Mechanics Of Solids
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Lecture – 04
FBD with examples on modelling of typical supports and joints

Welcome back to the course; mechanics of solids. So, we are basically talking about free body diagram with examples on modeling of typical supports and joints conditions for equilibrium, already we have covered in the last lecture in 3D as well as 2D friction limiting and non limiting cases. So, these are the things we are going to discuss. So, already we have talked about the equilibrium condition right and in the equilibrium condition we have seen that your resultant force must be 0. And your resultant moment must be 0. So, these 2 things are your necessary and sufficient conditions to have the equilibrium for any system.

So, now we are going to see few things few concept of forces. So, basically when the body, if I say the body is under equilibrium then the externally applied forces cannot be random. As I told you in the very first class that in mechanics of solid you first study the force, then you study the deformation. And then you try to establish some relation between these 2 by following some laws and these laws are very stringent laws. So, these laws are nothing, but the physics of the problem. So, you cannot have violate the laws.

So, what I mean to say if the body, if anybody if I say the body is under equilibrium and there are 2 forces acting on this body. So, no random orientation of the forces is possible please try to understand.

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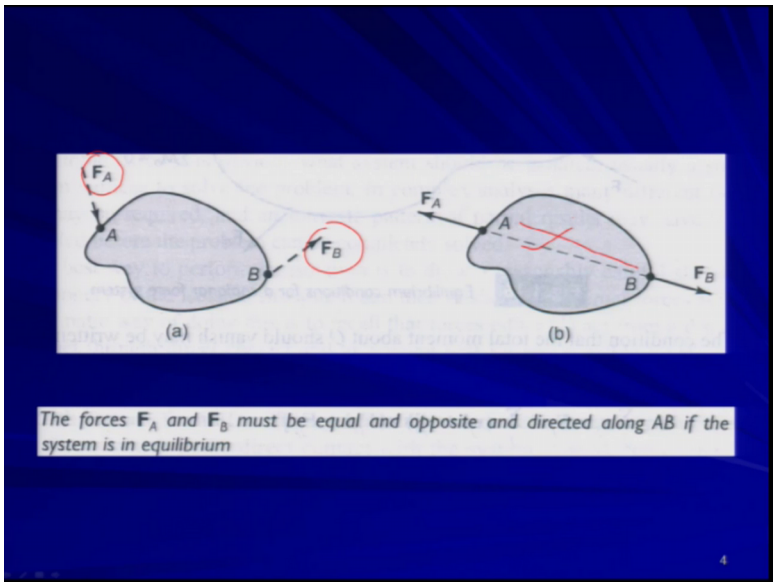

So, now suppose, if I say here, this body is under the action of 2 externally applied forces F A and F B, they cannot be randomly oriented, if I say the body is under equilibrium if the body is not under equilibrium, then it can be anything I mean any direction or any orientation is possible, but if the body is under equilibrium, then I cannot have the random orientation of these forces so; that means, this force F A and F B should have some proper orientation.

Now, if you think about the equilibrium condition. What was the equilibrium condition? So, only forces are acting now the resultant force must be 0. Now to have the resultant force must be 0; that means, F A plus F B must be 0, like I mean what I can write F A for this kind of situation F A plus F B must be 0, you cannot go beyond the law this is the rule of the game.

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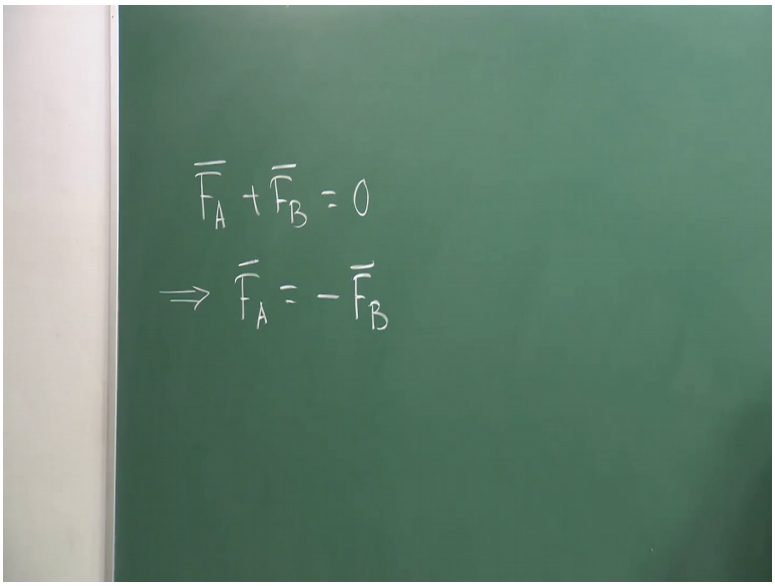

So, from this I can simply write F A is equal to minus of F B. So, what you understand from this there are 2 information you are getting from this one is magnitude wise F A must be equal to F B, otherwise the body will not be in equilibrium and they will be acting in the opposite direction, if F A is acting from this side to this side F B should act from this side to this side they cannot be in the same direction. Then only you can say the body is under equilibrium under the 2 force system. So, when I am talking about the 2 force member or 2 force system; that means, the system is under the action of 2 forces and if I say the body is or the system is under equilibrium then this must be valid and this must be satisfied.

So, the forces F A and F B must be equal and opposite and directed along A B, directed along A B. So, this is the line of action. So, write it along A B if the system is in equal if I say the system is under equilibrium, then F A and F B must be equal and opposite and directed along this is the rule this is the rule of the game, you cannot violate that similarly if you have 3 force systems; that means, the system is under the action of 3 forces say F A, F B and F C.

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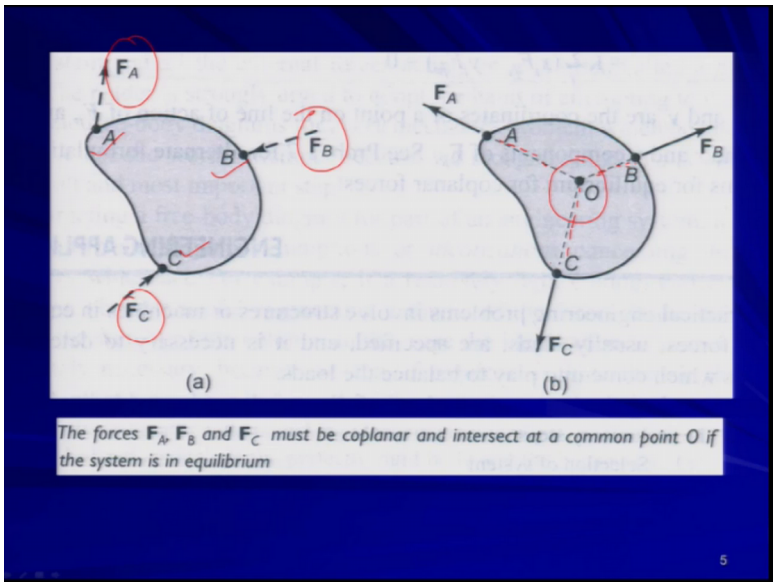

And the point of application of these forces already you know the point of application is very important. So, point of application of these forces is A B and C.

Now, again there is some rule the rule says that you cannot have the random orientation of these forces. So, what is the rule means I am talking about the body is under equilibrium of the system is under equilibrium. If the system is under equilibrium, then the rule prevails. So, what is the rule the rule is the forces F A, F B and F C must be coplanar on the same plane, fine. And intersect at a common point o if you see their line of inter line of action if you extend. So, these are all line of actions lines of action. So, these lines of action will intersect at a common point o if the system using the equilibrium.

So, this is the rule for 3 force systems. So, whenever you are getting this kind of things I mean 2 force system 2 force member or 2 force system or 3 force member 3 force system something like that. So, these rules must be recalled and must be satisfied.

Now, we are going to discuss a very important concept in mechanics. And the whole see I mean discussion of this particular course is based on this concept. If you understand this concept very clearly then the mechanics problem will no longer be very tough and difficult. Generally, people have the fear that mechanics is very difficult, but mechanics is not difficult you know to love the subject and as well as you have to follow the rules of

the game. If you follow the rules of the game then it is a very imp I mean very interesting subject.

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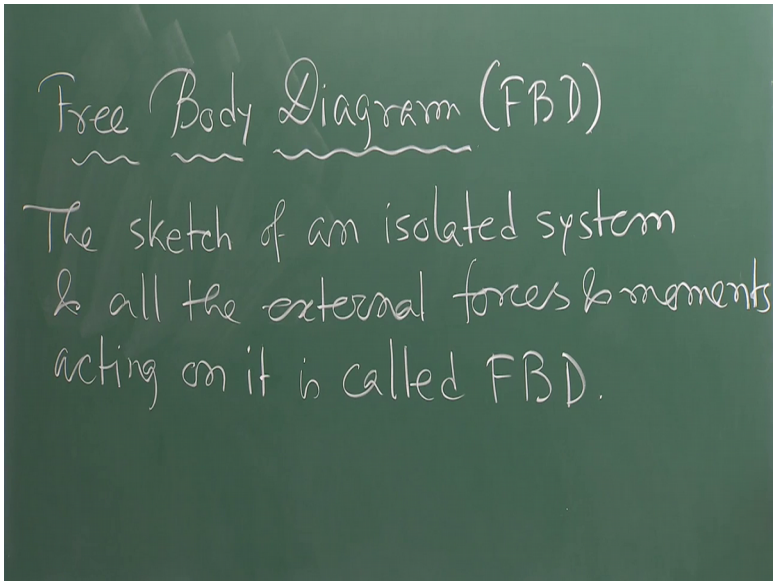

So, the very important thing is that, free body diagram. In short from now onward I will be calling as FBD that is very important concept, very important phenomena and you must understand this thing very clearly to have the interest in this particular subject to understand this particular subject. So, what is free body diagram? So, the by definition the free body diagram is the sketch of an isolated system. And all the external forces and moments acting on it is called free body diagram that is FBD. What does it say? It says the sketch of an isolated system and all the external forces and moments acting on it is called it?

So, what does it mean suppose you have a very complicated system? If you are going to analyze that particular system analyze means you want to study the forces, you want to study the moments you want to study the deformation. So, if you want to study these things by following the rules of mechanics. Then basically it is always convenient to have the free body diagram. And the this must be the you try to get or try to I mean think in that way that free body diagram is essential part of the analysis. For any kind of analysis in this particular course it should have the FBD at the very first point. So, it should be the first job to analyze any system.

So, what does it mean? So, this is the statement now what does it mean suppose you have.

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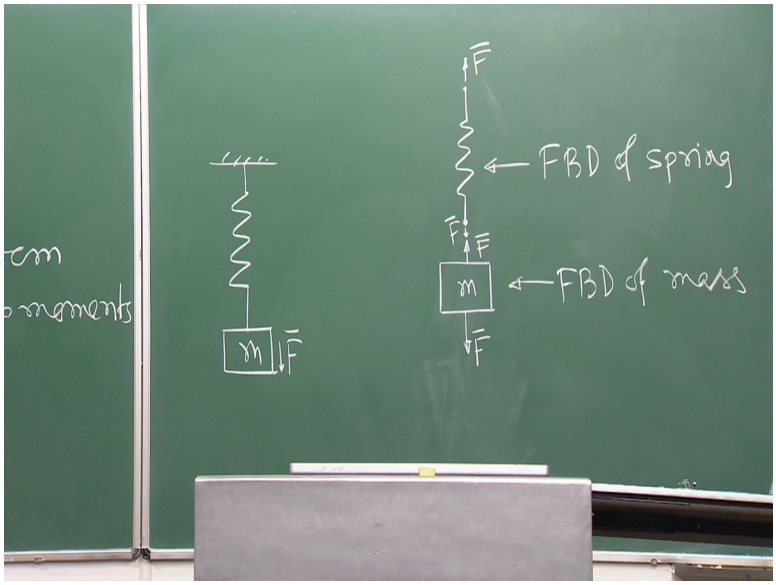

One floor or roof from the roof say one spring is hanging and at the end of the spring you have one mass which is giving some force F. Very simple system though, but if you want to draw the free body diagram of this system, then first you identify what are the components are basically forming this system. What are the components can you please tell me? In this system there are 2 components, basically if I do not consider this roof and that floor whatever from where the spring is hanging, then I can say my system is having 2 components? The first component is spring and the second component is this mass all right or not is not it.

So, I have 2 components one component is spring another component is this mass. And now what is the statement. The statement is that the sketch of an isolated system; that means, I want to isolate this system. So, I want to isolate the components. So, this is one component that is the spring and this is another component that is mass. So, these are 2 components this is the mass and this is a spring.

Now, I am saying that the body is under equilibrium, if I say if the if the system is under equilibrium then all the components must be in equilibrium. So, this force is acting they say in downward direction. This is the weight say some force. So, this is the force F. So, these are 2 components. So, this is the force acting in the downward direction. So, this

mass is basically is under 2 force system right. So, it should have an equal and opposite force F right.

Now, if you see the spring what are the forces are acting here the same equal and opposite force must be acting on this point and same force F will be acting on this point because this is again the 2 force systems. So, this should be equal and opposite right, now, if you look at now if you want to analyze the system. Then basically your analysis is very simple, when this system was there though the system is very simple. So, at the time you not appreciate that if the system is very simple then why should I do all those thing, but you will appreciate, that if I have one to analyze the system analyze the spring then basically this spring is under the tensile force F. And I can analyze the system if I know the spring constant all those things I will be knowing the displacement or how much deformation is happening in the spring right.

Similarly, this this is the force these are the forces acting on the mass. Now in that way basically what you have done from this complicated system, you are separating out or isolating all the components only by showing the external forces and external moments if they exist. So, only the external forces and moments you are showing all the isolated system and that isolated system is known as free body diagram.

So, this is your FBD of spring and this is your FBD of mass is appear. Now we will take few more examples and we will try to show the free body diagram of those complicated systems and then you will appreciate that how FBD can be drawn, and I am telling you and I am advising you FBD is must for any problem you are going to analyze. So, without drawing the FBD it is very difficult to solve the problem. Even if you can solve the problem that will not be perfect and that will not be the complete. So, FBD is the basic component of your mechanics of solids.

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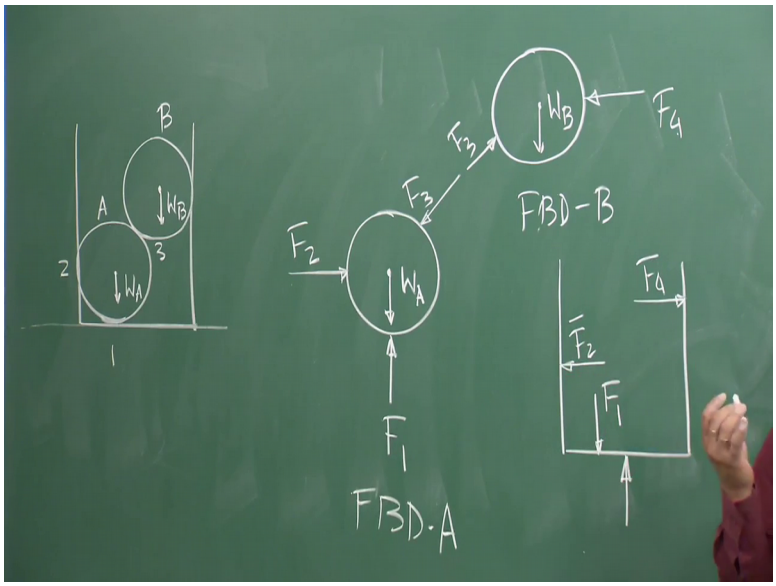

So, now we will take some few more examples where we can show the FBD. So, the problem says you have a can like your Pepsi can or some container you have. And in that container there are 2 say smooth spheres. So, these are 2 say smooth balls or whatever are resting. So, you have to analyze that how much forces are acting on the on the spheres or how much forces are acting on the container. So, those things you are going to analyze those I mean the forces whatever forces are there externally effect forces you are going to study those forces.

the weight of sphere a is W A, I am not using the vector sign all the times it is quite understood that whenever I am showing the force moments all those things would be having the vectorial notation. So, I am not writing all the kinds that vector notation it is quite understood. So, this is the weight of the sphere A W A and this is the weight of the sphere B W B now what is your first job to analyze the system draw the FBD.

So, let us draw the FBD of each ball as well as the container. So, if I draw the free body diagram of ball A. So, this is my ball A or sphere A I am taking it out I am isolating the system and with only the externally applied forces. So, what are the externally applied forces are acting here. So, when we are taking it out basically it should have the same effect try to understand what is the meaning of FBD. So, when you are taking this ball out from the actual system separating out or isolating from the actual system basically that ball will be experiencing the same effect as if it was there in the actual system.

So, now this ball if you look at this ball, this ball is having the weight say Wa. This is the point of application and we can consider this point of application is the center of gravity of that sphere or that ball. And now this ball is having 3 contact points, if you look at in the actual system. This ball is having one contact point is here another contact point is here. So, this is the contact between ball and container this is the contact between the ball and container again and this is the contact between ball and ball; that means, between ball A and ball B.

So, all the contact points will be experiencing some external forces because of something, because of the reaction because every action will be having some reaction as you know from the Newton's law. So, if I want to replace this point of contact if I say this is my point of contact 1 and 2 and 3. Then if I want to replace the point of contact one then basically I will be replacing that thing with a force. I do not know the magnitude of the force that we have to solve by satisfying the equilibrium condition we can solve this problem, but before that you should know how to draw the free body diagram. So, we are just drawing a free body diagram.

So, we are just replacing this point of contact by this force. Similarly, the point of contact 2 can be replaced by another force. Similarly point of contact 3 can be replaced with another force like this. So, if I say this is my F 1 this is F 2 and this is F 3.

Now, I want to draw the free body diagram of ball B or the sphere B, this is denotes sphere B say W B is acting here. Now you please identify how many contact points are there for sphere B 2 1 is here that is the between ball and the container. And another contact point is here that is the between the balls right. So, ball and container that contact part can be replaced by some force say F 4. And what will get this force? This force must be equal and opposite of F 3. Because if I say this body is under equilibrium; that means, there is no either there is no movement or it is moving uniformly. So, I am not talking about the movement uniform movement because as I as we decided that in this course we will not be talking about the motion.

So, this is stationary, this is a static problem and the bodies are if the body is under equilibrium. So, there will be a force here now if you analyze that system then you will be seeing this force is exactly same equal and opposite of F 3.

Now, this is the free body diagram of these balls this is free body diagram of ball A, this is free body diagram of ball B. Similarly, you can draw the free body diagram of the container. So, let us draw that. So, this is your container. So, every, so 3 components will be conferred will be will be there will be forming this whole system 2 balls, and one container. So, we have drawn the free body diagram of these 2 balls. Now we are going to draw the free body diagram of this container. So, how I will draw that first of all if I say thus container is resting on some on some say floor or table or whatever. So, there will be some reaction for same agreed.

Now, this ball is giving this F 1 is basically replacing this contact point. So, therefore, I will be having one course here at this contact point contact point between ball A and container. Similarly, at this contact point I will be getting one force and at this contact point I will be getting one force so which will be equal to F 4 F 2 and F 1.

So, this is your free body diagram of the container, how am I missing anything no. So, this is the free body diagram of the container, now, if you want to analyze each component then basically all the forces. So, earlier when you are saying this complicated system basically it is very difficult to find out these forces, because you would you do not know what are the forces acting on these balls as well as container. Now after drawing the free body diagram the picture is very clear, what are the different forces are acting and how you can analyze. Now you satisfy the equilibrium condition of on each say component and then you find out all these forces, so fine.

So, I will stop here. Today we will take few more examples on free body diagram in the next lecture.

Thank you very much.