Bewegungsgesetze der geradlinig gleichförmigen Bewegung mit SMARTsense (Item No.: P1003869)

Curricular Relevance

Area of Expertise: Physics → **Education Level:** Age 14-16 → **Topic:** Mechanics → **Subtopic:** Linear motion → **Experiment:** Laws of uniform linear motion with SMARTsense

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	2 Students

Additional Requirements:

- Tablet

Experiment Variations:

- Classic student experiment: Laws of uniform linear motion (P1003800)
- Classic student experiment: Laws of uniform linear motion with the 2-1 timer (P1003805)
- Classic student experiment: Laws of uniform linear motion with Cobra4 (P1003862)

Keywords:

instantaneous velocity, average velocity, distance-time-diagram, velocity-time-diagram, velocity measurement

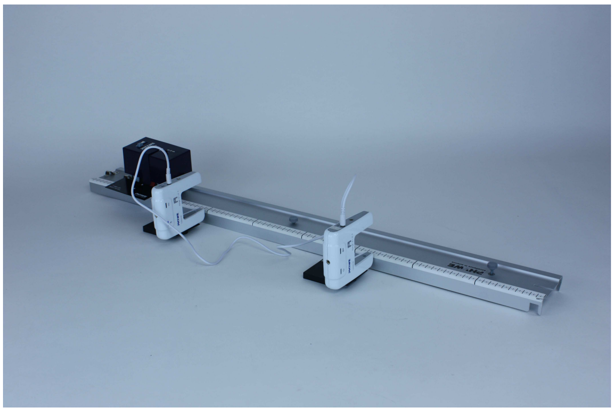
Information for teachers

Introduction

Application

Uniform linear motion is not really a typical form of motion. However, some examples can be found in our everyday life. We encounter uniform linear motion in railroad traffic, escalators, and conveyor belts, for example.

ICE 3 train in the Oberhaid forest (picture: Sebastian Terfloth)



Experiment set-up

Educational objective

The aim of this experiment is to familiarise the students with the laws of uniform linear motion in greater detail. An important factor is to ensure that the students become increasingly experienced in the representation of the laws in the form of diagrams. They should be able to determine the acceleration based on a velocity-time-diagram.

Tasks

1. In the first part of the experiment, the students let a motorised cart run on the track at the lowest possible velocity. The two light barriers at the side of the track measure the time that the cart needs for covering the distance between them.

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The distance between the light barriers is varied. Then, the measuring mode is changed and the students measure the instantaneous velocity with the help of the last light barrier. The position of this light barrier is also varied.

2. The experiment is repeated as described for task 1, but this time with a medium velocity setting of the battery-powered cart.
3. The students calculate the average and instantaneous velocity (based on the length of the shutter plate) of the cart as a function of the location.
4. Based on the diagrams resulting from the measurement value tables, the students see that it is a linear motion.

Prior knowledge
The students should be familiar with the difference between instantaneous and average velocity and they should be able to calculate both velocities based on a given distance and known time.
Principle
The motorised cart runs on a track at constant velocity within a series of measurements.
As a result, the instantaneous and average velocities that are calculated based on the measurement values are always identical.

Note
The velocity of the battery-powered cart depends rather strongly on the charge of the battery. In order to be able to reproduce the times of motion that have been measured by PHYWE, proper power supply of the cart must be ensured.

Safety instructions

For this experiment, the general notes and instructions concerning safe experimentation in science classes apply.

Versuch: Bewegungsgesetze der geradlinig gleichförmigen Bewegung mit SMARTsense (Item No.: P1003869)

Introduction

Application and task

What are the laws governing uniform linear motion?

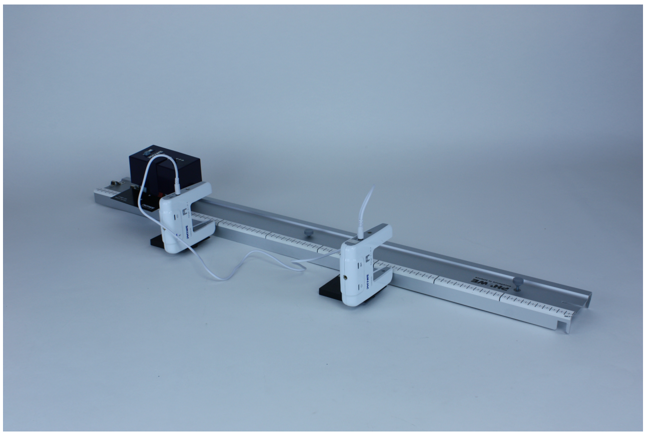
Introduction
How can you represent the motion of a vehicle in a clear, graphical form like the one that you might know from images in the sports section of a newspaper?
What kind of information is provided by such diagrams?

Application
Uniform linear motion is not really a typical form of motion. However, some examples can be found in our everyday life. We encounter uniform linear motion in railroad traffic, escalators, and conveyor belts, for example.

ICE 3 train in the Oberhaid forest (picture: Sebastian Terfloth)

Tasks

1. Adjust the lowest velocity of the motorised cart and let it run on the track. Measure the time that the cart needs for covering the distance between the two light barriers. Then, measure the shading times of the last light barrier.
2. Set the speed controller to the middle position and perform the experiment as described for the first task.
3. Calculate the average and instantaneous velocities of the cart based on the measured times.



Experiment set-up

Material

Position No.	Material	Order No.	Quantity
1	Track, l 900 mm	11606-00	1
2	Meter scale, demo. l=500mm, self adhesive	03005-00	2
3	Car, motor driven	11061-00	1
4	Shutter plate for car, motor driven	11061-03	1
5	Adapter plate for Light barrier compact	11207-22	2
6	Cobra SMARTsense - Photogate, 0 ... ∞ s	12909-00	1

Set-up and procedure

Set-up

Fasten the shutter plate on the cart and position the latter at the end of the track (Fig. 1).

Fig. 1

Connect the light barriers to the adapter plates so that they can be set up along the track. Put the photogate marked "B" at the second position. Ensure that the shutter plate of the cart can pass through the light barriers without touching them (Fig. 2).

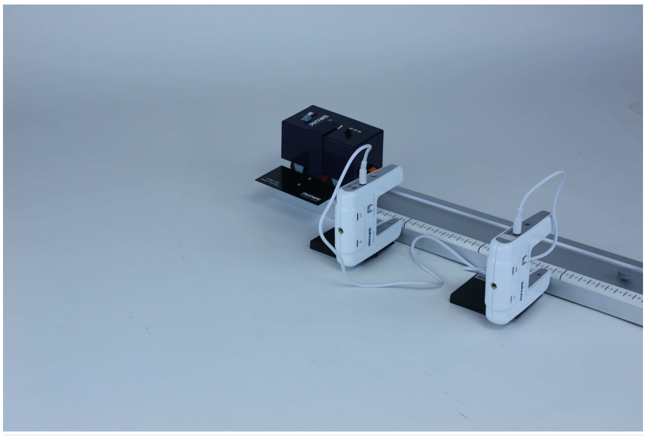


Fig. 2

Connect the light-barriers with the stereo jack-cable and switch both of them on. Select then the photogate in measureAPP in the menu "sensor". Pick the option "Run times" in the menu that opened. (Fig. 3).

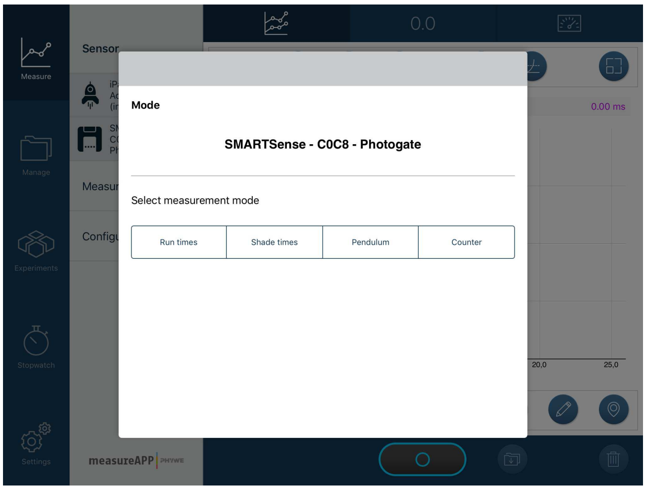


Fig. 3

Position the starter light barrier (A) at the 20-cm mark of the track and the stop light barrier (B) at the 30-cm mark so that there is a distance of 10 cm between them (Fig. 4).

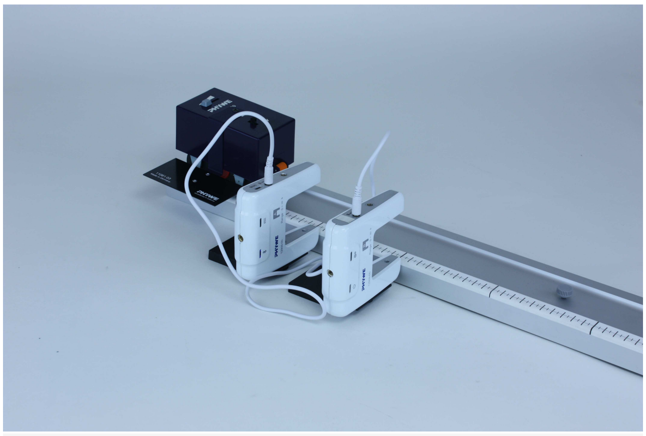


Fig. 4.

With these settings, measureAPP measures the time that the cart needs for covering the light barriers after measurement started.

Procedure

First part of the experiment: low velocity

a) Time of motion between the light barriers

Set the speed slider of the cart to the lowest speed setting (Fig. 5).

Fig. 5

Switch the display mode in measureAPP to the "0.0" option (fig. 6) and start the measurement by pressing on
Start the cart in the desired direction by way of the direction selector switch (fig. 7).
After the shutter plate of the cart has passed through both light barriers, tA and tB indicate at which time after start the cart passed photogate A and B.
Stop the measurement by pressing on .

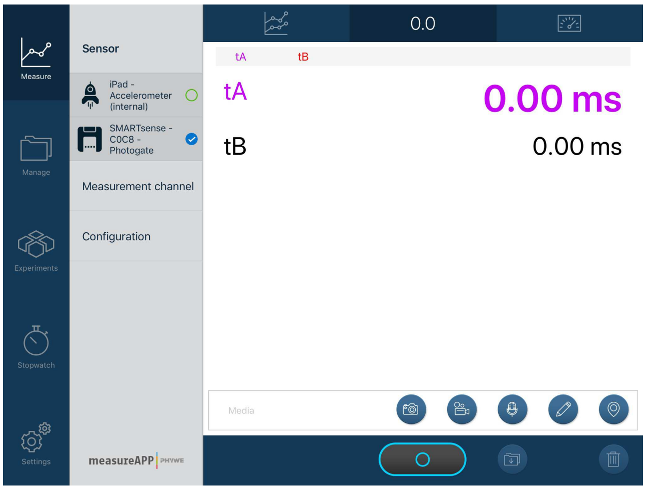


Fig. 6.

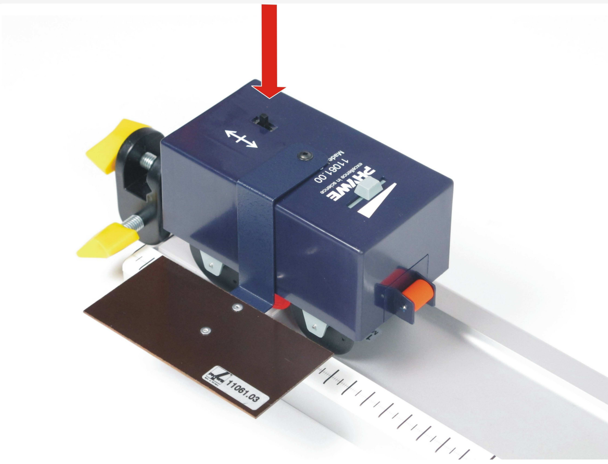


Fig. 7

Calculate the difference between both values, convert the value into seconds, round it to a hundredth of a second (i.e. you need to have two digits after the decimal point), and enter the value into table 1 of the experiment report.

Repeat the measurement with the following positions of the stop light barrier: 40 cm, 50 cm, 60 cm, and 70 cm (the resulting distances between the start light barrier and stop light barrier are 20 cm, 30 cm, 40 cm, and 50 cm).
The start light barrier remains at the 20-cm mark during the entire experiment.

b) Shading time of the stop light barrier

Select "Sensor" > "Configuration" > "Mode" and change the operating mode to "Shade times" and press "Save". As a result, the light barrier will now measure the shading time. You can then calculate the instantaneous velocity based on this shading time (Fig. 8).

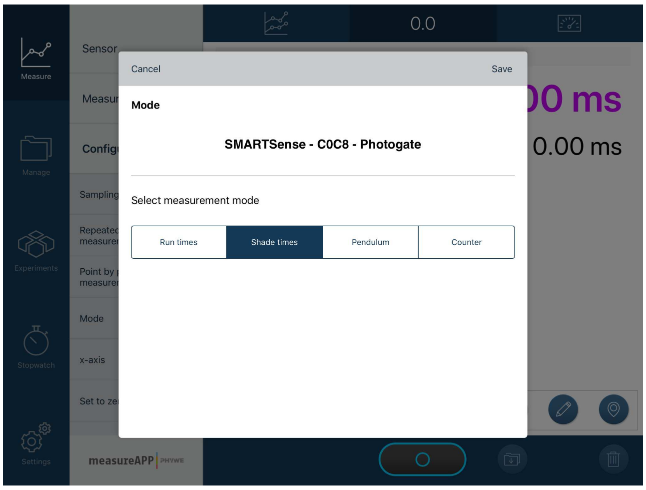


Fig. 11

Press the button to start the measurement and measure the shading times for the same positions of the stop light barriers as in experiment part 1 a).
Enter the values into table 2.

Second part of the experiment: medium velocity

Set the speed slider of the battery-powered cart to the middle position.
Proceed as described in the first part of the experiment. As a result, you will measure

a) the time of motion between the light barriers (note the value into table 3)
and
b) the shading time of the stop light barrier (note the value into table 4)

for all of the light barrier positions.
Do not forget tochange setting of the measureAPP!

Report: Laws of uniform linear motion with SMARTsense

Result - Table 1

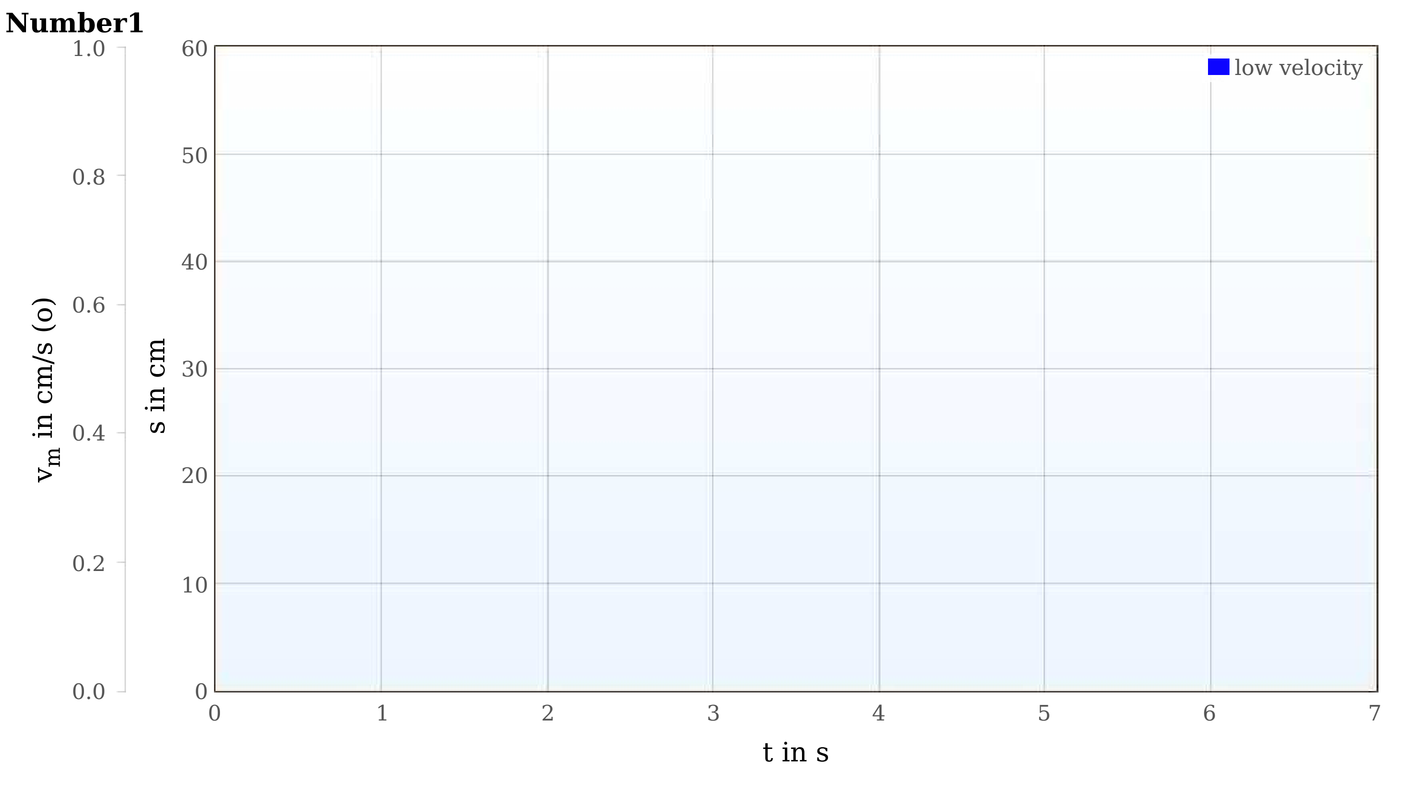
Enter the measurement values for *t* (time that the cart requires for covering the distance *s*) for the low and medium velocity and the shading time Δ*t* into the corresponding columns of the table.

In this case, the measurement distance is the actual distance covered by the cart and not the absolute position of the stop light barrier at the track.

Calculate the average velocities $v_a = s/t$ based on the distances *s* and times *t*.

Then, calculate the resulting instantaneous velocities $v_i = \Delta s/\Delta t$ based on the width of the shutter plate $\Delta s = 10$ cm.

s in cm	*t* in s (low)	Δ*t* in s (low)	v_d in cm/s (low)	v_m in cm/s (low)
10	1 ±0.2	1 ±0.2	1 ±1.5	1 ±1.5
20	1 ±0.4	1 ±0.2	1 ±1.5	1 ±1.5
30	1 ±0.6	1 ±0.2	1 ±1.5	1 ±1.5
40	1 ±0.8	1 ±0.2	1 ±1.5	1 ±1.5
50	1 ±1	1 ±0.2	1 ±1.5	1 ±1.5



Evaluation - Question 1

What are the resulting graph shapes in the distance-time-diagram and velocity-time-diagram?

Describe the graphs.

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Evaluation - Question 2

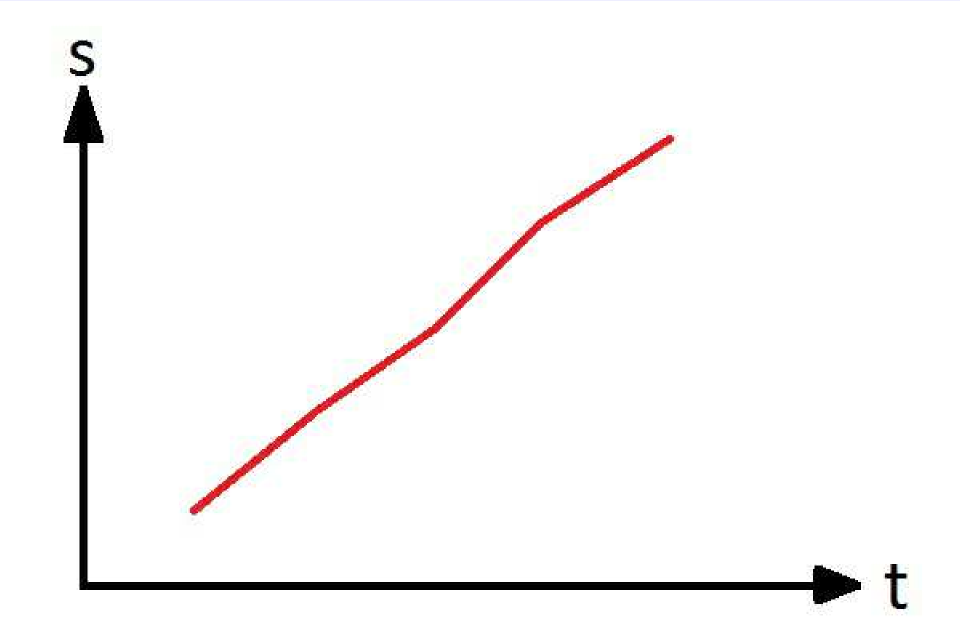
Look at the distance-time-diagram and tick the correct statements!

- ☐ The gradient indicates the velocity of the cart.
- ☐ The gradient indicates the acceleration of the cart.
- ☐ The flatter the line is, the faster the cart will be.
- ☐ The lines end at the same time t.
- ☐ The lines end at the same distance s.

Evaluation - Question 3

Based on the distance-time-diagram, make a drawing that shows how you determine the distance *s* that the cart has covered after a specified time *t*.

Use arrows to indicate how you do this.



Evaluation - Question 4

Tick the correct statements.

- [ ] Since the velocity graphs in the velocity-time-diagram have a gradient of zero, it is a uniform motion.
- [ ] Since the velocity is time-independent, it is a uniform motion.
- [ ] The average velocities correspond rather well to the instantaneous velocities.
- [ ] The instantaneous velocities strongly differ from the average velocities.
- [ ] The slight bends in the distance-time-diagram and velocity-time-diagram are due to measurement errors.
- [ ] The flatter the graph in the distance-time-diagram is, the higher the velocity in the velocity-time-diagram will be.

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