

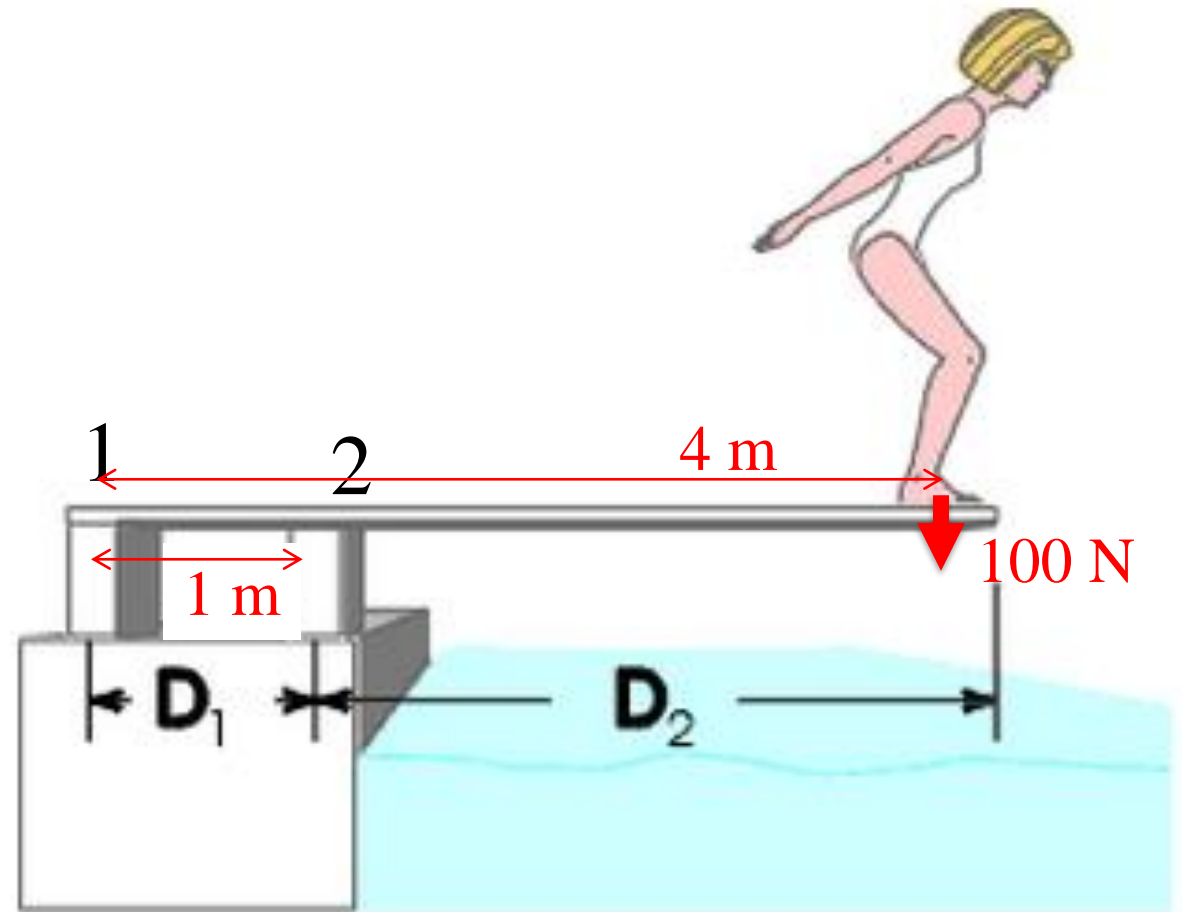
PHY131H1F - Class 19

- **Today, Chapter 12:**
- Conditions for Static Equilibrium
- Center of Gravity
- Static Equilibrium Problems
- Stability

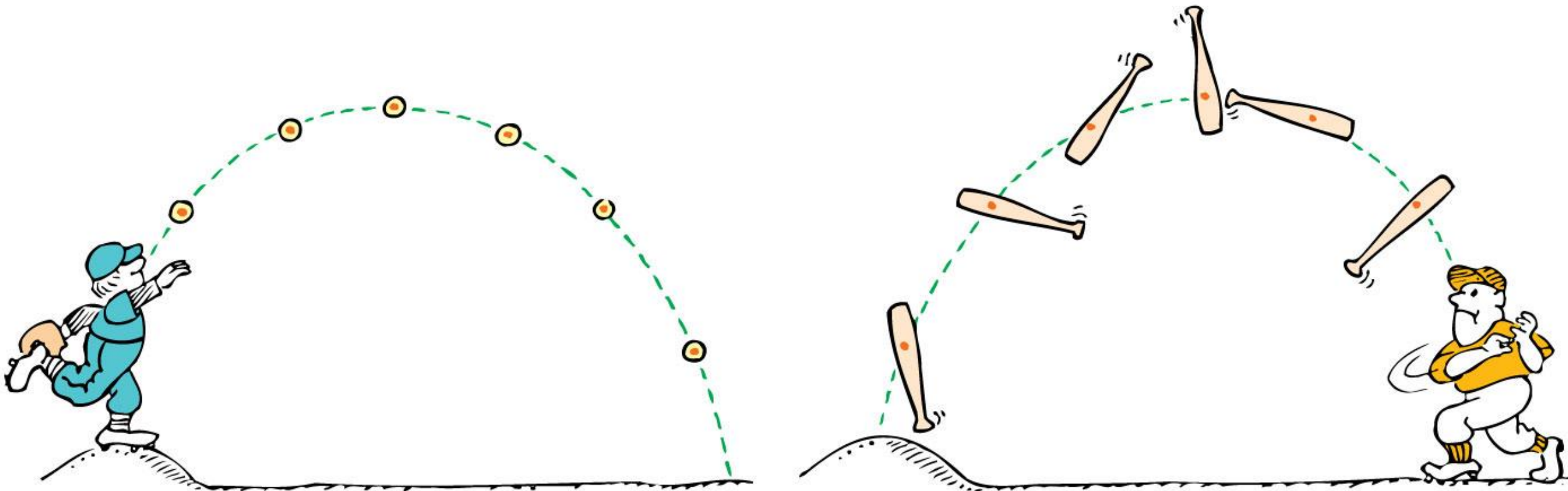


Last day I asked

- The supports to the diving board provide a vertical force on the board so the diver will not fall. What are the directions of the force on the board at point 1 and point 2: up or down? Why?



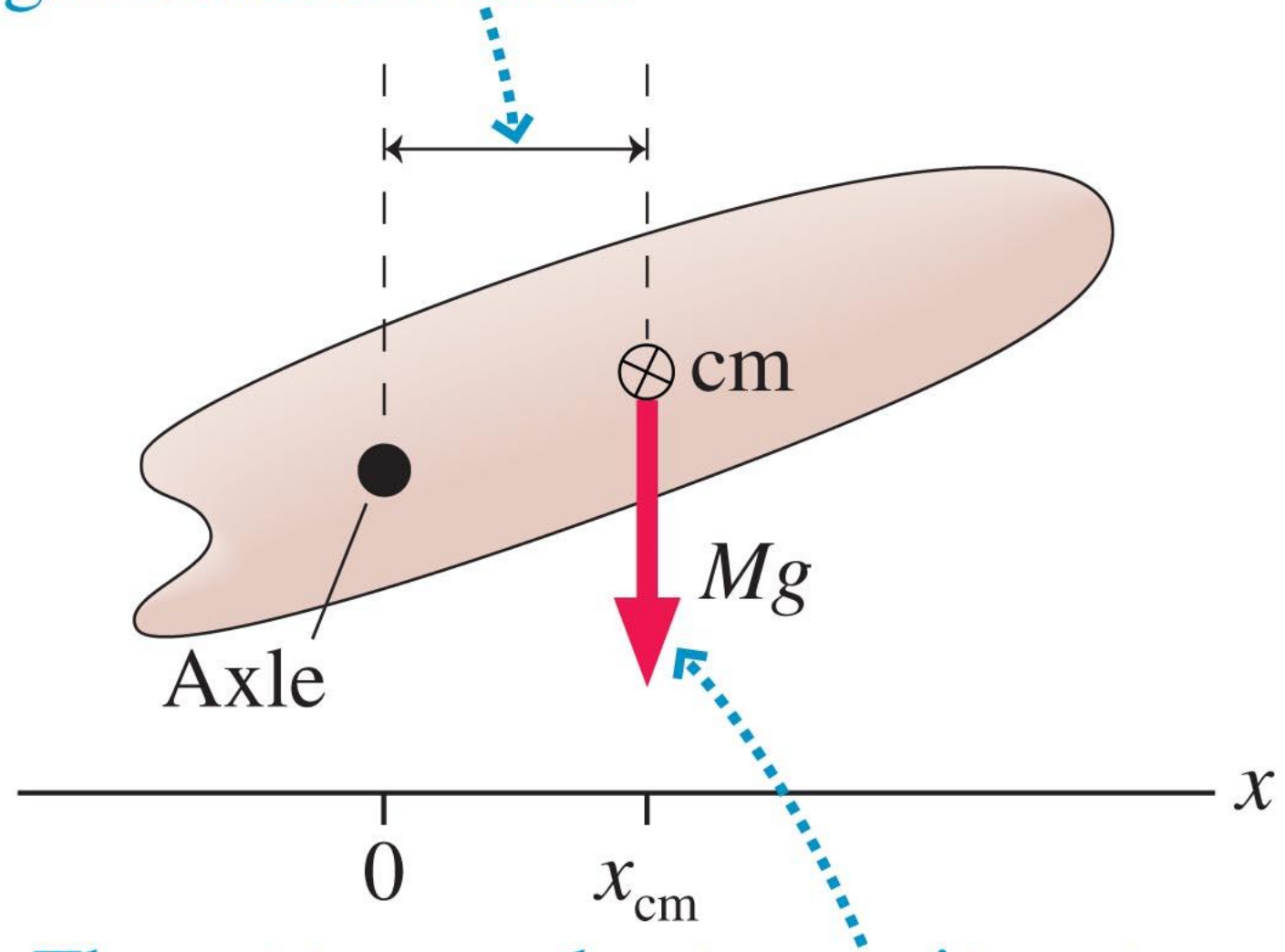
- **Centre of mass** is the average position of all the mass that makes up the object.
- **Centre of gravity (CG)** is the average position of weight distribution.
 - Since here on Earth weight and mass are proportional, centre of gravity and centre of mass always refer to the same point of an object.



Gravitational Torque

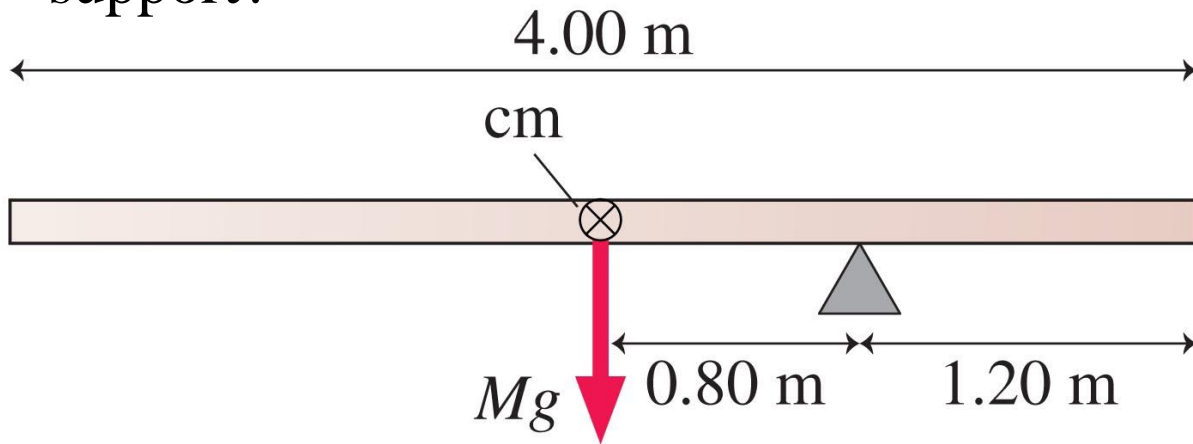
- When calculating the torque due to gravity, you may treat the object as if all its mass were concentrated at the centre of mass.

Moment arm of the net gravitational force



The net torque due to gravity acts at the center of mass.

- A 4.00 m long, 500 kg steel beam is supported 1.20 m from the right end. What is the gravitational torque about the support?



Equilibrium When Rotation is Possible

- The condition for a rigid body to be in *static equilibrium* is that there is no net force and no net torque.
- No matter which pivot point you choose, an object that is not rotating is not rotating about that point.
- For a rigid body in total equilibrium, there is no net torque about *any* point.



Static Equilibrium Problems

- In equilibrium, an object has no net force and no net torque.
- Draw an extended free-body diagram that shows where each force acts on the object.
- Set up x and y axes, and choose a rotation axis. All of these choices should be done to simplify your calculations.
- Each force has an x and y component and a torque. Sum all of these up.
- Three equations which you can use are:

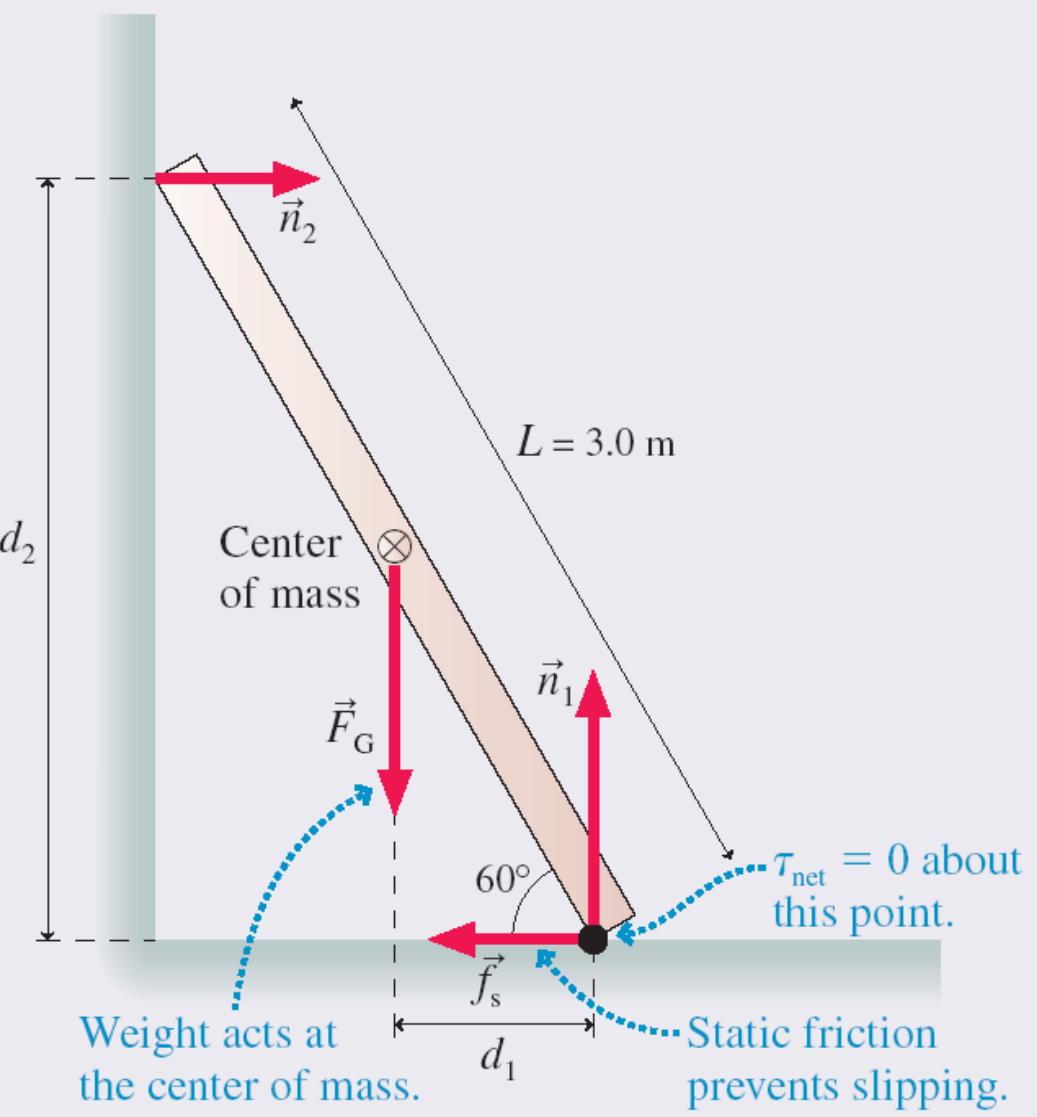
$$\sum F_x = 0 \quad \sum F_y = 0 \quad \sum \tau = 0$$

Learning Catalytics Question.

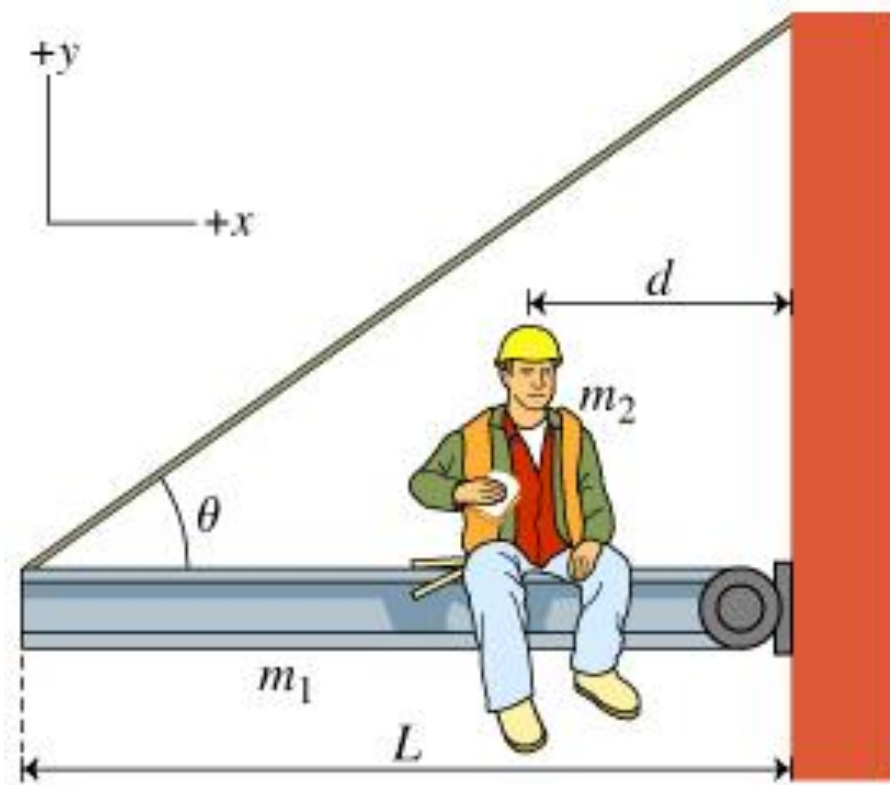
An object could be in static equilibrium when

- A. only one force is acting on it.
- B. two or more forces are acting on it.
- C. only one torque is acting on it.

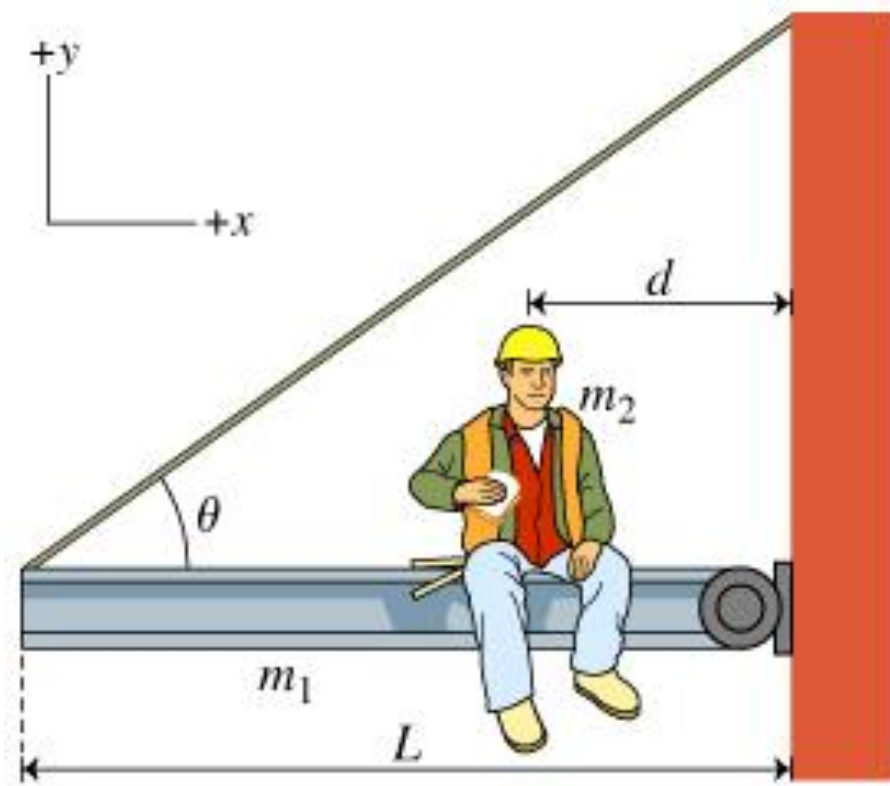
A 3.0-m-long ladder leans against a frictionless wall at an angle of 60° . What is the minimum value of μ_s , the coefficient of static friction with the ground, that prevents the ladder from slipping?



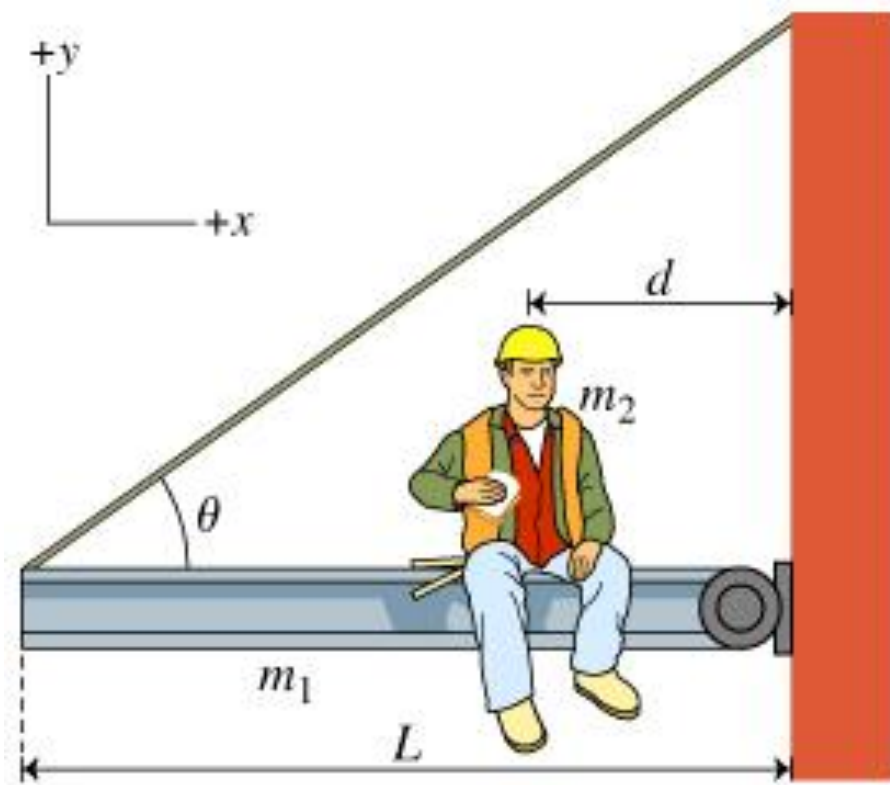
- A uniform steel beam of length L and mass m_1 is attached via a hinge to the side of a building.
 - The beam is supported by a steel cable attached to the end of the beam at an angle θ , as shown.
 - Through the hinge, the wall exerts an unknown force, \vec{F} , on the beam.
 - A workman of mass m_2 sits eating lunch a distance d from the building.
- Find T , the tension in the cable.
 - Find F_x , the x -component of the force exerted by the wall on the beam (\vec{F}), using the axis shown.



a. Find T , the tension in the cable.



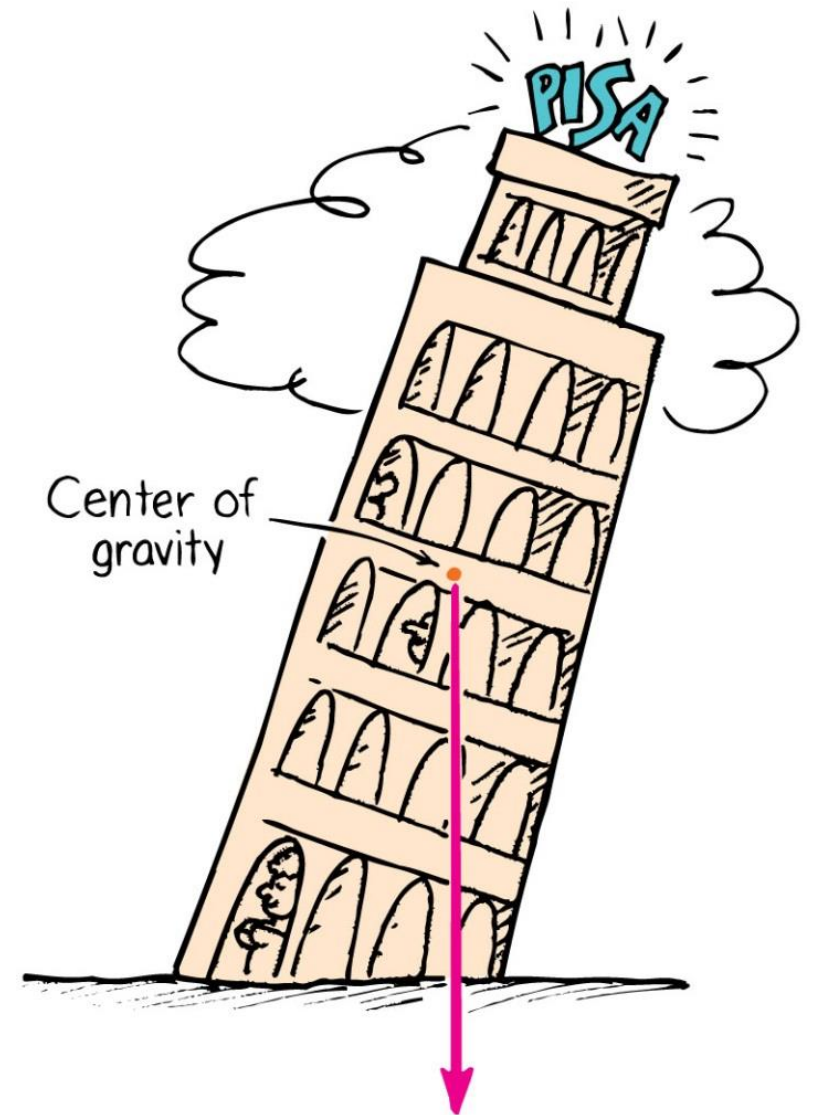
- b. Find F_x , the x -component of the force exerted by the wall on the beam (\vec{F}), using the axis shown.



Centre of Gravity—Stability

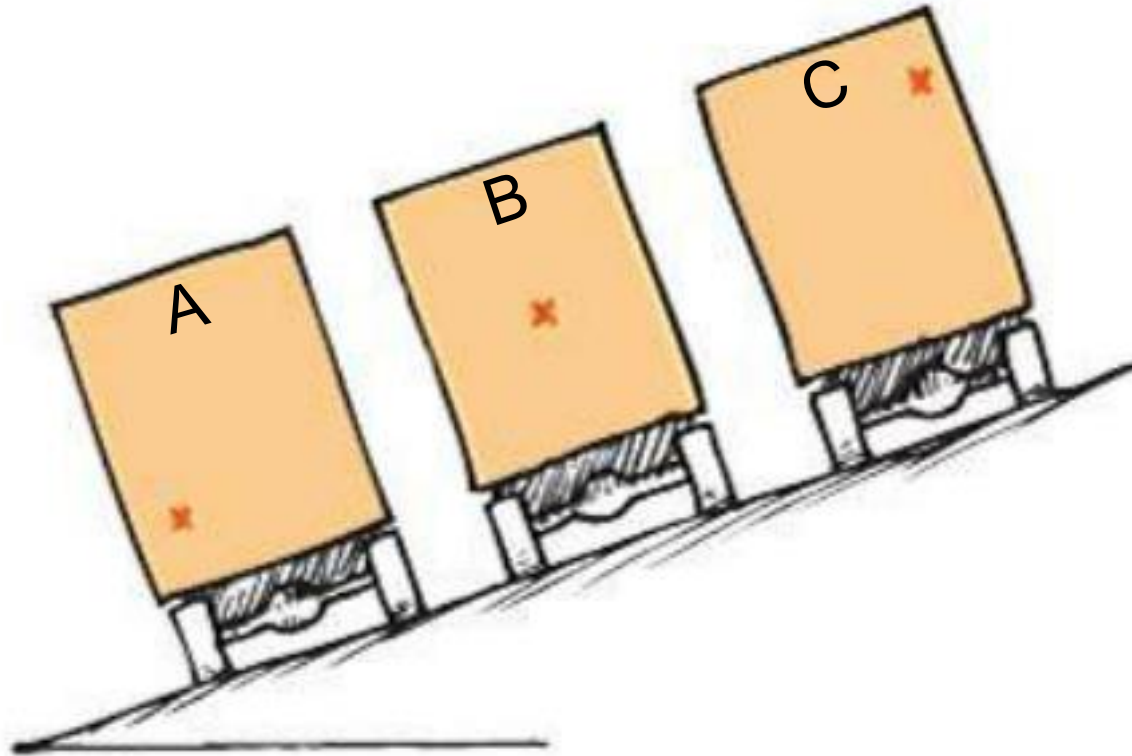
The location of the centre of gravity is important for stability.

- If we draw a line straight down from the centre of gravity and it falls inside the base of the object, it is in stable **equilibrium**; it will balance.
- If it falls outside the base, it is unstable.



Learning Catalytics Question

The centers of gravity of the three trucks parked on a hill are shown by the Xs. Which truck(s) will tip over?



- D. All three of the trucks will tip over.
- E. None of the three will tip over.

Demo and example

- One block of length L is hanging off the edge of a table. How far off the edge can it go without tipping?



Demo and example

- Two blocks have length L . The top one is hanging a distance $L/2$ off the one below it.
- How far off the edge can the bottom block be before the entire stack topples over?



Demo and example

- Three blocks have length L . The top one is hanging a distance $L/2$ off the one below it. The one below that is hanging a distance $L/4$ off the one below it.
- How far off the edge can the bottom block be before the entire stack topples over?



Demo and example

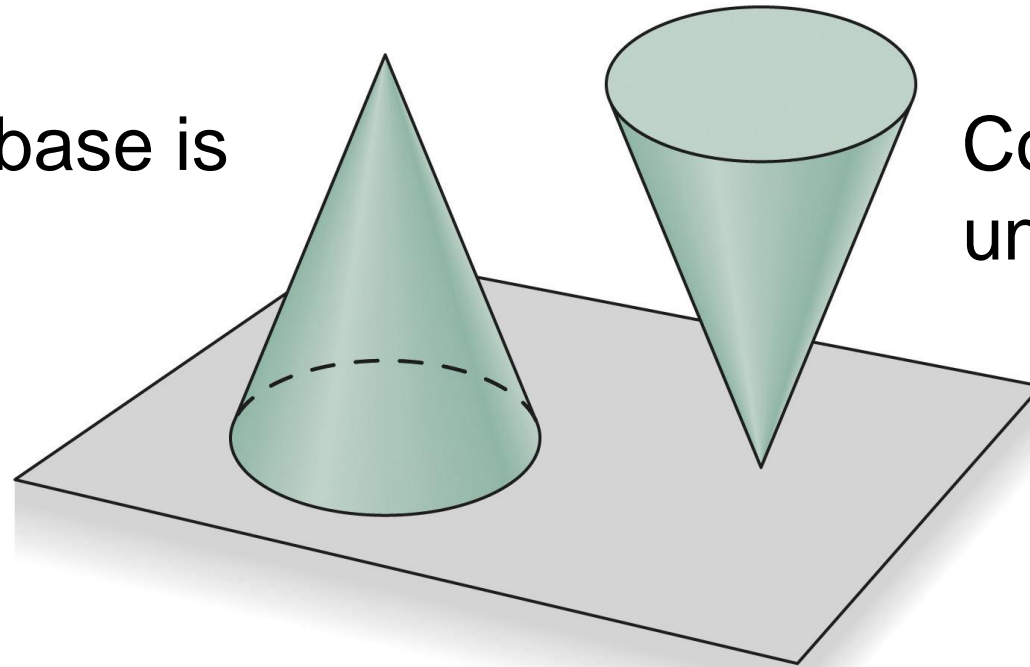
- Three blocks have length L . The top one is hanging a distance $L/2$ off the one below it. The one below that is hanging a distance $L/4$ off the one below it. The one below that is hanging a distance $L/6$ off the one below it.
- How far off the edge can the bottom block be before the entire stack topples over?



Stability

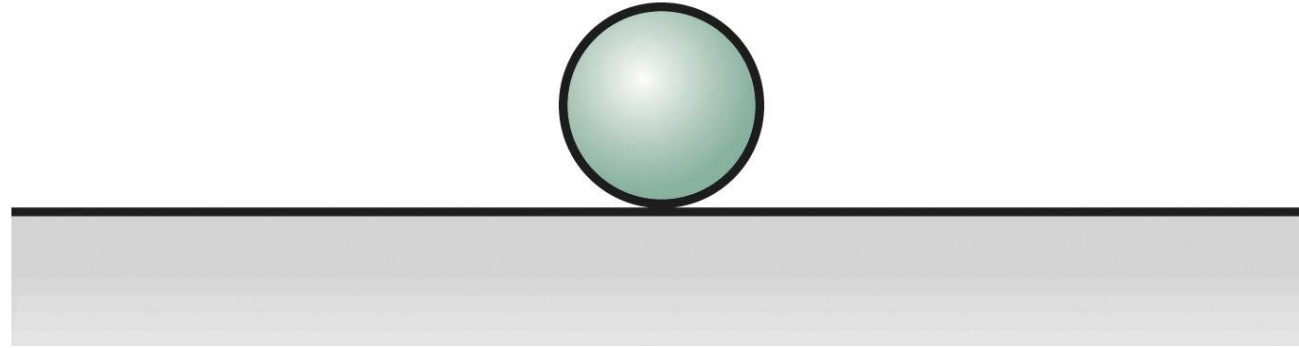
- An equilibrium is stable if a slight disturbance from equilibrium results in forces and/or torques that tend to restore the equilibrium.
- An equilibrium is unstable if a slight disturbance causes the system to move away from the original equilibrium.

Cone on its base is
stable



Cone on its tip is
unstable

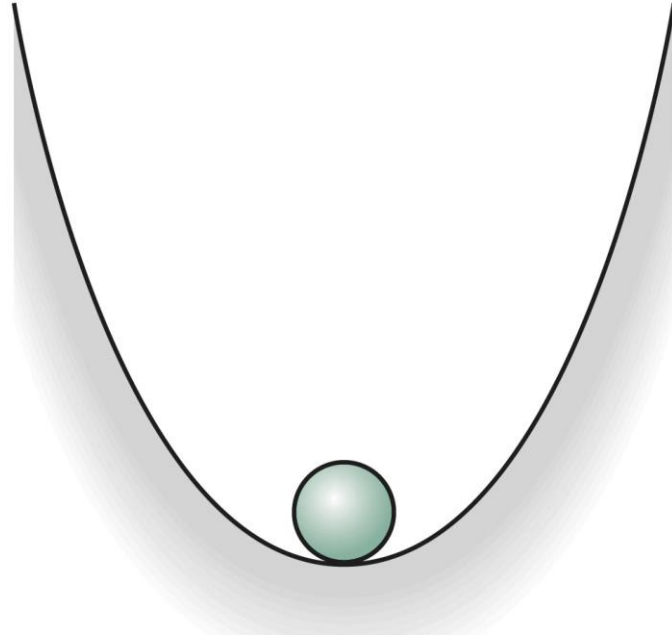
Kinds of Stability



What kind of equilibrium is this?

- A. Stable
- B. Neutrally stable
- C. Unstable
- D. Metastable

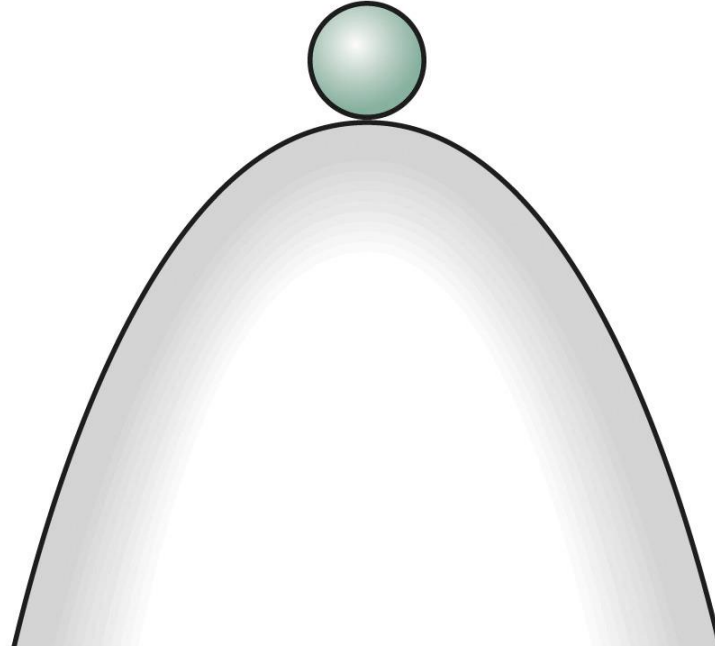
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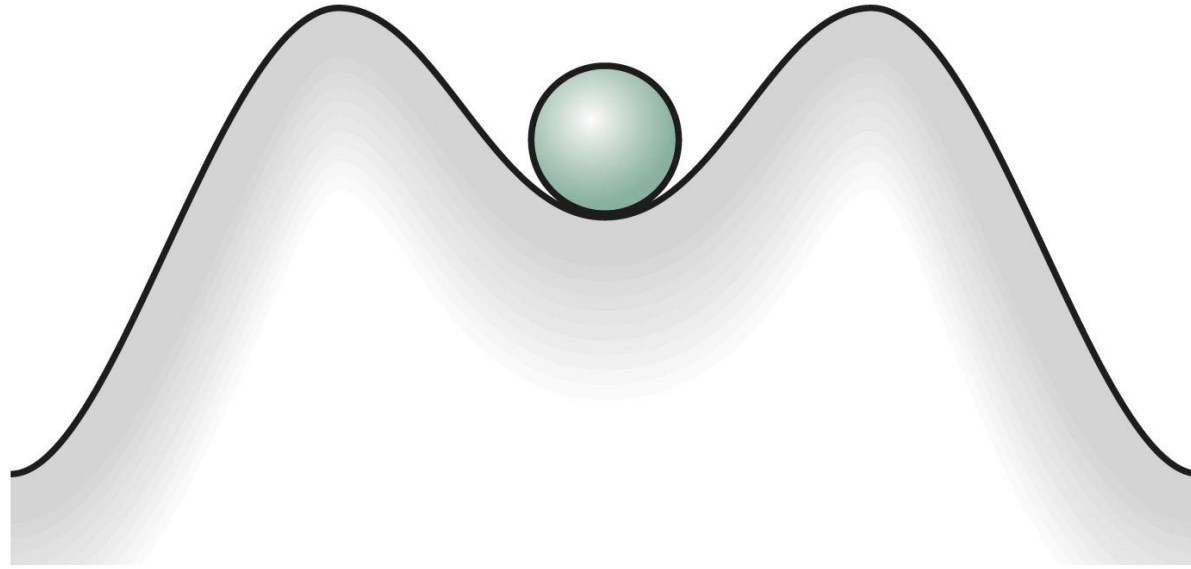
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Kinds of Stability



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Before Class 20 on Monday

- Please read sections 13.1 and 13.2 of chapter 13 on oscillations, or at least watch the Preclass 20 Video
- The preclass quiz is due Wednesday morning at 8:00am.
- Something to think about over the weekend: A spring with a mass attached to it is stretched and released. When the spring returns to equilibrium, is the mass moving?

