Fluid Machines.
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Tutorial - 02

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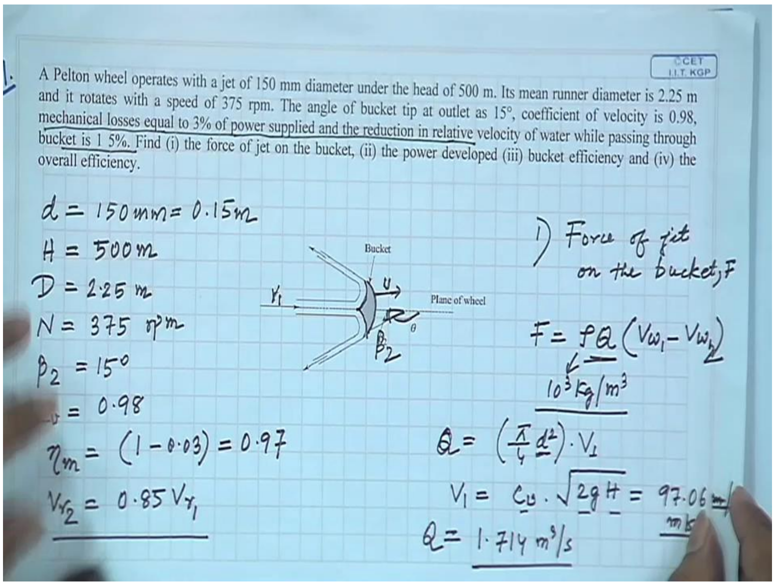

Today we are going to solve 2 problems on Pelton wheel, Pelton turbine. So the 1st problem, let me read it out. A Pelton wheel operates with a jet of 150 millimetre diameter under the head of 500 meter. Its mean runner diameter is 2.25 metres and it rotates with the speed of 375 rpm. The angle of the bucket tip at the outlet is 15 degree, the coefficient of velocity is 0.98, the mechanical, mechanical losses equal to 3 percent of power supplied and the reduction in relative velocity of water while passing through the bucket is 15 percent. Find, so we have to find the force of the jet on the bucket, the power developed, the bucket efficiency and the overall efficiency.

So as you can see, this is the bucket of the Pelton wheel, this is the peripheral velocity of the bucket, this is the absolute velocity of water at the inlet or the jet velocity. This is the angle by which the jet gets deflected after it hits the bucket and this angle is beta-2. So let me write, write the things, the parameters that we are given. Firstly we are given the jet diameter which is 150 millimetres or 0.15 metres. The head at the inlet is given as 500 metre, the mean runner diameter is given as 2.25 metres, the rotational speed of the runner is given as 375 rpm.

The angle beta-2, that is this angle is given as 15 degree, the coefficient of velocity is given as 0.98, now this line, this line actually signifies the, tells us the mechanical efficiency. So from this line we can actually say that the mechanical efficiency is given as 1 - 3 percent, that is 0.03, that is 0.97, so this is the mechanical efficiency. Also we are given that the relative velocity, relative velocity the outlet has a reduction of 50 percent compared to that of the relative velocity at inlet.

So we can write VR2, that is the relative velocity at outlet is equal to 0.85 into VR1. So these are what we are given. So 1^{st} we are going to find out what is the force of the jet on the bucket, that is F. Now we know that the force is given by the expression rho Q into the tangential velocity at the inlet minus the tangential velocity at the outlet. Q is the flow rate of the jet, so we know already the rho which is the density of water. And that is 1000 KG per metre cube, so we have to find out the flow rate of the water at the inlet and also the tangential velocity components at the inlet and the outlet.

So for the flow rate we know, it is given by into the jet velocity. Where d is the diameter of the jet. We know the, we have been given this value, so we have to find out the jet velocity which is given by V is equal to, the coefficient of velocity into root over of 2 into G into the available head. Now we know, we know all these quantities, all these quantities have been given, so if we substitute the values the jet velocity comes out to be 97.06 metre per second.

So substituting the value of V into the above expression we find out the value of Q which comes out as 1.714 metre cube per second. Next we have to find out the tangential velocity at the inlet and the outlet. For this we refer to the velocity diagram for the Pelton turbine.

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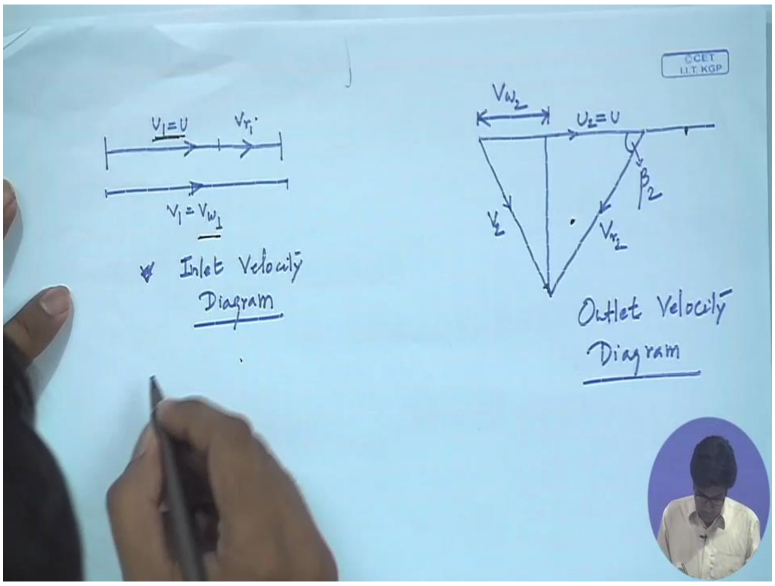

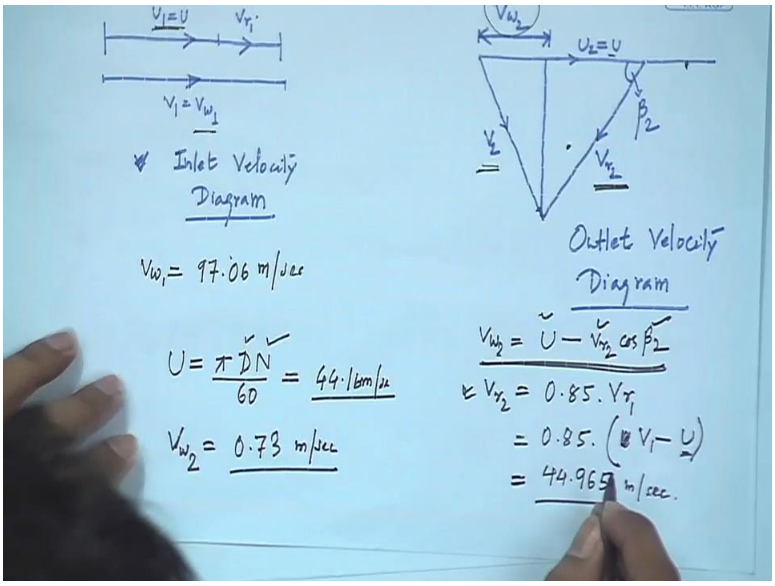

So here 1st we see the inlet velocity diagram. Here this is the peripheral velocity of the blade, this is the relative velocity at the inlet and this is the tangential velocity which is also equal to the absolute velocity of water at the inlet. So from here we can write, we know that the tangential velocity at the inlet is nothing but the jet velocity. So we know, we have already found out the jet velocity and which is 97.06. So let us move onto the outlet velocity diagram. In the outlet velocity diagram, this is the tangential velocity at the outlet, this is the relative velocity at the outlet and this is the absolute velocity of water at the outlet.

And this is the peripheral velocity of the blade or the wheel. So here we can write the tangential velocity as, from the velocity diagram we can clearly see that it is equal to U minus

VR2 cos of beta-2. Now beta-2 is given, VR2 as was already said in the problem is equal to 0.85 into VR1. Now from the inlet velocity diagram, we can see that VR1 is sorry, V1 minus U. So substituting, so okay, we have not found out U also, so you have to find out U, that is the peripheral velocity of the blade.

So the peripheral velocity of the blade is given by pie into the runner diameter into the speed of, rotational speed of the runner, divided by 60, since N is in rpm. So we know the runner diameter and also the value of N which is 375 rpm, so substituting the values, we get the value of U as 44.16 metre per second. So from this expression we get the value of VR2, that is the relative velocity at the outlet as 44.965 metre per second.

So, after all, so finally we have found out the relative velocity at the outlet, so returning to this formula, to this expression we find out the velocity of VW2, we know U, we know VR2 and this has been already given, so the velocity for the tangential velocity at the outlet, so the value of tangential velocity at the outlet is 0.73 metre per second. So finally the force whose expression whose expression was given as, so substituting all the values here we finally get the value of the force on the bucket by the jet as 165.15 kilo Newton.

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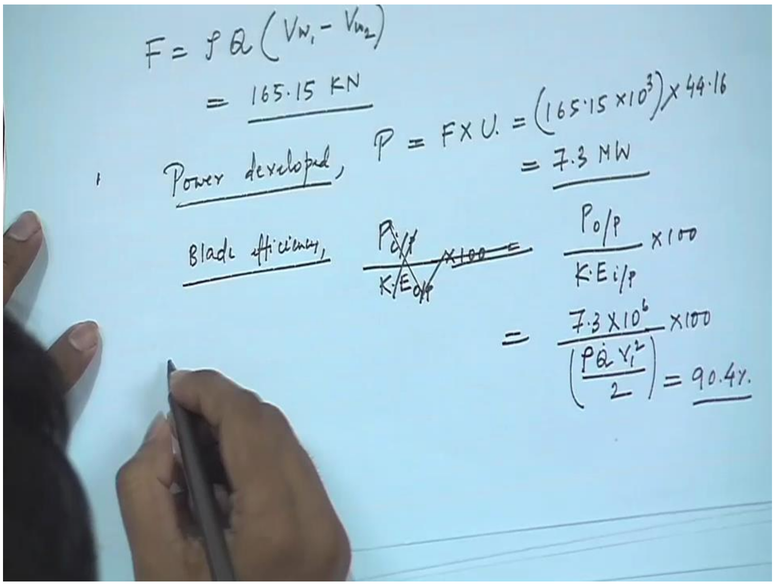

So moving onto the next part where we have to find out the power developed. This is given by the above force multiplied by the peripheral velocity of the blade, which is, the peripheral velocity of the blade was found out earlier and as 44.16 metres per second and which, this comes out as 7.3 megawatt. Next we have to find out the blade efficiency. The blade efficiency is the ratio of the power input to the output kinetic energy into 100. So the output, the output, the input sorry sorry, I made a mistake.

The blade efficiency is the ratio of the output power divided by the kinetic energy, input kinetic energy of the jet. The output power is, we just found out earlier as 7.3 megawatt and the input kinetic energy is basically given as the kinetic energy of the jet which is rho Q V1 square, rho Q, rho Q dot V1 square by 2. So we know the value of Q dot, we know the density and we have found out V1 earlier, so substituting the values, we find it to be 90.4 percent.

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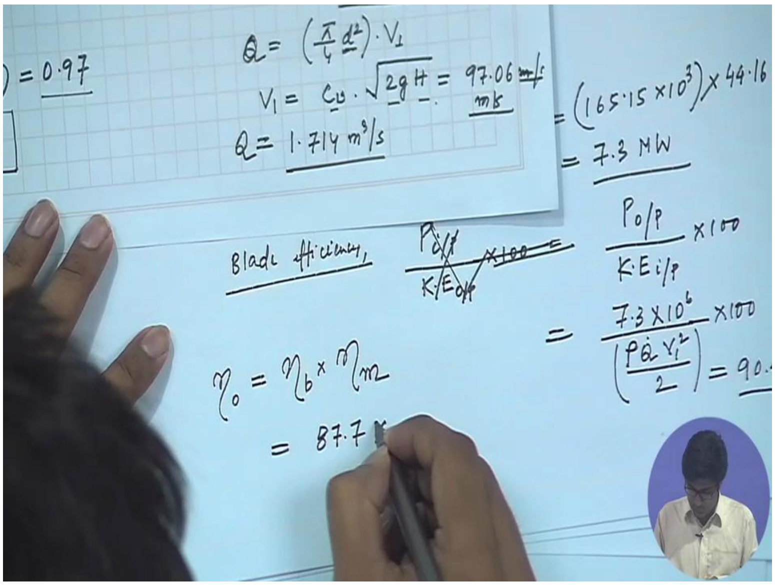

Finally we have to find out the overall efficiency which is the product of the blade efficiency and the mechanical efficiency. As we are, while I was reading the, while I was writing out the data, we find out that the mechanical efficiency was 0.97. So from here, substituting the values of the respective parameters, we find out the overall efficiency as 87.7 percent. This is the end of problem 1. Now I will be moving on to the problem 2.

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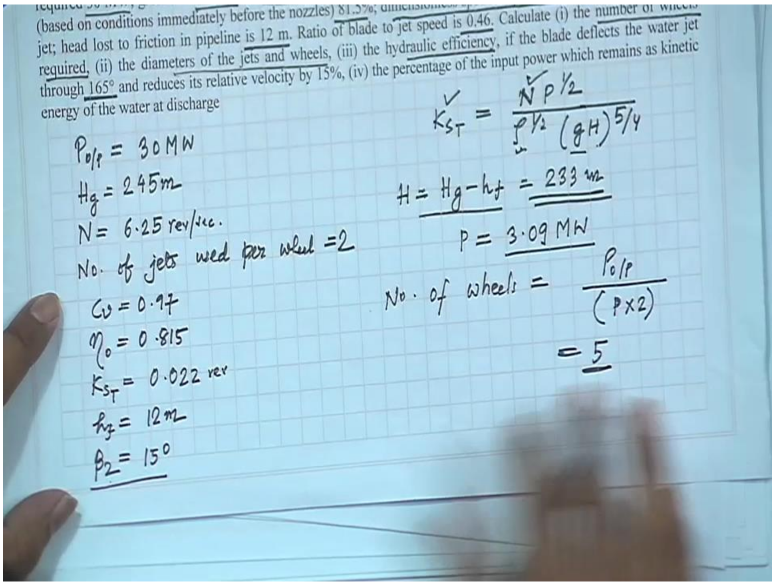

So let me read it out. In a hydroelectric scheme, a number of Pelton wheels are used under the following conditions. The total output power required is 30 megawatt, gross rate of 245 metre and rotational speed of the runner is 6.25 revelations per second, per wheel there are 2 jets used, the coefficient of velocity is 0.97, the maximum overall efficiency is 81.5 percent, the dimensionless specific speed or the maximum value of the dimensionless specific speed is given as 0.022 revolutions per jet. The head loss due to friction in the pipeline is 12 metres.

Ratio of the blade to the jet speed is 0.46, so we have to find out the number of wheels that are required, the diameter of the Jets and the wheels, the hydraulic efficiency, also we are given that the deflection angle of the waterjet after hitting the blade is 165 degree. And the land again as a previous problem, the relative velocity at the outlet is 15, is reduced by 15 percent compared to the relative velocity at the inlet. So also we have to find out the percentage of input power which remains as kinetic energy at discharge.

So let us write down what we are, what what are given in this problem. So 1st, we are given the power output, output power that is required, which is 30 megawatt. The gross rate is given as 245 metres, the rotational speed of the runner is given as 6.25 revelations per second, number of jets used per wheel is 2, coefficient of velocity is given as 0.97, the overall efficiency is given as 0.815, the dimensionless specific speed of the turbine is given as 0.022 per jet and the head loss due to friction is given as 12 metres.

Also the angle beta-2 is given as 15 degrees, just like in the previous problem. So 1st let us try to find out the number of wheels that are required. For this, we need to find out the power,

power, output power required per wheel. So 1st, 1st let us write down the expressions for the specific speed for the turbine. It is given as the rotational N into P to the power half divided by rho to the power half into GH hold to the power 5 by4. So from here we know the value of the specific speed, maximum specific speed which is given.

The rotational speed of the runner is also given. We know the value of the density of water, we know the value of G and H. This H is the net head available at the inlet, which is actually the gross head minus the frictional head loss. That is 233 metres. So from this we can find out the power required per wheel for each jet and if we put the values, it comes out to be 3.09 megawatt. So the number of wheels is the total power output divided by the power per wheel, per jet into 2, since 2 wheels are, since 2 jets are required per wheel.

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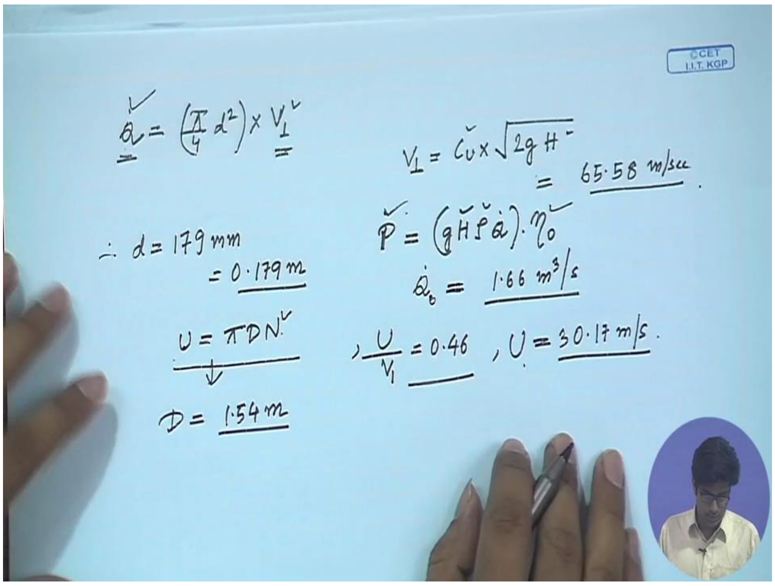

So this comes out approximately as 5 which is nearest whole number and we have to take the whole number for this case since we have to find out the number of wheels. So moving on to the next part where we have to find out the diameter of the Jets and the wheel. So to find out the diameter of the jet, we can write that the flow rate of water of the jet is pie by4 D square into the jet velocity. Now this is also known and as well as the velocity of the jet is also unknown. So let us find out the velocity of jet which is given as CV into root over of 2 into G into net head available.

We know all the values, so substituting them we find out the value of the jet velocity as 65.58 metre per second. Also the flow rate we have to find out, so for this we, we write an expression for the power output per wheel per jet as GH rho Q dot into the overall efficiency.

So we know the net head available, density of water and we know the value of the power per jet, we found out earlier. So from, we know the overall efficiency also, so from here we can find out the flow rate per jet for for one jet as 1.66 metre cube per second.

So right now we know what is the value of Q dot and as well as the velocity of the jet. So we can find out the velocity, diameter of the jet as, by substituting values which comes out as 179 millimetre or 0.179 metres. Next we have to find out the diameter or the mean diameter of the runner. So we know that the peripheral velocity of the blade can be expressed as pie D N, where N is in revelations per second. So here we have to find out the peripheral velocity of the blade.

Now in the problem it was given the duration of the blade to jet speed is 0.46, that this U by V1 was given as 0.46. So from this we can find out the velocity, peripheral velocity of the blade as 30.17 metre per second. So substituting this value of U in this expression, we know the value of N, so we get the runner diameter as 1.54 meter.

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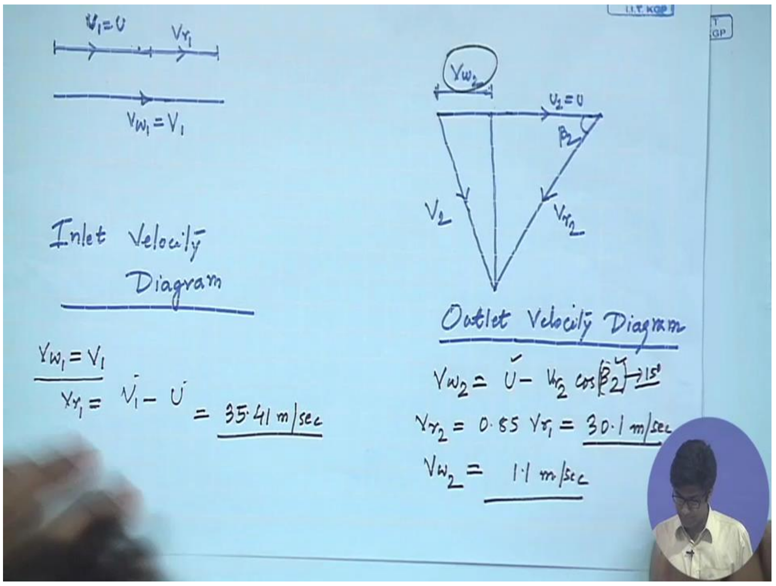

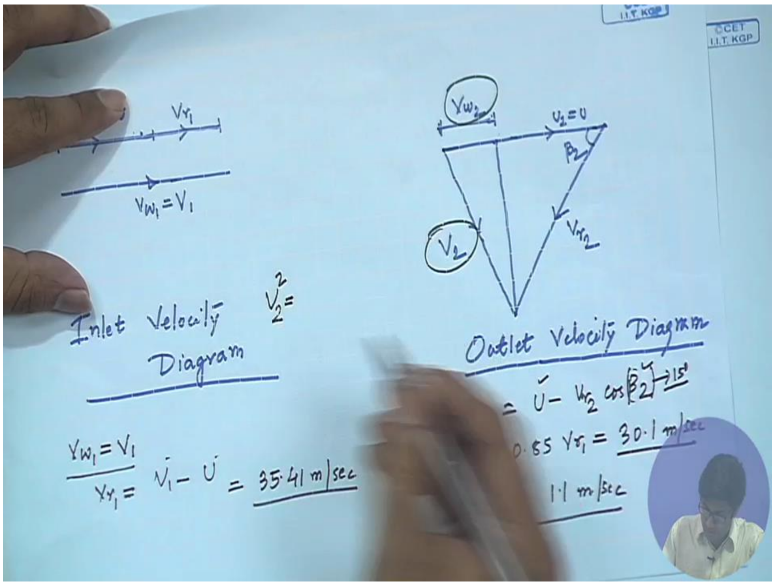

Next we have to find out the hydraulic efficiency, the hydraulic efficiency is given as the tangential velocity at the inlet minus the tangential velocity at the outlet multiplied by the blade peripheral velocity divided by G into net available head into 100. So let us move on to the velocity diagrams to find out these quantities. Here V W1 as earlier we have said, V W1 that is the tangential velocity, the inlet is equal to V1, the jet velocity. So V R1 is equal to V1 minus U or U1.

So substituting the values of V1 and U, we find out the value of relative velocity at the inlet which comes out as 35.41 metre per second. Next from this triangle, from this velocity velocity diagram we have to find out the tangential velocity at the outlet which is given as VW2 is equal to U minus VR2 cos beta-2. VR2 as we already know is given as 0.85 into VR1. So substituting the value of VR1, we ultimately get the radio velocity at outlet as 30.1 metre per second.

From this we know the value of U, we know beta 2 is equal to 15 degree centigrade, 15 degree, sorry and we get the tangential velocity at the outlet as 1.1 metre per second. So right now we have known the values of V W1 and VW2, we know the value of the peripheral velocity of the blade, we know the net head available, so we can find out the hydraulic efficiency by substituting the value which is 35, sorry, 65.58 minus 1.1 divided by 9.81 into 233 into the peripheral velocity of the blade which is 30.17 into 100.

Calculating this, we ultimately get the hydraulic efficiency as 85.1 percent. Finally we have to find out the percentage of the input power which remains is kinetic energy of water at discharge. That is we have to find out the ratio of the kinetic energy at output with respect to the input power. We find out this ratio for both the quantities per unit mass, so the kinetic energy output per unit mass is given by V2 square by 2. Now from the velocity diagram, we have to find out V2.

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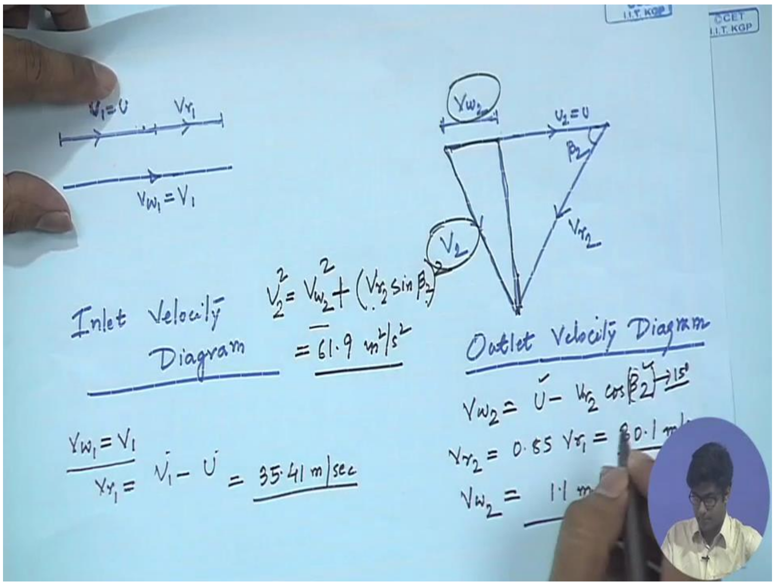

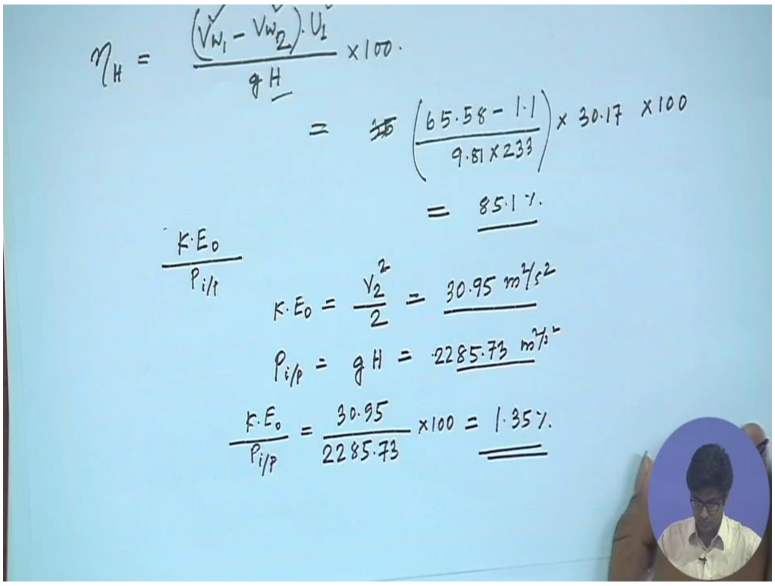

Now as you can see V2 is given as or V2 square is given as VW2 square from this triangle, VW2 square plus VR2 sin beta-2 square. We know the tangential velocity at the outlet of VR2, we know beta-2 and we also know, we also know the value of VR2 and beta-2. So substituting the values, we get the value of VR2 square as 61.9 metre square per second square. So substituting the value of VR2 square here, we get the value of kinetic energy at output as 30.95 metre square per second square.

And the power input at the inlet per unit mass is given as G into the net head available, which is to 2285.73 metres square per second square. So the ratio comes out as, the percentage ratio comes out as 1.35 percentage. So all the parts of this problem have been discussed. So by this I end the lecture on Pelton wheel, Pelton turbine. In the next lecture we will start with the Francis turbine problems.