Hydraulic Engineering
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Lecture - 45
Pipe Networks(Contd.)

Welcome back.

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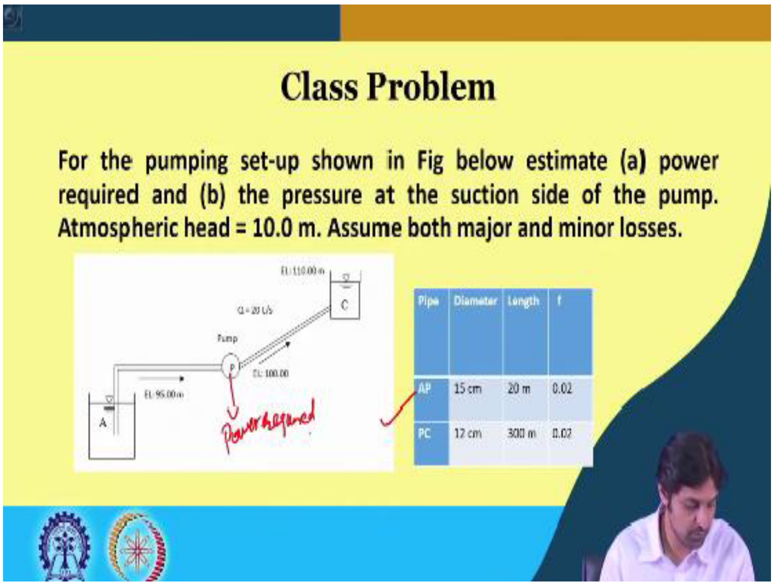

Last class we solved this particular problem which is shown in the slide and we are going to continue in this lecture. I am going to solve yet another question. The question here is, for the pumping set-up shown in figure below, this figure, estimate the power required and the pressure at the suction side of the pump. We see that the atmospheric head here is 10 meters and we have to assume both the major and the minor losses.

You see there are two pipes and these things are given AP the diameter of the pipe is given, the length is given, the friction factor for each of these pipes is given. So how do we solve this? We have to estimate the power required by this pump and pressured required at this suction side of the pump.

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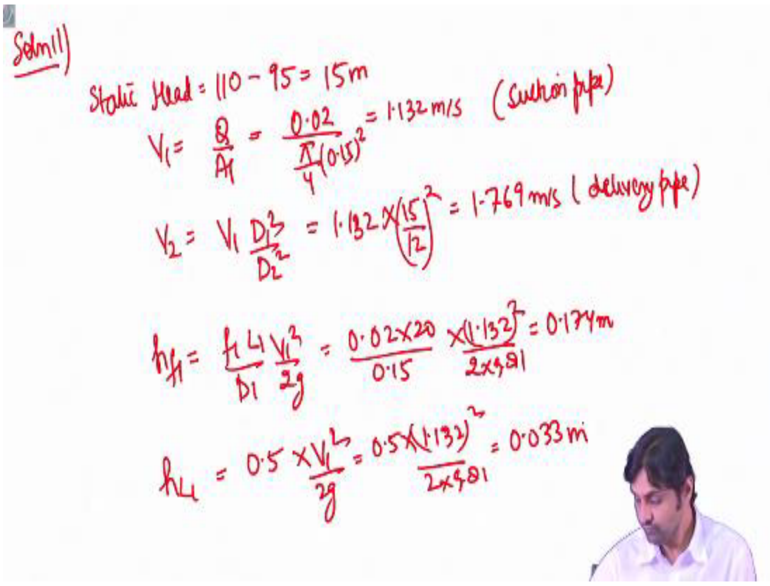

So we will continue with 11. So static head is 110 – 95 you see, that is the static head. If you remember the figure and that is 15 meter, velocity in the pipe 1 would be Q/A1, the pipe 1 was before the pump, the pipe 2 was after the pump. Therefore, V1Q is given as 20 liters per second, so it is 0.02 and area is pi/4 and the diameter is also given 0.15, so it will come out to be 1.132 meters per second.

Similarly, for the delivery pipe, that is, velocity in the delivery pipe, this is a suction pipe and V2 is the delivery pipe, we can, A 1 V1 = A2 V2 and therefore V1 can be written as D1 square/D2 square and therefore 1 point or you can do also Q/A2, 15/12, D2 was 12 and therefore it will come to be 1.769 meters per second in the delivery pipe. So the major loss in pipe 1 will be f1 L1/D1 into V1 square/2g, f1 is also given in pipe 1.

Length is 20 meters it is given, diameter we already know 0.15 meter into V1 we found out, 1.132 whole square/2 into 9.81 and this comes to be 0.174 meter. So there will also be a inlet loss and that is 0.5 into, this is the minor loss, V1 square/2g, so 0.5 into 1.132 whole square/2 into 9.81, so 0.033 meter. So this was the losses in pipe 1.

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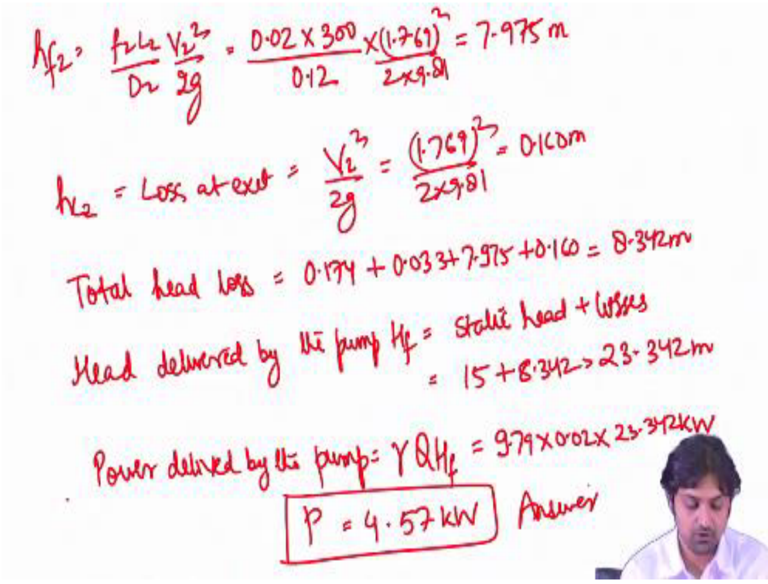

We are going to see the hf2, so major loss in pipe 2 will be f2L2 / D2 into V2 square/2g. So f2 is also given 0.02, length is 300 meters that is given into D2 was 0.12 into 1.769 whole square/2 into 9.81, that comes out to be 7.97. Similarly, there will be a loss at exit and at exit it is simply, V2 square/2g, because k here is 1, so 1.769, it is 0.160. So total head loss is going to be 0.174 + 0.033 + 7.975 + 0.160 and this is going to be 8.342 meter.

Now the head delivered by the pump Hf will be static head, first it has to overcome this static head plus the losses. So it is going to be 15 + 8.342, that is, 23.342 meter. Therefore, the power delivered by the pump is gamma Q Hf, that is, the total head. So 9.79 into Q is 0.02 into 23.342 kilowatt. If you find 4.57 kilowatt. So the first part we have got this as the answer. Now we also have to find the pressure at the suction side of the pump.

So for that we are going to use the Bernoullis equation and also taking the head loss into account.

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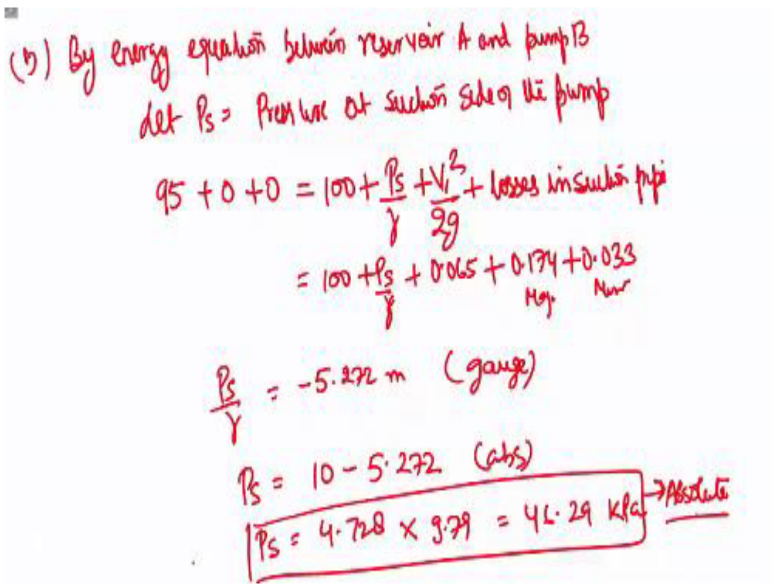

So part B will be solved by energy equation between reservoir A and pump B. So let Ps be the pressure at suction side of the pump, then we put the Bernoullis equation 95 + 0 + 0 will be equal to, the pump is at z = 100 and if the pressure Ps/gamma + V1 square/2g + losses in suction pipe. So this will be 100 + Ps/gamma and V1 square/2g is going to be 0.065, because V1 we have already found out, plus losses in the suction pipe is 0.174 major and the minor losses 0.033.

This is major loss, this is minor loss. So Ps/gamma can be found out to be – 5.272 meter. This is gauge. So the real pressure is going to be 10 – 5.272, because we have already been told the absolute is 10, so it is going to be Ps = 4.728 multiplied by 9.79 to get it into form of kilopascal, so 46.29 kilopascal absolute. This is the value that we have got. So both the answers we got.

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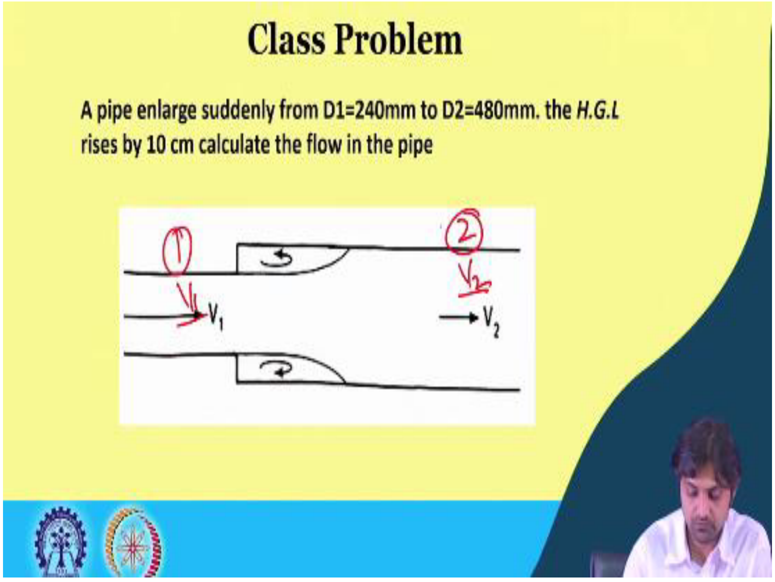

Now we proceed next and we solve one more problem. A very simple problem, we say a pipe enlarges suddenly from D1 = 240 millimeters to D2 = 480 millimeters and the HGL rises by 10 centimeters, calculate the flow in the pipe. So this is V1 and this is V2, so this is 1 and this is 2.

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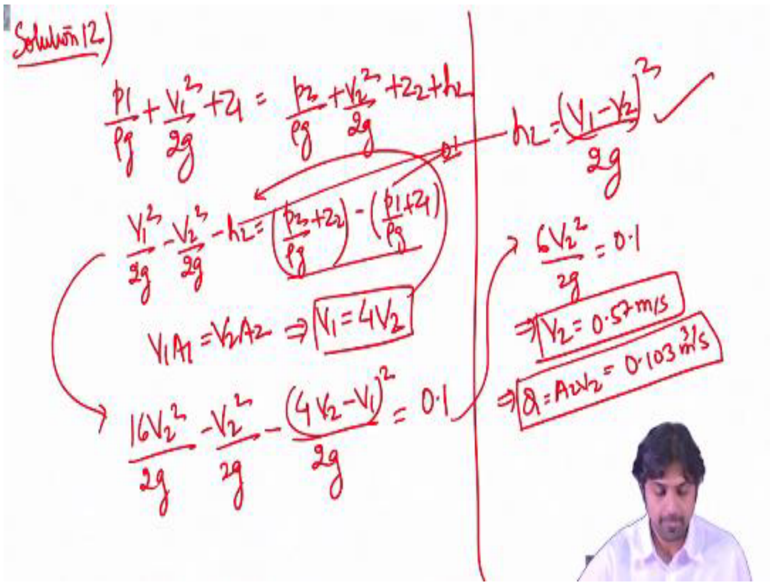

So we are going to solve this as well. So we can write Bernoullis equation p1/rho g + V1 square/2g + z1 will be = p2/rho g + V2 square/2g + z2 + whatever the head loss is. So we take V2 on this side, so we can write V1 square/2g – V2 square/2g – hL = p2/rho g + z2 – p1/rho g + z1 and. So to find the relation between A1 and V1 sorry V1 and V2 we can say V1 A1 = V2 A2 which will give us, so the areas are double, so we are going to get V1 = 4V2.

And if we put this in these equations here and we also know that this is 0.1 that is what it says that HGL rises by 0.1. Therefore, this will become 16 V2 square, this equation here, by 2g – V2 square/2g = 4 V2 – V1 square/2g sorry this is minus because there was an entrance, you know, head loss is, what is this hL, hL is V1 – V2 whole square/2g, if you remember the minor loss formula, is equal to 0.1 and if you solve this equation, you are going to get 6 V2 square/2g = 0.1, which will give V2 as 0.57 meters per second, implies Q is A2 V2, which will give 0.103 meter cube per second.

Very simple formula, the application we have seen using Bernoullis equation, equation of continuity and because there is going to be a minor loss which is equivalent to V1 – V2 whole square/2g. As we have said we have read the minor loss, the topic on the minor losses in the pipes. So we proceed forward from this question.

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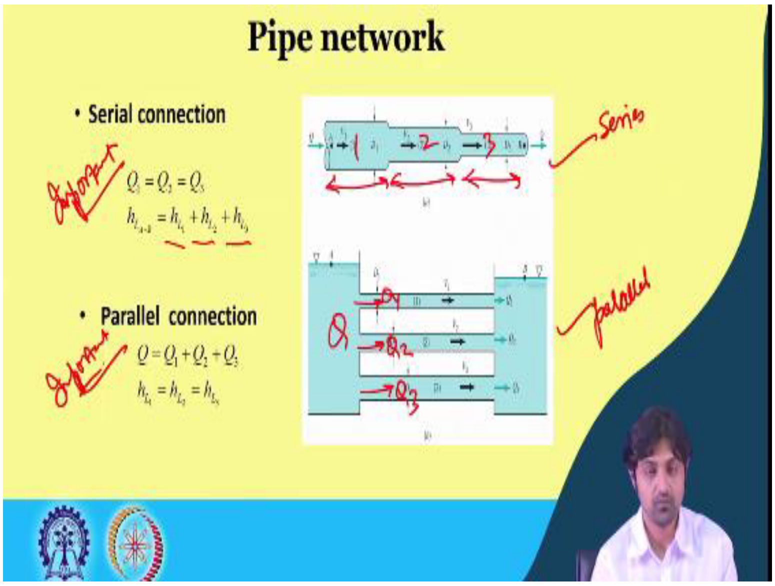

So we talk about pipe networks. Pipe could be connected in series or parallel or combination of both. So this is a serial connection. So in the serial connection the important properties are that discharge Q1 in this section, this section 2, this section 3 will be the same. However, the total head loss will be the sum of the head losses of individual sections, whereas in case of parallel connection the discharge will be the sum of all three.

So if there is a discharge Q, Q1, Q2, Q3, but the head losses will be the same in each of the pipe. So this is thumb rule, important thing to remember when you are dealing with pipe networks.

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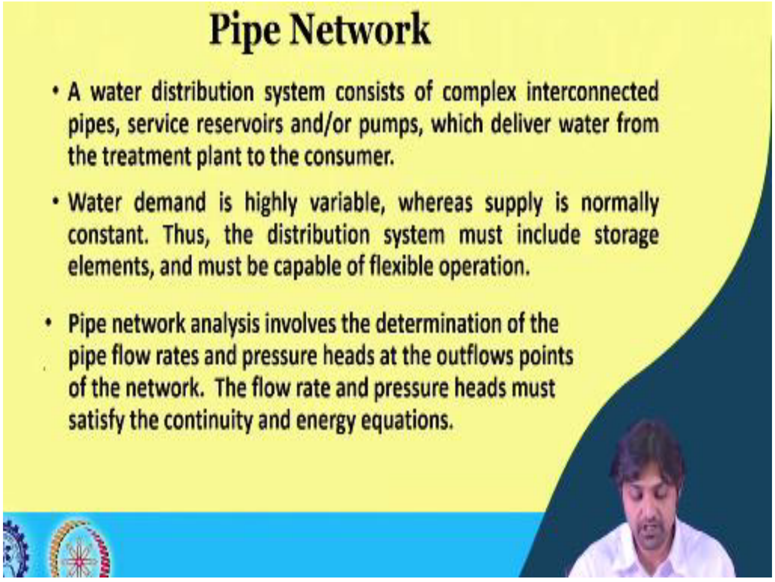

So a water distribution system consists of complex interconnected pipes, service reservoir and or pumps which deliver water from the treatment plant to the consumer. The water demand is highly variable, whereas supply is normally constant. Thus, the distribution system must include storage element and must be capable of flexible operation. So pipe network analysis involves determination of pipe flow rates.

And pressure heads at the outflow points of the network. The flow rate and pressure head must satisfy the continuity and the energy equation. This is very true, as I told you in the last slide.

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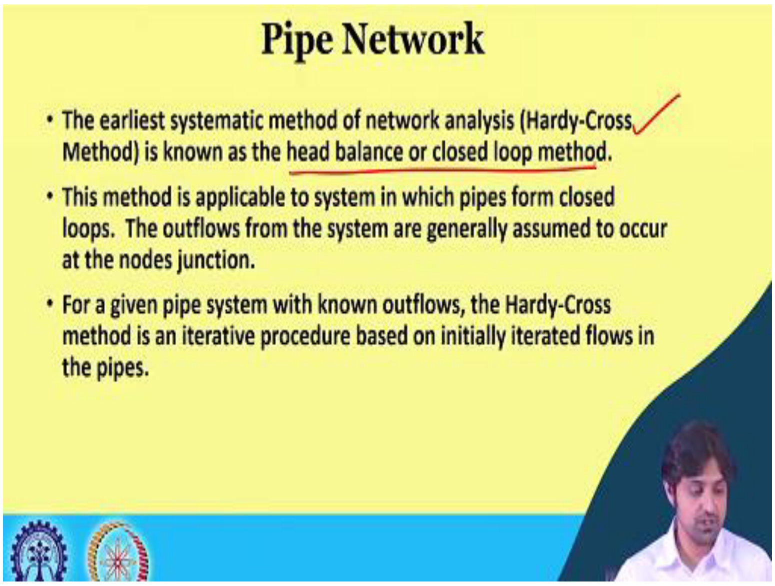

The earliest systematic method of network analysis is called the Hardy Cross Method and is known as the head balance or the close loop method. So pipe network is a topic where we are going to study this famous method of Hardy Cross Method. It is known as the head balance or the close loop method. It is a very, very systematic way which can be used for solving the pipe networks.

So this particular method of Hardy Cross is applicable to a system in which pipes form closed loops. So the outflow from the system are generally assumed to occur at the junction nodes. For a given pipe system with known outflows, the Hardy Cross Method is an iterative procedure based on initially iterated flows in pipes. So Hardy Cross Method has a set rule and procedure, but this is for the solution, it is an iterative procedure.

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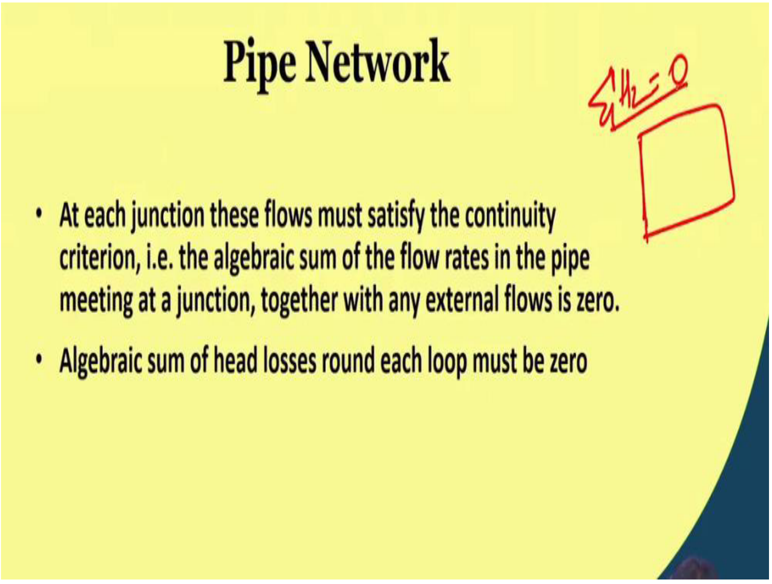

So what are the important points to remember in solving pipe networks using Hardy Cross Method? That at each junction the flow must satisfy the continuity criterion. What are these continuity criterion? The continuity criterion is that the algebraic sum of the flow rates in the pipe meeting at a junction together with any external flows is 0. Suppose, this is a node there is Q1, Q2, Q3. So Q1 = Q2 + Q3,

So the net outflow at any junction should be 0 is the continuity criterion. Secondly, the algebraic sum of head losses round each loop must be 0. So sigma of head losses in one loop, like this, should be 0.

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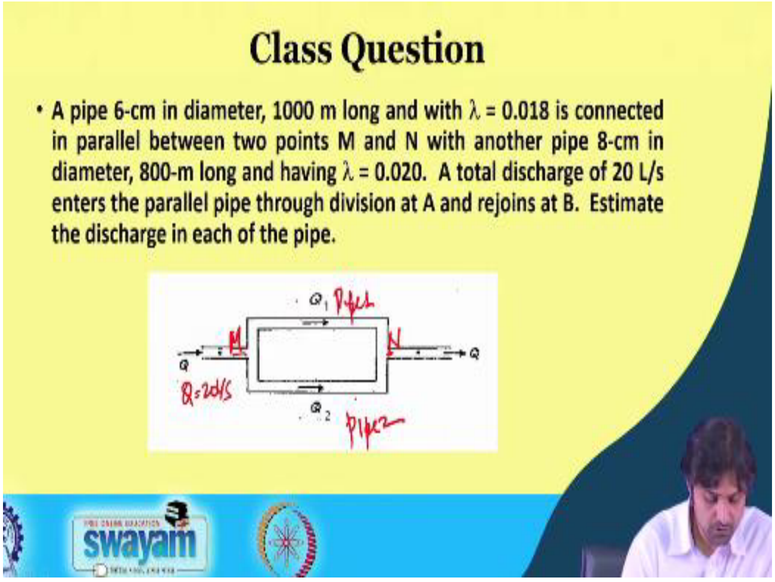

So with a simple continuity equation we are going to solve one class question. The equation is a pipe 6 centimeter in diameter here and 1,000 meter long and with lambda = 0.018 is connected in parallel, so this is pipe 1 and this is pipe 2, between two points M and N and this other pipe is 8 centimeter in diameter and 800 meter long. So this was 1,000 meter long, this is 800 and the diameter was 6 and diameter was 8.

And this has a lambda of 0.020, a total discharge of 20 liters per second enters. So from here something 20 liters per second enters the parallel pipe through division at A and rejoins at B. So it here and it rejoins here. Estimate the discharge in each of the pipe, very simple application of the concepts we have learned till now. So we are going to solve this question.

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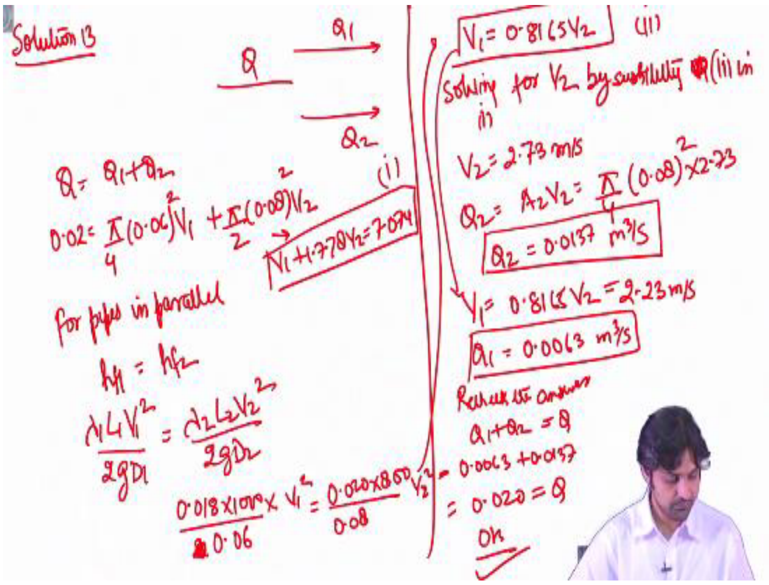

So there was pipe, so Q will be = Q1 + Q2. So total discharge is 0.02 and we know the areas pi/4 into 0.06 let say velocity is V1 here and in the pipe 2 it is V2 0.08 V2. So this is the equation for the continuity equation for discharge. So for pipes in parallel we also know that the head losses should be equal in both pipes. So this actually can be written as V1 + 1.778, V2 = 7.074, if you solve this, it will come this.

This is the one equation that we have got from here and now hf1 = hf2 which means lambda 1 L1 V1 square, this is the major loss in pipe 1 = lambda 2 into L2 into V2 square/2g D2. So let us substitute the value, lambda 1 was 0.018, length was 1,000 first pipe into V1 square/2, so 2g D1 comes out to be 0.06, this will be 0.020 into 800, this comes to be 0.08 into V2 square. So taking it here, we will get V1 = 0.8165.

So we have two equations in V1 and V2, so 1 and 2. Solving for V2 by substituting V by substituting 2 in 1, we will get V2 as 2.73 meters per second. So Q2 will be A2 V2, so pi/4 0.08 whole square into 2.73, so Q2 will come to be 0.0137 meter cube per second. Now if we know V2, we can get V1 from here, V1 will be 0.8165 V2, this will give us V1 as 2.23 meters per second.

And therefore, Q1 will be A1 V1 will give us 0.0063 meter cube per second. So this is the answer, but one important step is it is better if we recheck the answer by Q1 + Q2, if it is equal to Q or not. So 0.0063 Q1 + 0.0137, it is coming out to be 0.020 which is equal to Q. So our answer is okay. So this was one other question.

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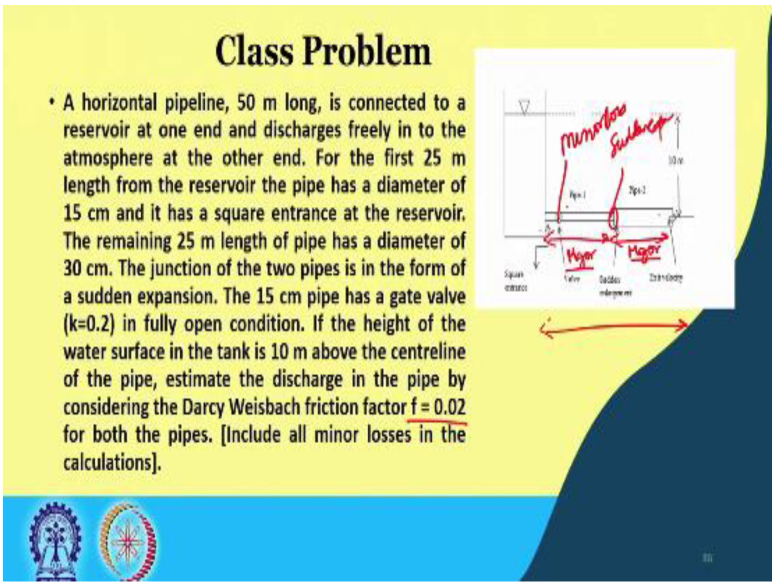

Now the one more question is there is a horizontal pipeline which is 50 meters long and is connected to reservoir at one end and discharges freely into the atmosphere at the other end. So for the first 25 meters, I have shown this diagram here. So the first 25 meters length from the reservoir, the pipe has a diameter of 15 centimeter and it has a square entrance at the reservoir. The remaining 25 meter length of the pipe has a diameter of 30 centimeter, so this is the long, long pipe.

And this is pipe 1, I mean the things that we were talking about, diameter is different here, diameter is different here. So junction of the two pipes is in the form of a sudden expansions. So we have been told sudden expansion that means there is going to be a energy loss, minor loss. It is also told that there is going to be a there is a gate valve in a 15 centimeter pipe. So there is going to be another minor loss here.

So if the height of the water surface in the tank is 10 meter above the centerline and the velocity, estimate the discharge in the pipe by considering the Darcy Weisbach friction factor of 0.02 for both the pipes. So this is given because there will be also major losses between this two sections, major losses. So we have to, this is a wholesome, a complete question that involves both the major and the minor losses.

So we are going to, actually I think this is a nice point to stop. In the next class we are going to solve this particular question in detail because then it will be fresh in your mind and then we will proceed to our last topic that is Hardy Cross Method. So thank you so much for listening. I will see you in the next lecture.