Computer Methods of Analysis of Offshore Structures
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Module – 02
Lecture – 23
Triceratops – 2 (Part – 2)

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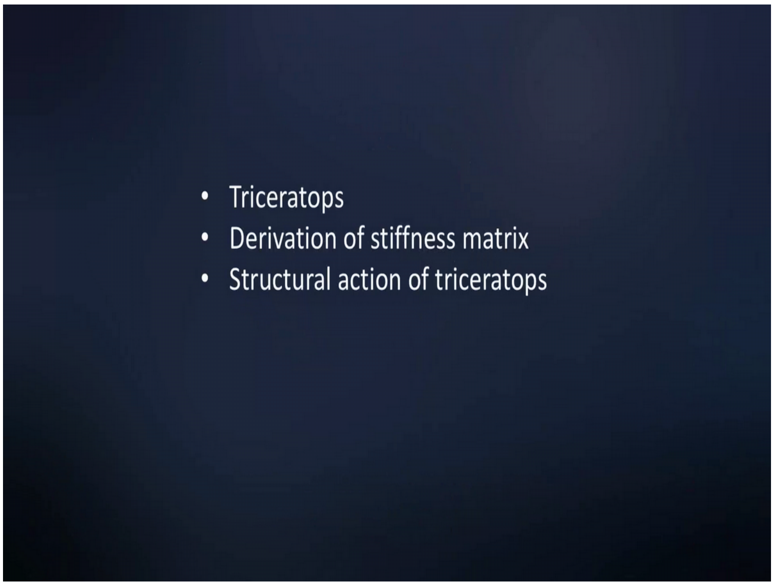

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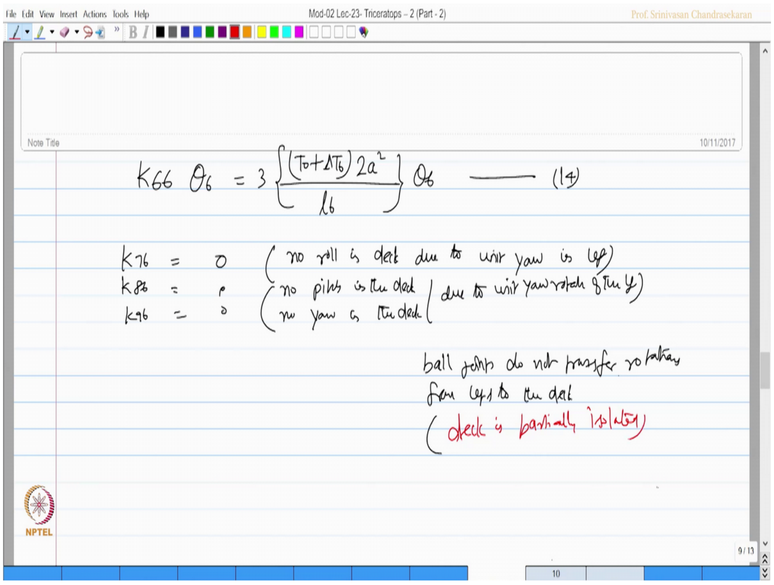

Let us try to find out what will be the value of K 66. Now K 6 is rotational degree of freedom. So, into theta 6 will be equal to T 0 plus delta T 6 of 2 a square by l 6, there are 3 such legs equation number 14. K 76 will be actually 0 because no roll in deck due to unit yaw in the leg. Similarly K 86 and K 96 will also be 0 due to no pitch and no yaw in the deck, due to unit yaw rotation of the leg. The answer is very simple this is because of a simple reason that ball joints do not transfer rotations from the legs to the deck. So, that is deck is partially isolated. Now let us try to go to the unit rotations in deck.

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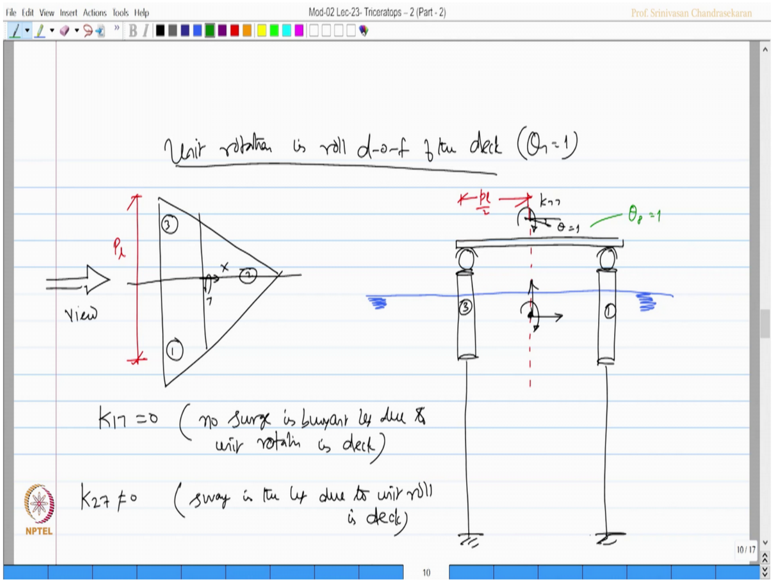

Let us say we want to now give unit rotation in roll degree of freedom of the deck that is theta 7. So, if I draw the figure say this is my deck position, supported by the ball joints the buoyant legs which are tethered to the sea bed. If I have the deck plan which is triangular which has got 2 legs on one side, and one on other side and if this is my c g if this my x axis this is the roll which I am looking at to look at this I must rotate it about x axis. So, let us view this from here this is a view direction if I call this as a leg 1 and leg 3 and leg 2; obviously, this will be leg 1 and this will be leg 3, and I will have to from this direction you see if this is my P l this will be P l by 2 this will be P l by 2 correct this is the centre.

So, let us mark the water line, c g will be somewhere let us say here. So, at the point on the deck we are giving unit rotation and I will be able to get K 77 right. So, we will be able to get 3 corresponding degrees, which we will mark as we derive them. Now let us understand very clearly that K 17 will be 0, that is no surge in buoyant leg due to unit rotation in deck please understand this because rotation is not transferred. Let us try to find out K 27 will not be equal to 0. So, K 27 will be sway in the legs unit roll in deck.

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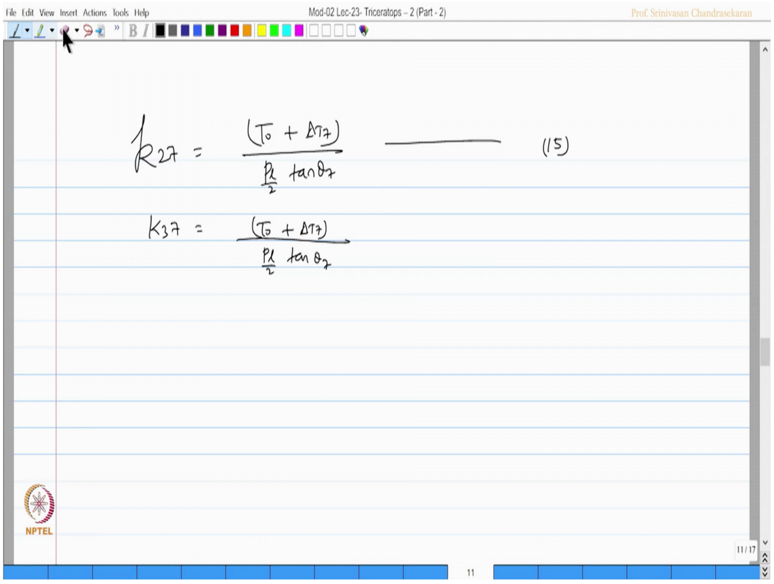

Which will be equal to T 0 plus delta T 7 that is a new tension divided by P l by 2 tan theta 7 that is equation number 15. K 3 7 will be T 0 plus delta T 7 by P l by 2 tan theta 7.

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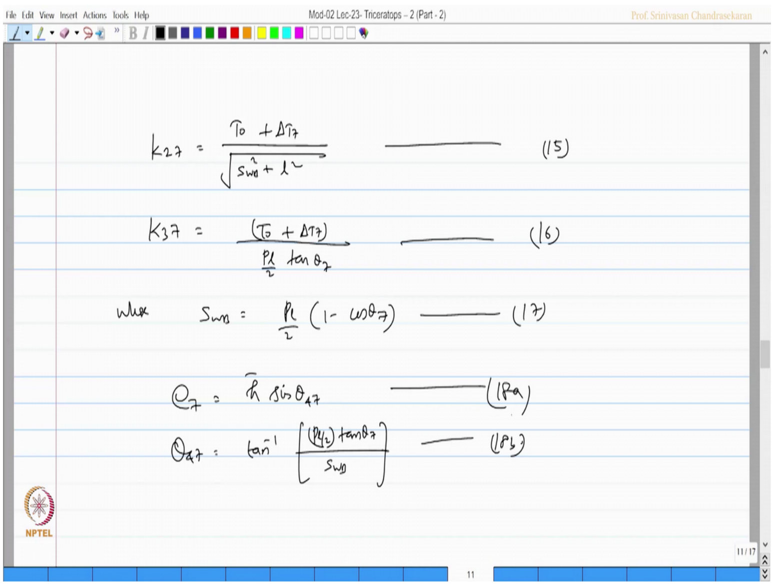

K 2 7 is T 0 plus delta T 7 by square root of S w B square plus l square, where S w B is actually P l by 2 1 minus cos theta 7.

So, e 7 eccentricity will be given by h bar sin theta 7 or let us call this as theta 4 7. So, theta 4 7 is actually tan inverse of P l by 2 tan theta 7 by S w B. It is very important to note that S w B given by the equation 17 depends on K 4 7 ok.

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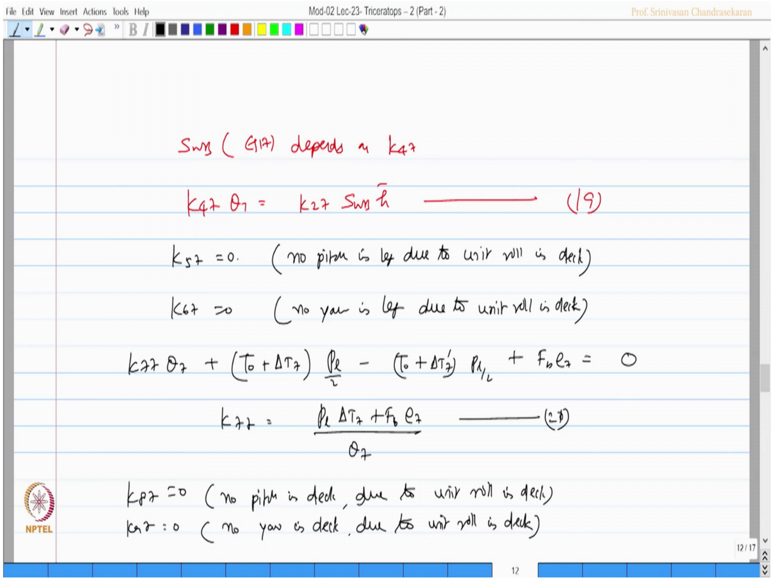

So, K 47 into theta 7 is actually K 27 into S w B into h bar equation number 19. K 57 will be 0 that is no pitch in leg due to unit roll in deck, K 67 will also be 0 because no yaw in legs due to unit roll in deck. K 77 can be computed by this equation which is equilibrium in the roll degree of freedom delta T 7 of P l by 2 minus T 0 plus delta T 7 of P l by 2 where we can say letter T 7 dash that is the tension in the father leg P l by 2 plus buoyancy into eccentricity this should be equal to 0 that is the equilibrium equation.

From this one can estimate K 77 as P l delta T 7 plus F b e 7 by theta 7. K 87 will be 0 that is no pitch in deck due to unit roll in deck, K 97 will also be 0 that is no yaw in deck due to unit roll in deck. So, we have worked out the seventh column of the stiffness matrix.

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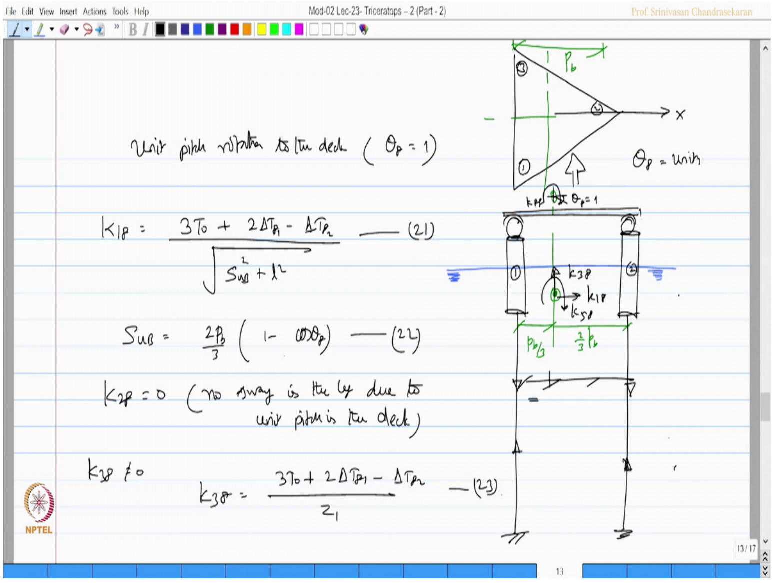

Let us give unit displacement or unit pitch rotation to the deck, that is let us give theta 8 as unity. So, the figure is similar to what we have here. So, we want to give unit rotation now. So, let us do that. So, we will be getting portion of the deck, which is connected by the legs these are the buoyant legs, which are connected to the sea bed by tethers let us mark the water line ok.

Let us draw the plan on the top. So, this is my x axis, I am now giving unit pitch that is theta 8 is unity. So, I must look at the system from this view. So, if this is like 1, this is like 3 and this is leg 2 this will be leg 1 and 3 this will be leg 2 and the c g will be here somewhere here. So, this distance is P b by 3 because this is P b and this is two- third P b let us now mark the degrees of freedom corresponding to the deck and to this these are the points where I am going to mark the degrees of freedom. So, this will be K 1 8 and of course, this is K 88 sorry this is K 58 and this is K 38 and we are giving unit rotation theta 8 therefore, this will be K 88 on the deck. So, K 18 will be 3 2 0, plus 2 delta T 8 minus delta T 8, but let us keep this as 1 and this as 2 that is the delta T is in different legs are going to be different because this legs are closer this legs are farther.

So, I had taken 2 different notations here to arrive at them divided by SuB square plus l square the root. So, let this equation be equation number 21, where SuB is given by 2 P b by 3, 1 minus cos theta 8. Now K 28 will be 0 that is no sway in the leg due to unit pitch in the deck rotate will not transferred. K 38 will not be equal to 0. So, K 38 is given by 3

T 0 plus 2 delta T 8 1 minus delta T 8 2 because one will be slacking and one will be on increase in tension divided by Z 1 equation 23.

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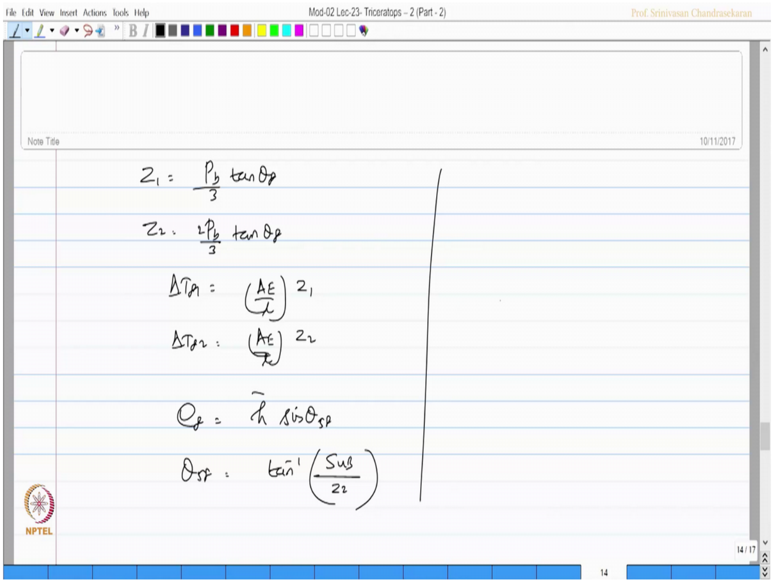

Where Z 1 is P b by 3 tan theta 8 and Z 2 is two- third P b half tan theta 8, delta T 8 1 the nearer leg will have A E by l of Z 1 and delta T 8 2 the farther leg will have A E by l of Z 2. So, now, eccentricity will be e 8 h bar sin theta 5 8 and theta 5 8 is given by tan inverse of SuB by Z 2.

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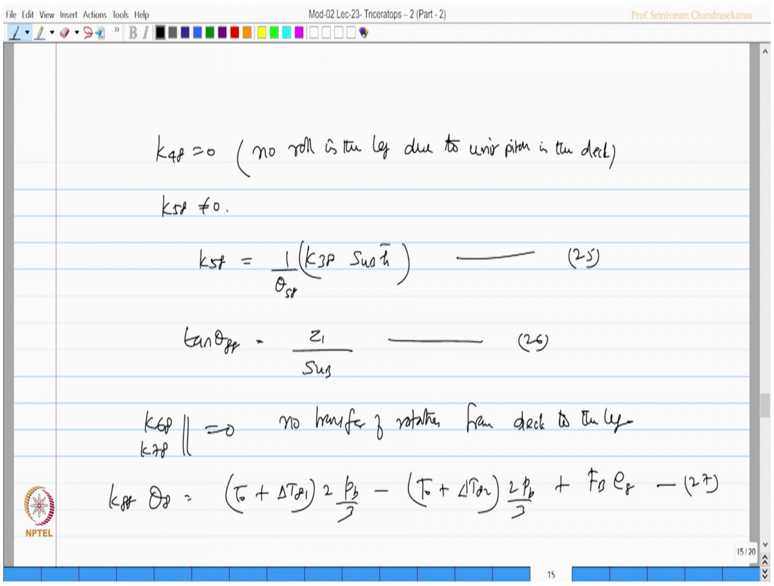

So, let us say equation number 24. Now K 4 8 will be 0 that is no roll in the leg due to unit pitch in the deck. K 5 8 will not be equal to 0 because there is a differential heave K 5 8 will be equal to K 3 8 SuB h bar by theta 5 8 equation number 25, where theta 8 8 is given by Z 1 by SuB equation 26. Now K 6 8 and K 7 8 will be 0 because no transfer of rotation from deck to the leg K 8 8 into theta 8 will be given by T 0 plus delta T 8 1 of 2 P b.

By 3 the closer legs minus T 0 plus delta T 8 2 of 2 P b by 3 plus f b into e 8 where e 8 is given by this equation.

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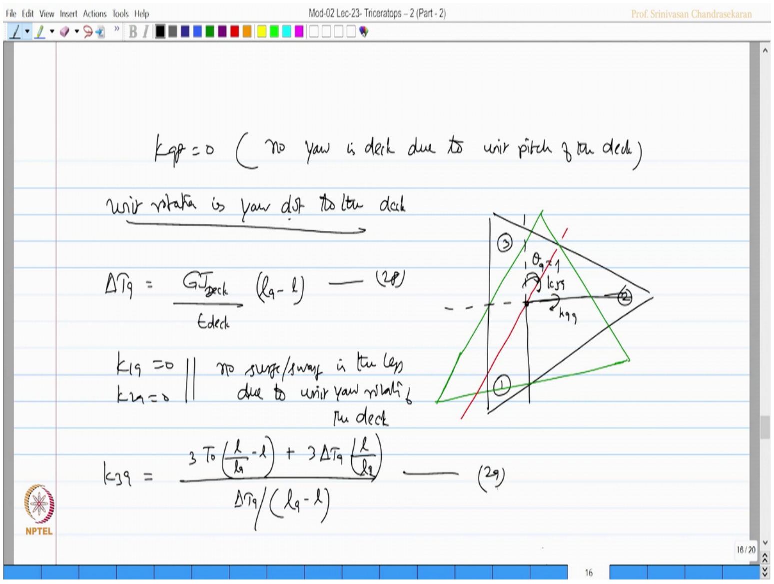

So, 27 K 98 will be 0 no yaw in the deck due to unit pitch of the deck. Lastly let us give unit rotation in yaw degree of freedom to the deck, let us say this is my original position leg 1, leg 3 and leg 2 we get a new position because let us mark the c g and give unit rotation about this point, let us say unit rotation about this point, let us say its rotated like this or let us slightly increase this line and let us mark it like this ok.

So, I get at the c g we have rotation theta 9 as unity, I get K 99 and I will also get K 5 9. So, change in tension delta T 9 is given by GJ of the deck by t of the deck into l 9 minus l equation number 28; where K one 9 will be 0 K 2 9 is also 0 because no surge and sway in the legs due to unit yaw rotation of the deck, because ball joint is not trans to the rotation K 39 will be T 0 change in length minus original length of 3 legs min plus 3 delta T 9 l by l 9 of delta T 9 l 9 minus l ok.

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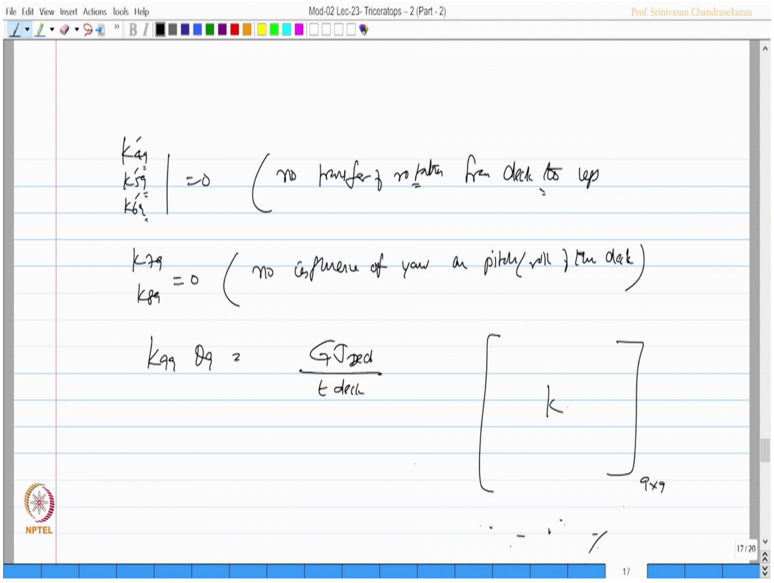

Equation number 29. K 49, K 59, K 69 all will be 0 because transfer of rotation from deck to legs because you know 9 is rotational degree of the deck and 4 5 and 6 are rotational degrees of the legs. K 79 and K 89 will also be 0 because no influence of yaw on pitch and roll of the deck they are independent, and K 99 theta 9 will be GJ of the deck by t of the deck.

So, by this logic we have derived the entire stiffness matrix 9 by 9 of the triceratops.

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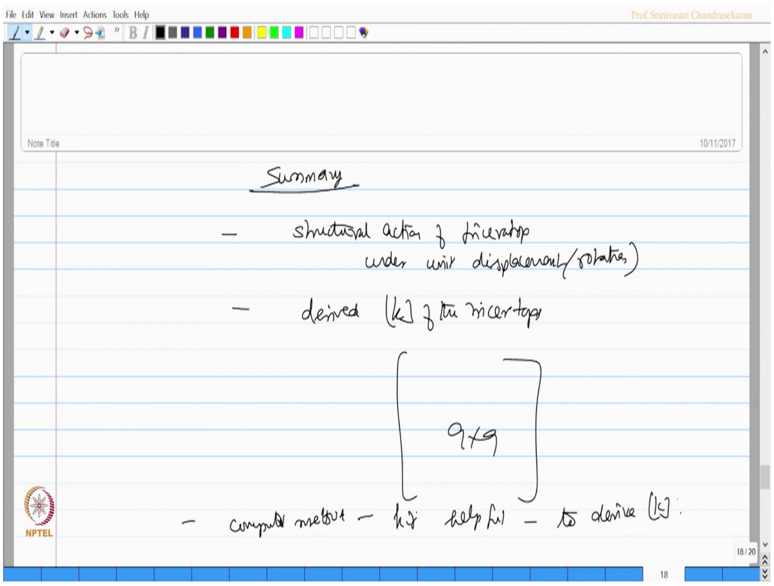

Let us look at the summary; friends, in the 2 lecture this lecture and the previous lecture we understood the structural action of triceratop under unit displacements and rotations. We derived the stiffness matrix of the triceratop we have stiffness matrix now which is 9 by 9 which we expected to derive from the beginning from first principles. So, the computer method of deriving stiffness matrix by knowing the coefficients k ij will be helpful to actually write a program to derive this matrices on first principles.

Thank you very much.