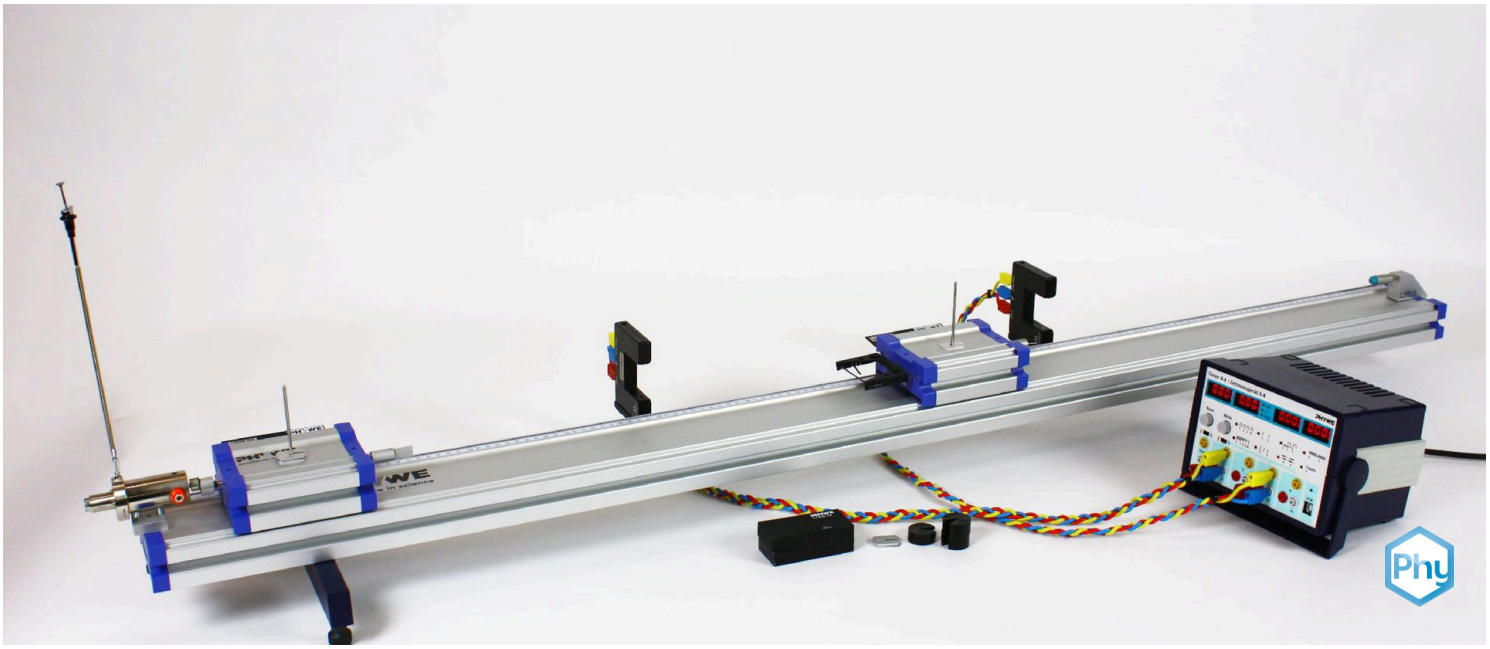
Conservation of momentum in inelastic collisions with thedemonstration track and the timer 4-4



Physics | Mechanics | Energy conservation & impulse

Difficulty level	Group size	Preparation time	Execution time
medium	2	20 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/600497ff27aa1c00038a12e9

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General information

Application

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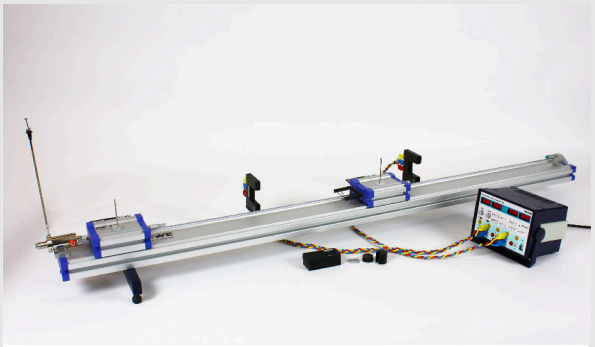

Experiment set-up

If two bodies collide inelastically with each other in a closed system, the momentum *p* remains in the overall system. Both bodies move on together with an impulse that corresponds to the sum of the individual impulses before the impact.

The kinetic energy of the entire system, on the other hand, decreases, since kinetic energy is converted into deformation energy for the inelastic impact.

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Other information (1/2)

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Prior knowledge

The basic concept of an inelastic collision and classical mechanics should have already been covered in class.

Scientific principle

If two cars collide inelastically, they move together with the same speed in one direction. The momentum of the movement corresponds to the sum of the individual momentums before the collision:

$$p_1 + p_2 = p'$$

Other information (2/2)

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Learning objective

The kinetic energy decreases after the inelastic impact due to the deformation of the plasticine between the two cars.

Nevertheless, taking into account the deformation energy, the energy of the overall system remains ΔE:

$$E_{kin} = E'_{kin} + \Delta E \ .$$

Tasks

1. Determination of the impulses before and after the inelastic impact of two moving cars with opposite directions of motion.
2. Determination of the kinetic energies before and after the inelastic impact of two moving cars with opposite directions of motion.

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Equipment

Position	Material	Item No.	Quantity
1	Demonstration track, aluminium, 1.5 m	11305-00	1
2	Cart, low friction sapphire bearings	11306-00	2
3	Shutter plate for low friction cart, width: 100 mm	11308-00	2
4	Needle with plug	11202-06	2
5	Tube with plug	11202-05	2
6	Plasticine, 10 sticks	03935-03	1
7	Weight for low friction cart, 400 g	11306-10	2
8	Slotted weight, black, 10 g	02205-01	4
9	Slotted weight, black, 50 g	02206-01	3
10	End holder for demonstration track	11305-12	1
11	Starter system for demonstration track	11309-00	1
12	Magnet w.plug f.starter system	11202-14	1
13	Light barrier, compact	11207-20	2
14	Holder for light barrier	11307-00	2
15	PHYWE Timer 4-4	13604-99	1
16	Connecting cord, 32 A, 1000 mm, red	07363-01	2
17	Connecting cord, 32 A, 1000 mm, yellow	07363-02	2
18	Connecting cord, 32 A, 1000 mm, blue	07363-04	2
19	Portable Balance, OHAUS CR2200	48914-00	1

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Setup and procedure

Set-up (1/4)

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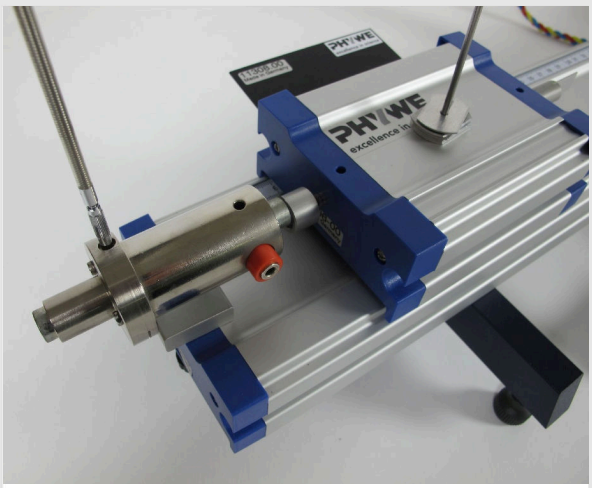

Launching device for shock

1. The track should be aligned as accurately as possible horizontally using the three adjusting screws on the feet.

2. A launching device shall be installed at the left end of the runway.

Note; to start the trolley with initial impulse, the starting device must be mounted in such a way that the trolley receives a force impulse from the ram.

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Set-up (2/4)

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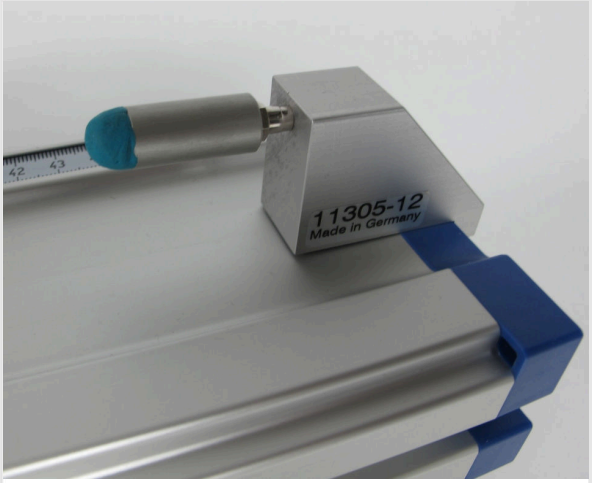

End bracket with plasticine

3. A tube filled with plasticine is attached to the end bracket at the right end of the track to slow the car down without hard impact.

4. The two forked light barriers are mounted with the light barrier holders on the roadway and positioned approximately at the markings for 40 cm and 100 cm. The light barrier which is closer to the starting device is designated as light barrier 1, the other as light barrier 2.

Set-up (3/4)

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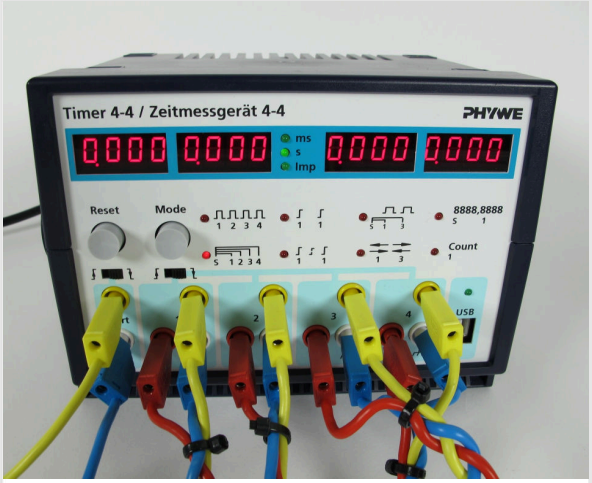

Connecting the light barriers

5. Light barrier 1 is connected to the sockets in field "1", light barrier 2 to the sockets in field "3" of the timing device. The yellow sockets of the light barriers are connected to the yellow sockets of the measuring device, the red sockets to the red sockets and the blue sockets of the light barriers to the white sockets of the time measuring device.

6. The two slide switches on the timing device are set to the right-hand position "falling edge" ( ) to select the trigger edge.

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Set-up (4/4)

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7. The two measuring cars are placed on the roadway.

- The left wagon, which is closer to the starting device (in the following referred to as wagon 1 with speed v_1) is fitted with the holding solenoid with the plug in the direction of the starting device and with the plate with plug in the direction of travel.
- Into the sides of the right wagon (wagon 2 with v_2), a tube filled with plasticine is inserted in the direction of carriage 1 and the needle with plug is inserted facing the end bracket.
- In both wagons, the panels for measuring wagons (*b*= 100 mm) is latched into the side on which the forked light barriers are to be located.

Procedure (1/4)

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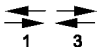
1. To carry out all measurements, the chronometer must be switched to operating mode 6 "Shock" (

). Only control inputs 1 and 3 are active.

Up to two shading times are measured at each light barrier.

The shading times at light barrier 1 are shown on the first two displays, the times of light barrier 2 on the rear two displays.

The first interruption of a light barrier is shown on the left display, the second on the right display.

2. At the beginning of the measurement, the masses of the wagons must always be determined by means of the balance.

For small corrections (especially when equal masses are desired) the 1 g slot weights can be used.

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Procedure (2/4)

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3. Before starting each impact test, press the "Reset" button to reset the displays.

4. The measuring trolleys are positioned on opposite sides outside the light barriers. Carriage 1 is accelerated with the starting device, carriage 2 is pushed lightly by hand. After the inelastic impact, both carriages move away together in one direction. So that they do not stop within the light barriers, due to a total impulse that is too low, care must be taken that one carriage receives a significantly higher initial impulse. Since the impact must necessarily take place within the light barriers, it may be that the trolleys have to be started with a slight time delay.

5. In order to be able to distinguish between the different measured data of the wagons, the shading times are to be destinguished with t_1 and t_2 before the impact, and after the impact with t_1' and t_2'.

The same nomenclature shall be used for the calculations of the velocities and impulses.

Procedure (3/4)

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5. After the impact, the light barrier is interrupted in the direction of movement of both carriages.

This only records the shading time of the aperture on the front carriage, as the time of a carriage before the impact has already been measured.

However, since both cars are moving at the same speed, this shading time is valid for both cars.

6. The speeds $v_i = b \ / \ t_i$ during all shading times t_i are calculated with the aperture length b = 100 mm.

Since the speeds are vector quantities, the signs of the values must be observed. All velocities that are opposite to v_1 have the opposite sign to v_1.

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Procedure (4/4)

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7. In order to be able to distinguish between the different measured data of the wagons, the shading times are to be designated with t_1 and t_2 before the impact and with t' for after the impact.

The same nomenclature shall be used for the calculations of velocities and impulses.

8. The measurement times are to be recorded and averaged for up to five repetitions.

The measurement is then repeated both for different wagon masses and for different mass ratios.

Evaluation (1/6)

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Observation

Both cars collide and move together at the same speed in the same direction.

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Evaluation (2/6)

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Measurement example for inelastic impact

m_1 in kg	m_2 in kg	t_1 in s	t_2 in s	$t_2' = t_1'$ in s
0,4	0,4	0,162	0,591	0,447
0,8	0,4	0,237	0,664	0,461
0,4	0,55	0,162	0,593	0,598

Evaluation (3/6)

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Measurement example for inelastic impact

v_1 in m/s	v_2 in m/s	$v_2' = v_1'$ in m/s	p_1 in kg·m/s	p_2 in kg·m/s	$p = p_1 + p_2$ in kg·m/s	p' in kg·m/s
0,617	-0,169	0,224	0,247	-0,068	0,179	0,179
0,422	-0,151	0,217	0,338	-0,06	0,277	0,26
0,617	-0,169	0,167	0,247	-0,093	0,154	0,159

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Evaluation (4/6)

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Measurement example for inelastic impact

E_1 in kg·m²/s²	E_2 in kg·m²/s²	E_{kin} in kg·m²/s²	E_{kin}' in kg·m²/s²	ΔE in kg·m²/s²
0,076	0,006	0,082	0,02	0,062
0,071	0,005	0,076	0,028	0,048
0,076	0,008	0,084	0,013	0,071

Evaluation (5/6)

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1. For the individual measurements, the impulses are calculated from the wagon masses and the speeds p_1 and p_2 before the impact and $p' = (m_1 + m_2) \cdot v'$ after the impact.

Since the carriages remain together after the inelastic impact, they can be considered as one carriage with a larger mass. A comparison of the total impulses (see measurement example) shows that, within the limits of measurement accuracy, the law of conservation of momentum applies:

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v' .$$

2. The kinetic energies E_1 and E_2 of the two cars before the collision and the energy *Ekin*' of the joint motion after the collision. A comparison of $E_{kin} = E_1 + E_2$ with E'_{kin} shows that the kinetic energy has become significantly lower after the impact (see measurement example). The law of conservation of energy does not seem to be fulfilled:

$$\tfrac{1}{2} m_1 v_1^2 + \tfrac{1}{2} m_2 v_2^2 \neq \tfrac{1}{2} (m_1 + m_2) v'^2 .$$

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Evaluation (6/6)

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3. However, in a closed system, the energy must be conserved and cannot be lost.

This is due to the fact that energy is used to deform the wrought rubber during the impact.

This deformation energy ΔE leads to a reduction of the kinetic energy.

Accordingly, the law of conservation of energy is as follows:

$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = \frac{1}{2}(m_1 + m_2)v'_2 + \Delta E$$

The absorbed deformation energy ΔE is therefore equal to the difference between the initial kinetic energy and the remaining kinetic energy after the impact.

Notes

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1. To accelerate trolley 1 with the launcher, the ram is pushed in until it locks into place. Since the starting device provides three different sized steps, care must be taken to use the same lock for each experiment so that the same force is transmitted when the starting device is released.

2. The correct fit of both panels on the carriages should be checked before each measurement, as they can slip due to abrupt braking.

3. The plasticine should be remodelled in between collisions if necessary, so that the impact of the car is always cushioned in the best possible way.

4. The cars do not move completely frictionless, there remains a residual friction and the total momentum decreases slightly. This also causes a loss of energy, so that the difference in kinetic energies before and after the impact does not fully correspond to the deformation energy ΔE of the plasticine.

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