Impuls mit SMARTsense (Item No.: P1004469)

Curricular Relevance

Area of Expertise: Physics → **Education Level:** Age 16-19 → **Topic:** Mechanics → **Subtopic:** Energy and momentum → **Experiment:** Momentum with SMARTsense

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

Additional Requirements:

- Tablet

Experiment Variations:

- Classic student experiment: Momentum (P1004400)
- Classic student experiment: Momentum with the 2-1 timer (P1004105)

Keywords:

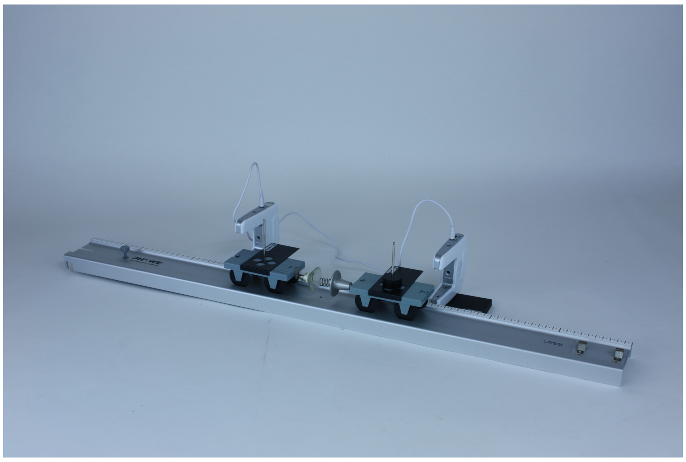
momentum, conserved quantity, collision

Information for teachers

Introduction

Application
The momentum is a fundamental conserved quantity in physics.
An interesting application of the law of conservation of momentum can be found at goods stations, for example, where goods waggons roll down a hump, collide with other waggons, and continue their movement either together with other waggons or alone at a different speed.


Canon


Experiment set-up

Education objective
The aim of this experiment is to familiarise the students with the concept of momentum as a fundamental conserved quantity and to provide them with an initial idea of the usefulness of the conserved quantity for calculations.
Another aim is to hint at the fact that the momentum, just like the velocity, has a direction (vector quantity) in contrast to substance-like (scalar) quantities such as mass.

Tasks

1. The students connect two carts at rest having the same mass m to an equiforce launcher (spring with a suction cup) so that both carts are started in a sudden manner. The two carts pass through a light barrier that measures the respective

shading times $\Delta t1$ and $\Delta t2$. The students record three measurement values.

2. The students increase the masses of both carts in an identical manner and they repeat the measurements.
3. The students then reduce the mass of one of the carts so that one cart is heavier than the other and they repeat the experiment.
4. The students calculate average values based on the shading times and they use these average values and the width of the shutter plate to calculate the velocity of the two carts.
5. When answering the questions in the experiment report, the students should realise that momentum is a conserved quantity.

Prior knowledge
The students should be familiar with the concepts of velocity and motion.
They should be proficient in working with equations.

Principle
Before the start, both carts are at rest and the individual momenta of the carts as well as the total momentum of the combined system of carts are zero.
The potential energy stored in the equiforce launcher sets the carts into motion when the experiment is started.
In accordance with the law of conservation of momentum, the sum of the signed individual momenta remains zero after the start. The velocity of the carts also results from law of conservation of momentum $0 = m1 \cdot v1 + m2 \cdot v2$.

Note
In order to prevent the carts from skidding, it may be useful to shift the centre of gravity of the carts more towards the middle by way of a counterweight (with regard to the parts of the equiforce launcher): Connect a socket element for 4-mm plugs 11060-11 and therein a tube with plug 11202-05 to the cart ends facing away from the equiforce launcher. This increases the mass of the carts by 12 g, i.e. the basic set-up of the carts then weights 94 g instead of 82 g.

However, the values measured by PHYWE refer to the standard set-up of the carts: The results of the table must be adapted accordingly.

Safety instructions

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

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Versuch: Impuls mit SMARTsense (Item No.: P1004469)

Introduction

Application and task

What is momentum in physics?

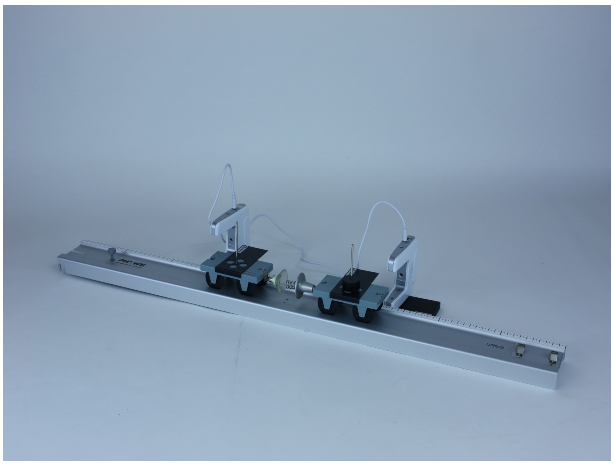
Introduction
Surely, you have already taken a ride in a bumper car at a funfair or amusement park where you have collided with other cars with a lot of momentum.
During the collision, your direction and speed have changed, depending on the impact angle, mass (of both carts), and impact speed.
How are all of these quantities interconnected?
After the completion of this experiment, you should be able to answer this question.

Application
At a goods station, waggons roll down a hump and collide with standing waggons. Then, all of the waggons continue to move at a lower speed: The velocity (or speed) can be calculated with the help of the law of conservation of momentum.
The recoil of a canon after it has been fired can also be explained and calculated with the help of the law of conservation of momentum.

Canon at the Edersee lake in Germany

Tasks

1. Connect two carts at rest having the same mass m to an equiforce launcher (spring with a suction cup) so that both carts are started in a sudden manner. The two carts pass through a light barrier that measures the respective shading times Δt_1 bzw. Δt_2. Record three values.
2. Increase the masses of both carts with a slotted weight of 50 g and repeat the measurements.
3. Remove one of the slotted weights (50 g) from one of the carts and repeat the experiment.
4. Calculate the average values of the shading times (Δt_1 and Δt_2) of the light barriers and use these values to calculate the velocities of the carts (v_1 and v_2).Enter the values into table 1. Use these values to answer the questions in the experiment report.



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	Cart for measurements and experiments	11060-00	2
4	Shutter plate for cart	11060-10	2
5	Holding pin	03949-00	2
6	Cobra SMARTsense - Photogate, 0 ... ∞ s	11207-20	1
7	Adapter plate for Light barrier compact	11207-22	2
8	Slotted weight, black, 50 g	02206-01	2
9	Slotted weight, black, 10 g	02205-01	1
10	Plug 4 mm, for cart, 2 pcs.	11060-11	1
11	Equiforce launcher	11311-00	1

Set-up and procedure

Set-up

Unscrew the screw in the middle of the track and put it to the side (Fig. 1).

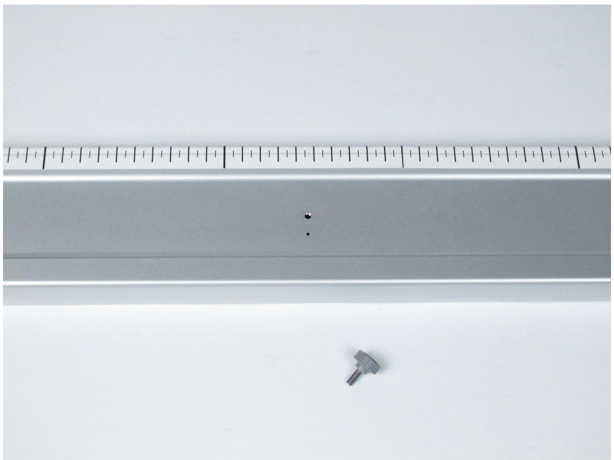


Fig. 1

Equip both of the carts with a socket element for 4-mm plugs (Fig. 2). Fasten the parts of the equiforce launcher in the socket elements for 4-mm plugs. Equip both carts with a holding pin and fasten a shutter plate to each of the pins (Fig. 3).

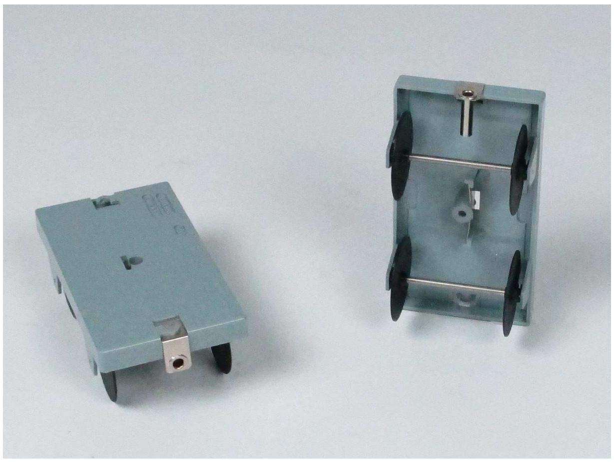


Fig. 2

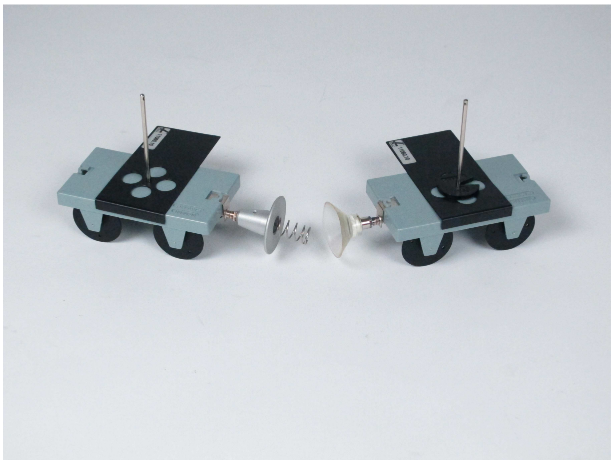


Fig. 3

The plate with the spring is 10 g heavier than the suction cup. This is why, as the basic set-up, the cart with the suction cup is equipped with a slotted weight of 10 g so that both carts have the same mass.

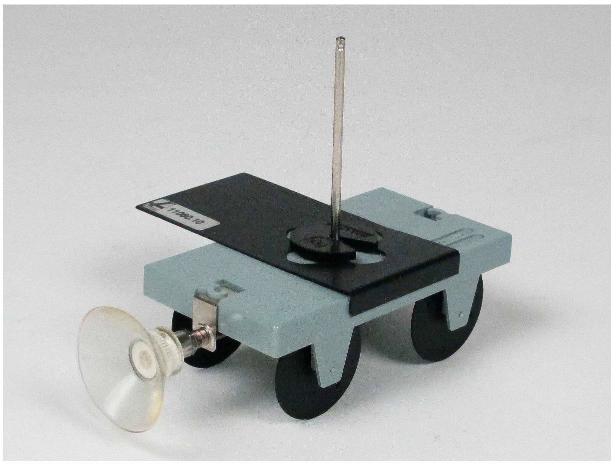


Fig. 4

Connect the light barriers to the adapter plates so that they can be set up along the track. Ensure that the shutter plate of the cart can pass through the light barriers without touching them. Set them in the middle of the track with a distance of 30 cm (fig. 5).

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. 6).

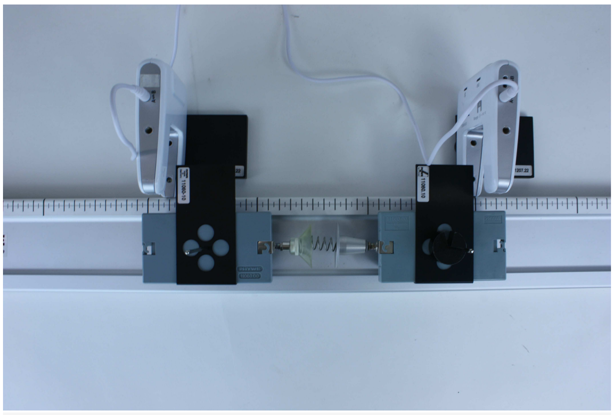


Fig. 5.

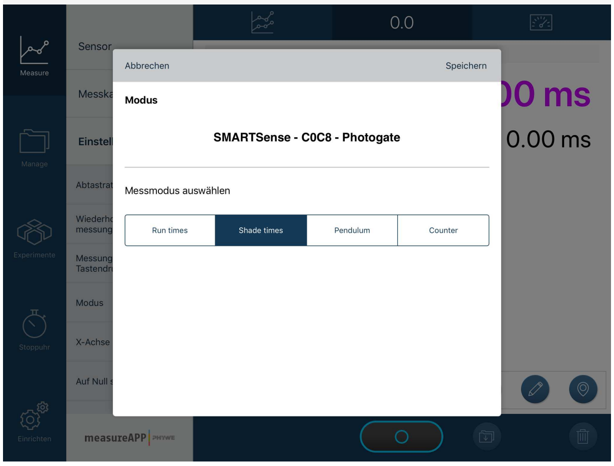


Fig. 6.

With these settings, two channels, (each light barrier has its own channel) for measuring the time during which the light barriers are interrupted, i.e. the shading times Δt are used.

Procedure

Use both carts with their respective basic set-up, i.e. without any additional slotted weight of 50 g, so that both carts have the same mass. Name the mass of the left cart m_1 and the one of the right cart m_2, for example.

Compress the equiforce launcher as shown in the picture (fig. 7) and not by pressing against the cart ends. The spring should be located exactly in the middle of the suction cup.

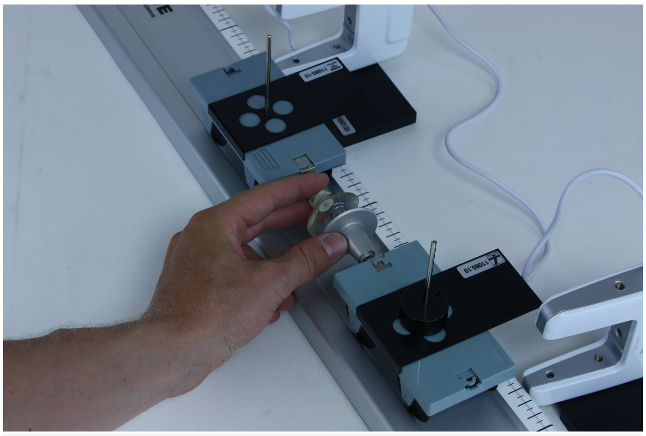


Fig. 7.

Switch the display mode to numeric mode 0.0 (fig. 8).
Start the measurement by pressing on . measureAPP is now ready to record shade times.
Release the equiforce launcher. If you have compressed the equiforce launcher to a maximum degree, it will release the carts after approximately 5 seconds.

If a cart starts to skid after the launch, reject the associated measurement values.
Skidding can be avoided by pressing the suction cup centrally against the plate.

Catch the carts before they can roll off the track.

Note the measurement values Δt_1 and Δt_2 down on an extra sheet and calculate the average values based on the three values of Δt_1 and Δt_2. Enter the average values in milliseconds into table 1 of the experiment report.

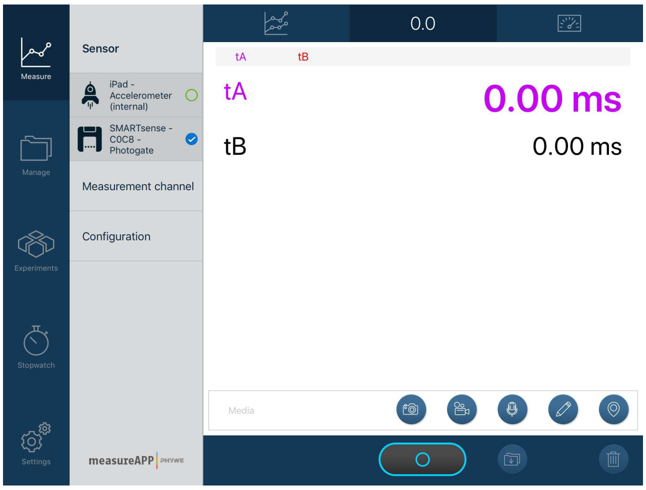


Fig. 8.

Then, add a slotted weight of 50 g to the holding pins of both carts and repeat the experiment.

Remove one of the slotted weights (50 g) from the cart that you have named m_2 (mass 2) and repeat the experiment.

Report: Momentum with SMARTsense

Result - Table 1

Enter the average shading times (in seconds) of the two carts calculated based on three measurement values into the columns $\varnothing\Delta t_1$ and $\varnothing\Delta t_2$.

Based on the shading times $\varnothing\Delta t_1$ and $\varnothing\Delta t_2$, calculate the values of the velocities v_1 and v_2 of the two carts with the shutter plate width $\Delta s = 5$ cm and with the formula $v = \Delta s / \Delta t$ and enter them into the table.

Question 2 describes what you need to do with the last two columns.

m_1 in g	m_2 in g	$\varnothing\Delta t_1$ in s	$\varnothing\Delta t_2$ in s	v_1 in m/s	v_2 in m/s	$p_1 = m_1 v_1$ in 10^{-3} Ns	$p_2 = m_2 v_2$ in 10^{-3} Ns
82	82	1 ±0.015	1 ±0.015	1 ±0.21	1 ±0.23	1 ±18	1 ±19
132	132	1 ±0.02	1 ±0.02	1 ±0.18	1 ±0.17	1 ±18	1 ±19
132	82	1 ±0.03	1 ±0.015	1 ±0.21	1 ±0.17	1 ±18	1 ±19

Evaluation - Question 1

What can you say about the velocities of the carts?

- ☐ Carts with the same mass have the same velocity within the scope of the measurement accuracy.
- ☐ It is not possible to make a definite statement concerning the velocity.
- ☐ The heavier cart is always the faster one.
- ☐ The lighter the carts are, the faster they are.
- ☐ The slower a cart is, the smaller its mass will be.

Evaluation - Question 2

The momentum *p* is defined as the product of the mass *m* and velocity *v* of an object: $p = m \cdot v$.

Calculate the momenta (absolute values) for cart 1 and cart 2 and enter the values into table 1.

(Calculate the momenta *p* with the mass in grams *g* and the velocity in m/s.)

Which of the statements can you confirm?

- ☐ Regardless of the cart masses, the momenta p1 and p2 in the same line of the table are identical within the scope of the measurement accuracy.
- ☐ The absolute values of all of the momenta are identical.
- ☐ It is not possible to make a statement concerning the momenta.

Evaluation - Question 3

Let us assume that the absolute values of the momenta p_1 and p_2 are identical: What is still the difference between the motions of both carts?

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Evaluation - Question 4

What is the value of the momenta p_1 and p_2 of the carts prior to the start?

What is the role of the mass *m*?

Justify your answer by way of the defining equation of momentum.

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Evaluation - Question 5

If a motion on the track from the left to the right is defined as positive, the motion of a cart from the right to the left can be marked with a negative sign in order to indicate that the cart is moving to the left.

The velocity is defined as a directional quantity. In mathematical terms, it is a vector. The mass *m*, on the other hand, is a scalar quantity: It has a value and a unit, but no direction.

The momentum $p=m \cdot v$ as the product of a scalar quantity and a directional quantity is a directional quantity itself.

Which of the statements can you confirm based on this knowledge and the value table?

- [ ] Regardless of the cart mass, the momenta p1 and p2 of the two carts cancel each other out to zero within the scope of the measurement accuracy.
- [ ] The sum of the momenta p1 and p2 of the carts strongly depends on the cart masses.
- [ ] Therefore, the sum of the momenta p1 and p2 is always negative.

Evaluation - Question 6

Based on the finding of the previous question, what can you conclude in terms of the creation and annihilation of the quantity momentum?

Tip: How does the total momentum (p_1 + p_2) change after the start of the carts?

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Evaluation - Question 7

If the mass m_1 and the velocity v_1 of one object have been measured and if the mass m_2 of the other object is known: How can the velocity v_2 of the other object be calculated?

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