Physics Cycle I
Motion Analysis. Body velocity.

Topic	We interpret graphs describing motion.
Duration	4 lessons (4 x 45 minutes)
Class/Age	The cycle is primarily intended for primary school classes (grades 7-8) and first year secondary school classes. It can also be implemented at later stages of education.
Objective	*The aim of this module is to introduce and consolidate concepts such as:* • *location,* • *displacement,* • *displacement vector.* • *Body velocity – definition* • Analysis and interpretation of velocity and instantaneous velocity graphs
Description	Students learn what a coordinate system and a reference system are, and learn the conditions for a correct description of motion. They learn about and define different coordinate systems, create and examine motion graphs describing changes in position over time using "embodied" experiments. Students create graphs describing changes in position over time for uniform motion and motion with variable velocity, in particular describing uniformly variable motion. During the lesson, students use the EMPE sensor with software that measures distance and visualises in real time changes in distance from a selected object, in this case a plane/surface, e.g. a wall, defined as the origin of the reference system relative to which changes in position are described. An important difference between the proposed lesson and experiments and traditional forms of teaching is the change in the role of the student. The student moves from the position of an external observer to an object moving in a selected reference frame or a point constituting the origin of the reference frame. Students are involved in "embodiment" experiments by walking with a sensor and analysing a real-time graphical interpretation of changes in their position. They have the opportunity to create and observe many graphs (functions) of different shapes, and they also perform reverse activities – they move in such a way as to reflect the movement shown in the graphs provided, and they interpret and analyse various movement graphs. They realise that in the world around us, we most often deal with variable motion along a path other than a straight line. They realise that uniform, uniformly variable, and rectilinear motion are special cases of motion – a form of simplification, idealisation, which

	is intended to facilitate the description and understanding of the essence of motion and its description. From the point of view of the mathematics curriculum, the module leads to an intuitive understanding of (functional) relationships and their interpretation in the form of graphs (functions) at the pre-definition stage.
Teaching aids	- EMPE sensor with software - desktop computer or laptop - projector/screen or multimedia board - work sheets for students

Students' independent work. Students complete **the worksheet by** drawing the predicted shapes of the graph on the worksheets they have received:

Sketch in a single coordinate system what the graphs of both movements will look like.

1. *The student walks slowly at a steady pace for 15 seconds, stops for 5 seconds and returns quickly for 10 seconds*
2. *The student walks quickly at a steady pace for 15 seconds, stops for 10 seconds and then walks slowly towards the wall for 10 seconds.*

The content of the instruction should be visible on the projector at all times so that pupils with reduced auditory perception have the opportunity for visual perception, which will help them understand the course of the experiment they are to draw.

Experiment 1

3. *The designated student, holding the EMPE sensor motionless in their hand, walks towards the wall. They complete steps 1 and 2, starting each time at the same distance from the wall.*
4. *They describe the movement by observing the generated graph.*
5. *They verify the accuracy of their predictions.*
6. *The pupils discuss and verify the correctness of the answers given on the worksheet.*

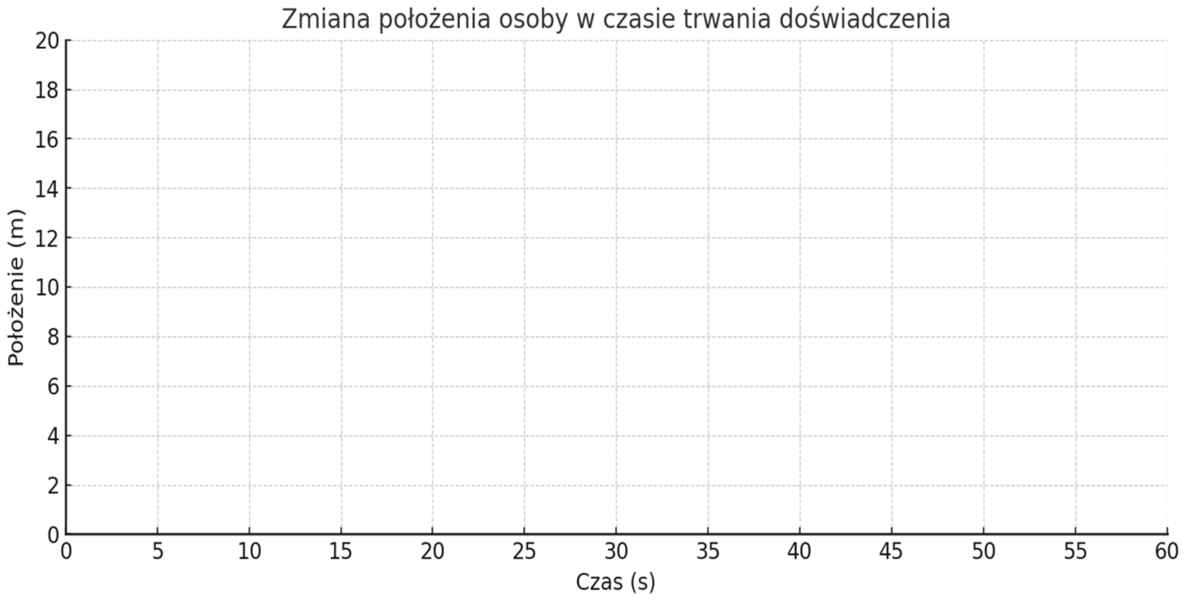
It is a good idea to involve pupils with special educational needs in this task so that they have a chance to practise the movement before the actual experiment begins.

Possible difficulties during experiment 1:

- autism spectrum disorder (ASD):
  - in order to precisely follow the instructions contained in the movement scenario, the student may need to be given (told) the specific number of steps to be taken or the point to be reached (this can be marked on the floor, e.g. with adhesive tape). The number of steps or the indicated point will, of course, depend on the size of the room in which the lesson takes place.
  - the student may expect (e.g. by asking questions) additional instruction,
- Aphasia (A):

- the student may have difficulty understanding the content of the movement scenario and will therefore need the help of the teacher, who will read the scenario and perform the desired movement, and only after this help will the student perform the task,

- mild intellectual disability (ID):
  - similarly, a pupil with aphasia may have difficulty understanding the content of the movement scenario and will therefore need the help of a teacher who will read the scenario and perform the desired movement at the same time, and only after this help will the pupil perform the task,
  - the student may need to be told (spoken) the specific number of steps to take or the point to which they are to go (this can be marked on the floor, e.g. with adhesive tape). The number of steps or the point indicated will, of course, depend on the size of the room in which the lesson is taking place.



Write down in your own words below the diagram how to tell from the diagram when the movement was towards the wall, when it was slow, and when it was fast.

Create conditions for pupils to express themselves in writing and present their ideas: give them more time to answer, make sure they are not interrupted by other pupils.

Possible difficulties during work;

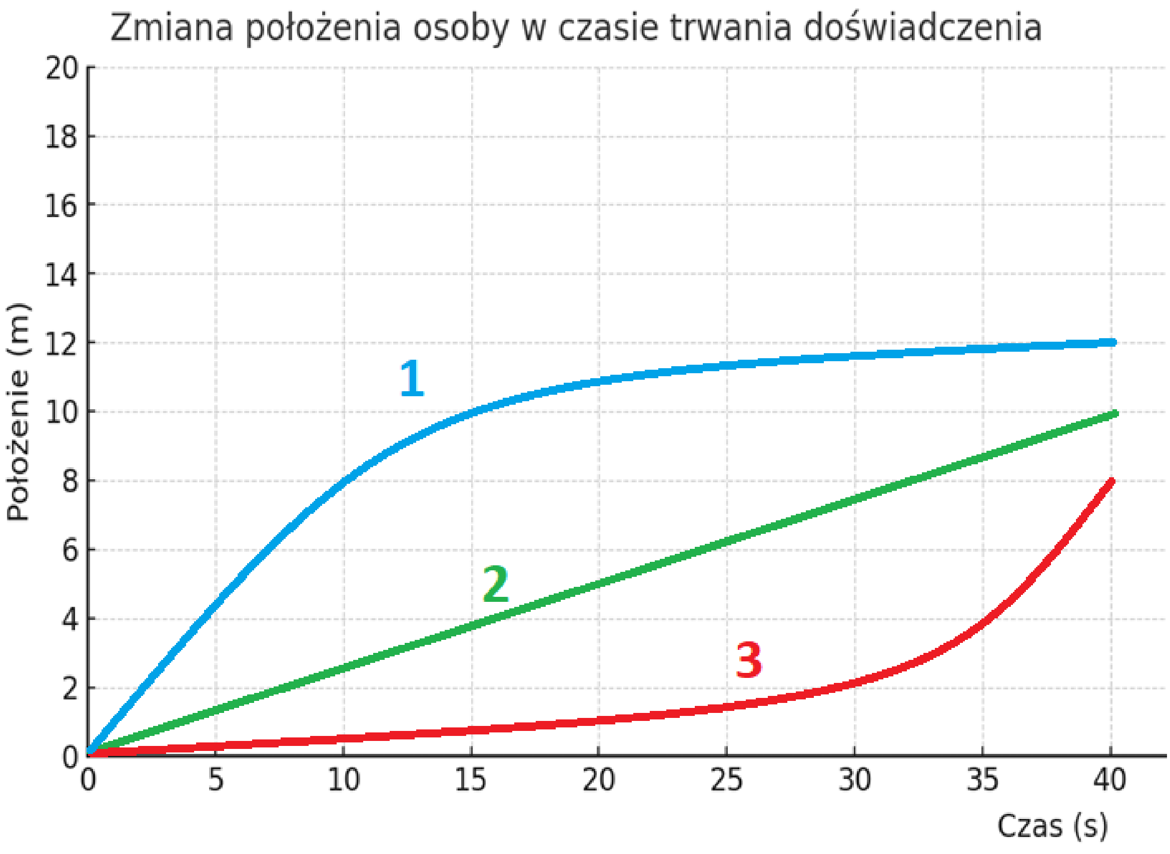
- autism spectrum disorder (ASD):
  - the student may have difficulty thinking in terms of cause and effect,
  - the student may ask additional questions,

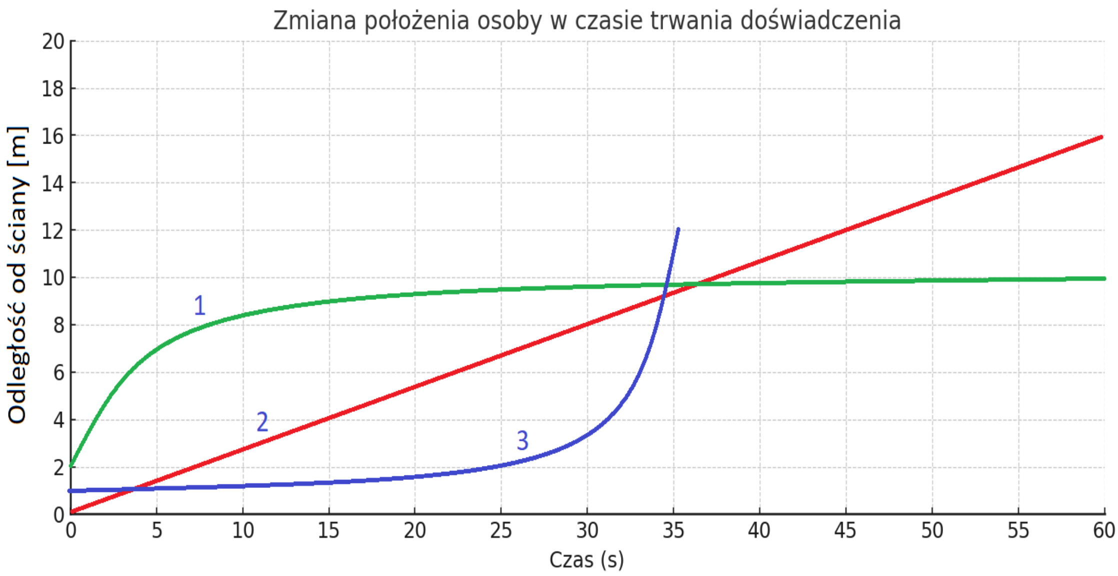
- aphasia (A):
  - the student may have difficulty verbalising their thoughts correctly and should be helped, e.g. by suggesting appropriate words,
- mild intellectual disability (ID):
  - the student may have difficulty formulating their thoughts independently in writing and, if necessary, will need the teacher's support, e.g. by suggesting words.

Selected students read out their statements and justify them.

Experiment 2.

Hold the sensor and suggest/perform a movement that will give you a graph shape most similar to those shown in the graphs below, which illustrate three different descriptions of the student's movement.





During the discussion, the teacher should encourage (but not force) pupils with autism spectrum disorder (ASD), aphasia and mild intellectual disabilities to participate actively. Conditions should be created for pupils to speak and present their ideas: give them more time to speak, and ensure that they are not interrupted by other students. This will not only allow them to be actively involved in the lesson, but also enable the teacher to ensure that students understand the content being taught and to correct any mistakes.

Possible difficulties during work;

- autism spectrum disorder (ASD):
  - if a student has difficulty thinking in terms of cause and effect, they will be a passive participant in the discussion,
  - by making specific mental associations, they may express themselves in a way that is surprising to the teacher,
  - the student may ask additional questions,
- aphasia (A):
  - the student may have difficulty verbalising their thoughts correctly and should be helped, e.g. by suggesting appropriate words,
  - having problems drawing conclusions, their statements may deviate so significantly from what is expected that in order to properly guide both the course of the discussion and the student's train of thought, it will be necessary to calmly and tactfully, but firmly, correct their statements,
- Mild intellectual disability (ID):
  - expressing movement in the form of a graph is based on thought processes, which in the case of this student are at a significantly lower level of functioning, and their

statements may be completely inadequate to the topic being discussed, which will necessitate a similar approach as in the case of a student with aphasia; calm and tactful, but firm correction of their statements.
- the student may have difficulty formulating their thoughts independently and orally and, if necessary, will need the teacher's support in the form of, for example, prompting words.

Activity 3. Introduction to the concept of speed.

To describe **how fast a body is moving**, we compare the distance it has travelled to the time it took to do so.

where:

$$v_{śr} = \frac{s}{t}$$

Where

- $v_{śr}$ – prędkość średnia,
- s – droga (w metrach [m]),
- t – czas (w sekundach [s]).

The average value of speed is often referred to as the average velocity of a body.

The unit of speed in the SI system is:

$$1\,\mathrm{m/s}$$

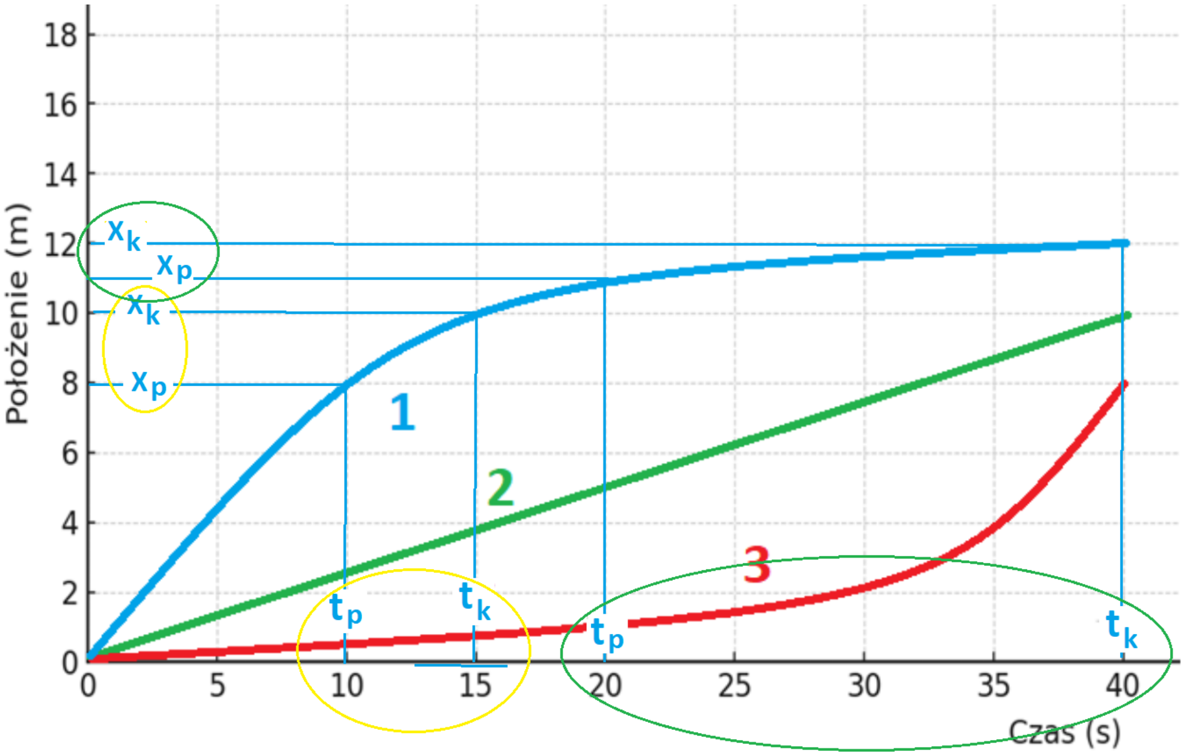
i.e. **metres per second**.

However, in everyday life, the unit **kilometre per hour (km/h)** is often used

e.g. to determine the speed of a car.

We determine the average speed using our graph on the worksheet, we will calculate the average speed for the time interval between 10 and 15 seconds of movement (the change in position coordinates and time are marked in yellow, for the blue graph, marked with the number "1":

Students with disabilities should have a printed instruction sheet so that they can paste it into their notebooks. This will make it easier for them to take notes during the lesson.



Let us calculate the average speed between 10 and 15 seconds of movement:

The distance travelled, which we denote by the symbol S, is equal to the difference between the position coordinates X_k and X_p
(the distance the student is at 15 seconds minus the distance they were at 10 seconds of movement):

$S = X_k - X_p = 10 - 8 = 2$ [m]

The duration of the movement is the time that elapses between 15 (denoted by the symbol t_k) and 10 seconds of movement (denoted by the symbol t_p), i.e. the duration of the movement in question is

$t = t_k - t_p = 15 - 10 = 5$ [s]:

The information and concepts contained in the rest of the scenario are taught in secondary school.

Instantaneous velocity – definition

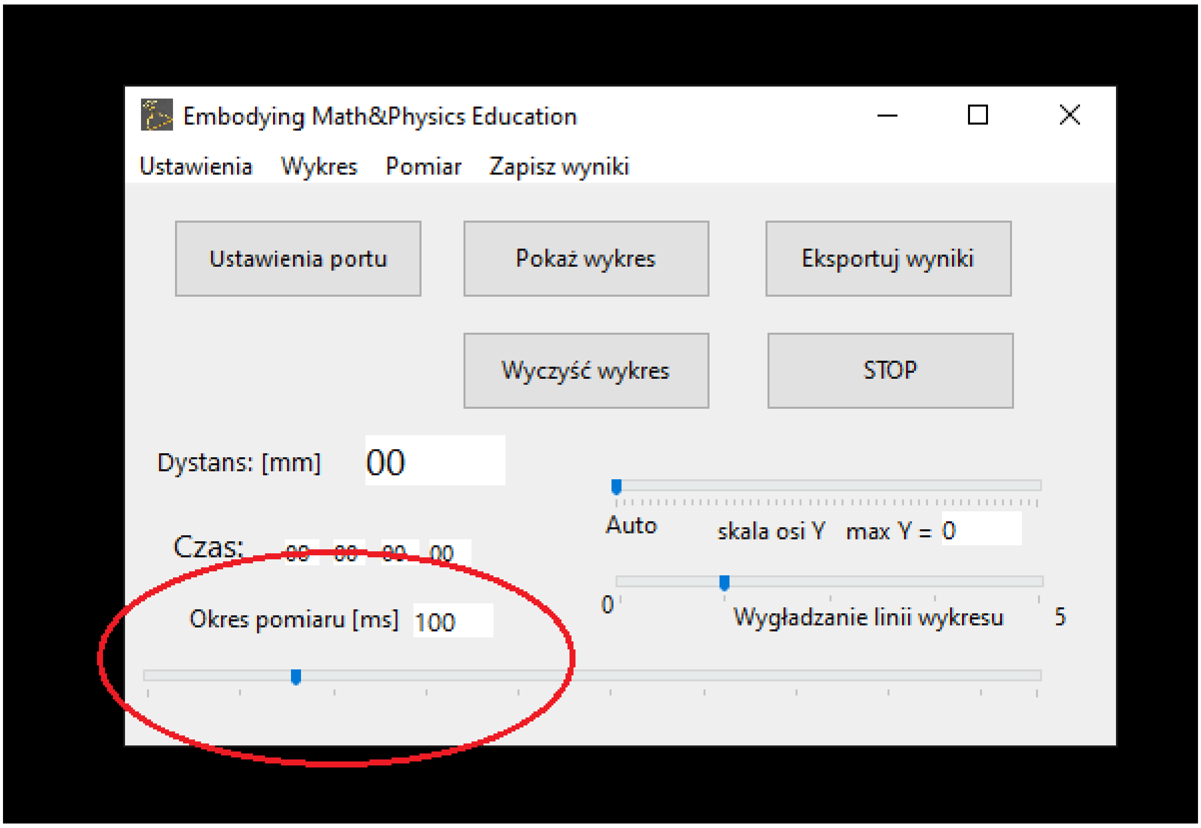
Instantaneous velocity is **the velocity of a body at a given moment in time**.
It determines how fast and in what direction and towards which side the body is moving **at that very moment**.

If, in the definition of average speed, for which we analysed changes in position, we assume that we are considering the shortest possible time intervals that we are able to measure, we will obtain speed values that we will refer to as instantaneous speed **values**. In more scientific terms: instantaneous velocity is **the limit of average velocity** when we consider **increasingly shorter time intervals.** In the notation below, delta t, or $t_k - t_{(p)}$,tends to zero. In the language of differential calculus, this is **the derivative of distance with respect to time**. We describe this limit with special symbols:

$$v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

Instantaneous velocity is **the velocity at a given moment** – the value shown, for example, by a car's speedometer. We know that a car does not always move at a constant speed: it starts, accelerates, brakes... In variable motion, i.e. motion during which the speed changes over time, the instantaneous speed changes over time. In uniform motion (at a constant speed), the instantaneous speed is the same as the average speed.

In practice, we can easily achieve this using EMPE software:



By moving the slider in the EMPE programme, we can change the number of measurements taken by the software in 1 second. The setting shown in the figure indicates that the measurement period is 100 [ms], i.e. the software takes 10 measurements per second. Therefore, we can now talk about the instantaneous speed value and its changes, which we can analyse 10 times per second, which is difficult to do using other methods, such as a stopwatch.

Lesson 2. We analyse the instantaneous velocities of a falling body.

Experiment 1.

We set a trolley or other object with a flat wall/surface in motion and analyse changes in its position at specific intervals during this movement.

Place the EMPE sensor more than 30 cm above the object whose changes you want to record.

We start the EMPE programme and set the data recording frequency to the highest possible value, e.g. 10 measurements per second.

Drop an object with a flat surface, e.g. a weighted box/board, and analyse the changes in its position at specific intervals during the movement.

Place the EMPE sensor at a distance of more than 30 cm above the object whose movement you want to record.

Start the EMPE programme and set the data recording frequency to the highest possible value, e.g. 10 measurements per second.

Fig. Example of using the EMPE sensor and a trolley with a flat wall to improve the precision of measuring changes in distance from the sensor.

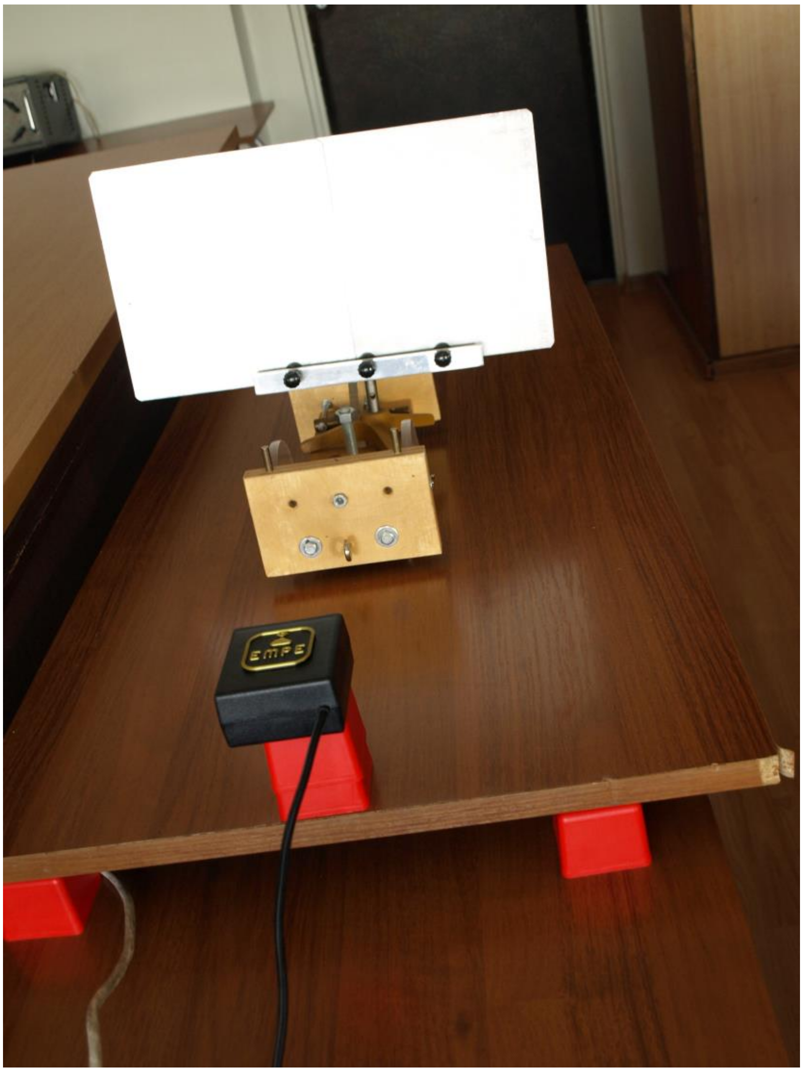


Fig.. Example of using an inclined plane created by raising one part of the table.

Mechanics trolley with an additional flat plate attached to facilitate the measurement of distance changes. Place the sensor in a stationary position.

If the sensor is placed on the mechanical trolley and wireless communication is used, we can measure changes in distance relative to one of the walls of the room.