# Analysis of Uniform Linear Motion (Item No.: P6200400)

## Curricular Relevance

**Area of Expertise:** Physics
**Education Level:** Age 14-16
**Topic:** Mechanics
**Subtopic:** Linear Motion
**Experiment:** Analysis of Uniform Linear Motion

| Difficulty | Preparation Time | Execution Time | Recommended Group Size |
|---|---|---|---|
| Difficult | 10 Minutes | 30 Minutes | 2 Students |

**Additional Requirements:**

- Tablet PC with DigiCart App

**Experiment Variations:**

**Keywords:**

Acceleration, Velocity, Kinematics

## Information for teachers

## Introduction

Übersicht Versuchsaufbau.

**Educational objective**
In this experiment, the students learn something about the physical significance of acceleration. They will also learn how to obtain the position-time diagram from a velocity-time diagram.

**Tasks**
1) Use the app to record several speed-time diagrams. Select a measuring range and calculate the acceleration for the recorded curves.

2) Determine the position-time diagram of the movement using the speed-time diagram.

**Prior knowledge**
This experiment requires the concept of velocity and elementary knowledge of integration.

**Principle**
*Acceleration*

Acceleration is one of the basic concepts of kinetics. It indicates how fast an object changes its speed and is measured in the unit $\frac{\mathrm{m}}{\mathrm{s}^2}$.

The concept of acceleration is based on average acceleration. If $\Delta v$ denotes the change of velocity in a period of time $\Delta t$, you can use

$$\bar{a} = \frac{\Delta x}{\Delta t}$$

to calculate the average acceleration $\bar{a}$.

*Momentary velocity*

Speed is one of the basic concepts of kinetics. It indicates how fast an object moves in space and is measured in meters per second.

The concept of instantaneous speed is based on average speed. If $\Delta x$ denotes the change of position in a period of time $\Delta t$, you can use

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

to calculate the average speed $\bar{v}$. If now the time interval $\Delta t$ is made smaller and smaller, it goes over to the infinitesimal object $\mathrm{d}t$ and the quotient of the above formula becomes the time derivative of the position. This is the definition of the instantaneous velocity at a time $t$:

$$v(t) = \frac{\mathrm{d}x}{\mathrm{d}t} = \dot{x}(t)\,.$$

From integration theory it follows for the distance $x$ travelled between times $t_1$ and $t_2$, that

$$x = \int_{t_1}^{t_2} v(t)\ \mathrm{d}t.$$

Since the value of the integral corresponds to the area under the velocity curve, we have the possibility to calculate the distance $x$.

## Equipment

| Position No. | Material | Order No. | Quantity |
|---|---|---|---|
| 1 | DigiCart white | | 1 |
| 2 | 1.2 m track | | 1 |
| 3 | Height adjustable holder | | 1 |
| 4 | DigiCartAPP | | 1 |
| 5 | Weight 20g | | 2 |
| 6 | Weight 10g | | 2 |
| 7 | Film box with cord | | 1 |
| 8 | Brass screw for force sensor | | 1 |

## Safety information

For this experiment, the general instructions for safe experimentation in science teaching apply.


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# Introduction

## Application and task

**Application**
Is it possible to determine the distance travelled from the velocity curve of a motion?

In this experiment you will learn something about the physical significance of acceleration. You will also learn how to get the position-time diagram from a velocity-time diagram.

**Task**
1) Record several speed-time diagrams using the app. Select a measuring range and calculate the acceleration for the recorded curves.

2) Use the velocity-time diagram to determine the position-time diagram of the movement.

## Equipment

| Position No. | Material | Order No. | Quantity |
|---|---|---|---|
| 1 | DigiCart white | | 1 |
| 2 | 1.2 m track | | 1 |
| 3 | Height adjustable holder | | 1 |
| 4 | DigiCartAPP | | 1 |
| 5 | Weight 20g | | 2 |
| 6 | Weight 10g | | 2 |
| 7 | Film box with cord | | 1 |
| 8 | Brass screw for force sensor | | 1 |

# Set-up and procedure

## Set-up

Figure 1: Overview of experimental setup.

- The track must be positioned so that the impeller protrudes beyond the edge of the table. The table should be about 1 m high.
- Bring the track into a horizontal position. Place a 10 gram weight in the film box and close it with the lid. Fasten the cord of the film box to the force sensor of the DigiCart using the brass screw and guide the cord over the wheel of the track.
- Place the film box on the edge of the table.
- Start the DigiCart App.
- Select experiment 4 from the overview. The measurement window opens.
- Connect the DigiCart to the app (see Figure 2). Two steps are required. First, press the ON switch on the DigiCart for at least 3 seconds. Then open the connection window in the app via the bluetooth symbol (1.). The DigiCart should now be displayed there. If not, you can update the list by clicking on scan (2.). Now, one taps the DigiCart from the list once and establishes the connection via the connect button (3.). You can now hide the window again by pressing the Close button (4.).

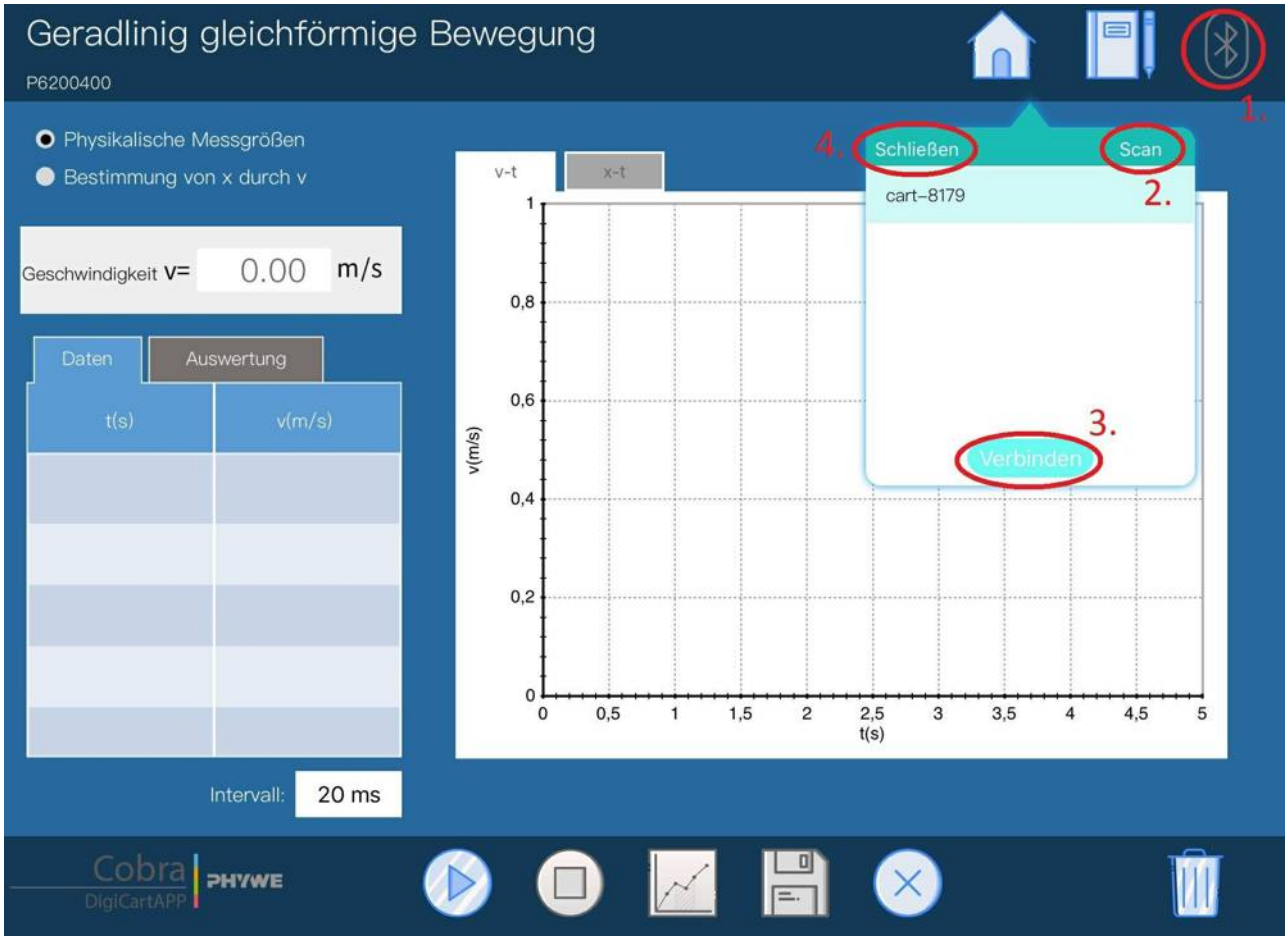


Figure 2: Connecting to the DigiCart.

## Procedure

**Part 1**

- Figure 3 shows the steps for the measurement process.
- Click in the upper left part of the window on the physical measurands button (1.).
- The velocity display below (2.) shows the instantaneous velocity.
- Before each measurement, it is possible to select the time between two measurement points (3.).
- The DigiCart is placed and held at the height-adjustable end.
- The film box with the weight is removed from the table and hangs freely over the edge of the table.
- Start the measurement by clicking on start measurement (4.).
- Let go of the DigiCart. The falling weight causes the DigiCart to move.
- Stop the measurement by clicking on stop measurement (5.) as soon as the DigiCart reaches the end of the track.
- Click on select measurement range (6.) to select a measurement range in the speed-time diagram for which the acceleration is to be calculated. The selection is made by sweeping the interval with the finger.
- Save the measurement by clicking the save button (7.).
- Above the diagram you can switch to the position-time diagram by clicking on the tab "x-t" (8.) to view the temporal course of the position.
- Return the DigiCart to its starting position and increase the weight in the film box by another 10 grams.
- Repeat the last 7 steps until four measurements have been made.
- Continue reading in section evaluation part 1.

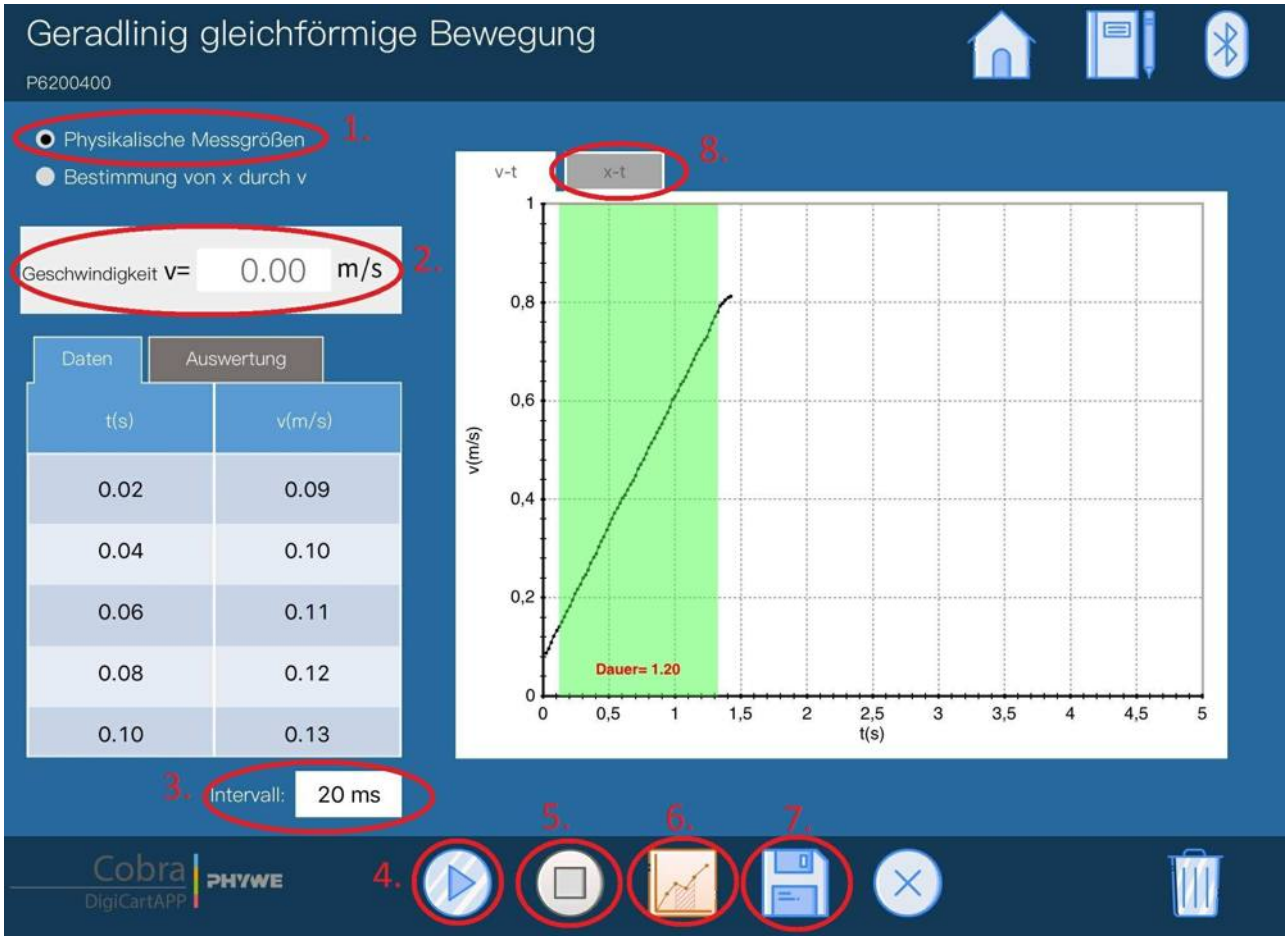


Figure 3: Measurement procedure - Part 1

**Part 2**

- Figure 4 shows the steps for the measurement process.
- Click in the upper left part of the window on the determination of x by v button (1.).
- The DigiCart is placed and held at the height-adjustable end.
- The film box is filled with a 10 gram weight and removed from the table so that it hangs freely over the edge of the table.
- Start the measurement by clicking on start measurement (2.).
- Let go of the DigiCart. The falling weight causes the DigiCart to move.
- Stop the measurement by clicking on stop measurement (3.) as soon as the DigiCart reaches the end of the track.
- Select a point in the velocity-time diagram by clicking on select reference point (4.). The selection is made by sweeping the interval with your finger.
- By clicking the "+" and "-" buttons (5.) a green area appears, which increases with the number. Select the number 1 and then click on the add button (6.).
- Increase the number with the buttons (5.) by the value 1 and click again on add (6.). Repeat this until the table is completely filled with values.
- To delete a row from the table, tap it once and then click the remove button (7.).
- Now click on the tab "x-t" (8.) above the diagram to switch to the position time diagram.
- Continue reading in section evaluation part 2.


Figure 4: Measurement procedure - Part 2

## Evaluation

**Part 1**

- Figure 5 shows the steps for the evaluation.
- The table on the left side (1.) shows for each of the recorded curves the speed change within the selected measuring range as well as the time interval. The acceleration is calculated from this.
- If a single measurement is to be repeated, first tap on the corresponding column in the table. This column turns green. Now delete the values with the delete button (2.) and repeat the measurement.

The acceleration is calculated here as the average acceleration over the selected time interval. You can see that it increases with increasing weight. The higher the weight of the film box is, the stronger the DigiCart is accelerated.

- Continue reading in section procedure part 2.

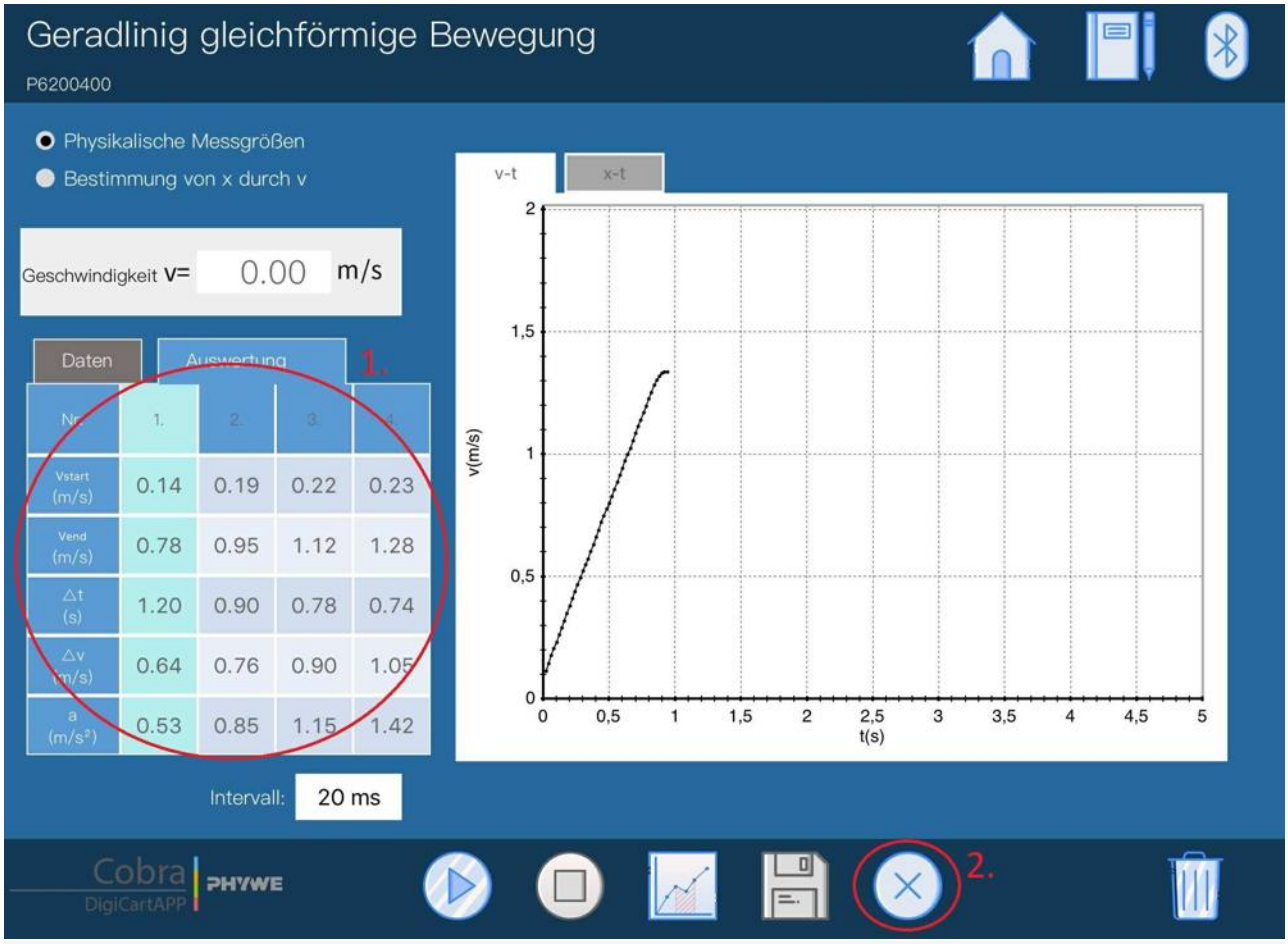


Figure 5: Evaluation procedure - Part 1

**Part 2**

- Figure 6 shows the steps for the evaluation.
- The values from the table are already displayed in the position-time diagram. With a click on draw graph (1.) a curve is laid through the points.

The values calculated in the table for location x correspond to the area between the time axis and the velocity curve in the velocity-time diagram. This is measured from the selected reference point to the end of the green area. The curve drawn in Figure 6 represents the result. The shape of the curve is already known to us from part 1 of the experiment and thus confirms the correctness of the position-time curve obtained here from the speed-time diagram.

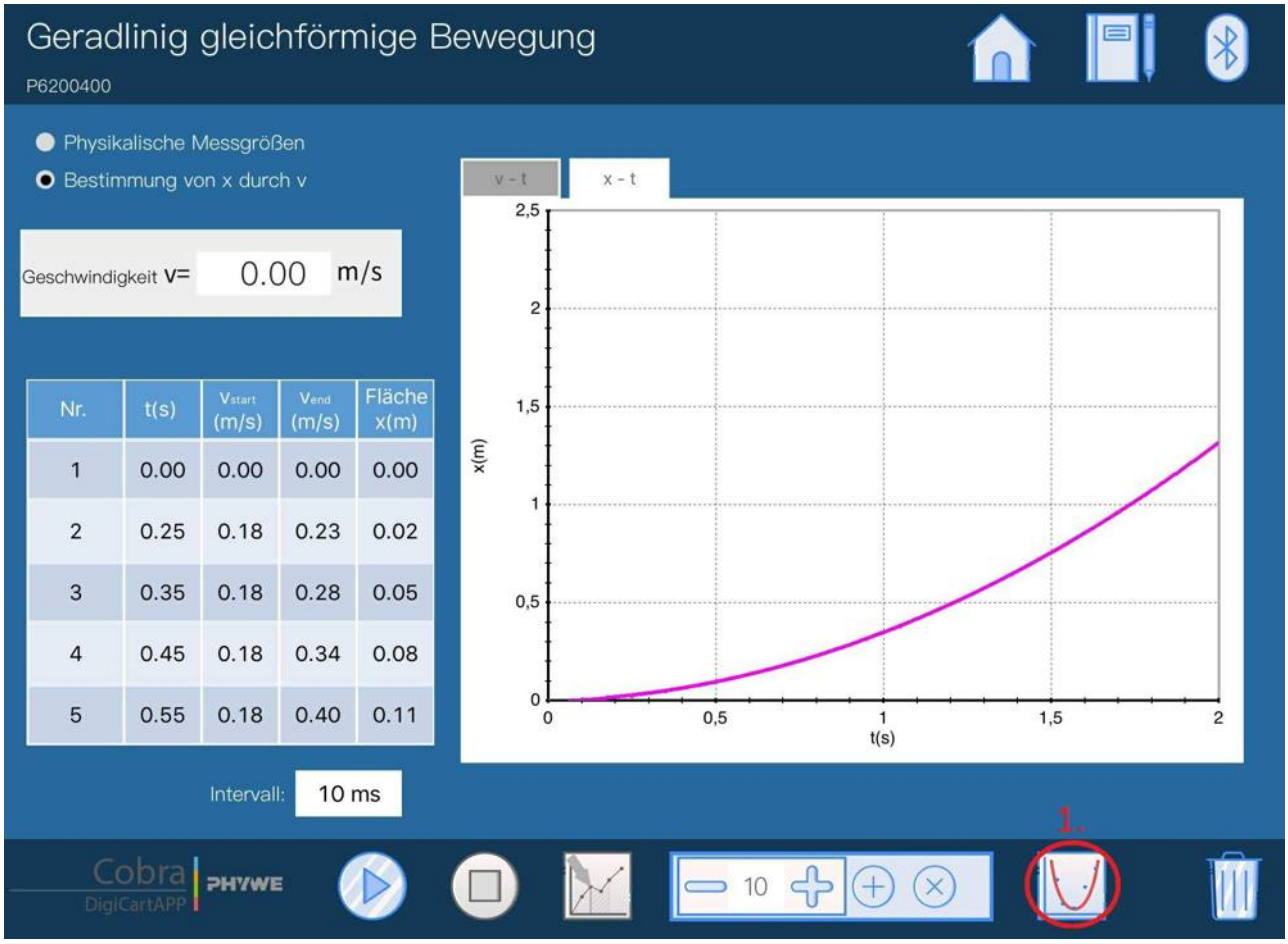


Figure 6: Evaluation procedure - Part 2

# Uniform acceleration

## Results - Evaluation 1 (1 point)

How can you get a body to accelerate on a straight track?

Score is granted based on the occurrence of the following keywords:

- By connecting it, for example, with a freely falling object that pulls on the body.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

## Results - Evaluation 2 (1 point)

On the basis of question 1, how can we increase the acceleration of the body?

Score is granted based on the occurrence of the following keywords:

- By increasing the mass of the free-falling object.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

## Results - Evaluation 3 (1 point)

How do you get a path-time diagram from a velocity-time diagram?

Score is granted based on the occurrence of the following keywords:

- Determine the area below the velocity curve (the area enclosed by the time axis and the curve).

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

## Results - Evaluation 4 (1 point)

Why is the reference point necessary?

Score is granted based on the occurrence of the following keywords:

- The reference point defines the zero position. The displacement is to be calculated from this point.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE



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