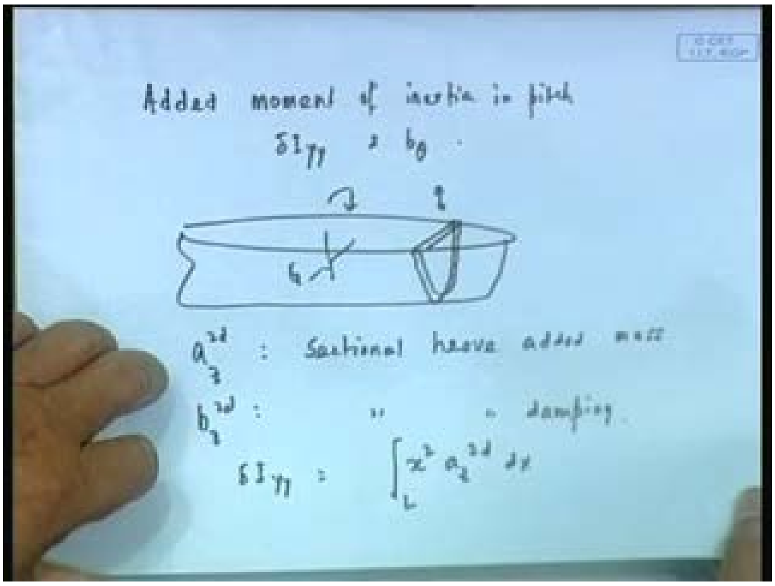
Seakeeping and Manoeuvring

Prof. Dr. DebabrataSen
Department of Ocean Engineering and Naval Architecture.
Indian Institute of Technology, Kharagpur

Lecture No. # 08
Uncoupled Heave, Pitch and Roll-IV

We will continue our talk on this uncoupled pitch and heave motions.

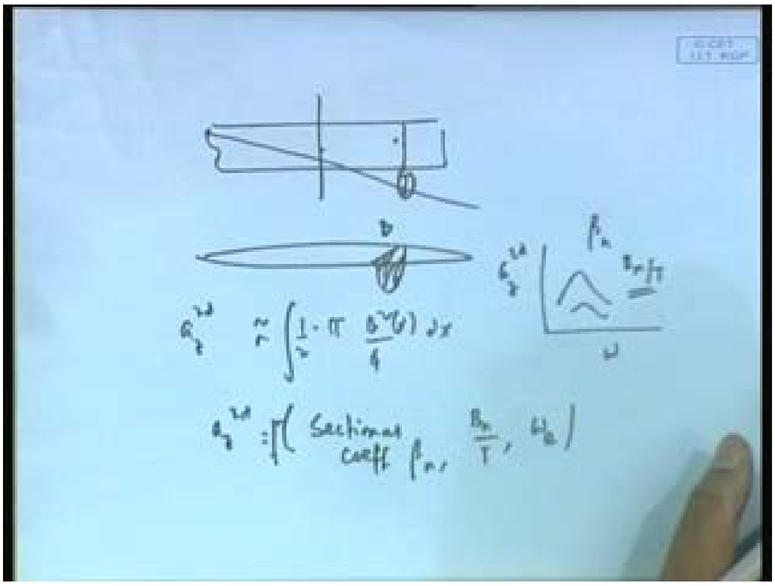
(Refer Slide Time: 00:32)



Let me look at this estimate for added moment of inertia in pitch and also the damping, that is basically del I y y and b theta. See just like heave, if I have this ship here, and if I took a section, and if I have my sectional added masses was a z 2 d, was my sectional heave added mass and of course, you can also have that similar damping, I can always call this.

Remember in previous class we mention about strip theory, that the ship was made in a strip and oscillating. Now, here what happen, see heave and pitch are so correlated, that if I were now oscillating this way, it basically mean sections are oscillating this way. So, what happen as far as pitch is concerned, this has an sectional added mass and what is my pitch moment of inertia that is delta I y y, it simply becomes integration of x square a z 2d into dx over the length. Of course, you have to take the x measure from the origin of the system C G. So, you see this how easily it can be found out.

(Refer Slide Time: 02:27)

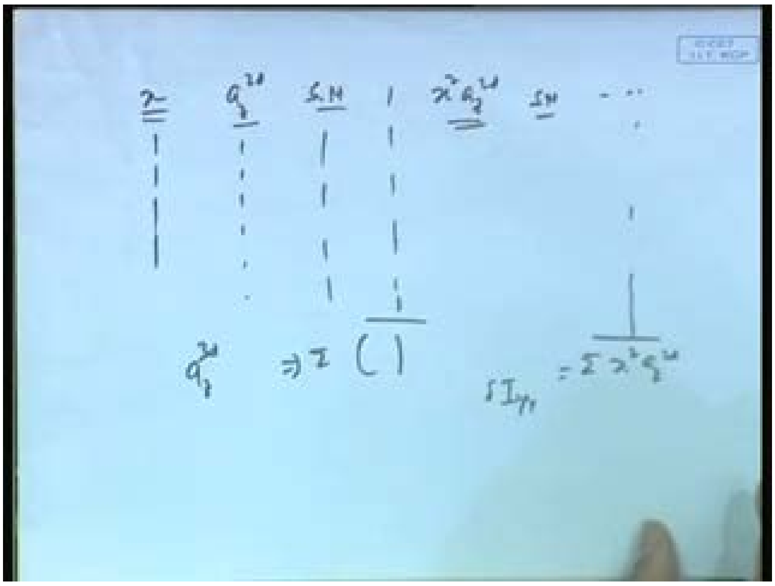


I will show this picture in this form again here, because it is easier to see a two dimensional forms. So, I have a section here, let us say this much is my added mass, body is rotating like that. So, what I am doing is that this of added mass, square of that integrating over it. So, you see what is happening is therefore, that if I, well I can estimate pitch moment of inertia also from sectional heave added mass and similarly, the damping part. And if you recall, we talk yesterday about different mean of estimating that one of the simplest one was also of course, that as I said that if I were to take these a sectional b by a z 2d, if nothing is available I will simply take it to be mass of this semi circle, how much is this? pi B square by 4 into half. And of course, I can integrate that if I do over dx I get a good estimate that is a very rough estimate. In fact, theoretical this is known as high frequency limit

Theoretically which means, this is strictly speaking valid in deep water which happens to be at high frequency limit, never mind that part, but it is a good estimate. It is this estimate, that is used in Bareilly's formula as somebody was asking, one of the student was asking in vibration, because vibration is a high frequency phenomena, and when you take a hull you vibrate it, what is the period? One second or so, is there any wave of one second No. Waves are mostly six, seven, ten etcetera.

So, 1 second is really high frequency, so you could use that. So, here also we can make a very rough case, if not as I mention in yesterdays class from that Luis form there are graphs and charts, where omega verses those sectional, you know like this values are given for different values of beta n and B n by T, etcetera, various graphs are given. The one that we have talked yesterday, there are charts available of this average as a function of sectional coefficient beta n, then with coefficient B n by T and of course, omega e. We have talked about that there are charts available; it is only a simple matter of going to the chart, taking up for relevant value of that, finding out this.

(Refer Slide Time: 05:14)



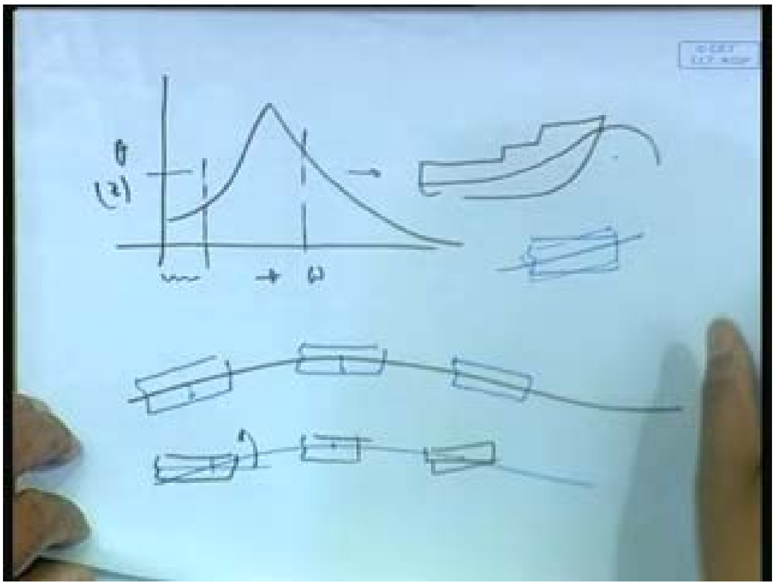
So, in one short, you can actually get always added mass in heave and added moment of inertia, very simple. You simply make a like typically hydrostatic type, I have got x here stations, I end up getting this a z 2d, then I have so called, if I want to use Simpson multiplier, then I get this one, this gives me by sigma I end up getting here a z 3d, and here I use x square into a z 2d, again I use Simpson multiply, again I get that, this will give me. So, essentially in one table I can get both of them, very simple, you know like straight forward. So, heave and pitch are really related to each other, you can get from one table in any assignment on any problem.

But these, having said that these are only approximate formulas. See the subject of this dynamics like in water wave resistance, evolved was last so many years. Today of course, we have got much more sophisticated programs, three dimensional c f d kind of course, to find out the same thing. But, I am talking of practical estimate when you go to shipyard, when you have to make a quick estimate, when you are doing a first design, you are not going to run probably a code very, you know expensive code. However, for offshore structure running such code have become important, it has become a routine industry affair, where you do run available codes to find out these things. Anyhow, so, this is only an estimate, I am focusing on, so that you get a rough idea as I mention repeatedly that rough case.

Somebody came to your company, you are in a shipyard and try to tell you, give me a guess of the natural period, etcetera. You can quickly use this added mass and moment of inertia, but this formula that is the high frequency formula, just this mass is slightly better than using a k y equal to 1 or some factor, slightly more accurate. So, you can always get to that.

So, these are all various levels of approximation that you should know. So, this is the same thing will apply to damping, exactly damping is also available in this way, like damping function of sectional coefficient, sectional with and frequency.

(Refer Slide Time: 07:50)



See, there is another very crucial thing that I want to tell, now from physical point of view, of the behavior. Remember, when this goes like that, this is my theta, or motion, or z in, and this is my omega. We said that this low frequency part, is the low frequency part dominated by hydrostatic force, this is my high frequency part, this is the damping part. Let us look at the pitch how it looks like in this case, see low frequency wave is like that. What happens you know, if you look at that, you will find out that the pitch is exactly in phase with this, that mean it is always aligning itself like that. The low frequency part one can show, it will be in phase with exciting moment, exciting moment is actually, with phase with this low that makes sense, because you see why I do not have to go through a math's to tell you.

You can always use your own kind of logic to find out. See, it is taking very small frequency means long time, so I have enough time. So, when suppose water waves, suppose this shape is there, the water wave become like that, It has there enough time for the hydrostatic to balance itself and make it align to, because this align position of course, is where my hydrostatic force exactly balances

Since the frequency is low means, period is high. I have enough time for the body to adjust itself to the local slope, because only in the local slope my dynamic force, my dynamic moment becomes 0. See, after all for equilibrium in hydrostatic equilibrium, what I need total hydrostatic force must be 0 moment must be 0, in this case that happens. So, this is why it follows that typically, remember this makes perfect sense. Remember here heave, this is what I will talk now, what happen to heave? Heave is also following this, remember if you go up and down it is exactly here, you stand here, you find same local draft or same free boat, which mean it is simply going up and down another way.

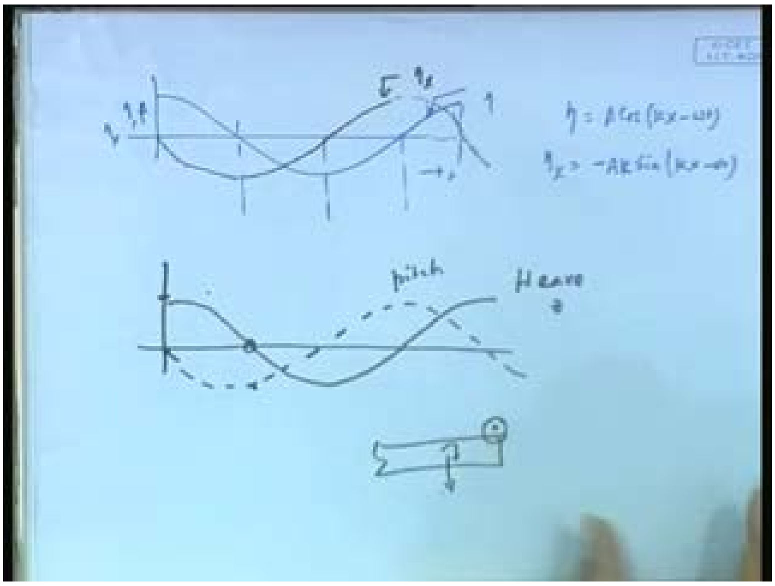
But, now I will tell that there is a interesting phase gap between the two motions, which I will come in a moment. But, before that let us talk about this side, what will happen? Just the opposite you will end up getting the ship, you try to see that it is slightly this way, which is more dangerous. Obviously, here you find out there is a tendency, because there is a phase gap for water to go on top of the deck, and here go to come out and slant.

So, you see here, because here when the water slope is rising, my ship is going down, right? So, there is a kind of opposite phase. So, one again the same thing is proven that situation where dynamics very important, becomes physically more significant in a sense, because that is more dangerous. After all, you do not want water to come on your take. In fact, you will find out many of the small boats of course, not only for pitch reason, the bow is very much like very much up.

Of course, this is for the wave raises wave, but also for pitch to some extent. So, this is another extreme of that. So, we must realize this part, where inertia is dominating, typically my exciting moment and my response are out of phase typically, or with respect to wave slopes, and as a result when water is rising, ship is tending go down. In this case, the bow is going to go down when this is going to rising. So, here there is a phase gap.

Now, let us look at this phase thing which is more easily seen, the relative phase between heave and pitch, in this case. We can, I want to show you that, you see when maximum, let us take an example of lower frequency. What we want to, I want to tell you is that, the maximum heave and maximum pitch, usually do not occur at the same time and which is good for us, because if it did occur at the same time for a given motion, you have got a very large motion.

(Refer Slide Time: 12:36)

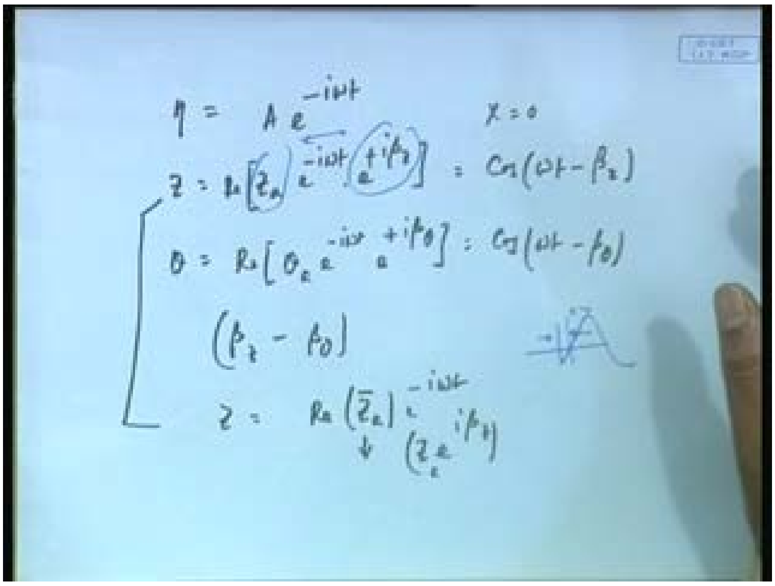


Now, how do I see that? See, let us take eta, so A cos curve. So, eta equal to A cos, what is eta x equal to d eta by dx? that gives you minus, right, minus A K. This is right K x minus omega t. So, this will be minus K sign means, it will look like, let us look another pen minus sign will look like this.

This is right. So, this is my eta x, this of course, is t this is my this is my eta, this is right. Now, you see what is happening, motion in low frequency, I am having my heave given by this blue line, in phase with blue line and that is heave is like that, this is my heave .Where is my pitch? my pitch is. So, you can see that there is a phase gap between heave and pitch. When my heave is maximum, my pitch is 0, when my heave is 0, my pitch is maximum. You see that phase gap between the two, this is important because when I want to find out what is happen when you are standing at some point, phase is important, I cannot add all the maximums together. See, I am standing at this location, we will discuss this later on. Ship goes down also ship comes down.

Supposing at the same time the amount it went down maximum, it came down maximum. It would have been much lower, but that is not happening, usually do not happen, why because there is a phase gap. The concept of phase is therefore, very very very important, if I was to write this as z equal to z A cos omega t, this will become theta A cos omega t plus a phase. Remember what we have done, we are always measuring the phase with respect to input web signal in our usual study, with respect to input web. In fact, what we do is that you see, that if I always say that, if I had eta equal to A e power of minus i omega t you know.

(Refer Slide Time: 15:30)



Let us say this at X equal to 0 then, I am writing my z to be z A e of minus i omega t into e of minus i beta z. This is all of course, real part, what is this? This is nothing, but cos of, we can say omega t actually, here I wrote plus, we can write plus also, you can say this way because it is beta z minus cos means, both are this thing and theta is going to be real part of theta a.

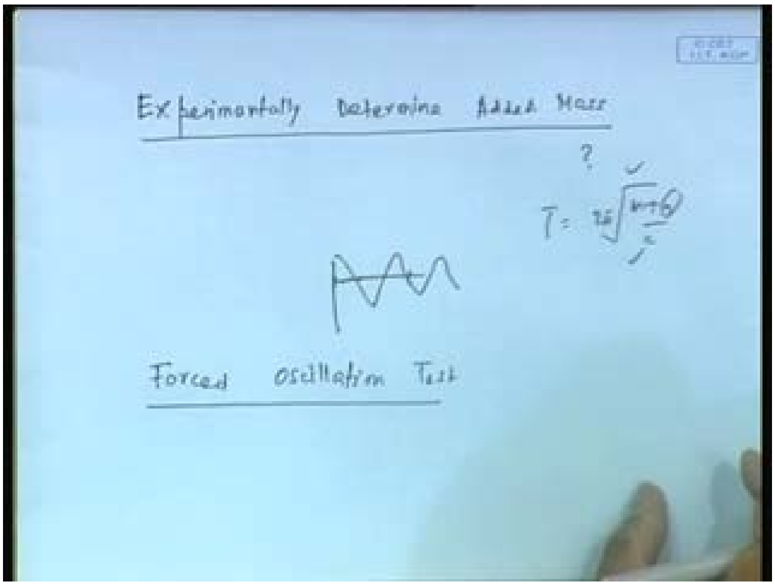
What I found, now relative gap between these two is beta z minus beta theta. This is my phase gap between z and theta, but normally what I am doing? I am always finding between this two, and you will find out in later solution I will tell, that we actually, we write this way, I will write this to be real part of z a bar e of minus omega t, when this is equal to z e of i beta z.

This term is known as complex amplitude, it is a complex number. Because you see, if I were making this, this part and this part combining and I call that z a bar; obviously, that number is a complex number z a bar. So, this signal is a sinusoidal signal in time with this amplitude, but this is complex amplitude. So, for manipulation part as you will find out later on, for solution purpose we actually, determine complex amplitude because complex amplitude tells me directly, phase and absolute value.

So, concept of complex amplitude is also important, we will see that eventually in when we actually do the calculation. Complex amplitude tells me that not only this value, also this gap that is where it happens, the phase gap. Anyhow, my point of course, is not so much to go into complex amplitude right now, but to tell you that there is a phase gap, phase is extremely important just by telling me that I have this heave and so and so pitch so and so, the story is not complete. You must also say when does it occurs, that is important. As we have seen in this case, yes pitch is so and so. Let us say, here the ship is pitching by 3 degree, but when does 3 degree occur? Well, let us say heaving by 4 meter maximum, is it pitching 3 degree when it is going 4 meter down or no? This is what I need to also know, because without knowing that I cannot really find out the actual history of the ship motion.

So, phase is the extremely important concept in any motion that you have to understand, without phase, it is not completed at all. Now, I will like to get back to some means of determining added mass

(Refer Slide Time: 19:20)



Once again I go back to added mass, because it is important. Can anybody give me a guess about how can experimentally determine added mass, why I am asking I will tell you, how do I do that? You see, people will say that many people do not agree all theories, they want an experimental verification, experimental measurement.

Now, resistance test, very simple, you have tore the model, just figure out how much is drag, As far as measurement is concern you have measured it, you just tore the model, find out the drag and what we debated, is not how to measure it, how to extra politic. That was our main debate scaling and all that. Similarly, for if I want a ship motion, maybe I will send a wave and I will find out how much it is moving, but added mass is an interim concept, somewhat. You do not see it, how do I measure it? that what my question is.

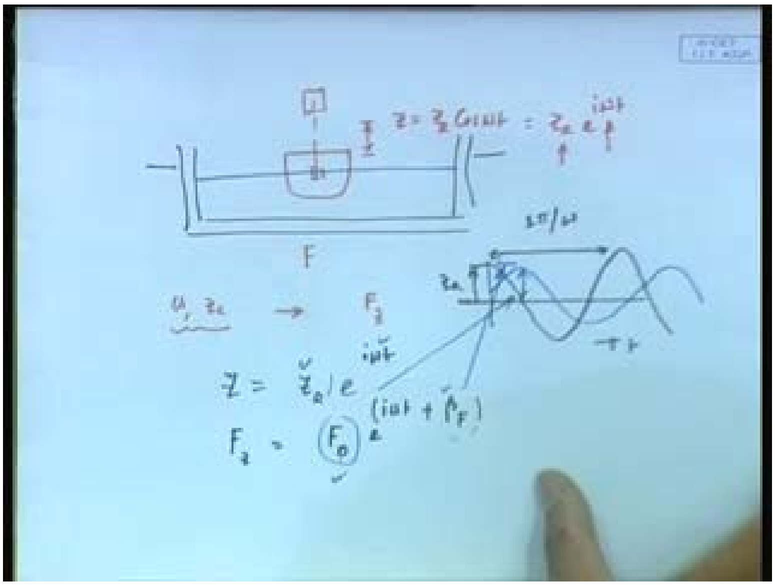
But having said that, added mass, I said yesterday is basically a force concept there is nothing like identified mass it is added mass force. So, you can immediately understand that the measurements system must consist of measuring some kind of force.

So, that is 0.1. 0.2 is that, see I now that this T equal to natural period equal to, like 2 pi into mass plus added mass by c. Now, here I know this for the geometry, I know this for the geometry, I have to only know this added mass. So, if I were to take a body and just push it down, it might go like that. So, I can figure out this period, and I can say well I know this anything, I know I can find out this.

But, there is something wrong, what is wrong? What I found out this is only for this period. Remember this a is the function of frequency, see I have no choice on the frequency variant, let us say it is a 11 second, scale down maybe 3 second. So, what I found a, is only for 3 second.

So, in order for me to find it out added mass which is over all frequency, I have to conceive a different experiment, very important to understand that. So, this is what is called, what we are going to talk to little bit is called forced oscillation test in only one mode heave I will tell, forced oscillation test. In fact, we can do that in our tank with the dynameters we have, provided we have a force mechanism.

(Refer Slide Time: 22:20)



What we do here, this is my tank here, say water tank. So, let us put the water like this, and I have the body here. What I do is that, see I want to give it a particular oscillation motion z, or say z a e i omega t, I am controlling it, omega and z a. I can have a mechanism, some kind of circular mechanism by which I can push it down. Then what I do by an instrument here, I measure the force that is been required to push it down, the force that is coming

So, what I do is that, remember this force oscillation test for a given non frequency omega and for an oscillation amplitude a, which should be sinusoidal, I am measuring F z. Once again, let me tell you this I have this body, I oscillate it. Oscillation frequency is decided by me, like I want to do the test for this frequency, ram number 1 omega equal to 0.1 to 0.15 like that. I decide a amplitude 1 centimeter or whatever, these are my input

But, this is the interesting point; see I am doing that of course, with shape of a pressure field here, so therefore, I have to walk against the water, so there is a force coming and that is what I measure by an equipment here, so I measure that force. Now, from this I can find out, you see this is called forced oscillation test, I can find out the added mass of damping, how we will tell? You see here the interesting point is that, I we will just work it out my z here equal to z a, I will write it again e power of, well we can do it plus or minus does not matter a real part is implied

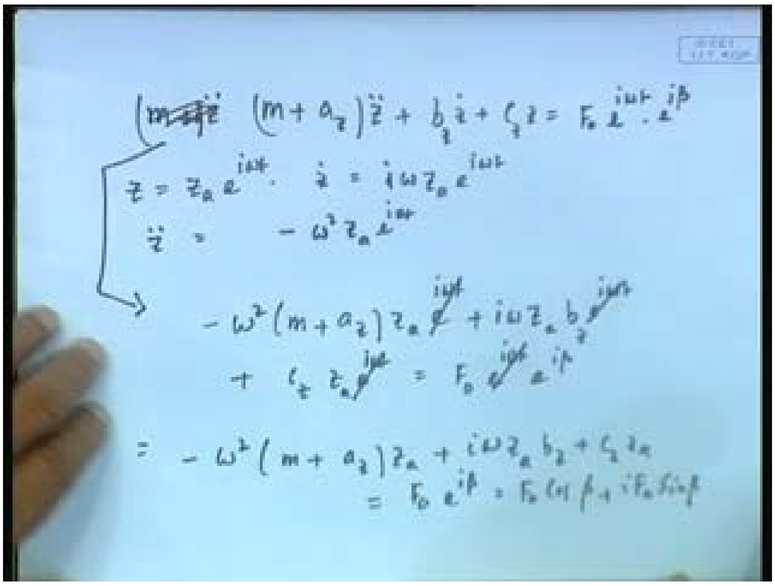
Now, F z that I measure will becomes F an amplitude, let me call it o e power of i omega t plus beta F. You see why this because remember that, how I get this beta a, I oscillated that, oscillation is this.

This is what I have given right, input data. This is my z a, if this my period t, this is my 2 pi by omega agreed. See, I have oscillated that, so I know of course, z a period 2 pi by omega, etcetera. What did I measure? The force history, remember history. So, force looks something like this, this is output, this is what I measure, the equipment have measured me this force.

So, the equipment that have measured me this force at every second I plot that, when I plot that it likely to be side to be sinusoidal, actually for that purpose I would do some kind of filtering, feeding, etcetera, but it will be taken as sign curve. What do I get of that, the amplitude here, that is my this and I will know my phase, remember that is important this phase.

This picture may not be correct, but the point is that, I would know that both these and these from the measurements. So, I have fate this and I have fate this, what I found out is this and this, this is always a harmonic test. So, I once again repeat this is input, this is for a given omega output is measure, what I measured is F 0 and beta F, now from there how do I find added mass? This is what I have put in and what I measure. Now, how do I find added mass, we will go to that.

(Refer Slide Time: 26:58)

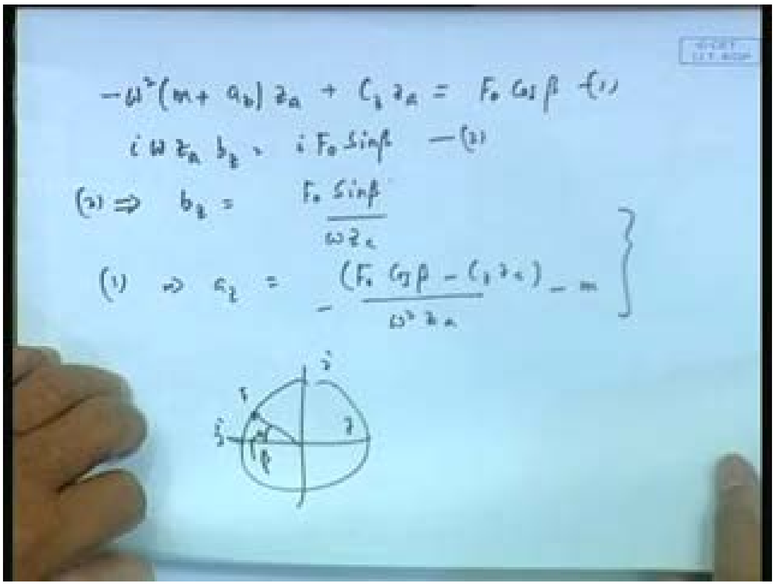


So, we now we have to go back to this equation of motion for heave m plus, we will work it out slowly, sorry sorry, not m plus a or rather we may cut it again a z, see in this case I have got F 0

Let me write in a complex number only, i omega t e i, you can just call beta, remember that this and this we have found out, this F 0 and this, Of course, z equal to z a e i omega t. So, what is z dot equal to, here I have written plus actually, this plus minus, remember again the way you proceed really does not matter. You can always write this as minus plus something else, instead of sin cos it it the answer will be the same thing.

I am only showing therefore, the principle of how we go proceed. So, here I wrote plus, I could have written minus also, does not, did not matter. Because both of them are cos omega t, remember real part. So, this is become I omega, how much is z dot dot; minus omega square. So, what happens to this equation minus omega square m plus a z, z a e I omega t, that is right, because z z a comes a e i comes here, minus omega square z double dot this is okay, know.

(Refer Slide Time: 30:46)



Next term is plus I omega z a, b z that is okay, b z into i omega z a this thing. The next one is c z into z a e i omega t this is equal to F 0 e i omega t e i beta. Now, you can delete all this. So, I end up getting minus omega square m plus i omega, we just see this also, i omega z a b z plus c z this is see this you all agreed with that minus omega m plus a z z a plus i omega b z z z a b z c z z a equal to F 0 e i beta that is F 0 cos beta plus i F 0 sin beta. So now, obviously, from this equation real part is real part, imaginary part is imaginary part. So, you end up getting the two equation from which you can find this thing

So, what I end up getting is minus omega square n plus a z, z a plus c z equal to F 0 cos beta and well i omega z a, b z equal to i F 0 of course, from here, this is 2, say this is 1 from two, I get straight forward b z equal to F 0 sin beta by omega z a, and from one I can get a z, well I can get a z as let us see how F 0 cos beta minus c z, z a divided by omega minus, omega square z a minus m, something like that. See, this divided by minus that gives you this, you divide by omega square z a, then take m on that side

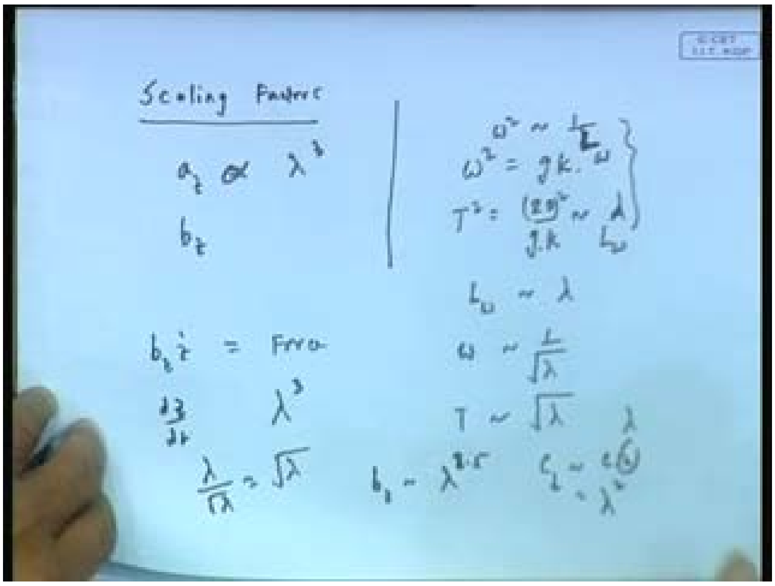
I mean, you can work it out whichever way. So, what I means is therefore, that this is what is called forced oscillation test, which is what you could do to find out basically like added mass experimentally. This is a very important test, why I mention to you this now in the class is because, usually, this is not so commonly known to people, because many test you do for design purpose is to directly find the output, but here you are finding the added mass

See added mass is just a quantity, which would be useful tomorrow, if you want to predict these motions, but you are not measuring ship motion directly, remember. Like resistance your measuring directly, somebody can figure out, so many kilo Newton is the total distance, meta centric height may be measuring sometime, you may be k g you are measuring inclining test. But, here added mass, if you go to industry and say I want to measure added mass, people will not know about it.

So, therefore, this experiment for added mass measurements force oscillation is not usually, commonly known. That is why I am trying to tell you, and you can also see here that experimental measurements here are not so direct, you have to make certain assumption, you measure something and go through certain equation to get something ultimately. That is very important and this also involves inherently a phase concept, you have to measure phase without, suppose beta was in fact, you will see beta is 0, b z is 0, that is what will happen in high frequency.

You will find that beta will become 0. In fact, one can again find out the same concept as I mention, that this is z z dot z dot dot, this is my F, this is my beta, this is my F, the kind of like how much it is lagging or leading. One can relate to that in principle. So, this is what is about is added mass. Now of course, you are doing a scale test, you are not doing a full scale, you do not have a full scale ship doing a test. So, what is the scale factor? Another point, that i should understand, scaling factors, when I do a measurements. Added mass is scale at what? See, added mass is proportion to mass.

(Refer Slide Time: 34:18)

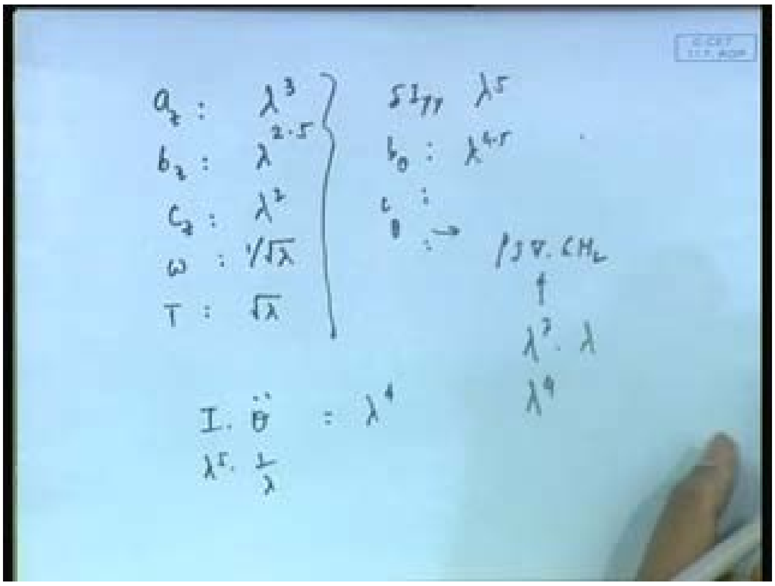


So, obviously, it will scale lambda q, tell me how, with what will scale? This is important, I want to tell you this, see maybe before that we should go to time part. Omega square is g k and T square is how much? T square will be 2 pi square by omega square. T square is going to be 2 pi square by omega square 2 pi square by g into k, 2 pi square by g k. Whatever, I mean its opposite, see what I am trying to say it is opposite, T square is listing it to lambda and omega square is in proportion to 1 by lambda. Now, lambda is wavelength is scaling well, wavelength here is lambda here, let me call it L w, otherwise you will have a confusion. See, what I am saying once again if you understand, omega square is g k; that means, omega square is inversely proportion to wavelength L w, you agree with that, omega square is inversely proportion to wavelength. So, T square is linearly proportion to wavelength.

Now, wavelength; obviously, scales at lambda, so frequency will scale at what, 1 by root lambda and T will scale at root lambda, this is important. That means, if natural period is 10 for actual body, one is to 10 scale body would have a period of one second 1 by root 10, please understand this very importantly. If a natural pair of a ship is 10 second, it is one is to 100 scale model would or should have natural pair of 1 second. If the frequency there are, is 10 second means 2 pi by 10, means about h 0.6. Here it is going to be 2 pi by 1 6.

So, frequency is much faster but period is much smaller, but they are not linear square root. Why I am saying this, because in b z I need that. Now, let us work out how do I scale b z? Anybody knows, you see how do I scale remember b z into z dot, this is a force, this scales at lambda cube, because force scales at lambda cube. Now, z, what is z dot? d z by dt. How does it scale at? Lambda by T is root lambda, that is a scaling at root lambda. So, what should b z scale at? Absolutely. So, b z scaling at lambda power of 2.5, everybody agrees. b z should scale lambda power 2.5, very simple to work out. What about c z, immediately one can tell, because c z is first of all, exactly, because it is c into z. So, this is; obviously, this is lambda. So, this must be lambda square.

(Refer Slide Time: 38:09)



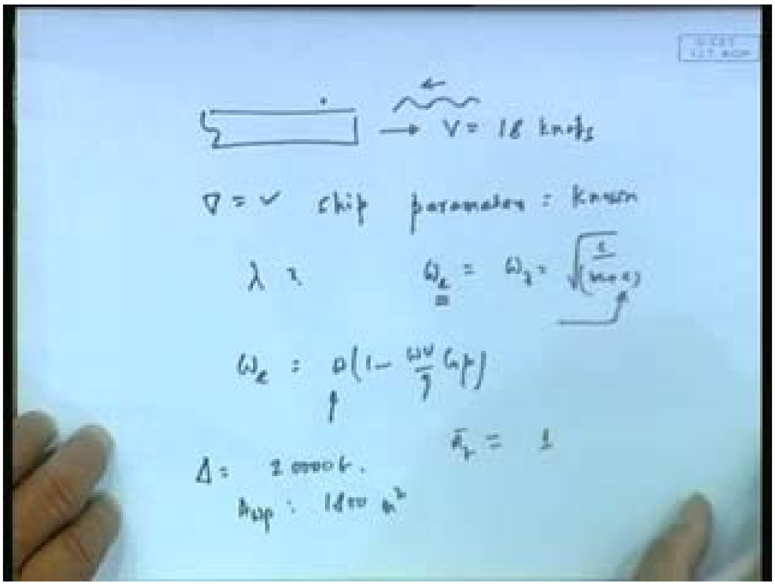
So, I will just organize and write it now. Therefore the scaling factor becomes the a z is lambda q, b z or damping, once again we will come to next level. These are all linear motion 2.5, c z equal to lambda square, omega of course, scale with root lambda, 1 by root lambda and T scale with root lambda. So, this linear you please work out yourself what will happen to dy y and I b theta and c theta, because they are moment there, what would happen to moment, force into distance? another L get's multiplied

So, you will end up getting this part, it is not going to be just 4 because moment of inertia mass into distance square. So, I will leave it to you as an exercise to work it out, you can work it out from elementary example, but this look at c theta straight forward, because it is o g into V into G M L. So, this is lambda cube, this is lambda, so lambda 4.

So, you will see this lambda 5, lambda 4.5, why this not 4? Because, remember it is theta dot, dot not z dot, dot. There is one lambda gets out from that side for moment because the motion here is theta which is actually only h there is not l there in other words I tell you I into theta dot dot this is my lambda 4, but this lambda 5 and this is 1 by lambda, gives me lambda 4

So, you can work it out this scaling. Very important to understand the scaling, because I do a test, I do not know how to scale up, I have no really meaningless thing. So, this brings me to some simple kind of a problem type, I thought I will spend some time to tell you about some very simple problems. Let us see this, I have a ship, I am standing here.

(Refer Slide Time: 40:28)



Now, I find out that at a speed of V, equal to say 18 knot, when waves are coming opposites, I find some regular wave field, I am heading into that and I find I have excessive heave motion. I have the ship parameters given, please understand I have the ship parameter, this is known, all the ship parameters is known.

I have a ship of course, I now the hydrostatic parameters unknown. I find out that in some wave condition, waves are coming, heading on at a certain speed 18 or some given speed, I have excessive heave motion. The question is, can I guess the length of the waves? Wave field, is regular wave field; that means, what will be the lambda? problem is very simple, because excessive motion means; obviously, wave frequency, exciting frequency omega is equal to natural frequency omega z; that means, and this is equal to of course, we know root over of c by m plus a of course, I have to make some estimate of a, without that you cannot proceed. So, how do I go, I can estimate a, I of course, now c and m from hydrostatic and mass inertia.

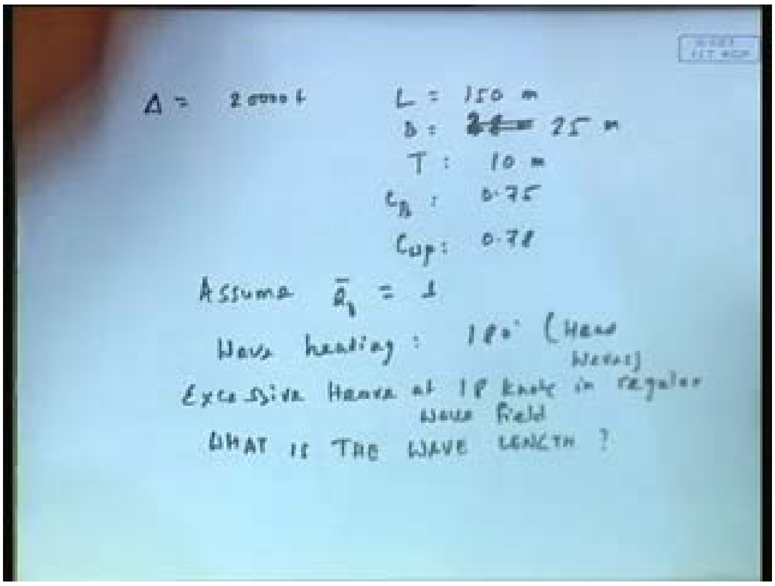
So, what will happen from there, from this relation, I will be able to find out my; well I know the natural period, so I know what is my omega e. Once I know omega e I can go back to the relation another equal to omega into 1 minus omega V by G cos mu, mu is given here. So, I can find out omega, once I know omega, I can find out lambda.

So, if you do that, I thought say this problem, I will give it to you with the numbers here, see this ship is there, let us say displacement of 20000 ton assume added mass to be equal to mass, which means added mass coefficient a z bar or what, I do not remember what I took a z bar as 1, you take it as that, you assume that.

What happen in the (( )) A w p, well actually, sometime what will happen will be L and B and del C w p, etcetera. Say, L w p is also given it can be, maybe 1500, it is 100 into 1800 meter square or something.

Something like that, find out the lambda for eighteen knots? So, let me organize this and write it properly, otherwise probably you are getting this thing.

(Refer Slide Time: 43:42)



So, I have displacement of 20000 ton, actually let me put the other way round. L of say 150 meter, B of maybe 20 meter which is of course, no. Let me 20, 30 meter, I do not want to make a distinct is 5, 28 meter I make it, because 30 makes it L by T 5 is too short, 25 makes it L by B of 6 so 25 is good number. T of 10 meter, let me out it deep vehicle, C B of 0.75, C w p of 0.78 say this all given to you, assume a z bar to be equal to 1, wave heading 180 degree, head waves excessive at 18 knots in regular wave field.

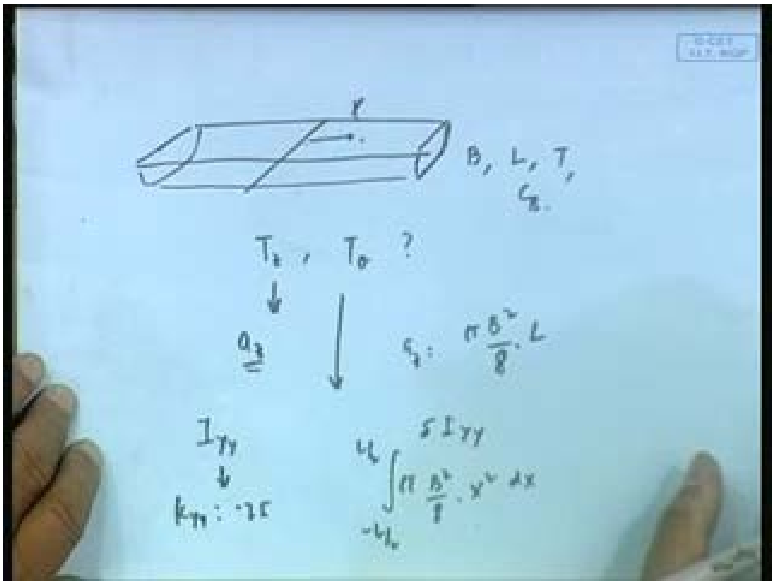
What is the, remember, please remember that this is forward ship problem. So, the omega you find out is omega e, omega e is equal to the natural period, natural frequency. Omega e is not omega is equal to, remember, that I mention here also. It is this some people make this mistake, instead of omega e you say omega equal to natural period and then.

In other words, you find out the natural period, let us say natural period happens to be, let us say something like 10 second. So, you think ten second has omega and find out the wave length, Some people do that it is the because this is omega e. So, from omega e I have to first find out omega and then find out what is the wave length for that omega.

So, I am repeating this because this is the common mistake people make, that is one common mistake people make, and the other common mistake people always make is in delta I y y and I y y part in pitch, because people always take I y y for a real. If I give a ship dimension and all that, estimate I will come to that, they always take I y y to be the moment of inertia for water wave. That is another mistake that is commonly made by people. So, this is a very simple problem we can do and we can manipulate with that in various ways, because it need not be a like a head waves, it can be some 45 degree waves, it can be falling wave, but essentially it does excessive motion.

The word excessive motion means, it is resonating. Now, let us look at another one that I have here, see there is an estimate of added mass, we will just do this based on some kind of a simple calculation, we have another maybe 5 minutes.

(Refer Slide Time: 47:41)



So, here it says I have a wooden log of uniform cross section or let us take a barge, I have a barge here of uniform cross section, which can be any uniform of side B with B length L and it is statistical stable. Now, here once again the question I ask was, what is my T z and T theta? Estimate that. What you see, then I said that use your engineering judgment, I mean I am trying to leave it to you, use your engineering judgment for that, for estimates

So, you understand now that T z I require to estimate, what added mass the other things are all known, this is the L B T, etcetera, mass and all is know, see this is the square bar L B, because I would have given also is L B and T and probably C B. So, mass and all is known in this problem.

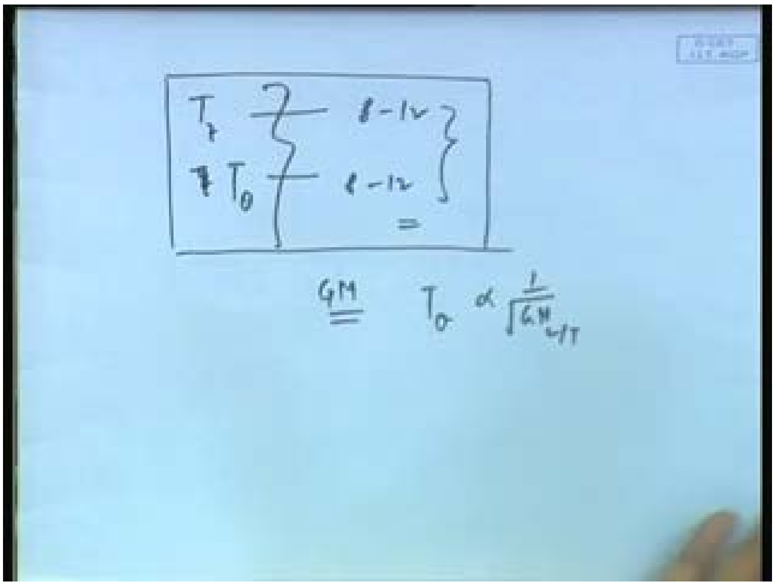
Now, for T z I need and estimate of a z, please do that. How would do it? Well I said when nothing is here, simply take this sectional added mass to be B square and this case is very simple, because the uniform cross section and B is constant throughout. So, I have B square by pi B square by 8 into L becomes a z, you understand that sectional added mass is pi B square by 8 integrate of length is L, that is one part.

What is my added moment of inertia and moment of inertia? For t theta I need two things, I need I y y as well as I need delta I y y, remember. Let us talk of delta I y y first, how much it is? It is a uniform cross section. So, I had actually pi B square by 8 into x square integration from minus L by 2 into plus L by 2 dx this is agree.

Because, take a next section, this turns x, sectional added mass is B square by 8 pi into x square, integrate that. Actually, it will be x cube by 3 and if you work it out, you will find out x cube by 3 L by 1 by root 12 or something, very easy. What about this? If you again, you have to make an estimate, realistic estimate. Make K y y to be maybe 0.25, I would not stick to only 0.25 suppose, you are making 0.30, make it 0.24. No hard and first rule, but try to make a realistic estimate.

If you do that, you will end up getting basically a estimate of this numbers and that can be of by 10 20 percent, not a big deal, but at least you get a good estimate I have still a few minutes for this and I want to touch upon just, not a problem one more thing.

(Refer Slide Time: 51:09)



This relation between this T z and T theta from design point of view. You see what would be your objective of design would you like them to be same or different; obviously, full aim for us will be to make sure that there are separated out because if they are not separated out I am going to have when the accelerating heave or accelerating pitch. So, always in turns out see this always around 8 to 12 seconds this also 8 to 12 second.

So, one of the thing that designer needs to worry and we have seen it practical experience is that there is a design is bad you actually end up having this two very close by and these two very close by means a very bad design. So, if supposing it happens you will try to see how can I separate out even if you separate by one or two second is good enough, but you must separate out that is an important thing it has happen to practical ships that exist where heave and pitch periods are closed by.

And therefore, everybody says ten on hundred to be on the boat because it is. So, bad motion and one of the thing that we could we will see again that we will see in a role motion later on and that an interesting inverse case occurs you actually might have to a raise of central gravity to lower meta centric height because you see G M say in off shore structure we have seen that period are in proportional to 1 by root G M.

Well L or T in the case off shore structure same we will talk about that in role. So, what happen if it is too high you have a very high means this low, but I want to have this low therefore, I have to go basically I must reduce it this we will see later on, but this for for a ship please remember this that unfortunately my heave and pitch periods happen to be very close to everyday waves it is sometimes known as everyday waves you know it is always 6 to 12 seconds 15 seconds waves and as a results at times resonance is unavoidable and therefore, I should try to design where I do not resonate together. So, that I have really really bad time.

So, therefore, I should design. So, that heave and pitch are slightly pushed out by a few seconds that is important. So, with that we will stop and next class we will now shift to roll motion thank you.