Lecture 28

Theory of Mechanism

Auxiliary Point Method: Contd.

Let's look at, another example today.

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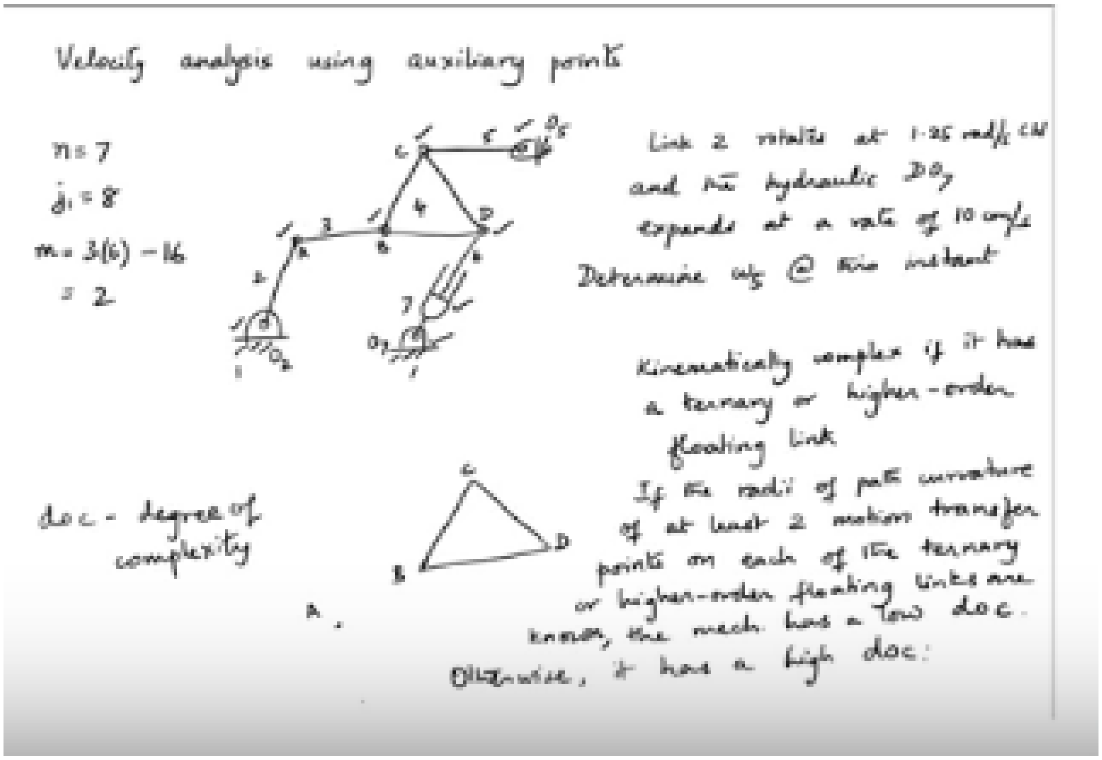

Which is quite different from, what we have seen. Okay? So, so this is a,, seven link mechanism ,so anytime you encounter a new mechanism, it's probably a good idea, to do a mobility check. Okay? Can you do a quick mobility check on this? So this is actually here, mechanism with mobility equal to two. Okay? The fact that the number of links, were not even, because that is the condition for, mobility to be equal to one. Okay? That itself should have given you a clue, that this is likely to not have a mobility of one and you know there are no idle degrees of freedom either, so it is a true-blue mobility equal to two mechanism .Okay? So that means, it needs two inputs, two velocity inputs, so let's say, link 2, rotates at some Omega, say one point two very clockwise and the hydraulic actuator, so say this is a, see the and this is 47, so the hydraulic actuator do7, expands at a rate of 10 centimeter per second .

So you want to find omega 5, at this instant. Okay? So what you're given here, when you say the hydraulic cylinder, do seven expands at that rate; I'm given the relative velocity between six and seven, along that. Okay? So that's, so it's the relative velocity component that I know, so I don't know the absolute velocity of D, would D have some other component of velocity as well, because of rotation about o seven, it would have a component, which is perpendicular to o seven D, but I don't know what that is, because I don't know Omega six, or Omega seven, both of which will be equal obviously here.

So this is not a typical problem, that you could solve using your velocity difference method, instant centers also you can try ,but you will find that this is not really amenable to that. So what we will, we will look at applying the auxiliary point method, to this, to solve this problem, so let's take the ternary link. Right, C, B, D, this is the floating link. Okay? I know the velocity of point a. Okay? point a, so B,C,D are my motion transfer points, to this ternary link and this is actually ,it's called this is a mechanism, that's considered, a mechanism with a high degree of complexity, kinematic complexity.

Because, so the kinematic complexity comes from, so mechanism is cinematically complex, if it has a ternary or higher order, floating link and if I don't know the path, of two of the motion transfer points on the, the path curvature of two of the points, motion transfer points on the ternary link, then it's called a mechanism with a high degree of complexity. Right, here I know the path curvature for Point C, because link 5 is pivoted to the ground. But B, as well as D, in this case, I don't know and even if I try inversion, or something like that, I'm not really going to, it's not easy to determine this one. Okay? It's not simple mechanism, so this is, let me just write down the definition of, if the radii I of path curvature, of at least two motion transfer points, links are known.

The mechanism has a low degree of complexity; otherwise it has a high degree of complexity, so doc is degree of complexity. Okay? So, in this case, you have a mechanism with the high degree of complexity, so let's try the velocity analysis, using the auxiliary points.

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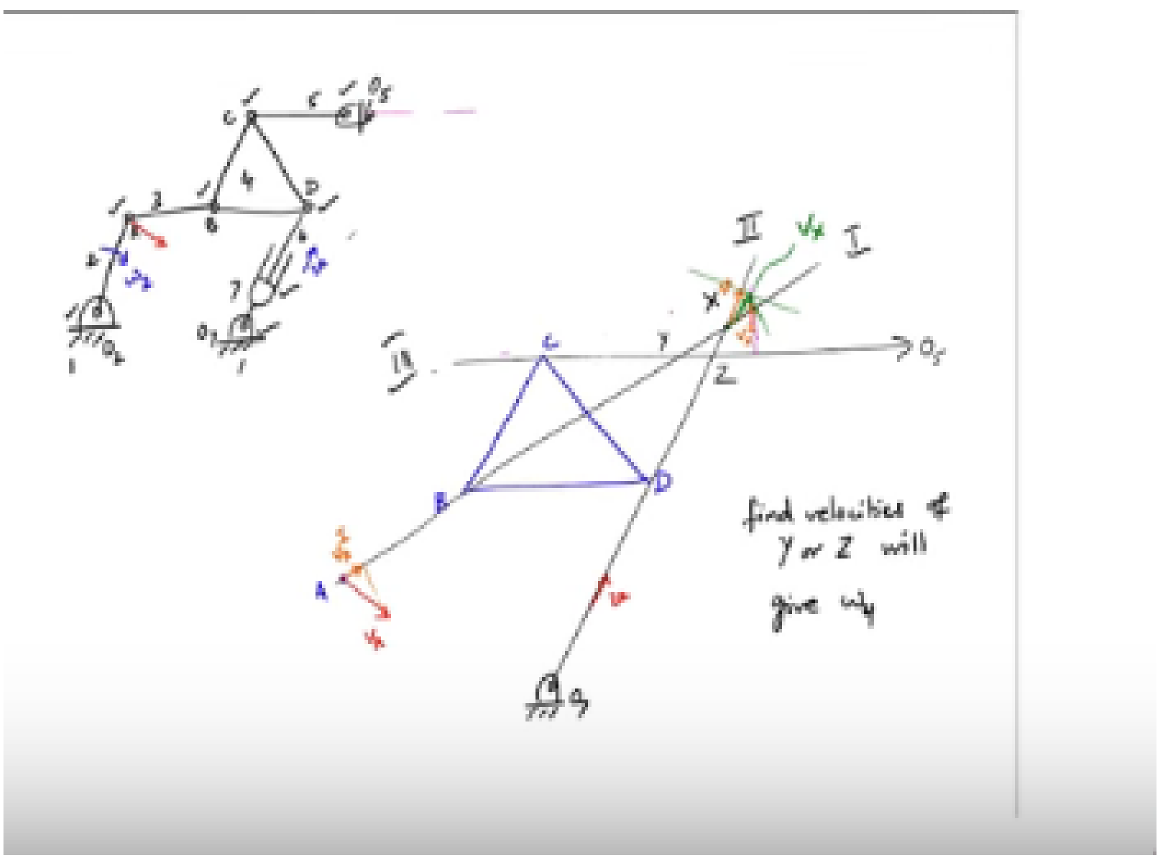

So let's look at the ternary link of this. Okay? I have this link, I'll just for clarity, just explode and it has the motion transfer points, B, C and D. Okay? And, I know the velocity of point a, so I'm given Omega 2 here and I am given this velocity here. Okay? Those are the two, things I know, two velocity inputs I have, I have Omega two and I'm given the velocity at which this, hydraulic cylinder is expanding. Okay? So if I look at a, I know the velocity of a completely.

Right, so this would be the velocity of a, so this is known completely and b is a motion transfer point, so I can take an auxiliary line, from a, through B, take that as my first auxiliary line. Okay? Now, there's another velocity I know, which is this velocity here and that is along this line O, seven, D. Okay? So the other component of the velocity is perpendicular to this, so that's not going to be transmitted, so if I take an auxiliary line, which is, said this is my O seven ,you know which is along this. Okay? Then, I know the component of the velocity that's transmitted, because I know that velocity, this V. Okay? So I have, V that is being transmitted in this direction, the other component is perpendicular to O seven D and therefore, is not transmitted through this, along this line, through some other line. Yeah, but along this line, it is not transmitted.

So now, if I look at this auxiliary point X, I know two components, along two different directions. Okay? So I know, so if I take, this is VA along one, that's going to be transmitted through B, to X, so this would be VX, along one. Okay? The second one is, this B, transmitted through D and that will be equal to this, so these are two components that I know. Okay? So that means, if I draw the perpendiculars to these two ,the velocity vector for that will lie on the intersection of those two. So if this is my point of intersection, they named this. Okay? Then this gives me. What is this? This gives me the velocity of X. Okay? So now, I know the velocity of one Point, on thee, as I still need one more, so I need one more auxiliary line. Right, so one thing that I know is O, 5, C. Okay? This is necessarily, the oh five X. Okay And O five I don't, so X I know the velocity, but this is not purely rotating about O five. Okay? So I cannot consider, O five and X, to be on the. Okay? So yes in, in case of A, B, so your question is, can it, can I draw O, 5, the third motion, the third auxiliary line from O five to X.

Yes, X is not a motion transfer point. How would you like to use it? If you want to use it, how would you like to use it. Okay? So this method will relies on, how the motion is transferred, through the motion transfer points. Okay? So with this, if I look at, there is one more motion transfer point, through which, I can draw the third auxiliary line and I do know something about, how the motion is transferred through this point C. Right, because Co, five is, so I can draw, let's say, I draw the third auxiliary line, through C and X. Because now I know the velocity of X is also on this coupler and I know the velocity of this, I know another component also, for the velocity of C, see that's the thing, I need to have to determine, the velocity of any point, I need two components, I need two components, so now because, I have the velocity of X completely determined, I can draw the third the auxiliary line, through C and X.

Now, I can find, the velocity of X, along the line three and that's what is going to be transmitted, that's going to be the same, as what is transmitted through C, along that line, so if this, so this one here, will be equal to VC along three, will be equal to VX along three, so the other thing I know is, because how is it. How is this, an auxiliary line, no, no so it is, a point for which, you know the velocity. Okay? You want to find two directions, for the velocity of a point.

Right, now I know the velocity of point X. Okay? So I know the, if I draw the auxiliary line connecting, see, see D, X, see there are now points on the same body. Okay? So that, that is the basis for what we are doing, here they're all points on the same rigid body, so if you take any line, there the velocity that's transmitted has to be equal. Because the distance between those don't change, so if I know the velocity of X and I draw the auxiliary line CX, then this velocity VX along three, will be equal to VC along three ,I am kind of working backwards now, drawing a line through co5. Okay? If it does yes, yeah you can do that, because you can in, in this case, so for instance, so if I have C, maybe actually, in this case probably, say O five is here. Right, you can, you can do that, you find another point like that, instead of, I can find another. Let me see, if I can, so I know that the velocity, the absolute velocity of C, has to be perpendicular to o5c.

We don't need, see we are talking, so this is O five. Right, so you're saying ,let me take, co5 an auxiliary line, through co5, what I know about C, is that zero velocity is transmitted ,so D necessarily, I know that the velocity of C is perpendicular, this is exactly what I am going to use. But I need another point also; I need another velocity component for C. Okay? That's what I used X for. Okay? So I have, this is one component, let's say I already have this now .Right, from X, I have this, the other thing is, I know that the other, the absolute velocity has to be perpendicular to O, 5, C. Right, so that means, so this, this would actually be like a, very short, if this is the other component is perpendicular to this, so the other velocity is this. Right and the sum of these two components, should be perpendicular to both O, five, C.

So that is, so these two will not meet, that's the problem here; essentially these two perpendiculars have to meet. Okay? Because of my choice of this, so let me just write down; write down the steps, instead. Okay? So you have VC, one component is V, X, 3. X intersects somewhere else, yeah so if you assume, x intersects somewhere else. Okay? So let's say X was here and we get, let's say VX, we see along three, is along this direction, then I have, the head of the velocity vector BC, should be on that line and it should also be perpendicular to, so if this is O 5 here. Okay? It should also be perpendicular to O, 5, C, so wherever these two meet. Right, that point will give me the absolute velocity of C. Okay? So this, because it resolves into these two perpendicular components. Okay? It, the problem was with, the choice of my X, so X if, if X is somewhere here, then my problem solved. Okay? So this would be my third auxiliary line, I could have picked, so I can pick, out of 1, 2 & 3, I can pick some other auxiliary point also.

You know, whatever is available in the, in my working area. Okay? So that, so this is the, so once I do this, now I have the absolute velocity of C, which means I can find Omega 5, will be this by O,5,C. And the direction would be in this case, it would be clockwise, because of the direction of this velocity, how is the second auxiliary point chosen, so in this case, I am just, so an auxiliary point comes at the interaction of two auxiliary lines. Okay? Here, there could actually be another auxiliary in this case, it’s no, so here I have taken, the third auxiliary line, between C and X here. Okay? So, I am using one auxiliary point and in slopes and I'm using C directly.

C is the auxiliary point in this case ,no but there is the second, you know here, it's not, because ,I know something about the absolute velocity of C. Okay? Otherwise I could take another auxiliary line, so here I have, let's see what, what are my other possibilities for auxiliary lines ,I can take suppose, I take the auxiliary line, through C and O five. Okay? Then, that would intersect, two and three at some other points. I can take any of those points, I can y & z, I could take those as well, here because ,directly I can find velocity of C, I use C, I, I could just take, the third auxiliary line, instead of between C and X, so instead of taking the third auxiliary line, through C. Okay? I could take the third auxiliary line, along C and O five. Okay? So this, is in the direction, you know this is a long, C and O5.

Then I have Y, I have Z also, I can choose any one of those, again the same thing, velocity of X, I know along that auxiliary line, I apply that to Y, and then do that. Okay? Yes, yes, yes, so if I want omega 4, I would need Y or Z. Okay? So Y or Z will give me Omega four, finding velocities of YRC will give Omega four and then I can use that to find that, here without finding Omega four, I can directly find omega five, by taking CES, my auxiliary point yeah, yeah once, once you find that you can find. Because I already know the velocity of two points, if I know the velocity of C and I even know the velocity of X, that's all I need to find Omega four, so I, so I can do that in one shot, basically if I take C, here I would find this and then I would have to find Omega five, because from this, from Omega four, I'll find the velocity of C and then calculate Omega five. Okay? So this is the auxiliary point method, so for example, we've not really analyzed, these kinds of mechanisms before, complex mechanisms, by any of the regular methods.

So the perpendicular component at D is not transmitted, so we are not really concerned, so in a practical situation, this is probably what you're going to know, if you know the hydraulic actuator you know, what at what speed, that's operating, so you would know that velocity, along the line of action of that actuator, it's unlikely that you would know both Omega, of the actuator and the line. Okay? Because that a typically not be an input, if this is the actuator, this is what you're going to give, you're going to give it a velocity along that direction. Okay? So that's what the auxiliary point method helps you to do. Okay? So now we have looked at graphical methods, which so can give you a quick, they are fairly quick, intuitively, they're quite intuitive and so they can give you, if you are only interested in a few positions, and you know the position analysis, they give you a good idea of how the mechanism is going to move.

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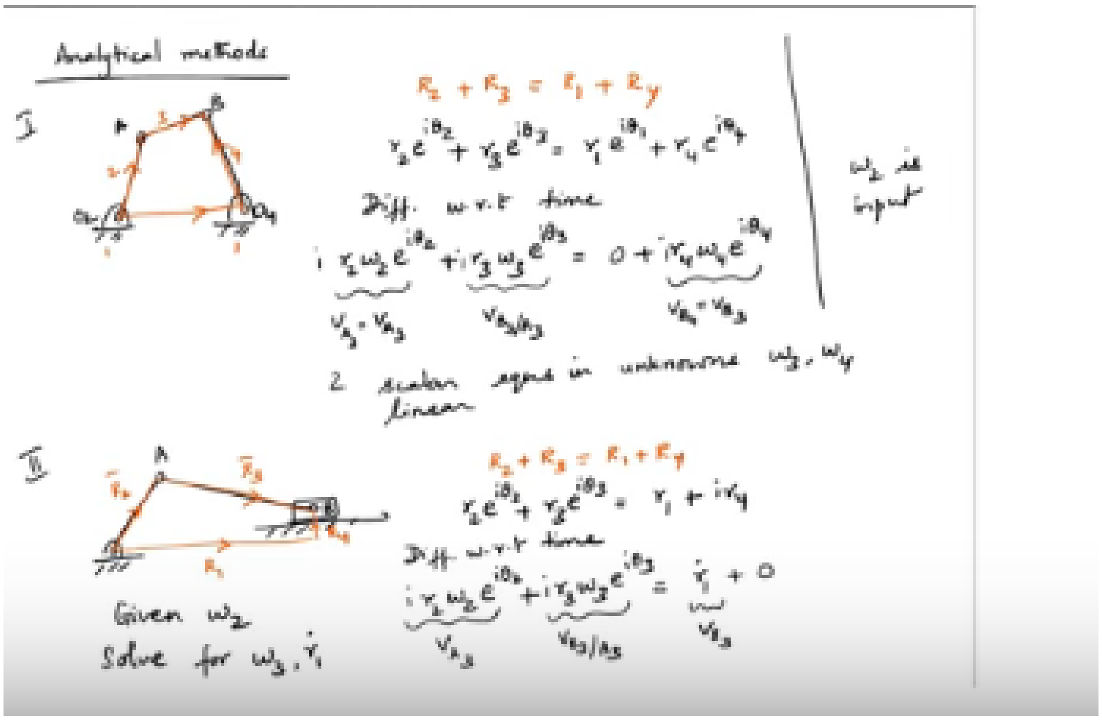
We look at the



analytical methods, now the idea is. Okay? Can be solve, you have already seen, I'll quickly, just it, go through, so I have O, two, O, four, A, B. Here, old friend the 4-bar, you have, so we do the loop closure. Okay? So say, this is linked to, say I can. Okay? So I have R 2, plus R 3, equal to R 1, plus R 4. So I have R 2, R 1, E bar, I theta 1, plus assuming position analysis is done, you know all the Thetas, you know all the R, you know all the Thetas.

You differentiate, with respect to time and you get R 2, Omega 2, E power, I theta 2, plus R 3, Omega 3, E power, I theta 3, equals the fixed link does not change, so you have theta 4. Okay? Now you should be able to recognize this. What is this? This is the velocity of a, on body 2, which is the same as, the velocity of a, on body 3, write this expression here, is the velocity of B, with respect to A and this, here is the velocity of B, on body 4, which is equal to the velocity of B, on body 3. So remember, the vector equation that we solved, for the graphical analysis, it comes directly from these equations, you have velocity of B on body 3, equals velocity of a, on body 3, plus, the velocity difference, B on body 3, with respect to a on body 3, so this is where that comes from, so again you have two scalar equations, in the unknowns.

What are the unknowns here? Omega3 and omega4, remember, Omega 2 is your input, it could be, I mean, if it's a mechanism, that’s driven by the coupler, Omega 3 could be the input, doesn't matter, but you need one velocity input and using that you have two scalar equations, in two unknowns, so you can solve for the other two angular velocities. Okay? So this is our four bar, slider-crank. So I have R 2 ,plus R 3, equal to R 1, plus R 4, R 2, E power I theta 2, plus R 3 ,R 1 plus I R 4.

Because, we choose R 1 and R four, such that, R 1 is along the sliding path, parallel to the sliding path and R 4 is perpendicular to the sliding path. Okay? Because it's easier to handle it, by separating out the sliding motion from thee, because R four remains constant, so again, now when we differentiate, with respect to time, the nice thing about the velocity equations, if you look here, even for the fourth bar, is that because, the position analysis is done.

The theta 2, theta 3, theta 4, they're all known. Okay? These are linear equations, to linear equations, in unknowns Omega 3, Omega 4, so velocity analysis is easy to do, once only the position equations are non linear, velocity equations become linear. Okay? So here, now when we differentiate with respect to time, I have R 2, Omega 2, e power I theta 2, plus R 3, Omega 3, e power I theta 3, is equal to R 1 dot, plus zero, the offset does not change with time, they're all right, right I hear it all gets canceled out, but here it doesn't. Thank you, so here also it's there, but what happens is, it will get canceled out, but you're here it doesn't, so thank you for pointing that out. Okay? So now when you look at this, this is the velocity of, what is this the velocity of, a on forty three, or two ,this is the velocity of B, on body three, relative to a on ,body three, and this is the velocity of B, on body three, absolute velocity of B ,on body three.

Because it moves along the slider path, so this is again the same equation that we used to construct your velocity polygon. Okay? So that follows from this, so if you, if you forget how we got that, this is how you get that. Okay? So that gives you this. Again you can separate into real and imaginary parts and solve for what are your unknowns here? Omega 3 and R 1 dot. Okay? Given Omega 2, could be R 1 dot is your input, that's also possible, in which case you solve for Omega 2 and Omega 3, either way you get a set of linear equations. Okay? Because, position analysis has to be completed, before you do the velocity analysis.

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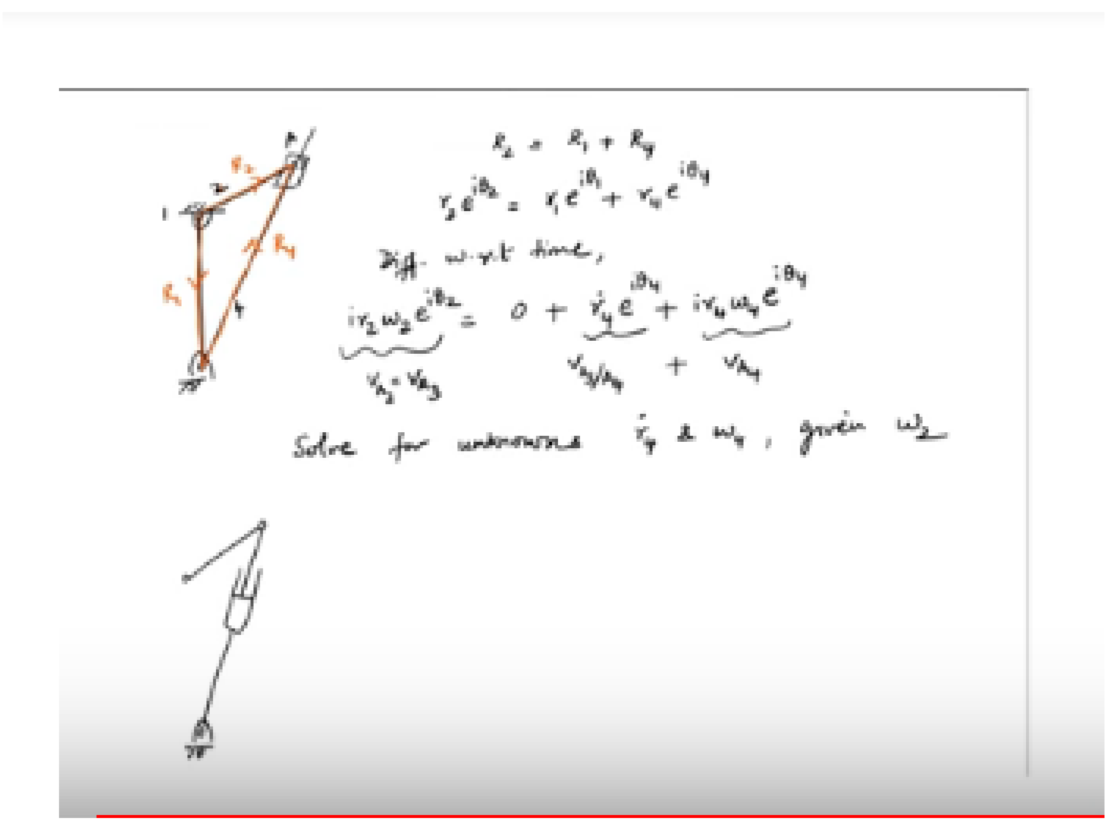

The third one, that we looked at earlier was, this case, the inverted slider-crank and length two, length three, this is length four, so I have r2, equals r1, plus r4 ,my loop closure equation R 2, E power, I theta 2. Okay? Now ,when I differentiate with respect to time, I have I, R 2, Omega 2, E power I theta 2, equals R 1 does not change and when I differentiate this, R 4, E power I theta 4. Okay? This is different, from the previous case, because R 4 is no longer constant. Okay? This point R 4, the length, R 4 is no longer constant. So I have an R 4 dot. Okay? E power, I theta 4, plus I, R 4 Omega 4, E power I, theta 4. Now if I look at this, this is the velocity of a. Okay? A on body 2, which is equal to the velocity of A on body 3. What is this? This is the velocity of a, on body 3, with respect to a, on body four, the coincident point at that particular instant, so this is your slip velocity.

R 4 dot and it is along the link four. Okay? Plus this velocity here, is the velocity of a, on body four. Okay? Remember what we, you be used coincident points to set up that vector equation earlier, it follows directly from the loop closure equation. Okay? Essentially again, vector equation two unknowns, solve for, what would be your unknowns, slip velocity and Omega four, given Omega 2. Okay? Or if you know the slip velocity, like we had in the case of a hydraulic actuator, then you can find the other two components of the Vela, you can find the other two omegas, if you know this. Okay? Because this you know, this could be configured as like this right.