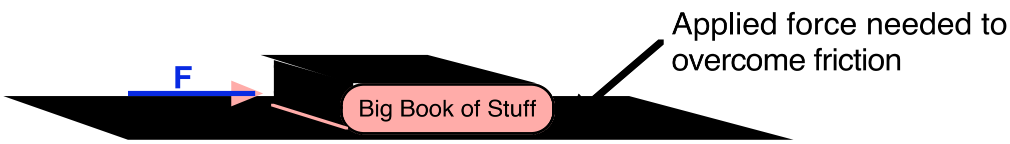
Lecture 6 - Friction

What's important:
- frictional forces
- coefficients of static and kinetic friction

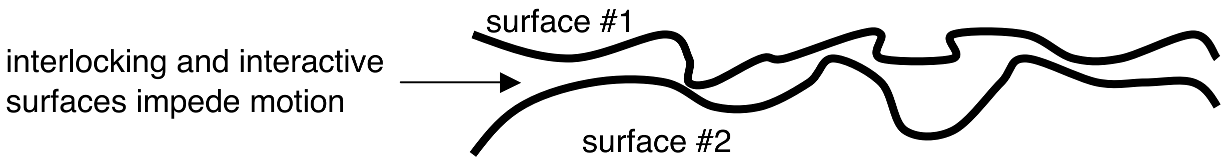
Demonstrations:
- blocks on planes, scales, to find coefficients of static and kinetic friction

Friction

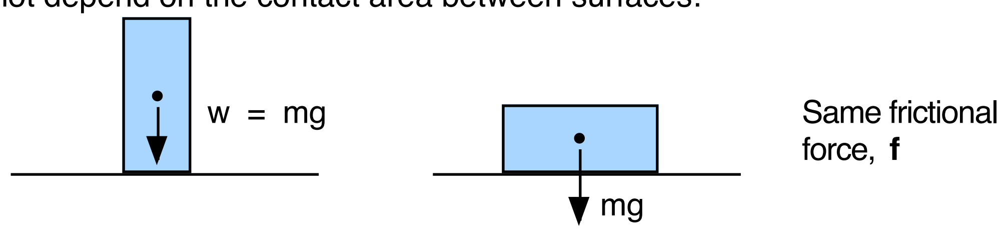
Where objects move in contact with other objects, we know that it may take a constant force to maintain a constant velocity. *E.g.*, motion of a book on a table



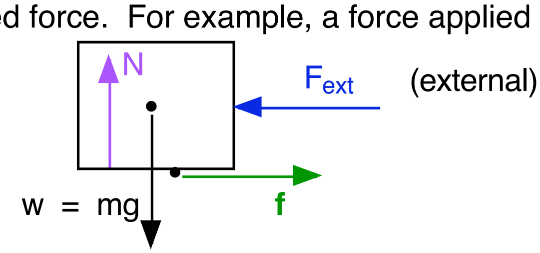
Friction arises on a microscopic scale because of the roughness and interactions of the surfaces.



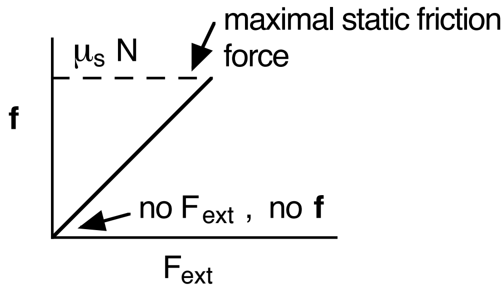
Various forces can give rise to friction, including fluid viscosity. Our focus here is friction from normal (perpendicular) forces. All other things being equal, this frictional force does not depend on the contact area between surfaces:



Here, friction depends only on the magnitude of the force N normal to the surface which reacts against the weight of the object, and the normal component of an applied force. Friction is present when an object is in contact with a medium or substrate. There may or may not be an applied force. For example, a force applied to a motionless block:



As can be seen in the demo, the force from static friction looks like:



f only opposes F_{ext}

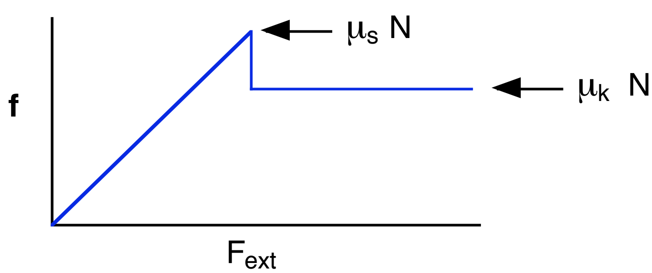
$\vec{f}$ is in opposite direction to $\vec{F}_{ext}$

The maximum force of static friction, f_{max}, is

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

where μ_s is the **coefficient of static friction**. The friction force cannot exceed the applied force, or else the object would move!

What happens when $F_{ext} > \mu_s N$? Then the object begins to move and the frictional force drops:



μ_k = coefficient of kinetic friction

In the class demo, the coefficients of friction are found for aluminum on wet wood:

$\mu_s \sim 0.6$

$\mu_k \sim 0.5$.

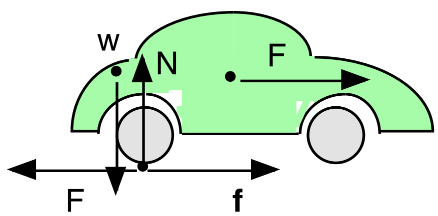
Some typical values for various material combinations:

smooth surfaces	μ_{static}	$\mu_{kinetic}$
steel on steel	0.7	0.6
glass on glass	0.9	0.4
teflon on steel	0.04	0.04
rubber on concrete (dry)	1.0	0.80
rubber on concrete (wet)	0.30	0.25
waxed ski on snow	0.1	0.05

Note the substantial coefficient of static friction for steel on steel, even though the surfaces are smooth. Railways couldn't work without it.

Example

The coefficient of static friction between a car's tires and a concrete road is 1.0. If 40 % of the car's weight is over the drive wheels, what is the maximum acceleration of the car?



$F \leq \mathbf{f}_{s\,,\,max}$ for no slipping

$= \mu N$

$= \mu\,(0.4 \cdot mg)$

But $F = ma$

$\Rightarrow ma = 0.4\, \mu\, mg$

or $a = 0.4\, \mu\, g$

$= 0.4 \cdot 1 \cdot 9.8$

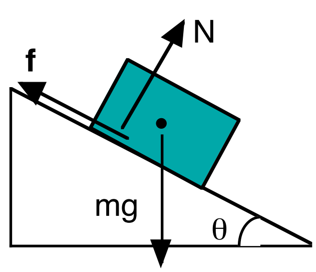
$= 3.9\ m/s^2$

The car is accelerated by the friction force *f*: no friction, no acceleration (*e.g.*, on ice)

How long would it take for this car to go from 0 to 100 km/hr = 28 m/s? From $v = at$, then $t = 28 / 3.9 = 7$ seconds. Theoretically, if all of the weight were over the drive wheels, then $a = 9.8$ m/s^2 and the time for 0 to 100 km/hr would decrease to 28 / 9.8 = 3 seconds.

Demonstration:

Find the maximum angle θ before the block slips. It's easiest to solve this question using a coordinate system which is perp / parallel to the plane, rather than perp / parallel to the horizontal.



$\mathbf{f} = \mu N$

$\mathbf{f} = mg \sin\theta$

$N = mg \cos\theta$

$\Rightarrow \mu\, mg \cos\theta = mg \sin\theta$

$\mu = \tan\theta$

$\therefore$ measure θ at slip point, find μ

In the demo, if $\mu = 0.6$, then $\theta = 31^o$.

We can use this as a method for measuring μ_S.