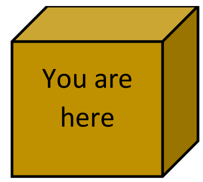
Lesson 2.1: Newton's Laws & Force Vectors

Unit 2: Dynamics and Equilibrium

Mr. Harris has been marathoning Breaking Bad and Better Call Saul lately. As such, he's watched a lot of people get transported across the US-Mexico boarder (illegally) hidden in trucks. Although he doesn't condone such illegal behaviour, he just can't help thinking about Newton's 1st Law while he watches.

Imagine you get into a crate, soon to be loaded onto a truck for transport. Currently, the crate is at rest.

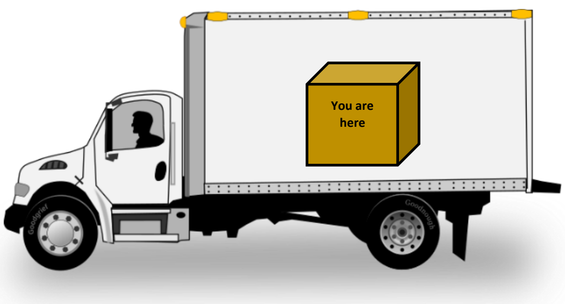
What does this mean? $\vec{a}=0$ → $\vec{v}=0$



Does this mean that there are no forces acting on the crate?

No – Gravity is pulling down
– the normal force of the ground is pushing up.

Free-Body Diagram ⇒ $\vec{F}_N$, m, $\vec{F}_g$



Now, some unruly types pick up the crate (with you in it) and load you onto a truck. You are now traveling at a constant highway velocity of 100 km/h.

This means the acceleration you feel = Zero.

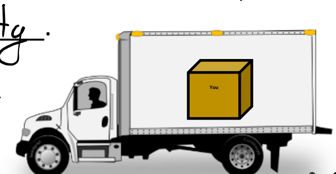
Therefore, the net force acting on you = zero.

Newton's First Law: If the net force acting on a system is zero, the velocity of the system will remain constant.

Also called: Inertia $\vec{F}_{NET} = \sum \vec{F} = 0 \Rightarrow \vec{a} = 0$

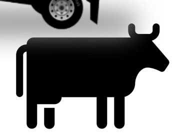
Inertial Reference frame:

Now you're whizzing by some farmland. In the reference frame of the ground at the side of the road, the cow is at rest and you and your crate are moving at a constant velocity.

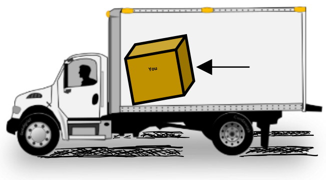


In the reference frame of the truck, the cow is moving at a constant velocity and the you in your crate are at rest.

Therefore, moving at a constant velocity or being at rest are relative to the…



reference frame you choose!



Back to the analogy: You've been driving down the highway at a constant velocity for a while now (not a lot of turns in the desert). You're a little board, when all of the sudden the driver hits the breaks to avoid a collision. The unsecured crate you are in (rude…) flies forward crashing into the front of the cargo box. The obstacle goes away and the driver hits the gas—hard (he has an agenda). You and the crate now go flying towards the back of the cargo box.

You—a moment ago at rest—suddenly accelerate forwards and backwards without a net force acting on you! Did you just violate Newton's First Law of Inertia?

No – the truck accelerated and became a non-inertial reference frame.

* You are continuing to move at a constant velocity while your reference frame moves.

Newton's Second Law: $\vec{F} = m\vec{a}$

Now you've reached Albuquerque in your crate and some cartel unload you. To do this, they need to pick you up, which means there is an applied force lifts you.

A system accelerates in the same direction as the net force acting on it.

$$\sum \vec{F} = \boxed{\vec{F}_{net} = m\vec{a}} \Rightarrow \vec{a} = \frac{\sum \vec{F}}{m}$$

* the magnitude of $\vec{a}$ is directly proportional to $\vec{F}_{net}$ on the system and inversely proportional to mass.

$\vec{F}_g = mg$ where $\vec{F}_g$ = force of gravity

$g = 9.81\,m/s^2$ (Earth

$= 9.81\,N/kg$

F is measured in Newtons (N)

as $\vec{F} = m\vec{a}$

$m \to kg$, $\vec{a} \to m/s^2$

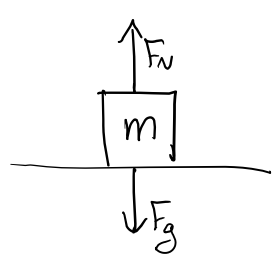
$$\boxed{N = \frac{kg \cdot m}{s^2}}$$

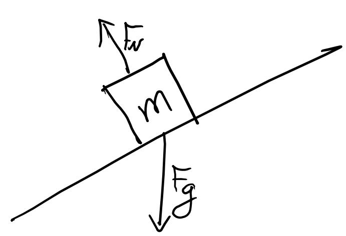
Newton's Third Law: For every force in nature there is an equal and opposite reaction (F).

$$\vec{F}_{A\ on\ B} = -\vec{F}_{B\ on\ A}$$

* F_N = normal force

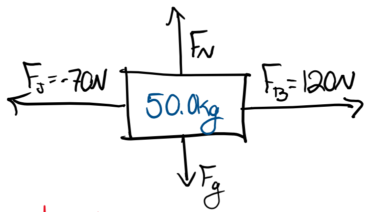
↳ ⊥ to the surface





Example 1: Jordan pushes a 50.0 Kg box with 70 N of force. Benji pushes in the opposite direction with 120 N. Find the acceleration of the box (ignore friction). Draw a FBD.

FBD:



$\vec{F}_{net} = m\vec{a} \Rightarrow \vec{a} = \frac{\vec{F}_{net}}{m}$

$\vec{F}_B + \vec{F}_J = m\vec{a}$

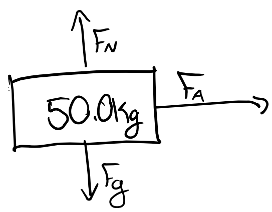
$120 - 70 = 50\vec{a}$

$50 = 50\vec{a}$

$\vec{a} = 1.0 m/s^2$

* Let the direction of motion be (+).

Example 2: Kate pushes the 50.0 Kg box from rest to 10 m/s in 2.0s. How much force is she applying? (Ignore friction).



$\vec{V}_0 = 0 m/s$

$\vec{V} = 10 m/s$

$t = 2.0s$

$a = ?$

$\vec{V} = \vec{V}_0 + \vec{a}t$

$\vec{a} = \frac{V - V_0}{t}$

$= \frac{10 - 0}{2}$

$\vec{a} = 5.0 m/s^2$

$\vec{F}_A = m\vec{a}$

$\vec{F}_A = 50(5)$

$\boxed{\vec{F}_A = 250 N}$

Assignment: WS 2.1 – Newton's Laws and Force Vectors Practice