PHY131H1F - Hour 23

This is a torque wrench.

Today:

8.1 Extended and Rigid Bodies

8.2 Torque (rhymes with "fork")

Mastering Physics

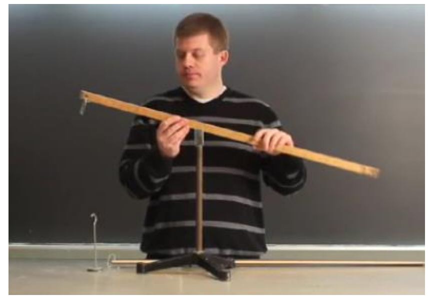
What's up on the MyLab and Mastering?

- Notice that Homework 8 has been posted on MasteringPhysics. It is due Friday Nov.16, which is after Reading Week.
- Also, I have posted an optional item called "Ch.8 Videos – Optional" which I recommend you check out.

Mastering Physics

Chapter 8 Videos (Optional)

- Return of "Buzzcut Guy"! Woot!



- Including, Buzzcut Guy walks the plank!
- And two Khan-Academy-style videos about solving Ch.8 problems.

Second Midterm

- The second midterm will cover chapters 5, 6 and 7 (and we expect you to still remember stuff from chapters 2-4):

Tuesday Nov. 13th, from 6:10pm - 7:30pm.

- The room you go to is based on the first letters of your last name:
  - A - LOCH = EX200
  - LOKE - ZU = EX100

- If you have a course conflict you will be permitted to register to write at the alternative sitting on Tuesday Nov. 13th, from 4:40pm - 6:00pm (in a room TBA).
- If you already registered for the first midterm for the alternate sitting, you do not need to re-register for the second midterm; you are automatically in the alternative sitting for the second midterm.

Ch.5 Review: Rolling without skidding

Homework 5

Problem 5.11

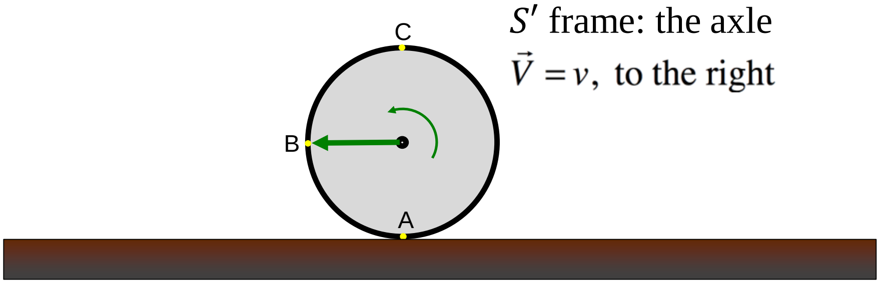
- Rolling is a combination of linear and circular motion.
- Determine the speed of the points A, B, and C **with respect to the ground** for the bicycle that is moving at a constant speed of 4 m/s.
- Determine the speed of the points A, B, and C **with respect to the bicycle**, assuming the bicycle is moving at a constant speed of 4 m/s.

Ch.5 Review: Rolling without skidding

S frame: the ground

S' frame: the axle

$\vec{V} = v$, to the right



The wheel rotates counterclockwise (CCW).

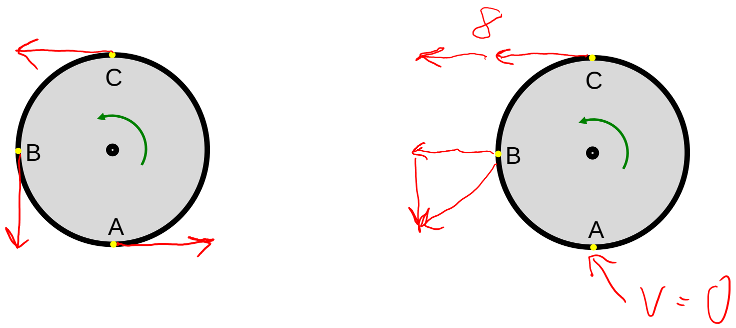
The tangential speed of a point on the rim is v = 4 m/s, relative to the axle.

In "rolling without skidding", the axle moves at speed v. This is the S' frame.

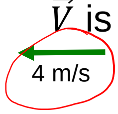
Ch.5 Review: Rolling without skidding

S' bicycle frame: the axle is at rest

S ground frame: the ground is at rest



$\vec{V}$ is the velocity of the axle relative to the ground.



$$\vec{v} = \vec{v}' + \vec{V}$$

Ch.5 Review: Rolling without skidding

❮Homework 5

Problem 5.11

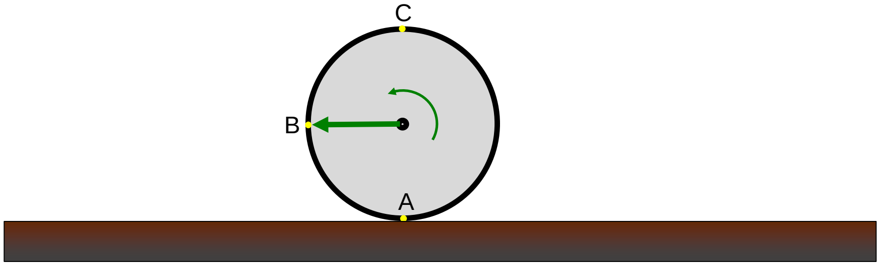
- Determine the speed of the points A, B, and C **with respect to the bicycle**, assuming the bicycle is moving at a constant speed of 4 m/s. Rotation only:

C: **4 m/s** to the left.
B: 0 + 4 m/s to the left = **0 m/s**.
A: **4 m/s** to the right.

- Determine the speed of the points A, B, and C **with respect to the ground** for the bicycle that is moving at a constant speed of 4 m/s. Add linear motion:

C: 4 m/s to the left + 4 m/s to the left = **8 m/s** to the left.
B: 0 + 4 m/s to the left = **4 m/s** to the left.
A: 4 m/s to the right + 4 m/s to the left = **0 m/s**

Ch.5 Review: Rolling without skidding



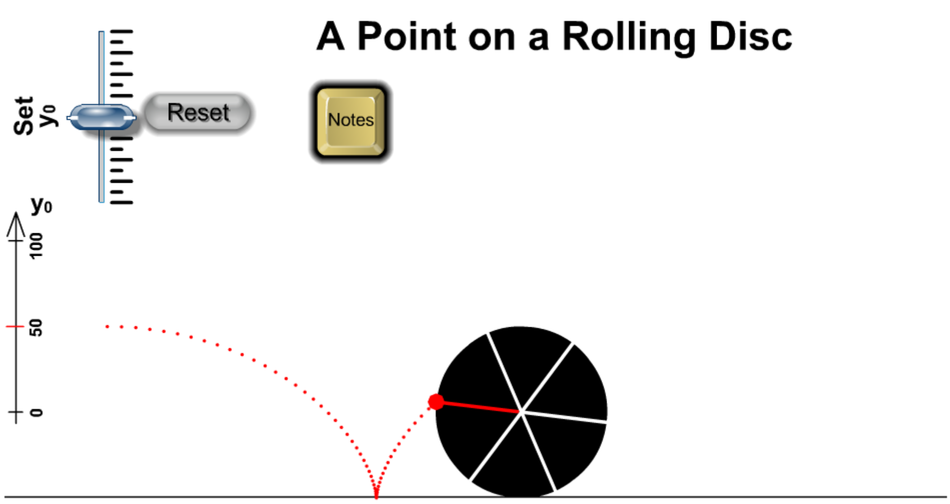
- In "rolling without skidding", point A, which is touching the ground, has a momentary velocity of **zero!**

- That means, if your car is accelerating or decelerating or turning, it is *static friction* of the road on the wheels that provides the net force which accelerates the car

[Animation]

Animation of Rolling Without Skidding

https://faraday.physics.utoronto.ca/GeneralInterest/Harrison/Flash/ClassMechanics/RollingDisc/RollingDisc.html



Ch.5 Review: Rolling without skidding

- No matter what the speed, four points on this car are always ***at rest!***
- Which points? The bottoms of the four tires!

- A wheel rolls much like the treads of a tank.
- The bottom of the wheel is ***at rest*** relative to the ground as it rolls.

Ch.5 Review: Learning Catalytics Question (part 1 of 2)

You are sitting in your car, and you step on the gas pedal. The car accelerates forward.

Since the car has a large forward acceleration, there must be a large forward force acting on the car, $\vec{F}_{1\ on\ 2}$.

Here, object 2 is the car.

What is object 1?

A. The Earth

B. The engine

C. The air

D. The gas pedal

E. An invisible string attached to the front of the car

Ch.5 Review: Learning Catalytics Question (part 2 of 2)

You are sitting in your **C**ar, and you step on the gas pedal. The car accelerates forward, due to the large forward force from the **E**arth, $\vec{F}_{E\ on\ C}$

What kind of force is $\vec{F}_{E\ on\ C}$?

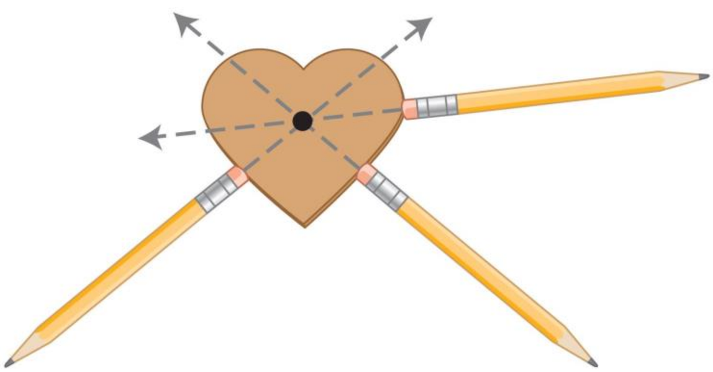
A. air resistance
B. applied force
C. electric
D. kinetic friction
E. magnetic
F. normal
G. spring force
H. static friction
I. tension
J. thrust

What's the Big Idea of Chapters 8 and 9?

- So far we've kind of been neglecting the fact that objects have size and shape.
- This has been the "point particle" approximation.
- For this chapter we will start thinking about "extended bodies", which just means objects that are not points, but have some shape and size.
- Force, momentum and energy are still important, but there are some new things, like:
  - **Torque:** kind of like force (with different units), but it's what get's objects turning.
  - **Rotation:** things can spin or roll!

- A **rigid body** is a model for an extended object.
- We assume that the object has a nonzero size but the distances between all parts of the object remain the same (the size and shape of the object do not change).

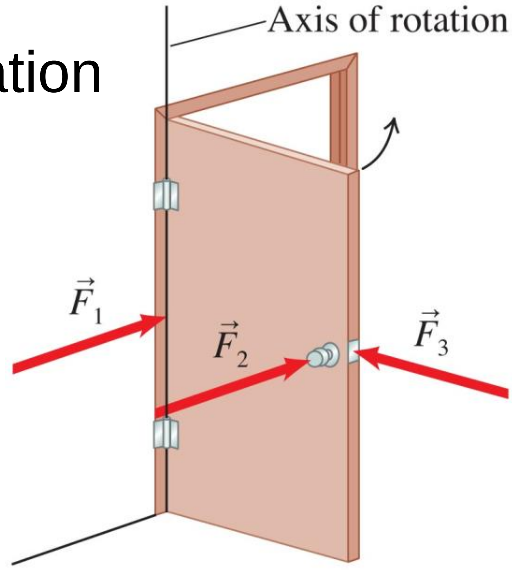
Center of mass



- A rigid body possesses a special point such that if a force is exerted on that point, the object will not turn.
- We call this point the object's center of mass.

Axis of rotation

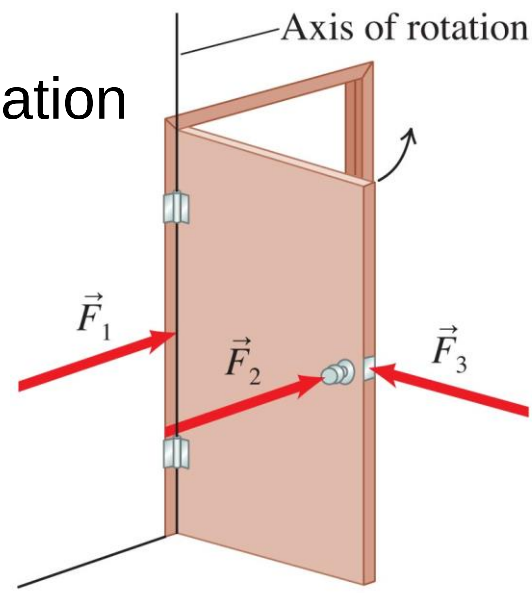
- When objects turn around an axis, physicists say that they undergo **rotational** motion.
- We call the imaginary line passing through the hinges the **axis of rotation.**



$\vec{F}_1$ and $\vec{F}_3$ do not rotate the door, whereas $\vec{F}_2$ moves it easily.

Causing rotation

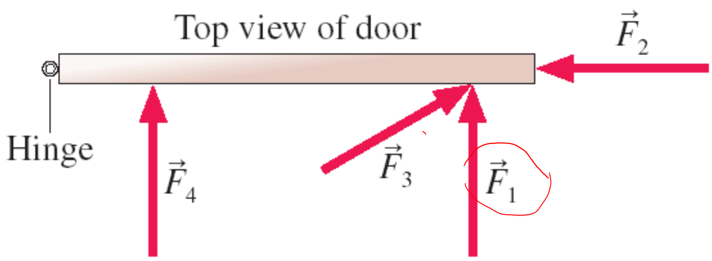
- Three factors affect the turning ability of a force:
  1. The **place** where the force is exerted
  2. The **magnitude** of the force
  3. The **direction** in which the force is exerted



$\vec{F}_1$ and $\vec{F}_3$ do not rotate the door, whereas $\vec{F}_2$ moves it easily.

Learning Catalytics Question

Consider the common experience of pushing open a door. Shown is a top view of a door hinged on the left. Four pushing forces are shown, all of equal strength. Which of these will be most effective at opening the door?



A. F_1

B. F_2

C. F_3

D. F_4

Torque τ produced by a force

Torque τ produced by a force The torque produced by a force exerted on a rigid body about a chosen axis of rotation is

$$\tau = \pm Fl \sin\theta$$

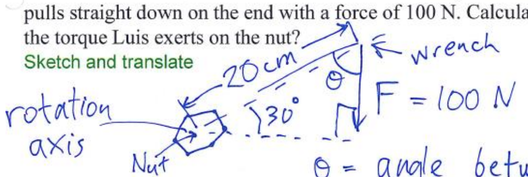
where F is the magnitude of the force, l is the magnitude of the distance between the point where the force is exerted on the object and the axis of rotation, and θ is the angle that the force makes relative to a line connecting the axis of rotation to the point where the force is exerted

- The SI unit of force is the Newton-meter (N-m).

[Doc Cam example]

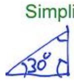
Ch.8 Example. Luis uses a 20 cm long wrench to turn a nut. The wrench handle is tilted 30° above the horizontal, and Luis pulls straight down on the end with a force of 100 N. Calculate the torque Luis exerts on the nut?

Sketch and translate



θ = angle between $\vec{F}$ direction and line connecting rotation axis and point where force is applied.

Simplify and diagram



$\theta = 90 - 30 = 60°$

Represent mathematically

$$\tau = \pm F \ell \sin\theta$$

clockwise ⇒ negative τ.

Solve and Evaluate

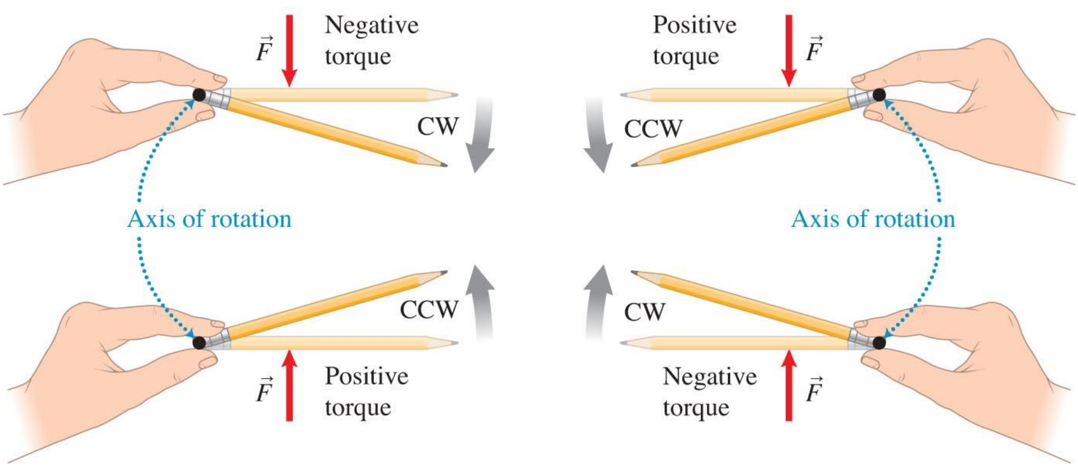
$$\tau = -(100\ N)(0.20\ m)\sin 60°$$

$$\boxed{\tau = -17.3\ N \cdot m}$$

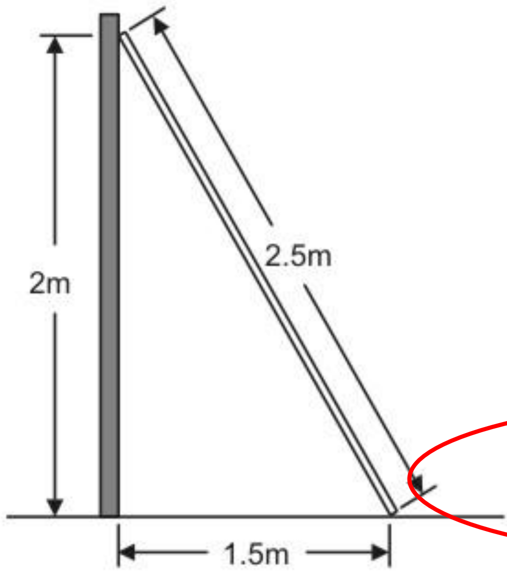
← I don't know how to evaluate torques.

Sign Convention for Torque (historical)

- If the torque tends to produce a **counterclockwise** rotation, this is **positive** torque.
- If the torque tends to produce **clockwise** rotation, this is **negative** torque.



Learning Catalytics Question



- A ladder leans against a wall.
- What is the sign of the torque of the normal force of the wall on the ladder, $N_{\text{W on L}}$?

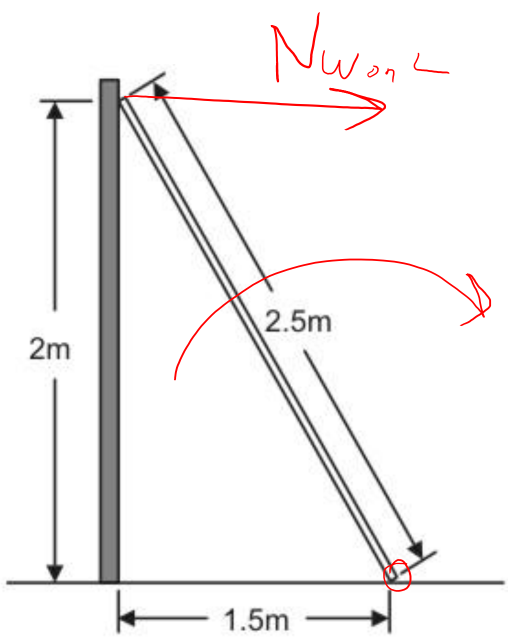
A. Positive

B. Negative

C. The torque is zero

D. It depends on where we choose the rotation axis to be

Learning Catalytics Question



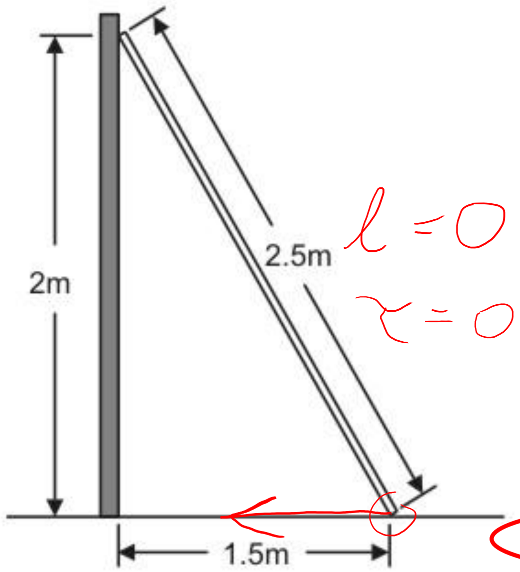
- A ladder leans against a wall.
- Let's choose the rotation axis to be at the bottom of the ladder.
- What is the sign of the torque of the normal force of the wall on the ladder, $N_{\text{W on L}}$?

A. Positive

B. Negative

C. The torque is zero

Learning Catalytics Question

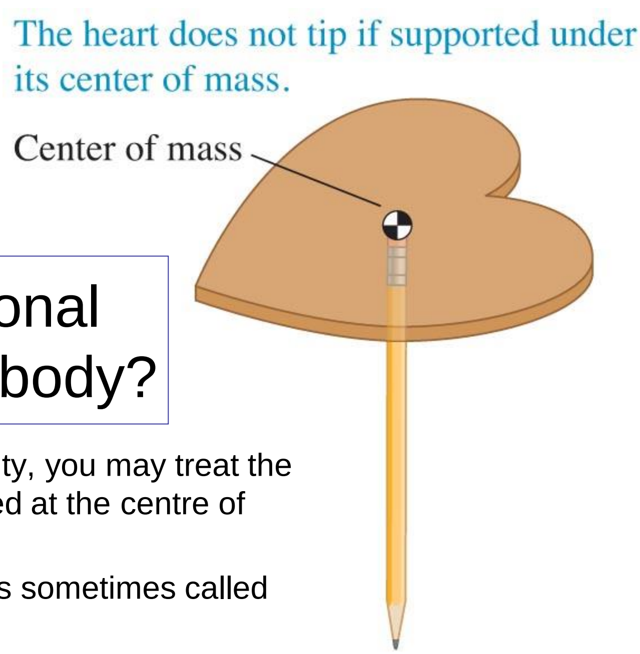


- A ladder leans against a wall.
- Let's choose the rotation axis to be at the bottom of the ladder.
- What is the sign of the torque of the static friction force of the floor on the ladder, $f_{\text{s F on L}}$?

A. Positive

B. Negative

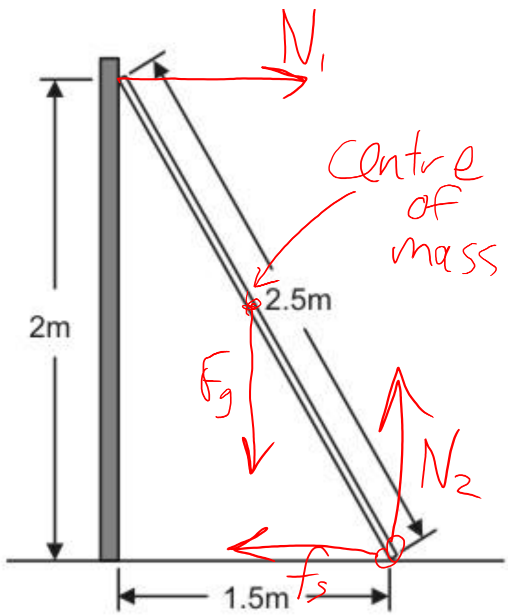
C. The torque is zero



Where is the gravitational force exerted on a rigid body?

- When calculating the torque due to gravity, you may treat the object as if all its mass were concentrated at the centre of mass.
- That is why the object's center of mass is sometimes called the object's **centre of gravity.**

Learning Catalytics Question



- A uniform ladder leans against a wall.
- Let's choose the rotation axis to be at the bottom of the ladder.
- What is the sign of the torque of the force of gravity of the Earth on the ladder, $F_{g\ E\ on\ L}$?

A. Positive

B. Negative

C. The torque is zero

Reading Week

- Nov. 5 - 9 is the "Fall Reading Week" – No Classes!
- So, I'll see you on Monday Nov. 12! We'll continue with Static Equilibrium problems from Chapter 8.
- And don't forget there's a test on Tue. Nov.13!
- Until then… have a great break!