

# Torque

## Representations Series

### *Instructor's Guide*

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DEVELOPED BY THE TEACHING AND LEARNING LABORATORY AT MIT  
FOR THE SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

# Introduction

## When to Use this Video

- In Phys 101, during class or recitation, during or after Lecture 33. This video is best suited to use in class or in a discussion section, rather than as homework, as substantial interaction with others is prompted for in the video.
- Students should be familiar with vector representations of force, displacement, and torque. They should be able to compute a cross product and use the Right Hand Rule to determine the direction of torque. Finally, they should have done problems involving the center of mass.

## Key Information

*Duration:* 20:11

*Narrator:* Prof. Sanjay Sarma

*Materials Needed:*

- Paper
- Pencil/Pen
- At least one chair

## Learning Objectives

After watching this video students will be able to:

- Draw torque diagrams.
- Practice setting up torque problems.
- Determine whether someone can balance.

## Motivation

- This video was created as a blended whole-class activity. It contains many opportunities for student-active learning, including mathematical, conceptual, and kinesthetic approaches.

## Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students will:

- Participate in physical activities involving torque and balance.
- Answer formative assessment questions.
- Create torque diagrams.
- Discuss and explain a chair-lifting trick.

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## Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
1:21	Partner activity	Students work in pairs to gently push each other over. This is followed by a discussion.
3:41	Martial arts throw clip	
4:31	Concept questions relating to throw	This is a good opportunity to use clickers and classroom discussion.
6:10	Detailed walk-through of the martial arts throw	This segment is written on whiteboard from 6:49 until 14:22.
14:03	Chair lifting demonstration	
16:26	Students' turn to try the chair lift	Instructions for the lift are given on-screen. This is followed by a discussion and group work.
18:03	Explanation of chair lift	
19:33	Review and wrap-up	

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### Video Summary

This video uses a series of examples and student-active segments to investigate the concepts and torque and equilibrium. The primary context is balance in the human body. Students are involved in partner activities, brainstorms, and problem-solving segments as the video progresses.

# Phys 101 Materials

## Pre-Video Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.



### 1. Torque Diagram Worksheet (Appendix A1)

This worksheet can be used in class or in a recitation after introducing torque diagrams, or assigned for homework. Some of the concepts needed in problem #3 in particular are similar to those used in the video activities.



### 2. Reference Points (Appendix A2)

This is a clicker problem designed to probe students' understanding of the "reference point" concept used in torque. Some students will attempt to determine symbolic expressions for the torque around each point for each force; this will come up with the right answer but will take a long time. Location 5 is the farthest from the line of action for both forces. The fact that it is outside of the object is likely to discourage some students from choosing it, but is immaterial.



### 3. Tension Comparison (Appendix A3)

This clicker question addresses a common misconception that objects held at a different height require different amounts of force to hold them in place. Some students may state that the end held higher has greater tension to keep it up higher; others may argue that the lower end must somehow be heavier and thus the tension in the rope must be greater.



### 4. Block Stacking (Appendix A4)

This is the classic block-stacking problem as described by Hall (see references), among others. It deals with center-of-mass issues similar to those seen in the video. The problem is best approached in a combination of calculation and hands-on stacking. Any shape block will do; a few pieces of lumber cut into squares will serve well. For extra shock factor (given the unusual answer), the problem should be tackled hands-on first, in small groups, with calculation to follow for homework. The problem has the same answer regardless of whether counterbalancing is allowed; it may be fruitful to have students break into teams where some counterbalance and some do not.



## Post-Video Materials



### 1. Human Balance Project (Appendix A5)

This fairly simple project is suitable for use in a recitation and/or for homework. Group work is encouraged, if only to prevent students from falling on the floor. If students have access to computer graphics packages and digital photography (via phone or computer), they can work on this during recitation, creating a model on paper and then testing it out. Results from this project can be compared to the placement of the male and female centers of balance in the video, and to the data in the Going Further folder.



### 2. Spool Pull (Appendix A6)

Another classic mechanics problem. Friction is particularly important; note that the problem does not make any statements about friction or whether the spool rolls without slipping. Time should be given for a full discussion.

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## Additional Resources

### Going Further

The Going Further folder contains an excerpt from The Physics Factbook by Glenn Elert (see the fifth reference below). This includes data on the centers of mass for human beings and a method for obtaining its vertical location. The raw data is included in the folder.

The same folder also contains a set of PowerPoint® slides intended for instructors who wish to discuss gearing and gear ratios. The first few slides give a basic introduction to gear ratios and their physical basis. The last two slides include images of gears with varying numbers of teeth for instructors who might wish to use such images in their own presentations.

### References

The resources below investigate student understanding of torque and rotational motion. The third paper deals specifically with student understanding of balancing.

- Steif, P. (2004). Initial Data from a Statics Concept Inventory. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*. Retrieved on Feb. 15th 2012 from [http://www.andrew.cmu.edu/user/steif/papers/ASEE\\_Statics\\_CI\\_Paper.pdf](http://www.andrew.cmu.edu/user/steif/papers/ASEE_Statics_CI_Paper.pdf)
- Roncato, S. & Rumiati, R. (1986) Naive statics: Current misconceptions on equilibrium. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 12(3), 361-377.
- Ortiz, L., Heron, P., and Shaffer, P. (2005). Student understanding of static equilibrium: Predicting and accounting for balancing. *American Journal of Physics* 73(6), 545-553.
- Ortiz, Luanna Gomez. (2001). *Identifying and addressing student difficulties with rotational dynamics*. University of Washington. ProQuest Dissertations and Theses, 503 p., Retrieved from <http://search.proquest.com/docview/304733739?accountid=12492>
- Gambino, S., Mirochnik, M., Schechter, S., Elert, G. (2006). Center of Mass of a Human. In *The Physics Factbook™*. Retrieved February 29, 2012, from <http://hypertextbook.com/facts/2006/centerofmass.shtml>

The block stacking problem (Appendix A4) appears in a highly readable paper. Instructors interested in teaching science from scientific literature are encouraged to assign it as reading:

- Hall, J. (2005). Fun with stacking blocks. *American Journal of Physics* 73(12), 1107–1116.

## Torque Diagram Worksheet

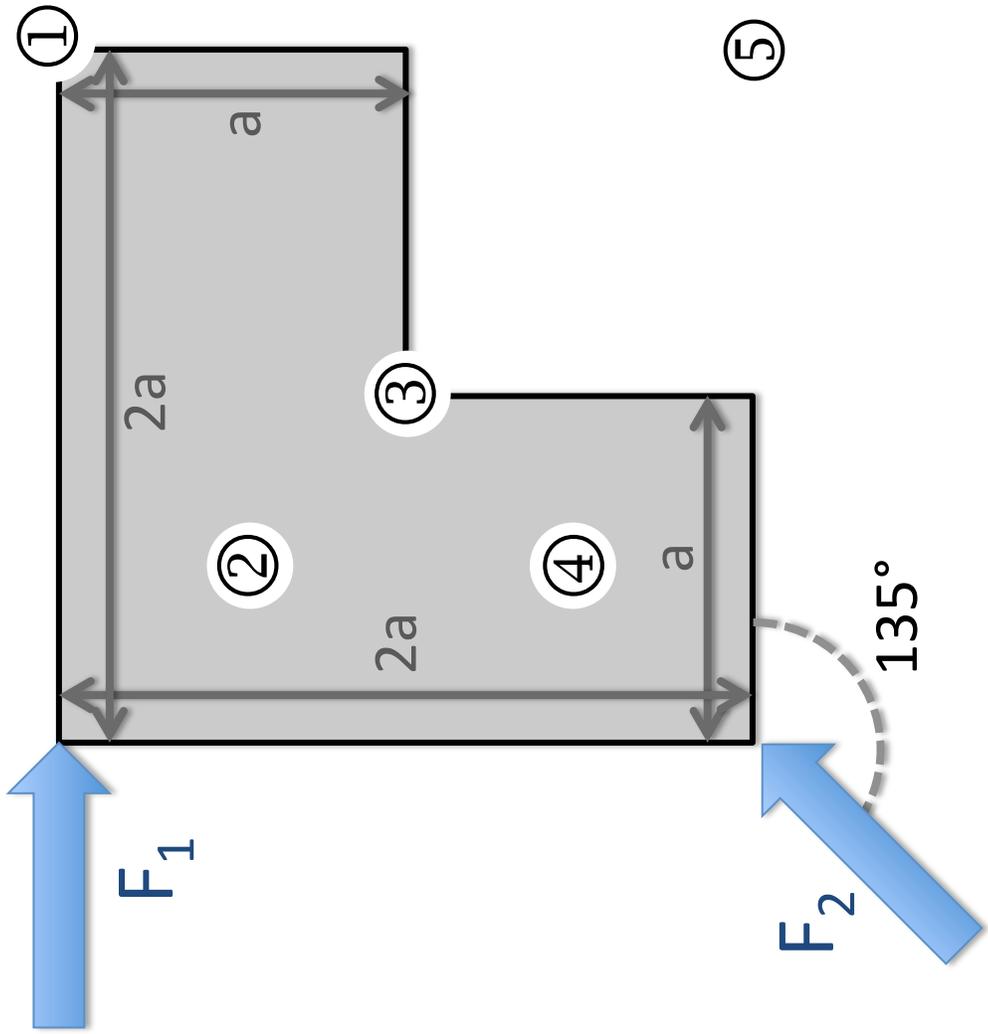
Draw a torque diagram for each of the following situations. You may make assumptions for the masses of the objects involved.

1. A block sits at the end of a table, with  $\frac{1}{3}$  of the block hanging off the edge.

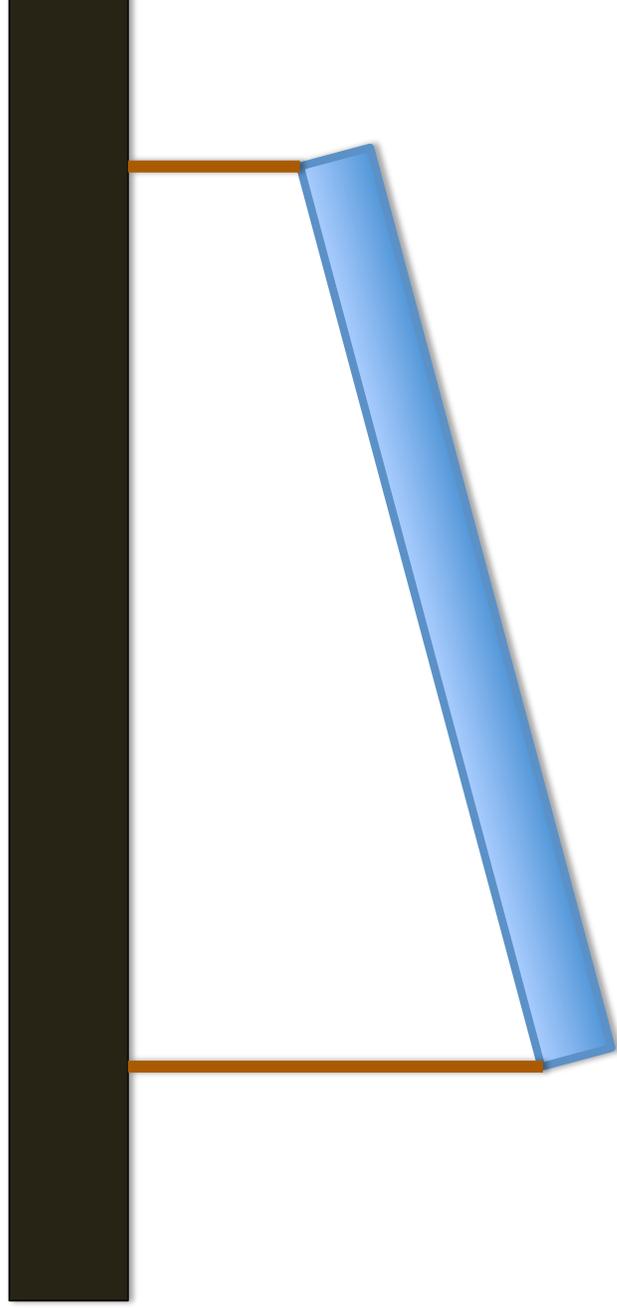
2. A sign is hung from the side of a building as shown.  
Draw a torque diagram for the **bar** on which the sign is hung.



Given two equal forces applied on an object as drawn below, choose the location about which the torque is greatest. If there are multiple locations with equally large torque, choose all that apply.



A rod of uniform density is hung from the ceiling as shown. If the rod is stationary, which of the following statements are true?



- ① The tension in the left-hand rope is higher.
- ② The tension in the right-hand rope is higher.
- ③ The tension is equal in the two ropes.
- ④ It is impossible to say which tension is higher.

## **Block Stacking Worksheet**

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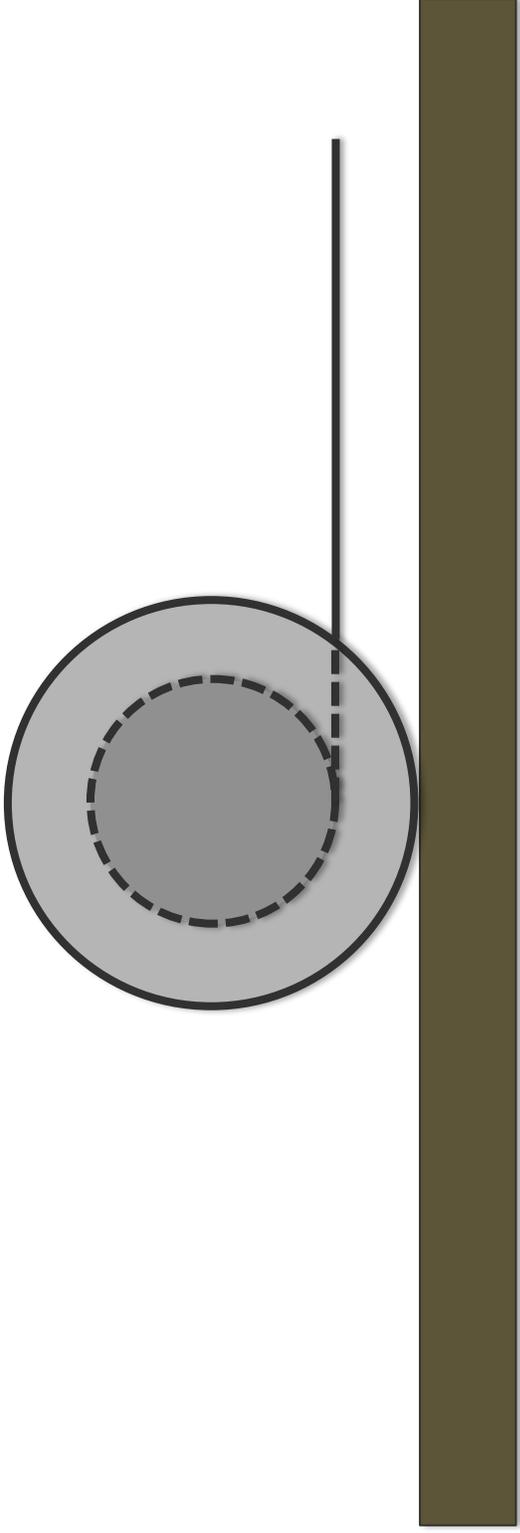
You are given a large number of wooden blocks of length  $L$  and height  $h$ . Your goal is to stack them on a table in such a way that the last block is above another nearby table. How far away can the second table be?

Note: you have no way to attach the blocks to each other – you cannot glue them together or tie them with string, for example. Ignore friction.

## **Human Balance Project**

Devise a plan by which a person's shoe size and the maximum angle at which they lean forward before falling can be used to locate their center of mass. Find the center of mass for several individuals.

A spool of thread is placed on a table as shown. The thread is gently pulled. Describe the motion of the spool. You should choose two answers.



- ① The spool rotates clockwise.
- ② The spool rotates counterclockwise.
- ③ The spool does not rotate.
- ④ The spool slides to the right.
- ⑤ The spool slides to the left.
- ⑥ The spool does not slide.

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