## RES.TLL-004 STEM Concept Videos, Fall 2013

## Transcript – Torque

Here are two people. They're both standing, but they're standing in two completely different ways. Which person would it be easier to push over? If you wanted to push this person [left] over, where would you apply a force? What about this [right] person? The answers to all these questions can be explained using the concept of torque.

This video is part of the Representations video series.
Information can be represented in words, through mathematical symbols, graphically, or in 3-D models. Representations are used to develop a deeper and more flexible understanding of objects, systems, and processes.

Hello. My name is Sanjay Sarma. I am a professor in the mechanical engineering department at MIT, and today I'll be talking with you about torque and balance.

In order to understand this video, you'll need a working knowledge of vectors and their uses. Specifically, you must be familiar with force, displacement, and torque. We will also assume that you know how to compute a cross product, and how to use the Right-Hand Rule, and that you have done problems involving the center of mass of an object.

Our objective is to improve your ability to draw torque diagrams, and give you some practice with setting them up. By the end you should also understand what is needed for human beings to balance.

We'll start with an activity. Everyone stand up and spread out across the room. You'll need a partner for this activity.

When I say "go," your goal is to carefully push your partner over. Use the smallest amount of force you can. You will switch partners halfway through, so be gentle.

When you push, consider where you should push, and in what direction. Try many different approaches.

Here are some questions that may help you think about this in a scientific manner. When it comes to your push, where will you push?

What direction will you push? How hard will you push? Consider your partner as well: how is your partner standing? What is the floor like under your partner's feet? Can your partner balance well?

Are you ready?

Go!

Switch partners!

Your teacher will now lead you in a short discussion about this activity. Pause the video here.

Let's continue our investigation of torque and balance in the human body. Take a look at this next video clip, in which MIT researchers Colin Fredericks and Jennifer French demonstrate the effectiveness of properly applied torque.

To analyze the situation, let's look at what physical properties are important here. What forces do you think are involved? Pause the video to discuss.

Next, draw a simple diagram that you can use to find the net torque on this man. Pause the video while you do this.

The simplest way to represent this man is with a rectangle. We remove any other details, and draw our forces so that we can tell exactly where they are applied to his body.

Finally, if you were to draw a diagram showing someone resisting a push, how would you do it? Which of these three is most appropriate? Pause the video to discuss.

You may be wondering why we can use a two-dimensional diagram to discuss a three-dimensional situation. The reason is that all of our forces are applied in the same plane, simplifying the problem. While our torque vectors point in and out of the screen on this diagram, we can represent that fairly easily. In a more complex situation, we may need to draw something more fully three-dimensional, as our torques might point in other directions.

This next video clip will walk you through a partial analysis of this situation. You will need a way to take notes and draw diagrams while you watch.

Now that you've seen torque and balancing in detail, let's consider a more complex problem. This one is a bit tricky. I'll show you how it works.

I'm going to take a chair and place it next to the wall. I'll put my toes up to the wall, and step back, toe-to-heel, twice. I step sideways until I'm over the chair. Then I bend forward until my head touches the wall, pick up the chair, and stand up... er... or not.

This is something that most women can do, but men cannot. Maybe you think it's a trick? Here's a video of some of your professors trying to lift chairs themselves.

Now it's your turn to try! Get together with your partner again and bring a chair over to the wall.

Why don't you pause the video and give it a try?

Now that you've attempted the chair lift, let's return to our seats and discuss what happened.

If you wanted to figure out why this happens, what information would you need? What assumptions would you have to make? Discuss the matter with your partner. Try to draw a diagram of the situation. Pause the video here while you work this out.

Many of you should be wondering about the center of mass for this situation. This diagram shows typical locations for the center of mass in men (on the left) and women (on the right). Not only are men typically taller, but their center of mass is usually higher in their bodies. This is not always true, but it is fairly typical.

Using this information, work with your partner to try to explain what is happening. Why can women lift the chair when men cannot?

You do not need to obtain a numerical solution! Instead, use reasoned arguments, diagrams, and well-supported assumptions to prove your answer. Only use calculations if you cannot support your answer in any other way.

Pause the video and give it a try.

Are you ready to see the solution? Let's take a look.

For this section we will measure torques around the center of mass. This will simplify our work so that we don't have to worry about the person's mass and the pull of gravity.

This diagram shows the man lifting the chair. You can see that the center of mass is outside his body, and has been moved farther forward and down by the chair.

This diagram shows the same for the woman. Her center of mass is also outside her body, but is much closer to her legs.

If we draw a line for the man to indicate where his toes are, we see that the center of mass is beyond the edge of his foot! No matter how hard he tries, he cannot apply force in the right place to lift that chair.

On our diagram, we can see that the torque will always point in the direction out of the screen. It will rotate the man counterclockwise, pushing his head harder into the wall. The harder he pushes, the worse it will be.

The woman, however, has her center of mass above her feet. She can stand up because her feet are able to apply force in the proper location and direction.

If we draw a torque diagram, we can see that the direction of torque applied by her feet will be into the screen. By applying more force, she can rotate her upper body clockwise and stand up, whereas the man cannot.

Today we hope that you have improved your ability to draw torque diagrams, and to analyze torque problems that occur in the real world.

Torque is an important quantity that comes into play in countless situations around us, from machinery to buildings to the simple act of walking. I hope you enjoyed this look at one of its fascinating applications.