Announcements 23 Mar 09

- Online homework #6 due on Wed by 8 am
  - Problem 5.22 Part A:
    give your answer with only 2 significant digits!
- Homework #7
  - Written homework due on Friday in class
  - Online homework due next week on Tuesday
- Exam #2
  - Tuesday April 7 from 7 to 9 pm

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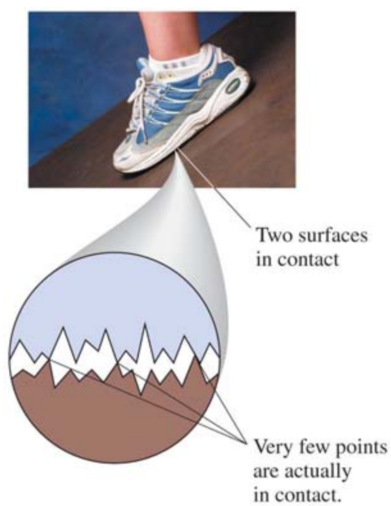
Friction

Friction occurs when two surfaces are in contact and (attempt to) slide over one another

Friction tends to prevent the two surfaces from sliding over each other

Friction is due to surfaces not being smooth

DEMOS:
- sliding table
- sliding brick with force gauge
- sliding block on inclined plane



Friction increases as the force that pushes the two surfaces against each other increases (actual surface area in contact increases)

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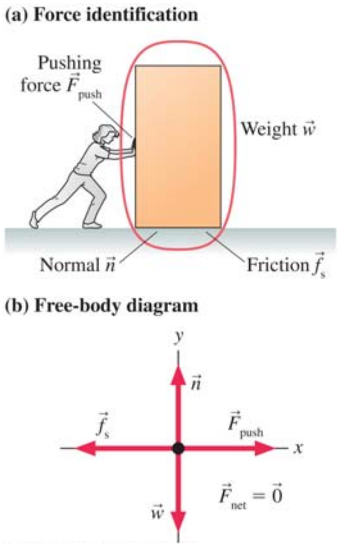
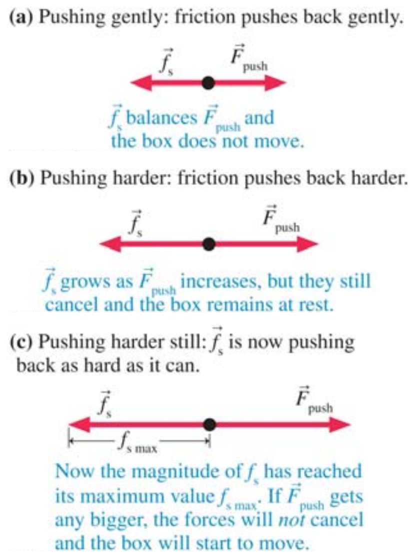
Static Friction





Static friction responds "as needed" to prevent slipping

$$f_{s\,max} = \mu_s n$$

μ_s = coefficient of static friction

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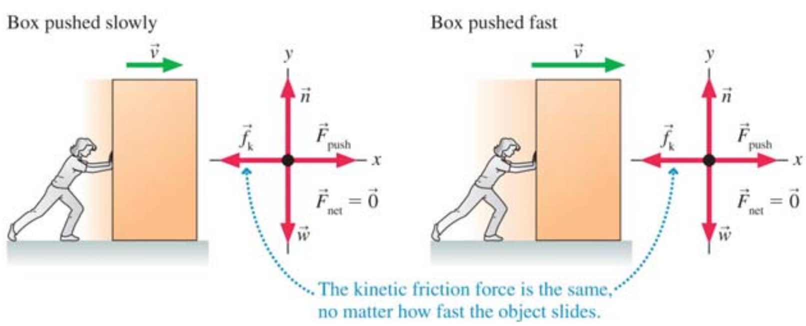
Kinetic Friction



$$f_k = \mu_k n$$

μ_k = coefficient of kinetic friction

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Friction and Materials

For nearly all materials,

$\mu_s > \mu_k$

Static friction > Kinetic friction

This is why drivers are always advised to **not lock their wheels** in emergency braking situations. Car manufacturers put anti-lock break systems (ABS) in cars for this reason.

	μ_k	μ_s
Rubber on concrete (dry)	0.80	0.90
Steel on steel	0.57	0.74
Glass on glass	0.40	0.94
Wood on leather	0.40	0.50
Copper on steel	0.36	0.53
Rubber on concrete (wet)	0.25	0.30
Steel on ice	0.06	0.10
Waxed ski on snow	0.05	0.10
Teflon on Teflon	0.04	0.04

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Working with Friction Forces

MP **TACTICS BOX 5.1** **Working with friction forces** Exercises 20, 21

1. If the object is *not moving* relative to the surface it's in contact with, the friction force is **static friction.** Draw a free-body diagram of the object. The *direction* of the friction force is such as to oppose sliding of the object. Then use Problem-Solving Strategy 5.1 or 5.2 to solve for f_s. If f_s is greater than $f_{s\,max} = \mu_s n$, then static friction cannot hold the object in place. The assumption that the object is at rest is not valid, and you need to redo the problem using kinetic friction.
2. If the object is *sliding* relative to the surface, then **kinetic friction** is acting. From Newton's second law, find the normal force n. Equation 5.13 then gives the magnitude and direction of the friction force.

If object is *not moving* relative to the surface it's in contact with: $f_k = 0$
If object is *moving* relative to the surface it's in contact with: $f_s = 0$

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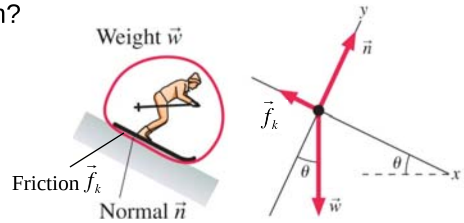
Applying 2nd Law (Revisited example with friction)

A 75-kg skier starts down a 50-m high, 10° slope. The coefficients of friction between the skis and the snow are $\mu_s = 0.12$ and $\mu_k = 0.06$.
What is the skier's speed at the bottom?



How to approach this problem?

1. Identify all forces acting on the skier (and only those)
2. Determine x- and y-components of the net force (using conveniently tilted x- and y-axes)
   $\Sigma F_x = w \sin 10^o - f_k$ $\Sigma F_y = n - w \cos 10^o$
   but $a_y = 0$, thus $\Sigma F_y = 0$ and $n = w \cos 10^o$
3. Compute acceleration from the knowledge of the net force and Newton's 2nd law: $a_x = \Sigma F_x / m = [w \sin 10^o - \mu_k(w \cos 10^o)] / m$
4. Given that acceleration, use kinematics equations to determine the skier's velocity: $(v_x)_f^2 = (v_x)_i^2 + 2a_x\Delta x$

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Friction Question 1

PRS

A moving block of mass M is continuously being pulled by a rope under tension T and the speed of the block is constant. [Friction is present.] If the same tension continues to be applied but the mass of the block were to suddenly become 2M, the block would

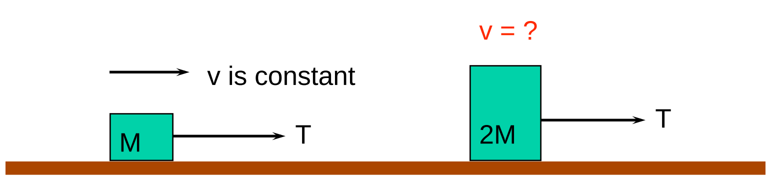
A. Keep moving at the same speed.

B. Move with half the speed.

C. Immediately slow down and later come to a stop.

D. None of the above.

Answer: C



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Friction Question 2

PRS

An automotive engineer suggests increasing the mass of a car to shorten its stopping distance, since the stopping force on a car goes as μ_s mg. Would this work?

A. Yes, cool idea!

B. No way!

C. I need help to answer this…

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Friction Question 2

An automotive engineer suggests increasing the mass of a car to shorten its stopping distance, since the stopping force on a car goes as μ_s mg. Would this work?

It's true that the stopping force is $f_s = \mu_s n = \mu_s mg$,

however we need to consider Newton's second law $\Sigma F = ma$

$$\Sigma F = ma$$

$$\mu_s mg = ma$$

$$\mu_s g = a$$

So the car's deceleration is independent of its mass,

and the stopping distance is independent of mass

Not going to work!

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Friction Problem

A car traveling at 20 m/s stops in a distance of 50 m. Assume that the deceleration is constant. The coefficients of friction between a passenger and the seat are $\mu_s = 0.5$ and $\mu_k = 0.3$. Will a 70-kg passenger slide off the seat if not wearing a seat belt?

How do we solve this problem?
What are we asked to find?
Where do we start?

We need to think about what is the force that keeps the person in the seat.

Friction Problem

Static friction is the only horizontal force that keeps the passenger in the seat

We need to find out what is the maximum acceleration from static friction and compare that to the acceleration of the car

If the car's acceleration is greater, the person will slide and if it is less then the passenger will remain in the seat

A car traveling at 20 m/s stops in a distance of 50 m. Assume that the deceleration is constant. The coefficients of friction between a passenger and the seat are $\mu_s = 0.5$ and $\mu_k = 0.3$. Will a 70-kg passenger slide off the seat if not wearing a seat belt?

Max Acceleration from friction

$$\sum F_x = ma$$

Acceleration of car

$$(v_x)_f^2 = (v_x)_i^2 + 2a\Delta x$$

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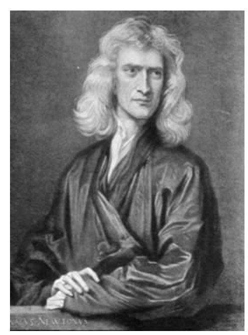
The Force of Gravity

Sir Isaac Newton



?

Is there a connection between these two motions?

Apple falling from a tree vs. Moon orbiting Earth

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