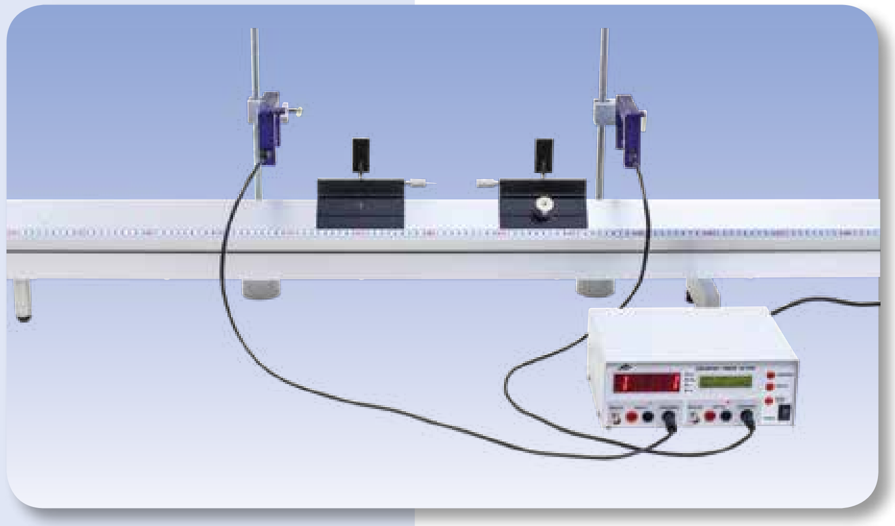
LAWS OF COLLISIONS



OBJECTIVE

Investigate uni-dimensional collisions on an air track

SUMMARY

One important consequence of Newton's third law is the conservation of momentum in collisions between two bodies. One way of verifying this is to investigate collisions between two sliders on an air track. When all of the kinetic energy is conserved, we speak of elastic collisions. In cases where kinetic energy is only conserved for the common centre of gravity of the two bodies, we use the term inelastic collisions. In this experiment, the individual velocities of the sliders are determined from the times that photo-electric light barriers are interrupted and the momentum values are calculated from these speeds.

EXPERIMENT PROCEDURE

- **Investigate elastic and inelastic collisions between two sliders on an air track.**
- **Demonstrate conservation of momentum for elastic and inelastic collisions and observe the individual momenta for elastic collisions.**
- **Investigate how energy is distributed in elastic and inelastic collisions.**

You can find technical information about the equipment at 3bscientific.com

REQUIRED APPARATUS

Quantity	Description	Number
1	Air Track	**1019299**
1	Air Flow Generator (230 V, 50/60 Hz)	**1000606 or**
	Air Flow Generator (115 V, 50/60 Hz)	**1000605**
1	Digital Counter with Interface (230 V, 50/60 Hz)	**1003123 or**
	Digital Counter with Interface (115 V, 50/60 Hz)	**1003122**
2	Photo Gate	**1000563**
2	Barrel Foot, 1000 g	**1002834**
2	Universal Clamp	**1002830**
2	Stainless Steel Rod 470 mm	**1002934**
Additionally recommended		
1	Mechanical Balance 610	**1003419**

BASIC PRINCIPLES

One important consequence of Newton's third law is the conservation of momentum in collisions between two bodies. One way of verifying this is to investigate collisions between two sliders on an air track.

In the frame of reference of their common centre of gravity, the total momentum of two bodies of masses m_1 and m_2 is zero both before and after the collision.

(1) $$\tilde{p}_1 + \tilde{p}_2 = \tilde{p}'_1 + \tilde{p}'_2 = 0$$

$\tilde{p}_1$, $\tilde{p}_2$: Individual momenta before collision, $\tilde{p}'_1$, $\tilde{p}'_2$: Individual momenta after collision

The kinetic energy of the two sliders in the same frame of reference is given by

(2) $$\tilde{E} = \frac{\tilde{p}_1^2}{2m_1} + \frac{\tilde{p}_2^2}{2m_2}$$

Depending on the nature of the collision, this may be converted partially or even wholly into other forms of energy. When all of the kinetic energy is conserved in frame of reference of the common centre of gravity, we speak of elastic collisions. In an inelastic collision, all the energy is converted into another form.

Using the track itself as the frame of reference, conservation of momentum is described by the following equation:

(3) $$p_1 + p_2 = p'_1 + p'_2 = p = \text{const.}$$

p_1, p_2: Individual momenta before collision
p'_1, p'_2: Individual momenta after collision

As a result of conservation of momentum, the velocity of the centre of gravity

(4) $$v_C = \frac{p}{m_1 + m_2}.$$

and its kinetic energy

(5) $$E_C = \frac{m_1 + m_2}{2} \cdot v_C^2.$$

are also conserved. This is true of both elastic and inelastic collisions.
In this experiment, the second slider is initially at rest before the collision. Therefore the conservation of momentum (equation 3) is given by

(6) $$p = m_1 \cdot v_1 = m_1 \cdot v'_1 + m_2 \cdot v'_2,$$

Here v'_1 and v'_2 have different values after an elastic collision, but are the same subsequent to an inelastic collision. In an elastic collision, a flat buffer on the first slider collides with a stretched rubber band on the second slider. An inelastic collision involves a long pointed spike being pushed into some modelling clay. The masses of the sliders can be modified by adding weights.
After an elastic collision the following relationships apply:

(7) $$p'_1 = \frac{m_1 - m_2}{m_1 + m_2} \cdot p,\ p'_2 = \frac{2 \cdot m_2}{m_1 + m_2} \cdot p$$

and

(8) $$E = \frac{m_1}{2} \cdot v_1^2 = \frac{m_1}{2} \cdot v_1'^2 + \frac{m_2}{2} \cdot v_2'^2.$$

In the case of an inelastic collision only the kinetic energy of the centre of gravity remains conserved. This can be calculated using equations (4), (5) and (6)

(9) $$E_C = \frac{m_1}{m_1 + m_2} \cdot \frac{m_1}{2} \cdot v_1^2 = \frac{m_1}{m_1 + m_2} \cdot E.$$

EVALUATION

The time intervals Δt saved by the digital counter are to be matched with experimental procedures. The following applies to the velocities of the sliders

$$v = \frac{25\,\text{mm}}{\Delta t}$$

If no weighing scales are available, it may be assumed that the mass of a slider is 204 g. The mass of all the weights together is 200 g.
A precise consideration of the velocity and momentum distributions should also take into account frictional losses. For the momentum values obtained here, they should amount to some 5% and for the energy values 10%, see Figs. 1 to 5.

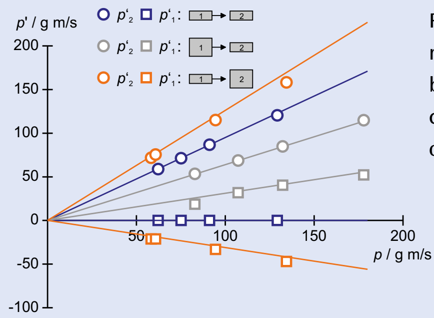


Fig. 1: Individual momenta for colliding bodies after an elastic collision as a function of initial momentum

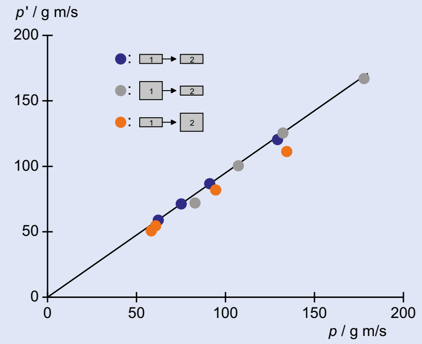


Fig. 2: Total momentum for colliding bodies after an elastic collision as a function of initial momentum

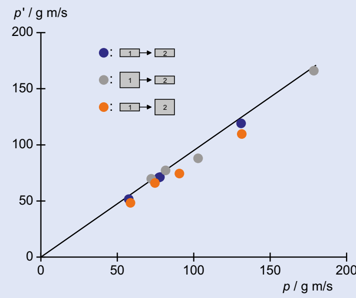


Fig. 3: Total momentum for colliding bodies after an inelastic collision as a function of initial momentum

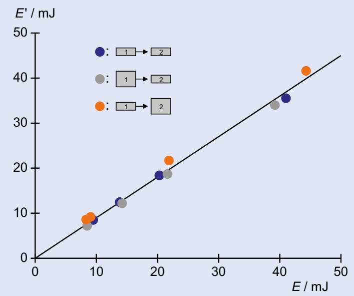


Fig. 4: Total energy for colliding bodies after an elastic collision as a function of initial energy

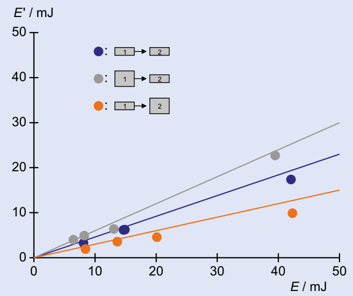


Fig. 5: Total energy for colliding bodies after an inelastic collision as a function of initial energy

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