

Lecture 7: 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

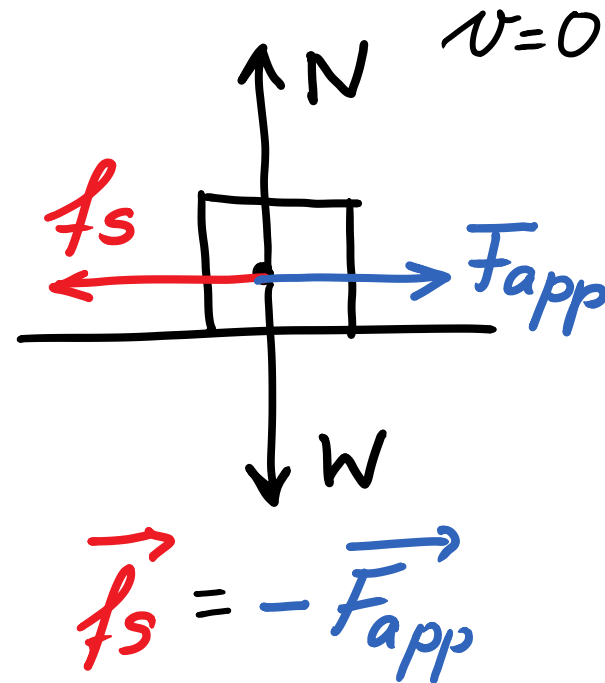
Kinetic — opposes motion in progress

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

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

μ_s **coefficient of static friction**

a positive number, depends on the materials

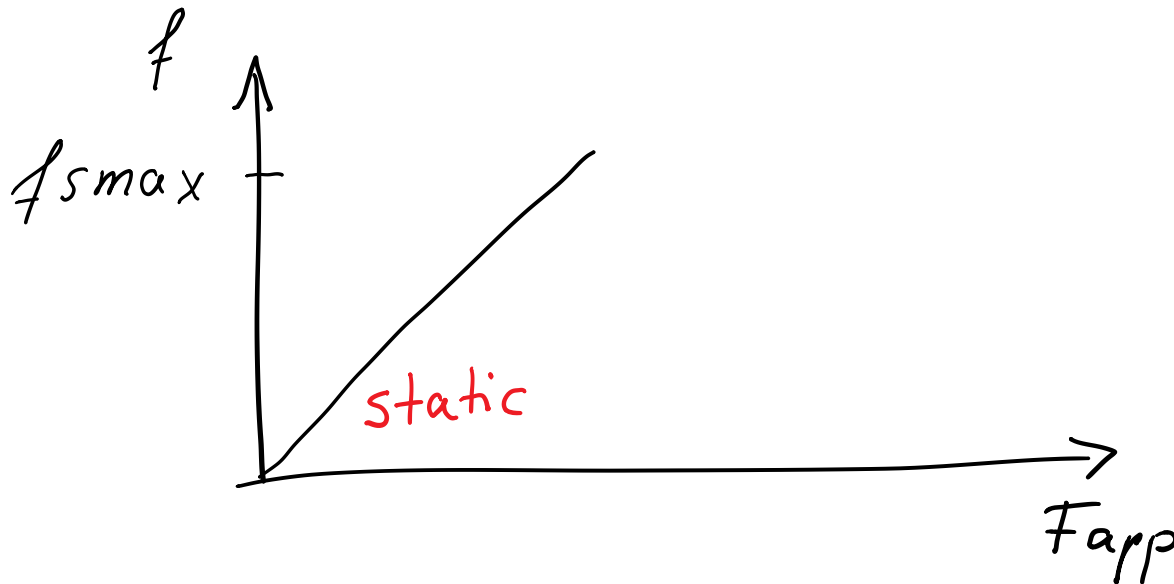
N is the **magnitude of the normal force**

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

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

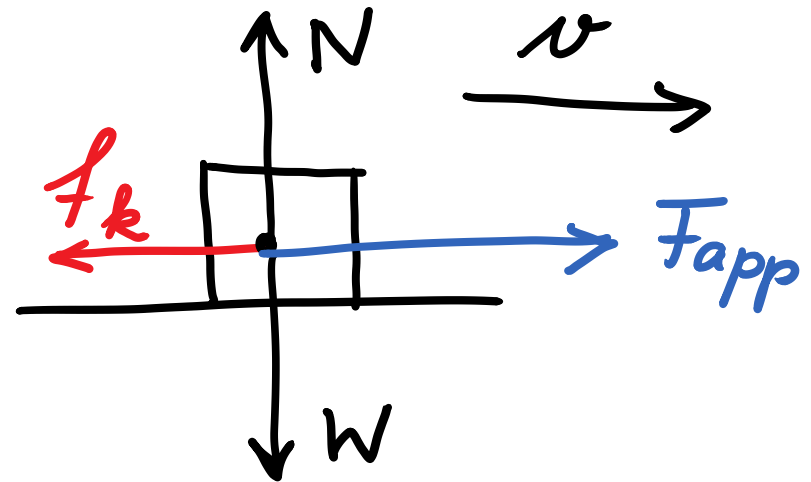


Demo: μ_s for truck on horizontal surface

Kinetic friction

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

Directed opposite to velocity relative to surface.

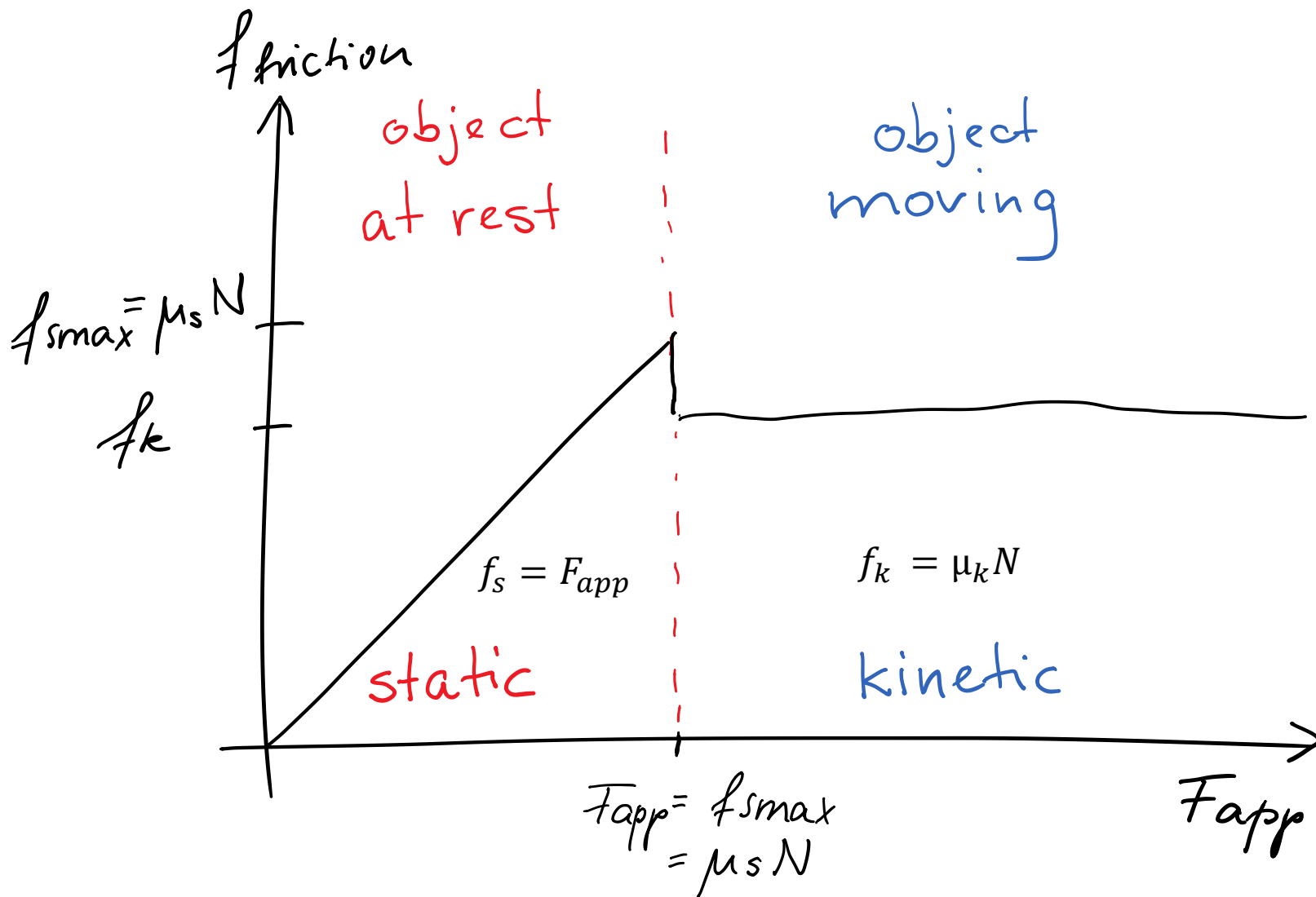


$$f_k = \mu_k N$$

μ_k is the **coefficient of kinetic friction**
a positive number, depends on the materials

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

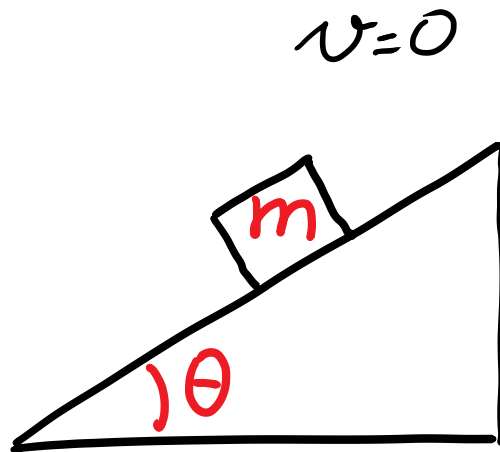
Static and kinetic friction



Discussion question

A block of mass m is at rest on an incline that makes an angle θ with the horizontal. The coefficient of static friction between block and incline is μ_s . What is the magnitude of the frictional force, in terms of system parameters?

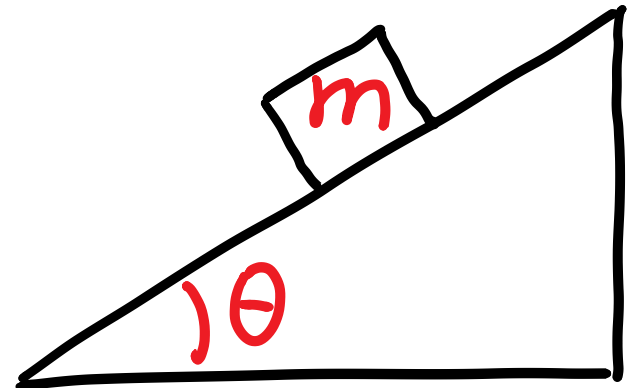
- A) $\mu_s N$
- B) $\mu_s mg$
- C) $\mu_s mg \cos \theta$
- D) $mg \sin \theta$



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 θ_{\max} for which block won't slide? Does it depend on mass of the block? $v=0$

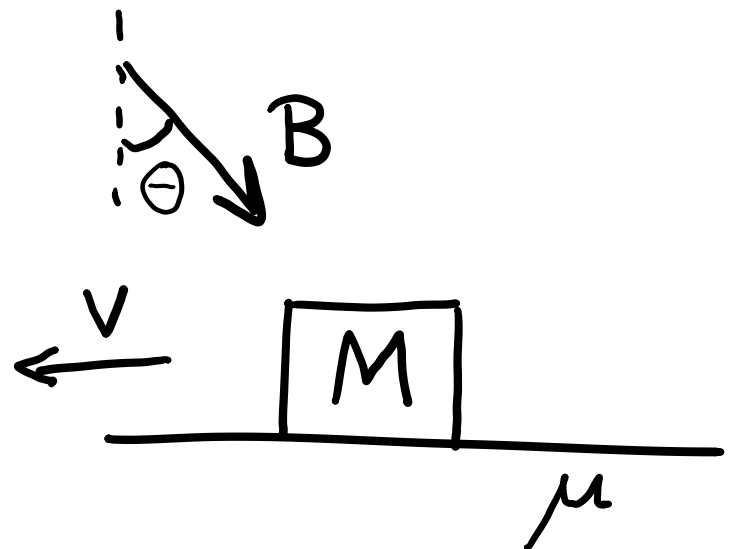


Demo: θ_{\max} for truck on inclined plane

Example with kinetic friction

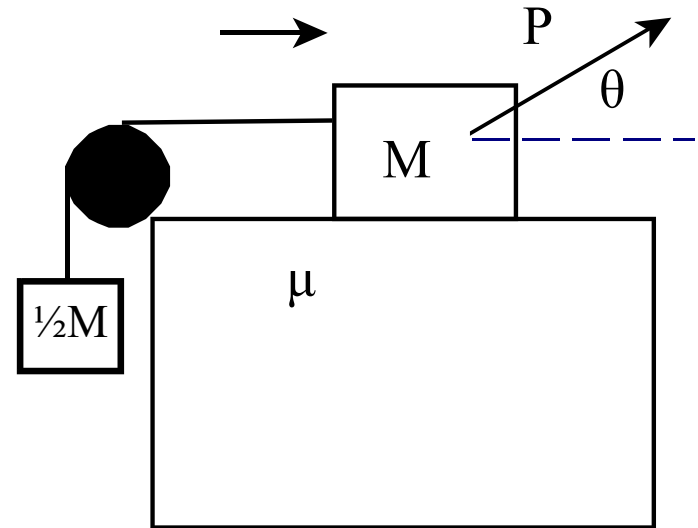
A block of mass M is moving to the left with initial speed V on a rough horizontal surface. The coefficient of kinetic friction between the block and the surface is μ . The block is moving against a constant wind that is blowing down on it at an angle θ with respect to the vertical and produces an effective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

Derive an expression for the block's acceleration.



Example with friction and two objects

A block of mass M is moving to the right on a rough horizontal surface because a pulling force of magnitude P is applied to the block at an angle of θ with respect to the horizontal. The block remains in contact with the surface at all times, and the coefficient of kinetic friction between block and surface is μ . The block is connected to the end of a massless string that runs over a massless frictionless pulley. A block of mass $\frac{1}{2}M$ is suspended from the other end of the string. Derive an expression for the tension in the string.



If we don't have enough time in lecture to finish working through the problem, please see video on the course website.