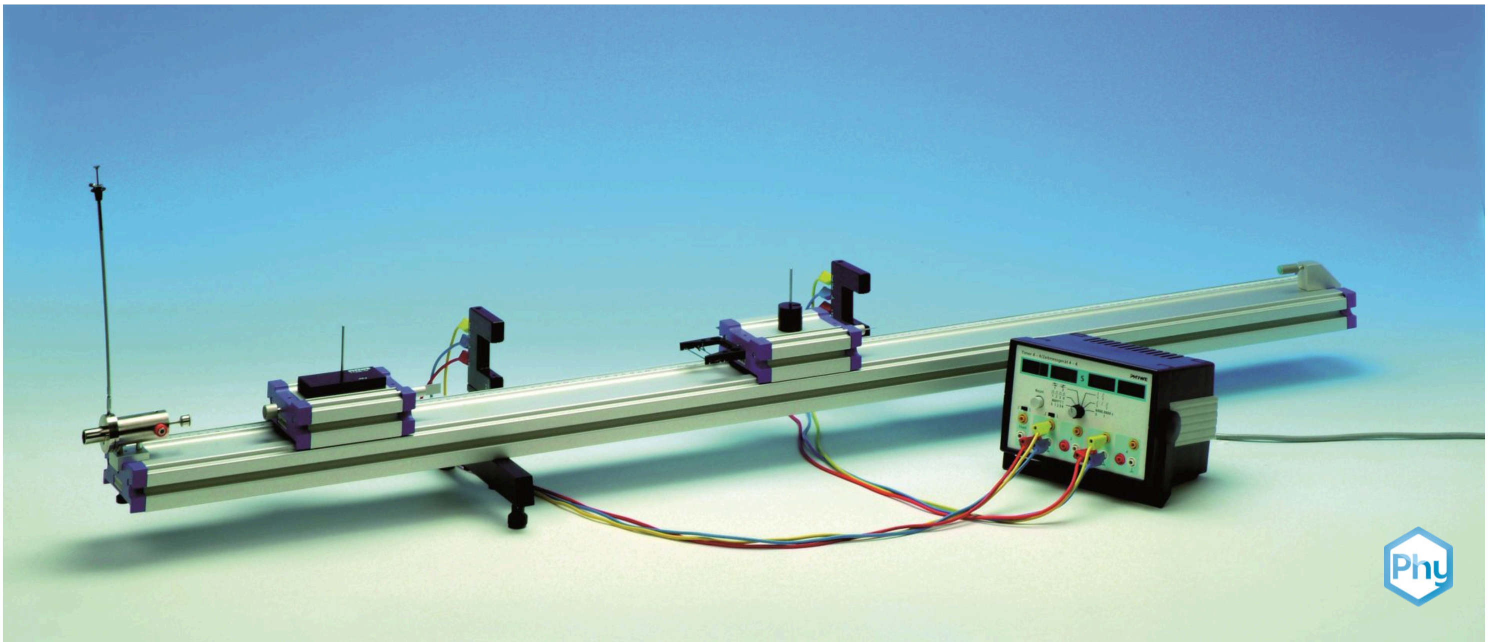
Laws of collision/ demonstration track with a 4-4 timer



Physics	Mechanics	Dynamics & Motion
Physics	Mechanics	Energy conservation & impulse

Difficulty level	Group size	Preparation time	Execution time
easy	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/60105c568b903a00038a5383

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

General information

Application

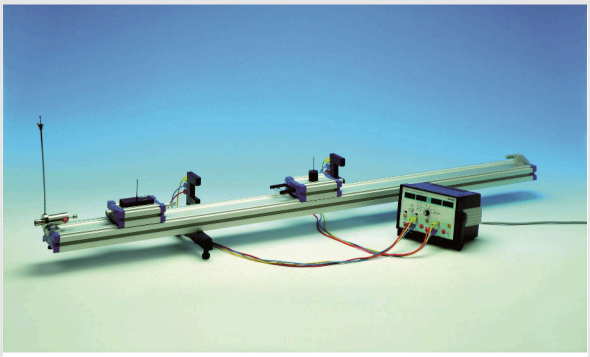


Fig.1: Experimental set-up

The laws of collision are fundamental for the field of mechanics. As such it's understanding is very important for the study of this field and any other, as they imply general relations in regard to momentum.

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (1/2)

PHYWE

Prior knowledge

The prior knowledge for this experiment is found in the Theory section.

Main principle

The velocities of two carts, moving on a demonstration track, are measured before and after collision, for both elastic and inelastic collision.

Other information (2/2)

PHYWE

Learning objective

The goal of this experiment is to demonstrate the laws of collision.

Tasks

1. **Elastic collision;** A cart collides with a second resting cart at a constant velocity. A measurement series is conducted by varying the mass of the resting cart: The corresponding velocities of the first cart before the collision and the velocities of both carts after it are to be measured. Plot the following parameters as functions of the mass ratio of the carts
2. **Inelastic collision;** A cart collides with a constant velocity with a second resting cart. A measurement series with different masses of the resting cart is performed: the velocities of the first cart before the collision and those of both carts, which have equal velocities, after it are to be measured.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Theory (1/2)

PHYWE

In the elastic collision of two bodies having masses m_1 and m_2, kinetic energy and momentum are conserved:

$$\frac{\vec{p}_1^{\,2}}{2m_1} + \frac{\vec{p}_2^{\,2}}{2m_2} = \frac{\vec{p'}_1^{\,2}}{2m_1} + \frac{\vec{p'}_2^{\,2}}{2m_2}$$

$$\vec{p}_1 + \vec{p}_2 = \overrightarrow{p'}_1 + \overrightarrow{p'}_2$$

where $\vec{p}_1, \vec{p}_2$ are the moments before the collision and $\vec{p}_1', \vec{p}_2'$ those after the collision.

Due to the unidimensional sequence of movement, we will dispense with the vectorial notation. For a central elastic with $p_2 = 0$:

$$p_1' = \frac{m_1 - m_2}{m_1 + m_2} \cdot p_1 = -\frac{1 - \frac{m_1}{m_2}}{1 + \frac{m_1}{m_2}} \cdot p_1$$

$$p_2' = \frac{2m_2}{m_1 + m_2} \cdot p_1 = \frac{2}{1 + \frac{m_1}{m_2}} \cdot p_1$$

From the contribution of the impulse p, the energies E are calculated with $E = p^2/2m$

$$E_1' = -\left(\frac{1 - \frac{m_1}{m_2}}{1 + \frac{m_1}{m_2}}\right)^2 \cdot E_1$$

$$E_1' = -\frac{4}{(1 + \frac{m_1}{m_2})^2} \cdot \frac{m_1}{m_2} \cdot E_1$$

Theory (2/2)

PHYWE

In an inelastic collision, only the momentum is conserved. In addition, the velocities after the collision are equal:

$$p_1' = \frac{m_1}{m_2} \cdot p_2'$$

Therfore $p_1' = \frac{1}{1 + \frac{m_2}{m_1}} \cdot p_1$

$$p_2' = \frac{1}{1 + \frac{m_1}{m_2}} \cdot p_1$$

The following is obtained for the energies of the two carts after the collision:

$$E_1' = \frac{1}{\left(1 + \frac{m_2}{m_1}\right)^2} \cdot E_1 \qquad E_2' = \frac{1}{\left(1 + \frac{m_1}{m_2}\right)^2} \cdot \frac{m_1}{m_2} \cdot E_1$$

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	Tube with plug	11202-05	2
2	Needle with plug	11202-06	2
3	Fork with plug	11202-08	1
4	Rubber bands for fork with plug, 10 pcs	11202-09	1
5	Plate with plug	11202-10	1
6	Magnet w.plug f.starter system	11202-14	1
7	Slotted weight, black, 10 g	02205-01	10
8	Slotted weight, black, 50 g	02206-01	6
9	Light barrier, compact	11207-20	2
10	PHYWE Timer 4-4	13604-99	1
11	Portable Balance, OHAUS CX2200	48921-00	1
12	Demonstration track, aluminium, 1.5 m	11305-00	1
13	Cart, low friction sapphire bearings	11306-00	2
14	Starter system for demonstration track	11309-00	1
15	Weight for low friction cart, 400 g	11306-10	2
16	Shutter plate for low friction cart, width: 100 mm	11308-00	2
17	Holder for light barrier	11307-00	2
18	End holder for demonstration track	11305-12	1
19	Connecting cord, 32 A, 1000 mm, red	07363-01	2
20	Connecting cord, 32 A, 1000 mm, yellow	07363-02	2
21	Connecting cord, 32 A, 1000 mm, blue	07363-04	2

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and Procedure

Setup and Procedure

The experimental set-up is performed as shown in Fig. 1. The starting device serves to start the cart; three defined and reproducible initial energies can be selected with the various latch positions. It is recommended that the second position is used for all measurements.
Connect the light barriers with input jacks 1 and 3 on the timer [connect jacks having the same colours (red and yellow) and the two earth (ground) jacks to each other]. Select the “Collision experiments” operating mode (2 double arrows printed on the front panel). In this mode, up to two shading periods are measured and displayed for each light barrier. When varying the mass ratios, ensure that the additional masses are added symmetrically in each case. Before initiating the measurements, check the track’s adjustment. The momentum is determined by measuring the velocity of the cart. For this purpose, the time during which the screen fitted on the cart impinges on the light barrier is used, in accordance with:

$$v = \frac{\Delta s}{\Delta t}$$

(Δs = length of screen, Δt = shading time)

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Evaluation

Results (1/5)

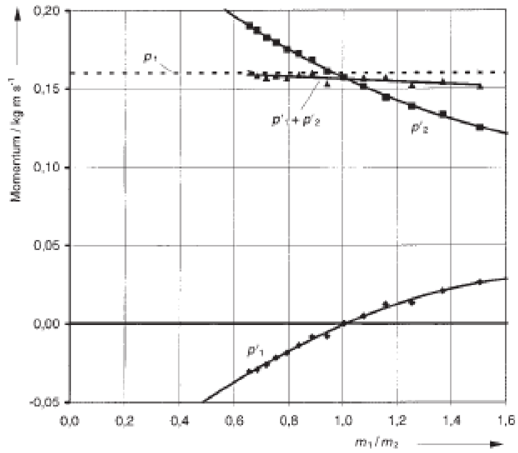


Fig. 2: Elastic collision: moment after the collision as functions of the mass ratio of the carts.

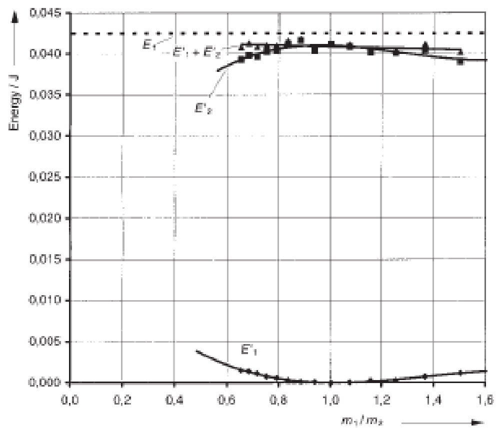


Fig. 3: Elastic collision: energy after the collision as functions of the mass ratio of the carts.

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Results (2/5)

PHYWE

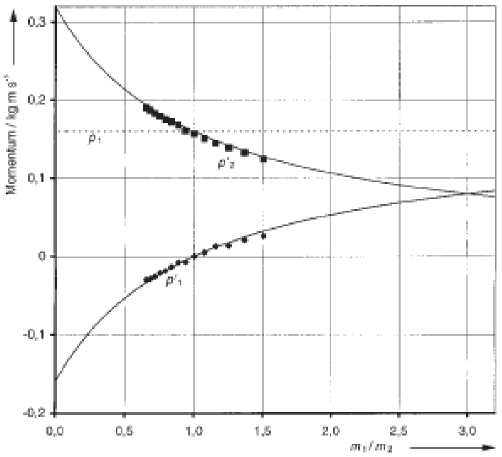


Fig. 4: Elastic collision: calculated momenta after the collision as functions of the mass ratio of the carts.

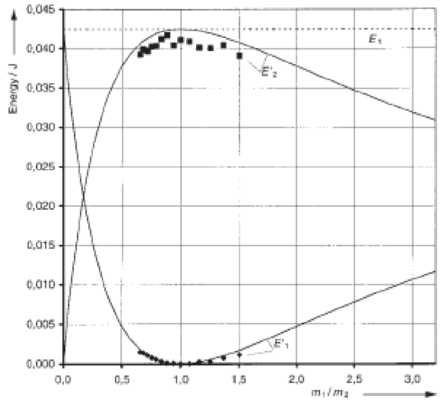


Fig. 5: Elastic collision: calculated energies after the collision as functions of the mass ratio of the carts.

Results (3/5)

PHYWE

The evaluation of a sample measurement (Fig. 6 and Fig. 7) shows that also for an inelastic collision, the total impulse is conserved; whereas, depending on m_1/m_2, a substantial energy loss occurs.

The theoretical curves are compared with the measured values in Fig. 8 and Fig. 9. In Fig. 9, the energy loss is additionally plotted [energy loss = $E_1 - (E'_1 + E'_2)$). One sees that for a mass ratio of 1, the kinetic energy is reduced by exactly 50%.

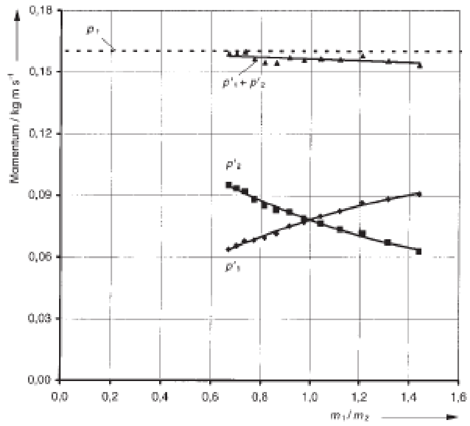


Fig. 6: Inelastic collision: momenta after the collision as functions of the mass ratio of the carts.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Results (4/5)

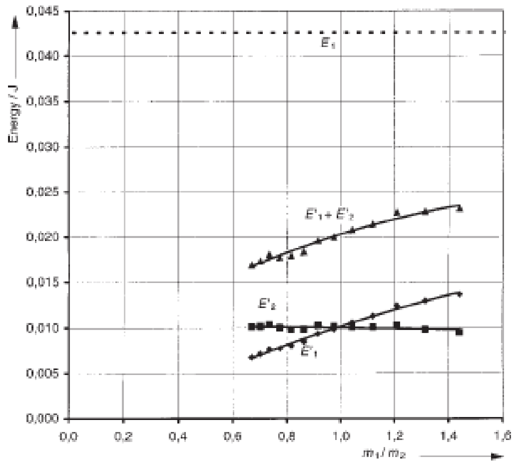


Fig. 7: Inelastic collision: energy after the collision as functions of the mass ratio of the carts.

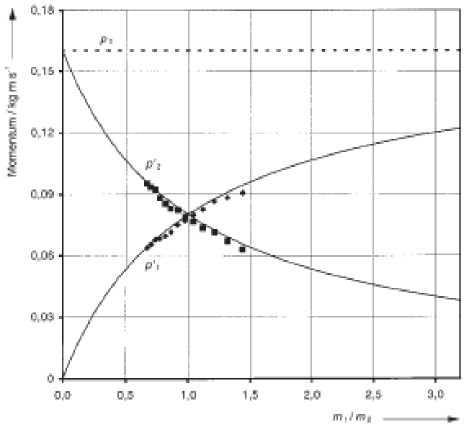


Fig. 8: Inelastic collision: calculated moment after the collision as functions of the mass ratio of the carts.

Results (5/5)

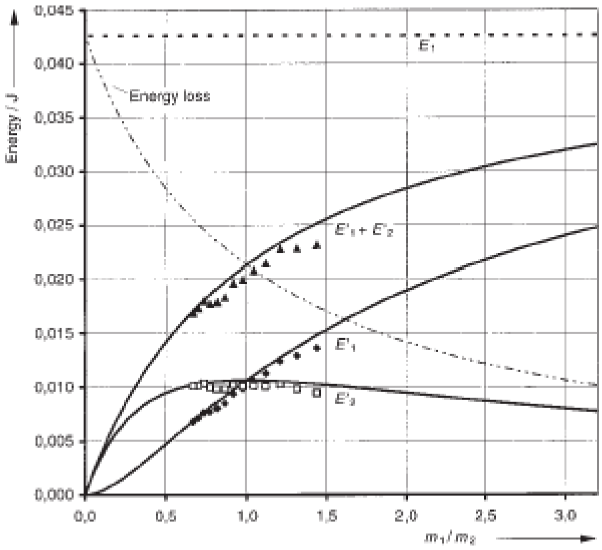


Fig. 9: Inelastic collision: calculated energies after the collision and energy loss as functions of the mass ratio of the carts.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de