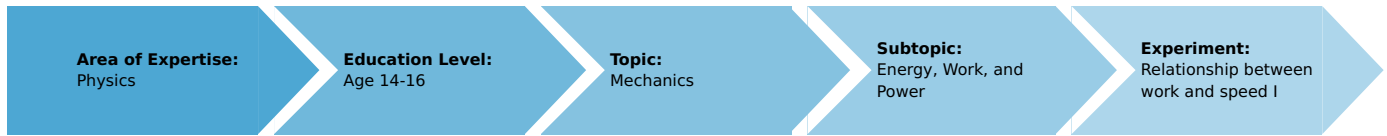


Relationship between work and speed I (Item No.: P6200700)

Curricular Relevance



Difficulty



Intermediate

Preparation Time



10 Minutes

Execution Time



20 Minutes

Recommended Group Size



2 Students

Additional Requirements:

- Tablet PC with DigiCart App

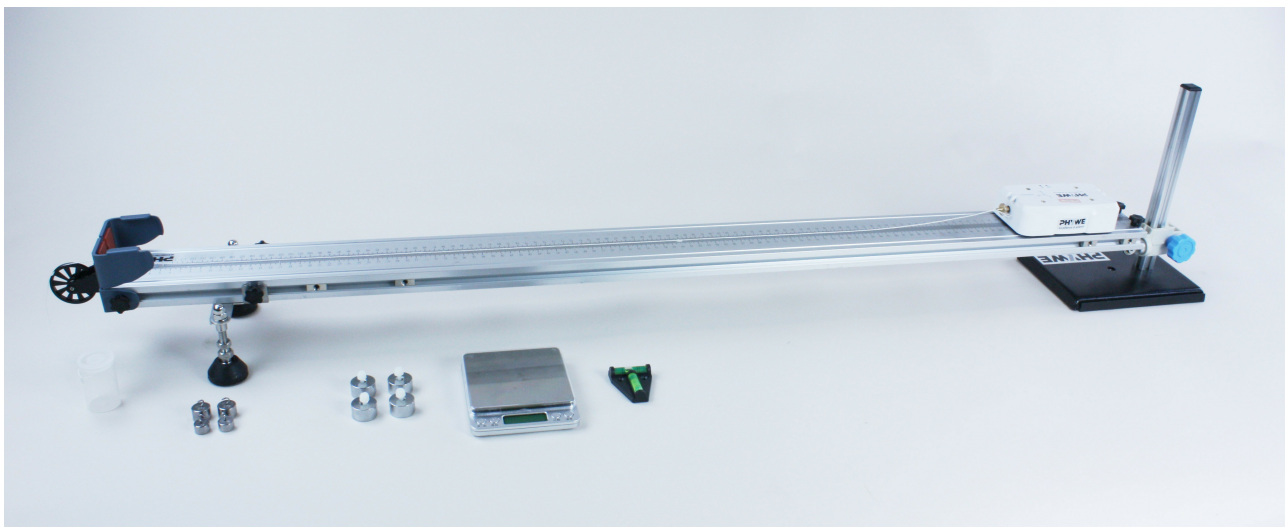
Experiment Variations:

Keywords:

Kinetic energy, Work, Energy conversion

Information for teachers

Introduction



Overview experimental setup.

Educational objective

In this experiment, students learn about the mathematical relationship between mechanical work and speed.

Tasks

1) Accelerate the DigiCart several times at a constant mass using different forces on a defined distance and analyze the relationship between the mechanical work performed and the velocity.

2) Accelerate the DigiCart with a constant force on different defined distances and analyze the relationship between mechanical work and velocity.

Prior knowledge

This experiment requires the concept of kinetic energy and physical work.

Principle

Kinetic Energy

For the kinetic energy E_{kin} of a body of mass m and velocity v the following equation applies

$$E_{\text{kin}} = \frac{1}{2} \cdot m \cdot v^2 .$$

If the body accelerates from the velocity v_1 to the velocity v_2 , the energy increase is as follows

$$\Delta E_{\text{kin},1 \rightarrow 2} = E_{\text{kin},2} - E_{\text{kin},1} .$$

Work

If the force F acts on a body on a distance s , the work W carried out on it is calculated as follows

$$W = F \cdot s .$$

So work is energy that is transferred to a body by forces. It is important that the force acts along the travelled path.

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	Weight 50g		4
8	Plastic screw		4
9	Film box with cord		1
10	Brass screw for force sensor		1
11	Scale		1
12	Spirit level		1

Safety information

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

Introduction

Application and task

Application

In this experiment you will learn something about the mathematical relationship between mechanical work and speed.

Tasks

1) Accelerate the DigiCart several times at constant mass by different forces on a defined distance and analyze the relationship between the mechanical work performed and the velocity.

2) Accelerate the DigiCart by a constant force on defined distances of different lengths and analyze the relationship between mechanical work performed and velocity.

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	Weight 50g		4
8	Plastic screw		4
9	Film box with cord		1
10	Brass screw for force sensor		1
11	Scale		1
12	Spirit level		1

Set-up and procedure

Set-up

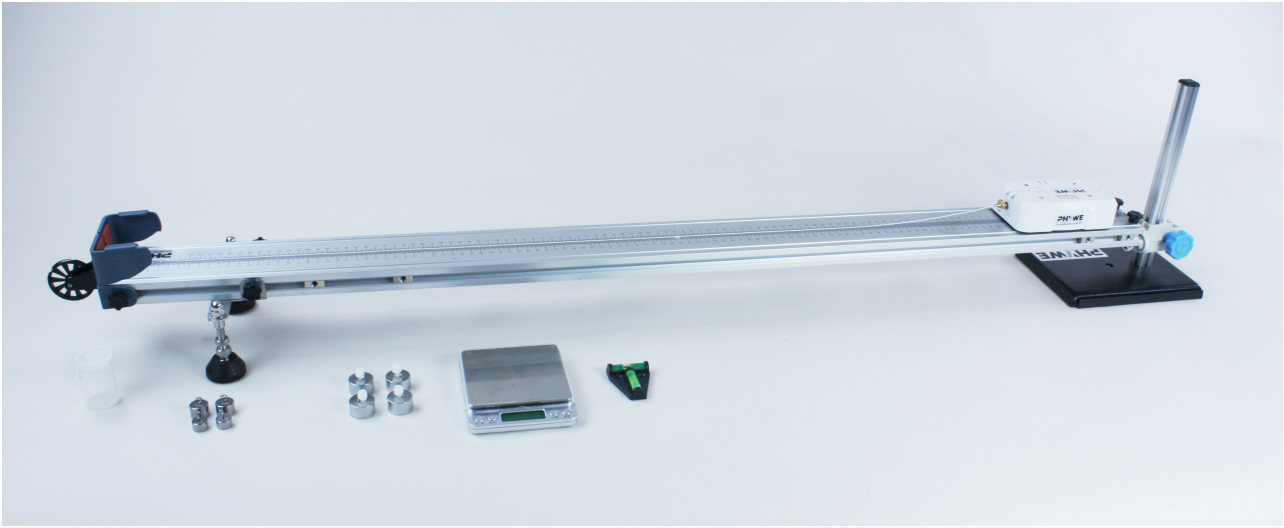
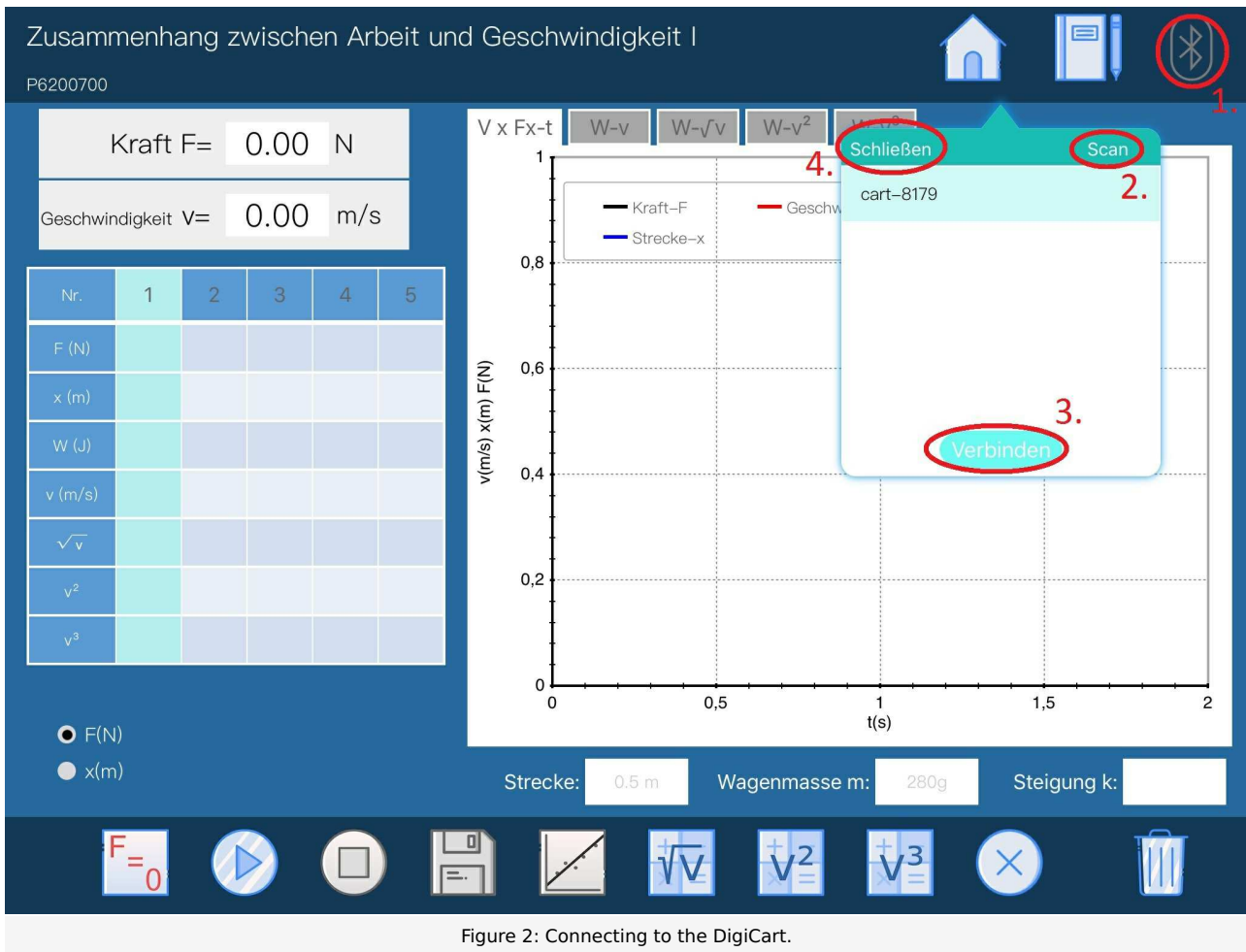


Figure 1: Overview of experimental setup.

- Fix the four 50 gram additional weights on the DigiCart using the plastic screws.
- Use the scale to weigh the weight of the DigiCart. Make sure you also weigh the brass screw on the force sensor.
- The track must be positioned so that the impeller protrudes beyond the edge of the table. The table should be about 1 m high.
- Place the track in a horizontal position and place the DigiCart on it. 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 impeller at the end of the track.
- Place the film box on the edge of the table.
- Start the DigiCart App.
- Select experiment 7 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.).



Procedure

Part 1

- Figure 3 shows the steps for the measurement process.
- Click on the button "F(N)" (1.) in the lower left part of the window.
- The force and velocity display (2.) shows the instantaneous force and the instantaneous velocity.
- Enter the mass of the DigiCart in the car mass field (3.).
- The value 0.5 meter is entered in the distance field (4.). This is the distance on which we want to measure the mechanical work.
- The force at the sensor is now set to zero via the calibration button (5.). It must be ensured that the thread is not tensioned and that no force is acting on the sensor.
- 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 (6.).
- Let go of the DigiCart. The falling weight causes the DigiCart to move.
- The measurement ends automatically after the distance travelled is 0.5 meters.
- Click on the save button (7.). The measured values are transferred to the table.
- Increase the weight of the film box by 10 grams. Then repeat the last 6 steps.
- Repeat the measurement until you have made five measurements. After each measurement, the weight must be increased by another 10 grams.
- To delete a column from the table, touch it and then click the delete button (8.). By a further measurement the column can

be filled with new values.

- Continue reading in section evaluation part 1.

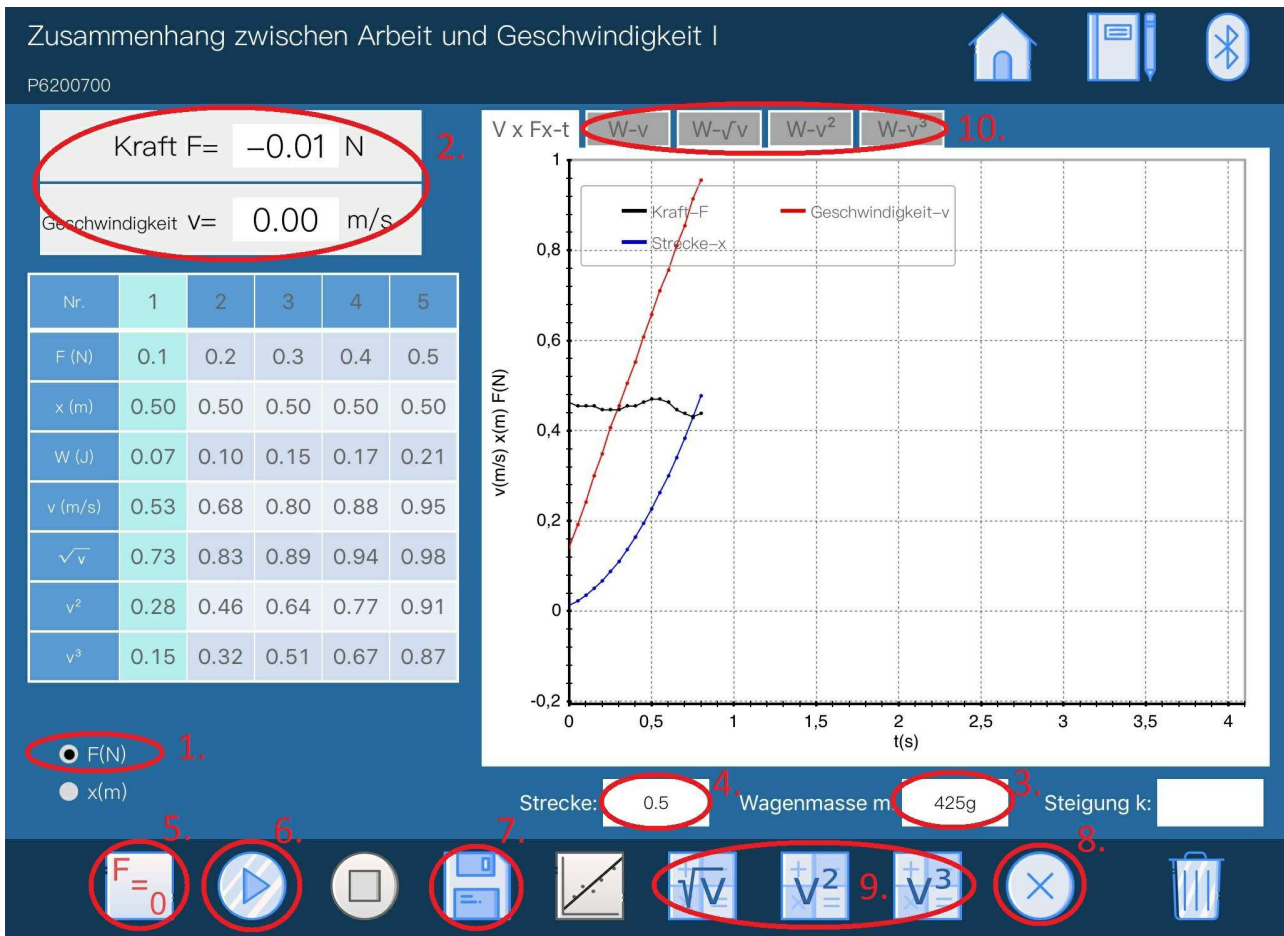
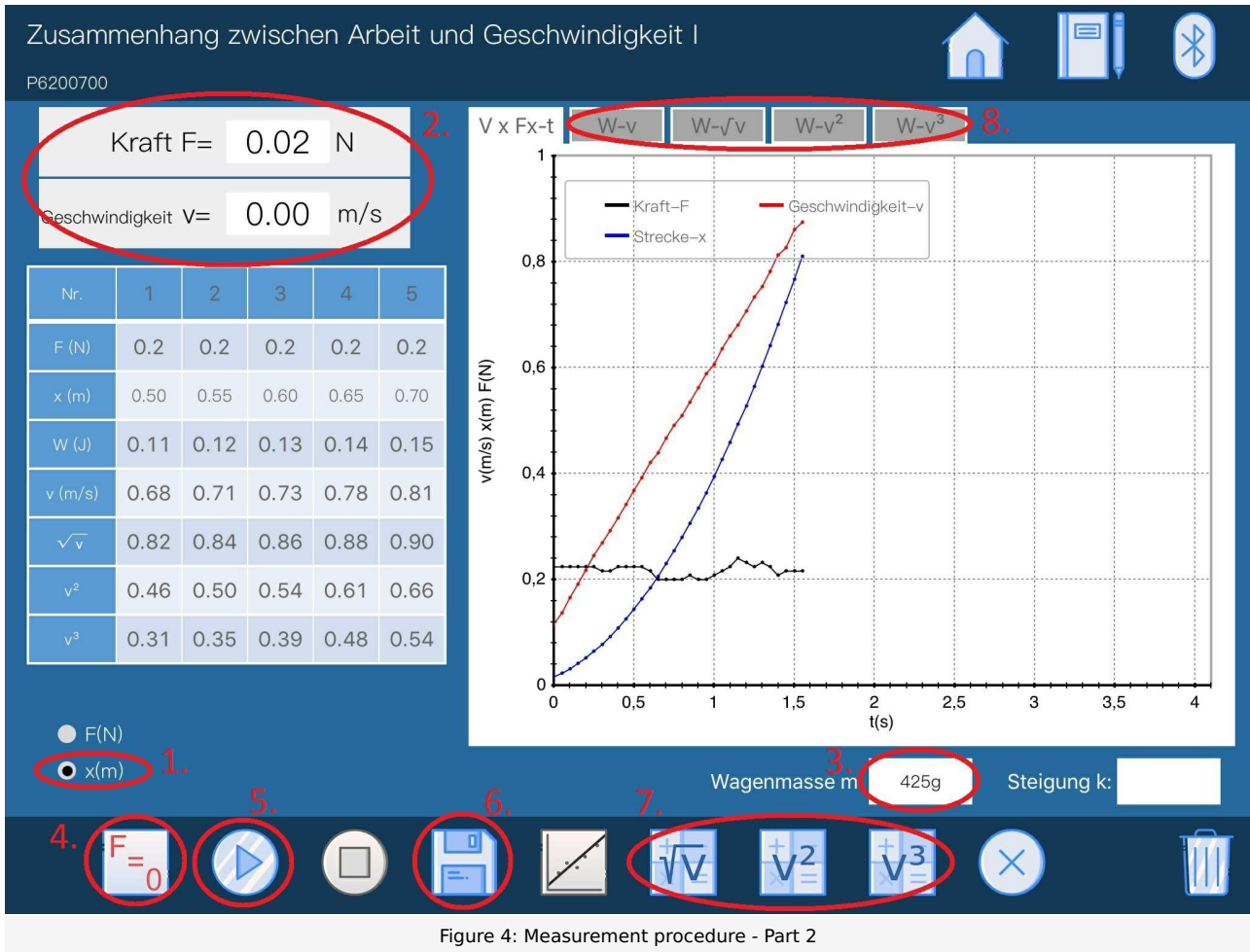


Figure 3: Measurement procedure - Part 1

Part 2

- Figure 4 shows the steps for the measurement process.
- Click on the button "x(m)" (1.) in the lower left part of the window.
- The force and velocity display (2.) shows the instantaneous force and the instantaneous velocity.
- Enter the mass of the DigiCart in the car mass field (3.).
- The film box is filled with a 20 gram weight and placed closed on the table.
- The force at the sensor is now set to zero via the calibration button (4.). It must be ensured that the thread is not tensioned and that no force is acting on the sensor.
- 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 (5.).
- Let go of the DigiCart. The falling weight causes the DigiCart to move.
- The measurement ends automatically after the distance covered is 0.7 meters.
- Click on the save button (6.). The measured values are transferred to the table.
- Continue reading in section evaluation part 2.



Evaluation

Part 1

- Figure 3 shows the steps for the evaluation.
- Click on the buttons " \sqrt{v} ", " v^2 " and " v^3 " (9.) in order to calculate the corresponding values from the velocity and enter them in the table.
- Now click on a tab (10.) above the diagram.
- Figure 5 shows the further steps for the evaluation.
- The corresponding points from the table can already be seen in the diagram. Select straight line (1.) to insert a straight line through the point.
- Proceed in this way with all tabs above the diagram.
- In the field slope (2.) the slope of the calculated straight line is displayed.

The mechanical work was done by the falling weight, it applies $W = F \cdot x$. In this part of the experiment, the work performed was varied by varying the effective force F (x remained constant at 0.5 metres). The work done was converted into kinetic energy, i.e. $W = E_{kin} = 0.5 \cdot m \cdot v^2$.

If you look at the drawn lines, you can see that only under the tab " $W - v^2$ " the points follow the line approximately. This is confirmed by the above formula that the work done is proportional to the square of the velocity, $W = 0.5 \cdot m \cdot v^2$. The value of the slope in the " $W - v^2$ " diagram was 0.224. This corresponds approximately to half the mass of the DigiCart, as predicted by the above formula.

- Continue reading in section measurement part 2.

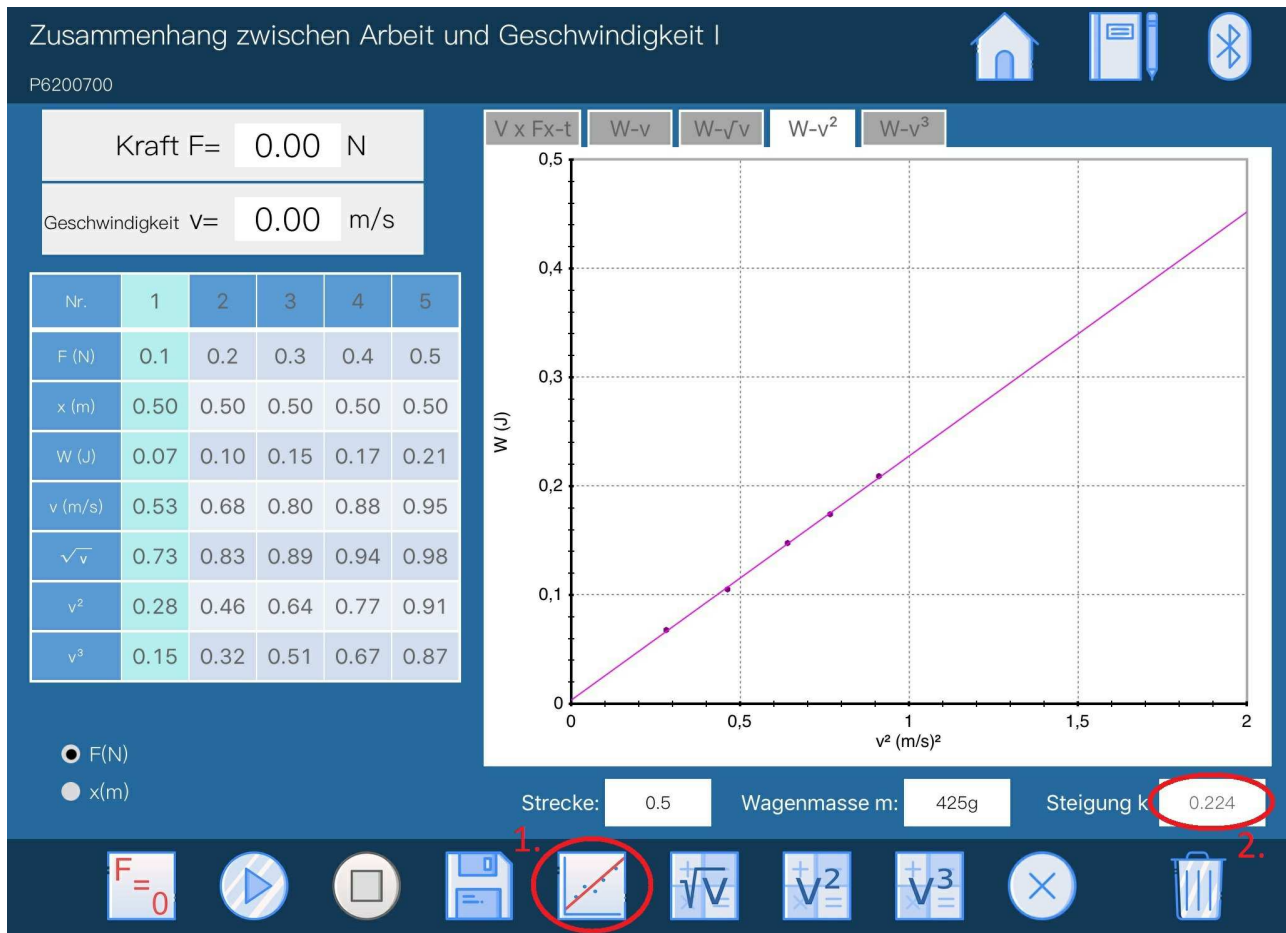


Figure 5: Evaluation procedure - Part 1

Part 2

- Figure 4 shows the steps for the evaluation.
- Click on the buttons " \sqrt{v} ", " v^2 " and " v^3 " (7.) in order to calculate the corresponding values from the speed and enter them in the table.
- Now click on a tab above the diagram (8.).
- Figure 6 shows the further steps for the evaluation.
- The corresponding points from the table can already be seen in the diagram. Select straight line (1.) to pass a straight line through the point.
- Proceed in this way with all tabs above the diagram.
- In the field slope (2.) the slope of the calculated straight line is displayed.

The mechanical work was done by the falling weight, it applies $W = F \cdot x$. In this part of the experiment, the work performed was varied by varying the distance x (F remained constant). The work done was converted into kinetic energy, i.e. $W = E_{kin} = 0.5 \cdot m \cdot v^2$.

If you look at the drawn lines, you can see that only under the tab " $W - v^2$ " the points follow the line approximately. All other straight lines deviate strongly from the points. This is confirmed by the above formula that the work done is proportional to the square of the velocity, $W = 0.5 \cdot m \cdot v^2$. The value of the slope in the " $W - v^2$ " diagram was 0.218. This corresponds approximately to half the mass of the DigiCart, as predicted by the above formula.

Zusammenhang zwischen Arbeit und Geschwindigkeit I

P6200700

Kraft $F = 0.00$ N

Geschwindigkeit $v = 0.00$ m/s

Nr.	1	2	3	4	5
F (N)	0.2	0.2	0.2	0.2	0.2
x (m)	0.50	0.55	0.60	0.65	0.70
W (J)	0.11	0.12	0.13	0.14	0.15
v (m/s)	0.68	0.71	0.73	0.78	0.81
\sqrt{v}	0.82	0.84	0.86	0.88	0.90
v^2	0.46	0.50	0.54	0.61	0.66
v^3	0.31	0.35	0.39	0.48	0.54

F(N)
 x(m)

Wagenmasse m: 425g Steigung l: 0.218

1. 2.

Figure 6: Evaluation procedure - Part 2

Relationship between work and speed I

Results - Evaluation 1 (1 point)

What work is done on a distance of 1 metre when the acting force is along the path and is 10 N?

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

- $W=F*x=10\text{ J}$.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 2 (1 point)

In the $W - v^2$ diagram the points were on a straight line. What is the slope of this straight line?

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

- Since $W=0.5*m*v^2$, the slope is given by $0.5*m$.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 3 (1 point)

Which forms of energy were converted into each other in this experiment?

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

- The potential energy of the film box was converted into kinetic energy of the DigiCart.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 4 (1 point)

Which formula can be used to calculate the kinetic energy?

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

- $0.5 \cdot m \cdot v^2$, where m is the mass of the body and v its velocity.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE