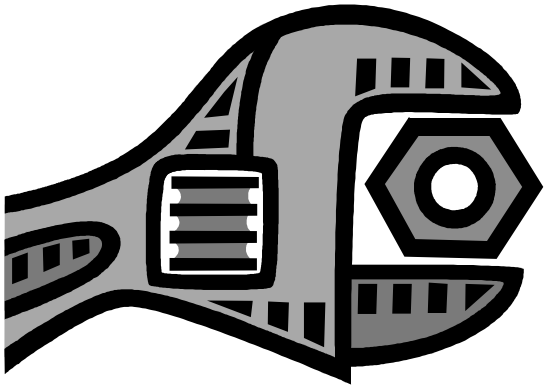
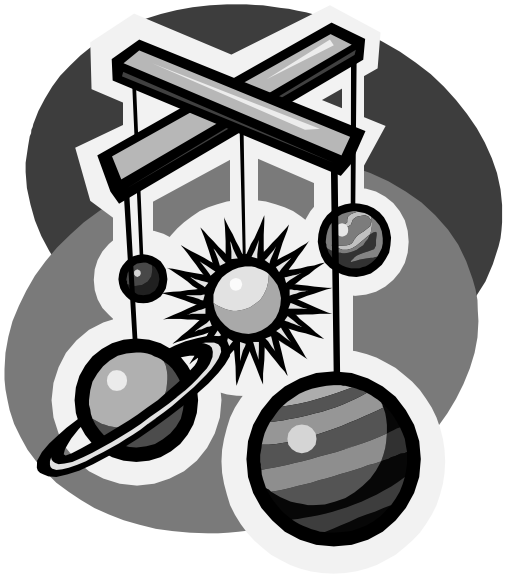
Physics 101: Lecture 14
Torque and Equilibrium

- Today's lecture will cover Textbook Chapter 8.2-8.4





Review

- Rotational Kinetic Energy $K_{rot} = \frac{1}{2} I \omega^2$
- Rotational Inertia $I = \Sigma m_i r_i^2$
- Energy Still Conserved!

Today

- Torque

You Know Torque!

- A meter stick is suspended at the center. If a 1 kg weight is placed at x=0. Where do you need to place a 2 kg weight to balance it?

A) x = 25 B) x=50 C) x=75 D) x=100

E) 1 kg can't balance a 2 kg weight.

Torque

- "Turning force"

- Rotational effect of force. Tells how effective force is at twisting or rotating an object.

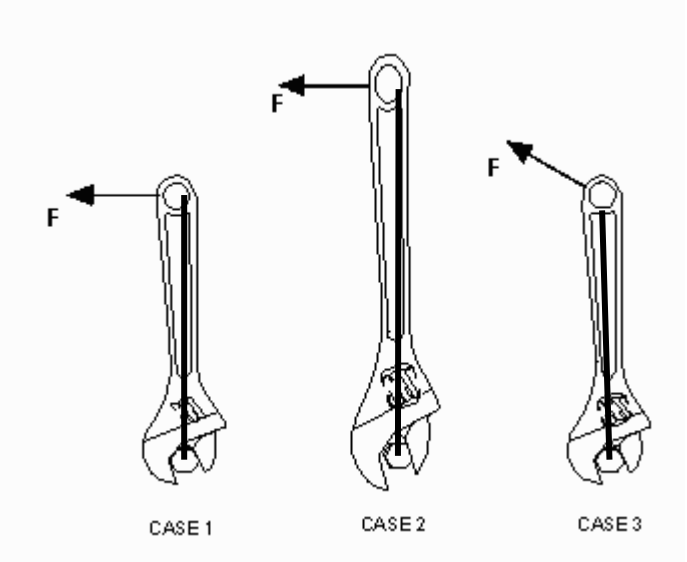
- $\tau = \pm r F_{perpendicular} = r F \sin\theta$
  - ➔Units N m
  - ➔Sign, CCW rotation is positive

ACT

The picture below shows three different ways of using a wrench to loosen a stuck nut. Assume the applied force F is the same in each case.

In which of the cases is the torque on the nut the biggest?

A. Case 1
B. Case 2
C. Case 3

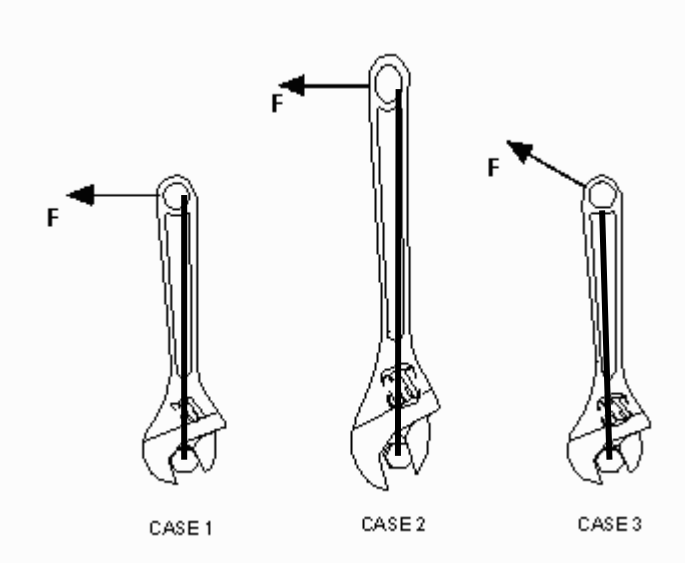


ACT 2

The picture below shows three different ways of using a wrench to loosen a stuck nut. Assume the applied force F is the same in each case.

In which of the cases is the torque on the nut the smallest?

A. Case 1
B. Case 2
C. Case 3



Torque Example and ACT

A person raises one leg to an angle of 30 degrees. An ankle weight (89 N) attached a distance of 0.84 m from her hip. What is the torque around her hip due to this weight?

1) Draw Diagram

2) $\tau = F\ r \sin\theta$

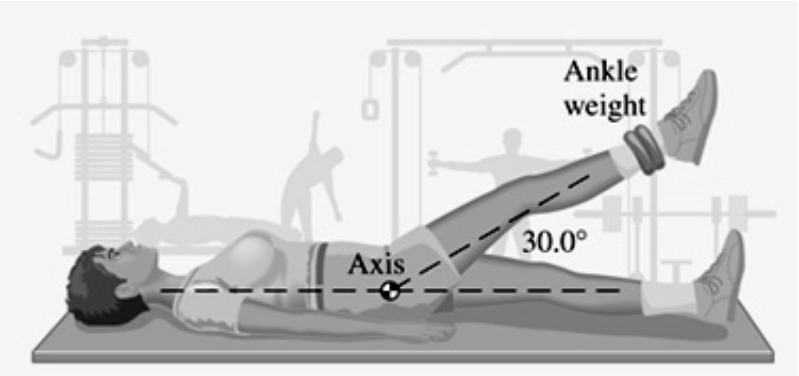
$= F\ r \sin(90 - 30)$

If she raises her leg higher, the torque due to the weight will

A) Increase

B) Same

C) Decrease

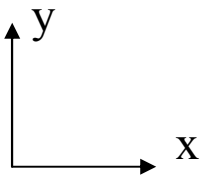


Equilibrium Acts

- A rod is lying on a table and has two equal but opposite forces acting on it. What is the net force on the rod?

A) Up B) Down C) Zero

- Will the rod move? A) Yes B) No



Equilibrium

- Conditions for Equilibrium
  - ➔$\Sigma F = 0$ Translational EQ (Center of Mass)
  - ➔$\Sigma \tau = 0$ Rotational EQ
    - » Can choose any axis of rotation…. Choose Wisely!

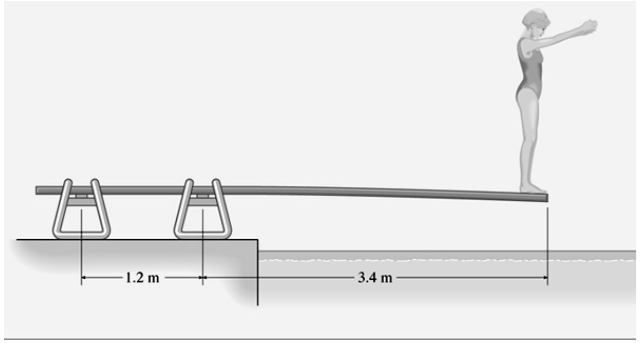
- A meter stick is suspended at the center. If a 1 kg weight is placed at x=0. Where do you need to place a 2 kg weight to balance it?

A) x = 25 B) x=50 C) x=75 D) x=100

E) 1 kg can't balance a 2 kg weight.

Equilibrium Example

A 50 kg diver stands at the end of a 4.6 m diving board. Neglecting the weight of the board, what is the force on the pivot 1.2 meters from the end?



1) Draw FBD

2) Choose Axis of rotation

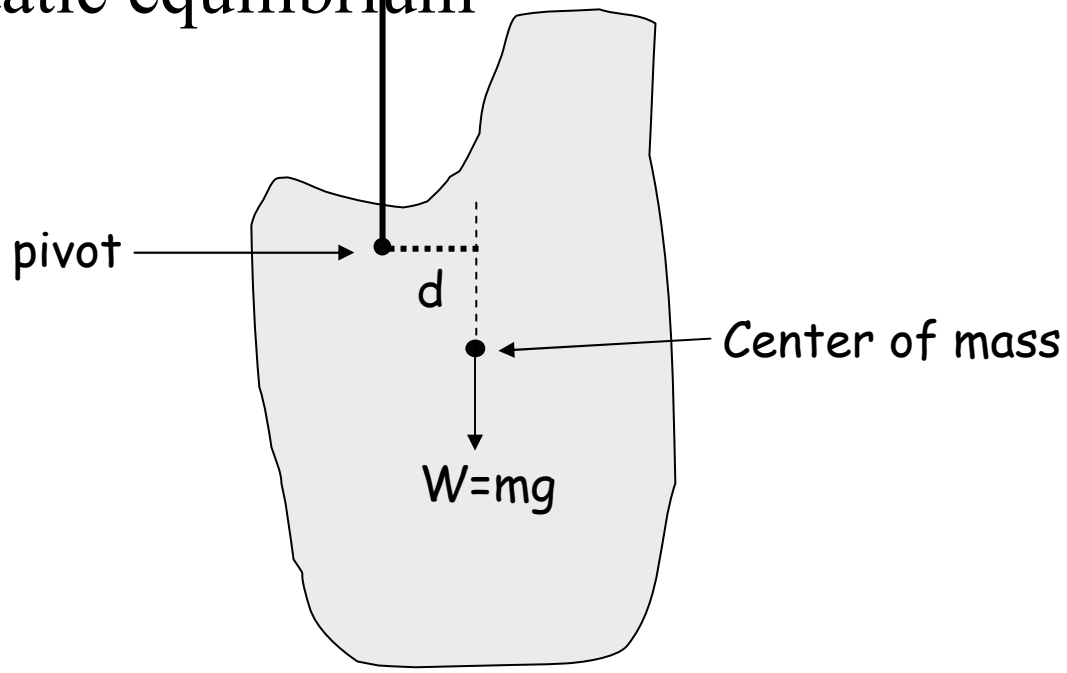
3) $\Sigma \tau = 0$ Rotational EQ

4) $\Sigma F = 0$ Translational EQ

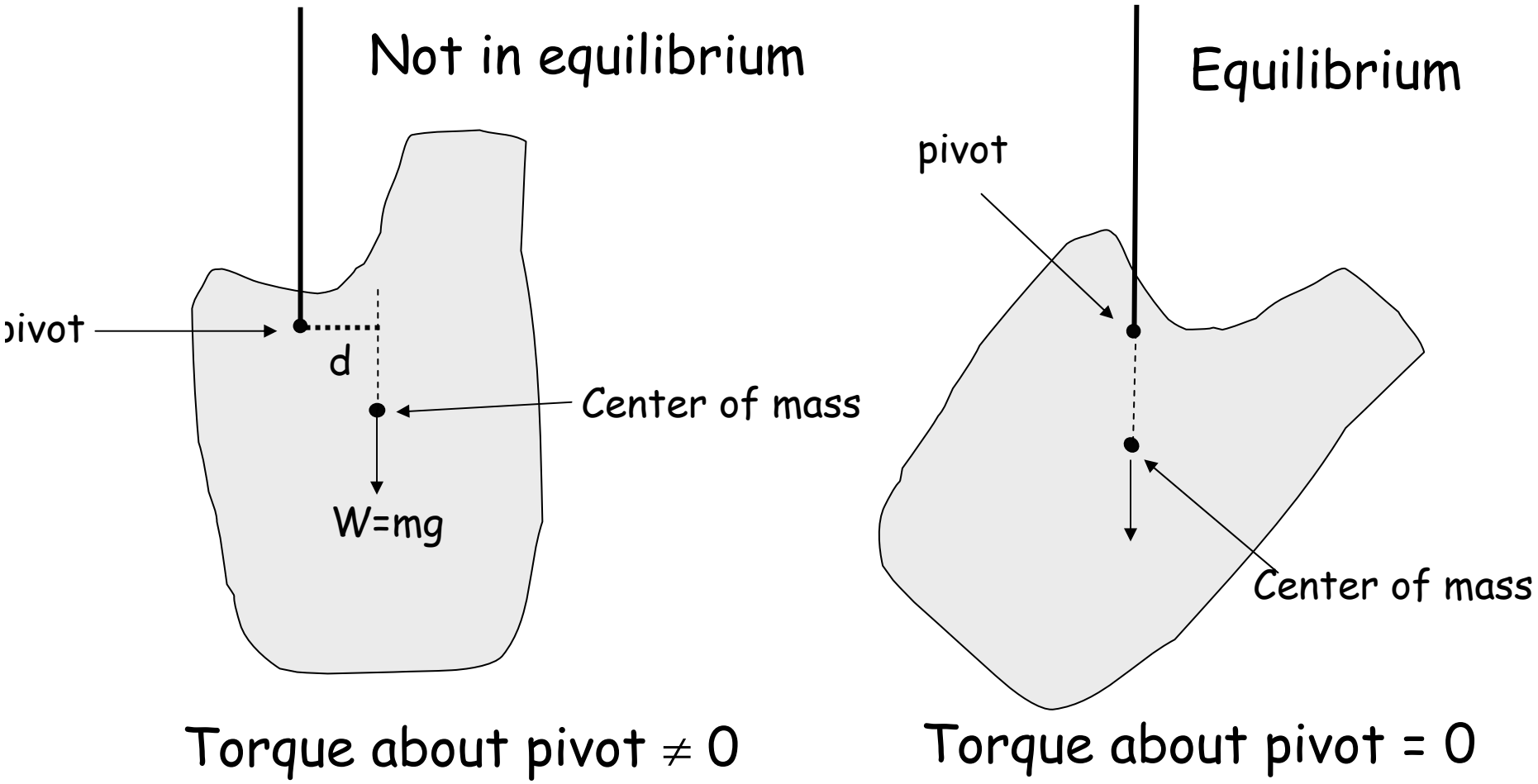
Static Equilibrium and Center of Mass

$$r_{cm} = \frac{\sum r_i m_i}{\sum m_i}$$

- Gravitational Force Weight = mg
  - ➔Acts as force at center of mass
  - ➔Torque about pivot due to gravity τ = mgd
  - ➔Object not in static equilibrium



Static Equilibrium



Torque about pivot $\neq 0$

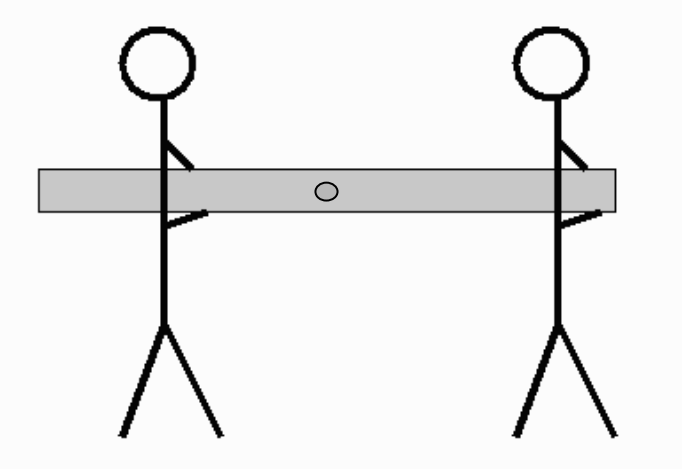
Torque about pivot = 0

A method to find center of mass of an irregular object

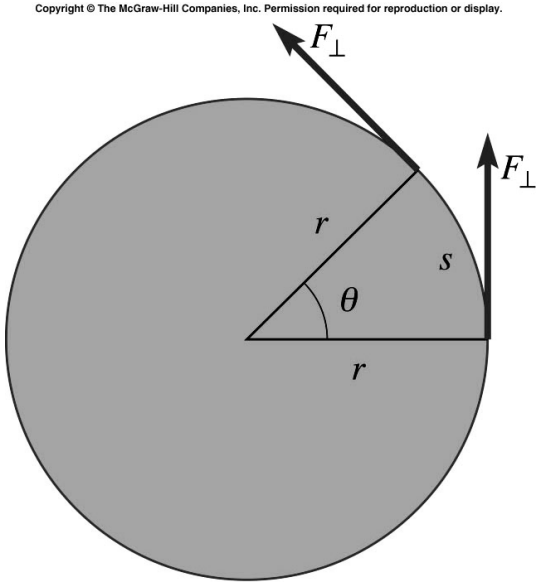
Preflight

The picture below shows two people lifting a heavy log.
Which of the two people is supporting the greater weight?

1. The person on the left is supporting the greatest weight
2. The person on the right is supporting the greatest weight
3. They are supporting the same weight



Work Done by Torque



- Recall $W = F\ d \cos\theta$

- For a wheel

  ➔ $W = F_{tangential}\ d$

  $= F_{tangential}\ 2\pi r\ \theta / (2\pi)$ (θ in radians)

  $= F_{tangential}\ r\ \theta$

  $= \tau\ \theta$

  ➔ $P = W/t = \tau\ \theta/t$

  $= \tau\ \omega$

Summary

- Torque = Force that causes rotation
  - ➔$\tau = F\ r \sin\theta$
  - ➔Work done by torque $W = \tau\ \theta$
- Equilibrium
  - ➔$\Sigma F = 0$
  - ➔$\Sigma \tau = 0$
    - » Can choose any axis.