Aircraft Structure - 1
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Lecture-15
Space Structures (Contd.,)

Welcome back to aircraft structures one this is Professor Anup Ghosh from aerospace engineering IIT Kharagpur. We are in the third week's lectures this is lecture number 15 covering space structures.

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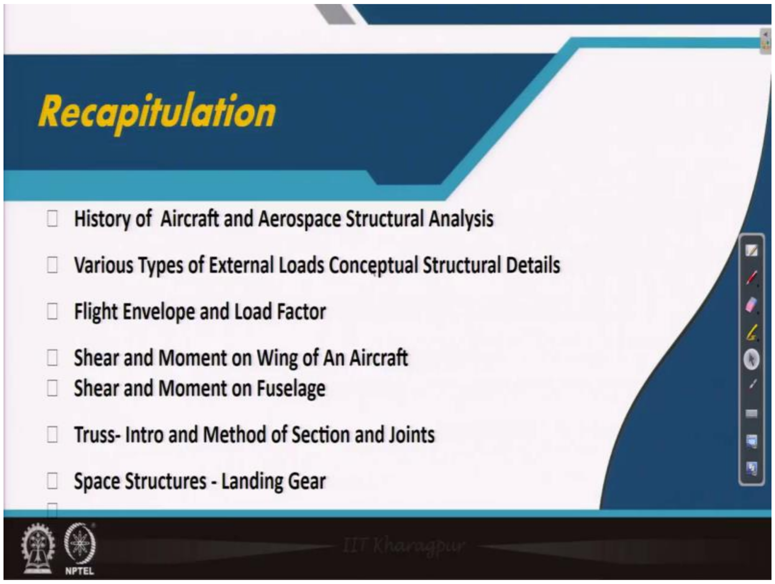

And we have solved problems related to space structures one landing gear problem has been solved in our last lecture. We will attempt one more to solve but before that this is simple recapitulation that is the reason in the last line you see the mention of a landing gear problem. Other things it is better to keep in mind what we have learnt so far that is the reason I have put all the points in this way points are history of solid mechanics structural analysis and different types of aircrafts and then we went to the loads.

We have also learnt details of aircraft structures how thin wall structures are used and in we have learned the flight envelope. We have learned the load factor, how load factor varies at different situations, limit load, ultimate load all those things we have learnt shear and moment on wing we have learnt. How it comes, how do we need to calculate those from the external loads as well as on the fuselage?

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So, with that introduction and recapitulation let us go for today's problem solving we will get introduced more in the space structures.

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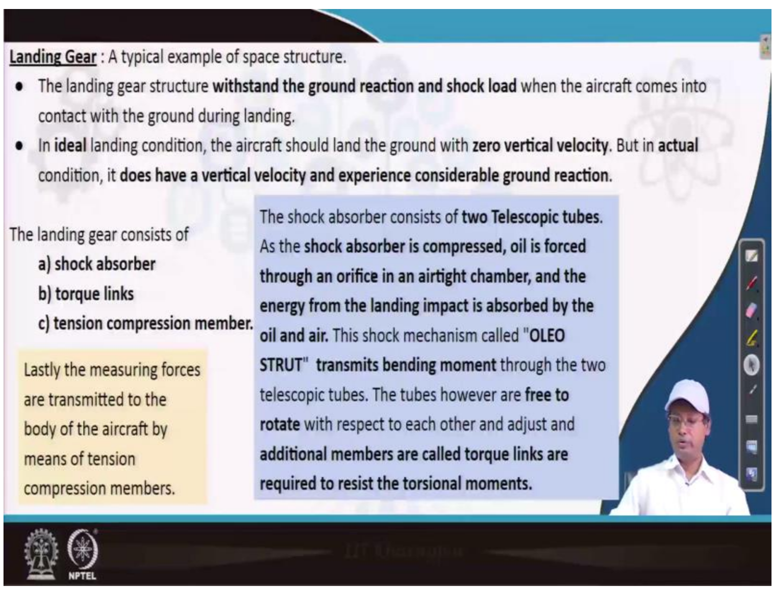

So, before we continue further it is time to introduce the landing gear in a proper way. So, what we have done here is that what are the key components of landing gear and how do those things act that has been describes let us see. Landing gear a typical example of space structure, the landing gear structure withstands the ground reaction and shock load when the aircraft's come into contact with the ground during landing.

In ideal landing condition the aircraft should land the ground with zero vertical velocity but the actual condition it does have a vertical velocity and experience considerable ground reaction. So, this is the reason we need to need to design the landing gear properly. So, that it withstands the ground impact and it facilitates the landing in all aspects. Landing gear consists of basically three parts we say that shock absorber, torque links, tension compression member.

Here is a brief description of the members let us have a look. The shock absorber consists of two telescopic tubes as the shock observer is called compressed, oil is forced through an orifice in an art airtight chamber and the energy from the landing impact is absorbed by the oil and air. This shock mechanism is called olio strut transmits bending moments through the two telescopic tubes. The tubes however are free to rotate with respect to each other and add just the additional members.

It is free to rotate with respect to each other and adjust and additional members are called torque links are required to resist the torsional moments. So, this is all about the oleo strut member if I give you a one modern-day example is available in all motorbikes almost so those are the oleo strut member. And then this as it is mentioned using those tubes it carries the bending moment but since the tubes rotate on one on the other it is not able to resist the torque but we need to resist the torque that is the reason we need to put the additional torque links.

Lastly the measuring forces are transmitted to the body of the aircraft by means of tension compression members. So, there are tension compression members in addition to that we will see with the example how it is carried out. In our example we will not come consider that the oleo strut member is under bending will only try to find out loads at the ends of the members.

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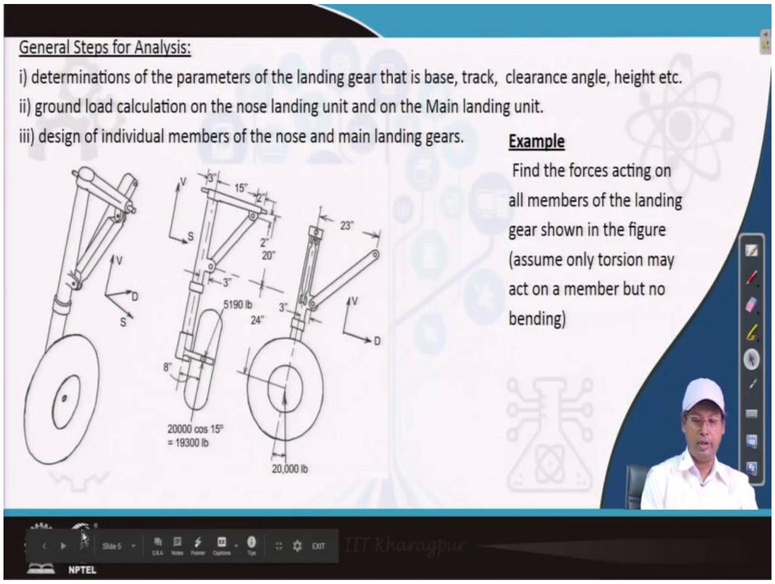

This is the example we will understand, this is the figure this is the oleo strut rod. So, it has to withstand these are the two force members this is a two force member, this is a two force member you please look at the there is a projection from here to here where the wheel is attached please observe the coordinate system this is the drag direction and this is the vertical direction this is the side direction.

So that is the reason here it is shown that VS plane that means if you if you look from this angle this is the view that is the reason we see this projected one and if you look from this side we have this view that is on the VD plane this is the VD plane on that VD plane we have this look. Please keep it in mind the dimensions because all the dimensions are not mentioned in the other diagrams I have tried my best to keep associated with these figures show that dimensions you see.

Some important points let me hear that this hinge point is below the top level this is the top level if we see. This point has a distance of three inch from the center line of the oleo strut. This is also at three inch apart so please note these two points this level as it is mentioned is here and this is also that level. So, please keep it in mind these levels, so other things if we see the general description, general steps for analysis determination of the parameters of the landing gear that is this track clearance angle height etcetera.

Ground load calculation on the nose landing unit and on the main landing unit design of individual members of the nose and main landing, yes this is about overall landing gear analysis. The example what we will be solving is find the forces acting on all members of the way landing here shown in the figure assume only torsion may act on a member but no bending. So, with that consideration we will try to find out let us see how the problem has been considered.

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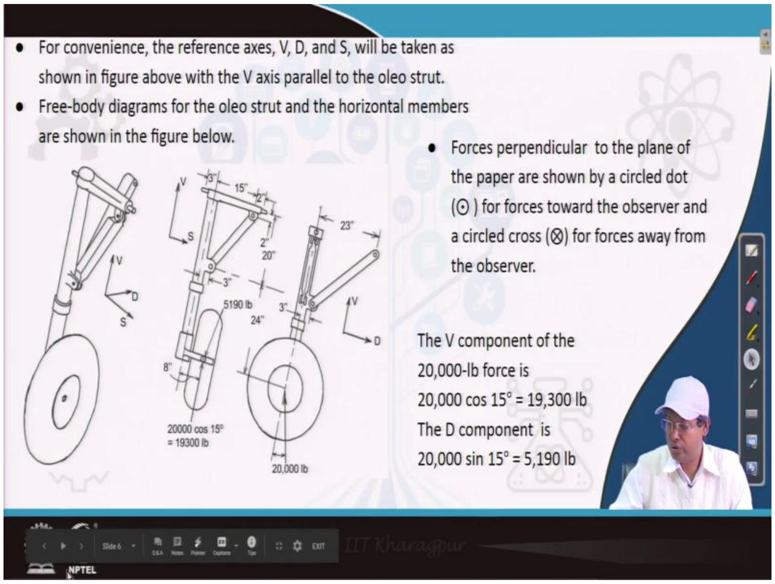

Some more preliminary understanding we need to follow otherwise it will be difficult to understand the problem properly for convenience the reference axis VD and S will be taken as shown in figure above with the V axis parallel to the oleo strut. Free body diagram of oleo strut and the horizontal members are shown in the figure below. This is in the next slide that figure is there this figure is not exactly the free body diagram.

Free body diagrams will come in the next slides this is again repeated for understanding of other features. Force perpendiculars to the plane of the paper are shown by a circular dot or a cross for a force towards the observer is the dot that means this force is towards me. If we look at in this diagram this force is actually acting this way that is the reason it is towards me. And this component this component is nothing but this component.

So, those two components are found out this please keep it in mind these are not very precise calculation these values are approximated to these values so that the calculation becomes easy.

But principle is only to find the sine and cos component of that particular angle 15 degree this angle is 15 degree. So, with that understanding we can easily resolve the forces from the tire to the landing gear. The V component of 20000 pound force is 20000 side not 20000 cos 15 degree is 19300 pound and V component is 5190 pound I repeat these are approximated to close rounded figure. So, that calculation becomes easy.

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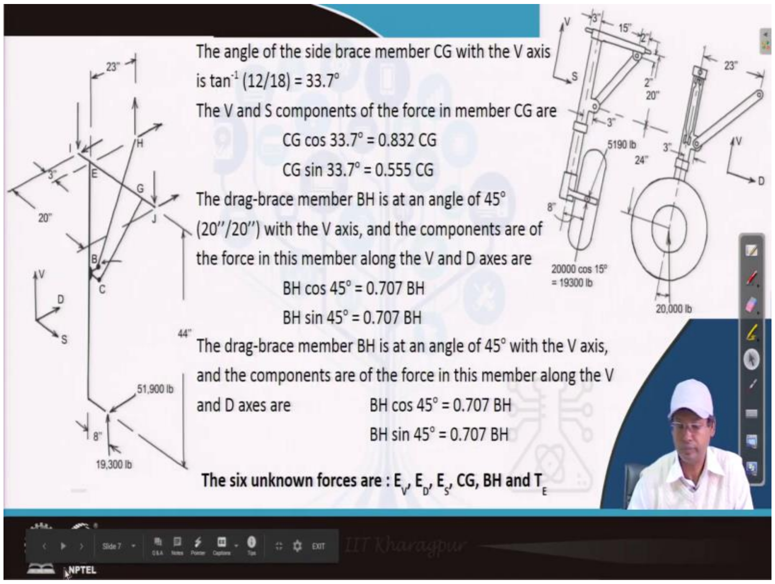

So the free body diagram what we are discussing is this free body diagram where we need to find out torsions at this point also this point is joined with this IG member this I J member. So, there will be torsion here torsional moments here that we need to find out and other force components are shown here. What are to act at this initially we will not consider this top member IJ we will consider the remaining portion this member as well as that means I want to say we will be considering this point as AE.

We will be considering CG will be considering EH for our analysis. And then we will find out the other forces will also find out here it is as mentioned that E_V, E_D, E_S also we need to find out along with the torsion T_E here. So, let us see this is what understanding we need to solve the problem let us see what is scripted here. The angle of the side brace member CG with the V axis is tan inverse 12 by 18, $\tan^{-1}(12/18)$. I think you can get from here this is the 18 and the 12 is coming from; this three is getting minus this is the 3 this is the angle.

So this is 12 this is 18 so from there we get the angle necessary angle to resolve the CG, CG is on that plane that this is the CG this plane view is put here and from there we get the components. The V and S components of the force in member CG our CG cos 33.7 degree it comes 0.832 of CG and CG the other component that is S component this is V component and this is S component.

So, the drag brace member BH is at an angle of 45 degree that is quite clear from here because you see why it is 45 as it is said this is 23 these two are at the same level this is this is 3. So, this is 23 - 3 is this is 20 and this is also 20 so that makes the angle 45 degree and accordingly we get that V and D. This is with respect to V this is with respect to D. The drag brace member BH is at an 45 degree angle V axis and the components are in force member along V and D axis are it is a kind of repetition by mistake. So, please ignore that part let us proceed to the next page.

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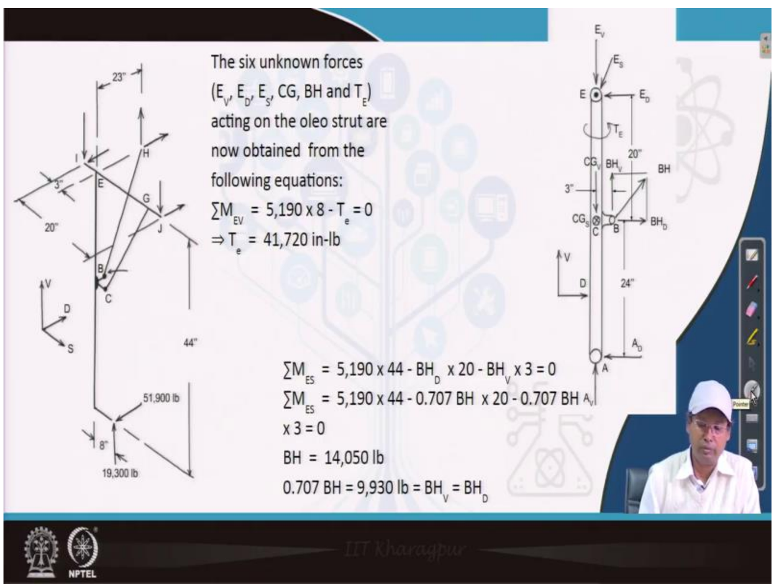

So we have found out in the last slide that components of the CG and the CG and BH in vertical and horizontal direction, horizontal in the side as well as in the drag direction let us see how do we proceed further to find out other forces. The 6 unknown forces E_V, E_D, E_S, CG, BH and T_E acting on the oleo strut are now obtained from the following equations to find out T_E what we can do we can consider a moment as it is mentioned here moment E_V that means in vertical direction E_V at through the point E in the vertical direction.

If we consider that what do we have we have component of this only because on this line if we consider the plane this way these two are acting in the same plane so then that would not have any torsion as well as the CG components which is acting this way and this way this way as well as this way where this one this way I think this is may be corrected this is acting this way. So these two are on the same plane so that that is the reason you do not have any component and what we have only component of this which is 8 inch apart from the line and that gives us the torsional moment acting at this point E.

If we proceed further this oleo strut member is again put here in a different view VD view is put here that means we are looking from this direction we are looking from this direction. So, as it is convention we have seen this is the force this is the force which is from me towards the board acting or acting on this particular point CG_S, CG_S is acting in that direction and other forces are shown. So, if we put it here that direction this is this way and this is this way this is CG_S.

So we are considering moment about M_{ES} about point is this, in the direction of S which is the direction of S here it is D that means direction of S is along this line along this line we are considering the moment. If we are considering moment along this line what will happen CG and CG_S and CG_v would not have any component on that moment equation. Even this and this will have some component our vertical force BH_V and BH_D will have component BH_V is apart say three inch apart this is the BH_V inch apart and BH_D which is 20 inch apart as it is mentioned in the previous diagram here also it is mentioned 20 inch so that is coming.

And the directions is as it is shown it is acting this way this is A_D in this direction this is definitely in the other direction about this point this way this is this way this is also this way so that is the reason these two are minus and this is plus is considered. So, if we if we write that with the components as we have done in the last slide what we get that BH value is 14050 pound and since we have the relation with the BH_V and BH_D those are equal and that value is 9930 pound.

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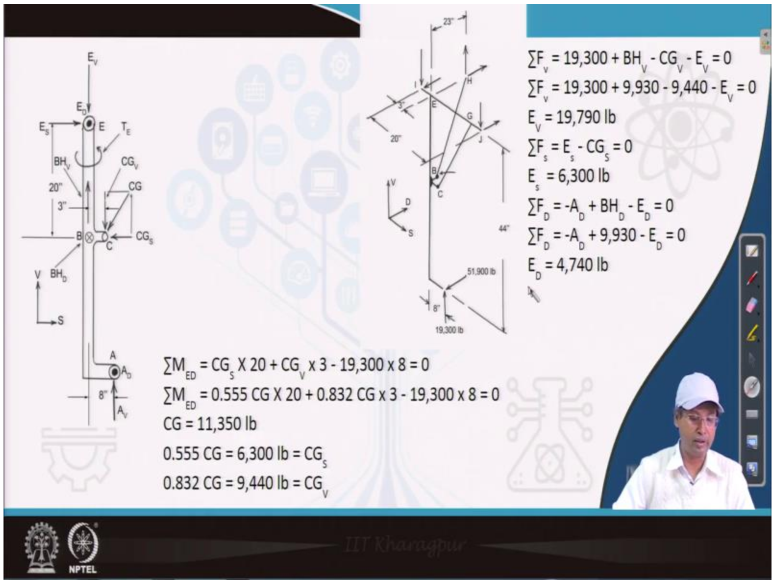

So we have come to the stage where we need to find out the other forces in the member CG in the last slide we have found out the member force of BH. In this slide before we go forward for any other thing it is better to correct a small mistake. This value is by mistake has one 0 has come extra. In all previous figures also you please consider that this value is 5190 pound. So, with that value we will continue and we will see how the other forces we get.

So with this slide will be concentrating to find out the member forces in the member CG_S as well as CG_D, CG_S and CG_V will become finding out that means vertical as well as the horizontal in the side direction forces we need to find out. To do that we are considering the free body diagram as it is shown here all the forces are acting as we have mentioned dot is something which is acting from the board towards B.

So the other force may must BH_V, BH_D already we have described those are not having any component here particularly because we are considering from the point E in the direction D from the point E in the direction D that is in this direction in this line we are considering the moment equation. So, if we are considering moment equation in that line what will be the components? Components will be from the vertical force 19300 pound which is 8 inch apart will have components from in this point as CG_S as well as CG_V it is that is also shown here.

CG_V is 3 inch apart if you look at the other drawings in previous case this is 3 inch distance from here to this point from the center line to this point, this is 3 inch, so that is that 3 inch comes here and the 20 inch as it is mentioned here is this is 20 inch oh here it is mentioned sorry these 3 inches already mentioned here. So, now about the direction see this A_V is about this about this point in this figure we are considering moment.

So this is rotating in this direction that means anti-clockwise direction. About this, this is rotating CG_S rotating in the class clockwise direction that is there is in CG_S is the opposite of sign than this vertical force and CG_V that is also in clockwise direction that is the reason these two are considered positive and this is considered negative. So, if you solve this algebraic equation what do we get that CG is equals to 11350 pound and the components as we have already found out from the angles that CG_S equals to 6300 pound and CG_V is equals to 9440 pound.

Now with the other forces let us see how do we find out we are considering the horizontal vertical that means horizontal two directions S and D and vertical one direction summation of forces will be considering and we will try to find out the forces acting at E that means E_V, E_S, E_D. So, how do we do this is from this figure if we look at summation of vertical direction forces we are to consider from vertical direction forces what are the components will come CG_V will come.

This is there CG_V is coming here one more will come here this is $BH_V$and this is CG_V so direction I have by mistake even opposite CG_V is downward but the BH_V is actually upward that is the reason these two this 19300 and $BH_V$are acting in the same direction and see CG_V is acting downward direction. E_V is considered along the direction of CG_V and it is found that the direction assumed is correct that the reason we are getting the value of E_V as 19790 pound.

Similar way if we consider the S direction in the S direction we have E_s and CG_S only CG_S and E_s only so that gives us the value of 6300 pound yes E_D direction if you see E_D will have two forces one is this as I have mentioned this zero is not there so that is the reason we have these two forces that is the BH_D and A_D and E_D. So, assume direction is on that same direction of A_D and we get the E_D value as for say 4740 pound.

So the unknowns what we have we have considered for the member oleo strut is known now. The torsional moment at end E as well as 3 components of forces and the other forces acting on this like this member this member force, this member force coming here 3 components here and T_E that makes the that means 4 unknowns here this is 5th unknown this is 6th unknown. All the 6 unknowns are determined for the oleo strut member.

We have one more member at the beginning as we have already mentioned that I J we need to find out the forces. So, we will see in our next drawing the detailed drawing of figure of IJ and how all those forces are acting on it.

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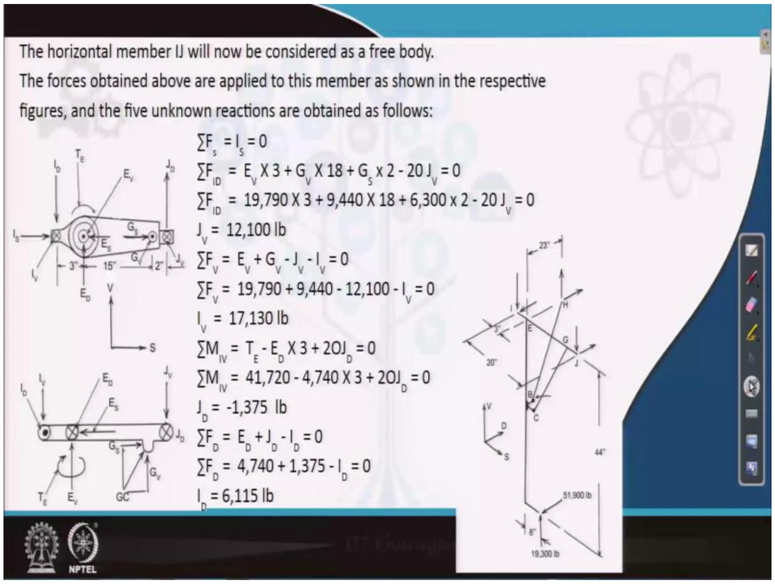

So we had to find out the horizontal member forces in the member IJ and the field body diagram is shown below IJ will now we considered as a free body. The forces obtained above are applied to this member as shown in the respective figure and this 5 unknown reactions are obtained as follows. If we consider in the S direction the member forces we have already found out that the $E_S$and G is values these two values are same that is the reason it is acting one to the opposite to the other and that that gives us that I_S is equals to 0.

Now we are supposed to find out along the sorry son of forces along I_D. At point in the direction drag in the direction drag. In this direction if we see what we have we have E V this is not F this is M_{ID} this is in we are considering moment about I_D from the point in the direction D. So, if we consider that what we have E_V which is I_D is in which direction is in this direction and that is in this direction about this point.

So this E_V is 3 inch apart that has a component acting here it is acting downward it is acting towards me this force so that direction is considered positive. So, if we look at here this is acting E_D is E_V is acting this way this is positive G_V what is G_V? That is also acting this way multiplied by 18. This is the distance 18 and G_S into 2 G_S into 2 this distance from here to here this is 2 inch this is 2 inch G_S into 2 - 20 J_V this is J_V acting in the direction opposite to the E_V that is the reason it is minus.

So these 3 are acting in the same direction it is acting in the opposite direction that gives us 0 and if we solve this equations from this equation we get the value of J_V as 12100 pound. Now again if we consider the summation of forces in the vertical direction as it is shown here E_V, G_V, J_V is already known I_D also need to be found out that that gives us since these 3 are known this is known this is known and this is known that leads to the solution of I_V as 17130 pound.

Similarly we are supposed to consider moment about I_V here we considered about I_D that means in the drag direction from the point I here from the point I in the vertical direction about this line. So, this will help us to find out. So, if we see that T_E is acting here, this is the force T_E is acting clockwise that is considered positive. E_D cross 3 this is acting in the opposite direction that there is in minus.

And 20 J_D is acting in the opposite direction as in the direct sorry 20 J_D here it is shown opposite along E_D but here it is considered in this direction and it is giving as a force. So, if we consider this way that solves the gives the understanding better. And considering that direction we have the J_D force as 1375. So, similarly if we consider in the drag direction the summation of forces that gives us the value of I_D.

So with these considerations all the unknowns in the landing gear are solved even in the torque links the forces are also solved and we can have a check we which we need to do in our next slide.

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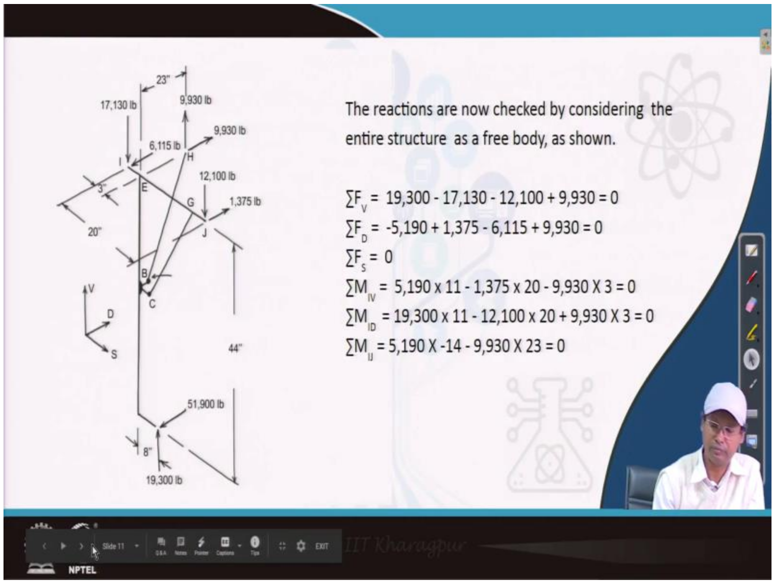

But we will see is it may be considered as homework what you have seen. So, in this slide what we see is that the reactions are now checked by considering the inter structures as three body diagram. And summations in all the direction V D and S has been checked and moments equations are also checked and it gives us zero. This may be considered as homework and you can solve this problem.

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So with this solution of learning problem two examples we cover the landing gear solutions and we will move forward to the next lecture.

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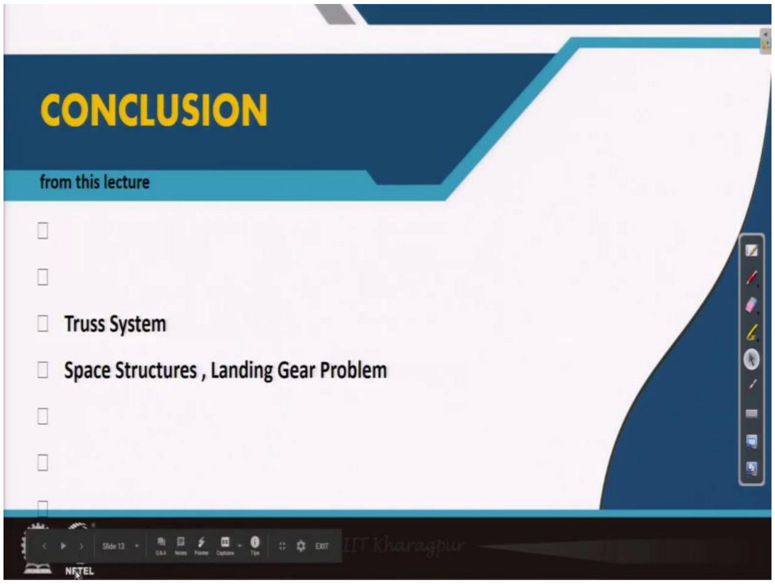

And in this lecture what we have learned is that how to solve the landing gear problems considering that as a space structure. And thank you for attending this lecture we will meet again in the next lecture with some other problem, thank you.