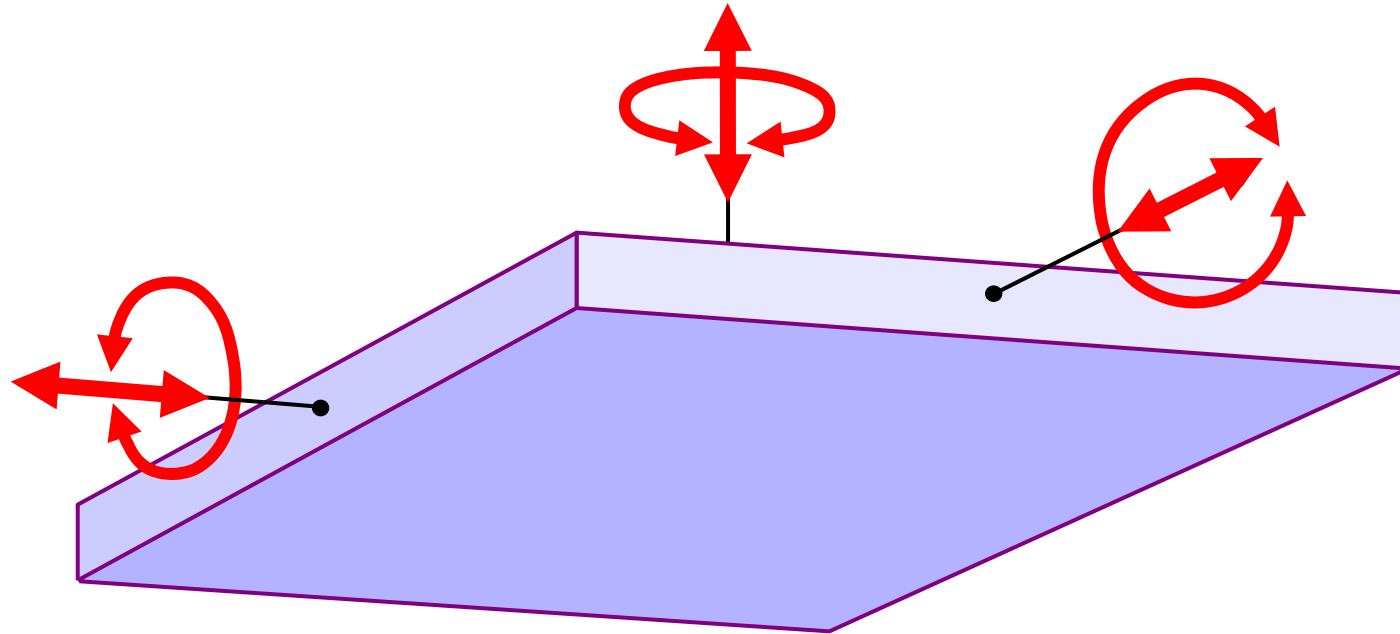


Bio-Inspired Design

Wb2436-05

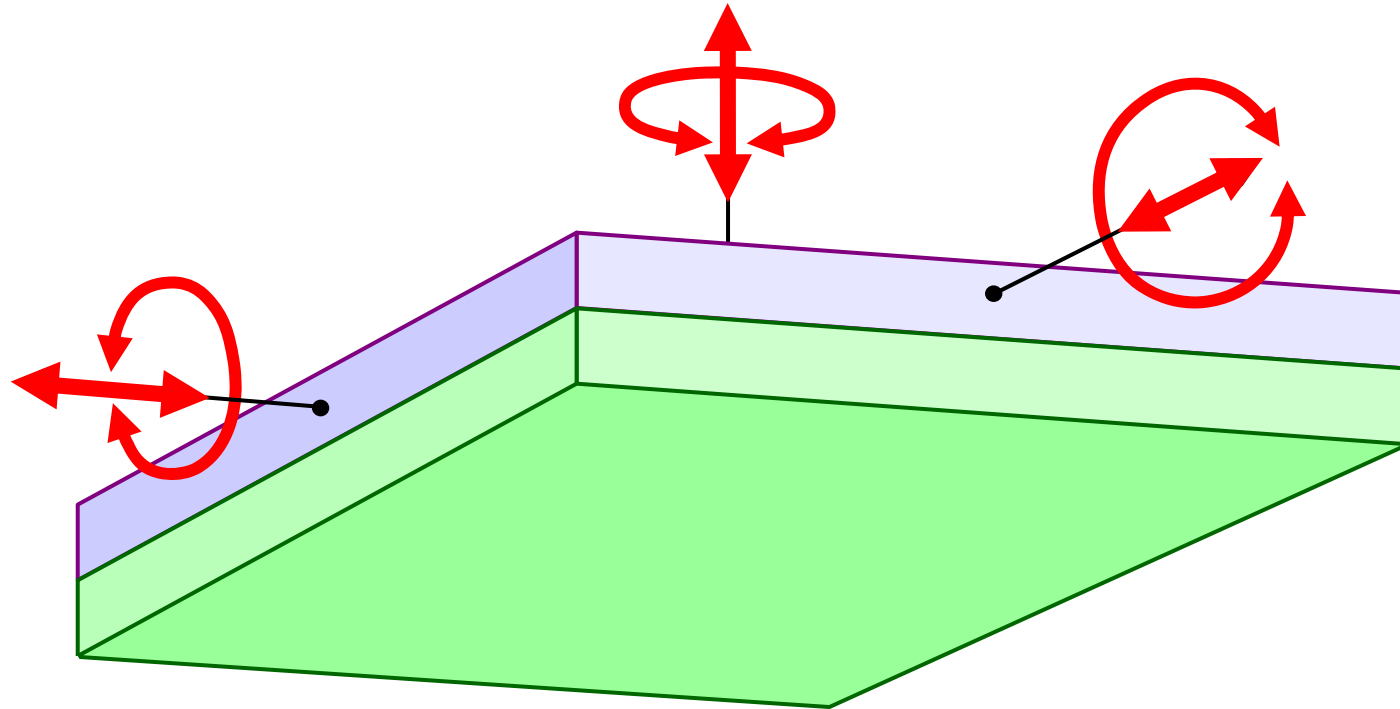
On Friction..

Surfaces in contact



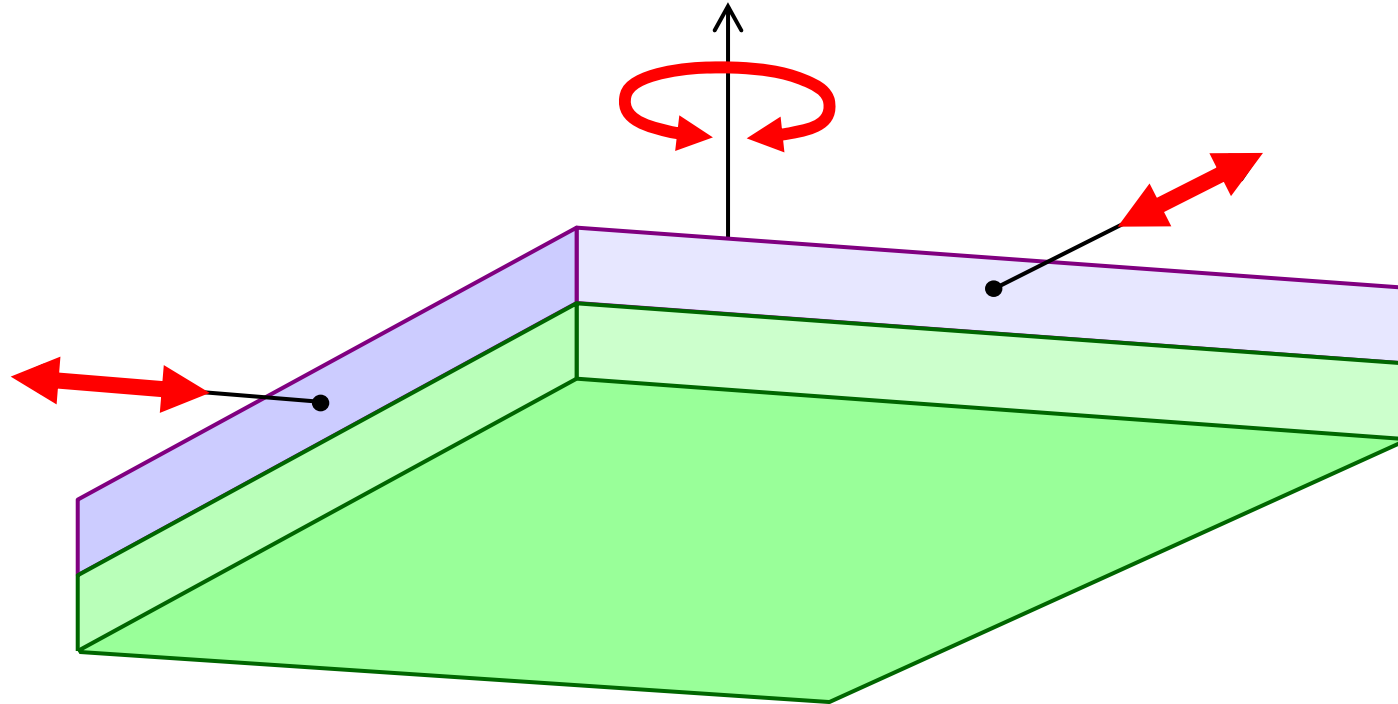
Rigid surface from below, free in space
6 degrees of freedom

Surfaces in contact



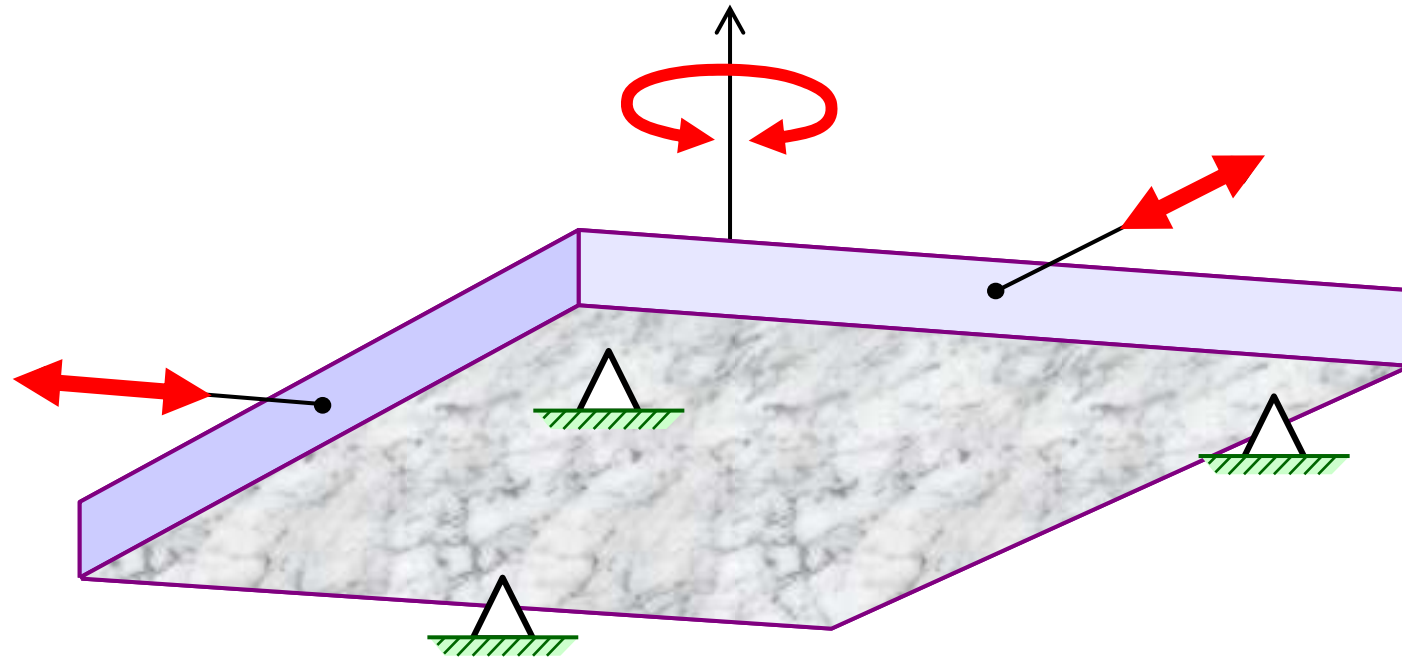
Surface supported by another, fixed surface
3 degrees of freedom remain

Surfaces in contact



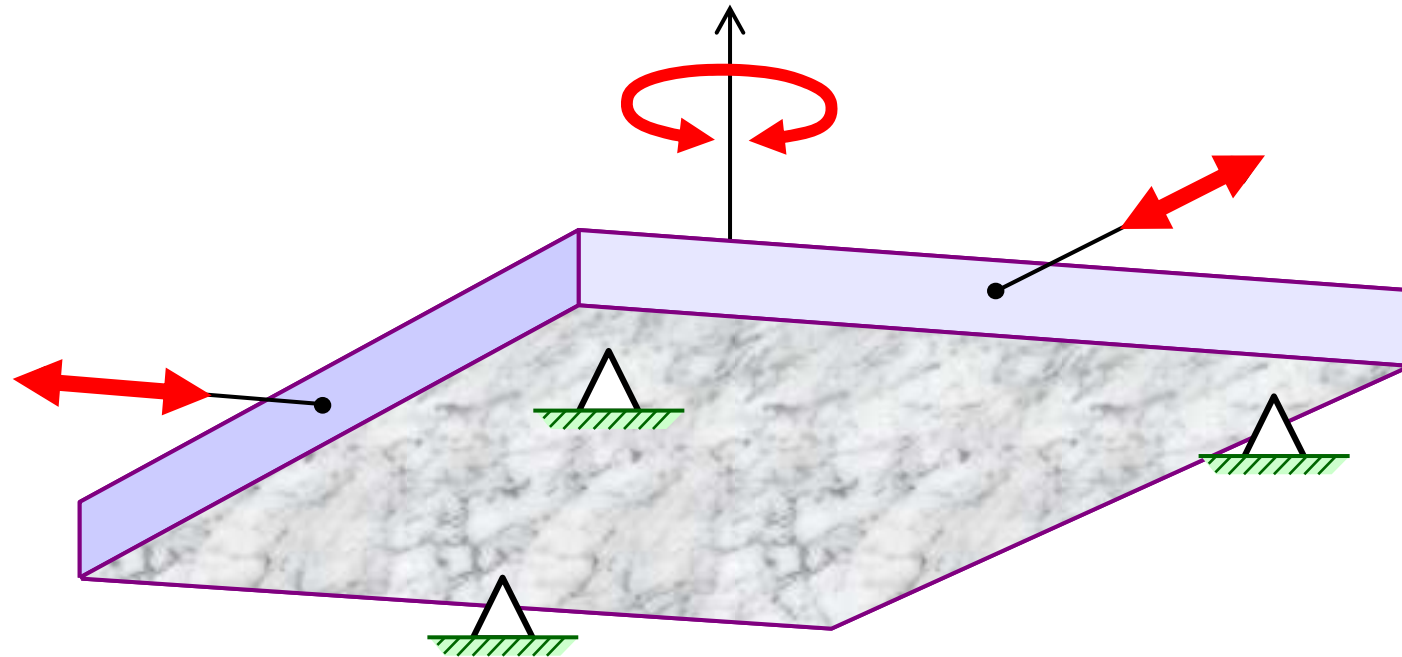
Identical situation:
Surface supported by 3 contact points
3 degrees of freedom remain

Surfaces in contact



On a microscopic level, a surface shows always irregularities, is never completely flat

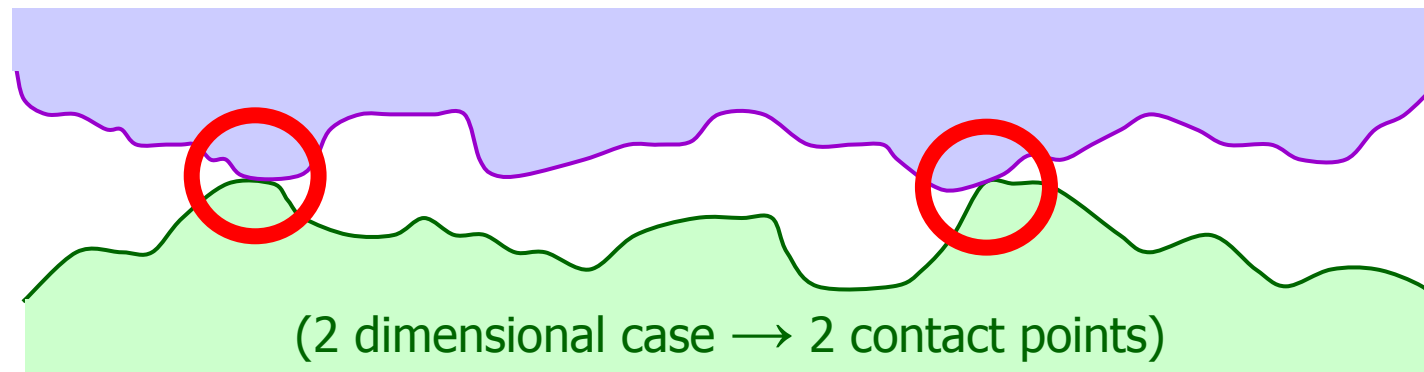
Surfaces in contact



Two rigid surfaces always touch each other
at 3 contact points

The friction occurs only at these contact points

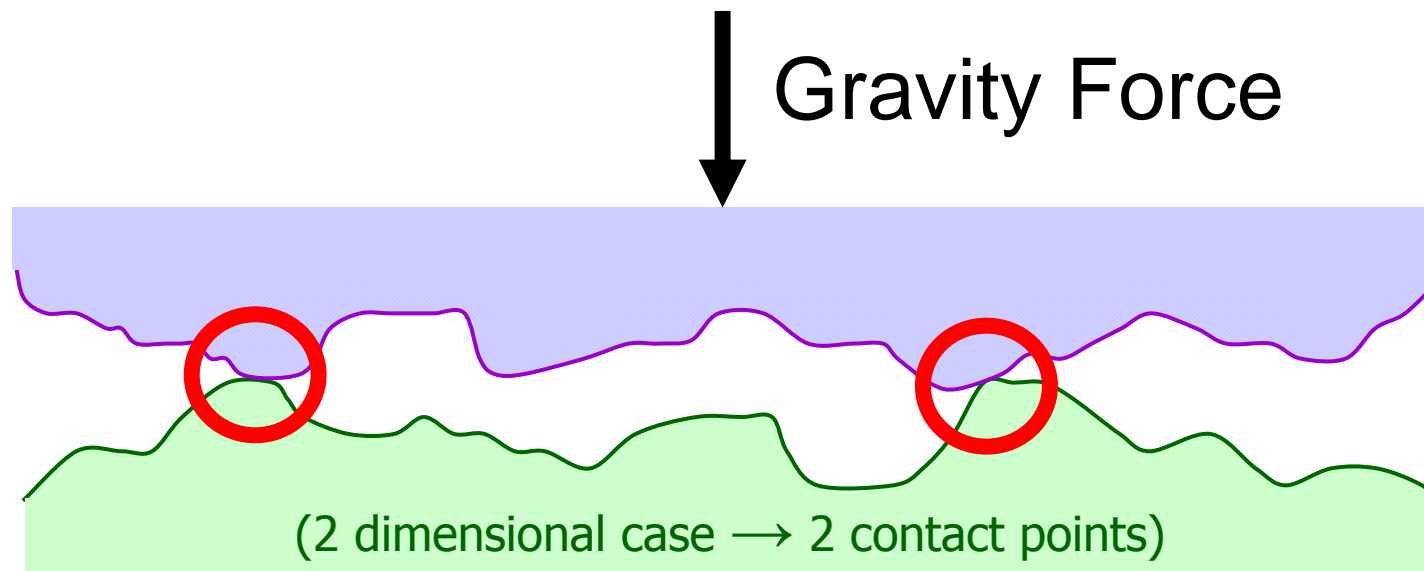
Surfaces in contact



Two rigid surfaces always touch each other
at 3 contact points

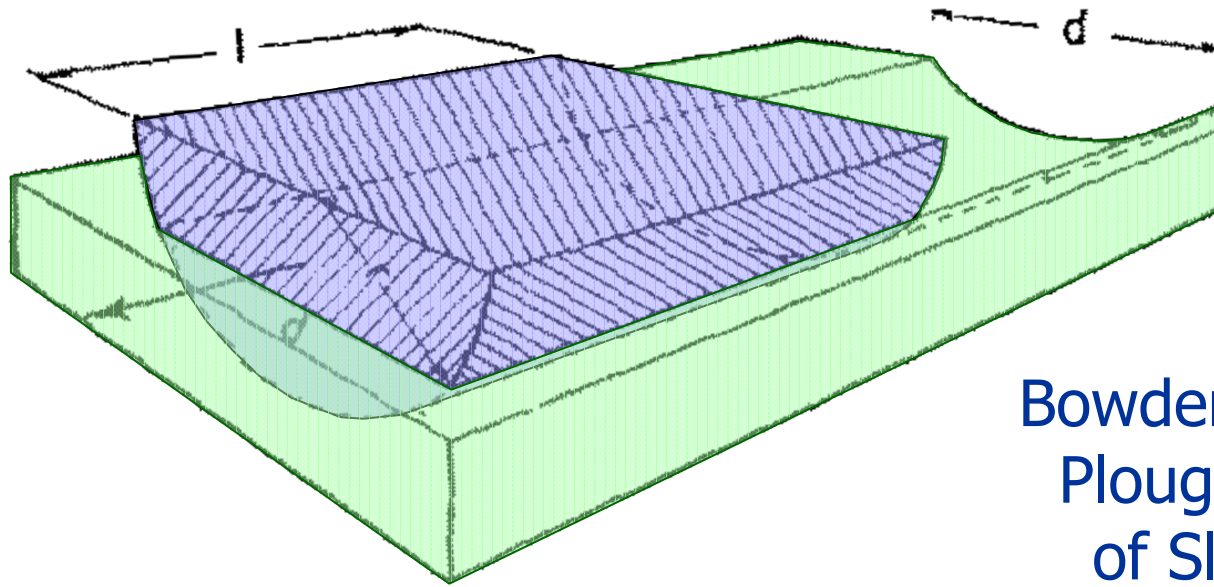
The friction occurs only at these contact points

Coulomb Friction Law



Coulomb friction law:
Dry friction stays equal
when surface area changes
Dry friction only depending on normal force

Coulomb Friction Law



Bowden & Tabor (1942)
Ploughing & Adhesion
of Sliding Materials

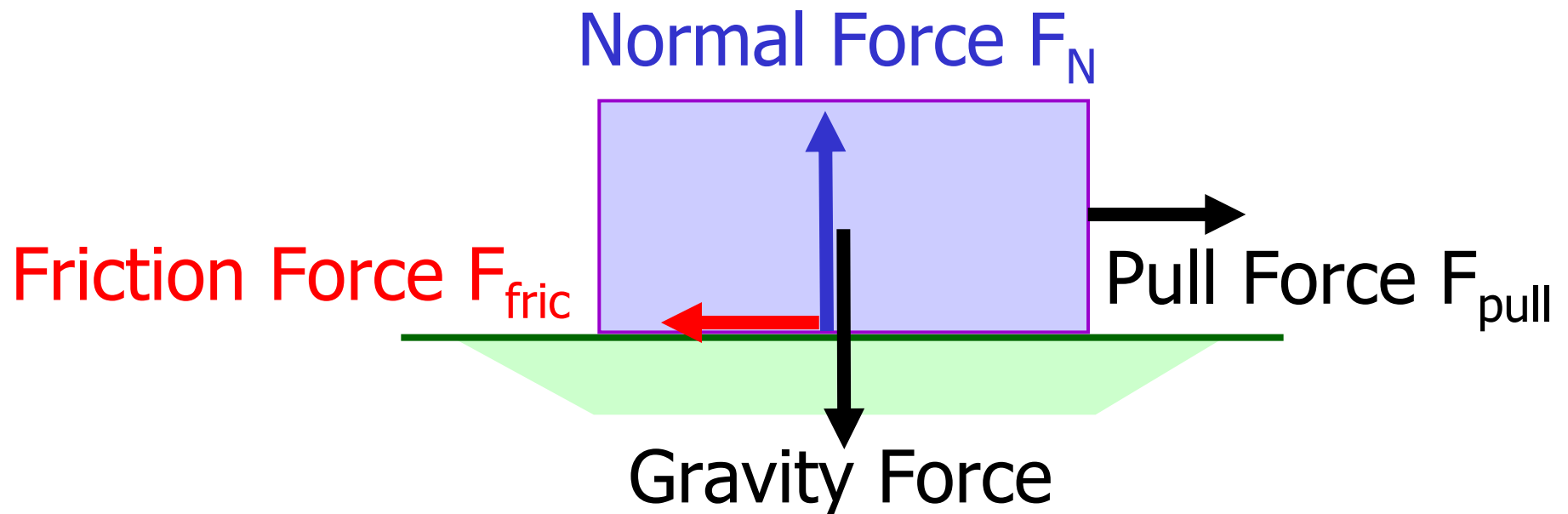
Coulomb friction law:
Dry friction stays equal
when surface area changes
Dry friction only depending on normal force

Coulomb Friction Law

$$F_{\text{fric,max}} = \mu \cdot F_N \quad (\mu = \text{friction coefficient})$$

$$|F_{\text{pull}}| < F_{\text{fric,max}} \rightarrow F_{\text{fric}} = F_{\text{pull}} \rightarrow \text{standstill}$$

$$|F_{\text{pull}}| \geq F_{\text{fric,max}} \rightarrow F_{\text{fric}} = \pm F_{\text{fric,max}} \rightarrow \text{slide}$$

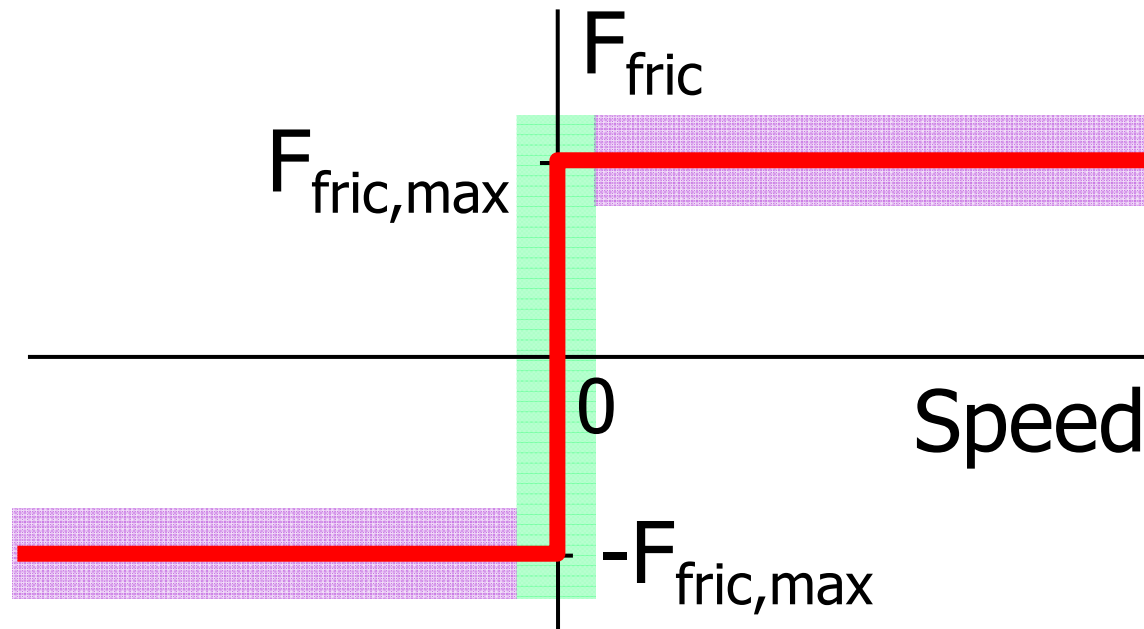


Coulomb Friction Law

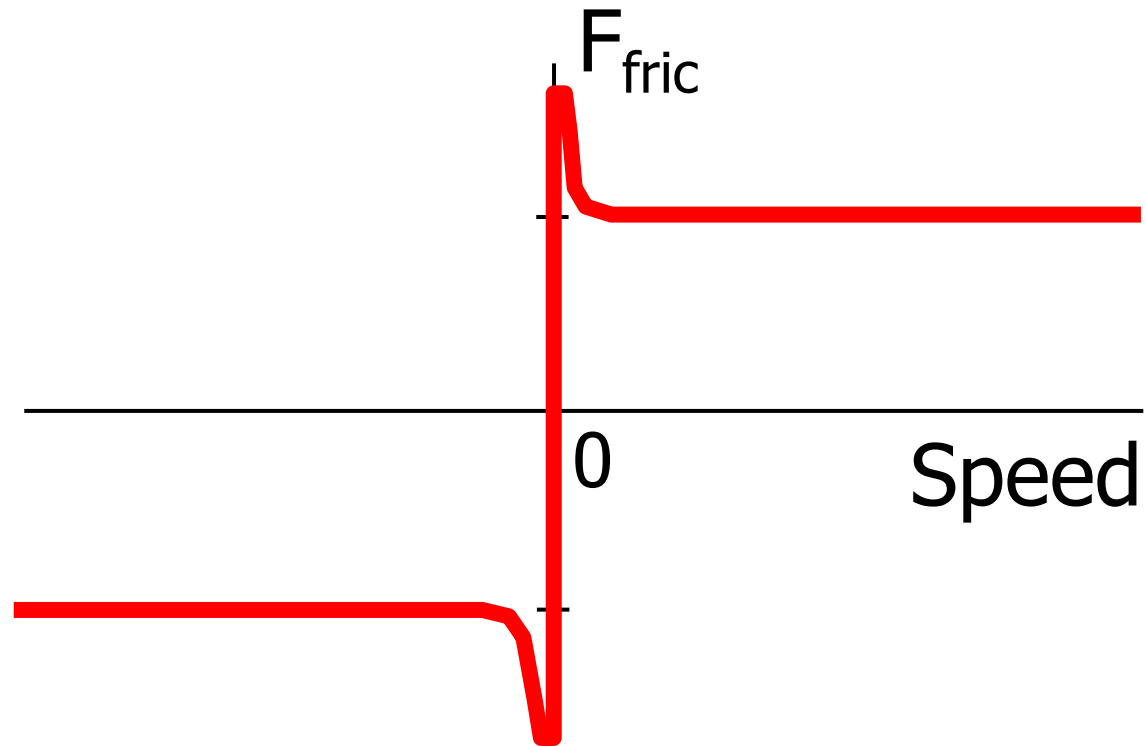
$$F_{\text{fric,max}} = \mu \cdot F_N \quad (\mu = \text{friction coefficient})$$

$$|F_{\text{pull}}| < F_{\text{fric,max}} \rightarrow F_{\text{fric}} = F_{\text{pull}} \rightarrow \text{standstill}$$

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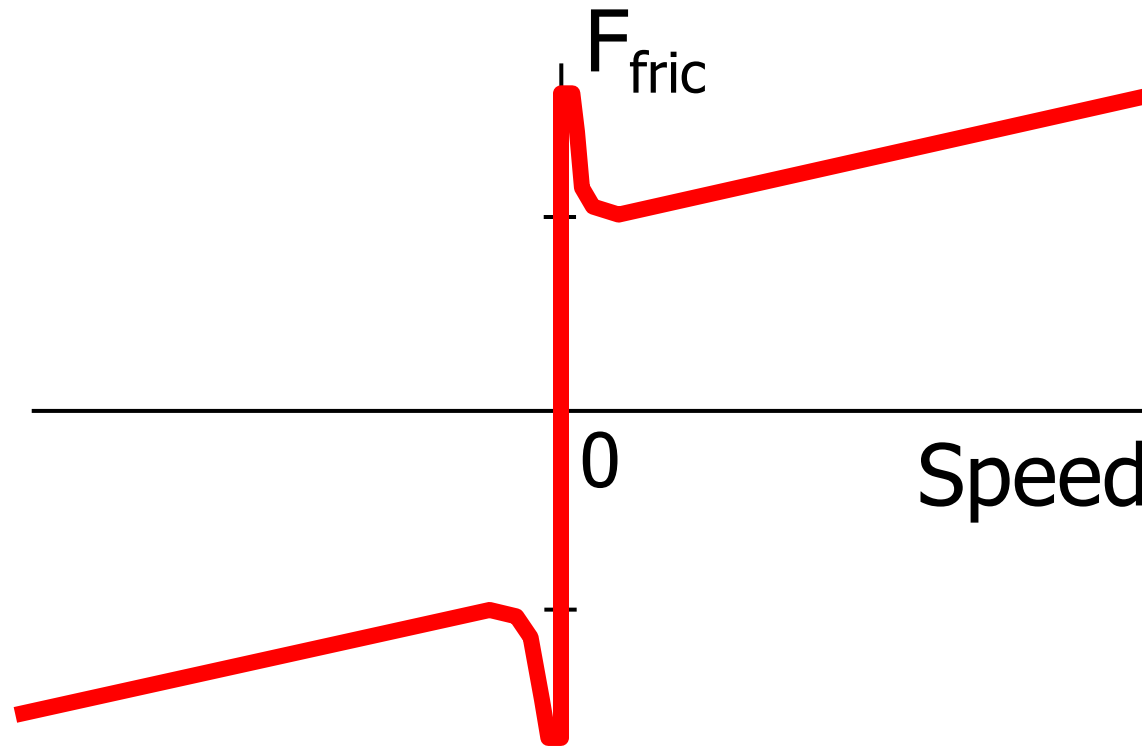


Coulomb Friction + Stiction



Higher friction at standstill because surfaces are sticking to each other

Coulomb Friction + Stiction + fluid friction



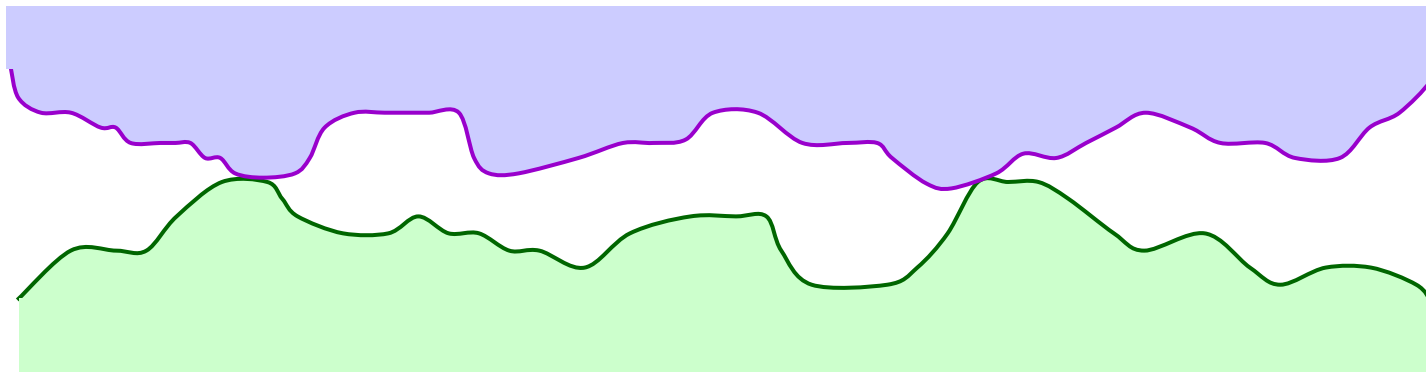
Friction increases when speed increases because *lubrication* between surfaces gives increasing resistance

From rigid to flexible

2 rigid objects:

3 contact points

Dry friction not depending on surface area

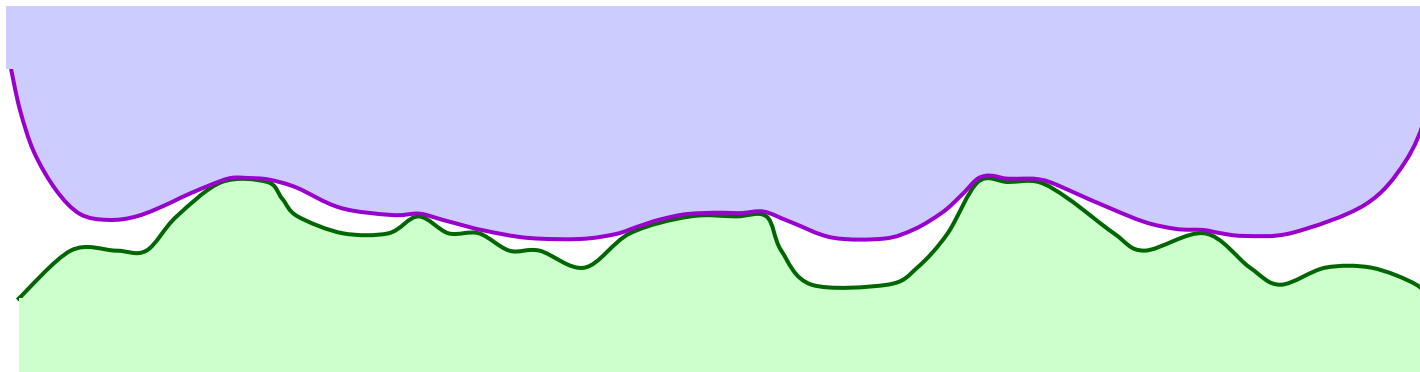


From rigid to flexible

1 (or 2) flexible objects:

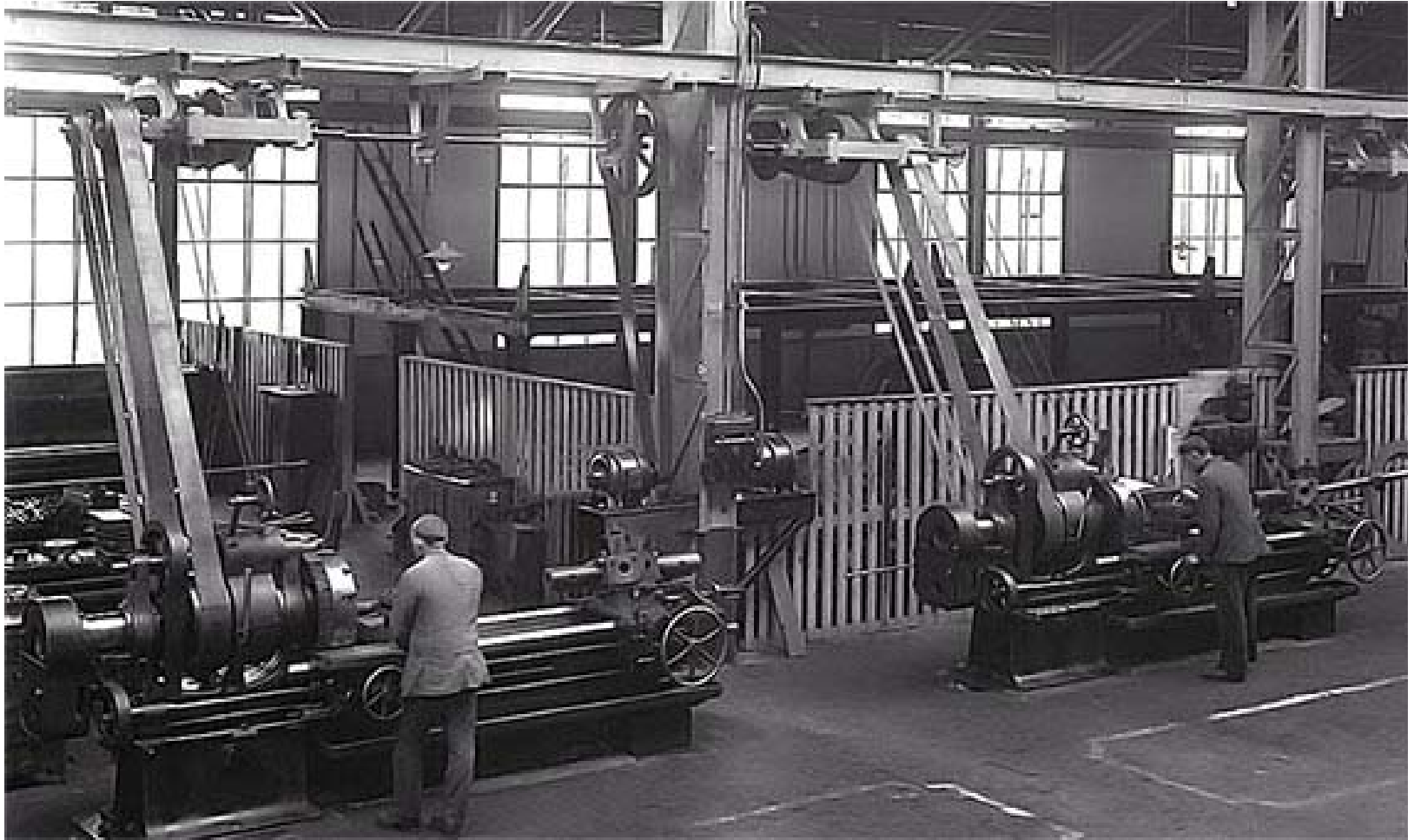
Larger number of contact points

Dry friction strongly depending on surface area



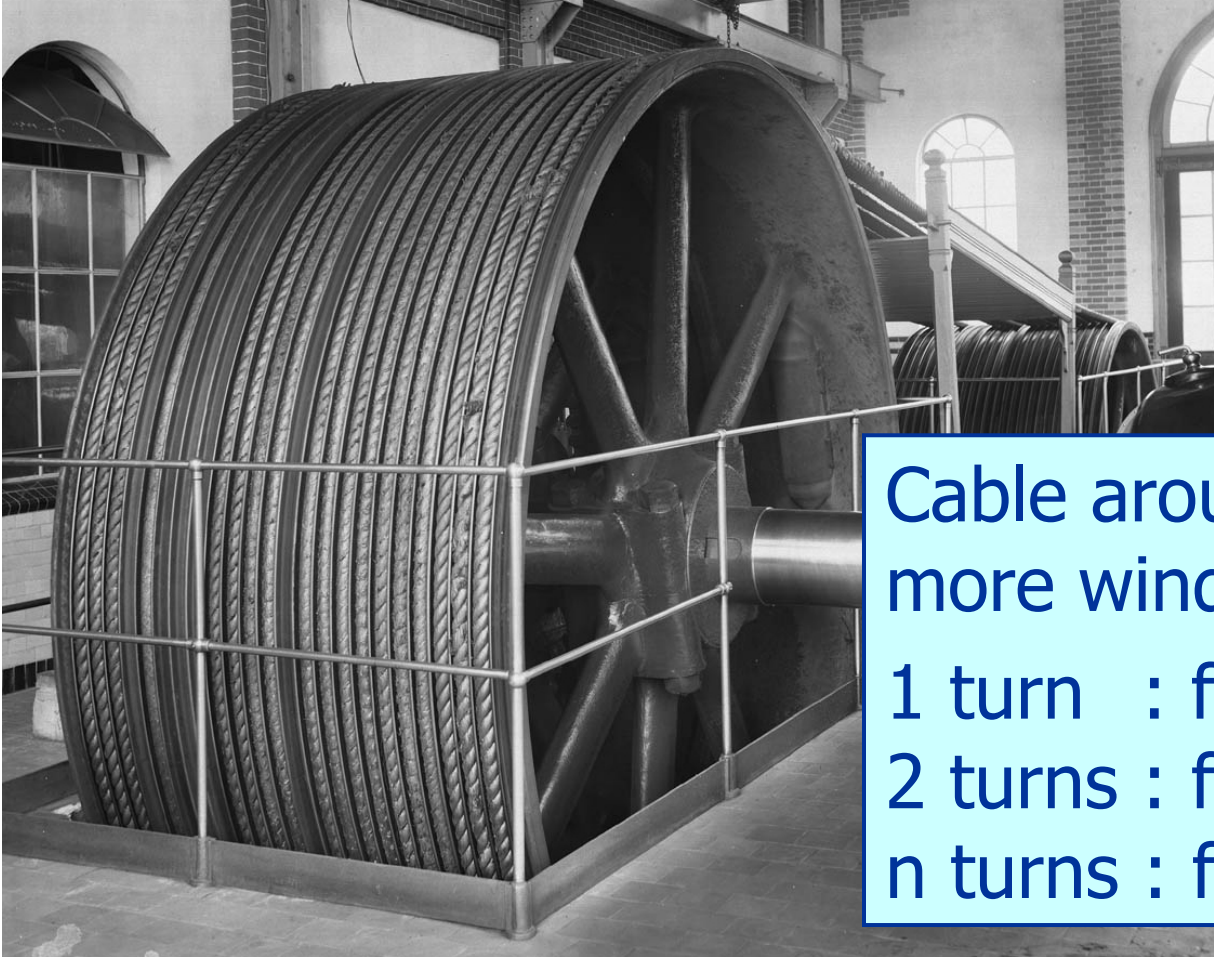
Few technical applications:

From rigid to flexible



Belt Drive (rigid disc, flexible belt)

From rigid to flexible



Cable around pulley:
more windings, more grip

1 turn : friction = F_{fric}

2 turns : friction = $2 F_{\text{fric}}$

n turns : friction = $n F_{\text{fric}}$

Cable Drive ("snaarschijf")

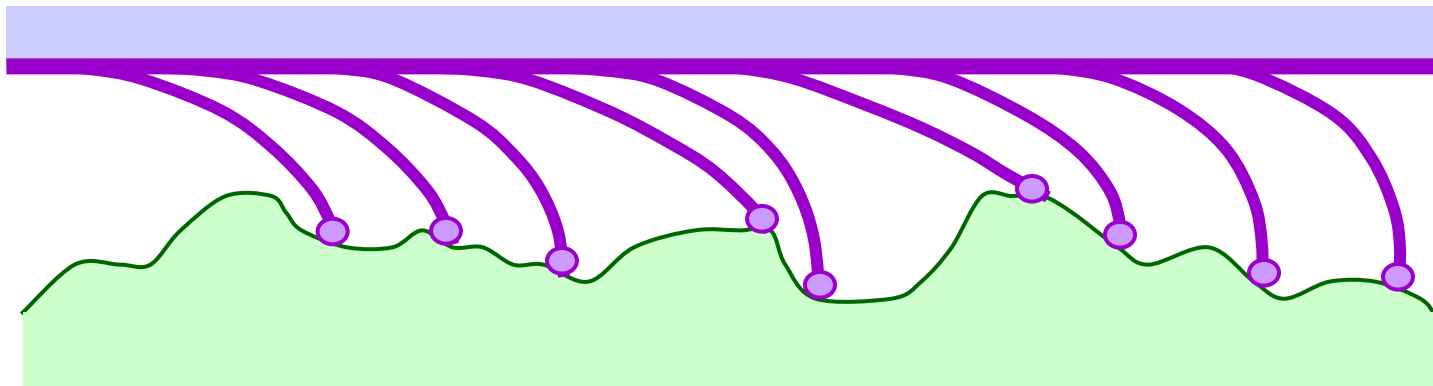
Coulomb is not valid
in our case!

http://en.wikipedia.org/wiki/Mark_I_tank



From rigid to flexible

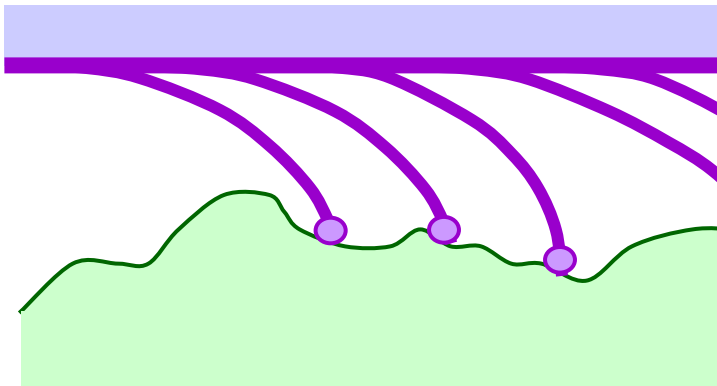
1 (or 2) flexible objects:
Maximizing number of contact points
by using leaf spring construction



This situation occurs hardly in technology
But very often in nature!

From rigid to flexible

1 (or 2) flex
Large number of
Dry friction strongly dep



Multiple leaf spring
"Setae" under feet of
"Gecko" lizard



From rigid to flexible

1 (or 2) flexible objects:

Large number of contact points

Dry friction strongly depending on surface area



Multiple leaf spring construction in wiper blade
(ruitenwischer)