Problem **5**

In this problem, block A is sitting on a surface and is being pulled by force T, this force T is applied at a height of 0.4 meters on the right. And we're asked to determine whether this block tips or slips first and the force T required for this to happen. So, block A has a force of gravity that points down, located at the center of gravity. And this is countered by normal force that points upwards from the surface. And this creates a force of friction, depending on which way you're pulling the object. Since the block is starting stationary, it's going to be subject to static friction. If the block does begin moving, then we are going to be subject to kinetic friction. But we're pulling this block with a force T to the right, and this is offset by a height h one. So let's go ahead and draw the freebody diagram with all the forces. So at the center of gravity over here, we have the force of gravity. So f g, eight points downwards. And we have our T. That points to the right. And then we have our for our normal force and our force of friction, right. So our normal force points upwards, and a, and then we have our force due to friction. And since this T pose to the right, we're going to assume that we either that the force of friction is going to point to the left to counter that. So we're going to draw a force of friction as follows F of F, A, to the left. So it's really important to note that this force of friction here acts at this point when there is no T, right. But in reality, when we apply T, this force here creates a moment, right? It wants to tip the block in this direction, which means that this normal force and this force due to friction, are going to shift, in this case to the right to counter that moment, and balance that moment in order to prevent tipping, right. So if we shift this point all the way to the end over here, to that edge. At this point, the force T that's pulling and creating that moment, is going to be the maximal force we can apply before we tip, right? So in the case of tipping this normal force, and the force of friction will actually act at that point over there, right? Because this point here cannot go further past the end of the object, or else we'd be outside of the object, right. But once so for the case of tipping, we're going to have to move these two forces to the extreme over here. In the case of slipping, we don't actually care about the location of these two forces. Because in the case of slipping, we only care about the sum of forces in x and y direction, right? The force of gravity is going to be balanced by the normal force. And that is going to give us the force just a balance, right mg equals to NA, this and he is going to give us the friction force and this friction force is going to be countered is going to be countering the force T, right? If the force of friction is larger than T, then we have no slipping, right? But if t becomes larger than the force of friction, then we have slipping, right? The forces one is larger than the other, we have slipping, we're gonna move to the right. So slipping we don't really care about the location of these two forces. With tipping we do care about the location of these two forces. Now this problem also asks us to determine which one is occurring first. So these two phenomena are competing with each other. So as we start with a zero force, so there's no t, this normal force is going to perfectly balance F G, and this friction force is not going to be present because we're not pulling with T so there's nothing countering and any is perfectly aligned with f g of a on the same line and nothing interesting, right? As we start increasing this force T, what happens is this force T is going to have to be countered by a force of friction to prevent slipping. But also, this force T creates the moment that we discussed, which is going to shift this point a little bit to the right. Okay. Now, as we keep on increasing and increasing increasing T, one of the two phenomena is going to occur first. So it's either this point reaches the maximum over here, and leads to tipping or this force becomes too large to be countered by the force of friction. And the point is not at the end, so it might be halfway. And we actually get slipping before the tipping. So what we have to do in this problem is determine which one occurs first. So we do this with balancing the forces and determining this tension force. And between the two methods, whichever tension force is smaller will lead to that event occurring first. So let's start with our force balance. But first, let's redraw our freebody diagram to include what I discussed. Okay, so let's start with a with slipping. So for slip, we care about the sum of forces in the x and sum of forces in the y. So sum of forces in x, this is going to be equal to m A, a of x, right. But in this case, we do not have any acceleration in x, so we can set that to zero. And we take the sum of forces, which is equal to T minus F cos F A. And this is going to be equal to zero, right? We do a sum of forces in the y, which is equal to m times a y. And again, just like I said, before, six elevation goes to zero because we're not moving up. And this is going to be equal to f of g minus and the normal force, and this yields the following: m a times g is equal to N A, which is equal to 117.7 Newton's right? I just plugged in G, which is 9.81 meters per second squared, and then the mass and I get the normal force. Okay. Now, I can take this normal force and use it to calculate the friction force, right? So for the slipcase, we have that the force of friction is equal to the static coefficient of friction times the normal force, which is 0.35 times 117.7 Newtons and so t is equal to 41.2 Newtons right? So what we calculated here, this is T slip, right? This is the force, the minimum force that is required for this block to overcome this force of friction, right? We don't know if there's tipping with this force yet. Right. But we know that once we go past this force, then the block is going to slip. It might tip before that, but we for sure know that anything above this will slip. So in this is because this tension force overcomes the maximum friction force, which is due to the force of gravity, which determines the normal force. Alright, so this is just what we got from these two, sum of forces. So now let's look at the tipping case. So in the case of tipping, I said, we're going to look at the moments right, because we want to see if that moment created by the tension force actually overcomes and begins tipping. So the sum of sum of moments about o, is equal to i alpha. Now we know that alpha, just like any other cases, is going to be equal to zero. So we can actually calculate the sum of moments now I picked to do a sum of moments at o which is that point over there? For simplicity, right. You always pick to do some moments where you have the most forces pointing, right? So you can eliminate these two forces, if you do it with respect to this point, or this point, because ideally, you always want to do it where there's a force, right? You will get the same answer. But you'll have to plug into relationships for the normal force, and of course of friction from these two equations over here, right? By taking an O, I'm eliminating these two. So I do not need to use this equation over here. And I just, I can just find a relationship of f g of A, which I know because I know the mass with T. Right? So what does this get me? So the sum moments is going to be t times h one. So again, going back to here, H one is this distance here. So this distance times t, they're perpendicular, I can just multiply them directly gives me the moment about o, and then I can I need to look at the force of gravity minus f g times with over two. Now, why is that because I am looking at this distance of here and this is the radius and this is my force, right? So I multiply this force times this radius perpendicular, and I can get the moment about oh from that force, now, these two W and H one are given in the problem. So I can go ahead and solve this equation and get the following results. So, we calculated f g of A which is 117.7. So in the case of tipping we have t being equal 217.7 Newton's times 0.2, which is the width over two because the width is 014 divided by height, all right, h one sorry, which is 0.4 meters. And there's also a meters this is equal to 58.9 Newtons. So what is this this is T tip right. So this is the force T, that we have to apply in order for this system to actually tip Okay, for the moment of created by T to overcome the maximum moment generated by these two forces, which leads to tipping, okay, because this point can't move any further to the right to overcome the moment generated by t. Now, we can see that T slip is smaller than t tip. Therefore, T slip when we add a T of 41.2. The block will start slipping to the right, but it hasn't tipped yet and it will not tip Okay. Therefore, it will slip before tipping so we don't have to worry about tipping we just have to worry about slipping right and the force required is 41.2. So to recap, since T tip is bigger than T slip we have slipping before tipping and T is going to be equal to 41.2 Newton's and this is the required force for this to happen