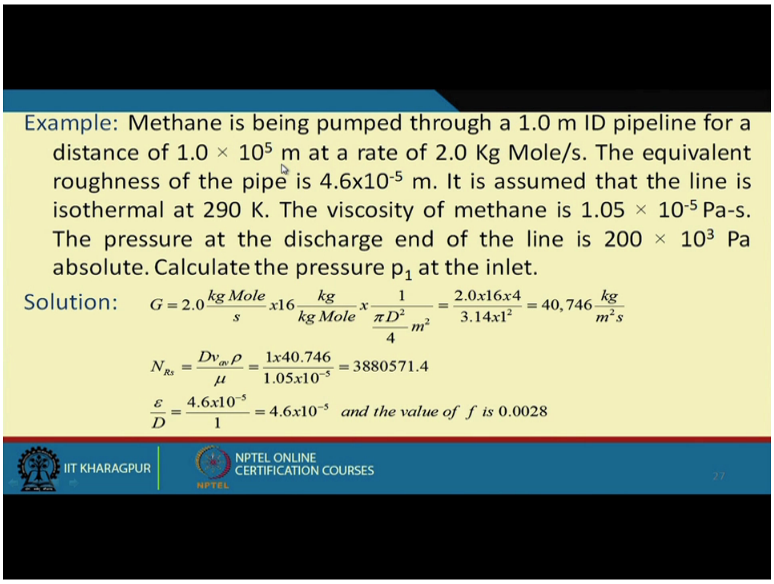

So let us look into one like Methane is being pumped Methane is being pumped through a 1 meter ID pipeline for a distance of 1 10 to the power 5 meter at a rate of 2 Kg moles per second. The equivalent roughness of the pipe is 4.6 into 10 to the power minus 5 meter. It is assumed that the line is isothermal at 290 kelvin. The viscosity of Methane is 1.05 10 to the power minus 5 pascal second. The pressure at the discharge end of the line is 200 into 10 to the power 3 pascal absolute. Calculate the pressure p1 at the inlet, right.

So I repeat Methane is being pumped through a 1 meter ID pipeline for a distance of (10) sorry for a distance of 1 10 to the power 5 meter at rate of 2 Kg moles per second. The equivalent roughness of the pipe is 4.6 into 10 to the power minus 5. So equivalent roughness is given here that means absolute is given (())(3:09) we have to find out and from there the frictional factor value from the (())(3:15) discharge right.

So 4.6 into 10 to the power minus 5 meter. It is assumed that the line is isothermal at 290 kelvin. The viscosity of Methane is 1.05 10 to the power minus 5 pascal second. The pressure at the discharge end of the line is 200 into 10 to the power 3 pascal absolute. Calculate the pressure P1 at the inlet, right.

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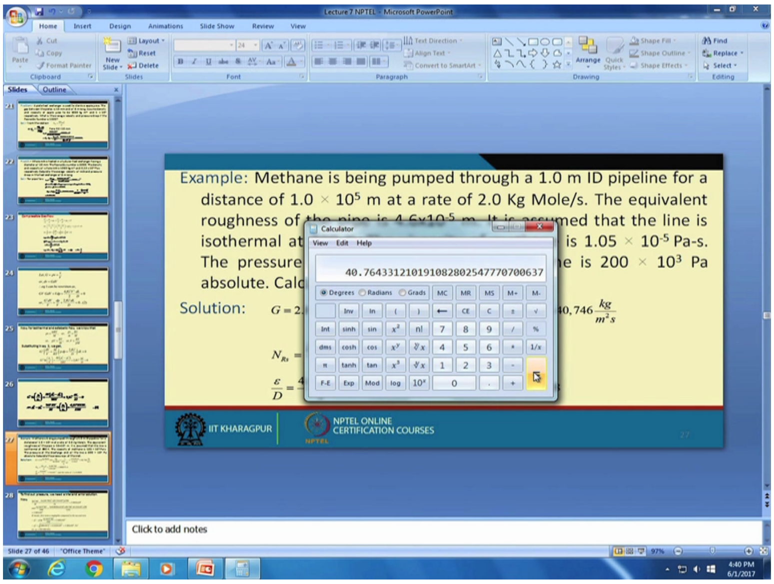

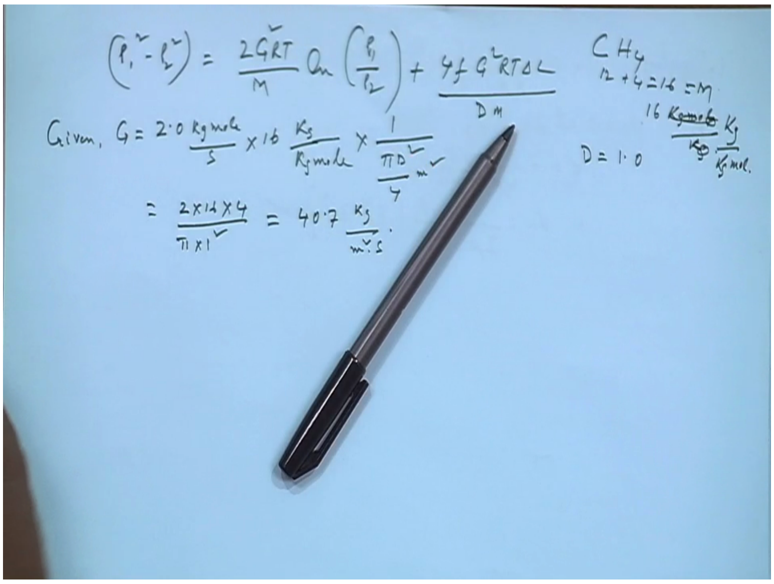

So if we remember the relation of p1 right pressure that we said P1 square minus P2 square right this is equals to 2G square RT by M right into ln of P1 over P2, right plus 4fG square RT delta L over DM this was the relation for the pressure at isothermal condition, right.

However given things let us write down given G is equals to 2.0 Kg mole per second right 2.0 Kg mole per second and this was for the gas Methane Methane is CH4. So CH4 means 12 plus 4 is equals to 16, molecular weight is 16, right. So this 16 molecular weight means 16 Kg mole per Kg right. So if we multiply this with 16 then it becomes 2 Kg mole per second right so into 16 this is how this is Kg per Kg mole sorry the reverse Kg per Kg mole 16 Kg per Kg mole so that is the molecular weight. So 16 Kg per Kg mole right into area right into 1 upon this (())(5:57) divided by area that is pi D square by 4 meter square, right pi D square by 4 meter square this means this Kg mole Kg mole goes out Kg per second per meter square, right.

That is nothing but mass flux right so if we substitute the values then it becomes 2 into 16 divided by pi into D square given D is equals to 1.0 meter ID so 1 right and other than D we need here nothing. So 2 into 16 into 4 this 4 goes up pi this square is 1 square right so pi we can take as 3.14, right then if we if we if we put it into the calculator then we can say that 2 into 16 into 4 is equals to this divided by pi pi if it is not there then let us take 3.14 right 3.14 into 1. So that means it is 40.76, right 40.76 (7) say so much of Kg per meter square per second that is the mass velocity or mass flux this g slow into v mass velocity or this is called mass flux Kg per meter square second, right.

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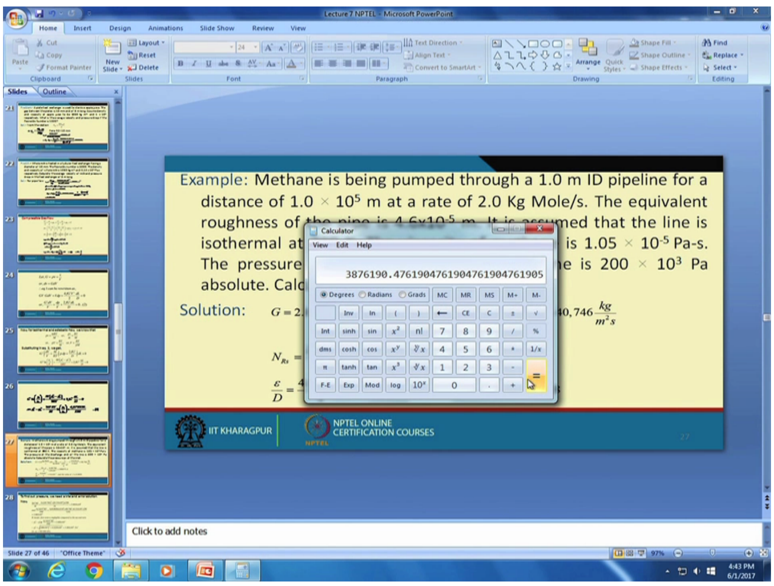

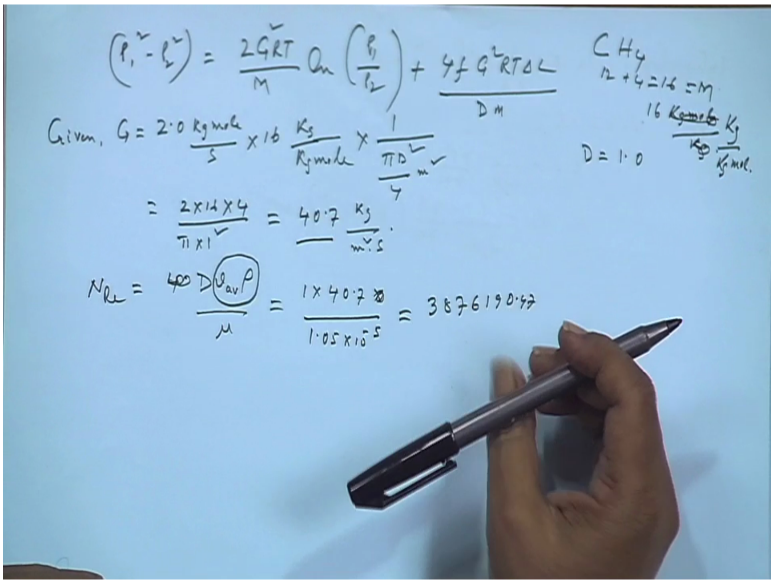

So once we know the Kg per meter square second, then we can now say that NRe is equals to 4.6 into D rather Dv average rho by mu right D is given 1 v average we assume 40.7 right and rho is given as the viscosity this was absolute or this is (())(9:12) this much roughness is this much viscosity of Methane is this much right, ok. Then then then then we have to find out who is the 200 line (())(9:35) roughness is so much, Methane is being formed at a distance 1 meter to (())(9:45) meter right oh.

So G rather rho v we have already found out right rho v we have already found out so this is rho v is G, so G is 40.7 so 1 into 40.7 this divided by mu mu was 1.05 into 10 to the power minus 5. So if we again look into that calculation so we can see that 1 into 1 into 40.7 7 is equals to this much divided by 1.05 divided by 10 to the power minus 5 right, it is 3876190.47 right.

So so much the value of (())(11:01) so here we see 3876190.47 but there it is coming 3880571.4 the reason being we have taken 40.7 as the G value and it is taken in the problem as 40.746, right so that is why the the change.

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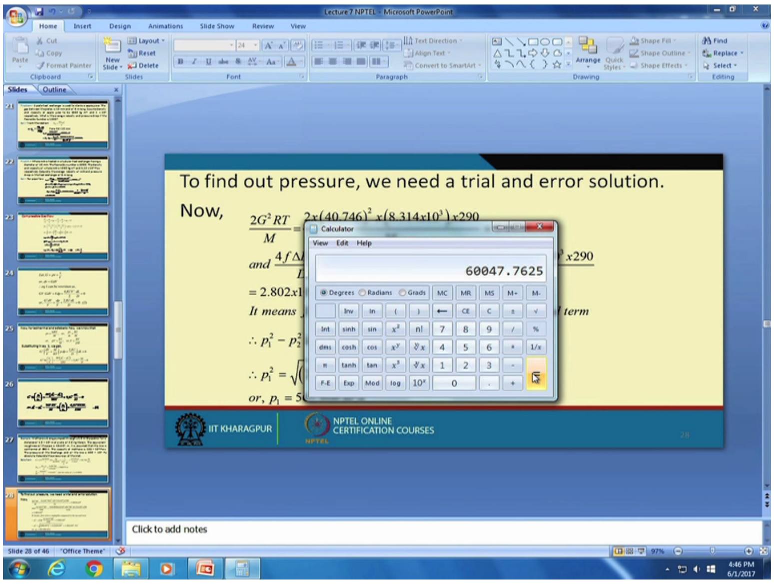

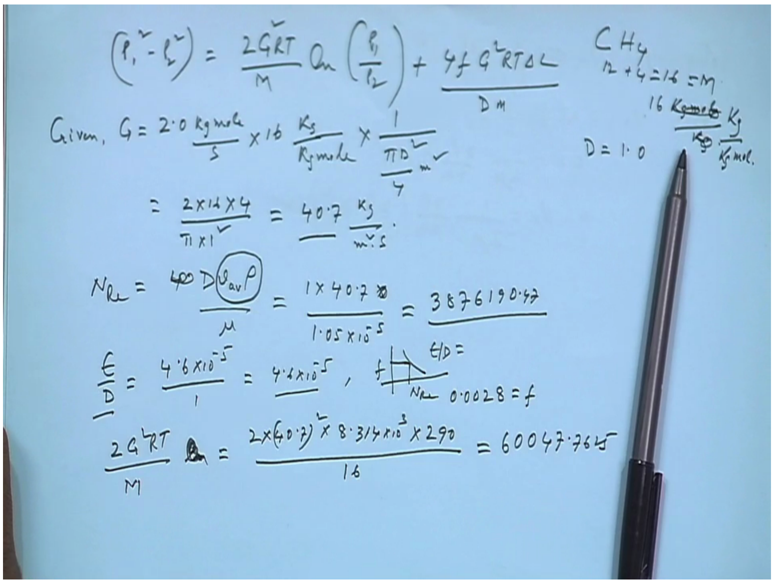

Now epsilon by D right this value epsilon is given as 4.6 into 10 to the power minus 5 and the value of D is 1, so this is 4.6 10 to the power minus 5. So corresponding to NRe is equals to this and epsilon by D is equals to this if we see the (())(11:58) NRe versus f for epsilon by D equals to this 1.6 etc we get a value of f right and this value of f we assume is now to be seen as 0.0028, right.

So if we assume that the value of f is 0.0028 then we can then substitute f this is equals to f so we can substitute and this 2G square RT by M of ln P1 by P2. So first find out this constant value. So 2G square 2 into 40.7 square into R right 8.314 into 10 to the power 3 right into R into T T is 290 given 290 kelvin right divided by molecular weight is Methane CH4 16 right. So if we find out this value this becomes equals to this becomes equals to the rest we can do how much this value comes in that 2 into 40.7 square 40.7 square into 2 into 290 this divided by 16, this is 60047 60047.7625, right.

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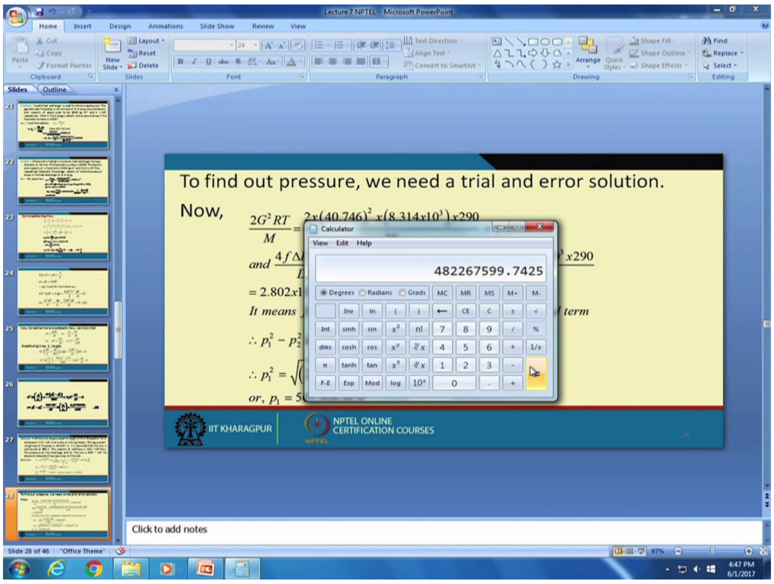

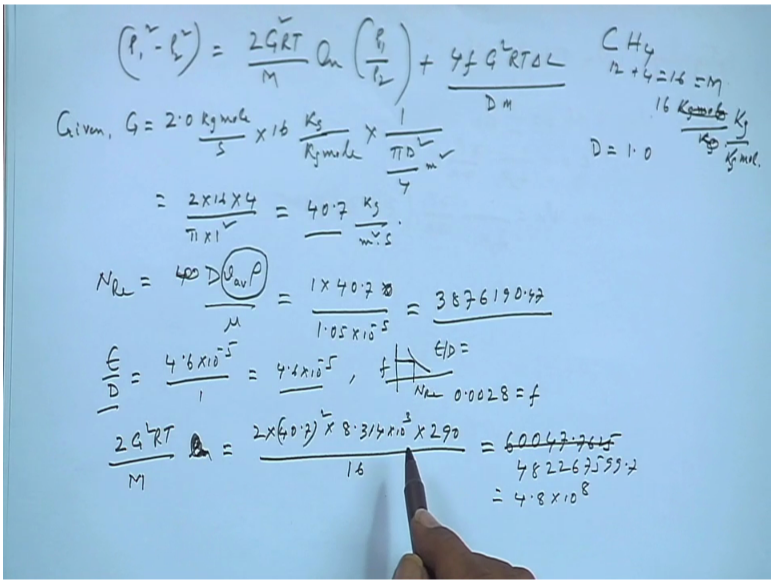

This is coming to be equals to 1, 2, 3, 4, 5 oh ho ho no no no we missed we missed out we missed out this so that is what the problem you do this you do some another 40.7 40.7 square right into 2 is equals to so much into 8.314 oh ho 80 ok 80.314 into 100 not into 3 into 100 into 290, this is so much divided by 16, this is 48 not this 60, we missed out this terms so it 482267599.7 425 means 1, 2, 3, 4, 5, 6, 7, 8 is equals to 4.8 10 to the power 8, right 4.8 10 to the power 8, right that is what it is 4.8 and 5.06 the difference again differs 40.7 and 40.745 or 754, ok.

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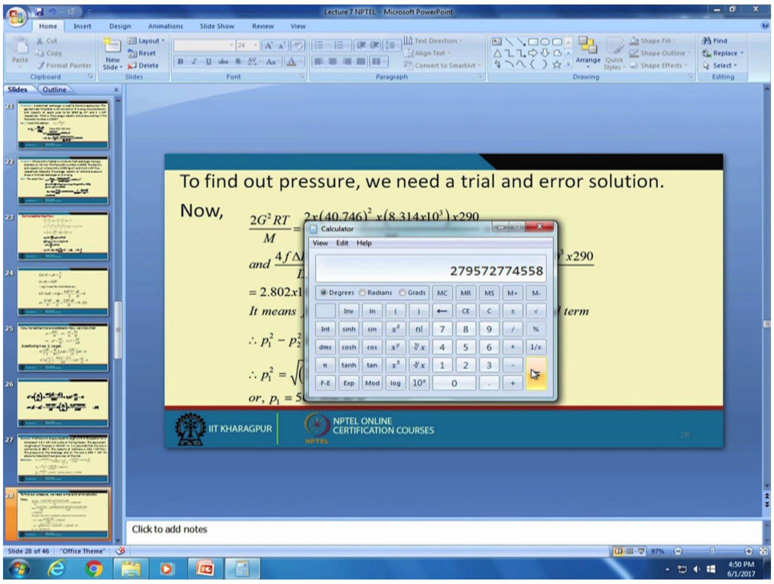

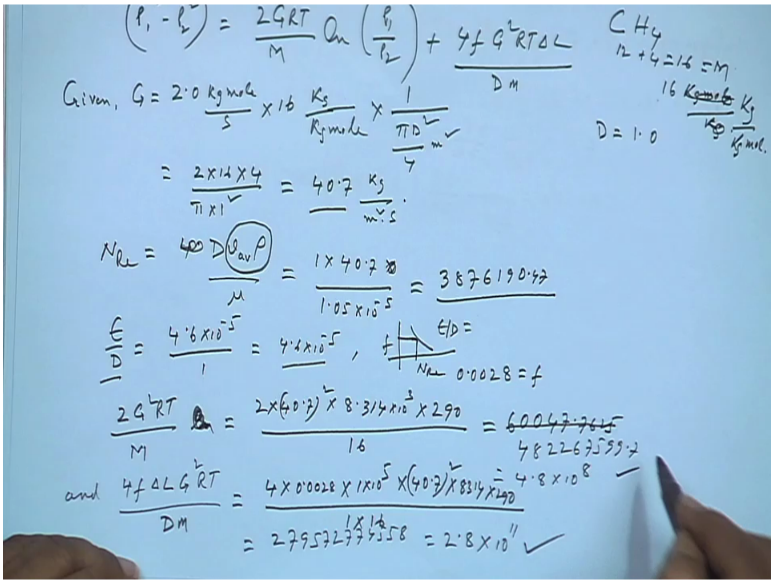

Now once we know this then the other term that is 4f delta L G square RT divided by DM the values are 4 into 0.0028 into delta L length is given as length is given as 1 into 10 to the power 5 most likely 1 into 10 to the power 5 right. 1 10 to the power 5 meter it is 1 into 10 to the power 5 meter into G square 40.7 square into r 8314 let us take this way into 290 T divided by diameter second 1 and molecular weight is 16.

So this comes into as 4 into 0.0028 into 1 into 10 to the power 5 into 40.7 square is equal to so much into 8314 into 8314 into 290 is equal to so much divided by 16, right. So this is equals to (279) 279572774558 means 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 that is 2.8 into 10 to the power 11 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, right so if that be true 2.7 into 10 to the power 11, right 2.8 10 to the power 11, then this term is much much bigger than this term, right 4.8 10 to the power 8.

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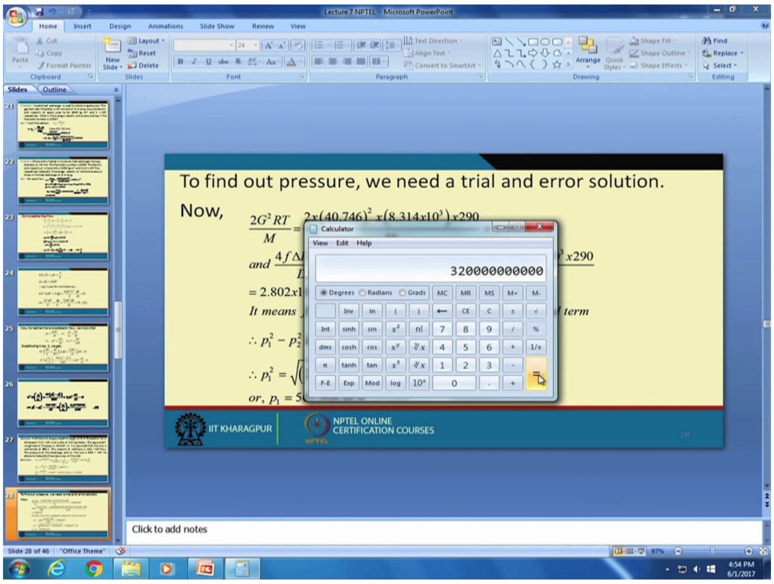

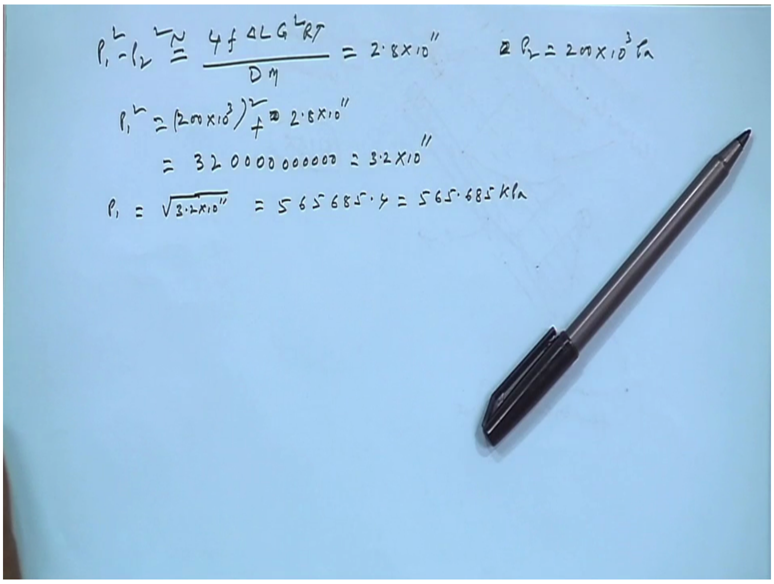

So what we can do that we can then neglect the first term that is we can neglect this term this P1 by P2 or enough this if we neglect that then we can write P1 square minus P2 square that is roughly equal to right 4f delta LG square RT over DM, right. So if that is we have found out to be equals to 2.8 10 to the power 11, right. One is given the value of output 200 10 to the power 3 into that means given is P2 is equals to 200 10 to the power 3 pascal, right 200 10 to the power 3 pascal, that is 200 kilopascal.

So if we substitute this in this we can write P1 square is equals to 200 into 10 to the power 3 square right square this is equals to or rather this is equals to this plus this plus 2.8 10 to the power 11, right. So on on simplification this gives let us see what it gives this gives on simplification that 200 into 10 to the power 3 right, this is square so square of it right plus plus 2.8 2.8 into 10 to the power 11, right. So this becomes equals to this 32 (1, 2) how many zeros 1, 2, 3, 4 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 that is 3.2 into 10 to the power 11, right.

So therefore we can write that P1 is equals to under root of 3.2 10 to the power 11 and that comes to equals to square root of this square root ok, 56 this is equals to 565685.4, right. So that means this is equals to 565.685 kilopascal right.

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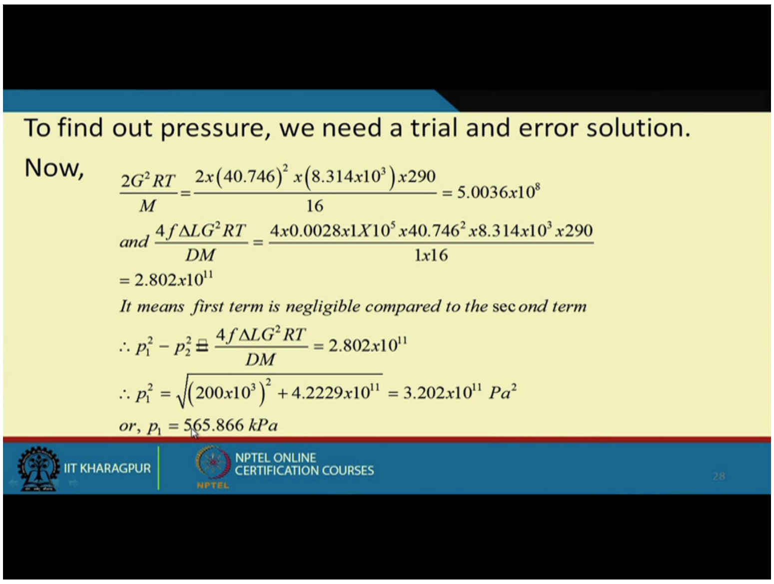

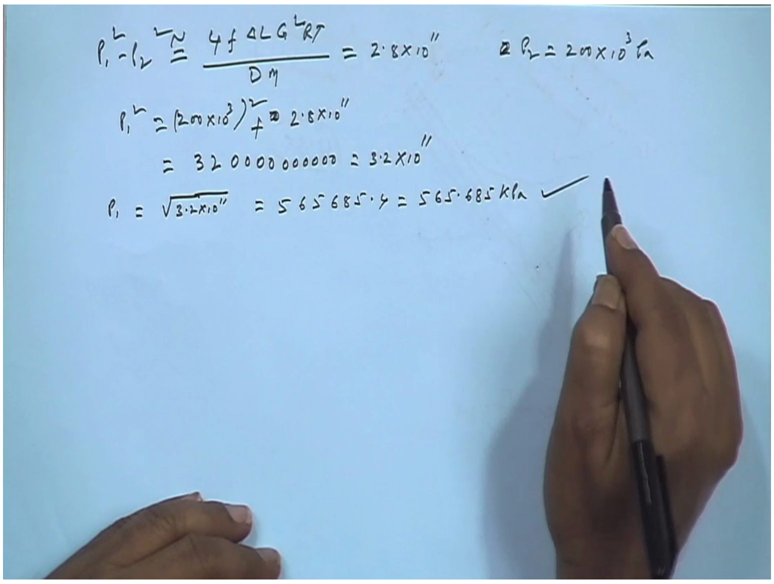

So let us look into how much it is obtained yes 565.865 or 866 kilopascal. So this is one way of (())(23:12), right. So another way of course can be that whenever you are making it that time you have to be sure that this P1 we have not taken into P1 by P2, right so it may so happen that P1 by P2 may be required.

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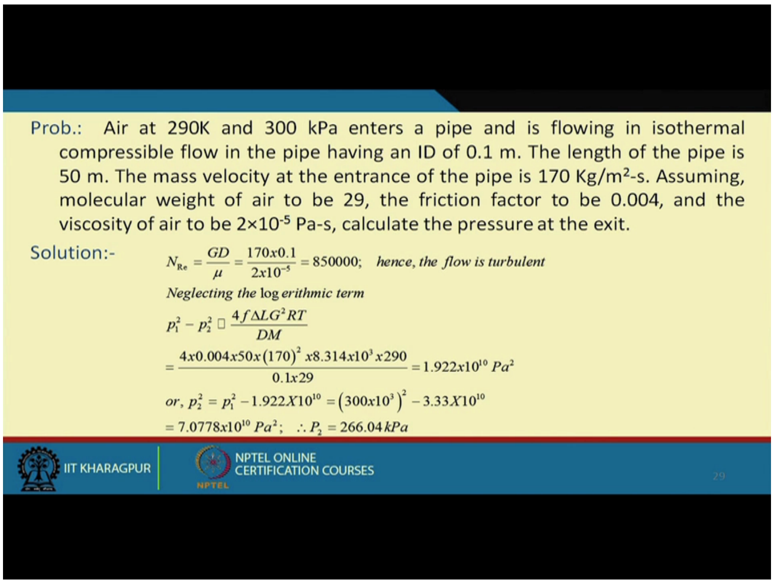

For example another quick one, Air at 290 kelvin and 300 kilopascal enters a pipe and is flowing in isothermal compressible flow in the pipe having an ID of 0.1 meter. The length of the pipe is 50 meter. The mass velocity at the entrance of the pipe is 1700 (kilo) Kg per meter square second. And assuming molecular weight of air to be 29, the friction factor to be 0.004, and the viscosity of air to be (2 point) 2 into 10 to the power minus 5 pascal second, calculate the pressure at the exit. So inlet pressure is given 300 kilopascal, exit pressure we have to find out, right.

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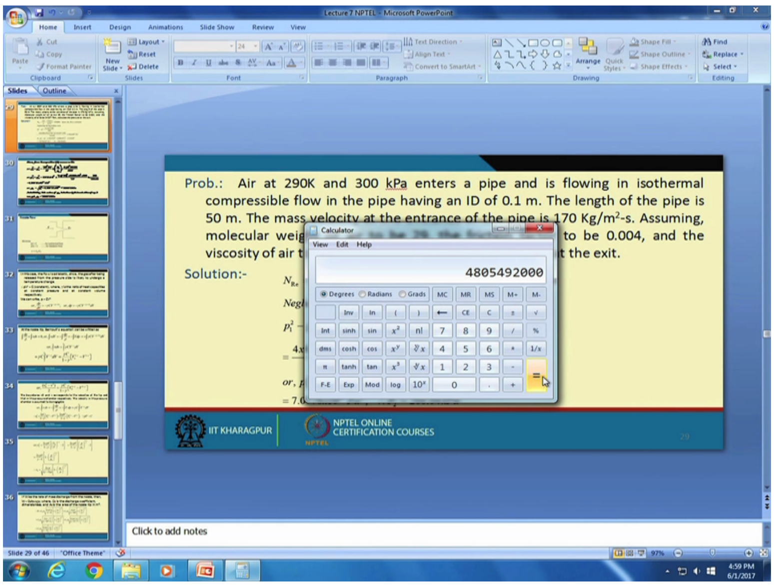

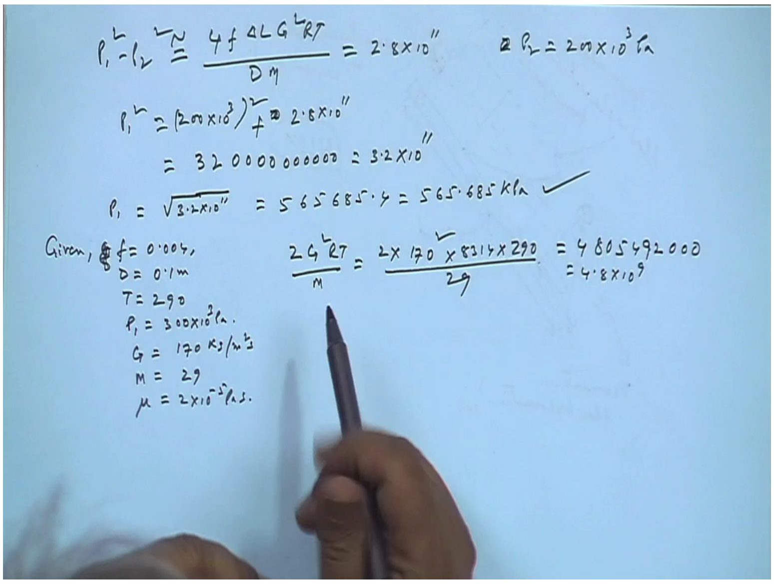

So we start with again from what r given given r given r epsilon by D no epsilon by D is not required. So f is given directly 0.004, then D is given is equals to 0.1, then T is given to be 290, P1 is given to be 300 into 10 to the power 3 pascal right, 3 and 10 to the power 3 pascal and mass velocity G is given 170 Kg per meter square second, right and molecular weight of the gas or air to be 29, viscosity of air to be 2 10 to the power minus 5 pascal second.

So from there if we if we if we find out that 2 2G square RT by M that is equals to 2 into G air is 170 right square R is 8314 into (R) T 290 by M molecular weight is 29, if we look at quickly what is the value coming then we will see this is 2 into into 170 into 170 square ok into 8314 8314 into 290 into 290 is equals to this divided by 29 right so that becomes equals to 4805492000 1, 2, 3, 4, 5, 6, 7, 8, 9 is equals to 4.8 10 to the power 9, right that was one.

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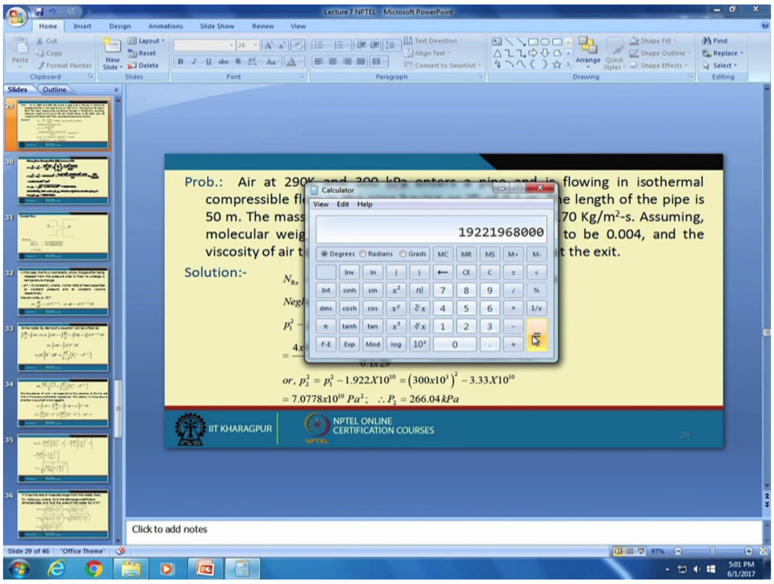

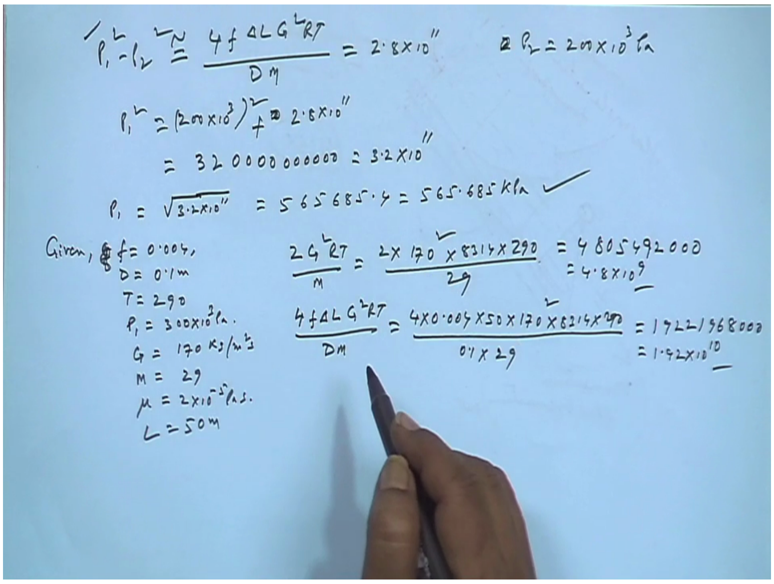

The other one which we found out 4f delta L G square RT by DM so in this case 4f is 0.004 delta L right it was perhaps given that ID so much 50 meter length of pipe is 50 meter L is 50 meter. So we can write this 0.005 into 50 into G is given over is 170 right square R is 8314 into 290 divided by D diameter is 0.1 into into M molecular weight molecular weight is 29, right.

So if we look at this value quickly this is coming 4 into 0.004 0.004 into 50 into 50 right into 170 square 170 square right 170 square into 8314 8314 into 290 is equals to so much divided by 0.1 divided by 29, this is equals to so much is equal to 19221968000 that is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 is equals to 1.92 10 to the power 10. So one is 10 to the power 9, another is 10 to the power 10. So in this case then what we need the inlet is more right outlet has to be found out right.

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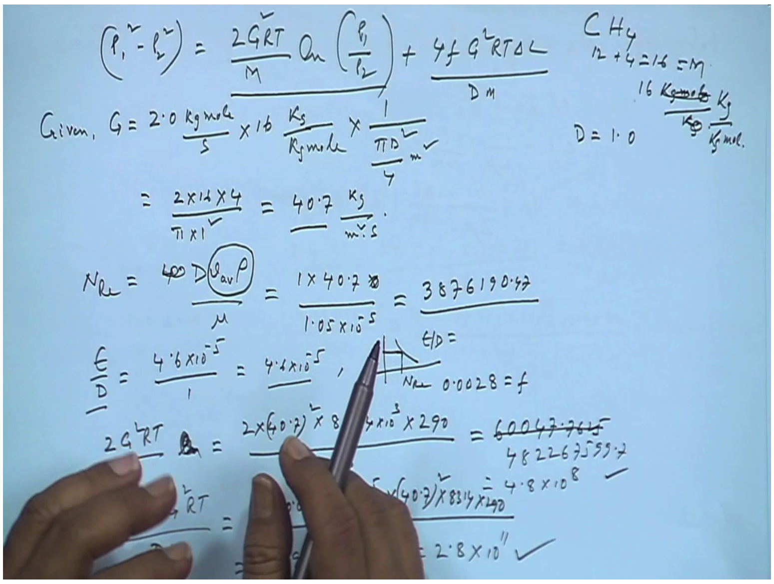

So from the equation which we had shown earlier that this equation P1 is known P2 has to be found out and this value we have found out, this value we have found out. First assume the value of P1 and next is ln of P1 because these two values are not very far away so we cannot neglect.

So take one P1 assumption find out what is the value of for P1 real. So assume them real when they r very close and to be pascal second decimal it is accurate filled that time we can say that this has been upto the first or second decimal according to your (())(30:42) is true or is done or it is the value real value which is upto first decimal or second decimal, ok this way by (())(30:58) we have to do find out the pressure, ok thank you.