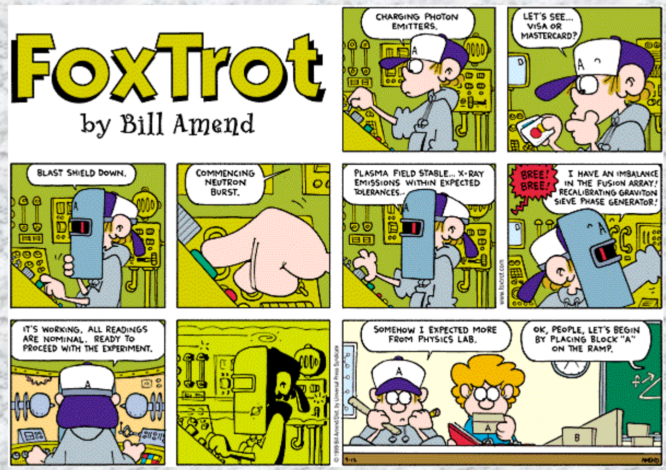
Announcements 13 Mar 09

- **Online homework #6 due on Tue March 24**
  - **Problem 5.22 Part A: give your answer with only 2 significant digits (i.e. round answer and *drop* less significant digits)**



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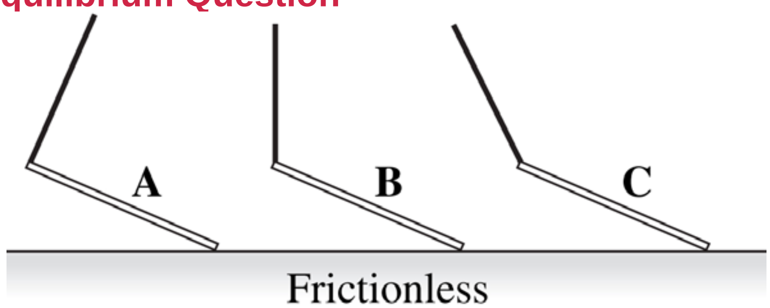
Equilibrium Question



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Using Newton's Second Law

PREPARE Sketch a visual overview consisting of

- A list of values that identifies known quantities and what the problem is trying to find.
- A force-identification diagram to help you identify all forces acting on the object.
- A free-body diagram that shows all the forces acting on the object.

If you'll need to use kinematics to find velocities or positions, you'll also need to sketch

- A motion diagram to determine the direction of the acceleration.
- A pictorial representation that establishes a coordinate system, shows important points in the motion, and defines symbols.

It's OK to go back and forth between these steps as you visualize the situation.

SOLVE Write Newton's second law in component form as

$$\sum F_x = ma_x \quad \text{and} \quad \sum F_y = ma_y$$

Link between force and motion

You can find the components of the forces directly from your free-body diagram. Depending on the problem, either

- Solve for the acceleration, then use kinematics to find velocities and positions, or
- Use kinematics to determine the acceleration, then solve for unknown forces.

Two different types of problems

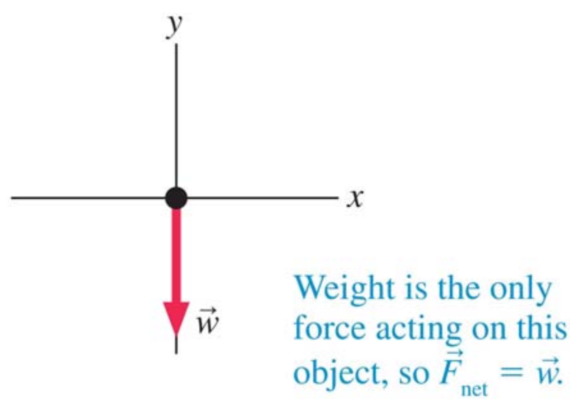
ASSESS Check that your result has the correct units, is reasonable, and answers the question.

Mass and Weight

Object of mass m in free fall (neglecting air resistance)

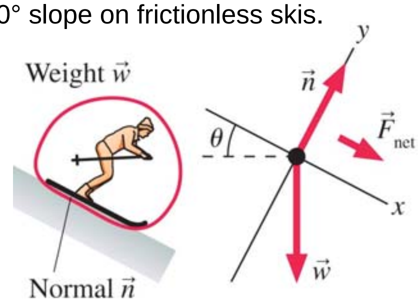
$-w = ma_y = m(-g)$

$\boxed{w = mg}$



Applying 2nd Law Example

A 75-kg skier starts down a 50-m high, 10° slope on frictionless skis. What is his speed at the bottom?



1. Use rotated coordinate system with a y axis perpendicular to the slope
=> Skier is in equilibrium along the y axis i.e. $\Sigma F_y = 0$ and $a_y = 0$

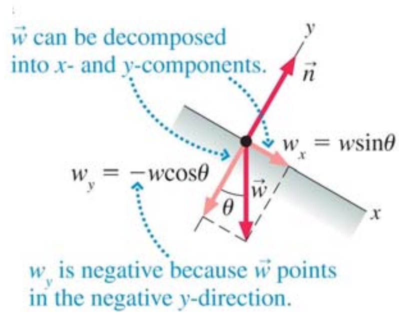
2. Use Newton's 2nd Law to find the acceleration along x

$$\Sigma F_x = ma_x$$

$$w_x = w\sin\theta = mg\sin\theta$$

$$\Rightarrow mg\sin\theta = ma_x$$

$$\Rightarrow a_x = g\sin\theta = 1.70 \text{ m/s}^2$$

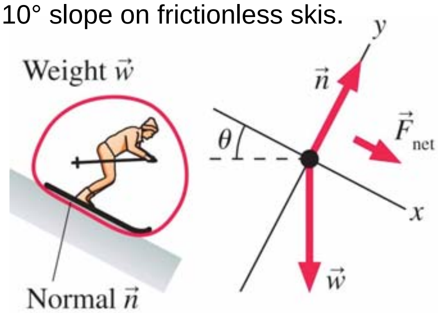


Applying 2nd Law Example

A 75-kg skier starts down a 50-m high, 10° slope on frictionless skis. What is his speed at the bottom?

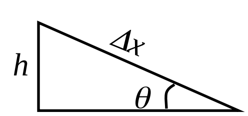
3. Given a_x, use kinematics equations to find $(v_x)_f$

$t_i = 0$	$t_f = ?$
$x_i = 0$	$x_f = ?$
$(v_x)_i = 0$	$(v_x)_f = ?$
$a_x = 1.70 \text{ m/s}^2$	$a_x = 1.70 \text{ m/s}^2$



Use $(v_x)_f^{\,2} = (v_x)_i^{\,2} + 2a_x\Delta x$

with $\Delta x = \dfrac{h}{\sin\theta} = \dfrac{50 \text{ m}}{\sin 10°} = 288 \text{ m}$



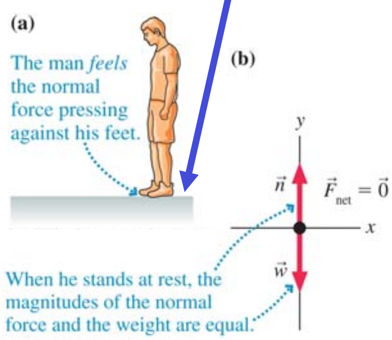
$$\Rightarrow (v_x)_f^{\,2} = 0 + 2(1.70 \text{ m/s}^2)(288 \text{ m}) = 979 \text{ m}^2/\text{s}^2$$

$$\Rightarrow (v_x)_f = 31.3 \text{ m/s}$$

Apparent Weight

How does the sensation of weight depend on your acceleration?

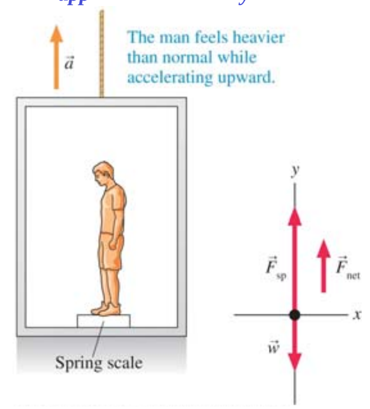
Normal force is the spring force exerted by the surface being pressed against



DEMO: 1 kg mass with force gauge

Apparent weight = normal force pressing against man

$$w_{app} = mg + ma_y$$



Apparent Weight Question

PRS

An elevator that has descended from the 50th floor is coming to a halt at the 1st floor. As it does, your apparent weight is

A. More than your true weight
B. Less than your true weight
C. Equal to your true weight
D. Zero

Example

A 50 kg student gets in a 1000 kg elevator at rest. As the elevator begins to move, she has an apparent weight of 600 N for the first 3 s. How far has the elevator moved, and in which direction, at the end of 3 s?

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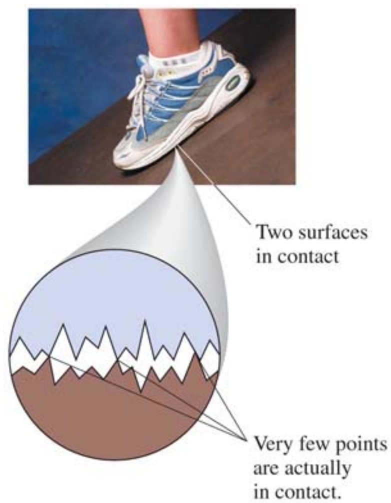
Friction

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 block 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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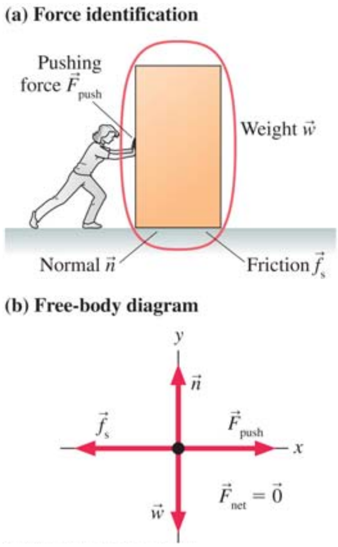
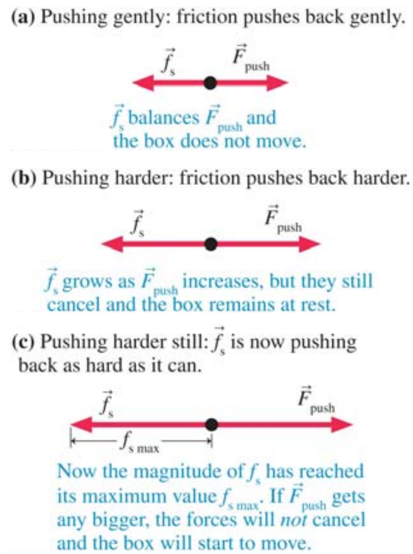
Static Friction





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

μ_s = coefficient of static friction

Static friction responds "as needed" to prevent slipping

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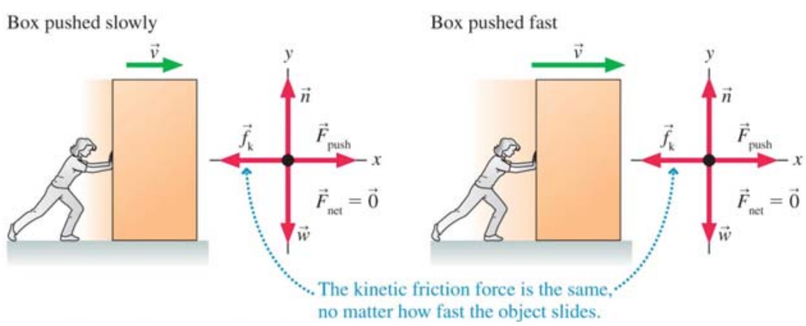
Kinetic Friction



$$f_k = \mu_k n$$

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 ABS systems 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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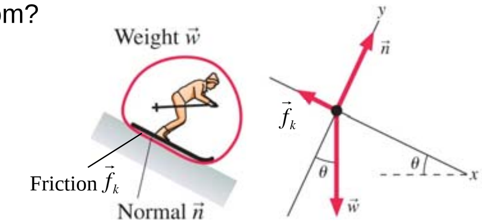
Applying 2nd Law (Revisited example with friction)

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

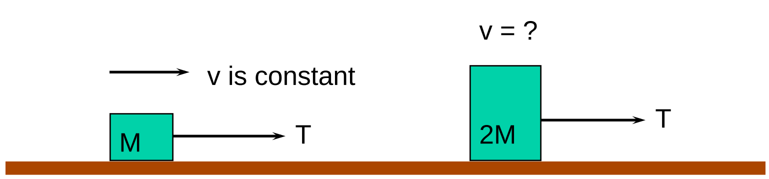
A block of mass M sits on a horizontal surface having friction. When the block is pulled by a rope under tension T, the block moves with constant speed. If the same tension were applied to a mass of 2M at rest, the block would

A. remain at rest.

B. accelerate until the speed is half.

C. move with the same constant speed.

D. none of the above.



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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 μ_s = 0.5 and μ_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.

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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

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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

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

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