Hydrostatics and Stability
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Module No. # 01.
Lecture No. # 05
Problems in Stability-1

So, we did in the last class, one problem dealing with the stability. We saw how the condition GM greater than 0 is it is it indicates the presence or absence of stability.

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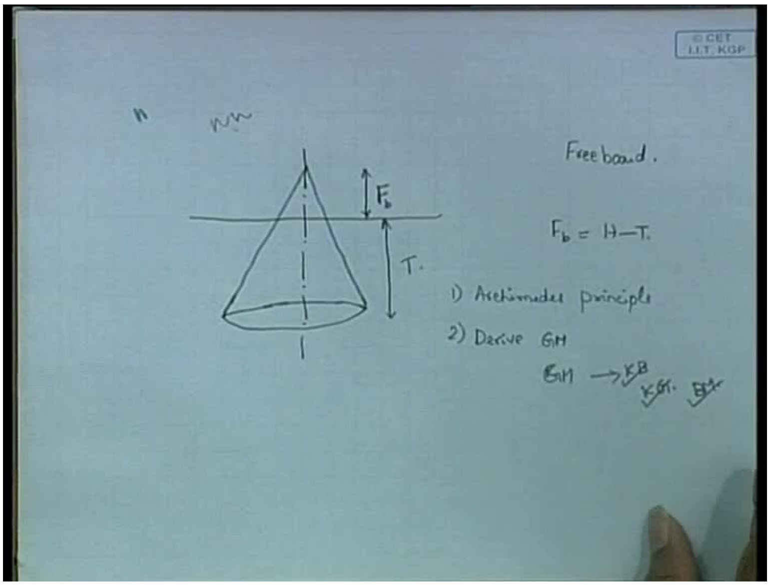

Now, we will do a couple of problems to make the whole concept clear. The first one is a very similar problem, but this is slightly different, that is you in this case, you have a cone; there is floating top up like this.

You know it is a cone that is floating; it does matter how much it is floating in or out; that is, we bring and a new term which we do not know till now. That is, we say that, when you are told that, for example, the free board - the word is free board; the meaning of that is the exact opposite of draft; means it is the amount of region that is outside the water. That is called a free board.

So, when you have a ship, you will have a draft, the underwater region and you will have a free board that is above water region. So, just remember the word called free board.

Now, we are told that the free board of the system of the body is F or F b; this is the freeboard. So, you can immediately derive this relation and let us say that this is a draft. Therefore, F b equal to H minus T, where H is the total depth of the cone.

Now, the question is similar to what has been done. Before, we asked what is the condition for the upright stability of this system. Now, the problem is similar. So, first of all, we will just do the couple of similar problem, so that we know how to approach this thing. So, first course you applied… there are two step in this: the first step always is application of the Archimedes principle and the second step needs to derive GM. So, these are two steps that we need to follow, in all these problems, throughout this method; these two steps.

First you apply Archimedes principle. Then some mathematics might be required and then you do derive GM and you have, you know that by now you cannot get GM straight away. You need all these parameters to get GM; KB KG and BM because GM has no formula as such. To get GM, so you have either of formulas and or methods to point KB where B is the canter of buoyancy, KG where G is the center of gravity and BM known as the metacentric radius which is I by del.

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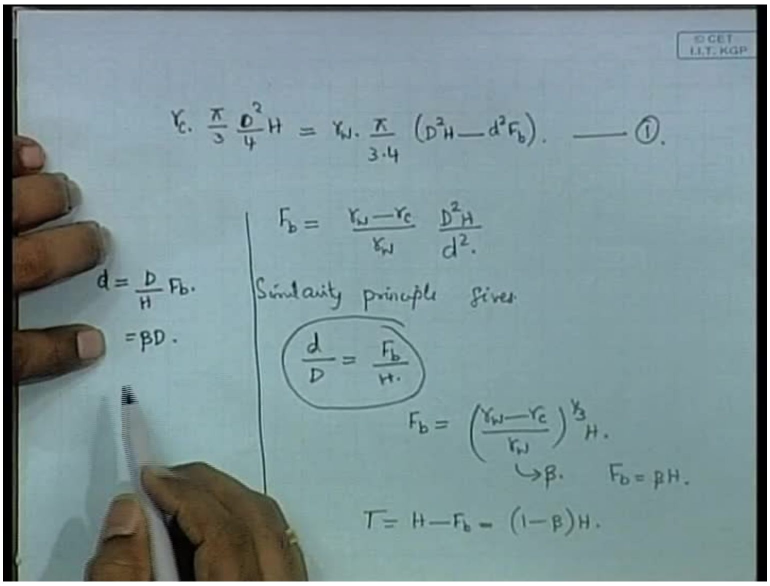

So, from this, you get GM. So, we adapt this method here. First of all, we apply the Archimedes principle; that is we say that gamma, let us say, the gamma c is the specific gravity of the cone.

1 by 3 pi D square by 4 pi r square H. This will give you the total weight of the cone. This is given balance by the mass of water displaced which is equal to gamma w specific gravity of water into pi by 3 into H 4 into D square H minus D square F b; so, this is at any rate; then you are doing the right hand side; It should be the volume of the water- the volume of the cone that is under the water.

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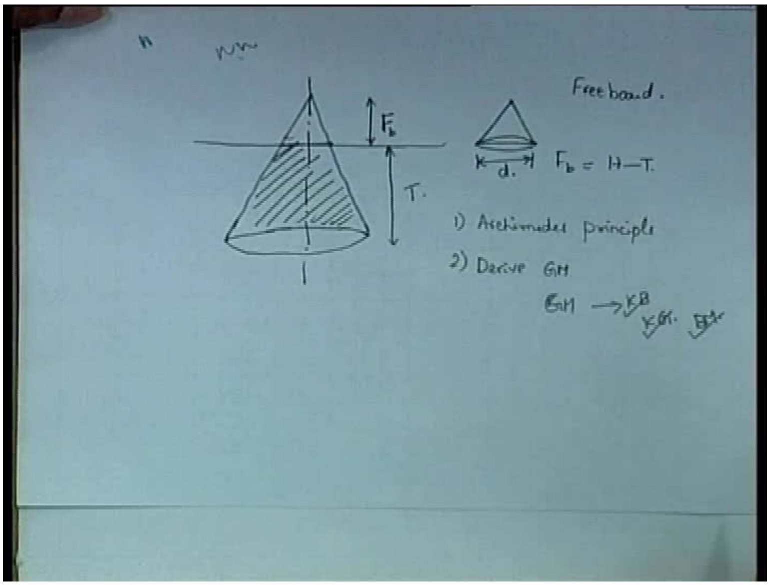

So, in this case, this is the volume that we need. Because we are doing the Archimedes principle, this is the volume that we need. Now, this volume, just look here; it is the total volume of the cone minus the volume of this cone; that is what they have done here. This small d represents the diameter here; this diameter (Refer Slide Time: 04:34) like, if you have the cone here, you have a, this is called the water plain area, as we know. So, this diameter is d. So, 1 by 3 pi r square H for the whole cone minus 1 by 3 pi r square H for the small cone will give the total volume that is under; that is what they have done here; this is the Archimedes principle.

So, this is the first step. So, you have, in a way, completed something like one-third of the problem if you know this. This is the Archimedes principle.

Now, from this, you get F b is equal to gamma w minus gamma c by gamma w into D square H by d square. This just comes from the manipulation of this above equation. And then, this is something you might have to do in your problem. That is you are applying this similarity principle; we have all done in the previous problem also. That is, similarity principle is just saying that both of them represent the same angle. So, it will give you the d by D is equal to F b by H. It is like, last time you wrote it as F minus b by H. So, this time we can write it as F b by H; F b is the free board; you see what it is.

Now, combining these two equations, you will get F b is equal to gamma w minus gamma c by gamma w whole power 1 by 3 H and this we can put it as beta. Therefore, F b is equal to beta H. So, you get a solution; you get a relation like this. Then, therefore, T is equal to H minus F b equals 1 minus beta into H; this just comes directly.

Now, the diameter of the water plain section (Refer Slide time: 06:49 to 06:56). This is again from the similarity principle; it is just this formula. So, d by D is equal to…. So, d is equal to capital D into F b by H. And D by h, we write it as beta, I mean F b by h; F b by h we write it as beta. So, we get this beta D.

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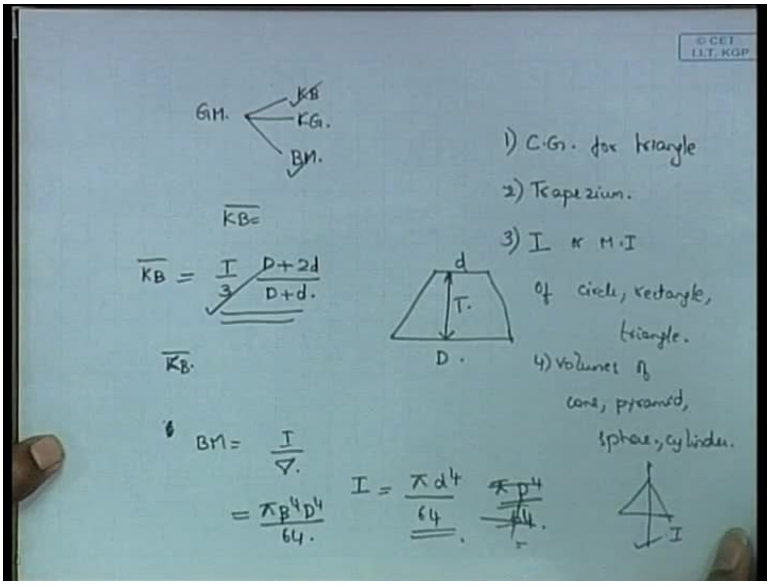

Now, there are first thing we need to… Now, what we have to calculate? GM.

So, to calculate GM, we need three things: KB first, KG second and GM and BM. We need three things to calculate the GM. So, first we have to calculate KB; by KB, we mean the center of buoyancy of this figure.

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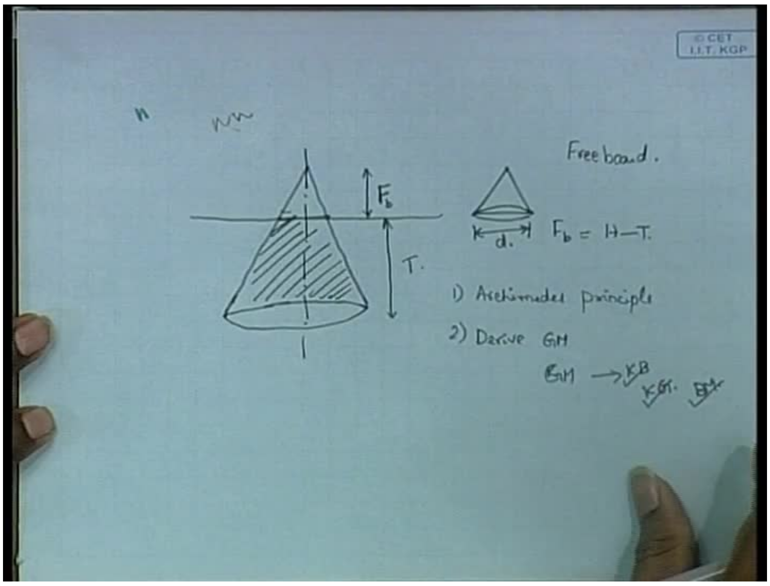

You see this trapezium. So, we need the center of buoyancy of this trapezium. Now, this is, this might be a problem for you because I am sure none of you will be remembering right now what is centroid of a trapezium or… So, what you have to do for this course at least is, I want you to remember couple of things: you need to know first, it is the same thing, whether it is a centroid or center of buoyancy, it is always it is the same thing. So, I mean, the formula is the same.

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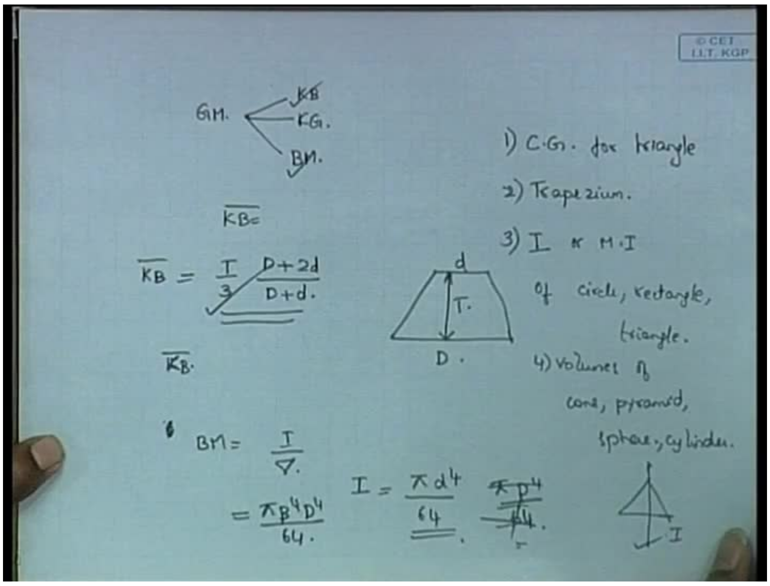

So, what you need to remember is couple of things. you need to I will tell you; write this down. This definitely for the exam you have to remember. So, first things is you have to get the center of gravity for a triangle; of course, rectangle I would not write straight forward; very simple; then, for a trapezium. So, these two you have to know.

And similarly, you need to know I, what we call as, momentum inertia of… you need to know the momentum. So, this center of gravity you should know from both sides; 2 by 3 from one side; 1 by 3 from the other side. You have to know which side; that you have to know. Then trapezium, I will tell now. This, just have to remember; there is no other way. Then, I or the momentum inertia, similarly, you have to know for a circle, rectangle and for a triangle - three things. These three you remember. And of course, you need to remember a couple of things like volumes; that also you might have forgotten volume of a cone, a pyramid, a sphere and a cylinder.

Such figures you just by heart it. There is That is the only way. So, once you have this, so here, we need KB for the trapezium. This is the formula for centroid of the trapezium (Refer Slide time: 09:34). So, there is no way to derive anything; we just have to remember it. Here, it is like this; that is, you are having a trapezium and one side is D, one side is small d and the distance between them is T. If you have this to be the case, then the centroid of this region will be at this point (Refer Slide Time: 10:04).This is the given by this. Now, this from this, you get the value of KB for this trapezium. So, for the exam, as I told you, these things I would not give for this much; if there is by any chance something extra, then I will give you, but these things you have to memorize.

So, KB you get from this expression in the above equation. Then, next you have to calculate let us calculate BM. So, we have calculated KB. Now, BM is again I by del. So, this I should be the I of what? I of what? Not submerged body; water plain. What is it? It is a circle. So, It is just the moment of inertia of the circle. And for a circle, it does not matter, but remember, if you are doing for some other body, if it is not a circle, if it is like for example, a triangle or a rectangle, means if it is a pyramid or something like this and if you are talking, we are most likely talking of tilting like this. So, you should be doing the momentum inertia about this axis (Refer Slide time: 11:10).

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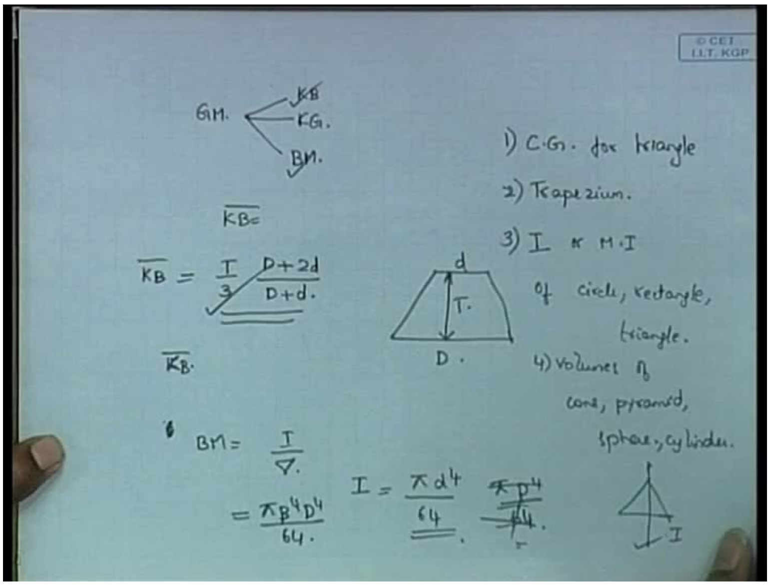

So, that you have to look at your some mathematics book; find out what that I is; I do not remember right now, but you just you have to remember for a triangle. So, that is important. So, in this case it just becomes I for a circle. I for a circle is very straight forward; pi d power 4 by 64. And for exam, do not come later saying writing this like this for this (Refer Slide time: 11:40) because this does not carry any mark. This is definitely wrong. This is not the I you have to have this water plain d; it does not make any sense if you put the capital D; it is completely wrong. So, this is pi d power 4 by 64. This is your I. Of course, in this case, it will become pi beta power 4 d power 4 by 64 because d is equal to beta D, capital D.

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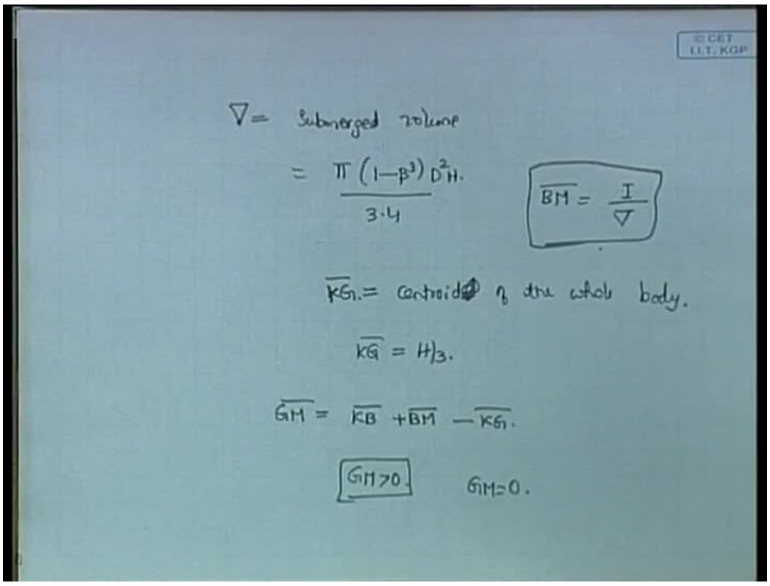

Now, once you have that del I am doing this so that everything, these point are important; like BM, what is that I of what; similarly, del - what del is it? Del is actually the submerged volume. So, in these things, there should not be a mistake. This submerged volume such thing there should be a mistakes do not take the whole volume you are talking about the submerged volume. So, this is again equal to… actually you can just do it; pi - it actually comes to (Refer Slide Time: 12:43 to 13:01). So, what you are doing here is this submerged volume of this.

That actually brings, mind you, you have to remember the volume of a trapezoid; it is a trapezoid; actually, if you know the area of a trapezoid, you multiply with the thickness and you will get the volume of the trapezoid, but you might as well study that also. Trapezoid - it is like rectangle; instead of rectangle, you have a trapezium; so, trapezoid. You find out you these things. So, I will keep it here; please write it down; do note this. We have to know this much, mainly these things; volumes of cones, pyramid, sphere, cylinder and trapezoid.

So, once you have that, you get the submerged volume of the… and you get the del. And once you get the del, you can just apply BM is equal to I by del. So, this formula is applied to get BM. Now, KG; remember what is KG. KG is the center of gravity of what? Whole body. It is not the KG of the submerged portion or anything; it is the KG means, it is the centroid of whole body. So, if these things are clear, then you will not have any problems at all. centroid of the whole body.

So, there is just a triangle; centroid of that triangle; it becomes b by 3 from the bottom; I mean, the whole distance H by 3 from the bottom. So, KG is equal to H by the 3 and always take the coordinate system starting from the bottom. So, the keel is always 0; so, H by 3 from the bottom.

And then, you just apply GM equals KB plus BM minus KG. So, this is the usual formula again. You apply this. Of course, you have got all these in terms of beta H d; you have that; those expression you just applied and then you substitute GM greater than 0; this is the condition and you will get some condition. That is, if you are given the value, of course, you can get the solution. Something might be missing in that; for example, your d might missing; small d or capital d will be missing. You just solve for that using this condition. Now, you are asked what is the limiting way value; you just put GM equal to 0 and solve for the limiting value.

So, this is this problem is very similar to previous one. Now, the next one is a little more complicated. This we have to do. So, this is actually the simpler type of problem where it is just application. next one you have to…

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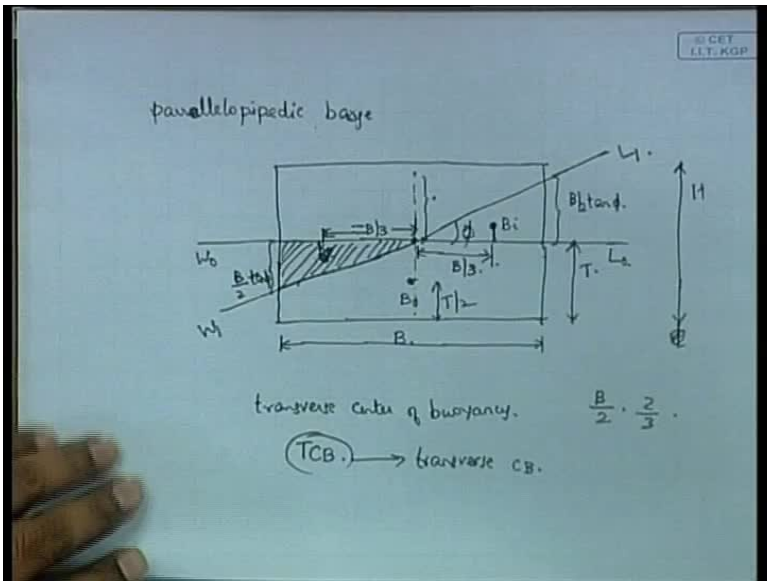

Now, suppose this is a particular kind of problem that is we call it a parrellelo parrellelopipedic barge; parrel it is called a it is a parellopiped pipidic barge; the meaning of that is, it is a it is a rectangle; it is just a rectangular box actually. It is like this. Like this, it is a rectangular box with some thickness and some length. So, there is no slanting, no angle, nothing; it is just all 90 degrees. Now, in this case, you are asked…

So, initially, you have this barge and you are told that this is a transverse view; transverse view means I am looking like this. So, transverse section; it is a transverse section. So, this is B; this is B - the breadth of the barge; then, this is the water line w 0 l 0. Now, this is the center line, center point and now the barge is tilting or inclining, heeling, different words - the inclining, heeling, same thing. it is now heel to different angle w 1 l 1.

Now, this is the triangle. Now, it is heeled about its centroid; remember the axiom that we have developed. If it heels about the centroid, there is no change in its volume. Whatever volume comes out is equal to whatever volume that goes in. It is heeling like this, such that whatever is coming in is going out coming out is going in. So, the total volume that is submerged does not change. Now, this is like that. So, what has happened here is one volume has immersed, this region has immersed and this volume has come out.

Now, let us call the centroid of this. So, this is called a wedge (Refer Slide Time: 18:10); this is called a wedge and this is also wedge; this is the wedge that comes out and this is the wedge that goes in. So, this is now let us call the centroid of this. Then, you called this region; let us assume that this is the center of buoyancy. Center of buoyancy means the centroid of the volume of that point is, let us call it B 0 or B e; B e - B emerged. And this is the centroid of this wedge that has come out, gone in; so, this is B i - B immersed. So, this is B i and this is B e (Refer Slide Time: 09:05).

Now, I will just give some dimension. So, this is b; then this is H. This is H; this is T. Now, this is b 0 which is the center of buoyancy of the whole system, whole body. This b e is the center of buoyancy of the wedge that has emerged. B i is the center of buoyancy; just the center of buoyancy of this. It has nothing to do with whole other part of the body, just this wedge. B i is the center of buoyancy of this wedge, b e is the center of buoyancy of this wedge and B 0 is the center of buoyancy of whole body capital B 0 (Refer Slide

Time: 09:35). Now, this B 0 as you can imagine will be a T by 2; it is a centroid of this which will be a T by 2 always. it is It has to be because it is the centroid and the volume, this total volume length is T. So, it is then T by 2.

Now, next thing also you will you will you should know is what will be this distance (Refer Slide Time: 20:06). B by… It is the rectangle. It is the it is the wedge. It is the triangle. So, what will be the centroid? It is B by 3; B by 3. No, no, wait; actually, this B by 2 into 2 by 3; 2 by 3; it is B by 3 only. I am saying it comes like this: B by 2 into 2 by 3. It is not it is not because it is B by 3, from it is one-third of this distance which is one-third of B by 2; two-third of B by 2. So, it is correct; B by 3 only; correct. So, this is B by 3.

So, this distance is B by 3. That is what, you do not get confused; do not say B by 2 because is not a triangle; I mean it is not a rectangle; it is a triangle. So, again, B i, I repeat it again. It is the centroid of this triangle; this wedge (Refer Slide Time: 21:05). The centroid of wedge will be a B by 3 from this point and similarly, here this will be B by 3.

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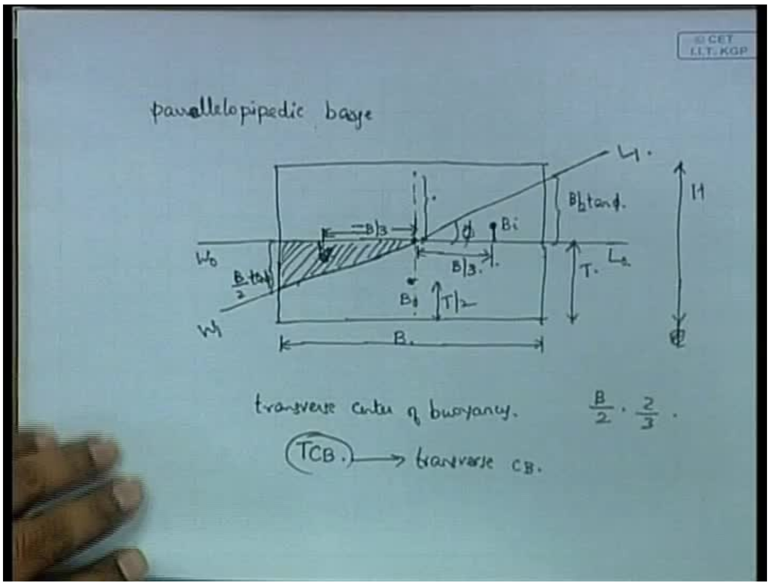

Or let us call this minus B by 3; this distance is minus and that distance is plus; that is plus B by 3. Now, if this is B by 2. What will be this? Let us say this is heeled through an angle phi. What will be this? (Refer Slide Time: 21:36 to 21:51)Yes. Someone has told me that that is correct B by 2 tan phi B by 2 tan phi. So, this distance will be B by 2 tan phi. Similarly, this distance this will be B by 2 tan phi and what will be this height? I will come to that now.

First, we have to do a couple of things. We will make a table like this. We need this figure and we will make a table here like this. Before I do that, there is one definition; that is, we have already defined what is the metacenter; means, it will be somewhere here. In this figure, it is already drawn. Because it tells the center of buoyancy moves to new point and when you draw vertical from there, where it needs the old vertical, it is called metacenter. Now, metacenter - this distance, this height is usually what we call as metacenter (Refer Slide Time: 22:44).

This height metacenter is always measured in vertical. Now, another thing that comes here is transverse. This I did not see. One minute; transverse center of buoyancy that is this distance. The center of buoyancy has two coordinates in this figure. It will have a vertical coordinate and a transverse coordinate.

The transverse distance of the center of buoyancy from the center line the transverse distance of the center of buoyancy from the center line is known as the transverse center of buoyancy. When you generally say center of buoyancy, it means the point, and of course, in most cases, it actually represents the vertical distances; means this height, but this is the particular word TCB which it actually represents this transverse distance.

Again, transverse distance is the y coordinate always. When you have a ship like this, this is the transverse, this is the y coordinate, this is the longitudinal, this is the x coordinate and this is the vertical z coordinate (Refer Slide Time: 23:55).

So, TCB is known as transverse center buoyancy. So, when you are trying to find the transverse center of buoyancy, the meaning of that is you are trying to find this distance means this is B 0, initially. The transverse center of buoyancy of this is 0 because it is at exact center. So, the ship is like this and it is not heeled. When it is not inclined at all, it is not heeled at all, its center of buoyancy, it is here B 0. It is exactly at the vertical middle. So, it is 0. Later, when the ship heels, you have seen in that figure B 0 will ship like this. Then, it will have a transverse center of buoyancy.

Now, this problem the question is to find the transverse center of buoyancy and the vertical center of buoyancy; means, what is your horizontal distance of this B 0 and how much has it gone up as B 0. So, that is the problem. Now, how do you find out the center of buoyancy, both of them? Transverse… You always follow this method. It is proven to mistake. So, you make a table like this.

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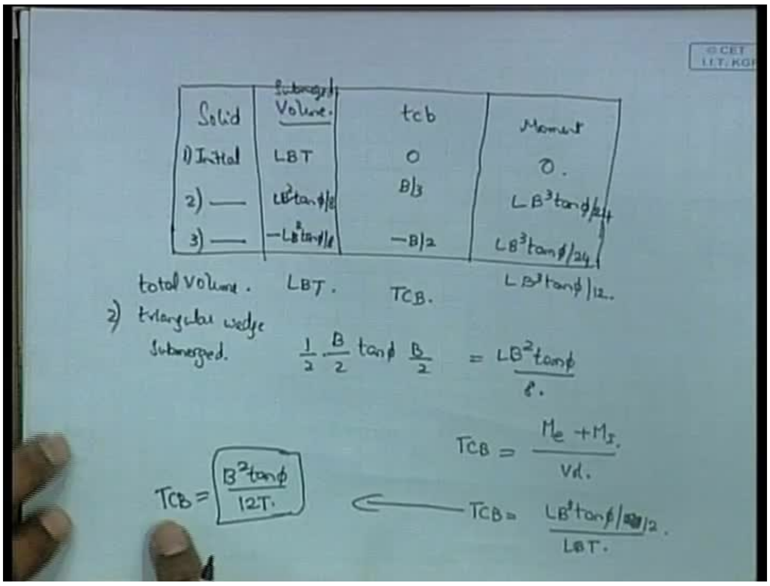

This TCB is the capital TCB only. You know that, to find a centroid, you need to find the moment at any rate because it is the sum of the moments divided by the total area or volume; in this case, volume. So, we are trying to find the moment of volume and divide it by the total volume.

So, first, let us consider the wedge in the initial case; that is before heeling at before heeling means the body has not inclined at all. What is the volume? It is L into B into T. Remember, it is not the total volume. This is this I will write here, submerged volume. So, it is L into B into T. This you know length into breath into trap. Now, transverse center of buoyancy is 0; transverse center of buoyancy 0. So, the moment is, moment by moment we mean volume into transverse center of buoyancy or column 2 into column 3; this is also 0 here.

Now, the second one is the second one I will write here in the detail. That is second one is let us consider the submerged wedge - this one (Refer Slide Time: 26:37). Wedge means it is just that triangle. You are not considering the whole body. Here, you are just considering that triangular wedge.

So, it is the triangular wedge submerged. Now, the first question is what is this volume? This is here. What is this? This is the triangular wedge and what is its volume?

What will be it is volume? It is the volume of that… first you have to find the area of the triangle, multiply with L; that will give the volume of that wedge; means, it is this area, this triangle, that wedge; that triangle here (Refer Slide Time: 27:18) into that volume that whole length of the ship of that box. This is called a parrellelopepidic- that box barge; It is called a box barge actually.

So, the volume of the area of a triangle is given by (Refer Slide Time: 27:30) for KB this distance is B by 2 tan phi; B by 2 tan phi into half base into altitude half basis. This is this is the base half B by 2 into right correct; half base into altitude half basis B by 2. This is B by 2 into altitude b by 2 tan phi.

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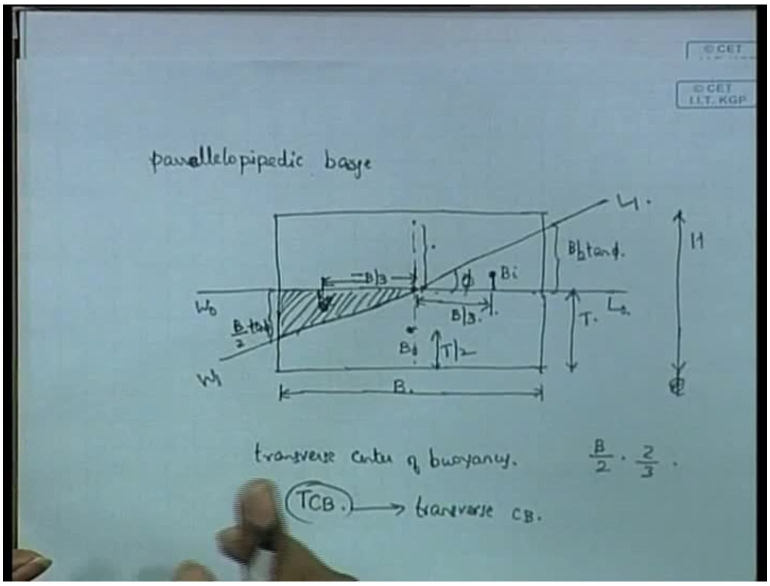

So, this becomes B square tan phi by 8. So, this you have to write here B square tan phi by 8 into L. Yes. That is the volume into L. Yes. L B square tan phi by 8. Now and this is your transverse center of what is the TCB of this wedge B by 3. Let us call this distance that is also another point you have to note. Remember you are putting this to be the center of coordinates; if you put this should be the center of coordinates then you put this as positive; this has to be put as negative. So, when you say this is B by 3, this distance when you are putting in that table, it should become minus B by 3. So, you should not forget; otherwise, your answer will be wrong. Actually, you can see if your answer is wrong, I will tell you.

Now, this is B by 3 is your TCB and your moment will be the product - LB cube tan phi by 8; no by 8, 24; LB cube tan phi by 24. Just multiply the submerged volume with TCB; that gives you the moment. Now, your next question is, I mean next part is the volume of the emerged part. This region is immersed. Now, I want to find the find the moment of this emerged region, this wedge. So, we have taken this wedge. Now, we have taken this. We have taken this wedge (Refer Slide Time: 29:38). Now, we need to take this wedge this region.

Now, that is actually very simple because it is very similar to this. There is no difference. you see a submerged volume; it is again same thing, but it is negative; so, minus LB square tan phi by 8. This is again minus B by 3. So, this will become positive again; LB cube tan phi by 24.

Now, as I told you, how to find if there is a mistake. See, now you find out the total volume here (Refer Slide Time: 30:20); means the total body. When you add these two, what will you get? It has to become 0; that is the way to check; means this is very simple. There are only two - one wedge and another wedge. When you have many case, many shape, many bodies, you have to divide it - many bodies. It becomes very complicated; make sure that the total volume is always LBT; means, you add these three.

It is always LBT. Thus, one that is immersed, the volume immersed is equal to the volume submerged. So, these two will always sum up to 0, and therefore, your total volume should always be LBT. So, in this table, just sum this up to make sure there is what you are getting.

Now, the total moment is obviously the sum of these two. So, this will be LB cube tan phi by 12. Now, how will you find the total TCB of the system?

This is the means this is here. You will get the TCB of these two wedges together. How will you get that? It is just a moment. You divide the total moment by the total volume. What have we done? You have actually done moment of the M emerged plus moment of the M immersed divided by the total volume. This will give the total distance total TCB rather net TCB.

We have introduced no new formula here. This is just the formula that says if you want to calculate the centroid, centroid position is given by moment, total moment; moment of one section plus moment of another section plus moment of all the section together basely divided by the total volume. That will give you the centroid centriod of that volume. Now, that formula we are using. So, TCB you will get here; just put it here (Refer Slide Time: 32:08); this TCB will become LB cube tan phi by 24 divided by the total volume LBT. LBT is again the total volume. Now, you just divide this; this will become B square tan phi by 12 T.

So, this is one of the… what by 12. Yes; not 24. Yes, LB cube tan phi by 12 divided by LBT. Yes. So, it will become B square tan phi by 12 T. Now, this is one half of the problem. You are asked to find out what is the transverse center of buoyancy. So, now, you have got it. That is what this method is. This is for a simple case. Now, a couple of things is - I would not give you problems where you have to do the, I mean there is a change in the whole volume itself; that becomes very complicated, means whatever is coming out will be equal to whatever is going in for all your problems.

So, you will just have this particular kind of problem. Of course, the shape might be different, such things might be different, but this is the method of doing it.

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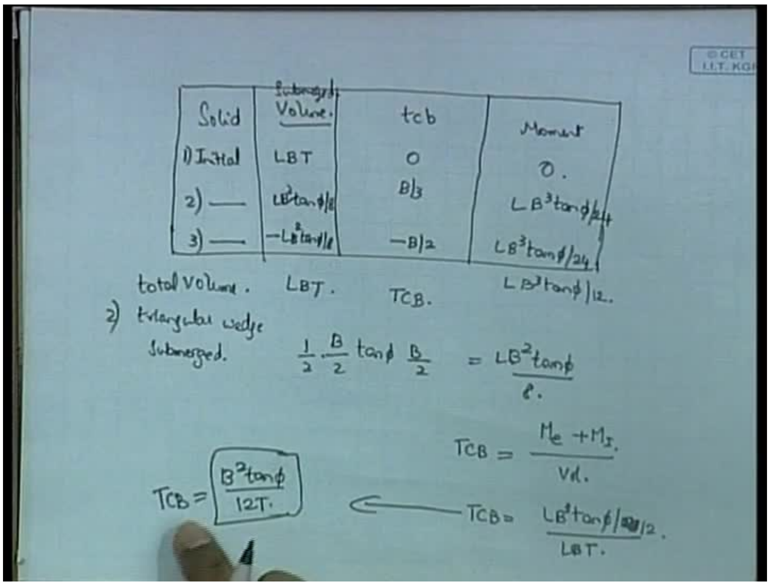

So, this gives to the transverse center of buoyancy B square tan phi by 12 T. Now, you also are asked to find out what is the vertical center of buoyancy; means, you have to find for the new B final B, what is its vertical coordinates? How far is it from the keel?

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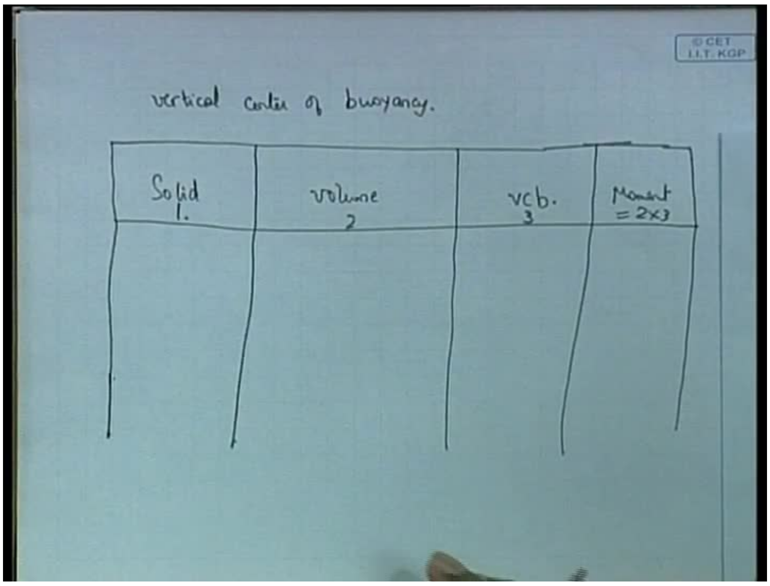

So, you are asked to find vertical center of buoyancy. This also you are asked to find. I will use this figure now. Now, we make we have to make a similar table to what we have done previously, same thing. So, your problem here is to find the v c b. No, this is written like this vcb vertical center buoyancy; other one is small TCB center transverse center of buoyancy. So, you need to find both the y and z. This is your z part; the method is the same.

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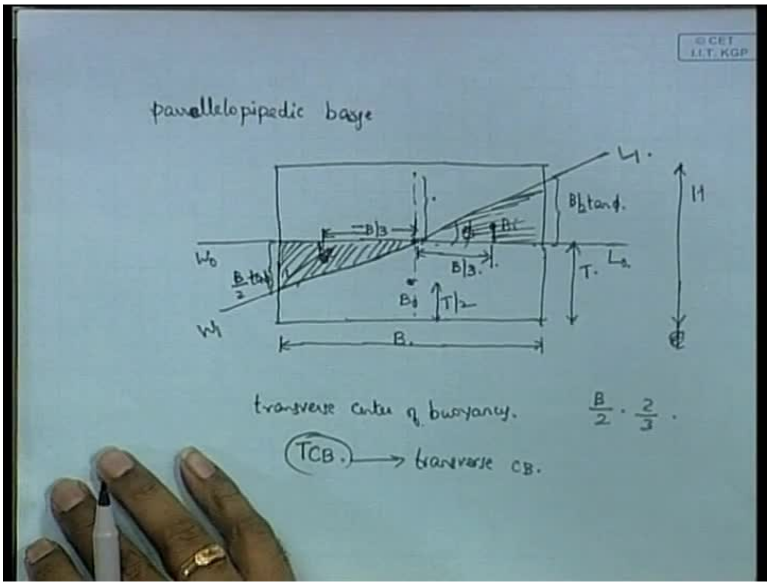

So, as you can see the important thing in this figure is to… I mean in first thing is to draw this figure properly; otherwise, you would not get your constant correctly. So, this you draw the figure first properly with the dimension like B T and everything. Then and the thing that will determine the answer is basically getting these things correct.

This is B by 2; this is B by 2 tan phi; this is B by 3. Similarly, what will be this distance? What will be this distance? (Refer Slide Time: 35:38) It will be b by 6 tan phi, exactly. It will be half of I mean 1 by 3 of this distance b by 6 tan phi. So, in a way, if you get this correct, then the problem is very straight forward now.

So, this is what is that is actually the vertical coordinate or the vertical center of buoyancy of that wedge. So, you have a vertical center of buoyancy for that wedge, this wedge; you have vertical center of buoyancy for this wedge which will be negative and you will have the vertical center of buoyancy for the whole system; that is your question.

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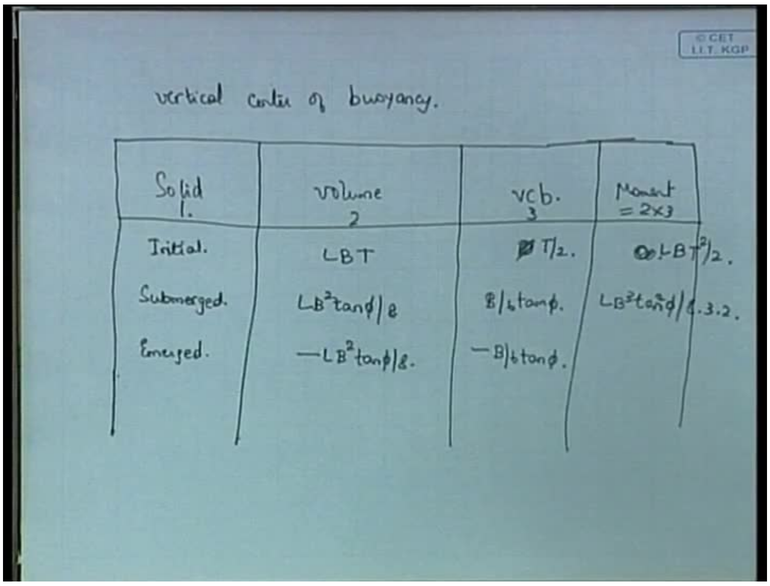

Now, first you have the whole initial width, before it is the whole, before the whole thing is inclined. So, the volume is again LBT vertical center of buoyancy that is 0 0. Then, submerged, the volume is again the same. This is the volume that is submerged. We have done it last time. In the previous table, we did this by 8 and this we just the what is this v v c b of that wedge; you said that is b by 6 tan phi.

for which one. For the whole body… actually that is correct. It is not 0; it is wrong here; written wrongly here. You are right. It is T by 2; it is not 0. It is actually the centroid of that volume that is submerged. So, it is correct; that is T by 2.

Now, so, make the correction in the book. It is correct. It is T is T by 2. So, B by 6 tan phi. Now, you multiply this; you will get the moment - LB cube tan square phi by 8 into 3 into 2; 8 into 6; basically what? Then moment would not be 0. L B into T square by 2. So, this is the submerged. Now, the emerged will be just negative in sign. This volume will become negative minus LB square tan phi by 8; vertical center of buoyancy will be minus b by 6 tan phi.

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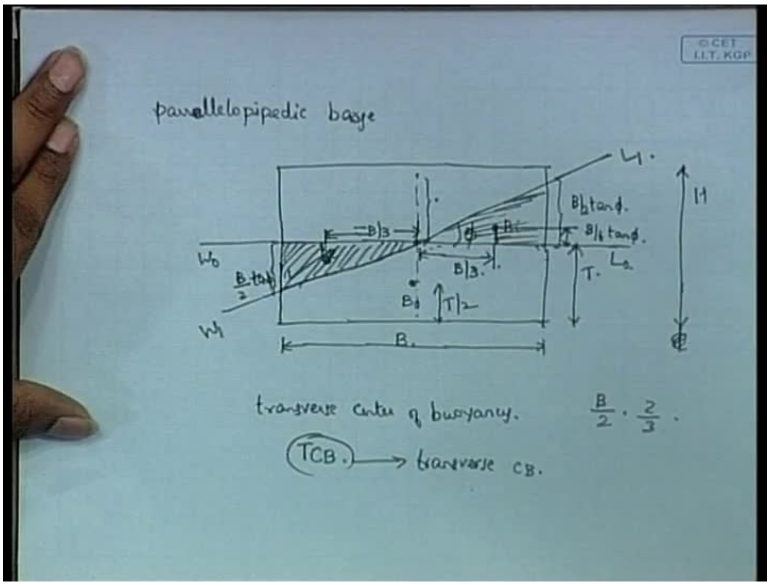

Yeah Actually, that is the that is a good point; do it; that means they have taken this to be 0 and they have done the problem; it does not matter. If you do it, the answer will be different, but remember your answer will be based on the coordinate system at the bottom. This will be based on coordinate system at the centroid; it does not matter.

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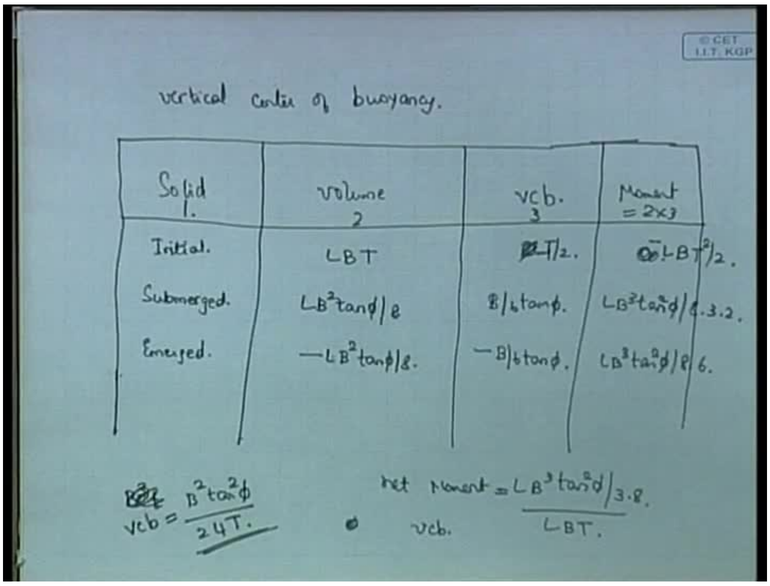

So, in this problem, since they have to done, it will follow the same. So, will get vcb has minus b by 6 tan phi, but it does not matter. When you are doing the problem, you can do it other way also; you can put it there.

[Noise] what? what? one vcb of the first body this is minus T by 2 you are saying; actually they have put it as 0; that is the mistake. It should be minus T; minus T by 2, as it should be the centroid of the volume. Yes, correct; it should be minus T by 2 and this will be therefore, minus then.

Therefore, the emerged volume is this. So, this LB cube by L cube; again same thing tan square phi by 8 into 6 and the total change is therefore, the submerged plus submerged plus what has come emerged.

So, that will be given by repeat again LB cube tan square phi by 3 into 8 by 3 into 8. So, this is the net what? moment; net change in moment due to the coming out and going in; the volumes going out and coming in. So, this is net change in moment; net change in moment divided by the net volume. Net volume is again LBT because whatever has gone in has come out; so, LBT. This should give your change in vcb. Given your vcb, they are not given to value here, but I think you can do it quickly. It is, it will be B cube tan no B square tan square phi by 24T, I think.

So, this will be your vcb and just to note that, this will be the distance from their centroid from their 0. If you do with other way, you will get distance from your center; just get that.

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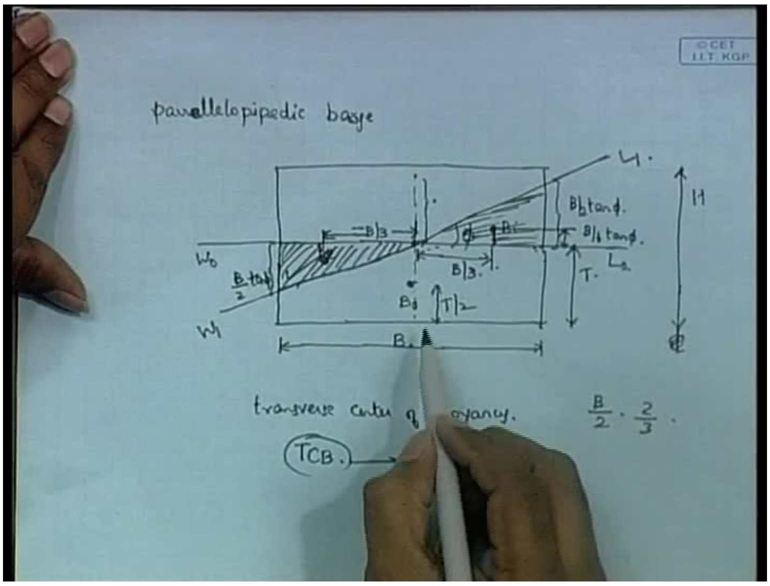

Once you know that clearly, then it is it does not matter, where if choose the centroid center. Well, the advantage with this is that in many cases it is done like this; means where ever it is heel, it takes it as a centroid, but in some of the other problem, most of the other problem, you take this to be the heel to be the 0 and go about it. It does not matter. It is up to you; for the problem, whichever way you want to do it, but just get these things. Here, the value should be correct; the volume should be correct and that whatever is the origin, the distance between the origin to the point should be correct.

So, if you just write clearly in your answer script; where you have taken origin, it does not matter.

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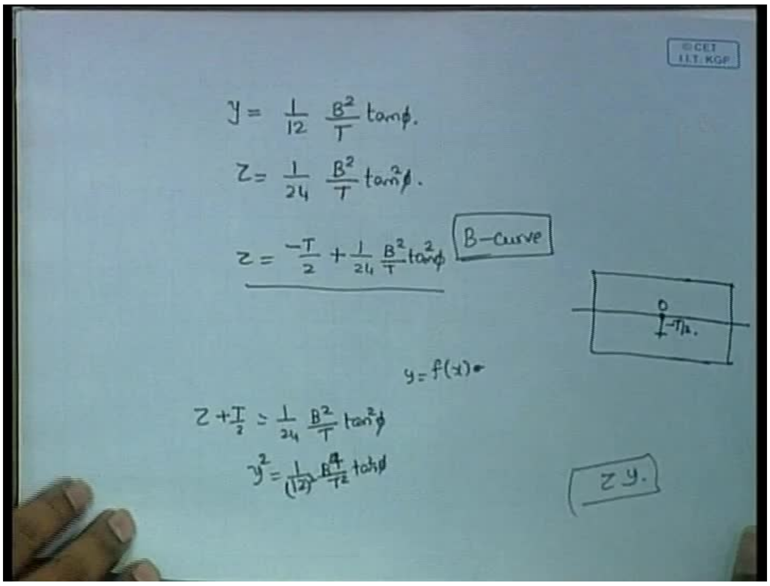

So, you get the vcb. Now, you are ending up with the coordinate of the center of buoyancy becomes… no no, we are changing, finding the changing moment that is the initial moment. That change in moment, the change in moment is what is this submerged minus what has comes out; it does not matter what the old moment is. Let it be there.

Then, show them the way y is given by… So, this is what you are getting B square by T tan phi and z; this one, this is just the solution to the equation. I mean solution to that tables, two tables B square by T tan square phi.

So, what you have is you are you are seeing that your B that is the center of buoyancy moves, such that y is given by this equation and z is given by this equation (Refer Slide

Time: 43:15) if the body heals by an angle phi. Now, we always say something that is we called it a B curve.

[Noise]

So, we have to add initial. They have here as 0; that is why they have added it. Yes, the center- initially, it should be at minus T by 2.

Let us do this. So, here, you have this to be… So, their origin is here. This is their origin 0. So, here, initially it is minus T by 2. So, this is the initial vcb. So, your new will be distance from this; that is what you say it is. So, it is always minus T by 2 plus this; otherwise, minus T by 2 plus 1 by 24 b square by t tan square phi. Yes. It should be given like this; actually, z co-ordinate.

That will give you the position of the center of buoyancy of the vertical coordinate of the center of buoyancy. It is correct. Actually, when you are doing this, you will have to correct the book entirely because that is minus T by 2. Then, now, we have to… what exactly do we mean by B curve? There it is this that is that The y and z is called the B curve .

Now, what we can do is you make it one equation. You have an equation, you know, like like f of x; y is equal to f of x. You have an equation like this. This is what you called as a curve, basically. Now, we can put it in this format. So, what you do is you remove this phi from both the equations. You can square this and becomes a little more complicated. You have to do it like this. This is your z now. So, it is z plus T by 2 will be given by 1 by 24 B square by T tan square phi tan square phi and y is given by 1 by 12 B square by T tan phi. So, i am going to square the y. So, y square 1 by this square 4 square and you divide; you remove the phi from the two equations and you will get; again you would not get this. This is not correct. So, you will get an equation between y, z and y; that is known as the equation of the B curve.

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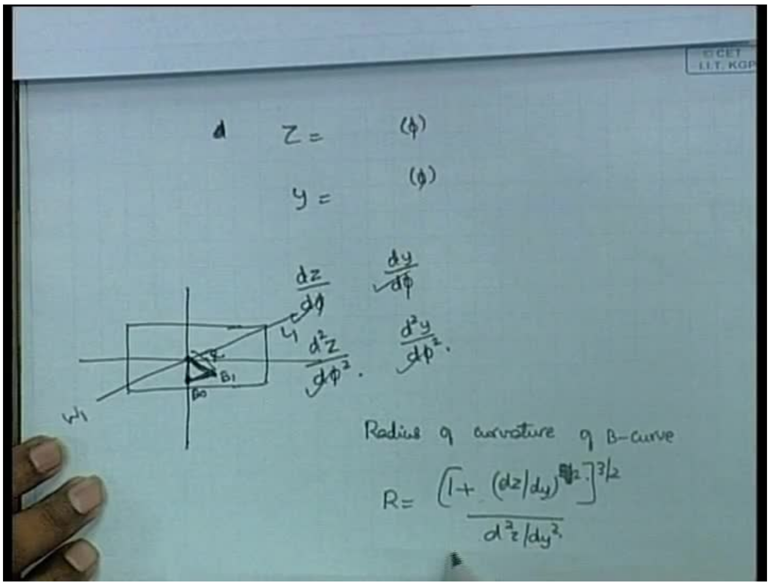

Now, you can always do. Similarly, you have you can do it like this. There is one more thing that you can derive from this B curve; that is, you have now an equation for z is equal to something as a function of phi. You have one equation y is equal to something into function of phi; you have two equations here.

What you could do is first do this d z by d phi. You do calculate this d z by d phi; also calculate d square z by d phi square. Similarly, you calculate d y by d phi and you find d square y by d phi square. Find these things; calculate these things; four of these. Then you can calculate one more thing; that is you can calculate the radius of the curvature of the B curve. Now, there is a formula for radius of curvature. you Most likely, we know it from geometry itself (Refer Slide Time: 47:35).

Now, that is square power 3 by 2. I think have you come cross this. I think you should have done. You would have You will be knowing this. So, this is how you find out the radius of curvature of a curve. So, at any point, so this r you calculate. what you what are you doing now what you what you meant by the radius of curvature; that is you have this box and the body is now…

So, initially this is the water line and the body heel like this into new water line w 1 l 1 and the radius is here. It was B initially here B 0. This was B and then it went to this point B; B 1 and this. So, by the radius, this curve B 0, B 1 curve (Refer Slide Time: 48:18).

How B 0 varies is what is you are calling at B curve. That is how your center of buoyancy keeps moving from B 0 to B 1. As phi keeps changing as the body keeps inclining or heeling, the B 0 that is the center of buoyancy starts shifting from this vertical point to this B 1 or other keeps moving because more volume is coming in one side; it will slowly move in that direction, center of buoyancy. The curve that is known as the b curve; that is what we called as b curve and this is what you are calling as the radius of curvature; this distance.

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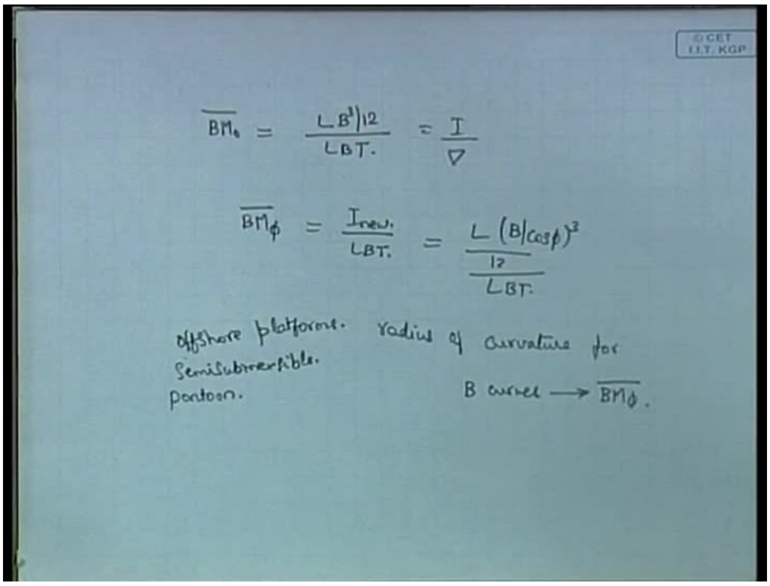

That distance is what you are calling as radius of curvature of B curve and that value is given by this expression. Now, of course, we can also find this BM 0. This is directly an application of the formula. This is I by del. I is the… this is the one point I want to make it that is BM 0; means you are talking about the metacentric radius, given the body has not inclined; that is meaning of 0 0 means the body has not inclined so far.

So, it is remaining vertically like this and this area you have to have. That is the area that gives to the center of I. It is the area that gives to the moment of inertia I; that is, this is basically I by del; del is of course of base LBT.

I am just trying to show y. It is you know y is LB cube by 12 because we start this rotating like this. Because of that, it is LB cube by 12. Now, it is inclined. Let us say now what will be its BM; Its BM is not BM 0; in fact it is actually BM phi; it meant the body has inclined by an angle phi. Now, what is its BM?

It will be the new I divided by LBT. What has changed here? Here B is not B anymore; it is that is that is that is it is now.

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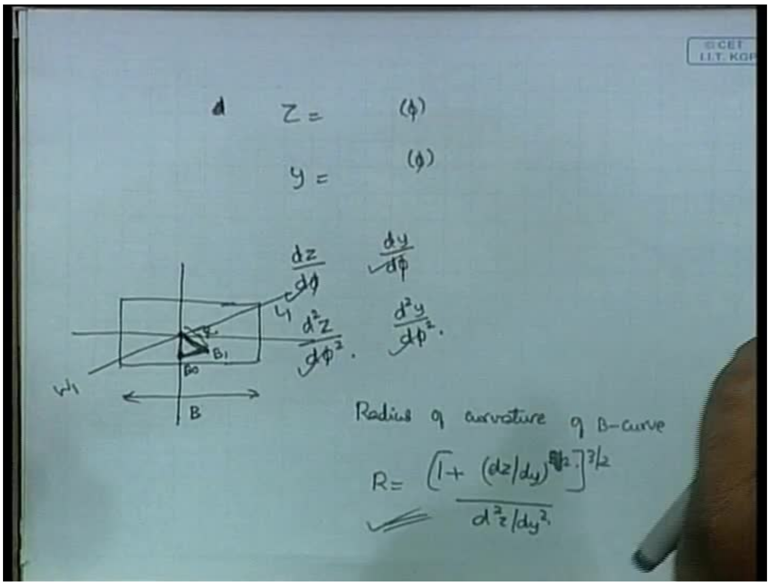

I will show this figure; may be this figure, it will help; that is, this is B. When it was vertical, this distance was B, but when it is tilted like this, this distance is not B anymore; it is slightly more than B. Then, B by cos phi it just it [jus/just] is just the algebra; it gives to B cos phi cube by 12 divided by LBT.

Just know this one. This is the new metacentric radius. So, BM 0 is actually BM 0 is very straight forward; BM phi slightly more complicated because it tilts and the distance is no longer B. Actually, it is slightly more than B; it gives to BM phi.

Now, you will see that if you calculate, it should properly go to the old book to see that you will see that the radius of the curvature, which we calculated for this B curve will start becoming tending towards this value of BM phi. So, at that, we will do later. Since the time is up, then. So, this is you how you get a B curve. Now, this problem, now actually we have to go to another problem. See, in the class now, then alright. Now, it is a different problem. I do not think we have time now.

So, we have a two or three more problems. I will just end with what is meant by that problem - this the one thing you have to know for the problem; that is, just know this word; just know this is word. It is there are two things that come out in this problem.

This is way; this is also, of course, naval architecture. Only that is not ships is not really ships; as such we called them also offshore platforms.

So, in general, we are now having the problem. You will This we will be dealing in much detail. We will be dealing what are known as offshore platforms; these like oil rig is also platform; means these are not ships; really, they do not move in the ocean. They are fixed more or less and you study different stability aspect related to them.

Their hydrostatic and stability concepts are same as that for that ship because it is after all floating in water only, but it has moving, then slightly different. Now, this is one problem related to that and one type of an offshore platform is called semisubmersible. And related to semisubmersible, we have these things called pontoon. We will actually do that detail in next class. Tomorrow morning, we will do that.

Thank you