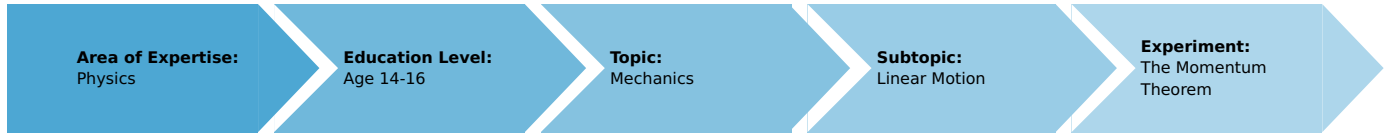


The Momentum Theorem (Item No.: P6200900)

Curricular Relevance



Difficulty



Intermediate

Preparation Time



10 Minutes

Execution Time



20 Minutes

Recommended Group Size



2 Students

Additional Requirements:

- Tablet PC with DigiCart App

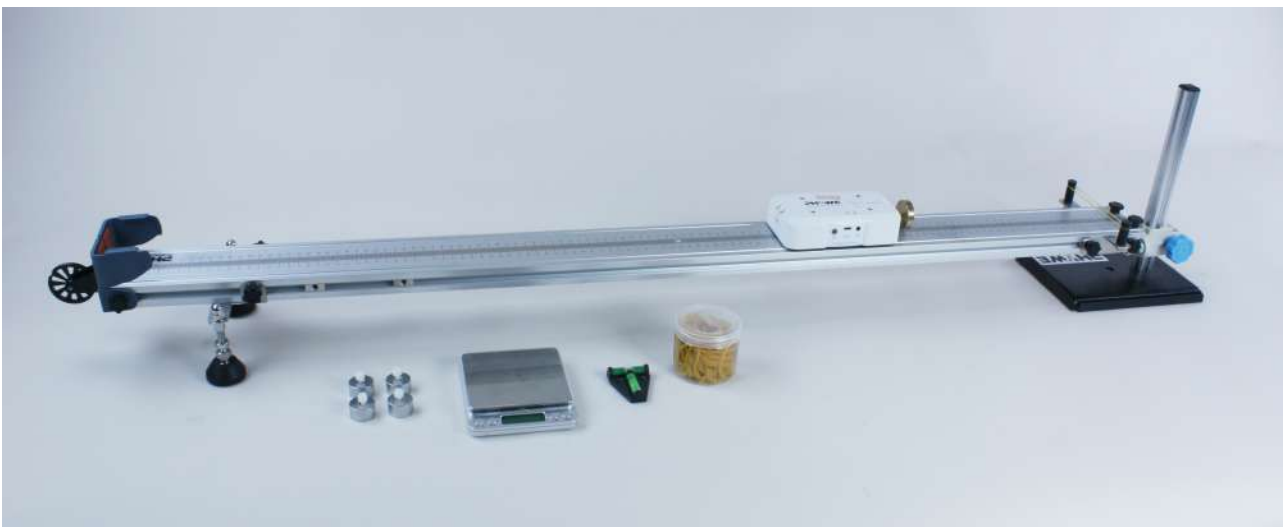
Experiment Variations:

Keywords:

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 the momentum. They also use Newton's second law and see it in its most general form.

Task

Let the DigiCart collide with a tensioned rubber band with the force sensor ahead and analyze the impulse change.

Prior knowledge

This experiment requires knowledge of Newton's second law and basic knowledge of integration.

Principle

Momentum

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

$$p = m \cdot v.$$

Newton's second law

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

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

From integration theory it follows now for the change of the impulse Δp collected between times t_1 and t_2 that

$$\Delta p = \int_{t_1}^{t_2} F(t) dt.$$

Since the value of the integral corresponds to the area under the force curve, we have the possibility to calculate the momentum change Δp .

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	Weights 50g		4
6	Plastic screws		4
7	Brass screw with circular closure		1
8	rubber bands		1
9	Scale		1
10	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 physical concept of momentum. We also use Newton's second law and see it in its most general form.

Task

Let the DigiCart collide with a tensioned rubber band with the force sensor ahead and analyze the impulse change.

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Set-up and procedure

Set-up

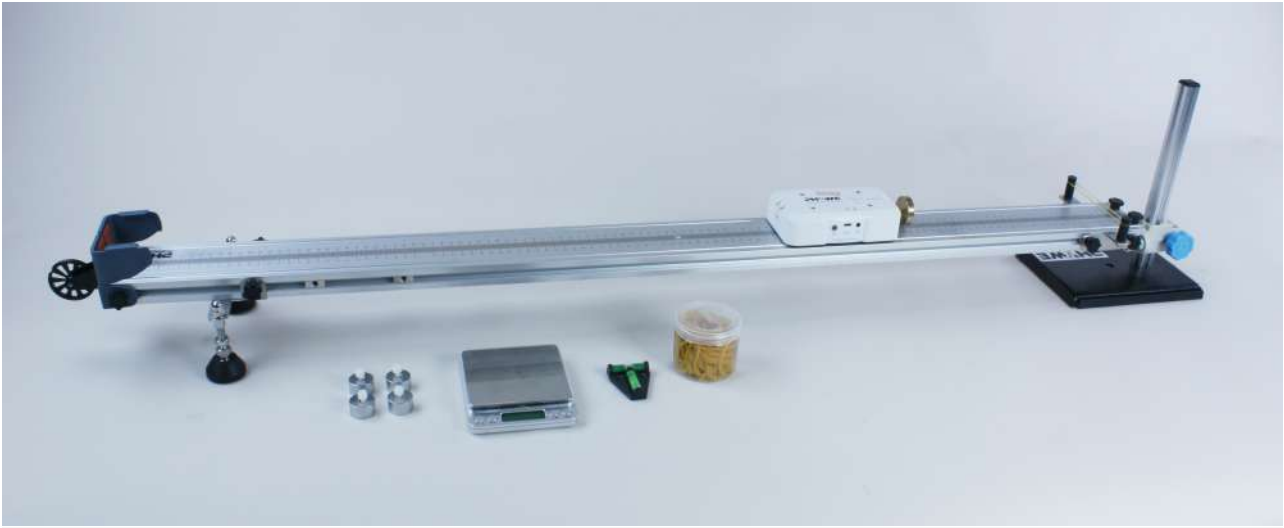


Figure 1: Overview of experimental setup.

- Use the scale to weigh the weight of the DigiCart. Make sure that you also weigh the circular shaped force sensor.
- Bring the track into a horizontal position using the spirit level. At one end of the track, tighten a rubber band on the black cylinders provided for this purpose.
- Place the DigiCart on the track so that the force sensor points in the direction of the rubber band.
- Start the DigiCart App.
- Select experiment 9 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 chooses 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.).

Der Impuls
P6200900

Kraft F= 0.00 N
Geschwindigkeit V= 0.00 m/s

Nr.	1	2	3	4	5
v ₁ (m/s)					
v ₂ (m/s)					
m (g)					
p ₁ (N*s)					
p ₂ (N*s)					
Δp (N*s)					
I (N*s)					

Force-F Vel

cart-8179

v(m/s) F(N)

t(ms)

Intervall: 0.4 ms Wagenmasse m: 280g

Cobra PHYWE DigiCartAPP

$F=0$

Schließen Scan Verbinden

Figure 2: Connecting to the DigiCart.

Procedure

- Figure 3 shows the steps for the measurement process.
- The force and speed display (1.) shows the momentary force and the momentary speed.
- The force at the sensor is now set to zero via the calibration button (2.).
- Enter the mass of the DigiCart in the car mass field (3.).
- Start the measurement by clicking on start measurement (4.).
- Give the DigiCart a short swing with your hand so that it moves towards the rubber band. It is important that your hand releases the DigiCart before the collision.
- The measurement only takes place automatically when a collision occurs and also stops automatically shortly afterwards.
- By clicking on select measuring range (5.), select the range in the force-time diagram in which the pulse transfer takes place (where the force shows a deflection). The measuring range should start about 100 ms before the deflection and end about 100 ms after the deflection. 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.
- Repeat this measurement at least twice. One or more additional weights can also be attached to the DigiCart. Don't forget to change the mass of the cart in the field provided (3.).
- To delete a column from the table, touch it and then click the delete button (7.). By a further measurement the column can be filled with new values.



Figure 3: Measurement procedure.

Evaluation

- The table in Figure 3 shows the measured velocities before (v_1) and after (v_2) the impact with the rubber band. With the given mass the impulse before (p_1) and after (p_2) the impact is measured. The impulse change results from the difference $p_2 - p_1$. In addition, the impulse change is also determined from the effective force. For this the area between the time axis and the force curve is calculated.

It turns out that both variants provide the same values for determining the pulse change in good approximation. This is confirmed by Newton's second law, according to which the change of the momentum is equal to the integral of the force over time (i.e. the area below the force curve).

The Momentum Theorem

Results - Evaluation 1 (1 point)

How can the momentum 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)

What is Newton's second law in its general form?

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

- $F = dp/dt$.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 3 (1 point)

Which two ways do you know to determine an impulse change?

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

- On the one hand one can determine the difference of `pulse_after` - `pulse_before`. Or you can determine the area below the force diagram in that part where the collision takes place.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE