Laws of Motion
Friction

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Last time

- objects moving together
- pulleys
- Atwood machines

Overview

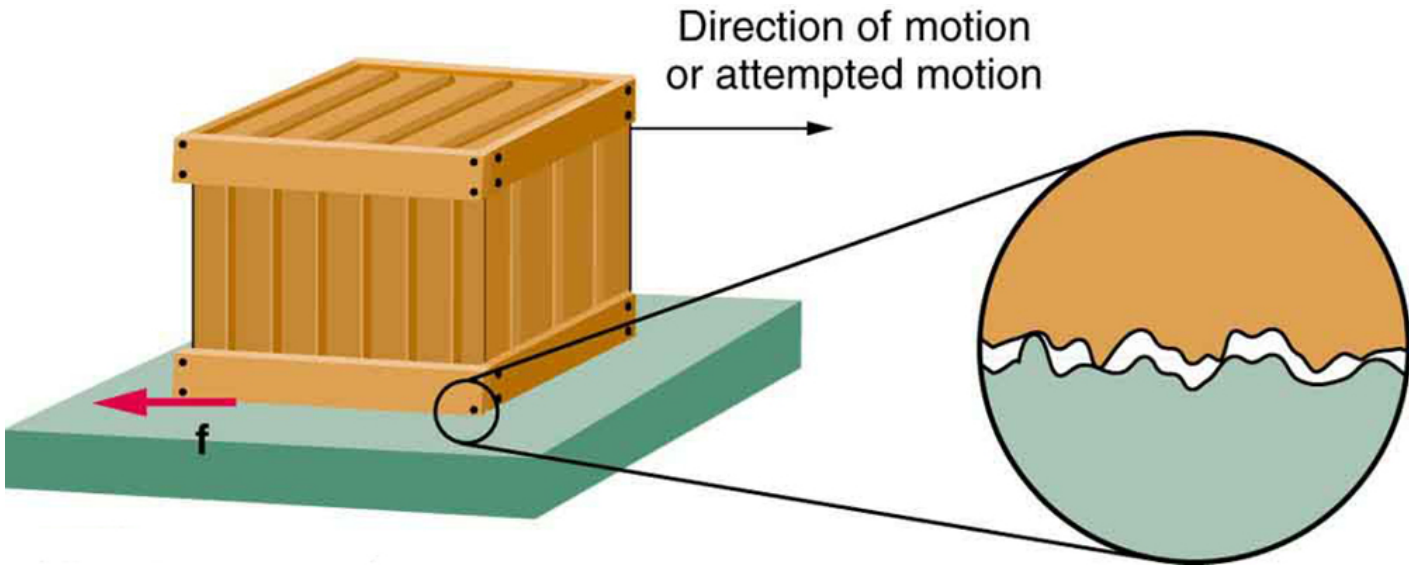
- friction

Friction

friction

The force caused by small-scale roughness of surfaces or even electrostatic attractions between surfaces. It dissipates energy and resists motion.

Friction opposes the motion of one surface relative the other.



Friction

Kinetic friction is the friction force that acts on moving objects. It is given by:

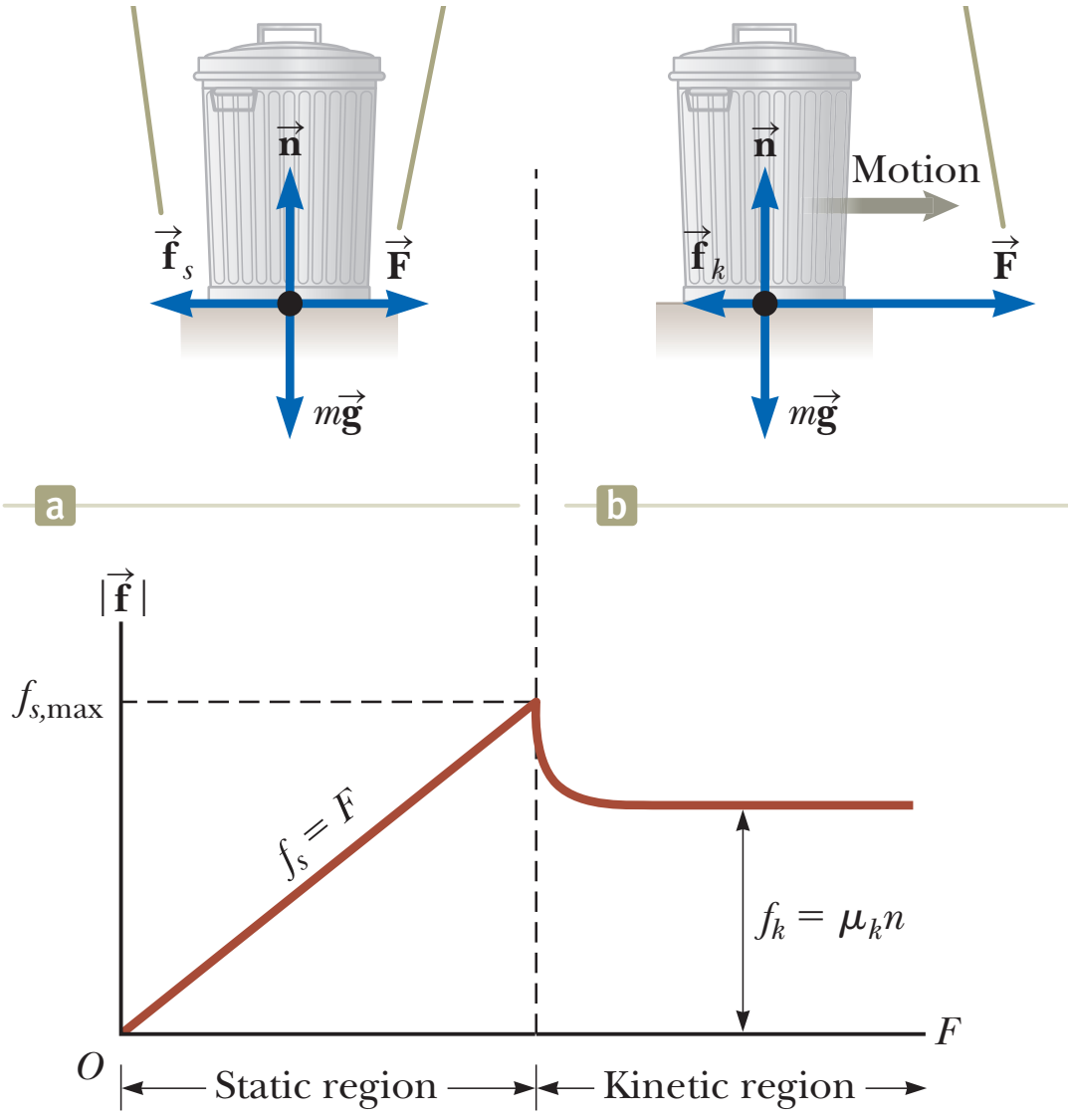
$$f_k = \mu_k |\vec{\mathbf{n}}| = \mu_k n$$

Static friction is the friction force that acts on objects that are at rest:

$$f_s \leqslant \mu_s n \qquad f_s \leqslant f_{s,\max}$$

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

Friction


$\vec{\mathbf{n}}$
$\vec{\mathbf{f}}_s$
$\vec{\mathbf{F}}$
$m\vec{\mathbf{g}}$
a
$\vec{\mathbf{n}}$
Motion
$\vec{\mathbf{f}}_k$
$\vec{\mathbf{F}}$
$m\vec{\mathbf{g}}$
b
$|\vec{\mathbf{f}}|$
$f_{s,\max}$
$f_s = F$
$f_k = \mu_k n$
F
O
Static region
Kinetic region

Friction Example

According to the textbook, for waxed wood on wet snow $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

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To get the sled moving $F_{app} \geqslant f_s$

$$\begin{aligned} f_s &= \mu_s n \\ &= (0.14)(10\text{ kg})g \\ &= 13.7\text{ N} \end{aligned}$$

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$$
\begin{aligned}
F_{\text{net},x} &= ma_x \\
F_{app} - f_k &= ma \\
F_{app} - \mu_k n &= ma \\
F_{app} - \mu_k mg &= ma \\
a &= \frac{F_{app}}{m} - \mu_k g \\
&= \underline{0.39 \text{ ms}^{-2}}
\end{aligned}
$$

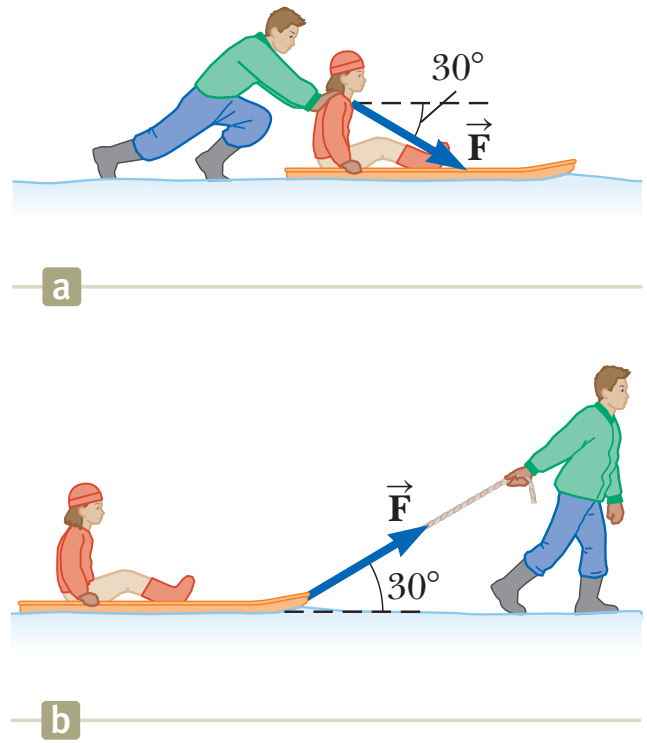
Friction Question

Quick Quiz 5.7.[1] You are playing with your daughter in the snow. She sits on a sled and asks you to slide her across a flat, horizontal field. You have a choice of:

(A) pushing her from behind by applying a force downward on her shoulders at 30° below the horizontal or

(B) attaching a rope to the front of the sled and pulling with a force at 30° above the horizontal.

Which would be easier for you and why?



[2]Serway & Jewett, page 132.

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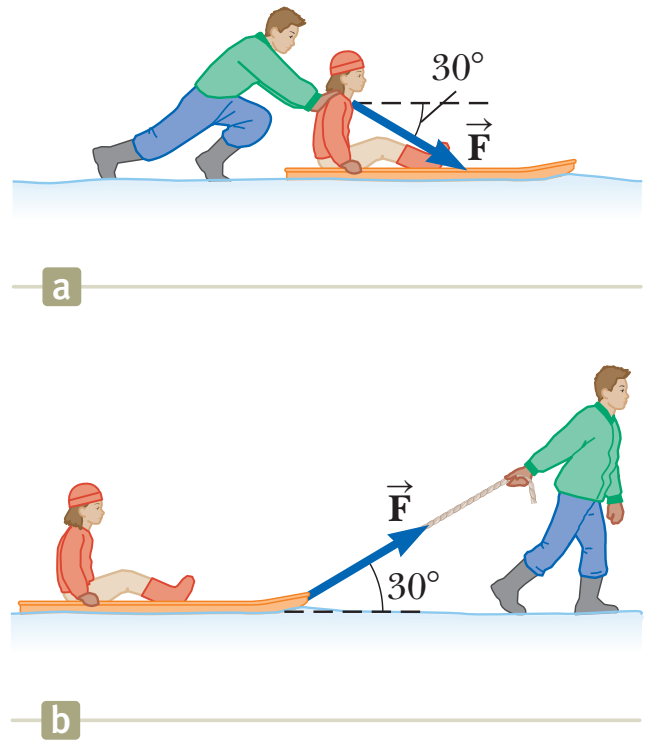
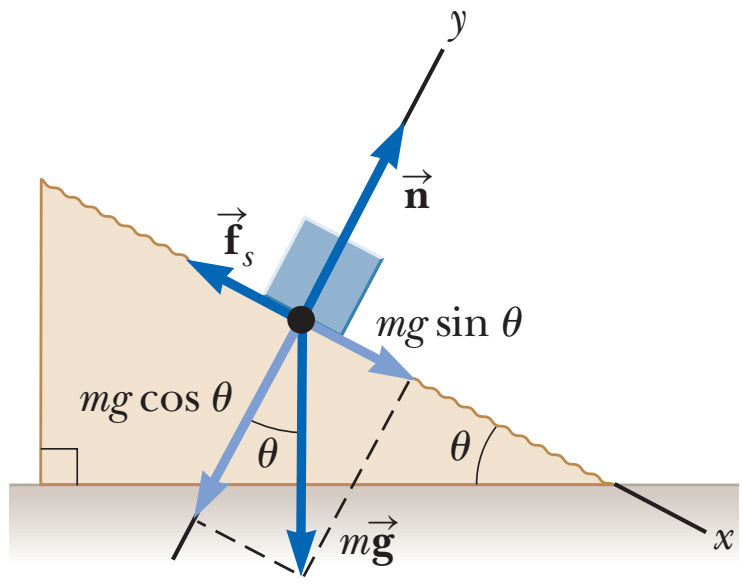


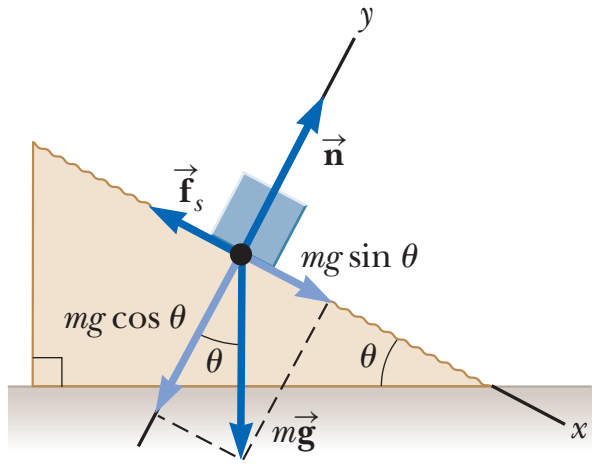
[2]Serway & Jewett, page 132.

Incline with Friction

Given a block of mass $m = 1$ kg on an incline of $\theta = 30^\circ$ with a coefficient of static friction of $\mu_s = 0.3$, will the block slide?



Incline with Friction



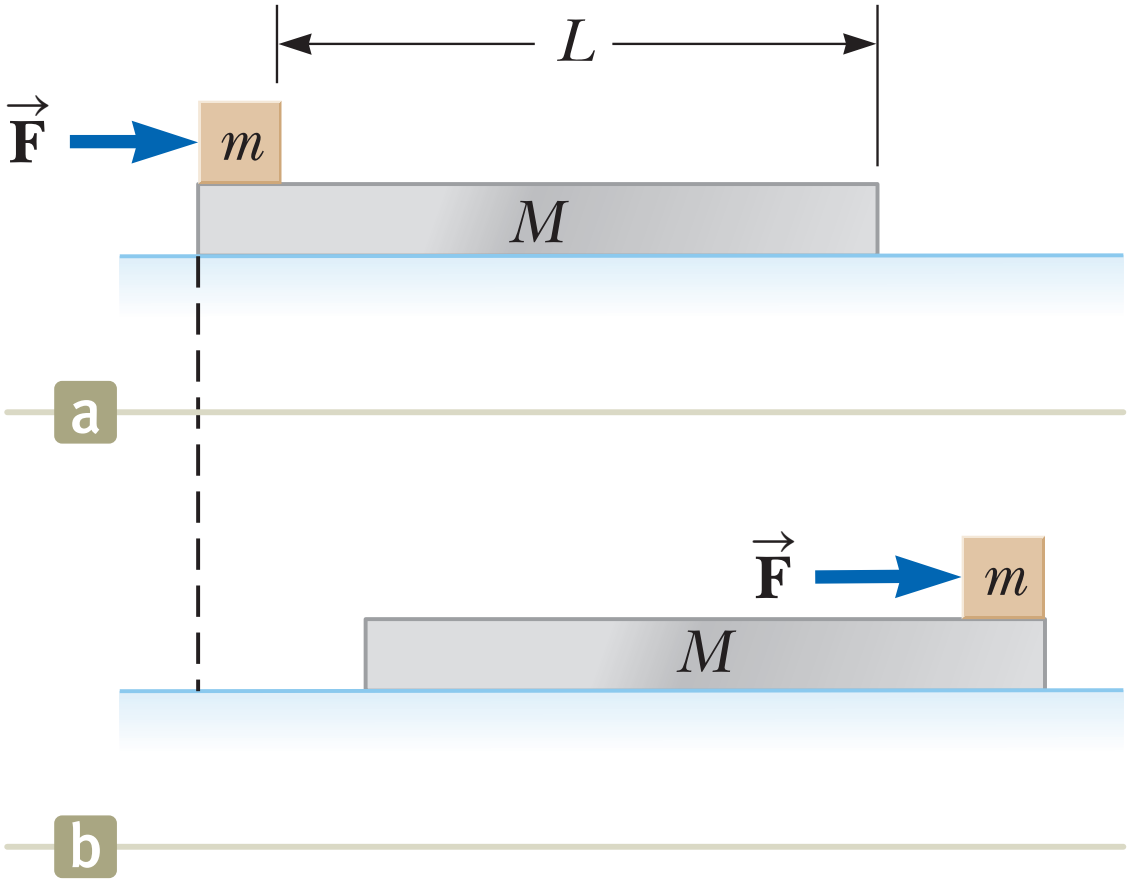
If the net force is not zero, it will be downward parallel to the slope.
x-direction:

$$F_{\text{net},x} = mg\sin\theta - f_s$$

Block will slip if:

$$\begin{aligned} mg\sin\theta - f_{s,\max} &> 0 \\ mg\sin\theta - \mu_s(mg\cos\theta) &\overset{?}{>} 0 \\ (1\text{ kg})g\left(\frac{1}{2} - 0.3\frac{\sqrt{3}}{2}\right) &\overset{?}{>} 0 \\ 2.35\text{ N, downward along the incline} &> 0 \Rightarrow \underline{\text{Yes, it slides.}} \end{aligned}$$

Sliding Blocks with Friction: #103, page 149



Between m and M is friction, coefficient μ_k.

How long does it take for the little block to reach the end of the long block?

How far did the long block move?

Summary

- friction

First Test Monday, 10 Feb.

(Uncollected) Homework Serway & Jewett,

- Work through Example 5.13 on page 134 and understand it.
- Ch 5, onward from page 136. Obj.Q 1; Problems: 61, 65, 89, 103
- Ch 6, onward from page 169. Probs: 1, 5 (can try these now)