

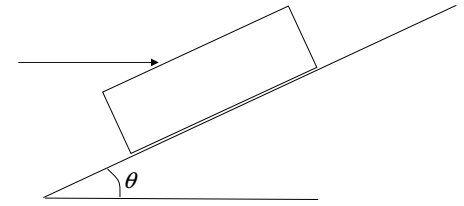
Announcements

- If you have **questions on exam 1**:
 - Look over your own exam.
 - Look over the exam solutions, see if you can figure out what you got problems wrong.
 - Only then should you come talk to me about things you still don't understand.
- Extra credit** opportunity—remember to turn in a short (1 page max) summary of the event.
- Newton's 2nd Law Problems**
 - Inclined planes
 - Pulleys
 - Ropes
 - Friction
 - Etc

→ Remember N2 is a **blueprint** for obtaining a useful equation; it's not really the equation itself.

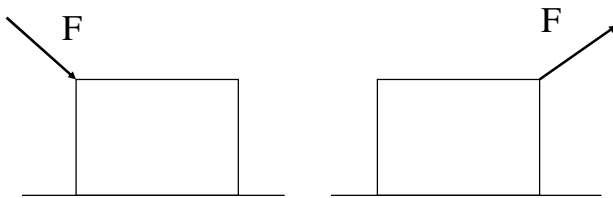
Review Problem:

If you push *horizontally* with a force F on a object with mass m as shown, what will its acceleration be?



Friction: *kinetic* and **static**

Clicker quiz: Same box, same magnitude of F : which box is easier to get moving?



- left is easier
- right is easier
- same

Static Friction:

Grows with sideways force, to a point...

at slipping pt: $F_f \sim$ Normal force

$$F_f = \mu N$$

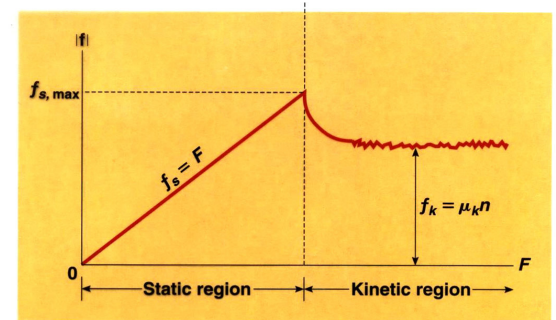
“coefficient of friction”

Demo: Friction blocks

Kinetic “aka Moving” Friction

Demo: static vs. kinetic friction

Book figure:



Compare with the forces in breaking a rope... you pull on a rope tied to the wall. What is the tension in the rope?



Friction, Summary:

Static: $F_f (\text{max}) = \mu_s N$

Kinetic: $F_f = \mu_k N$

TABLE 4.2

Coefficients of Friction^a

	μ_s	μ_k
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Copper on steel	0.53	0.36
Rubber on concrete	1.0	0.8
Wood on wood	0.25–0.5	0.2
Glass on glass	0.94	0.4
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	—	0.04
Metal on metal (lubricated)	0.15	0.06
Ice on ice	0.1	0.03
Teflon on Teflon	0.04	0.04
Synovial joints in humans	0.01	0.003

^aAll values are approximate.

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Worked Problem

Mary pulls a box of books with mass 25 kg to the right with a rope.

$$\mu_s = 0.5 \quad \mu_k = 0.3 \quad (\text{Let } g = 10 \text{ m/s}^2)$$

a. First she pulls horizontally on the box with a force of 40 N. The box doesn't move. What is the frictional force of the floor on the box?



b. What minimum force will she have to exert to get it moving?

Clicker quiz: If she pulls with force 175 N, what will the acceleration be after it starts moving?

- a. 1 m/s^2 c. 4 m/s^2
 b. 2 m/s^2 d. 6 m/s^2 e. $> 6 \text{ m/s}^2$

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Worked Problem

If Mary instead pulls the 25 kg box with force 180 N at an angle of 60° above the horizontal, what will the acceleration be?

FBD:



Strategy: Think about x- and y-directions separately!

- x-direction stuff:
 - i.
 - ii.
- y-direction stuff:
 - i.
 - ii.
 - iii.

N2 for x:

N2 for y:

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The tires on a 5000 kg truck have $\mu_s = 0.8$, $\mu_k = 0.6$ (tire to road friction)



What is the maximum stopping *deceleration*?

What is the maximum stopping *deceleration* if the wheels are locked?

→ What do anti-lock brakes do?

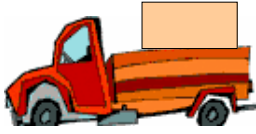
Warmup: Pushing against a refrigerator... which is correct?

- Friction was smallest just after the fridge started to move.
- Friction was largest just after the fridge started to move.
- Friction was largest just before the fridge started to move.
- The friction force was constant the whole time.

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Worked Problem

In the back of the open truck is a large box of mass 300 kg with $\mu_s = 0.4$, $\mu_k = 0.3$

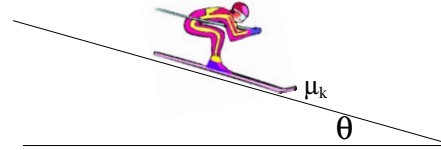


What is maximum acceleration the driver can give the truck if the box is not to slide out?

Friction on slopes

Clicker quiz: For the same skis and snow, as the slope angle **increases**, the ski/snow **frictional force**

- a. increases
- b. decreases
- c. stays the same



Man with mass m : what is his frictional force on a slope?

Caution: Always start with $F_f = \mu N$; do not use this result for problems in general

Warmup: A block is sliding down a ramp with constant speed...the friction force is:

- smaller than the component of gravity down the ramp
- larger than the component of gravity down the ramp
- equal to the component of gravity down the ramp

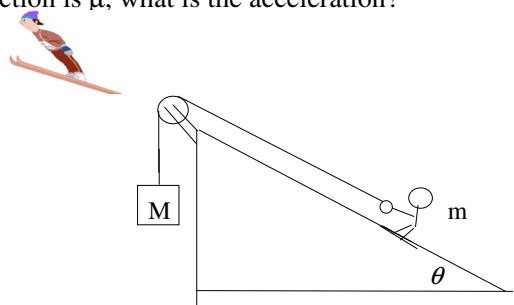
(Remember the monkey?)

Demo: adjustable ramp

Demo Problem: a block on a ramp doesn't slide until the angle is _____° from horizontal. What is μ_s ?

Demo Problem: Once the block starts to slide, it takes _____ s to slide down the _____ m of the ramp. What is μ_k ?

Worked Problem: You invent a new olympic sport called pulley ski jumping. If the kinetic coefficient of friction is μ , what is the acceleration?



"x" direction

"y" direction

Good exam problem: How far does the jumper travel?