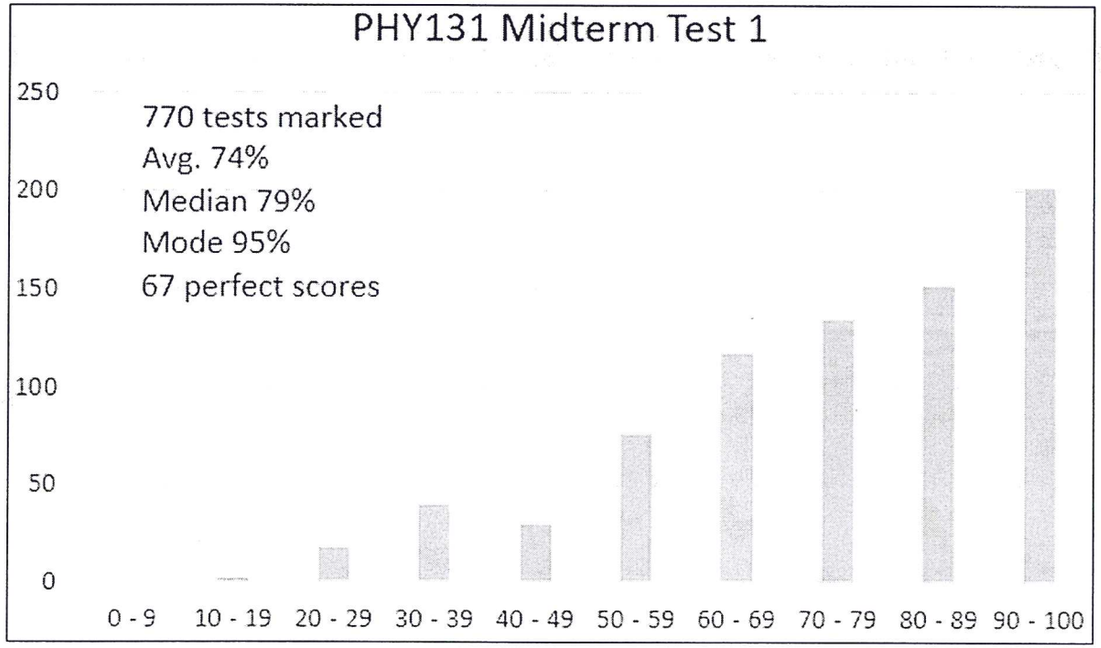
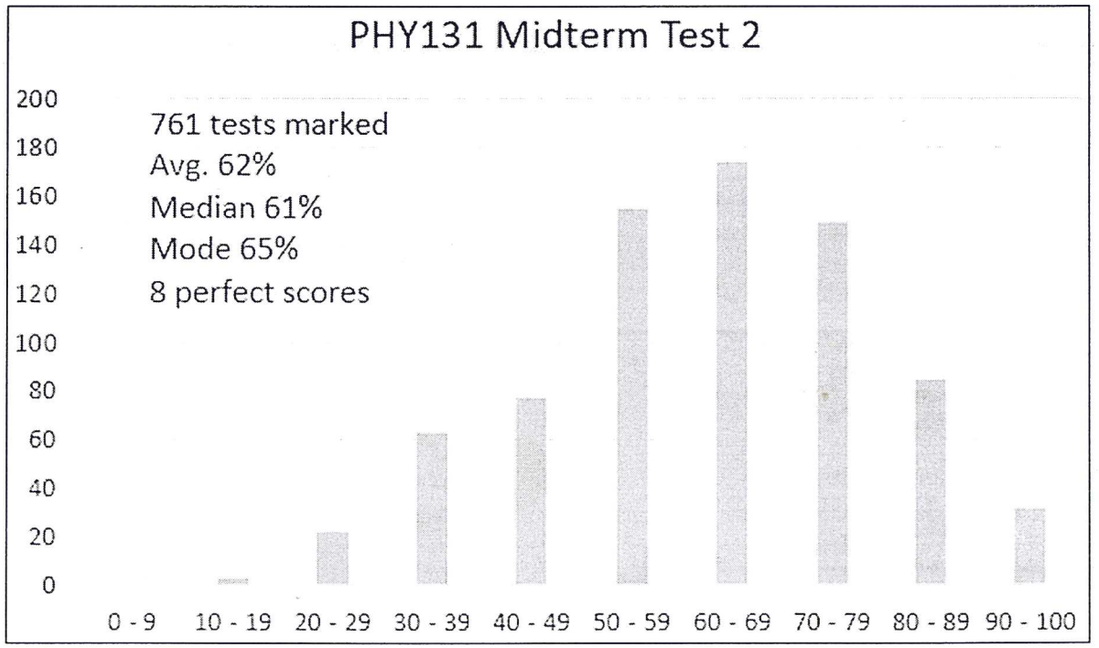
PHY131H1F - Class 19

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

Test 2 is marked





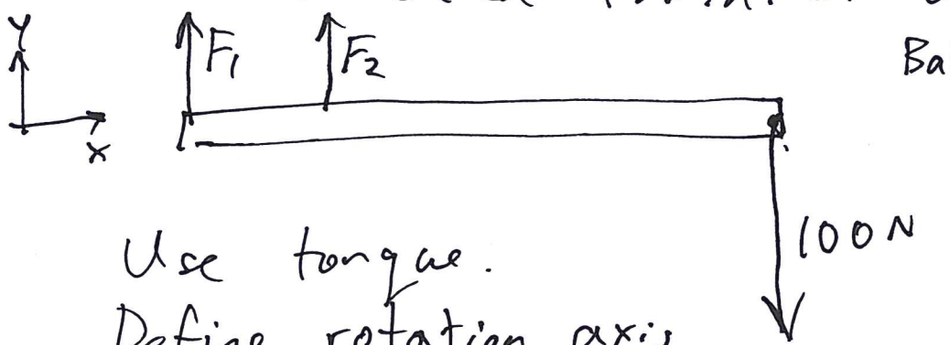
- The raw average on Test 2 was [redacted]. 57 %
- In order to give a boost to students' marks, some partial credit was awarded to multiple choice questions.
- Correct answers are still worth 2 points.
- Though all of the distractors are wrong, for some questions, there were some **very wrong** distractors that could have been ruled out by common sense. In *some* of these cases, the less wrong distractors were given 1 point.

- These single points are by *Professor's Discretion* (Harlow,Wilson,Sealfon), and the choices will not be changed.
- The marking scheme is posted on portal under Course Materials
- You will receive your marked test back in Practicals by Nov. 28.
- The deadline for requesting a regrade is Tue. Dec.5 by 4:00pm to April Seeley in MP129.

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?

Draw extended f.b.d. of board. Neglect weight of board.



Balance y-forces:

$$\Sigma F_y = F_1 + F_2 - 100\,N$$

$$\Rightarrow F_1 + F_2 = 100\,N$$

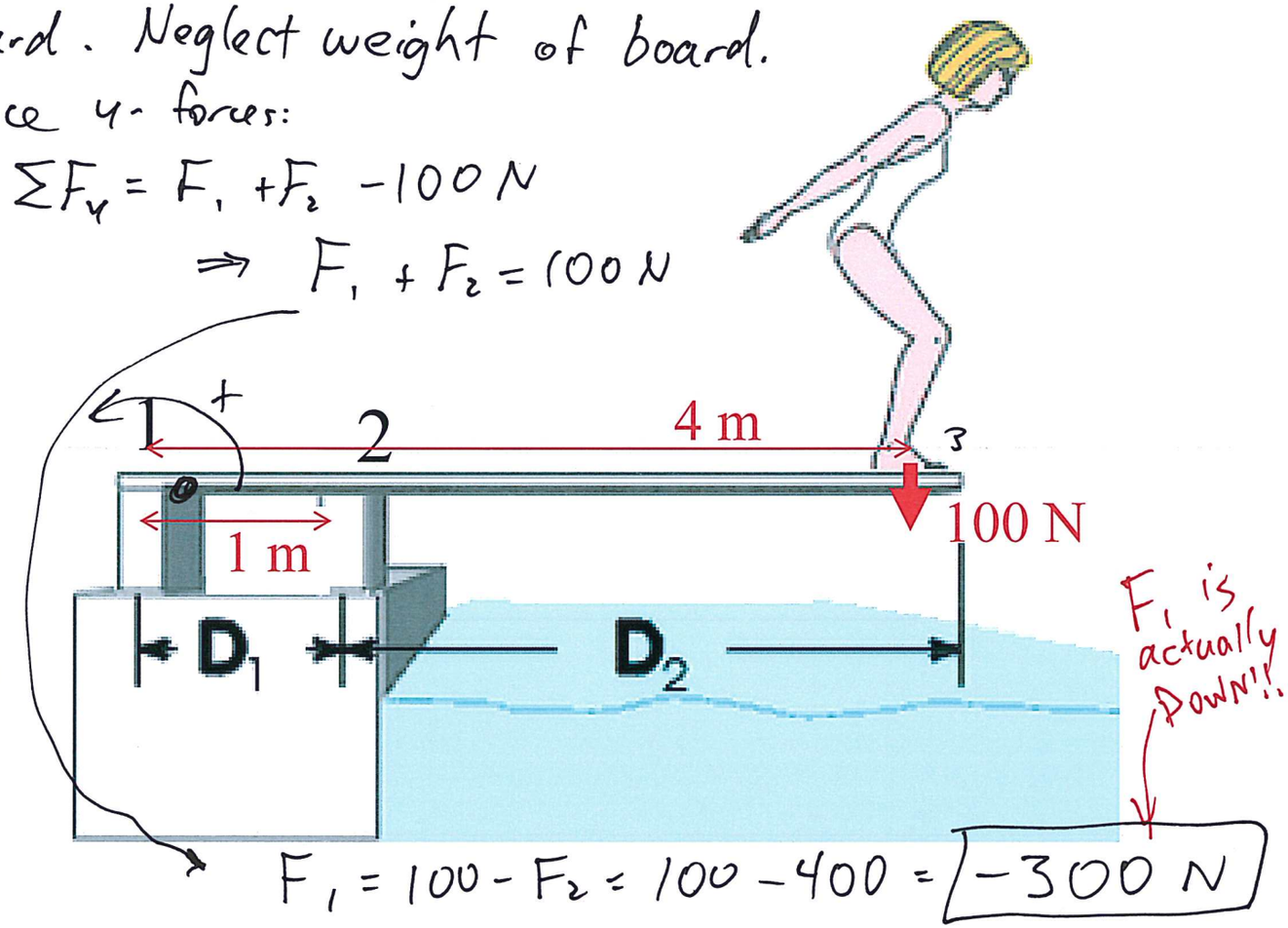
Use torque.
Define rotation axis left end (where F_1 acts).

$$\Sigma\tau = \tau_1 + \tau_2 + \tau_3$$

$$0 = F_1(0) + F_2(1\,m) - 100N(4\,m)$$

$$0 = F_2 - 400$$

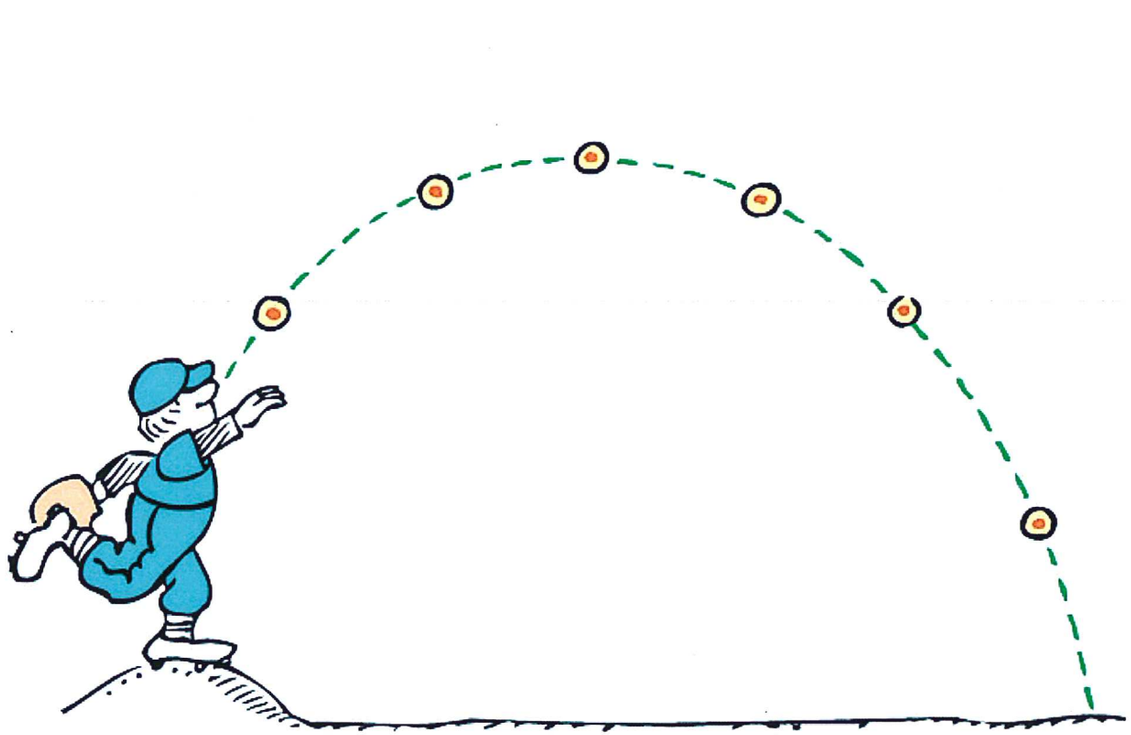
$$\boxed{F_2 = 400\,N.}$$

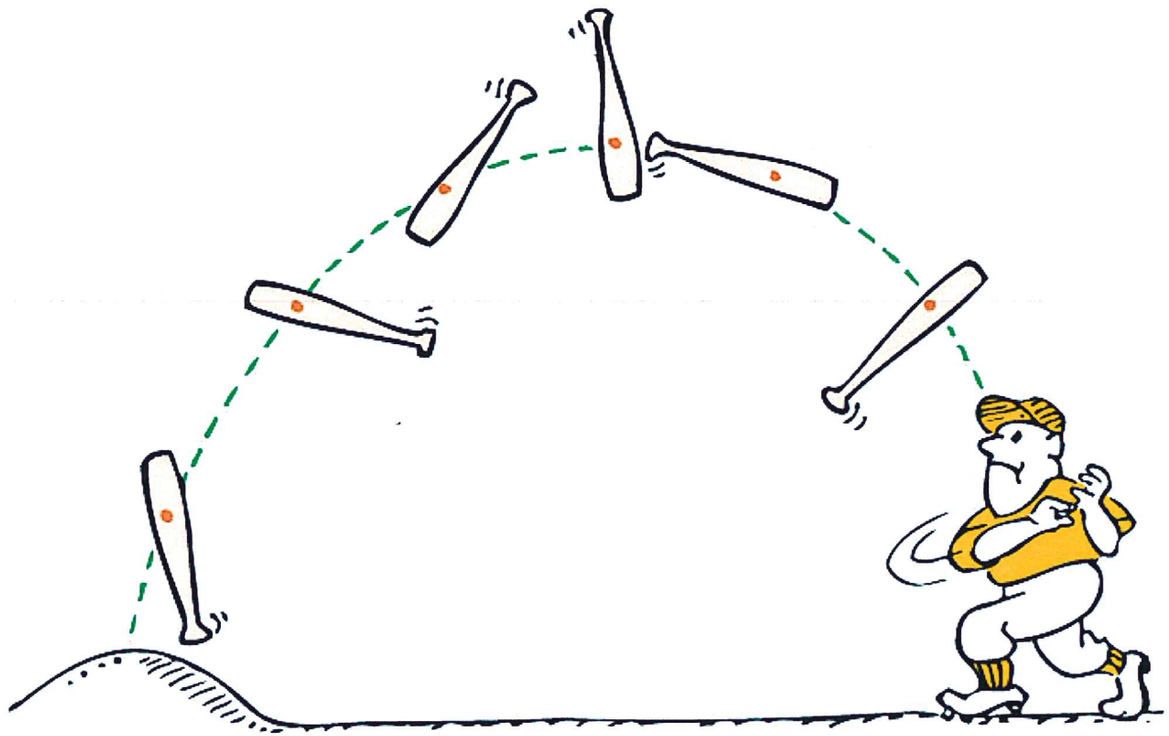


$$F_1 = 100 - F_2 = 100 - 400 = \boxed{-300\,N}$$

- **Centre of mass** is the average position of all the mass that makes up the object.

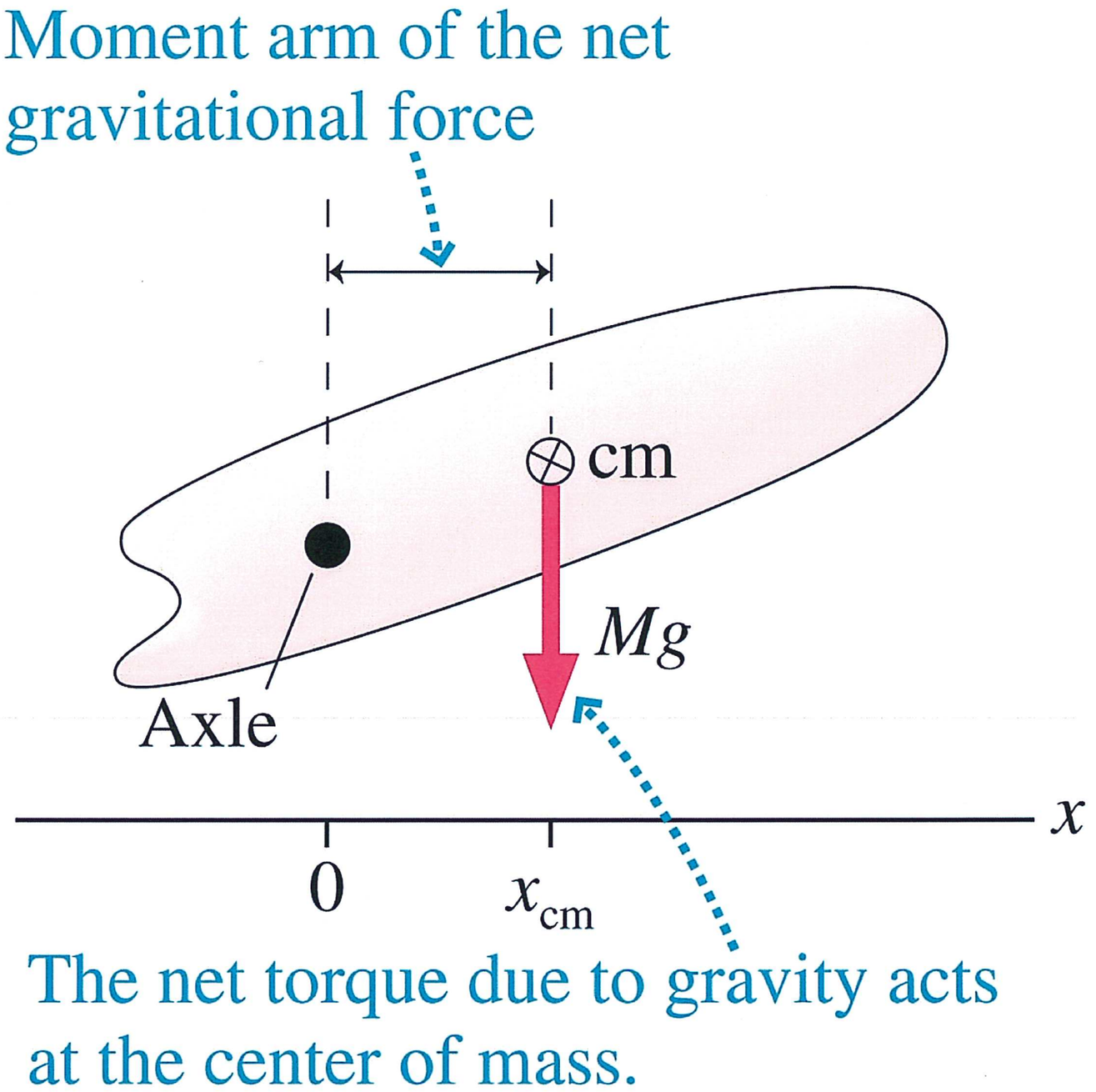
- **Centre of gravity (CG)** is the average position of weight distribution.
  - Since here on Earth weight and mass are proportional, centre of gravity and centre of mass always refer to the same point of an object.



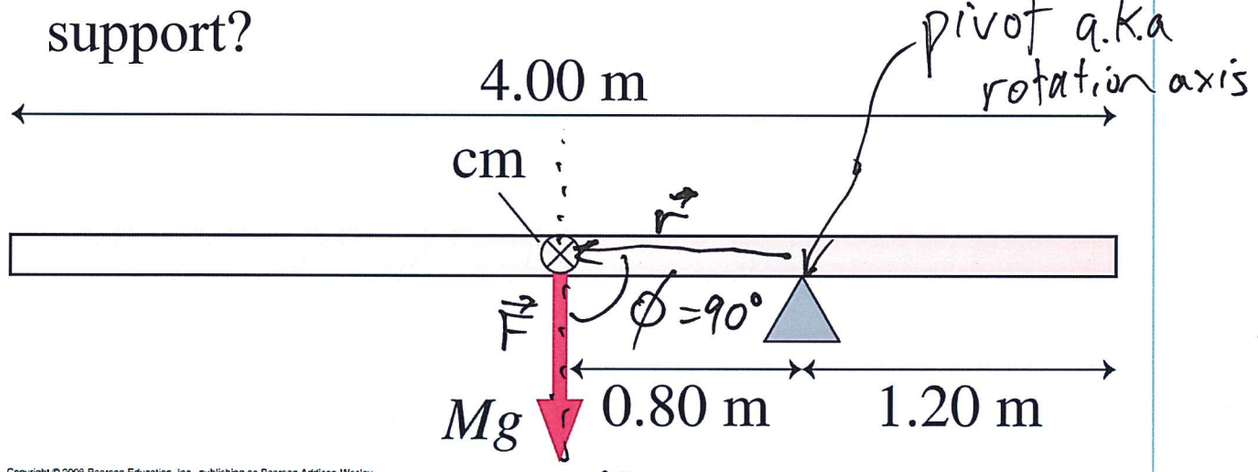


Gravitational Torque

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



- 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?



$\vec{\tau} = \vec{r} \times \vec{F}$

$\tau = r F \sin\phi$

$\tau = F \ell$, where ℓ = lever arm

$\ell = r \sin\phi$.

distance between force line & pivot.

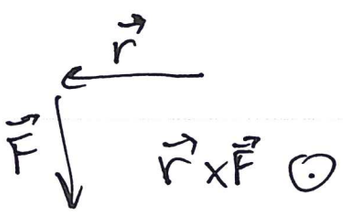
$\ell = r$

$\tau = Mgr = (500)(9.8)(0.8)$

$\tau = 3920$ N·m

Vector:

$\vec{\tau} = 3920$ N·m, out of page



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:

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

Learning Catalytics Question.

An object could be in static equilibrium when

A. only one force is acting on it.

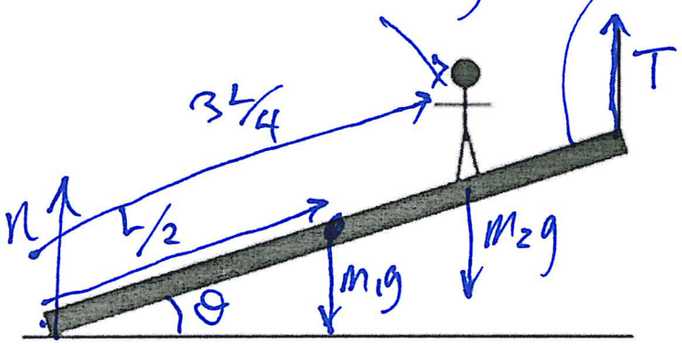
B. two or more forces are acting on it.

C. only one torque is acting on it.

Pre-class 19 Results

2. numerical

A 20.0-kg uniform plank is supported by the floor at one end and by a vertical rope at the other as shown in the figure. A 50.0-kg mass person stands on the plank a distance three-fourths of the length plank from the end on the floor. What is the tension in the rope?



$m_2 = 50\ kg$ — plank $= m_1 = 20\ kg$

Define $\uparrow y$, $\rightarrow x$

529 responses, 67% correct

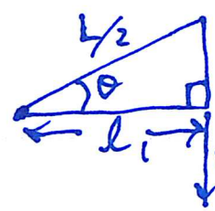
466: 62%

Try $\Sigma F_y = n - m_1 g - m_2 g + T = 0$, $n + T = (m_1 + m_2)g$

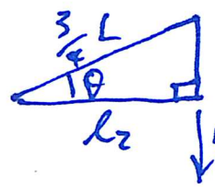
[Enter your answer as a number only, using the units of Newtons.]

Use torques... Define left end to be rotation axis.

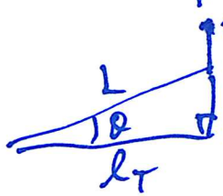
lever arms:



$\cos\theta = \frac{l_1}{L/2}$, $l_1 = \frac{L}{2}\cos\theta$



$l_2 = \frac{3L}{4}\cos\theta$



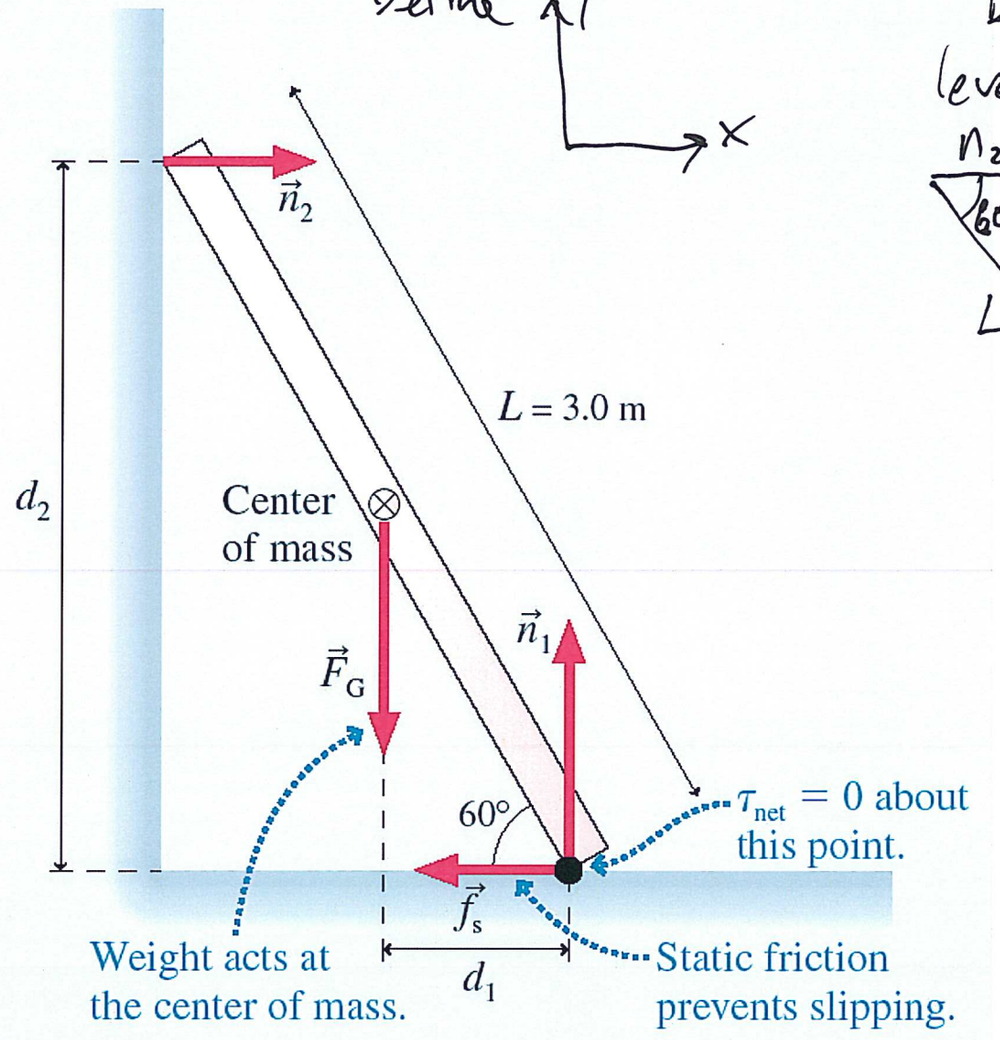
$l_T = L\cos\theta$

$\sum \tau = \tau_n + \tau_1 + \tau_2 + \tau_T$

$0 = 0 + m_1 g \frac{L}{2}\cos\theta - m_2 g \frac{3L}{4}\cos\theta + T L \cos\theta$

$0 = \frac{m_1 g}{2} - \frac{m_2 g 3}{4} + T$, $T = \frac{m_1 g}{2} + \frac{3 m_2 g}{4} = \boxed{465.5\ N}$

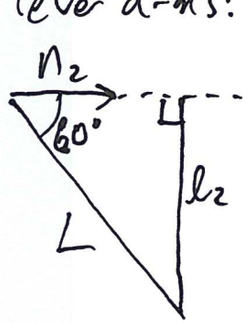
A 3.0-m-long ladder leans against a frictionless wall at an angle of 60°. What is the minimum value of μ_s, the coefficient of static friction with the ground, that prevents the ladder from slipping?



Define y, x

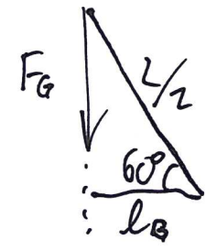
Define rotation axis to be base.

lever arms:



$\sin 60° = \frac{l_2}{L}$

$l_2 = L \sin 60°$



$\cos 60° = \frac{l_G}{L/2}$

$l_G = \frac{L}{2} \cos 60°$

$$\sum \tau = \tau_n + \tau_G = -n_2 l_2 + mg l_G = 0$$

$$n_2 L \sin 60 = mg \frac{L}{2} \cos 60$$

$$n_2 = mg \frac{L/2 \cos 60}{L \sin 60} = \frac{mg \cos 60}{2 \sin 60}$$

$$\sum F_x = n_2 - f_s = 0 \quad \Rightarrow n_2 = f_s$$

$$f_s = \frac{mg \cos 60}{2 \sin 60}$$

$$\sum F_y = 0 = -mg + n_1 = 0 \quad , n_1 = mg$$

Set $f_{s,max} = f_s$

$$\mu_s n_1 = \frac{mg\cos 60}{2\sin 60}$$

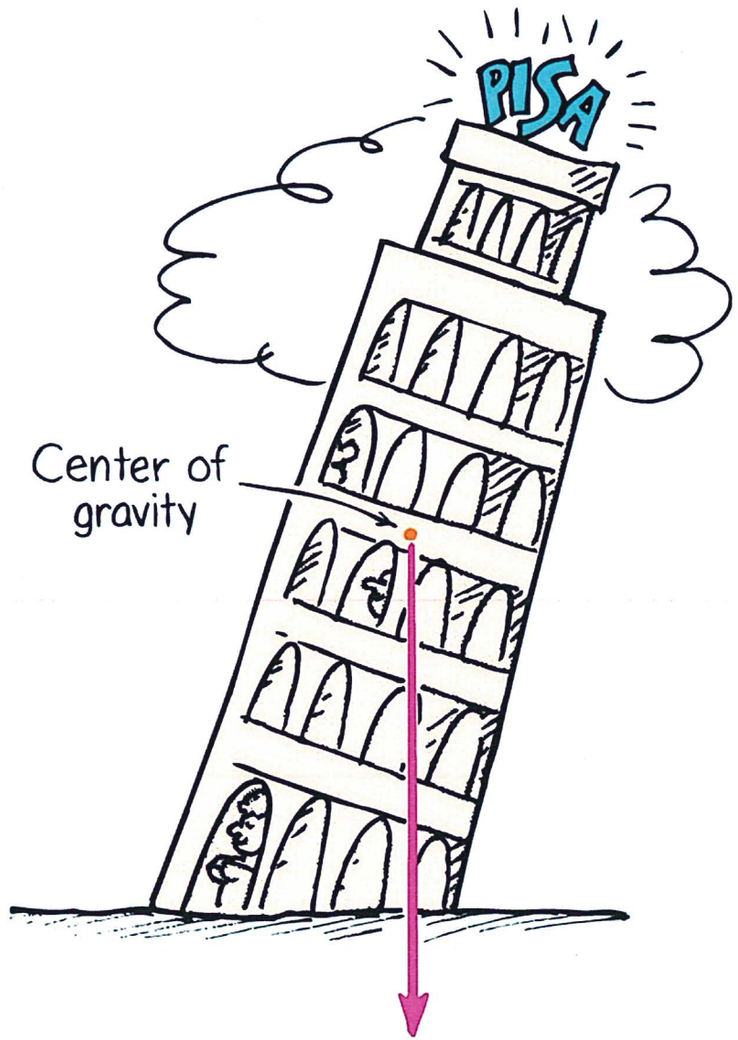
$$\mu_s mg = \frac{mg\cos 60}{2\sin 60}$$

$$\mu_s = \frac{\cos 60}{2\sin 60} = \boxed{0.29}$$

Centre of Gravity—Stability

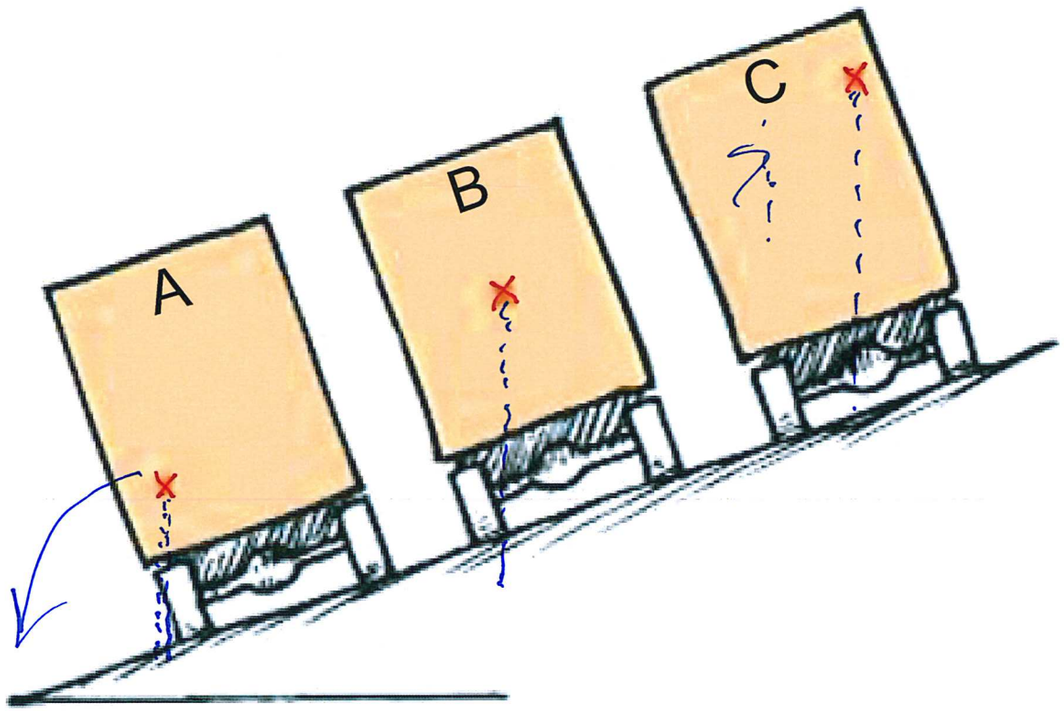
The location of the centre of gravity is important for stability.

- 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?



72

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

.... Are you really here? Or are you voting from home?
(...just curious)

Number: 93

11 AM number

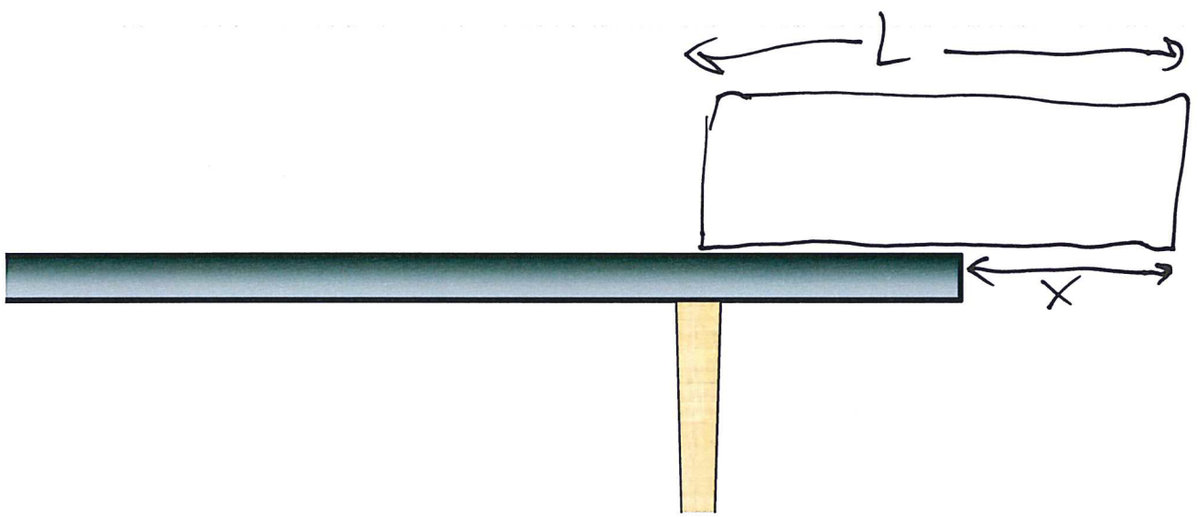
Are you really here?

If so, this is

the number: 72 ← 5 pm

Demo and example

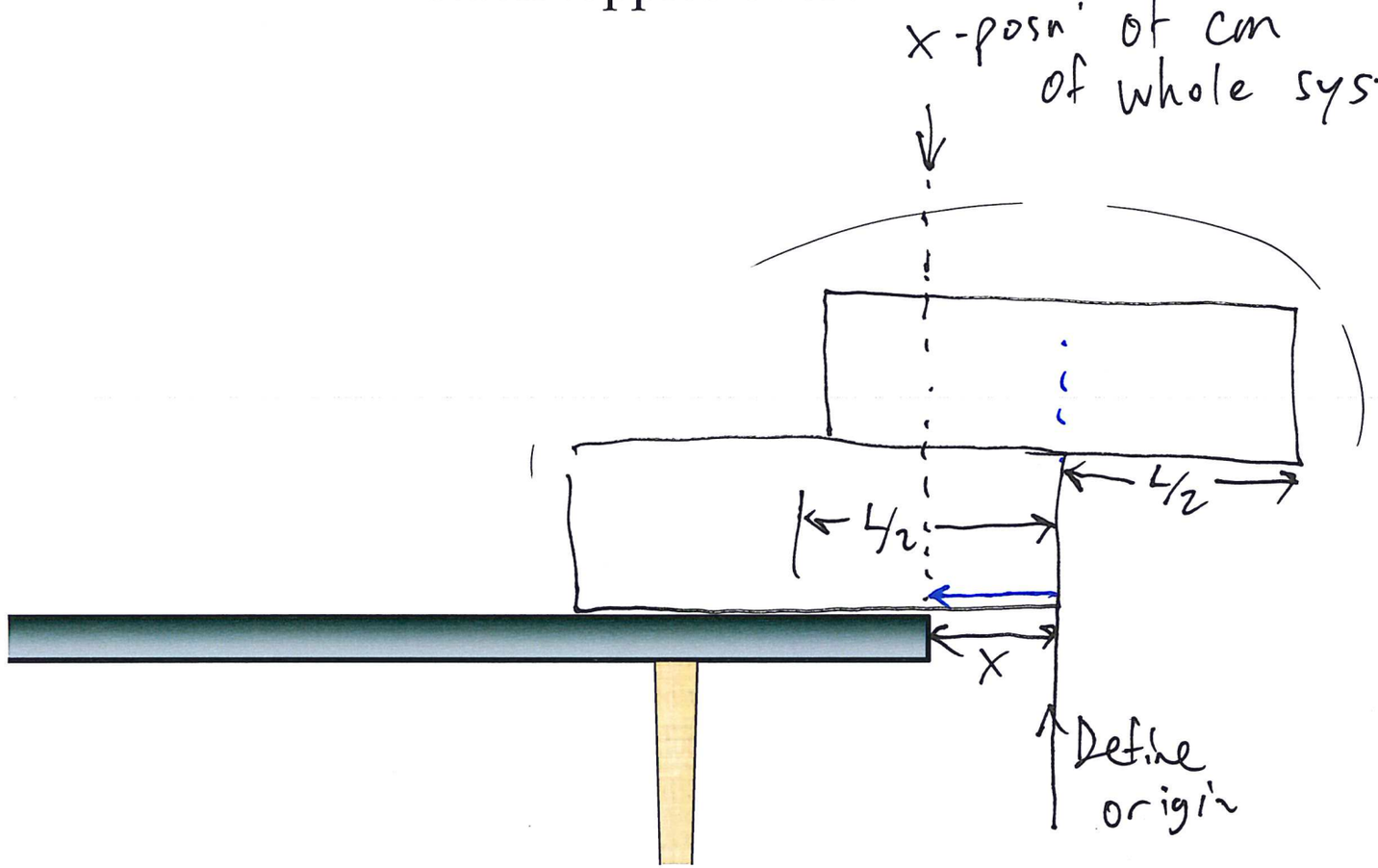
- One block of length L is hanging off the edge of a table. How far off the edge can it go without tipping?



$x = L/2$

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?



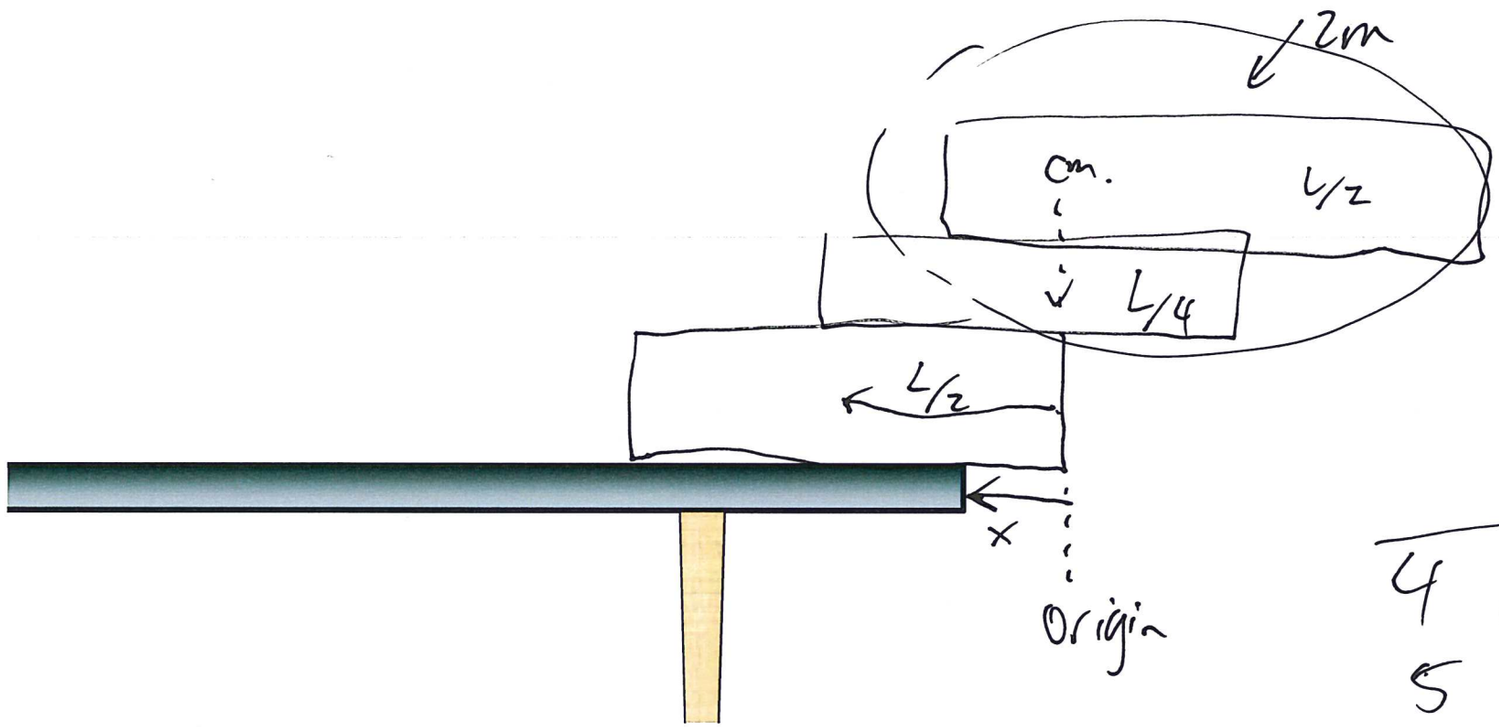
$$x_{cm} = \frac{x_{top}m + x_{bottom}M}{m+m}$$

$$= \frac{0\,m + L/2\,m}{2m}$$

$$x = \frac{L}{4}$$

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?



$$x = \frac{0 \cdot 2m + L/2\, m}{2m + m} = \frac{L/2\, m}{3m}$$

$$x = \frac{L}{6}\, m$$

4 blocks: $x = L/8\ m$

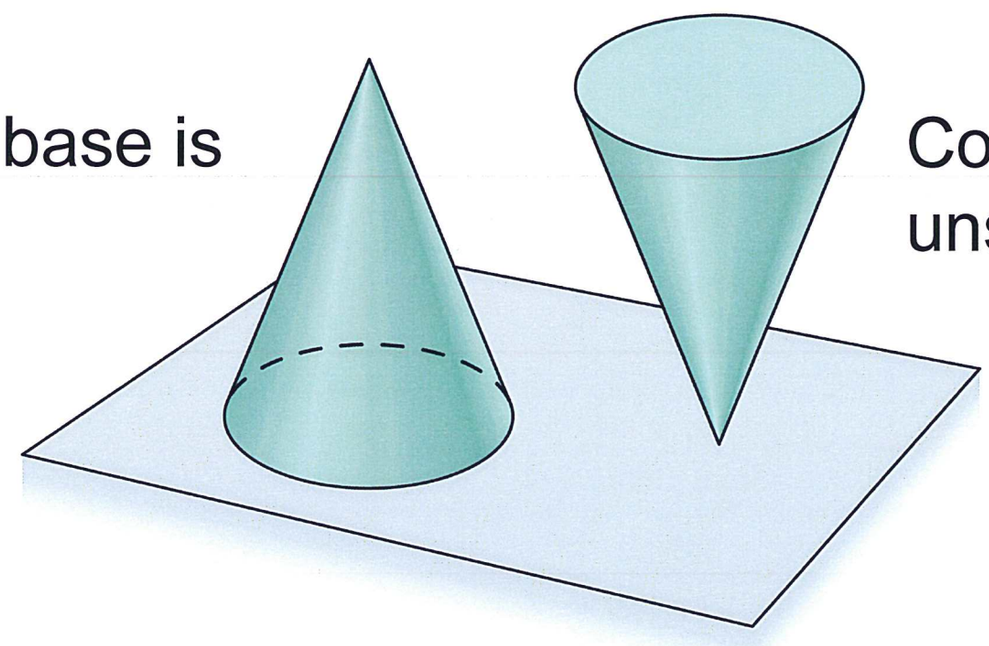
5 blocks $x = 2/10\ m$, etc..

Stability

- An equilibrium is stable if a slight disturbance from equilibrium results in forces and/or torques that tend to restore the equilibrium.

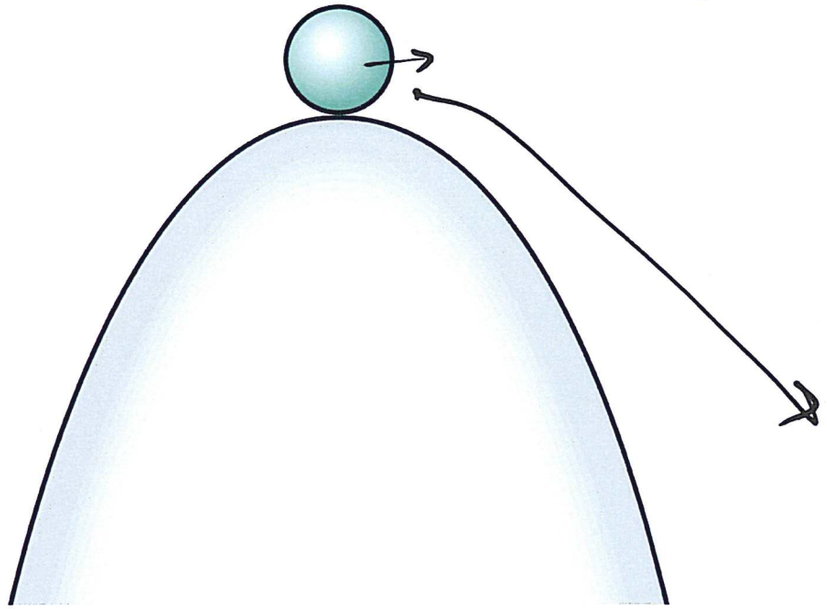
- An equilibrium is unstable if a slight disturbance causes the system to move away from the original equilibrium.

Cone on its base is stable



Cone on its tip is unstable

Kinds of Stability



What kind of equilibrium is this?

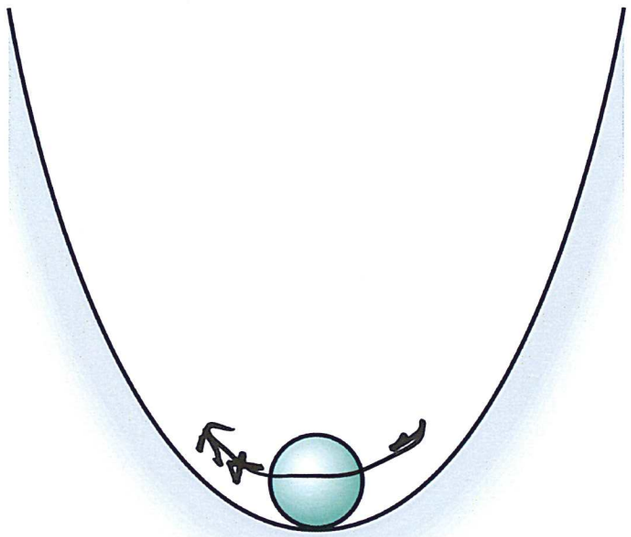
A. Stable

B. Neutrally stable

C. Unstable

D. Metastable

Kinds of Stability



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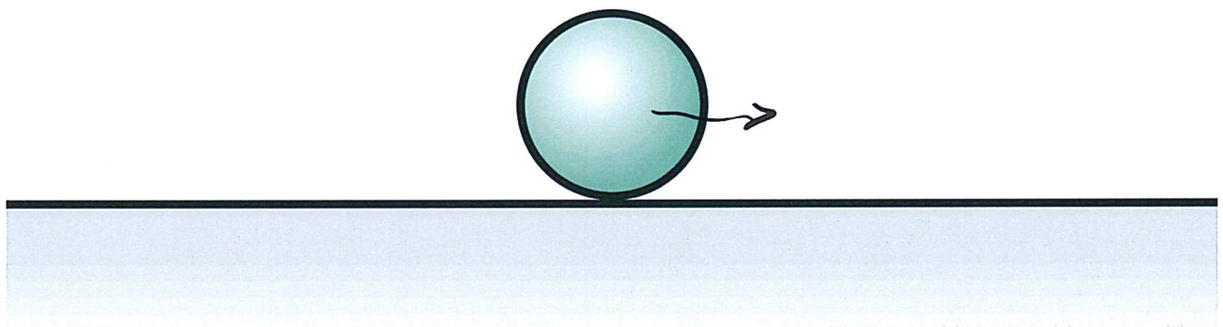
Kinds of Stability



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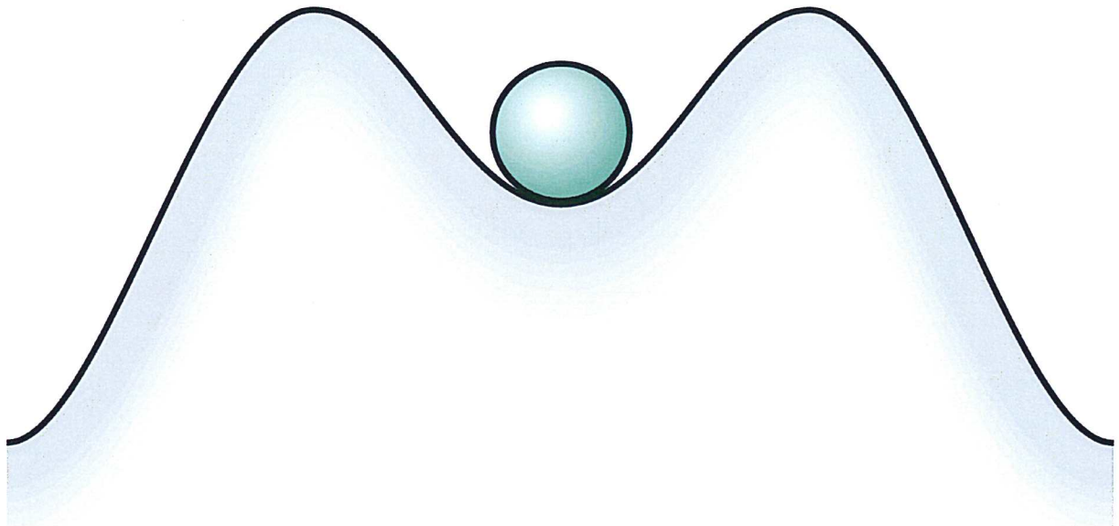
Kinds of Stability



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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?