Mechanism and Robot Kinematics
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Lecture – 05
Degree of Freedom – II

We have looked at examples of mechanisms with one degree of freedom. Now this one degree of freedom mechanism has a very special place in the study of kinematics. So since, these are very special; they also have a name.

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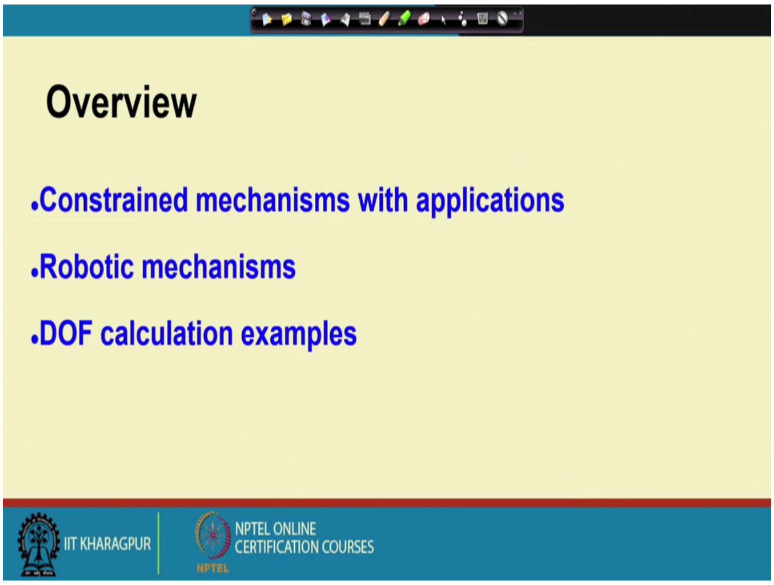

They are called constrained mechanisms, so in today's lecture; so this the overview of today's lecture. We will discuss constrained mechanisms with applications; then we will go over to robotic mechanisms and calculate their degrees of freedom.

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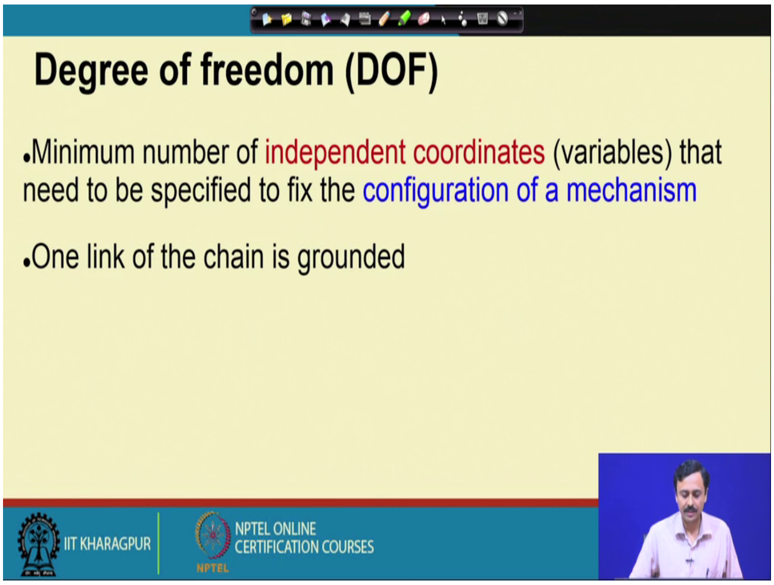

So, just to review what we have discussed previously; so, degree of freedom is a minimum number of independent coordinates that need to be specified to fix the configuration of a mechanism; one link of the chain is grounded.

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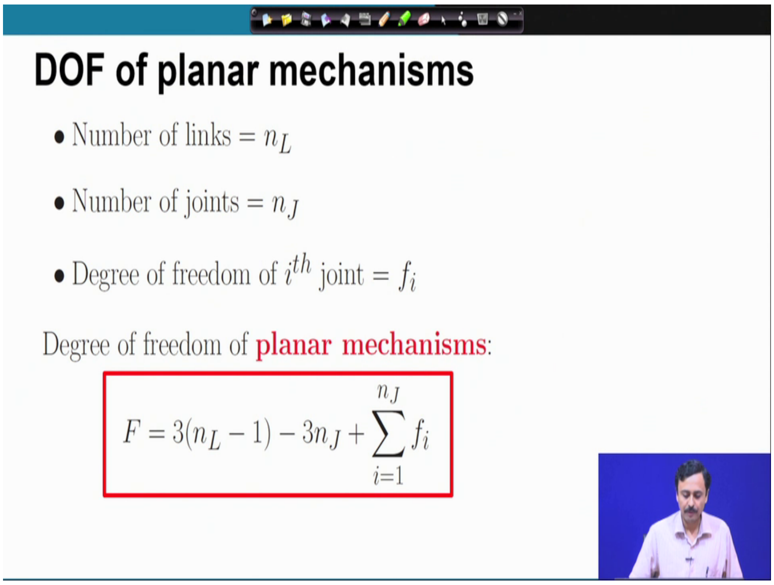

And we have looked at this calculation in detail. So, this is for the planar mechanism; where I would like to point out that here for a planar mechanism, we have 3 because in a plane every rigid body has 3 degrees of freedom.

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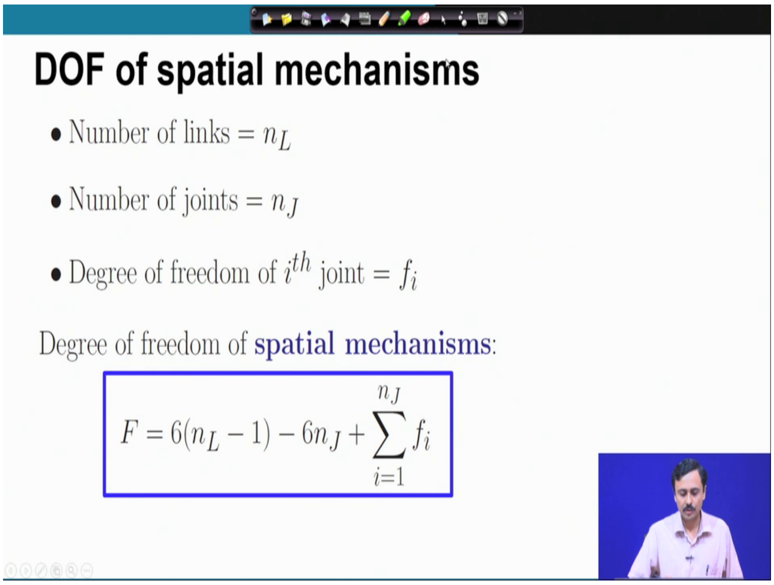

On the other hand, when we go to spatial mechanisms; we have 6 degrees of freedom, so this number become 6.

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Then we also discussed that a mechanism must have at least 1 degree of freedom. A structure has 0 degree of freedom and an over-constrained structure has negative degrees of freedom.

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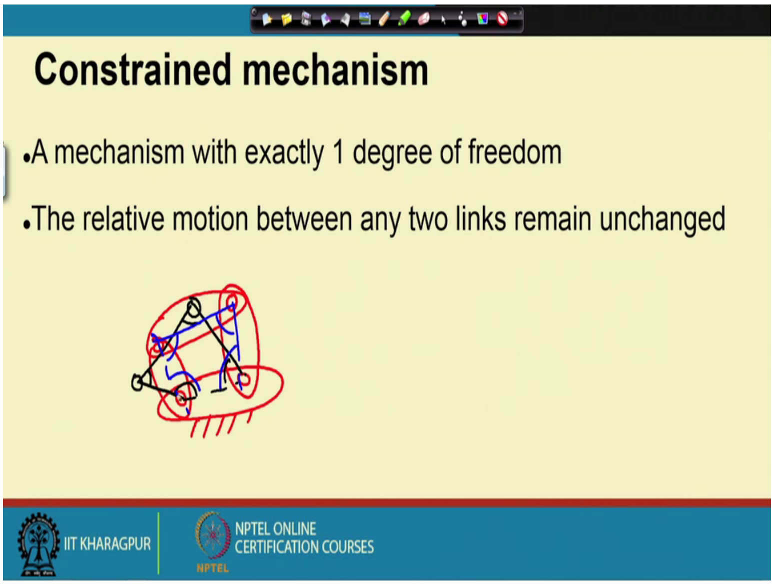

Now, we come to this definition; a constrained mechanism. A constrained mechanism is one which has exactly 1 degree of freedom. So, in a constraint mechanism the relative motion between any two links remain unchanged. Now what do I mean by that? So, suppose I have this combination of links and when this moves; you see at this configuration; however, you come these angles will be only this it cannot have any other combination. Or in the starting configuration, these angles will only be this there is no other possibility since this has 1 degree of freedom. If I fix one, all the other angles will get fixed.

So, there the relative motion between any two links remain unchanged if it has 1 degree of freedom but suppose I have something with more than 1 degree of freedom. For example, my hand I can choose to move this without moving this joint or I can move this joint without moving this joint. So, individual links can make different angles and that gives us this ability of maneuvering. So, we do not have fixed motion between my forearm and the arm; had it been so, I would have been able to move only like this; nothing else for example.

So, in mechanisms with higher degrees of freedom the relative motion between these links can change.

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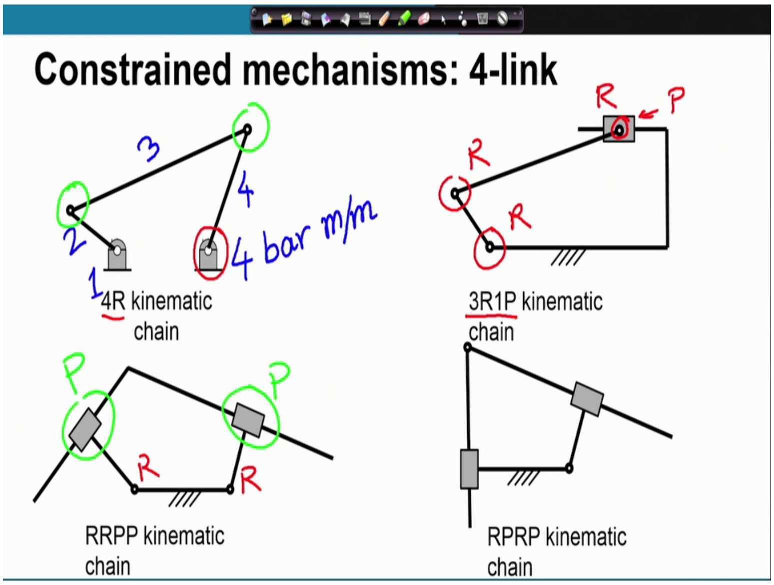

Let us look at some examples of constraint mechanisms. So, this is a four link constraint mechanism; we have seen this. So, ground is 1, this is 2, this is 3, this 4, so we call it a 4 link mechanism or if sometimes a 4 bar mechanism.

Now, let us see what happens; if I start replacing these kinematic pairs; in this case they are all simple hinges they are revolute pairs rather; here there are revolute pairs. So, that is why it sometimes called the 4R kinematic chain. Suppose I start replacing one by one by prismatic, suppose this kinematic pair; I want to replace by a prismatic pair then I have this.

So, here I have a prismatic pair; so this is called 3R1P kinematic chain, so R; R here there is one more R and P. Now if I replace this; these two revolute pairs by prismatic pairs, so here there are two prismatic pairs, so this becomes RRPP. So, here we have R; here we have R, so RRPP kinematic chain. Finally, if I replace two opposite revolute pairs by prismatic pairs; then I have RP; RP kinematic chain, as I have shown here.

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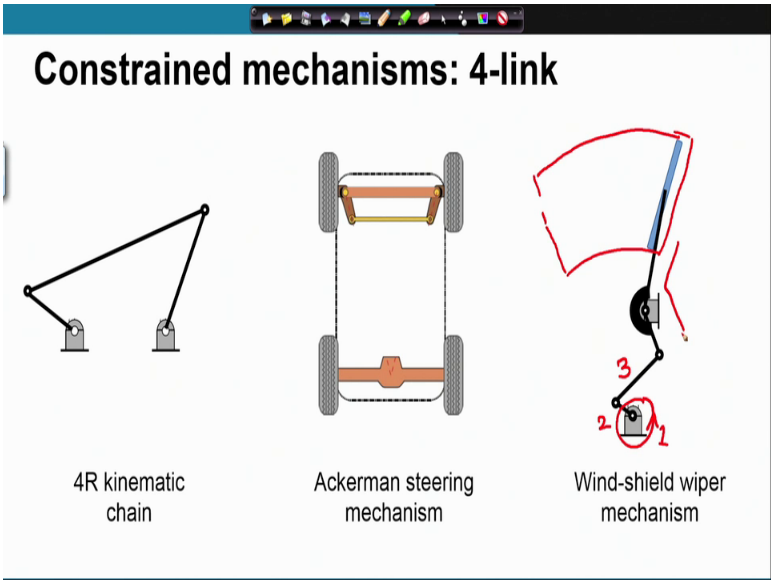

Let us now look at some applications say 4R kinematic chain; we have looked at this Ackerman steering wheel mechanism; we also have this windshield wiper mechanism. So, here is the wiper which is going to wipe the windshield or windscreen. So, here you have a motor which is rotating this link; this is the coupler and so 3, 2, 1; 1 is the ground, 2 is the crank here. So, this link; 3 is the coupler and 4 is connected to the wiper.

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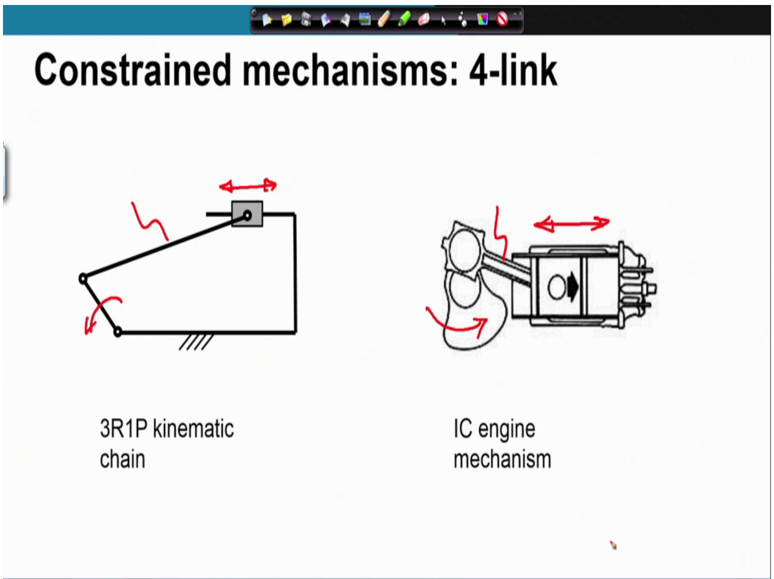

So, these are applications of the 4R kinematic chain; 3R1P, a very standard application is an ice engines. So, you have this piston which is oscillating; so, this is our PPR and this is connected to the crankshaft and this is the coupler; this is the connecting rod.

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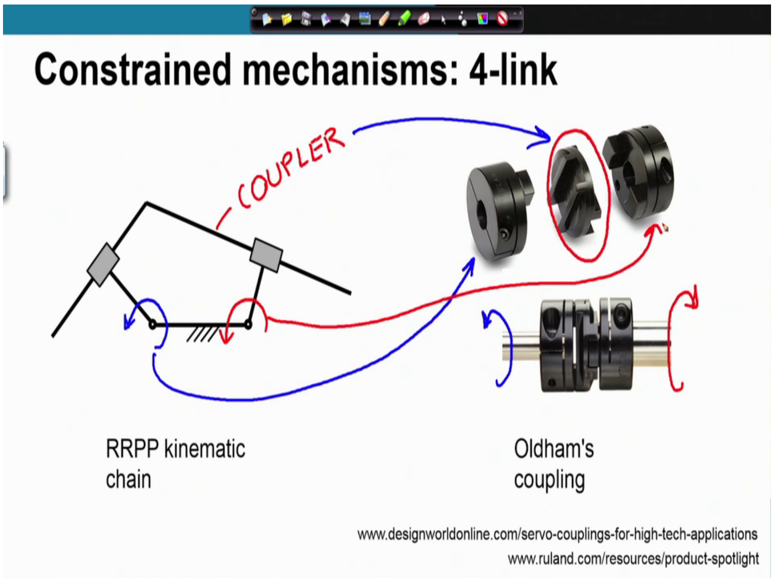

An application of RRPP kinematic chain; this is the Oldham's coupling; this is used to connect two parallel non collinear shafts. So, let me mark out; so, this is one shaft; which is this one let us say, this is the other shaft and there is a coupler, which is this piece.

So, this goes here, this goes here and you have that coupler. So, this is an application of the RRPP kinematic chain; the Oldham's coupling.

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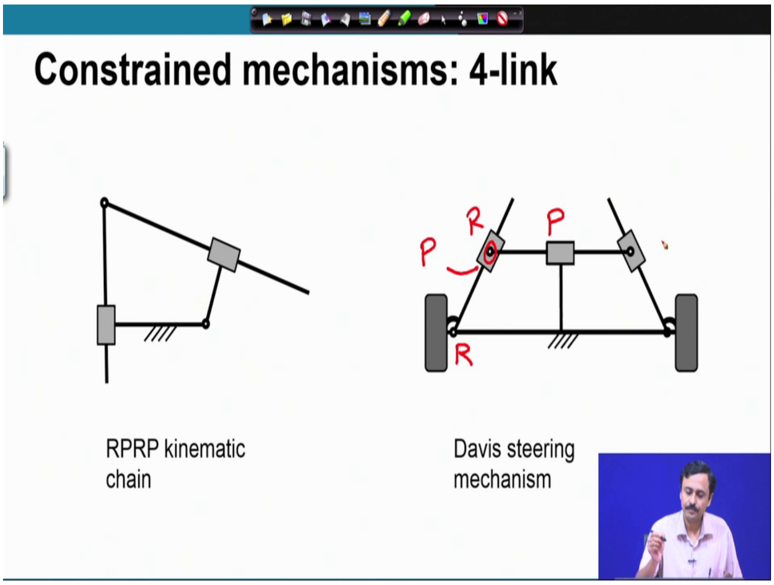

Then RPRP kinematic chain, this is the Davis steering mechanism which use the RPRP kinematic chain, but there are two copies of this kinematic chain; let us mark them out. So, this is R; here you have a P, this is the next R and this is the P and then there is another set of RPRP for the other wheel. So, this is the Davis steering mechanism; which uses the RPRP kinematic chain.

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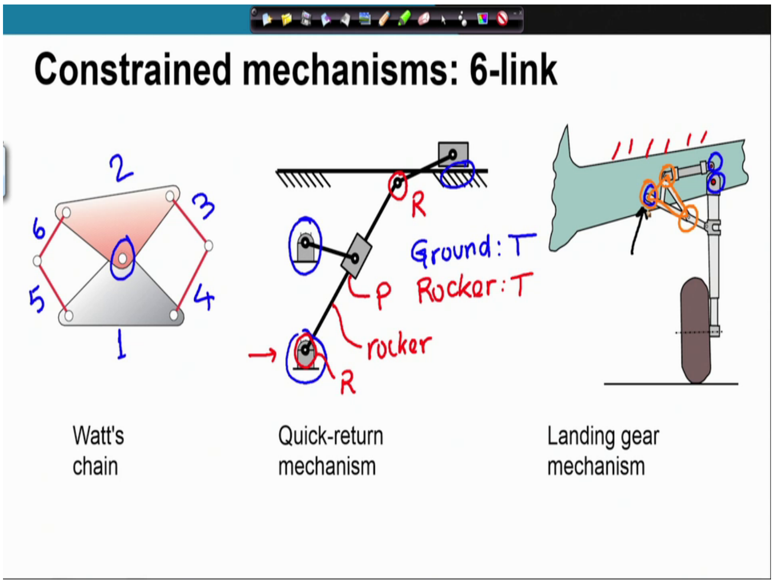

Let us go over to 6-link where we have been talking about 4-link kinematic chain, now we go to 6-link kinematic chain this is called the Watt's chain. So, it has got two ternary links as you can see; so 1, 2, 3, 4, 5, 6, so links 1 and 2 are two ternary links and these two ternary links are connected at this kinematic pair.

So, that is a characteristic of the Watt's chain; the two ternary links are joined at a kinematic pair. Let us look at some examples; this is known as the Quick-return; Witt Watt quick return mechanism which is used in shaping machines; shapers. So, this is a Watt's chain, so we must identify first what are the two ternary links. This is the ground hinge, ground hinge and again there; there is a ground.

The slider makes a P pair contact with the ground, so there is a prismatic pair between the ground and the slider. So, ground is a ternary link; so that is a ternary link, which is the other ternary link? You see here there is on this link; on this rocker, there is this kinematic pair revolute; here there is a prismatic. So, this is revolute; this is a prismatic and here there is a revolute.

So, this rocker is also a ternary link; so, therefore these are the two ternary links and both are connected at this kinematic pair, so that is a Watt's chain. This is the landing gear mechanism; let me mark out first of all let me mark the ground. So, let us say the aircraft body is the ground; then what are the ground hinges? Here you can see 1, here 1, so 3 ground hinges; so aircraft body is a ternary link.

Which is the other ternary link? You can see this; this is a ternary link with kinematic pairs here, here and here. Once again you have two ternary links; the aircraft body and this triangular link and they are connected at this kinematic pair. So, this is also a Watt's chain; there is another combination with 6-link kinematic chains.

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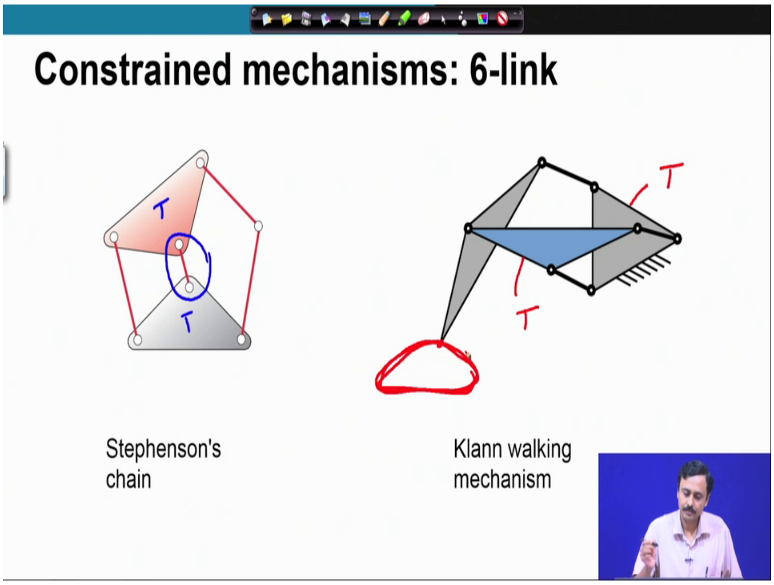

Which is known as the Stephenson's chain; here you can see that there is a binary link connecting the two ternary links. So, this is a ternary and this is a ternary and this is a binary link connecting the two ternary links; that is a Stephenson's chain. So, the combination in which these links are joined is different from the Watt's chain. So, in the Stephenson's chain; the two ternaries are not directly connected, which is there in the Watt's chain. An example of this is; this Klann walking mechanism, so let us identify the ternary links. So, this ground is a ternary link and this is a ternary link and you see they are not connected directly; the two turneries are not connected directly.

Now, this mechanism is used for in walking robots because it generates; this point generates a profile which looks like this, which is required for walking machines; now we come to robotic mechanisms.

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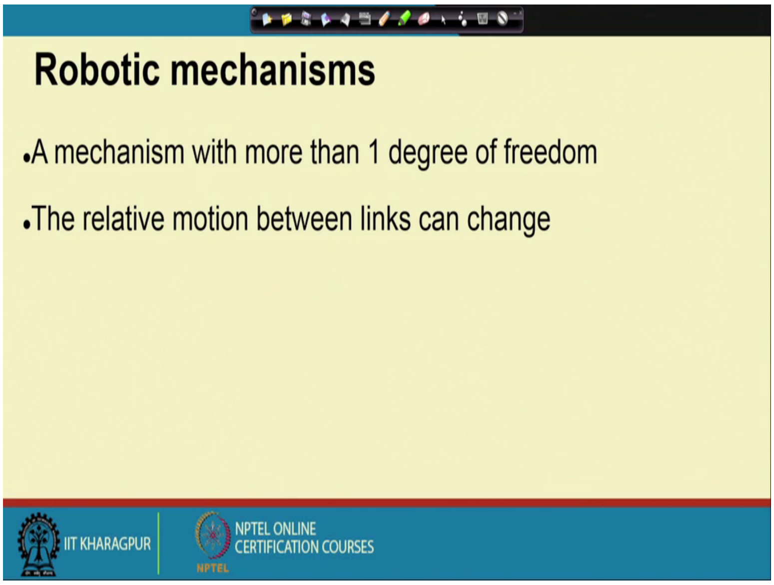

Now, in this course we will define robotic mechanisms as those which have more than 1 degree of freedom; that means, two or higher; they will be termed as robotic mechanisms. Now as I have told you in mechanisms with degree of freedom more than 1; that means, 2 or higher; the relative motion between the links can change. Now that is an advantage and in some situations or in a way that brings in some complicacy; so that is what we are going to look at now.

Now, what is the advantage of having more than 1 degree of freedom? So, my hand as I said; if I had only 1 degree of freedom, I could have only done this; maybe; it could have been this way also one; just 1 degree of freedom, but because I have multiple degrees of freedom at my hand, so I can perform various tasks like writing or doing sports.

Now we do not realize this that when we grasp an object, we are planning the motion of the hand; here in time planning the motion of the hand. When we are writing, we have to move in a certain way; now this has come to us I mean instinctively by training. But when you want 2 degree of freedom or a higher degree of freedom mechanism to do a certain task, you have to tell the mechanism which joint to move in which way so that at the end point it does the specific task.

So, you have this problem of motion planning in higher degree of freedom mechanisms. So, while you have this complicacy of motion planning; you have the advantage that you can do multiple things. That is why you have robots because it they can do various kinds of tasks whereas, constraint mechanism; they can do only one task, so they are designed that way.

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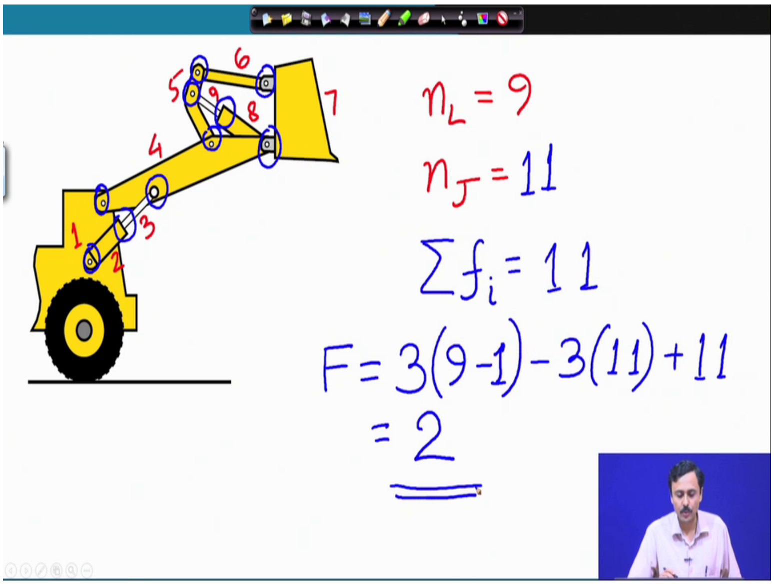

So, we look at some robotic mechanisms this is the first example; the excavator. We are going to calculate the degrees of freedom, now to do that; we must first calculate the number of links. So, ground is 1; I will consider that body of the excavator is the ground 2, 3; this quaternary link as 4, this turnery as 5, this binary as 6, the bin as 7 the cylinder of this actuator as 8 and the piston as 9.

So, number of links is 9; number of joints 1, 2 is the prismatic here; 3, 4, 5, 6, 7, 8. Now here we have two kinematic pairs; so 9, 10 and here 11. So, number of joints is 11 and summation of degree of freedom of each joint, as you have seen they are all hinges either either revolute pairs or prismatic pairs. So, number of degrees of freedom; summation of degrees of freedom of individual kinematic pair is also 11.

So, therefore degree of freedom this is a planar mechanism; 3 times number of joints plus summation of degree of freedom of individual joint. So, this gives 35 minus 33; that is 2, so this excavator has 2 degrees of freedom and that is why we require two actuators to actuate these 2 degrees of freedom. Otherwise the mechanism will not get fixed, so because we have 2 degrees of freedom; in order to fix the configuration of this excavator, we require two inputs; so, these are provided by these hydraulic actuators.

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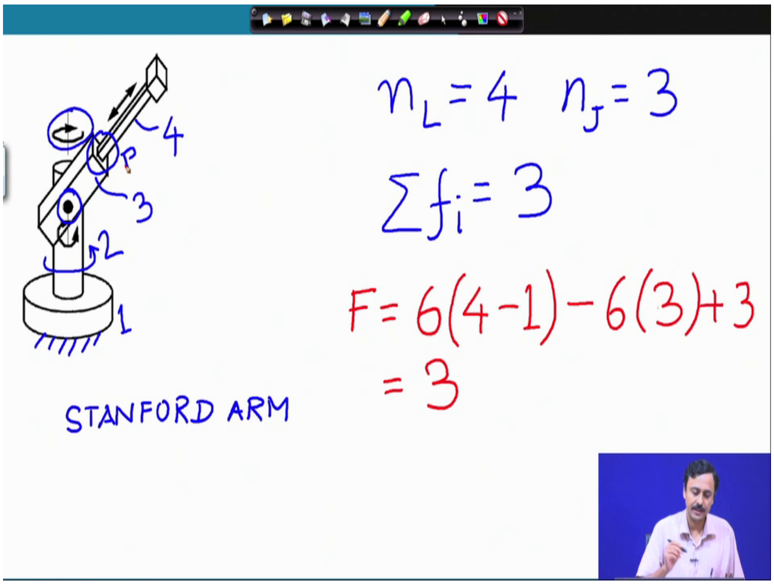

Then we have this robotic mechanism; this is known as the Stanford Arm; let us calculate the degree of freedom of this. Now this is a spatial mechanism as you can see; let me fix this as ground, with respect to this ground, this cylindrical member can rotate as has been shown. So, ground is 1; this cylindrical member is 2; this is 3 and the slider is 4.

So, in this case number of links is equal to 4, number of joints. As you can see, there is one revolute joint here; so 1, another revolute joint here; 2; one prismatic joint here. So, number of joints is 3; now summation of degree of freedom of individual join; so, they are revolute or prismatic. So, they have individually 1 degree of freedom; so 1 plus 1 plus 1; so, 3.

Now the degree of freedom calculation, remember this is a spatial mechanism. In a spatial mechanism, we have this as 6 because rigid body in space has 6 degrees of freedom. So, number of 6 times number of links minus 1; minus 6 times, the number of kinematic pairs. Number of kinematic pairs is 3; plus the summation of degree of freedom of individual joints. So 18 minus 18; plus 3, so this has 3 degrees of freedom, this a robotic mechanism with 3 degrees of freedom and we need therefore, 3 actuators. So, for these revolute joints we need revolute motors, rotary motors and for this prismatic joint; either we can have a linear motor or we can have a screw pier; the powered screw pier to move this slider. Then we have this example of what is known as a puma robot.

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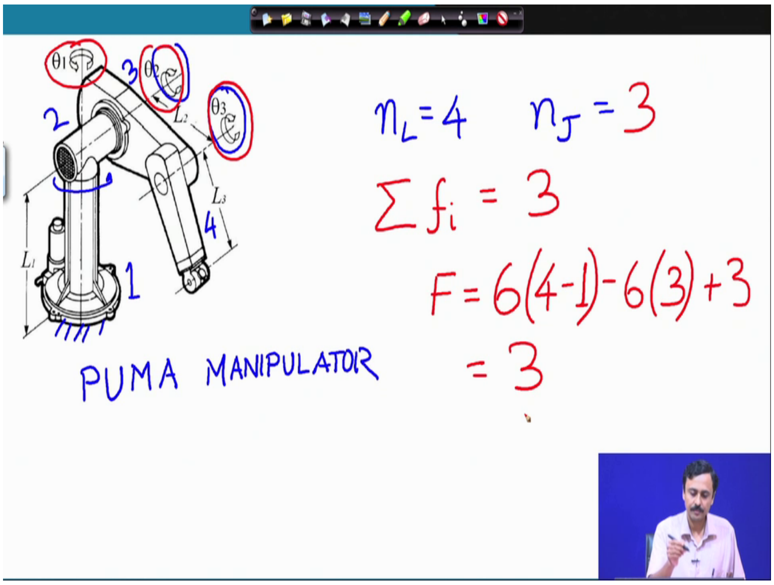

It is a puma robotic manipulator; let us calculate the degree of freedom of this. This is also spatial mechanism, this is grounded; ground is 1, here there is a revolute pair. So, this is another link 2; which can rotate with respect to 1. There is another revolute pair here as indicated here; so, this is 3, another revolute pair here; so, this link is 4. So, once again our calculation is straightforward; number of links is 4, number of joints; so we have 1, 2, 3; so, 3 revolute pairs; so 3 joints; degree of freedom of individual joints, they are all revolute pairs.

So, 3; therefore, degree of freedom is 6 times; 4 minus 1; minus 6 times number of revolute pairs plus degree of freedom of individual pair. So, this again turns out to be 3;. so this puma manipulator has 3 degrees of freedom. And these 3 degrees of freedom are actuated by rotary motors as has been indicated.

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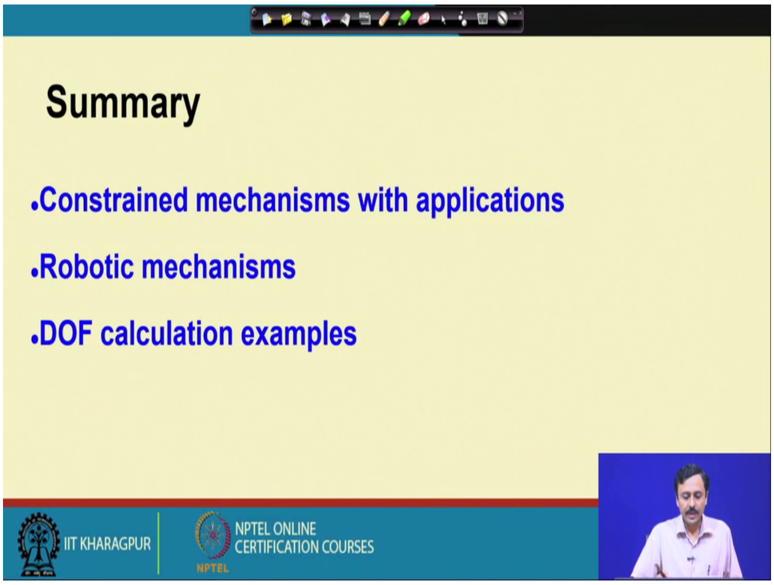

So, let me summarize what we have discussed today; we have defined and discussed about constrained mechanisms and looked at a number of applications. Actually this constrained mechanism because it is so special; it has a very special place in study of kinematics.

Because of its applications, there are huge number of applications of constrained mechanisms. Most of the time we would like to have a constrained mechanism then having a robotic mechanism. Because a robotic mechanism comes with that additional requirement of motion planning, so if it is a routine kind of manipulation or task that needs to be performed, then a constrained mechanism is the best choice.

So, we have huge applications of constrained mechanisms in automation; mechanization and we have seen many examples of that. We have looked at robotic mechanisms and we have calculated degrees of freedom of robotic mechanisms and spatial robotic mechanisms, so with that I close this lecture.