Introduction for Explosions and Explosion Safety
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Lecture No - 01
Loud Bang and Disruption

Good morning, welcome to this course on introduction to explosion and explosion safety.

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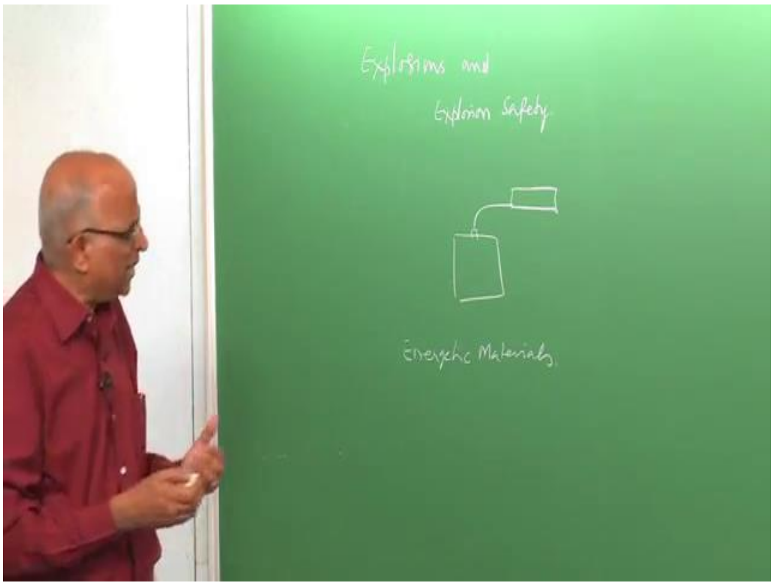

All of us would have heard this word explosion, normally we associate an explosion with a loud noise and a loud bang and destruction of things from the place of the explosion by destruction. I mean things fly out, there is total damage in at the place and therefore, all of us are used to connect the word as we say explosions with a loud noise or loud bang and disruption of things at the place wherein the explosion occurs. In this particular course, we will look at what causes an explosion, what are the different types of explosion and being disruptive in nature.

We will try to see how to mitigate the effect of the explosions and also we will try to see whether we can institute some steps to we can prevent some of the explosions. Let me start with an example, all of us are aware that may be in the kitchen, we use cooking gas and very often may be three or four times a year. We read in the newspaper some reports that there is a blast due to some leakage of gas from the cylinder containing the cooking gas or from the stove or from the line which conveys cooking gas in to the kitchen. What really happens is maybe I have a cylinder of gas which is connected to the stove over here, maybe there is some leakage of gas from the cylinder in to the kitchen room.

It mixes with air forms a compostable if it finds an accidental spark in the kitchen light, maybe when it is leaking, some mixture is formed, somebody goes and puts on an electrical switch, which creates spark. What happens is you immediately have a loud bang done and then you have the kitchen shatters, why then kitchen alone the entire building which is part of the kitchen is totally demolished. That means an explosion is something which is undesirable which causes lot of hake around you, this is what we should study, this is a simple example, but there are many more examples like in the cracker industry or in the fire work industry.

They handle what we call as energetic materials by energetic materials, we mean materials, which gives some energy and very often during processing of these crackers processing of these fireworks, we have a explosion. Especially in this state of Tamil nadu in the southern belt like Sivakasi, we have lot of accidental explosion taking place. Well, we look at two examples we will deli bate on these during the course of our lecture, but we also find it is not only these accidental cause, which cause an explosion and very often we find explosion do occur in nature.

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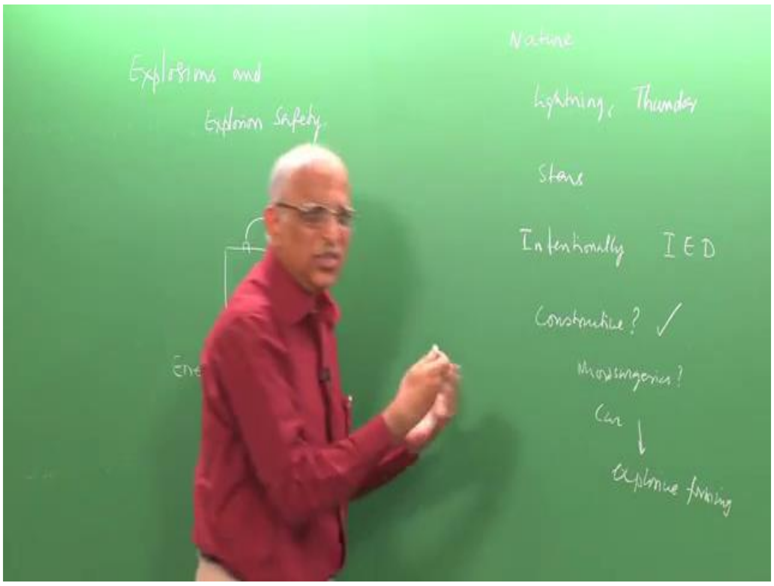

For instance, we have lightening, that means we have these clouds with high velocities and accumulate charge and when they have a high charge on them or high voltage is built up. What happens is you have this high voltage, which gives earth and you have an electrical discharge, this electrical discharge again create have and not only that, you have lightening associated with thunder. That means there is a noise component to the naturally occurring explosions, it is not only lighting which causes the explosion in the nature, you have these asteroids commodes which enter the atmosphere and they also cause an explosion.

Recently, we had one in Siberia and not only these two, now we have these stars which explode using nova super nova explosions, may be these are the things which occurring in nature and which we should also concerned above. In addition to accidental explosions, explosions occurring in nature, obviously we find we have some anti social elements, who intentionally promote explosions.

What they do is, they take these energetic materials and explored them in crowded places and cause grievous harm to people around them. What we say is improvised explosive devices is what they use, maybe we should find out how do they do and how to prevent such explosions taking place.

Therefore, I would like to say well explosions occur in nature, they are sometimes caused intentionally, but very often most often they occur accidentally. As engineers, you know since we handle substances which are energetic it is necessary to sort of design our chemical plants our plants in practice such as we do not have the disruptive explosions taking place even though. So far, I have been telling explosions are disruptive and that is how we have been connecting ourselves with the word explosions. We do fine explosions could also be very constructive, what you mean by a constructive explosion?

I would as of now tell you may be we would not have reached the present state of our development or civilization had it for the explosions. Maybe, I would like to say yes we need explosions to make tunnels we need explosion to make canals we need explosions to be able to large rocks with which we make buildings, we need these materials of construction.

Therefore, there are constructive uses prevail we could also need we can use these explosions for having micro surgeries and why not only for micro surgeries may be for injecting some medicines into the body. I can use explosives or even the safety devices, we can use it for explosive forming of materials may be for fabrication. For explosive forming, the list is endless, the constructive uses are particularly large and we will look at some of these also during the course of these particular lectures.

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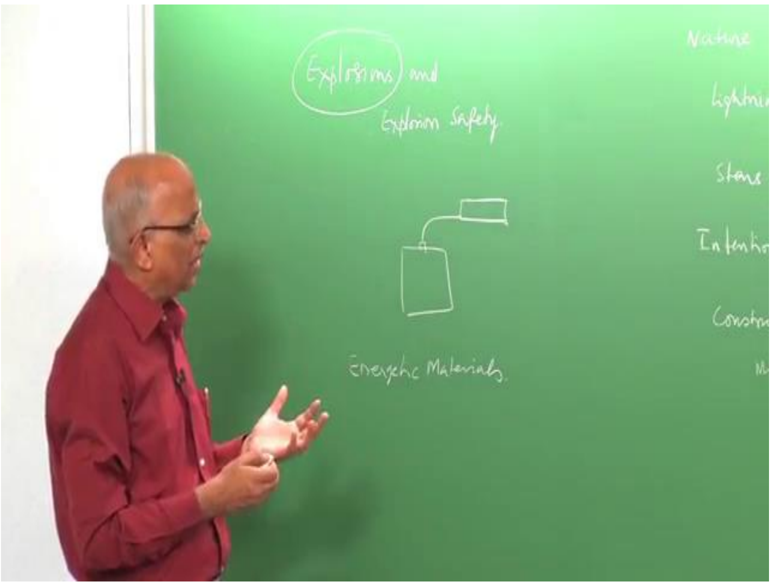

Having said that, let us go back and see what an explosion really means and we will try to define what an explosives explosion is in the particular talk today and then may be as time progresses. We will learn more about explosions about the blast way generated from explosions may be we will look at the energy release from the substances during chemical reactions rate of energy release. We will look at the thermal theory of explosions, we will look at gaseous may be liquid explosives, we will look at explosives, which comes from ordinary food stuff like dust wheat sugar.

All that may be we call it as dust explosion we will look at the physical explosion and so on. Therefore, broadly I can say the explosion can be categorized into eight categories. These, each categories we will study during the course of talks once we are very clear about these different types of explosions. We will look at the destructive effects of how to model, the yield of how an explosion occurs and how the damage occurs, and then we will look at the risk analysis in risk analysis.

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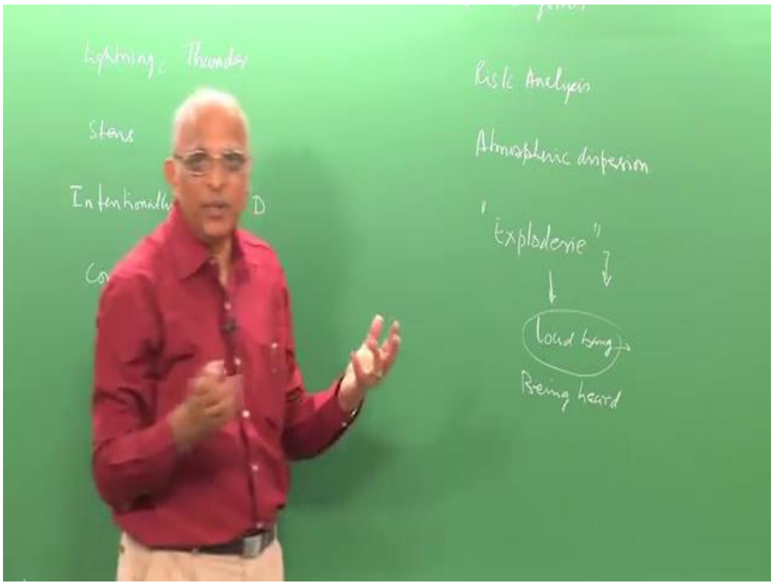

We will particularly look at how to calculate the probability of an explosion taking place and also the detrimental effects of the explosion having said that something which I wanted to introduce at this point in time. We said about the gas leaking and defusing in a kitchen or in some an open environment. Therefore, we would also like to take a look at atmospheric disruption before looking at the quantitative effects of cataloguing damaging.

This will be the overall over view of the course. Therefore, with this background about the course is about let us try to define, what is really meant by the word explosions. You know when we look at the genesis of the word explosion, it comes from the Greek word explodry. You know in the olden times especially in then the advanced countries like Greece, we had these operas in which the performers used to come and give a lot of talks the keep on talking about different aspects.

Sometimes, these people used to carry away that they kept on talking on hours together this irritated the audience. The only way to chase out the people by all the people clapping together and this loud clapping got so loud that the performer was forced to leave the hall. That means by the word explodry, what is mean what is meant is chasing out the people or driving out by a loud noise.

Therefore, since explosion is associated with a loud bang and disruption of things the genesis of the word comes from the Greek word explodry. That means making a loud noise which is by clapping a chasing out the concerned people or things whatever it is, so we would like to first know what is mean by the word loud bang. That means all what we are saying is an explosion to be capable of being heard being heard means I have a loud noise, what it causes a loud noise, what is this causes the disruption? This is what I would like to tell on today having said that let us try to understand the little bit more, we are talking about a loud bang from an explosion.

Therefore, let me go forward and try to build up a case and under what condition can I hear a loud bang and disruption of things from the place they are being in, therefore to do that let me start with a simple example. I brought with me a flute over here and what I do is, I take the flute and blow into it, it makes a noise it makes some sound, how do this sound wave propagate from this flute?

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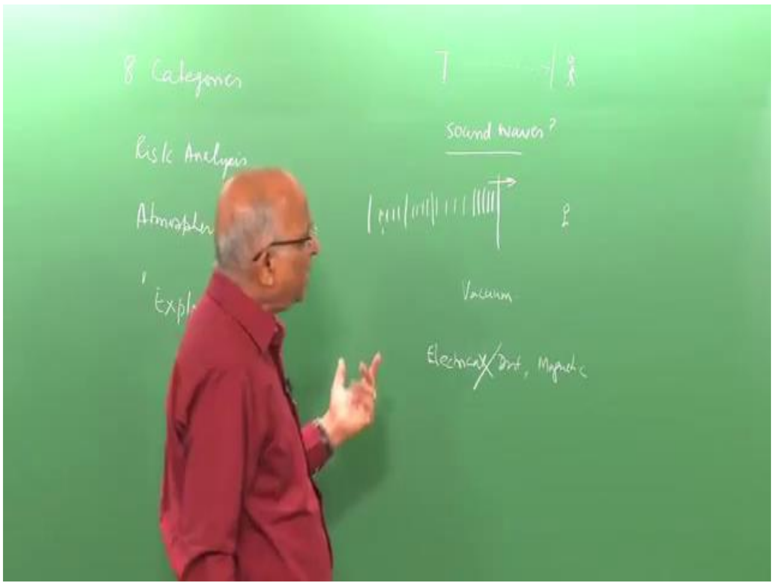

I will create some disturbances, let us say tip over here I create some disturbances and these disturbances which propagate and reach and observe over here. This is what you hear as a noise or a music and how does this disturbance propagate, you say it propagate through sound waves when you say sound wave.

What do you mean by a wave? A wave could be mechanical wave could be electromagnetic like for instance, you go to the beach, you go to the ocean you finds the waves coming over here may be during earth quakes, you have the earth on the earth on the a in the earth which we call as seismic waves. We talk over sound waves, what is the characteristics of the sound wave, what happens may be when I create some disturbances I create some compression over here followed by rarefaction. That means I expand the gases and followed by compression followed by expansion over here.

Therefore, I have a series of compression followed by rare faction followed by compression followed by rarefaction over here. It is the front of this wave which comes and gives the message to us saying, well this is what I hear you know when I say this, when I say a wave it is a progression of disturbances. But the matter from here the does not really travel and reach me over here and it is only the matter at each particular point vibrates over here either as a rarefaction or a compression. It is it is progressively sort of transmitted to the adjacent layers and I have and the wave does not have any mass as such, even though it is able to carry the information to you.

It does not have any mass even though let us say the energy from here is reaching you over here. Therefore, let us say these are the mechanical waves we could have electromagnetic waves, but in electromagnetic waves can travel through vacuum compared to a sound wave, which require some medium. Why should it require a medium? I need the progression of these, progressive movement of these disturbances from here the particle transfers from here, next to the next and so on.

Whereas, in vacuum I do not have this possible, so for a sound wave or any of these mechanical waves cannot travel through vacuum, but when we talk about electromagnetic waves it can travel through vacuum. The reason being an electrical disturbances creates an oscillatory electrical disturbance creates mechanical disturbance. It creates a magnetic disturbance a sort of electrical disturbance oscillatory creates a magnetic disturbance and this oscillatory magnetic disturbance again creates a electrical disturbance. This oscillatory electrical disturbance again creates a magnetic disturbance and so on.

That is how the electromagnetic disturbance propagate through a vacuum, we are not interested in the electromagnetic waves. We are more interested in sound waves and we say the progression of the disturbances through a medium is by compression and rarefaction. I am just telling you some sound waves propagate through a series of compression and rarefaction.

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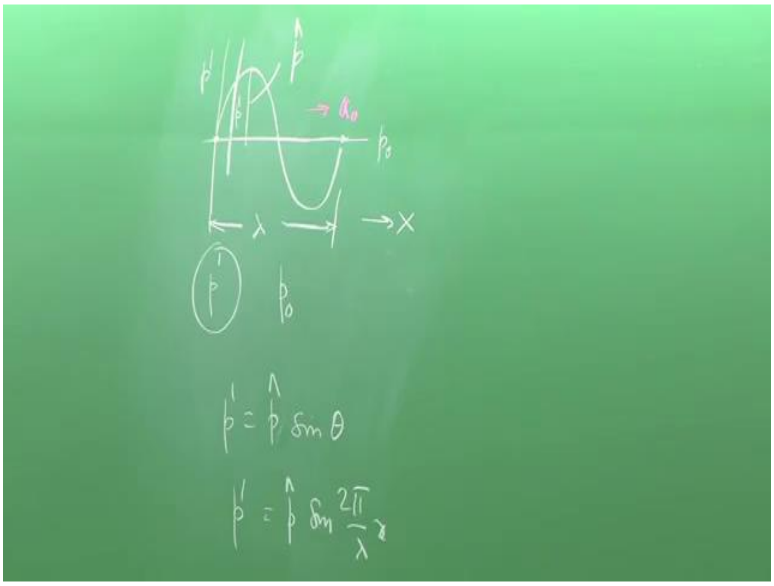

Through a compression and rarefaction as it is it is possible to say I have disturbances in pressure as which I denote disturbance as p prime the ambient pressure is pressure p naught. That is 1 atmosphere, let us say 10 to the power 5 Pascal or 100 Kilo Pascal is the ambient pressure at sea level over and above this I have a small oscillatory component. This oscillating component or the disturbance which is propagates I can represent this.

Therefore, say p prime at any instance this is the ambient value of pressure p naught over it I have the maximum, amplitude is equal to h hat. Therefore, I can write p prime is equal to p naught p p hat into I have sine theta which tells me the shape of the sign wave, I know the well the phase here and the phase here are the same. Therefore, the wave length is given by lambda that is between the points having the same phase over here.

Therefore, if I where to put this is the direction of my propagation x, I can write this is equal to p hat into sine of 2 pie by lambda into x, because it is at the same phase 2 pie corresponding to lambda at any distance x. If I am interested in p prime, I have p prime is equal to p hat into sine of 2 pie by lambda x, this gives me the type of compression and rarefaction which I can describe by p hat equal to p p prime equals to p hat into sine 2 pie by lambda x.

What is said is the wave has disturbances travelling and this disturbance is travelling in the speed of sound. If the speed of sound is let us say is 0, let us say now the wave is travelling at the speed a 0, how do I represent it? Now, I have to take into account the way which is travelling, let us put together on this part of the board.

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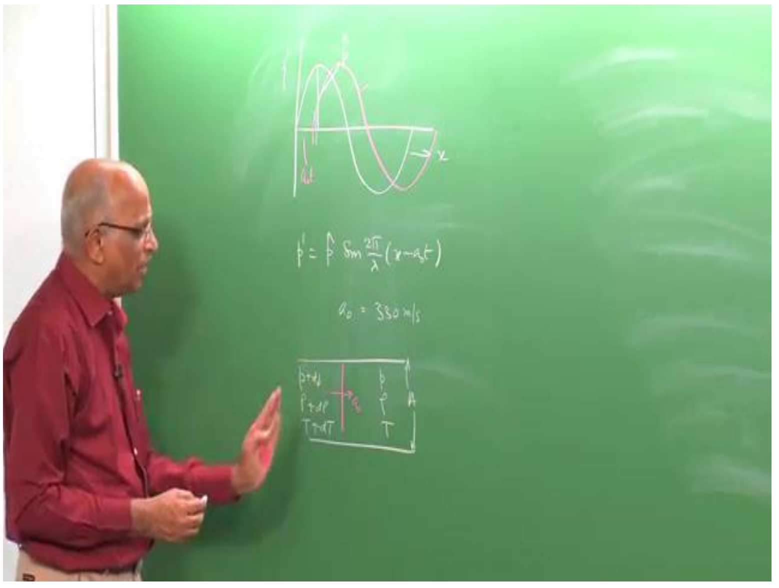

This is now x, this is equal to the disturbance p, initially we said well this is the compression and rarefaction over here. Now, this is equal to p hat over here the maximum amplitude what happens the wave is travelling at the speed a 0. Therefore, at time t may be over a time t starts at 0, therefore at time t, the distance is travelled would have been over here. Therefore, now the wave progressively shifts over here come over here it comes over here and reaches over here.

This is the amplitude or the wave form at a time t where in this distance is equal to a 0 into t because over a time t travels this particular distance. Therefore, the equation format might before any point over here for this x is going to be p prime is equal to p hat were p hat is the maximum amplitude into sine of 2 pi by lambda in to x minus 80. Therefore, the way which reaches me and supposing am somewhere over here, this disturbances and I hear it as sound as simple as that. Now, what is this velocity we say the sound velocity a or let us say a 0 as I have been telling and a 0 is the sound velocity which all of us know and under ambient conditions which is around 330 meters per second.

Maybe in gases having low molecular mass the sound speed is higher, maybe in metal the sound speed is higher may be in water, it is also higher the order of almost nine hundred to 1,000 meters per second. How do I get this expression? How do I find the expression for the sound sped, therefore again in tell to myself this is the way the disturbances propagate. Now, I have a pipe of some area cross section maybe I have cross section of pipe, let us say a and let us say a sound wave travels at the speed a 0. Now, the medium ahead of this is at condition, let us say p it is condition density low pressure is p density and the temperature is t and what happens when sound propagates into this medium.

It changes the pressure slightly there is some disturbance p prime at any point it could be positive or negative may be I have wrote as 0 the density changes as the pressure changes the density also changes the temperature should also changes slightly. Therefore, I tell to myself that the effect of the propagation of sound at a velocity a 0 is to change the properties of the medium romp to p plus d row to row plus d 0 t to t plus t over here.

Now, I want to write an expression I want to calculate how these sound speed changes with pressure temperature and density and to be able to do that I write the momentum of equation I write the continuity equation. Let us see what is the continuity equation should be well I have the wave which it is travelling and to write an equation the wave is travelling is difficult. Therefore, I try to write an equation with the frame of the reference of the wave itself rather I sit on the wave.

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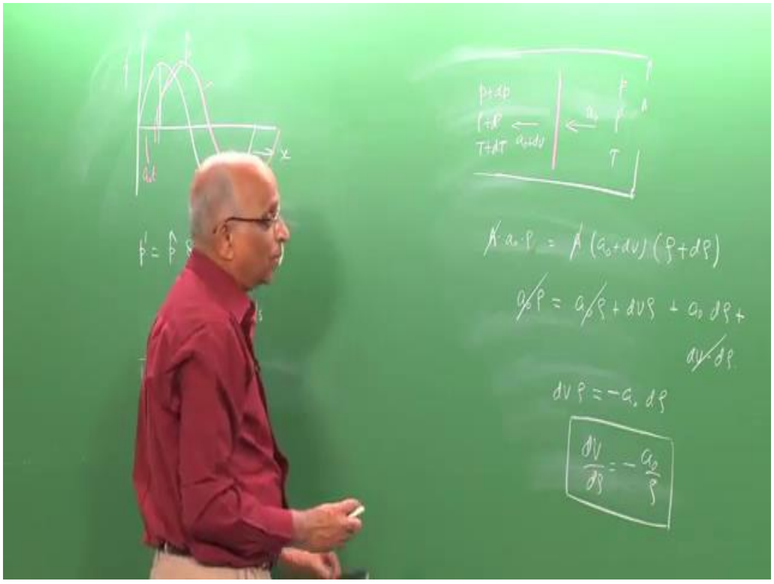

In another words, in the reference of the frame of wave itself that means now I keep the wave stationary. Once I say I am sitting on the wave that is with reference to the wave I am writing the equations the medium at pressure p density row temperature t travels towards the wave at the speed a 0. Here, it was not the medium was stationary, it was not moving, now with the wave stationary well the medium moves towards the a 0, then over here I have a 0 plus d v over here and because I get a small velocity over disturbance over here, d v over here. The pressure now becomes p plus d p as earlier density is row plus d over here at the temperature is t plus d t over here.

Now, if I have to write the continuity equation and continuity equation is very easily written in the frame of reference of wave because it is now stationary medium is moving. Therefore, what is it I find in the cross sectional area of this pipe is a, then the mass which is moving towards is a into a 0 into row 0 is the mass which is moving towards this and which is moving away from the wave is equal to a into a 0 plus d v. I have density which is now row plus d over here now I find get cancelled and therefore now I have row 0 row 0 of a 0 into I just used the word row not the row 0 over here a 0 into row is equal.

I expand this I get a 0 row plus d v row plus I have a 0 row plus d v row plus a 0 in to d row plus I also have the last term namely d v into d row, but if the disturbances associated with the sound wave are very small. Well, d v is small d row is small I can neglect the second order straight and therefore if I write the look at the equation a 0 a 0 row a 0 row get cancelled and I get d v row is equal to minus a 0 into d row.

Rather, I can d v by d row is equal to minus a 0 by row, this is from the continuity equation for a wave propagating. Now, I am interested in calculating the value of a 0 well I do not know velocity changes and this may be I would not like to look at the momentum equation. What is momentum equation, we use the newton’s second law the rate of change of momentum is equal to the impresses force and what is the impressed force d into the area.

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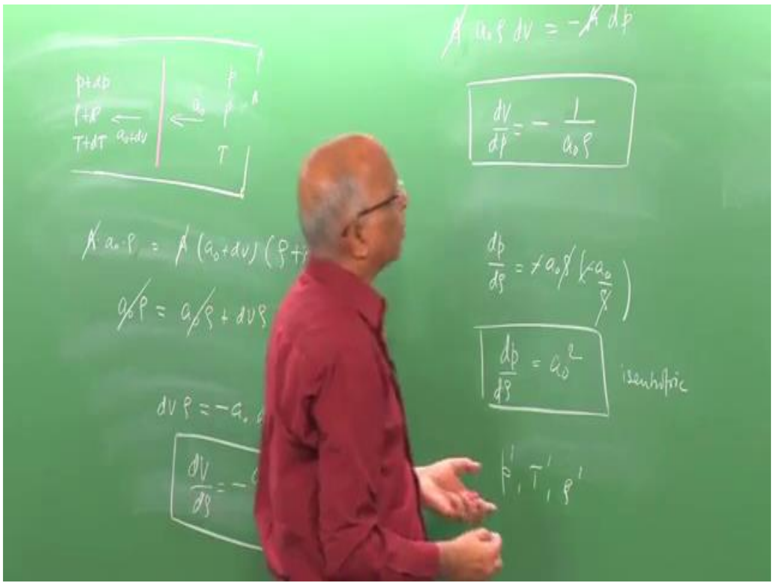

The rate of change of momentum, the mass a mass rate is a into value a 0 into the value mass floor rate of change of velocity is d v the rage of change of momentum is equal to the impressed force impressed force is to pressure into. The pressure acts opposite over here for I get is equal to a that is the area of the pipe a over here a 0 into d v is equal to a into d p over here rather a and a get cancelled.

I get d v by d p is equal to minus of d v by d p is equal to minus a 0 into row over here, this is the momentum equation, I will put the continuity equation and the momentum equation together. Now, if I take the inverse of this I get d p by d v is equal to minus a 0 row and I multiplied by this I get d p by d row is equal to minus a 0 row because I have d p by d v I multiply by this. I get into minus of a 0 by row or rather I get d p by d row minus and minus becomes positive and I get d p by d row is equal to a 0 square. Therefore, we find sound velocity can be given d p by d row is equal to a 0 square of course this implicitly assumes and amplitude of wave motion including p prime p hat are very small size.

So, I can neglect the second order it gets over here now if I look at this particular expression d p by d row is equal to a 0 square I will not be still able to rely I would not be still able to relate to the properties of the medium. Now, I tell now the amplitudes of the oscillations or the disturbances are so small that it could be reversible what it could mean well the value of p prime the value of t prime or d p d t. Let us say d row call it is d prime t is t prime d t is t prime d row is row prime are so small, it could go either way that means it is some more reversible and medium like air is something like an insulator and when it is an insulator there is no heat transfer.

Therefore, I can tell myself well the preservation in pressure with density and temperature is so small that it could be reversible. Well, not only reversible air is a air is an insulator therefore, there is no heat transfer, therefore the process of sound propagation we say is both reversible as well as adiabatic. It means it is isentropic and therefore, I can say well d p by d row is equal to a square would be for an isentropic process of sound propagating and for isentropic process well I can write p by row to the power gamma is a constant.

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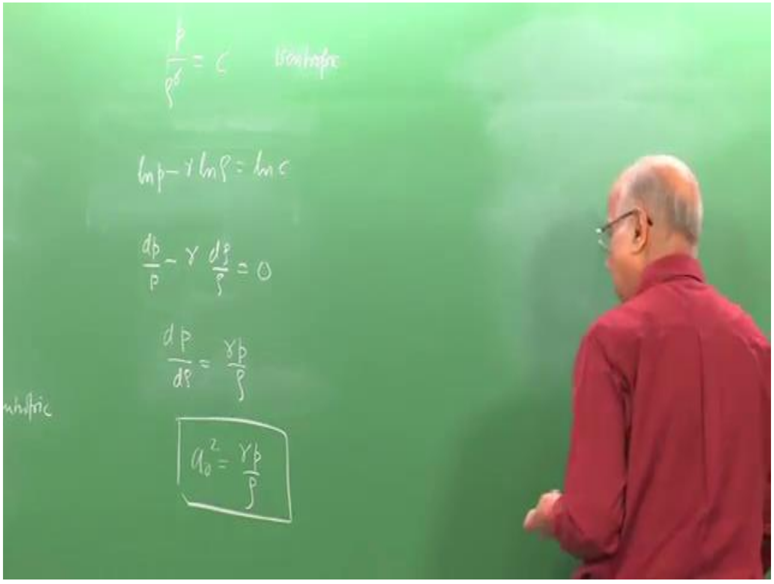

Let us try to change it again p by row to the power gamma is constant or an isentropic process. Therefore I can write it as long p minus gamma long row taking long on both sides is equal to long c I differentiate this I get d p by p minus gamma d row by row is equal to 0 constant is equal to 0 is differentiated. Therefore, I get d p by d row is equal to gamma p by row, therefore for the particular case may be when I talk of small amplitude waves and sound waves of or of small amplitude.

I can write the sound speed a 0 square is equal to d p by d row which is equal to gamma p by row and therefore, I have the expression for sound speed a 0 square of this sound speed is equal to gamma p by row. That means you know I am able to relate this to the pressure to this medium to the pressure to the density in the medium. We know for medium like air which is which can be assumed to be an ideal gas or a perfect gas well and ah and a perfect gas in which the specification are also constant.

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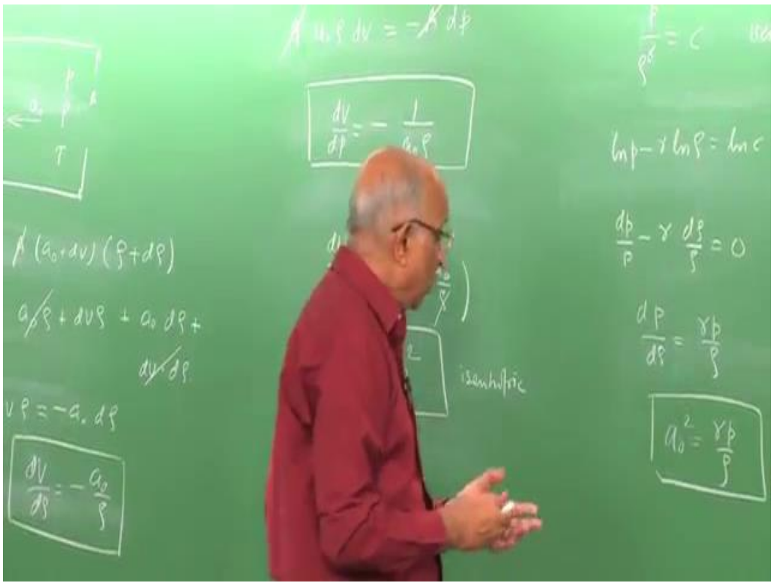

Well, I can write p is equal to row or t rather I get the value a 0 square is equal to gamma r t rather the value of sound be equal to under root gamma r t. Therefore, I am able to relate the sound speed to the temperature of the medium, so well we can tell the pressure it is equal to the ratio of the pressure to the density which is the square of the sound speed. Having said that, well we tell ourselves that if I were to calculate r is the specific gas constant you know the r is joule power kilogram kelvin t is the temperature.

The value of sound speed at the temperature around let us say 300 Kelvin gamma for air 1.4, this works out to be three thirty meters per second well. Therefore, we say well we say the sound speed depends on the temperature it also depends on the pressure for an ideal gas I related over there.

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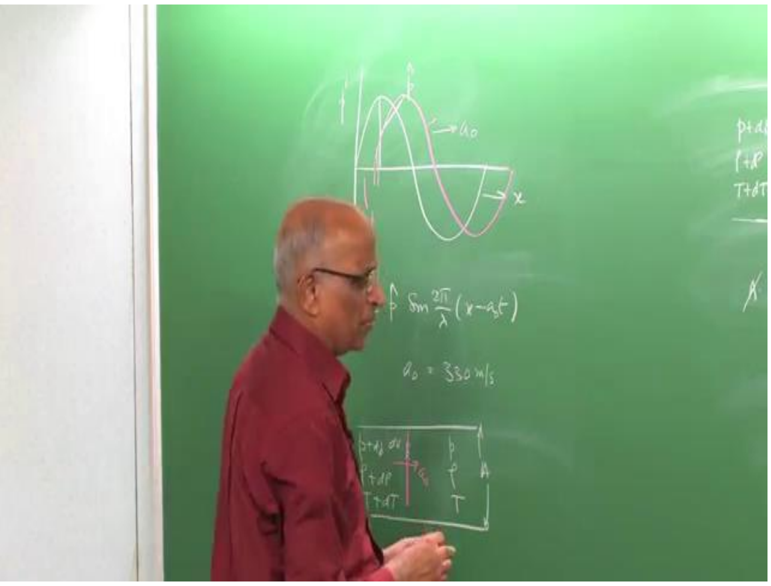

Let us look at the propagation again well the sound wave propagating at a speed a 0 and whenever you have pressure disturbances, I have temperature disturbances how do I get the magnitude from the temperature disturbances pressure disturbance is the question. Let us put it together to try I am able to relate the sound why in some cases I have loud bang and in some cases I have this music from the flute.

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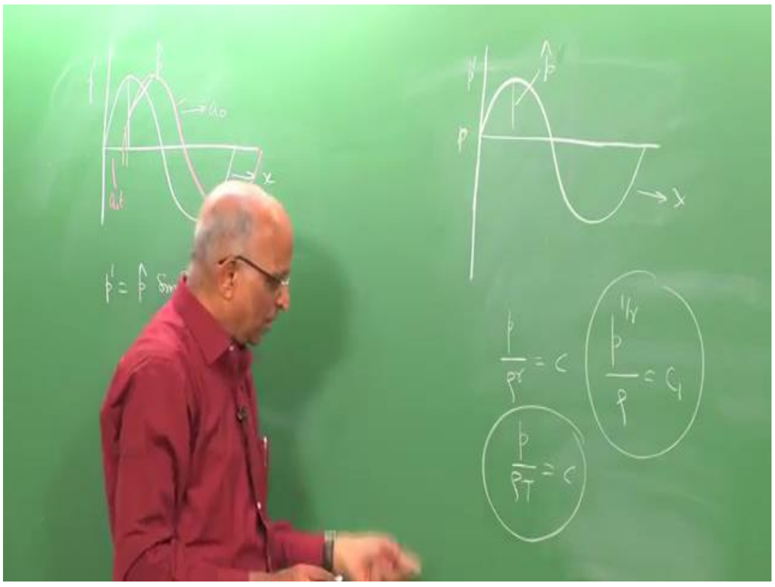

Well, I now plot well this is my wave propagation of disturbances I just take one wave length this is the value of p prime, this is the value of p hat this is the value of the pressure of the medium. How it is propagating in the x direction associated with the pressure disturbances I also get with associated with temperature disturbances and how do I get the magnitude of the temperature disturbance.

Well, I again say the propagation of the wave is isentropic therefore, I write p by root to the power gamma is a constant. I also know from the gassy equation by p by root t is a constant sell this equation I can write it as equation as p to the power 1 to the gamma divided by a row is a constant. Let us say c 1 is use this equation alone with this equation now you know I am interested in getting rid of density because I want to find out the magnitude of the temperature oscillation, therefore I divide one by the other.

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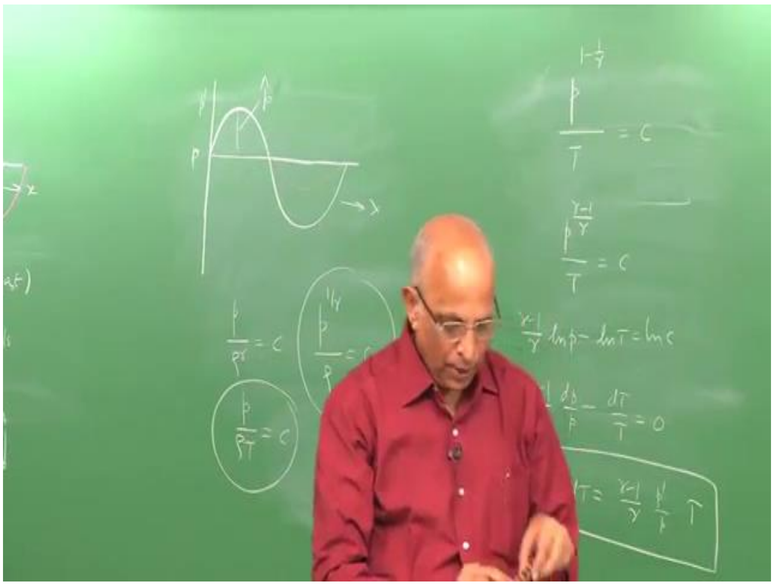

Therefore, what is I get I get p to the power over here 1 over gamma I will divide this by this I get 1 minus 1 over gamma and row gets cancelled because I dividing the row comes on the top divided by t p by t divided by the t to the power gamma row. This is equal to constant rather I get to the p to the power gamma minus 1 divided by gamma by t is constant. Again, I take the logarithmic differentiation I get gamma 1 minus gamma into long p minus long t is equal to long c I differentiate, I differentiate this I get gamma minus 1 by gamma in to d p by p minus d t by t is equal to 0 right hand side being a constant.

The differential or rather I get d t is equal to the value of gamma minus 1 gamma into d p is the small pressure disturbance p prime by p into I get the value of t over here.

Therefore, we are able to find out whenever there is a fluctuation, well I get a temperature fluctuation t prime is equal to d t. Therefore, I get temperature fluctuation over here, but mind you whatever we did we did for very small amplitude wave such as sound wave and which propagate is entropic ally. Now, I tell myself well I know little bit about the propagation of sound in a medium which we just reviewed over here. Now, I want to, supposing by chance the amplitude of p prime p hat is large what could happen let me let me start with an example.

Let us say blowing in to flute to make a particular sound over here I take a balloon Let us say and into this balloon instead of blowing constantly into this flute I blow air into this balloon I keep on blowing air into this balloon. That means what am doing is I am increasing the potential energy of air into the balloon I am pressuring the air over here the temperature may still be ambient the pressure is higher, it has a potential energy. So, keep on blowing and when I blow when I am making this balloon sufficiently large and the fabric of the balloon is unable to contain, what is going to happen?

Well, it is going to burst as well you know the fabric is strong it holding the pressure, but I keep on blowing it just going to burst and am going to here a sound wave over here. This sound what appears as thud or a bang why should it happen, let us try to understand more about this particular equation you know what happens in this case for a sound wave. The amplitude of pressure is small may be if I can contain the energy which is realised at the source like the flute over here. You know what did I do I take I deliver some energy over here which is propagating as sound wave instead of that. I have a large amount of volume here or large amount of energy here, which liberates the energy all of a sudden then what is going to happen, let us try to what could happen over here.

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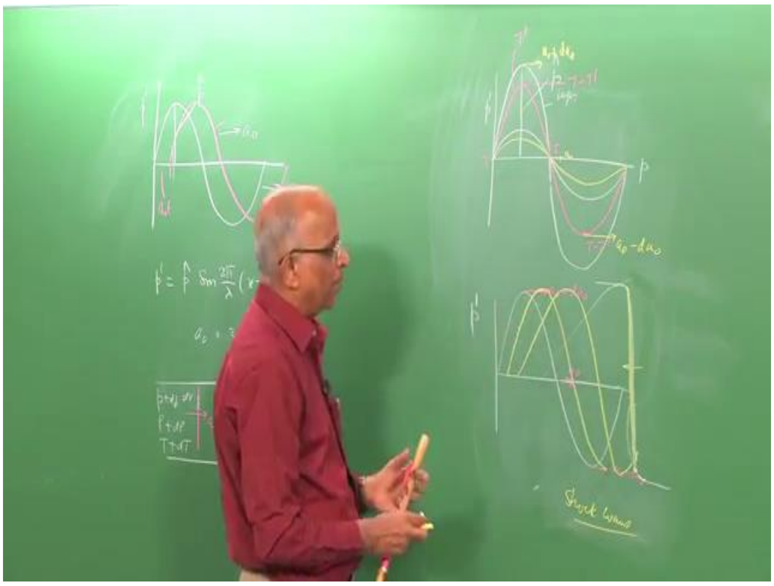

You know in other words previously I have a sound wave p prime over here the ambient pressure is p I have compression and rarefaction over here. Now, what is it have done instead of small amount of energy I give a larger amount of energy, therefore since the larger amount of energy is given the that is the amplitude the p hat of my wave grows. This is what it is look at when I have larger amount of energy being released over here a sort of I have a larger amplitude over here. Therefore, what is going to happen I have a larger amplitude and therefore, if I have to look up on temperature disturbance previously.

Let us say I got the temperature disturbance may be associated with a sound wave type of temperature disturbance, what I have and when my amplitude is higher. Well, the temperature disturbance is also going higher somewhere here shown by their d line over here. Now, what is it I find well this is my t prime over here over the base t over here and now crest of the wave now the amplitude is large has a higher value of temperature equal to t plus t prime here. The temperature is still the ambient value there the temperature is going to be t minus t prime and what did we find we found that the value that means the pressure is higher my temperature fluctuation is higher and slow.

We found we just derived this expression namely the sound speed is proportional to the temperature therefore, what did I find I find that the wave here moves at a higher value of sound speed compared to value of sound speed. Here, if it is a 0 here it is going to be a

0 plus d a 0 over here because the temperature is higher, it moves faster it is going to move slower over here it is going to be a 0 minus d a over here d a 0 over here. Therefore, what is the effect let us try to re plot it such that they are very sure about what is happening. We therefore have p prime we have x over here well I have a larger amplitude in pressure over here. Therefore, I find that the speed over here is equal to a 0 here d a 0 the speed here is a 0 the speed here is equal to a 0 minus da 0.

Let us make sure that we make this arrow corresponding to its speed little bit higher over here this is normal over here this is smaller over here. Therefore, after a small time when the wave has come over here what is going to happen this point is larger this point moves just a 0 here. Therefore, the wave form looks something like this its gets little distorted well this fellow does not go very far and therefore it comes over her comes over here it comes over here and then it comes. Now, what happens, the wave has got some what steepen its no longer symmetric, but this is steeper and as it progresses.

Further, what is going to happen it is going to become more and more steep and steep which is going to become like this it becomes even steeper something like over here and ultimately what is going to happen this is going to become like this. Therefore, it is going to become almost plane, that means it goes like this it comes like this it becomes steep like this and therefore, instead of having a smooth wave front in which I have a smooth compression followed by a smooth expansion. I have all of a sudden wave becomes steep like this well you could tell it could also become something like this like this and it moves much faster at a particular point at a particular point I cannot get three different values.

Therefore, maximum what will happen is this it will become steep like this and therefore, when the initial amplitude of wave is large the wave steepens something like suddenly it becomes a spike like this. This is what we call as a shock wave what is attribute to the short wave well it is a steep front wave across this across which there is a sudden change in property, here in change in property gradual. Here, the change in the property was gradual, whereas what is here happened from here all of a sudden I go to a particular property over here.

There is a sudden jump in property and this sudden change in property sudden this wave in which I have steep fronted wave that have in which there is a sudden change in property is what we call as the short wave. The velocity of this wave is at higher speed and therefore, it propagates the speed higher than the sound speed and therefore we tell our selves if the localizer energy release is such that I can instead of forming a sound wave if I form a large amplitude wave. Well, I could have something like that short wave and the attribute of a short wave is well it propagates at supersonic speed higher than that.

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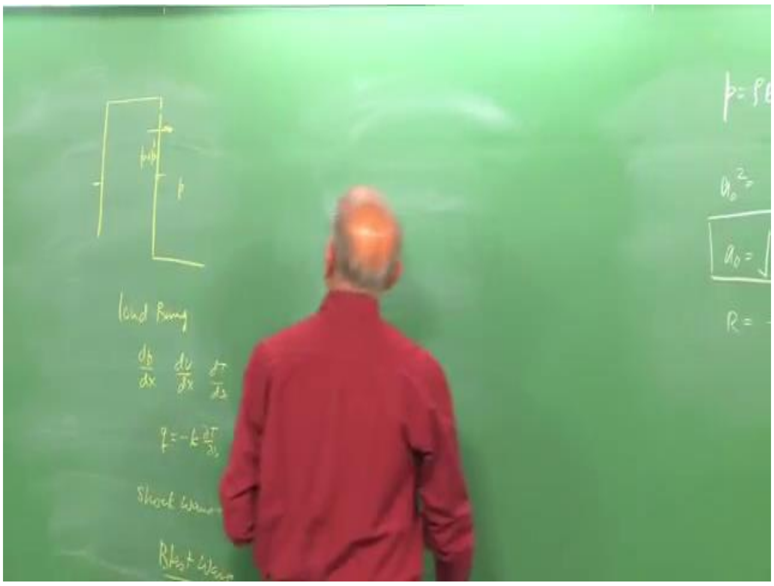

Moreover, it is something like a front here it is very steep where I have p all of a sudden it becomes p plus p prime over here the p prime is also large and this sudden change is what we experience as a loud bang. All of a sudden you have a high pressure and you characterize it as a loud bang and there is another aspect to this you know not only due to pressure all of a sudden a jump to a high value, but you know there are great gradient pressure. That means d p by d x I have gradient in velocity d v by dx that means along x I have d t by dx which is very high because all of a sudden there is a change. Now, I have heat transfer is equal to minus k into d t by d x heat generation with in the wave, I have sheer forces due to the velocity gradients.

Therefore, what is going to happen because of these gradients the magnitude that means the jump conditions are going to decrease. Therefore, this wave as it propagates going to decrease in amplitude rather instead of having wave which travels at the constant speed a 0 I create a wave which travels at a speed supersonic speed. This speed will keep on decreasing with time not only does it decrease because of dissipation, but what is going to happen I have a wave like this the here I have compression, here I have rarefaction. The rarefaction is travelling in a medium with high temperatures this rarefaction is going to catch up with the front end and decrease the amplitude of the front.

Therefore, the strength of wave is going to keep decreasing such a shock wave whose strength keeps on decreasing gas it progresses forward is what we call it as blast wave. This will consider the details of the blast wave in the next class, but to summarize at this particular point I would like to say the following.

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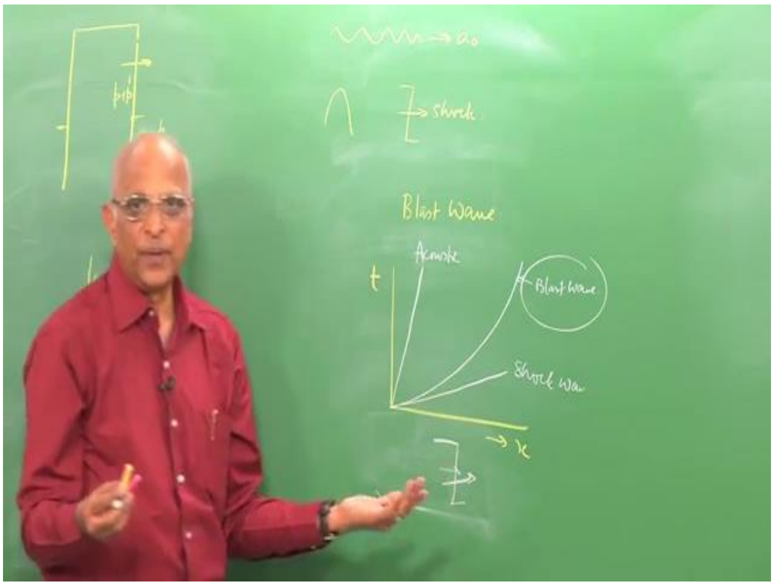

Whenever we talk in terms of sound speed we talk in terms of let us say a disturbance propagating at a small velocity a 0. Now, if the amplitude of the disturbances are large such as ii release some energy instantaneous at a point I start with the large amplitude and intensify it a short wave. Now, this short wave what happens this keeps decaying as it progresses further rather the velocity keep decreasing and this decaying short wave what we call it as a blast wave. If I want to put it together in graphical form may be in a form where I have the axis over here t I show the time on this axis, I show the distance over here.

Well, what is going to happen well the acoustic wave travels at sound speed a 0, this is the sound wave initially ii start with a strong shock travels with much faster. Therefore, this may be my shock wave the shock wave, therefore this is my acoustics wave or a sound wave this is what I call as a shock wave travelling at high speed.

The shock wave decays with respect to time and this becomes blast wave therefore, the blast wave is a decaying shock wave the pressure continually decreases with in this because of this changing pressure. I have wind or blowing of air in to this and that is what we call as a blast of air and therefore, a blast wave is associated with air moving at high velocities. Therefore, what happens a blast wave is a finite amplitude wave all of a sudden it takes place and here a loud bang and the velocity behind it or the blast behind it disrupts the thing.

That is what causes an explosion, therefore an explosion basically categorised by a sudden phenomenon namely having a blast wave and the blast wave has a pressurize across it travels at a supersonic speed. All of a sudden the incidents happens that means there is a sudden over of pressure that there is a wind set behind it that is the blast effect and this blast effect disrupts the thing. Therefore, to come back to the point that we were started is well an explosion is categorised is or should be capable of being heard or rather we tell ourselves to summarize what we started with today we tell ourselves.

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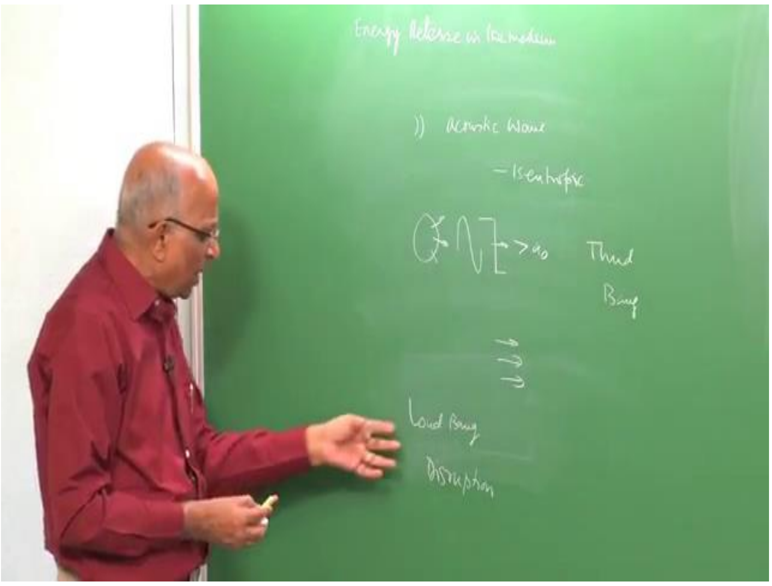

If I have energy release in the medium which creates a small disturbance like am talking to you like my throat is creating some disturbances the compression and rarefaction from it reach you as sound wave.

Well, I have something like acoustic wave instead of creating small disturbances and these small disturbances we say isentropic in nature what I do is I create much larger disturbances to create much larger disturbances. I took the example of a balloon may be I put lot of potential energy into it and burst it all of a sudden the energy gets released here. Then, this energy get realised I start having large amplitude wave which found something like steep fronted wave that have a speed greater than the sound speed over here. If it is not supported by the continual energy release, what happens it gets decaying as it progresses because of dissipative effects at the wave front because of this steep because of the high gradient in velocity is no longer gradual in continuity.

We hear it as nice music or nice sound, but here as a sudden we hear something like a thud or like a loud bang and in addition to this bang because it is decaying the pressure gets changing. They have the wind effect the blast wind affects and at the zone of explosion the wind effect scatter or disrupts the thing. Therefore, an explosion is associated with a loud bang and disruption of things from the place they from the place of explosion. Having understood this, what we should do is we should look at more characteristics of a blast wave and in the next class, what we do is I will take a look what are the how to model this blast wave.

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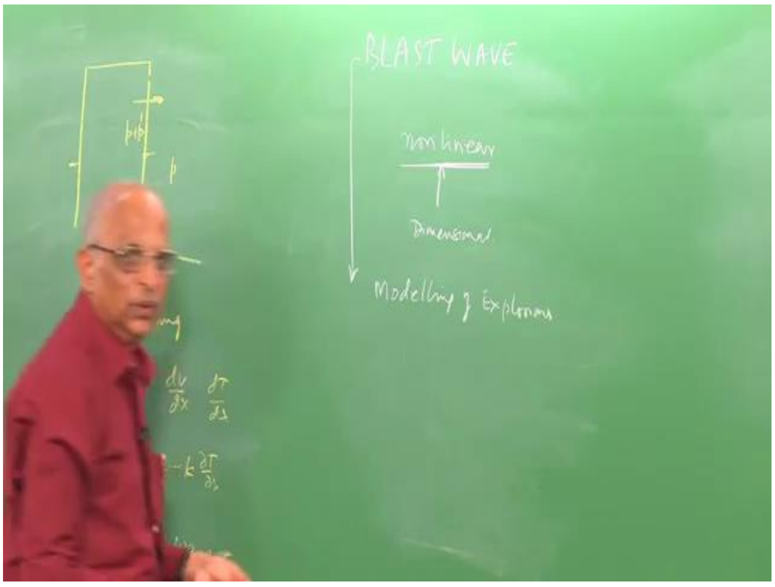

Well, it is not that simple for the reason let us let us put some features in to it, then what is going to happen a blast wave if I were to write over here what is created by a finite energy release a sort of non linear. What you mean by non-linear, you know it is something which is not like sound which can go either which is sort of organized regarding something sudden happening over here. That is dissipation of energy taking place and as the blast wave is going the strength is changing.

Therefore, it is highly non linear phenomena and therefore, in the first part what we do is since the problem tends to be complicated. We will do some simple dimensional analysis to be able to have some idea of the blast wave and then we will go into different types of explosions. We will study what are the different types of intentional explosions what are the different types of natural explosions accidental explosions. Then, we will come back to the problem of details of blast wave and modelling of explosions.

Well then, thank you.