

Homework 3

Inertia and the first Newton's law.

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 a simple form of the first Newton's law, also called as 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.

Second Newton's law

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 histor

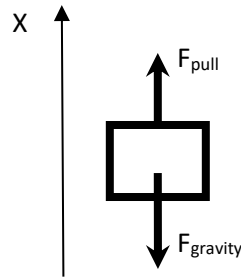
Sir Isaac Newton (www.wikipedia.org)

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.

Third Newton's law

During last class we have discussed another interesting property of our world. It can be simply formulated as follows: every time one object applies force to another object, this "another" object applies force to the first object. The forces have equal magnitudes and opposite directions.

For example, imagine that you try pushing a heavy 20 kg stone while both you and the stone are on ice. You push the stone with a force of 80N. What happens next?

Both you and the stone will slide in opposite directions. What is acceleration of the stone while you are pushing it? It is simple to calculate it:

$$a_{stone} = \frac{F}{m} = \frac{80N}{20kg} = 4 \frac{m}{s^2}$$

What about your acceleration? Assume that your mass is 40kg. But what about force which made you slide? Its magnitude is equal to the magnitude of the force you applied to the stone, but it is directed oppositely. It looks like the stone pushed you with the same force of 80N:

$$a_{you} = \frac{F}{m} = \frac{80N}{40kg} = 2 \frac{m}{s^2}$$

So your acceleration is be smaller, because your mass is higher and the magnitude of the forces applied to you and the stone are same.

This "picture" is universal. Whenever you apply force to something this something applies force of equal magnitude and opposite direction to you. *These forces do not compensate each other because they are applied to different objects.* We know that we can add and subtract only the forces applied to the same object.

Problems:

1. You pull up a 2kg brick with a force of 30N. At the first moment the brick was at rest. Find the displacement of the brick in 3 seconds.

2. You push a loaded shopping cart with a force 100N. The mass of the cart is 40kg. Find the velocity of the cart in 2 seconds if the cart was initially at rest.

3. A 40 kg boy is inside the elevator. Elevator goes up with the acceleration of 2m/s^2 . Find the force which is applied to the boy by the elevator.

4. A slightly compressed very light coiled spring is released and pushes two carts in opposite directions (see figure below). The carts are different. After the spring is fully stretched the left cart has a velocity of 4cm/s and the right cart has a velocity of 60cm/s . Which cart has higher mass and how many times this mass is higher than the mass of the other cart?



5. Assume that the mass of the right cart is 50g. What is the mass of the other cart? (Use data of the problem 1)