

## Homework 5

### Inertia and Newton's laws

We have learned that 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.

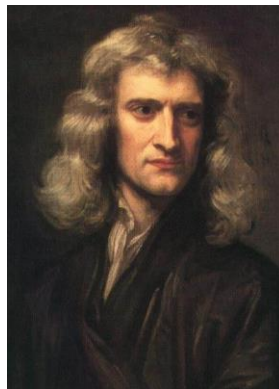
Let us consider the following imaginary experiment: if you push with the same way an empty shopping cart and a heavily loaded shopping cart. The first one will move faster (check it). A physical quantity which expresses the property of an object to resist acceleration is called *mass*. The mass is measured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

It is very important not to mix mass and weight. The weight (in common, “everyday” meaning of this word) depends on how strong an object presses to the surface supporting the object. Weight of the same object is different on different planets. The mass express the fundamental property of an object to resist acceleration. Any object with nonzero mass will resist acceleration even in deep space.

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  $1\text{m/s}^2$  to an object with a mass of 1kg. The unit of force is named after Sir Isaac Newton (1643-1727)– one of the brightest geni in human history.



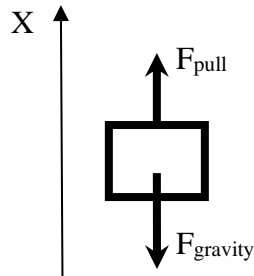
Sir Isaac Newton ([www.wikipedia.org](http://www.wikipedia.org))

Arrows over “ $F$ ” and “ $a$ ” remind us that both force and acceleration are vector quantities, which means that they have both magnitude and direction. You can see from the formula that the more mass of the object the more force is needed to provide same acceleration. A heavy object is difficult to accelerate.

However, if an object is not accelerating it does not mean that no forces applied to the object. In most of the cases it just means that forces applied to the object compensate each other. In other words, the sum of all forces applied to the object is zero. So the **force  $F$  in the formula above is the sum of all the forces applied to the object**. We will call this sum as *total net force*. How we can sum forces?

*Example:* You pull up a 10kg load with a force of 150N. Is this force enough to lift the load? What is acceleration of the load?

*Solution:* First, let us make a picture



Let us choose “positive” direction as “down to up”. So the “pulling” force is positive because it looks up and the gravity force is negative because it looks down:

$$F_{pull} - F_{gravity} = ma$$

or

$$F_{pull} - mg = ma$$

We do not know yet what the acceleration (magnitude and sign) is. Let us calculate it:

$$150N - 10kg \cdot 9.8 \frac{m}{s^2} = 10kg \cdot a$$

$$a = \left( 150N - 10kg \cdot 9.8 \frac{m}{s^2} \right) \div 10kg = 5.2 \frac{m}{s^2}$$

The acceleration is positive. It means that it is directed up, along our "positive" axis. It also means that the applied force is enough to lift the load.

Problems (very simple today):

1. Why do we need seatbelts in a car?
2. Many automobile passengers have suffered neck injuries when struck by cars from behind. How does the law of inertia apply here? How do headrests help to guard against this type of injury?
3. 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 closed containers look the same, but one is packed with lead and the other with few feathers. How could you determine which had more mass if you and the containers are orbiting in a weightless condition in outer space?
5. You pull up a 2kg brick with a force of 30N. At a first moment the brick was at rest. Find the displacement of the brick in 3 seconds.

(Questions 3 and 4 are taken from "Conceptual Physics" by Paul G. Hewitt. I would highly recommend this book for its simple and clear explanation of basic physical laws).