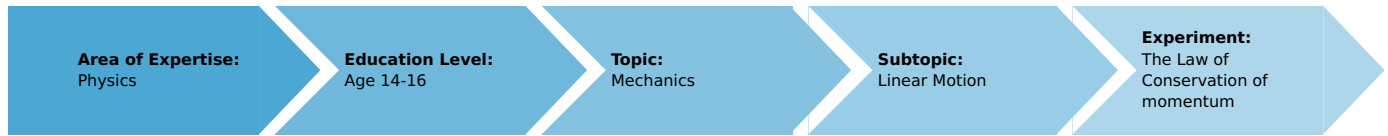


The Law of Conservation of momentum (Item No.: P6201000)

Curricular Relevance



Difficulty



Difficult

Preparation Time



10 Minutes

Execution Time



30 Minutes

Recommended Group Size



2 Students

Additional Requirements:

- Tablet PC with DigiCart App

Experiment Variations:

Keywords:

Momentum, Conservation of momentum, Newton's second law

Information for teachers

Introduction



Overview experimental setup.

Educational objective

In this experiment the students learn something about the physical concept of impulse and energy conservation. They can carry out the elastic as well as the inelastic collision.

Task

- 1) Perform an elastic collision with both DigiCart. Analyze the momentum and energy change of the system before and after the collision.
- 2) Perform an inelastic collision with both DigiCart. Analyze the momentum and energy change of the system before and after the collision.

Prior knowledge

This experiment requires prior knowledge of the momentum and of Newton's second law. The students should also have understood the concept of a closed system.

Principle

Momentum

For a body with mass m and velocity v the momentum p is defined as

$$p = m \cdot v.$$

Conservation of momentum

Newton's second law states that the temporal change of the momentum corresponds to the acting external force:

$$\dot{p} = \frac{dp}{dt} = F$$

The total momentum of a system is thus conserved exactly when no external forces are acting. The total momentum is constant at all times. In the following, two different collision types are presented. A collision is a physical process in which two or more bodies briefly exert force on each other.

Collision processes

Elastic collision

Two bodies meet without energy being converted into heat or deformation. The energy of this collision thus remains constant.

Inelastic collision

Two bodies meet and energy is converted into heat or deformation. The energy of this impact is therefore not constant.

If no external forces act, the total momentum of the system before and after the collision is constant, i.e.

$$p_{\text{before}} = p_{\text{after}}.$$

Equipment

Position No.	Material	Order No.	Quantity
1	DigiCart		2
2	1.2 m track		1
3	Height adjustable holder		1
4	DigiCartAPP		1
5	Weight 50g		4
6	Plastic screws		4
7	Magnetic bumpers with screw		1
8	Velcro bumpers with screw		1
9	Rubber bands		1
10	Scale		1
11	Spirit level		1

Safety information

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

Introduction

Application and task

Application

In billiards you try to pocket a coloured ball with the help of the white ball. Physically, this situation represents a collision.

In this experiment you will learn something about the physical concept of momentum and energy conservation. You can perform the elastic as well as the inelastic collision.

Task

- 1) Perform an elastic collision with both DigiCart. Analyze the momentum and energy changes of the system before and after the collision.
- 2) Perform an inelastic collision with both DigiCart. Analyze the impulse and energy changes of the system before and after the collision.

Equipment

Position No.	Material	Order No.	Quantity
1	DigiCart		2
2	1.2 m track		1
3	Height adjustable holder		1
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Set-up and procedure

Set-up

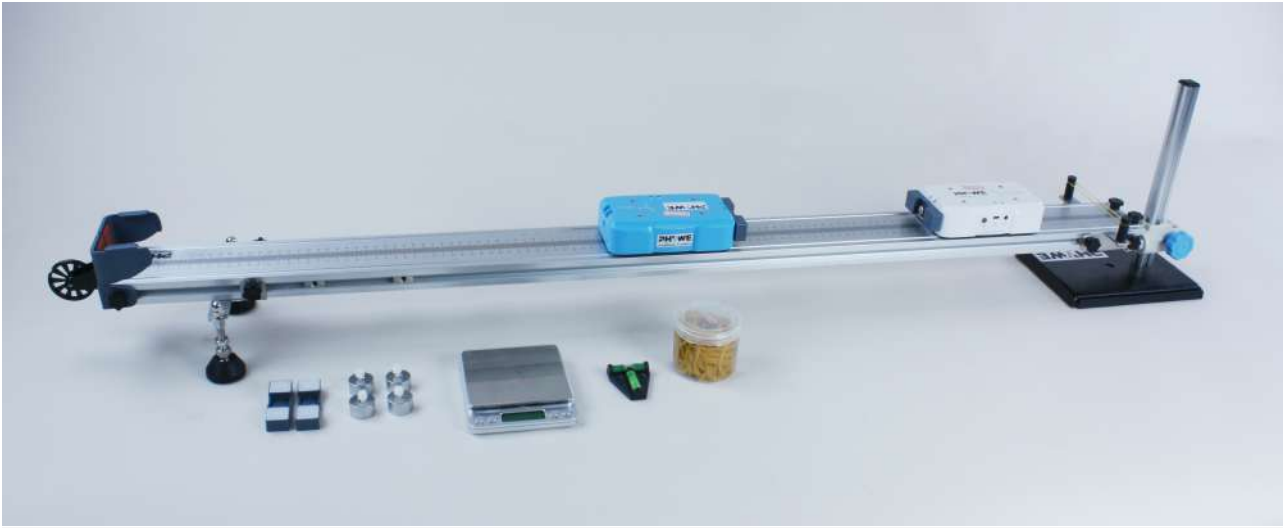


Figure 1: Overview of experimental setup.

- Bring the track into a horizontal position using the spirit level. At the end of the track, tighten a rubber band on the black cylinders provided for this purpose.
- Place two additional 50 gram weights on each DigiCart and fix them with the plastic screws. Then weigh both cars and note the weight.
- Mount a magnetic bumper to each of the two DigiCart and fix it with the screws. Place both DigiCart's on the track so that the bumpers face each other and meet north to north pole and south to south pole (cars should repel each other as they approach).
- Start the DigiCart App.
- Select experiment 10 from the overview. The measurement window opens.
- Connect both DigiCart units to the app (see Figure 2). This requires two steps. 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.). Both DigiCart should now be displayed there. If not, you can update the list by clicking on scan (2.). Now, one taps a DigiCart from the list once and establishes the connection via the connect button (3.). Proceed in the same way with the other DigiCart. You can now hide the window again by pressing the close button (4.).

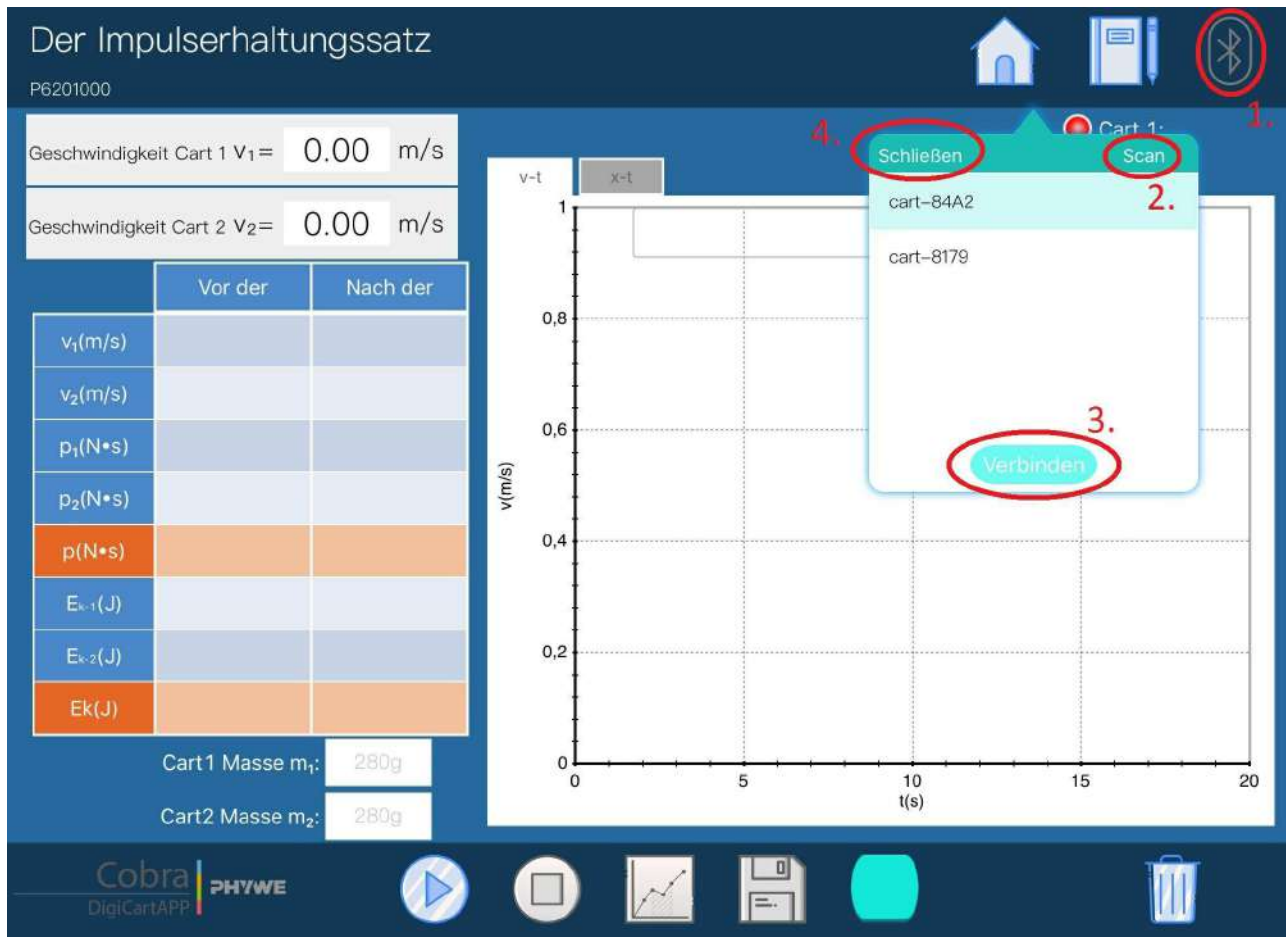


Figure 2: Connecting to the DigiCart.

Procedure

Part 1 (elastic collision)

- Figure 3 shows the steps for the measurement process.
- The speed display (1.) shows the instantaneous speed of the two DigiCarts.
- Enter the masses of both DigiCart units in the fields provided (2.).
- Place a DigiCart in the middle of the track (carriage 2). Press the other DigiCart into the tensioned rubber band so that it is tensioned and held (carriage 1).

Important: The bumpers are still facing each other in such a way that the North Pole points to the North Pole and the South Pole points to the South Pole.

- Start the measurement by clicking on start measurement (3.).
- Let go of car 1 so that it moves towards car 2.
- The measurement can be stopped by clicking on stop measurement (4.) as soon as carriage 2 reaches the end of the track.
- By clicking on select measuring range (5.), select the range in the velocity-time diagram in which the collision takes place. The range should start shortly before the impact and end shortly after the impact (see Figure 3). The selection is made by sweeping the interval with the finger.
- Save the measurement by clicking the save button (6.). The values are now written to the left table.
- Continue reading in section evaluation.



Figure 3: Measurement procedure - Part 1

Part 2 (inelastic collision)

- Replace the magnetic bumpers of both cars with the Velcro bumpers.
- Figure 4 shows the steps for the measurement process.
- The speed display (1.) shows the instantaneous speed of the two DigiCarts.
- Enter the masses of both DigiCart units in the fields provided (2.).
- Place a DigiCart in the middle of the track (carriage 2). Press the other DigiCart into the tensioned rubber band so that it is tensioned and held (carriage 1).

Important: The bumpers are still facing each other. In the collision they get stuck together by the Velcro fastener.

- Start the measurement by clicking on start measurement (3.).
- Let go of car 1 so that it moves towards car 2.
- The measurement can be stopped by clicking on stop measurement (4.) as soon as carriage 2 reaches the end of the track.
- By clicking on select measuring range (5.), select the range in the velocity-time diagram in which the collision takes place. The range should start shortly before the collision and end shortly after the collision (see figure 4). The selection is made by sweeping the interval with the finger.
- Save the measurement by clicking the save button (6.). The values are now written to the left table.



Figure 4: Measurement procedure - Part 2

Evaluation

- Figure 3 or 4 shows the steps for the evaluation.
- Click on the calculate button (7.) to fill the table with values.
- The table shows the velocities v_1 and v_2 of both DigiCarts before and after the collision. In addition, their impulses p_1 and p_2 are calculated before and after the impact. This results in the value of the total impulse of the system of both cars before and after the impact, stored in red.
- In addition, the kinetic energy of both DigiCarts is calculated before and after the collision. This results in the red value of the total energy of the system of both cars before and after the impact.
- By clicking on the tab "x-t" above the diagram (8.) you can switch to the path time diagram. Try to reconstruct the movements of the DigiCarts using the diagram.
- Repeat the elastic and inelastic impact also for different masses of DigiCarts by distributing the additional weights differently to the carts.

Part 1

If one compares the values of the total momentum of the system before and after the collision with each other, it can be seen that these correspond in good approximation. The same can be seen with the total energy of the system. It has the same value before and after the collision. The momentum and the energy are thus conserved in the elastic collision.

Part 2

If one compares the values of the total momentum of the system before and after the collision with each other, it can be seen that these correspond in good approximation. But this time this does not apply to the total energy of the system. It has different values before and after the collision. The momentum is thus conserved for the inelastic collision, but the energy is not. Losses occur.

The Law of Conservation of momentum

Results - Evaluation 1 (1 point)

How can the impulse p be calculated?

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

- $p=m*v$, where m is the mass and v the velocity.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 2 (1 point)

At which type of collision is the energy conserved?

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

- At the elastic collision.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 3 (1 point)

At which type of collision is the impulse conserved?

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

- At the elastic and inelastic collision.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 4 (1 point)

Which processes cause energy to be lost during inelastic collisions?

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

- Energy is used, for example, for deformation work. In addition, an inelastic impact generates heat.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 5 (1 point)

Under what conditions is the momentum of a physical system conserved (Hint: 2. Newton's law)?

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

- According to Newton's second law, $dp/dt = F$ applies. The momentum does not change if no external forces act on the system.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE