**Hydraulic Engineering**
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**Lecture - 44**
**Pipe Networks(Contd.)**

Welcome back students. Last lecture we were talking about the minor losses due to the contraction.

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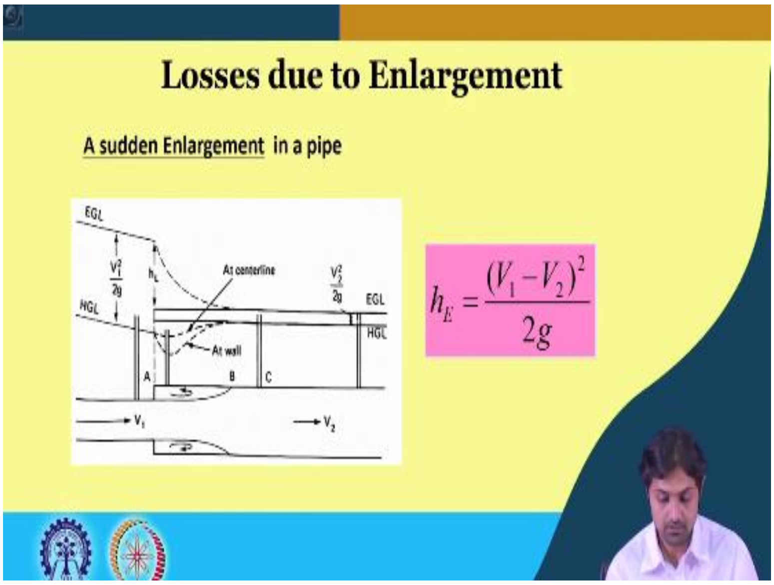


And this week and in this lecture we are going to start the losses due to enlargement. So what is sudden enlargement? A sudden enlargement in a pipe is something like this you see if there is a pipe which is going in a reservoir for example reservoir or any structure that is bigger than this pipe. So going from one smaller pipe into a large pipe for example so this is enlargement okay.

So in that case what happens the head loss can be simply given as $h_L = \frac{(V_1 - V_2)^2}{2g}$ okay in a sudden enlargement it will be given as $h_L = \frac{(V_1 - V_2)^2}{2g}$.

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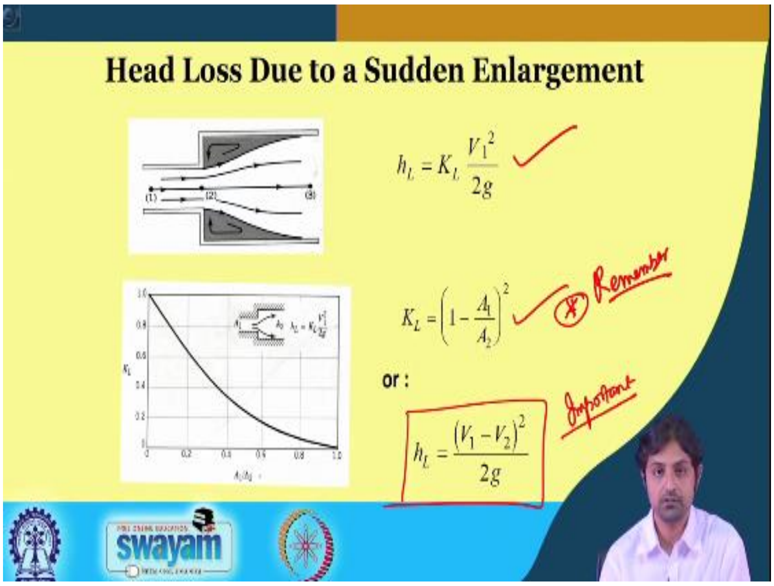


So if there is point 1 here, 2 here and 3 here the head loss can also be referred as KL into V1 square/2g where V1 is the velocity in the narrower tube and what that KL is going to be this KL will be again a ratio of A1/A2 where A1 is the smaller okay. Suppose the second area is very large all right. You see here so suppose this is very large so A1/A2 is tending to 0 and therefore the entire energy will be lost.

This is just a matter of interpretation from the curve. So best is to find the ratio of the areas of A1 and A2 and take the KL from here put it here and multiply it by V1 square/2g. You saw in the contraction it was V2 square/2g and in case of expansion it is V1 square/2g. So those velocities needs to be considered where the smaller pipes are there. So the smaller pipes in case of contraction was at 2 so we had K into V2 square/2g.

Here in case of enlargement this smaller pipe is at 1 so it is KL into VL square/2g okay. A KL will have a general formula as 1 – A1/A2 whole square you can also use this equation for KL. Okay you put A1/A2 = 0 that means KL will be 1 so whole energy is going to be lost. I think it is better to remember in case of sudden enlargement the KL = 1 – A1/A2 whole square remember this one it is easier and of course this one okay.

And in case of sudden contraction KL was 0.5 if you remember. So if you put this we come back to the formula which we saw in the last page. You can also see head loss is going to be V1 – V2 whole square2g as we saw in the last slide here okay. This is also important.

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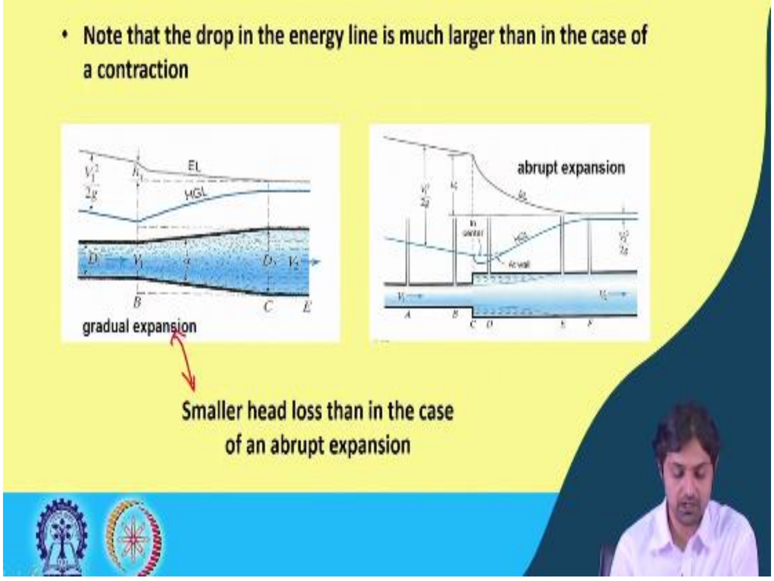


Now you note that the drop in energy line is much larger than in case of the contraction of course you will see that because see in most of the cases in case of sudden contraction the KL was 0.5 wherein case of sudden expansion KL was (()) (04:37) so whole energy is going to be lost. So in case of sudden expansion the drop in the energy line would be very rapid all right and this is abrupt expansion this is gradual expansion this is abrupt.

So see the sudden fall in the line this is gradual this is abrupt all right. So smaller head loss than in the case of an abrupt expansion is for the gradual expansion like we had the gradual contraction we have something called gradual expansion.

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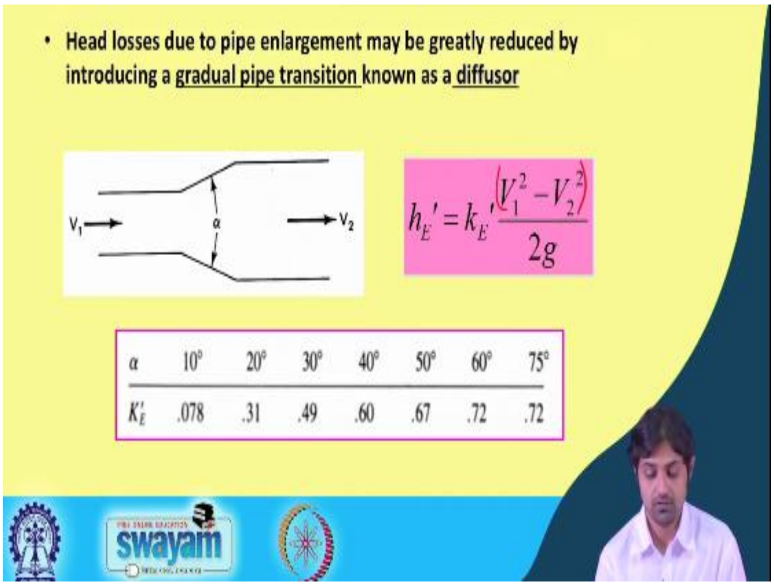


| $\alpha$ | 10° | 20° | 30° | 40° | 50° | 60° | 75° |
|---|---|---|---|---|---|---|---|
| $K_E'$ | .078 | .31 | .49 | .60 | .67 | .72 | .72 |

So head losses due to pipe enlargement maybe greatly reduced by introducing gradual pipe transition known as diffusers that was (()) (05:36) and this was diffuser something like this.

In this case also we will have a formula for the head loss as KE dash into V1 square – V2 square/2g okay and KE can be taken from this table. When you will be provided with those values if at all some questions comes for the gradual pipe transition or gradual contraction or gradual expansion, but you have to remember for the scenarios like this okay.

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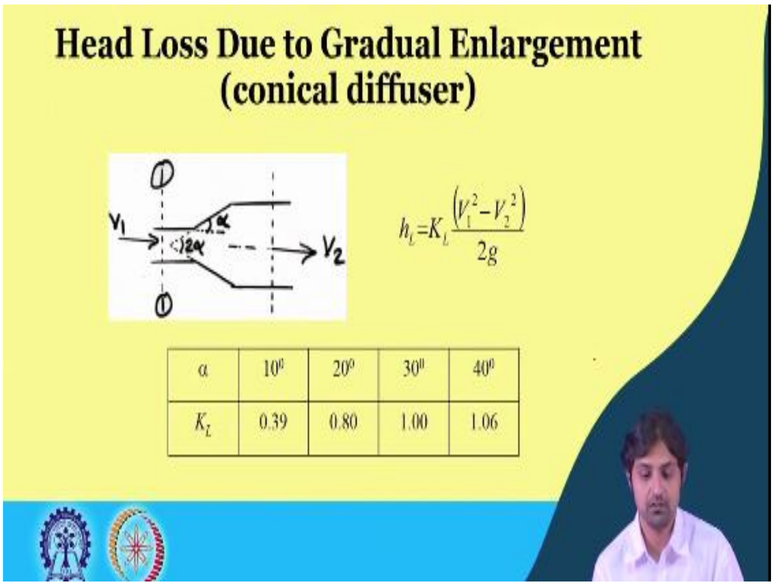


So now head loss due to gradual enlargement again the same thing as we had in contraction conical diffusers in this also it will be hL is given as KL into V1 square – V2 square/2g where you can there are many, many experiments that have been done and you will find a different value of KL based on different alpha and more or less every value would be more or less similar okay.

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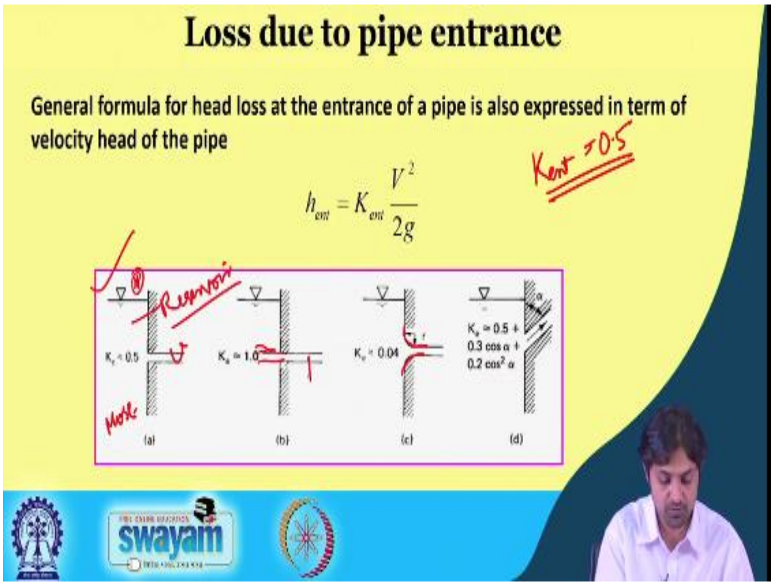

Now loss due to pipe entrance. So general formula for head loss at the entrance of the pipe is also expressed in terms of velocity head. So if there is an entrance pipe entrance okay so the loss will be V square/2g into K entrance. So for different configuration this is the most common one that you will encounter. So you just need to remember this one pipe entrance if nothing is given you have to take the K entrance as 0.5 all right.

In this case where the pipes are protruding inwards Ke is going to be 1.0 so all the energy is going to loss. If there is a smooth curve like this you saw in the third one here it is going to be 0.04, but this is most important. So K entrance you have to remember if nothing else is given is 0.5 and V square of course V should be calculated here because this is a reservoir. In reservoir there would be very little velocity okay velocities should be here.

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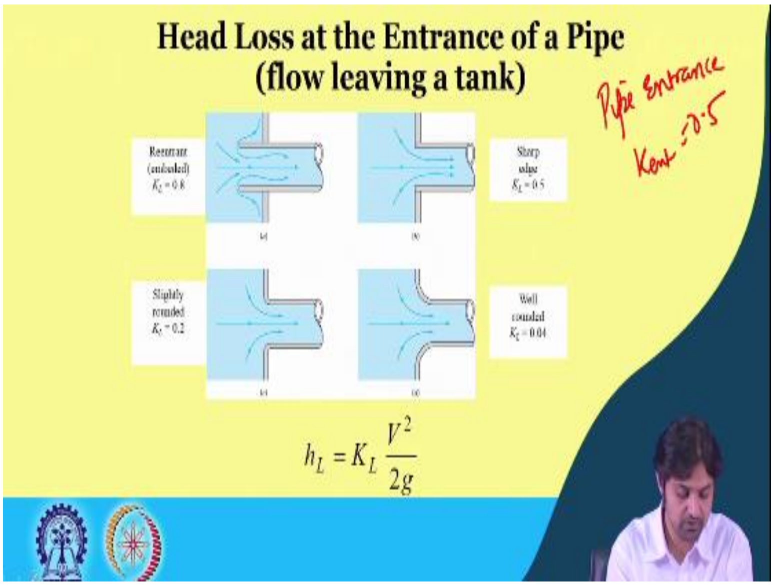


Now the head loss at the entrance of the pipe that is when the flow is leaving a tank in this case it is the same thing all right. So sharp edge this is also entrance only this is the one that we studied in the last slide. If it is well rounded you saw that there was a value of 0.04 it is a much more you know good looking figure but the message is the same. If it is well rounded KL is 0.04.

If t is slightly rounded it is 0.2 if it is embedded inside you saw we had one figure where everything was inside therefore there KL was = 1, but in this case it is 0.8. So this is nothing, but pipe entrance by default just take 0.5 if nothing else has been given.

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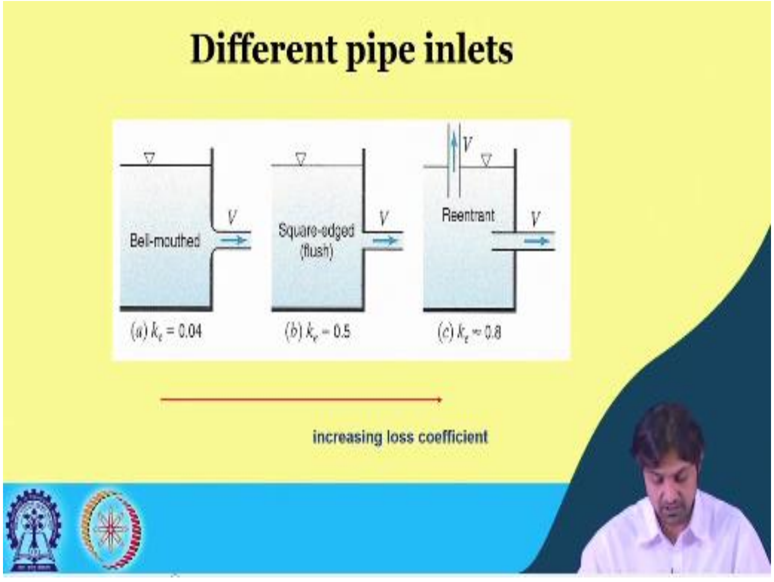


Now different pipe inlets again the same thing you see K inlet, K entrance. So these many equations you cannot remember I mean these many values. So only the most common one which the one which I have been telling try to remember those. So increasing loss coefficient has been demonstrated here like this.

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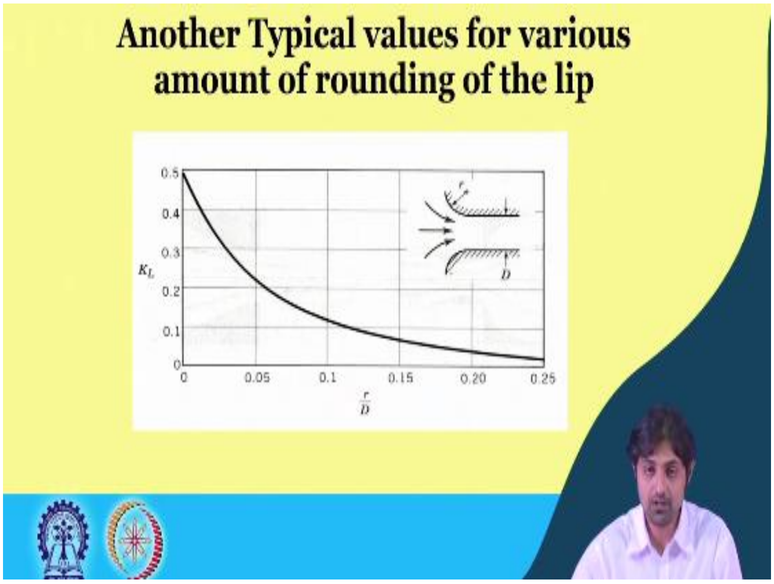


Another typical values for various amounts of rounding of the lip you see these are based on all the different experiments that people have done.

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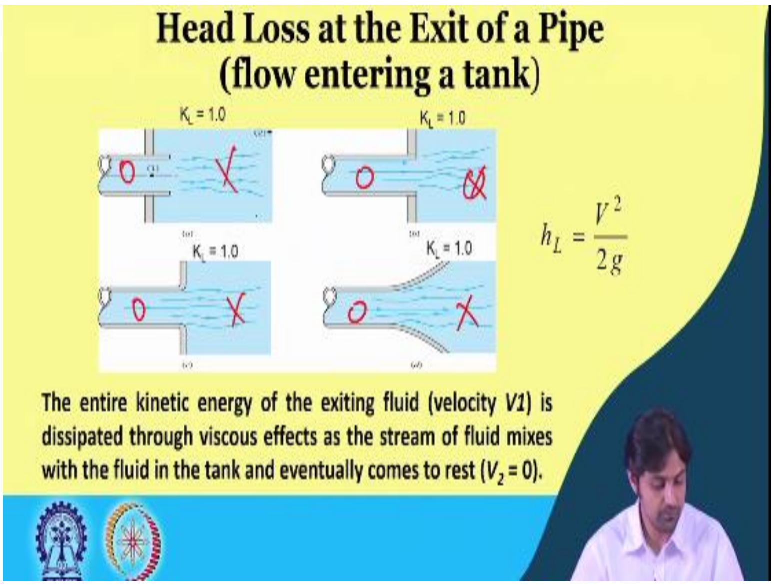


So these curves will be now we have talked about entrance, we have talked about contraction, we have talked about expansion. Now we have talked about entrance to the pipe. Now what is the head loss at the exit of the pipe something like this when the pipe is terminating in a reservoir okay when the pipe is terminating in the reservoir what is going to happen whole velocity because reservoir is so big everything is going to be lost right.

So if K exit is always going to be one remember that. You see whatever this thing is KL is always going to be 1.0 very easy to remember and head loss is simply V square/2g where V is calculated at these points okay do not try to calculate V here because it will come to be 0 in the reservoir. The kinetic energy of the exiting fluid that is velocity V1 is dissipated through viscous effects as stream of the fluid mixes with the fluid in the tank and eventually comes to rest this is what exactly I have told you.

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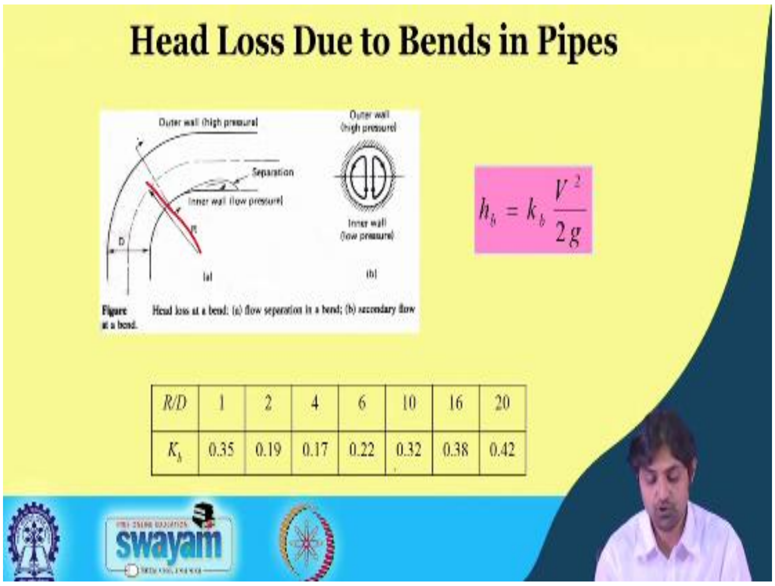


Now the head loss due to bends in the pipes so many formulas are there we say kb into V square/2g okay velocity will remain the same even the bend is there so we need to need kb for different values of R/D D is the diameter of the pipe and R is the radius of the curvature of the pipe. There are different values of Kb either you will be given these tables or given the values.

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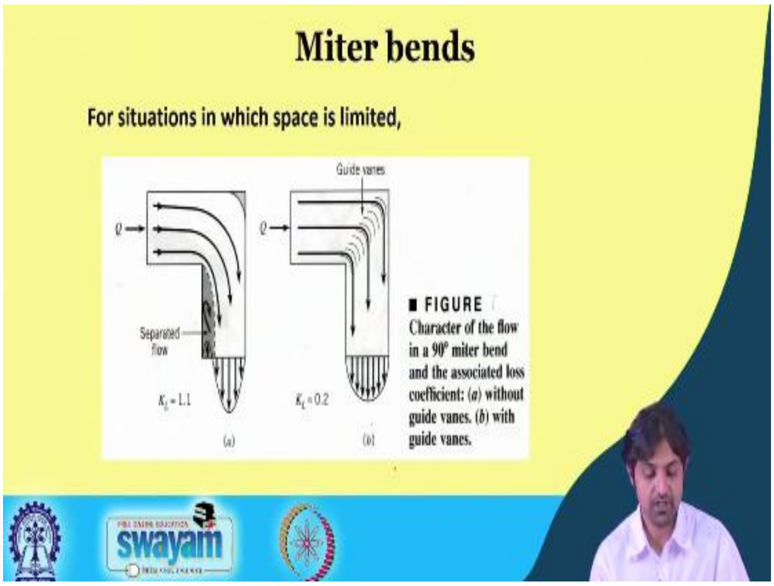


Miter bends.

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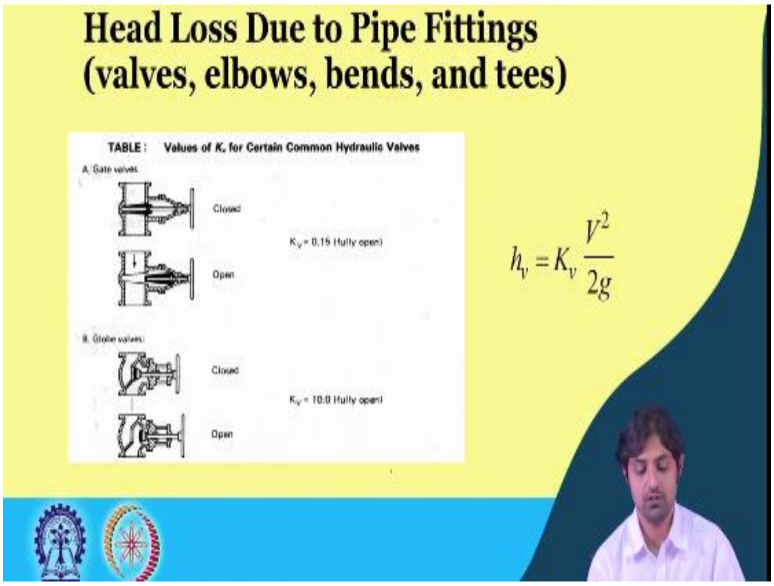


So due to the head losses due to the pipe fitting you see different type you will be provided with these values okay everything will be K all the minor losses of the form K into V square/2g okay.

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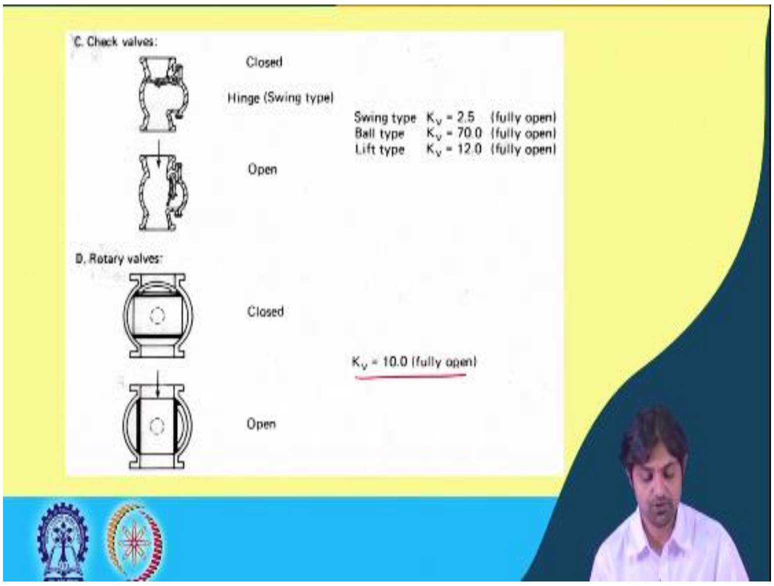


So it is a closed valve there is open valve see there are losses of the order of 10.0 if the valve is fully rotary value it is fully open.

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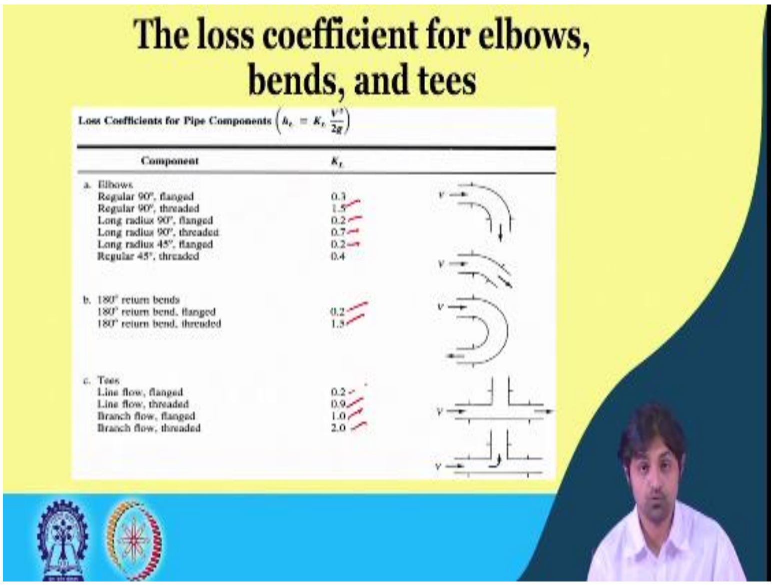


So the loss coefficients has been summarized here for elbows, bends and you know tees. You see 0.3, 1.5, 0.2, 0.7, 0.2, 1.5, 0.2, 0.9, 1.0, 2.0.

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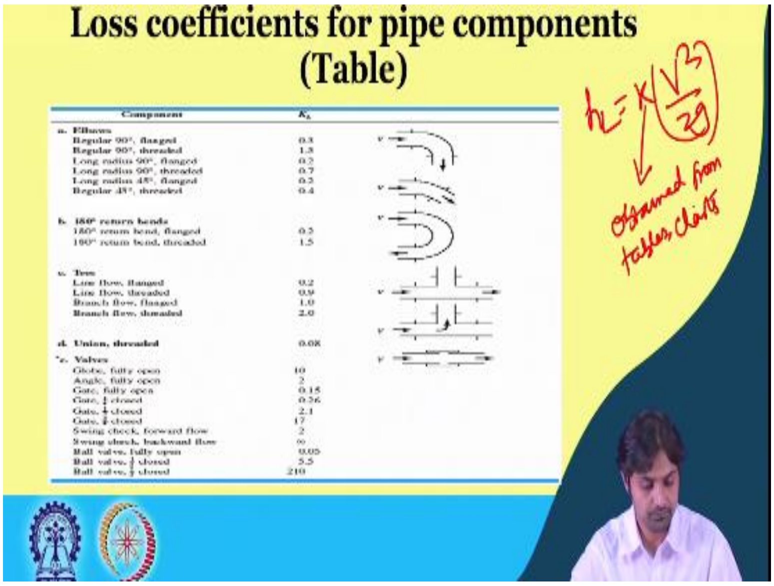


So this is a table again for pipe components. So for the examination and assignment purpose assignment purpose you can look back I mean you can keep the tables with yourself, but in exams these values will mostly be provided only those values which are very common like the K entrance, K exit, sudden contraction, sudden expansion and things like that, that would not be provided.

Those values will not be provided and you are expected to know this the formulas okay. So important message is that minor losses is K into V square/2g and the K can be obtained from tables or charts okay.

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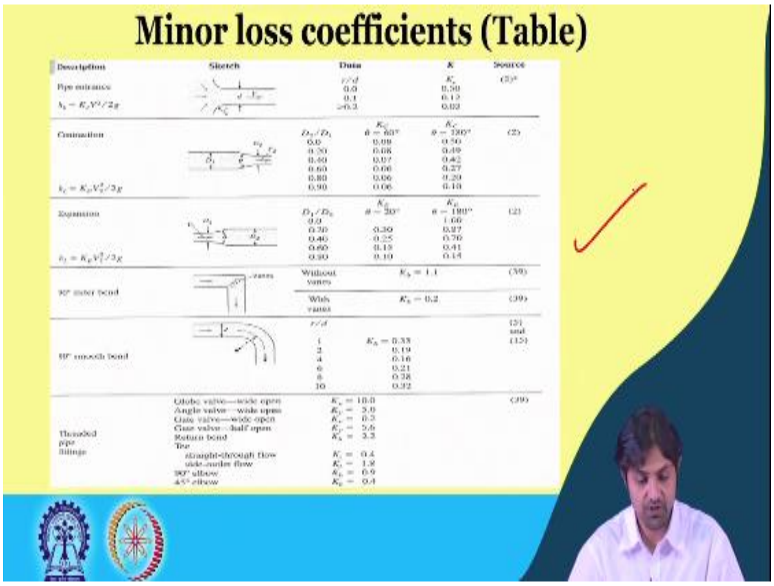


So this is a table of minor loss coefficient I said this is a summary do not have to worry about it. This is when you go and start working in a company where this pipe losses are in relevant than you can make the use of this type of charts and tables for quick reference all right.

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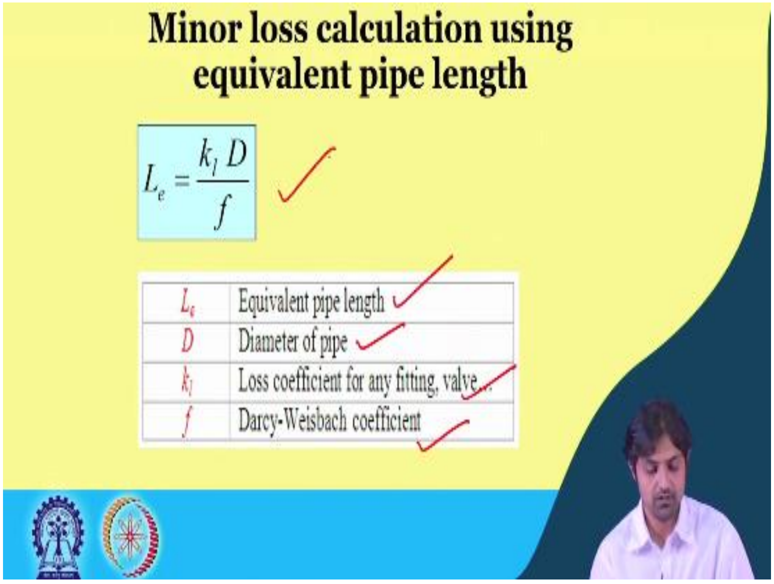


So minor loss calculation using equivalent pipe length. So equivalent pipe length can be kl into D/f where Le is the equivalent pipeline that we are going to calculate D is the diameter of the pipe k1 is the loss coefficient for any fitting valve and f is the Darcy Weisbach coefficient. For example there are several pipes connected in either series or parallel or combination of those.

And somebody ask you to calculate the equivalent pipe length if there was one single pipe with equivalent pipe you know with equivalent pipe diameter what would be the effective pipe length so you can use this formula.

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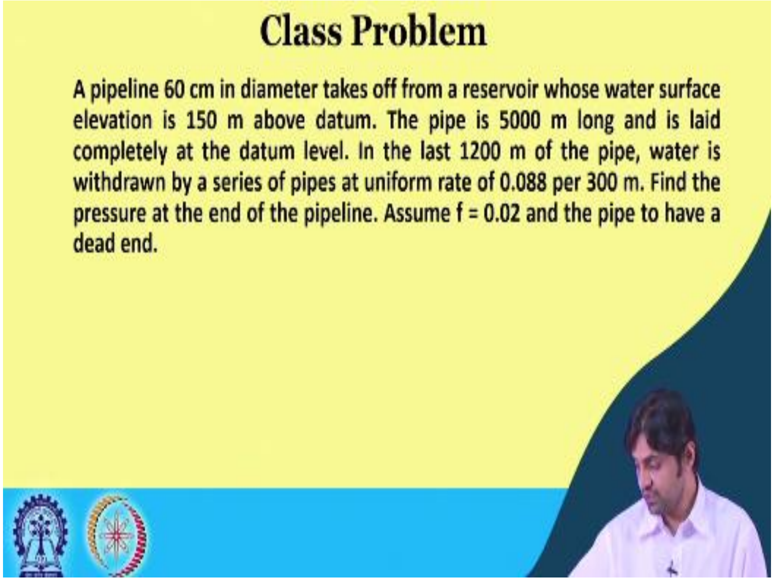


Now let us solve a question so that gives us more confidence these questions is about major and minor losses mainly and it stands at a pipeline of 60 centimeter in diameter takes off from the reservoir whose water surface elevation is 150 meter above the datum okay. The pipe is 5,000 meter long and is laid completely at the datum level. In the last 1,200 meter of the pipe water is withdrawn by a series of pipes at uniform rate of 0.088 per 300 meter.

Find the pressure at the end of the pipeline assume f = 0.02 and the pipe have a dead end okay. So if you understand this question.

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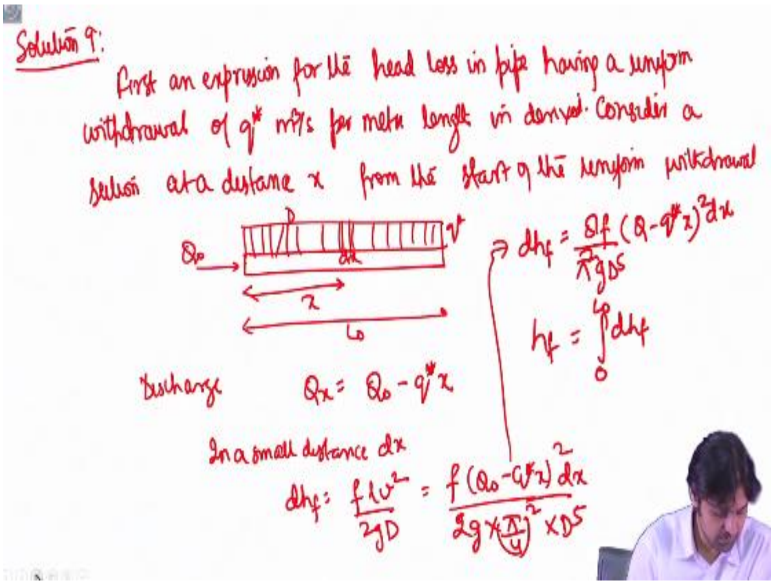


So I am going to solve this so first an expression for the head loss in pipe having a uniform withdrawal of q* meter cube per second per meter length is derived because it says the water is withdrawn by a series of pipes with a uniform rate all right. So to be able to do that we consider a section at a distance x from the start of the uniform withdrawal okay. So this is a pipe so diameter is D and we have Q0 and from here we assume a distance x okay.

And this distance is L0 all right and the withdrawal is uniform that is q*. So discharge is going at x will be Q0 – q* into x right. So in a small distance dx so at x we assume small distance dx here. The head loss is going to be flv square/2g D right or instead of v we write Q correct so we can write f Q0 – q* x whole square 2g into pi/4 whole square into D to the power 5 all right.

So after so I will take this here now so I am just writing dhf will be just writing 8f/pi square g D to the power 5 into Q – q*x whole square dx all right. So hf is going to be integral of dhf and from there 0 to L0 this is going to be from 0 to L0 okay.

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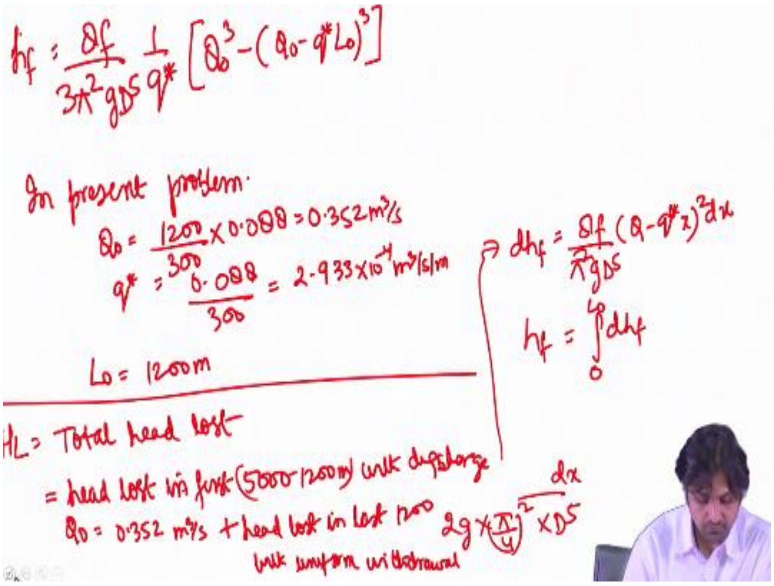


So now we calculate so hf comes to be 8f/3 pi square g D to the power into 1/q * Q0 cube – Q0 – q* L0 whole cube all right. So this is the general head loss for the continuous withdrawal that we have found out. So in present problem Q0 is 1,200/300 into 0.088 all right. So we have 0.352 meter cube per second and this q* is 0.088/300 that is 2.933 into 10 to the power -4 meter cube per second per meter and L0 has been given as 1,200 meter all right.

So apart from that if we say HL = total head lost okay. What is the total head lost so head lost in first 5,000 meter with discharge Q0 = 0.352 meter cube per second + head lost in last 1,200 with uniform withdrawal. So total head loss is going to be the head lost in first 3,800 meter with discharge Q0 that is going to be the major head loss right and the second one was we use differential equation and that is what we wrote hf2 okay here hf.

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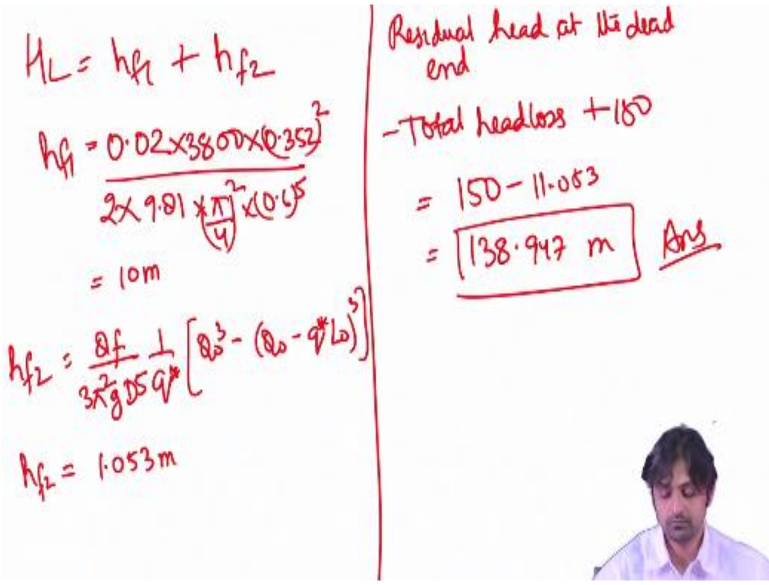


So total HL will be hf1 + hf2 and what is hf1 it is the major loss right and that is going to be 0.02 that is already given into the length was 3,800 into 0.352 whole square because that is the velocity 2 into 9.81 into pi/4 whole square into 0.6 to the power 5 and this comes on calculation as 10 meter. What is the hf2 is the last 12,00 meters where we have derived that equation which was 8f.

This was what we derived 3 pi square g D to the power 5 into 1/q* into Q0 cube – Q0 – q* L0 whole cube and if you solve this with the appropriate values of f is 0.02 and other things you will get hf2 as 1.053 meter. Now the question is what is the residual head at the dead end. So this is going to be residual head at the other end all right. 134.947 meter okay. So these are lengthy questions.

But the idea of covering this is that you are able to solve any type of problem after learning this course, of course the assignment will have simpler problem because it will be mostly objective type or fill in the blanks. So there will be small, small problems rather than such big and complicated problems, but this is a nice practice and we will expose you to all type of problems that you can encounter in pipe flow.

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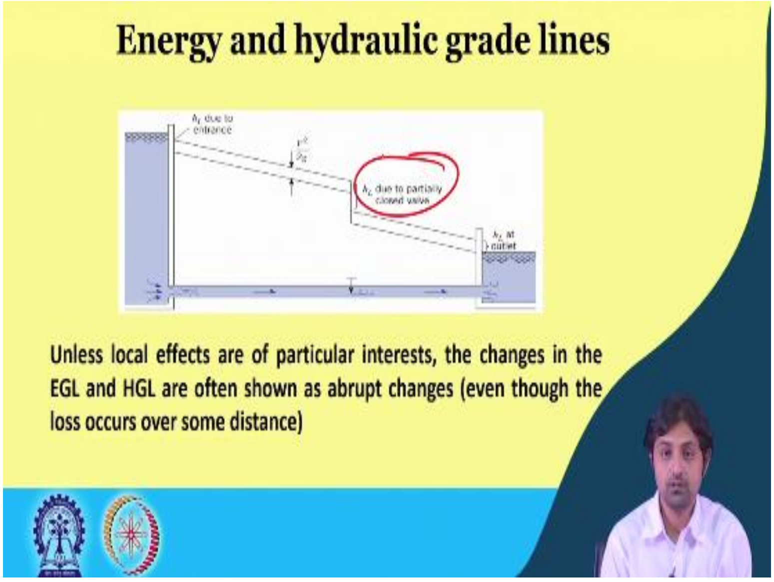


Now something about energy and hydraulic and energy grade line you see. So unless the local effect are of particular interest the changes in EGL and HGL are often shown as abrupt changes even though the loss occurs over some distance you see okay.

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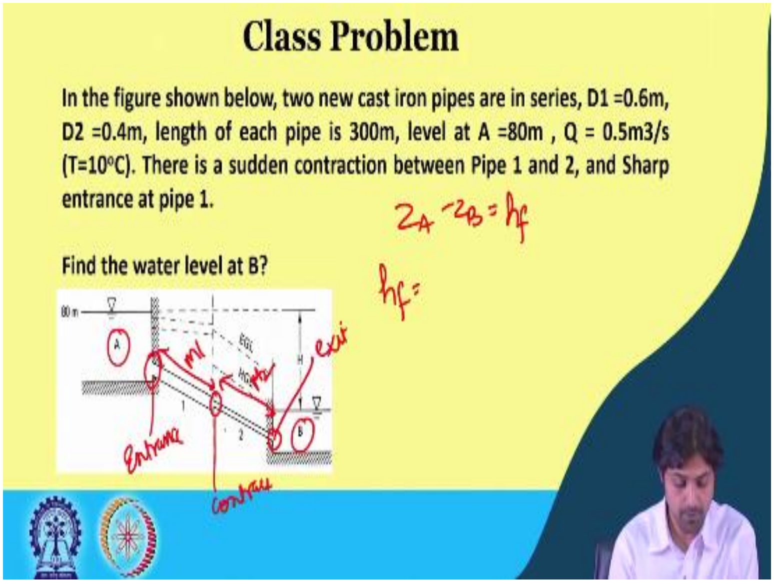


So in the figure shown below two new cast iron pipes are in series, length of each pipe is given and level at A is also given all right. Now we have to find the water level at B a very simple and good question okay. So see whatever be the difference between the levels at A and – B this ZA – ZB should be = hf that is the head loss between point A and point B all right okay and now this hf should be the sum of energy loss I mean the losses.

Now can you think where this losses will occur there will be loss at the entrance here right, there will be a loss here okay due to contraction and there will be a loss due to exit apart from that these are the three minor losses. There will be one loss major loss M1 here and there will be loss M2 here due to the flow in the sections of the pipe long sections of the pipe all right good.

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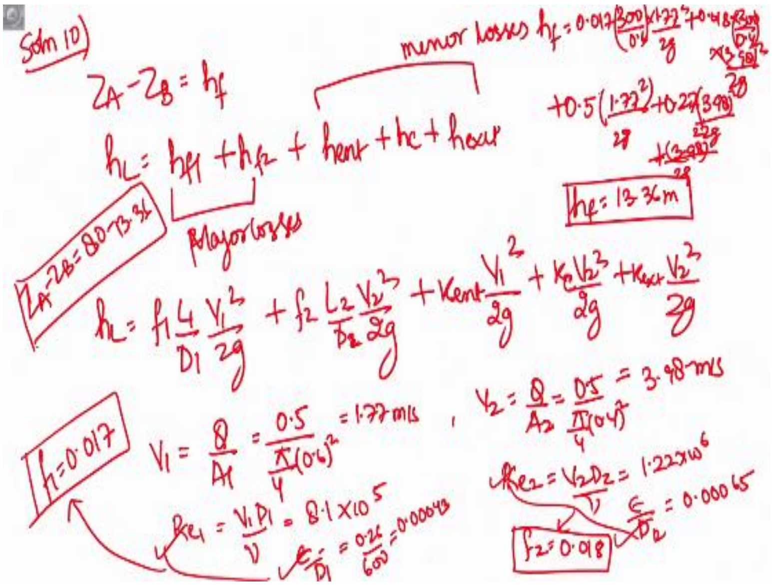


So to solve that we will take the help of white screen again so solution number 10 ZA – ZB = hf and this total hf or hL will be hf1 + hf2 + h entrance + hc + h exit. The three minor losses and there are two major losses. F1 means major loss in pipe 1 major loss in pipe 2 okay. So we can simply write the formula first f1 L1/D1 into V1 square/2g + f2 L2/D2 into V2 square/2g + K entrance V1 square/2g + Kc into V2 square/2g + K exit into V2 square/2g.

This is an important formula that now we need to find out the flow properties in pipe 1 and 2. So simply pipe 1 they will be discharged by area 1, discharge is given 0.5 and this is the length and diameter everything is given. So it will come 1.77 meters per second whereas V2 will come out to be Q/A2 0.5 diameters are different so pi/4 into 0.4 whole square and this will come to be 3.98 meters per second all right.

So if we know (()) (29:59) we know Re1 V1 D1/nu and you put the value of velocity D and mu you will get 8.1 into 10 to the power 5. Similarly here Re2 will come out to be V2 D2, but you would be wondering why we need to calculate with Reynolds numbers and those parameters. The reason is we want to calculate the major head loss and major head loss will depend upon f.

F is the friction factor which will depend upon Reynolds number and epsilon/D all right. So this come out to be 1.22 into 10 to the power 6 okay. So we have calculated Re1, we have calculated Re2 here epsilon/D1 will be 0.26/600 and here epsilon/D2 is going to be so this comes out to be actually 0.00043 and this one comes out to be 0.00065. So we know Re1 here we know epsilon/D1 here we know Re2 here we know epsilon/D2.

So we can actually use the Haaland equation or the Moody Chart and find out f1if you look at the Moody Chart or find the Haaland or use the Haaland equation it will come 0.017 and this f2 is going to come to be 0.018 all right. So now it is just the matter of putting everything together. I am going to use this slot so hf so we know everything 0.017 into 300/0.6 into 1.77 square/2g + 0.018 into length is 300 only/0.4 into V2 square is 3.98 whole square/2g.

These two are major losses plus minor losses. The entrance was the 0.5 into 1.77 square/2g and this 0.27 is given to us or we can look up at the table 3.98 whole square/2g. The last one is exit so whole energy is going to be lost so 3.98 whole square/2g. So if you calculate in the end the total loss is going to be 13.36 meter. So let me rub something here okay. So the final solution the head loss is going to be 13.36 meter.

And therefore ZA – ZB is going to be 80 – 13.36 all right. I think we should not make it so much cluttered, but now you understand the process. We calculated the major losses, we calculated the minor losses and we calculated the total thing and here we get the level at ZA as 80 – 13.36 as 66.64 meter okay this was the elevation. Good so I think with this I will end today’s lecture and continue in another lecture when we meet next. Thank you so much for listening have a good day.