

# Lecture 14: Friction

- Static and kinetic friction
- Relationship with normal force magnitude
- Problem solving involving frictional forces

# Frictional forces

## Frictional force

- opposes motion or impending motion relative to a surface.
- caused when two surfaces rub against each other.
- acts parallel to surface

Two types of frictional forces:

**Static** — prevents motion from starting

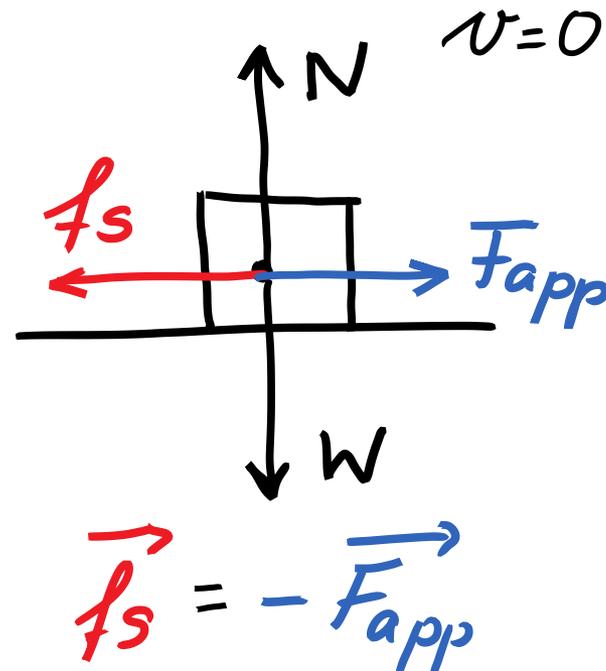
**Kinetic** — opposes motion in progress

# Static Friction

Static friction vector  $\vec{f}_s$  directed opposite to the direction of motion an object *would* have relative to the surface if no friction were present.

Determine direction:  
which way would object  
move without friction?

$\vec{f}_s$  is aimed in the  
opposite direction.



# Maximum static friction

$|\vec{f}_s| = |\vec{F}_{app}|$  until maximum is reached

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

$\mu_s$  **coefficient of static friction**

a positive number, depends on the materials

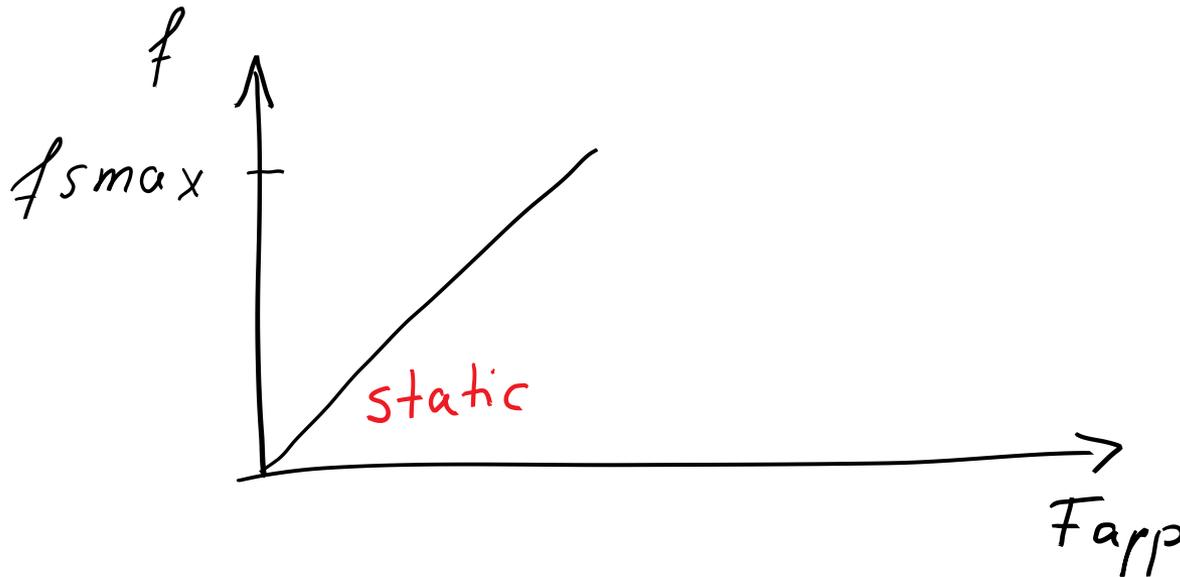
N is the **magnitude of the normal force**

$$f_s \leq f_{s \max} = \mu_s N$$

## Getting object to move

$|\vec{f}_s| = |\vec{F}_{app}|$  until maximum is reached

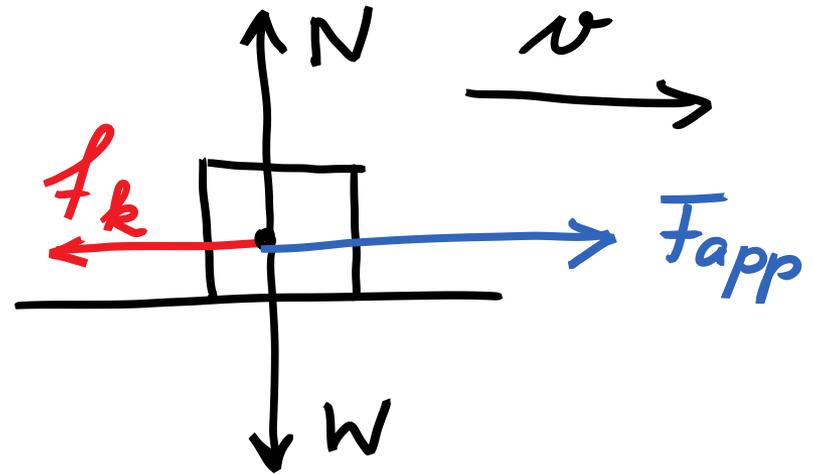
When  $|\vec{F}_{app}| > f_{s\ max} = \mu_s N$ : object begins to move



# Kinetic friction

If object is moving relative to surface: kinetic friction  $\vec{f}_k$

Directed opposite to velocity relative to surface.

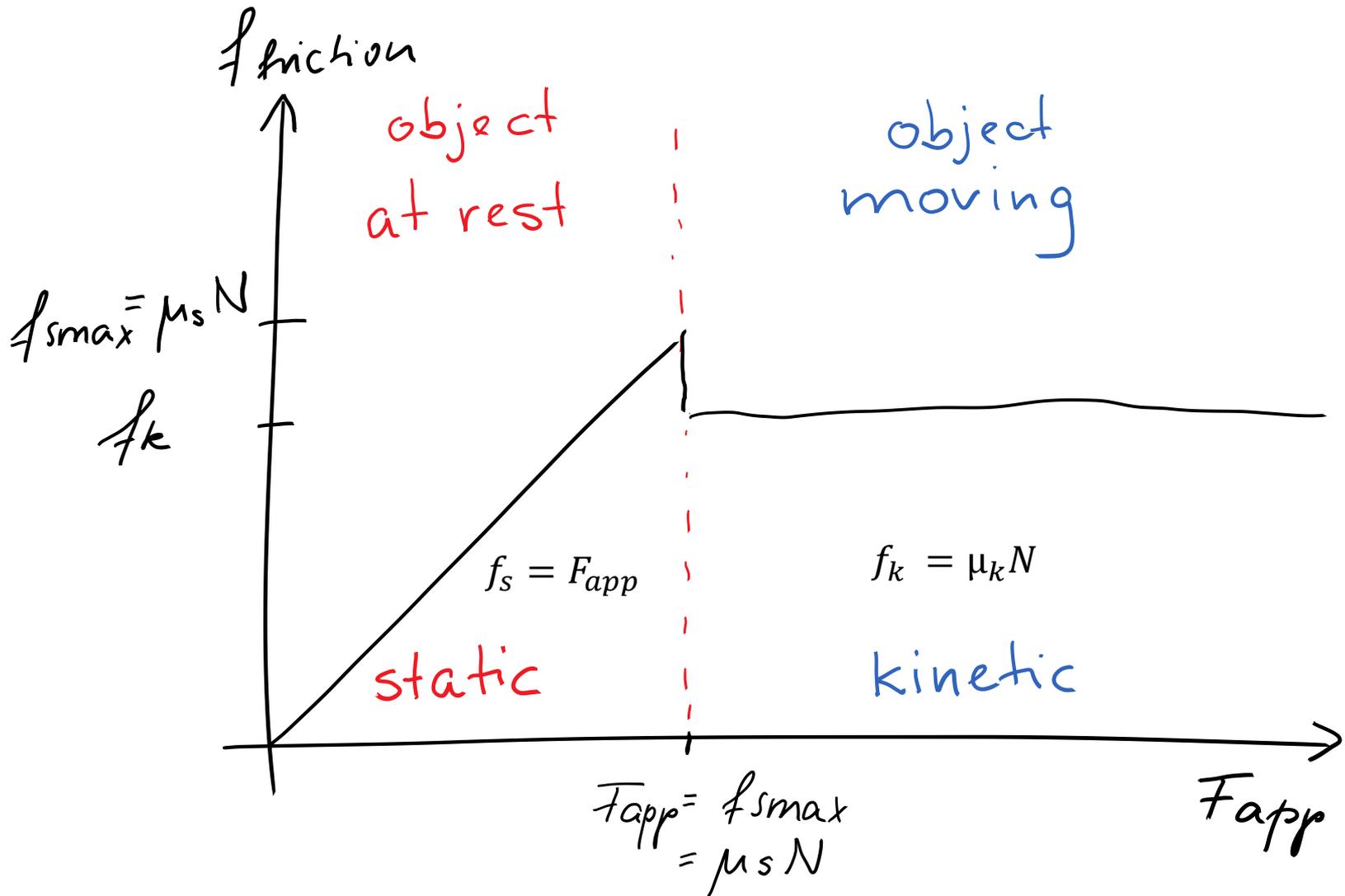


$$f_k = \mu_k N$$

$\mu_k$  is the **coefficient of kinetic friction**  
a positive number, depends on the materials

N is the **magnitude of the normal force**

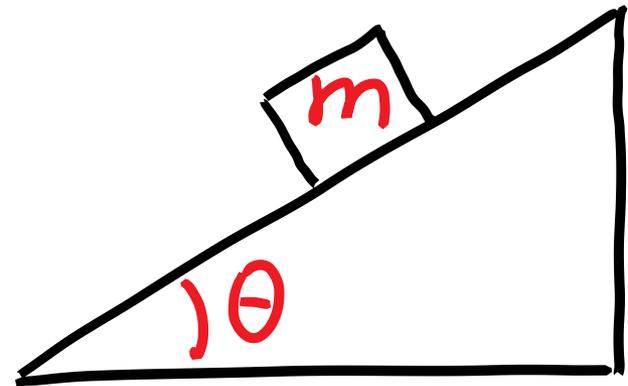
# Static and kinetic friction



## Example: block on incline

If the incline is too steep, the block will not be able to remain at rest because the necessary static friction would exceed the possible maximum.

What is maximum angle  $\theta_{\max}$  for which block won't slide? Does it depend on mass of the block?  $v=0$



Demo:  $\theta_{\max}$  for truck on inclined plane

## Example with kinetic friction

A block of mass  $M$  is moving to the left with initial speed  $V$  on a rough horizontal surface. The coefficient of kinetic friction between the block and the surface is  $\mu$ . The block is moving against a constant wind that is blowing down on it at an angle  $\theta$  with respect to the vertical and produces an effective blowing force of magnitude  $B$ .

Derive an expression for the block's acceleration.

