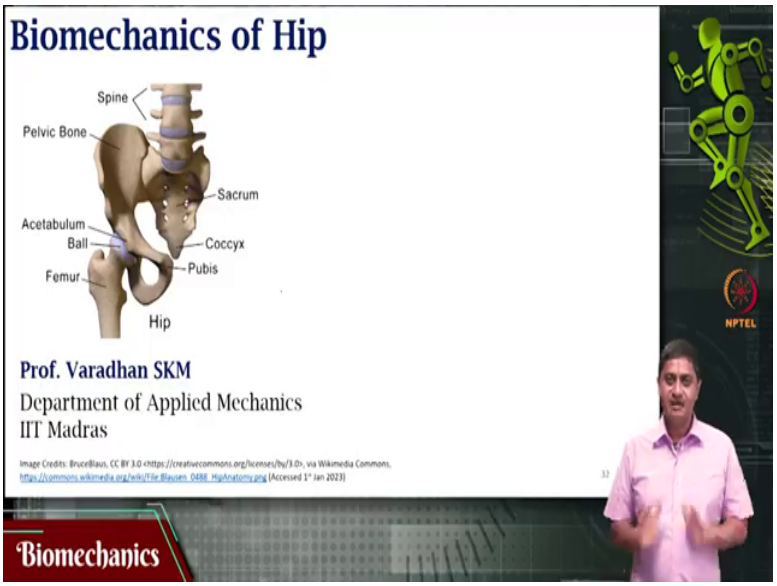
Biomechanics
Prof. Varadhan SKM
Department of Applied Mechanics
Indian Institute of Technology – Madras

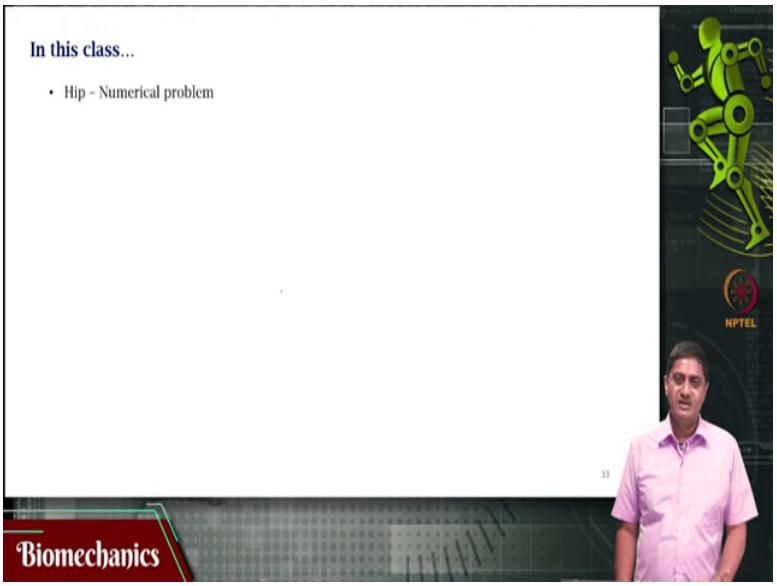
Lecture – 36
Hip Problem

(Refer Slide Time: 00:17)



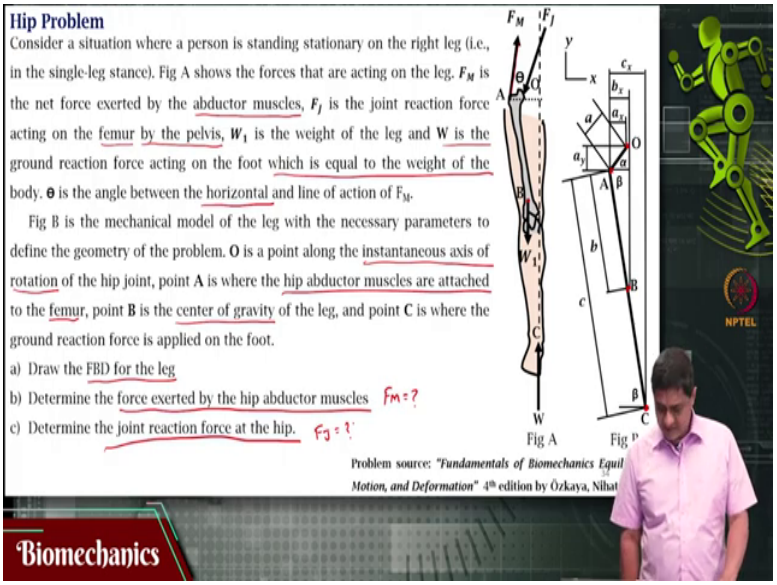
Welcome to this video on biomechanics, we have been looking at biomechanics of hip. We looked at the anatomy of the hip joint, the movements that are possible in the hip joint. And in the next video we also looked at the muscles that support and that are responsible for movements are the hip joint.

(Refer Slide Time: 00:44)



In this video we will be looking at a numerical problem, a simple problem involving the hip joint. This is static analysis of the hip joint.

(Refer Slide Time: 00:56)



Let us read this problem. Consider a situation where a person is standing stationary on the right leg that is, this person is standing only on one leg single-leg stance. For the purpose of this problem, let us assume this is true. Figure A shows the forces that are acting on the leg. Capital F suffix M is the net force exerted by the abductor muscles is the force that is exerted by the abductor muscles.

Capital F suffix J is the joint reaction force acting on the femur. It is the force that is exerted by the pelvis on the femur. W 1 is the weight of the leg that is acting from a point B that is shown there W 1 is the weight of the leg. And W is a ground reaction force. This is the force due to the mass of the person. This is the weight of the body. Theta is the angle between the horizontal and line of action of F M.

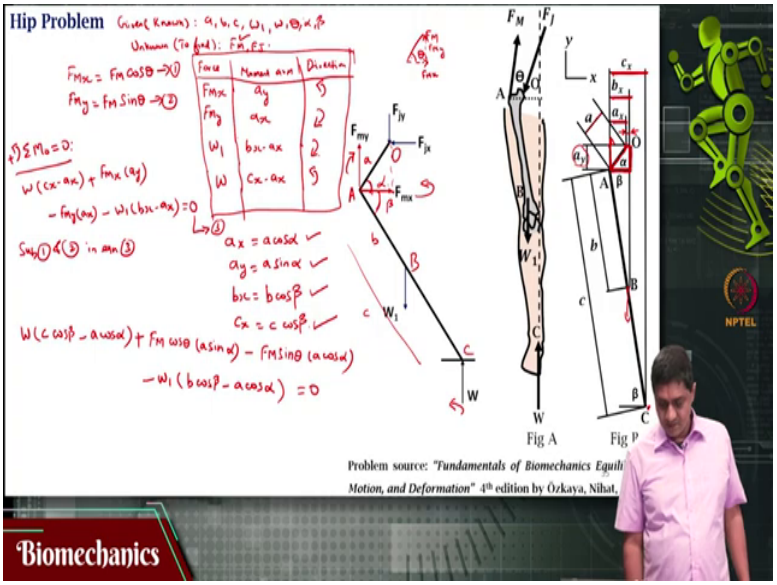
Theta is angle between the horizontal and the line of action of the muscle force, F M. Figure B that shows a simple mechanical model of this leg, with the corresponding parameters to define the geometry of this problem. O is a point along the instantaneous axis of rotation of the hip joint. O is this point this is the point that is along the instantaneous axis of rotation of the hip joint.

Point A is the point where the muscles are attached to the femur, where the hip abductor muscles are attached to the femur. Point B is the centre of gravity of the leg. That is where the

weight of the leg is acting from the C G of the leg. And point C is where the ground reaction force is acting. Now, the corresponding moment terms are given. Question is rather free body diagram for the leg let us show.

Determine the force exerted by the hip abductor muscle. That is find F M. Determine the joint reaction force at the hip. That is find F J. If this is a problem that we have sourced from a textbook with do thanks to the authors.

(Refer Slide Time: 04:23)



Now, let us start with the free bar diagram. This is a free bar diagram. A simple free bar diagram of the situation. F M is acting at this point A and F J is acting at that point O. W 1 is acting at this point B. And W is acting at this point C, capital ABC. What are the known in this? What is known are given? Well, what is known is the distance is A, B etcetera, known. W 1 is known. W is known.

The distances, A, B, C are known that is A that is B and this whole distances these things are. And for convenience the angle that the line A O makes with the horizontal that is that angle is given to be alpha. And that angle is given to be beta that is known. And F M itself is acting at an angle of theta to the horizontal that is also known. Now, can I resolve F M in terms of theta. So, what is known? As you know small a, b, c, W 1, W are unknowns to find.

What is that to find? F M and F J this is what we need to find. Can I write out F M in terms of it is components? The answer is yes, I can do that because theta is given theta is also known by the way theta is also known. So, F Mx that is it not I am interested in knowing that

because this is F Mx and that is F My. F Mx then is F M cos theta. And F My is F M sin theta. Now, if I want to write out the equation of moment about say the point O.

What would be the various forces and the corresponding moment arms that cross this? Now, let us write out the various forces, the corresponding moment arms. And whether that is a clockwise or counter-clockwise movement for each of the force F Mx. Force moment arm direction it is useful to come up with a table like that for your own understanding and clarity. F Mx the corresponding moment arm is you see, F Mx is acting in this direction is it not?

That corresponding moment arm is ay, that is that distance ay. That corresponding moment arm is ay. And that will be causing a counter-clockwise movement. Is it not? Because this is important to determine the sign of this. Then F My the corresponding moment arm is ax. So that is the distance for the y component of the force. That is where the y component of the muscle force is acting around.

So that perpendicular distance is this because I am taking the moment about this point O. And that will cause because this will be the force that will cause a clockwise movement. So, the two components of the muscle force cause moments in two different actions, something to keep in mind. W 1 is acting from that point. Is it not from that point? It is a point that is located that is not bx.

Because I am interested in finding moment about this point O. Remember moment I can take about any point I want in this system. I am interested the way I have drawn that is O actually, technically. So, this is the distance that I am interested in finding out. That distance is bx – ax. So, there is small distance that is bx – ax. Remember it is not bx alone. It is bx – ax why? Because I am taking moment about O.

And I am only interested in knowing the perpendicular distance with respect to the point O. That is what I am interested in finding out and that is bx – ax. That will actually, cause a clockwise movement. Is it not? That will actually, cause a clockwise movement. Then what? Then W is acting at that point C. And that distance is cx – ax is it not? And that force is acting in this direction. So, it will be causing a counter-clockwise movement.

Note, I do not know what is ax, bx, ay, by, is? I only know a and b the corresponding alphas and betas are given. Now, not only the forces have components moment arms also have components. So, I need to write out ax, ay, bx, by, in terms of alpha and beta respectively. This is something that I need to do. Why is that? Because the moment arms have components I need to do that.

So, the component ax, what is ax? That is ax not that is they said this is a that is the distance between this. The corresponding angle is alpha we said. And I am interested in finding out. What is that distance? That is ax for me that is, if I know this to be a this is the distance that I need to know and I am interested in knowing what this value is? What is that? That is the adjacent side of this triangle with angle alpha that would be a cos alpha is it not?

Check this please spend a few minutes and go back to your resolution of vectors and forces. And check whether I am correct. I know that I am correct. But please do check ay likewise is that distance. That is the opposite side to angle alpha in the right triangle, this right triangle. That is a sin alpha cx is what? That is c cos beta. Because I only need ay, ax, bx, ax and cx. I do not need by and cy.

So, I need to know cx, cx is c cos beta and bx is b cos beta, check this. Now, I am writing out the equation sigma M = 0 counter-clockwise is considered positive. That is the equation I am writing. What would that be? That would be W into cx – ax. I am writing out the counter-clockwise components. First, plus F Mx into ay – F My F My into ax – W 1 into bx–ax that anything else that causes a moment. No, the whole thing is 0.

Substitute for values of F Mx and F My in this equation. That is, if I call F Mx and F My as 1 and 2, sub 1 and substitute equation 1 and equation 2. In this equation which I am calling as 3. And also substitute for values of ax, ay, bx, cx in your equation 3. Substitute all these values F Mx, F My, ax, ay, bx, cx everything I am substituting in one go in this equation 3. When I do that what will I get?

I will get something that is going to look very scary. That is okay. This is where bookkeeping helps, so, you need to know the variables that you are working with. You need to know. What are all the variables that I am working with? I am able to do this because I am having a calm

mind. And I am not having any exam pressure. If you practice doing this several times, you will also develop the calm mind that you can use in your exam critical.

Because in the exam, if you miss one of these variables, you will get the wrong answer. And if you get the wrong answer, you will lose most of the grade most of the points for that question. It is very crucial that you develop the discipline of bookkeeping. What are all the variables that I am working with? What are the corresponding moment arms? What is the direction of the moment?

Because now I am going to directly substitute in one equation all these variables. It is likely that you will make a mistake if you do not keep your books clean. Something to keep in mind, simple tip, pro tip. If I substitute, I will get W times cx – ax, what is cx? cx is c cos beta – ax is a cos alpha. Remember that I told that we are going to get something that is going to look scary. That plus sin F Mx ay.

What is F Mx? F Mx is F M cos theta ay is a sin alpha. Why am I having this theta and alpha? I am having an x component of force. And the y component of the moment arm. That is why I am having an alpha and theta. I am having a sinusoid and I am having a cosine. I am having a sin of alpha and I am having a cosine of theta all these things it looks scary.

This is because you are having ay component of the moment arm that is multiplying that is working with an x component of the force. This is how it will work. Because these are perpendicular. This will always be perpendicular. Because these are components you will always have an alpha and theta coming into the picture which is why bookkeeping is absolutely crucial in these kind of problems.

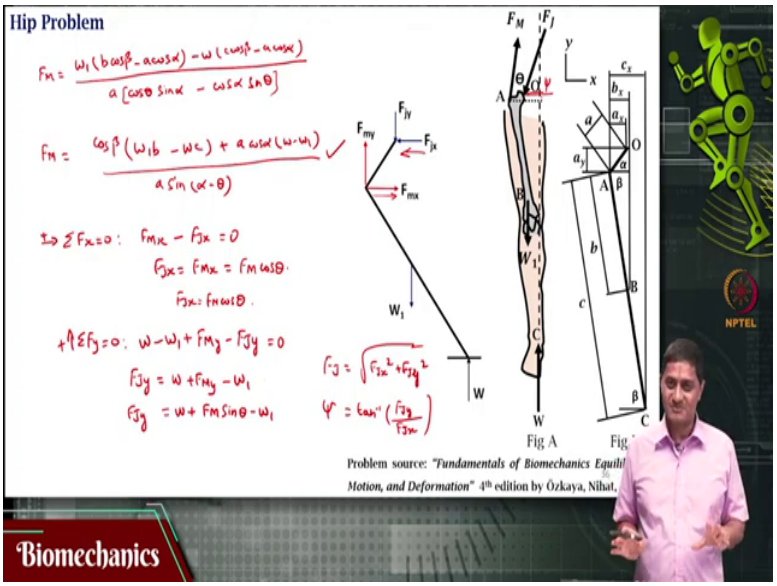
Otherwise, you will get lost very easy to make mistakes. Please keep your books clean and practice this problem and problems like this many times before the exam very crucial. Now, F M cos theta times a sin alpha. Then what else F My times ax – F My times ax but what is F My? F My is F M sin theta times ax. What is ax? ax cos alpha not be done the answer is no.

There is one more thing minus W 1 times bx – ax – W 1 times bx is b cos beta – ax, ax is a cos alpha this whole thing is 0. In this the only unknown in this equation the only unknown is F M everything else is done. I know W, I know C, I know beta, I know alpha, I know theta, I

know a, I know b, I know everything. I know W 1 and I know W. So, I know everything except F M. And F M is what I need to find because that is an unknown.

F M is what I need to find? I know everything else, theta is known, alpha is known, beta is known and everything is known. Now, after some algebra I request you to please do this algebra.

(Refer Slide Time: 20:50)



After some simplification, isolate F M, separate F M from the rest of the equation. And find the expression for F M in terms of all of this that would be. What would that be? That would be W 1 times b cos beta – a cos alpha – W times c cos beta – a cos alpha. The whole thing, divided by a times cos alpha sorry cos theta sin alpha – cos alpha sin theta. I can further simplify this.

That will give me F M as cos beta times W 1b – W c + a cos alpha times W – W 1. This whole thing divided by a times sin of alpha – theta. That makes sense because cos theta sin alpha – cos alpha sin theta looks like cos of alpha – sorry cos theta sin alpha – cos alpha sin theta looks like sin of alpha – theta. We know this from trigonometric identities. So, this is the expression for F M.

This you will get only after you do a substantial amount of simplification and careful bookkeeping something that you need to develop as a go along. In an NPTEL course like the one that you are now taking the motivation for doing well in the course is left to the students

like you. You need to put the fight, you need to keep the books. You need to learn how to do that?

And I know that you are all self-motivated students which is why you have come this far in the course. Invest a little bit more time and energy into keeping that discipline. Learn the art of bookkeeping and keeping it neat disciplined set of variables that you are working with. For example, like the table that I developed. We developed this table like this. Now, let us proceed we are not done yet because we only found F M.

We have to find F J that is more to go. Now, I can say sigma F x = 0. This will mean F Mx minus so that would mean F Mx is in the positive x direction. And F Jx is in the negative x direction. Any other x component, no other x component F Mx – F Jx is 0. That is what it means. That would mean that F Jx is F Mx. What is F Mx? We know what is F Mx? F Mx is F M cos theta is it not? So, F Jx is F M cos theta. We are not done yet.

We have to find F Jy sigma F x = 0 right side going is considered positive. Sigma F y upward force is considered positive. Where sigma F y = 0. What are all the various forces? W is the ground reaction force that is acting in positive y direction W. W 1 is the weight of the leg that is acting downward W – W 1 plus what else F My is in positive y direction + F My – F Jy. Any other forces along the y direction and answer is no. This whole thing is 0.

So that would give me F Jy as W + F My – W 1 but I know F My. What is F My? F My is F M sin theta this is F Jy. F My is F M times sin theta remember this is F M substitute for this value of F M in your F Jx and F Jy equations. Then you will find F Jx and F Jy. What is F J? F J itself is square root of F Jx squared plus F Jy squared is it not? This is the value of F J.

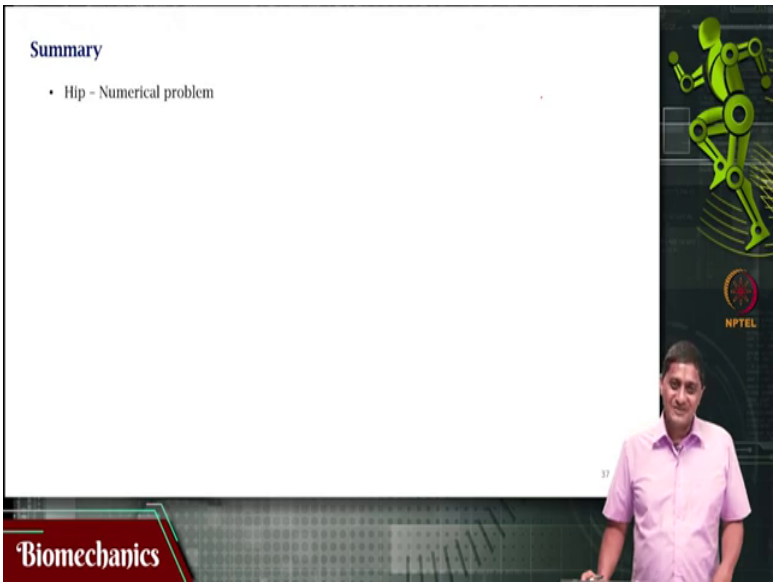
And the direction that it is acting along is some psi which is tan inverse of F Jy by F Jx. This is the angle that F J mixed with the horizontal psi, is the angle that angle. Simplify for this and you will find an the value of F Jx and F Jy. In the exam, you will be given numerical values of small a, b, c, theta, alpha and beta and weights. You will be asked to find the numerical value of F M and F J.

This would, of course, involve quite a bit of computation. So, unless you practice this with dedication and motivation. It will be very challenging for you to solve this in the exam. So,

my request is take some time out and practice this problem. And these types of problem from the same book are other books and get ready for the exam. Preparing for the exam is a semester-long process.

Remember this preparing for the exam is a semester-long process. It is not something that you do the day before the exam remember this.

(Refer Slide Time: 28:13)



So, with this we come to the end of this video. In this video, we saw a simple numerical problem involving the hip or rather a problem in the statics of the hip joint. It was a simple problem but there were many variables involved and it required a lot of bookkeeping. I request you to practice this problem when you have the time and get ready for the exam. Thank you very much for your attention.