Introduction to Explosions and Explosion Safety
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Lecture - 39
Quantification of Damages in an Explosion: Dose Response Curves, Probit and Probit Parameters, Examples

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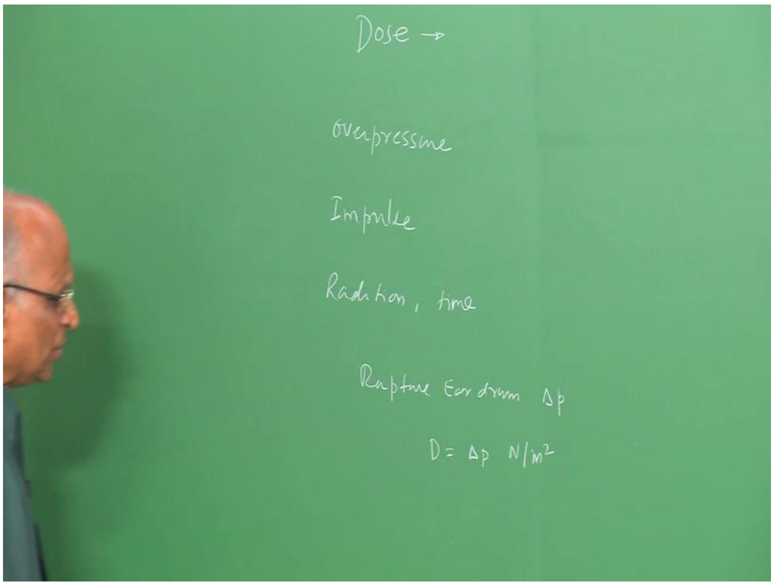

Good morning, you know while addressing the quantification of damages in the last lecture, we introduce the term dose. We said dose consists of may be one or two parameters, which describe the consequence of an explosion namely like for instance from an explosion you have an over pressure, may be you have the impulse. Well you could have something like heat radiation from my huge fire ball in the after math of an explosion or else you should also you could also have effective time over which the fire ball loss.

And may be either singly or collectively like in some cases where overpressure and impulse could result in toppling a person or in damaging a building or over pressure alone could result in may be leading to the loss of hearing like rupturing the eardrum. Therefore you know you could have different types of consequences of the explosion these are the parameters, and one or two of them are more combine together is what we called as a dose.

For example, let us repeat this again. Supposing we say, well the hearing that is let us say rupture of the ear drum. Ear drum is something which responds to very high frequencies, and therefore over pressure delta p from the explosion is sufficient to burst it or rupture it. Then in that case, we say well the dose can be represented by over pressure in Newton per meter square. We also said may be when we look at different dosages or different over pressure, and what did we tell?

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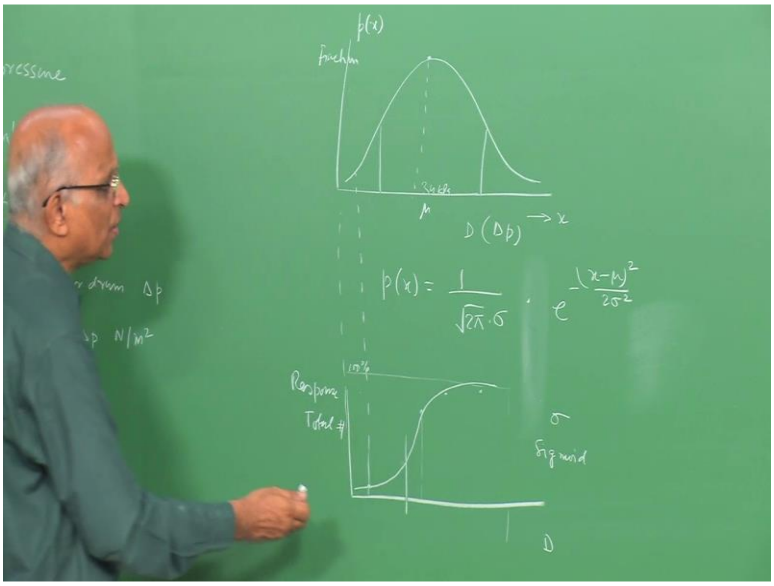

Well I could plot, let us say the dosage in terms of the over pressure delta p in this particular case. And I say, well if you have an over pressure of the order of let say 34 k Pa, then may be many people lose their hearing, but we also said some are more vulnerable than others, for in some cases may be a lower level itself causes the ear to get or the eardrum to get ruptured. In some cases may be people are so resistant that even a larger value of overpressure they can withstand. Therefore we say, well this is the fraction or we said that the fraction of people, who are getting affected.

And this is something like a Gaussian distribution, and we said well I could represent it by if I denote this scale as x. And this fraction has a probability fraction, I could write it as Gaussian distribution has equal to 1 over root to pi into sigma into, well this is the mean value who get affected at this value, this is a mean, we get e to the power minus x by mu x minus mu whole square divided by 2 sigma square into d x, well I am talking in terms of a probability fraction therefore there is no integral, it is just into exponential of this, this node d x had the therefore the probability is this, and this gives the probability fraction.

Now, what is it we are saying well, some people get there ear drum affected at a lower value of over pressure, some are resistant even at a higher pressure. And if we were to take a look at the symptoms of dosages, well an average dose is 34 k Pa over pressure, some have it at lower value some have their hearing impact at the higher value, and what does this give us you know let us take a look at it. If I am going to take a look at the total response or the total number of people who are affected, then I say well I again re plot this figure over here.

I say well I am not talking of the response or rather the total number of people who are total number of people who are getting affected. Well for this low level of over pressure, a small number of people get affected, at this value well some more get affected, this plus this much gets affected, for the mean well some more people get affected. And now we have going, well the increment is little smaller, the increment get smaller. And therefore, the total response or the total number of people who are getting affected goes as may be something like this.

This curve is something like a sigma that is the let us sigma, and it is we call it as sigmoid, and this gives the total response as a function of the dosage d, and it has a sigmoid shape. Now, the total response for a given dosage, well this is for this dosage; well this is the number of people who are affected. Well, when the dosage is extremely, extremely large, well all the people are affected this is100 percent over here.

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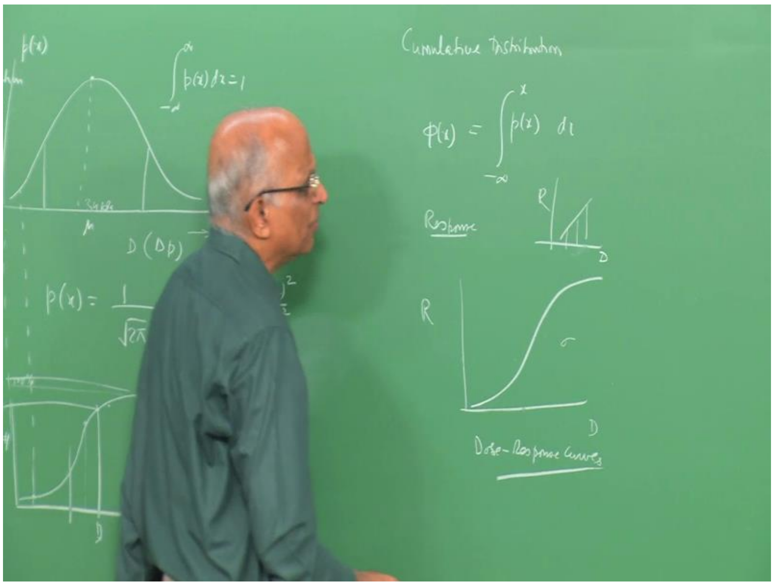

And this is something like a cumulative distribution, rather the total number which we called as cumulative distribution, and what is this? Cumulative distribution function compare to p (x) which is the probability distribution function or a Gaussian distribution function over here. You say p (x) going from minus infinity to x d x is what we call as a cumulative distribution function or rather here the total response is nothing but may be up to this up to this level let say d 1 over here, this is the cumulative number up to here, it is the cumulative number.

And therefore, this cumulative distribution is minus infinity to x, because on the left hand side, I start from minus infinity to the right side of plus infinity, because the total value of in this particular Gaussian distribution is minus infinity to infinity of the standard distribution function, the area under this curve is 1. Therefore you have the cumulative distribution given by pi x is equal minus infinity 2 x of p (x) d x. And well, the cumulative distribution function is the total response.

Therefore for any dose, like we have in this case we are talking of over pressure may be I could have a dosage, and the dosage for may be radiation could be something like intensity of radiation to the power 4 by 3 into the effective time over which radiation is that, I have a similar figure. In other words, I call this as a dose and then I plot, well the cumulative distribution function tells me response or the cumulative value as a function of dosage, well it looks like this.

We have a series of such curves, and these are known as dose response curves, the thing to notice all the dose response curves are something having a sigmoid shape, and therefore had some ((Refer Time: 08:00)) non-linear. We would like to make use of the dose response curves, and still define the or quantify the destruction due to an explosion, and that is what we attain, is it possible to have another parameter which does not have this non-linear shape.

And some what can I have something like a shape where in r, what is a sigma is little more uniform or little more linear, such that I can always use such type of response over the dose curves. You know, since that dose response curves tends to be important not only to get the hazard of the explosion, but also find out the acceptable doses at which the response is smaller, you do not have many people dying or many people getting affected or many buildings being shattered, you know since these dose response curves are important.

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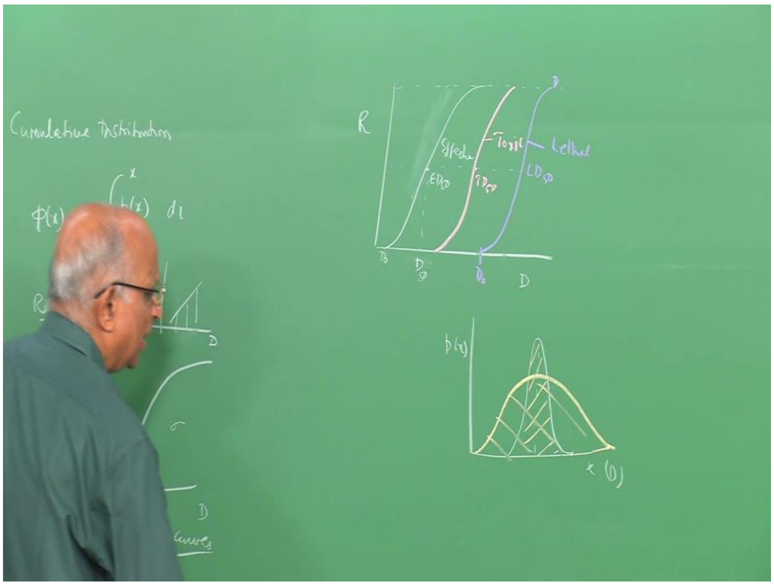

We also looked in the last lecture, at the value of response verses dose. We talk of a very heavy dosage where in things were prattled, this is let us say100 percent line, and when we had a lethal dose that means people dying, well the curve was like this that means, you had this is the starting point at which may be people started dying, this point at which all the scent percent everybody to get finished. We have in between a 50 percent line at met we called it as a lethal dose 50, because this was the lethal line for the dosage.

We also add another curve which we called as the E D line, sort of the effective dosage. And the effective dosage the shape was little different, that shape was something like this little, little more, this is almost vertical. This went more like started gradually had a longer range of dosage, and this was something like effective dosage 50; that means 50 percent of the people got affected at this level of dosage that is D 50, the D 0 for effective dosage is here, this is the value correspondent to100.

When we say effective dosage it means that yes people are affected, but the influence on people could be reverse by treatment and all that, and therefore we got called it as effective dosage. In between the E D effective dosage and lethal dosage, we could have something like a toxic dosage, this is mainly from spills where in may be some permanent harm is done, here also you have T D toxic dosage 50, this is the toxic dosage you have a lethal line, you have a toxic dosage line, you have the effective dosage line over here.

Now, if you see these 3 curves you know the level of dosage in the case of toxic or in the case of lethal dosage is very high, because apparently you are finishing, it is also steep. Therefore if I will to plot, the probability distribution let say p (x) as a function of x, x denoting the dosage D, what is it we will get in this case. In the case of the toxic dosage, well these curves would be somewhere over here, this is the shape of the Gaussian distribution. Whereas, when I talk of effective dosage, well the curve will be little more smooth little more uniform something like this.

Well in this case may be the standard deviation or deviation is larger standard dilation is larger, in this case standard deviation is smaller. Therefore, you know whenever we talk of high values and the small range over which, the entire dosage affects the response, and they are interested in rows in terms of the response verses the dose, dose response curves. You know in this case also the area under both the curves is unity, but in this case it is much more peak over here that means, a small range of high dosage cause the lethal effect, large range of dosage in this case causes the effect over here.

Of course, whenever we are talking of dosage, the dosage here is different from the dosage over here, the two curves should not be drawn on the same axis, but this is what I have drawn over here. Therefore, what I find is, well this is for the lethal dose, this is the distribution over here; this is for the effective dose over here. Well mind you as I say the x axis in the two cases are not the same, you know it becomes necessary for us before we go further to be able to look at the standard deviation in some detail, because as I said you know the range here is smaller, whereas the range here is larger. Therefore, let us take a look at standard deviation in the context of let us say the Gaussian distribution, what is the standard distribution really represent?

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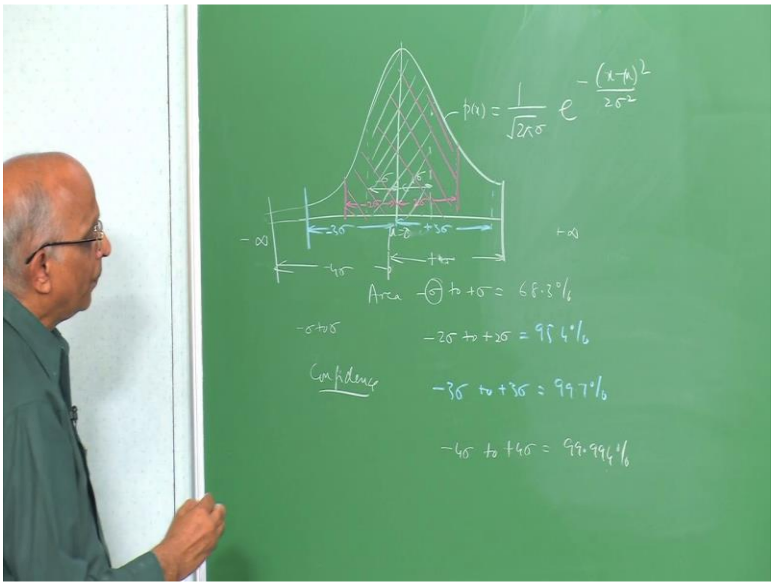

You will recall we had talk about it when we discuss atmospheric dispersion. And now if we take a mean value mean is 0 let us say, and we say well I have a Gaussian distribution p (x) over here, this is equal to p (x) which we said could be written as1 over under root 2 pi sigma into exponential of minus x minus mu square divided by 2 sigma square. Now, we know what is the standard deviation represent?

Well, here I have a standard deviation, here I have a standard deviation I say this value is minus sigma; this value is plus sigma over here. I take twice the value that means, I take another value here which is equal to this distance this I say is equal to minus 2 sigma, and similarly I take a value another sigma over here, well this becomes 2 sigma. I still do one more exercise, I take 3 sigma, sigma plus sigma plus sigma this becomes 3 sigma over here minus 3 sigma to something like plus 3 sigma over here, what does this sigma represent?

If I take the area of the curve, and I take the area of the curve between minus sigma to plus sigma in the standard distribution that is the Gaussian distribution, then that is the standard distribution. The area of this curve comes out to be equal to area between minus sigma to plus sigma is equal to something like 68.3 percent of the total area, mind you that the total area from minus infinity to plus infinity is 1, this is 68.3 percent of that. If I take from minus 2 sigma to plus 2 sigma which means, I take the area of the curve between this minus 2 sigma that is from here to here.

The area of the curve is something like 95.4 percent; between minus 3 sigma to plus 3 sigma, the value is something like 99.7 percent. Well I can keep on doing this may be I go to 4 sigma let us say, I go to something like 4 sigma over here minus 4 sigma to the mean to plus 4 sigma over here, I take another sigma over here 4 sigma. The area of the curve minus 4 sigma to plus 4 sigma, this is something like 99.994 percent that means, I am covering almost the entire distribution, what is the physical significance of the standard deviation?

Well the standard deviation is something which tells, now if I have to do an experiment let us say an experiment in a lab, and I say well my certainty my confidence in the experiment is between let say minus sigma to sigma level, which means that is my confidence is up to the sigma level. Then I mean, I am sure that my experiments are certain within 68.3 that means the chances of if I do any other experiment, most likely 68.3 percent of the times, the point will lie within the range what I have done or within my particular experimental times, that means it tells us something like the confidence.

But, we must also remember that when we are talking of sigma, we are going along the dose axis or along the x axis. Therefore to a large extend when I come back, and look at this cumulative distribution that means the response over here. If my value of this value you know, we are talking of sigma values which have somewhat smaller that means, may be my minus 3 sigma to plus 3 sigma is within this that means, it is a very mocked sort of a distribution is like this compare to a distribution like this.

But, since we are talking in terms of cumulative distribution, and our importance is not on sigma alone, but on the rows response dose upon the dose verses the response curve. I would like to still try to see, whether it is possible for me to have something like linear relation between the dose and the response.

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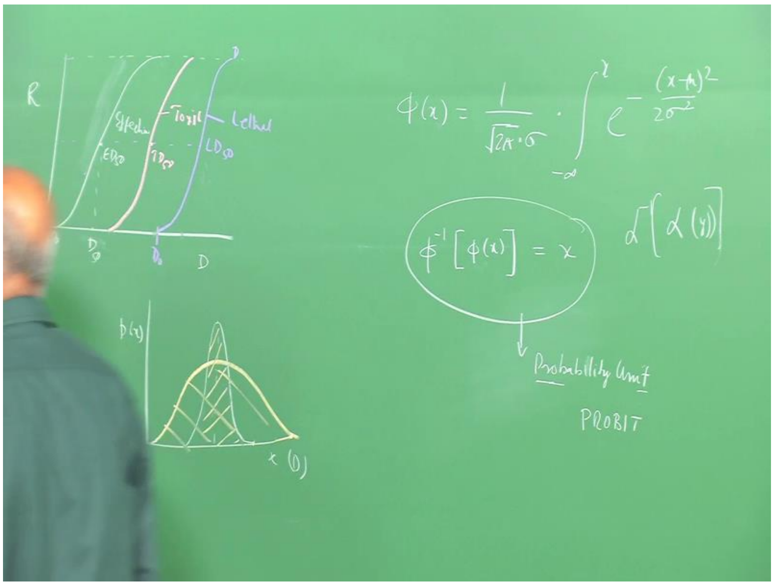

For this I again revisit the cumulative distribution, what I do is? I say well phi (x) is equal to 1 over root 2 pi of the standard deviation, mind it we again come back we will come to standard deviation into minus infinity to the value of x over here into e to the power minus x minus mu whole square divided by 2 sigma square, this is the value of the cumulative distribution. Now, if I can have a transform, something like I transform my cumulative distribution by taking inverse of it itself, rather I say if I can take inverse.

I can take inverse of the cumulative distribution itself phi of phi (x), you know what is it

I meaning. If I see phi inverse phi x I know the answer is x, like we take Laplacian transformation, and I take inverse of the Laplacian transformation of let say y. Well, I take the Laplace transform, and I take inverse of the Laplace transform, so also I take the cumulative that is inverse of the cumulative distribution, and I take inverse of the cumulative value that means, I take inverse of the cumulative of distribution of the cumulative distribution itself.

I get back my x axis, and along the x axis is what we have is the something like the standard deviation along the x axis. Therefore, let us try to understand what I mean by this, and if I take the value of the inverse of the cumulative distribution, I get along the x axis therefore let us see some values, so that I can make some sense of over it. And if this definition is what is known as a probability unit, which is known as pro p r o b i t is known as probit, but we must understand this before I start doing anything on probit.

Therefore, let us take a look at this particular distribution over here. I said that the area between minus sigma to sigma is 0.683. Now, you know the area under this curve gives me the cumulative distribution that is the total value. And therefore, I can say phi of minus sigma 2 sigma or let us say phi of minus sigma is equal to what, can I get the cumulative distribution up to sigma, let see that is possible, let me do it over here.

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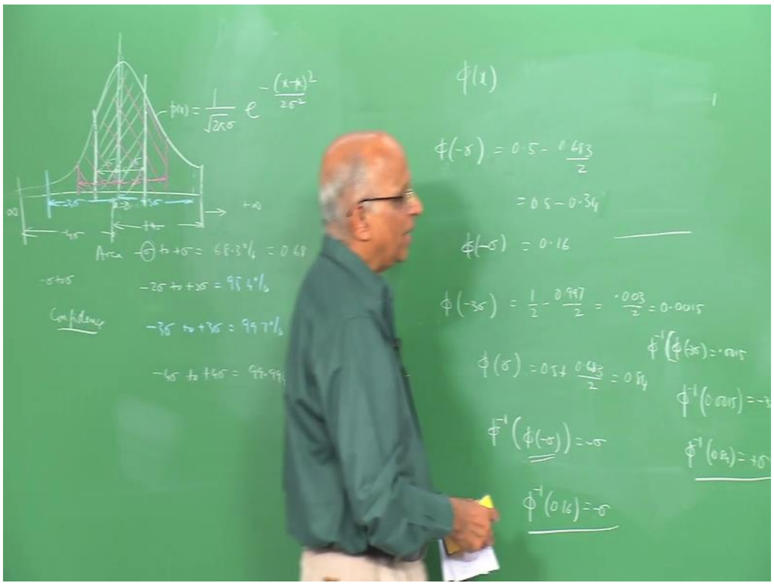

Let see let say I am interested in phi (x), phi (x) is up to any x. Now, I am interested in phi of let us say minus sigma. If I say I am interested in phi of minus sigma I am interested up to this particular point that means I am interested in the cumulative or in the area up to this particular place, and the area up to this place is equal to let us see, what is the area of the cumulative distribution? The total area is1, the area up to the centre line up to here is 0.5 because it is symmetrical I consider the value of mu corresponding to the value of x is equal to 0.

Therefore, I have is equal to 0.5 minus the total area between minus sigma to plus sigma we said is 0.683. Therefore, it is going to be this I subtract this portion that is half of it minus 0 .683 divided by 2, this is equal to 0.5 minus 0.34 let say 341 which is equal to or let say just say 0.34 which is equal to 0.16, this is the value of the cumulative distribution up to minus sigma. If I am interested in let say up to minus 3 sigma 5 of minus 3 sigma, what is the value I get?

Well, I get up to this I want, I know from here to here it is symmetrical, and the total area is 0.997, therefore I get it is equal to half minus 0.997 divided by 2 is equal to 0.003 divided by 2 is equal to 0.0015. Similarly, let us try to write one more value, if I way to say I am interested in the cumulative distribution up to plus sigma, up to plus sigma I am interested in a value somewhere over here, this is the value, and what is the value I get. I have 0.5 plus I have this value that means 0. 5, 0.5 plus 0.683 which is up to sigma divided by 2, which is equal to 0.84.

Now, I have may be the value of phi up to minus sigma, the value of response or the cumulative distribution up to minus plus minus 3 sigma up to plus sigma and so on. Now, if I were to take the inverse, if I take phi inverse of phi of minus sigma, well at this means minus sigma, because phi inverse of phi that is I take inverse of the operating the inverse function again on the function is the value over here. But, minus phi sigma is equal to we just now said phi of minus sigma is equal to 0.16, therefore I can say inverse of 0.16 is equal to minus sigma.

So, also I can say well minus 3 sigma phi inverse of phi of 3 minus 3 sigma is equal to

0.0015 or rather phi inverse of 0.0015 is equal to minus 3 sigma. And similarly I said phi inverse of 0.84, let us write it down phi inverse of 0.84 is equal to plus sigma. Therefore, we see that the inverse of the cumulative distribution gives you something like the standard deviation or along the x axis the distance along the x axis, because we are talking in terms of minus 3 sigma to plus 2 minus 2 sigma minus sigma 0 plus sigma, plus 2 sigma, plus 3 sigma, plus 4 sigma and so on.

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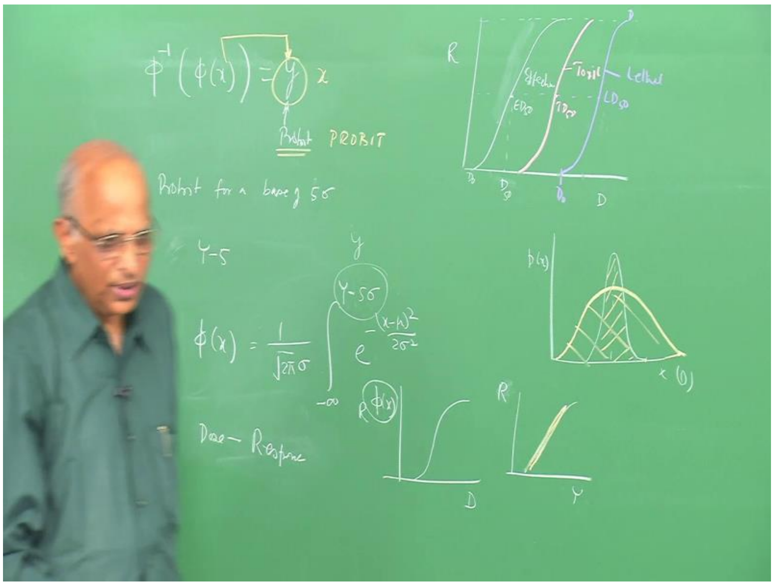

And this value of when I say phi inverse that means, you take the inverse of the cumulative distribution is what we call as a probit, that means we are converting the cumulative distribution into the length scale along the dosage line, and this is what we call as a probit. But, when we say the probit you know we do not want to end up in numbers along the x axis in terms of let say negative number and positive number. Therefore, we refer to the probit for a base or for a reference of 5 sigma is what is normally adopted.

And therefore, we say well phi I refer to the thing as y minus 5 or rather my cumulative distribution, now becomes equal to1 over under root 2 pi sigma into I have minus infinity into probit minus the value of phi sigma into e to the power minus x minus u whole square by 2 sigma square. You know I think I should again sort of repeat to some extent what we mean by probit, by probit we mean the inverse of the cumulative distribution of the cumulative distribution, that means inverse cumulative distribution of the cumulative distribution which give gives back the x axis, and normally this is the value of y.

And therefore you find that yes, this is what I am looking at may be the value along the x axis which we said is probit. And now, instead of choosing y, I choose a value with respect to minus 5 sigma such that I am we back over here. I refer to this such that even if I get number here it is going to be positive, even a very small number we said 4 sigma corresponds to 99.994 of the area, if I take 5 sigma is going to correspond to 99.9999 something. Therefore, it is always going to be positive, and to make sure that you get a positive value of y we choose the base as 5 sigma.

Therefore, this is how a probit is and why we use a probit is maybe we are interested in having the response curves, response namely the dose response curves. And what we are really looking at is response is nothing but the cumulative function phi (x) which is the response, we are having the dose curves in practice we get a curve like this. We would like the dose response curves, the row the response which is cumulative, instead of d if I were to plot it with respect to y over here, maybe I plot response verses y.

Well the curve will be a little more linear, so that I can use my linear approximation, and I will be able to do these things without really looking at the statistical relations. You know now a days we have computer we always use formally and do it, but if somebody wants to do it on the field, you know it is much easier to use a linear relation, and this is what I show in a slide I will showing it shortly. But well what I show is, I will show the values of the cumulative response as a function of Y.

And how is Y defined, y is defined as y minus 5 sigma which is the probit as of, and this is given by the inverse cumulative distribution function of the cumulative distribution function which gives me back the value of this. Actually here you should have been x over here, and this is what I denote by probit and call it as y, actually it is getting back on the x axis where actually I should have got x, but I call it as y two term the value probability unit probit. Therefore, let us take a look at this particular figure over here.

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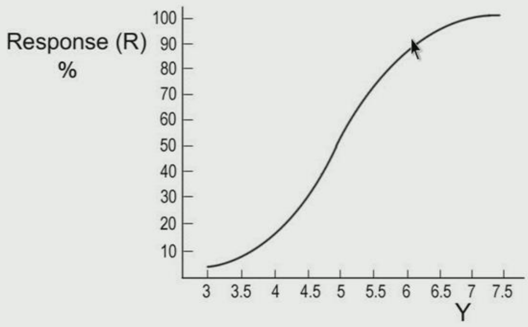
Y	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
R (%)	2.3	6.7	15.9	30.9	50	69.1	84.1	93.3	97.7	99.38



This is the cumulative distribution R which is the response, which is cumulative function that is phi. And this is the value of the probit, when the probit value is 3, the response is 2.3, that means we are plotting the cumulative value over here that means for 3, that means instead of plotting the dosage I am plotting now Y over here or instead of plotting x I am plotting it is capital y. When the area of the curve is 6.3 percentage, the value of y is 3.5, for 15.9 the value is 4 and so on this is the value.

And what I get is I get a curve something like this, which is little more linear. It is linear in the range between let say 4 to something like 6.5 values of y. For which the response varies between something like normally we are looking at responses between 25 to 90 percent for which it is fairly reasonably linear.

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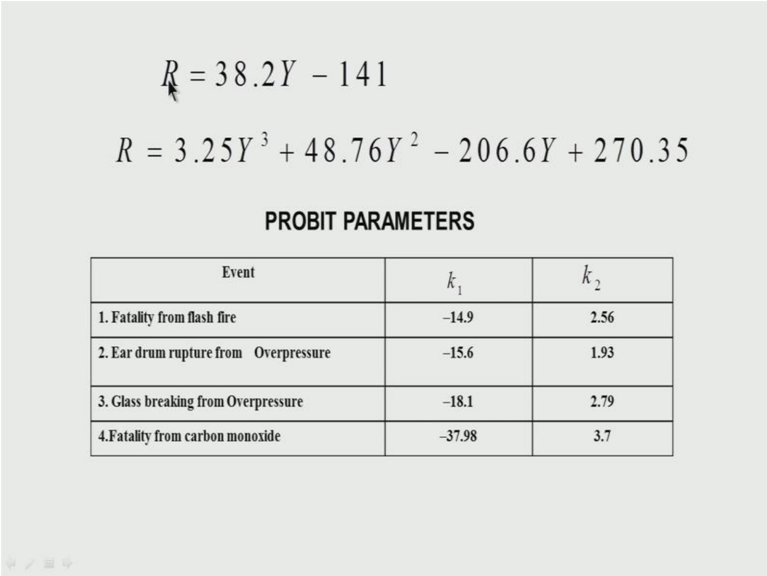

And such a linear relation is what I show in the next slide, you know people use the linear relation of the response as a function that means a cumulative distribution as a function of the probit Y as 38.2 Y; this is just a curve fit of the previous figure which I have over here in this particular range. For values between let say 5 percent response to something like you know almost 90 percent response I get a curve over here, and this curve is fitted by a cubical equation for probit as R is equal to 3.25 Y cube plus 48.76 Y square minus co efficient 206.6 Y plus 270.35.

Therefore, what it the problem really reduces is, if I can calculate the value of the probit Y, I can directly get the value of R, and that is been the endower while talking in terms of quantification of damages to be able to express the damages in terms of probit Y. Let me again go to the board and clarify this particular point, what is it I mean.

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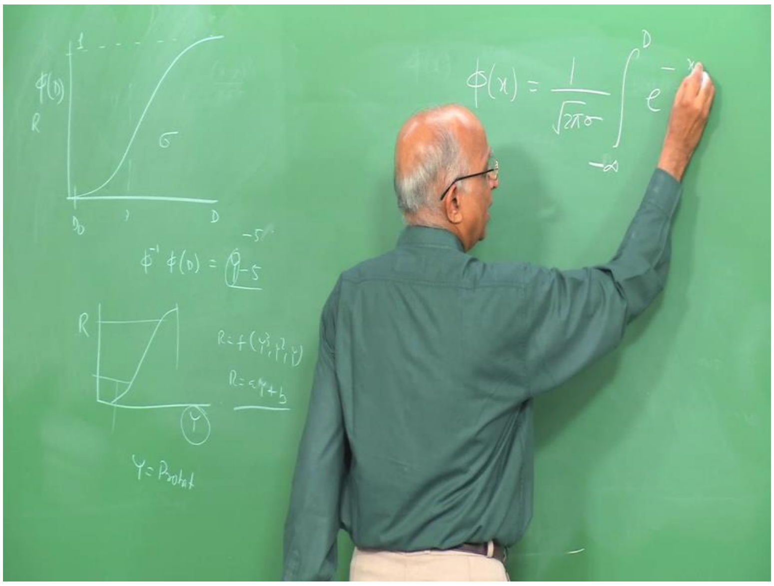

we said that the response is a cumulative distribution function, where in you say phi of the dosage as a function of the dosage, and you have the cumulative distribution which starts at a value let say D 0. And this is where, here all the people or the total responses available, and this is what we say dose response curves, instead of having dosage here which gives a sharp sigmoid type of a shape. All what we do is, you take the inverse cumulative distribution of this cumulative distribution, and you have phi inverse of phi which for any dosage D, we could write it as may be any dosage D could be written as the dosage D itself, and this is what we call as y.

When the value of capital y is based on standard deviation of minus 5 sigma that means I call this Y as Y minus 5 sigma or since along the x axis I have sigma, therefore this becomes Y minus 5. This is maybe I start with minus 5 sigma, and therefore this becomes my value of the x axis, and this become the probit as it well. Therefore, instead of plotting the response curve like this, I show the response curves as a function of Y, in which case it is more linear, and it is something like this.

If I have to consider this shape itself, well I could also fit in a value of R has a function of may be Y cube Y square Y, if I am only interested normally we are interested only in this range, in which case I can say R is equal to a Y plus b which is a linear curve that is

Y is equal to m x plus c over here. Therefore, we need to now get back to what is this probit parameter? We say Y is a probit, and therefore let us take a look at what this probit parameter could be expressed as?

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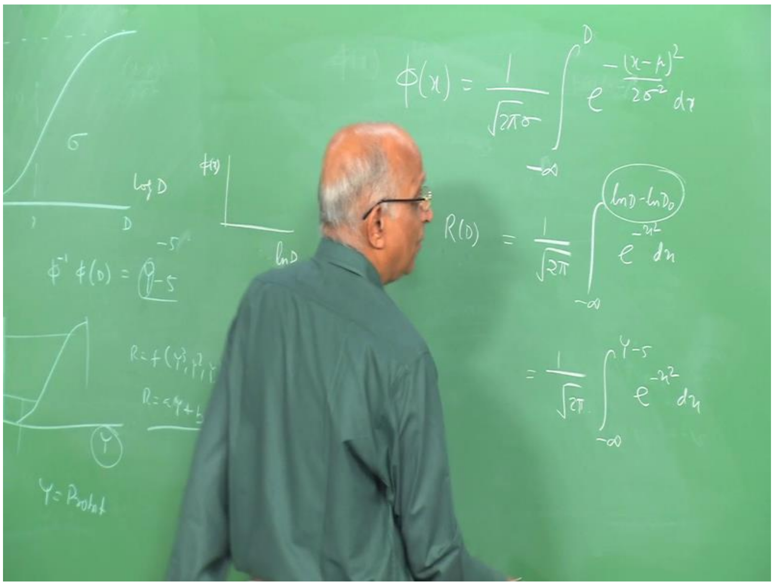

You know instead of writing the cumulative distribution as phi of x as equal to1 over root 2 pi sigma into minus infinity to something like the value of dosage with which I am interested into exponential of minus again I write this, because this is the starting point 2 sigma square into d x, this is the cumulative distribution. You know if I have to write this in terms of dosage, but we also said I recall yesterday. We said normally the dosage is on the x axis, we put it in terms of logarithmic of dosage such that, we are able to put more dosage into the x axis that means, the small dosage is get expanded out, the large dosage is get contracted out that is why we have a log scale.

And therefore, the tendency is to plot it as a function of log D or let us say Lon D, and if I plot it as a Lon D verses the value of x. Well, if I were to write phi (x) I can also write it as equal to phi x is the total response at the dosage D. Therefore, response at dosage D is equal to I can write it as also if the mean get shifted, I can write it as 2 p into minus infinity. The dosage gets started when I have D 0 that means, I have the dosage is Lon D minus Lon D 0 into e to the power minus I have a dummy variable u square into du, this is one way of writing it that is the cumulative distribution which is the response can be written in this form.

And we just now said, well the cumulative think can also be written as 1 over 2 pi into minus infinity of the probit, this is equal to the your value of the probit, this is the type of response what I get when my value is y minus 5, and that is equal to minus u square of d u per rather from this I can also write, the value of Lon D minus Lon 0 which is along the x axis, which is precisely the same as the probit over here.

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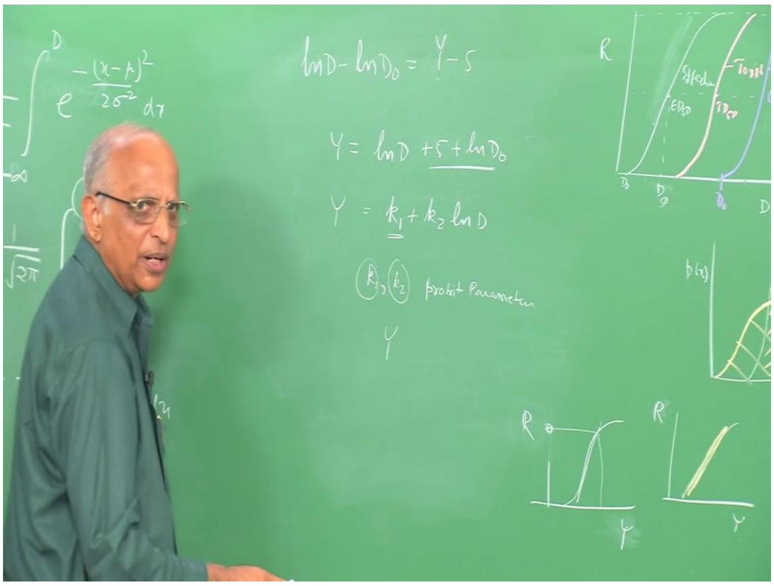

Therefore, I get the value of Lon D minus Lon D 0 is equal to y minus 5 probit minus 5. And therefore, I can write the value of y as equal to Lon D plus 5 plus Lon D 0, you know for any generally I can write this as equal to k 1 plus k 2 Lon D, this becomes sort of like k 1 I have some other factor coming in maybe I try to non dimensional may be log, Lon and all that. Therefore, where I can write the probit as equal to k 1 plus k 2 Lon D that D is dosage that k 1 and k 2 are known as probit parameter.

And in general for most of the explosion, most of the events which cause disaster, the k 1 and k 2 parameter are sort of available, and all one what one has to do is define the probit for a given dosage. Using the dosage I can find out using the probit parameters the value of the probit. And using the probit, and using the curve for probit may be the relation which we just now had for response verses the value of Y for the probit which is more or less linear, I can get at this value of Y, well this number of people get affected, and this is the use of the probit.

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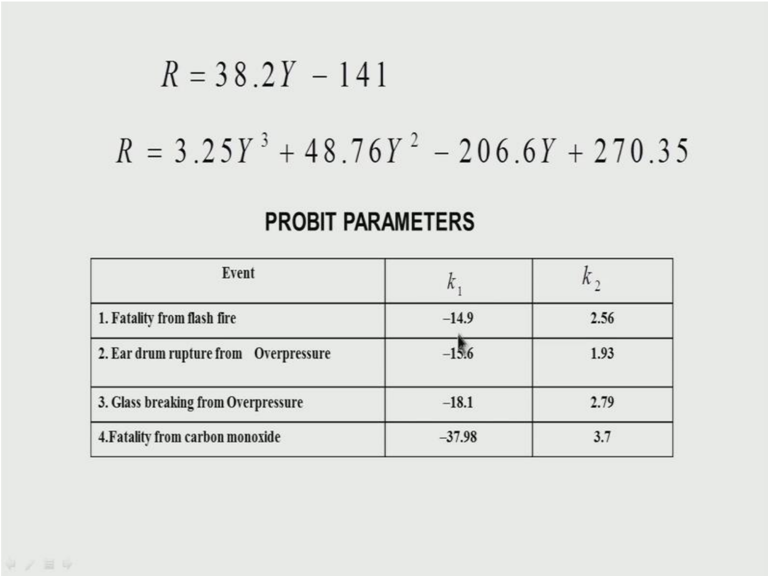
$$R = 38.2Y - 141$$

$$R = 3.25Y^3 + 48.76Y^2 - 206.6Y + 270.35$$

PROBIT PARAMETERS

Event	k_1	k_2
1. Fatality from flash fire	–14.9	2.56
2. Ear drum rupture from Overpressure	–15.6	1.93
3. Glass breaking from Overpressure	–18.1	2.79
4.Fatality from carbon monoxide	–37.98	3.7

Therefore, let us take a look at the probit parameter k 1 and k 2, and these are determined for different types of explosions let us say, whenever I have a flash fire the value of k 1 is minus 14.9, the value of k 2 is 2.56 where as I said earlier, the value capital y which is probit is equal to k 1 plus k 2 Lon of the dosage. Similarly, for ear drum rupture from over pressure, the value of k 1 is equal to minus 15.6, the value of k 2 is1.93. If I have glass breaking because of over pressure, we found that this over pressure was of the order of something like 0.75 k Pa at which the glass burst, the probit parameter k 1 is equal to minus 18.1, the value of probit parameter k 2 is equal to 2.79.

Similarly for dispersion of the axis, the value of k 1 is minus 37.98, the value of k 2 is 3.7. Therefore, once the probit parameters are available, I can always calculate the particular response, and this is what we do to quantify the damages. Therefore, let me take one or two small examples to be able to illustrate the method by which we apply the probit, you know all what we do is well.

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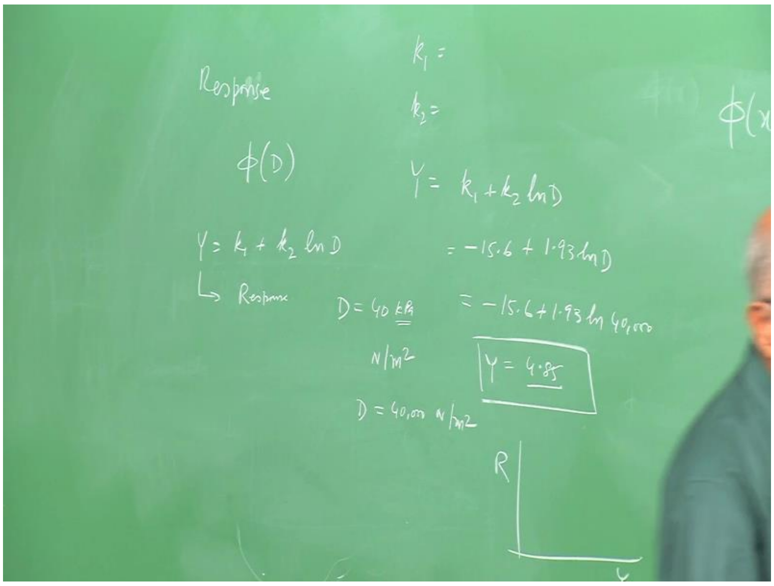

We said well we are interested in the total response, the total response is what we call as phi that is a cumulative value phi of the particular dosage, and we also said that the probit Y is equal to k 1 small k 1 plus k 2 Lon of the dosage. And once you get the dosage is available to you, I can determine the probit from probit I can determine my response, how many number of people getting affected. Let us take an example, the number of people, total percentage of people or number of people who get affected, when I have an overpressure of let us say 40 k Pa, that means I have an explosion.

And in the explosion blast waves are generated, you have at some particular distance a number of people who are standing around the explosion. Out of this what is the percentage over people, who lose their eardrums or the eardrum get ruptured, eardrum get ruptured how many what is the percentage of people who get affected in a particular zone where in the over pressure is 40 k Pa.

You know immediately we tell us as well this in this particular problem, if I could have the value of the probit for let us say rupture of eardrums, and that is available in literature, but I know that the dosage is equal to 40 k Pa. Therefore, I say well what are the values of probit k 1 and k 2? You know this is available, and as I shown in this particular slide over here, the ear drum from ear drum rupture from over pressure, the value of k 1 is minus 15.6, the value of k 2 is 1.93.

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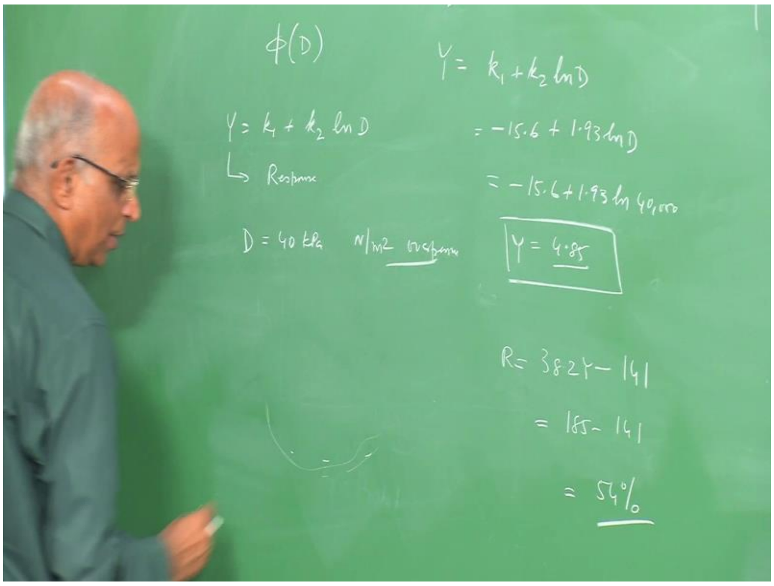

Therefore, now I write the value of the probit is equal to k 1 plus k 2 Lon of D which is equal to minus k 1 was minus 15.6, k 2 was 1.93 Lon of D. Therefore, the value of Y you know in this particular case we said that the dosage is equal to 40 k Pa. And therefore, when I say k Pa the dosage is expressed in terms of Newton per meter square. Therefore, the dosage is equal to 40 into 1000 Pascal that is so much Newton per meter square, And therefore, the value of probit works out to be minus 15.6 plus 1.93 of Lon of 40000, and this gives me the value if I solve for this, I get the value of Y as equal to 4.85.

I go back and look at the curve, which tells me what is the value of response for a particular value of probit, and I had plotted this curve in the last slide, let us take a look at this particular slide. When we have something like 4.85, we had something like may be 50 percent of the people. Therefore I look at this probit, and I say well around 50 percent of the people get affected or if I want to use the I am on the linear curve I can also use the linear relation.

And let us use that relation that means, I can write the response of the curve, response as R is equal to 38.2 Y minus 141 which is equal to Y is 4.85, 38.2 into 4.85 gives me 185 minus 141 which is equal to 54 percent, that is 54 percent of the people who are in this range, where in the overpressure is 40 k Pa will have their ear drums rupture, this is the way to use a probit.

Well you know mind you the unit of dosage is important, in this case we said dosage is equal to 40 k Pa, but when we looked at the dosages which define in the last class, we said that the dosage is expressed as Newton per meter square for over pressure. Let us take one more example such that the unit becomes a little more clear, let us take a little more complicated example, in which case the dosage is a function of two parameters describing a particular explosion or a fire ball.

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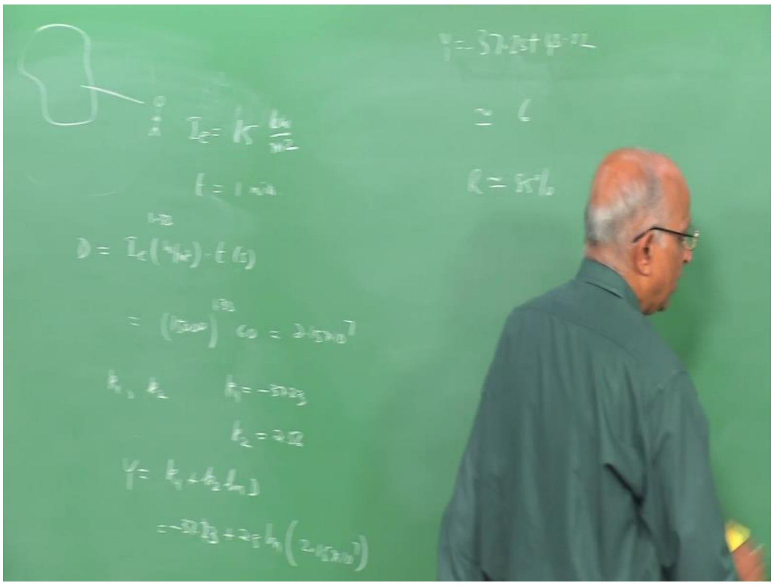

Let us consider the case of may be have a fire ball, the heat radiation from this fire ball on to certain people around the fire ball at some distance, let say is equal to the heat radiation, intensity of heat radiation is equal to15 kilo watt per meter square. Let us say this fireball is therefore a time equal to1 minute, when we talk of in terms of the dosage for heat radiation fire from a fire ball. Dosage is defined as equal to I intensity of radiation in watts per meter square to the power 1.33 into effective time in seconds, this is the definition of dosage.

Therefore, I convert this into watts per meter square that is 15000 watts 15 kilo watts into 1.33 into time in seconds is 60 seconds, therefore the dosage comes out to be in this particular units of watts per meter square to the power 1.33 into seconds as equal to 2.15 into 10 to the power 7. The probit parameters k 1 and k 2 for the case of radiation from a fire ball which is again available, and this also was there in the slide k 1 is equal to minus 37.23; the value of probit parameter k 2 is equal to 2.56.

With the result the value of probit Y is equal to k 1 plus k 2 Lon of the dosage, in which case it becomes equal to minus 37.23 plus 2.56, Lon of the dosage which is 2.15 into 10 to the power 7. And this works out to be equal to 37.23 plus 43, this is minus plus 43.22 which is around 6, and when why is 6? Immediately I use the table let us say I go back to the particular response over this I have the value of 6, and this 6 gives me a value around 85 also 85 percent or I use the formula.

And if I use the formula I can get the value again of response as something around 85 percent, that means 85 percent of the people who get who are affected or who probably get killed, because of this radiation from the fire is this, and this particular value of probit was for the people who are killed by radiation from a particular fire ball. And this is how we do the different problems, and may be since we are been talking of glass break is let us do one last problem involving the effect of glass breakage from an explosion, that means window pane shattering.

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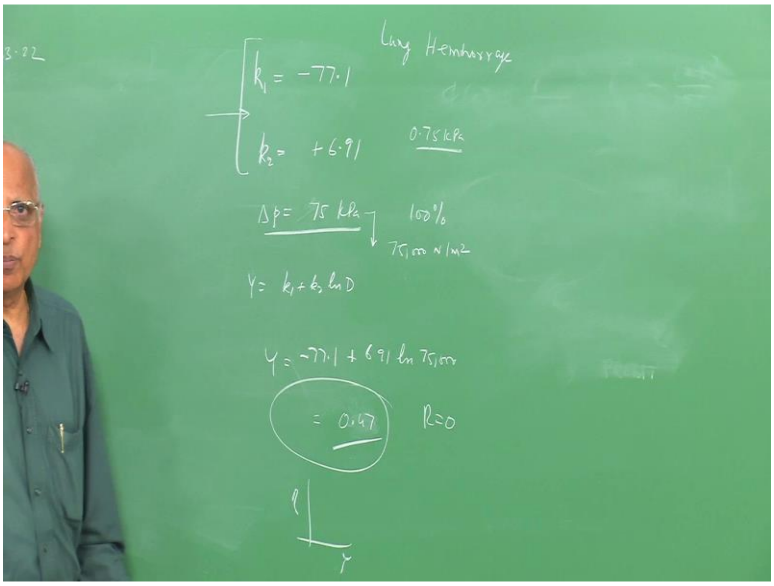

And in this case, the probit parameters k 1 is defined as minus 77.1, the probit parameter k 2 is defined as plus 6.91, and if I am considering a case where in I have an over pressure delta p of let say 0.75 or let say I have 75 k Pa, well this expression is extremely, extremely large that means, well all the100 percent of the a window piece will break. But if I were to now say I am looking at this over pressure, and these two probit parameter are for the case of may be the lung getting ruptured or let say hemorrhage of the lung.

Well these two parameters correspond to hemorrhage of the lung when I am talking of an explosion, and the blast ways causing the destruction to the lung. Then in this case the probit parameter Y is equal to, I have k 1 plus k 2 Lon D, and in this case I talk of delta p is equal to75 k Pa in which case may be all the glass breaks, but I want to find out the percentage of people whose lungs get affected. Therefore, 75 k Pa is 75000 Newton per meter square, and therefore my value of Y is equal to minus 77.1 plus I get 6.91 into Lon of 75000, and which gives me a value of probit as equal to 0.47. You know if I will take a look at 0.47 in my particular figure.

Well, it is almost 0 that means, none of the peoples lungs are getting affected, even though all the glass windows get ruptured and all that people are still say the response is

0, because my value of probit is so small that the response for this particular probit Y, I have the response to be 0 that means nobody lungs get ruptured. But, since my over pressure are very large compare to something like we are talking of 0.75 k Pa to rupture a window pane I have a something like 75000, well all the window panes get ruptured. This is how we do problems involving quantification of damages. Well we have reached almost the end of our course, and in the next lecture we will take a look having studied about quantification of damages, different types of damages, and what a blast wave we will do, maybe we will try to take a look at what are the risks involved?

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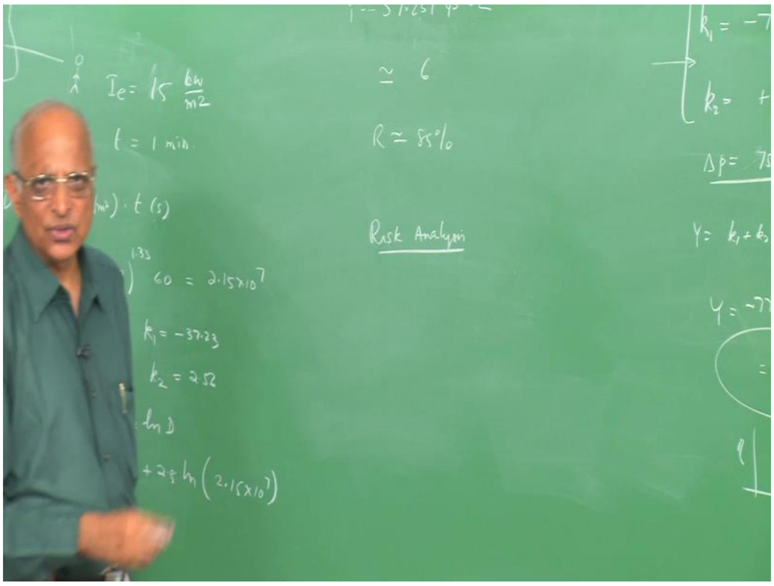

And do a small lecture on have a small lecture on risk analysis, and this is what I do in the next lecture.

Well, thank you.