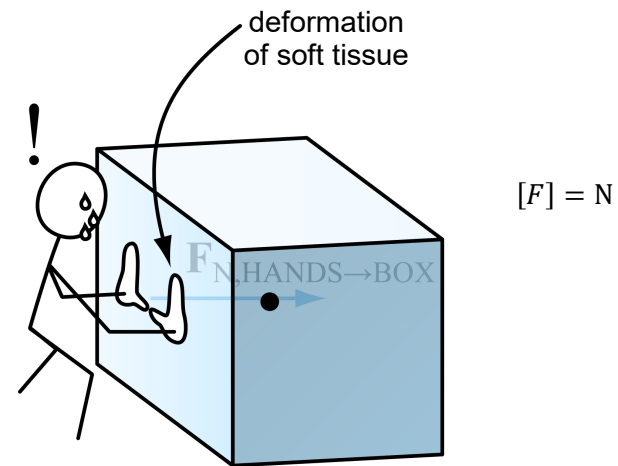


Forces

Forces occur through interactions between pairs of objects

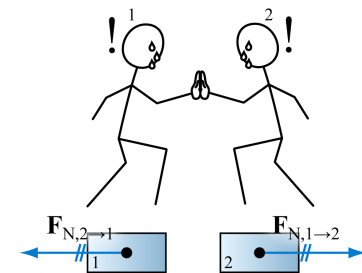
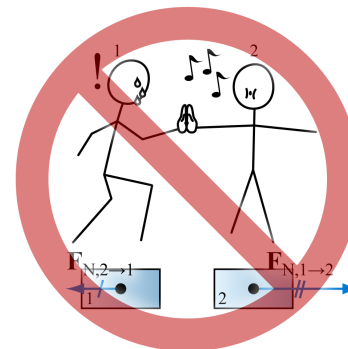
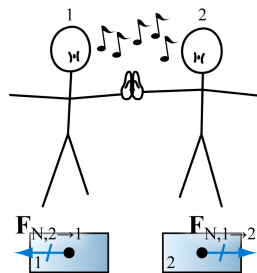
A **force** is a directed push or a directed pull exerted on an object by *another* object.

The preceding statement merely associates one term, force, that is yet to be defined with alternative terms, “push” and “pull,” that are likewise not defined. **Force is a postulated (vector) quantity.**



Newton III

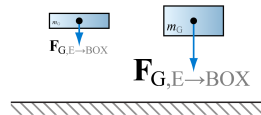
There exists $\vec{F}_{_,2 \rightarrow 1}$
 \Rightarrow
there also exists
 $\vec{F}_{_,1 \rightarrow 2} = -\vec{F}_{_,2 \rightarrow 1}$



Forces

Examples of common forces

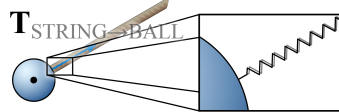
Weight ((nearly) on Earth)
toward Earth



$$F_G = m_G g$$

$$[m_G] = \text{kg} \quad g = 9.8 \frac{\text{m}}{\text{s}^2}$$

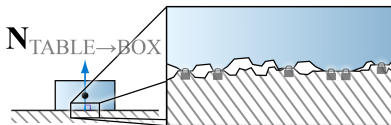
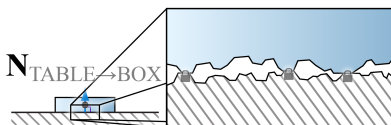
Tension
back into string



T

No memorized formula

Normal
 \perp push



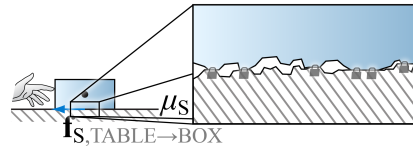
N

No memorized formula

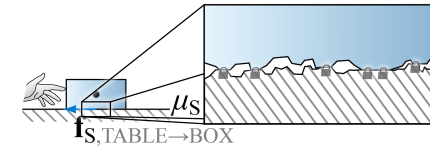
Static friction

\parallel to interface, opposes interfacial slippage

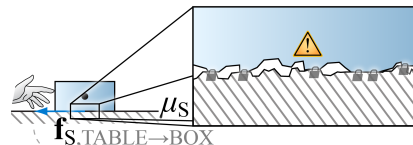
Case I. Less than maximum that can be sustained for a given normal force



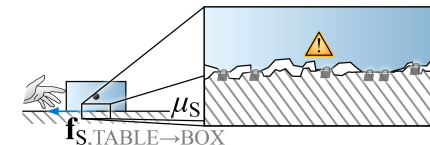
$$f_s < \mu_s N$$



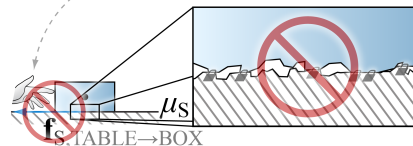
Case II. Maximum that can be sustained for a given normal force



$$f_s = \mu_s N$$



Case III. Beyond maximum that can be sustained for a given normal force

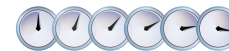
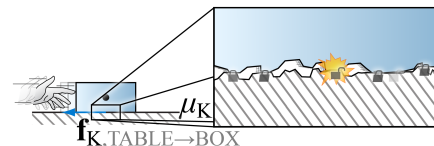


"According to $f_s \leq \mu_s N$, f_s cannot exceed $\mu_s N$. If ... were stuck, ... f_s would need to equal ..., exceeding $\mu_s N$. So, instead of being stuck, ... must have slipped."

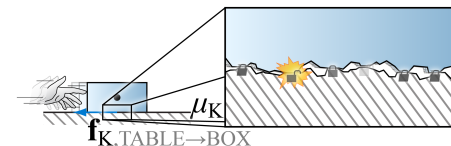
$$f_s > \mu_s N$$

Kinetic friction

\parallel to interface, opposes interfacial slippage



$$f_k = \mu_k N$$



Forces

How are force and acceleration related for material objects?

	$\vec{a} = \vec{0}$ constant \vec{v}	$\vec{a} \neq \vec{0}$ changing \vec{v}
$\Sigma \vec{F} = \vec{0}$	<p>Diagrams illustrating objects with zero net force ($\Sigma \vec{F} = \vec{0}$) and constant velocity (\vec{v}). The velocity is either zero ($v=0$) or constant ($\Delta v=0$). Examples include a block at rest, a block moving at constant velocity, and a block with balanced forces.</p>	<p>Diagrams illustrating objects with zero net force ($\Sigma \vec{F} = \vec{0}$) but changing velocity ($\Delta v \neq 0$). A large red 'X' is placed over the diagrams, indicating that this situation is impossible according to Newton's laws.</p>
$\Sigma \vec{F} \neq \vec{0}$	<p>Diagrams illustrating objects with non-zero net force ($\Sigma \vec{F} \neq \vec{0}$) but constant velocity ($\Delta v=0$). A large red 'X' is placed over the diagrams, indicating that this situation is impossible according to Newton's laws.</p>	<p>Diagrams illustrating objects with non-zero net force ($\Sigma \vec{F} \neq \vec{0}$) and changing velocity ($\Delta v \neq 0$). Examples include a block accelerating from rest, a block accelerating at constant velocity, and a block with unbalanced forces.</p>

Newton I for material objects

$$\Sigma \vec{F} = \vec{0} \Leftrightarrow \begin{cases} \vec{a} = \vec{0} \\ \text{constant } \vec{v} \end{cases}$$

inertial frame – frame of reference in which Newton's first law holds

Newton II for material objects

$$\vec{a} = \frac{\Sigma \vec{F}}{m_I}$$

An object's **inertial** mass is the amount of that object's tendency to not accelerate.

$$[m_I] = \text{kg}$$

An **inertial** mass of 1 kg requires precisely 1 N of net force in order to have an acceleration of $1 \frac{\text{m}}{\text{s}^2}$.