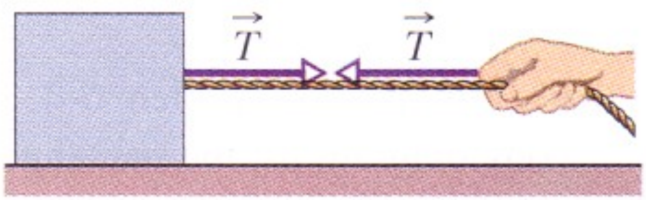
# Chapter 5: Using Newton's Laws
## Tuesday February 3rd

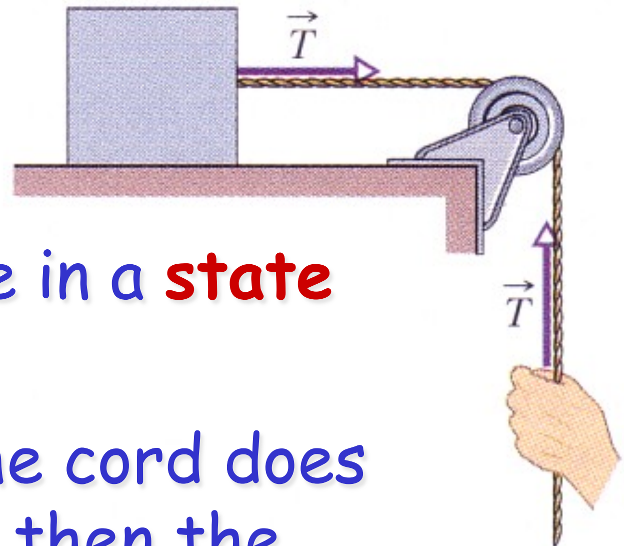
- Review: Tension force as an example of the 3rd law
- Finish example problems from last week
- Friction forces
- Spring forces
- Demonstrations and examples + iClicker problem

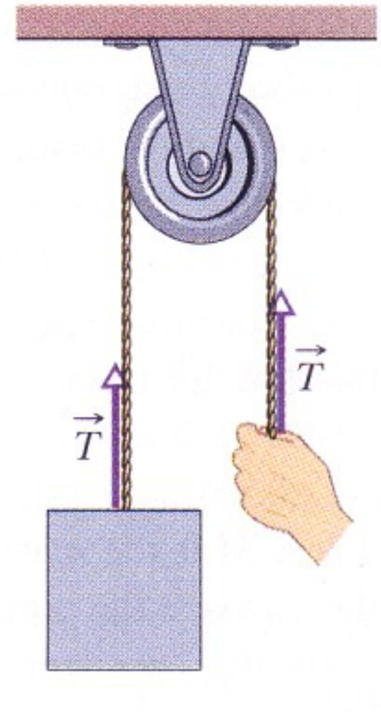
Mini Exam II this Thursday
- Will cover LONCAPA #3-6 (2D motion and Newton's laws)

**Reading: up to page 79 in the text book (Ch. 5)**

# Tension



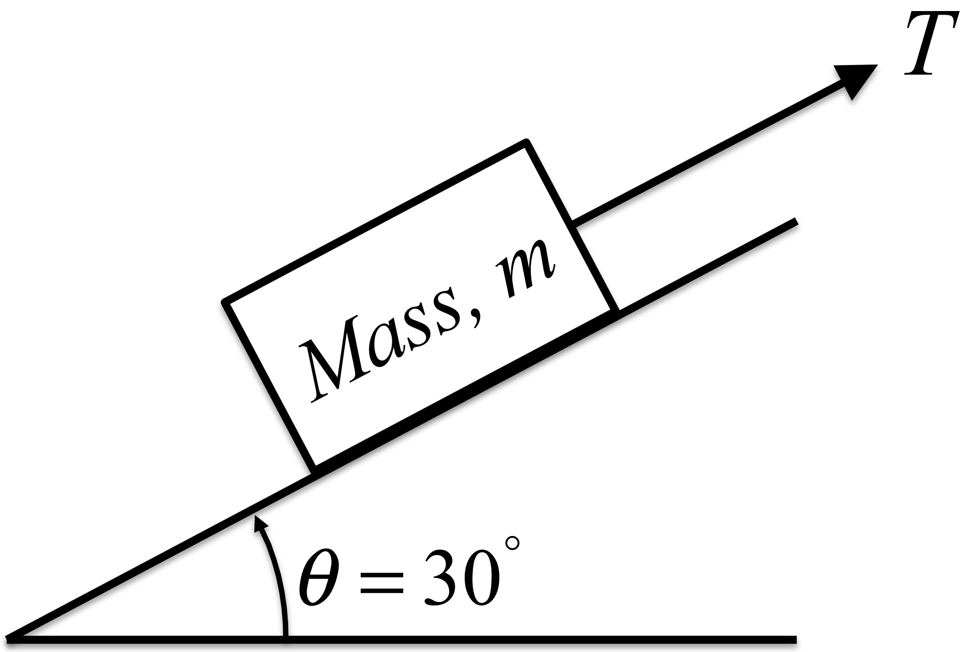



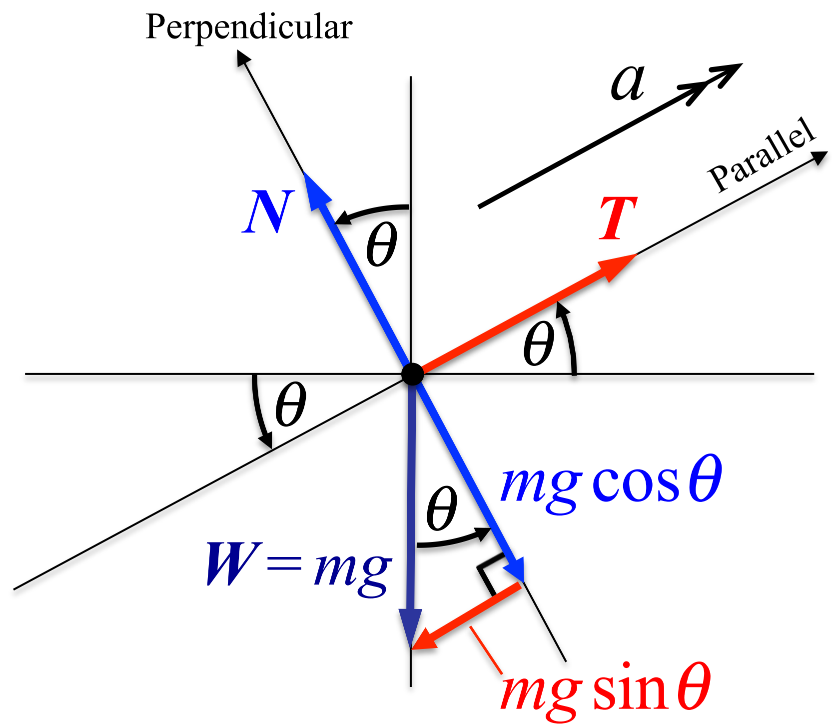




- A **taut cord** is said to be in a **state of tension**.
- If the body pulling on the cord does so with a force of 50 N, then the tension in the cord is 50 N.
- A taut cord pulls on objects at either end with equal and opposite force equal to the tension (Newton's 3rd law).
- Cords are massless, pulleys are massless and frictionless

# Frictionless Inclined Plane

1. What is the tension, $T$, if the mass is static?
2. What is the acceleration if the tension, $T = 0$?



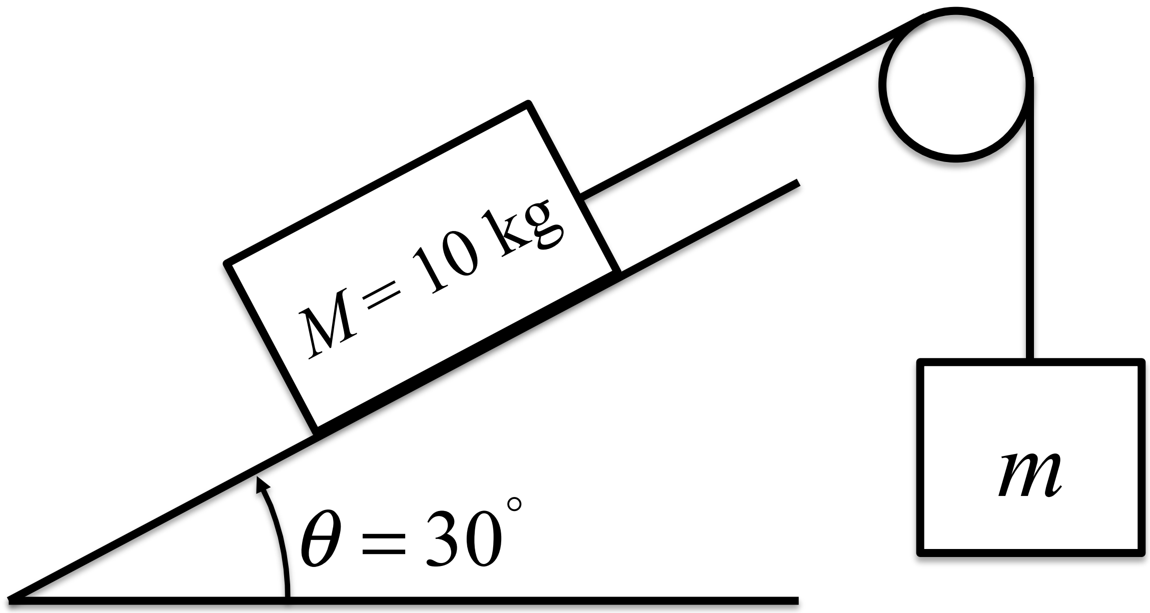




Perpendicular: $N - mg\cos\theta = 0$

Parallel: $T - mg\sin\theta = ma$

# Frictionless Inclined Plane

1. What happens if $m = 5$ kg?
2. What happens if $m = 6$ kg?
3. What happens if $m = 4$ kg?

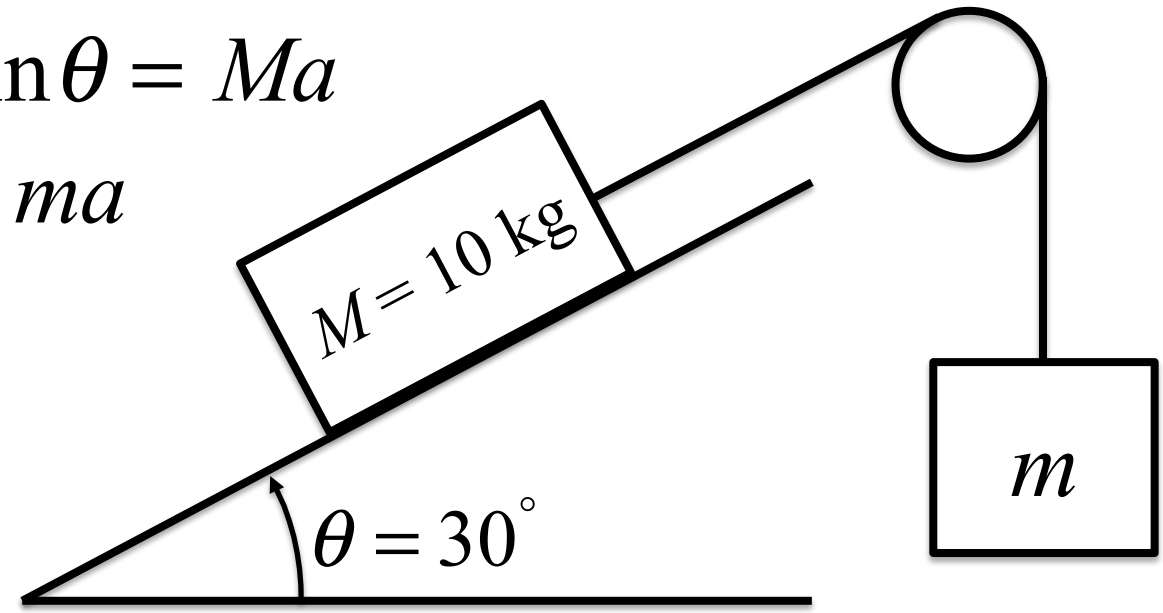


# Frictionless Inclined Plane

1. What happens if $m = M/2$?
2. What happens if $m > M/2$?
3. What happens if $m < M/2$?

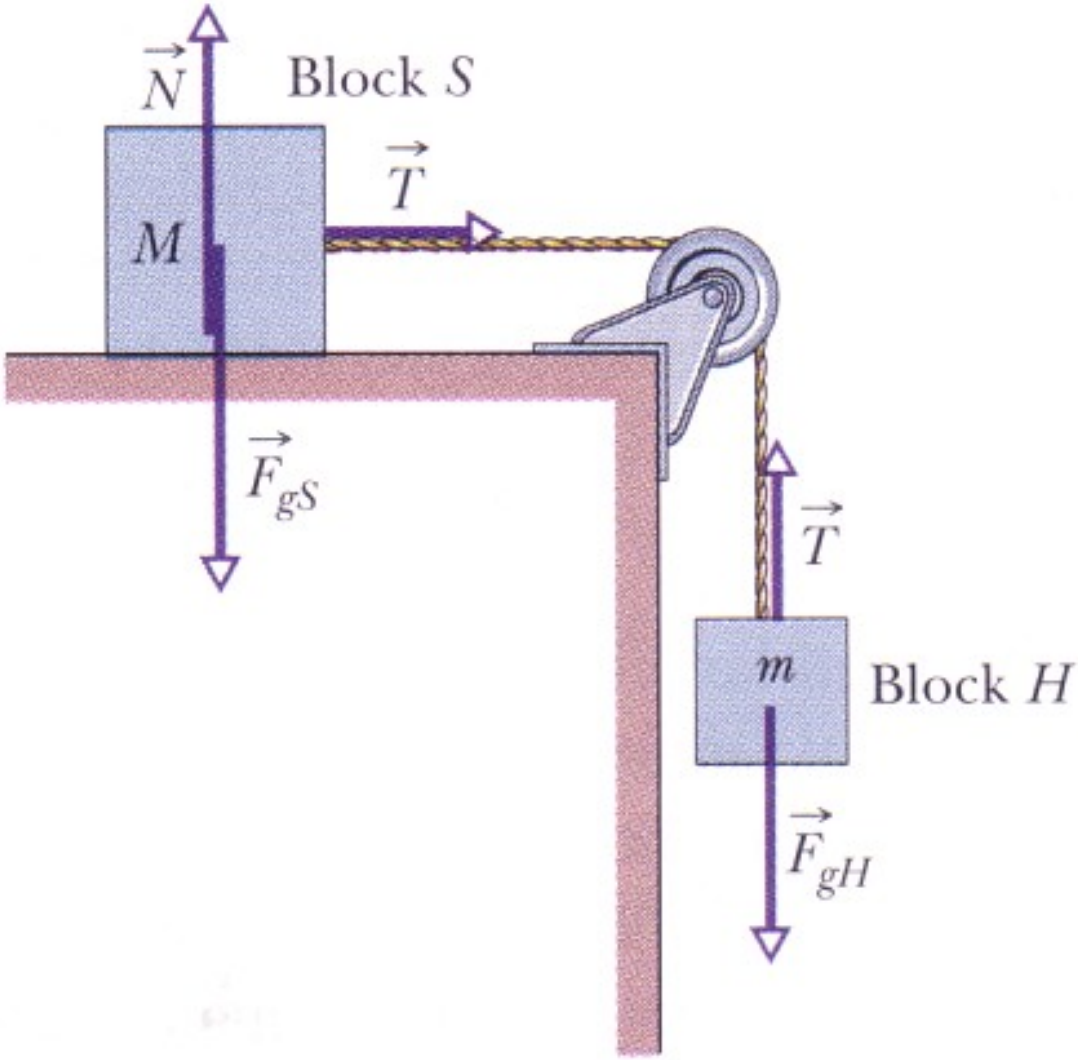
$$T - Mg\sin\theta = Ma$$

$$mg - T = ma$$




$$\boxed{a = \frac{m - M\sin\theta}{m + M}g}$$

# Special case: $\theta$ = 0




$$a = \frac{m}{m+M} g$$

Experience might lead you to believe that if $M$ was very large, say 2000 Kg, $m$ would not budge.

This is where **friction** comes in.

# Characteristics of Friction

1. When you set an object in motion on a typical surface, it slows down and stops if you do not continue to push.
2. Even if you continue to push with the same force, the object does not accelerate.
3. If you try to push an extremely heavy object, it does not move, no matter whether you push hard or gently.
4. If you really push with all of your might, it eventually gives way and begins to slide.

1 and 2, along with Newton's second law, tell us that there must be an unseen force - **friction** - which opposes the motion. In 1, this frictional force is the only horizontal force on the object, and it causes a deceleration. In 2, the frictional force is equal and opposite to the pushing force.

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- 3 tells us that, in static cases, the force due to friction adjusts so as to exactly oppose the applied force.
- 4 tells us that there is a maximum magnitude for the static frictional force; when you exceed this, the object slides.

# Characteristics of Friction

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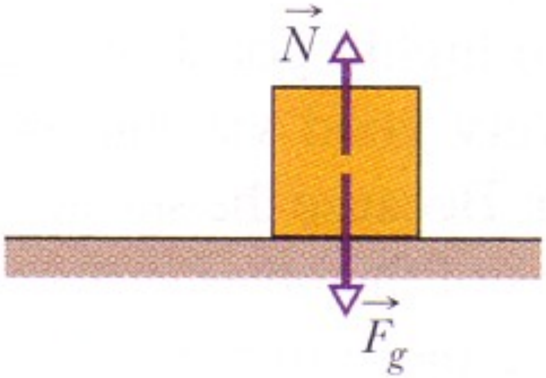
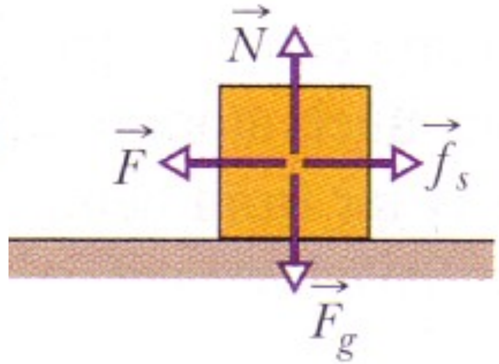
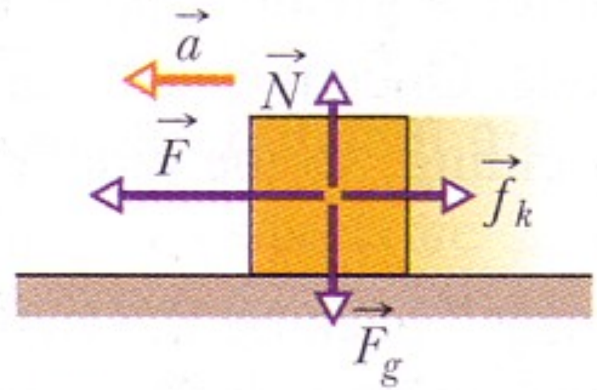
- 3 and 4 tell us that the frictional force is greater for heavier objects.

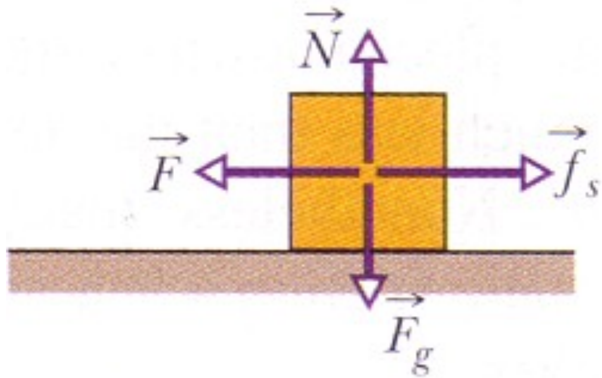


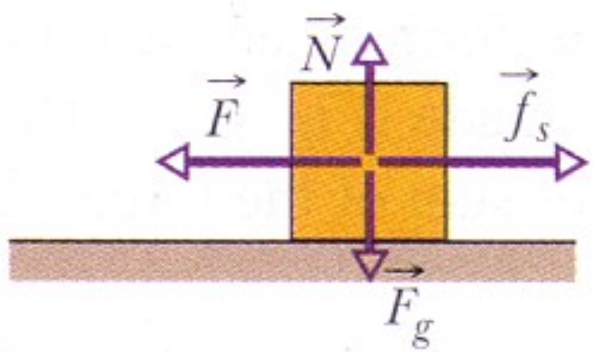



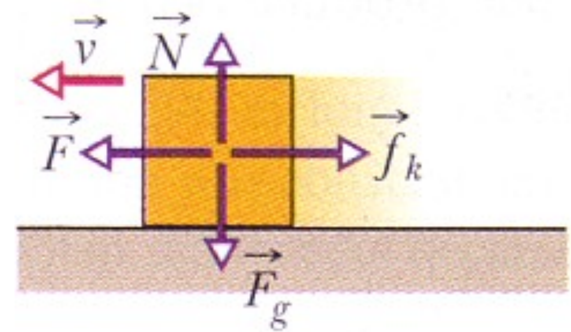

$f_k$ is the kinetic friction force

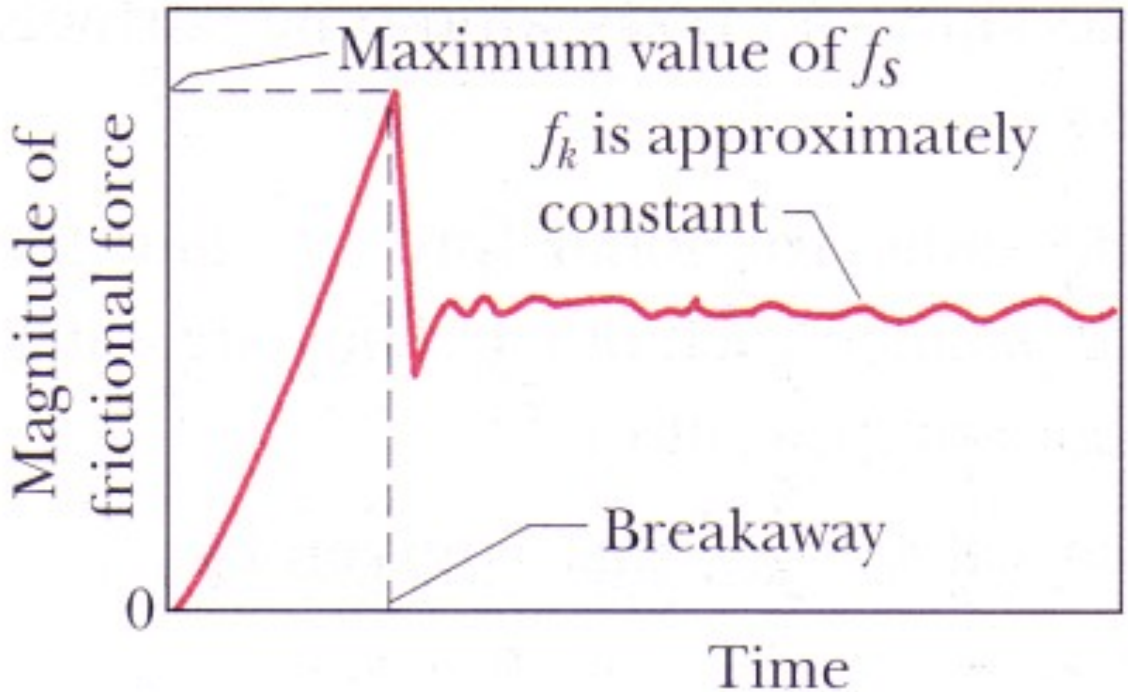


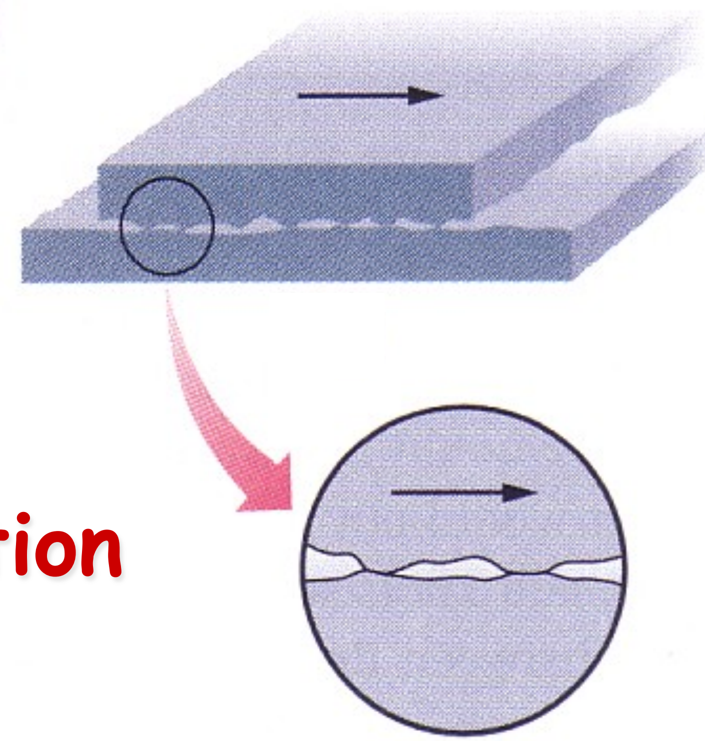

$f_s$ is the static friction force





**Microscopic origin of friction**

# Static friction

1. In static situations, the static frictional force exactly cancels the component of the applied force parallel to the surface.

2. The heavier an object, the more difficult it is to make it slide. Evidently, the maximum frictional force depends on the normal force between the surface and the object, i.e.

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

where $\mu_s$ is the **coefficient of static friction** and $N$ is the magnitude of the normal force. $\mu_s$ is a parameter that depends on both surfaces. Once the force component parallel to the surface exceeds $f_{s,max}$, then the body begins to slide along the surface.

# Kinetic friction

3. If a body begins to slide along the surface, the magnitude of the frictional force instantly decreases to a value $f_k$ given by

$$f_k = \mu_k N$$

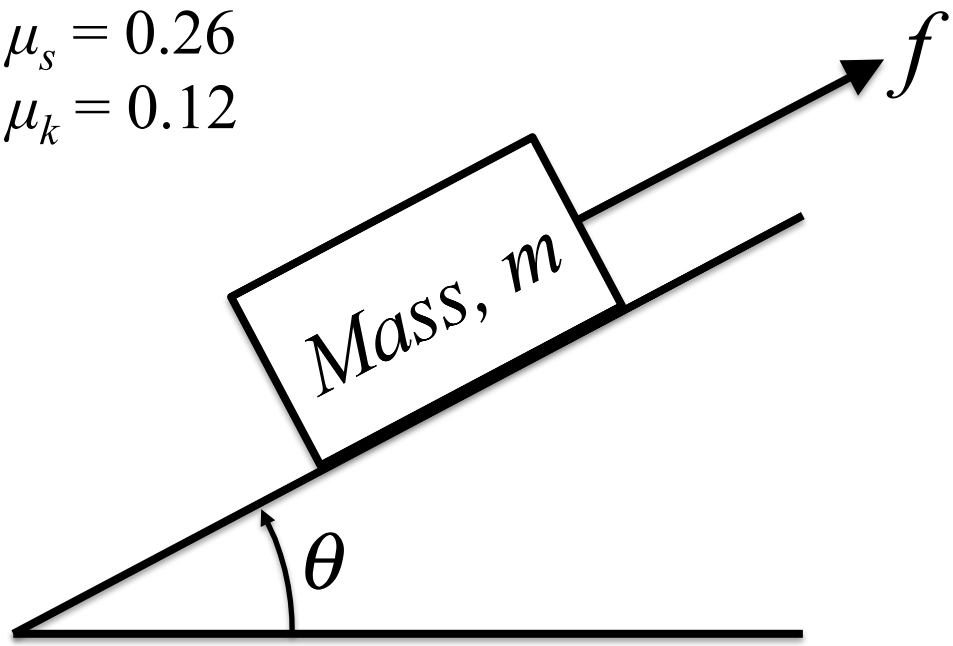
   where $\mu_k$ is the **coefficient of kinetic friction** and $N$ is the magnitude of the normal force. Therefore, during the sliding, a kinetic frictional force of magnitude $f_k$ opposes the motion.

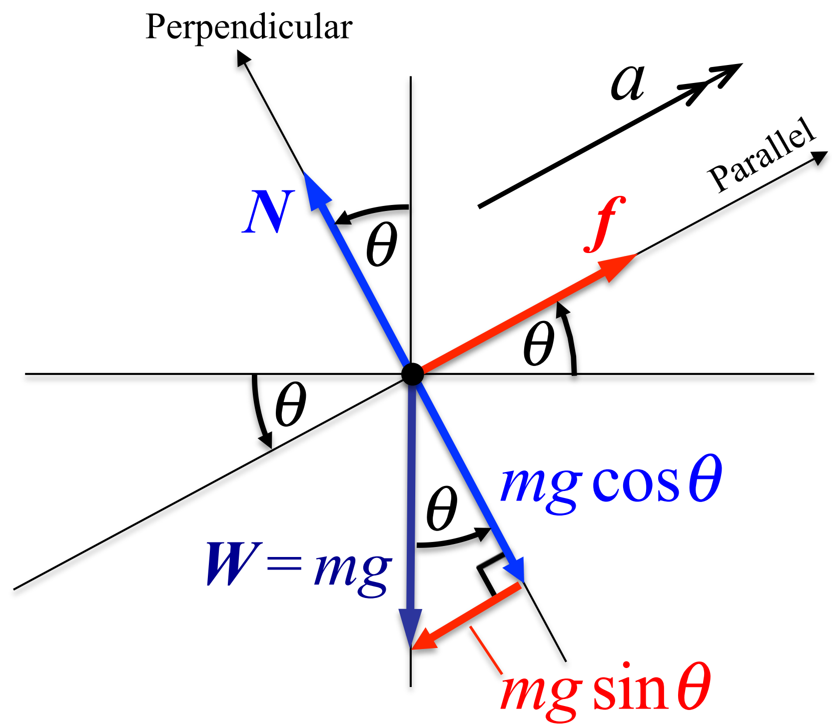
4. When several agents push in different directions on an object, the frictional force opposes the component of the net force on the object which is parallel to the surface.

# Inclined Plane with Friction

1. At what angle does it begin to slide?
2. What is the acceleration at this angle?

$\mu_s = 0.26$
$\mu_k = 0.12$




Friction opposes the tendency for the block to slide downhill, so the frictional force must act uphill and parallel to the slope

# Inclined Plane with Friction

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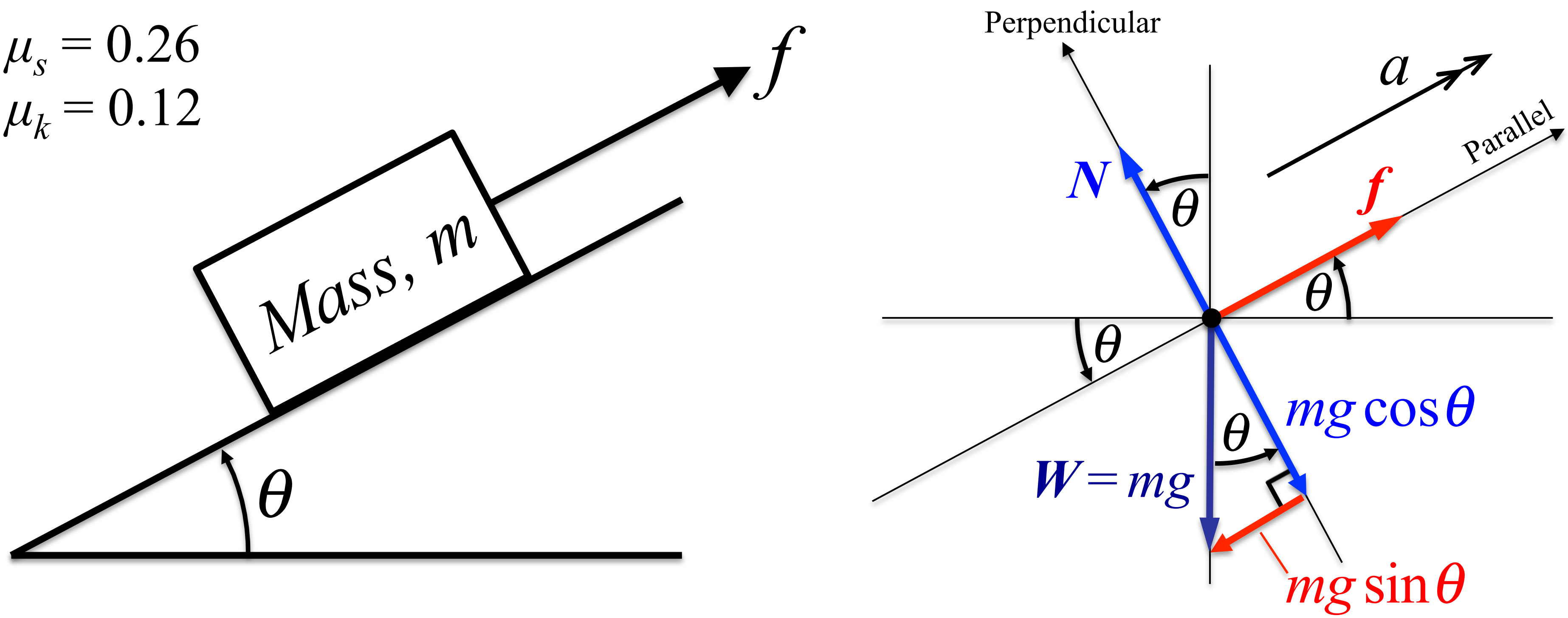


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