## Study of inelastic collisions in the air rail

## 1. Introduction

The objective of this laboratory session is to study the collision between two objects. In this practice we are going to produce a totally inelastic collision between two objects (cars) and we will systematically study the relationship between the input speed and the output speed of the two coupled masses. We will explore to what extent the conservation of the linear momentum in the collision is satisfied.

## 2. Theoretical background

The cars will collide as shown in Fig. 1, the car on the right will be thrown with a small initial impulse and this car will collide with the second car on the left.


Fig. 1. Launch sequence and time measurement.

Car A holds a flag at the top which will allow us to calculate the speed of the car when passing by using two photoelectric cell, the first photoelectric cell will measure the speed of car A alone and the second photoelectric cell will measure the speed of the coupled system cars A+B. If $e$ is the length of the flag, the instantaneous speed before and after the collision are

$$
\begin{equation*}
v_{1}=\frac{e}{t_{1}} \tag{1}
\end{equation*}
$$

$$
\begin{equation*}
v_{2}=\frac{e}{t_{2}} \tag{2}
\end{equation*}
$$

In a collision we have two fundamental conservation laws. If the external forces are negligible, the total amount of movement

$$
\begin{equation*}
p_{1}+p_{2} \tag{3}
\end{equation*}
$$

is constant. Therefore, in the collision of Fig. 1 it will be fulfilled

$$
\begin{equation*}
m_{A} v_{1}=\left(m_{A}+m_{B}\right) v_{2} \tag{4}
\end{equation*}
$$

The other conservation law is the conservation of energy, which is valid only in elastic collisions. Our experiment is a totally inelastic collision and therefore the energy is not conserved.
We can write equation (4) as

$$
\begin{equation*}
v_{2}=\frac{m_{A}}{m_{A}+m_{B}} v_{1} \tag{5}
\end{equation*}
$$

We may define the quantity $Q_{m}$, which is the ratio between initial mass and the final mass in the collision

$$
\begin{equation*}
Q_{m}=\frac{m_{A}}{m_{A}+m_{B}} \tag{6}
\end{equation*}
$$

If we apply equations (1), (2), (6), we obtain the following theoretical expression

$$
\begin{equation*}
t_{1}=Q_{m} t_{2} \tag{7}
\end{equation*}
$$

which relates the measured times with the two cells and the number $Q_{m}$, which can be extracted from the masses according to equation (6).

## 3. Experimental procedure

We will use a nearly frictionless-platform, car \#1 (red in Figure 2) and car \#2 (blue in Figure 2). In car \#1 we place a 10 cm flag to measure the speeds. We will place two photoelectric cells at different locations of the rail. The first photoelectric cell will be located after the release point of car 1 and will be used to measure the speed of car \#1 alone $\left(t_{1}\right)$. A second photoelectric cell will be placed after the collision point, to measure the time of the set of the two cars ( $t_{2}$ ). The experimental setup sequence can be seen in Fig. 2 (before the collision) and 3 (after the collision).


Fig. 2. Experimental assembly for the study of collisions before the collision


Fig. 3. Detail of the configuration of the skates after the collision.
We complete the experimental setup as follows:

- Ensure that the rail is completely horizontal. If a still standing cars moves to one side of the rail use the screws on the base to balance the car.
- Place the flag on car 1 (red). Ensure the Velcro accessory is properly fixed on the two surfaces of car \#1 and \#2 so that they stay together when they come in contact.
- Locate the photoelectric cells. In principle, the distance between them is not important since the speeds of the cars are constant. However, you need to make sure that both are sufficiently separated so the first photoelectric cell measures the speed of car \#1 alone and the second measures the speed of the couple \#1 and \#2.
- Release car 1 with your hand, and you make sure that you can measure both times correctly, measured times "makes sense" according to kinematic equations. Ensure that the collision is not violent, and that the cars do not move too slowly to avoid appreciable effects of friction.
- Complete 20 launches with variable speeds (variable initial impulses), in each of the indicated cases.

Experiment 1. In the first experiment, we will weigh out the cars and complete the experiment without additional mass. We release car 1 and record the $t_{1}$ and $t_{2}$. As always in the laboratory, these data should be recorded in a table, where the values $t_{1}$ and $t_{2}$ should appear. In total we acquire a set of about 20 measures with variable times, trying to cover a wide range of values. Put
the values of the table that you have obtained in an Excel spreadsheet.
Experiment 2. Carry out the same measurements and analysis increasing the mass of car 2 by using additional weights with 250 g .

## 4. Data processing and results presentation

From the table $\left(t_{1}, t_{2}\right)$ of each experiment, note that according to Eq. (7)

- $t_{2}$ will play the role of $x$ and
- $t_{1}$ will play the role of $y$.

The hypothesis of the conservation of the momentum in the inelastic collision implies that the relation between the initial and final times is a straight line with $P$ as slope

$$
\begin{equation*}
y=P x+C \tag{8}
\end{equation*}
$$

Consequently,
$t_{1}=P t_{2}+C$
According to the theory, in equation (7), implies that $P=Q_{m}$ and $C=0$.
Order the data with increasing values of $\boldsymbol{x}$. Plot a graph where $\boldsymbol{t}_{\boldsymbol{z}}$ is the $\boldsymbol{x}$ and $\boldsymbol{t}_{\boldsymbol{t}}$ is the $\boldsymbol{y}$. By using least squares linear regression determine the value obtained from the slope of the graph and the independent term $C$. Compare $P$ with the value $Q_{m}$ obtained from the measured masses, and determine the deviation $A$
$P=Q_{m}+A$
Give the results of the measured masses, the table with the times, the regression line, and the comparison of the values, $P, Q_{m}$. Also give the deviations $A$ and $C$.

## 5. Additional questions

Answer the following questions in your lab notebook:

- Which other methods are used in the transportation industry to minimize the friction between the wheels of the vehicle and the road?
- In addition to the friction between the cars and the ground, at high speeds (For example> 200 $\mathrm{km} / \mathrm{h}$ ) Which other type of interaction would lead to energy losses due to friction?. How could these interactions be minimized?

