Mechanics Of Solids
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Lecture – 02
Analysis of Mechanical System

Welcome back to the course mechanics of solids. So, in the last lecture, we were just talking about how to analyse a mechanical system, right.

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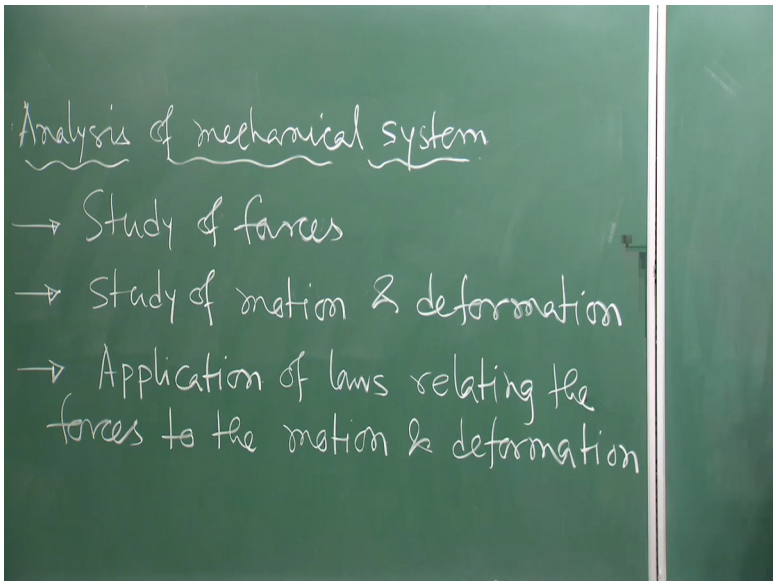

So, what are the steps involved to analyse the mechanical system by following the laws of mechanics. So, first step was study of forces. As we have seen in the last class or the last lecture. Then the second step involves study of motion and deformation that is one is the cause another one is the effect. And then finally, we are trying to correlate or trying to establish a relation between the cause and the effect that is application with some laws through some laws. So, application of laws relating the forces to the motion and deformation, these 3 steps we have discussed in the last 2 lecture which are required to analyse any mechanical system.

Now, in this particular course, basically if you see the content or if you see the title of the course basically we are talking about only the static part; that means, we are not talking about any motion of the mechanical system. Suppose if I want to analyse a building that is one static part, if I want to analyse a beam or column all are static, if I want to analyse

a particular machine which is not moving. So, these are static system and we want to analyse those systems in this particular course. We are not talking about or we are not interested to talk about the motion of the mechanical system, when it is a motion.

So, in this particular course we will be analysing the system by following these steps like first one is study of forces, then in the second step study of deformation and in the third step we will be coordinating will be establishing the relation between applications of laws relating the forces to the deformation.

So, in this particular course we will be following all those basic steps all those 3 steps, but excluding the motion part. So, we are not talking about anything any mechanical system which is in motion understood. So, there is no problem I hope well. So, now, when we are talking about these steps, now we need to know when we are talking about or when we are trying to study the forces involved in the system, then the obvious thing is that the first thing is that we should know what is force. So, you know what is force, but for the sake of completeness we will try to get the definition of force.

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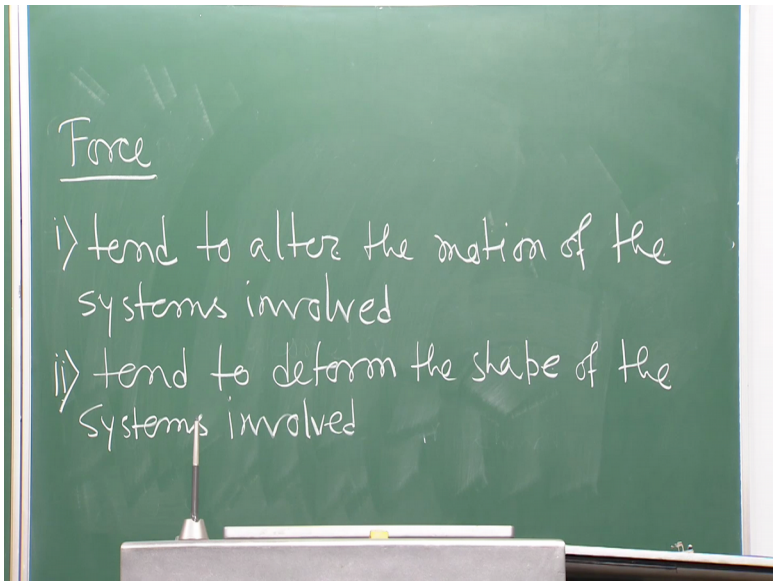

So, force is nothing, but a vector interaction as you know this is not the scalar thing this is a vector right. So, force is nothing, but a vector interaction. Now 2 principal effects the force can give, the first one is that it might tend to alter the motion of the systems involved. So, it can give 2 different effects. So, we will come to those effects right now. So, first effect could be it might tend to alter the motion of the systems involved.

Suppose you throw one ball in the in the upward direction. Now what will happen now? You are not applying any force, but it will try to come down.

Now, what force is causing this alteration of the movement because you are throwing the ball the ball should go in the upward direction continuously right, but it will not go it will fall down. So, your gravitational force trying to alter this motion your gravitational force will try to alter this motion of the ball. So, that is why the ball will actually or eventually coming down. So, this is your alternation of the movement.

The second effect it might tend to deform the shape of the systems involved. So, what does it calls it might tend to deform the shape of the systems involved. So, there are 2 effects either it can alter the motion or it can deform the shape of the systems involved right. Now how you can you can think of that kind of deformation.

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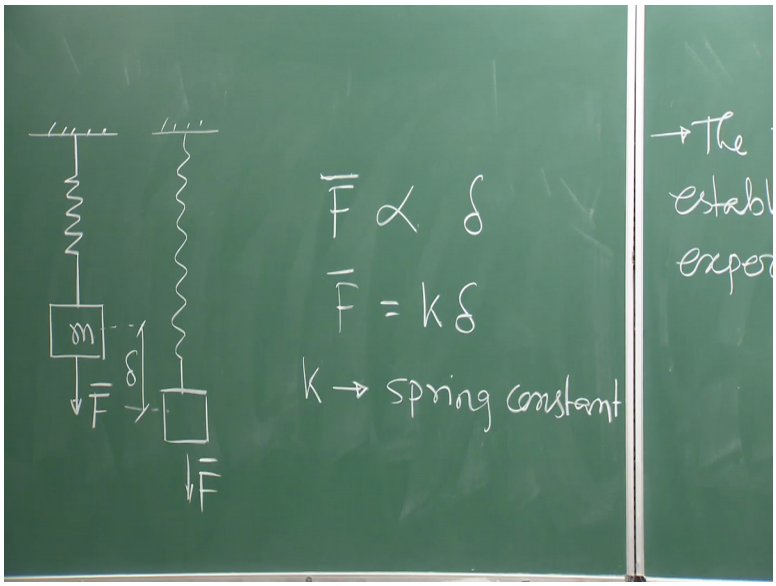

Suppose from a wall you are hanging one spring, and there is a mass attached at the bottom of the spring.

Now, what you are doing you are applying some force here. So, what will happen the that the force F will try to stretch the spring out right; that means, if you see the deformed shape. So, this might be the deformed shape. So, this time the force is not altering the motion, because this is a static system. Unless until we are talking about the oscillation of the spring this system is a static system, this static system when the mass

was attached at the base at the bottom of the spring and then after that you are applying one force F. So, when you are applying some force here. So, that force will try to deform the shape of the spring now you see this is this is not the exactly the same shape whatever you started with. So, this kind of deformation might happen due to the application of the force. So, the force will caused these 2 effects, one is alteration of the motion and the second is alteration in the deformation, or the alteration in the shape rather the deformation of shape.

So, now we should know few things about the force. So, you should know few things about the force.

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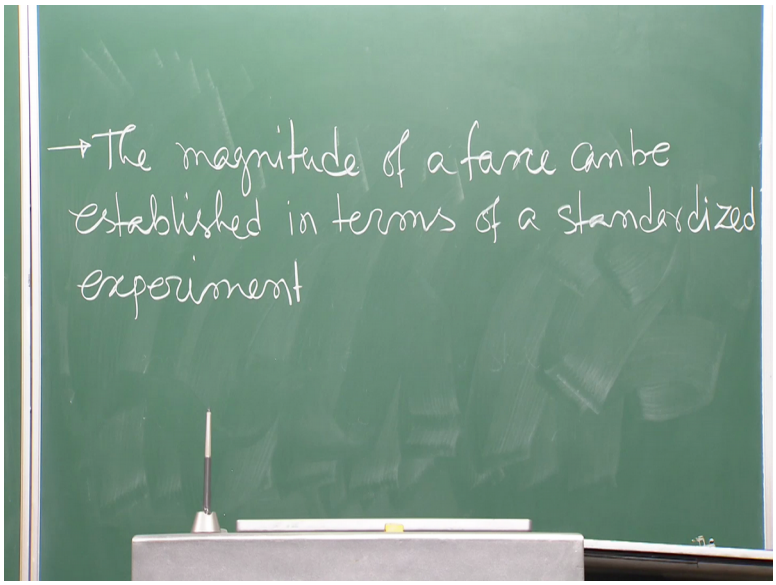

The first one is the magnitude of a force can be established in terms of a standardized experiment. So, these are the few points to be remembered, when we are talking about the force. The first one is that how we will get the magnitude of the force I am applying a force here right, in this spring I am applying the force and this much of deformation is happening in the in the in the in the spring, but how do I get the magnitude of force, how do I say that this much of force will cause this deformation. So, for that you need some standardized experiment the magnitude of a force can be established in terms of a standardized experiment like for this example. So, this is a standardized say experiment.

Now, if I say the spring is linear elastic spring, and then the deformation of the spring will be proportional to the force. That you know, that as you increase the force as long as

because these terms are not I mean we are not supposed to say those terms because we are not equipped to say all those terms like linear elastic and all those things, but; however, for the time being we are we are using these terms later on we will be seeing the actual meaning of these terms in a detailed manner.

So, now if I look at this spring the spring for that spring I am applying some force F. So, if I apply say delta amount of force. So, I am ex I will be expecting some delta amount of deformation. If I increase the force deformation also will be increasing right. So, if I mean for example, if I apply 1 kg of load. So, I will be getting some same say for example, say point one millimetre of deformation then, if I increase 2 kg that will be say something some value of deformation like that right.

So, what we can say what law is it is following that F that force is proportional to your deformation delta right. So, this is your nothing, but your deformation. So, this much is your deformation. So, originally it was here. Now it has gone up to this position for the application of load F. Now F is proportional to delta directly proportional to delta. So, we can write F is equal to some constant some constant into delta. And this is known as spring constant right.

So, now this is, I mean if we considered this is a this is a standardized experiment, now if I know the spring constant, if I know the value of the spring constant and from the experiment if I observed the value of delta, then basically we can quantify or we can establish the value should of the force F is not it? Yes, or no right.

So, in that way for any mechanical system if you want to quantify or you want to establish the magnitude of the force F. Then basically this is the way we will find out; that means, you see from this experiment. So, what are the steps involved, we studied the force we studied the deformation, and we established the relation between the force and the deformation. And then finally, our job is done. So, we have analysed the complete mechanical system we can say right.

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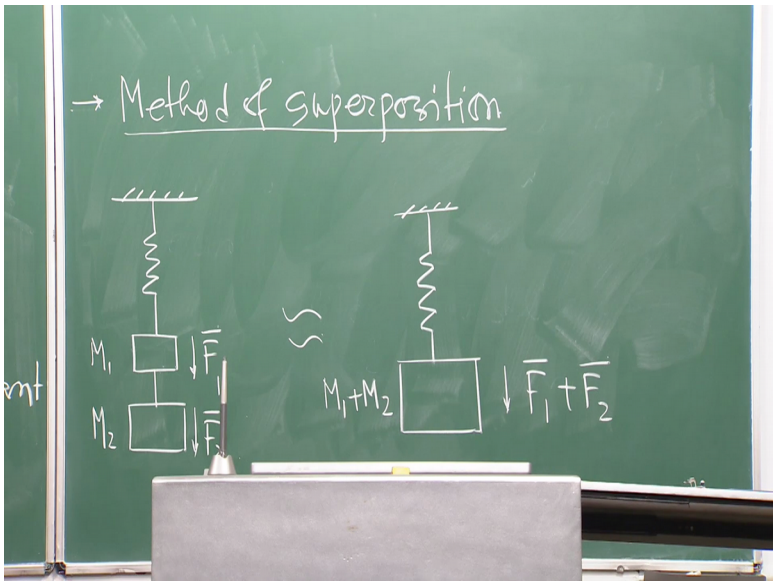

So, now the next point to be remembered when we are talking about the force that is method of superposition. The method of superposition is valid till we are talking about the linear elastic system. So, method of superposition is valid. So, what does it mean; that means that when suppose I have the spring, I have 2 masses attached to different masses. That is M 1 say and that is M 2 say. And this is giving me the force F 1. And this is giving me the force F 2. So, try to understand the system mechanical system, I have one spring and this is attached with 2 different masses mass M 1 and mass M 2, which are giving or which are which are imparting all the system by an amount of force F 1 and F 2.

Now, this is equivalent to another system made of the same spring, where I am applying a single say mass which is nothing, but M 1 plus M 2 that is a summation of these 2 individual masses and which is causing a force F 1 plus F 2.

Now, this system whatever effect you will be getting whatever response you will be getting from this system the same response you will be getting from this system also. So, only thing is that instead of having 2 different or 2 individual masses, I am having only one mass, but the total magnitude of mass is same. In this case it is M 1 plus M 2 and this case only single mass and that is M 1 plus M 2, which is giving F 1 plus F 2 force. And here actually individual forces you are getting F 1 and F 2. So, the response of this system and response of this system will be same the effect will be same and this is

known as method of superposition; that means, instead of having a single force also having a individual force, you can go or you can switch over from this system to this system or you can switch over from this system to this system. So, there is no problem at all.

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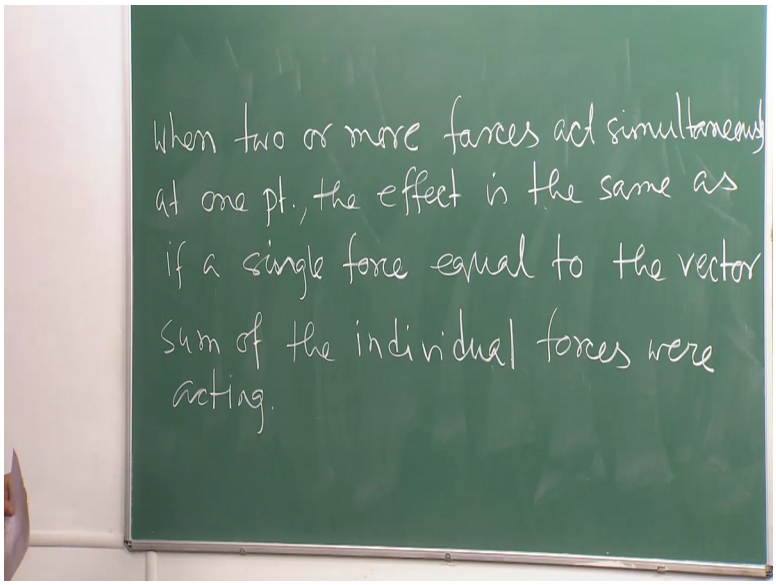

So, if we try to try to write down in same case. So, what is your method of superposition. So, we can write down like this. When 2 or more forces act simultaneously at one point, the effect is the same as if a single force equal to the vector sum of the individual forces were acting. So, what does it say? It says that when 2 or more forces like F 1 and F 2 act simultaneously. So, you it has to act I mean they have to act simultaneously. They have to be applied simultaneously at one point please try to understand at one point; that means, the point of application of that force will come to that point, one point of application of that force will be same. The effect is the same as if a single force that is F 1 plus F 2 say that is single force F equal to the vector sum of the individual forces vector sum of the individual forces F 1 plus F 2 why.

So, this is known as method of superposition and you will appreciate later on that this method is very handy and very helpful, and very important to analyse the system when you are having very complicated system. So, you can say you have say n number of forces, and if you think that if you consider n number of simultaneous force, at the same time then basically your system may get complicated. So, what you can do you can use

or you can apply individual forces and you can get the response. And you can add the response together later on to get the total response obtained from the complete simultaneous force system right. So, this method is known as method of superposition. We will use this method later on and you will appreciate this method is very handy.

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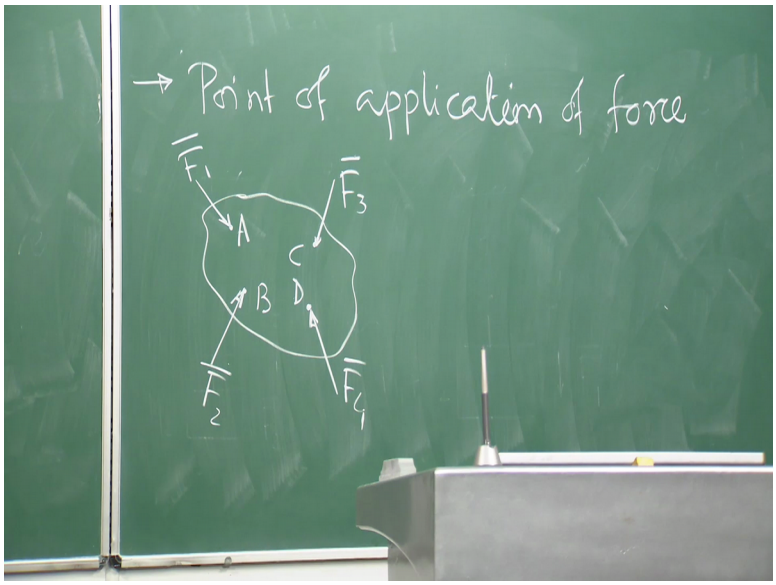

Now the third point is point of application of force, which is very important - Point of application of force. Now in any system if you consider force can be applied at different locations different points, based on that basically you will be getting the different response. So, point of application is very important when you are studying the force. So, these are the things basically you should remember when you are analysing the force, when you are studying the force what was the first one, first one is that quantification of force the second one is that method of superposition that is valid for the force system. And the third one is the point of application of force that you must know. So, what does it mean suppose this is the body, now you are having different points and in this points basically say these points are A B C and D and your force is applied at these points.

So, this point, points of application of force is very important, like suppose F 1 is acting at point A F 2 is acting at point B similarly F 3 and F 4. Now for example, if you are if you are thinking that whatever effect you are getting from this system, like the way the forces are acting on these points. Now if you if you if you think or if you say the F 1 is acting at b F 2 is acting at C and so on if you just I mean change the points of application

of the forces, you will not be getting the same effect. So, points of applications I mean when you are studying the force the point of application must be known otherwise you will not be getting the same effect or the same response from the system.

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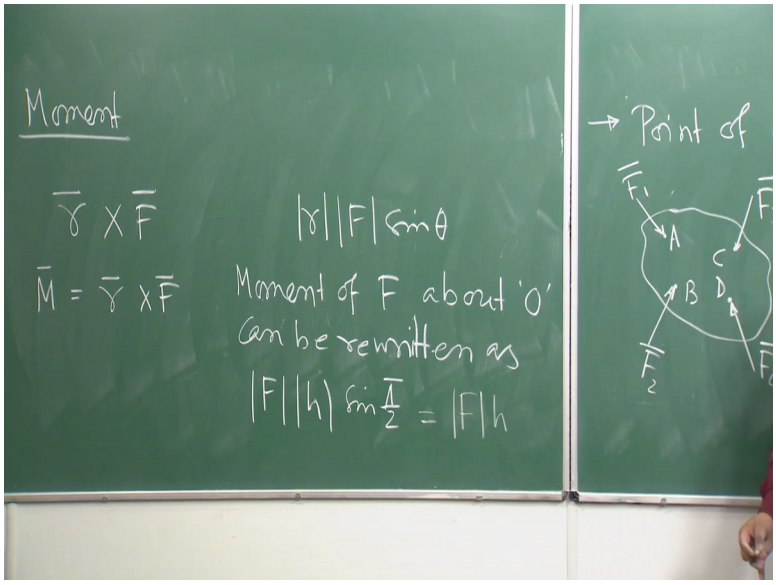

So, now we will talk about the next thing is that moment, that is another effect due to the application of force that is called moment.

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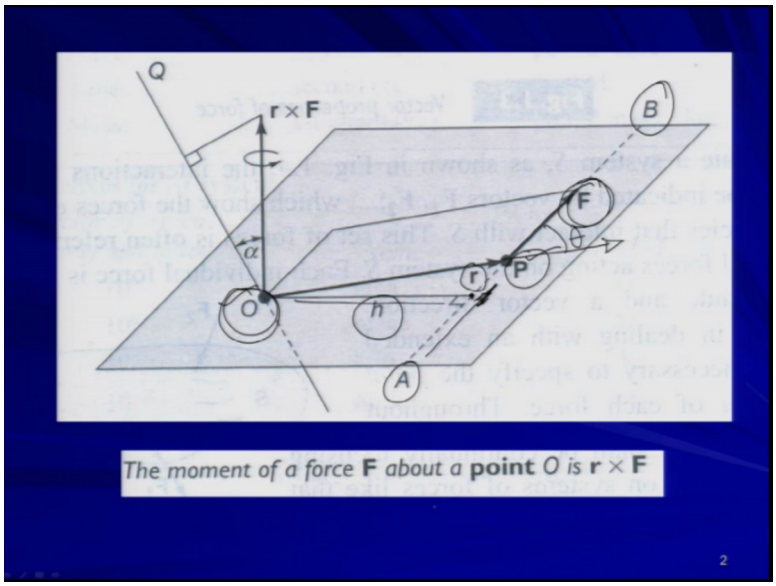

So, if you look at this figure, in this figure this force F, in this figure this force F is acting along the line of action A B. This is the line of action along that line of action this F is

acting and the point of application of this force is P as we have we just saw in the on the board, that point of application is very important. So, the line of action is very important and at the same time the point of application of the load is also important. So, this force F is acting on point F, oh sorry point P along the line of action A B.

Now, this O is another point on the space on the space whatever is shown here. So, on that particular space the O is any arbitrary fixed points. So, that point is fixed. Now if I want to calculate the moment. So, moment will be the vector cross product of the moment will be the vector cross product of r vector and force vector. What is r vector? R vector is the displacement vector. So, r vector is the displacement vector if you look at this figure this is your r, from O this displacement vector between point O and P.

So, now you understand the importance of the point of application. So, if you do not know the point of application then basically your displacement vector cannot be established. So, once you know the point of application then only you can establish the displacement vector. So, this point P and O in between that whatever displacement vector you are getting that is nothing, but your r. So, the vector cross product of displacement vector r and force vector F will give you the moment of force F. And that will be acting normal to the plane whatever plane we are showing here normal to the plane and that will basically follow the right hand thumb rule; that means, if this is the direction. So, this is your direction say if this is the plane on which the force is acting the moment will be in this direction in this direction. So, this is your right hand thumb rule. So, this is the direction of your moment this this will give you some rotation the moment will give you the rotation right.

So, from the vector algebra if you recall your vector algebra from the mathematics what we can write for this moment. So, moment if I want to find out the magnitude of moment. So, basically I can write, this is your r cross F and the magnitude is nothing, but magnitude of r magnitude of F, sin theta. What is theta if you come back to this figure this is your theta right. So, this is the angle between r vector and your force vector. This is the angle between your r vector and force vector. So, this is your force vector and if you extend this r vector, this is your angle theta. So, this will give you the magnitude of moment.

Now, if you look at this, if you look at this expression. The moment of a force at a given point, moment of a force at a given point say at a given point mean say O the moment of a force F at a given point O is invariant under the operation of sliding the force along the line of action. What does it mean? Now this force this is the force vector along the line of action A B. Now if you slide the force vector along the line A B any dire I mean from A to B wherever you slide, and if you want to find out the moment with respect to point O. There is no problem it will be always remaining same because the force vector the magnitude of force vector is not changing.

What are the things are changing the displacement vector and your angle between the displacement vector and the force vector? So, these 2 things are changing. And because of this change you are I mean your both the things are changing and therefore, ultimately you will be getting this moment is same. So, as long as you slide the force along the same line of action with respect to some fixed point on the space, you will be getting the same amount of moment. If it is so then why should we not take some advantage of defining the displacement vector in such a way that we will be getting this thing, very is not it?

Now, what we can get from here, moment of force. So, moment of F about the fixed point O can be rewritten as force and then h and sin pi by 2; that means, we are defining the displacement vector in such a way that it will make an angle 90 degree between the displacement vector, and the force vector which is shown here. So, if you look at this figure h is F. So, I am sliding the force this force, I am sliding say at this point now this is my point of application.

Now, this line will become the displacement vector that is nothing, but the perpendicular distance from O to the line of action A B. So, this h is coming here and the angle between h and the force vector F is nothing, but the 90 degree that is pi by 2. So, from this expression we can simply write the moment is equal to F h. So, what does it under what does it mean actually. So, if you can manage to get the displacement vector in such a way that it will give the normal distance or the perpendicular distance from the fixed point to the line of action of the force then basically your force multiplied by that perpendicular distance will give you the moment of that force, with respect to that point that fixed point O in the space.

So, I will stop here today thank you very much. I hope that you have enjoyed the discussion on force and moments. So, in the next lecture we will be going or we will be talking about different concept like equilibrium conditions free body diagram and other important issues.

Thank you very much.