Seakeeping and Manoeuvring

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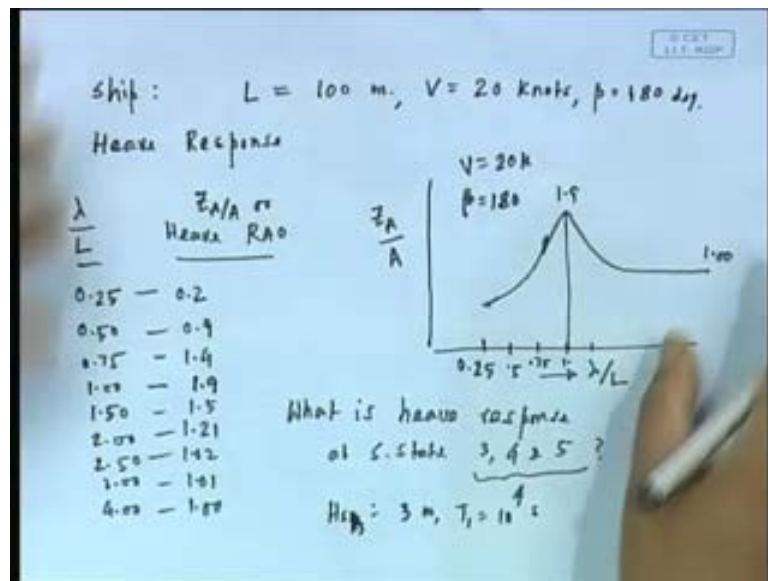**Indian Institute of Technology, Kharagpur**

Module No. # 01

Lecture No. # 16

Ship Motion in Irregular Waves – III

See, for the past two hours, we have discussed about ship motions in irregular waves. So, I thought today, we are going to go through a kind of a problem. How we proceed very slowly. So, that you know it gets to us.

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So, I have not and the numbers are not there. So, we will work it out. So, we know know how it goes. So, let us let us take an example, let us say that I have a ship, say let me also put (( )), you know say it is length is given say 100 meter.

Various particulars are given and its heave response, heave R A O. Let me also say V equal to, let us say 20 knots and wave heading, let us say beta or whatever you call, for this heave response is given let us say, which let me because I am inventing the problem.

We plot with respect to lambda. So, let us say, I guess put some numbers here. Let us say it is given like that etcetera So, I will just <mark>I will just</mark> put some numbers here, I want to put this as one, say something like that. I just well you know thought to take a realistic value. This what typically happens.

This is how you are going to be given in actual cases, for a given speed in this case 20 knots heading angle of one 180 degree, heave R A O is given. The question that is asked is determined by heave response that is significant heave etcetera. In say sea state 3, 4 and 5, let us say that is the question, we will just take up some sea state and we will try to do. So, question is that, what is say some sea state or rather for that I will take some sea state say 4. Because after all the calculation is going to be repetitive, not only that. When I say heave response everything of heave. You have, we have to get the spectrum, we have to get the area, then probably we have to write down things like what is significant heave height? Heave absolute amplitude? What is significant heave velocity? What is significant heave acceleration? What is the chance of, if there other question ask that also. Essentially say significant values.

And say sea state is 3, given is you know like, we will pick up some sea state H s one third T is given. We <mark>we</mark> will say that for <mark>for</mark> say, example is H s one third or H s rather H s is say 300 meter or something like that and T 1 or whatever is say 10 second. Some <mark>some</mark> value is given. This is the question right? So, how do you proceed, see the number 1, first of all we have to transform this to a basis of omega e versus R A O. No <mark>no no</mark>, let us get the R A O first in the omega e basis.
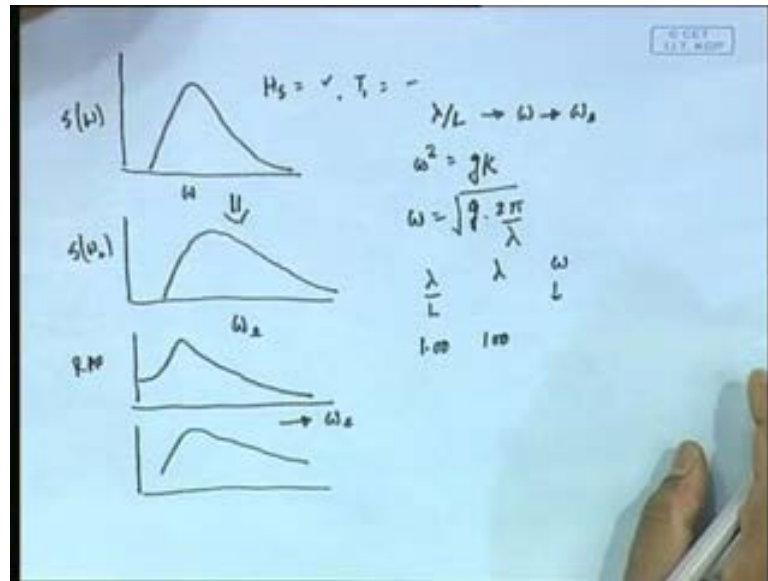
See, this is what I am saying, that the procedure says like this. Now look at the procedure, I have S omega, which will be defined like that. This is, I have way for H s equal to some given value and T 1 some given value. So, I will be knowing this as function of omega, this is what will be known from this formula. Which will be in a computer program or something input, you know and a spectrum type of formula say it will say I T T C spectrum etcetera. Now our calculation starts from here. From here I had to get, then my this R A O, I have to get see this RAO will look like here in this case, this frequency is this thing, but I must transform that back to omega e and then of course, I get the response, taking exactly same points. So, I have to have a common basis first, no. So, let us take an omega e as a basis, we will keep this in mind and get back to that. So, we will have to keep that omega e in basis.

Now, you see here I have been given lambda by L. L is 300 hundred meter. How do I do it? First of all remember that omega square, see I have to transform lambda by L to omega to omega e. That is the first thing that I have to do, my I know this formula that is omega equal to g into2 pi by lambda. So, what I have see here, lambda by L, I have got let us say just take say 1. So, that will give me lambda equal to 100 because L is 100 meter. So, that will give me omega. Here there is a square root there, I am ==sorry,== this is. So, it will give me omega right? See I have to first transform this basis, this lambda by L to omega e or rather I will get back to that.

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 So, I have got here lambda by L values. So, I need to find out omega e. So, first thing is that I am just going step by step slowly. So, that now I can regard L here. See, here if I take this 1.00 L is100, this particular line. What is my omega? Omega is; so, let me work it out this one, I just got that that is why. Now about point 0.78 right? Now what is omega e, remember I need what is omega e formula, but this cost beta whatever. Now here 180 degree. So, this is coming to be omega into 1 plus (( )). So, this will be I we can work it out this. This omega 1 plus omega v is how much, v is 20 knots 20 into 0.5144 by 9.8, omega 1 plus 20 into 0.5144 divided by 9.8, 1.049 right? This coming to 1.049. Is it correct?

Something like that it is coming. So, here, this is going to become then this plus 1, no sorry, 1.05 into, I am just going very slowly because we should too understand this, 0.64 something, it may be whatever. So, I am getting this. So, you see now I am getting this new numbers and of course, I have the R A O. This you can check the numbers. So, I am now got this table, where I will write separate R A O table now. The R A O that I have got here, I have got this this plots, this this values. So, I have essentially transformed that to this, some values and not may not be equidistance, some value.

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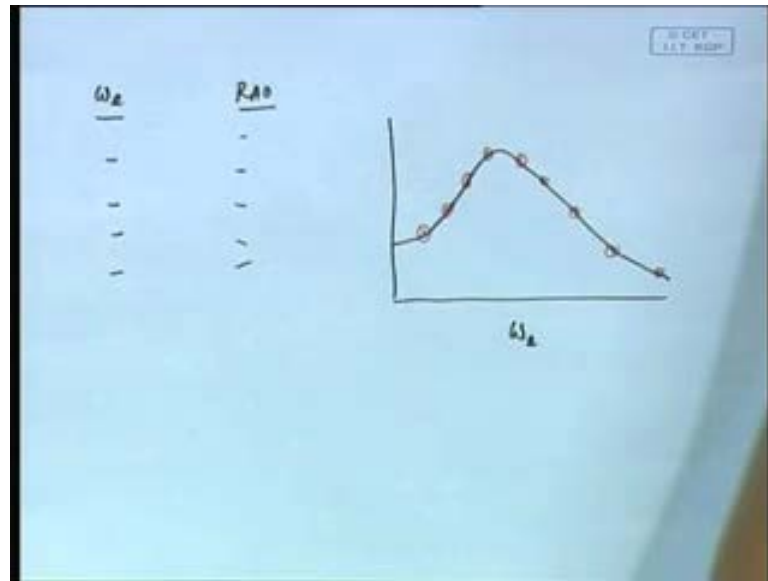
So, this part is coming here. So, I have got now R A O value like that. So, I have got omega e, remember these values are somewhere here. Why I am doing it because we will later on find out that it is important for us to know. We have got only something like I had given 1 2 3 4 5 6 7 8 9 points. So, we have got 9 points some here. See remember, I have no control on this distance, they they they may be equidistance. I have no control on this spacing, this this arbitrary has come. This whatever omega is up there arbitrary it is come.

Next question, I have to go to the spectrum. Now here I must understand one thing you know. See here, this point and this point I need to have this spectrum only within that region may be may be more, but let us whichever way I wanted to see I can see that because I have only this much given data given. Actually, what happens in this kind of problems, you will find out that in case I need data beyond 4, I can make it one. Because it is becoming asymptotically 1, this. If I want it below this, I simply take it 0 because it is already too small. In fact, it is already, in fact, my diagram it was something here.

In case I have a spectrum which is spread, you do that. Because my spectrum may come out to be something here, which will we will discuss that in a minute. Suppose, my spectrum comes out to be something beyond that beyond that data given then I should extrapolate this R A O. Now for spectrum what I should do? First of all you see, that we we realize one thing, that my I have got this omega is, now omega is got stretched on this

side. So, what I could do? Just generally speaking, I could take first of all omega verses S omega, some omega. So, I have to take certain omega that I have to choose flows. So, now, we come into the spectrum part.

So, what I am going to do is that? So, now, this I have again no choice for the particular spectrum for for H s given and T 1 given by formula. So, what I will do I will use some omega and S omega. So, there will be some values coming. So, let us say, I will take this to be say 0.2, 0.3, 0.4 like that I go. Now omega this this of course, I will find out. Whatever the value you know, let us say this will turn out to be 0.5, say 1, say 2.5, say 3.9 like that. Some number comes in meters square second, let us say. Of course, here I will immediately go for omega e, this to this, what is omega e? Once again that we found out, omega into 1 plus (( )), in this case that is what it turned out to be. So, 0.2 will become, let us just take an example; 0.2 will become, 1.05 into 0.2, 0.242 or so. This formula and S omega e, this will become as you know something like that. So, this will become for example, this number 3.9 will come down, may be it will become may be three 0.1 because you know it will come down slightly and get stretched. So, my point is, remember that this point that I got again some arbitrary number. I do not have much choice.

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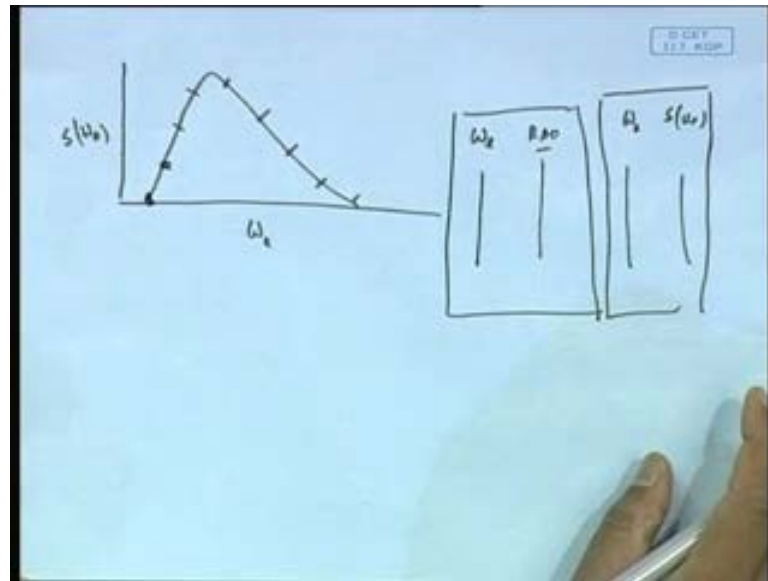
So, here comes; that means, what I end up getting is now, if I were to plot here omega e verses S omega. Now, I have got actually some points, this, this, this, this, this, this, this, this, this. Some point of which I do not have basically a control. I can have a control you may say on omega because I could choose 50 points etcetera, but the point is that making too many points will make no sense because ultimately I have only data points given for the R A O fix, 7 number points. So, I have got 2 bases. So, here I want to tell you this.

So, I have got 2 data thing one is omega e verses R A O and another one, this is one, another one is omega e verses S omega e. This and this are not necessarily coincidental. So, therefore, when I want to make a table then I will have to make an interpolation. So, what we will do is that, we will take the first one to be the correct one; that means, now I will I will you had to do. So, I will write down here the final one, omega e and RAO.

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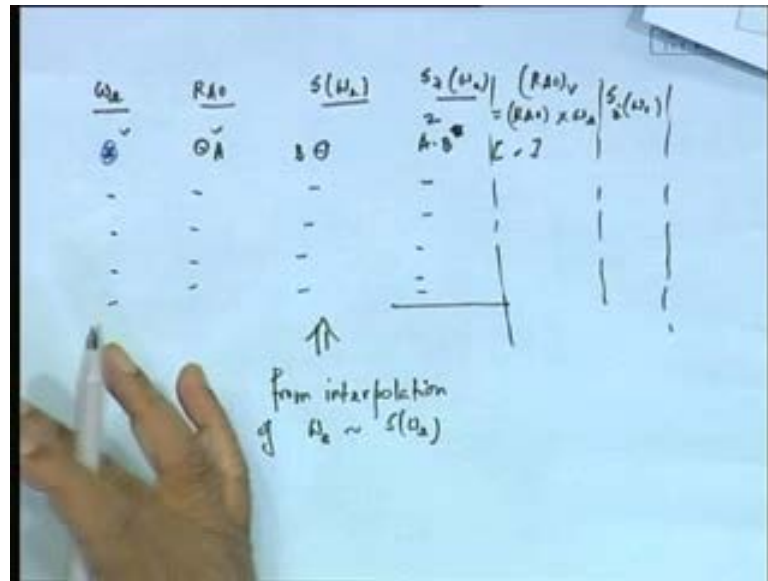
So, I have got this, whatever that values that I have got omega e verses R A O. let us say some values, now see when I write this S omega e here, this I am going to get from interpolation. Which means, see I have got this. My, if I were to plot here, my R A O points were this one, this one, this one, this one, this one, this one, this one. So, what I am doing is that, I am trying to find out for this one, what is this value? This one, what is this value? This one, what is this value? My blue line is the base, this is my R A O, this is my S omega e.

So, you see here what I have done that my omega e must be R A O. This this points are the blue points, say that is this points. For the same one, I must produce this from interpreting from the that omega e is omega e graph. This is very important, this this interpolation part, interpolation extrapolation whatever you call.

See here this particular one, once again I had this black line. As an example if I just want to give an example omega e here, R A O. I have again just given an example; say this was 0.56, this was 0.79, this was 0.85 etcetera. And I have separate diagram of omega e, say 0.5, 0.7, 0.9, 1.1 S omega e, some values are there.

now what I need at 0.56, I want to find out S omega e. So, I need to interpolate from there and get this value. I had 0.5, 0.7, 0.9, 0.5, 0.7, 0.9, this is 0.56 this one. I need at 0.56 my S omega e. So, I need to interpolate that. Very very important that we have to

get the same same value here. So, we are getting it now. So, once I get that value, now the basis is clear.

So, now I have got for the same one these lines are form by interpolation. Then my rest part is all all very simple. Now the rest part of calculation is only calculation part. Now next slide is going to be, what is going to be? See here, R A O is a S omega z is there. Therefore, I can straight forward write actually, that my S z omega e, it is going to be R A O is going to this, that is if if if I call this A, if I call it B, this is going to be A into B square, straight forward. So, you can fill it up this column, but now an interesting point. Remember, I wanted to also find out velocity and acceleration. What is my velocity R A O? It is this R A O into omega. So, if I want R A O of velocity, what is this R A O of velocity? R A O of motion into omega e. So, all I do is get this value here, multiplying this column with this column. I get this value. This value is this into this. So, this column I get, so, once I get this column. Once again I get the S z dot omega e, that is velocity. See, response spectrum is going to be (( )), sorry sorry sorry, absolutely sorry, yeah yeah A square B, yeah because we have done it, absolutely sorry. This is square of this into this because I B into A square. So, I get this one. Now what is happening in order for me to do velocity and acceleration, all I have to do is to get the just replace this. Replace this is what? Velocity R A O is going to be this into this column. So, it is it is like you know excel file means you simply multiply this with the you know this this two square. So, you end up getting this column.

If I have an acceleration, what I should do? Well, in fact, you can also see, that because there is a square here. In fact, I could have got this by simply squaring, you know that the data R A O power of 4 into this would have been given me this straight forward is the same thing, but does not matter we can go go this way. So, what I will do next one, I have to simply replace this by omega e square into R A O for acceleration.

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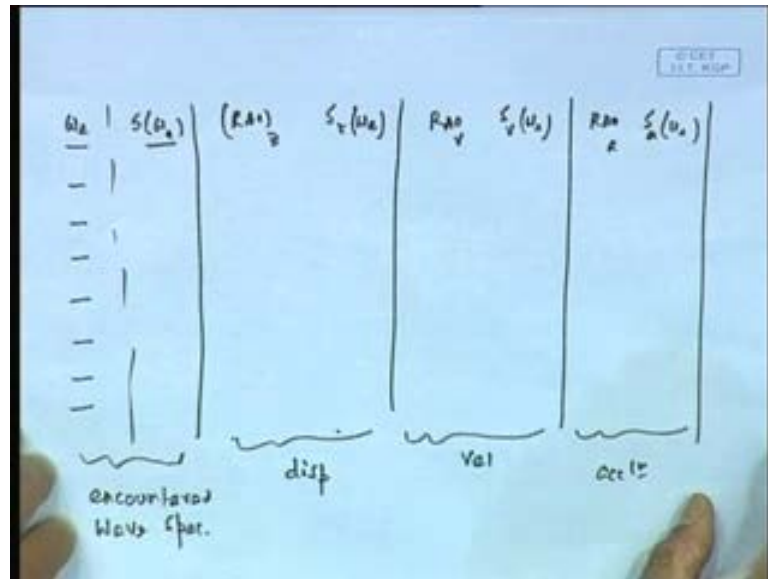
So, I end up getting, if I with this thing ran out. So, I end up getting omega e, S, let me write the other way round here S omega e. R A O z, S z then I will write R A O velocity, in S velocity omega e, then R A O acceleration and S acceleration omega e. So, you see this, this, this. So, this is my all these values, this is my transforms wave spectrum. This is my heave R A O and heave spectrum displacement.

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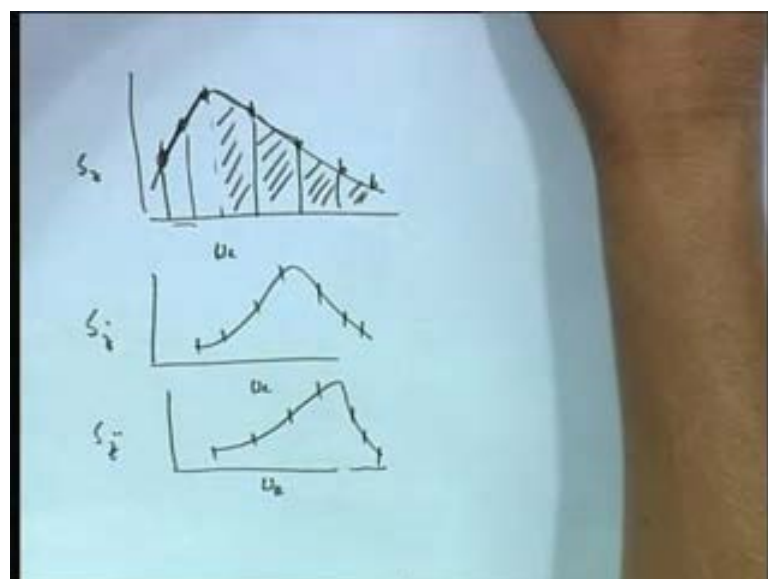
So, having done that of course, very simply you can plot the graphs, at the then having done that then we are going to we will be doing that and then you simply plot this graph

this going to be S z, which may turn out to something like that. Then S z dot may come out to something like that. You end up getting because you have got these points. So, this we have done, but you know typically. So, I have to do spectrum plot, but this not where we normally would end. We would like to know as I said (( )) the significant heave. So, of course, at the then what happen, you must actually integrate this area numerically or whatever. Now, typically what happen in these kind cases it is easier to use trapezoidal integration straight forward, if you have a two small part here. Because it is you need not do our traditional 1 4 1 type of rule. So, I can simply, in fact, integrate whichever way you like trapezoidal mean just take sum of that entire thing with only the first two half and then multiply with whatever, but here is the problem, actually you need to do. We cannot use 1 4 1 rule in in any case. Why? Because this number remember, I am not (( )), you have no control.

So, this and this not uniformly uniformly distributed spaced. So, the spacing of omega e is not uniform at all. What you have got here in this diagram is that, this point, this point, this point, this point, this point, this point etcetera. These gaps are not uniform. So, better is to simply use trapezoidal, you know like trapezoidal distribution. This area, this area etcetera. This area, this area etcetera. So, better way off for this spectrum is to use an integration and it is good enough to use trapezoidal integration. If you use trapezoidal integration, you get them. So, you will end up getting these areas m 0's, m 0 for z, m 0 for V, m 0 for acceleration. Then the rest part is very simple, then you find out what is my heave one third 4 2 square root of this, what is my velocity 2 square root of this etcetera.

You will end up getting that check the so called your units, you will also find the units properly. So, this is what is a procedure that applies to any response, you know. And if you work it out you will be able to find out, whichever we will like. Now, my point of saying is again that, remember one thing that initially I have started this saying is that that the data is given in terms of lambda by L. It may not be lambda by L, it can have been given in terms of omega e, it can be given in terms of something else, does not matter.

Whichever way it is given, please understand the response would be given always against in some sense frequency or period. You have to transform that to a corresponding omega e, that is a first step. That is very very important, you have to transform that to the

corresponding omega e. The the spectrum of course, you are doing against omega not omega e, but then for the given V and beta you have to transform to omega e. So, this way we can do etcetera.

Now so, this is should be very clear, we could end up doing this problems several times and it is not really a problem. This particular process should be automated in a computer program or something. So, you read the R A O over a base, whichever way it is you read as an input data H one third significant or sea state. Immediately, you construct you have to have your in-built points. So, only thing that one have to remember that, when you are doing this points this coming back again to this. See, I have given this R A O's. So, R A O's has given from here to here. So, the spectrum that you use should cover at least that much. Because if it did not cover, supposing I use spectrum only up to some point. Well, you are missing out something.

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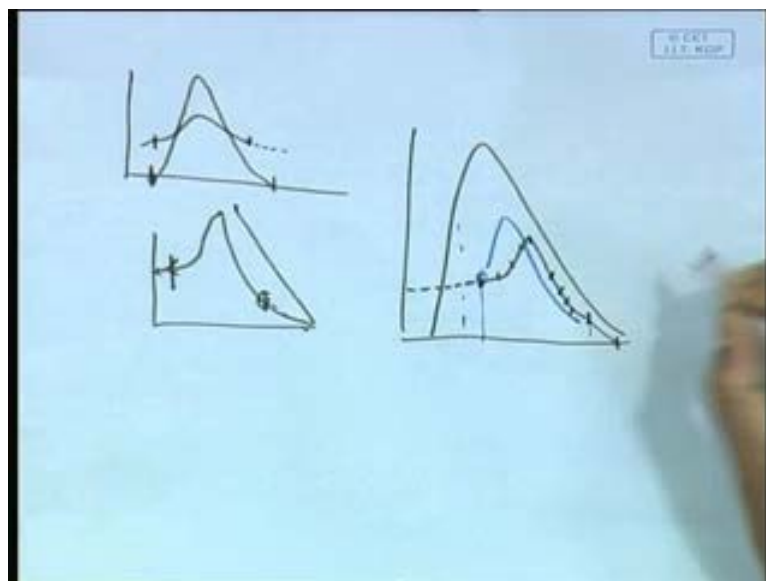
So, in in other words, this point I will elaborate here. That suppose my R A O is given only this much. The spectrum that I used should cover actually technically it should 0 to 0 almost. So, it should cover wherever it coming zero, all the way towards coming zero. At least this much it should cover. Although this is given this to this, then of course, you may say I do not know this side. Well, there are many ways, sometime you can just extrapolate this this side, if you want the R A O base. Typically as I said R A O will always be given starting from very small going to an asymptotic limit. R A O typically

for heave and all that has a very small value. Well, small value peaks and it approaches an asymptotic value. So, it will be given now somewhere here to here, this side if you not you take it 0, this side you take that last value. Typically, for extending it.

Are you getting what I am saying? See, once again I will repeat in a bigger graph, I have the spectrum like that. But somebody gave me R A O, which is just this much of point from here to here, this is my R A O, but my spectrum is see here. I have, that means what? I have lot of waves of this type, but no R A O is given. So, if I were to use spectrum only up to using this much point <mark>this much point</mark>. Then I am not getting the full spectrum, see I end up getting a response spectrum which may look like that, but I have missing out some part.

So, what I could do is, I could use here an asymptotic extrapolation to the last value and here I can take it simply going down to 0. Then I will even once you do it few times you will know you will get an idea, otherwise the point is consider all waves that exists in the ocean and their response. Even if the response is otherwise, you would have being missing out that. That means, there are some waves existing, whose response you did not consider in calculating this value. This is how we kind of go. Now there is a reverse issue also involved you know.

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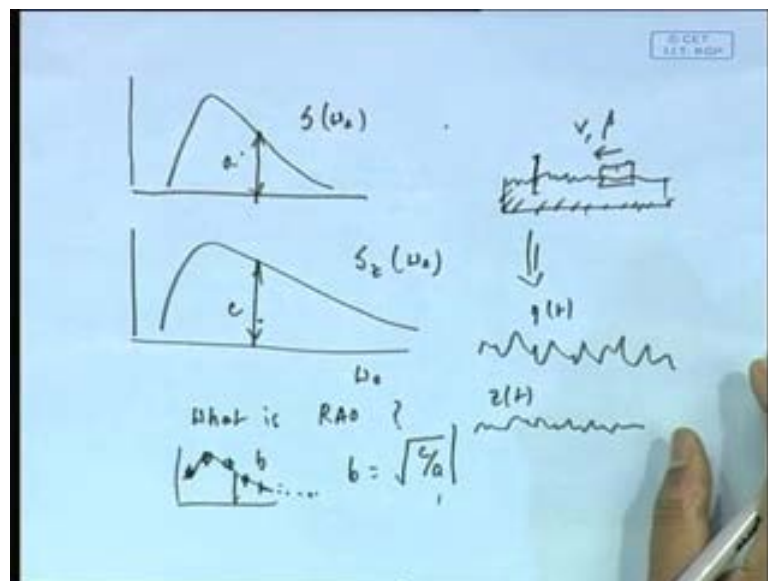
The reverse is like this, which is sometimes done in experiment and all that. Supposing I have which <mark>which</mark> also we could do here. I think there is a problem here, I should do, just

one second, what is happen is something like that. Sometime in experiment and also in measurement you you know this, you have measured well. You have this S omega e and you have measured your spectrum is given input spectrum and your response spectrum is given. What it means is that, you are doing an experiment; you have send an irregular signal irregular wave. You measure the response and you end up getting this graph. How you are doing? Remember, you are you are its very interesting, see you are basically making only 1 run, 1 run because you have a tank, you are sending this signal, you are sending this signal. Remember, I have this tank here or in a ship or rather let me let me put it the other way round also, that I have I have basically going on on board a ship, I know the sea state there, I might have measured by some equipments.

So, I know this, absolute sense or in in encountered sense and I measured the heave response of the hull. It is more relevant in experiment, that I send the spectrum I would be sending this; that means, I am sending input spectrum. In a in a tank here I am sending this spectrum. So, I have probe here it measures this, understand that. There is a probe here which is measuring this. Obviously, because I am sending the signal.

And there is a ship here, which is moving forward at certain model V and at certain beta. Now I measure on that its response; that means, I am measuring here eta t and I am measuring here in absolute sense z t. That can be done by one series of test because once I send that I am sending it once and I. So, am doing test number one run number one send this signal get this, find out the question is what is the R A O? Find out what is R A O?

Now, if I had to find R A O then I had to find individually this R A O. So, remember I have to send once a sin wave of frequency equal to some value, next time another one. So, each one of them represents one, one, one experiment. Whereas, here I am getting this from one experiment, the entire graph. See, I am doing an experiment. Now in the experiment what I do I send an irregular wave signal. Which is possible to send from one side an irregular signal.

Which means I am sending a signal which is like this measured at some space fix point. Which is how you do it because you have no control, I mean like you cannot you are not measuring with respect to this, do not put a stick on that. So, this is your input spectrum. What did you measure? You measure for this ship for that particular speed and heading,

you measured it is z t heave; obviously, this can be broken down by standard spectral method and spectrum can be plotted.

So, you have given this, measured this. One run, run number one H S one third equal to 3 meter equivalently, you have produced this signal and broken it down made it up. Find out what is R A O? What I can do; obviously, here a very simple, I can take this, I can take the corresponding value of this. You know if I take this as bell a, this as c remember b becomes that is R A O, this b square root of c by a. Now you see here what happen? I will get the entire plot because I can now take various points and I can get the entire plot. So, here I am getting this entire graph, now see the reverse, if I were to do this experimentally, if I had to find this experimentally. Then I had to do so many test for each point one one test because each point represent one regulars wave test. I am sending a regular wave and I am finding out the response. So, here the each say say, I need something like twenty points to represent the graph.

So, I have to do twenty test which is replaced by one test now. Sometime it is done that is what I am saying, sometime you can get back R A O or you can of course, get back R A O provided, you know this because this formula holds good. In experimentally sometime if you can control where you can actually measure this given this and get back this rather than the other way round and a better experiment of course, will be that you do this also and you also do this and then compare the two and therefore, you know how good your tests are in a sea keeping test. So, this is how we we could kind of you know like do this sort of calculations for, you know like what I should say, this ship motions part.
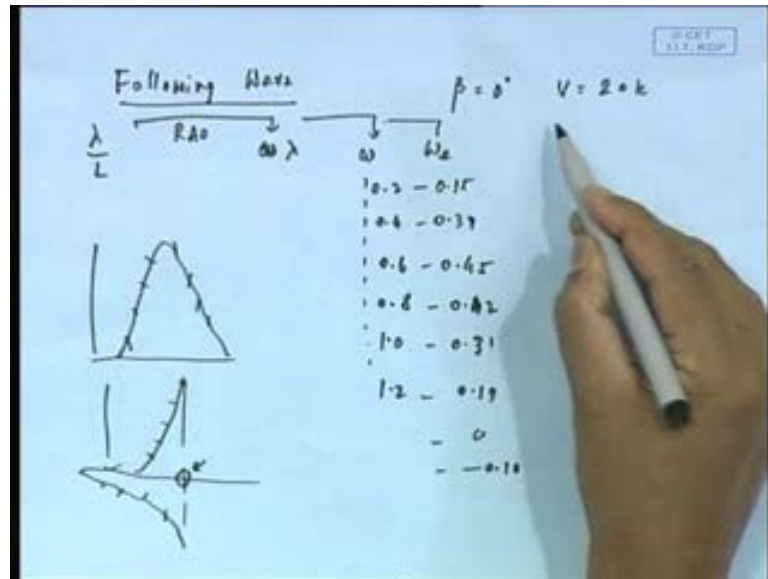
Now one another thing I want to tell you now, let us say you are doing a ship motion part 1, 1 part. In following wave now, following wave. So, I have you know say in now take a following wave. Say now now, my beta is 0 degree some v is very high, say v is again 20 knots. So, I have this lambda by L verses R A O. So, this lambda by L becomes omega, this you know basically becomes lambda, from there I can find out, now the point interesting point here is that see this omega is increasing, but this omega e, see what would happen say 0.2, 0.4, 0.6, 0.8, 1.0, I am just being arbitrary. This turns out to be 0.15, 0.39, 0.45, 0.42 comes down, 0.31, 0.19, 0, minus 0.10 like that it will come in a following wave. See here, this base now is not increasing, see it is increasing here and coming down. So, that is what I was trying to tell this graph, now each point got transformed to like this, like this. This point is 0.45, 0.6, this 0.6 is 1, then it is coming back.

Not only that, here when I now here at this point, when I do now we are do S omega e, but the formula this comes out to be in this point. Basically, something like infinity, say you are running a computer program, it may happen. You are not getting it clearly, I have to again explain that properly.

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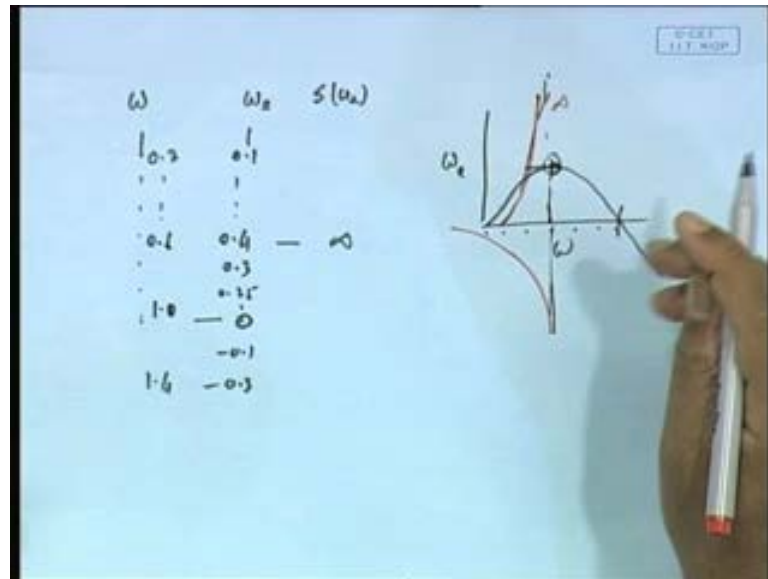
You see the point here is that I have this omega, then I have to make omega e, following wave. Remember, following wave my my omega e against omega looks like this. What would happen is that, omega is keeps on going up. Omega increasing, but omega e increases up to this much. So, omega that is what said 0.2, 0.6 then say 1.0, say 1.4. So, it increases, say this is 0.1, it increases to say one 0.4, that is this value.

After that it is begin to decrease 0.3, 0.25 like that. At this point it becomes 0 here and here it becomes minus 0.1, minus 0.3. What is my S you will find that at this point, my S omega e at this point is infinity. Because omega e is will become infinity here, another graph, the S omega e goes to infinity. Then comes back to infinity not like that, this is infinity at this point.

When you are doing this program you are going to encounter a problem, for the spectrum. You are going to find problem for the spectrum and remember I have this then next level is R A O of course, I have given then I have got S z, which is square of that and this and this also is going to be infinity or something is not it? It at this point. Because this is infinity square of that it will give you this infinity. How are you going to find the area? You will have a lot of trouble. Because what will happen? You are going to find, I will give an example you will find something like that ultimately omega e verses your S z you will find like that.
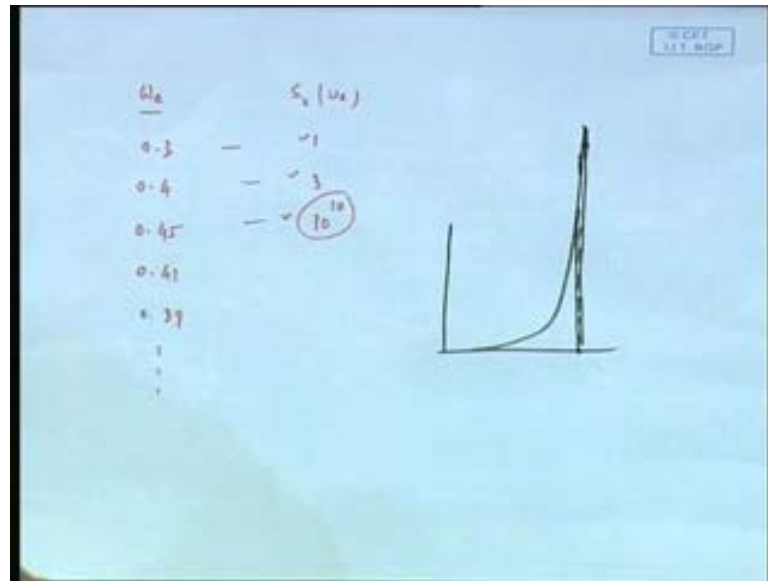
Something like say 0.3, 0.4, 0.45 then 0.41, 0.39, it will come down like that. And here you will find some value, some value, some value. Actually, may be this actually going to be much smaller. In fact, it is going to be, let us say, this you might end of getting a 5 value ten to 10. This is actually is a 3, this is 1 then again this is going to be some value. So, you see here this value. So, when you are trying to find the area by trapezoid, you are going to have trouble because if you do in a computer program with a trapezoid then you are going to end up getting even though it is very large number 10 power 10. You'll end up getting a very large m 0, if you do not take care properly.

But what is the physics the physics of course, I told before this graph is actually like this infinity, but it is a singular point. This area under that is actually very small. So, what we should do in order to get around this, see the reason way of doing this getting around this. You see for area of finding, we are not going to use this at all. We will operate on the omega domain. Remember, what I need to do? I will come back to this on this part.

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See, S z omega e is given by R A O into S omega, S omega e. So, integration of that d omega e is integration of that d omega e. This is the area; this is the area under the response graph. What we should do is that, this part we will write this way we will call it R A O square. Now, S omega e d omega e, you will write as S omega d omega. Because it is a same thing, integrate over the omega domain. You see, what is happening I had a problem this becoming infinity, this becoming small. So, I do not know how to find the area under that. So, I had when I did that this also is a infinity, but what I will do? I will do this and if I did that then I do not have a problem. Of course, you say this omega e, what I will do? I will write this as R A O omega v mu. Because v is fixed mu is fixed. So, I will operate on the omega domain. So, as far as area is concerned in following wave the problem gets automatically sorted out because I will operate on the omega domain if I want to.

Because the energy remains constant, if I were to run a computer program with omega e and if I did not have a control, the way I broke it down, I may end up getting and hitting an omega e which is corresponding to this peak point. And then you will find out, I mean, see for example, I did not choose, no I choose some value, some value here. If supposing my this discrete value one of them are chosen was this one. Let us say this is 0.4 and I use omega 0.1, 0.2, 0.3, 0.4, 0.5. At 0.4, I will find omega is to be 0.2 and S omega is going to be infinity. If by luck I had instead put the 0.4 at 0.399, it will become

ten to the power of nine. So, what happen what what I am saying is that, to avoid this it is better to always operate on the omega domain as well as area is concerned.

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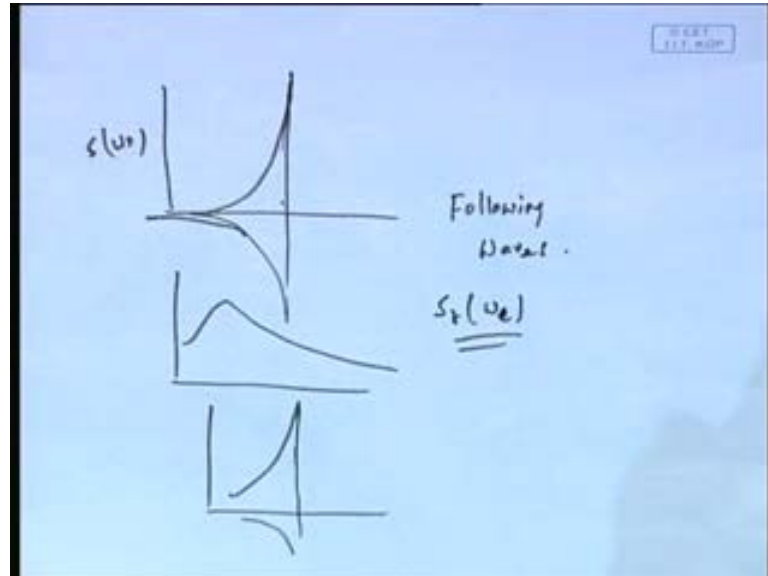
And frankly the shape of this graph basically people do not realize it so. Because when I have a spectrum looking like this, infinity going like that and all that infinity and all that, my response spectrum, you know this is my so called my a that S omega e and my R A O is of course, is something like this. If I multiply this two, this will also look something like this etcetera, you know like that. And nobody really appreciate this kind of diagram because this diagram does not reveal much.

So, in following waves, what I am saying is that in following waves, the shape of the spectrum may not be very important. In any case the shape of the spectrum is only for illustration purpose. What is is important is of course, finally, finding out what is z one third, what is z dot one third etcetera etcetera. Which are of course, functions of m 0 the area under the spectrum. And m 0 here, is this one, which is this one and you are better off doing operation in this way this. So, this is one trick that we have to follow, when we are doing this following wave condition. Actually, I did not mention then then, I will try to mention this this part little bit because we have a few minutes time.

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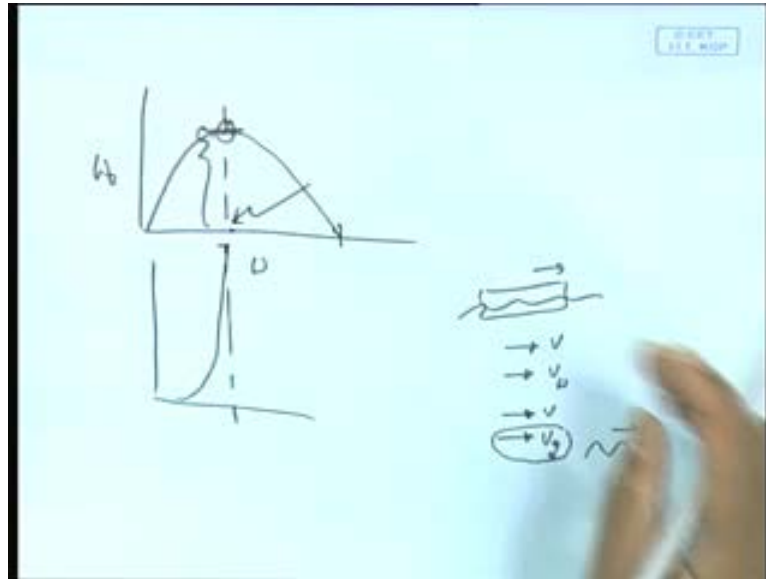
See, what is the physical significance of this? This omega e verses omega, what is the physical significance of this part, spectrum going here to infinity. This you know what this correspond to, this corresponds to the group speed of the waves and energy travels at group speed. So, what happen, when the ship is travelling same as the group speed of the wave then the energy of the wave cannot get away from the ship and as a result the energy appears as infinity, rather it energy appears as infinity, energy gets trapped so called. Just the same phenomena as sonic boom same resistance in in a in a shallow water etcetera.

So, what is happening here the ship is moving, you see the waves are moving. Now, what happened, 0 frequency is of course, when the the speed of the ship and the speed of the waves are same, but this one corresponds when speed of the ship is same as the group speed of the wave which is half the wave speed. This is the speed at which the energy is travelling the energy of the wave is travelling at that speed; ship is also travelling at the same speed. Therefore, energy cannot get away from the ship and as a result it what is called a trapping phenomena it gets trapped this is why this infinity comes in.

This is the physical significance of this infinity and this is that is why in deep water it is half. See here, this value is half of this value; this value is where the phase speed and the ship's speed is same 0 frequency. This value is where it is half, that is why the energy goes and this value is same as this value, this value is same as this value that is what we

will find out in the calculation part. So, this is one point that we need to realize when we are doing following wave.

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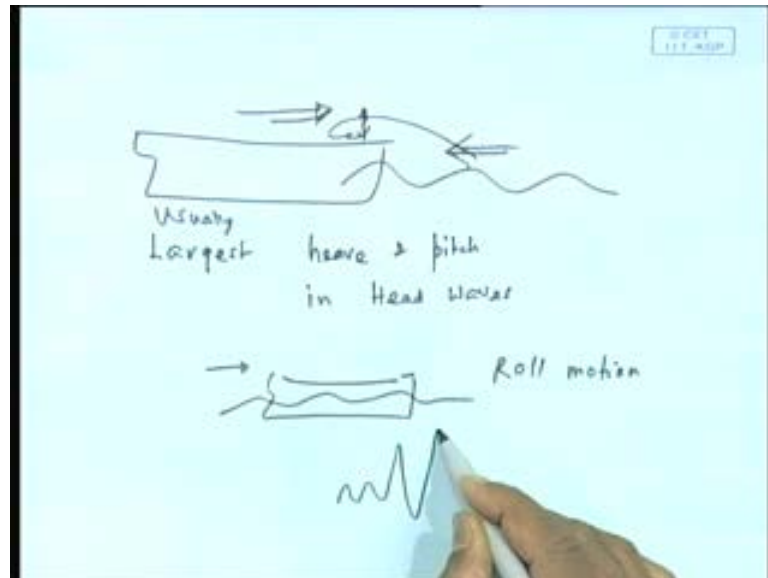
Now, let me also continue, how important now following wave you have a problem, you have seen this calculation how we can do? Is it important for following wave, should we worry about it that is another question? See, from physical (( )) point of view, it turns out that when a ship moves, it has the usually the largest, usually that is one. Second thing remember, that this part violently goes up and down and as it goes and hits below, which is what we call slamming, which we will discuss eventually. And if this comes down the water goes up on a top, we call deck wetness or green shipping of green water is called, you know the ship, you will have seen I have got, I will show it to you sometime excellent videos clips. You know of seeing, how the nose of the ship has completely gone down to water and it comes up fully, you know the water comes up entirely on top and all this are vertical modes of motion, heave and pitch combine. All these are more important or significant in head waves, as as a result it is a and following waves it is less not not so much important, not it is usually not so.

This is why what is happening is that it is a head wave that that on condition that has become more important, which is exactly why, we did not pay enough attention in typical courses and all for how to get spectrum in following waves. Does it mean following waves are not important? The case where following wave is important, that is

when the ship goes here and the waves follow is actually in roll motion. It turns out that in following wave roll motion can become very uncontrollable, it may end up getting kind of a very transient response and increase an capsizing.

This phenomena is somewhat similar to a gripping phenomena, you see what happened? When I at a speed as the wave, then my restoration forces become very small in some sense, it is something like you are trying to walk on a very slippery, you know ground. So, when you go on a slippery very slippery ground then what happen? You have no grip. Actually, I learn this experience from, you know like this a driving on in in Canada for example, in this parking lot used to be full of ice and you try to drive in put a break and there is just no grip. You just feel there is no control, you it goes in that side, similar phenomena.

So, normally what what I am want to conclude saying that, following wave is important, but normally from day to day sea keeping evaluation following wave is less important and that is the reasons why in doing the spectral calculation all the problems that we give normally. It has not been given such due importance, but having said that, you can always do this and that is why all the problem that you end up getting that there is an infinite S omega etcetera.

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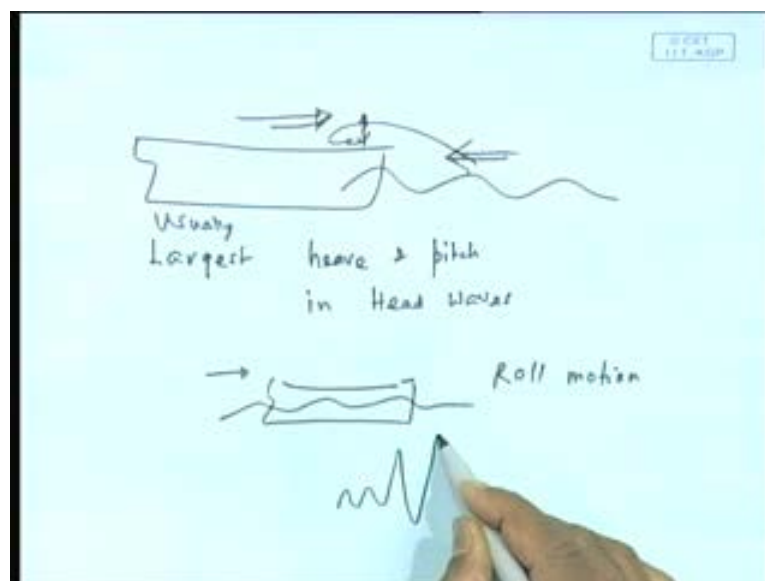
You know we do not talk about it too much because we do not use it following waves, but if you were to use it and if it had to be done then it is better to always use it in this

formula never mind the spectrum shape. So, with that I am going to end today and we are going to go to next class. Now we will go back to the next level of different spectrum. So, the 2 D spectrum motions I am finishing it here, we will go to the 3 D spectrum tomorrow. <mark>Thank you.</mark>

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