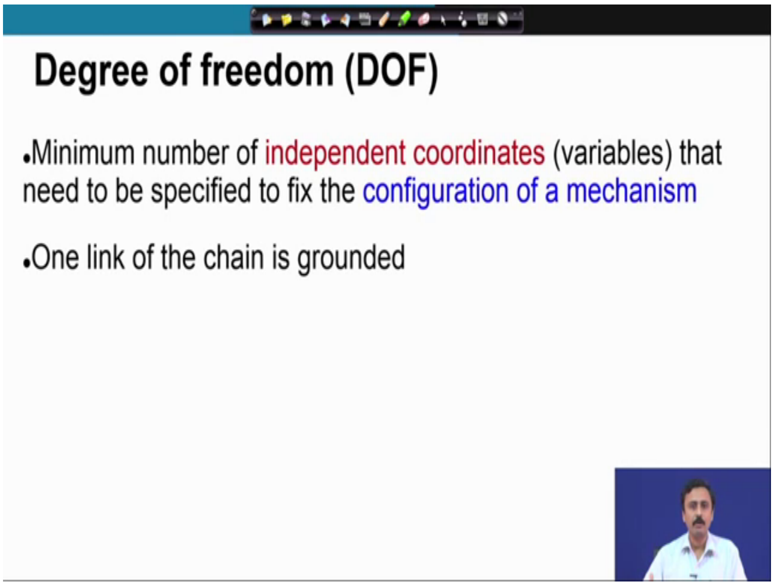
Kinematics of Mechanisms and Machines
Prof. Anirvan Dasgupta
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

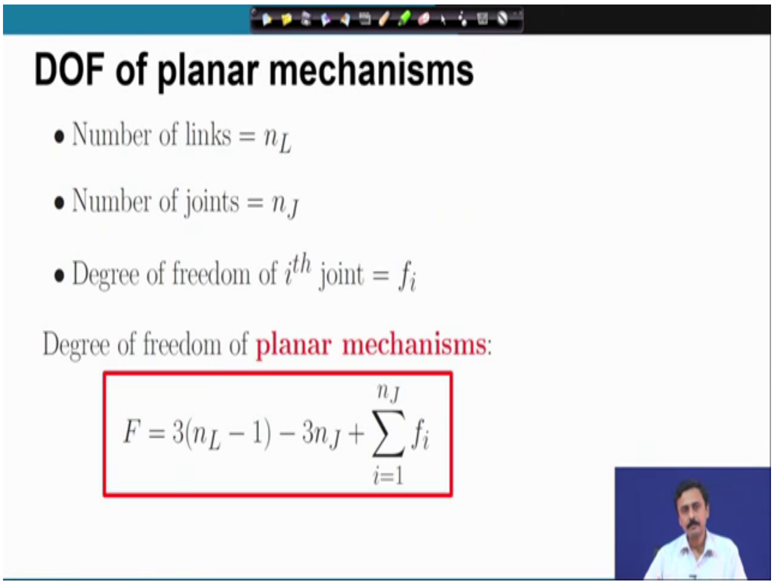
Lecture – 05
Constrained and Robotic Mechanisms

(Refer Slide Time: 00:17)



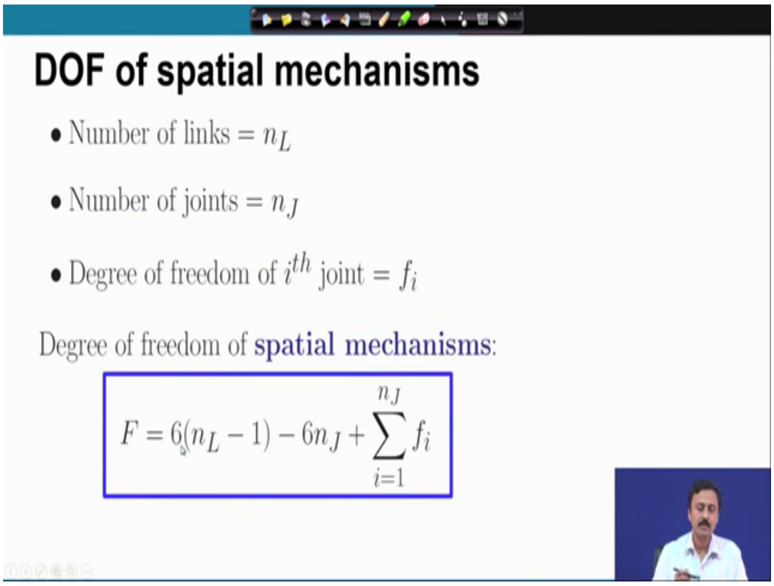
As we have already discussed the degree of freedom indicates the number of minimum number of independent coordinates that are required to be specified to fix the configuration of a mechanism or a kinematic chain. And when we define this in the context of mechanisms one of the links must be grounded.

(Refer Slide Time: 00:37)



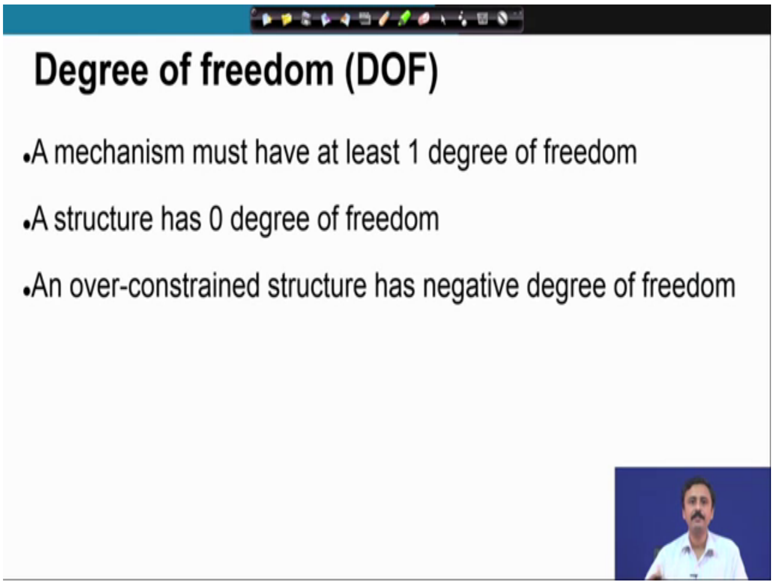
I have shown you how to calculate degree of freedom. This is the formula for the linear situation. And in the case of spatial mechanisms it is this. So, the difference is in this 3 whether you get a 3 or a 6.

(Refer Slide Time: 01:01)



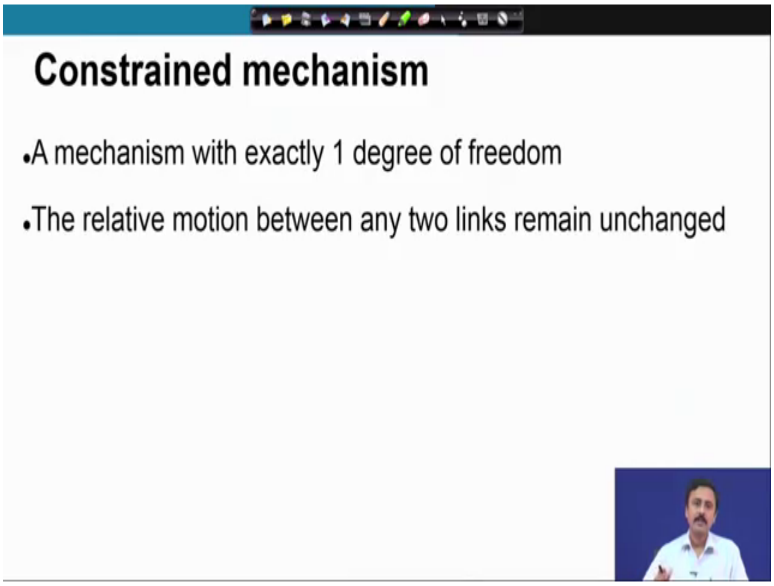
So, in the case of a planar mechanism, it is with 3; for a spatial mechanism, it is with 6.

(Refer Slide Time: 01:08)



And we have also seen what a mechanism it is a collection of links with connect interconnections, which has at least 1 degree of freedom. If it has got 0 degree of freedom, then it is a structure. If it has got negative degrees of freedom, then it is an over constraint structure.

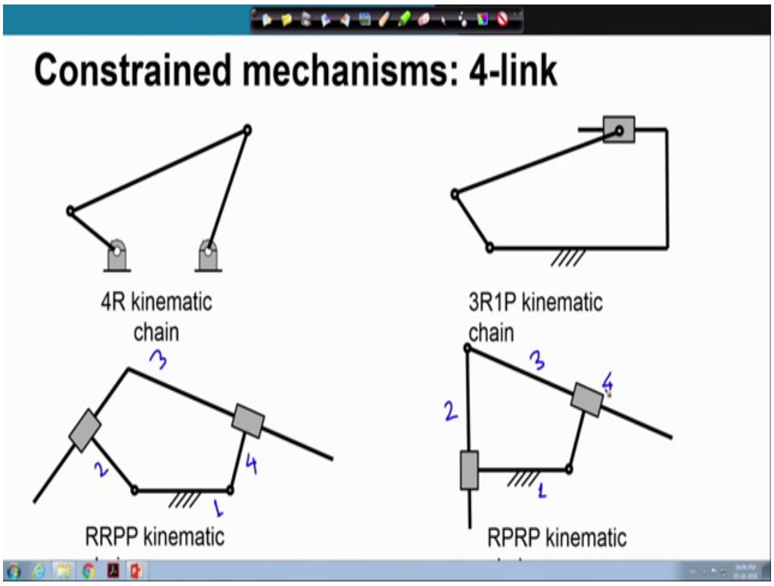
(Refer Slide Time: 01:24)



Now, in a mechanism having 1 degree of freedom, the relative motion between two links always remains fixed. Let me give you an example. Suppose, I say that I will move my hand imagine that my hand is a planar mechanism, and I will move this hand only on this line.

Then whatever you do, when I bring my hand to this position, if this is the angle, this is not going to change. I cannot change this relative motion between these two when I am moving it on a line. I am moving this; my palm on a line. But if I say my palm is free to move then you can see that this angle can be very different at different locations, it can be different. This is the difference between a constraint mechanism and a robotic mechanism. A constraint mechanism is one in which the relative motion between the lengths remain fixed. Therefore, a constraint mechanism is one in which has only 1 degree of freedom.

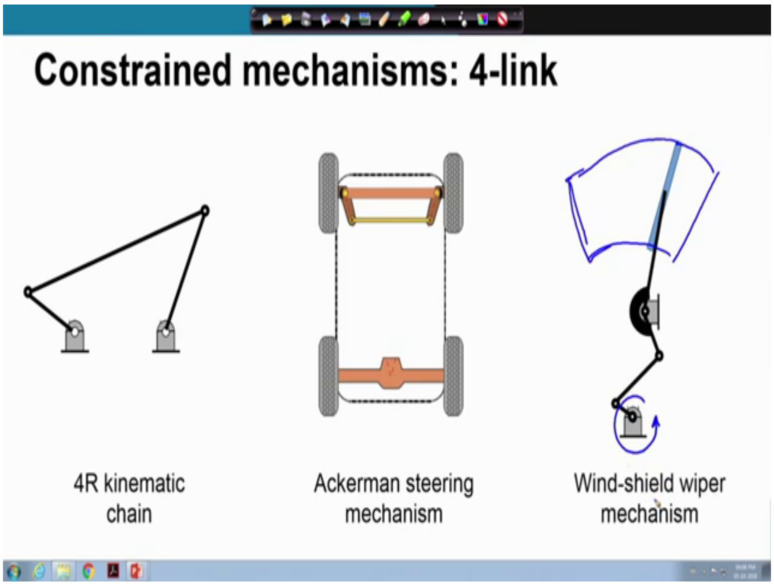
(Refer Slide Time: 02:42)



Let me look at it take some examples. This is a 4-link mechanism; we have already calculated the degree of freedom of this chain. This has 1 degree of freedom, and the relative motion of the links is fixed. There are variants of this chain, for example, this is 3 R 1 P, we have calculated the degree of freedom for this in the context of IC engines. This has 1 degree of freedom.

You can also calculate the degree of freedom of this chain RRPP all of these have 4-links. There is another example this RPRP. All these chains have 4-links as you can count 1 is the ground 2, 3, 4. In this case, 1 is the ground, 2, 3, 4; therefore, these are variants of the 4 bar mechanism or 4-link mechanism. They all have 1 degree of freedom and therefore they are all constrained mechanisms.

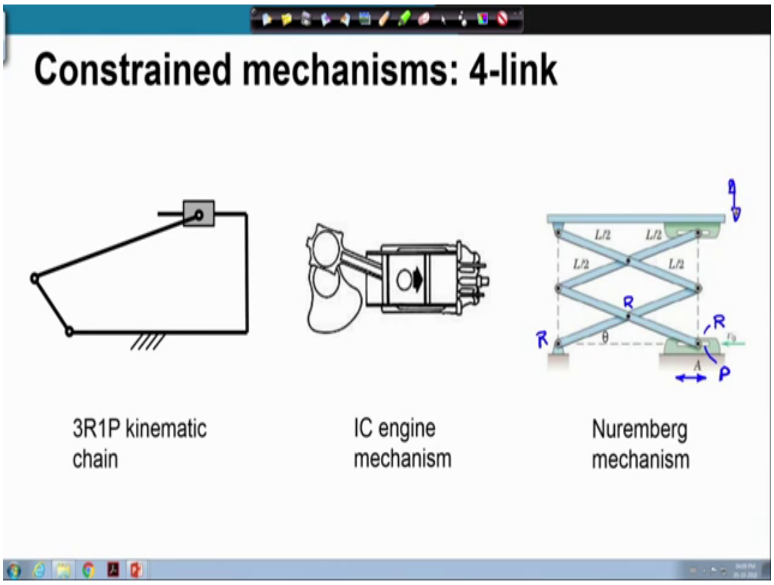
(Refer Slide Time: 03:57)



Let us look at some applications of these kinetic chains. The Ackermann steering mechanism is one application of a 4 R kinematic chain. The wind shield wiper mechanism this is also another application of this 4 R kinematic chain. As you can see here, in the steering wheel mechanism, it is the steering wheel that we control in order to steer the car that is the input to this steering wheel mechanism.

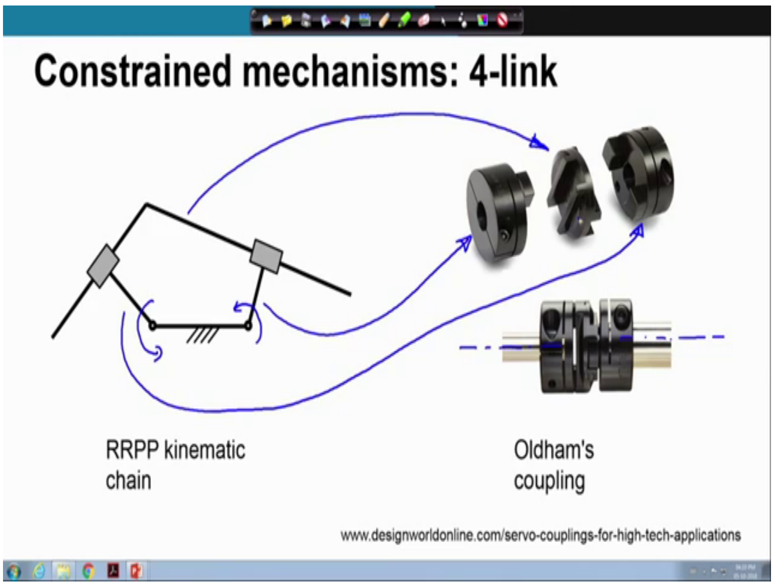
On the other hand, for the wiper mechanism, you have a motor, which is rotating here and which drives the wiper to wipe the windscreen, because they have 1 degree of freedom these mechanisms have 1 degree of freedom. They will require only one input to be specified. In the case of the steering wheel, it is the input from the driver. In the case of the windshield wiper mechanism it is the input of the motor.

(Refer Slide Time: 05:13)



The 3 R 1 P kinematic chain, we have already looked at the IC engine mechanism, which is an application of 3 R 1 P chain this is the Nuremburg mechanism which also uses this 3 R 1 P chain. So, let me point that out here there is R, this is another R here there is another R and a P so the R and P are combined at this spin that forms a higher kinetic pair actually. But this is a an application of this 3 R 1 P kinematic chain and by shifting the spin you can make this platform move up and down.

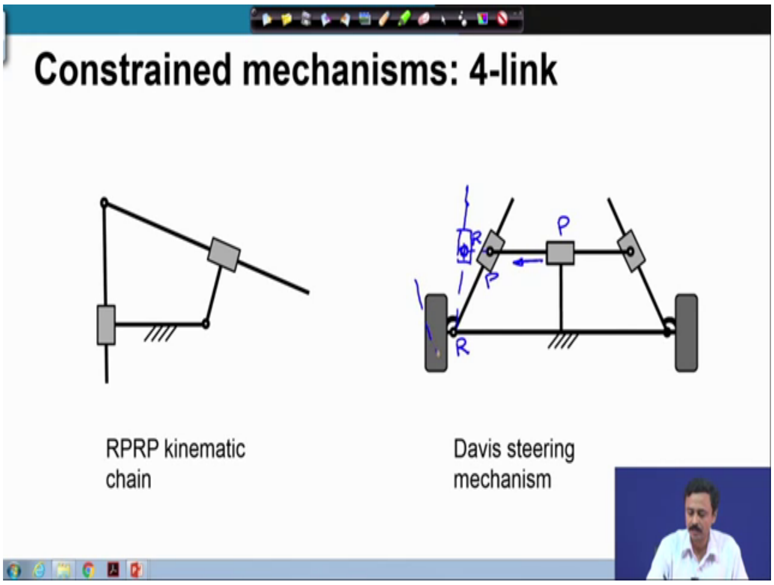
(Refer Slide Time: 06:21)



This is the RRPP kinematic chain. The application is in Oldham coupling as you know the Oldham coupling is used to connect two shafts which are not aligned. So, this shaft and this shaft they may not be aligned, there might be slight misalignment to take care of that to connect these two shafts, we use the Oldham coupling and that is an application of this RRPP kinematic chain. This link, this is one of the shafts, this is the other shaft as you can see they are misaligned their centers of rotation are not the same and what couples is this coupler.

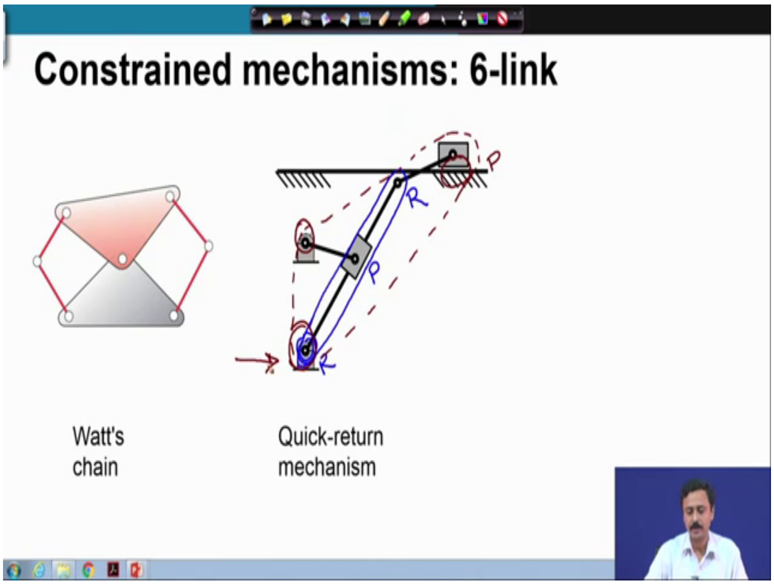
So, I can imagine that this is connected to one shaft, this element is connected to the other shaft; and in between this is coupled by this coupler, this is the Oldham coupling.

(Refer Slide Time: 07:34)



Now, RRPP kinematic chain the application is in Davis steering wheel mechanism. So, you have this P R then P and R. So, this is RPRP kinematic chain used in the Davis steering wheel, when you move this rod in one direction. This will rotate this link and hence turned the wheel.

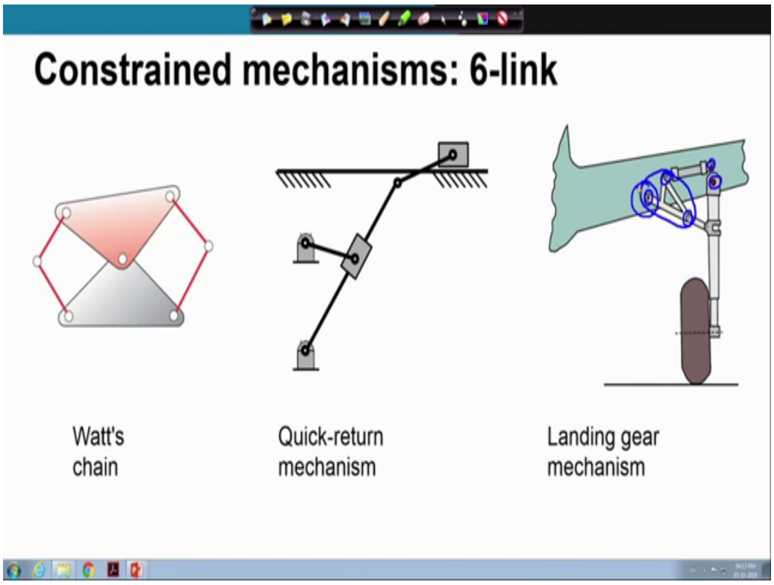
(Refer Slide Time: 08:31)



Let us move onto 6-link mechanisms. There are two variants of the 6-link mechanism one is the Watt's chain. In the Watt's chain you have these two ternary links, they have that direct connection a quick return mechanism is an example of the Watt's chain. So, let me show you what, what are the ternary links as I have mentioned this link this link is a ternary link, why this is a ternary link there is a revolute here, there is a prismatic here and again there is a evolute here. So, this link is a ternary link.

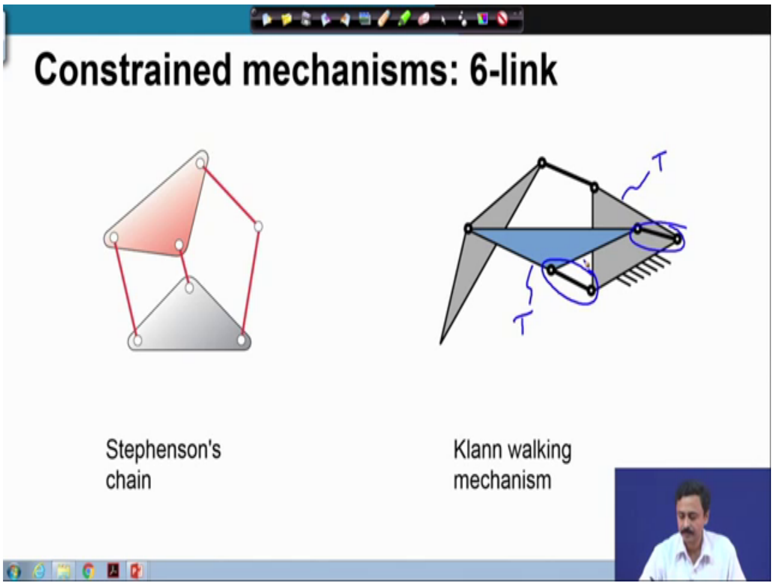
The other ternary link is the ground. So, the ground is a ternary link here there is a revolute pair here, there is a revolute pair and here there is a prismatic pair. This makes the ground a ternary link now these two ternary links are connected at this kinematic pair. Therefore, this is the Watt's chain the aircraft landing gear mechanism is also an application of the Watt's chain.

(Refer Slide Time: 10:06)



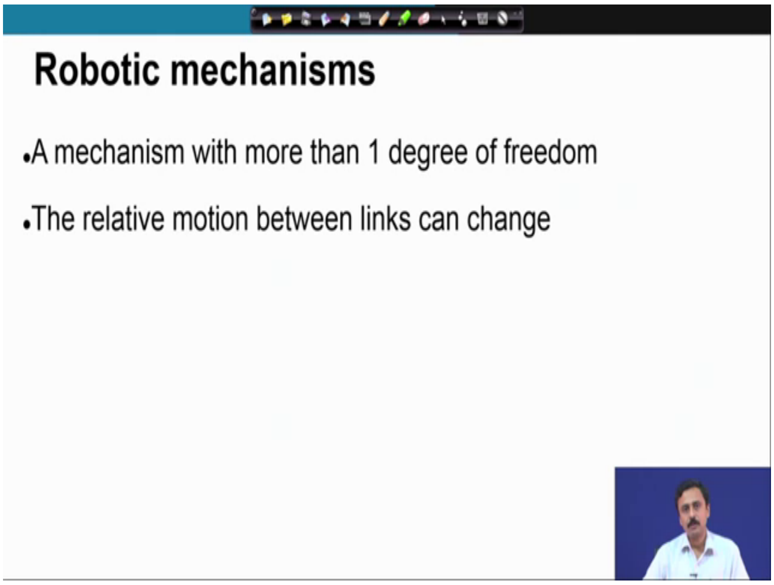
Let us see how the aircraft body is a ternary link there are three hinges, the three kinematic pairs on the aircraft body, so that makes it a ternary link. The other ternary link is this. This has again three hinges, three revolute pairs that is the ternary link, and these two ternary links are connected at this revolute pair. So, this also is an example of the Watt's chain.

(Refer Slide Time: 10:52)



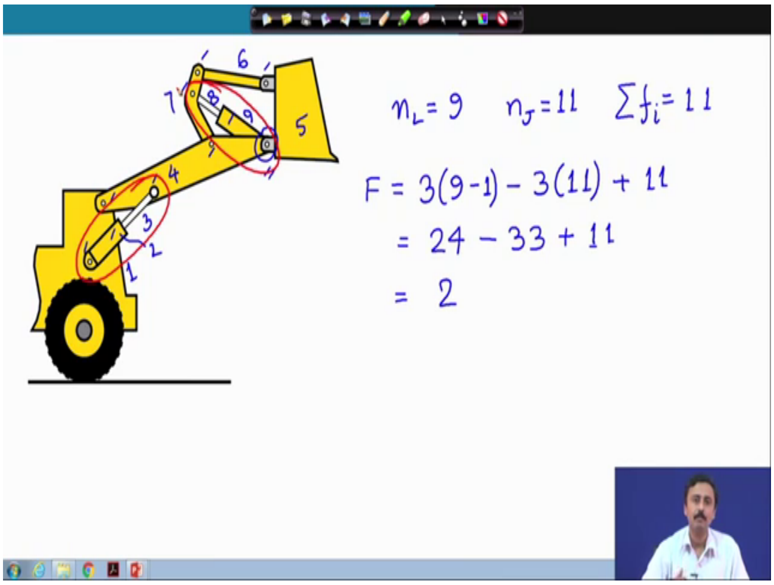
The other variant of the 6-link mechanism or 6 bar mechanism is the Stephensons chain. Here you can notice that the ternary links the two ternary links are not directly connected they have by a binary in the Watt's chain you had a direct connection here and this binary appeared here, but in the Stephenson's chain that two ternaries are now not directly connected. The Klann walking mechanism is an example of this Stephenson's chain this is one ternary and the ground is the other ternary, these two ternaries as you can see are not directly connected. So, there is this binary and this binary. So, the Klann's mechanism Klann walking mechanism is an example of the Stephenson's chain.

(Refer Slide Time: 12:07)



Now, we come to robotic mechanisms a mechanism with more than 1 degree of freedom will be defined as a robotic mechanism. As I have already explained in the robotic mechanism. Therefore the relative motion of the links can change.

(Refer Slide Time: 12:28)

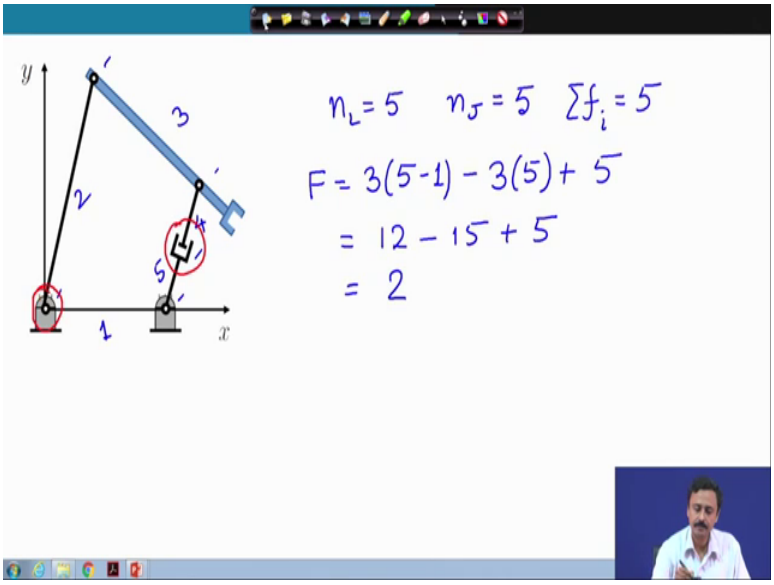


Let us look at some examples this is the excavator first. Let us calculate the degree of freedom. So, ground is 1 this is 2, 3, 4 let us a bin is 5, 6, 7, 8 and 9. Therefore, the number of links is 9 number of kinematic pairs here 1, 2, 3, 4. Here there are two kinematic pairs 5, 6, 7, 8, 9, 10, 11.

Therefore number of joints is 11 and summation of degree of freedom of each joint. As you have as you can see that each kinematic pair has actually 1 degree of freedom. Therefore, the total degree of freedom of all the kinematic pairs taken together is also 11. Therefore, degree of freedom is 3 times 9 minus 1 minus 3 times 11 plus 11. This becomes 24 minus 33 plus 11 that gives us 2.

So, this excavator has 2 degrees of freedom and that is why you have 2 actuators. As you can see, there are two actuators in this mechanism, this is one and this is one. These two actuators control these two degrees of freedom. And because the relative motion of links is not unique that is why this excavator can reach any point and move the bin in a particular manner to lift refuse or rubble. And take it to some point and dump it had it been only if it had only 1 degree of freedom, then this would not have been possible this relative, because the relative motion of links is fixed.

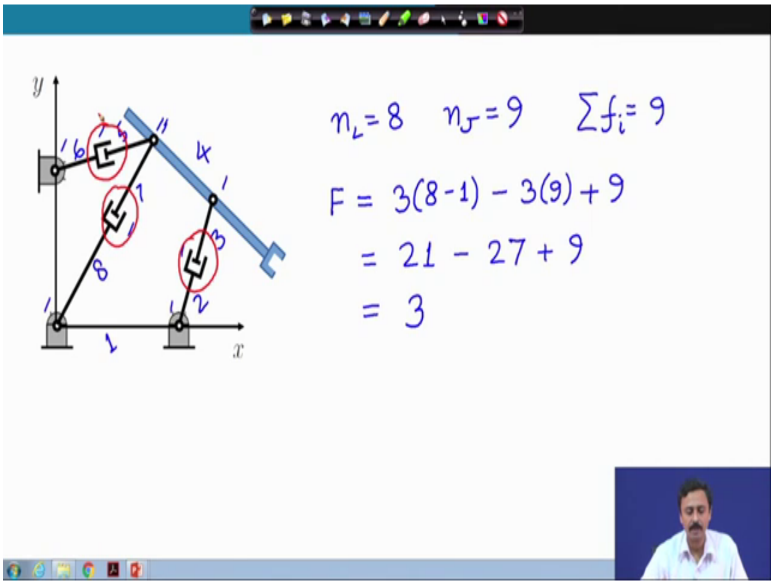
(Refer Slide Time: 15:20)



Let us look at this example. This is also a kind of robot. These are called closed chain robots or sometimes parallel manipulators. Let us number, number the links ground is 1, 2, 3, 4, 5. So, number of links is 5 number of joints is 1, 2, 3, 4, 5. So, number of joints is also 5 degree of freedom summation of degree of freedom of individual joints, they are all one degree of freedom kinematic pairs. So 5, therefore, degree of freedom is 3 times 5 minus 1 minus 3 times 5 plus 5 that gives us 12 minus 15 plus 5 that is 2.

Therefore, this also has two degrees of freedom. Now, how do you actually you must actuate let us say this hydraulic or pneumatic actuator and one of the joints may be here you can put a motor. In that case, this will be completely controllable manipulator and this is a closed chain manipulator.

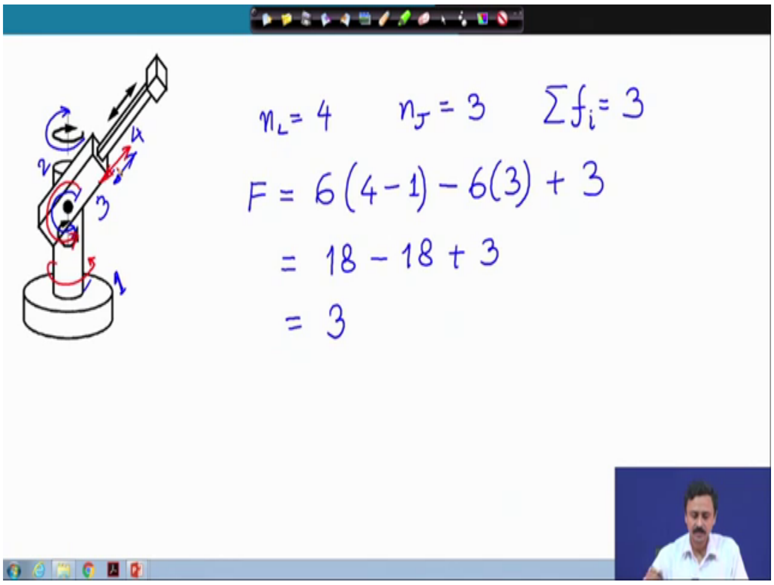
(Refer Slide Time: 17:14)



This is another example of a close chin manipulator; this number the links 1, 2, 3, 4, 5, 6, 7, 8. So, number of links is 8 number of joints 1, 2, 3, 4, 5, 6, 7, 8, 9 number of joints is 9 and summation of degree of freedom of each joint as you can see these are all R or P pairs. So, they have all one degree of freedom therefore, the summation of degree of freedom is also 9. Therefore, degree of freedom becomes 3 times 8 minus 1 minus 3 times 9 plus 9 21 27 plus 9 that gives us 3.

So, this manipulator has 3 degrees of freedom and they are controlled by these 3 actuators this prismatic actuator, this prismatic actuator, this prismatic actuator. So, this becomes completely controllable manipulator.

(Refer Slide Time: 19:10)

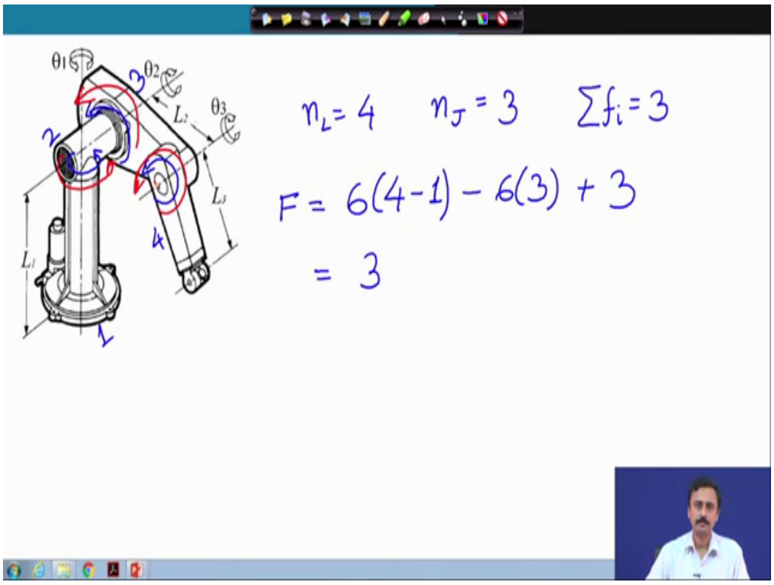


This is the Stanford arm the base is 1 this is 2 this is 3 and this is 4. Now, this is a spatial kinematic chain as you can see you have the ground as 1 and between 1 and 2 you have this rotation between 2 and 3 you have this rotation and between 3 and 4 there is this prismatic actuator.

So, therefore, the number of links is 4 number of kinematic pairs is one revolute here second revolute third is prismatic; therefore, 3 joints and summation of degree of freedom of each kinematic pair. So, these are revolute, revolute prismatic. So, they have all one degree of freedom. So, we have summation as three; therefore, degree of freedom now becomes 6 times this is a spatial mechanism remember.

So, this is 6 times 4 minus 1 minus 6 times 3 plus 3 that gives us 18 minus 18 plus 3. Therefore, this has 3 degrees of freedom and as I have mentioned these are the 3 actuators that are there we have a motor here, we have another motor here, and we have a linear motor for the prismatic actuator. So, this has 3 degrees of freedom.

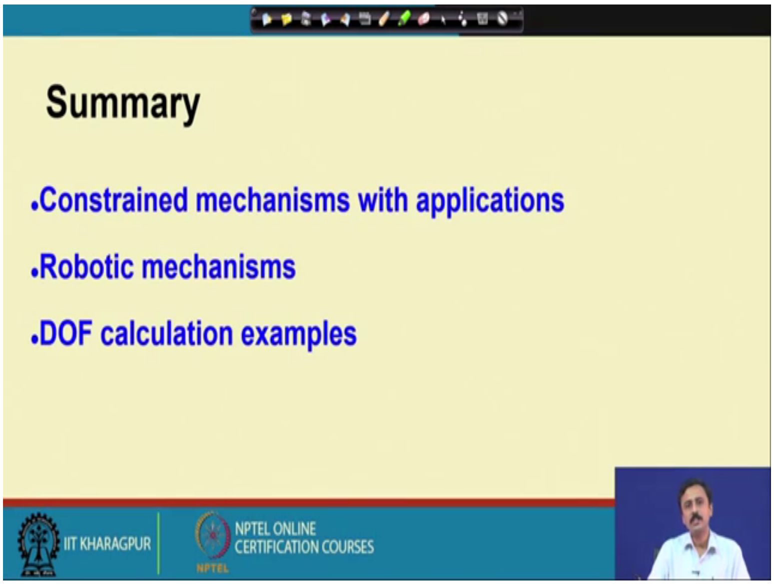
(Refer Slide Time: 21:18)



In the case of the puma manipulator ground is 1 this link is 2 there is a revolute pair here this is 3 and this is 4. Here there is a revolute pair and here also there is a revolute pair. Therefore, number of links again is 4 number of joints is 3 revaluates and summation of degree of freedom of each revolute is 1. So, 1 plus 1 plus 1 that gives us 3. Therefore, degree of freedom is 6 times 4 minus 1 minus 6 times 3 plus 3 that again gives us 3.

Therefore, this arm also has 3 degrees of freedom which are controlled or actuated by these 3 motors. This is the first motor; this is the second motor; and this is the third motor. So, this is completely controllable; so 3 degrees of freedom and 3 actuations.

(Refer Slide Time: 22:40)



So, let me summarize we have defined what are constraint mechanisms what are robotic mechanisms. As I mentioned constraint mechanisms are those which have exactly 1 degree of freedom; and in constraint mechanisms, the relative motion between the links is fixed.

On the other hand, robotic mechanisms has degree of freedom higher than 1, so it is 2 and above. In robotic mechanisms, the relative motion between links can be varied and this is what makes robots very flexible, because it can generate arbitrary motion. Then we have looked at examples and calculated the degree of freedom, and we have also looked at parallel manipulators, their degrees of freedom. And therefore in this lecture we have considered this classification of constrained and robotic mechanisms.

With that, I will close this lecture.