

First name

Date

Last name

Degree program name

Exercise 114

Collisions - the change in momentum of the body and the momentum of the force

Car number:

Car weight: kg

Calibration mass: kg

Calibration weight: N

SPRING	N	v_{\min}	v_{\max}	Δv	Δp	$\int F dt$
		[m/s]	[m/s]	[m/s]	[kg·m/s]	[N·s]
SOFT	1					
	2					
	3					
HARD	1					
	2					
	3					

Exercise 114: Collisions - the change in momentum of the body and the momentum of the force

AIM

Study of elastic collisions. During the experiment, the change in momentum of the carriage and the corresponding total momentum of the force will be measured.

THEORY

Momentum is the product of mass and velocity ($\vec{p} = m\vec{v}$). Momentum is a vector quantity, that is, in addition to a value, it has a direction and a return. It is enough that one of these characteristics changes for momentum to change. A change in momentum is the difference of two vectors: final momentum and initial momentum:

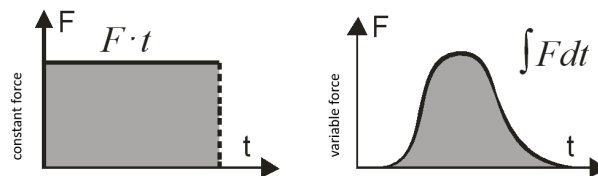
$$\Delta\vec{p} = \vec{p}_k - \vec{p}_0.$$

For example, if a body with mass $m = 2 \text{ kg}$ and velocity bounces elastically off a wall, the velocity after the bounce is equal to (-2 m/s) . The velocity and momentum of this body have changed because the return of the vectors has changed. The change in momentum of this body is equal to 8 kg ms^{-1} :

$$\Delta\vec{p} = \vec{p}_k - \vec{p}_0 \Rightarrow \Delta p = p_k - p_0 = mv - (-mv) = mv + mv = 2 \cdot 2 + 2 \cdot 2 = 8 \quad \text{SI: [kg}\cdot\text{m/s]}$$

The general form of the second principle of dynamics says that the change in momentum is equal to the momentum of the force. When the force is constant, the momentum of the force is the product of the force and the time of its action. $\Delta p = F \cdot t$.

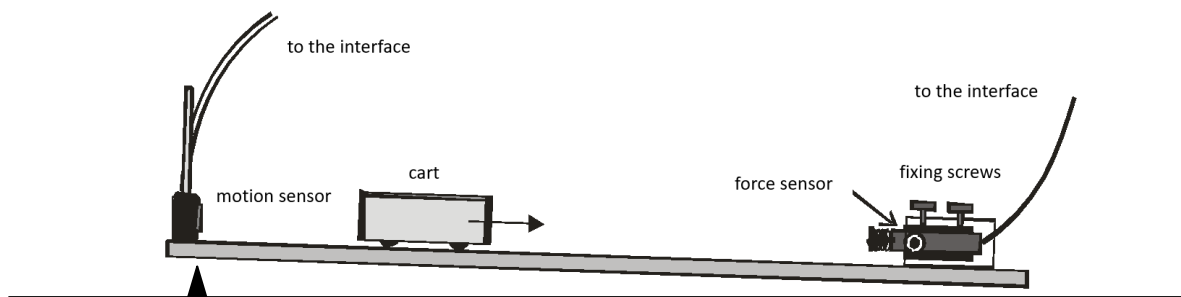
On the chart $F = F(t)$ The momentum of the force is equal to the area under the graph. If the force is not constant then, to calculate the field, you need to calculate the integral. Then the change in momentum, equal to the momentum of the force, is equal to this integral, $\Delta p = \int F dt$.



When a body hits an obstacle, the force acting on the body changes during the collision. Therefore, when counting the total momentum of the force, we do not count, but integrate.

A specific change in momentum can be achieved in two ways:

1. acting with great force in a short period of time,
2. acting with a small force over a long period of time.



The figure above shows a schematic of the measurement system.

EXERCISE MANUAL

EQUIPMENT NEEDED (Pict. 1)	<ul style="list-style-type: none"> • Cart
<ul style="list-style-type: none"> • PASCO universal interface 	<ul style="list-style-type: none"> • Two springs: soft and hard
<ul style="list-style-type: none"> • Motion sensor 	<ul style="list-style-type: none"> • Hook
<ul style="list-style-type: none"> • Force sensor 	<ul style="list-style-type: none"> • Heavyweight

In the experiment, the motion sensor will record the movement of the carriage before and after the collision with the spring, screwed to the force sensor (the spring plays the role of a bumper). The PASCO program will determine the velocity just before and just after the collision, and calculate the total momentum of the force.

SETTING UP THE MEASURING SYSTEM

1. Turn on the power of the table (see the dashboard of the table - by your left leg when sitting in front of the computer) - turn the red "knob" in the direction of the arrows (it should pop out), turn the key as in a car and let go.
2. Turn on in the following order: (1) PASCO universal interface, and then (2) computer.
3. Connect to the PASCO interface (if necessary): the force sensor to the analog channel A, and the position sensor to the digital channels: yellow tip - channel 1, black tip - channel 2. (Fig. 1).
4. To run the program, select profile **114** on the computer. Chart window (Fig. 1) shows the dependence of force and velocity on time.

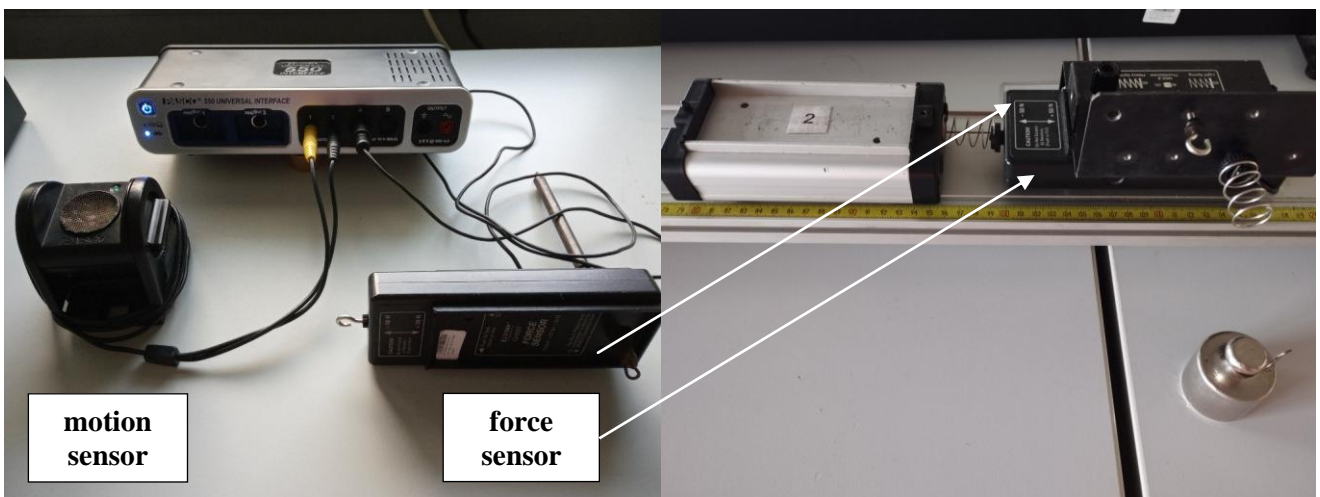
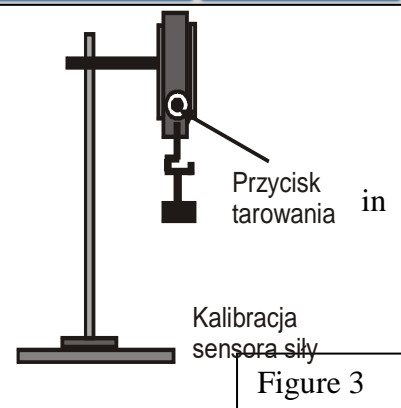
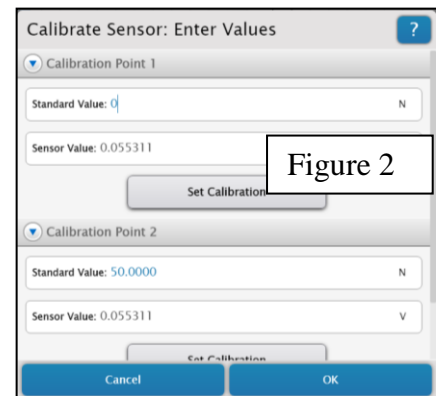


Figure 1

CALIBRATION AND PREPARATION OF SENSORS

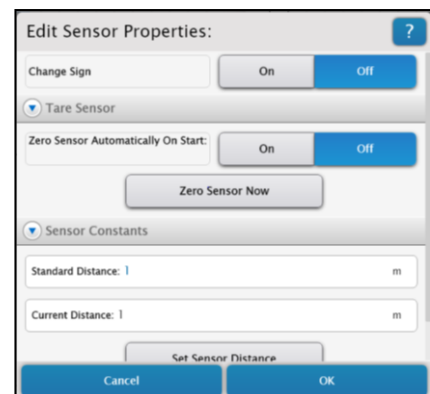
Calibration of Force sensor.

1. Press the icons: **Force** and next **Calibrate measurement**. (Fig. 1).
2. In the calibration window, select **Continue**.
3. The "Calibrate Sensor: Enter Values" window will appear. Here you will need to enter force sensor calibration values for the "0" position and with a given load.
4. Unscrew the spring and the screws maintaining the force sensor in the holder and hang the sensor on the tripod. Press the TARE button located on the side of the sensor.
5. In the calibration window in the section "Calibration point 1" in the line "Standard value" enter "0". Click **Set Calibration** button.
6. Screw the hook to the sensor.
7. Weigh the weight and hang it on the force sensor hook.
8. In the calibration window in the section "Calibration point 2", the line "Standard value" enter the calculated **weight Q of the hanging mass**. Click **Set Calibration** button, and **OK**.
($Q = m \cdot g$, mass in kilograms \cdot acceleration due to gravity 9.81 m/s^2)
9. Attach the force sensor to the holder on the rail.
10. Change the hook to a "soft" spring.



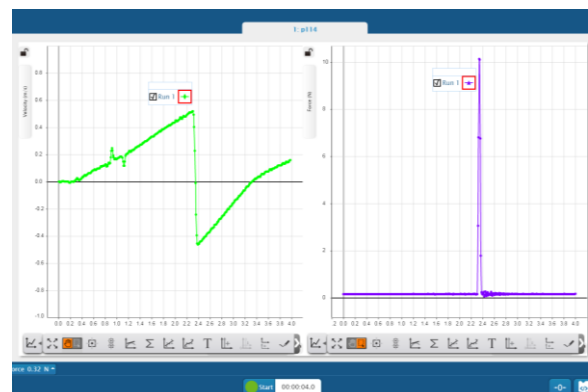
Calibration of velocity sensor

1. Place the cart on the rail.
2. Press the icons: **Velocity** and **Calibrate sensor**.
3. Press **Zero sensor now** button.
4. In section **Sensor Constants** in the line **Standard Distance** enter the distance value between sensor and cart (**in meters**). **NOTE!!! Use a dot instead of a comma in your entries**. Press **Set Sensor Distance**
5. The system is ready for the measurements



COURSE AND RECORDING OF MEASUREMENTS

1. Weigh the cart. Record the weight and number of the cart in the table.
2. Press the TARE button on the side of the force sensor before starting the registration.
3. Hold the cart at a distance of about 40 cm from the **motion sensor**. In subsequent measurements, let the cart go from the same place.
4. Press the button **Start** and release the cart.
5. Registration will be completed automatically after 4 seconds (see picture beside).
6. In the program window, a record of data from the first measurement will be displayed on the graphs as "Run 1". You can repeat the



experiment if the measurement is unsatisfactory. The program records successive measurement series and they are visible in the graph windows. You can select the best measurement data by marking the appropriate series in the window (Run 1, Run 2,...).

DATA ANALYSIS

1. To find the value of velocity directly before and after the collision, mark Σ and press **Maximum and Minimum**. (Picture below). The relevant values will appear on the graph.
2. To determine the total momentum of the force, mark the area of the peak on the force (force) vs. time (time) graph, then mark Σ and press **Area** (Picture below).



3. Take measurements three times.
4. Replace the spring and again take measurements three times.
5. Calculate the change in momentum for each measurement. Record the results in the table.
6. You can take a photo of the best measurement to insert the graph into the Report.
7. Turn off the PASCO universal interface, the computer and press the red "knob" on the table dashboard.

QUESTIONS FOR DISCUSSION

1. Is the value of the momentum of the force equal to the corresponding change in momentum?
2. What are the differences in the crash course of the tested springs?
3. What motion is the body moving before and after the collision?