# Gas Dynamics

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**Module - 16**
**Lecture - 38**
**Fanno Flow-Numerical Examples**

Hello every one welcome back, we were discussing Fanno Flow and most likely today will be the last class of Fanno Flow. And next class on wards we will talk about heat transfer. I will just recap quickly and then we will go to numerical example.

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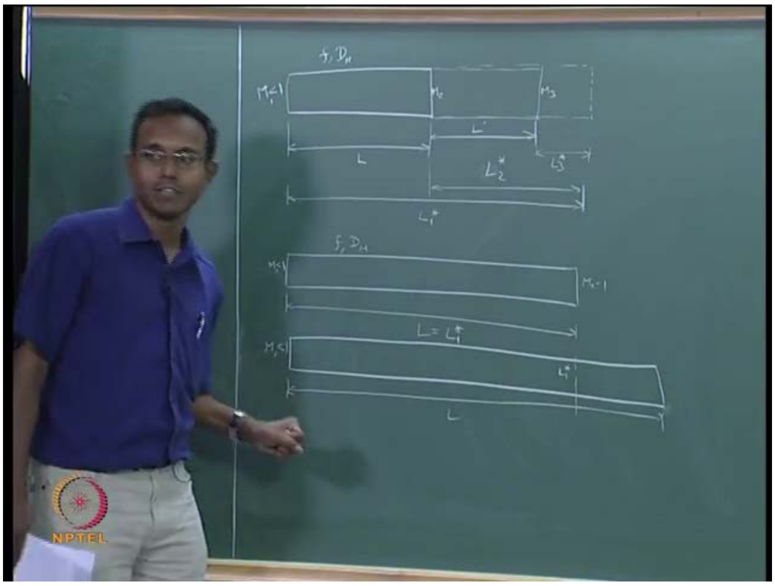

Lets us say, I have a duct and we are starting with let us say M less than 1, M 1 less than 1 the inlet and I am going to say this is my duct length and some length L and for this mark number M 1 I am going to say that, the for that particular friction factor and the hydraulic diameter of my duct, the L star happens to be this long L max or L star happens to be this long and if I have only this length. Then now, I can say that my flow since, it started subsonic it is going stay subsonic up to here, but it is going towards M equal to 1, from here it is going towards M equal to 1.

Now, we look at it is similar to the way we did the expansion fans, frankly meant curves I am going to say from M 1 it is going to reach mark number 1 and somewhere along the way it reaches M 2. Now, if think about M 2 as my starting point, then it will take exactly this length to reach this L star. So, this length will be that particular L star for this exit not number M 2 for this particular problem. That is the way I want to think about this is the way to solve the problem.

I am going to say, if this is my M 2 then this is my L 1 star that is L max based on that f that D h and this mark number M 1 that is this length. And this will be my L 2 star, which is for that f for that D h if I use M 2 I will get this length. Now, the difference happens to be the length that the float x to go from M 1 to M 2 till it reaches M equal to 1, this is the way I am going to think about this Colum, this is one simple application.

Now, I will make the case little more complicated I will just say I extended the length, up to some length only up to here, not past my l star and what will happen I will consider this as an M 3. If I start from M 2 and think of this problem it is a duct of this length whatever, this length L prime x say, then I will just add that L prime here L prime. And now, adding one more section of this pipe, with same the enough and same area of diameter I am adding one more section here.

Then I can just think of this problem from M 2 onwards as if it is same as the previous problem, just 1 is replaced by 2 and 3 is replacing 2 here. That kind of problem just coming around here, that is all it should be I am going to think about I am starting with M 2 and that will have a L 2 star. And now, I have a M 3 such that if I go this extra length, that will become a L 3 star, this is the way to think about this problem.

So, if I say this is the initial length, what is the mark number then if I add this much length to way total will be the ma k number that kind of a problem, then I will approach it this particular method I am just going to find L 3 star L 2 star etcetera. And then based on that I can find the answer, will go through numerical examples that is just one part, if my length of my duct is exactly equal to L star then that is the simplest case you can ever have. I have a duct f and D h are given and I am going to say some M 1 less than 1 and I am going to say this length L equal to L star.

If I have this case, then I am going to say fully it is going to become M equal to 1 at that exit, simplest case really think about it for this L equal to L 1 star I should say, for this mark number M 1 this is the length needed and I am providing exactly that length. So, it is just going to reach it, that is one simple case, where I will have M 2 equal to 1 here. Now, the next case is if I have again M 1 subsonic, but I am having a length greater than

I call this again L while my L star is still the same, this my L 1 star ends there from the starting point if I think of that way.

Now, I have more length, what will the flow do it will decrease, it will send out extra compression waves from this excess length such that, those compression waves go and it subsonic. So, it will go faster it will go reach this point where thinking only steady state as of time. So, all that compression waves will go ahead and make this flow come slower into it. So, M 1 will now, change to M 1 prime which will be less than M 1 value.

Such that, it is equivalent to thinking about let us say, I will pick this problem, this equivalent thinking about I am having a case where this length is extended more here, such that I have M 1 prime here, M 1 prime more in this side and now, that will be equal to that that M 1 prime giving L 1 star L 1 prime star let us say, going from this M 1 prime to L 1 prime star. That will be equal to your new value, that is how this problem goes at that point it is decreased such that, that we have.

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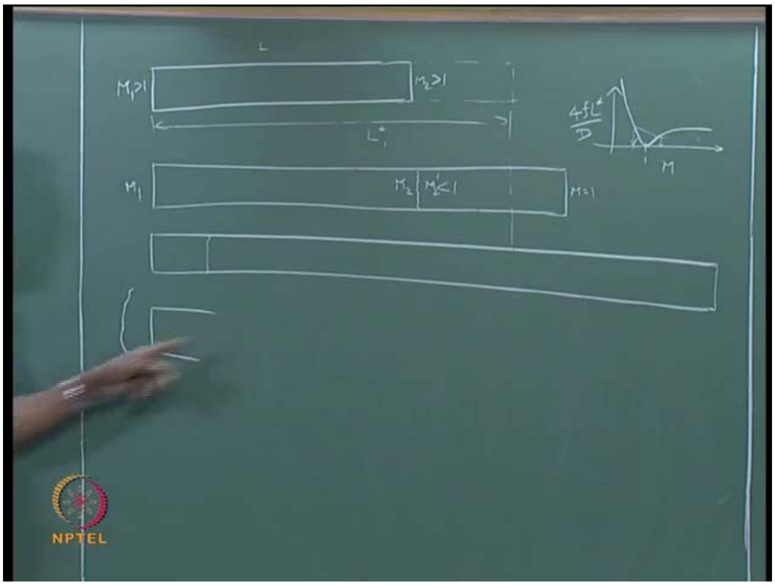


Now the next thing is I will do the whole thing for supersonic. So, little different in supersonic, simple cases are that exactly the same M 1 greater than 1 this is my L star L 1 star and this is my L if I think about M 2 greater than 1. It is just decreasing from M 1 towards M 1 M exit equal to 1, but before that we stopped the duct. So, it is not exactly equal to 1 slightly greater than 1, it is decreasing monotonically towards there that is the simplest case, similar to subsonic case.

If I make this equal to L 1 star then also it simple case exit will be M equal to1. Now, I will go for more than that length case, say I am just slightly more than that L star case, if I have this case then typically there will be a shock by the way it will be ahead of this L 1 star value that location in a shock let us be a head of this, what is the rational for that, this extra length is what is going to cause excess resistance. And, so that will send out the set of compression waves and as they come in they find higher and higher mark number flow resisting it.

So, there will be a point where those set of compression waves coming in coming to an equilibrium against the flow, it is like spread well shock wants to run ahead and flows going this way, it will come and stay stabilise somewhere typically. So, there will be a shock sitting here, it is subsonic flow now, I will call this as my M 2, M 1 M 2, M 2 prime I will call this there are just downstream of the shock immediate downstream of stock is less than 1 and after that it takes a subsonic part, we discuss this on the plot that day.

Because, in the subsonic section 4 f L star by D versus mart number, we found that in subsonic region L star can be much higher. So, instead of going to the supersonic wave where L star is only this length, instead of this it takes subsonic solution, where it has higher length. That is the idea for this same f and D this curve will just become like L star curve it has higher L star. So, it jumps there, that is the idea behind this going to subsonic side, after that it will still want to reach to M equal to 1 and the exit this will be the case.

If I keep on extending this length, then will go to situation where the shock goes more and more upstream, if I extended any further then the shock will goes set outside this duct, set outside this duct after that if I will look at what is the flow inside the duct it is only subsonic flow I will go back to either more here, and the problem just becomes this.

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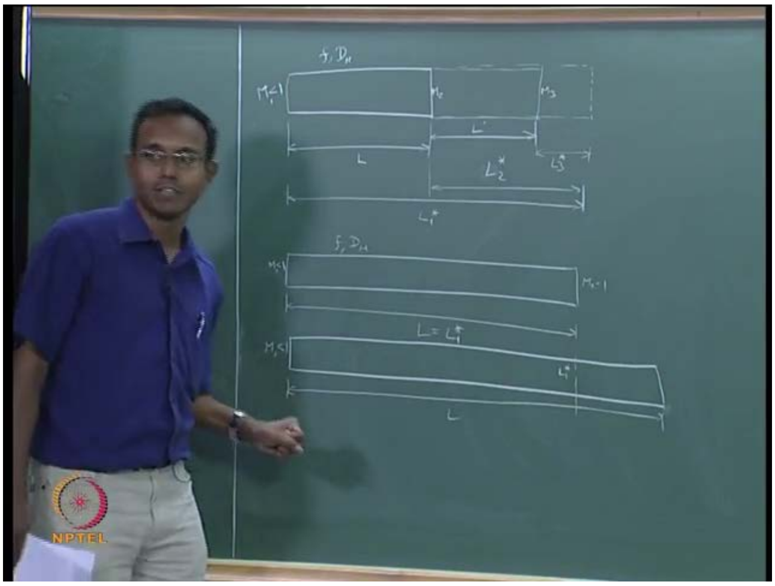

Of course, there may be a shock sitting in front of it and before that there could be a supersonic flow even here, I am not showing you that part here that is all it should be.

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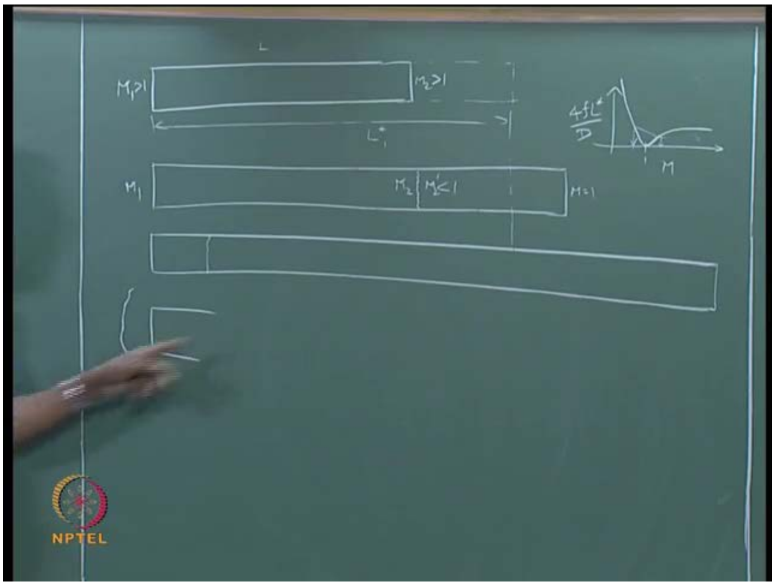

With this idea exist wanted to re iterate this whole thing in one sequence, want up I will start with M l equal to 1 in here, M 1 equal to 1 I cannot send M 1 equal to 1 flow into any duct because, immediately after that there is be a friction which will send compression waves, which will slow down the flow and immediately we will get only a subsonic case behind, that is why transonic problem is very, very difficult it could become M equal to 1 immediately it forms a shock and decreases somewhat now immediately after that.

And you will sudden have lower flow rates, that is the way it goes.

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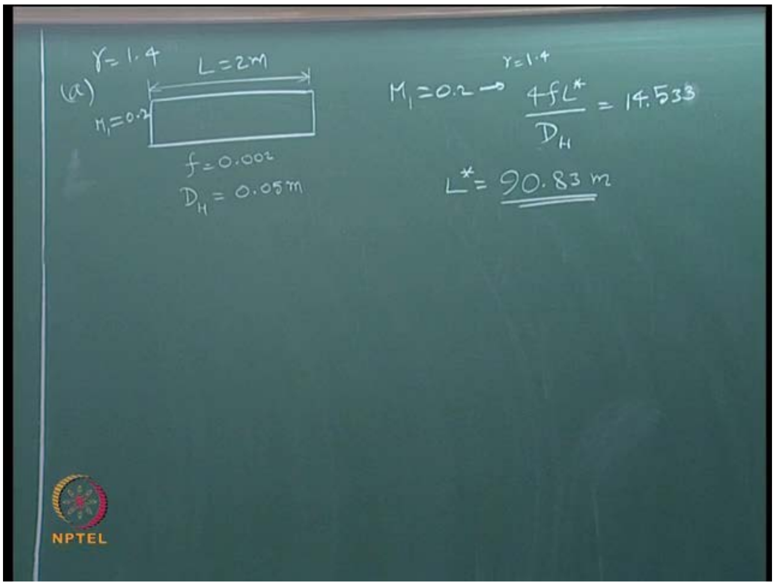


Now, we will go pick numerical example, I will deal with only with only gamma equal to 1.4 typically, air as what I am considering as my fluid, and I am having a simple case I will consider this as problem a where I am having a duct with f equal to 0.002 hydraulic diameter given to be 5 centimetres 0.05 m m or 0.05 meters. And L s given to be 2 meters, I am having M 1 equal to 0.2 mark number I want to find what does the exit mark number that is the idea.

To start this problem always if it is a friction problem immediately I want to find L star because, based on L verses L star whether L is less than or greater than L star, my approach to the problem changes. So, first thing I need to do is find L star. So, M 1 equal to 0.2 from tables gamma equal to 1.4 tables. So, if I go look at it 4 f L star by D h is given to be 14.533. So, based on f and D h given for my friction factor for my particular duct I am going to get L star as 90.83 meters.

Now, your numbers look ridiculous at L is 2 meters and L star is 90 meters, only when it goes 90 meters long my mark number will ever reach M equal to 1, I am starting with very, very low mark number that is why this case is happened. If I started with 0.9 it may not be very long, it may be just 2 meters also you remembered that curve that was looking that actually I had a curve in this port. A curve is looking like this

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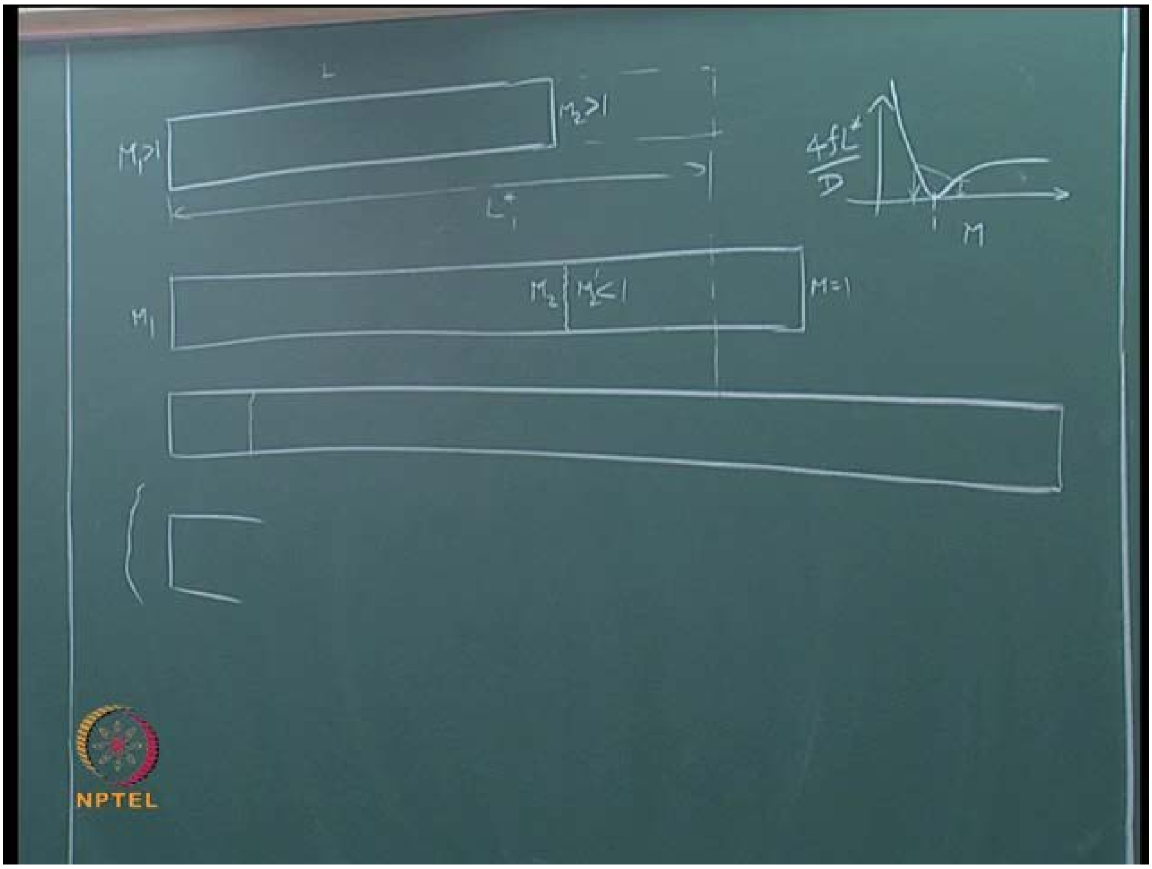


and mark 0.2 is somewhere their high out there that is why it is looking like this, the numbers may look ridiculous at beginning we know it immediately.

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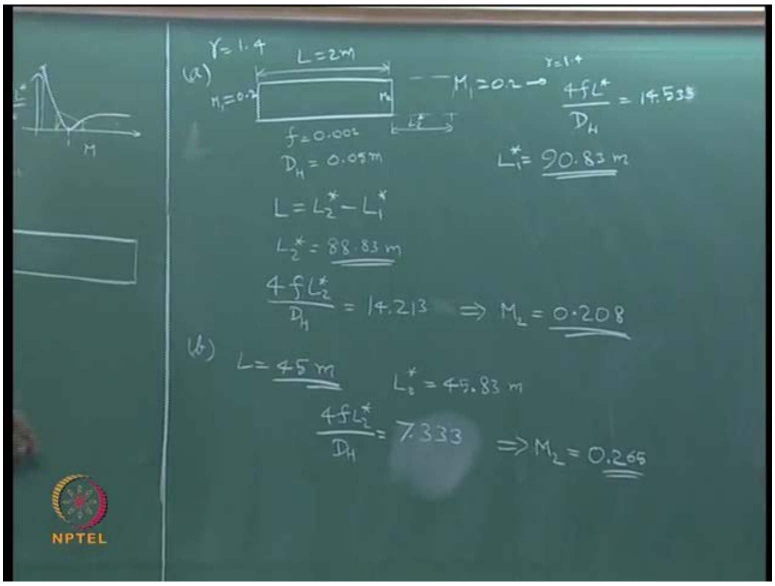


If this is the case what should I do I just have to go and draw some dotted line and L star somewhere out there, this will become L 2 star, where this is my M 2. So, this is the remaining length I know this is 2 meters from M 1 from the inlet to the star is L 1 star that is given here, I will make it L 1 star this my L 2 star. So, L equal to L 2 star minus L 1 star which means I can find my L 2 star, L 2 star value is to 88.83 meters.

So, I will go and find 4 f L by d 4 f L 2 star by D h that comes out to be 14.213 meters. Previously, it was 14.33 for M equal to 0.2 from there it has become slightly lesser this mark number increased little bit that is what we have, from here I should not be putting meters here it is not meters sorry no unit is it is not dimensioned L by D. So, from here I am going to find my mark number M 2 this will give me a M 2 of 0.028, we will look it does change only from 0.208 because, this length is far small compare to my L 1 star that I have here L is 2 meters L 1 star is 90 meters it is not that much of change when I look at the overall needed length.

So, there is not much of change. So, this is the first problem, let us pick some other length let say L equal to 45 meters the same problem as before. Let us want to see what if I go half way to L 1 star perfectly. So, since I know the problem I just go through the same process nothing changes, I know that length is less than L 1 star. So, if I go through this one L 2 star is 45.83 meters.

So, 4 f L 2 star by D h is going to be 0.265 sorry I jumped 0.265 is my mark number this comes out to be 7.333. And this gives me a mark number of 0.265 you still find that even if I go half way through L star it does not gone too much away from mark 0.2.

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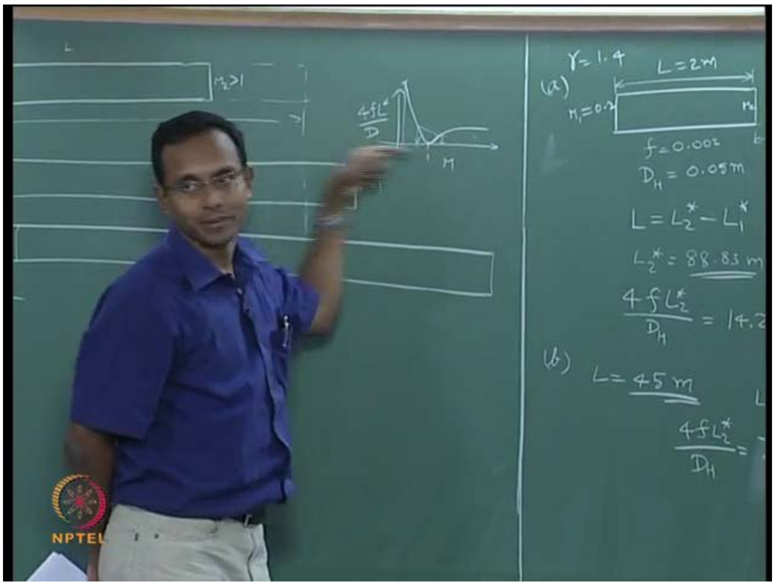


This is the idea of this particular curve I will go back to this curve. I am having 4 f L star by D verses mark number, this curve is very steep at the beginning and then it turns to become shallow, only when it is shallow there will be too much change in mark number till that time it changes only in L star L basically, changes mainly in the length of the duct not much change in M 1 that is what is currently happen.

So, when you get an answer like this you should think about either it is ridiculous or not currently it is not. So, you can leave with this particularly problem. Now, I will change the problem in another way around solve it and mark number the way, suddenly I want to solve the problem by saying how much length should I have. So, that my pressure at the exit is half of pressure at the inlet I am changing the problem.

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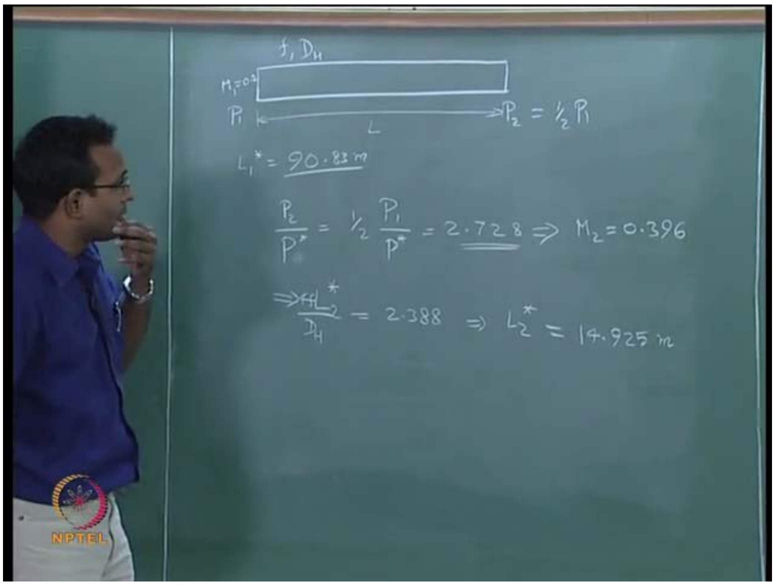


I am going to say, I am having the duct f and D h are given for my cube, I am going to say there is some M 1 let us say this again 0.2 and I am given some P 1 I want to know what should be the length L such that P 2 equal to half of P 1 this is a problem I want to solve. So, how I will approach the problem it is not very difficult I am again going to say for this M 1 I know my L 1 star from problem a I know the L star it is 90.83 meters and I know this number.

Now, the only thing I had to think about is, what should be my mark number such that I will get half the pressure. So, it is very difficult to do, it is not very, very difficult to do, but as just look through that problem. It is, so happens that there is a another column called P by P star given in your tables. If you have that it is easy otherwise it is little more complicated to solve this problem. It, so happens that in my tables I have it. So, we will just use this directly for this example.

P 2 by P star we know it is equal to P 1 P star looks like I am switching star up and down this keep it as up now. So, we know this because, P star is going to be the same whatever my initial condition is fixed, I am going to end up with this I am going to say this is equal to 2.728 that is I already divided by 2 to get this also I am having this also. Now, this from my tables gamma equal to 1.4 and this P by P star, will give me my M 2 as 0.396 this is the value I get, now my actual objective is to find length of the duct.

So, what should I do I should go and find L 2 star again from there. So, from my tables again for this mark number my L 2 star actually, what will get from tables is 4 f L star etcetera. So, if my L 2 star will be actually, I will put 4 f by D h this number will be 2.388. So, from here I will find my L 2 star, L 2 star happens to be 14.925 meters. Think about this when I started with M equal to 0.2 my number was 90 meters, and it became roughly 0.4 I have only 14.9 meters. So, the curve is starting to turn, that particular curve here.

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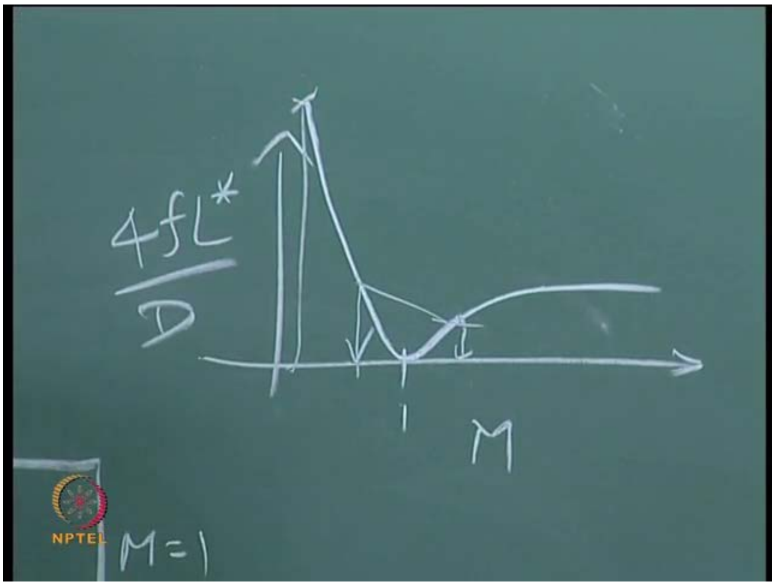


This particular curve is starting to turn around 0.3 plus it will start turn steeply, initially it was out there now, I slowly turning, turning, turning that turning point start seriously only after 0.3 mark number, above 0.3 mark number there is more sensitivity to mark number. And when we are going very close to M 1 there is lot more change to it.

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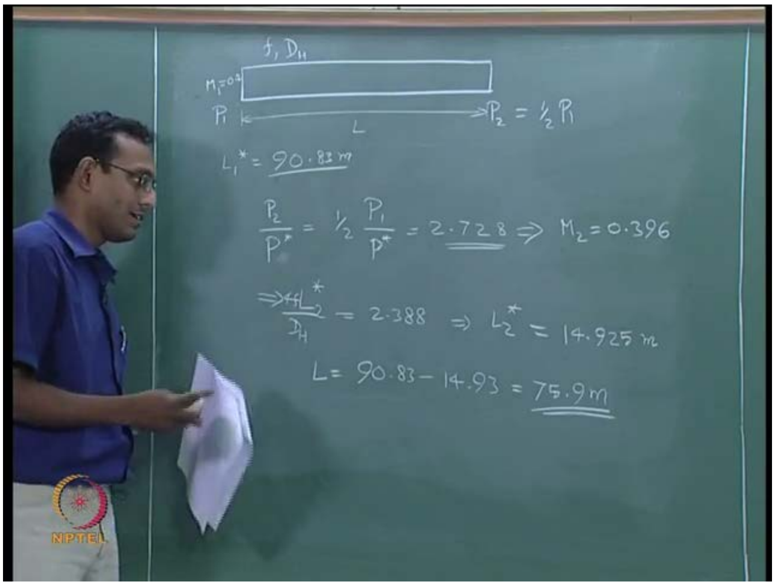


So, we know that from here my star value is 90 meters away, and from this point my star value is only 14.9 meters away. So, the difference must be my L, L happens to be 90.83 minus 14. I will make it 14.93 because, it gives me nearest number, 75.9 meters is the distance I need to extend this duct before it goes half the pressure at the end line that is the current situation, we have that is the idea of that particular problem.

Now, we still did not do a case where I have a subsonic entry and my length is more than my L star. So, if we pick a case where I have a subsonic entry and my length is more than L star let us say I have only 100 meters, 100 is a very next number slightly above 90. So, I will just pick 100.

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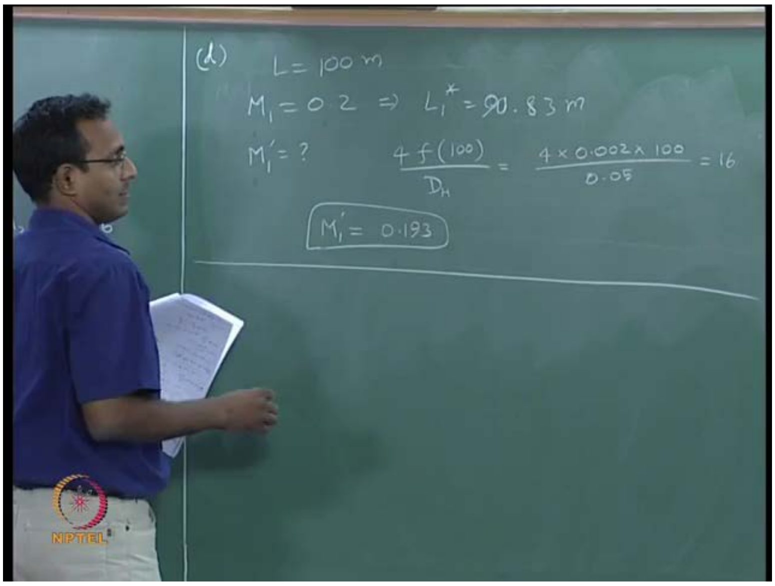


So, I am going to say my L equal to 100 meters M 1 equal to 0.2 which gives my L 1 star is equal to 91.83 meters these are the numbers we have. Now, we know that 90. sorry 90.83 meters, we know that now, there will be a compression waves travelling upstream and adjusting this M 1 to M 1 prime I do not know what value it is, but I know my M 2 the exit of the duct will be M equal to 1. So, it will be getting adjusted to some M 1 prime.

And what it will get adjusted to M 1 prime will now, have a L star of 100 that is how it will get adjusted. So, only I have to do is 4 f into 100 divided by D h, if I do this of course, I am still using same f and same D h for all my problems if I use that it will be 4 into 0.002 into 100 divided by 0.05 meters, this number comes out to be 16. So, my M 1 prime comes out to be 0.193.

So, I started with 0.2, but since the length is more than this length the flow immediately got adjusted to M at the inlet happens to the 0.193 and after that it is just a simple fan of flow the condition, where it is just chopped at the exit it is M equal to 1 very nice problem. So, it is just go slowly increasing math number and eventually it will go a point where it is M equal to 1. if you want to find any other variable I am sure you can find out from just going to supersonic cases from now.

Of course, I can now, tell that find temperature at some location or tell me when the temperature goes triple the initial temperature all those kinds of problems we can solve. I am just avoiding those you know you can calculated actually, temperature decreases at subsonic to M equal to 1. So, temperature should goes to one third of I want to ask a question. So, now we will look at supersonic inlet, I just add here.

So, I am going to say it is all subsonic cases and this I believed was problem d a b and this was problem c just did not number there.

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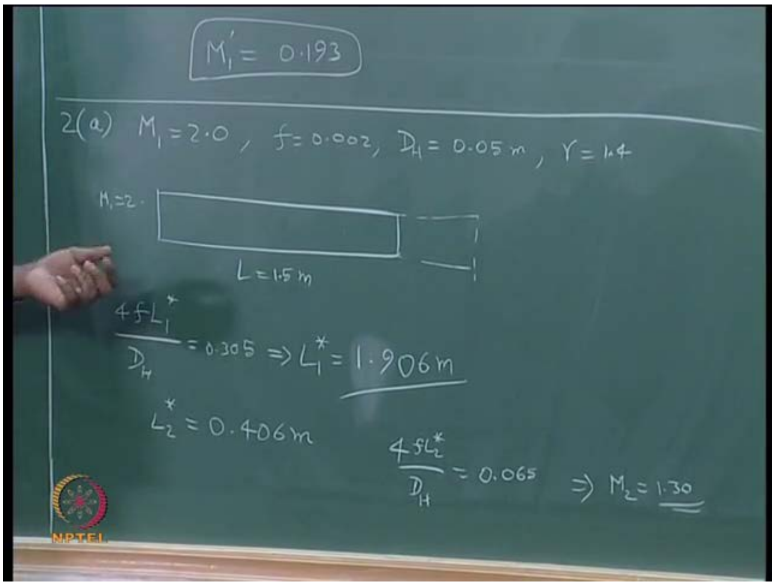


Now, we will go for next problem, I will call this 2 a now, I am going to say M 1 is 2.0 instead of 0.2 same f, same D h just for simplicity I did not want to change this numbers. Of course, I will give you another exercise with this, with all this numbers varying not very difficult to calculate, but it is just something you want to get use to.

These numbers you can make a mistake typically, in looking up a tables the gamma can be different in, different books some books will give you, so many gamma values, different tables for each gamma values should not be looking at the wrong gamma value you will get all wrong solutions, typically the mistake made by the most students. So, I will pick a case and being careful and I am going to say L equal to 1.5 meters, previously we had case a was L equal to 2 meters I am picking 1.5 meters you will see while in a minute.

I already calculated some things M 1 equal to 2 if I start here of course, the very first thing I want to find the math number at the exit that is the overall objective of my problem. Now, to find that half curve of course, I had known how close to M equal to 1 am I at the exit. So, I will first fine L star, L 1 star, if I find 4 f L 1 star by D h for this mark number for that gamma equal to 1.4 I am are going to get a number 0.305 which is going to give me L 1 star as sorry 1.906 meters this is the reason I did not choose 2 meters.

Because, I already calculated this one before coming to class now. We are finding that now, I chosen a case L less than L 1 star which is very simple now, it is supersonic it will end with supersonic about lesser mark number than the initial. Similar, thing I need to do now I will just find that it has 0.406 meters from this point to L star, that is the distance it has. So, I have to find L 2 star happens to be 0.406 meters, this 0.406 meters I just had to find 4 f L 2 star by D h and 4 f L 2 star by D h for that f and D h given happens to be 0.065.

Now, I have to go to gamma equal to 1.4 tables look for where this occurs in that table and choose that mark number, that mark number comes out to be 1.30 I started with mark 2 and I am ending with 1.3 marks. And within that 0.4 meters left it is going go to M equal to 1 that is what we are seeing, here you are seeing that there is a lot of sensitivity to length in terms of mark number change for small length change mark number changes a lot, that is about supersonic case. Now, we will choose a case where L is greater than L star.

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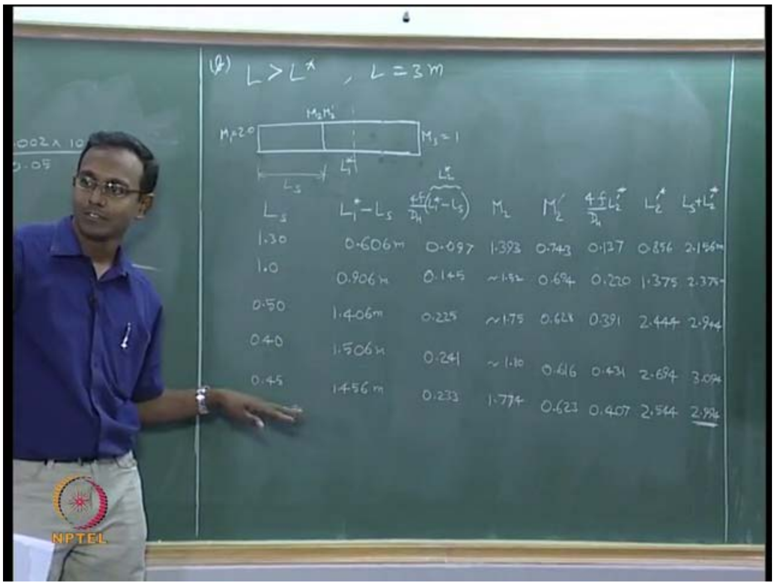

Now, I will choose L greater than L star. So, I am going to pick L equal to 3 same M equal to 2.0 as my mark number I begin L equal to 3 meters. So, we except a shock let us say this was my L 1 star I am going fast that point and M equal to 2.0 as the beginning. Now, I know my shock should sitting slightly inside of this, I told you already. So, I am excepting a shock somewhere here and I am going to say mark number before as M 2 and mark number after M 2 prime just after the shock, shock has happening at that infinite as minute as can in location.

So, I want to find that particular length at which the shock occurs, I will call this as location or shock L s a length at which shock occurs, such that I will get M 3 equal to 1 that is the overall thing. I am just doing mark number variation extra in my tube of course, I know that once know my mark number distribution in my tube I can find any other property because, I have fan flow of tables with me, for a given mark number I can just go and find any other property.

If want to find say somewhere in the middle I can just go and calculate from M 2 prime I went, so much down steam with this f and D h I can solve that problem, it is not very difficult to solve and if I want P y by P star whatever I can get every number. So, I can change pressures also across. So, I am not solving those that probably I will give those as exercise problems. So, how will I solve this.

So, I am going to first read this part of the problem, as supersonic flow going some length less than L star which is just now, we did a of second 2 a right that was this problem. And this of 2 b I keep forgetting to label these problems these 2 b. And, so I will solve this as it is 2 a, after that I will have a normal shock problems, I will just go to normal shock tables and jump from here to here across this, once I do this from here to here remaining portion. Now, I have to see if I get this mark number to be 1 at the exit. So, again I will solve this as 1 a problem.

And I will see if this much is 0 how will I check that simplest way to check, what if it is more than the length of this particular M 2 star, M 2 prime star that is the case. So, all I need to do find the remaining length and see if that is more than L star corresponding to M 2 prime, that is all I need to do if it is equal to that L star then I have solved my problem. So, I have to go through some iteration here, I cannot directly guess what my L s will be. So, I had to go through a set of iterations I have gone through iterations.

So, I will just give it to you I will tell you how it works I am going to have a full column L s L 1 star minus L s 4 f by D h times L 1 star minus L s and that is going to give me my M 2 just to be clear I have written this L s L 1 star minus L s that happens to be my L 2 star really, if you go and look at problem 2 a that is was those are L 2 star. Now, I will say L 4 f L 2 star by D h from here I will go read out M 2 from there.

Once I know M 2 I will go to normal shock tables and find M 2 prime from there, from there I will go to 4 f by D h times L 2 prime star from this mark number I will go to fine flow of tables find this of course, now you have to pick only subsonic solutions. Now, I will pick only subsonic solution from here, and from here I will get a L 2 prime star I will just have to multiply appropriately D h by 4 f you will get that, after all this finally, I have to check whether this distance is more than or less than my that L 2 prime star.

So, the way I want to do it I will find L 2 prime star that will be distance from this shock till where M equal to 1 occurs, that plus this L s must be equal to full duct length. So, I will do it that way, I am going to say I have L s plus L 2 prime star, as my last column I want to make this last column equal to L my 3 meters, that is the overall objective of my solving this that is my iterative process.

So, now I am going to pick let us say 1.3 because, I already have answer for 1.3, 1.30 I am picking. So, if I pick 1.30 again you get numbers and I said that L 1 star was 1.906

meters. So, I can get the L 1 star minus L s that will be 0.606 meters from here, I am going to get 4 f L 2 star by D h that number happens to be 0.097 from this I can back calculate I can go to my fan of tables get a mark number for gamma equal to 1.4 1.393 is my mark number.

And M 2 prime and now, going to normal shock tables across this 2 columns alone 0.743, again draw the normal shock tables when you flirting pages you should go to the correct gamma of tables. Now, I will go back to fan of flow tables, from here to next one that number is 0.137 from here I will calculate my L 2 star 0.865. Now, I will add L s plus L 2 star that comes out to be 2.156 meters.

So, I am finding that in my shock is here, my duct becomes L equal to 1 somewhere here itself, that is what I find in this case, if this is where it becomes M equal to 1 and I have a extra length or have not there will be more compression waves generated and it will go upstream and push this shock further up stair. So, my logical way to go is I have to decrease my L s. So, I will go decrease my L s I will make it 1.0 I initially when I iterate call I p call as nice numbers eventually when you are getting close to the answer we will think about something else.

So, from here 1 minus 10.906 minus 1 0.906 from here I will write the next number 0.145. Now, this if I go to the tables I do not get exact number I have to interpolate. So, I will just pick a curve of estimate of the order of 1.52 I will just pick the closest 1 to interpolate, from here I go to normal shock tables across here, 0.694. Now, I from here, to fan of flow tables and get the next number 0.220 which will give me my L 2 star as 1.375. So, my L s plus L 2 star is 2.375 meters that is what I have finally, 2.375.

So, of course, here 2.15 begin 2.375 still not enough, my shock has to go further upstream. So, I will change more drastically I will make it 0.5 meters it has gone well ahead 0.5 meters. Now, I will go through the same process 1.406 meters 4 f L by d will give me 0.225 M 2 is approximately 1.75 mark number from their normal shock tables gives me 0.628 mark number, downstream of the shock from here I will go back to fan of flow subsonic solution gamma equal to 1.4 I am going to get 0.391 from there I can calculate my L 2 star 2.444 and that gives me 2.944 meters getting close to the answer.

So, I still have to go further upstream, but I am close to the answer. So, now I will start changing slowly I will go to 0.40 that number is 1.506 that I do 4 f L by D 0.241 and this is approximately 1.80 till I am doing, approximately I will do more better I have interpolation at the last step. The next across the normal shock that number is 0.616 after that I will do 4 f L by D 0.431 which will give me my L 2 star as 2.694 which now, has crossed 3.094 meters.

So, now, I find that if put my shock at 0.4 meters from inlet I am going to have mark 1 slightly downstream of this exit which means now, my answer is between the last 2 iterations. So, now, I will do more careful iteration. So, now onwards I will not do this approximates shock I will try to end the correct interpolation in the everything, I will pick of course, I want to pick the midpoint 0.45 I will pick the midpoint, that gives me 1.456 that gives me the next column 0.233.

Now, from here I want to go find mark number ahead of shock that value now I will do more carefully 1.744 even more approximate methods doing it little more carefully 774 sorry 774 of course, the way I check my answer was because, 744 was not in between these 2 numbers when you are iterating just go through this simple checks 774. Now, I will go look at normal shock tables and that gives me 0.623 from here I go back to the fan of flow tables 0.407 and that is giving me 2.544 meters.

So, I am getting 2.994 of course, I can go one more iteration and try 0.46 should I go down or up 44 or some again try a 0.44 and I may get a answer even closer to 3 when I want to stop at this 2.994 I will stop, this where it goes at this point, this is the iterative procedure where you have to follow to get to problem solution of this type. Once I solved up to this point this is the starting point if I want to know more properties.

Now, I know that my shock sitting at 0.45 meters up to that it is supersonic after that it is also subsonic, that is what I figured out after that if I want to know the final x it exit pressure or my P naught at the exit all those things I have to go through the calculation all the way P naught 2 by P naught 2 star at etcetera has to go through and find out all these details. And remember that there is P naught change across the shock also you have to take that also into occur.

Of course, I am not doing that right now, I will give you another problem with pressure change. So, I think this will be your last numerical example I would not give you any more of numerical examples.

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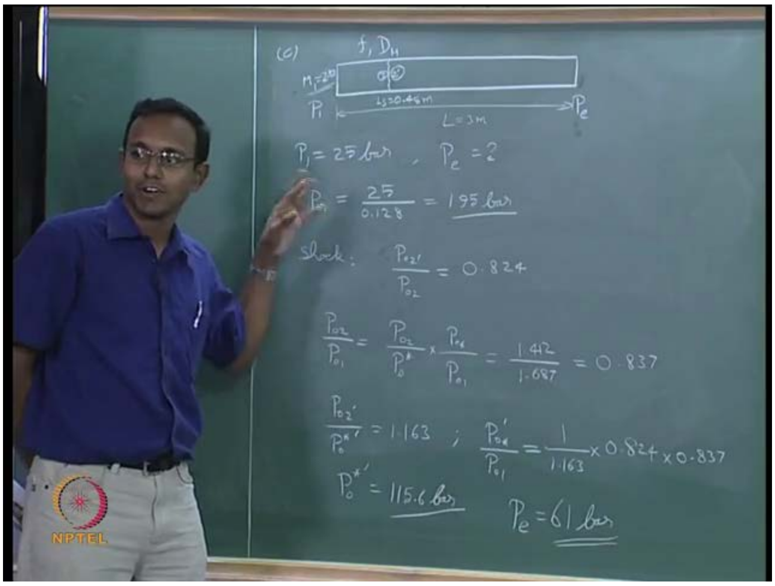


So, now, this becomes here 2 c I am starting with M 1 equal to 2.0 same f same D h. Now, I am telling I have that exact situation like in problem b I am having length equal to 3 meters. And we started at M 1 equal to 2.0. So, we know my shock location is L s equal 0.45 meters, may be I am right may be it has to be 442 something I will just assume it 45 right. Now, I did not go through one more iteration to make it any more accurate. So, we will keep it as 0.45 meters.

So, if the question is this if P 1 is equal to 25 bar find P exit, that is my P exit find my P exit that is the question I want to ask. It is easier to work with P 0. So, I will switch to P 0 from here itself I know P 1 and I know M 1 I can find P 0 where should I go I said graphic tables gamma equal to 1.4 I said graphic tables there is, so many tables in compressible flow tables books. So, you have to choose the correct table and correct gamma value.

So, now I will go find P 0 1 that will be 25 divided by P by P naught that is for M equal to 2 that is 0.128 that gives me 195 bar of course, I could work with just P by P star all through I just wanted to work with P 0 by P 0 star just for one of it. So, now, I want to find we know this is a P 0 1 we will keep this. Now, I will look at shock we know the shock mark number right, from the previously problem we know that shock mark number is 1.774.

So, I will go and find that value P 0 to prime by P 0 2 we labelled this as 2 this as 2 prime then I have exit, these are the values I have P 0 2 by P 0 2 prime I really tried that value 0.824 I have this number. So, I want to find what is be the P 0 star at this point, by the way since it is all subsonic flow here P 0 star here is same as P 0 star here, p 0 star does not change P 0 star will be the same value and we know that at exit M equal to 1. So, P 0 here is equal to P 0 star.

So, all I need to plan P 0 only up to here that is enough of course, if I started at working with P star then I have to track only P star up to here and that will be the pressure at the exit I wanted it to take a longer path. So, now actually I want to find P 0 2 by P 0 1 is equal to P 0 2 by P 0 star into P 0 star by P 0 1 I told you gas most people like ratios multiplication multiplying it. So, this is equivalent to I am in my tables given as P 0 by P 0 star. So, I will go find at M 2 what is this value divided that with M 1 what is that value.

And that comes out to be 1.412 divided by 1.687 that value is 0.837. So, now look at these numbers P 0 2 prime P 0 2 I have, I have P 0 2 by P 0 1 only thing left is P 0 2 prime divided by P 0 2 star P 0 prime star downstream star value. So, I have to just find that value P 0 2 prime divided by P 0 star prime, that value happens to be 1.163. Now, if I multiply all these appropriately I can get P 0 star prime divided by P 0 1 that what you need to do I will just do that right here P 0 star prime by P 0 1.

So, of course, I had take reciprocal of this 1 by 1.163. So, now, I have P 0 prime at the denominator I go multiply with this I get P 0 2 at the denominator and it comes out to be 0.824 and I will take this number then I will have P 0 1 at the denominator which is what I want. So, I multiply with this 0.837 I actually, then find number for this I just use this I know P 0 1 is given to be 195 bar we calculated. So, I am going to multiply this ratio with P 0 1 value to get P 0 star prime happens to be 115.6 bar.

Now from here of course, I can go to isotropic tables and find M equal to 1 what will be the P value, that comes out to be P at exit happens to be 0.528 of that you should know gamma equal to 1.4 is 0.58 is the ratio that comes out to be 61 bar this what I end of it. Now of course, it look like I went through as little bit longer path because, it is P naught I wanted to solve a problem in class with P naught variations, so I went through it we could have solved it with P star then I would have avoided going to my isotropic tables completely that is the only difference.

Now, I started with 25 bar and I am ending with 61 bar is that logical, flow is going from low pressure to high pressure it looks like is that right. It happens to be correct what will be the reason I give my momentum is decreasing I am going from M equal to 2 to M equal 1 finally, that is why it is matching otherwise, the flow will never go from low pressure to high pressure think about it, but I had other energy not just pressure energy I had also other energy here momentum or kinetic energy I had excess of it.

And that is now, decreasing and that is becoming pressure energy during the process that is what happened here, I will probably show some animation tomorrow if not we will just start heat transparent wave duct and what happens to it has turn x during duct, inside the duct that we will start with tomorrow see people in next class.