PHY131H1F - Class 23

This is a torque wrench.

Today:

8.1 Extended and Rigid Bodies

8.2 Torque (rhymes with "fork")

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Ch.7 Pre-Quiz

- The uploads to crowdmark so far look pretty good. I think we'll use crowdmark again for the Nov.17 Midterm Assessment #4.
- I'll try to issue marks for this in the next couple of days, but it will be based on legibility *only* - this will not be carefully marked. 16/16 means I could see what you wrote and it wasn't too blurry or dark.

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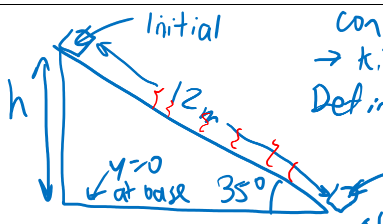
Ch.7 Pre-Quiz Q1. A 75 kg crate slides 12 m down a ramp that makes an angle of 35° with the horizontal. If the crate slides at a constant speed, how much internal thermal energy is created?

SKETCH & TRANSLATE.



constant speed.
→ kinetic is constant.
Define System: crate + Earth + surface
$\Delta U_{int} = ?$

SIMPLIFY & DIAGRAM

Assume Energy becomes ΔU_{int}. No External Work done.

$K_i + U_{gi} + W = K_f + U_{gf} + \Delta U_{int}$

REPRESENT MATHEMATICALLY

$K_i = K_f = K_0 = \text{constant}$

$\cancel{K_0} + mgh + 0 = \cancel{K_0} + 0 + \Delta U_{int}$

$mgh = \Delta U_{int}$

$\sin 35° = \frac{h}{12\,m}$

$h = 12 \sin 35°$

SOLVE & EVALUATE

$\Delta U_{int} = (75)(9.8)\,12 \cdot \sin 35$

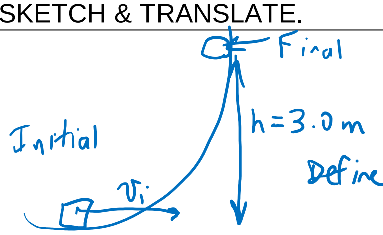
$\boxed{\Delta U_{int} = 5100\ J}$

positive. SI unit of energy

U_g was converted to thermal.

Ch.7 Pre-Quiz Q2. A 55 kg skateboarder wants to just make it to the upper edge of a "half-pipe". He starts at a distance of 3.0 m below where he wants to be. What's the minimum speed v_i that he needs at the bottom if he is to coast all the way up?

SKETCH & TRANSLATE.



Find v_i min. This will be when $v_f = 0$

Define System: skateboarder + Earth.

SIMPLIFY & DIAGRAM

Assume no air resistance or friction. No external work or loss to internal energy.

$K_i + U_{gi} + W = K_f + U_{gf} + \Delta U_{int}$

REPRESENT MATHEMATICALLY

$\frac{1}{2}\cancel{m} v_i^2 + 0 + 0 = 0 + \cancel{m}gh + 0$

$v_i^2 = 2gh$

$v_i = \sqrt{2gh}$

SOLVE & EVALUATE

$= \sqrt{2(9.8)3.0}$

$\boxed{v_i = 7.7\ \frac{m}{s}}$

$\sim 28\ \frac{km}{h}$, reasonable skateboard speed.

Mastering Physics

What's up on the MyLab and Mastering?

- Notice that Homework 8 has been posted on MyLab and Mastering. It is due Monday Nov.16, which is after Reading Week.
- Also, I have posted an ~~optional item~~ called "Videos and Practice for Chapter 8" which I recommend you check out.

not for homework cred.

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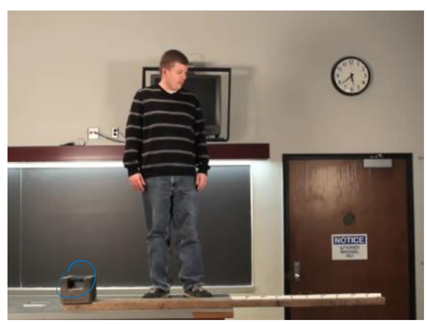
Mastering Physics

Videos and Practice for Chapter 8 (Optional)

- I just call him "Buzzcut Guy"



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

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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 chapters 8 and 9 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!

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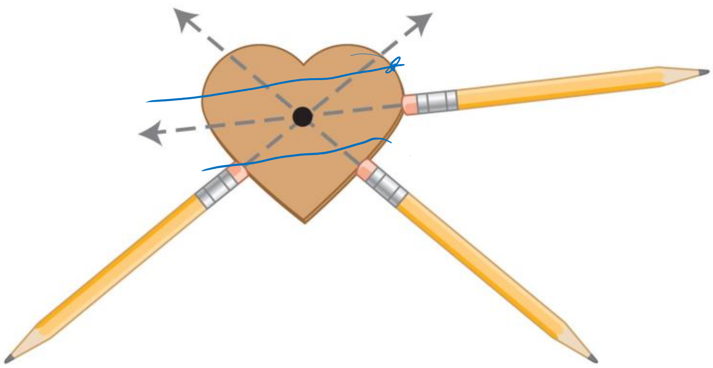
- A **rigid body** is a model for an extended object.
- We assume that the object has a nonzero size but the distances between all parts of the object remain the same (the size and shape of the object do not change).

8

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.

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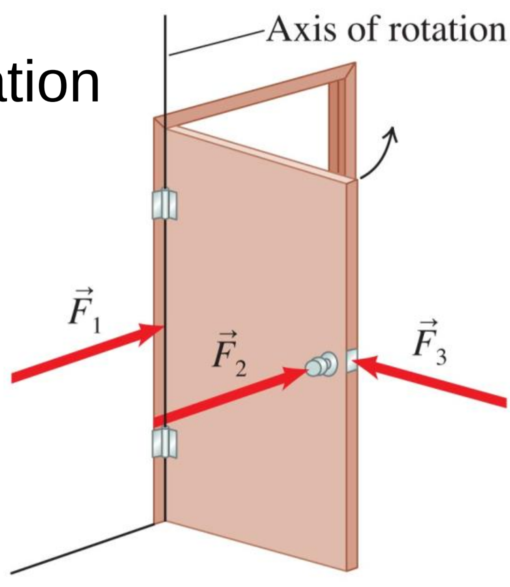
Axis of rotation

- 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.

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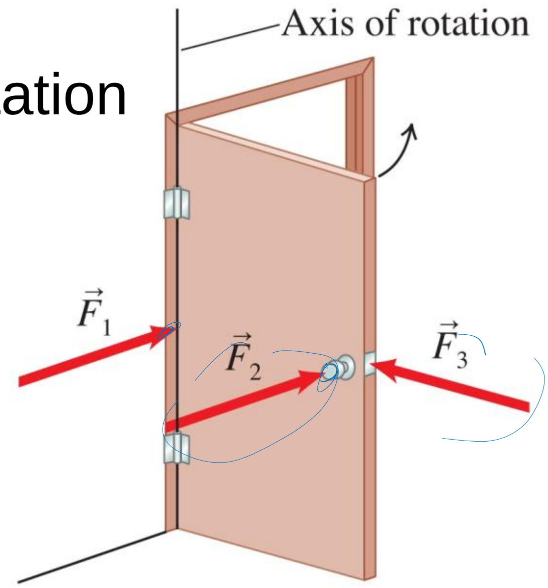
Causing rotation

- 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.

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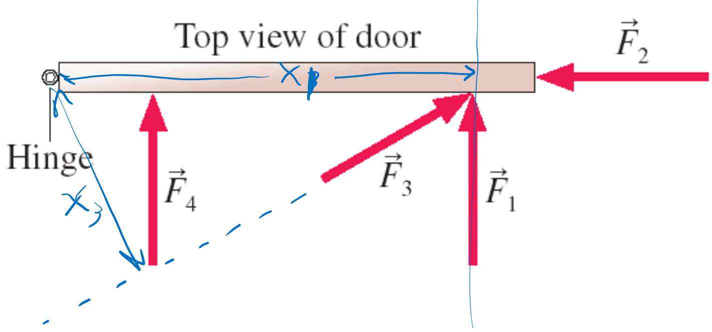
Poll Question

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

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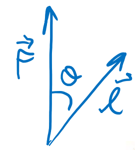
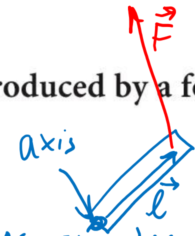
Torque τ produced by a force



Eq. 8.1

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



we treat τ as a scalar here. → $$\tau = \pm Fl \sin\theta$$ ± determine clockwise or counterclockwise direction.

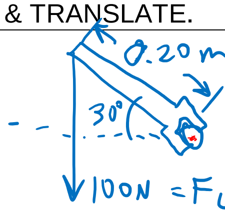
where F is the magnitude of the force, l is the magnitude of the distance between the point where the force is exerted on the object and the axis of rotation, and θ is the angle that the force makes relative to a line connecting the axis of rotation to the point where the force is exerted

torque is a vector.

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

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 exerted by Luis.

SKETCH & TRANSLATE.

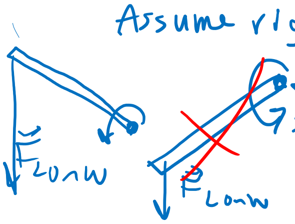


Unknown: τ

System = wrench + nut.

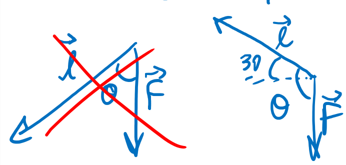
SIMPLIFY & DIAGRAM

Assume rigid body. wrench + nut connected.



REPRESENT MATHEMATICALLY

Use Eq. 8.1: $\tau = \pm Fl \sin\theta$ ← choose + since wrench turns counter-clockwise.



$\theta = 30 + 90 = 120°$

SOLVE & EVALUATE

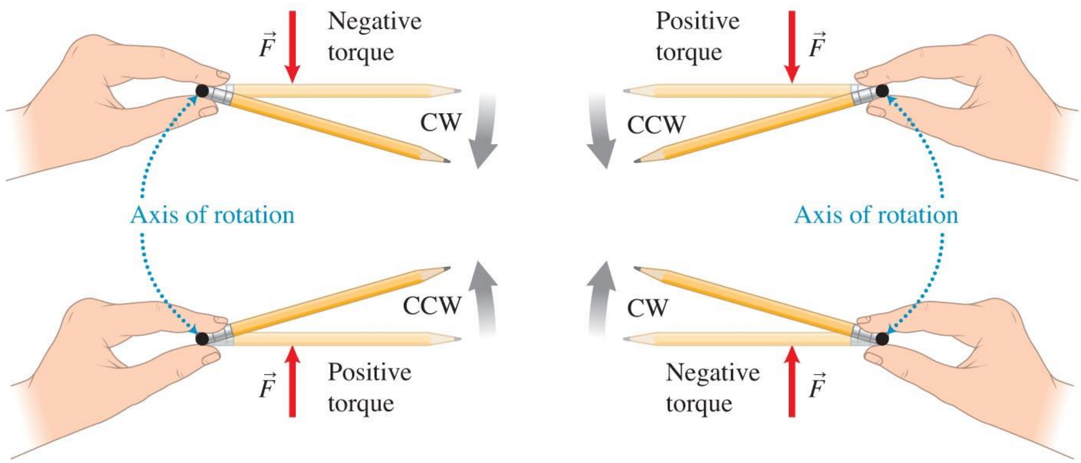
$\tau = (100)(0.2) \sin 120°$

$\tau = 17$ N.m

↑ positive, since system turns counterclockwise

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.



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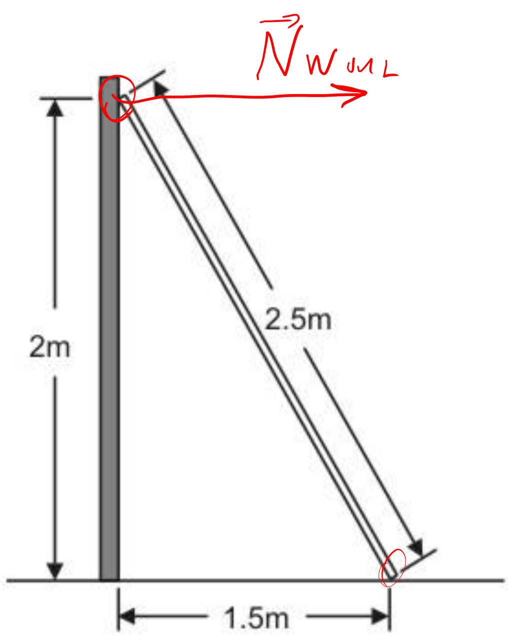
Poll Question



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

A. Positive

B. Negative

C. The torque is zero

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

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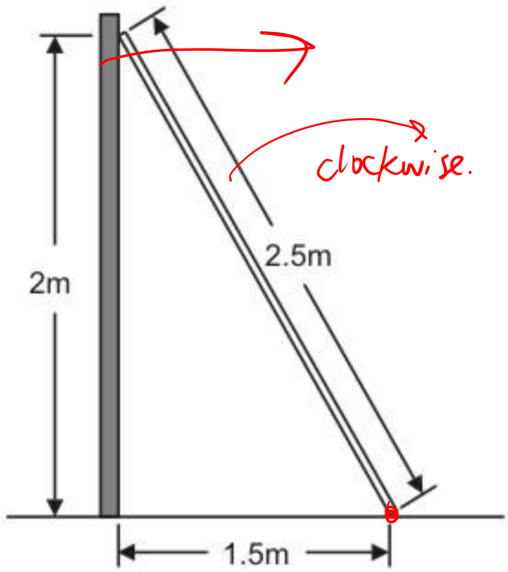
Poll Question



- 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

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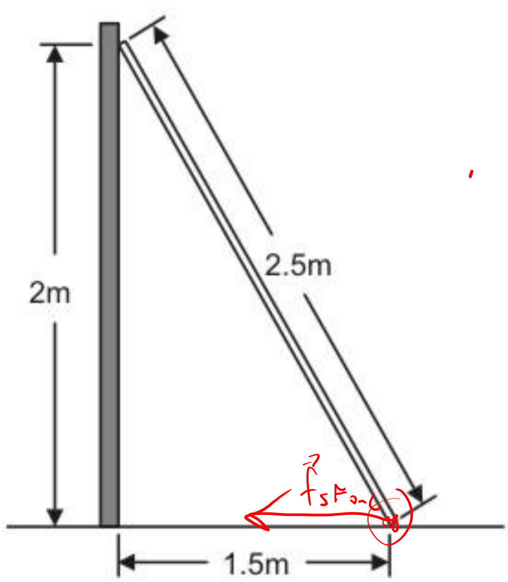
Poll Question



- 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

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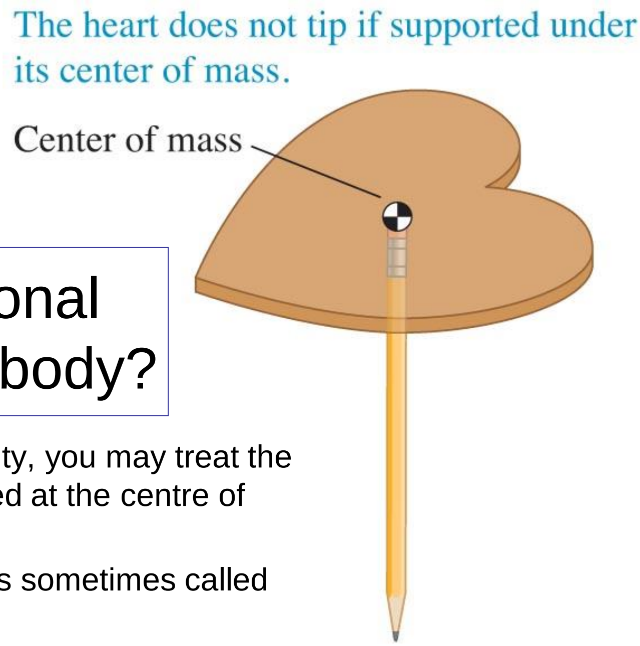

Where is the gravitational force exerted on a rigid body?

- 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.**

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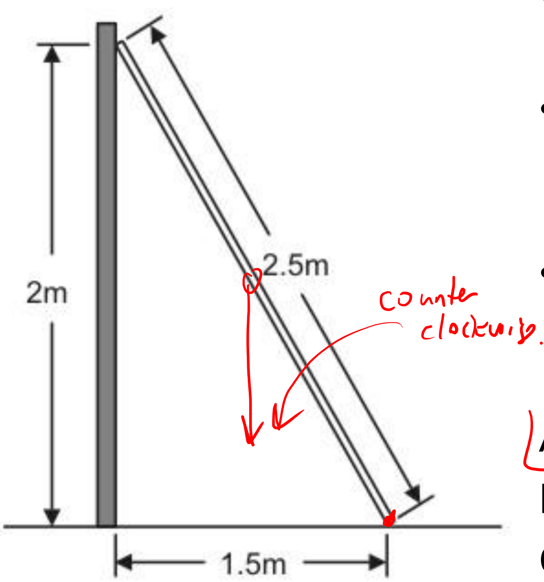
Poll Question



- 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, $F_{\text{g E on L}}$?

A. Positive

B. Negative

C. The torque is zero

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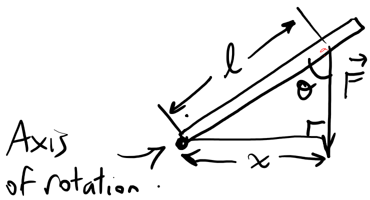
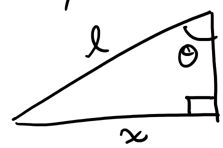
Trick: "Lever Arm" = x

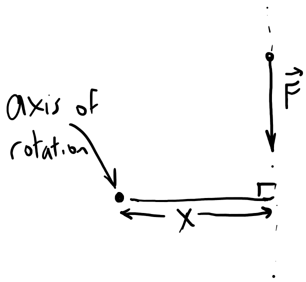
$\tau = \pm Fl\sin\theta$ Eq. 8.1 : $\tau = \pm F\,(l \sin\theta)$



By geometry:



$\sin\theta = \dfrac{x}{l} \Rightarrow x = l\sin\theta$



x = "lever arm" = perpendicular distance from force line to axis of rotation

$\tau = \pm F x$

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Before Class 24 on Friday

- Please continue reading Chapter 8:
- 8.3 Static Equilibrium
- 8.4 Centre of Mass

- Plan to meet up with your Practical Pod during Friday's class – you should be able to turn on your microphone in order to participate in the TeamUp Quiz Module 4 Ch.8.
- If you cannot do the TeamUp quiz during class, it can be done either with your pod or on your own at any time over the weekend.

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