Hydrostatics and Stability

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Module No.# 01

Lecture No.# 06

Problems in Stability – II

We will start off with the problem that we had started in the previous class; that is, as I told you before, we are dealing with what are basically called as offshore platforms.

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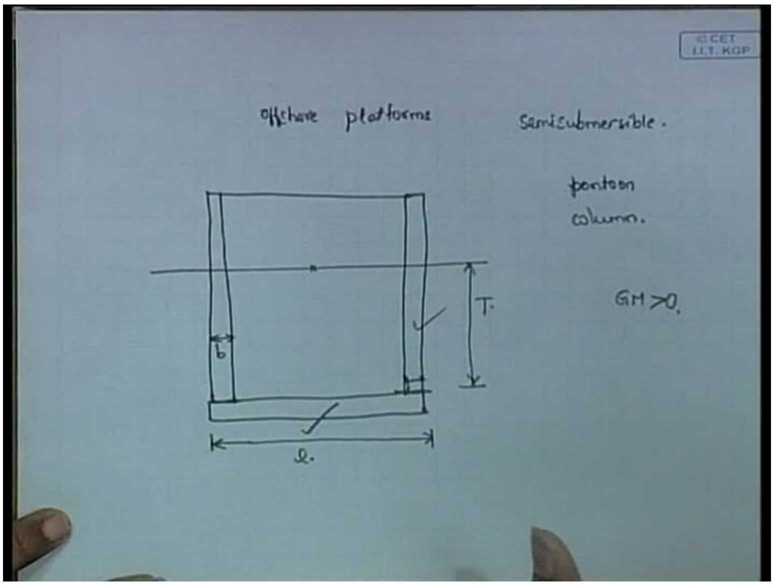

These are different types of - it is not vessels really different type of constructions in the offshore, they will probably be in a depth of about 50 meters. You have to think like Bombay High and all that; these are oil rigs mostly making oil and natural gas.

Now, this is the problem related to that, it is called as semisubmersible. There are different kinds of platforms: there are jacket platforms, semisubmersibles, tensionless platforms, different types of such things. But, one of these things is semisubmersible which we are doing in this problem.

So, this is the problem. There is a platform and you have four cylindrical rods - 1, 2, 3 and 4; 4 such rods which have rectangular strip at the top. Above that, you will have the buildings and all that; that is how it is constructed

There are two rods like this - horizontal rods. There are rods like this - 1, 2, 3,and 4 - horizontal rods. So, first you have the top like this - you have 4 rods and connecting the rods like this; these are all cylindrical rods.

When you have these kinds of rods, means connecting like this, they are called pontoons. These you can call as columns, these are vertical types and these are called pontoons; these are used as general names. I mean, if you are told that the size of pontoons is this, you should know in the figure, which is the pontoon and the column. Pontoon is this and the column is this; so, this is the set up. You are told that this diameter is b - this one - you are told that length of this is l and you are told that this is T.

Now, the same question - what is the condition for stability? First of all, you can see one thing - how should it heel? I mean, you always define heeling in one way only, that is, we take the center and heel about that.

Actually, one thing I wanted to mention is that the problem that we did in the previous class, we saw that there was a mistake and we saw that the draft to be minus d by 2 - they have written it as 0. Actually, there is one way to make the calculations correct; that is, if you take that minus 3 by 2 to be the origin, that is the best thing. Then you do not have to change any of these calculations; it will be exactly correct. So, when you are doing this problem, that is, I am talking about the problem 2.5, just note that. You do not have to really change the answers, just change the origin to that minus 3 by 2, it is important that you know that is minus 3 by 2.

Now, we come back to this problem, you are told that the draft is T and you are told that this is l and diameter is b. Now the question is - what is the condition for stability? As you can see, the condition for stability is you always do this; the only problem in this is to find GM.

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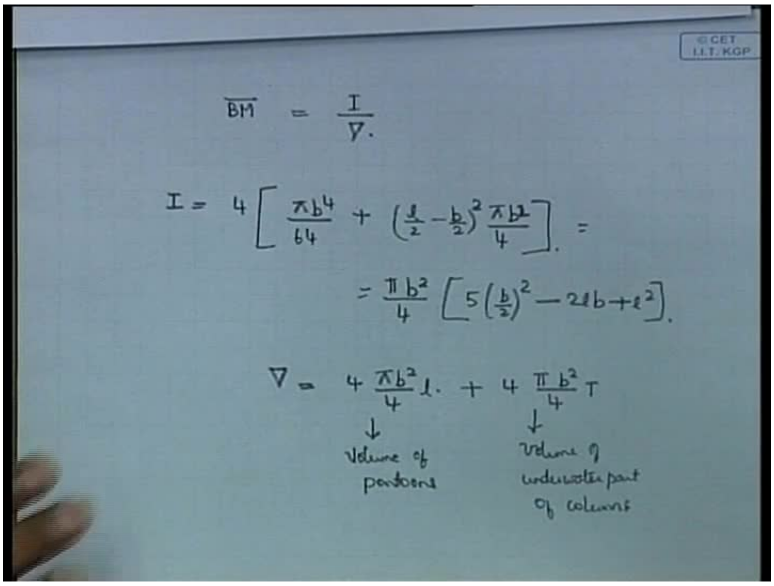

Let us see how to find GM - first, let us calculate the most difficult part of this; that is, BM. BM is equal to I by del. Now, what is I here? That is the only important thing in this problem - how do you calculate I? What is I here, I of what?

I is always the I of water plane; so, what is the water plane here? 4 circle means – 1, 2, 3, 4 circles. And I is about what? About which axis? It is not about the center of the circle; it is about the center of that whole thing. In fact, if you see that you know the concept? It is equal to I about the centroid plus, At some other point, it is I about the centroid plus AY square or AR square; that is the only thing that we will do.

I is equal to four times, it is same for all the four circles, so we have done it for one circle. Now, I the centroid of the circle is pi b power 4 by 64; plus I about that ar square. First, let us calculate the r square; r square will be this distance from this center to that center; so it will be l by 2 minus b by 2 the whole square is r square.

This whole thing till here is l, so l by 2 will be from here is l by 2; minus b by 2, this distance from here is from this center to this center; that is the problem; so that is more or less important thing of this - l by 2 minus b by 2 the whole square r square and a pi b square by pi b square by 4; so this will give you I; this will give you (( )) if you simplify it, it will come to something like this.

Now, del - what is del? Del is the volume of the underwater portion. So, what is the total volume? It is whatever is under the water. Let us look at this figure; It is the horizontal distance it is tilting like this; it is the horizontal distance between the two. Because of the way it is tilting, it is only the horizontal distance that matters.

So, del is the underwater volume, there are 4 things under the volume. You need the volume of these 4 columns under the water; and you need the volume of the 4 pontoons also - this is the total volume under the water. Again perfect problem, do not take the total underwater volume - means do not take this volume. It is the volume of the substance that is under the water so this volume plus; this volume; plus this volume; plus other sides.

So, del is 4 times pi b square by 4 into l - this will give the volume of the pontoon; 4 pontoons plus 4 pi b square by 4 into T - that is giving you the volume of your columns underwater part of the columns. So, if you do this much, you have solved the problem mainly.

The idea is to get I - what is I? You can always expect different kinds of submergible like this - with different shades in your exam .For example, you have to know two things with different shades - the moment of inertia and moment of inertia of circle and you should know about the concept of ar square; you should also know the volume of couple of figures, once you know that you know this concept it is very easy then.

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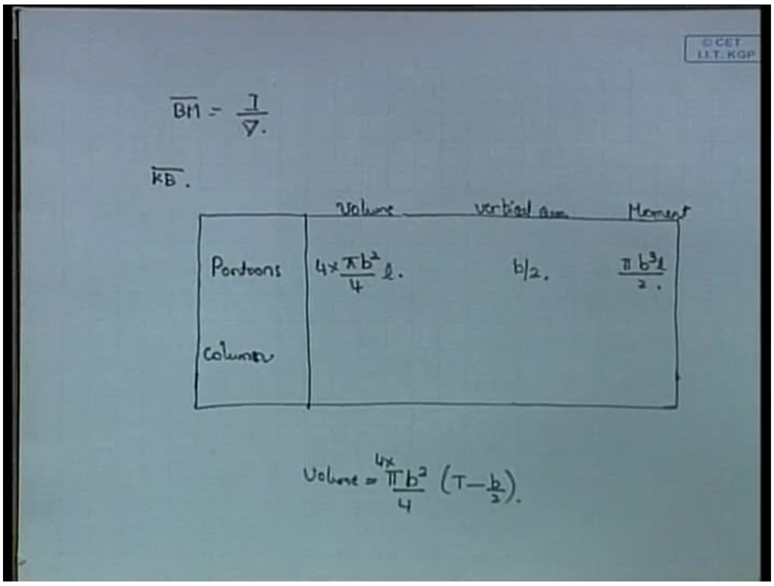

The rest you do just automatically that is BM, you do this - I by del that will give you your BM. Actually, there is one more thing in this that is - to calculate the KB. You have to find the KB for the whole system means, the vertical center of buoyancy of the whole system of 1, 2, 3, 4 and these 4 - 4 columns,4 pontoons you have to find the KB of that whole system.

Now let us see that, that is more or less automatic - but let us do (10:43) (( )). First let us take the pontoons - the volume is pi b square; we are talking about the pontoons that is, the 1 at the bottom - horizontal lines. So, 4 times pi b square by 4l - there is no doubt about that. It is pi b square l, which is your volume.

What is the vertical arm of that or should we say the KB of that section? It is b by 2. Then, the next one is, the moment. We just multiply these two things and it becomes pi b cube l by 2l so, this will give you the moment due to the 4 pontoons. As you can see here, we have taken the origin to be at the keel - the bottommost point and that is why this becomes b by 2 - the vertical arm. From here, distance of its center of buoyancy is here, so this is b by 2.

Now, we consider the column, we have to find the volume of the column; let us see. 4 times pi, let me write what is given is correct - 4 this T minus b by 2 this is TT minus b by 2 will be this one.

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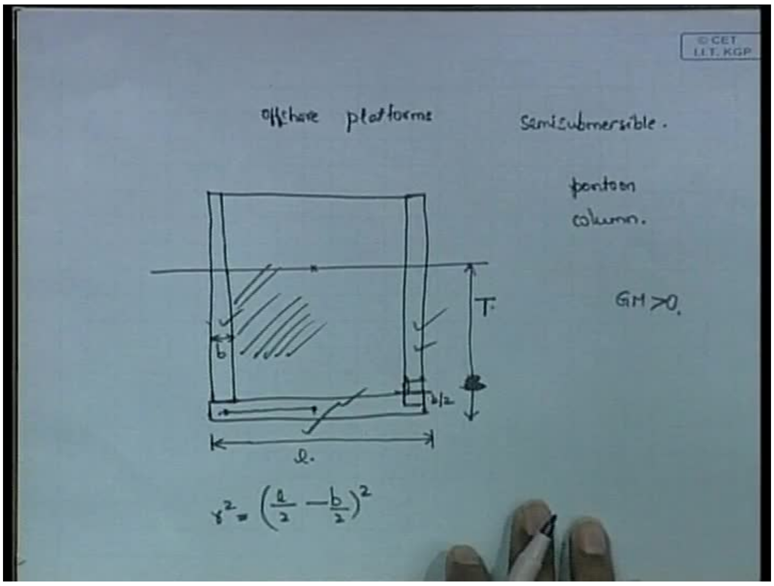

Actually, this figure should be drawn very clearly I have not drawn it properly. Let us look at this figure, it is like this - this distance is T and this comes up to the center, up to this point, b by 2 up to the center. So, this T minus b by 2 will give you the draft of this section and the volume is pi r square h - it is a cylinder. So, pi into r square is b square by 4 into h, h is - just look at the figure, it is because of you have to just look at the way in which the figure is designed, so it might vary depending on where your column extends till and all that. This whole thing is T and this extends up to this - the center; therefore, this is T minus b by 2 - this distance. This is just T minus b by 2. Is it clear? This whole thing is T and this is only up to T minus b by 2.

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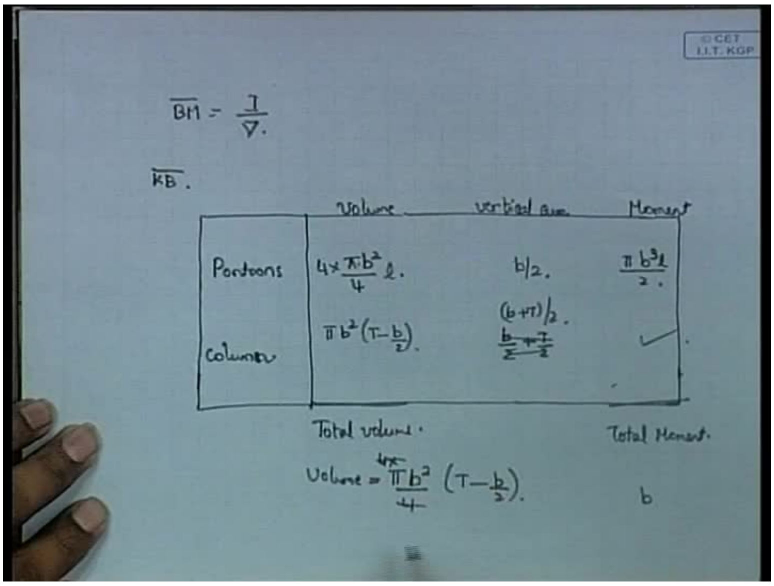

So, 4 into pi b square by 4 into T minus b by 2, this 4 cancels off, so pi b square into T minus b by 2.

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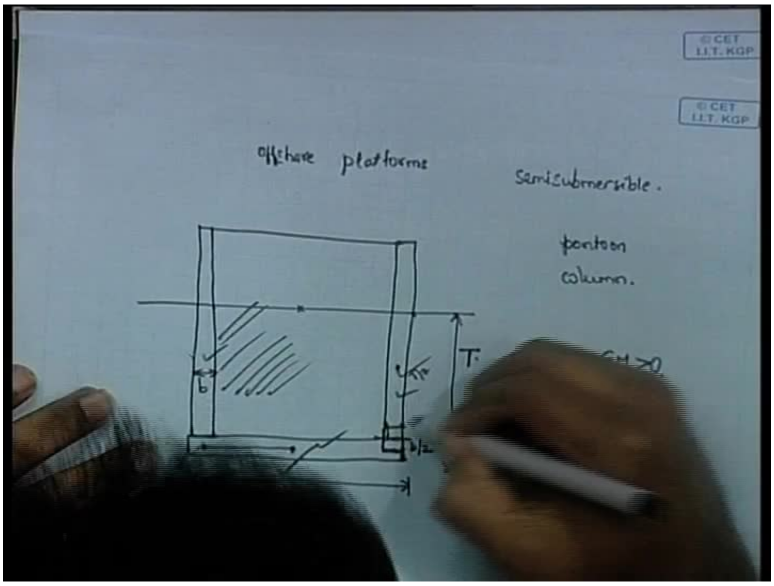

Now, what will be its vertical arm? b by 2 plus centroid of this will be here at T by 2 - so, b by 2 plus T by 2.

or b by 2 plus; T by 2 or b plus; T by 2 - that is correct. So, this is b plus; T by 2 – correct. And the moment will be just the product of these two; just multiply this and put it there.

Now, how will you find the KB - KB for the whole system? You sum up these two moments, you will get the total moment and if you sum up these two moments, you will get the total volume.

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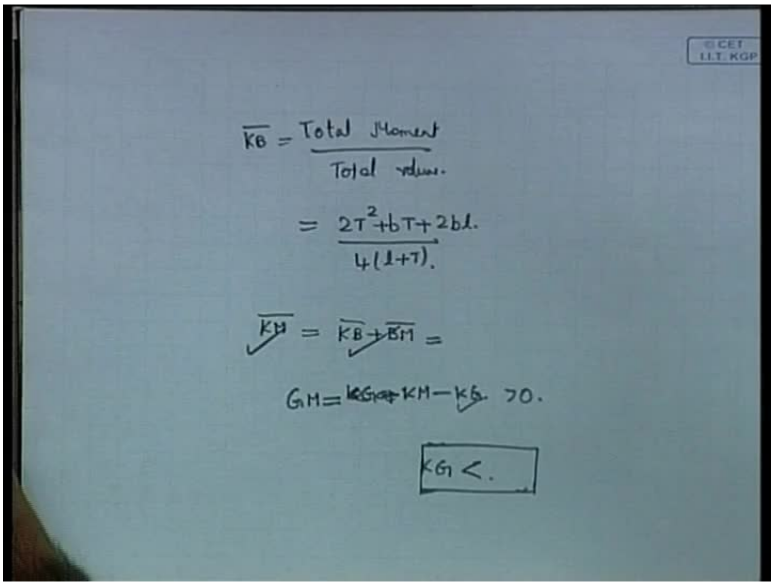

When you divide the total moment KB will be given by the total moment divided by the total volume. I am not putting the terms here, you can just do that and it comes out something like, it does not matter - so, you will get this.

Now, just substitute, KM is equal to KB plus BM is equal to - you just do that, you have already calculated BM, now you have calculated KB. KB plus BM will give you KM. I think GM is KM minus KG, this should be greater than 0. Now, you know KM here, you know KG - KG is the center of gravity of the whole system and that also you can calculate. They have not done it here.

They have written this final solution as KG should be less than some value. They have given this to be the answer - final value KG should be less than(()). This is the condition for the stability of the whole system.

So, this is how you will have the problem - finding the volume KB, KG, I and del - these are the parts of this problem. Now, I have some other problems which I will take from this book.

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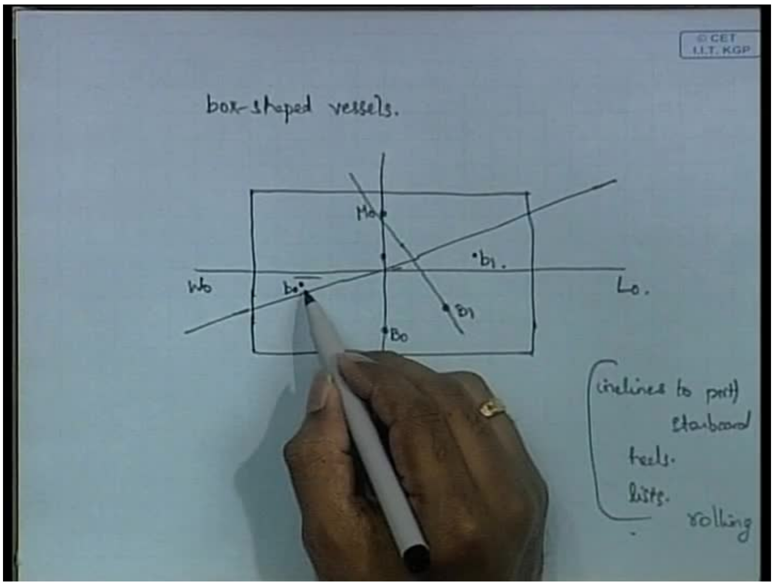

This is something very similar to what we have done so far, but it is slightly different - something that you can know. Again, we will talk for the time being, at least for the next half an hour about box shaped barges. ((You have already seen what it is - the same type problems that is - basically length, breadth and draft.)) There is no curve anywhere, it is just a straight line - it is just a rectangular box. So, we will talk about box-shaped vessels or box-shaped barges.

Let us look at this problem. This is the transverse section of that barge, it is bounded by a water line W0L0 and initially, it has these points - B0, M0 and at some point it has its weight g. We are mostly interested in B here. Now, the body heels; there are two or three names for this what we call as inclines to - port or starboard. Now, the problem will be stated in. These are the three things which mean the same thing, when you say something as - inclined to, port or starboard - like this it has inclined heeling means the same thing and listing is the same thing; body lists means it moves like this the same thing.

If it is moving like this continuously, means it is not shifted and stayed there; it is not about inclining. We are talking about dynamic situation where it goes up and down like this - that is called rolling. We are not bothered about that in this course but this movement, if it is a continuous movement - if it keeps moving like a pendulum, if it keeps going like this and it keeps moving like this then, it is called rolling. Otherwise, in hydrostatics, we use these words - inclined to, ports or starboard, heels or list.

The body here lists or heels let us say that this is the new B1 - this is the center of buoyancy of the new position of the whole system. Here, we see again and I will define it - This is a small wedge. One wedge has gone in and one wedge has come out. In this figure, it does not show it, but this wedge volume is equal to this wedge volume; it is always defined like that. We do not do other more complicated problems for this, we do only this.

Let us suppose that the center of buoyancy of this is b0; and center of buoyancy for this is b1 - small b and small 1. You have to note the difference between the capital B and the small b. The small b is actually denoting the center of buoyancy of that triangular wedge alone; and this of this triangular wedge; whereas, this capital B - B0 is the center of buoyancy of the whole system of the whole body.

Now, what has happened? Because of this shifting, the center of buoyancy one wedge is going into the water and one wedge is coming out of the water. It is almost like this b0 is shifting to b1, because one keeps going and the center of buoyancy of that wedge keeps moving.

We need this figure. We have already defined the expression for B0B1 for the whole body, provided we have the B0B1 - means we have already seen, if you have a body - big body, in which there is a small body - means capital body of mass capital M, small body of mass small m and this mass moves by a distance d; you have seen that the center of buoyancy or the center of gravity in this case shifts by an amount d into m - small m - divided by total mass that is, small m plus capital M.

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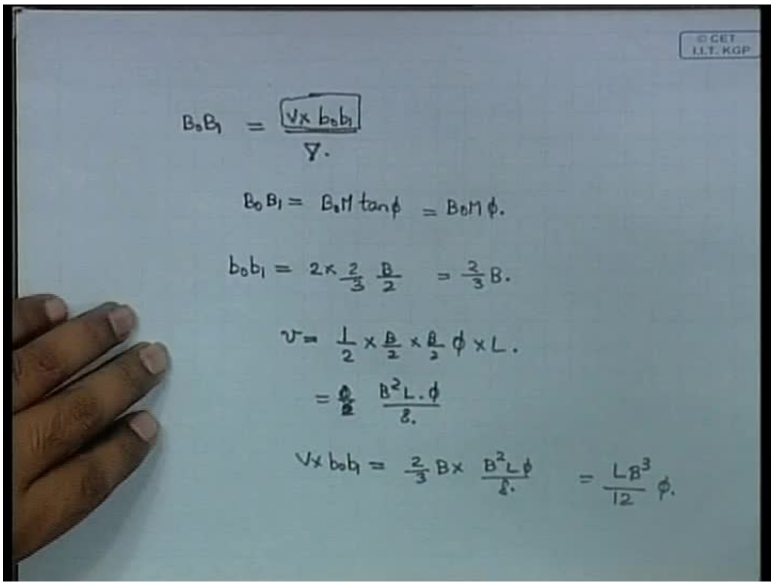

Just like that this B0B1 will be given by small v into this b 0 b 1 divided by capital del ; small v is the volume of this wedge and b 0 b 1 is the distance moved by this wedge. This is b 0 b 1 and this divided by del will give you B0B1. This is the same concept that is, the is the almost volume as some here and or you can say that this volume has been shifted from here to here it looks like that, it is the same thing.

Now B0B1 this I have done in one of the previous derivations. if you remember, we have done it in the derivation. If you draw that figure it becomes very clear. Now, B0M tan phi and we have said that this tan phi is small tan phi, so it can be written as phi. So, this we can write it as or you write it like this.

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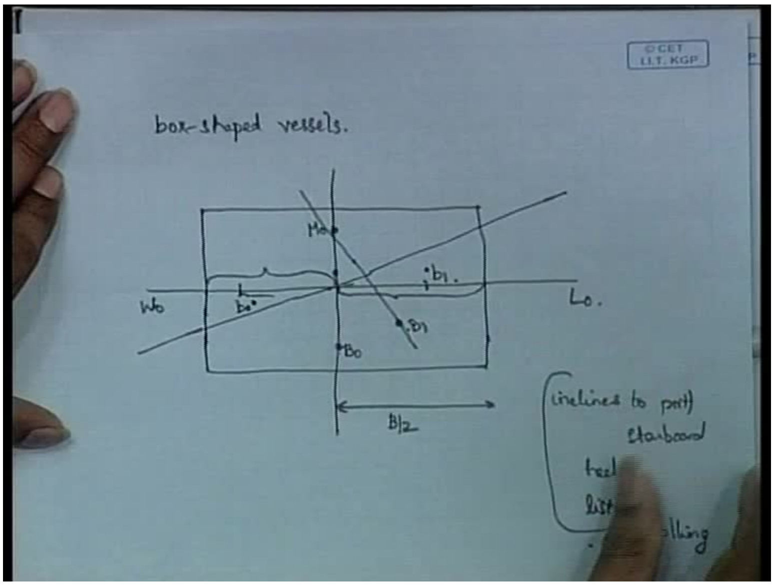

What is b 0 b 1? What is this distance? We know that this distance is 2 by 3 of this whole distance that is, the center of buoyancy of a triangle. And this distance is 2 by 3 of this whole distance. So, this 2 by 3 plus this 2 by 3 will give you the distance between b 0 and b 1.

b 0 b 1 will be given by - it is twice, it is an exactly symmetrical bar so this side is the same as that side so, twice 2 by 3 of B by 2. This is B by 2, so 2 by 3 of B by 2 will give you this distance and, twice that will give you the distance between b 0 and b 1.

Actually, note that we are just looking at the horizontal moment, we are not interested in the vertical part of it. We are only interested in horizontal moment of this 2 into 2 by 3 into B by 2 that is, exactly equal to 2 by 3B.

Now, what is the volume? The small v is the volume of that wedge. What is that volume? It is equal to area of the triangle into length, Area of the triangle is half, base is B by 2 and altitude is B by 2 tan phi or let us call it phi; tan phi is almost equal to small phi into L – this will give you the volume. This will give you B square L phi by 8 - this gives you the volume of that wedge that has shifted. Therefore, v into b 0 b 1 is equal to 2 by 3B into B square L phi by 8, so what does it become? It becomes LB cube by 12 phi - it becomes like this. This is the part that we have calculated here - v into b 0 b 1 is equal to LB cube by 12 phi.

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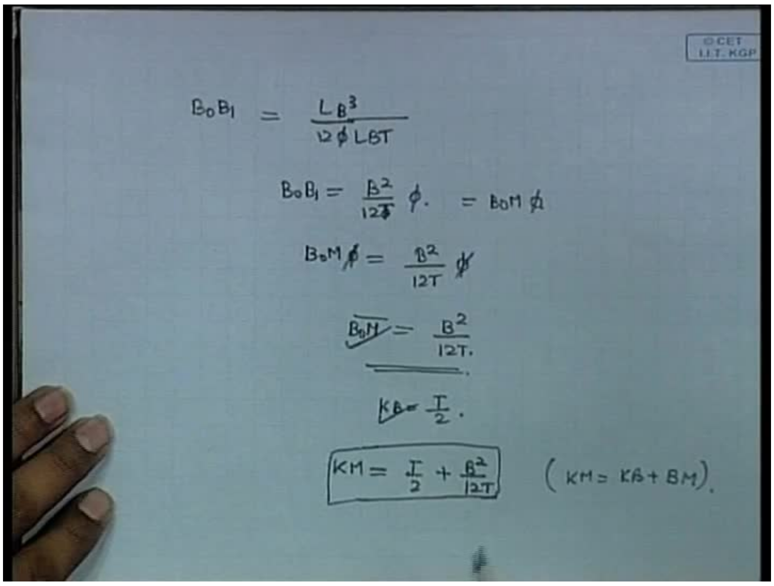

Now, we need B0B1 which is the horizontal distance through which the center of buoyancy of whole system, this is equal to what is del? LBT – this becomes LB cube by 12 phi divided by LBT. So, B0B1 becomes B square by 12T into phi. We have already seen that this is equal to B0M phi, so I am going to equate them - B0M phi is equal to B square by 12T into phi, we are cancelling off phi, so you will get B0M equals B square by 12T; this is an important point. What is KB? KB is equal to T by 2 - this is obvious as KB is the center of buoyancy of the system. Therefore, KM is equal to T by 2 plus B square by 12T. Now, using this formula - KM is equal to KB plus BM - this BM plus this KB - that will give you the KM for the system.

Actually, it will be good if you remember this formula because I am going to give you some problems. If I give you a box-shaped barge and I say the problem explicitly as a box-shaped vessel, something like box–shaped basically, you can automatically assume this value - KM is equal to T by 2 plus B square by 12T that goes without saying; otherwise, you have to derive the whole thing. If you want, you can just memorize this value of KM is equal to this. I will do some problems, in which, you will be required to apply this continuously. So, I suggest you remember this for a box-shaped body.

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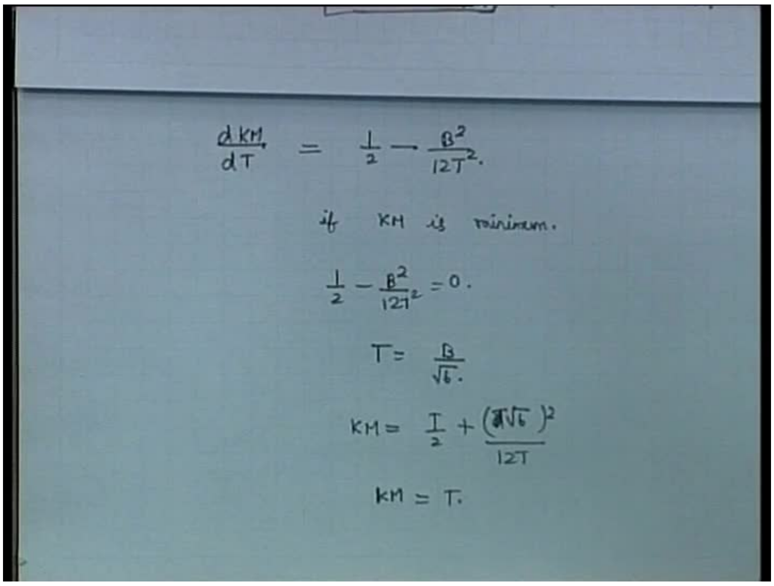

Just a couple of extensions to this that is, suppose we want to find the minimum KM then we can do this - d KM by d T - that will actually give you half minus B square by 12T square. Now, if KM is minimum, I am just telling you how you have to approach the problem in case, you are asked something like this. If KM is minimum, you just do like this. And obviously, if KM is minimum, this differential is 0 and you will get half minus B square by 12T square is equal to 0. Therefore, T becomes B by root 6 and the corresponding KM becomes T by 2 plus T root 6 the whole squared by 12T. Actually, when you do this it will come to T.

So, this is the minimum KM; the minimum KM is equal to T itself. Of course, we can derive all these quickly by differentiating. But just remember all these things this is how you find out the minimum KM and that value of minimum KM is T. Minimum KM occurs when T is equal to B by root 6, where B is the total breadth of that vessel.

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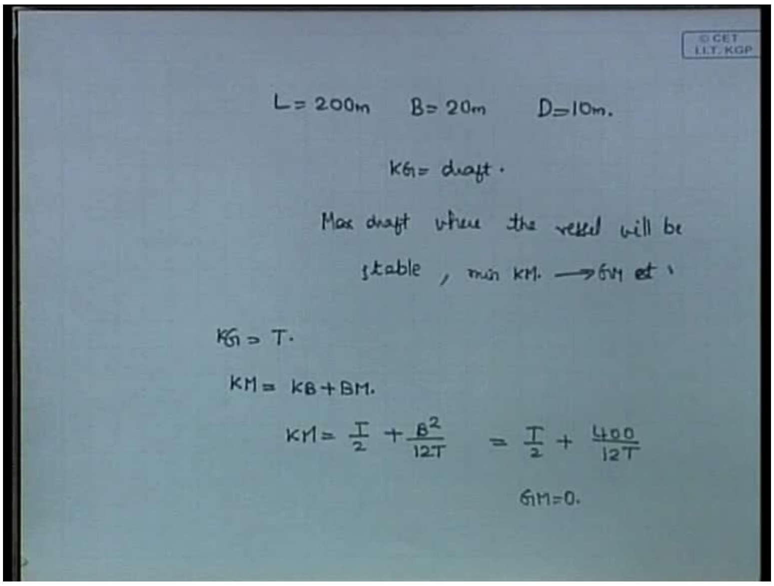

Now, just to clear this up let us do some two or three problems on this, the problem is like this - a box-shaped vessel has a length of 200 meters, it has a breadth of 20 meters and it has a depth of 10 meters. It is said that it is loaded in a fashion, such that, KG is always equal to the draft. You are asked to find - what is the maximum draft where the vessel will be stable. You are also asked to find the minimum KM; You are asked to find the GM at that value of minimum KM, these are the problems.

We can proceed like this. First, you are told that KG is equal to the draft. What it says is that you can start with this concept - KG is equal to T - you are given that. Now, what is KM? KM is equal to KB plus BM. Suppose the problem is, this what if you have to derive the entire KM. This becomes little about it we would not be able to find time to solve it and complete the paper. So, just remember that KM in case of a box-shape is equal to T by 2 plus B square by 12T.

This is the general expression for KM and it is equal to T by 2 plus 400 by 12T. Now, we are asked - what is the condition of stability? The best way to do that is to put GM equal to 0 – that is a limiting case; GM equal to 0 is always the limiting case. GM greater than 0 is stable but GM less than 0 is unstable, so GM equal to 0 will give you the limiting case.

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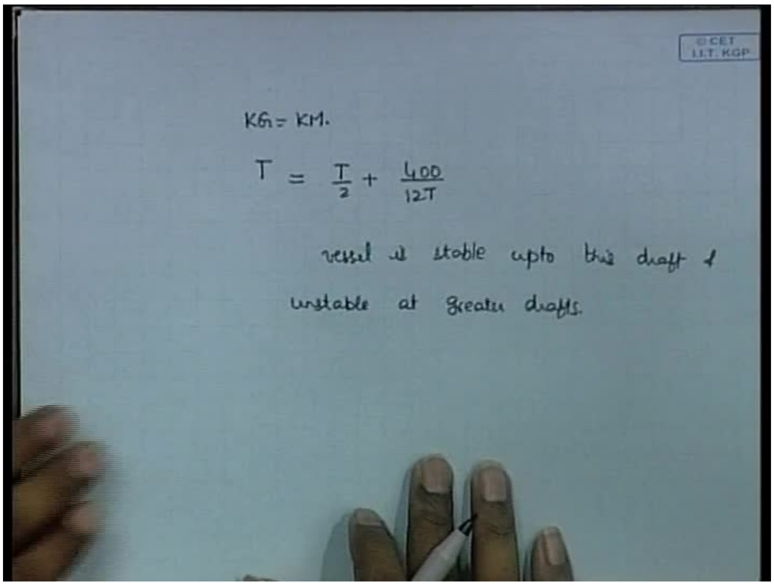

So, GM is equal to 0 and if GM is equal to 0, then KG is equal to KM. You already have what KG is? KG is given to be T and KM; you have calculated using that formula, so that is T by 2 plus 400 by 12T. Just before we did that and now we will just solve the equation.

When you solve that, you will get the value of T, this is the draft so, you can say that this is the only difficult part of this. Other things that you are asked is - minimum KM, just do differential and then do that, that is very simple. So, this is the thing.

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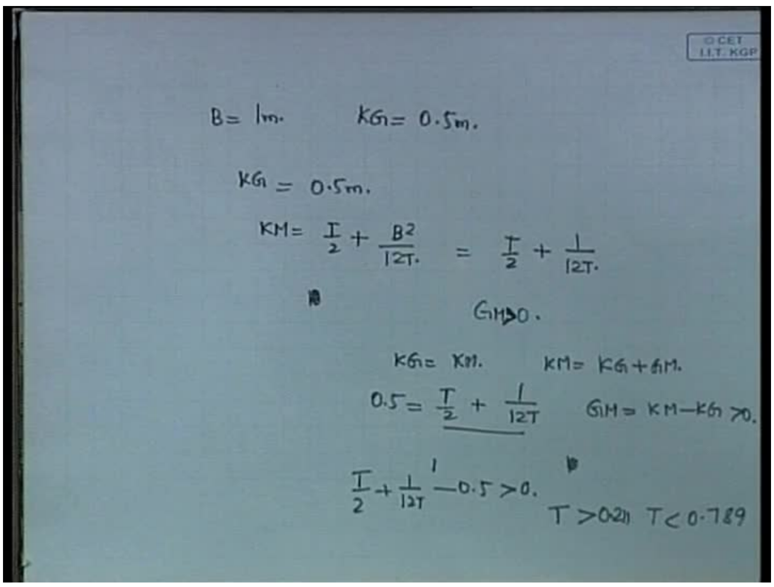

This is the problem. Now, something similar we will have one more that is, You are told that you have a box-shaped vessel and its side breadth is given to be 1 meter and it said that KG is always equal to 0.5 meters. You are asked what are the range of drafts over which the body will be stable or unstable when floating in fresh water.

(36:01)(( )) Let us see - KG given is 0.5 meters, then KM - since we have this formula it is very simple. Note that it is only for box-shape; do not use this formula for ship. If it says that it is general ship-shape or if I say that it is for cones and other problems we did, an even though that cone and all that we did the other problems that do not use this formulas there; it is definitely wrong I mean, you will not get anything for it.

So, B square by 12T and we have told that B is equal to 1, so this is equal to T by 2 plus 1 by 12T - this will give you KM. Again, you are asked the same condition - if you want to find out what the limiting case of stability, you just put GM is equal to 0.

At that stage, you will have KG equal to KM, because GM equal to 0; therefore, KG given is equal to KM which is equal to T by 2 plus 1 by 12T. Just solve the equation and you will get T. In fact, you will get T or the best thing is to do this - KM is equal to KG plus GM, therefore, GM is given by KM minus KG. Now, GM greater than 0 is your condition for stability, so this KM plus T by 2 plus 1 by 12T minus 0.5 greater than 0 - call this inequality. You will get two values of T and you will get two values for the draft. So, T greater than something and T less than something means, it will be something like - T less than 0.789 and T greater than 0.211; you will get something like this. The draft - the T you will get at these two values.

The range in which the vessel is stable is from 0.211 to 0.789; that is the range in which, you have a stable value of draft and other values are unstable. If you are asked - at what value KM minimum occurs? KM minimum occurs when KM is equal to B by root 6; just do that and you will get it.

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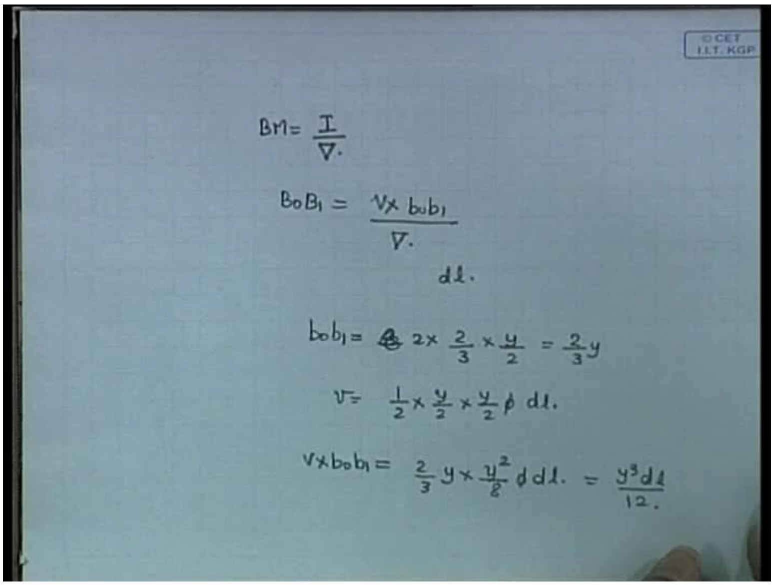

These are some simple problems. In our previous two or three classes, we have derived this equation, there is a much simpler way of deriving this equation that I will do; you can follow whichever way you like.

Let us see this. In this case, we have a wedge; this is the simplified derivation, the real derivation is what we did in the class. In this book, what we did is the general very broad derivation. This is really true for all cases. This is a very simplified kind of derivation; we will just do it and see that it is true for all the cases that it is same thing that is we have for that body wedge is. There is a wedge moving from this side to the other side, as we have seen the same figure in this way. So, here you have the wedge moving from b0 to b1; you are having it as a result of center of buoyancy moving from B0 to B1 of the system, we have already done B0B1.

This is the whole ship; we are considering a wedge like this - a wedge here and a wedge going there. Let us consider the thickness of dl of the ship we say there is a ship of length dl.

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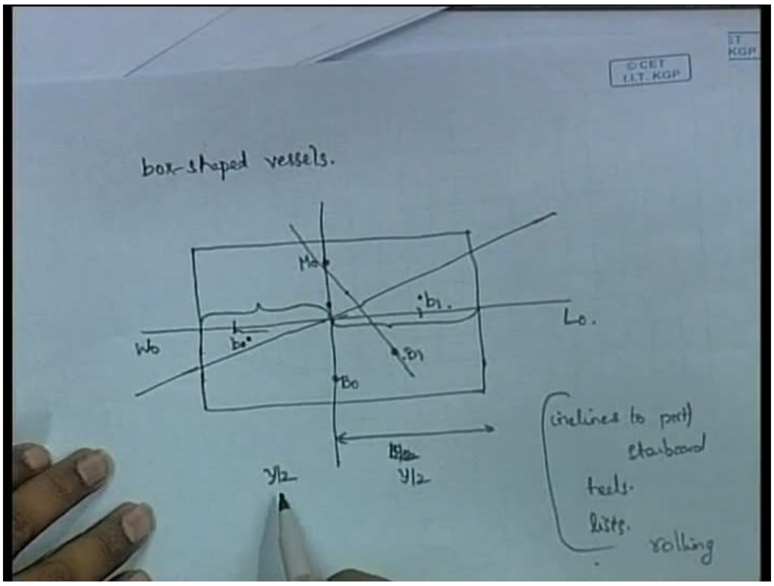

The volume of the wedge is v and centroid is moving from b 0 to b 1. b 0 to b 1 is equal to 2 twice this same as what we did last time, just before - 2 by 3 into y by 2 is equal to 2 by 3 y, where, in this derivation we are just putting this to be y by 2 and this is y by 2. This distance is - Because we are deriving something, let us put it as y - this is y by 2 and this is y by 2.

The volume v is equal to half base into y by 2 phi into dl. Because we have considered a ship of length dl, we have the volume of the wedge that moves from here to the other side. Its half base is y by 2; altitude is this distance which is y by 2 tan phi which is y by 2 phi itself. We have seen that tan phi is equal to phi so, it becomes this into dl - dl is the length, so area into length will give you the volume. So, there is a volume of the wedge that moves from one side to other side; therefore, v into b 0 b 1 becomes 2 by 3 y into y square by 8 phi dl which is equal to y cube dl by 12.

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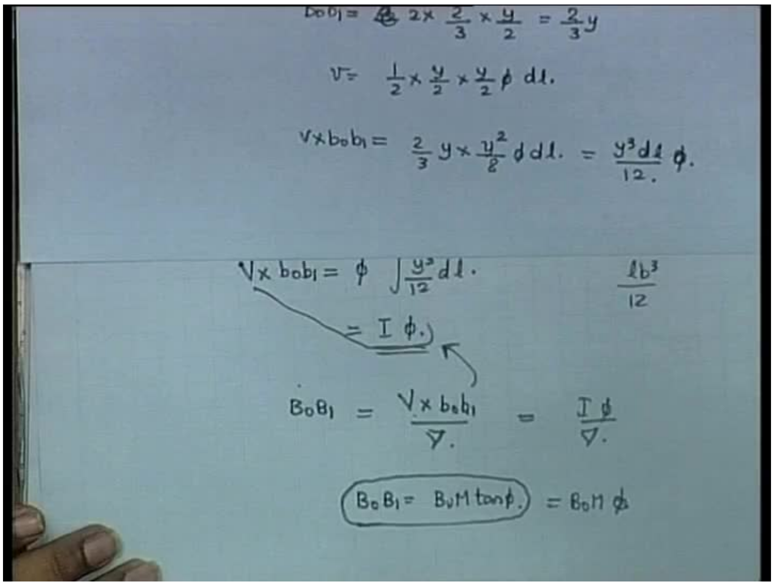

When you take the whole ship, this becomes the total volume; The total becomes total that wedge, this is now just for dl. Now, we consider the whole ship; it is not just for dl, but we are going to integrate with over the entire the length of the ship. Therefore, let us call it capital V into b 0 b 1 is equal phi into there is a phi also here - b 0 b 1 phi into integral of y cube by 12 dl.

The question is what is y cube by 12 dl? It is like this - it is giving you this value. This is what if you integrate if you second moment integrate if you are I. This is I phi. And that will give you I phi.

We need to find just keep this - what is B0B1? We have already seen that this is equal to this whole volume into b 0 and b 1 divided by del. So, this is equal to - I am using this formula here for V into b 0 b 1, so this b 0 b 1 I am replacing by I phi by del. Again, we have seen that B0B1 is equal to B0M tan phi. There are a couple of formulas here; this is a very important formula. I think, you should memorize this - B0B1 is equal to B0M tan phi - is an important formula; you memorize that. So, which is equal to, in this case, we write it as B0M phi itself.

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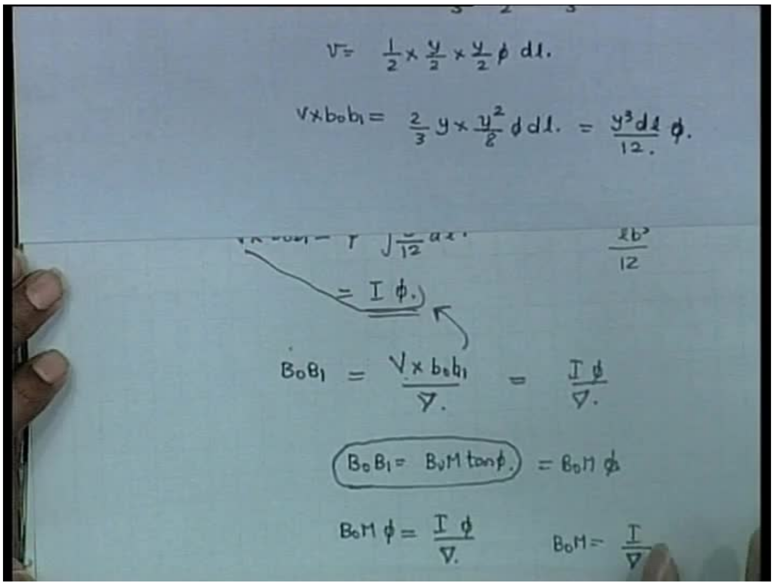

Therefore, what do you get? B 0 M phi equals I phi by del, which implies that B0M is equal to I by del. This shows that this is true only for a box-shaped body. You could probably use this method to really derive the general expression, if you want. It is not that difficult, because the only thing that will change is probably the volume which you cannot define so specifically; but, if you work on this you might be able to do it.

This is a sure problem for the exam. You definitely will have to show that B0 M is equal to I by del, because it is very important. You are told that metacentric radius is equal to I by del, it is very important and its derivations are also important. So, you can do two things - you can either derive it in this format, it is all right or that old thing - that is a more general derivation; you can do either of these.

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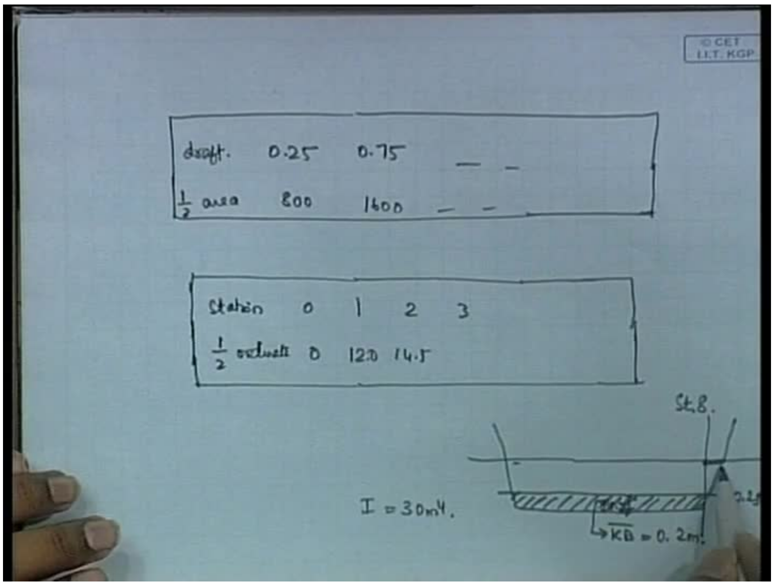

Now, we will do a problem that probably will tell you how it is just this constant, but there are lots of details that you need to take. This problem, actually, it gives you an idea of how little bit complicated things can get. Look at this - it says that First of all, you are told that there are different possible drafts starting from 0.25, 0.750, 1.25 - like that the draft goes for different water lines.

For different values of draft, you are told that the half, Also, remember that the problem will be like this. You have to understand what is it means and that is why I am drawing the whole table here; you have to look at the table and understand what the table is saying.

You will be just told this, that is, the vessel has the following half area of the water plane at the drafts given - what does it mean? It means that you are given the half area of the water plane means, if this is a vessel and this is the whole water plane, half of that is called half area of water plane. So, you are given the half area of the water plane at different drafts means, first you assume the draft to be 0.25.

What is the half area water plane at this, what is the half area water plane at this, what is half area water plane - like that, so that is the meaning of this. This table itself will be like this - this is the draft, you are told that the half area is 800; this is 0.75 and like this - you will have this entire table. I think, you can read this table now.

You are also told that the next table says this; let us also understand what the table says. At a draft of 5.25 meters, you are told that you are fixing the draft, so this is for different draft that means the vessel is not really put into the water and it has not reached the draft. We are generally saying that if the draft is so much, this will be the water plane here. If the draft is here - that is the first table. In the second table, you have put the vessel into the water as such and the vessel has come to a draft of 5.25 meters, so it says this - at the draft of 5.25 meters, the vessel has the following half ordinates of water plane commencing from aft.

Is it clear to you what that means? The half ordinates of water plane means - what? It means that you have different stations - commencing from aft means you know what is aft – ((I will define that.)) Let us say, this is the aft and this is the forward; so, commencing from aft means starting from here, you are given the half ordinates. What does it mean? What are the half ordinates? This thing - it means this is the vessel, so this is the depth and this is the transverse - that is y. This is given here, it is given here – The vessel will be like this, so it is this, this, this, this, this, this - like this - that is the meaning of half ordinates. I will just write this, because I do not think I have to explain in the exam what half ordinate and all are.

The problem will be like this and you should be able to understand what it means. Like definitely you should know that these are the stations, these are the water lines and these are (()). There should be no confusion about that.

For each station, you are given your half ordinates; the meaning of half ordinates is always this - half of the total breadth at each station. It will be like this - station 0, 1, 2, 3, 4 - like that and half ordinates 0, this is 12 - like that; it does not matter. So, you have these values.

The problem to 150 meter cube and it has KB - this has a KB. Let us say, this is the center, so it has a KB of 0.2 meters goes a little further; it says that below the 2.5 meters draft, there is an appendage volume 150 meter cube with a KB is equal to 0.2 meter. The meaning of that is from 0.25 meters on - it is given in a different table. What is the difference area is not before I going to. What this line means is that below the 0.25 meters - the ships is like this and let us say, this is the 0.25 water line; so, below this means - this distance they are saying that there is an appendage volume - means there is a volume here which is equal.

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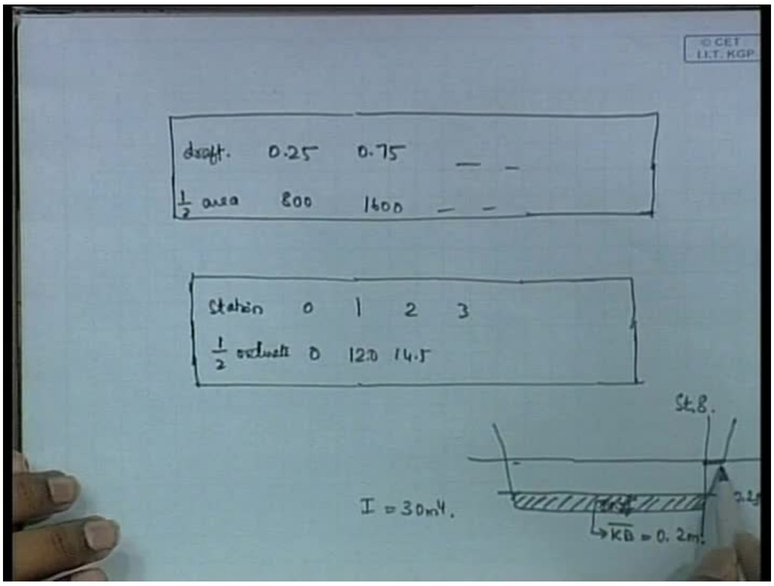

Why is this important? This is because we are going to have a lot of KB's here. KB for this small appendage volume you will have - I mean, the draft will be here, so there will be KB for this. Then, based on this KB, this KB and the respective volume, you will have to find the average KB or the net KB. That is why you have to consider all these things when you do such a big problem.

Now it even says no wit likes this sot. They have said that starting from station 0, it actually goes up to station 8 - let me call this station 8. The problem also says that forward of station 8, there is an appendage, second moment of area, 30 meter power 4 means similarly, for that draft here - this region alone has an I equal to 30 meter power 4 - this region alone. As you can see, you have to find I for this, then you have to add the I for this also; only then, you will get the total I for the water plane. This is just to confuse you and there is nothing else. So, you are told that the I of this region forward of station 8 is 30.

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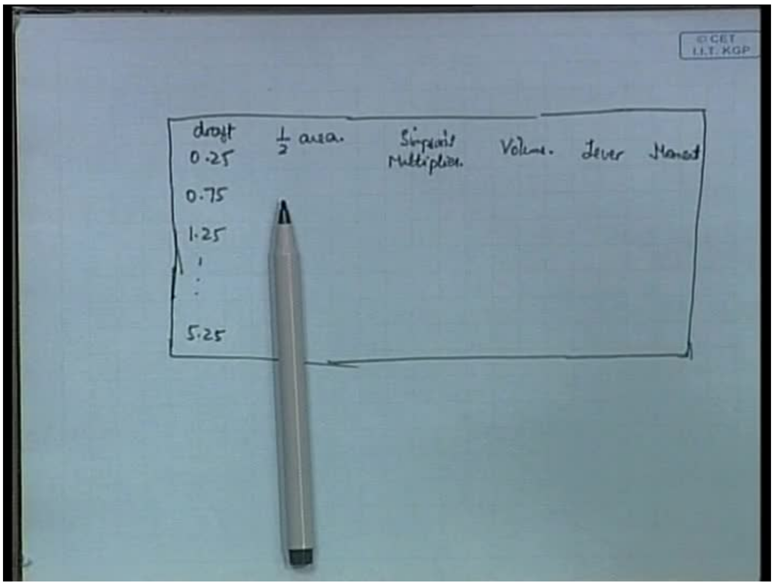

Now, I will just explain this table also. Another table is given to you, which says like this. Maybe I will do one thing; I will explain it in the next session.

Thank you.