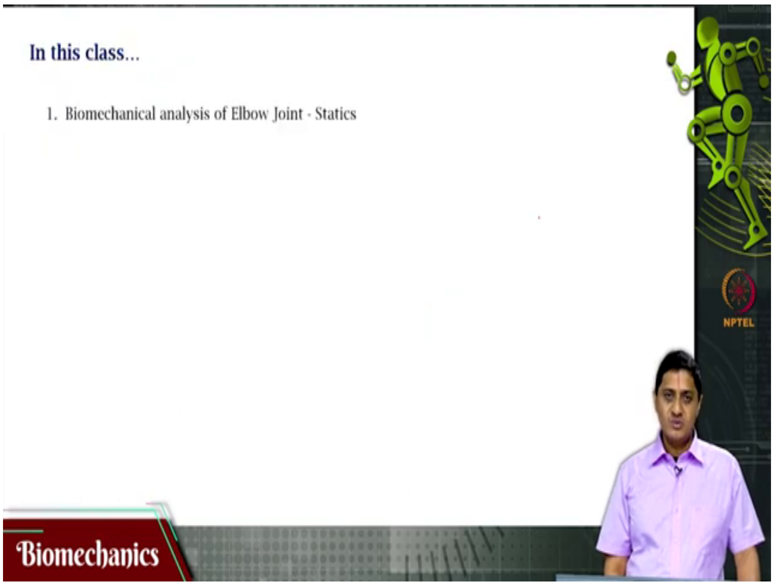
Biomechanics
Prof. Varadhan SKM
Department of Applied Mechanics
Indian Institute of Technology – Madras

Lecture – 26
Elbow problem 2: Biomechanical Analysis of Joints of Upper Limb

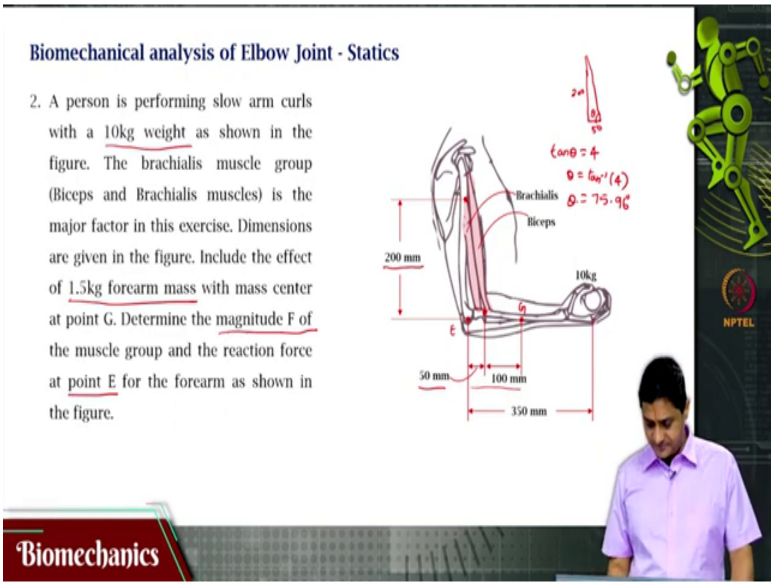
(Video Starts: 00:17) Welcome to this video on Biomechanics. We have been looking at biomechanical analysis of the joints of the upper limb. Specifically, we have been looking at a static analysis of the elbow joint. In the previous video, we saw one simple problem involving statics of the elbow joint. **(Video Starts: 00:41)**

(Refer Slide Time: 00:41)



In this video, we will see one more problem involving the elbow joint static equilibrium.

(Refer Slide Time: 00:48)



Here is the problem a person is performing slow arm curls with a 10 kg weight, as shown in the figure. The brachialis muscle group actually the brachialis, brachioradialis and the biceps brachium. This is what is called as a brachialis muscle group. Rather the biceps and brachialis muscle group is the major factor is the major muscle that is involved in this exercise which is for your information that exercises.

I am performing elbow flexion, the muscle is responsible for elbow flexion are biceps a brachioradialis and brachialis. Dimensions are given in the figure include the effect of 1.5kg of forearm mass. Forearm mass is acting from this point G which is at a distance of 150 mm from the elbow joint. This is the elbow joint G is at a distance of 150 mm from the elbow joint.

Determine the magnitude F of the muscle group is not a single muscle, group of muscles. So, we let us assume that the total force produced by all these muscles is some force F and that is what is required to be determined. Determine the magnitude F of the muscle group and the reaction force at point E of the forearm as shown in the figure. We need to find the reaction force also.

So, we have to write the sigma F x = 0 sigma F y = 0 equations also as required. What I know is that the point of attachment or the insertion of this muscle group is given to be 50 mm. That is my understanding and that is correct I mean this is the elbow joint here. And the point of insertion is a single point assumed to be a single point here is acting at a distance of 50 mm that is fine.

But I do not know the angle at which this force is acting. So, I do not know the direction of the force interesting. Because I do not know the magnitude of the force. I also do not know the direction of the force. But what I do know is? That the point of origin is given to be 200 mm. I do not know the direction of the force. But I know where the origin and insertion are in the global reference frame or in the reference frame involving the elbow joint.

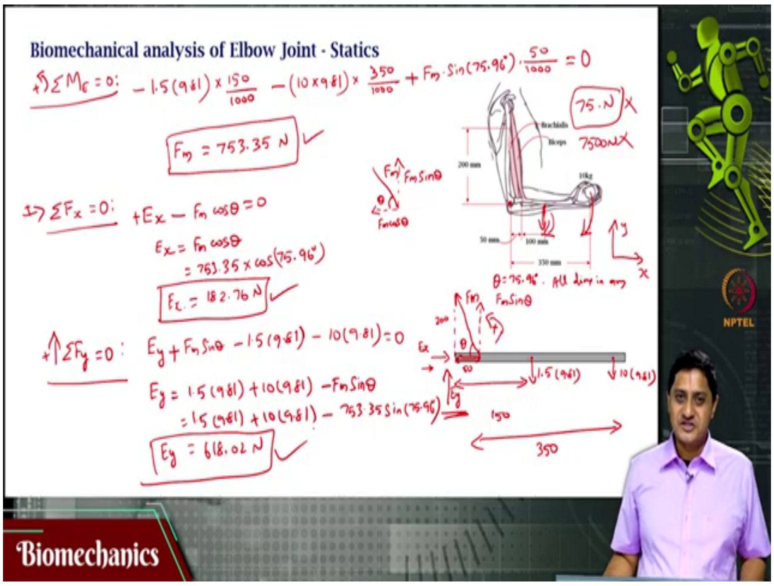
So, I know this may be using that I can compute the direction I still have to compute the magnitude. So, it seems like this problem is slightly more involved than the previous problems. We need to practice more problems. So that we will be in a position to solve these kind of problems and more difficult once and more challenging once in the exam. And maybe in a position to apply this on our day-to-day life or as needed by you.

Now, first of all, let us try to see if our understanding of the direction is correct. So this distance is given 50 mm and that distance is given. That is 200 mm. This Is 50 mm. That distance is even 200 mm and the muscle is attaching like this. Is it not? This is the muscle attachment. Well, actually, it is not a single muscle but let us assume that for the purpose of this. This is the point of origin and this is the point of insertion.

The question is what is this? Why do you have to know this? Because in my computation of the forces, I will need to resolve for these forces as a function of that data. Is it not? This is something that we do on a daily basis or problem to problem basis. We need this direction, we need this data. So, what I say is? This distance is 50 and that distance is 200 mm. Well straight away I know the opposite side and the adjacent side is it not.

So, I say tan theta is opposite side by adjacent side. Is it not? So that is force theta is tan inverse of force which is 75.96 degrees. This is the angle at which the muscle forces acting with respect to the horizontal. Now, I am in a position to start solving this problem.

(Refer Slide Time: 05:52)



Now, let us draw the free board diagram of this. This is the elbow joint, elbow joint is free to rotate but it cannot translate in the y direction or in the x direction. So that means that it will have reactions along the x direction and along the y direction. At a distance of 50 mm, this force is acting. What is the value of this force? I do not know that. That is what I need to find. This is the angle theta. I am going to write out this value of theta as 75.96 degrees.

How do we know this? I just found it in the previous slide, this is 50, this is 200 all dimensions in mm. And about 150 mm from the joint I have a 1.5 kg mass that is acting so that is 1.5 into 9.81 force is acting. And an external load is acting that is 10 kg into 9.81 so much is a way. This is 150, this is 300 or is it 350 is it sorry this is 350 I mean this distance is when you say 150.

I am talking about the distance from the elbow joint. For clarity it is not the distance from the point of insertion. The total distance from the elbow joint to the forearm centre of mass is 150 mm. Let us be clear about that 150 mm is the total distance. Now, I can write out sigma M about the elbow counter clockwise considered positive is 0. Now, let us start the reaction forces at the elbow joint will not cause a moment.

Because they both will have momentum 0. The muscle force will cause a moment but the horizontal component of the muscle force will not cause a moment. Only the vertical component will cause a moment. Remember this only the vertical component will cause a moment. The weight of the forearm will cause a moment. The external load will cause a moment. The corresponding moment terms. We will have to write out.

And we will have to write out the corresponding directions. This is what we will have to do. Let us start with the knowns. The 1.5 kg load of the forearm will cause a clockwise moment. Because the elbow joint is here, the mass is acting like this. This will cause a clockwise moment, so that would be –1.5 into 9.81. This is the weight times 150 by 1000 or rather 0.15 this is the momentum.

Then the 10 kg mass, the 10 kg load will cause a clockwise moment so again –10 into 9.81 this is the weight times. The total momentum from the elbow joint is 350 mm or rather 350 by 1000 or 0.35 meters. Are we done? No, no, we are not yet done. The most important thing is yet to come. That is that component of the muscle force the vertical component of the muscle force will cause a counter clockwise moment that would be what is this component?

What is this vertical component? That is Fm sin theta. Is it not? Theta is 75.96 degrees, Fm sin theta, so plus I do not know the value of Fm. So, I am writing as Fm sin of 75.96 times the perpendicular distance of from this component is 50 mm only. Times 50 divided by 1000 remember either you write it as 0.05 meters or you write it as 50 by 1000 like I am no writing. Will the horizontal component of the muscle force caused the moment.

The answer is no because the moment arm is 0. This is the horizontal component. That will be causing 0 moment. Any other force we have left off. The answer is no, equal to 0. Now this is one equation in single variable I request you to try and simplify this algebra. After some algebra you realize the value of Fm is about 753.35 Newton's. Once again, it is useful to get an intuitive understanding of this.

But sometimes it is not clear how to get this? Because 10 kg load is acting at a distance of 350 mm. But it is overcome by a 50 mm this 50 mm as in a muscle force that is acting with a momentum of 50 mm. But there is a problem that muscle force is not acting perpendicular. So that muscle force is not going to be a simple multiplication. There is going to be something else. There are the sin theta that is coming into the picture.

Let us assume for the sake of discussion that this is acting vertically upwards. Well then in that case there are seven 50s in 350 there are seven 50s. So because 10kg is about 100 Newton's not exact. I know that this is the back of the envelope calculation. So, about 100

Newton's my expectation is that the answer is somewhere around 700 Newton's. But there is a caveat this assumes that theta is 90 degrees.

And we are getting an answer that is close to 700 Newton's. But this will not always work if theta is below 45 degrees, it will be wildly different. So, because 75 is very close to 90 you are getting an answer that is very close to 700. So, we will have to be conscious but here the idea is not to get an approximate solution. Here, the idea is to get the order of the solution correct.

My expectation is that the answer is somewhere in the vicinity of 700 Newton or at least in the hundreds of Newton's. It is either anywhere between 100 Newton and 900 Newton, not necessarily only 700 Newton. The order or the scale of the solution is what I am looking at? If you are getting an answer that is 750 instead of 750 you are getting 75 Newton's. If you are getting an answer something like this well that answer is likely wrong or if you are getting 7500 Newton's that answer is also likely wrong.

With this you will get a rough idea of the order or the scale at which you are working. We are not done yet because we will also have to find the reaction forces. Is it not? Let us not assume that we are done. Because I am interested in finding the reaction forces sigma F x = 0 will give me, what are the various forces that are acting along the x direction? Well E x is along the positive x direction, so +E x for this muscle force.

For this muscle force I can resolve this muscle force as a force Fm sin theta in the positive y direction and a force Fm cos theta in the negative x direction. So that would be minus Fm cos theta = 0, any other force in the x direction have I missed anything else. In the x direction there is no other force, so that is it. So, I can straight away write E x as Fm cos theta Fm is 753.35 cos theta is 75.96 degrees.

The whole thing if I compute I will get the answer as about 182.76 Newton. We are not done yet because we still have to find the other reaction force which is E y. The reaction force of the elbow sigma F y = 0 upward considered positive in this case. Right side is considered positive. For the x case it is right side consider positive sigma F y = 0. Here, there will be many terms because there will be E y in the positive y direction plus Fm sin theta y plus I already resolved this for you.

We already resolved Fm to act along the positive y axis. And the components of Fm is along the positive y axis. And the negative x axis which is why it is going like this which is why the y component will have plus Fm sin theta then –1.5 kg is acting at a distance of 150 mm. But that distance does not matter to me now because I am only solving sigma F y = 0 –10 kg is acting.

Anything else any other thing that I have missed nothing else. The whole thing is 0, so that means E y is 1.5 into 9.81 + 10 into 9.81 – Fm sin that I am taking the whole all the things to the right hand side. And I know Fm sin theta as let me write this out plus 10 times 9.81 – Fm is 753.35 times sin 75.96 degrees. That not substitute for this all this and do the algebra.

You will find E y to be 618.02 Newton. These are the three answers that are required. Of course, it is not trivial to come up with the back of the calculations for the reaction forces. That does not mean that you cannot do that with some practice you can. But it is not immediately obvious how to do that? With this we come to the end of this video. In this video, we saw one more problem involving the static equilibrium of the elbow joint.

In the next video, we will see one more problem involving the static equilibrium of the elbow joint. Thank you very much for your attention.