Projekt współfinansowany w ramach programu Unii Europejskiej Erasmus+

Physics Cycle I
Reference systems. Motion. Description of motion in various reference frames.

Topic	We create and interpret graphs describing motion.
Duration	2 lessons (90 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:* • *reference frame,* • *motion,* • *relativity of motion,* • *coordinate system,* • *position,* • *displacement,* • *displacement vector.*
Description	Students learn what a coordinate system and a reference system are, and learn the conditions for correctly describing motion. They learn about and define different coordinate systems, and create and examine motion graphs describing changes in position over time using "embodied" experiments. During the lesson, students use the EMPE sensor together with software that measures and visualises in real time changes in distance from a selected object, in this case a plane (e.g. a wall surface), defined as the origin of the reference system against 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 interpret and analyse various movement graphs. They realise that in the world around us, we most often deal with variable

	curvilinear motion. They realise that uniform, uniformly variable 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 - worksheets for students

LESSON PLAN

During the lesson, the teacher and students use the EMPE sensor with EMPE software developed as part of the EMPE project (https://empe.uken.krakow.pl).
Instructions for using the sensor can be found in the file available on the project website:

PRE-TEST

At the beginning of the lesson cycle, we ask students to individually and in writing complete a short PRETEST. Its purpose is to test their intuitive understanding of the concepts of motion and relativity of motion.

Students with autism spectrum disorder (ASD) complete a test called: pretest (ASD).pdf
Students with aphasia complete the test called: pretest (A).pdf.
Students with mild intellectual disabilities complete the test called: pretest (NI).pdf
In each version of the pre-test, the content of each task fits on one page – we do not transfer it from page to page. The font is enlarged to facilitate students' visual perception of the verbal content. Some content is written in bold, while other content is underlined to draw the student's attention to the most important points. It is a good idea to print the test on both sides of the page.

Possible difficulties when working with the pre-test;

- autism spectrum disorder (ASD):
  - in order to follow the instructions precisely, the student may need more time than other students to complete the tasks,
  - the student may ask additional questions,
- aphasia (A):
  - the student may have difficulty reading and understanding the content of the tasks on their own and will therefore need the teacher's help,
  - working slowly, the student may need more time than other students to complete tasks,
- mild intellectual disability (ID):
  - the student may have difficulty reading and understanding the content independently and will need the teacher's support if necessary,
  - the student may have difficulty formulating their thoughts in writing independently and will need the teacher's support if necessary,
  - check questions must be used to ensure that the pupil understands the content of the task to be performed,
  - the necessary assistance from the teacher will require an extension of their working time.

Activity 1

1a) Formulating hypotheses.
The pupil or teacher moves towards a large, flat surface, e.g. a wall, and performs the activities described below.
We recommend moving around the entire classroom. You can stay at a distance of up to 20-30 metres.

1. *At the beginning, I stand still for a moment.*
2. *I walk for 15 seconds at the same very slow pace towards the wall,*
3. *stop for 5 seconds,*
4. *and then walk away from the wall at the same pace for 10 seconds.*
5. *I stop for 5 seconds.*
6. *Then, in 5 seconds, I walk at a steady and fast pace towards the wall,*
7. *I stop for 5 seconds*
8. *and then move away from the wall at a fast pace for 5 seconds.*
9. *I stop.*

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

Students with autism spectrum disorder (ASD), aphasia, and mild intellectual disabilities will need clarification through the teacher demonstrating the phrases: walk very slowly, walk at a steady and fast pace. It would be a good idea to designate a person to time the activity and tell the students when to stop.

The pupils and/or teacher read the instructions, set the time and instruct the person moving what actions they should perform. It is worth starting the walk from the back of the room and moving towards the blackboard, as this position will cause typical mistakes and it will be possible to correct them during the demonstration later in the lesson.

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

Possible difficulties during activity 1;

- autism spectrum disorder (ASD):
  - in order to precisely follow the instructions in the movement scenario, the student may need to be told (spoken) the specific number of steps to take or the point to which they are to walk (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):
  - similar to a student with aphasia, they may have difficulty understanding the content of the movement scenario and will therefore need the help of a teacher who will simultaneously read the scenario and perform the desired movement, and only after this assistance will the student perform the task,
  - the student may need to be told (spoken) 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 point indicated will, of course, depend on the size of the room in which the lesson takes place.

After following the above instructions, the teacher distributes cards with a coordinate system to the pupils, and their task is to make a first intuitive attempt to sketch the shape of a graph showing the changes in distance from the wall of a moving person during the movement described above.

Possible difficulties during the activity:

- autism spectrum disorder (ASD):
  - the student may expect additional instruction because they may feel confused by such freedom of action,
- aphasia (A):
  - the student may have difficulty reading and understanding the movement scenario and will therefore need the help of the teacher, who will read the subsequent stages of the movement to them,
  - it may be necessary to show the student where to start the chart,
- mild intellectual disability (NI):
  - just like a student with aphasia, they may have difficulty reading and understanding the movement scenario, and therefore will need the help of a teacher who will read the subsequent stages of the movement to them,
  - in the case of difficulties with reading comprehension, it may be necessary to work in stages. The teacher reads a fragment of the movement scenario and the student draws it on a chart. Then the teacher reads the next fragment and the student proceeds as before. The sequence of actions is repeated until the end of the scenario.

- It will most likely be necessary to show the student where to start the diagram.

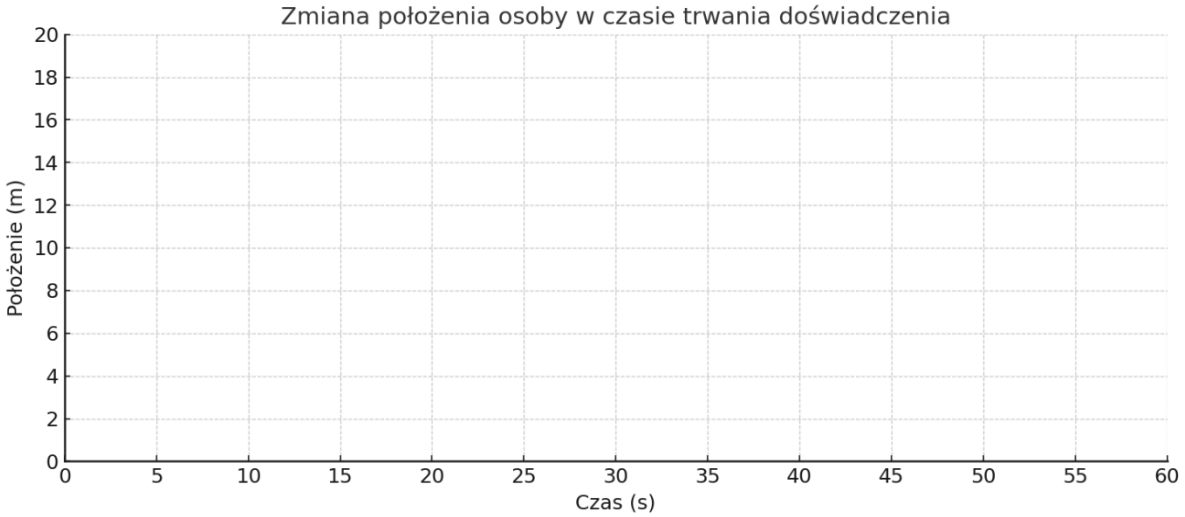


Figure1 , Worksheet 1 – p. 1

1b) Discovering how the sensor works

The teacher shows the sensor, opens the software and shows how the graph is generated, displays it on the projector and starts the measurement. They point the sensor in different directions. The pupils observe how the graph is created in the application at this time.

Ensure that the teacher and their actions are clearly visible from every part of the classroom.

The teacher asks the question:

- What can you say about this graph? What is being measured?

We wait for the pupils' answers, which will be:

- *the sensor measures the distance in a straight line from a selected obstacle/plane,*

During the discussion, the teacher should encourage (but not force) students with autism spectrum disorder (ASD), aphasia and mild intellectual disabilities to participate actively. Create conditions for students to speak and present their ideas: give them more time to speak, 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 make sure that the 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.

The teacher explains what is necessary to describe movement.
How do we describe movement, how do we define the point (in our case, the plane) relative to which we will describe the change in position of the selected person?

The definition of the concept of motion and reference frame should be supported by appropriate examples.

2. The teacher introduces the concept of a reference frame.

We discuss whether, for the purposes of our experiment, this can be any point/plane? The floor, ceiling, wall?

A **reference frame** is a point in space, an object or, in our experience, a group of points – e.g. a wall – relative to which we describe movement.

We discuss why, in our experience, the selected reference point/plane cannot be, for example, the ceiling or floor.

3. Performing the experiment with the sensor. Verifying hypotheses

The student or teacher holds the EMPE sensor facing a large, flat surface, e.g. a wall, and performs the described actions.
We recommend setting the number of measurements to approximately 3-5/sec. Move over long distances, e.g. across the entire classroom, which will make it easier to differentiate between the shapes of the graphs. The EMPE sensor measures distances between 0.3 and 50 metres.

The teacher reads the instructions during the exercise.

Comment: Students should be instructed to hold the sensor in the same position (e.g. perpendicular to their body) and not to move it. It is worth repeating the experiment several times, asking different students to perform it.

A correctly drawn graph should have significantly different slopes of the straight lines:

Figure – graph produced by the sensor during workshops at UKEN, with the teacher holding the EMPE sensor, operating in wireless communication mode, still and recording changes in its position relative to the wall.
Measurements can be taken in the range from 0.3 to 50 metres.

It is possible to carry out the same experiment in a system where the student, instead of being an object moving in a given reference system, becomes an external observer. We move an object with a flat surface, as shown in the diagram, relative to a stationary sensor, which is the origin of the reference frame. *To obtain accurate results, ensure that the distances measured are within the range of 0.3 to 10 metres*.
However, we do not recommend conducting this type of experiment at primary school level. Our research results indicate a significantly higher "didactic effectiveness" of experiments in which the student moves themselves, where the student and their body are part of the analysed system, whose position changes are presented in real time on a graph.

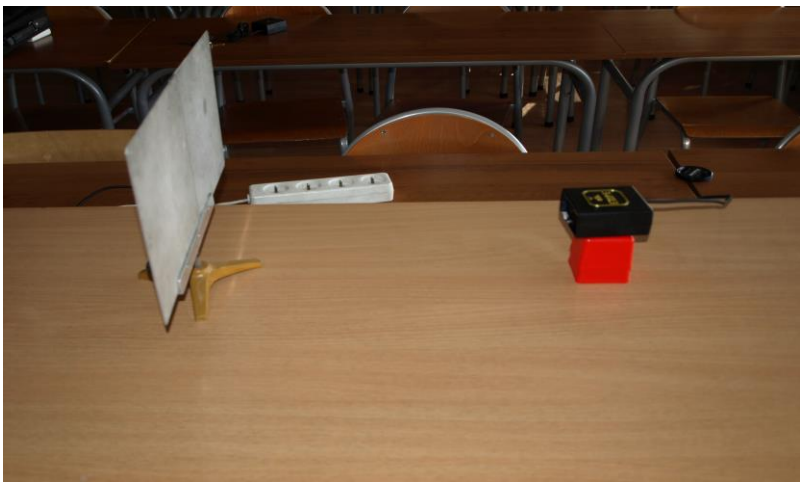


Fig. Example of using a sensor to analyse changes in the position of an object with a flat wall/surface. To obtain accurate results, ensure that the measured distances are within the range of 0.3–10 m.

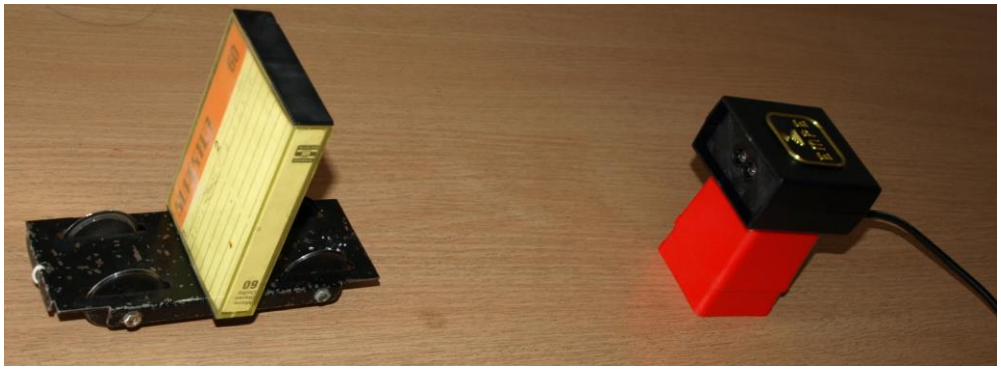


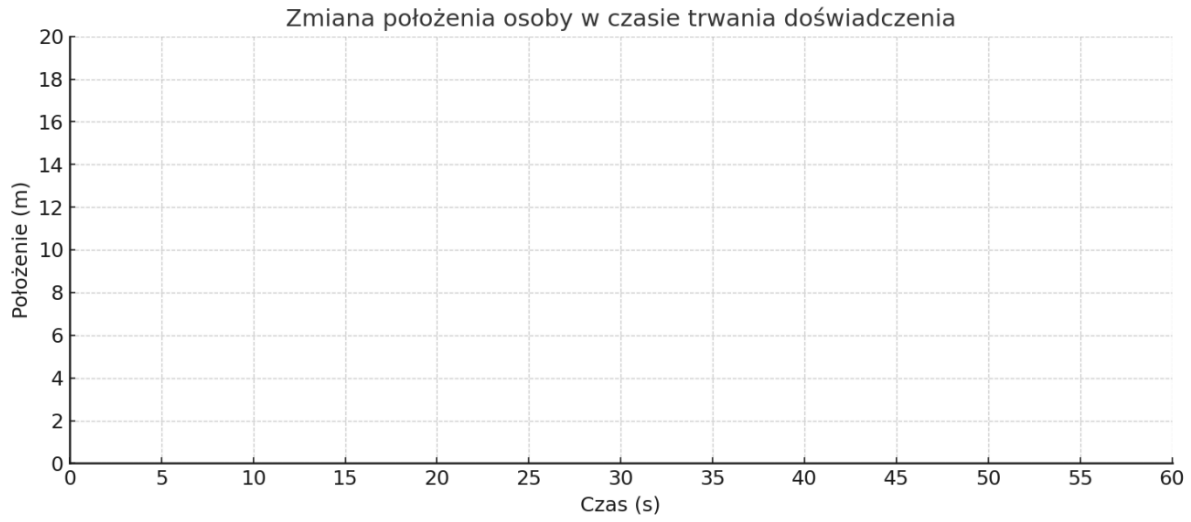
Fig. Example of using a sensor to analyse changes in the position of an object with a flat wall/surface. To obtain accurate results, ensure that the measured distances are within the range of 0.3–10 m.

Students redraw the correct graph and discuss other variants of the experiment that the teacher could carry out.

If possible, for students with autism spectrum disorder (ASD), aphasia and mild intellectual disabilities, it would be a good idea to print out the graph created during the experiment so that they can paste it into their notebooks.

Possible difficulties during the activity:

- autism spectrum disorder (ASD):
  - if the student does not have graphomotor difficulties, they should not have any major difficulties with this task,
  - if graphomotor difficulties occur, the teacher's help will be necessary,
- Aphasia (A):
  - as the student may make significant mistakes when redrawing the graph, it is necessary for the teacher to monitor their actions and provide assistance if necessary,
- mild intellectual disability (ID):
  - similar to a student with aphasia, they may make significant mistakes when redrawing the graph, and supervision and assistance from the teacher will be necessary.



4. Graph analysis

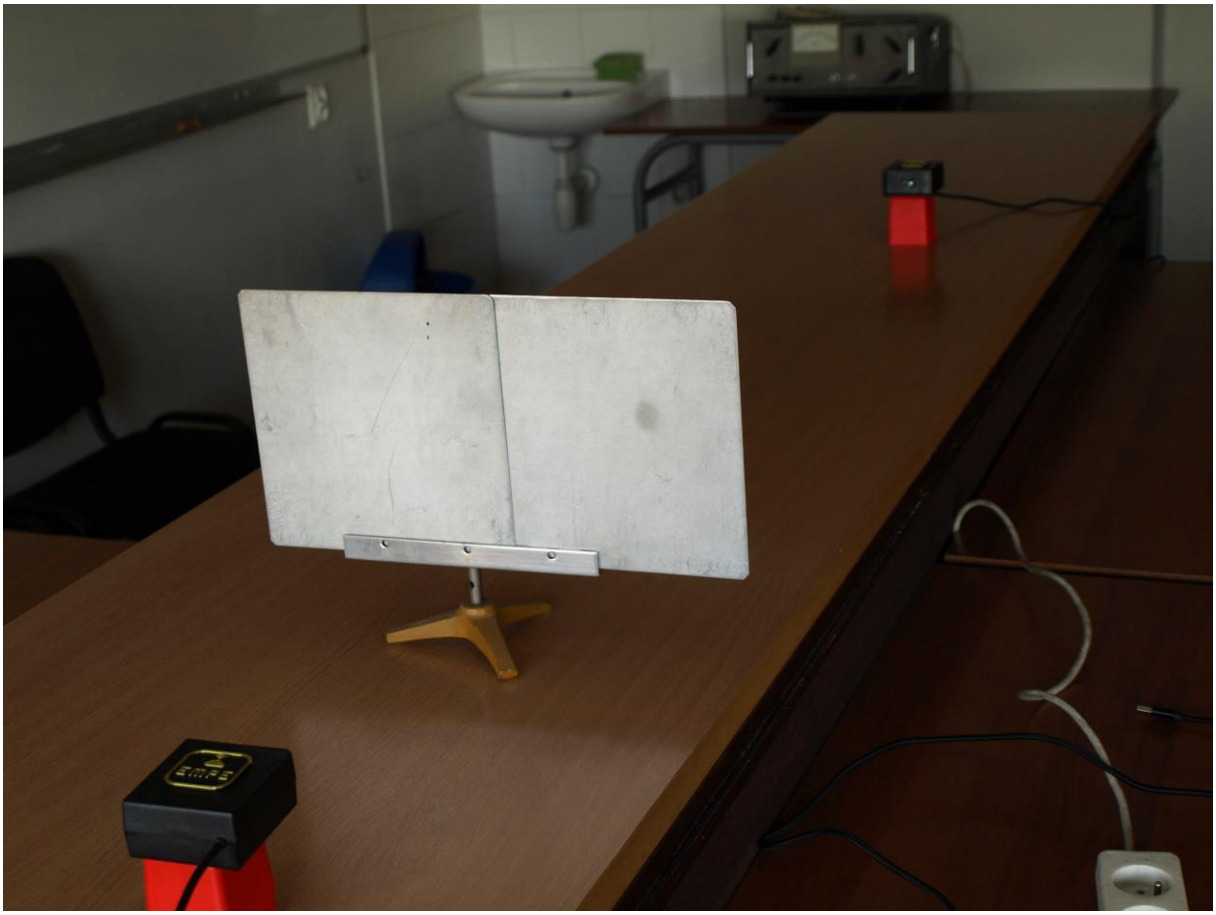


Fig. Example of the simultaneous use of two sensors and description of the movement of an object between them from the point of view of two observers and the selection of two different reference systems.

We can transfer this situation to the description of the movement of a train from station A to station B, described from the point of view of passengers on the platforms of station A or station B.

The teacher discusses the shape and individual sections of the graph with the pupils.

How does the distance between the sensor and the wall change as the student/object moves towards/away from the wall?
What do you observe on the graph? (the distance decreases)

This horizontal section should be indicated on the graph. Students with autism spectrum disorder (ASD), aphasia and mild intellectual disability with aphasia may be instructed to mark

this section of the graph with a selected (second) colour. Under the graph, the statement " " (the distance from the wall decreases) should be underlined in the same colour. After completing the task, check that it has been done correctly.

- How does the distance between the sensor and the wall change as it moves away from the wall?
What do you observe in the graph? (the distance increases)

Indicate this horizontal section on the graph. Students with autism spectrum disorder (ASD), aphasia and mild intellectual disabilities may be asked to mark this section of the graph with a selected (third) colour. Underneath the graph, underline the statement: the distance from the wall increases. After completing the task, check that it has been done correctly.

- Why is the graph horizontal at the beginning? (We are standing, so the distance from the selected point/plane relative to which we are describing the movement is the same).

Indicate this horizontal section on the graph. Students with autism spectrum disorder (ASD), aphasia and mild intellectual disability with aphasia may be asked to mark this section of the graph with the selected colour. Under the graph, underline the statement: the distance from the wall does not change with the same colour. After completing the task, check that it has been done correctly.

How can we tell from the graph how far the student moved from the starting point during the experiment?

- How can we tell from the graph when we were walking slowly? (smaller slope of the line – more horizontal segments of the line, distance covered in a long time)

- Was the break in movement the same length each time?

- Was the break in movement the same distance from the board each time?

Care should be taken to ensure that students with disabilities are able to express themselves freely. They should be given more time to do so, and other students should not interfere. If they have difficulty verbalising their thoughts, they can show what they have come up with. During their presentations, the teacher may need to help them, for example by prompting them with words. Sometimes, due to problems with mental operations, the statements of students with mild intellectual disabilities may differ 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.

5. The teacher introduces the concept of displacement vector.

- **A displacement vector** is a vector that connects the starting point of the movement with the end point of the body's movement. It shows the direction and direction of movement.

  Its length (value) is the distance in a straight line between the initial and final positions. It does not depend on the distance travelled by the body, but only on the change in position.

$$\vec{s} = \vec{r_2} - \vec{r_1}$$

where:

- $\vec{s}$– displacement vector,
- $\vec{r_1}$– initial position vector,
- $\vec{r_2}$– final position vector.

The teacher shows the possibility of changing the measurement frequency in the software options. He/she discusses with the pupils whether the measurement made by the EMPE sensor can be considered an experimental method of determining the value of the displacement vector during the pupil's movement and our experiment.

The students indicate the direction and orientation of such a vector.

6. Summary of the lesson:

The teacher discusses the most important concepts and summarises the lesson based on the graph generated on the projection screen.

The teacher again presents the definitions of the most important concepts:

- *reference system, coordinate system*
- *position,*
- *displacement, displacement vector*

- *motion,*
- *relativity of motion,*

7. Students complete a test to check their knowledge and understanding of the concepts after the lesson.

Students with autism spectrum disorder (ASD) complete a test called: posttest (ASD).pdf
Students with aphasia complete a test called: posttest (A).pdf.
Students with mild intellectual disabilities complete a test called: posttest (NI).pdf
In each version of the post-test, the content of each task should fit on one page – it should not be spread across multiple pages. The font size has been increased to make it easier for students to perceive the verbal content visually. Some content is written in bold, while other content is underlined to draw the student's attention to the most important information. It is a good idea to print the test on both sides of the page.

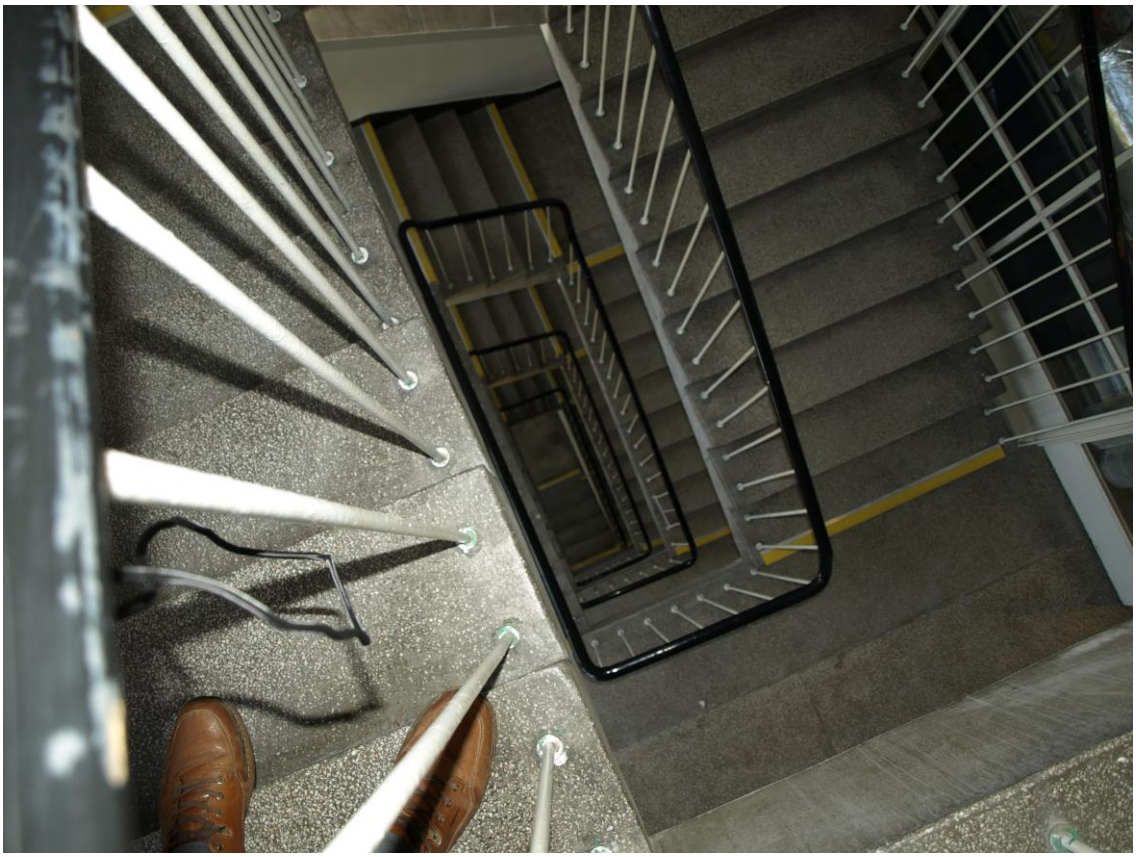
Possible difficulties when working with the pre-test;

- autism spectrum disorder (ASD):
  - in order to follow the instructions precisely, the student may need more time than other students to complete the tasks,
  - the student may ask additional questions,
- aphasia (A):
  - the student may have difficulty reading and understanding the content of the tasks on their own and will therefore need the teacher's help,
  - working slowly, the student may need more time than other students to complete tasks,
- mild intellectual disability (ID):
  - the student may have difficulty reading and understanding the tasks on their own and will need the teacher's support if necessary,
  - check questions must be used to ensure that the pupil understands the task to be performed (marking only the correct answer),
  - The necessary assistance from the teacher will require more time to complete the task.

8. Homework

Students with autism spectrum disorder (ASD), aphasia and mild intellectual disability will need the content of the task to be visualised through a short demonstration by the teacher (reminder) of how to hold the sensor and a verbal reminder of what happens when a person holding it in their hand moves.

A) Draw a graph describing the change in distance from the ground floor of a person holding the EMPE sensor and climbing the stairs shown in the photo below at a steady pace to the 5th floor.



B.) Present a graph for the same situation, but with the sensor held towards the ceiling of the 5th floor. As in the photograph below.