Course on Momentum Transfer in Process Engineering
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Lecture 34
Module 7
Variable fluid flow-problems and solutions

So we have seen that what is a variable flow and how much time it takes for the pressure to drop from an initial pressure to a final given pressure. And we also said that this will be under critical pressure ratio condition, right? p0 by p will be 0.528 till the pressure p by pa increases to the level that p equals to 1 by 0.528 that is 1.894 atmosphere it reaches the 1.894 atmosphere till it reaches that value it will be under critical pressure ratio condition, right?

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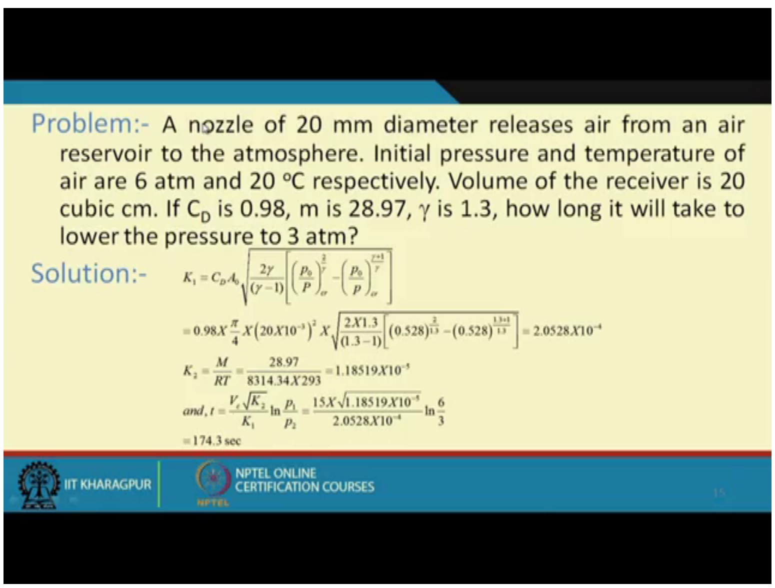

So if we do a problem on it like this that a nozzle of 20 millimeter diameter a nozzle 20 millimeter diameter releases air from an air reservoir to the atmosphere initial pressure and temperature of air are 6 atmosphere and 20 degree centigrade respectively initial pressure and temperature volume of the reservoir is 20 cubic centimeter. If Cd is 0.928 molecular weight is 820 8.97 this should be capital M molecular weight is 28.97, gamma is 1.3, how long will it take to lower the pressure to 3 atmosphere? Right?

So this is our problem, so from 6 atmosphere to 3 atmosphere how long it will take? So I repeat for benefit of yours, the A nozzle of 20 millimeter diameter decreases air sorry releases air from an air reservoir to the atmosphere. Initial pressure and temperature of air are 6 atmosphere and 20 degree centigrade respectively. Volume of the reservoir is 20 cubic centimeter. If coefficient of discharge Cd is 0.98 molecular weight of air is 28.97, heat capacity ratio is 1.3 or gamma is 1.3, how long it will take to lower the pressure to 3 atmosphere? Right?

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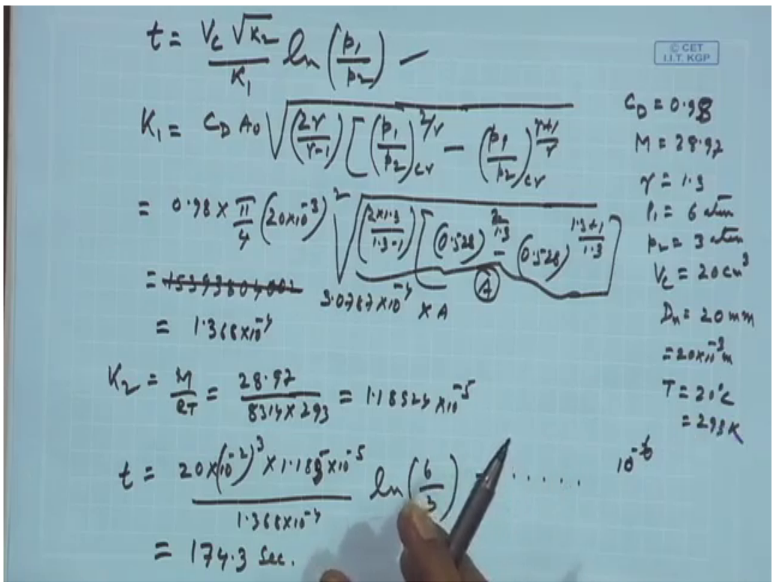

Now this we can solve very easily because we have seen in the previous class that the relation was t is equals to Vc under root K2 over K1 ln of p1 by p2, right? So if p1 is the initial and p2 is the final, right? So if that be true, we also said that K1 is equals to K1 rather it is equals to we had said to be equal to K1 K2 so that was in the other page, yeah K1 was Cd A0 under root 2 gamma by gamma minus 1 times p0 or p1 over p2 initial is p1 and final is p2, so in this case we should write that p okay p1 by p2 as we are writing here to the power this is under critical condition, right?

e to the power point 2 by gamma or rather 2 by gamma minus p1 over p2 to the power gamma plus 1 by gamma under critical condition this was K1, right? And since the values which are given to us are like this, Cd is 0.95 0.98 not 95, then molecular weight M is given 28.97, then we are given gamma to be 1.3, we are given p1 is equals to 6 atmosphere, you are given p2 is equals to 3 atmosphere and also we are given the volume of the container Vc is equals to 20 centimeter cube, right?

So these are the values we are given, then also we were given a nozzle of diameter that is D nozzle is equals to 20 millimeter, right? So 20 millimeter diameter is equals to 20 into 10 to the power minus 3 meter, right? So if we substitute, then Cd is 0.98 A0 is pi by 4 D nozzle square that is 20 into 10 to the power minus 3 whole square into under root 2 gamma 2 into 1.3 by 1.3 minus 1 times this ratio is under critical, so 0.528 to the power 2 by 1.3 minus 0.528 to the power 1.3 plus 1 divided by 1.3, right?

This was our K, now if we see this in the calculator what we can see that, yeah so we have 0.98 into pi divided by 4 into 20 into 10 to the power minus 3 whole square into 20 into 10 to the power minus 3 this my mistake, okay let us do this first 20 into 10 to the power minus 3 okay whole square this is the square, right? Into 0.98 into pi into say 1 is equal to this much by 4 is this side, right? Now what about under root? So let me also write it otherwise 15393804002 how come it is so, somewhere again something has been made wrong, how come it is 10 to the power minus 3 whole square, so it cannot be that.

So it is 20 into 10 x to the power y 3 plus minus is equal to this, now this square is this into pi by 4 into pi into (2.98) 0.98 is equals to this divided by 4 is equals to this, right? And now this into so this we can write this was 3.0787 into 10 to the power minus 4, right? Times this factor say this is A, right? So now what is A? Already we have made into, so we can write here 1, 2 in the second we can write or it can be third 2 into 1.3, right? Divided by 1.3 minus 1 that is 0.3 divided by 0.3, right? So this into first bracket that is 0.528 x to the power 2 divided by 1.3, right? Minus again 0.528 x to the power 1.3 plus 1 that is 2.3 divided by 1.3 something wrong 1.3 hopefully we have done wrong 9.4 which is not true.

So let us see this second part second part was 0.528 to the power x, y to the power 2 by 1.3 2 by 1.3 so this was this, right? Minus 0.528 x to the power 2.3 divided by 1.3 this 1 this 2, right? Into or we can make is equal to, my goodness we are making something wrong repeatedly, so it is 0.528 x to the power 2 by 3 so that becomes 2 by 1.3 pardon me for this, x to the power 2 by 1.3 is this is equal to this, right? Minus again 0.528 x to the power what 2.3 divided by 1.3 this again second bracket and this is equal to, right? 0.05 that is what should have been, fine. Into 2 into 1.3

divided by 1.3 minus 1 that is 0.3 this so this is this, right? Into we have 3.0787 into 3.0787 into 10 to the power minus 4 this is coming 1.3 10 to the power minus 4 1.368 10 to the power minus 4 this check whether this is correct or not, okay.

K2 is coming to be equals to M by RT M is given here as 28.97 R is 8314 and T is 20 degree centigrade which we have not written T is 20 degree centigrade that is equals to 273 so 293 Kelvin. So 293 Kelvin, so this is equals to 28.97 divided by 8314 divided by 293 so this is equals to 1.18, right? This is equals to 1.18924 10 to the power minus 5 K2, right? And therefore the time T we can write from here time t is equals to Vc is given this is 20 centimeter cube 20 into 10 to the power minus 2, right? Minus 3 somewhere this we made wrong here, okay square that was square but this Vc 20 into 10 to the power minus 3 minus 2 meter cube, right?

So into 3 that is it that what it should be, right? And this is that T, okay K2 is 1.185 10 to the power minus 5 185 not 9, okay 5 10 to the power minus 5 by K1, K1 we got 1.368 10 to the power minus 4, right? ln of p1 by p2, p1 is 6 initial final is 3, right? So if this is true, than we can write that Vc is 10 20 centimeter cube so 10 to the power minus 2 or minus 6, so rightly we write it to be 10 to the power minus 6 meter cube. So 20 10 to the power minus 6 meter cube that if we write if we put it here, then we get 10 to the power minus 6 into 20, right?

So this much meter cube is volume Vc, K1 is 1.185 into 1.185 into 10 to the power minus 5, right? So this divided by K2 that was K2 and this is K1 1.368 into 10 to the power minus 4 this is divided by so is equal to this divided by 10 to the power minus 4 so this is equal to this much, right? Times 6 by 3 that is 2 ln of 2 times 1.73 times 2 ln what is ln, yeah 1.7324 10 to the power minus 6, right? Times 2 ln, right? I again think we have done wrong 10 to the power minus 6 yeah we again done wrong perhaps, so it should be 1.713 10 to the power minus 6 plus minus, right? actually we are not so much used 1.713 into 10 to the power minus 6 plus minus this, right? Into let it be like this 2 of ln, ln of 2 is this so into this is 1.1873 10 to the power minus 6 somewhere we have done something perhaps wrong.

However, this comes to 174.3 second, right? So this comes to 174.3 seconds, so when we make it here we see that the thing where we have done wrong is K1 is given at Cd pi by 4 D square, okay. Into under root 2 gamma by gamma minus 1 p by p0 p0 by p to the power 2 by gamma minus p0 by p to the power gamma plus 1 by gamma so this comes to 2.0528 10 to the power minus 4, please check whether it is correct or not, right?

Then K2 as it is M by RT which we also got the same 28.97 by 8314, right? 8314.34 that you can take into 293 that comes to be 1.18519 10 to the power minus 5, right? And there by we get time t is Vc under root Vc into under root K2 by K1 times ln of p1 by p2, right? Now Vc here the difference is not 15 and 20 this 15 this 15 was perhaps 20 cubic centimeter so that is why our thing was coming so low, 20 cubic centimeter we had taken but here in the problem actually we have taken 15 meter cube, right? 15 meter cube into this root K2 that under root 1.18519 10 to the power minus 5 it was so divided by K1 that is 2.0528 10 to the power minus 4 ln of 6 by 3 p (())(28:05) p2 or p0 by p this should not be p0 by p this is p1 by p2 in that t expression which we got earlier, right? Here perhaps this p1 by p2, okay.

So got ln of 6 by 3 this on simplification gives 174.3 so the change is here 15 meter cube instead of 20 cubic centimeter if we take 20 cubic centimeter perhaps whatever we were getting that should come, right?

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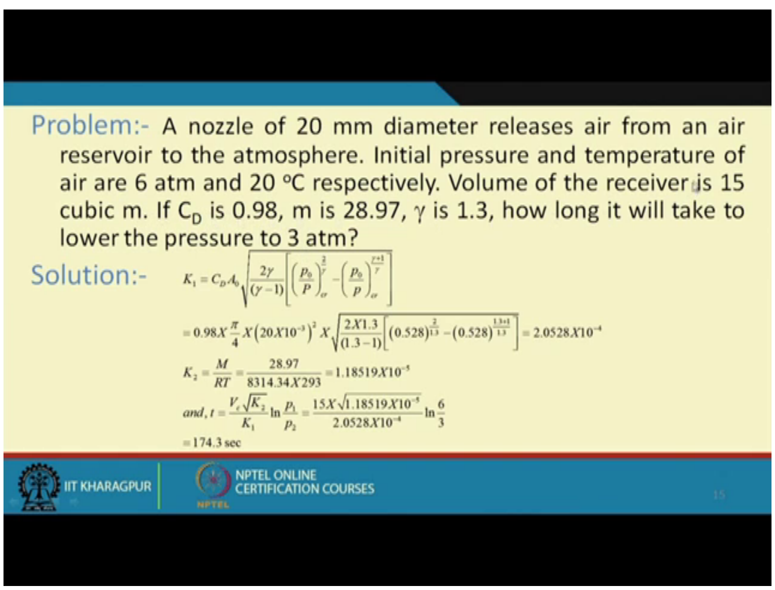

However, this is a this is only a calculation which you can do it with your calculator not like this online where lot many other difficulties are there please check and here in the problem let me also change here that will be better that instead of 20 centimeter cube let me write 15 cubic meter, right? So then only we can say that this is what is coming that cubic 15 cubic meter then only this is coming 15 times Vc is 15 15 times this over this K2 by K root K2 by K1 ln of 6 by 3, then it is 174.3, okay this also you practice and hopefully we can do as many problems we can come across and you also do some practice with other problems, okay. Thank you.