Introduction to Explosions and Explosion Safety
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Lecture - 8
Blast Waves: Overpressure in the Near and Far Field, Examples, Introduction to Impulse

Good Morning, you will recall that so far, what we have done is to determine, when some energy is deposited at some particular point.

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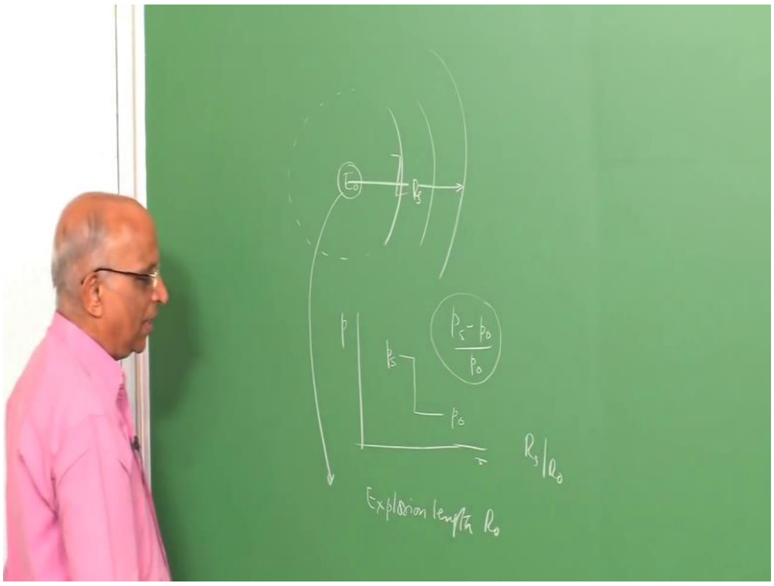

Let us say E 0 joules, what is the magnitude of the over pressure, which is form in blast wave, which is generated by this particular energy release. Therefore, what do we do, we said well a blast wave gets generated, it keeps travelling. And considered this the particular case of a spherical wave issuing from some energy release over here. We said, well the ambient pressure could be row 0.

Let us make a plot over here. The ambient pressure could be, let us say P 0. The pressure over here verses the distance, it travels from the center. The ambient pressure is P 0 and supposing the blast wave comes here, there is arise in pressure. They rise in pressure is P S. And the over pressure or the excess pressure, behind the wave to the ambient pressure is P S minus P 0, and that we non-dimension rise with the respect to the P 0. And this we called as the non-dimensional over pressure.

We determine this value as a function distance. And how did we do that, see mind you. When, some energy gets released, some blast wave gets generated. If more energy gets released well, the same strength of the blast wave is formed at a larger distance. Therefore, we scaled the energy release, in terms of the explosion length. Namely a characteristic length R 0. And we express the distance R S, may be over here. The blast wave, let us say comes an over a distance R S, we non-dimension is R S. In terms of R S divided by R 0. That means, we have the skill distance we called as shocks scaling.

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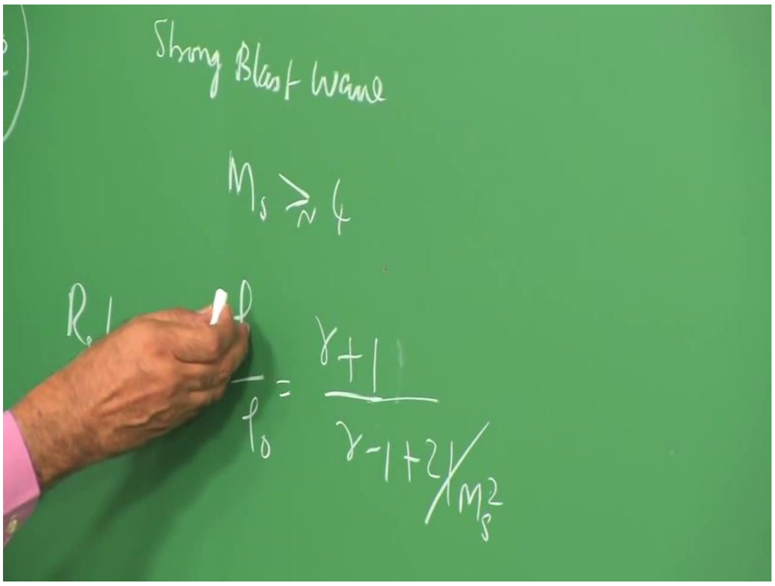

And we were able to determine, what did we determine, we said as R S by R 0 increases. We have P S minus P 0 divided by P 0, which keeps following down, which rapidly changes. Well, we did this for a strong blast or a strong blast wave, what do we mean by a strong blast wave. In the field, near to this, that means in the region very near to the source. Wherein, the much number of the shock wave, which is from is quiet large, may be typically greater than around 4.

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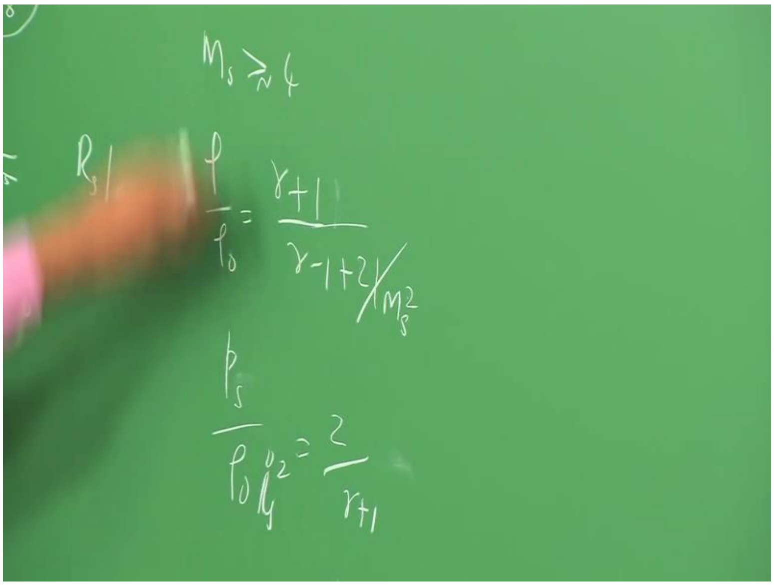

Because when it was greater than around 4. What happen? We had expressions like we had, the density behind the blast wave or behind the shock wave. Divided by row 0, was given by gamma plus 1 divided gamma minus 1. Because, the term like we had in the denominator over here, 2 over M S square. Since, M S is a last number, this can tended to get cancel and we got the density.

Similarly, we had P 0 or the pressure behind the blast wave order. Let us say, the P S divide by row 0 into R S dot square was equal to 2 over gamma plus 1. And the term, which had gamma minus 1, gamma plus 1 into gamma into 1 over M S square, got deleted, got diminish, because it is quiet as small number. Therefore, it was given by this and similarly u over R S dot was reverse of this.

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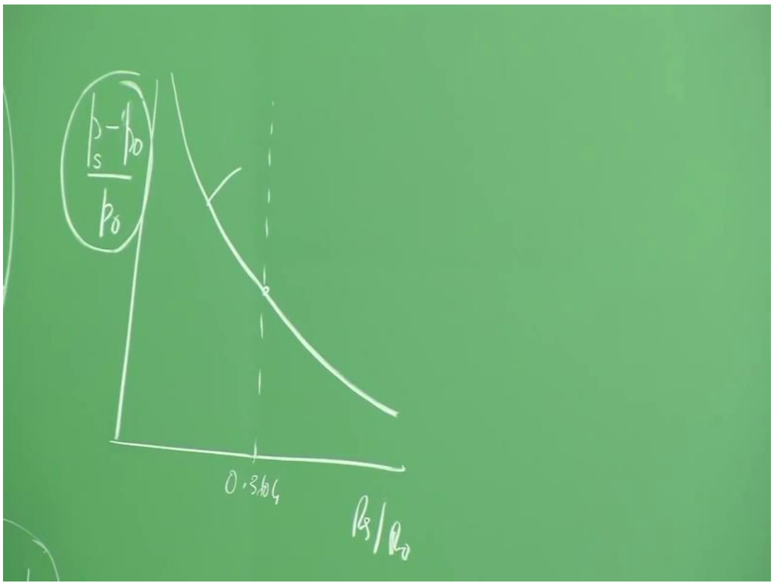

Therefore, they were independent of the mark number and thing independent of the mark number. We were able to say at distances close to the source, around let us say R S by R naught between, let us say 0.3 to 0.4. For which, we evaluated the Mach number, we said well I can calculate the value P. That is the over pressure, that is the pressure behind the blast to the ambient minus the ambient pressure, divided by this. And this is what we called as the dimensional the over pressure.

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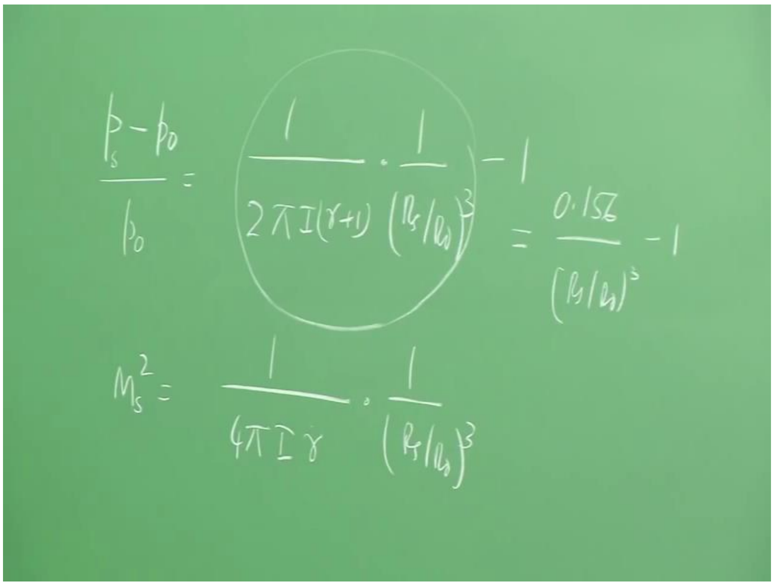

Let us write the expression what we got, we got P minus P naught. That means, the pressure, behind the way. Let us denoted by P S or simply P minus P naught divided by P naught. We got it equal to 1 over 2 pie into the integral. That is the integral, we said that at the front. Well, these values do not change with Mach number. We said, well the slopes behind the are about the same.

The evaluated the integral, which we said was propositional to the energy deposited. Divided by the kinetic energy of the medium, provided it travels at the total as the shock velocity. We got this as 0.423 into gamma into, we had 1 over R S by R naught cube. And since, it is minus P S by P 0 minus 1, well this is minus 1 over here. Similarly, we had the expression for M S square. That is the Mach number of this particular blast wave, which propagate out as equal to, we had something like 4 pie into I into gamma into 1 over R S by R naught cube.

Here, it should have been gamma plus 1, here it is gamma and this is the way it decays out. Now, when we evaluated these values, we got for a value, this particular value came out to be something like 0.156. Because, pie is 3.142, I was 0.423, gamma was 1.4. This became a value something like, 0.156 divided by R S by R naught cube minus 1 over here.

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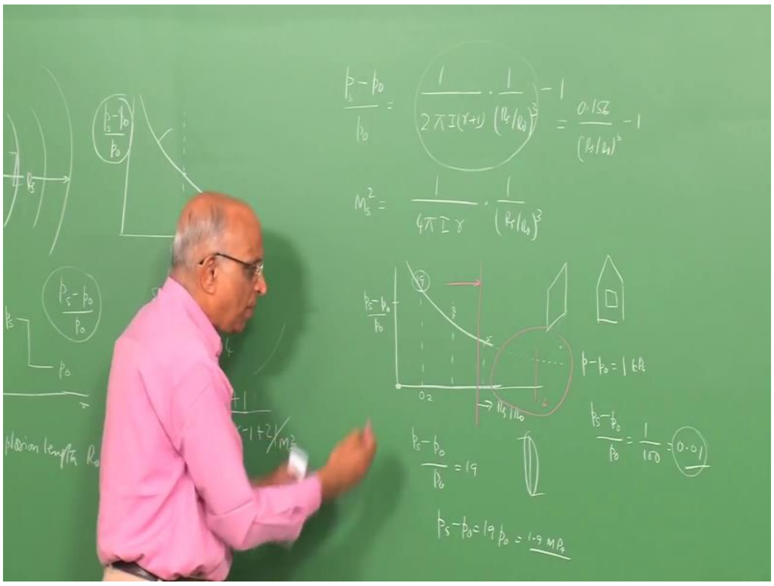

Now, when we got this over pressure, what did we find? Well, in the region, we let us say, that the blast wave starts here, it propagates out. We got the value of P S, that is the behind the shock front. We got the P S divided by P naught divided by P naught. We got for an R S over, let us say 0.2, this we say R S over R naught. For 0.2, we go it a value around 19, may be for 0.3 got a value around 5 or 6 or around 8 or so. For a value around 4, we got a value around 4 or 5; that means, it kept on decreasing.

And in these cases, we said well the Mach number in this case was still high. The Mach number in this case was very high. The Mach number in this case was around 5 or 6, no around 6, this was around 4.5. And therefore, we could get the value P S by P naught. Well, we could calculate these values. But, is it, we are talking of, we are talking of values, which are still high.

Let us calculate the value of pressure, behind the blast wave. Well, we have something like P S minus P naught, divided by P naught at this scale distance 0.2 equal to 19. Therefore, in the blast wave, what happens, from the ambient pressure, it jumps over here. Therefore, what is this magnitude, P S minus P naught, P S minus P naught is equal to 19 times the ambient pressure.

Well, the ambient pressure is 100 Kilo Pascal, 0.1 megapascal. And that is, that equal to something like, 1.9 megapascal. That is 19 times atmospheric pressure. That means, a very strong or a very high pressure ration is there across. Even, if we considered these values, it is quite high. But, in practice, what happens is, let us say, we have a glass in a building; that means, let us talk of this.

Well, we have, let say house, you have a window pane. The window pane, it is supposing a blast comes and hits the window pane. The window pane ruptures, when the pressure, that is the rise in pressure minus the ambient pressure is of the order of 1 Kilo Pascal itself, the glass paint ruptures. Therefore, we are talking of P S minus P naught; this is the shock pressure minus the ambient pressure.

We are talking of P S minus P naught is equal to 1. Ambient pressure, we said is 0.1 megapascal, 100 Kilo Pascal, that is divided by 100 is 0.01. Well, you know, we are talking of high value is, when we talking of these equations, which we derive. We are in practice, we are interested in numbers, which are quiet small over pressures, can do significant amount of damage.

And when I tried to extrapolate over this, when I tried to say, well I use the same formula and go forward. Well, I cannot solve for these conditions. Let us say, I am interested in solving. Let us say at R S over R naught of let us say point 6. If I say point 6 and calculate the Mach number, well the Mach number will come out to be even less than 1, which is just not possible, because the validity of the equations is only in the strong blast region.

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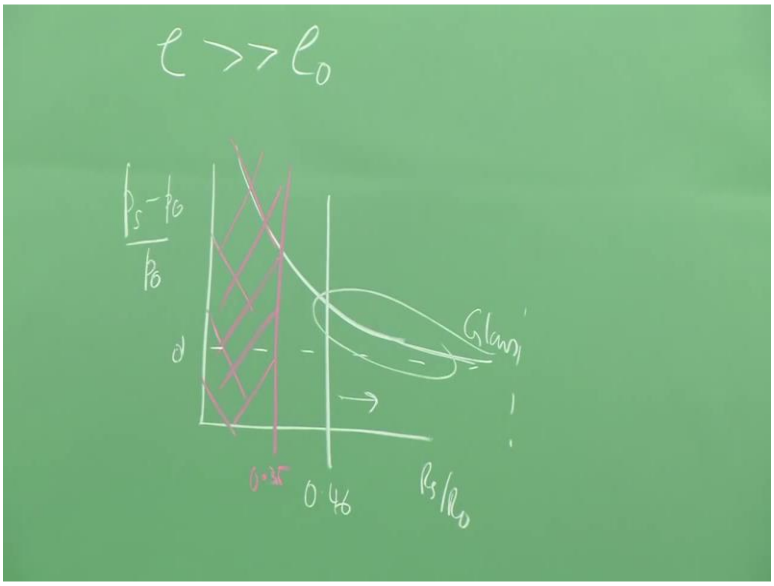

Why, was it in the strong blast region? We told yourself, well the assumptions were, well you are the energy, which is distributed by the blast wave from the explosion namely, e is very much greater than the ambient energy. And this is valid; that means, if we write, you will recall, again we had P S minus P naught divided by P naught into R S by R naught. Well, it kept falling, well the validity as per this is only 0.46.

But, if you look at the strong blast assumption, namely, M S greater than 0.4, it is only in the region between, let us say 0.35 over, so 35 to 0.4. That is 0.35 to 4. Therefore, only in this region, whatever we derive was useful. I cannot use it for week pressures, like am interested in the value of, may be a glass rupturing or window pain or a glass breaking, which the value is going to be 0.01, which very much in excess.

And we also told ourselves, I can ready use this formula, when the ambient energy is of the same order as the energy content or the internal energy contain within the blast way 0.1. And in these cases, the value of the shock from Mach number is low. What happens, let us go back to this particular equation, what I wrote over here, let us say P S by row naught dots square.

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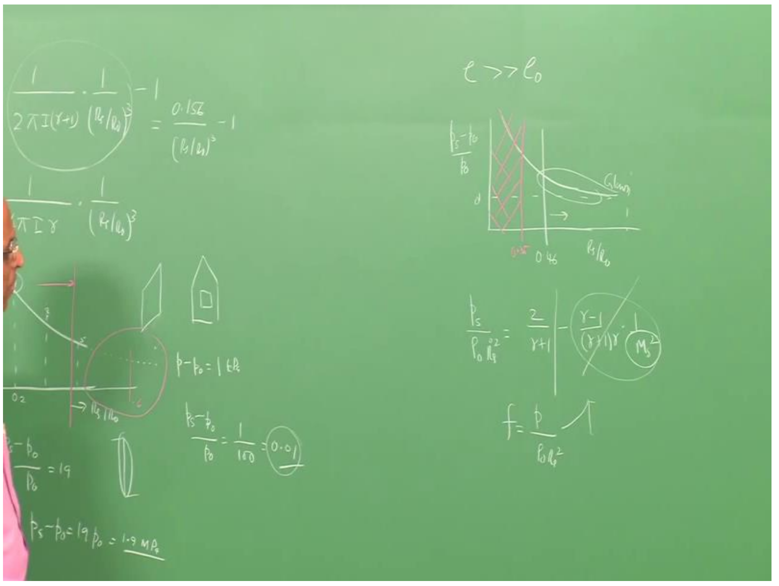

Let us just write it, if I write P S divided by row naught into R S dot square. Then, becomes 2 over gamma plus 1 minus, what is it we get, let us go back and see, what did, we get, gamma minus 1 divided by gamma plus 1 into gamma into 1 over M S square. If the at large scale distances, well M S has come down. Therefore, M S is small, this term dominates or this term also place a role.

And therefore, I will get the P S being affected by this. When, M S is very large, well this is negligible and it is just constant, whereas if M S is small, well this also begins play a role. And therefore, I cannot use the scaling law for which we assume that P S by row naught R S square is equal to this. And we said well, irrespective of Mach number, I get the value of F, which was equal to P at any distance away from the wave, divide by row naught into R S dot square was given in terms of R by R S. We had this particular curve. And therefore, it becomes essential to take care of the M S values. Similarly, I can argue in terms of row by R naught, but stopping over here and proceeding.

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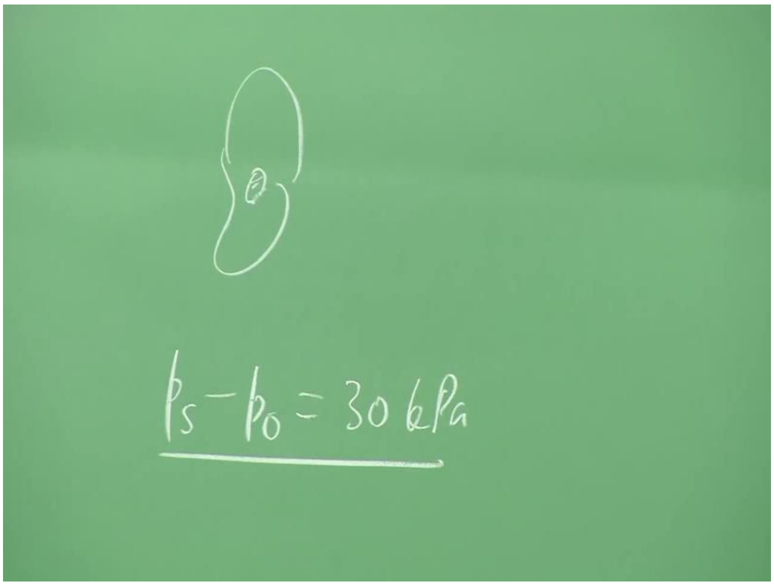

We tell ourselves well, not only in the case of thing, let us take an example. When, let us say standing near and explosion and let us say, my ear sort of is, I hear strong shock wave. My ear drum gets ruptured, when the value P S minus P naught is of the order of 30 k p a. I will look at this problem a little later, because am just looking at the total pressure, which ruptures the ear, will let us say, it is still 30 k p a. But, we will take a look at reflected pressures, after a class or 2.

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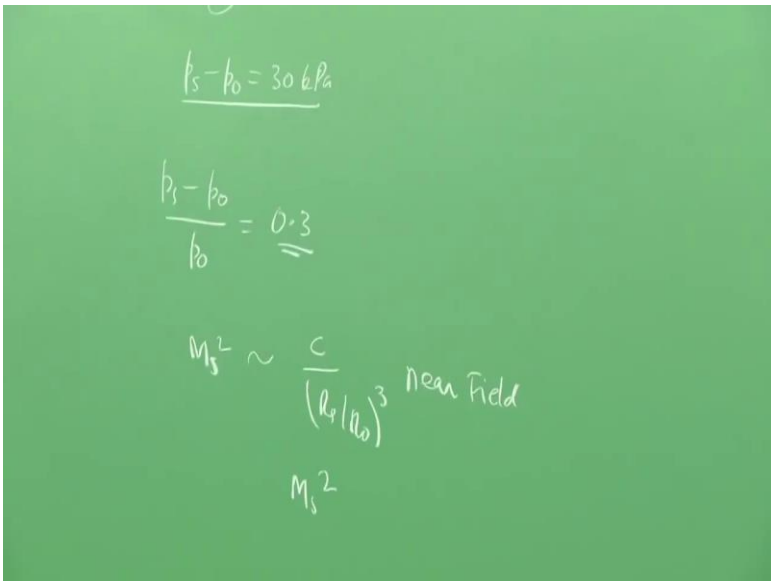

And you know, if we look at this particular value, I am talking of P S minus P naught, divide by P naught, ambient pressure is 100 Kilo Pascal, this becomes 0.3. Even, in the case of may be our ear drum getting ruptured, due to a blast wave, I am talking of much lower value. And therefore, it becomes necessary, that I evaluate e property, far from the sight of the explosion.

That means, in the near field, I have been able to derive this expression. But, I need to get the values in the far filed also. In the far field, the value of R S by R naught, will increase. And therefore, these values, the both the over pressure, dimensionless over pressure and the Mach number will come down. Therefore, how do I do it, I have to take into account the value of M S square.

But, let us go back and take a look at, what is the expression, I had for the Mach number. We had M S square is equal to 1 over for pie I gamma into R S. This overall constants phi gamma is 1.4, I, we said 0.423. I can write M S square is equal to a constant, divided by R S by R naught Q. In the near field, wherein, I have a strong blast, that means, the value of the Mach number is high.

But, in the far field, what is going to happen, M S square is going start affecting my blast. And therefore, people have been working at it; the problem becomes much more complicated. And what you do, you do either a numerical solution or you do, you can weekly bring this in. Now, how do I do this, let us say I write eta is equal to 1 over M S square. When, M S is a very large number, eta becomes the small number. And therefore, what I write is, I write R S, from this I can write, R S by R naught Q.

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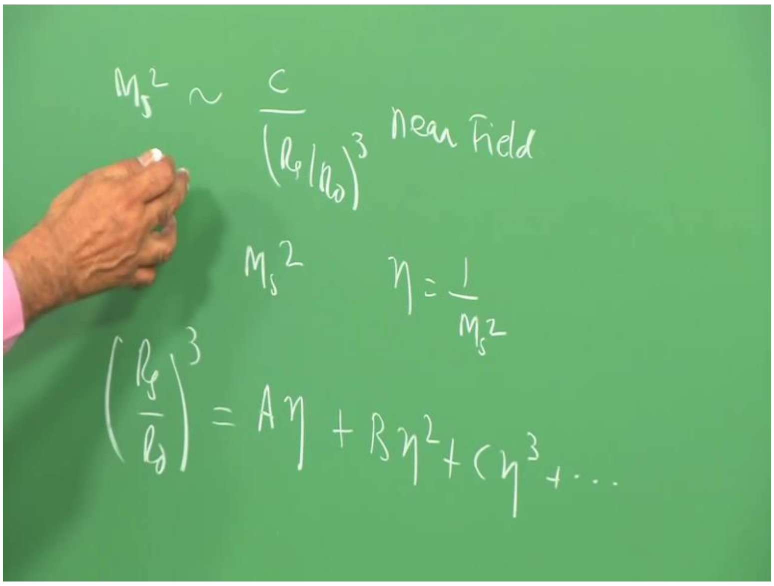

For a strong blast, I can write it as equal to, let us say an eta. That means, I just write R S by is equal to C by M S square, when the value of the Mach number begins to play a role. Well, the values are not that small over here. I can write it as B eta square plus C eta cube. May be, I have a series expansion in terms of M S square. And such type of analysis has been done, taking into account, the value of the rise in pressure, as a function of Mach number. Rise in density, as a function of Mach number at the blast. wave front.

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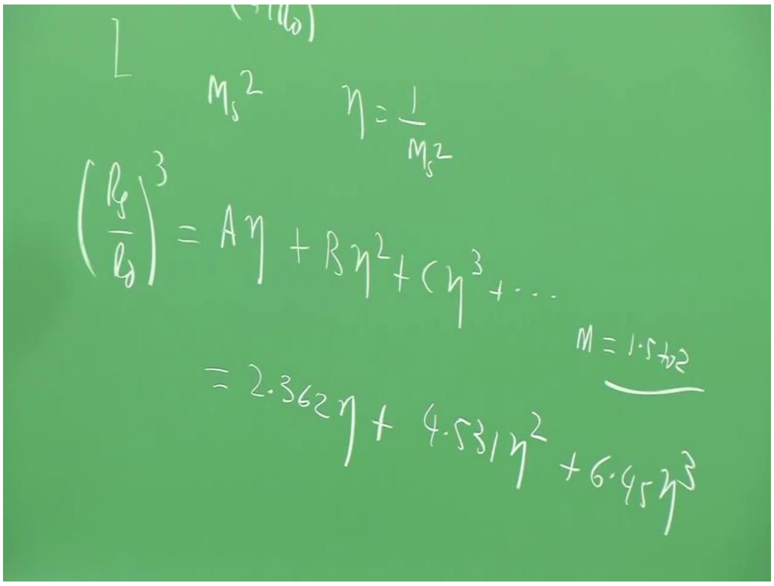

And when this is done, the expression, which was got was something like, let me put that down. It was equal to R S by R naught cube is equal to, we had 2.362 eta plus 4.531 into eta square plus 6.45 into eta cube. This was done by professor by Professor Mark C. lee at Meghalaya University. And you could have something like the dependence of the scale distance as a function of Mach number.

Typically, for Mach number as slow as, let us say 1.522. It is sort of matched well, and therefore, it such a syntactic series could be used. What I do is, I want to find out the value of M S square at the value of the R S by R naught. I can solve this equation at given value of R S by R naught.

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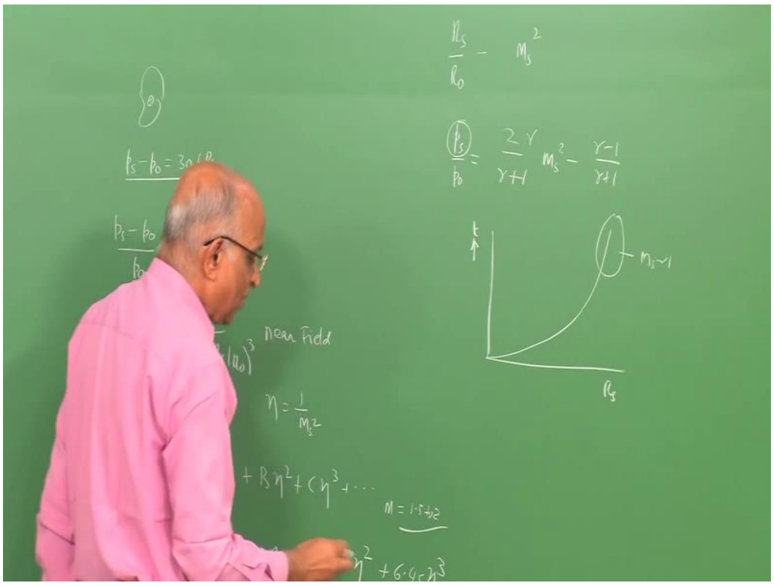

And I can calculate for a given value of R S by R naught; I can calculate the value of M S square. And once, M S square is known, I can calculate the value of P S by P naught is equal to. I use this particular expression again, which we derive for constant shock strength. Namely, I had just written the value, some were over here, S, P S by row naught R S dot square is equal to 2 over gamma plus 1 minus gamma minus 1, divided gamma plus 1 gamma into 1 over M S square.

Since, M S square is somewhat, now quiet small this fact a plays a role. And therefore, I can convert this into P naught as equal to 2 over gamma plus 1. And since, I have to put in terms of P naught. Well, I have the gamma and coming over here, 2 gamma M S square minus, I get the value of minus gamma minus 1 divided by gamma plus 1. Therefore, for a particular value of R S by R naught, using this asymptotic type of series.

I can calculate the value of M S square and using M S square, I can calculate this value and get the extension of my curve, from a point summer over here, till the Mach number, till much larger value of a R S by R naught. Well, we must also remember, that when we doing this scaling, we were also talking in terms of, let us say this is the tie maxes. This is the distance from the point of explosion R S. We said, well initially it is a strong blast. That means, Mach number is high in the near field.

Then, as we procedure it becomes it weakens, ultimately it becomes an acoustic wave. In the limit at which it becomes acoustic wave; that means, we are talking of the Mach number around 1. We use the acoustic theory and using the acoustic theory, I can again calculate the value of P S by P naught. And therefore, get the value of P S minus P naught by P naught. And one such acoustic theory, which we will not develop here, but we will just presume is, what is given as P S minus m P naught divided by P naught.

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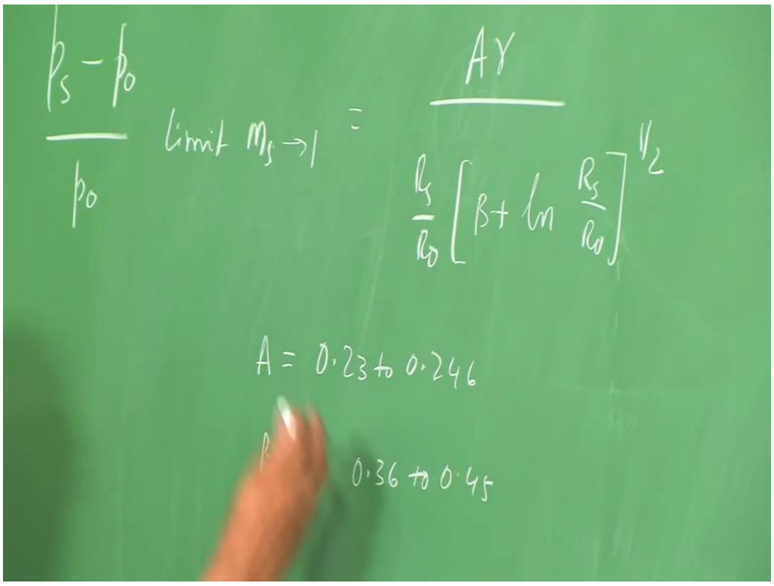

Let us write it off, in the limit, that the blast wave is a approaching the value around 1 is given as, A gamma divided by R S by R naught into B plus, l have l n, R S by R naught to the power half. Where, the value of A is typically around 0.23 to 0.246, while, the value of B is equal to 0.36 to 0.456. That means, in the far field, were in the blast wave decades when acoustic wave, well the over pressure is derive from the acoustic theory.

And now putting the far field and the near field together; that means, I have R by R naught. That is the distance R S by R naught. The value of P S minus P naught divided by P naught. What is it we say, well the in the near field, we derive the expressions, as we move away the Mach number affects begin to go and the shock further d k over here.

And in the very distant field, wherein you have the wave becoming almost an acoustic wave, well it is like this. And we get the composite over the entire thing, this is the near field, this is field, wherein M S effects begin to. Begin to shape of the effect of an internal energy of the free medium, begins to shape of and this is where, you have the acoustic effect. Therefore, this is for write up to 1.01, 1.02, I can predict using such equations. And all these, were put together by Professor Stiller and the type of figure, which we got was something similar to, what I show in the slide, which is shown here.

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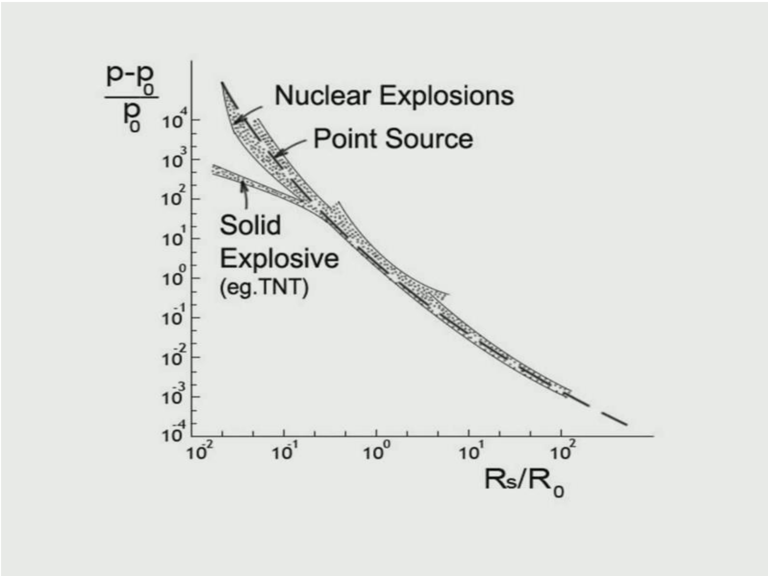

What is it, we see, well you calculate and this is shown by the dotted line over here. And what is it, we see, this is the strong blast region. Initially, I am just going to take a look at the doted, at the dash line over here. We say in strong blast region, I have this particular curve coming over here. And maybe, this is followed by this effect of the Mach number d k in the energy release, and then subsequently being followed by the acoustic over here.

This is a type of figure, which are normally available. But, you know in this figure, I also show some experimental points. I show well nuclear explosion, if they take place they seen to tally quiet well, with what we have being doing so far. And now, I need to qualify this and how do I qualify this. Let me get back to the board and see whether we can understand this in some better way.

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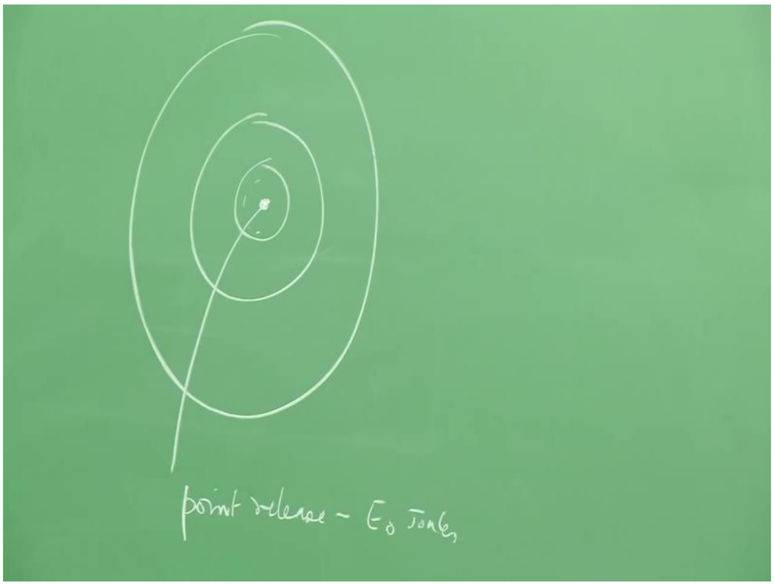

All what I tell now is, well I have been able to get this figure, which I say is for an explosion and what did we consider. We considered, when some energy is release that a point, let us say or energy is release, we told ourselves well as spherical wave propagate and spherical blast wave propagates out. We did not really consider the dimensions of this particular point, at which the energy is gets liberated.

In other words, we never made a mention. Well, the volume at which the energy gets liberated is so many cubic's centimeters or cubic meters and so on. We just assume that a wave gets, that means, we are not even giving any credits to the volume. We just said well could be a point release. At this particular point, we are releasing energy E 0 joules.

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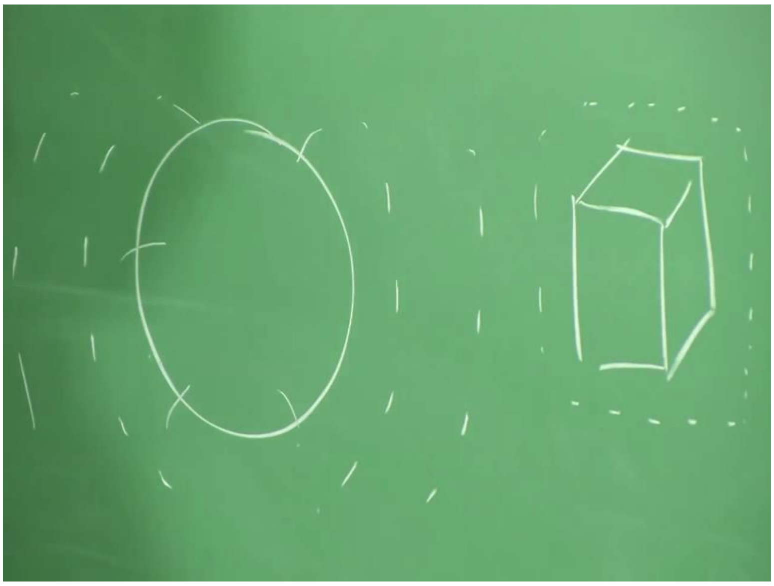

But, in practice, we all know, well if I have something like as sphere of a given volume. I keep on pressurizing at this as a particular volume and a keep on pressurizing at very high pressure. Well, the case bust and I have an explosion taking place, a blast wave propagate so... You know, this could be like this, it could be a cylinder curve, it could be a square or it could be a vessel, which is rectangular, which I pressurize. And therefore, in this case, I gets sphere, in this case, in the neighborhood, I will get something in the near field, which is a representative of this. It could be plainer waves, which are getting generated.

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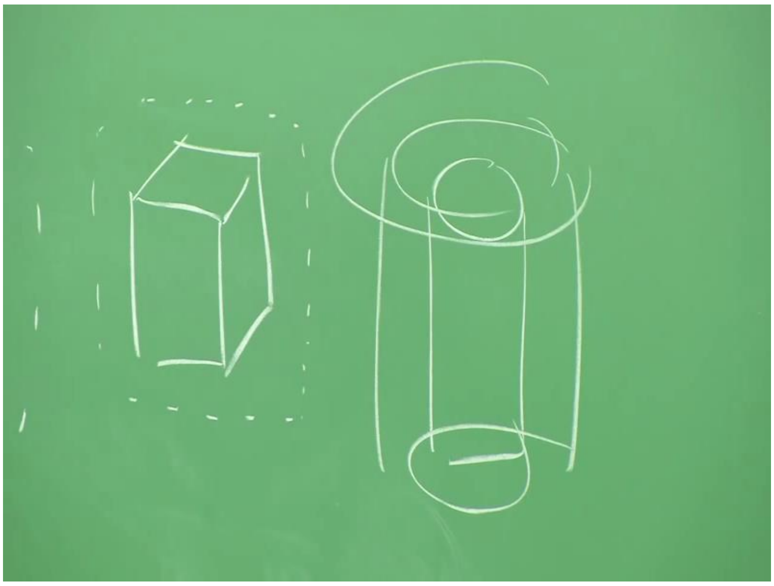

If I consider, may be a cylindrical vessel. Well, I could also get waves, which are cylindrical and it just moves forward from this as a cylindrical geometry. We did talk about some of these things earlier.

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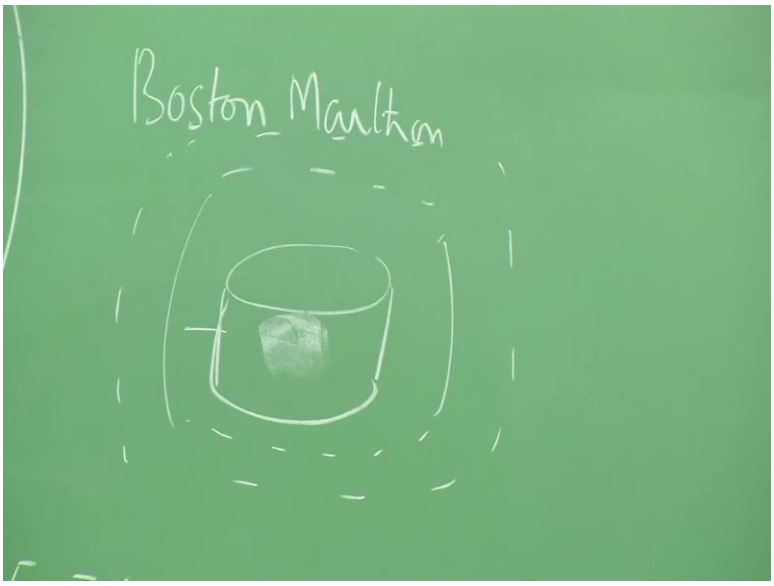

Why, we talked in terms of the explosion at the Boston marathon, earlier this year. What was there, in that, what happen there was, this particular pressure cooker. In the pressure cooker, some energetic material was kept over here and it exploded. And therefore, you had a given volume, and therefore we explosion would the blast wave in the near field would be something similar to this. And later on, we may, we must see, what is the shape of the thing. But, the point I am trying to make is, well I have a finite volume.

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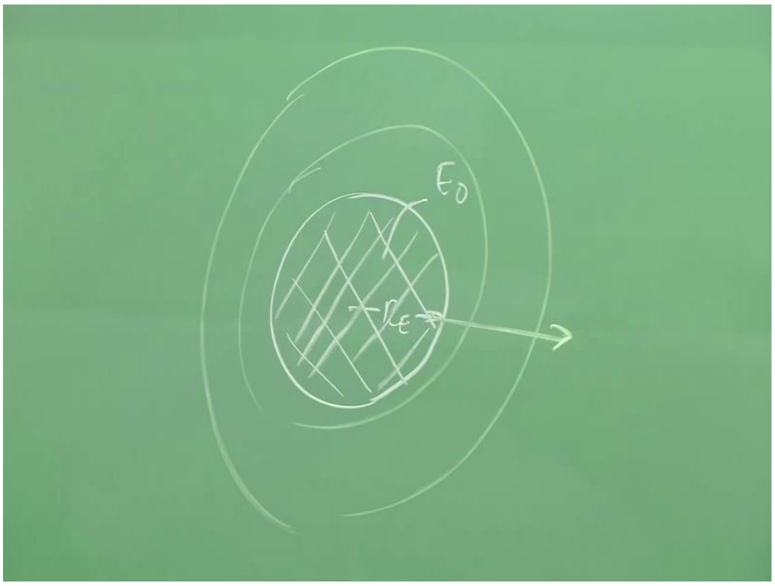

In the finite volume, if an energy is released, what is the effect on the value of the over pressure. And for that, we tried to again tell ourselves, well simplify the problem. We tell ourselves; well I am interested in say, a spherical volume as sphere. Let us say, that radius of the fear is R E. And the energy is gets liberated in this particular volume. This is where, now I say the energy is getting liberated.

And the energy at this volume now ruptures and I have something like a spherical blast wave, which moves of from this volume. It moves of over here. And how do I know model this and now I have a finite volume. Can I say something about in the near field, far field, how the explosion will be here.

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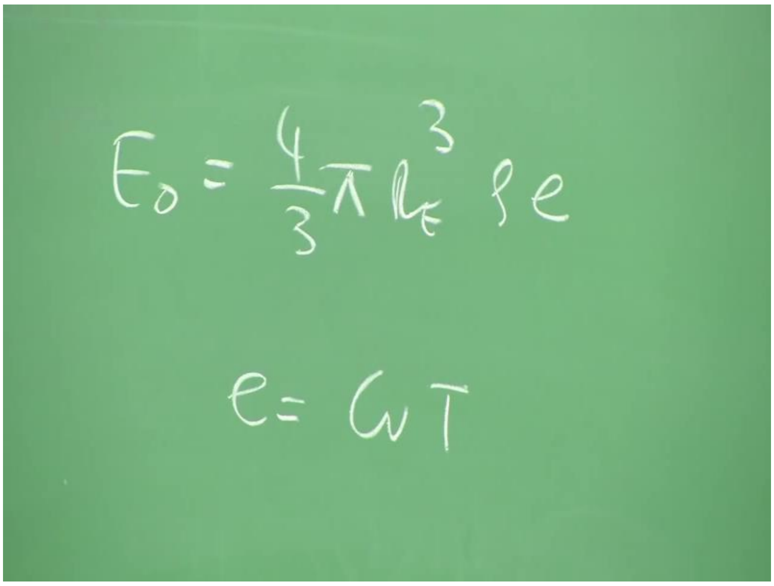

Therefore, let us again put it down, we say well the energy is released 0 joules is liberated in the volume. What is a volume, I say as sphere of radius R E. Therefore, I have 4 upon 3 pi into R E cube is a volume. Well, how do I liberated, maybe I put some it increases in pressure and temperature. And therefore, when the internal energy per unit mass is let say, E it explodes.

Therefore, I am saying, well the density at the point of explosion is a row. At that point the energy is the e over here. And can I now write some equation for this. We know, e energy is equal to we say per unit mass is equal to, it is a constant volume. You have C V into T is the energy per unit mass over here. Well, we already know that, C V can be written in terms of gamma and specific gas constant.

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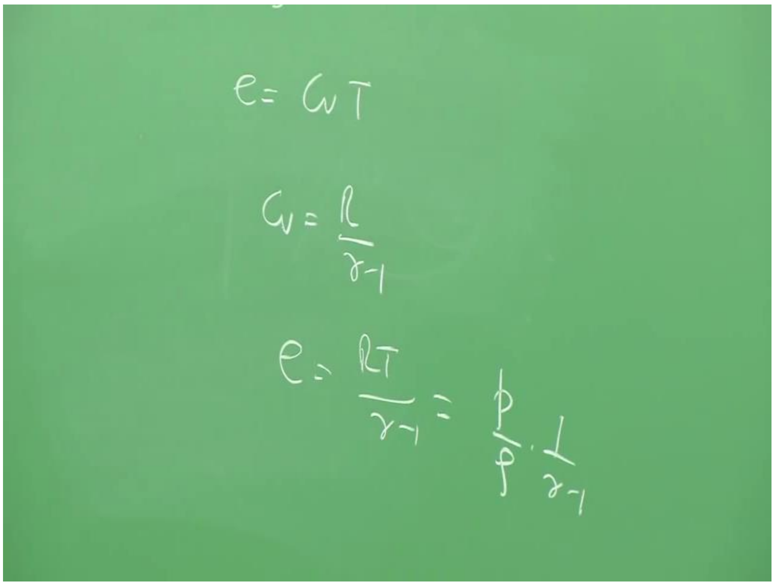

That is C V is equal to R over gamma minus 1. Therefore, I can write the energy per unit mass of the thing, which bust over here is equal to R into the temperature, which it busts into gamma minus 1. P V is equal to M R T or P by row is equal to R T. This becomes P by row into 1 over gamma minus 1. We are being doing this, such type of calculations are earlier.

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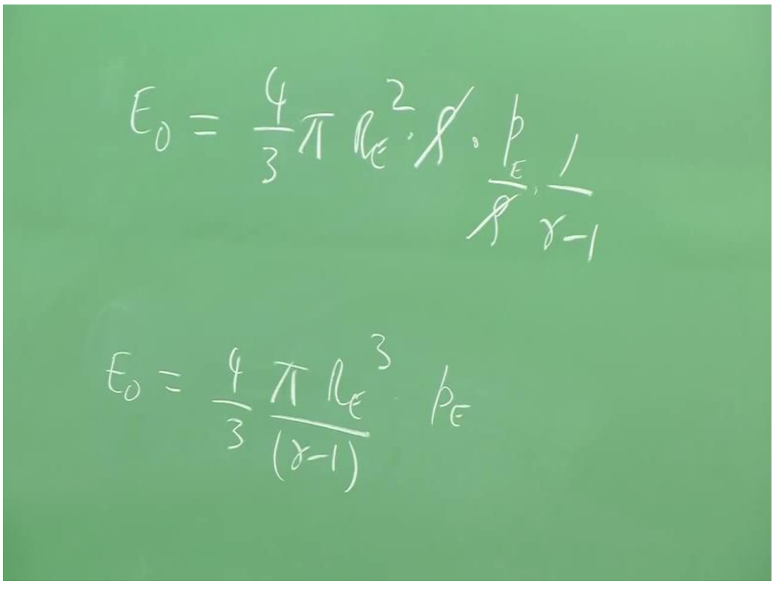

And therefore, if I write the value of the energy, which gets release, let us put that down. We get therefore, e not is equal to 4 upon 3 into pi into R E cube into grow into P by row into 1 over gamma minus 1, rather row. And row get cancel and this is the pressure of the explosion. Let me call it as P E to distinguish from the ambient pressure P naught. And therefore, I get the value of E 0 is equal to 4 upon 3 into pi R E cube into P divide by gamma minus 1.

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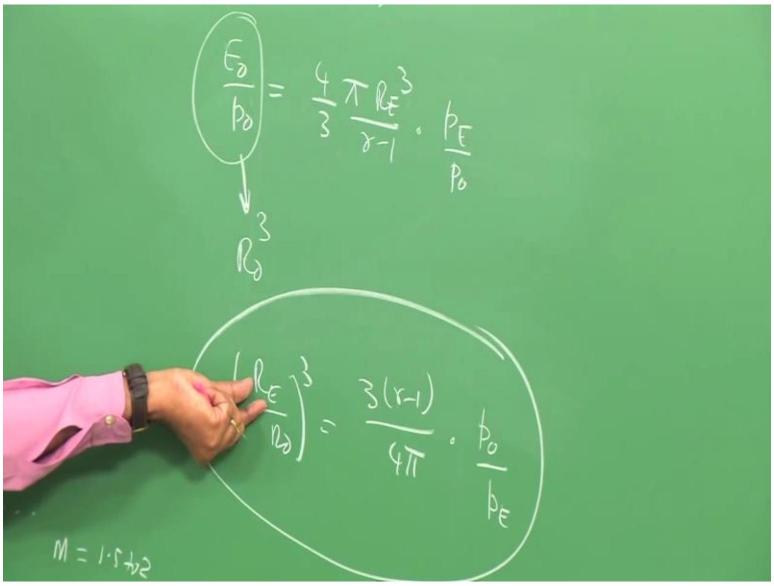

Let us divide both the size by the ambient pressure. And if I do that, I get E 0 by P 0 is equal to, I get 4 upon 3 pi into R E cube divide by gamma minus 1 into the value of P E by P naught. Or now, but we know that, E 0 by P 0 is what we called as the explosion length cube. We define E 0 by P 0 to the power 1 by 3 was equal to R naught. Therefore, this becomes your R naught cube. And therefore, what is it, I get the value of R E by R naught cube is equal to, I take this on this side and I bring the other terms on the left hand side.

I get 3 into gamma minus 1 divided by 4 pi into P naught divided by P E. In other words, we get and expression for the size of your vessel; that is the radius of the vessel divided by R naught is given by this particular expression. And taking the value of gamma is equal to 1.4 pi is 3.14. I get the magnitude of this. And if I solve for this, what is it, I get, let me get you the precise values.

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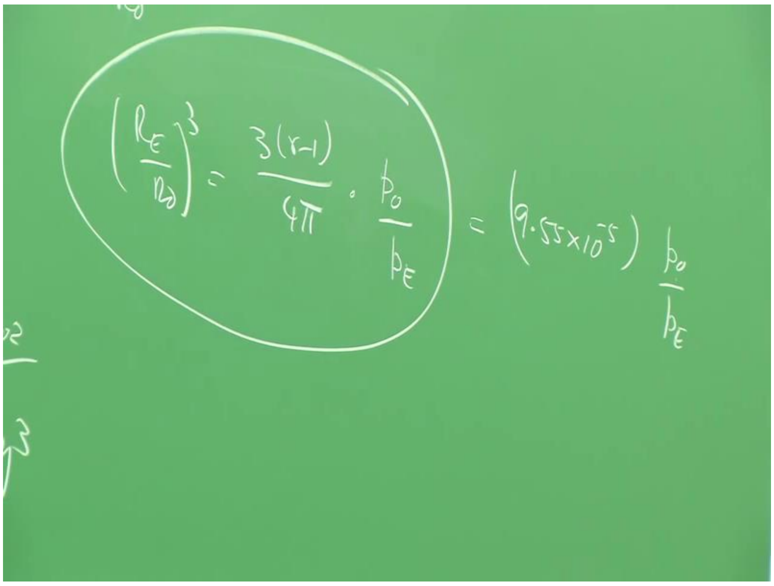

The values are the 3 into 0.4 divided by 4 into 3.142. This becomes equal to 9.55 into 10 to the power minus 5 of P 0 by P E or rather, what is it am looking at; I am looking at this value. Therefore, I can write the value of R E. Let me use the other part of the board.

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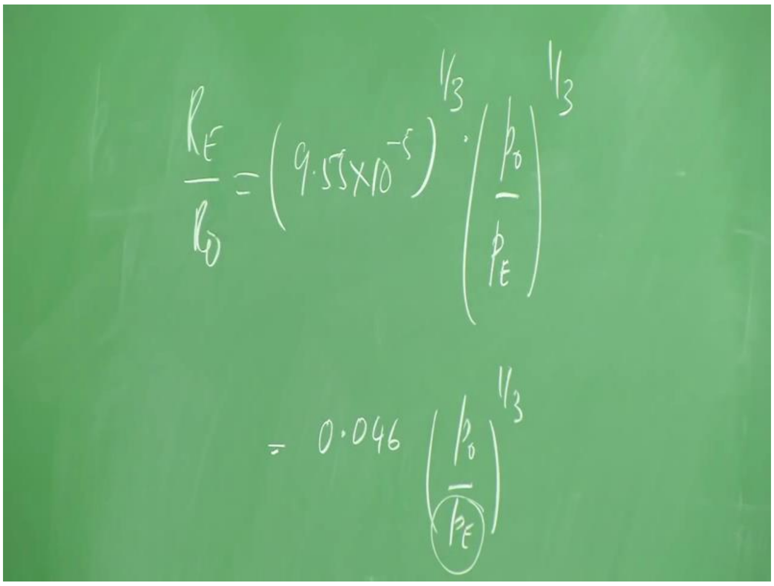

Rather I get the value of the R E by R naught is equal to, I get 9.55 into 10 to the power minus 5 to the power 1 by 3 into I have to get the value. Now, I get P naught by P E exactly, what got over there is, what have written over here. And this comes out to the equal to 0.046 into well this must also be one-third. Because, R E by R naught was this into I have P naught by P E to the power 1 by 3.

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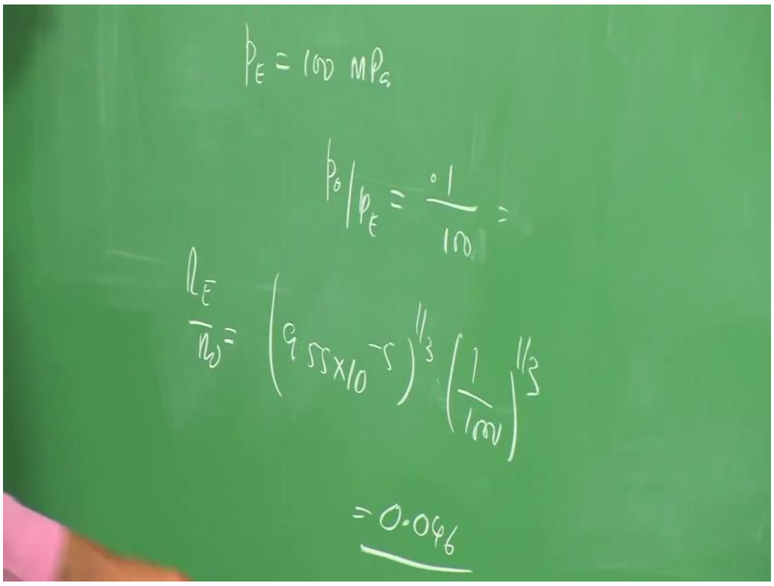

In the limit, now I tell myself, in the limit, were P is very large number. Maybe, the explosive is such that, I have intense pressure, pressure tends to infinity, when P E tends to infinity. Well, the value of R E by R 0 is that; that means, R E by R 0. When, I have a high pressure explosion tends to 0. Well, I am getting the point explosion like, what we are been considering, we do not even need to consider the effect of R E wave, when the pressure is very high.

But, when pressurize, let us say, instead of saying very high. Let us say, when the pressure a vessel could explode, when the pressure is around, let us say, 100 in MPa. If P E is equal to 100 in MPa; that means, equal to 1000 atmosphere. The value of P naught by P E is equal to 0.1 is the ambient pressure, 0.1 MPa divided by 100. That is equal to divided by 100.

Or rather, when I take the cube route of this particular expression, therefore, I get the value of R E by R naught is equal to, I should not have written this. The value here is equal to 9.55 into 10 to the power minus 5 to the power 1 by 3 as it well. Now, when I put this value over here and I substitute the value of 9.55 into 10 to the power minus 5 to the cube route into 1 over 1000 to the power cube route I get a value around 0.046.

In other words, even if the pressure is something like 100 megapascal, instead of being infinity, I get R E is a small number. And therefore, what is it I find, I find, well R E is very much less than R naught. When, the pressure is high and therefore, we can considered these thing R E to be negligible, when it is very much less than R naught. And therefore, whatever is deriving for a blast wave progressing from a point source is valid as long as the pressure of your explosion is quite high.

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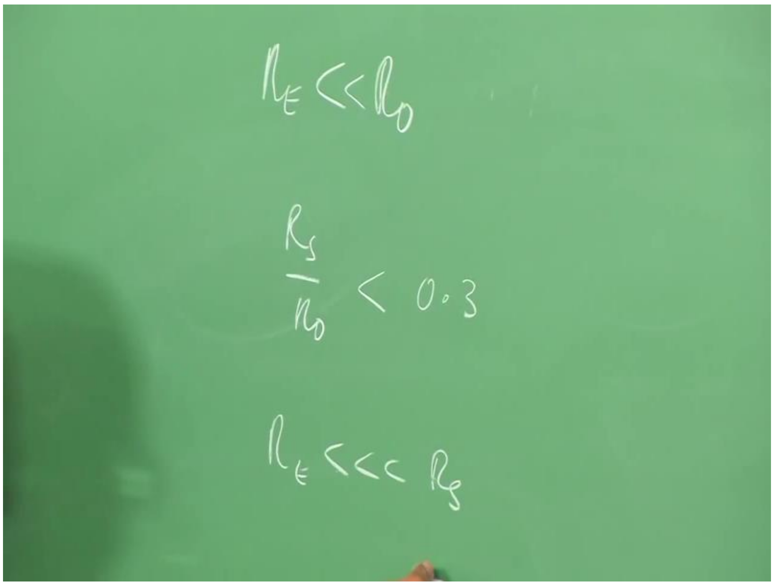

Let us put the whole thing together. Now, that we are done this problem and ask ourselves some particular questions. The questions we would like to ask under what conditions can I use. What are the predictions, which are done for point source? We tell ourselves, when R E is less than R naught. Well, it seems to be valid, because re something like point O 4 times in the pressure is high, when it is less than this.

We also know the region of interest is R S by R naught strong blast is something like a less than around 0.3 well R E by R naught was something like point O 4 were as R S by R naught is still less than R naught, but still R S is much greater than R E.

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Therefore, we find that, when R E is very much less than R S at which we are interested. And this R S is again less than the value of R naught. Well, for this we can say, well the point assumption is valid. And we can go ahead and predict over here. But, when we go back we look at the figures, what I just shown on the slide. ((Refer Time: 21:15)) We what do we find, we find when we have P S minus P naught, divided by P naught and we have R S by R naught over here.

Well, the point explosion gave this; we also had some deviation over here for finite volume. That means, when some explosive is bust over here. That means, these are the effects due to the finite volume effects. That means, the pressures, what we get, may not be, as we have assumed in this particular analysis. Having done that, let us take a look at, what is the effect of geometry. Like for instants, I have cylindrical vessel, which explodes or let us say rectangular geometry, which creates a plain wave in the near front.

In what is going to happen, well in this case, I am going to get cylindrical ways which propagate out from this. It is going to go may be at larger times. Well, I am going to get another cylinder over here is going to propagate out.

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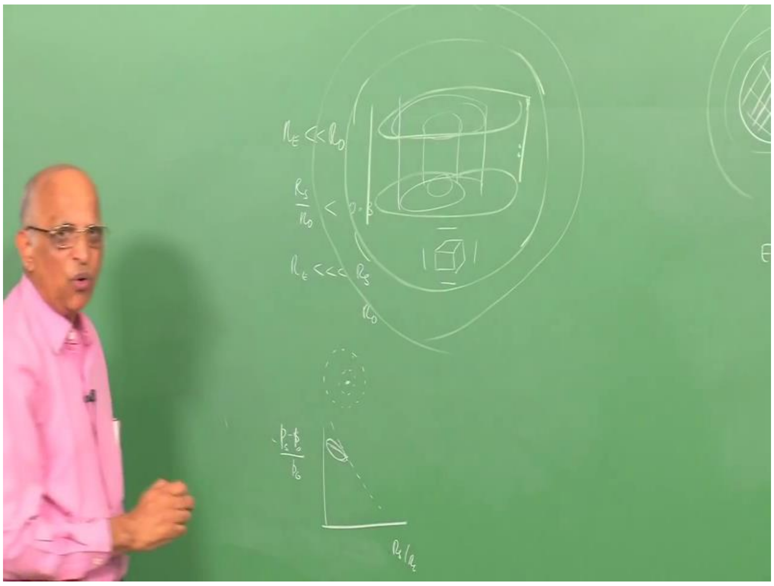

But, we also know, because the pressure behind the blast front is quiet high and the density is high. The temperature is here are very high. Therefore, the sound speed is very high and therefore, the high sound speed will clear out these corners. And therefore, what is happening is this corners will gets neared out. And as the blast wave propagates out, in the near field, may be the geometry of the source will have an effect.

But, thereafter, the effect will get nullified and ultimately in the far field, I will get spherical wave. Having said that, let us go back and again address the slide what we had, we said well, we were able to predict the over pressure as a function of the ambient pressure, dimensional is over pressure. As a function the distance scale by R naught, we were able to get the point. So, when we have the effect of the volume coming here, well some there deviations are the experimental point.

But, other than that, may be as we go ahead, all the point match with this and this is what we use to determine the overpressure from the explosions. That means, we have been able to get the effect of over pressure as a function of this is. And let us do one or two small problems, such that we are very sure about what we are learns so far.

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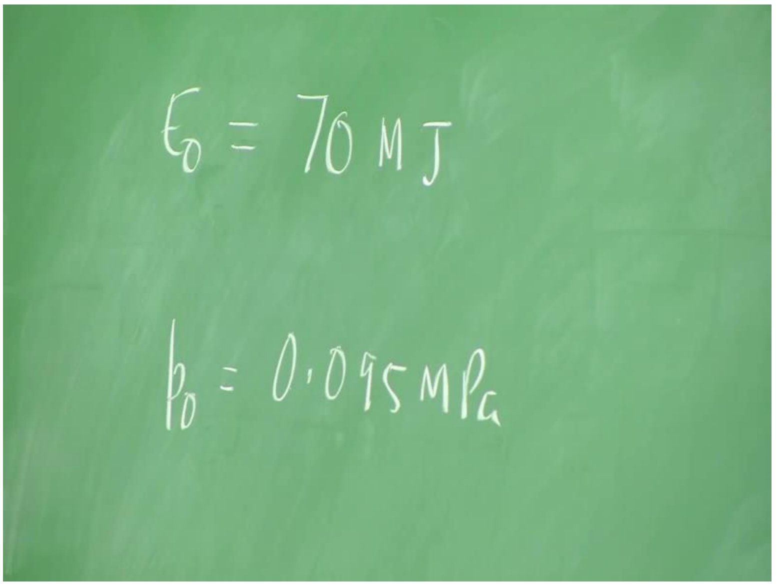

Let me do to model problem with that, may be, we will be able to see, how to predict the over pressure in an explosion. Let me considered one problem like this. Let us assume, I release an energy at a point or at some small source as equal to, let us say 70 Mega Joules of energy is what I release. And the ambient pressure at which I release this energy is equal to 0. 095 megapascal.

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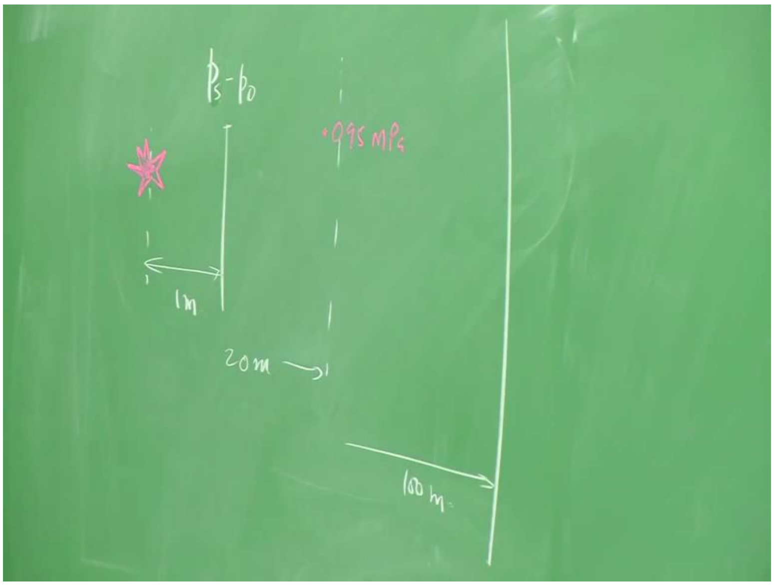

In other words, we are talking of a situation, wherein, some energy is released over here. All of sudden instantaneously, the energy releases is 70 Mega Joules, the ambient pressure at which this energy release is 0.095 megapascal. You know, 0.095 is very near to 0.1 megapascal and this might be at a slightly increase attitude. And now, I am interested in finding out, what is the magnitude of the over pressure, may be, I deposit this energy at a distance.

Let say, 1 meter away from the explosion sight, I want to evaluate the value of the over pressure. What is overpressure? The pressure behind the wave divided minus the ambient pressure, I want at 1 meter. I also want to find out, what is the value, let us say a distance let us say 20 meters away and at a distance of 100 meters away. That means, I am interested in finding out the ova pressure at a distance of 1 meter away from the explosion sight. At a distance of 20 meter away and at a distance of 100 meter away.

Therefore, this is the problem given and how do I solve it, may be, I make use of both the charts and whatever we learnt so far. We will try to do this problem and with that, may be, we will know, how to do such problems in practice. Well, the first thing, we say is, well I convert this energy into something like an explosion length.

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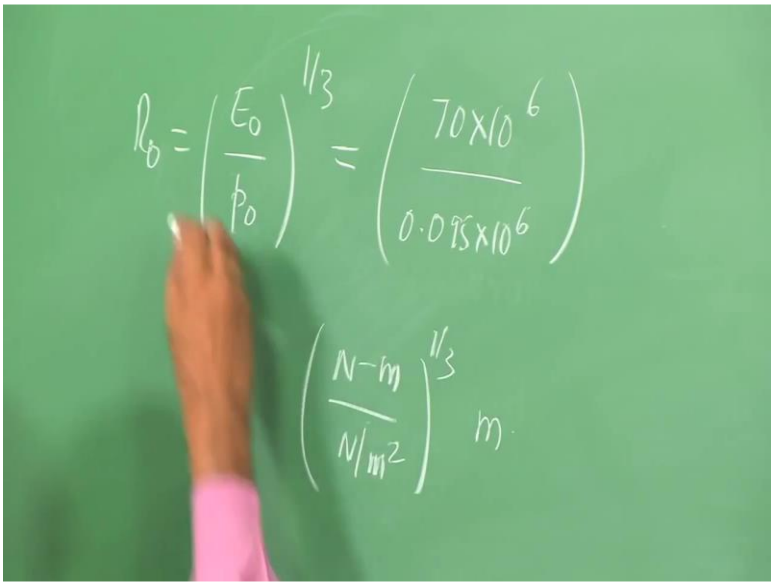

And explosion length R naught is equal to E 0 divided by P 0 ambient pressures to the power 1 by 3. In this particular case, the energy released is equal to 70 megapascal. That is 70 Mega Joules, 10 to the power 6 joules; the value of pressure is equal to 0.095 into 10 to power 6 Pascal. Units, please be careful about units, this is joules, therefore Pascal. Therefore, you have joules is equal to Newton meter divided by Pascal is Newton by meter square. Therefore, that numerated should be in joules P naught must be in Newton per meter square of Pascal. We have 1 by 3 and this gives me the value of meter. Therefore, I get the value of R naught, this I simplify, let me get the value is equal to 9.03 meters.

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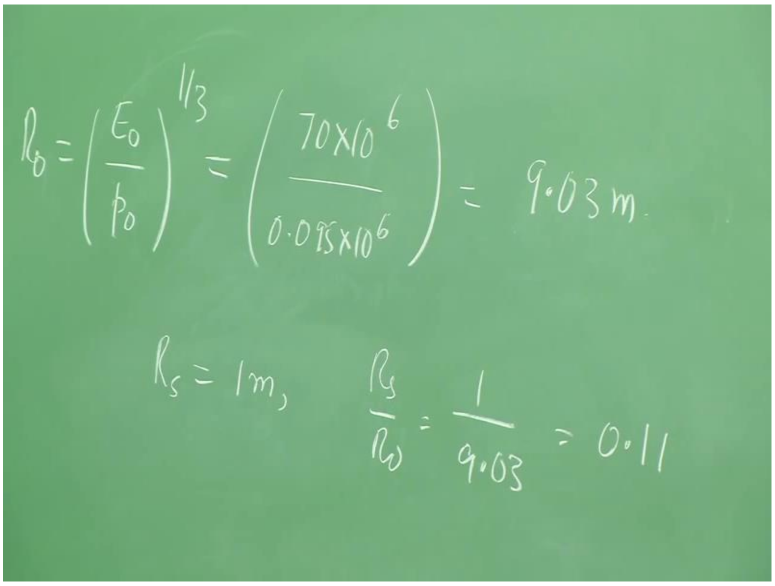

Now, I am interested, what will be the over pressure at a distance 1 meter away. Therefore, R S is equal to 1 meter at R S equal to 1 meter the value of R S by R naught is equal to 1divided by 9.03, which is around 09. That is 0.11 is a dimensionless value of this scale distance. Well, you know we have been telling ourselves, well at distances less than around 0.3, whatever we derived is valid.

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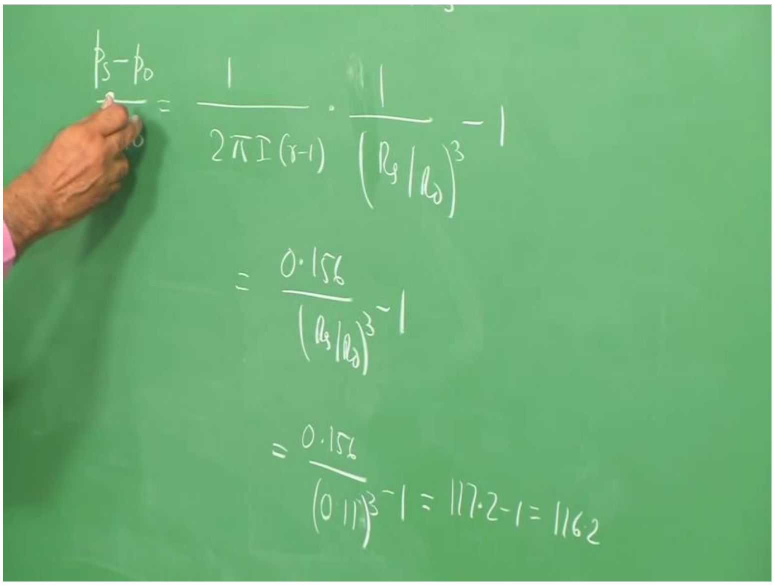

And therefore, I can write P S minus P naught divided by P naught was equal to the equation; we had reduced to the form. Let us first write the equation 1 over 2 pi I into gamma minus 1 into R S by R naught. We should have been in the denominator R S by R naught cube minus 1, which we said again was equal to 0.156 divided by R S by R naught cube minus 1. And therefore, I put in the value of R S by R naught is equal to 0.11. This give me 0.156 divided by 0.11 cube minus 1. And this gives me a value equal to 117.2 minus 1, which is equal to 116.2 is the value of P S by P naught by P naught. But, my P naught is equal to 0.095 megapascal.

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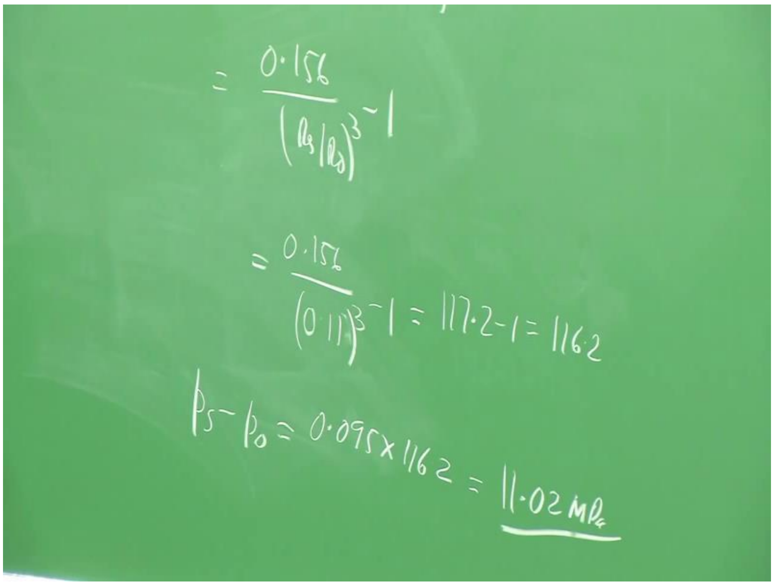

Therefore, the value of P S minus P naught is equal to, I get 0.095 into 116.2. So, much megapascal and this works out to be 11.02 megapascal. This is from the strong blast assumptions. If I want to use the figure, I go back to the slide; I am interested in the value of 0.11. And if I take the value of 0.11, maybe I take R S by R naught 0.11 over here.

Well, I get back something like 100 and if I look at this, it is something like 116, 117. What I get and this is how, I can use the figure or I can use this in the strong blast feature. I can say, well use the equation, which we derive in the earlier classes. Well, this how you evaluate at the distance of 1 meter away. When, I look at that distance of 20 meters away. Let us again do this problem.

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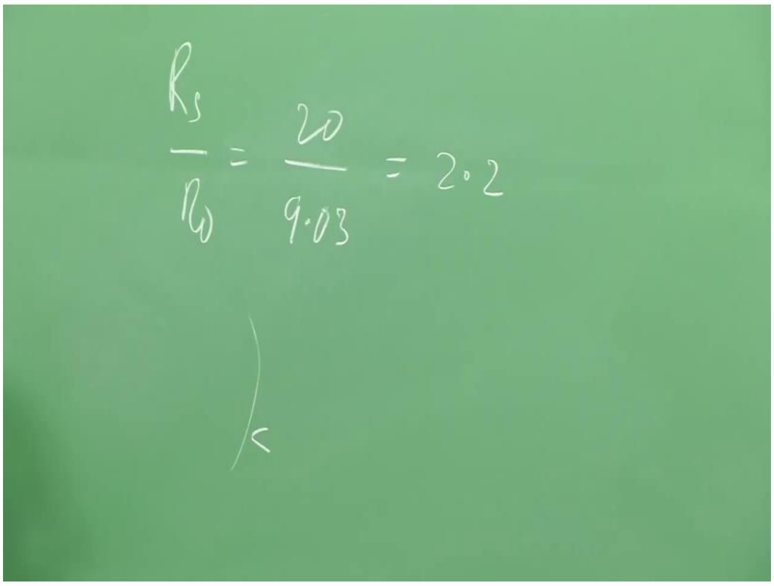

Well, at 20 meters, I am writing the value for R S by R naught is equal to 20 divided by 9.03, which is the R naught meter by meter, this equal to 2.2. Now, you know, 2.2, we said, well the strong blast assumption is valid, only when R S by R naught is less than around 0.4 or so. Because, after that the Mach number decreases, I cannot use this equations, which I derive.

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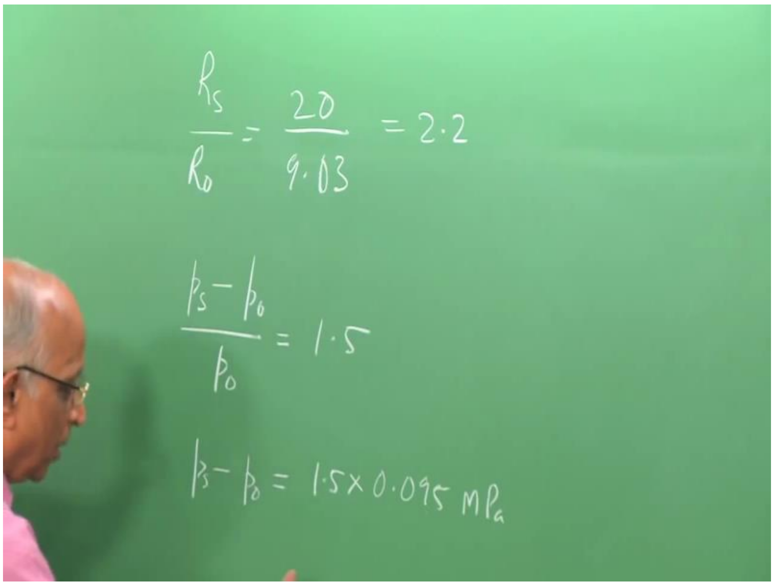

I have to necessarily us the chart or do some more calculations to that. Therefore, let us use the chart which is available in the slide for this particular point purpose. Therefore, I take a look 2.2; R S is equal to 2.2. ((Refer Time: 21:15)) Well, this is 1, 2.2 is over here, when I take the value, well it comes to something like 10 to the power 0, something like 1.5. Therefore, I get the value of from the chart, I get the value of P S minus P naught by P naught at the particular value of R S is equal to 1.5.

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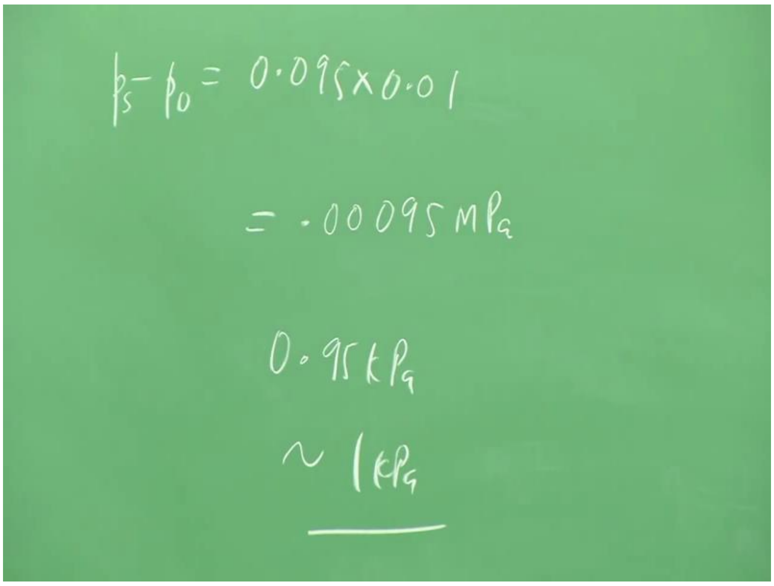

And therefore, I get P S minus P naught is equal to 1.5 into 0.O95 megapascal, which is equal to 0.143 MPa, which if it is expressed in Kilo Pascal, it is equal to 143 Kilo Pascal. This is the over pressure. Let us do the last part, wherein I am also interested in the value of over pressure at 100 meters. Well, at 100 meters, what happens, then value of R S by R naught is equal to 100 divided by 9.03, which is equal to 11.

And at the value of 11, I again read the value and if I look back at the distance of this is 10 over here. I am looking at 11. The value, if I were to put down, what is the value I get at 11. Well, I am somewhere over here, something like, I am having 10; I am having 11 over here. If I get the value somewhere over here, therefore, the value I think will come out to be, something like 0.11.

Let us put down the value 11, it difficult to do it, if have use the scale, I will say 0.011 or 0.01 is the value P S minus P naught divided by P naught. And therefore, in a similar way, I get the value P S minus P naught is equal to, this is from the chart. I get the value is equal to 0.495 into 0.01, which is equal to 0.00095 megapascal. That means, we are talking of something like, 0.95 Kilo Pascal or something like 1 Kilo Pascal, what is the magnitude required to break a glass window pain or a glass window pane.

Let us say, therefore, we unable to find out the over pressures, using the charts and also using the strong blast assumption and we know such problems.

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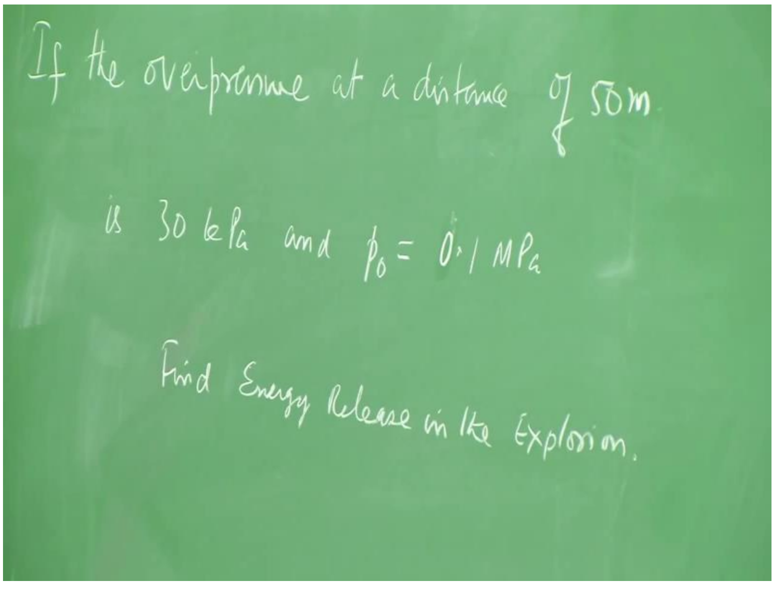

I take the case of trying to find out. ((Refer Time: 21:15)) In other words, if the over pressure at a given distances from an explosion, say at a distance of 50 meters from the sight of an explosion is, let us say 30 KPa. Then and the ambient pressure is equal to, let us say 1 or 100; that is 100 KPa, that is 0.01 MPa. That means, if the measure over pressure at a distance of 50 meter on the set of an explosion is 30 KPa and the ambient pressure is 0.15, 0.1 MPa.

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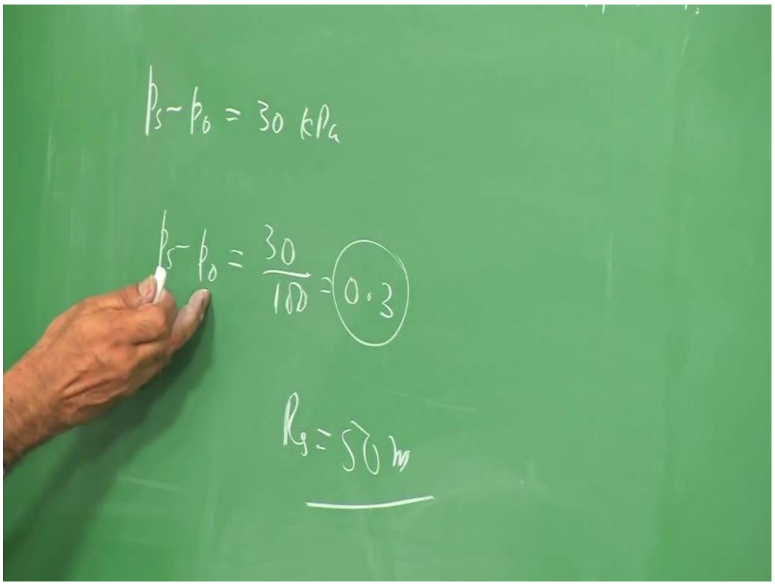

Find the energy release in the explosion, how do, we do this problem. Well, in this particular problem, it is given to me, that P S minus P naught is equal to 30 Kpa. The value of P naught is given as 100 MPa, 0.1 MPa. Therefore, I get P S minus P naught is equal to 30 divided by 100 is equal to 0.3 is a value. Now, I also know that this value is reach at a distance R S is equal to 50 meters away. Therefore, I again, I know, well this is my over pressure, this is my distance. And therefore, I use the chart again; I want to find out the value of the value of R S by R naught. Therefore, when P S minus P naught is 0.3.

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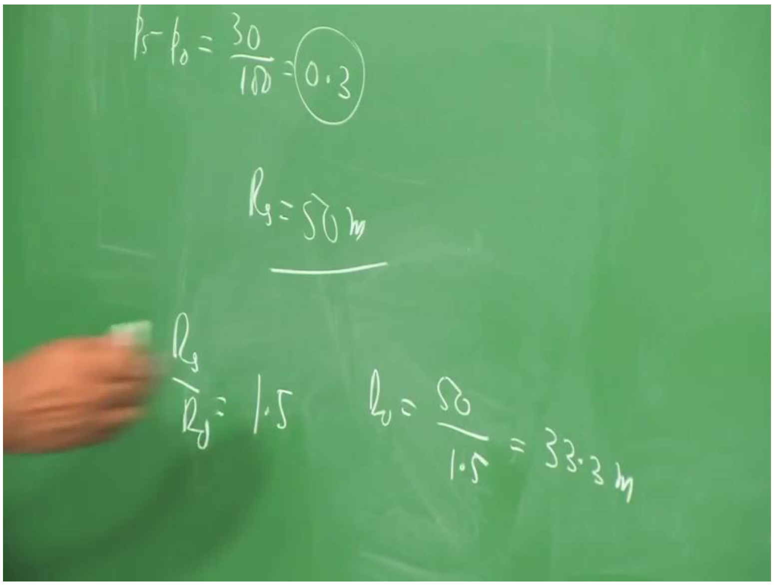

I want to find out the value of R S by R naught, I go to the slide again, ((Refer Time: 21:15)) I find the value of R S by R naught, when it is 0.3, this is 0.1, 0.3 is somewhere here. You value around 1.5 over so. This is a 0.3 comes out to be something like 1.5 5 let us say, R S by R naught is 1.5. And therefore, what is it I get; now I get the value of R naught from this expression as equal to 50 divided by 1.5. Let us again do this, the value is 0.3, at 0.3, the value of R S by R naught is at is 1.5 R naught is equal to 50 by 1.5 is 33.3 meters is a value of R naught.

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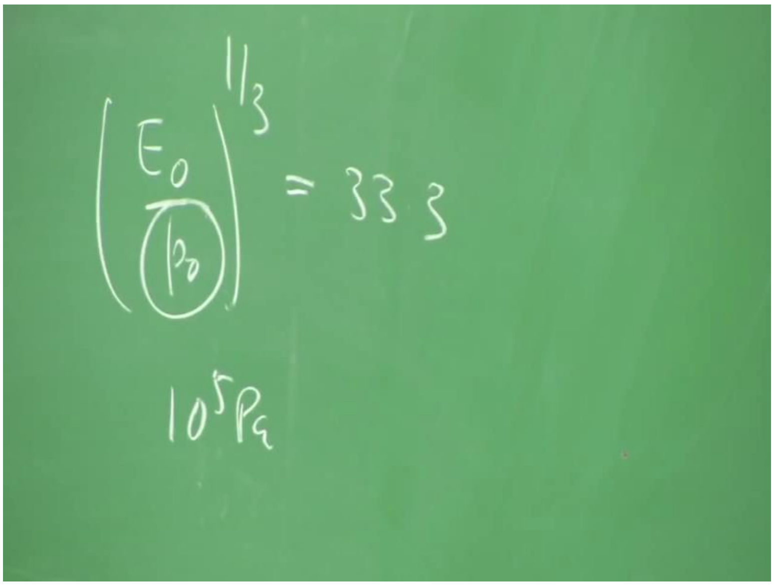

If R naught 3.3 meters, well the value of P naught by P naught to the power 1 by 3 is equal to 33.3. And therefore, I know P naught is equal to 2 is equal to 10 to the 5 Pascal. That is point MPA, I can find out the energy release. And then this how, we go problem. Therefore, what is it we have done so far, you know, by now; we must be clear about to do these problems. Involving overpressure in a blast wave and what is it, we have done, we started with the strong blast assumption, we just said well, it could be extended to lower Mach numbers. And we use the particular curve, what we had.

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In which case, we had over pressure on the y axis psi P naught divided by P naught as a function of R S by R naught. We use these curve in the strong blast region in the week end region to be able to predict the over pressures. The over pressures are available; I can predict my energy release. This is what we do in blast waves. Having said that let me spend a moment or 2.

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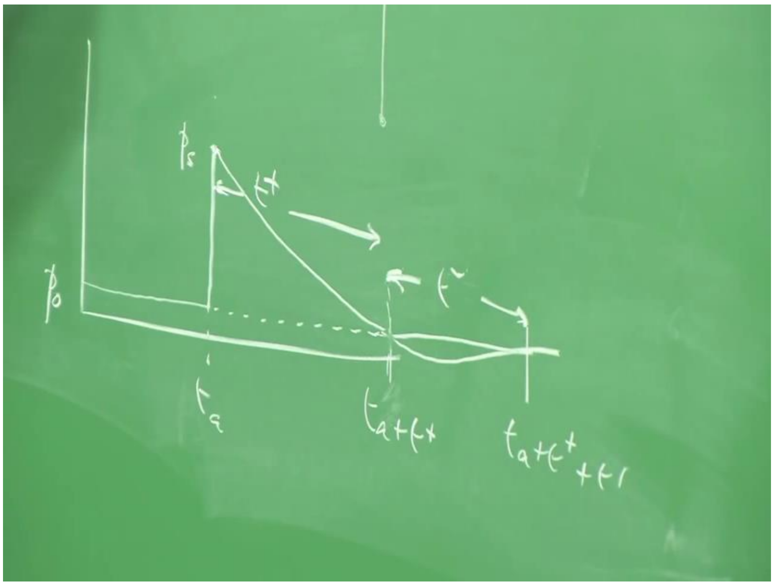

In the last part, namely a both impulses with which we will continue in the next class. We will just introduce the subject and carry forward in the next class. And what is the impulse, when we talked of over pressures, what we are basically considering is, we are having a blast wave, which is created. And the effect of blast wave is to create something like a pressure, which crushes.

But, we also told behind the blast wave, because of the varying pressure, you have the wind. That means, you have something like a blast wind and because of this blast wind, only it is called as a blast wave. Because, it creates that wind, what creates the wind, well let us assume I have an explosion over here. The blast wave is travelling forward; maybe I am standing over here and watching a particular point over here at which a wave comes.

And let us say, once the explosion is initiated, the wave comes here after a particular time; that means, I have my time axis over here. After a particular time, the wave come here, it is the arrival time of the wave. And once, the wave come, still the wave comes, the ambient pressure is just the ambient pressure, which is P 0, which is equal to, let us a 0.1 MPa.

Once, the waves comes, well the pressure suits up, I have the over pressure sums down to P S. And the wave continues to move forward, when the waves moves forward at this particular point, the gases expand. But, it is still process by this and therefore, the gas move forward, the pressure falls. And if by chance, pressure falls below the atmosphere at well it could come over here and it could here.

We say this is the time at which the pressure reaches the ambient, due to the expansion is equal to t a plus t plus. And it comes back over here into t a plus t plus, plus t minus. Well, this is the duration at which I have the wind blowing in this direction or that means, I have from the high pressure gasses it outward over here. This is the value of t plus.

And in this region, I have the wind blowing; inwards because the pressure is there I have t minus over here. In other words, I have a region having positive pressure above the ambient and having negative pressure over here. This is an ideal case of let us way which is travelling forward. And what happens, how do I define the wind condition? Well, the particles are carried forward.

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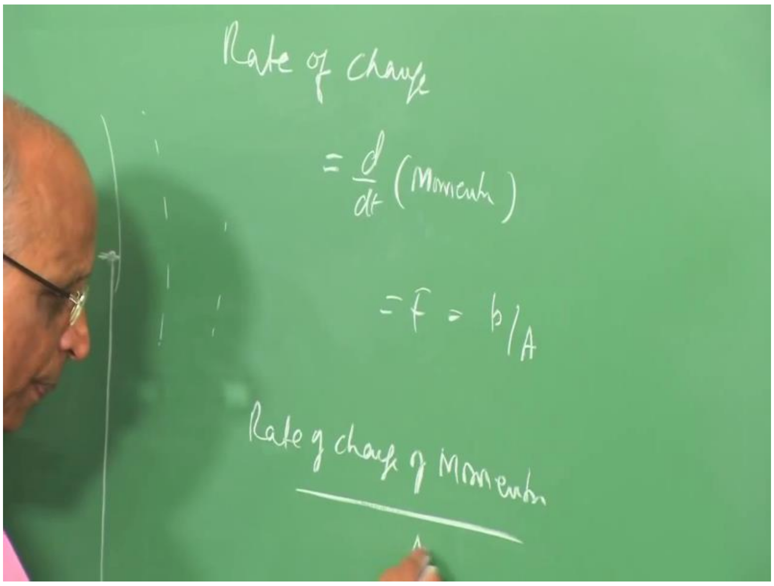

I have something like a momentum, when I have the momentum of the gases in a initial momentum is, when it is at rest, I have change of momentum. And what is weight of change of momentum, we had talked of this earlier. Weight of change of momentum is equal to, I get d by t of the momentum, change what is available. And this is equal to the impress force, because of this pressure.

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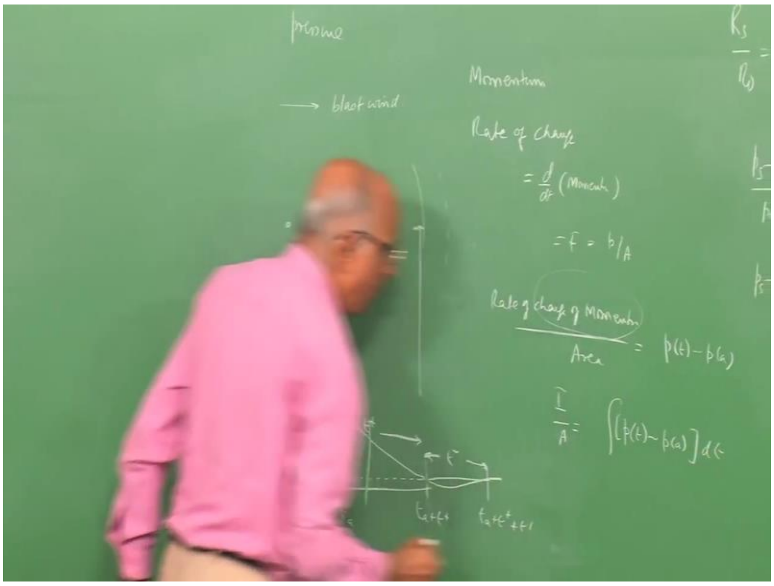

If I caught in terms of unit surface area, well for unit surface area, I can say well, force is equal to pressure by area or rather. I say rate of change of momentum or rate of change of momentum, per unit area is equal to, what is the difference between the excess pressure and the ambient pressure. That means, it is equal to something like, p t minus p at any time over here, minus vale of p a over here.

Or this is the rate of change of momentum per unit area, therefore, the change of momentum and change of momentum is, what we call as impulse. Therefore, impulse per unit area is equal to, I have to integrate this expression into p t minus p a into the value of d t. Therefore, I have something like a positive impulse over here, because the p t is greater than p a. I have a negative impulse, because the p t is less than p a.

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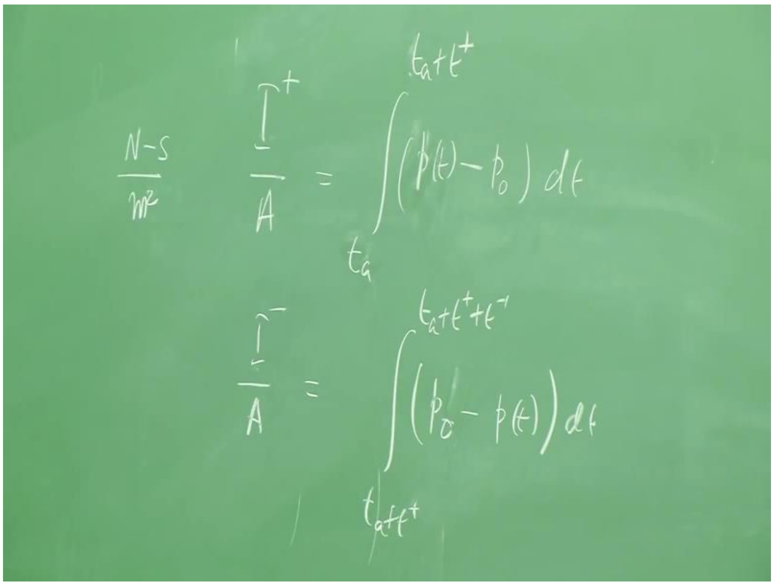

I can define the wind effect in an explosion as being, let us say, we have positive impulse, I call it as positive impulse per unit area. I have negative impulse, per unit area and this is given by integral 0 to t of p t minus the pressure at any time divided by minus the value of the ambient pressure into d t. And what is the time, from the arrival time, that is t a to the value of t a 2 t plus is the value positive impulse.

And what is the negative impulse; we have t a plus t plus is the starting over here. It finishes of at t a plus t plus, plus t minus into the value of p. In this case, it is this is higher; therefore, I am just looking at the negative impulse, it P 0 minus p t into the value of d t. And therefore, I said specific impulse per unit area, the unit being force into distance Newton second per meter square is given or positive impulse and for negative impulse by this particular area expression.

In the next class, what I do is, I will not do the details, but since we know the weight at which pressure is changing behind the explosion. I know this profiles, I will try to find out the value of the positive impulse and negative impulse. And then discuss further, how the effect of an explosion is to damage objection around at.

Well, thank you. Then we will see in the next class.