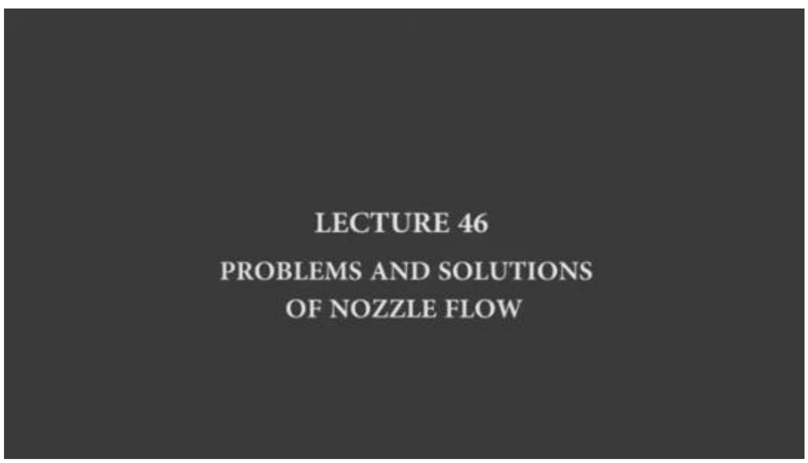
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

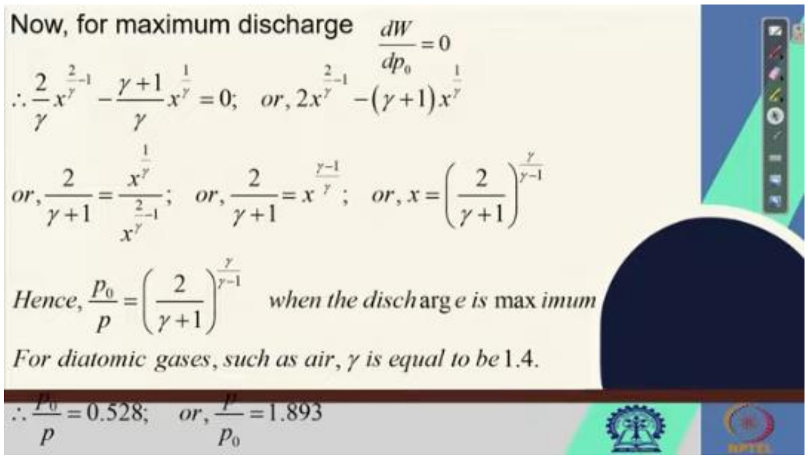
Lecture46

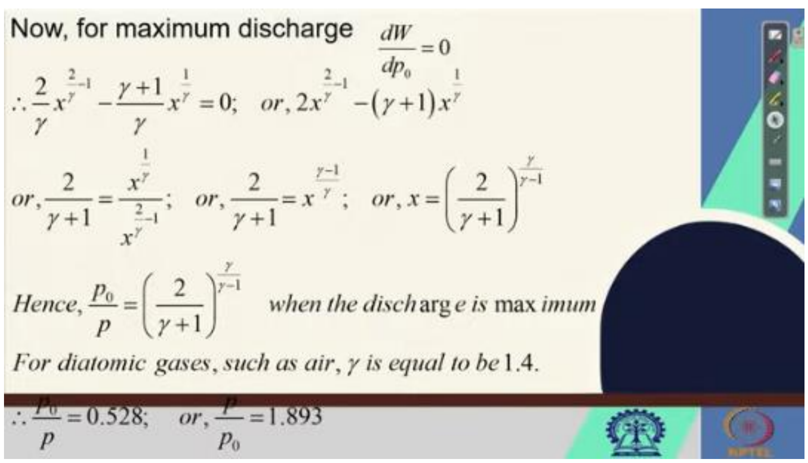
LECTURE 46 : PROBLEMS AND SOLUTIONS OF NOZZLE FLOW Unlisted

Good morning, my dear boys and girls, students, and friends. Right? We have established in the previous class, and earlier as well, in both classes, that the critical pressure ratio—that is, the tip pressure to the inlet pressure—has to become 0.528, right? We are continuing with nozzle flow.

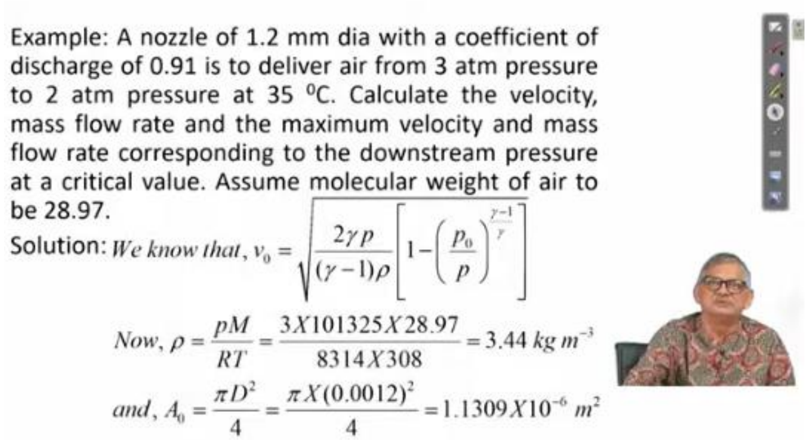


So, it has to become 0.528, right? Then only there will be a pressure ratio corresponding to the maximum discharge, right? So, maximum discharge occurs when the pressure ratio, that is P_o over P, is 0.528. Right? Or inversely, we can also say that the inlet-to-outlet pressure ratio is 1.893, right? This we have clearly established, and again, through repetition, we have reinforced why the adiabatic process is being considered, right?





Then we take an example. We have said many times that if we solve examples or problems, the concept becomes clear. Because you then find—you then get some numerical values that may be retained in your mind, right? The example problem is like this: a nozzle of 1.2-millimeter diameter with the coefficient of discharge—you see that C_D is already explained, is already given by the manufacturer—is 0.91 and is to deliver air from 3 atmospheres at a temperature of 35 degrees centigrade, right?



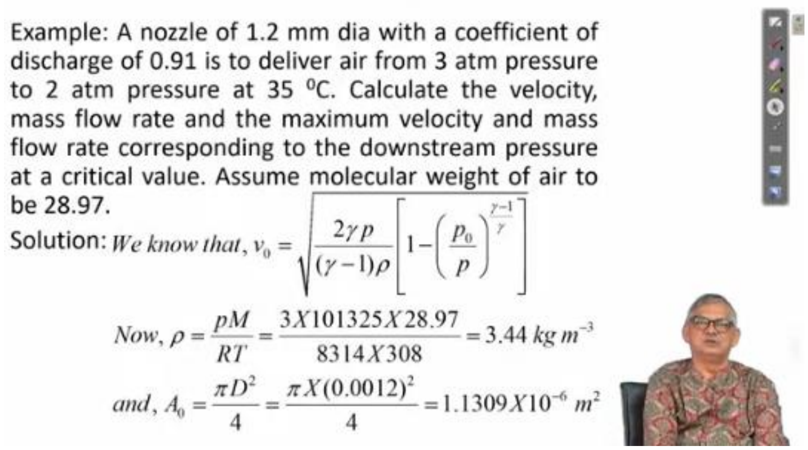
So, calculate the velocity, mass flow rate, and the maximum velocity and maximum mass flow rate corresponding to their downstream pressure at a critical value, right. Assume the molecular weight of air to be So, many things are given, and it is straightforward. It is not that there is any complication which you may have to struggle with, but yes, it will take a little time, but you can easily find out, right. So, we read the problem once more: a nozzle of 1.2 millimeter diameter with 1.2 millimeters, right? 1 millimeter we cannot see virtually.

So, a 1.2 millimeter diameter with a coefficient of discharge of 0.91 is to deliver air from 3 atmosphere pressure to 2 atmosphere pressure at 35 degrees centigrade. Calculate the velocity, mass flow rate, and maximum velocity and maximum mass flow rate corresponding to the downstream pressure. Air downstream means deep pressure. at a critical value.

Assume the molecular weight of air to be 28.97, right? Then we start with what we have been told: that you find out the velocity. I hope even in the last class also we it up that the velocity vo is defined as this is the velocity for flow of fluid through nozzles. So, the velocity vo is equal to under root 2 gamma p by gamma minus 1 into rho

into 1 minus P_o by P to the power gamma minus 1 by gamma is the velocity v_o. Here only one thing is not given that is rho. So, we find out rho as PM by RT. Which P we are taking? Any one of them,

here the higher one we are taking 3 atmosphere. So, 3 into 101325 into 28.97 divided by 8314 that is the value of R. into T, 308 right. It is said 35 degree centigrade that means 308 Kelvin. So, equal to 3.44 kg per meter cube that you check with your calculator because here I can also see it is not that I cannot because I also do have.

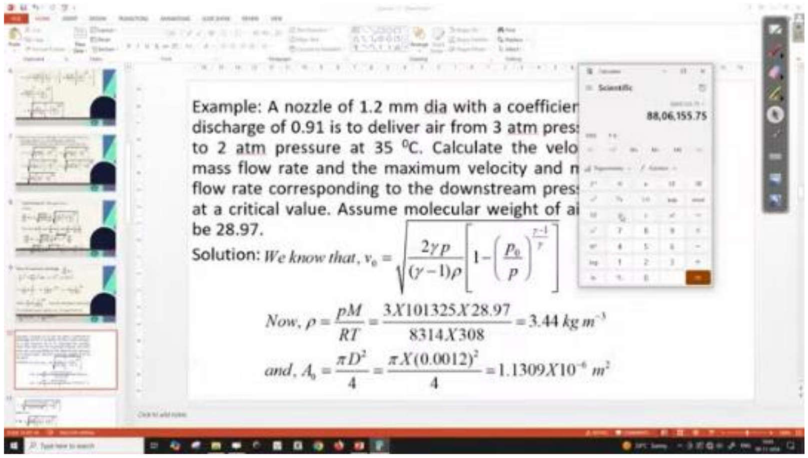


but that will take unnecessarily more time. If you want me to do for once, I have no problem, right? Shall we do? Okay. As you are thinking that we can take provided I get the calculator here because this system

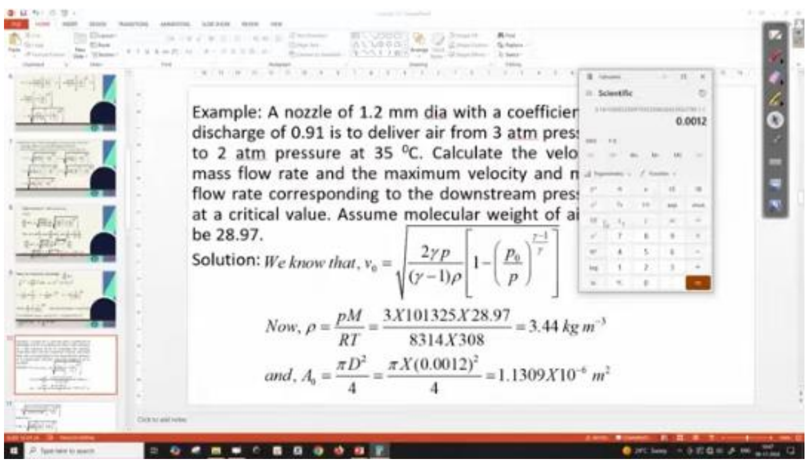
not our normal system, yeah this is typically for recording classes. So, let me check from there, here calculator. if we give calculator what happens? Yeah, it has come. What it is standard?

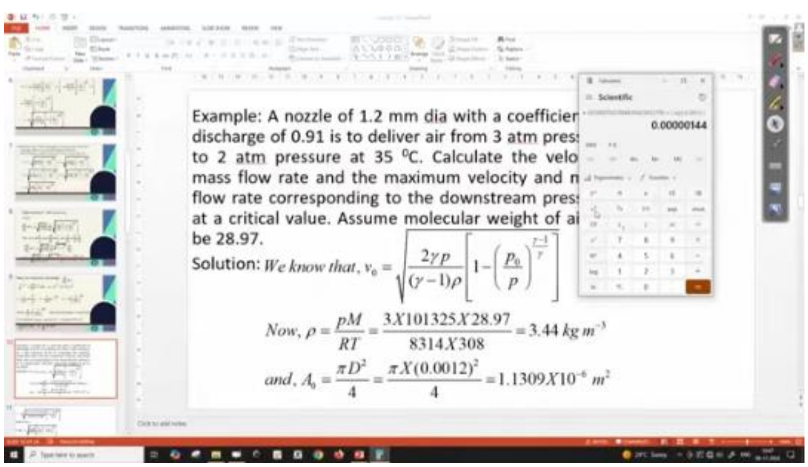
Let me check whether scientific is there. Yes, scientific is also there ok. Now, we have come and seen. So, we have opened that calculator. So, we can check that 3 into 1 0 1 3 2 5 into 28.97, 28.97, is equal to divided

in bracket 8 3 1 4, 8 3 1 4, right into 3 0 8, 3 0 8. So, this is that denominator and we are already given. So, it is 3.43 or 4 4 that means, we have rightly done. So, if that be true, then we come to A_o right. We come to then A_o equal to pi D square by 4 right, A_o is equal to pi D square by 4.



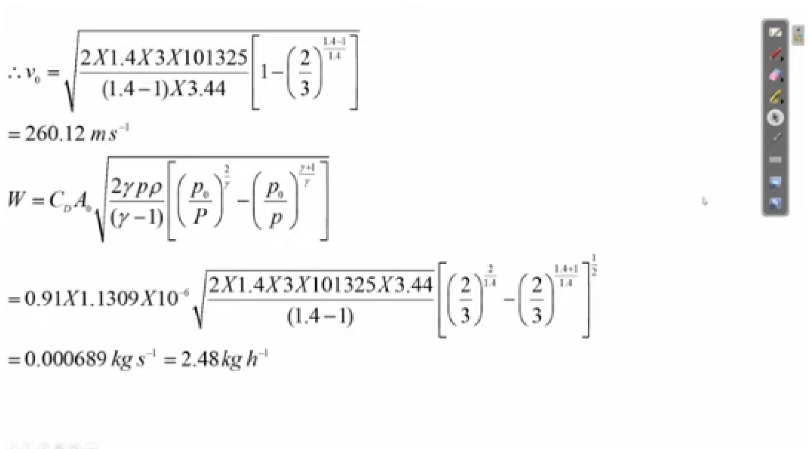
is equal to pi into 0.0012 whole square by 4 ok. If we want, we can also check this, whether it is coming or not, this is cancel, I hope you can see that pi. here in many many places pi is as such given, but pi into 0.0012 square into 0.0012 this here. So, that into pi is equal to this much divided by 4 that means, it is 1.1309 into 10 to the power minus 6, yes it is coming the same.



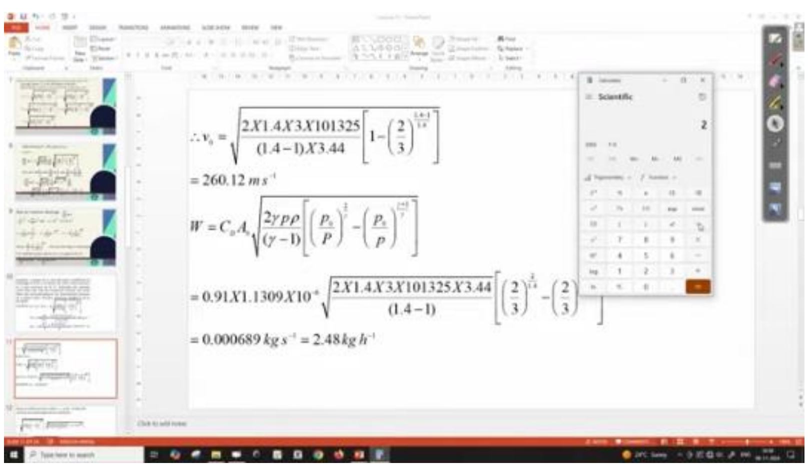


ok that means, our calculations what we have made at least two verifications we have seen we have done and it is seen that it is correct. It is likely to be correct, but still I request you, you do not know whenever we are writing, there could be some problem. Whenever we are calculating, there could be some problem, but we do not know. That is why it is better all the time you check it. Now, rho is known A_o is known, then vo that is equal to 2 into 1.4 into 3 into 1 0 1 3 2 5 by 1.4 minus 1 into 3.44 whole into 1 minus 2 by 3 to the power 1.4 minus 1 by 1.4.

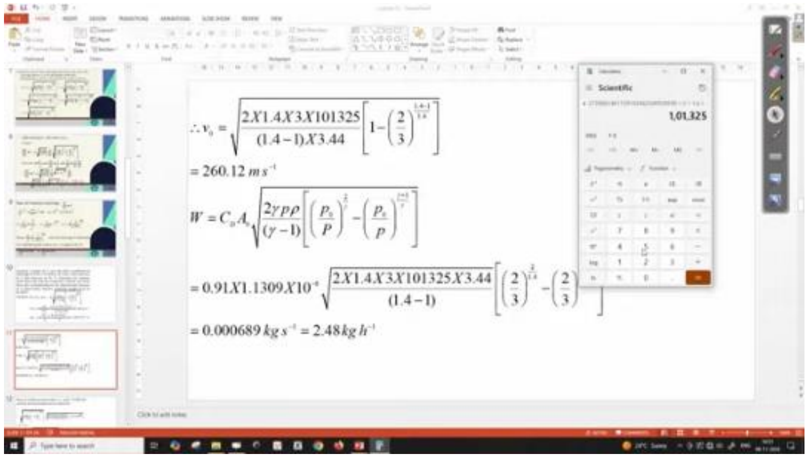
Again let us check whether it is coming correctly or not? No, it cannot be. Yeah. So, we write cancel.



First, let us do this part 2 by 3. 2 divided by 3 is equal to this much to the power that is x to the power y to the power how much? 1.4 minus 1, that is 0.4. 0.4 divided 1.4, yeah. So, the bracket closes. This becomes equal to this.



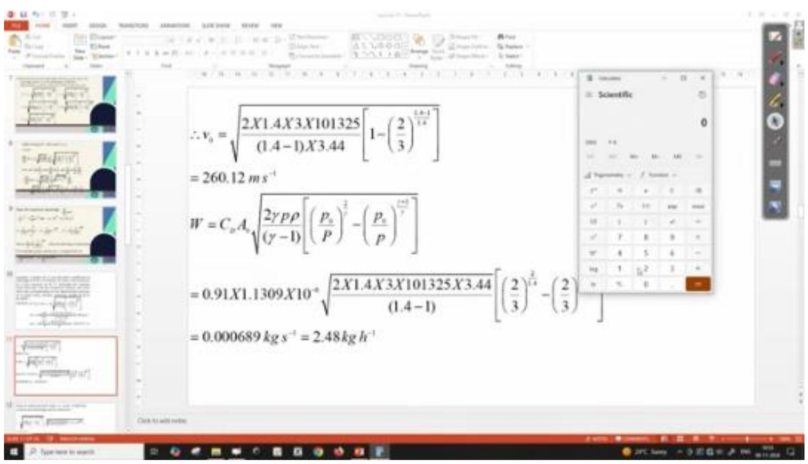
So, this is plus minus 1 plus minus this. We can write plus 1, right. So, it is 0.203 into 2 into 1.4 into 101325 Right, it is done divided by 1.4 minus 1, that is 0.4 into 3.44 bracket close, and this value Square root is this 204.65. That is why I am saying to you regularly that you also calculate. It is in the problem solution. It is shown 260.12, but here we are seeing that it is becoming



That means somewhere something is wrong. So, again we do. Let us see whether we made any mistake in between or not. That is the first thing, 2 over 3. So, this is becoming 0.66.

This to the power 0.4 by 1.4. So, bracket close 0.4, 0.4 by 1.4 that is 0.5 goes out 44, 54, 56. how come it is so much. So, it becomes 0.85 somewhere it is appearing something wrong might have happened.

I do not know why 2 by 3 is equal to this x to the power right. How much x divided by y? 1 minus 2 by 3 right to the power 1.4 minus 1 that is 0.4 divided by 1.4 oh not 1 0 1 point my goodness 1.4 1.4 ok.



So, it becomes bracket close and then 1 minus this. So, 0.85 into 2 into 1.4 into 3 into divided by 1.4 minus 1 that is 0.4 into 3.44. Yeah, it is coming now to 69. Yeah, somewhere something wrong we are making here.

However, you please look into very carefully so that the values are more or less correct right. Somehow I do not know we tried twice and twice the value is different 260.12 meter per second may not be coming with this now as here as I am telling that it could be from calculator to calculator not only that, in the house, you do with the computer. So, here it is with the calculator.

$$\therefore v_0 = \sqrt{\frac{2X1.4X3X101325}{(1.4-1)X3.44}\left[1-\left(\frac{2}{3}\right)^{\frac{1.4-1}{1.4}}\right]}$$

$$= 260.12\ m s^{-1}$$

$$W = C_D A_0 \sqrt{\frac{2\gamma p \rho}{(\gamma-1)}\left[\left(\frac{p_0}{P}\right)^{\frac{2}{\gamma}} - \left(\frac{p_0}{p}\right)^{\frac{\gamma+1}{\gamma}}\right]}$$

$$= 0.91X1.1309X10^{-6}\sqrt{\frac{2X1.4X3X101325X3.44}{(1.4-1)}}\left[\left(\frac{2}{3}\right)^{\frac{2}{1.4}} - \left(\frac{2}{3}\right)^{\frac{1.4+1}{1.4}}\right]^{\frac{1}{2}}$$

$$= 0.000689\ kg\, s^{-1} = 2.48\, kg\, h^{-1}$$

However, all put together, you check. That is the most fundamental. ok, that is velocity 260.12 meter per second. Now, discharge rate, discharge rate W is $C_D A_0$ root 2 gamma P rho by gamma minus 1 into P_0 by P to the power 2 by 3 or 2 by gamma rather minus P_0 by P to the power gamma plus 1 by gamma.

So, we can write C_D already given 0.91, A_0, we have found out it to be 1.1309 into 10 to the power minus 4 And on the root of 2 into 1.4 into 3 into 101325, this 101325 is coming in terms of Pascal into 3.44 by 14.2 by 14 minus 1 rather 1.4 minus 1. Therefore, 2 by 3 whole cube minus 2 by 3 to the power 1.4 plus 1 by 1.4 right. This has become 0.000030. 0.00030689 kg per second right.

$$\therefore v_0 = \sqrt{\frac{2X1.4X3X101325}{(1.4-1)X3.44}\left[1-\left(\frac{2}{3}\right)^{\frac{1.4-1}{1.4}}\right]}$$

$$= 260.12\ m\,s^{-1}$$

$$W = C_D A_0 \sqrt{\frac{2\gamma p\rho}{(\gamma-1)}\left[\left(\frac{p_0}{P}\right)^{\frac{2}{\gamma}} - \left(\frac{p_0}{p}\right)^{\frac{\gamma+1}{\gamma}}\right]}$$

$$= 0.91X1.1309X10^{-6}\sqrt{\frac{2X1.4X3X101325X3.44}{(1.4-1)}}\left[\left(\frac{2}{3}\right)^{\frac{2}{1.4}} - \left(\frac{2}{3}\right)^{\frac{1.4+1}{1.4}}\right]^{\frac{1}{2}}$$

$$= 0.000689\ kg\,s^{-1} = 2.48\,kg\,h^{-1}$$

So, which can be correlated with this can be a little You see that 0.00689 kg per second that we have converted into 2.48 kg per hour, right. So, this we are also not going to check because we have already done with the velocity. Now, maximum velocity for maximum velocity, we have said that the pressure ratio is 0.528.

$$\therefore v_0 = \sqrt{\frac{2X1.4X3X101325}{(1.4-1)X3.44}\left[1-\left(\frac{2}{3}\right)^{\frac{1.4-1}{1.4}}\right]}$$

$$= 260.12\ m\,s^{-1}$$

$$W = C_D A_0 \sqrt{\frac{2\gamma p\rho}{(\gamma-1)}\left[\left(\frac{p_0}{P}\right)^{\frac{2}{\gamma}} - \left(\frac{p_0}{p}\right)^{\frac{\gamma+1}{\gamma}}\right]}$$

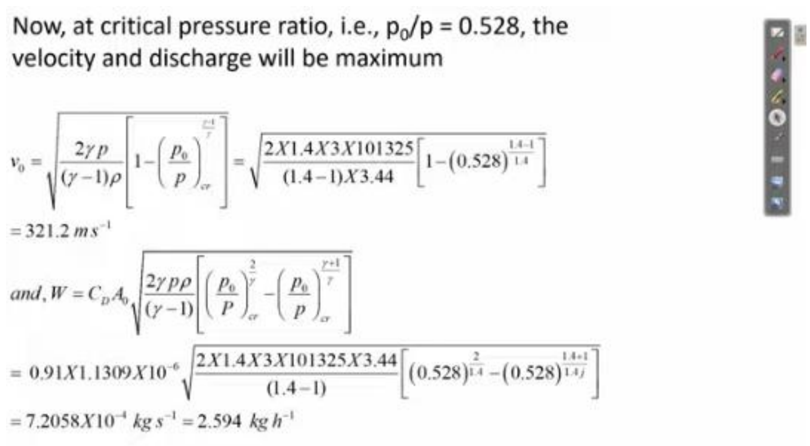
$$= 0.91X1.1309X10^{-6}\sqrt{\frac{2X1.4X3X101325X3.44}{(1.4-1)}}\left[\left(\frac{2}{3}\right)^{\frac{2}{1.4}} - \left(\frac{2}{3}\right)^{\frac{1.4+1}{1.4}}\right]^{\frac{1}{2}}$$

$$= 0.000689\ kg\,s^{-1} = 2.48\,kg\,h^{-1}$$

The velocity and the discharge will become maximum at this critical pressure ratio of internal and the exit pressure. We are saying v_o is under root 2 gamma P by gamma minus 1 into rho into 1 minus P_o by P to the power of gamma plus 1 by gamma. This is under critical condition. And, that is equal to 2 into 1.4 into 3 into 1 0 1 3 2 5 divided by 1.4 minus 1 into 3.44 1 minus 0.528 whole to the power 1 point 1 plus 0.4 yeah 0.5 3.44 divided by 1.4 minus 1 into 0.528 because it is already said that

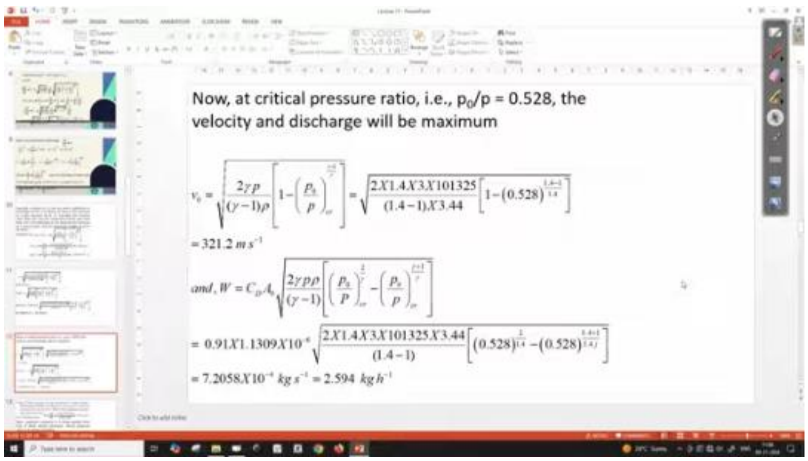
find out the flow rate say average velocity inside here, but here is also that 0.528 to the power 2 by 1.4 over minus 0.528 to the power 1.4 plus 1 divided by 1.4. Here we have simply substituted P_o by P critical because we have been asked that maximum discharge. What will be the maximum discharge? Velocity we have found out to be 321.2 meter per second, but here we are finding out that corresponding to that maximum velocity what could be the discharge coefficient yeah my how I mean discharge coefficient. This discharge coefficient 0.91 into 1.1309 into 10 to the power minus 6 into under root 2 into 1.4 into 3 into 1 0 1 3 2 5 into 3.44 by 1 4 1.4 by into 1 by 10

Point 528 to the power 2 by 1.4 minus 0.528 into 0.528 to the power 1.4 plus 1 by 1.4. Right. So, this we have calculated, and it has come to 7.2058 into 10 to the power minus 4. Kilograms per second, that is 2.5494 kilograms per hour. So, kilograms per second, 2 kilograms per hour divided by

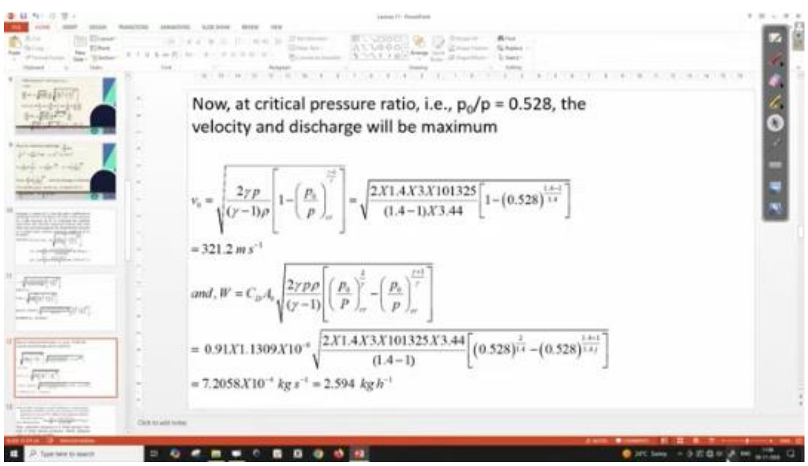


into 10 to the power minus 4, that is the kilograms per second converted into hours as 2.594 in kilograms per hour. Let us see this small one. So, we are doing 7.2058 7.2058 into 10 to the power minus 4 into 10 to the power minus 4. So, 10 to the power minus 4

It is 7. Did I do something wrong? 10, 4, yeah, plus minus, yeah, okay. 7 times 2 to the power minus 4 is not that. This way, we can find out the maximum discharge corresponding to the critical pressure ratio, okay. So, we have done a problem solution. With this, we come to the end of this class, and we hope



In subsequent classes, we will also solve more problems and solutions. Right?



Thank you. So nice of you.