Physics 1 Homework 1

Distance and displacement.

We started studying Physics. I believe that there are three major reasons why people do Physics. First, we need to know how the Universe works, and what is our place here. This urge, in my opinion, is one of the crucial features of the human mind. The second reason is practical: Physics made possible the creation of devices and gadgets around us. And, finally, it is so much fun to do experiments and solve problems! (Especially if you can check your solution experimentally).

We are surrounded by the physical phenomena: sunrise, water flow, hurricanes, candle flame etc., etc., etc. There are so many of them that it is hardly possible to make the complete list. However, all the physical phenomena can be explained using a number of basic principles or physical laws. It was very difficult to reveal the laws behind huge diversity of the physical phenomena. The first step includes *observations* and *experiments*. They are necessary to gather information about new and unexplained phenomena. Analyzing the information obtained, physicists try to find similar features between various phenomena and formulate the *theory* which explains the observations and the experiment results. The next step is to design a special experiment and try to predict its result using the new theory. If the prediction is correct, it indicates that the theory may be correct as well. So we can think how our new physical law can be used to make our life better.

The process I described is generally correct but oversimplified: usually it takes much more than one experiment to check a complicated physical theory. One can hardly count how many experiments were needed to create a car, or, say, a GPS navigator.

No physical experiment is possible without *measurements*. When we are measuring, say, the length of the pencil, we are comparing the pencil with some standard length. This standard length is called the *unit* of length. The units were developed as a result of agreement between the people. Each physical quantity has units. Usually, there are several units for each physical quantity. For example the length can be expressed in meters, inches, miles, light years etc. That is why you always have to point out what unit you use to express physical quantity.

Important note: *it is not possible to* ***add*** *and/or* ***subtract*** *the numbers corresponding to different physical quantities. You can* ***add*** *and* ***subtract*** *the numbers corresponding to the same physical quantity, but only if these numbers correspond to the same units. It is not possible, for example, to subtract inches from meters or add seconds and hours. However, as we will learn later, it is possible to* ***multiply*** *and/or* ***divide*** *the numbers corresponding to different physical quantities.*

We also became familiar with two kinds of physical quantities. First kind includes the quantities which are "consist" of just a magnitude, for example, time. Such quantities are called **scalar quantities or scalars.** The quantities from the second kind are described by both magnitude and direction. These quantities are called **vector** quantities. Examples of the vector quantities are force and velocity. A vector quantity or parameter can be represented by an arrow. The length of the arrow corresponds to the magnitude and the direction of the arrow corresponds to the direction of the vector parameter.

We started our physics course from mechanics. To my opinion, this is the most important part of the Physics. The mechanics describes the effect of forces on various objects. Later we will discuss in details what the force is. But even before this discussion it is intuitively clear that application of force generally leads to change of the position of the objects. One of the most important problems of the mechanics is to describe the position of the object, to which the force is applied, at any moment of time.

We know that the position of an object can be specified only with respect to some other object. For example, when I am saying that my house is in 5 miles, it usually means "my house is in 5 miles from my current position". We can use more physical language to say that: "in a reference frame connected to my current position the distance to my house is 5 miles".

An important physical quantity we discussed is *displacement*. This parameter describes the change in an object position. If the object was moved from one point to another, the displacement can be represented as an arrow connecting the initial and final positions. The displacement does not depend on the shape of the path, passed by the object as long as the initial and final positions stay the same. If the initial and final positions coincide, the displacement is zero. Displacement is a vector.

In contrast to the displacements, the *distance*, passed by the object depends on the object's path. We can define the distance as the total length of the object's path. Distance is scalar.

How to add and subtract vectors?

We can add and subtract scalars as regular numbers. As for the vectors, there is a bit trickier procedure. For example, imagine that you mover a chair 3 meters forward and 4 meters to the right (Figure 1a, black arrows), so the chair is moved from position 1 to position 2, then to position 3. However, we can move the chair directly from position 1 to position 2 along the red arrow. We can

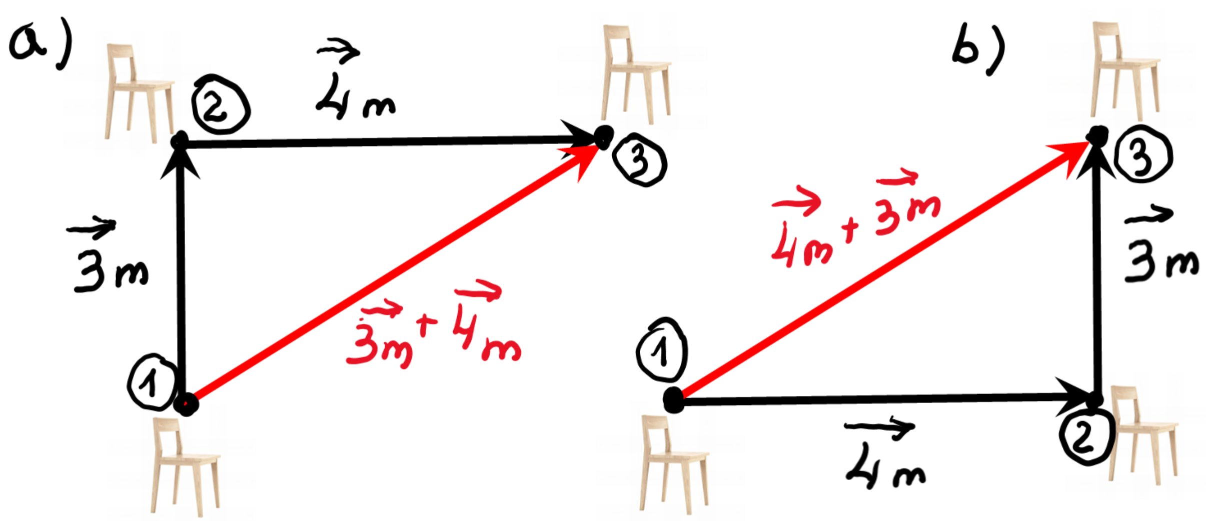

Figure 1. Vector addition.

replace 2 displacemets marked with the black arrows with just one, marked with red arrow. So the "red" displacement is a sum of the two "black" displacements. As we can calculate using Pythagoras's theorem, the distance, separating point 1 and 3 is 5 meters, while the total distance passed by the chair is 7 meters. The vector addition is commutative. It means than we can swap the order of displacements, i.e. first, move the chair 4 meters right and then 3 meters up. The resulting displacement will be the same. This geometrical method of vector addition is called "tip-to-tail".

We can also subtract vectors. To do vector subtraction, first we introduce negative vector. Negative vector has the same length and is parallel to the positive one (Fig 2), but has the opposite direction

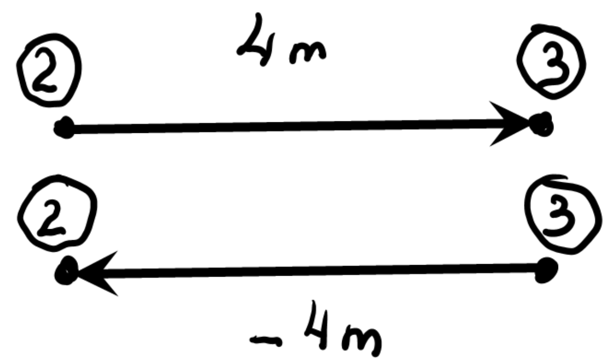

Figure 2. Negative vector.

Then we add 3m displacement and - 4m displacement (Figure 3a). The resulting displacement is the result of subtraction of the 4meter displacement from 3meter displacement. As for the numbers if we swap the terms in the subtraction and subtract the 3-meter displacement from the 4-meter displacement, the result will change the sign: the red arrow in Figure 3b has same length as the red arrow in Figure 3a, but the opposite direction.

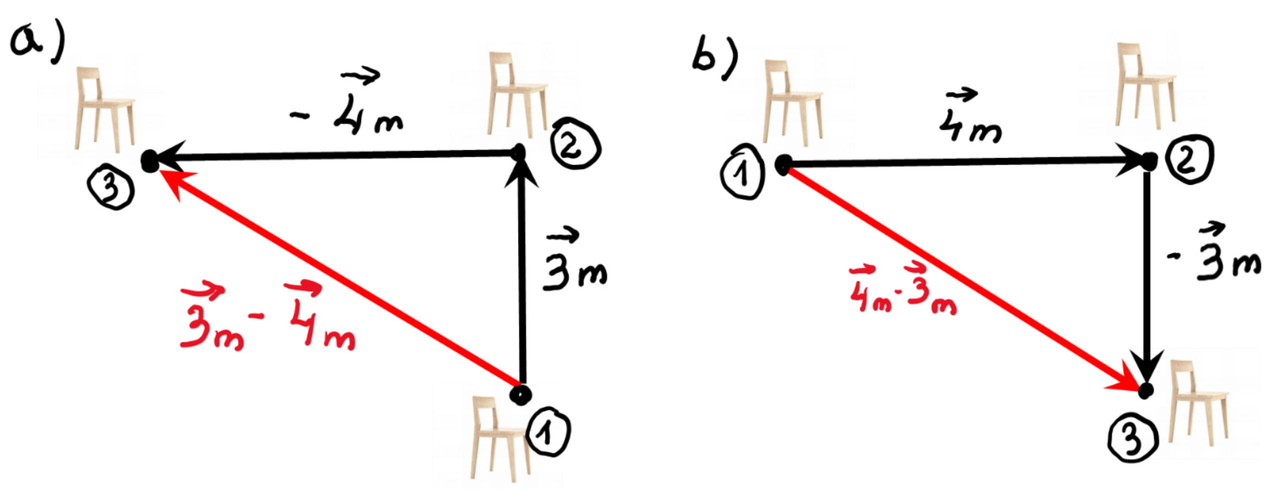

Figure 3, Vector subtraction.

Problems:

1. A cyclist rides **2 km north**, **5 km east**, **3 km south**, and then **2 km west** to avoid a lake.

(a) Find the total distance traveled.

(b) Find the net displacement (magnitude and direction).

2. A boat crosses a **200 m wide river**. The current carries it **50 m downstream** by the time it reaches the opposite bank.

(a) Find the distance traveled by the boat.

(b) Find the displacement (make a picture).

3. A robot moves on a grid:

- Forward 10 m
- Right turn, 5 m
- Right turn, 3 m
- Left turn, 7 m
- Left turn, 2 m

(a) Find total distance traveled.

(b) Find the displacement from its starting point (magnitude and direction).
(Hint: Keep track of orientation after each turn!)

4. Challenging problem (for volunteers)

A bug crawls on the surface of a cube with a side of 1cm from the lower left corner to upper right one (see Figure below). The bug takes the shortest path. Find the distance , passed by the bug.