Hydrostatics and Stability
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Module No. # 01
Lecture No. # 10
Inclining Experiment

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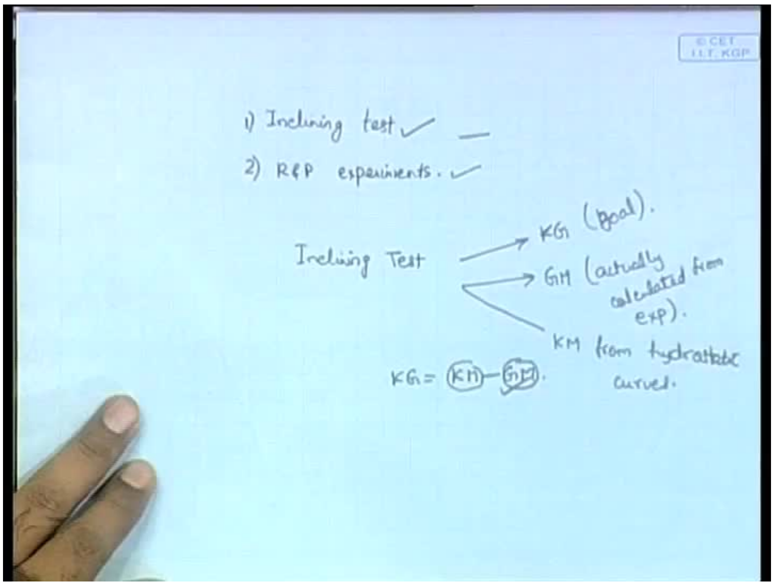

Today we will do something, which is a very important test; it is known as an inclining test or an inclining experiment. Whenever you are constructing a vessel - really constructing it in the shipyard you will see that you need to add…you need to do a couple of experiments; once you…so first of all you develop the hull; once the hull is developed you need to do stability calculations - you need to make sure that the stability of the ship is alright for that particular hull.

There are a couple of experiments: the first one is, in fact, of the two important experiments that are conducted one is this - this inclining test, and the next one is actually the resistance and propulsion experiments. Right now, of course, you would not know about resistance and propulsion; may be I will mention it a little bit later.

Right now, the first test is for calculating the resistance of the ship in some particular running condition; this is to calculate the stability of the ship and that is called the inclining test. The purpose of the test is to calculate - the real purpose of the test is to calculate KG, that is, the position of the center of gravity of the vessel; this is the purpose or let me call it the goal of the test is to calculate this.

But, what we calculate in this experiment is actually GM - what is actually calculated from the experiment is GM; but, the main purpose is to get KG - how do you get KG? KG you get it if you do KM minus GM, right? That gives you KG; therefore, the only other thing you need is KG KM; KM comes from hydrostatic data - hydrostatic that we will look into later.

You can get it from hydrostatic curves and hydrostatic data - you will get KM; that is actually a property of the ship as such - that we will get in a some other way; right now, let us assume that we know KM and once you know KM you get KG by KM minus GM. What the experiment does, is calculate GM.

Therefore, when writing about inclining experiment you need to write two things - the main goal of the test: the test is really done to calculate KG, but what we really calculate using the experiment is GM and from it, it is derived - from the use of KM we derive KG; this is the inclining test.

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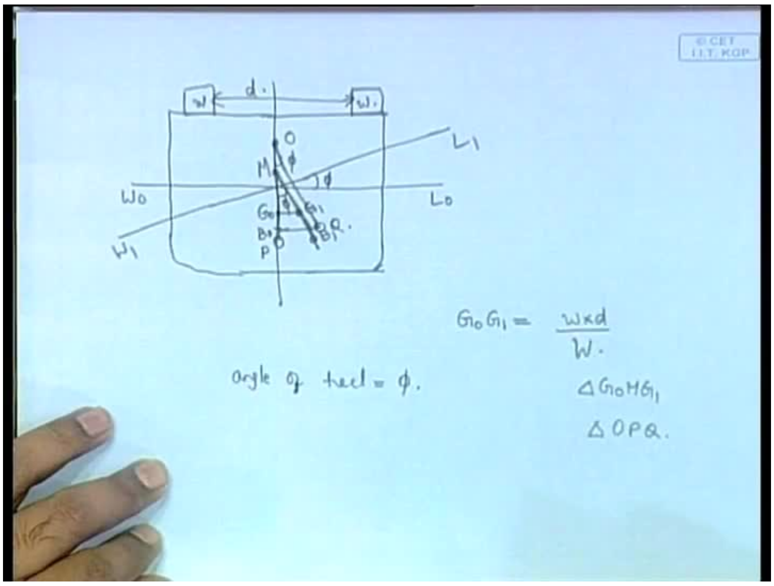

Let us explain what the test is: that is, suppose you have - this is your vessel cross section; now, what we are going to do is - this is the center line … suppose there is a weight here of - a small weight, small w - there is a small weight there of weight small w ; what you do is you hang from this point - some point here - ‘o’; we hang a pendulum and the pendulum will remain like this, right? When you hang a pendulum it always hangs vertical - if it is not moving it will always hang in a vertical direction, so the pendulum will be hanging like this.

Now, what we do is - this weight small w is shifted to the right side, here; therefore, what has happened? There is a shift in the center of gravity, when you move a weight here it will incline like this - it will incline; let us call this to be the initial water line w 0 L 0 and this to be the final water line w 1 L 1. As a result of this inclining, it will come and come to rest such a point that - let us call this G 1, initially this is G 0, G 0 G 1 and this is B 1 and let us say B 0 is here, this is M.

The position is that initially the ship is at in a upright condition when the weight is on the left side now the weight is moved to the right as the result of which the ship sinks on that side and as a result the center of gravity shifts to G 1, the center of buoyancy shifts to B 1, and you have the M - as you have seen - the metacenter.

How will the pendulum look? Actually, the pendulum will still hang vertically - vertically to the new position - it will still hang vertically, it will be hanging like this; this is the vertical - from o it will be hanging vertical; let us assume, this is the vertical, so pendulum will be hanging like this - pendulum remains there.

What is the distance through which the center of gravity of the ship has shifted? G 0 G 1 - this is again the same formula we have used many times, where d is the distance through which the weight has been shifted - this distance - small d is the distance through which the weight has been shifted; therefore, G 0 G 1 - this distance, will be given by w into d by capital W.

What you can see here is the angle of heel and this will be equal to phi - the angle of heel, this is equal to phi - this is just geometry, this is equal to phi as the result this will be equal to phi, this will also be equal to phi - it is very obvious; one is horizontal one is vertical so the angles are just same, so angle of heel is equal to phi.

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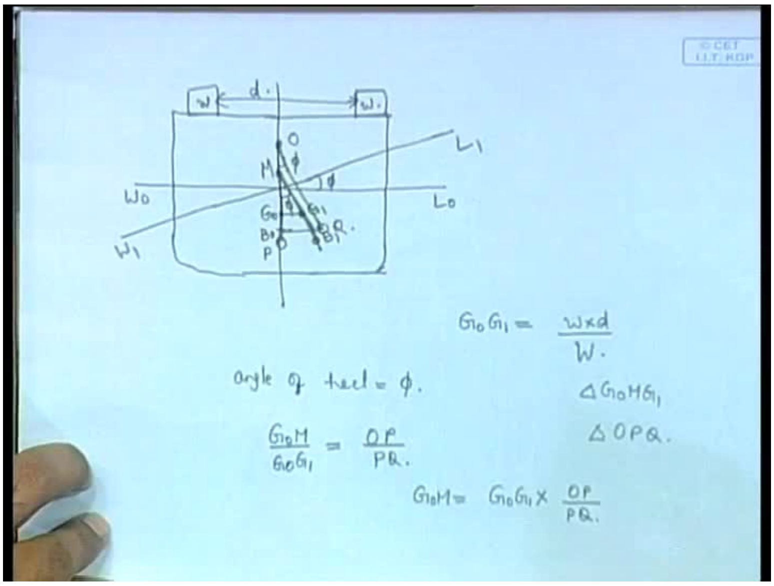

You will see that the two triangles - this triangle G 0 - that is the triangle G 0 MG 1, there is 1 triangle G 0 MG 1, and there is this triangle let me call this is P and let us call this Q and triangle O P Q is a 2 triangle. One is the triangle created due to the G - that is, MG and G 1 G 0 and G 1 that is a small triangle the other one is the triangle created due to the…where the pendulum is suspended - the hanging of the that bob and the final position of that - so, there is a triangle produced by that; now, this triangle and the other triangle will be similar because angles phi are same the other angle is 90 degree and third angle is 90 minus phi; all angles are same in both the triangles so they are similar.

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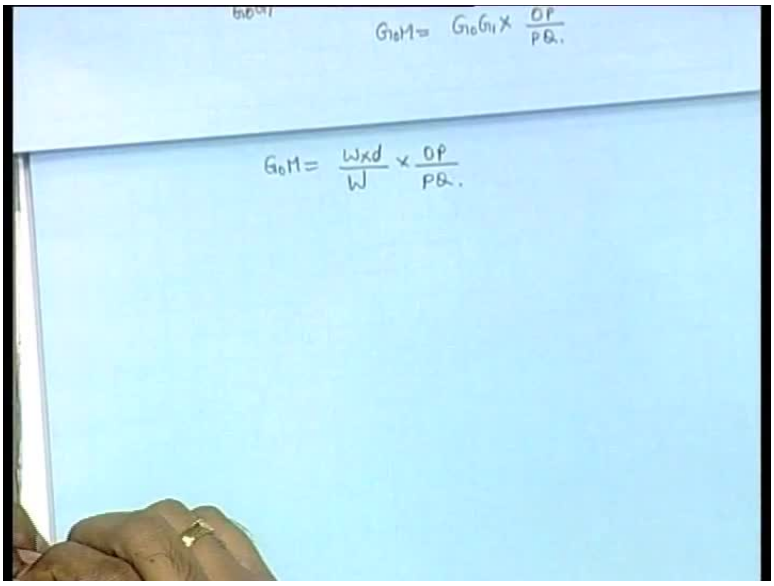

Therefore, we can say that G 0 M by G 0 G 1 is equal to - G 0 M - it is equal to O P by P Q - it is just the similarity; therefore, G 0 M is equal to G 0 G 1 into O P by P Q; now, G 0 M is equal to w into d by capital W into O P by P Q, so I have just replaced G 0 G 1 by that new value.

What do you have? You are actually having a pendulum, so the experiment is this…at some point on the ship, somewhere inside the ship or you can hang it from the deck of the ship - you can hang the pendulum there; sometimes, they hang it outside it, does not matter; what matters is that angle - the ratio of these two O P to P Q is what matters; O P to P Q is basically I think tan phi or is it cot phi? Maybe one of those - it basically depends on phi; it is that phi that you are actually measuring.

How do you do it? You…O P is actually the length of the thread in which you are hanging the pendulum; you take it a thread of known length and you hang a bob at the end - you hang it there; so, this distance is known and when it tilts you find out how much this distance is moving, you measure it using some calipers.

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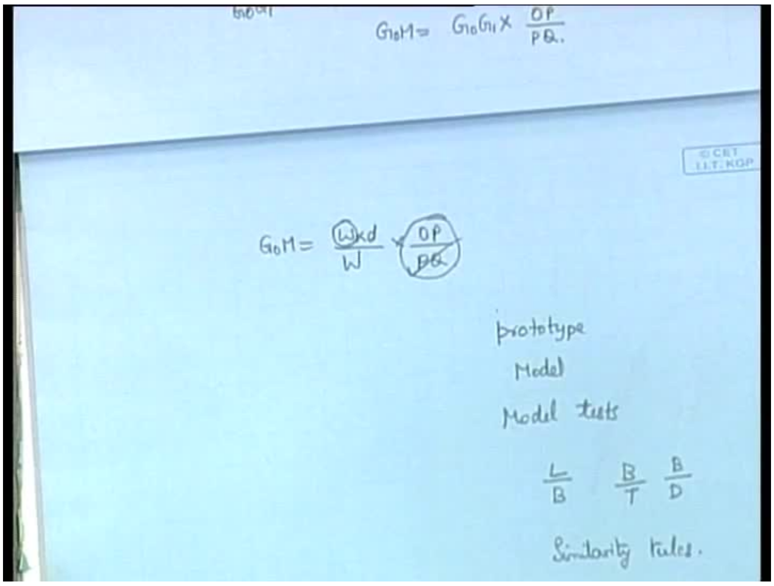

What you have is actually a model, it is not a huge ship; you most likely do it in a model - actually, you probably do not know that there is something called…we call this in naval architecture…actually same as in aerospace you do not do the whole experiment in the whole ship - the size of the ship is huge, it is probably 250 meters long if it is an oil tanker.

So, what we do is we take a model, which is of a smaller size; but, there are some criterion that you do - it is an actual replica of that ship; that means, things like L by B, B by T or B by D where D is the depth of the ship such things will be the same for the prototype and the model - prototype means the whole ship; the real ship is called a prototype and the small one you create in the lab is called a model.

The model is made such that the ratio of lot of factors… in fact, in our next class that is marine hydrodynamics today we probably will be doing with such… these are known as similarity rules and it so happens that in that class also we will be doing with this today; similarity laws it is called or similarity rules - you say that some factors should be similar between the ship and model you cannot make a arbitrary model that is obviously nonsense.

Some ratios you keep to be equal between the ship and the model and this is called model testing; this experiment is mostly done using a model, so it is like if you have gone to the towing tank in the department - in our department there is a towing tank and this test is conducted there usually.

Inclining experiment is done for the industry - they do it; you make a model of the ship - you make an exact replica, you make a model and in this model somewhere you hang a pendulum; you can hang a pendulum of known length and you measure the distance through which the pendulum has moved, that is, using some calipers you can measure it exactly.

Therefore, you have two thing - this length also you have this length also you have (Refer Slide Time: 12:27); therefore, you have the angle that the pendulum makes with the vertical when it is inclined or according to this derivation you will have O P by P Q; once you have this another thing you need is the weight that is moved - this small w; so, what you do is you take a known weight…actually the weighing which is done is - there are weights, you have seen in a measuring you put weights on right side and the material on the left side like that you do - so those weights are there like 50 grams, 100 grams, 150 grams, so inclining experiment is done in this way - first you hang this bob, you put a 50 grams on left side and this 50 grams is slowly moved to right side and you find the inclining - you find O P by P Q, you find small w and you should know the distance through which you are moving that small mass and you should know the weight of the ship, of course, that is important.

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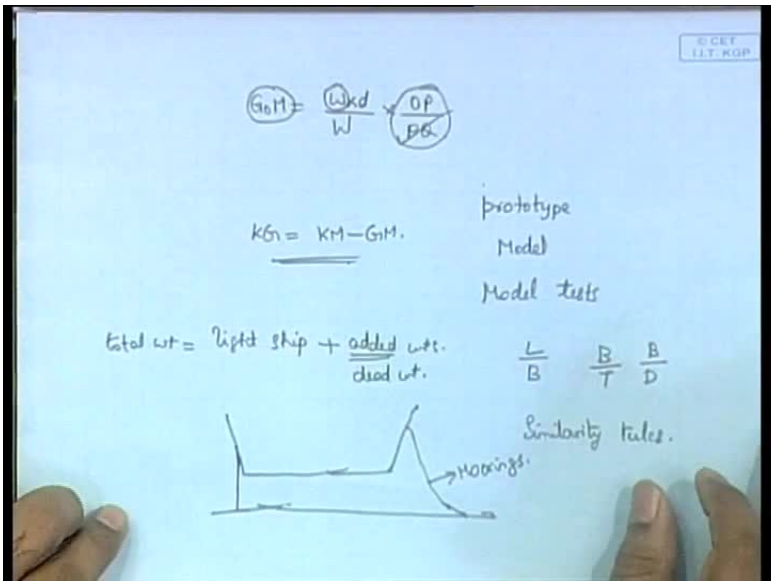

Once you have those things you will get G 0 M; it is not usually done for one mass you will do it like this 50 grams, 100 grams, 150 grams you do a lot and you take an average, so that you will get a fairly rough value of GM and you will get G 0 M properly; once you get G… this is the inclining experiment and this is the purpose of the inclining experiment - to get G 0 M, but the real goal is to finally find KG which comes from KM minus GM - this formula.

Now, KM is not calculated using inclining experiment that is calculated using something else and you use GM from here to calculate KG; this is the inclining experiment and it is a very famous experiment and again as I said people are likely to ask you this in - what is inclining experiment, you are supposed to know this; that name is very important - inclining experiment, that or inclining test - that name is very important.

One more important point here is that when you are doing this inclining experiment you are actually finding the KG of light ship - it means that when you keep adding weights for example in the real ship without oil, let us say if it is an oil tanker, without any oil without any oil, without any ballast water anything - without that is just the light ship weight - I think I have mentioned to you what is light ship weight; it is called a light ship, plus you have added weights, this gives you the total weight and the word used for this added weight is actually dead weight.

You have a light weight of the ship and dead weight - dead weight is the material that you have added and you get the total weight after that, as the summation of these two; this inclining experiment is an experiment done for light ship, so you do not have anything else on it.

This is the light ship weight; these are some of the conditions - that is, the vessel should be in a light condition, so there is no weight on it and next point is that…again this word you probably known know - you can have moorings there the meaning of the word moorings is - suppose, you have a ship like this, suppose it is connected…let say, this is the sea bed, if you connected like this you know in some cases you do that.

For example, some ships you do not want to move you connect it through moorings, the word for this is moorings (Refer Slide Time: 15.55); the other condition for that is, you do not have moorings in this - the ship is in a free condition, nothing else…it is very important when you are doing this experiment you should not have waves and all that that, because it is very important - if you have waves your results…it will incline much more than what this predicts.

It should be a absolutely calm water like you have in your towing tank, do not move anything - no ship should be moving, there nobody should be moving there; this model is put in exactly still water and then you hang the weight, you move this small weight, you see the inclining, you measure this, you know this distance through which the weight has moved and you get GM.

This is an important condition - that there should be no waves, which implies that there should no wind, there should be no current - you know the water current should not be there, there should be no wind then…these are the different points.

All right, now let us do a problem that will explain this. You are told that an inclining experiment is carried out on a vessel completing fitting out - fitting out means it is being constructed, fitting is part of it - the final part of it, fitting, is being done and you are doing the inclining experiment.

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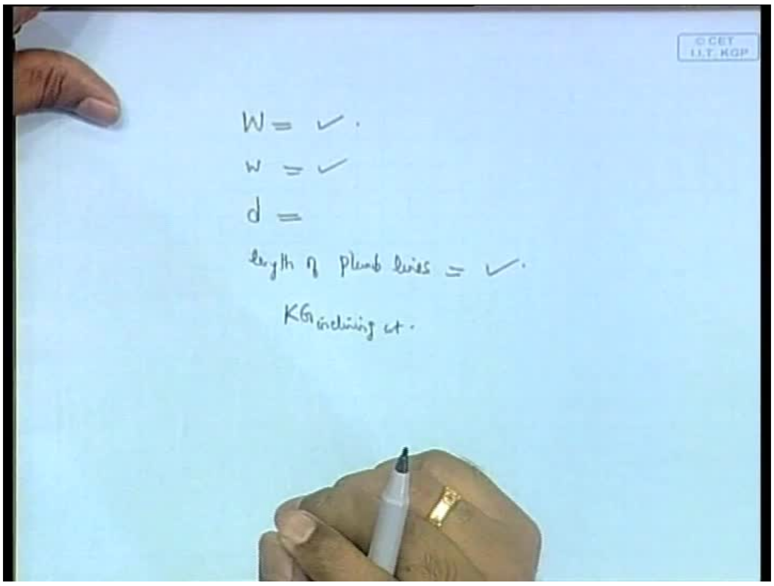

You are given the following data: you are given the displacement of the ship which is your capital W, you are given the displacement, then you are given small w the mass of the inclining weight, then you are given small d - the distance through which that small mass is translated, then you are told just write this the meaning of this is…length of plumb lines means the length of the pendulum - plumb line, that indicates the pendulum that is being hung there, that is given.

To be exact you need to have one more thing, which this problem does; you are given KG of the inclining weight, which means what exactly is it? This means that when you are doing this KG, for instance…I explained this…when you are doing this KG you will actually be including the KG of this weight that is translated.

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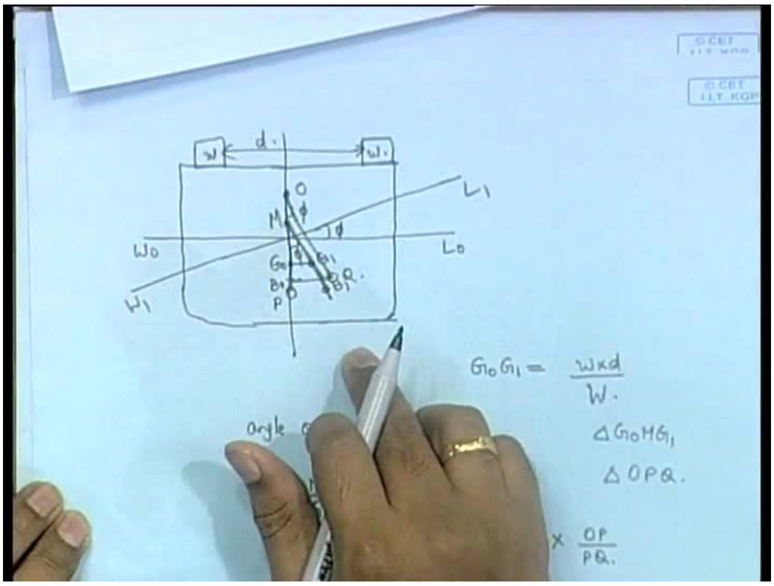

If you want to remove that weight and find just the weight of the light ship, which is what really the KG, which is really the GM that we should be giving as the result of inclining test; you need to subtract another KG, that is, a KG of that inclining weight alone or that shifting weight alone.

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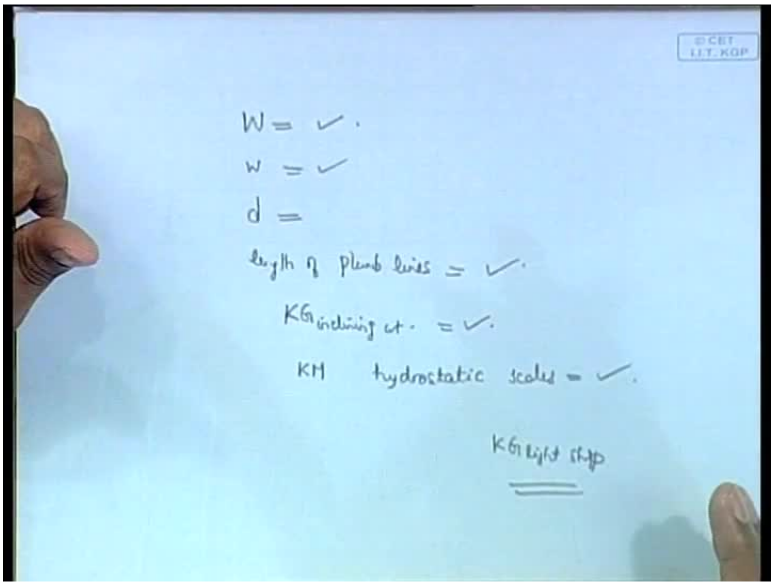

KG of that inclining weight is not the hanging weight, it does not matter how much weight you hang; inclining weight means the weight that is shifted. Inclining weight - you are given the KG of the inclining weight - and from… KM is given, otherwise you cannot do KG - you cannot get KG; KM is got from hydrostatics scales, I will explain later what it is, probably in the next lecture we will be stating with hydrostatic curves.

KM from the hydrostatic scales - you will get it as something, that is also given; this is the data given. Based on this you are asked to find KG of the light ship; in fact, this will be how your problem will be set up - this is what you are supposed to do in an inclining test.

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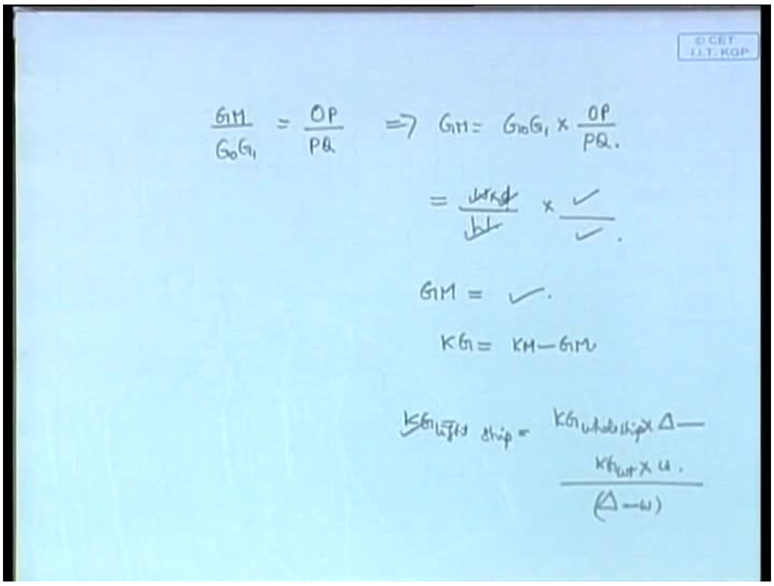

Once you have this let us write the formulas - you know that GM divided by G 0 G 1 is equal we have given it… O P by P Q which is equal to implies G M is equal to G 0 G 1 into O P by P Q that is equal to w into d divided by capital W into O P by P Q; now, O P by P Q you can find; you are given these two things - I did not write this actually - there is one more data given, it is the mean deflection of the plumb lines.

What do we need to do? What is O P by P Q? O P is the height of the pendulum, which is the length of the plumb line - that you will put here, divided by P Q - the defection of the pendulum, which is the called as deflection of the plumb lines they have written, so that you put here; you are given w which is the weight of the inclining mass, this is the distance through which the inclining mass is translated and this is the displacement of ship.

Once you have these things you will you will get GM - you get GM from this; you get KG as using KM minus GM; what we could do is…in reality the thing is this small w is so much smaller than the displacement of ship that it really does not matter - there is no difference in the KG of the ship; the weight of this whole ship might be let us say 5 kilograms - the model I am saying, the whole ship will be in many tons, that is different; let us say, this itself causes…weight of it is probably 5 kilograms we are adding some 50 grams it makes no difference really to find out the KG, but to be accurate in this we will do this.

You have the whole ship with the KG of this; you have a small weight with the KG of that; what will be the light ship weight? It is this concept. It is the final KG, it will be minus KG of that small weight into the weight of that small mass divided by the total; that will give you the no it should actually be delta minus w correct, it should be delta minus w, so it is the weight of this so this will give you the light ship weight; this will give you the light ship KG.

It does not matter even if you do not do this, but this is how you calculate the KG of the vessel - light ship; this is the problem. Here, there is another small problem, this also you will do just to indicate one point - that is, the problem is very similar yeah u where is u.

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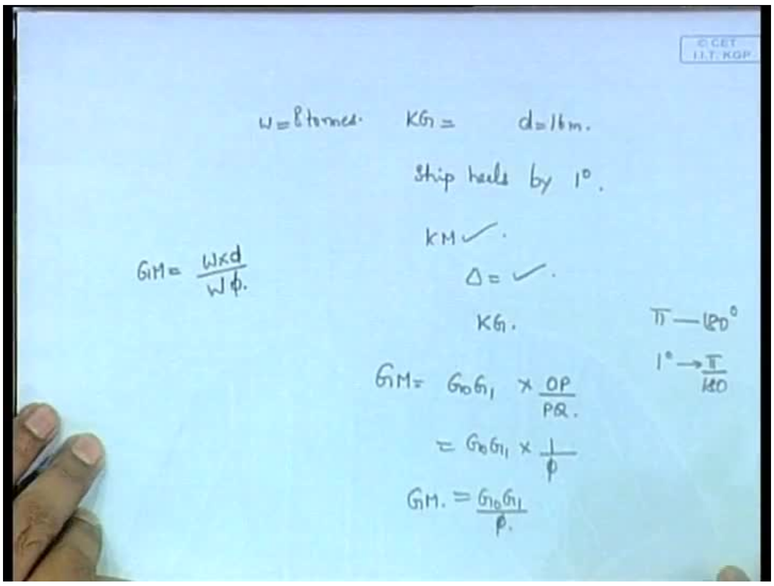

The problem says this: you are told that some weight or timber is moved from - something weighing 8 tons is moved from…8 tons with some KG; so this is the weight that is moved and it has a KG of something; it is moved a distance of 16 meters to one side of the ship or moved from one side of the ship to another and as the result of it the ship heels by 1 degree; the weight of 8 tons is moved from one side of the ship to another side of the ship - you are given some details of that weight, KG of that weight and the distance through which it is moved is given.

Because of this, the ship heels by an angle of 1 degree - inclines the vessel by 1 degree; KM is given and you are given the total displacement of the ship, then you are ask to find KG of the vessel.

How do you find GM? In this case, let us use the same formula: G 0 G 1 into O P by P Q; note one thing, what we are having is actually O P by P Q - what is it? It is actually tan phi cot phi; we can assume tan phi - this is very small angle, 1 degree is very small angle, so tan phi is like phi, cot phi is also like phi 1 by phi so it is like 1 by phi so this become; you can assume this to be G 0 G 1 into 1 by phi; the only thing…what is phi? phi is given, it is inclined by 1 degree - so 1 degree is your phi, of course, you have to change into radians - you have to remember that and that is pi radians is equal to 180 degrees; 1 degree is equal to pi by 180 radians.

This you have to do - you have to convert it to radians, that is all; G 0 G 1 by phi, GM, you have GM equals w d by W phi, that is all; it is just written in a different format that means instead of giving the length of the pendulum and the deflection of the pendulum you are given this divided by this completely - this angle itself is given. y z is same; it is because if the ship is heeled through phi the pendulum will hang always vertical, so that angle will be the exactly phi only.

Because, if this is heel through phi, this will be phi - from the vertical this will also be phi - as you can see from this figure (Refer Slide Time: 26:44); this is heeled through phi, now this is the center, let us say the pendulum is hanged here; it is hanging like this initially and now it is hanging like this; this and this will be phi - so, if this is phi this will be phi and once you have phi you just have tan phi is equal to the length through which the pendulum has deflected - not the length of the pendulum, it is the deflection of the pendulum divided by the length of the pendulum. This slightly different just to know how to do it.

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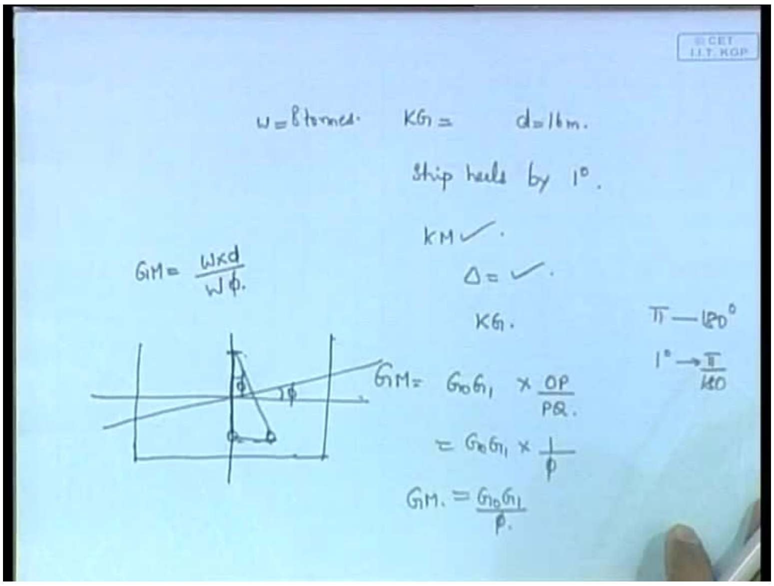

Next one - a very small point, but just note this - the implication of this I will tell you; suppose you have a ship in a condition upright condition and something causes it to roll - roll means it is a dynamic condition, is just keeps going like this; you can do one thing, you can actually consider the ship to be moving in a simple harmonic motion and you know just like a pendulum oscillating you can assume this oscillates like this and you can get an expression for the time period of this roll.

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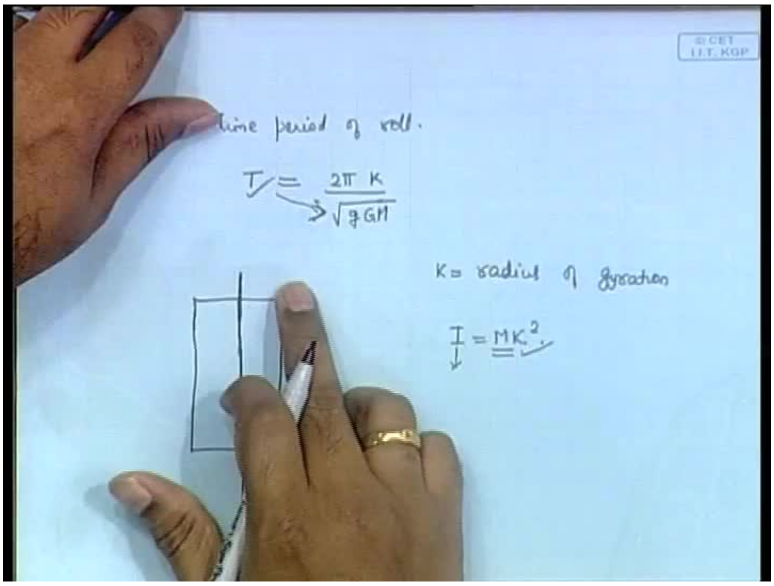

You will see that the time period of roll is…just remember this formula - we are not deriving it, so just remember this - the time period of this role will become 2 pi into k by root… that k is known as… I think you will know this - the word is radius of gyration; radius of gyration is defined as I is equal to MK square, you would have done this - this is known as the radius of gyration of the ship; 'I', remember, is the moment of inertia of the water plane area about the longitudinal axis - I keep repeating this because it is very important - if you say this is the length of the ship, you are talking about I about this longitudinal axis, this axis, about this axis, this longitudinal moment of inertia - this is the moment of inertia about the longitudinal axis and of the water plane area; this is I.

This is given by m is the mass of the ship into k square, that will give you the radius of gyration of that ship for that particular water line; you get k and once you have k you substitute here you will get T is equal to 2 pi k by this thing; from our definitions of stability, from our derivations of stability so far, I have said many times that GM should be as large as possible, right? I said that GM should be, of course, the minimum condition is that GM should be greater than 0; the more you have the more stable it becomes, that is the general law that - is the general principle.

So, you might think the best thing is obviously to keep on increasing GM by some way; for example, you can move weights to the bottom all the weights you keep pushing to the bottom of the ship and everything - top part - remains empty, relatively empty, and you will get G at the very bottom; G of the ship will come down because all the weights are shifted down. If that happens, is that good or bad? Just look at this equation, this expression for time period - this says that if GM increases very high time period keeps decreasing, right?

It is inversely propositional to root GM; therefore, if you keep increasing GM the time period keeps reducing, what does it mean? If the time period is reducing, it is moving like this; if you keep increasing the time period it will move like this, you probably might not feel it because it is very slow; but, if it is very high time period it moves like this - rapidly; it is obviously very uncomfortable, of course, it is just a matter of comfort only it does not matter; it does not capsize or anything, but it will just keep moving like this and you are not comfortable on the ship; that is why that sea sickness and all that comes.

From this we see that you really cannot increase GM very high, but of course you cannot reduce GM either so somewhere they drew an optimization - somewhere, that optimum value is there where this is also okay and stability is also okay.

This is actually… another question they keep asking in the interviews - first thing they will ask is what is the condition for stability and how do you design the ship so that the ship is very stable? The answer is GM should be made as high has possible, that is the condition; then, the question is - can you keep increasing the GM to any value? Let us suppose you increase the GM to the depth of the ship almost or even greater than that - you keep increasing M outside and if G inside - can you keep doing that? Your answer is no.

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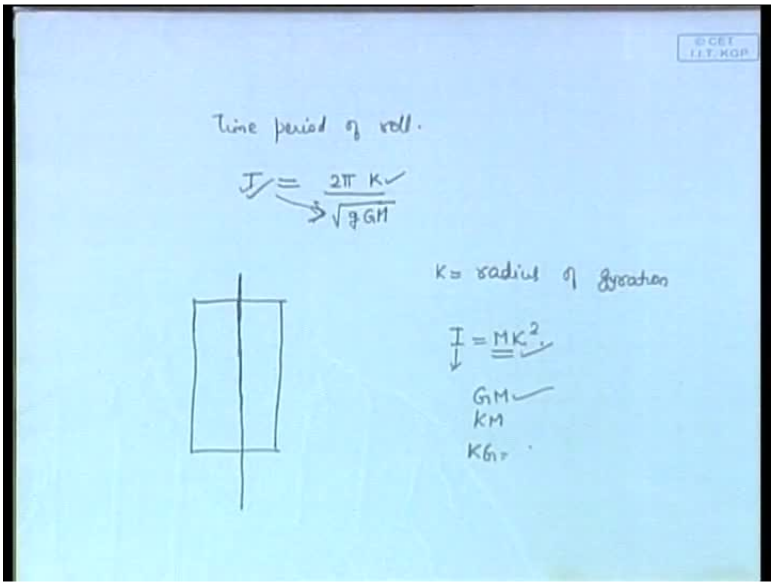

Because of this time period problem or this rolling problem you cannot keep increasing GM infinitely, but somewhere you keep you draw a line and you decide this is the optimum GM; I mentioned this that you cannot increase GM infinitely and this is the reason for it.

This is a straight forward problem: you are asked to find the GM of a vessel or KG of a vessel provided - you are given all these factors - radius of gyration, you are given the time period that is all and once you have that you can find the GM of the vessel and from GM you use KM and…first you get GM from the time period - these are all straight forward problems you can very easily solve - KG you get it as from these two.Then the next one I think you can do this also very easily now there is one more problem here I think this is all right;

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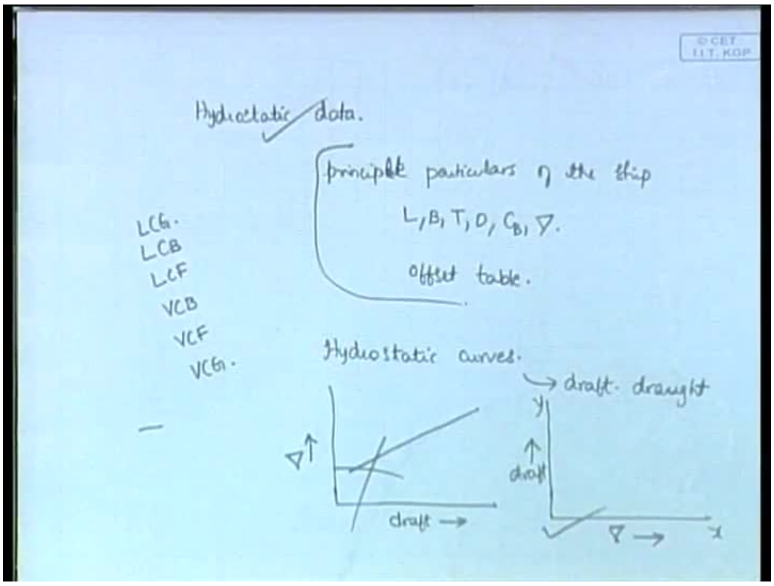

Going into the next section, actually that is known as the hydrostatic…we are going to hydrostatic curves - what are known as hydrostatic curves. You are a little ahead of time so; what do we mean by hydrostatic curves? First of all, let us define a couple of conditions - what do we mean by hydrostatic data, first of all? Now, hydrostatic data… primarily you need the principle particulars of the ship so these terms as we use should be clear - is a principle particulars of the ship - first of all you should be given the principle particulars of the ship this includes the length, breadth, depth, draft, C B and displacement; this includes the principle particulars of the…sometimes not the depth but draft depth, then C B and displacement.

This roughly represents your principle particulars; these are the basic things you need to… at least have some…make some design of the ship - you cannot design accurately using this, but there are software like max there - it is there in the department; you can just give this particulars and it will generate a very smooth hull of the ship; nowadays nobody does it by hand everybody does it in software only; in fact, given this hull particulars, known as principle particulars, you will get the hull of the ship.

Hydrostatic data includes one other thing - I have already shown you some time back, we call it is as the offset table - if you remember, I mentioned what is offset table - you have water lines, stations and you have the half breadths - half ordinates, something like this (Refer Slide Time: 35:45); you have the stations here, you have the water lines here and you will have the half ordinates - that is known as half set table. This whole thing together we call as the hydrostatic data; of course, once you have the offset table, then it is a very simple task to really design the ship - it is very straightforward; from this hydrostatic data we develop what are known as hydrostatic curves.

It is actually a plot of these; different kinds of graphs that indicate variations of hydrostatic - different hydrostatic - data, mostly with draft; that is, that also…by the way this is the same - these two are the same things, so you will see it written in both ways - that is a same thing.

Now, you can usually draw it like this - it can be either way, you can have draft here we can see it in both ways and you will have some particular here and one possibility - very simple possibility - is del; you find out how much displacement is there below the waterline of that ship for that particular draft; you are given the draft is some 1 meter what is the volume below? That is the displacement.

Like this, you have some curve and as draft will increase del should increase; let us say you have some curve…this is one of the hydrostatic curves; now, we will develop four or five types of curves or you could… but, in general it is more common is like this; del is given like this and draft is always given in the y axis, so this is x and this is y; draft is mostly given in the y axis of convenience; draft is always like this right in a vertical direction; from looking at it you can very easily say what is the… this is one draft, it is 1 2 draft 2 meter 3 meter, so it is intuitively very easy to understand; you do this in our course let us do this we do not do this; we will just fellow that del and draft.

These are different types of hydrostatic curves; instead of del you will have different parameters we will see - you can have - I do not know if I mentioned it, L C B, L C F, V C B, V C F then of course L C G, V C G. Since I probably have not mentioned the meaning of these things - G is associated with center of gravity, B is associated with center of buoyancy and F is associated with the center of floatation; now, what do each of them mean? Gravity, of course, center of gravity you know it is the centroid of the weights or the mass, B is the centroid of the immersed volume - volume that is under -

what the centroid of that volume is - that is B, and F is actually…what is… that I probably have not mentioned.

If you have a water - if you have a ship to some particular draft on that draft you will have a water plane area, now the centroid of that water plane area way is known as the center of floatation. It is a very important term; others mostly everybody answers when you are asked, but this one most likely goes away - that is center of floatation is the centroid of the water plane area.

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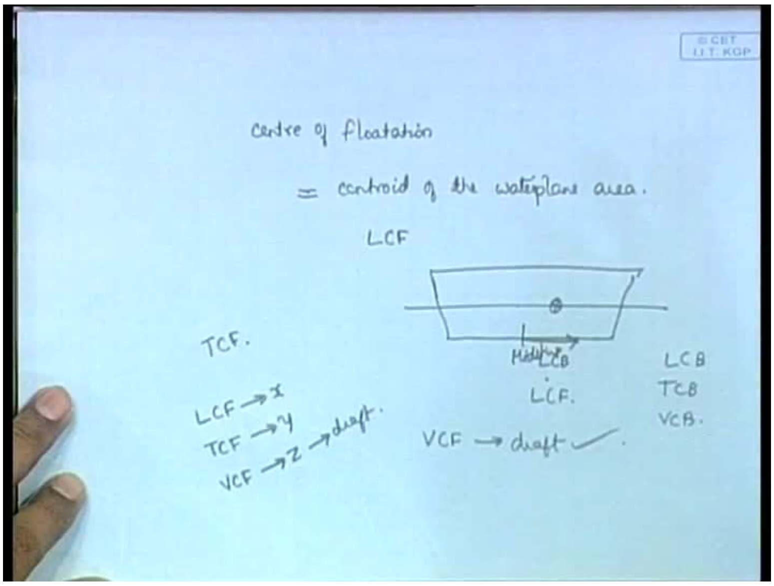

What will be the z? These things I will see… L C F means… longitudinal means like this (Refer Slide Time: 39:50); you know that this direction is called longitudinal - longitudinal means this length, this is known as the longitudinal center of buoyancy means the x coordinate of the center of buoyancy - most likely from midship; this is the midship, we call that as 0 usually; in some cases, you put the last station as 0 also we will come to that; let us call it from midship, so you have L C B is the longitudinal center of buoyancy, then you have…L C G will be the longitudinal center of gravity; again, this length x coordinate of the center of gravity, L C F will be the longitudinal center of floatation, which is the x coordinate of the center of floatation will be here - it will be on this line somewhere here somewhere it will be the centroid of this; it will always be on the draft - water line. Because, what is center floatation, again? Center of floatation is the centroid of that water plane area - water plane area is always on the water line, so center of floatation is always there; the vertical coordinate of the center of floatation will always be the draft.

Vertical center of floatation will always be equal to draft; we can easily see it if you know what is the center of floatation - it is the centroid of the water plane and you can also have of course…one more thing you can call it T C F transverse center of floatation - it is the distance of the center of floatation from the center line; if this is the ship, x coordinate of the center of floatation is the longitudinal center of floatation, y coordinate of the center floatation is the transverse center of floatation and the z coordinate of the center of floatation is the vertical center of floatation; so, you have L C F, T C F and V C F, so three things.

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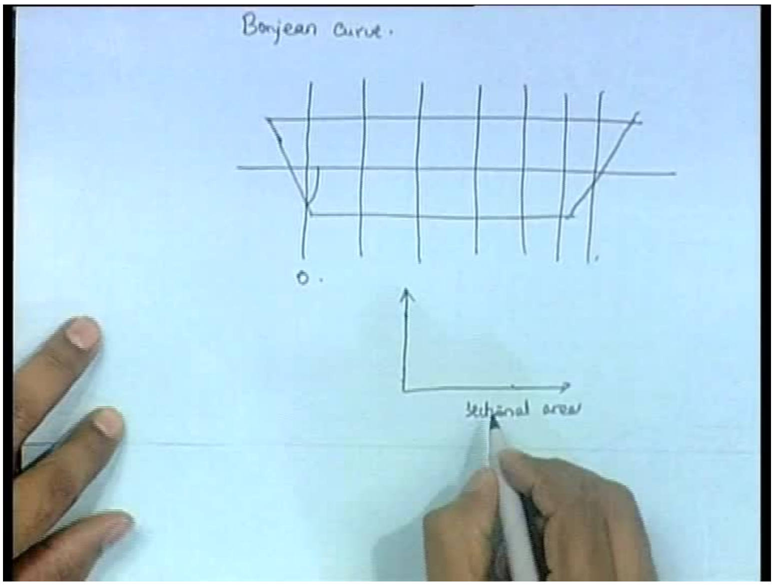

L C F is the x, T C F is your y and V C F is your z; this will always be your draft because it is the water plane area centroid and the centroid is always on that water plane. Similarly, you will have all these - L C B, T C B and V C B; same thing, longitudinal transverse and vertical; similarly, L C G, V C G and T C G - three things, all these things you have to know. Among these hydrostatic curves, one curve is slightly important and given a particular name its known as a Bonjean curve, this is one curve that is slightly important - it is very important for some calculation - it is known as the Bonjean curve. Bonjean curve means you have the you have a; let us suppose you have this ship and this water line, let us divide it into stations - this is divided into different stations and you take station 0 - let us take station 0 - and at station 0 suppose you find the sectional area like this - you have a sectional area there - sectional area up to the waterline, actually that is the meaning of sectional area I do not have to say about waterline; sectional area means…see it is like this - your ship is here at one station, any station…let us take the station 0, at station 0 this area up to the water line, not beyond the water line, up to the water line - that area is usually called the sectional area.

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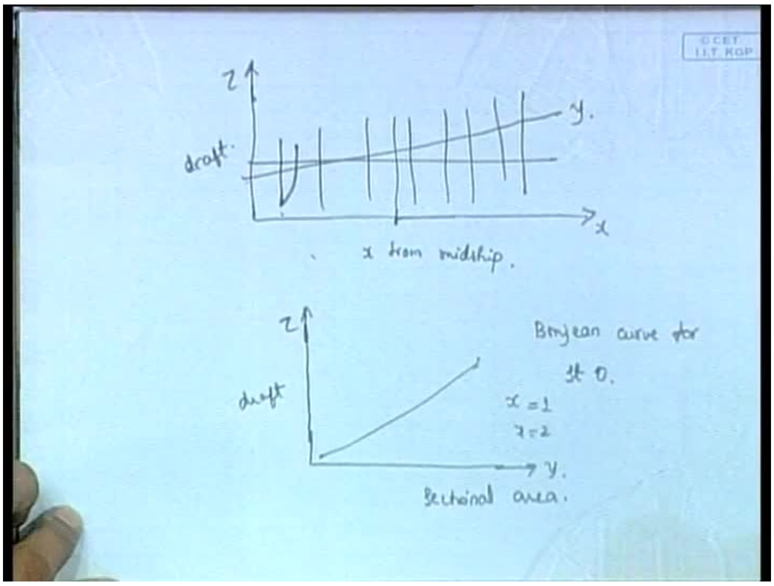

The shape will be like this and that area that whole area and that area is known as the sectional area; if you draw a curve - this curve, you draw like this actually it is a; it is not drawn like that, it is actually three-dimensional; it is like this, you will draw it in such a way… x from midship means this is all positive, this is the center of the ship so you will have stations here; this is your last station this is your last station means this is your first station this is your last station so you will have stations like this.

This is representing the length of your ship and here you will have a…it is a three-dimensional curve in which you will have a curve here which will give you the sectional area as a function of draft. Is it clear? It is not clear?

First of all there are three coordinates - this is representing x that is a length x from midship, this is representing draft and the third direction represents area - sectional area; what you are drawing here is…. at one particular draft, let us say, 1 meter - at that one draft let us take x 1 some value this is the first station; this represents the length; the ship is lying like this; these are different stations and this curve is representing that area up to that particular draft.

What you see is that if you draw a line here - let me draw a straight line like this; straight line means…it is a straight line between… let us call this direction - this is x, this is z and this is y; y is actually your sectional area; now, if you draw a line at a particular draft at…let us take one station, let us take this one station and at this station you draw a line at this particular draft; let us just draw the z y cross section and then it will be clear I think - z y cross section; what its showing…actually, it is like this - like the exact ship you have taken a cross section at one and you are drawing like this; for different values of z what will be the sectional area? If you have the ship of this height, if this is the draft and if the this is water line what will be the sectional area? It will be this area; if it is this what will be the area? It will be this area; If it is this, it this area.

With various drafts, you are getting the various values of areas, right? Initially, this much area, then this much area, then this much area - you are getting different values of areas, so those areas you plot; therefore, you get some curve, let us say, a curve like this; as the draft keeps increasing you get increased values of sectional areas; this is representing your draft - that is, increased values of sectional areas; therefore, you can do it in this fashion - you can draw a Bonjean curve for each station.

This is the Bonjean curve for station, let us say, 0; you will have such Bonjean curves for different stations 1 2 3 4 - like that, different stations will have different Bonjean curves depending upon the shape of the ship; depending upon the shape of the ship you will have different sectional areas as a function of draft or this relation between the draft and the sectional areas will be different at different stations; because, the ship is not exactly symmetrical from aft to forward; look people are looking confuse is it clear or should I repeated is it clear

This is what we call as a Bonjean curve; therefore, you will have Bonjean curves for different stations and if you put everything together - all the stations also together - it becomes a 3 dimensional graph between x draft and sectional areas and you can call that also a Bonjean curve; it is not a curve it is actually a three-dimensional curve.

When you are asked - Bonjean curve, you can say it is a curve either way so it is the curve it is; the important thing is that it is the curve between draft and the sectional area for different stations; you can say you have Bonjean curves for different stations, that is probably an easier way to visualize it.

That means, you have z y for different x (s); x equal to 1, x equal to 2 and x equal to 3 you have different Bonjean curves; this is the concept of Bonjean curves, now let us go into the derivation of hydrostatic data; one thing you can do is to find the displacement, no, suppose you are given one particular draft, now, you have the areas at different points you sum up the area into volume you get the draft - that is one possibility, in fact, that is one of the most important ones; moment of inertia - you do not need the sectional area, mainly it is to get the draft, that is probably the main application of this; so, you will get the - not draft, the volume displacement - that you get from sectional areas; in most of the derivations sectional area the volume becomes very important - that you can get from Bonjean curves.

One of the things is that, you once you make the full ship you take different sections and you plot it - that is the one of things to do; you will see different calculations can be done using different curves, like we will do now - we will do some calculations like moment of inertia, longitudinal moment of inertia, different kinds of moment of inertia and after that some mathematics - to deal with that you will use these different kinds of curves - hydrostatic curves - now, let us go to the mathematics of this.

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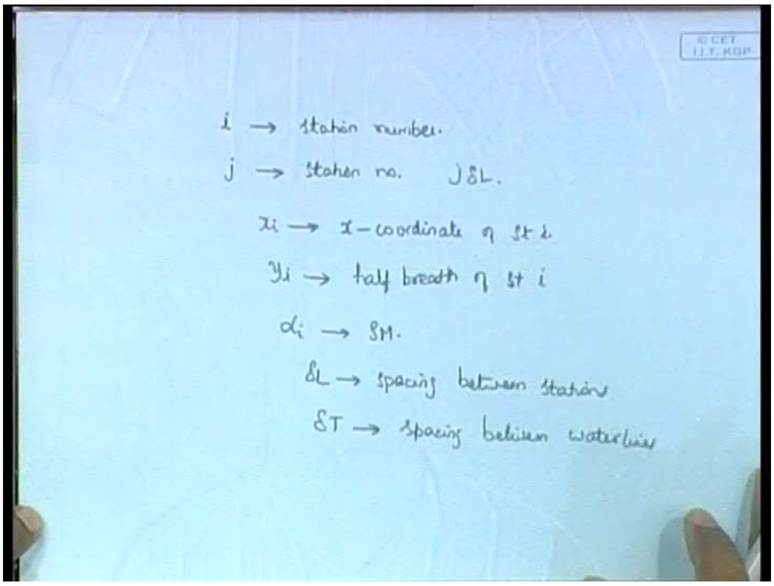

First of all, there are some notations we are going to follow in the next couple of derivations; first of all, I represents the station number, in some cases we use j also, I will tell you where it is used, which also represents station number such that the distance of that station from the 0 becomes j into delta L; let us suppose, that the distance between the two stations is delta L; therefore, the j th station is at a distance of delta L from origin - this is how we can use it sometimes.

Now, x i is the x coordinate of station I; y i is the half breadth of station I - it means at station i this distance - if this is the ship, this distance is y i; then, we use something called as alpha i for the Simpsons multiplier, most likely in this derivations they are using the trapezoidal rule so it is quite simple; then we use delta L for the spacing between the stations; similarly, we say delta T for spacing between different drafts, or spacing between water lines - let us use the correct terms.

We have different water lines and the distance between the water lines we call it as delta T - these are some of the notations we will be using in our following derivations, I am going to keep this away; you know, may be I will stop this class here and we can do this in the next class, thank you.