Introduction to Fluid Machines, and Compressible Flow
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Lecture - 36
Normal Shock Part – IV

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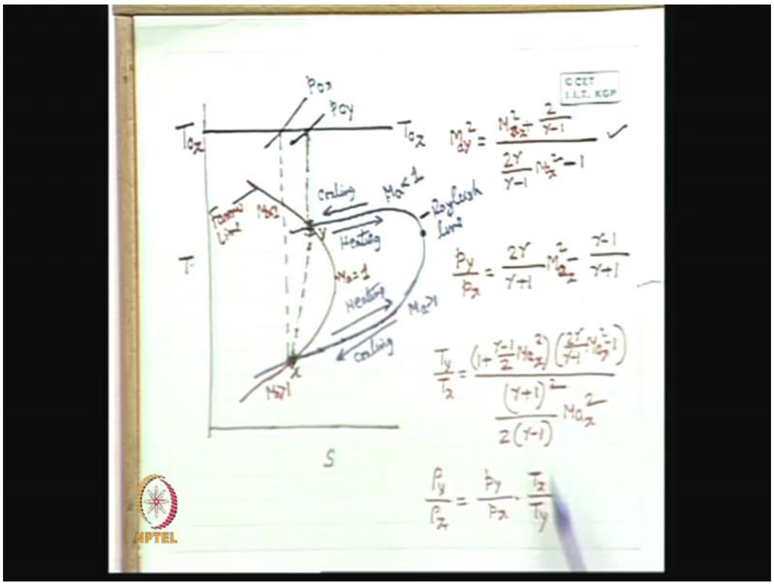

Good morning, I welcome you to this session. So, we will be starting with recapitulations of phenomena normal shock which we discussed earlier, let us see that we identified that the shock in that the upstream, and downstream of the shock lies in the inter section of 2 lines fanno lines, and Rayleigh lines you know this is the fanno line this is the fanno fanno line, and this is the Rayleigh line this is the Rayleigh line s this is the Rayleigh line I like to repeat it again, because here lies concept other parts of algebraic manipulations which we have already done.

Now, the inter section of fanno, and Rayleigh lines determine the 2 that is the upstream, and downstream that 2 state points before, and after the shock as you known again the fanno line is the locus of state points having the same stagnation enthalpy; that means, the same stagnation enthalpy or stagnation temperature the energy remaining same it is plotted in t s plane. So, the same stagnation temperature at all point, and the same mass flow rate. So, the only way of moving along the fanno line is by friction; that means, by the same stagnation enthalpy, and the same mass flow rate the fanno line can be we can traverse along the fanno line with friction, and you see the we can flow.

We can follow the fanno line along fanno line in such way that entropy should increase this is, because of the second law of thermo dynamic for an adiabatic process entropy should increase. So, therefore, the fanno line can be approached in this part either this way or in this part either this way, and we have. So, recognize that this part corresponds to mach number greater than 1 that is the supersonic flow, and this part corresponds to mach number less 1 sonic flow this is purely recapitulation, and this is the sonic condition mach number one. So, therefore, we have identified that for any flow where the totally energy remains constant; that means, an adiabatic flow the effect of friction in the supersonic region is to change the flow from supersonic to sonic.

Similarly, the effect of friction in an adiabatic flow in the subsonic is to change the subsonic flow to the sonic flow. So, this is the fanno line characteristics similarly another line which is we have drawn known as Rayleigh line this line is the locus of state points where the impulse function remains the same; that means, impulse function remains; that means, friction that is in the absence of friction we known the impulse function remains same the same impulse function, and the same mass flow rate the locus of state points are known as Rayleigh line. So, Rayleigh line in general indicates the heat transfer; that means, added or heat extracted from the system.

So, therefore, 1 can follow the Rayleigh line in both the directions; that means, we can go along the this directions, and we can also go or come along this direction. So, this direction while going this direction implies heating of the flow where the entropy is increasing while we can go along this direction of the cart which implies cooling that the entropy of the parking fluid decreases similar to the fanno line this portion of the Rayleigh line cart represents the sonic flow subsonic flow that is mach number less than 1 while this portion of the cart represents supersonic flow that is mach number greater than one.

So, therefore, 1 should know that in this case the heating; that means, increase in entropy means we can flow in this direction or we can go in this direction which means simply that a reversible heating in a supersonic flow changes the supersonic flow to the sonic condition similarly a reversible cooling in supersonic flow changes the supersonic flow to more supersonic region reverse is too for subsonic flow that is a heating in subsonic flow in a reversible manner why I am telling reversible manner this is in absence of friction otherwise the quality of impulse function it is a condition in drawing this line will not be maintained; that means, a reversible heating in subsonic flow it change the flow to sonic condition while the reversible cooling in the subsonic region will make the flow towards more subsonic region.

Now, the shock represents the inter section of this 2 points with the fanno lines there means there section of fanno line, and Rayleigh line why, because we know that across the shock there is no energy addition. So, therefore the 2 points should fall in the fanno line, and should correspond to the same stagnation temperature similarly the shock is. So, thin that we can neglect the effect of friction across the shock. So, that these 2 points should correspond to the same impulse function. So, that this 2 points must satisfy the Rayleigh line flow or the Rayleigh line conditions. So, therefore, they are the inter section points in Rayleigh, and fanno line, and from the second law of thermo dynamics again we have found that.

If the 2 points are the n points of a shock way, then the shock way upstream of shock wave should be this point, because the downstream point should be suck it should increase the entropy since the 2 points corresponds to the condition of know heat additions. So, therefore, entropy should increase. So, therefore, from here we also see that shock always occurs in a supersonic flow, and ends up to subsonic flow with the subsequent increase in entropy this has to be very much clear. So, therefore, we see another thing from where we can incur entropy change in the shock process positive that if we go along the Rayleigh line to reach the point x n y not why shock this is the line through which we reach across the that is the shock process this is a dotted line that is the through shock from x we reach y.

But the x, and y can be reached either via Rayleigh line or via fanno line if we want reach via Rayleigh line first we have to heat the supersonic flow, and then we reach the sonic region, then will have to cool the sonic flow, and come to the subsonic region, and these heating, and cooling will be such that the stagnation enthalpy or temperature will remains same; that means, the amount of heat added in this process should be balance by the amount of heat extracted in this process, and since you see the heat addition takes place at a lower temperature while heat extraction takes place at a higher temperature the entropy of system will increase.

While it will be move from this point to this point along the Rayleigh line you've understood. So, even along the Rayleigh line if we follow we can tell that the entropy of y will be more than the entropy of x or even in the simple t s diagram we see that the entropy has increased. So, therefore, it is very important concepts 1 should know that the shock takes place when the flow is the supersonic, and ultimately the flow becomes subsonic after the shock that is the y now last plus we also discuss the relationship of the flow properties after the shock in terms of the flow properties before the shock; that means, with known values of upstream sections of the shock how 1 can determine downstream values.

So, this is the mach number at downstream of the shock at a function of mach number upstream of the shock, and from this equation we can see that when m a x is greater than 1 m a y will be less than one; that means, after the shock the flow will be subsonic similarly we have deduced the ratio of pressure after the shock, and before the shock in terms of the mach number at the upstream of the shock well, and this can be found that when m a x is greater than 1 p y by p x is greater than 1 similarly we have found t y by t x as a function of the mach number at the upstream of the shock that before the shock again by exploiting the equation of state we can find out the density ratio that is the density after the shock to the density before the shock as a function of the mach number before the shock.

But now I will tell 1 important thing that if we use these equation of state, but do not replace p y by p x in terms of mach number, but if we only replace t y by t x in terms of the mach number upstream of shock we arrive a relation between density ratio, and pressure ratio which is very important.

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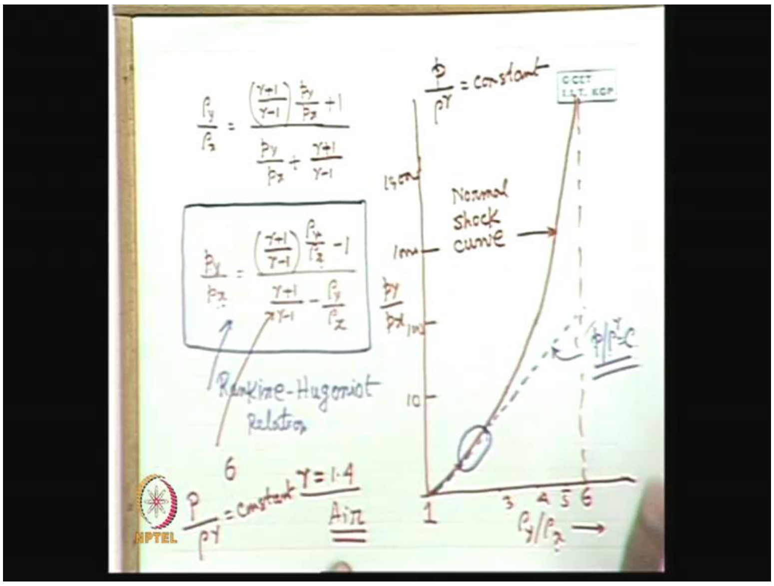

So, it is simply algebraic manipulation by which we get the density ratios after, and before shock in terms of pressure ratios or equating the pressure ratio finally, we can tell the pressure ratio in terms of the density ratio; that means, this is simply the manipulations of these equations; that means, here using the equation of state earlier we derived row y by row x as a function of mach number before the shock m a x.

But without doing that if I only substitute this t y by t x to express row y by row x as a function of p y by p x we get this 1, then from this if we equate p y by p x we get a relationship which describes the ratio of pressure after, and before the shock as the ratio of the corresponding density that is after, and before the shock this relationship is very important, and known as Rankine hugoniot relation. Now if an interesting thing we will see that if I we draw a variation for p y by p x with rho y by rho x for a that emit gas if we take 1 point four for example, usually air is the working fluid under all practical circumstances. So, air be a rather that emit gases where the ratio of the specific heats is 1 point four now you see if you put these value this values becomes that gamma 1 point four this becomes six.

So, therefore, we see the inspection of this equation tells us that when rho y by rho x approaches six p y by p x becomes infinity; that means, if we start at 1 for example, when rho y by rho x 1 p y by p x. So, these are trivial solutions we already recognized that earlier the 2 state point being same. So, the curve for p y by p x with rho y by rho x like this; that means, this is asymptotic to a density ratio of six let us do it in in a log log graph if you do like that you will see that it is better to show ten, then we can say hundred, then we can thousand ten thousand like that; that means, even.

If the pressure ratio to tends to infinity for a that emit gas the density ratio becomes six; that means, the downstream density can only approach to a value of is six times the upstream density even if the downstream pressure is many many times more than the upstream pressure rho this a very important relation moreover you know that if you draw in the same graph the relationship between pressure, and density for an isentropic flow; that means, we are again I write p by rho to the power gamma is equal to constant; that means, if I draw on the same figure the relationship between p, and rho for isentropic flow, then the equation will be like this this is the p by this is small p by rho to the power gamma is equal to constant.

So, this is the equation from here 1 interesting fact is depicted that in the this range when the pressure ratio is very small for the shock the isentropic curve which is a straight line in a logarithm plot log log plot it almost coincides with the shock curve this is known as normal shock curve normal shock curve or Rankine hugoniot curve, Rankine hugoniot curve. So, the part of the normal shock curve or Rankine hugoniot curve in the very low range of pressure ratio coincides with the curve of isentropic process this leads to the conclusion that if the ratio of pressure is very small in a shock, then the relationship between pressure, and density can be found out from isentropic relations; that means, the process of shock can be considered as an isentropic one.

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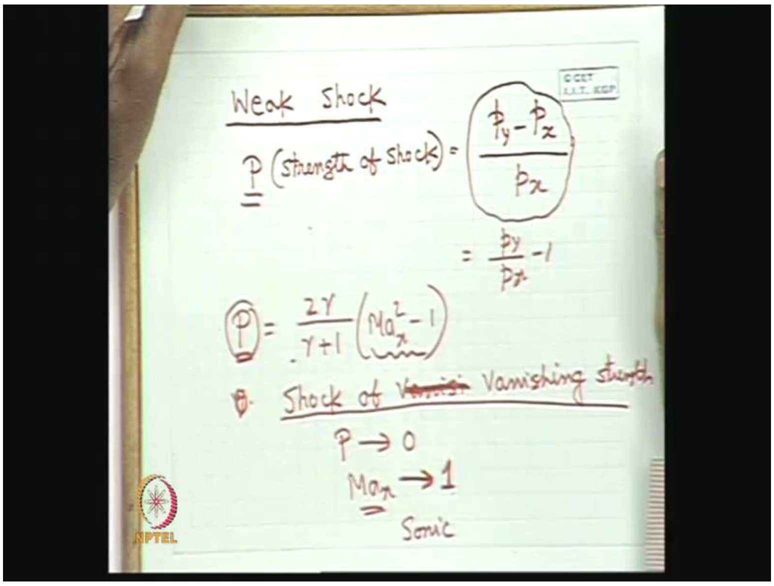

So, from this the definition of weak shock comes a weak shock is defined to be a shock where the pressure change change of pressure is very small as compared to the initial pressure. So, to define whether the shock is weak or strong a parameter known as the strength of the shock p I defined that the strength strength of shock is defined strength of shock is defined as the difference between the downstream, and upstream pressure; that means, sorry it is small better it is capital; that means, this is the increase in pressure divided by initial pressure. So, this is defined as the shock strain when the strength of the shock is very small, then the shock is known as weak shock. So, for a weak shock the isentropic flow relations for p, and rho coincides with the normal shock curve.

Now, we see from this equation if we just manipulate from this equation p y by p x is 2 gamma by gamma plus 1 now if both sides I subtract one. So, this side it will be this strength of the shock, because strength of the shock is p y by p x minus one. So, therefore, I can write from this equation by subtracting 1 from left hand, and right hand side that p becomes is equal to 2 gamma if you do it it will be coming like the m a x square minus one. So, an interesting feature comes out that when p is very small m a x square minus 1 is also very small. So, the strength of the shock is very much related to the initial mach number of the flow.

Now, we define a shock as the shock of vanishing strength shock of vanishing strength shock of vanishing shock of vanishing strength shock of vanishing strength as the shock where p tends to zero. So, for shock of vanishing strength p tends to 0 m a x tends to 1 from which we conclude that shock of vanishing strength or infinite small strength the m a x tends to one; that means, the mach number tends to on the flow condition is sonic which concludes that a shock of vanishing strength propagates in a medium with the velocity of some with respect to the medium; that means, the shock of vanishing strength occurs.

When the flow condition reaches the acoustic speed that is the sonic condition earlier we recognize that a small pressure pulse moves in a compressible medium with a velocity equal to the velocity of sound with respect to the medium at that condition. So, therefore, we can conclude that a small pressure pulse or a wave with small pressure disturbance is equivalent or a special case of a normal shock with vanishing strength, because a normal shock of vanishing strength occurs when the flow condition is sonic; that means, other we can tell that normal shock a normal moving shock propagates in the medium through the medium with a velocity equal to the sonic velocity or the acoustic speed with respect to the medium.

So, this is the thing about the weak shock we can also find out the relationship between density ratio for a weak shock if we express by rho y by rho x if we see that this equation when p y by p x is very small, then we can in fur that rho y by rho x also very small; that means, the change in the density similarly the change in the temperature will also be very small when for example, m a x is equal to 1 here t y becomes exactly equal to t x. So, for a weak very very weak shock that its shock of infinite small strain t y will be almost equal to t x similarly rho y will be almost equal to rho x, and p y will be almost equal to p x, and the sonic condition will be reached all right ok.

And the similarly the entropy change will be very small if we looked to the relationship for the entropy change you will see the entropy change will be very very small it will be almost 0, and that is the case where we have recognize that rankine hugoniot curve that is the curve for the normal shock, and the isentropic relation p, and rho coincides almost; that means, we can designate a normal shock of vanishing strength or infinite small strength as an isentropic process similar to that happens in case of a small pressure pulse or a small pressure wave in a compressible media I think that this is the course for you in the compressible flow now we will solve some simple, but interesting problems.

Let us see that this problem you see that what is this problem? You can take down note down this problem example one. So, how we can utilize straightforward the formulae of compressible flow the straightforward applications.

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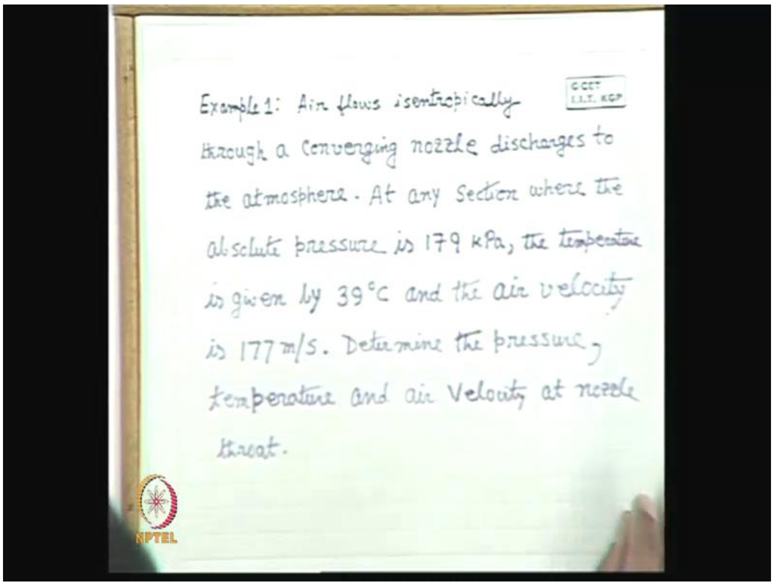

Example 1 air flows isentropically through a converging nozzle discharges to the atmosphere. So, a converging nozzle discharges to the atmosphere at any section where the absolute pressure is 1 seventy nine kilo pascal's the temperature is given by thirty nine degree celsius well, and the air velocity is 1 seventy seven meter per second well determine the pressure temperature, and an air velocity at nozzle throat ok.

So, again I read the air flows isentropically through a converging nozzle discharges to the atmosphere at any section, where the absolute pressure is 179 kilo pascal's the temperature is given by 39 degree celsius at a particular section, and he air velocity is 177 meter per second in that section determine the pressure temperature, and air velocity at nozzle throat it is a very simple problem, and straightforward application.

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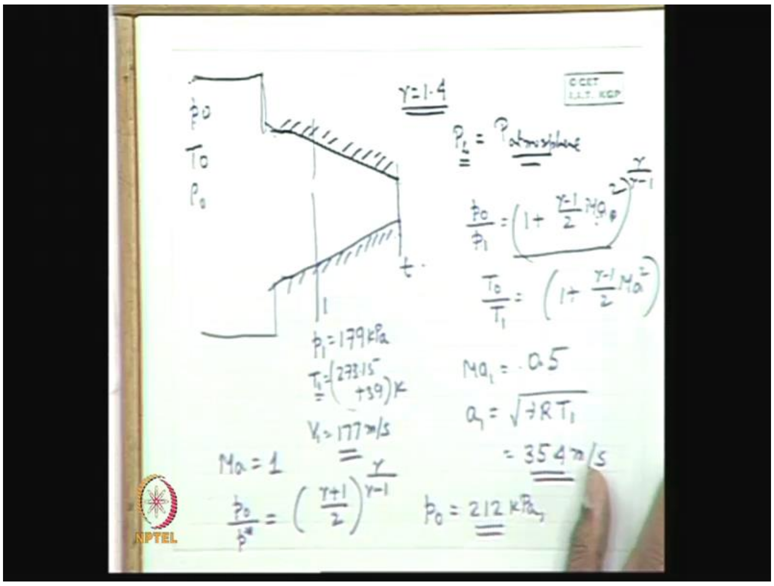

Let us find out that this is a problem converging nozzle is there. So, this is the discharge plane 1 thing is that it is discharging into atmosphere; that means, p b is p atmosphere now we do not have to be bias either way.

For example when you see that d has the problem as told determining the pressure at the throat converging nozzle throat means its discharge area. So, definitely pressure is not atmospheric pressure it is a choking condition otherwise a problem could not have been given do not be tempted like that it may. So, happen the choking may not be there in that case the pressure at the discharge may be atmosphere. So, first of all will have to check whether the pressure at the throat at the exit section atmosphere or not how do you check that now this nozzle may have a stagnation situation which can simulated as a big reservoir that this convergent nozzle may be related to a or may be connected to a big reservoir; that means, with respect to the flow through this nozzle is an isentropic flow there is a stagnation situation well there is a stagnation situation.

So, corresponding to this stagnation situation the properties are p 0 t 0 rho 0, we know all those things now here we have been told that at any section at an obituary section the pressure the pressure at the section is 1, let this section is throat t. So, section 1 we have been given p 1 is 1 seventy nine kilo pascal’s t 1 is given 2 seventy three point 1 five plus thirty nine that kelvin, and v in is given 1 seventy seven meter per second. So, now, we know that at any section the flow properties are related to the stagnation properties like this p 0 by p 1 is equal to 1 plus gamma minus 1 by 2 the local mach number whole square rather to the power gamma by gamma minus 1 simply we should start from t 0 by t 1 1 plus gamma minus 1 by 2 m a square.

So, from here using this equation now we can find out this stagnation pressure how e can find out we know v we know t one. So, we can find out m a 1 how, because a at the section a 1 is root over gamma r t 1 with this t 1, we can find out a 1 now before that we can check for this condition p 0 by p 1 that I will do afterwards now let us consider this a 1 is root over gamma r one. So, we can find out p zero. So, the value of p 0 comes out to be an also the value of t 0 the mach number comes out to be I am telling you this a comes out to be the problem answer is that three fifty four meter per second if you substitute this.

And with this a if you calculate if you calculate the mach number the mach number will be well the mach number will come out to be 0 point five 0 point five yes mach number will be straightway 0 point five if you put this mach number, and solve this with the value of gamma taken as 1 point four whenever the working fluid will be air we can take the value of gamma considering the air as a that omega is 1 point four. So, you get the value of p 0 is very simple problem p 0 to 2 hundred twelve you can check it if you perform this calculation, and t 0 well p 0 t 0 of course, you can calculate it is not giving here.

So, t 0 also you can calculate by substituting the mach number point five here with the gamma 1 .4 p 0 comes out to be this once the p 0 is coming out. We can check whether the nozzle is choked or not; that means, we can find out the corresponding pressure at the throat if it is choke now at the condition of the choke that m a is equal to one. So, let us find out what is the critical pressure p 0 by p star; that means, that if we put m a is equal to 1, this will be gamma plus 1 by 2 whole to the power gamma by gamma minus 1.

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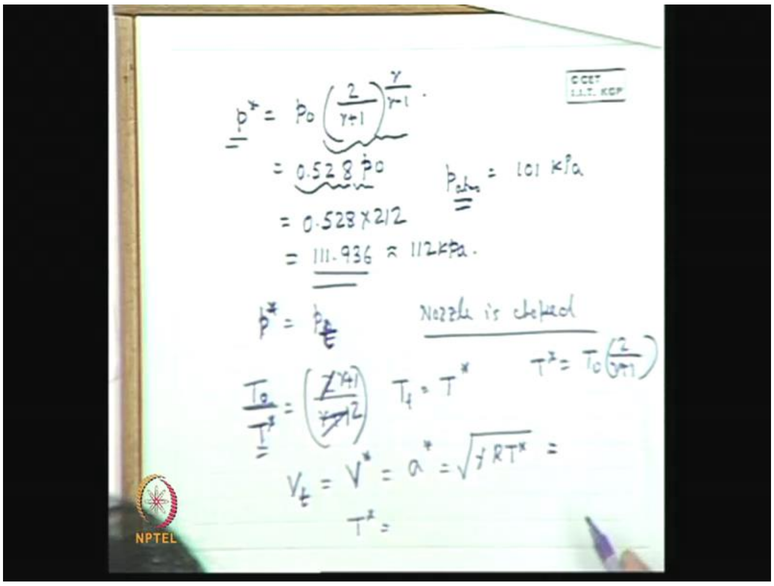

Which means that we can write this thing p star is equal to p 0 2 by gamma plus 1 by gamma by gamma minus 1, and this quantity with k gamma is equal to 1 point four is point five 2 eight this quantity is point five 2 eight of p 0 with gamma is 1 point four.

So, if you perform the calculation we will see that p star is more than that; that means, p is point five 2 eight now p zero. So, therefore, we see that p 0 if you consider p 0 is atmospheric pressure . So, therefore, we see that p star is sorry p 0 we have found out already 1 what is p 0 hundred, and twelve what is value.

212.

112. So, what is the value of p star.

111.93

111.

0.93.

So, therefore, automatically this is more than the atmospheric pressure p atmospheric is hundred 1 kilo pascal’s. So, therefore, nozzle is choked so; that means, the condition at the downstream will correspond to the choking condition. So, therefore, p star will be the p exit. So, if I denote the throat as t here we have denoted t. So, p exit or the p throat. So, throat condition means the exit condition will be p star here the nozzle is choked the nozzle is choked now when the nozzle is choked straightforward I can write t 0 by t star is what is that 2 by gamma plus one; that means, substituting the value of t 0 we can find out the value of t star, and the value of v at the; that means, t throat is equal to t star.

So, value of the throat is equal to v star which is equal to star which is equal to gamma r t star. So, this value becomes equal to well hundred eleven point nine three six this is hundred twelve kilo pascal's. So, only this problem refers to the pressure at the throat, but you can find out what is the value I have calculated see you can calculate from it the value of the velocity at the throat it will be simply gamma r type size star what is the value of t star what is the value of t star.

Two by gamma plus one.

Two by gamma plus 1 oh sorry it is sorry it is other way gamma plus 1 by 2 when you make t star it will be t 0 into 2 by gamma plus 1 I am sorry it will be gamma plus 1 have you calculated this if you calculate, then you will get the value. So, t star. So, therefore, in this case the most important part is that you have to first check whether the nozzle is choked or not; that means, will have to find out the stagnation conditions stagnation pressure stagnation temperature stagnation density; that means, usually the back pressure is given whether the back pressure is lower or more as high more or greater than the critical pressure that is p star corresponding to the stagnation pressure; that means, we can use this formula.

So, if we see the back pressure is lower than the critical pressure; that means, the nozzle will be unable to expand up to the back pressure it will choke; that means, the finally, it will expand up to the critical condition critical pressure, but if we see this critical pressure is lower than the back pressure, then the nozzle will be able to expand up to the back pressure; that means, it is simply expansion up to the back pressure continuous expansion up to the back pressure will be the pressure at the throat.

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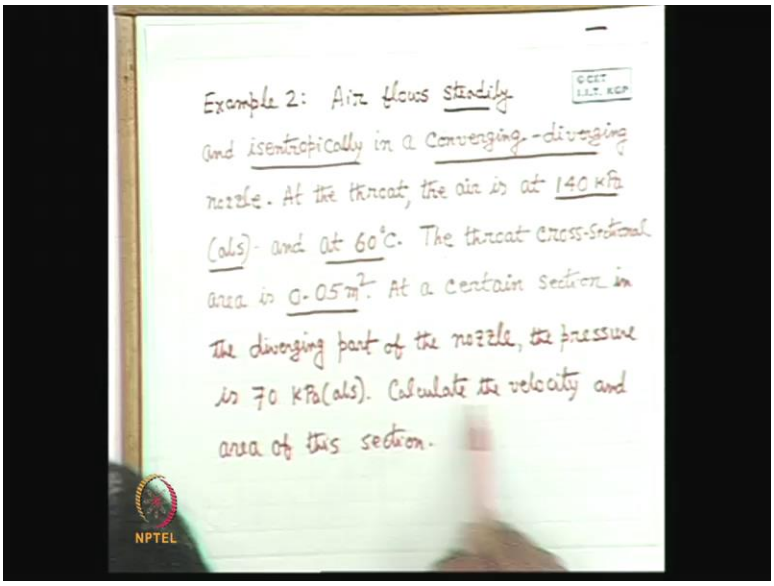

Now, next problem you please write another problem air flows another simple problems steadily you wrote this problem air flows steadily. And isentropically in a converging diverging nozzle at the throat the air is at 1 forty kilo pascal's the throat condition is given absolute; that means, this is pressure in absolute, and at sixty degree celsius well at the throat the air flows steadily, and isentropically in a converging diverging nozzle this a converging diverging nozzle at the throat the air is at 1 forty kilo pascal's, and at sixty degree celsius the throat cross sectional area is point 0 five meter square at a certain section in the diverging part in the diverging part a certain section in the diverging part of the nozzle of the nozzle of the nozzle well.

The pressure is seventy the pressure is seventy kilo pascal's absolute all pressures are in absolute calculate the velocity simple problem calculate the velocity calculate the velocity, and area of this section, and area of this section now I repeat this problem again air flows steadily, and isentropically a steday, and isentropic flow in a converging diverging nozzle here is the nozzle is a converging diverging nozzle at the throat air is at 1 forty kilo pascal's absolute, and at sixty degree celsius the throat cross sectional area is 0 point 0 five meter square at a certain section in the diverging part of the nozzle the pressure is seventy kilo pascal's absolute calculate the velocity, and area of this section.

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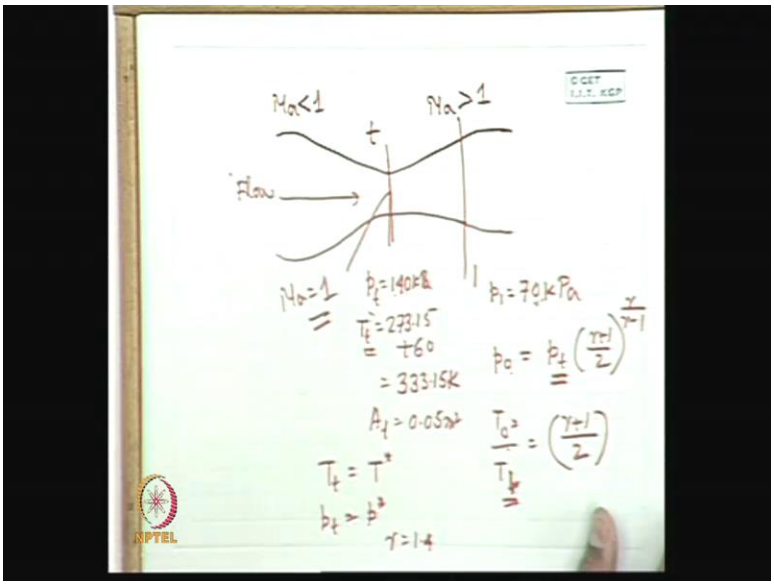

Now, the tips for this type of problem is like this when you have a v converging diverging nozzle now you may have 2 situations flow in this direction 1 is the venturi another is a nozzle though it is told a converging diverging nozzle whether I should converging diverging duct I will make it flows through a converging diverging, because the nozzle were me confusing. So, if tell a converging diverging duct. So, then you can take it both as a nozzle or a diffuser. So, what is the check. Now let us consider this is a throat an some section in the diverging duct portion is 1 now throat conditions are giving p t is equal to 1 fourty kilo pascal’s.

So, t t is equal to sixty degree celsius; that means, 273.15 plus 60; that means, three thirty point 1 five k, and area is given a t is 0.05 meters square now since p 1 is given as seventy kilo pascal’s. So, is it a venturi flow or a nozzle flow converging diverging nozzle.

Nozzle flow.

Nozzle flow yes that first you will have to understand, because in the divergent part the pressure is decreased; that means, until, and unless the flow is supersonic, and increase in area cannot be decrease the pressure which means that this part the mach number is greater than one; that means, it is a converging diverging nozzle which means that this part the mach number less than 1, and nozzle is the condition where mach number is one. So, therefore, we are identify these as a converging diverging duct. Since there is an expansion or a decreasing pressure in the divergent part of the duct this is the only tips or the track of the problem. So, therefore, we can find out the respective p 0 t 0 we can find out the respective p 0 respective t 0 what is t 0 t 0 is equal to t zero.

If you t 0 by t t t t is the t star t t is the t star that is t 0 by t star is gamma plus 1 by 2 similarly p 0 is p t into gamma plus 1 by 2 to the power. So, taking the value of gamma is equal to 1 point four, and p star p t t t is the p star t star, because p t is p star, because throat corresponds to the sonic condition for a converging diverging nozzle. So, therefore, if we know the t t, and p t we can find out the corresponding stagnation properties for that flow that is p 0, and t zero. So, this p 0, and t 0 values comes like this p 0 is.

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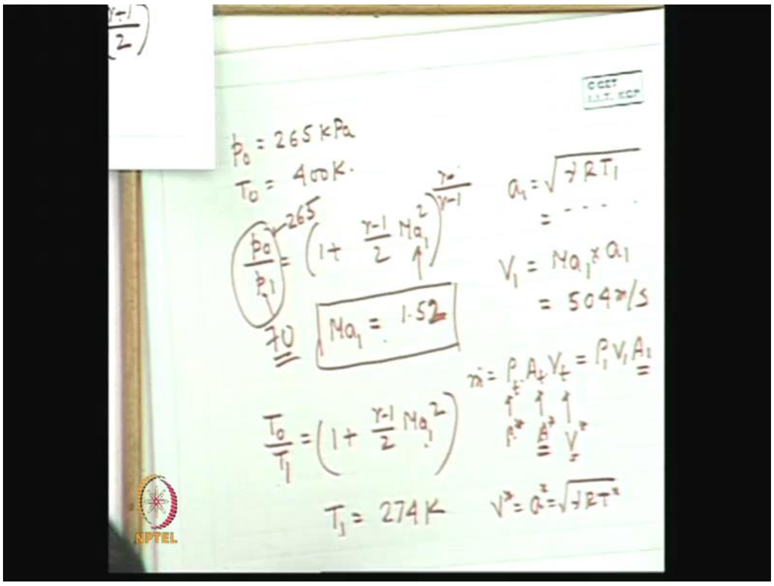

If you calculate p 0 comes out to be 2 sixty five kilo pascal’s, and t 0 comes out to be four hundred k well now what we will find out now since you find out the we have to find out what calculate the velocity, and area of this section to have to find out the velocity at that section first of all will have to find out the mach number at this section if we know the mach number at the section, and other properties like p 1 t 1 we can calculate the velocity. So, to calculate the velocity will have to know mach number; that means, m a 1 how to know the mach number we know p 0 we know p one. So, therefore, we relate this p 0 by p 1 this we use this equation. So, only you will have to see the which equations will be easy m a one. So, gamma by sorry gamma by gamma minus one; that means, we know this value p 0 is 2 sixty five p 0 is 2 sixty five, and p 1 is given in the problem as seventy.

And this mach number is found, and we see that this mach number correspond to a value which is more than one; obviously, and it is 1.52 this is by calculations all of you understand we find out mach number when you find out the mach number what we can find first of all we can find out the t well we can find out similarly the t t 0 by t 1 now when we know the mach number we can find out. So, we first find out the mach number by equating this p 0 by p 1 we are giving value giving the value of p 1 not the value of t one. So, once we find out mach number. So, put these mach number, and get the value of t 1 the temperature at that section which comes to be 2 seventy four kilo.

Now, everything is know if I know t 1 I know a 1 as root over gamma r t one. So, the value of a that section becomes well the value of a is not worked in this problem. So, a becomes root over gamma r t 1, and we can find out v 1 as mach number that is 1 point five 2 times the a 1, and that values becomes equal to five 0 four meter per second now to find the area of cross section velocity, and area of cross section now area of cross section here to be found out by equating the mass flow rate under steady condition. So, if write the continuity equation that is the mass flow rate under steady condition at throat.

And at this section, then we can write that m dot is equal to density at the throat into area at the throat into the velocity is equal to density rho 1 v 1 a one. So, what is to be find out a one. So, see that whether everything is known rho throat is rho star that we can find out a throat is a star, and v throat is v star. So, a star is given in the problem point 0 five meter square v star is what v star is same.

A star.

A star is root over gamma r t star. So, we know this thing. So, v star we know. So, a star is given in the problem, and rho star we can find out similarly from this type of relationship; that means, I write it that is rho 0 by rho star is equal to 1 plus gamma minus 1 by 2 into 1 by gamma minus 1, you cannot see rho 0 by rho star; that means, we can find out the rho star all right; that means, the quantities that is density area, and velocity required in determining the mass flow rate at the throat we can find out the same mass flow rate. If we equate with the quantities at the desire section at the steady state rho 1 v 1 even.

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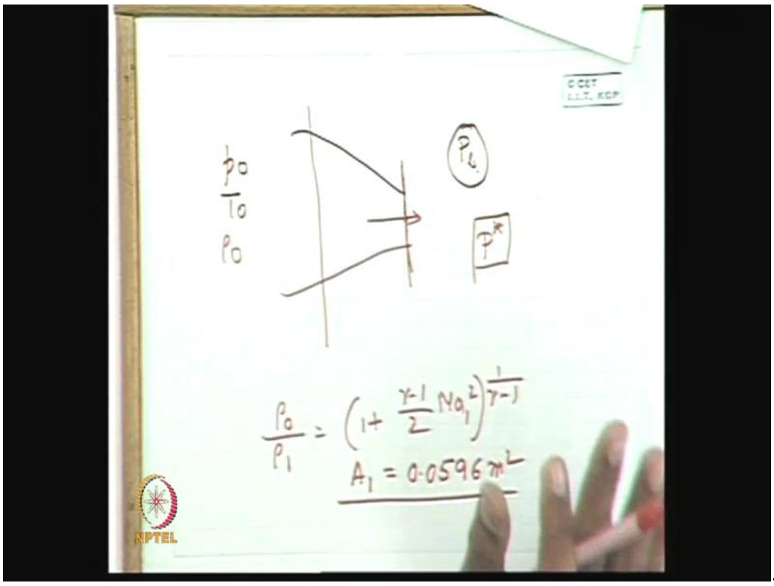

So, v 1 we know rho 1 we can find out by using the same equations same type of equation which connects rho 0 by rho 1 with the mach number; that means, its it will be this raise to the power 1 by gamma minus 1 rho 0 by rho one; that means, rho 0 by rho 1 for any local property will be gamma minus one; that means, once we know the mach number at any section we know the relationship of the flow properties like density temperature, and pressure with this stagnation properties through this relationship for isentropic flow. So, we know rho 1 v 1 is already known. So, we can find out a 1 the cross sectional area well.

So, this cross sectional area after calculation comes to be well the cross sectional area after calculation comes to be 0 point a 1 comes to be here I write a 1 can you see yes comes to be 0 point you can check your calculation nine six meter square. So, this 2 equation 2 problems sorry 2 problems highlight the basic understanding of the compressible flow, and the straightforward application of the formulae. So, what happens is that when these relates to a problem of convergen nozzle relates to a problem of convergen nozzle you first try to find out this stagnation conditions from the conditions given.

If stagnation condition the straightforward giving that is all right otherwise you find this stagnation properties, and check whether the back pressure which is usually given for a problem is lower or greater than these critical pressure; that means, you find out the critical pressure that is when the sonic condition is reached compare that with the back pressure, and determine whether the nozzle is choked or not, and accordingly solve the problem similarly when the problem will be flows tactfully a through a convergent divergent duct do not hurriedly consider this ducts as a nozzle or continuously a diffuser.

So, it will act continuously, and nozzle at diffuser when part is subsonic the part is supersonic; that means, a supersonic flow will be diffused in this part, and again a sonic subsonic flow will be this will acting as a continuous diffuser or a continuous nozzle. So, in that case the conditions will be accordingly given, but it can act as a venturi meter. So, that you first decide that whether it is nozzle or a diffuser or a nozzle, and diffuser makes through the flow is subsonic, and accordingly you find for example.

If it acts as a nozzle continuously; that means, this is the sonic condition this part is subsonic this part is supersonic, if you find that this acting as a continuous diffuser, then also this is a sonic in that case it is supersonic, and it is subsonic. So, first you decide that from the data given, and accordingly you solve the problem.

Thank you.