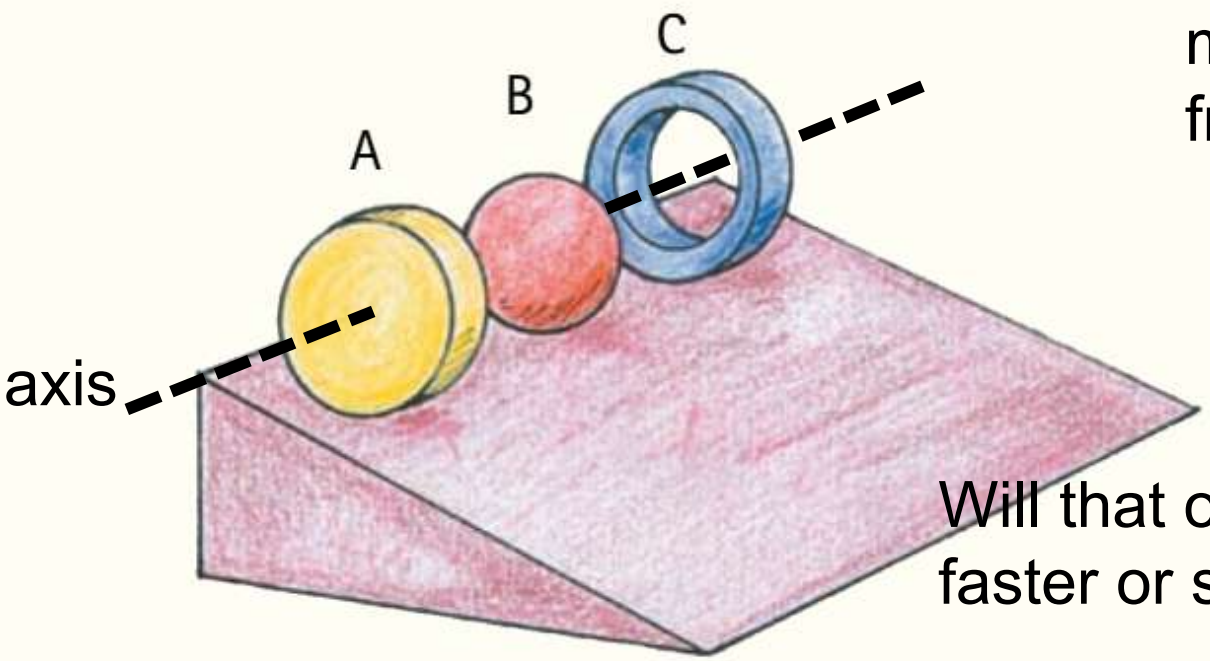
Review:

53. Beginning from a rest position, a solid disk A, a solid ball B, and a hoop C race down an inclined plane. Rank them in reaching the bottom: winner, second place, and third place.



Which has its mass furthest from the axis? C

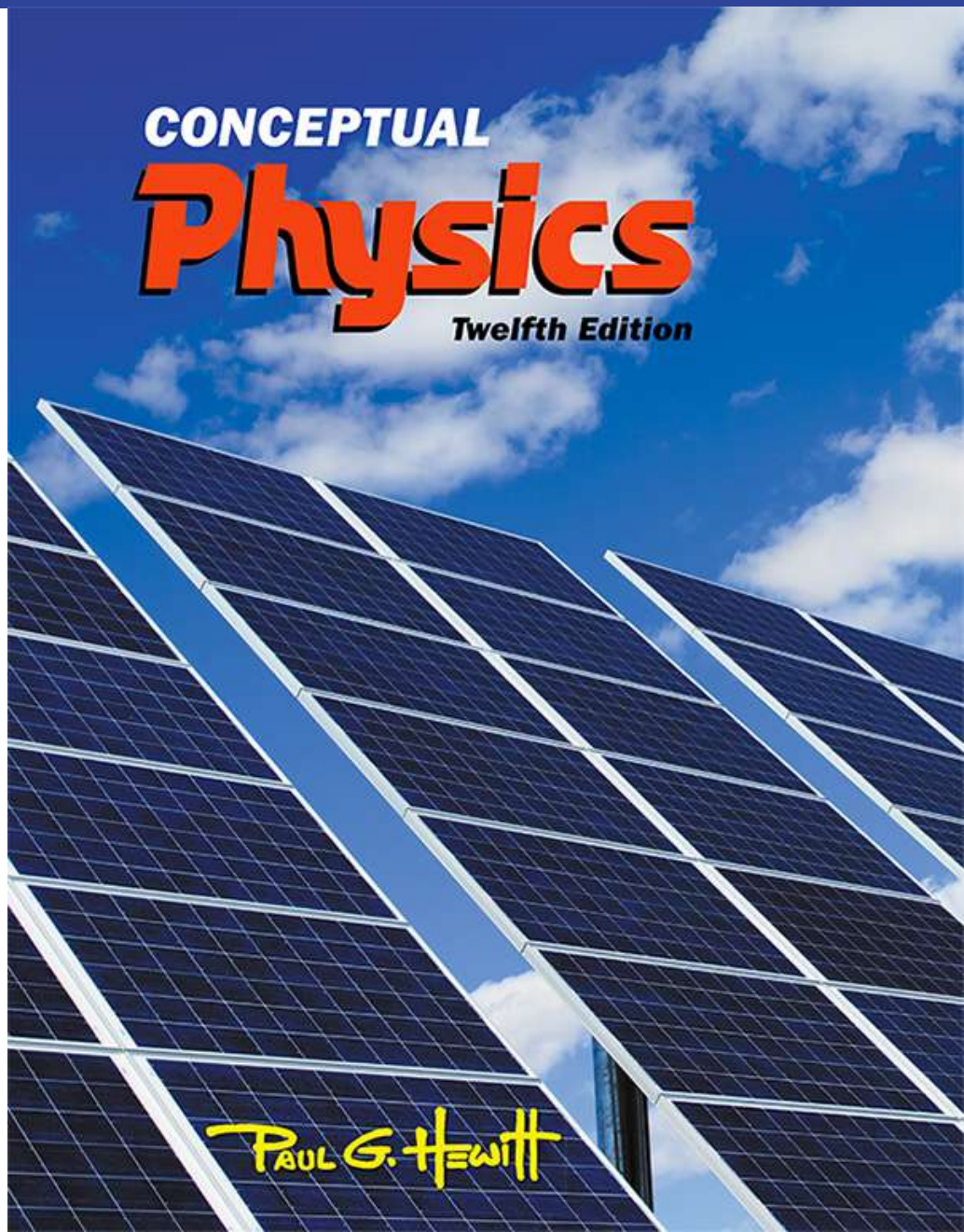
Does that one have more or less rotational inertia? more

Will that one roll faster or slower? slower

Which will roll the fastest? B Why? mass closest to axis less rotational inertia

Chapter 8: Rotational Motion

Section 8.3 Torque

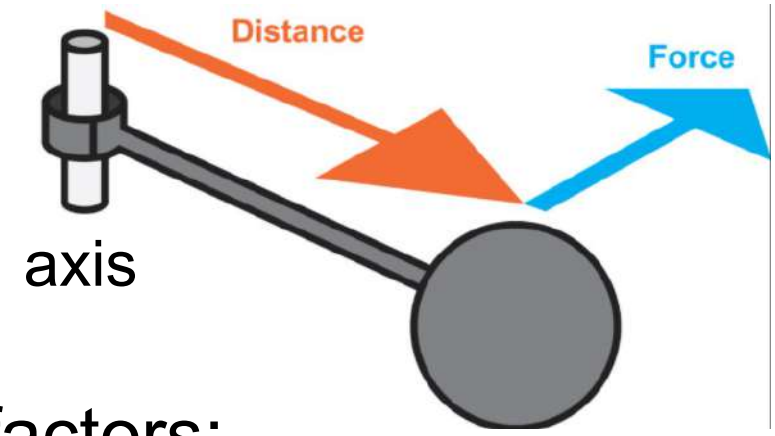


This lecture will help you understand:

- How a torque wrench works
- Why doorknobs are not in the center
- How to pedal a bike better
- How a clock turns
- How to balance on a teeter totter

Torque

- The tendency of a force to cause rotation is called **torque.**
- **Torque = turning force**



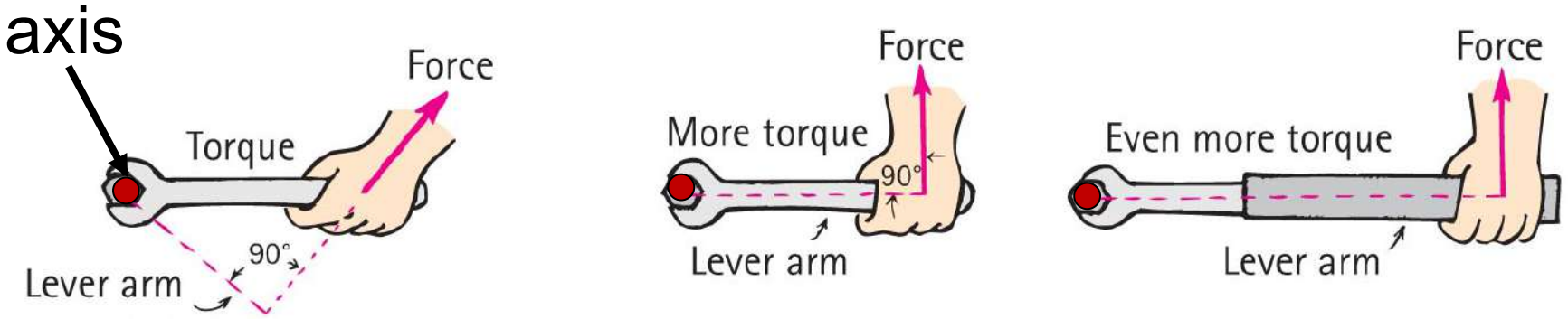
Torque depends upon three factors:

1) Magnitude of the force F
2) The angle (direction) at which it acts
3) The point at which it is applied on the object

The last 2 factors involve the **"lever arm."**

- The equation for Torque is

Torque = lever arm x force

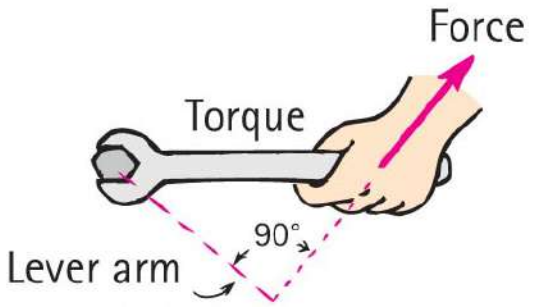


- The lever arm depends upon
  - how far the force is applied from the axis
  - the direction (angle) in which it acts.

The *lever* arm is sometimes called the *moment* arm.

Lever arm: the perpendicular distance from axis of rotation to the “force line”

- 1st picture: Lever arm is *less than* length of handle because of direction of force.
- 2nd picture: Lever arm is equal to length of handle.
- 3rd picture: Lever arm is longer than length of handle.



Most and least torque:

For a given force F…

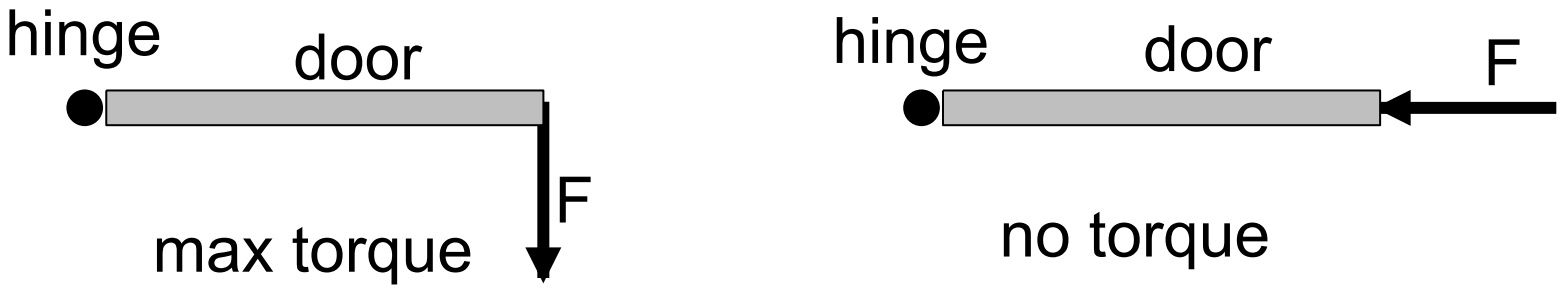
1) **most torque** when:

…F is perpendicular to the lever arm.

2) **least torque (none)** when:

…the lever arm is zero (F points at axis).

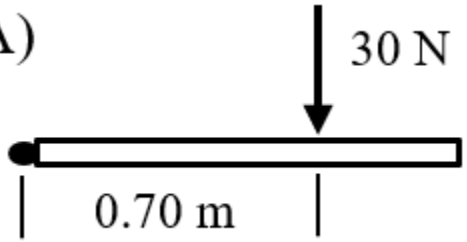
Example: Top view of door



Our calculations will only involve the “most torque” case.

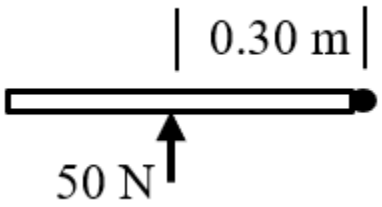
Ex. Calculate torque about the door axis (heavy dot)

A)



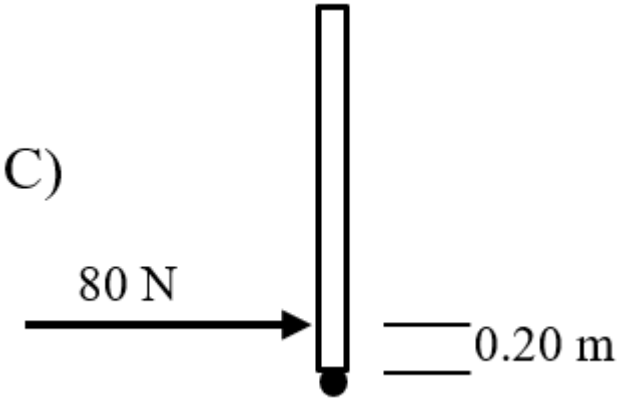
torque = lever arm x F
= 0.70 m x 30 N
= 21 N·m

B)



torque = lever arm x F
= 0.30 m x 50 N
= 15 N·m

C)



torque = lever arm x F
= 0.20 m x 80 N
= 16 N·m

Does maximum F mean maximum torque?

Increasing force or lever arm

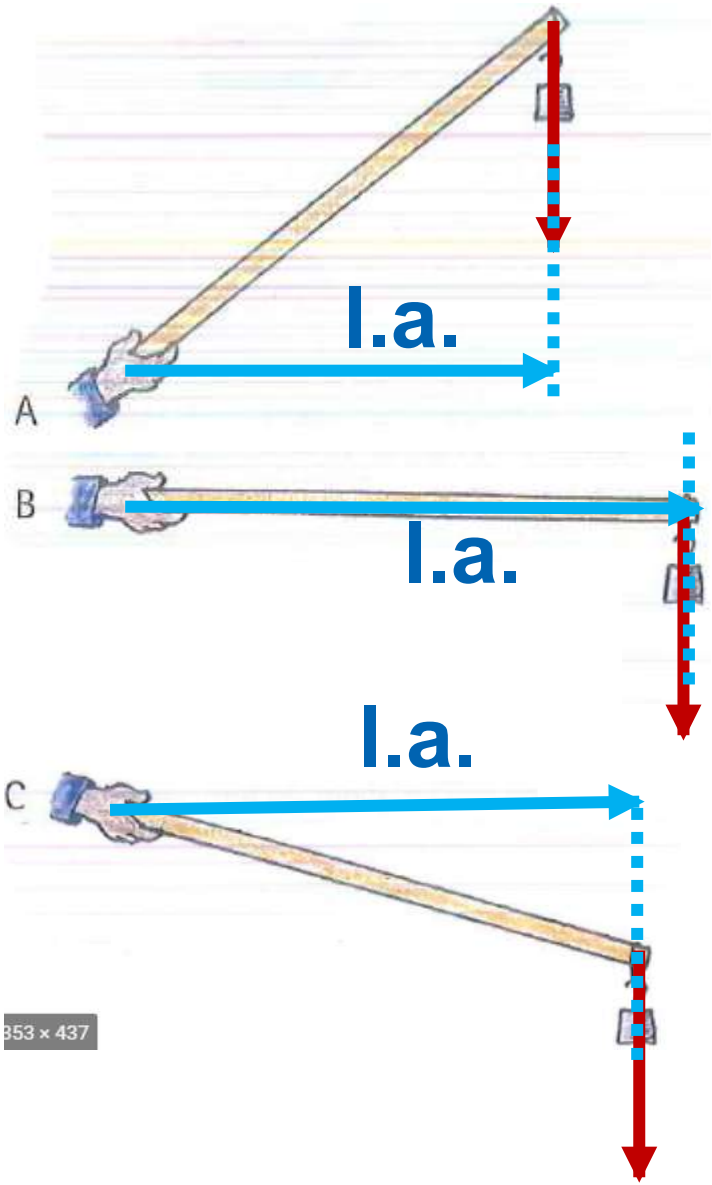
- You hold a meterstick at one end with the same mass at the opposite end. Rank the torque needed to keep the stick steady, from largest to smallest.

same

Torque = lever arm x force

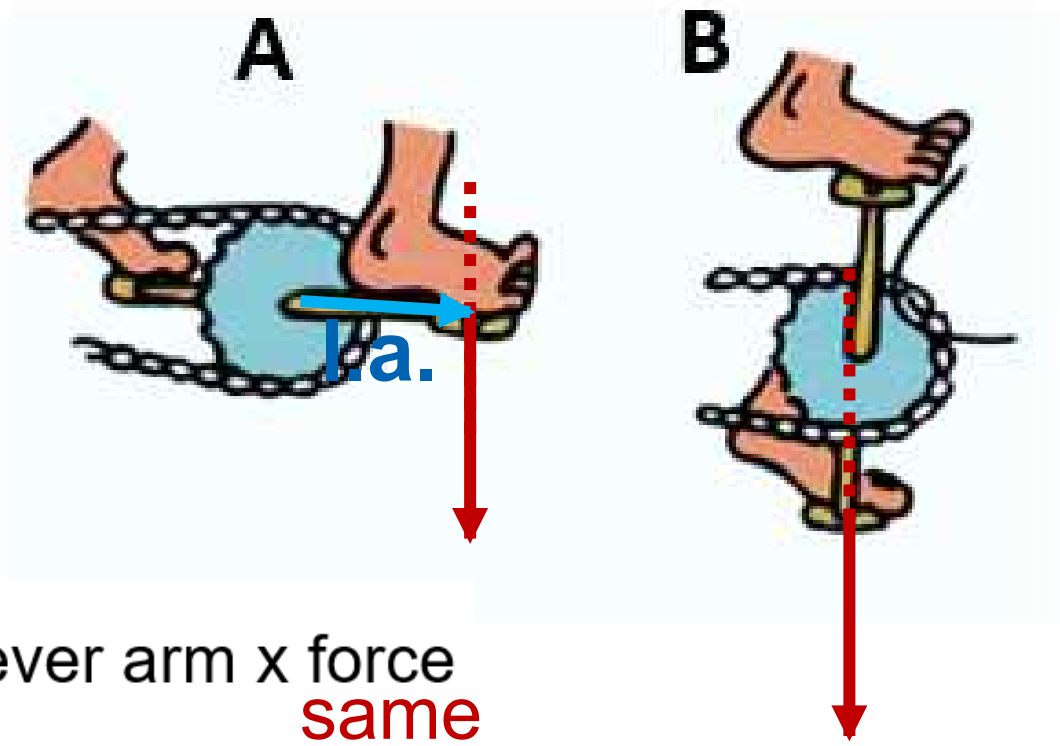
Which has longest lever arm?

B > C > A



Pedaling a bike:

Why do you get the most torque in A and no torque in B?



B has a lever arm = 0

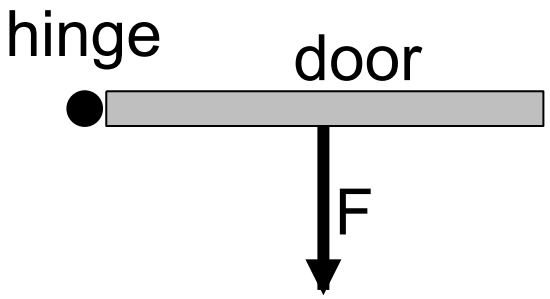
→ no torque

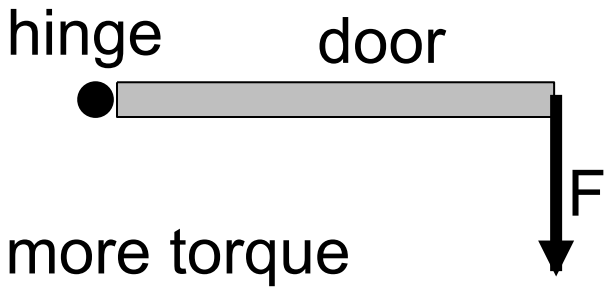
Torque = lever arm x force

same

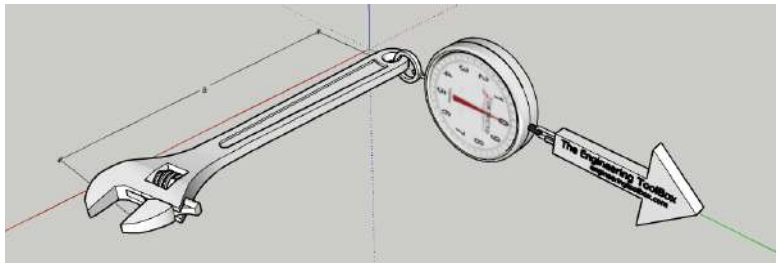
Which door is easier to turn? Why?

- Top view:





Torque wrenches allow you to set what the maximum torque will be, so that you don't overtighten:

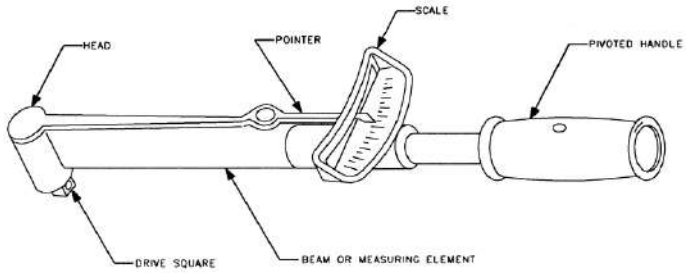


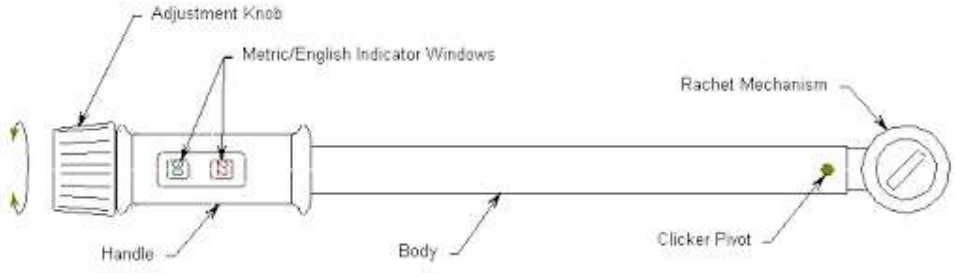
British torque units:

Foot-pounds

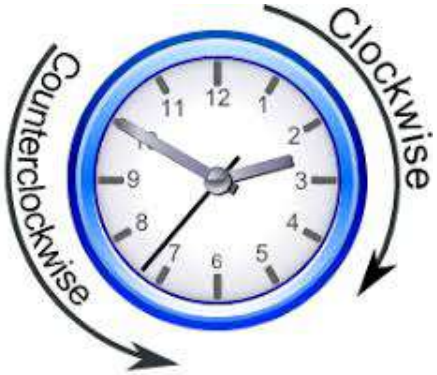
Metric units:

Newton-meters



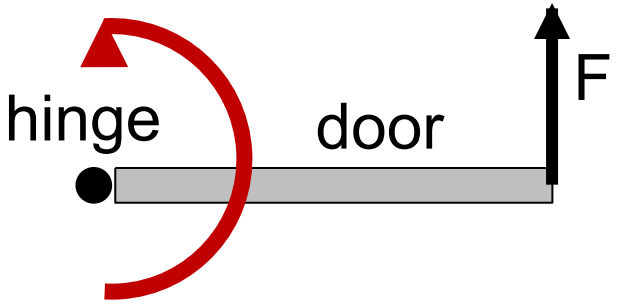


Clockwise (CW) torques vs. Counterclockwise (CCW) torques



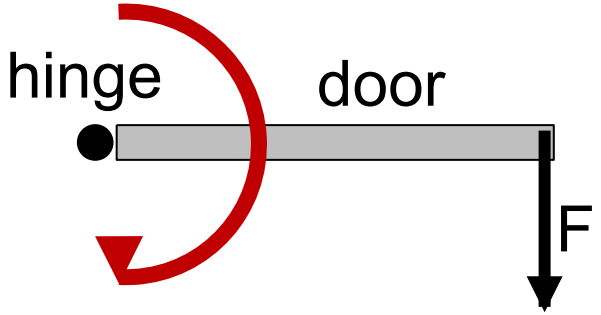
CW or CCW?

CCW torque



CW or CCW?

CW torque



Review: Equilibrium

An object is in **equilibrium** if the sum of the forces F that act on it equals 0:

$$\Sigma F = 0$$

The up and down F's balance.

The right and left F's balance.

If so, then an object is in **equilibrium**:

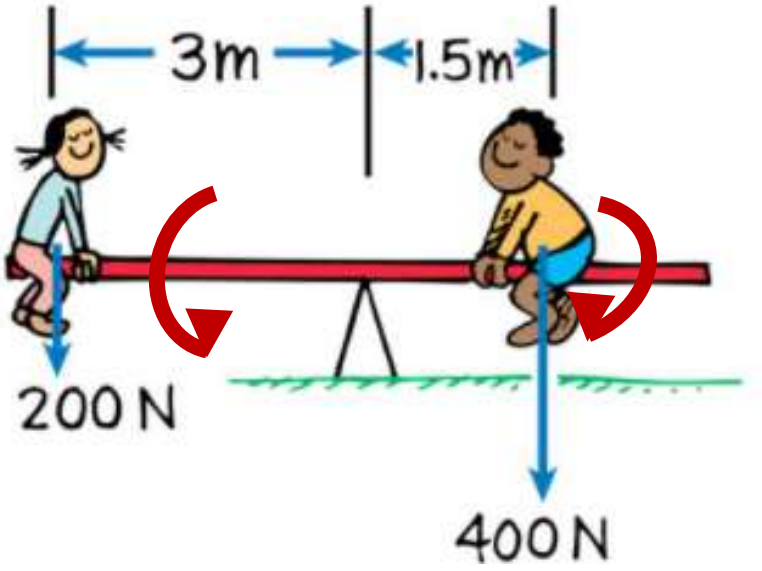
→it is at rest, or

→moving with constant velocity.

Rotational equilibrium occurs when **torques** balance:

Counterclockwise torque = clockwise torque

CCW torque = CW torque



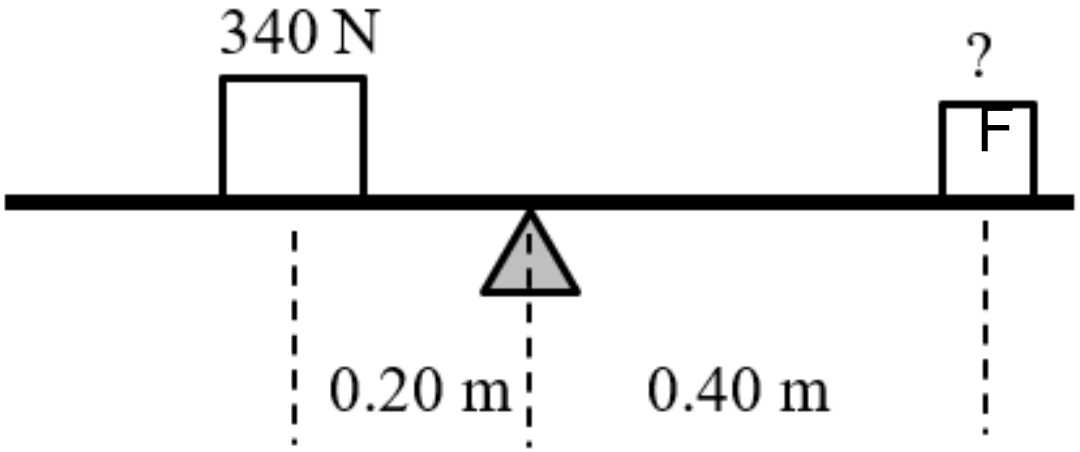
CCW torque:

torque = lever arm x F
= 3 m x 200 N
= 600 N·m

CW torque:

torque = lever arm x F
= 1.5 m x 400 N
= 600 N·m

Ex. Find the missing weight (F)



CCW torque = CW torque

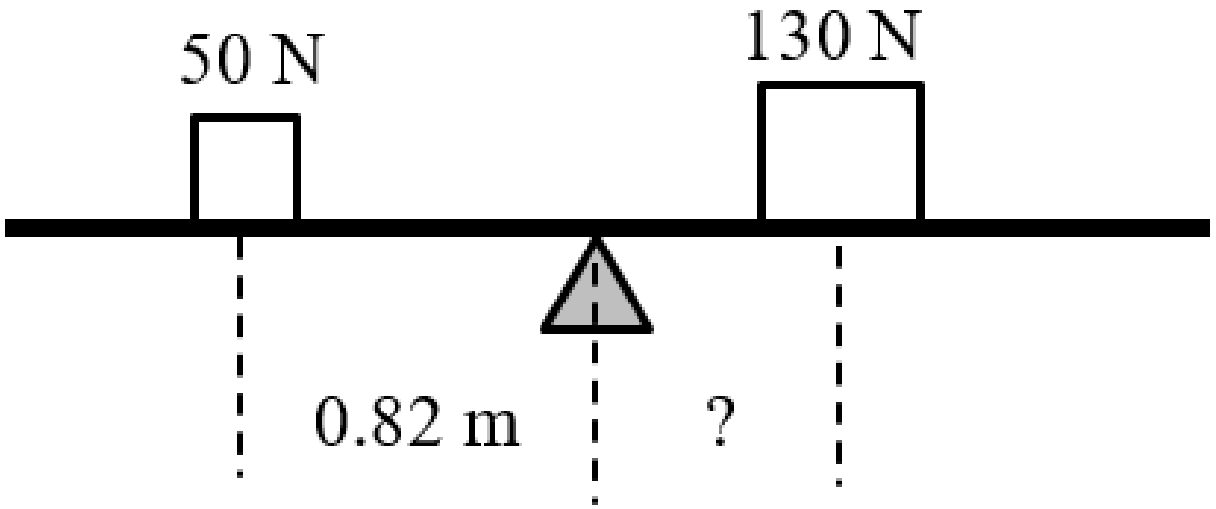
$0.2\ m \times 340\ N = 0.40\ m \times F$

$68\ Nm = 0.40\ m \times F$

$170\ N = F$

How could you have "guessed" the answer?

Ex. Find the missing lever arm (l.a.).



CCW torque = CW torque

0.82 m x 50 N = l.a. x 130 N

41 Nm = l.a. x 130 N

0.32 m = l.a.

Homework: due tonight by 7 pm

- page 153: # 12-14
- page 155: # 38, 39 and 45.

→ Show work (equation used, substitution with units, and answer with units).

- page 156: #54