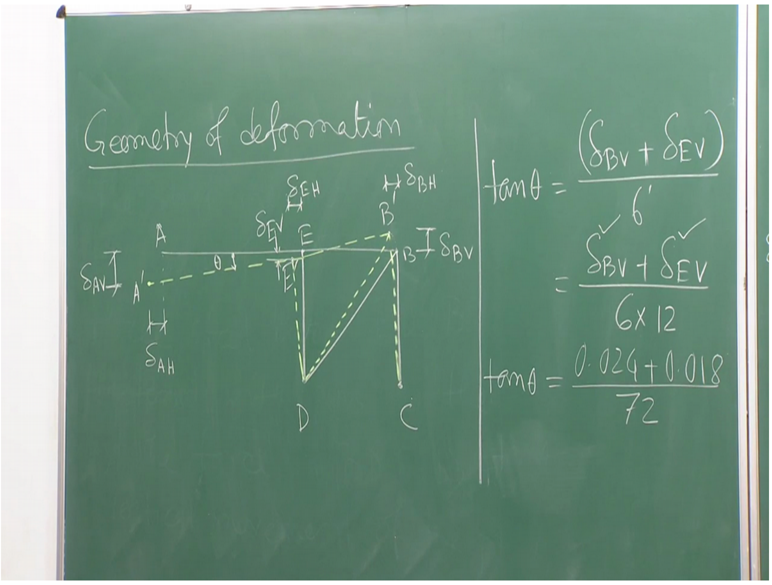
Mechanics Of Solids

Prof. Priyanka Ghosh
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Lecture – 18
Tutorial on Force Displacement Relationship and Geometric Compatibility-3

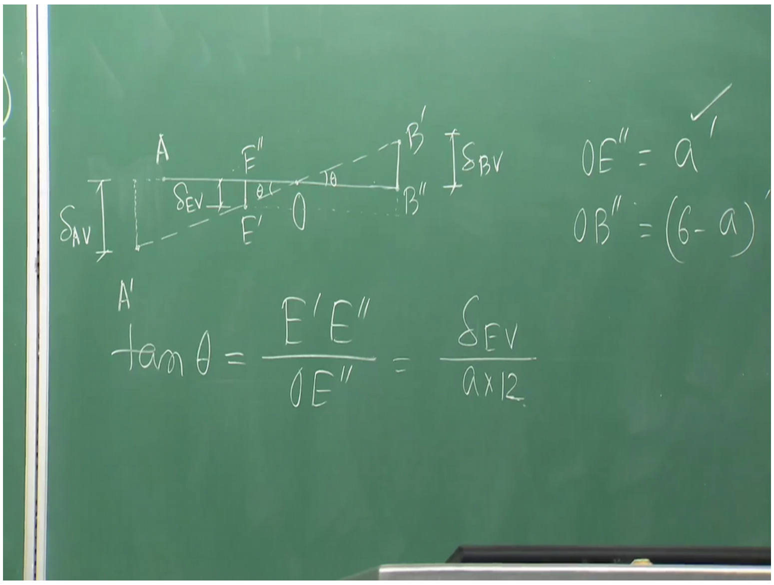
Welcome back to the course Mechanics of Solids. So, basically we are discussing about in the last lecture we were discussing about one numerical problem and that problem was like this right where A E B member was a stiff member, that is a rigid member we are not considering it deformation there and that member is connected by three steel rods that is D E, B D and B C.

(Refer Slide Time: 00:19)



So, in the last lecture we found out the member forces, forces in all members right B C, B D and D E, and we found that B C, B D is not carrying any load. So, therefore, B D must be equal to B prime D and at the same time B E must be equal to B prime E prime because that member itself is a stiff member we are not having any deformation there and A E is equal to A prime E prime and based on that we found out the horizontal movement of point A which was basically our one of the objectives right for this problem. So, horizontal displacement of point A was found as 0.024 inch if you recall.

(Refer Slide Time: 01:45)



So, now today basically we are going to find out the vertical movement of point A that is nothing, but delta AV. So, delta already has been obtained. Now let us see how we can find out delta AV. So, let me draw it very simple line diagram this is your A. So, this is your delta AV correct, now this is this point was E prime. So, this point was A prime and this point was B prime. So, if you just take out this configuration and if you blow it up, so it will look like this and this E double prime is the point where if you draw a normal from point E to the line AB, so that will be intersecting at E double prime. Similarly if you draw a normal from point B prime to member A B that is intersecting at B double prime and this is nothing, but your delta BV by definition.

This angle is a theta this angle is also theta and this is nothing, but the vertical movement of point E that is delta EV. I hope you have understood because this problem the conceptualizing this problem is difficult, once you conceptualize this problem then rest of the things is pretty simple if the calculation is pretty simple, only thing is that you have to you have to find out or you have to determine how it will deform fine.

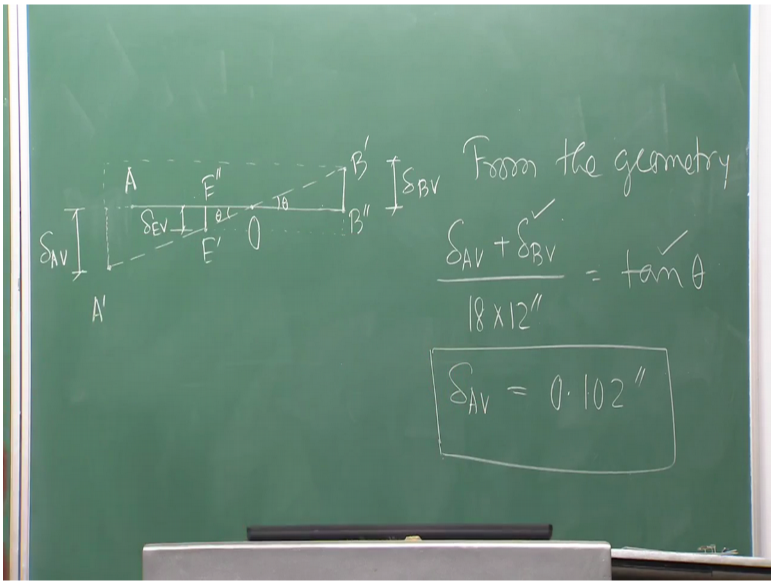
So, now this point I am saying as point O. So, what I can write, if I consider OE double prime is say a fit therefore, OB double prime OE double prime if I say a feet then OB double prime should be 6 minus a fit because the total length B E or B double prime E prime both are equal both I mean are equal and they are nothing, but 6 feet.

So, now if you look at this geometry I can simply write just say what I am writing tan theta is equal to E prime E double prime by OE double prime. So, write that very much. So, this is nothing but delta EV E prime E double prime is nothing, but delta EV as shown in the figure and OE double prime is nothing, but your A into 12 that is nothing, but you are in inch actually, a feet basically. So, OE double prime is nothing, but feet. So, I am multiplying 12 because I want to convert that thing any inch, fine. So, similarly tan theta can be written as if you look at the figure tan theta can be written as delta BV plus delta EV divided by the total length 6 feet.

So, if you consider one triangle like this. So, delta BV plus delta EV divided by 6 each, which can be written as delta BV plus delta EV into 6 into 12 that is an inch I am expressing everything in inch. So, from this you know delta BV right, you know delta EV right, in the last lecture we calculated that delta BV and delta EV both we have calculated in the last lecture when you are talking about or when we started this problem. So, from there if you put the value, so delta B V we obtained as 0.024 and delta EV you obtained as 0.018 divided by 72 that gives me tan theta. So, I can write here that gives me tan theta.

Now, from the geometry from the geometry what we can say that delta AB.

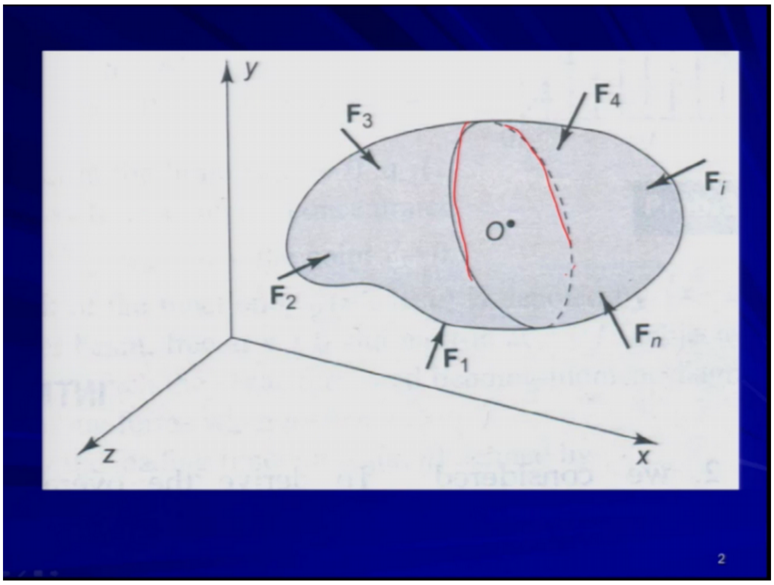
(Refer Slide Time: 08:00)



If you look at this delta AV plus delta BV by 18 feet 18 into 12 that is inch. So, what I am doing I am considering a big triangle something like this a big triangle I am considering just simple geometry class 8 standard geometric or 7 standard. So, that is nothing, but your tan theta. So, you know delta BV you know tan theta from there. So, you can find out delta AV which is equal to 0.102 inch. I hope you have understood this. So, delta AV is equal to 0.102 inch and in the previous lecture we found delta. So, our objective is fulfilled. So, we have got the deformation or the movement or point A in the vertical as well as horizontal direction.

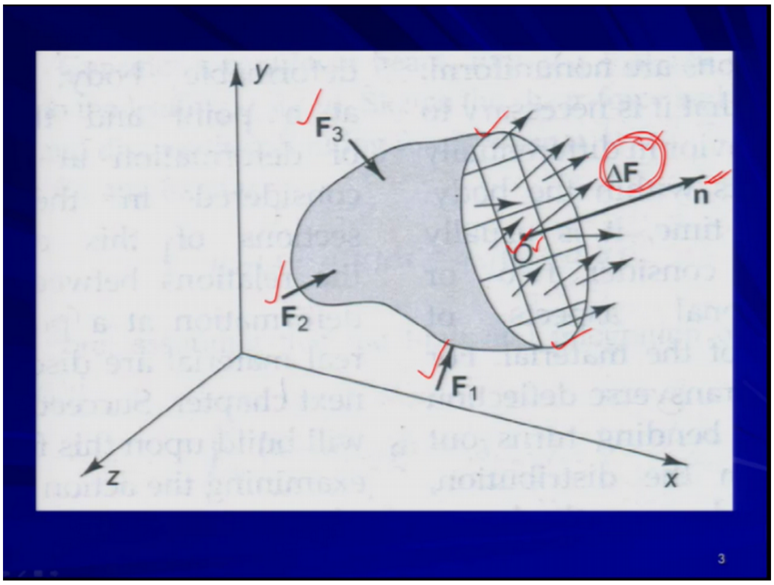
So, this is all about your second chapter. Now we will be moving to the next chapter that is concept of stress and strain. So, now, you should know what is stress first we will talk about stress and then we will go to the strain part well. So, now, we will start the new chapter that is concept of stress at a point plane stress case transformations of stresses at a point, principal stresses and Mohr's circle. So, first we should know what is stress, how to define stress. Now if you look at a body, anybody under the action of several external forces like here whatever is shown F 1 F 2 F 3 F 4 and so on up to Fn. So, there are n number of forces acting on this body.

(Refer Slide Time: 10:41)



Now, we are considering one plane, we are cutting this body in such a way that we can get this is the plane. So, this is the plane, this plane is containing one points say point O.

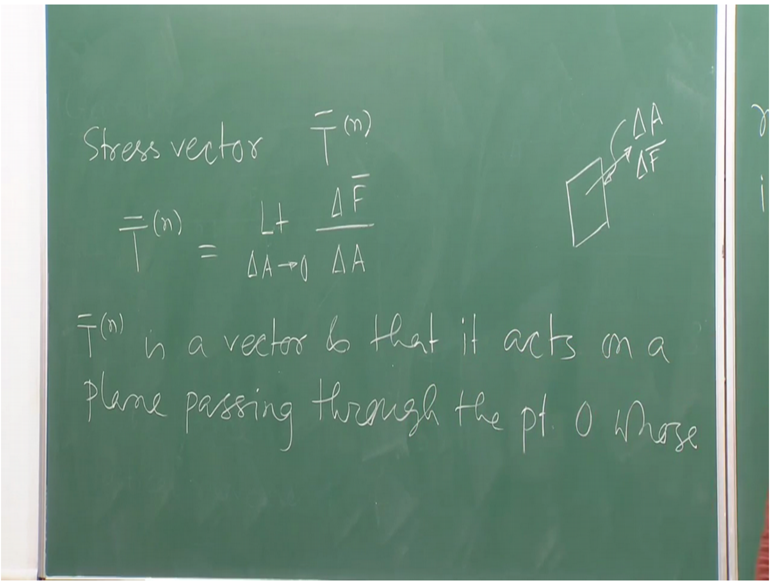
(Refer Slide Time: 11:12)



And now after cutting this body on this plane we are getting this plane like this. So, now, this plane is discretized with very small segments in number of segments or infinite number of segments and we are considering one plane which is containing point O and that plane is defined by the direction normal in and you know from your knowledge of physics that any plane can be defined by its direction normal. So, this plane this small segment can be defined by this direction normal and this on the small segments some delta F that force is acting.

Now, how this force has been developed? So, when you are applying some externally applied force right every system will be generating some internal forces; it will be developing some internal forces which will resist this external force. So, these are the external forces right these are the external forces now due to the application of these external forces when you are cutting the body with this plane and on this plane if you consider different or infinite number of segments small small segments and all those segments some internal forces will be acting and these internal forces will try to balance the external forces right. So, one such force one such internal force is say delta x which is acting on a small segment which is containing point O and this small segment is defined by the direction normal n, I hope you are understood this.

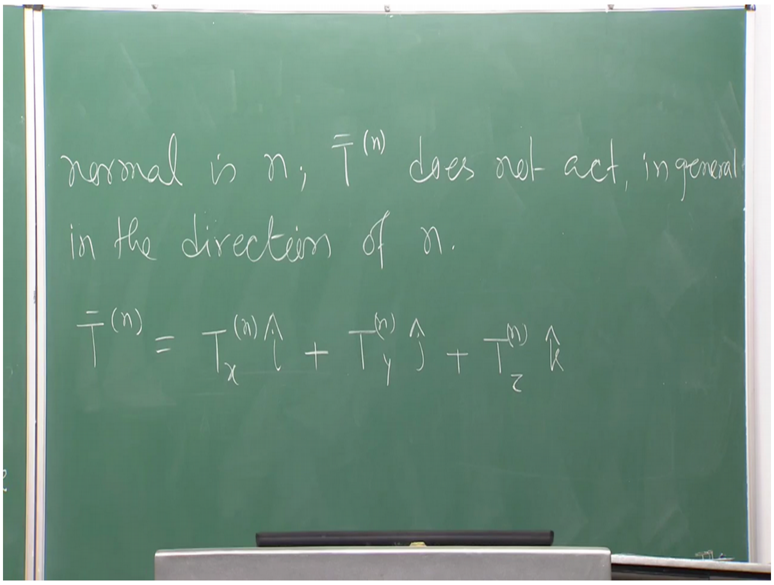
(Refer Slide Time: 13:23)



So, if that is there then I can define the stress vector T n I can define the stress vector T n like this. So, T n can be given by limit delta A tends to 0, delta F that is the force over this a here that is the limiting condition, that is the limiting condition of the force. Now what is delta A? Delta A is the area cross sectional area of this small segment which is containing point O. So, on that small segment on that small segment, this is a small segment whose area is say delta A on that small segment your delta A is acting right, the limiting condition when delta A tends to 0 try to understand when delta A tends to 0; that means, when delta A will tense will tend to 0 basically that will be becoming a point kind of thing. So, when delta A tends to 0 then the limiting condition of the force is known as stress. So, now, a few things you need to remember.

So, T n is a vector as I told you earlier and that it acts on a plane passing through the point O whose normal is n direction normal and the stress vector does not act in general in the direction of n.

(Refer Slide Time: 15:33)



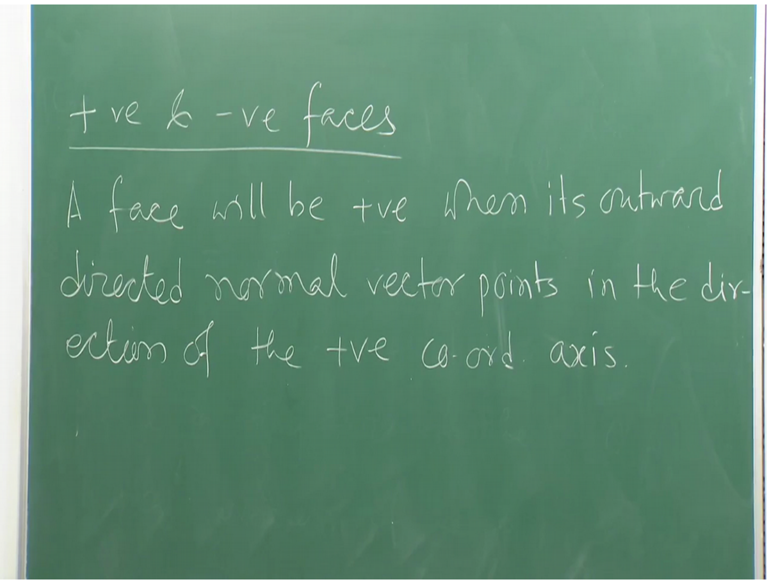
It is not necessary for the T n is acting along the direction of n. So, n is the direction normal; that means any plane. So, suppose this is my plane this is the plane how to define this plane you draw a normal direction normal from that plane and by that normal this plane will be defined. So, if the direction normally is n. So, I can call that plane as n plane right.

So, what does it say? So, T n is a vector which is quite obvious and that it acts on a plane passing through the point O as I showed you whose normal is n that also I have shown you right in the figure if you come back to this figure. So, this is the direction normal. So, this is the point O, this is the direction normal n and T n does not T n so delta F if you see delta F, it is not necessary your delta F will be always acting along the n direction or the direction normal right. So, F could be any direction it is not necessary, in generally it is not acting along the n direction, along the direction normal fine.

So, now what I can write then, then the stress vector in terms of its component that is x y z if you if you have the mutually perpendicular axis coordinate system then in terms of components what I can write this stress vector is equal to T x that is the x component multiplied by the unit vector along x direction, similarly T n y unit vector along y direction plus T n z into unit vector along z direction. So, where T x, T y, T z they are the x component, y component and z component of the stress vector T n that I can have because I have any stress vector that I can decompose or the resolved in three mutually perpendicular coordinate system xyz. So, they can be written like that.

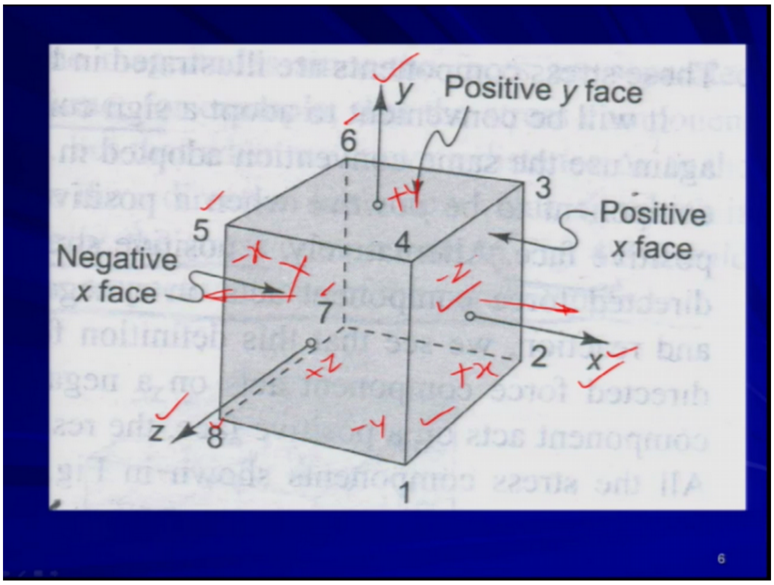
So, now we should understand, now one thing is very clear from this discussion that we should know the plane. So, without knowing the plane you cannot define the stress. So, when you are going to define the stress basically you need to define the plane also on which the stress is acting. So, the definition of plane is very very important, right. So, now, let us talk about that. Now we will define the positive and negative faces, positive and negative faces.

(Refer Slide Time: 19:17)



So, now if you come back to this figure, they are xyz coordinate system and we have drawn one parallelepiped in this xyz coordinate system and this is the parallel.

(Refer Slide Time: 19:28)



Now, we are going to define a face which is positive. So, if I define a face which is positive; that means, the face is positive when its outward directed normal is normal vector is towards the positive coordinate direction right. So, what does it mean? So, let us write down that statement and then we will we will basically explain a face because you need to define a plane before understanding the stress. So, a face will be positive when its outward directed normal vector points in the direction of the positive coordinate axis.

So, what is the definition? The definition says a face will be defined as positive when its outward directed normal vector points in the direction of the positive coordinate axis. Now if you look at this figure. So, if I consider one two three four plane or one two three four face this is my face 1 2 3 4 face. So, this face will be defined as positive as per the definition because the outward directed normal vector of this face is towards the direction of positive coordinate axis that is nothing, but positive x axis. Similarly 5 6 7 8 if you consider this face, this is the face what should I say? This face should be positive or negative this face will be negative because the outward directed normal vector from this face is towards the negative direction of coordinate axis that is negative x direction. So, that face will be defined as negative face.

Similarly you will be having three positive faces and three negative faces. So, this is my positive face this is my positive y face, this is my positive x face, this is my positive z face positive z face or as this will be my negative x face this will be my negative y face and this back side face will be my negative z face. I hope you have understood that. So, a face will be defined as positive when its outward directed normal vector points in the direction of the positive coordinate axis. Similarly a face will be defined as negative when its outward directed normal vectors points in the direction of the negative coordinator axis. So, then that face will be defined as negative I hope you have understood.

Well, so I will stop here today. So, in the next class we will continue with the further discussion on concept of stress.

Thank you very much.