Physics

Topic	Analysis of uniform rectilinear motion using a lidar sensor
Duration	2 or 3 lessons (90–135 minutes)
Class/Age	The cycle is primarily intended for primary school classes (grades 7-8) and first year secondary school classes.
Object	*The aim of this module is to introduce or reinforce concepts such as:* • *reference frame,* • *motion,* • *relativity of motion,* • *coordinate system,* • *position,* • *displacement,* • *distance* • *average speed (value)* .
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 various coordinate systems, create and examine motion graphs describing changes in position over time using "embodied" experiments. During the lesson, students use an 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 can move from the position of an external observer to become an object moving in a selected reference frame or a point constituting the origin of the reference frame. The student can repeat the same experiment but use a trolley for it, becoming an external observer. 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 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 - work sheets for students

2. Lesson objectives

2.1 General objectives

- Students will learn how to calculate distance and speed in uniform linear motion.
- They will understand how to use a lidar sensor to measure distance.
- They will analyse the graphs s(t) and v(t).
- They develop research and measurement data analysis skills.

2.2 Specific objectives (the student will be able to):

- explain the concepts of distance, displacement, uniform linear motion, and speed;
- operate the EMPE lidar sensor and software that records measurements at a frequency of 3–10 Hz;
- record a series of distance measurements;
- create a graph of distance versus time s(t);
- determine the average speed of movement based on the graph;
- analyse measurement errors and their impact on the experiment results.

3. Methods and forms of work

- Methods: measurement experiment, graph analysis, brainstorming, group work, discussion.
- Forms: group work (3–4 people), individual work (pre-test and post-test).

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4. Teaching aids

- lidar sensor with a measurement capacity of 3–10 times/second;
- computer with data acquisition software (real-time graph display);
- experimental table or track;
- moving object (trolley, pushed object, mobile robot, battery-powered toy vehicle);
- worksheets for groups;
- pre-test and post-test sheets;
- projector or interactive monitor.

5. Lesson plan

5.1. Introduction (10 min)

1. The teacher introduces the topic: *"Today we will examine uniform linear motion using the EMPE lidar sensor and learn how to analyse graphs showing the relationship between distance and time."*
2. **Activation of prior knowledge.** The teacher asks questions:
    - "What is uniform motion?"
    - "How do we calculate speed?"

Students with disabilities should be given more time to answer. Make sure that other students do not interrupt their answers. If they cannot remember the correct terms, ask them to look for the relevant information in their notebooks. When asking questions to students with disabilities, it may be necessary to repeat them several times. If they have problems with oral answers, guide their thinking, praise them, grade the difficulty of the questions, and divide the questions into parts. Provide additional guidance and explanations as needed. Avoid highly generalised questions, start sentences, and "throw in" missing words. Avoid giving several commands at the same time.

It would be good to clarify questions by adding each time what kind of movement is involved: uniform rectilinear motion.

- Autism spectrum disorder (ASD):
  - give short, clear commands and avoid complex sentences,
  - by creating specific mental associations, they may express themselves in a way that is surprising to the teacher,

- the student may ask additional questions,

- Aphasia (A):
  - give short commands; the teacher's help may be needed when answering questions,
  - having difficulty 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):
  - this student's thought processes 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 to that used with 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 will need the teacher's support if necessary.

3. **Pre-test (5 min)** – students individually complete a short diagnostic test (included in the additional documents).

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 the 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 content. It is recommended 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 pupil may have difficulty reading independently with comprehension 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 task to be performed,
- The teacher's assistance will necessitate extending the time required for the task.

5.2. Introduction to working with a lidar sensor (10 min)

1. **The teacher presents the EMPE device** and briefly discusses how the EMPE lidar sensor works as a sensor that measures distance based on the return time of a laser pulse.
2. **Illustration of how the sensor works:**

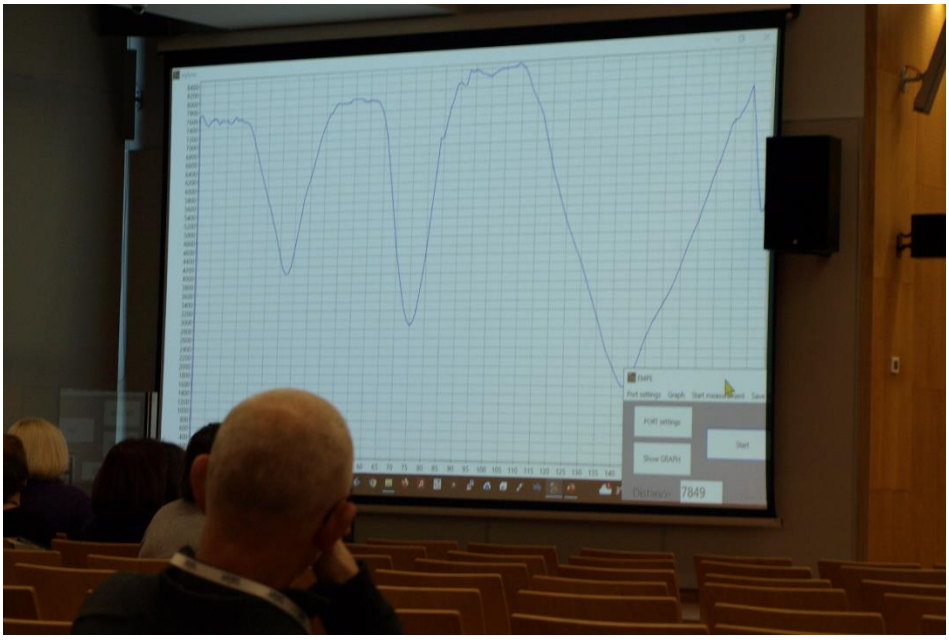
5.3. Main experiment (35 min)

Students work in teams. Each group receives a sensor, a computer and a worksheet.

5.3.1. Stage 1 – Setting up the workstation (5 min)

- Place the lidar sensor stably on the table, pointing along the track.
- check that the object is within the sensor's measuring range;
- start the measurement programme.

- Below are photographs of several implementations of the experiment.



5.3.2. Stage 2 – Movement recording (10–15 min)

Each group performs three series of measurements (the student walks with the EMPE lidar sensor, which measures changes in the distance of the moving trolley/object:

1. steady motion at low speed;
2. uniform motion at a higher speed;
3. non-uniform motion (for comparison).

Students with autism spectrum disorder (ASD), aphasia and mild intellectual disabilities will need clarification from the teacher on the terms: uniform motion at low speed, uniform motion at higher speed, non-uniform motion.

Possible difficulties during the experiment;

- 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 simultaneously 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 performed 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.

The software automatically saves the values (t, x(t)).

5.3.3. Stage 3 – Data analysis (15 min)

Students perform:

1. read the speed from the slope of the x(t) graph (uniform motion → increasing straight line);
2. comparing the speed values from different trials;
3. identify sections of the graph where the motion was not uniform;
4. calculate the average speed value from the numerical data.

Below is an illustration of the relationship between speed and the slope of the graph – carried out during workshops at UKEN, a person moves a distance of several dozen metres in uniform motion, measuring changes in their position relative to the wall, changing speed, stopping, and moving backwards.

5.4. Discussion of results (10 min)

The teacher moderates the discussion:

- What differences do you see between the graphs of uniform and non-uniform motion?
- How do measurement errors (data noise, delays, random errors) affect the shape of the graph?
- Does the frequency of measurements affect accuracy?
  (The higher it is, the more accurate the graph.)

During the discussion, the teacher should encourage (but not force) students with autism spectrum disorder (ASD), aphasia and mild intellectual disabilities to participate actively. Conditions should be created for students 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.

5.5. Summary and post-test (10 min)

1. Summary of key concepts.
2. Students complete **a post-test** to assess the effectiveness of the lesson.

Pre-test

This test is designed to check students' basic knowledge and intuition before introducing the main material.

1. Give a definition of **uniform linear motion**.

2. What does it mean when a car's speed is **0.5 m/s**?

3. Draw an example graph of the distance travelled by a vehicle moving at a constant speed.

4. State the formula used to describe speed.

5. What is **the difference** between the concepts **of distance** ("S") and **speed** ("V")?

6. What is the unit of speed in the SI system (International System of Units)?

7. Does a train travelling at a constant speed along a curve (bend) move in a uniform rectilinear motion?
Justify your answer.

8. If the movement time is 2 seconds and the distance travelled is 10 metres, what is the average speed of the moving object?

Post-test (After the lesson)

This test is designed to check whether students have mastered the skills of interpretation and analysis and are able to distinguish between uniform and non-uniform motion after the lesson.

1. Based on the graph of distance versus time S(t), explain how **to accurately calculate** (read) **the speed** of an object.

2. How does the frequency of time and distance measurements affect **the accuracy** of speed determination and the shape of the S(t) graph?

3. Give **two examples** from everyday life in which motion **is not uniform** (give a brief description of why it is not uniform).

4. Using the data and formulas from the lesson, describe **the difference** between **uniform** and **non-uniform** motion, referring to the concept **of acceleration**.

5. Draw **a sketch of the graph** of the relationship between speed and time v(t) for uniform rectilinear motion and describe its most important feature.