UEQ #1: How can the rotational motion be described in a measurable and quantitative way?

Unit 8
Rotational Motion

UEQ: How can rotational motion be described, measured, and quantified?

VOCABULARY

- Radians
- Angular Displacement
- Angular Velocity
- Angular Acceleration
- Frequency
- Period
- Axis of Rotation
- Moment Arm
- Torque
- Right-Hand Rule
- Static Equilibrium
- Cantilever
- Stable Equilibrium
- Unstable Equilibrium
- Neutral Equilibrium
- Moment of Inertia
- Rotational Inertia
- Rotational Kinetic Energy
- Angular Momentum

UEQ: What factors affect changes in an object's rotational motion?

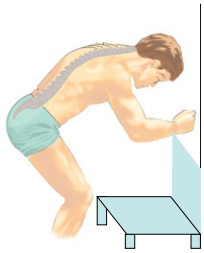
LESSON 4

Static Equilibrium

Rotational Motion: Static Equilibrium

EQ(s): How are torques used in natural and man-made objects and systems?

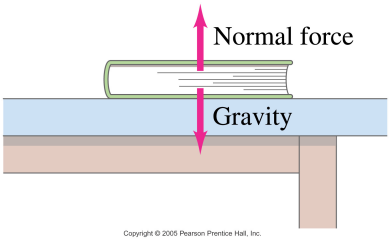
Start: Why are some manly individuals unable to take two steps away from a wall, lean over and place their head against the wall, lift a chair and then stand up?



How are torques used in natural and man-made objects and systems?

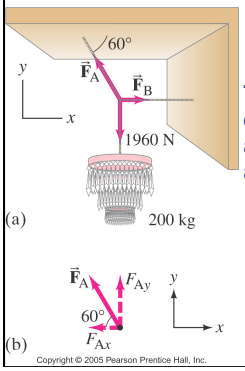
9-1 The Conditions for Equilibrium

An object with forces acting on it, but that is not moving, is said to be in **equilibrium**.



How are torques used in natural and man-made objects and systems?

9-1 The Conditions for Equilibrium

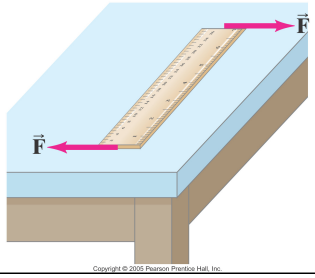


The **first** condition for equilibrium is that the **forces** along each coordinate axis add to **zero**.

How are torques used in natural and man-made objects and systems?

9-1 The Conditions for Equilibrium

The **second** condition of equilibrium is that there be no **torque** around any axis; the choice of axis is **arbitrary.**



How are torques used in natural and man-made objects and systems?

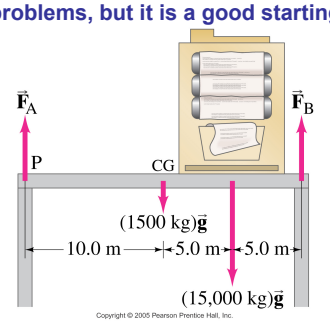
9-2 Solving Statics Problems

1. Choose one **object** at a time, and make a **free-body diagram** showing all the forces on it and where they act.
2. Choose a **coordinate** system and resolve forces into **components**.
3. Write **equilibrium** equations for the forces.
4. Choose any axis perpendicular to the plane of the forces and write the **torque** equilibrium equation. A clever choice here can simplify the problem enormously.
5. **Solve**.

How are torques used in natural and man-made objects and systems?

9-2 Solving Statics Problems

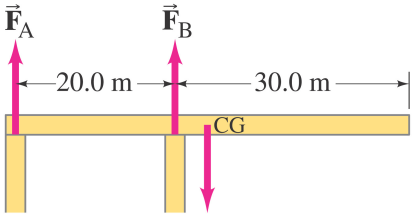
The previous technique may not fully solve all statics problems, but it is a good starting point.



How are torques used in natural and man-made objects and systems?

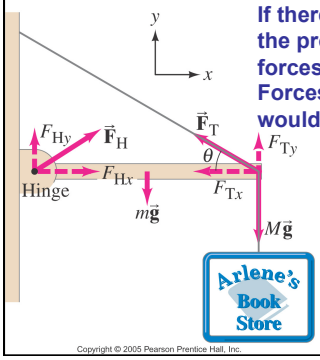
9-2 Solving Statics Problems

If a force in your solution comes out **negative** (as F_A will here), it just means that it's in the **opposite** direction from the one you chose. This is trivial to fix, so don't worry about getting all the signs of the forces right before you start solving.



How are torques used in natural and man-made objects and systems?

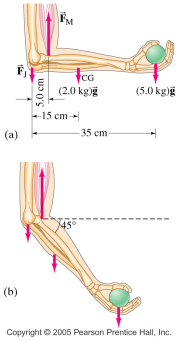
9-2 Solving Statics Problems



If there is a **cable** or **cord** in the problem, it can support forces only **along** its length. Forces perpendicular to that would cause it to bend.

How are torques used in natural and man-made objects and systems?

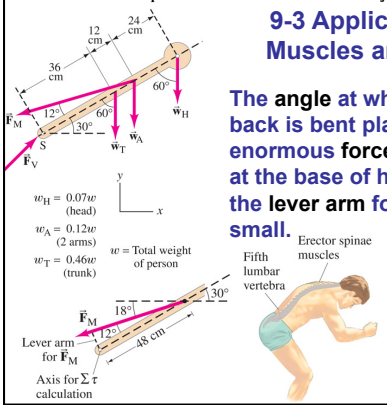
9-3 Applications to Muscles and Joints



These same **principles** can be used to understand forces within the **body**.

How are torques used in natural and man-made objects and systems?

9-3 Applications to Muscles and Joints

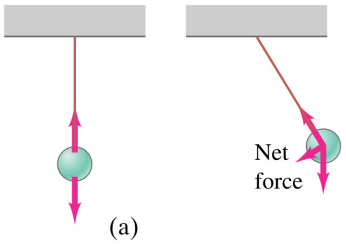


The angle at which this man's back is bent places an enormous force on the disks at the base of his spine, as the lever arm for F_M is so small.

How are torques used in natural and man-made objects and systems?

9-4 Stability and Balance

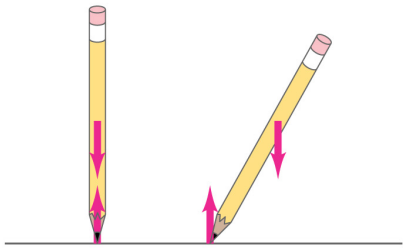
If the forces on an object are such that they tend to return it to its equilibrium position, it is said to be in stable equilibrium.



How are torques used in natural and man-made objects and systems?

9-4 Stability and Balance

If, however, the forces tend to move it away from its equilibrium point, it is said to be in unstable equilibrium. On the left, the object is at the critical point.



How are torques used in natural and man-made objects and systems?

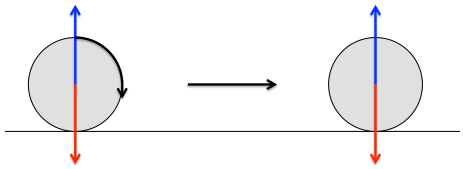
9-4 Stability and Balance

An object in **stable** equilibrium may become **unstable** if it is **tipped** so that its center of gravity is **outside** the pivot point. Of course, it will be stable again once it lands!

How are torques used in natural and man-made objects and systems?

9-4 Stability and Balance

An object is in **neutral** equilibrium when it is always in equilibrium. An example of this would a rolling wheel: If you stop it at any point, the wheel will be in a state of equilibrium. Another example is pushing a box on the ground.

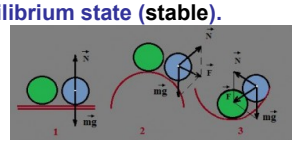


How are torques used in natural and man-made objects and systems?

9-4 Stability and Balance

When there is a small change in position from its equilibrium state . . .

1. the object remains in equilibrium (**neutral**).
2. forces emerge that tend to increase this deviation from equilibrium (**unstable**).
3. forces emerge that tend to return the object to its equilibrium state (**stable**).

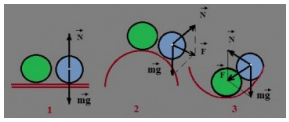


How are torques used in natural and man-made objects and systems?

9-4 Stability and Balance

In other words (soon), when there is a small change in position from its equilibrium state . . .

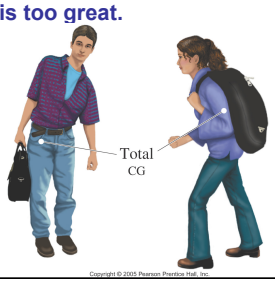
1. the object remains in its new position (**neutral**).
2. The objects moves even farther awary from its original position (**unstable**).
3. The object returns to its original position (**stable**).



How are torques used in natural and man-made objects and systems?

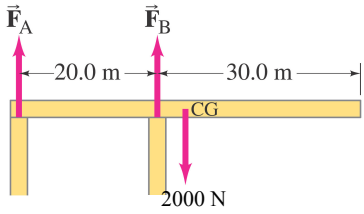
9-4 Stability and Balance

People carrying heavy loads automatically **adjust** their posture so their **center of mass** is over their **feet**. This can lead to injury if the contortion is too great.



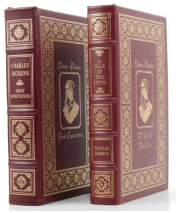
What affects the rotational inertia of an object?; How does the geometry of an object affect its moment of inertia of an object?

PRACTICE PROBLEM



How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

Reading Enrichment



- **Biomechanics of Safe Lifting**
  - http://ergo.human.cornell.edu/dea3250flipbook/dea3250notes/lifting.html
- **Under Pressure: Poor Posture Puts More Pressure on Your Spine**
  - https://www.gaia.com/article/under-pressure-poor-posture-puts-more-pressure-your-spine
- **Torque**
  - http://www.physics.usyd.edu.au/super/physics_tut/volume1/mi10sol.doc

How are torques used in natural and man-made objects and systems?

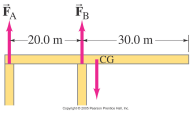
WebAssign/Lab Time

- Work on WebAssign PIM Ch.08D – Static Equilibrium
- Final Copy Criteria
  - State the problem (Ex. Find displacement)
  - Draw a picture/diagram
  - Provide a list or table of all given data (Ex. $\Delta t = 2$ s)
  - Solve the problem symbolically (Ex. $v=\Delta x/\Delta t \rightarrow \Delta x = v\Delta t$)
  - Plug in numbers and units to obtain answer. (Ex. $\Delta x = (5 \text{ m/s})(2 \text{ s}) = 10 \text{ m}$)
- Notes about WebAssign:
  - Positive vs. negative answers (Try a negative sign)
  - Look at the final unit (hours or minutes or seconds)

How are torques used in natural and man-made objects and systems?

Summary

- Answer the Essential Questions.
- Ticket out the Door:
  - What are the two formulas that are used to solve static equilibrium problems?
  - What is the net torque acting on an object in static equilibrium?
  - What is the net force acting on an object in static equilibrium?



- HW:
  - WebAssign PIM Ch.08D – Static Equilibrium