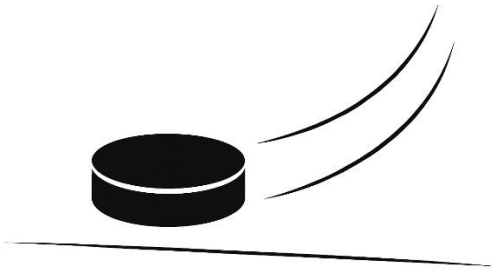
Force and Inertia

Our last class concluded our exploration of **kinematics**. Kinematics is a branch of physics that tells us how to describe motion geometrically: in space and time. We have learned about distance, displacement, speed, velocity, acceleration and relative motion. But we did not ask the question: what caused the motion?

Today we start considering **dynamics**. Dynamics is another branch of physics and, as opposed to kinematics, it is concerned with reasons causing motion. These reasons are interactions with other objects.

Any physical body being in motion tends to stay in motion (if the body is at rest it tends to stay at rest). This sentence is called "**the law of inertia**". It means the following: ***velocity* of an object does not change unless the object will interact with other objects**. Nothing starts moving by itself and stops by itself. We need another object to change velocity, or, in other words, to create acceleration. The interaction which causes acceleration of an object is called *force*. Force is a vector: it has both magnitude and direction. Examples of the force are gravity force, electric and magnetic forces, elastic force, friction force.

It makes perfect sense that if a body at rest does not interact with anything**,** it will stay at rest. It takes a little bit more effort to understand that the same principle applies to motion with constant velocity. Imagine a puck on very smooth ice. After being hit, it will go at almost constant velocity (almost because there is still a tiny leftover friction). If the ice is even smoother, the velocity will change even less. We conclude that if there was no friction at all, the velocity would just stay constant indefinitely.



We have learned that **force can be determined as interaction which makes the interacting object accelerate**. Force and acceleration are connected by a simple formula:

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

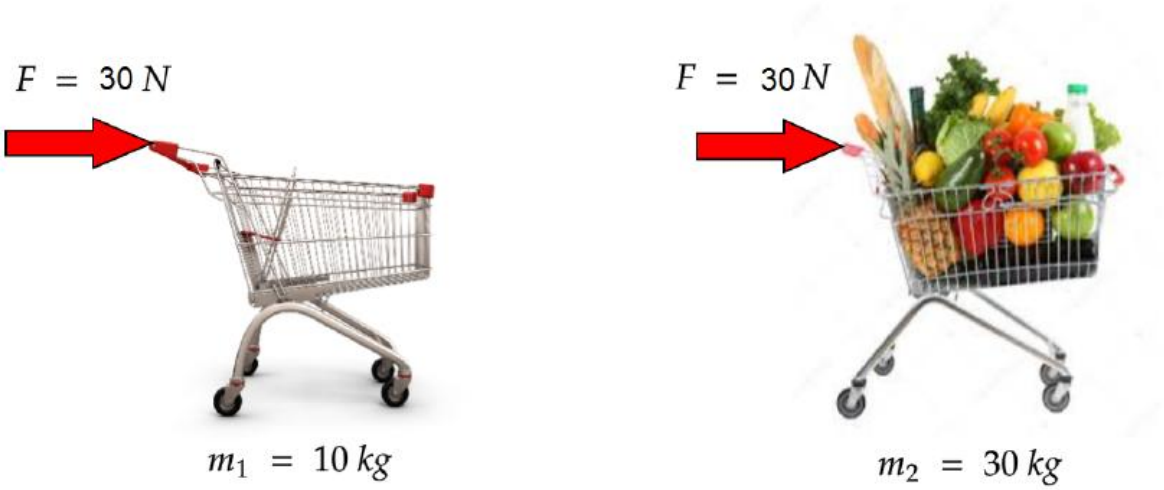
Here *F* is a force applied to an object, *m* is the mass of the object and *a* is the acceleration of the object. **Force is measured in newtons** (N). 1N is the force required to provide an acceleration of 1m/s^2 to an object with a mass of 1kg. The unit of force is named after Sir Isaac Newton (1643-1727) – one of the brightest genii in human history.

Let us consider the following imaginary experiment: if you push with the same way an empty shopping cart and a heavily loaded shopping cart. A physical quantity which expresses the property of an object to resist acceleration is called **mass**. The mass is measured in kilograms (kg) and grams (g). 1 kg = 1000 g

Example: Suppose an empty shopping cart has a mass $m_1 = 10$ kg. After you load it with groceries you need for the next week total mass of the cart becomes $m_2 = 30$ kg. If you push the cart with the same effort (same force), say 30 N, the heavier cart will have a smaller acceleration than the lighter cart. How much smaller? Denote accelerations of the carts by a_1 and a_2 respectively. Let us use Newton's second law:

$$F = m_1 a_1 \Rightarrow a_1 = \frac{F}{m_1} = \frac{30\ \text{N}}{10\ \text{kg}} = 3\ \frac{\text{N}}{\text{kg}} = 3\ \frac{\text{m}}{\text{s}^2}$$

$$F = m_2 a_2 \Rightarrow a_2 = \frac{F}{m_2} = \frac{30\ \text{N}}{30\ \text{kg}} = 1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$$



$m_1 = 10\ kg$ $m_2 = 30\ kg$

Homework:

1) Why do we need seatbelts in a car?

2) If an elephant were chasing you, it's enormous mass would be the most threatening. But if you zigzagged, its mass would be your advantage. Why?

4)Two pirates have found a treasure chest. Both want it for themselves, so they start pulling it in the opposite directions with forces 400 N and 250 N. In what direction will the chest move? What is the mass of the chest with the treasures if acceleration of the chest is 5 m/s^2?

