Collisions on an air track

Number	134720-EN	*Topic*	Mechanics, dynamics				
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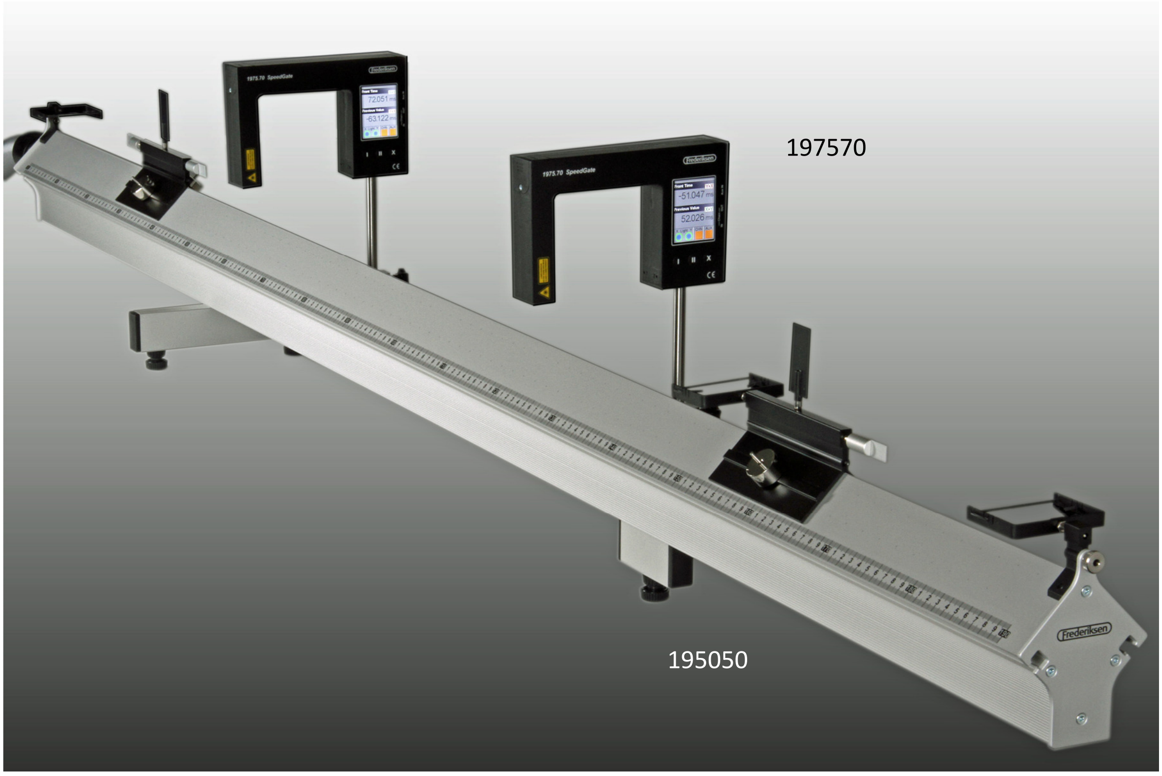


(The image shows our upcoming air track model 195050.
Measurements are performed just as well with older models 195000 or 195010)

Objective
We investigate elastic and inelastic collisions between two carts on an air track. For both kinds of collision, conservation of both momentum and energy are examined.

Principle
The air track enables virtually frictionless motion in 1 dimension. This ensures that the only forces acting parallel with the track are the mutual influence between the two carts. The carts can therefore be considered an isolated system.

The two carts are launched at each other with different speeds. The masses of the carts are also varied.

The speeds of the carts are measured by two SpeedGates that can display the speed when passed. SpeedGate remembers the previous measurement and fits perfectly with collision experiments where the cart typically passes the photogate once on its way to the collision and once on its way back.

Equipment
(Complete equipment list on last page)

Air track with accessories and blower

Two SpeedGates

Procedure

The setup is shown on page 1. Note that the two SpeedGates face the same direction.

Adjust the track to be horizontal. A cart on the track should be able to stand almost still everywhere. (*Very* small deviations can be neglected.)

Set the two SpeedGates to show *Speed* and *Previous Value*.

Remember to note the *sign* of the speed when values are read. The direction from front to backside is displayed as positive.

In some cases, both carts can move in the same direction after the collision. This calls for three speeds to be read off the same SpeedGate; the first (pre collision speed) of these must be written down before the last cart passes the photogate.

All collision experiments must be performed with *sufficiently small speeds*. Going too fast means that the carts can get into contact with the track during the collision – and the measurement is ruined and must be repeated. (You can normally hear this.)

When finding the weight of a cart, it must be weighed with all the relevant accessories mounted (flag, accessories for the ends, extra masses).
The accessories for the ends must always be mounted in both ends – or else, the cart will "surf" along with the heavier end at front.

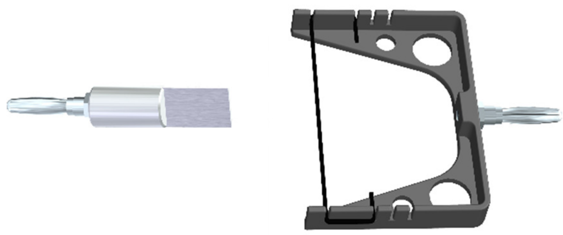
All results are entered in a table like the one below (using a spreadsheet is suggested):

Measured values						*Calculated values*			
		Before		After		Total momentum		Total kinetic energy	
m_1	m_2	u_1	u_2	v_1	v_2	p_{Before}	p_{After}	$E_{\text{Kin, Before}}$	$E_{\text{Kin, After}}$

Note: All values must be specified with both a *sign* and a *unit*.

1a – Elastic collisions, nearly identical masses

The carts must be equipped with the elastic collision bumpers (as seen below) but with no additional masses. Weigh each cart carefully.



Set the two carts in motion outside the two photo-gates so that they meet between them. Catch the carts when they get outside the photogates again. The two SpeedGates will now display the speeds both after and before the collision. These measurements are repeated a few times.

1b – Elastic collisions, different masses

Place two 50 g masses on one of the carts. Weigh both carts precisely.
Repeat the procedure form 1a. It is a good idea to start the heavier cart first with a somewhat lower speed than the other. The speed of both must still be moderate!
As a variation, you can let the heavier cart stand still between the photogates before the collision and only set the light one in motion. (Place the tip of a finger on the heavy cart until the other is within 15 to 20 cm.)

2 – Inelastic collisions

Replace the bumpers with a needle and a wax tube. Again, weigh both carts precisely.

When the carts collide they should stick together and continue with a common speed. (Such a collision is called a *completely inelastic* collision.)

Stop the "road train" when the first of the carts has passed a SpeedGate and use this velocity for both of them.
As before, repeat the measurements.
You may also vary the mass of a cart by adding cylindrical
weights. (Remember to weigh the cart again.)

Theory

The momentum p of a body is given by its mass m and its velocity v :

$$p = m \cdot v$$

In any physical process, the total momentum is conserved. As the two carts are considered an isolated system, for this collision process we have

$$p_{\text{Before}} = p_{\text{After}}$$

or

$$m_1 \cdot u_1 + m_2 \cdot u_2 = m_1 \cdot v_1 + m_2 \cdot v_2$$

where m_1 and m_2 are the masses of the carts. The initial velocity of the carts are u_1 and u_2 ; after the collision, their velocities are v_1 and v_2 .
For elastic collisions, the mechanical energy is also conserved.
As the motion happens along a horizontal line, there is no change in potential energy; this can conveniently be defined as zero. Looking only at the kinetic energy, we can expand the equation

$$E_{\text{Mech,Before}} = E_{\text{Mech,After}}$$

into the following:

$$\frac{1}{2} \cdot m_1 \cdot u_1^2 + \frac{1}{2} \cdot m_2 \cdot u_2^2 = \frac{1}{2} \cdot m_1 \cdot v_1^2 + \frac{1}{2} \cdot m_2 \cdot v_2^2$$

Note the fundamental difference between these two equations: Momentum is like velocity a signed quantity, while the kinetic energy is always positive.

Calculations

Before inserting numbers into formulas you need to ensure a consistent use of units. The easiest way may be to make a new version of the table with all values converted to SI units.
Fill out the four remaining columns in the table. Keep the signs consistent.

Discussion and evaluation

Can you demonstrate that there is conservation of momentum in all the situations?

Naturally, small deviations will occur.

To assess whether a deviation is acceptable, you can compare it with the (numerically) largest of the momentums before the collision.

Calculate the deviation as a percentage of this value. (Conversely, it is not reasonable to compare with the total momentum, as this is typically composed of two components with opposite signs. The total momentum can therefore be close to zero, making the calculated relative deviation very, very big.)

In which situations would you expect the kinetic energy to be conserved?

How well do measurements agree with the expectations?

Considering kinetic energy, the deviation can be compared with the total kinetic energy before the collision.

(Since all kinetic energies are positive (or possibly zero), we will not face a situation where relative deviations are artificially inflated.)

Teacher's notes

Concepts

Mass
Velocity
Momentum
Mechanical energy

Mathematical skills

Evaluation of expressions
Percent
Using a spreadsheet

About the equipment

SpeedGates measure the passage time between the two light rays based on the front of the object obscuring the light. The length of the two flag on the carts are therefore unimportant.
The air track must be adjusted to be horizontal before measurements start. This adjustment can be performed by the students - or it can be done in advance.
The blower should be turned up, until the carts are clearly hovering without touching the track.
On the other hand, it is no advantage with too strong air flows as a single jet of air can tilt the cart slightly, giving rise to a horizontal force component.

Detailed equipment list

Specifically for the experiment

195050	Air track (incl. accessories)
197070	Air blower
197570	SpeedGate (Qty. 2)
195055	Mounting bracket for 197570 (Qty. 2)

Standard lab equipment

102900	Digital scales, 300 g / 0,01 g – or similar

If an older air track is used (e.g. 195000) – replace the two 195055 by this stand material:

000100	Retort stand base, 2,0 kg (Qty. 2)
000830	Retort stand rod 50 cm (Qty. 2)
002310	Square bosshead (Qty. 2)