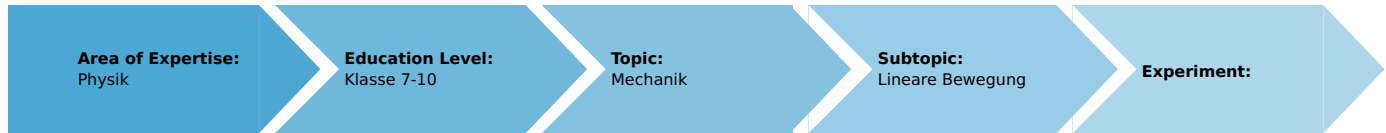


Law of inertia (Newton's first law) with the demonstration track and timer 4 (Item No.: P1199105)

Curricular Relevance



Difficulty



Intermediate

Preparation Time



10 Minutes

Execution Time



10 Minutes

Recommended Group Size



2 Students

Additional Requirements:

Experiment Variations:

Keywords:

Acceleration, frictionless motion, law of inertia, Newton's first law

Overview

Introduction

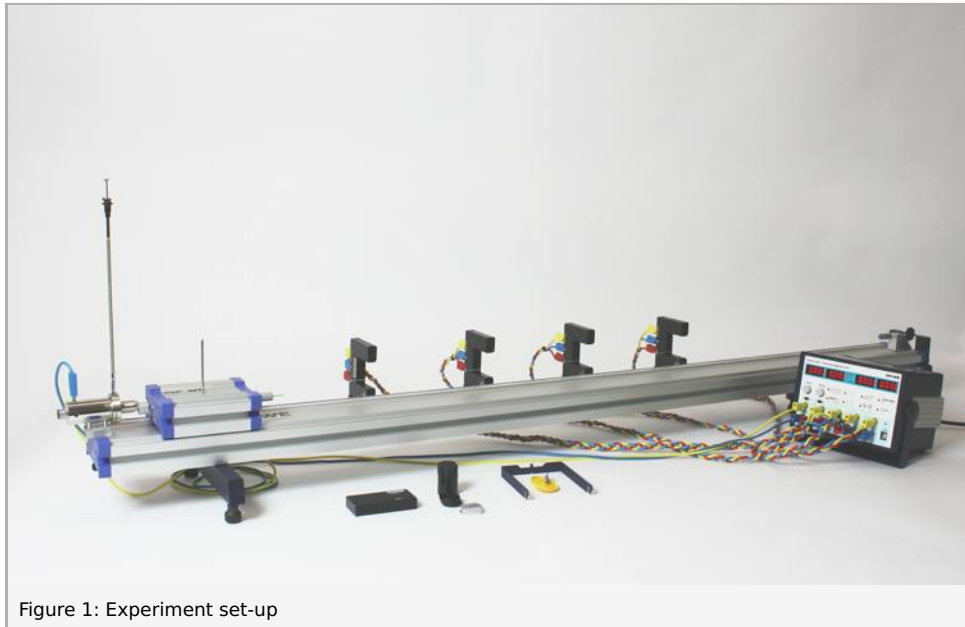
If, following an acceleration, an object is not subject to any external force, the object will remain in the state of a uniform motion. The aim of this experiment is to use the demonstration track and to measure the velocity of a uniformly accelerated cart in order to demonstrate that the velocity of the cart remains constant after the completion of the acceleration process.

Educational objective

Newton's first law states that an object at rest remains at rest if no external force acts upon it. An accelerated object maintains its uniform linear motion after it is no longer subject to any force acting upon it.

Related topics

The fact that an object with a constant velocity maintains this velocity as long as there is no friction has already been demonstrated in experiment P1198505 "Uniform linear motion".



Equipment

Position No.	Material	Order No.	Quantity
1	Timer 4-4	13604-99	1
2	Starter system for demonstration track	11309-00	1
3	Demonstration track, aluminium, 1.5 m	11305-00	1
4	Cart, low friction sapphire bearings	11306-00	1
5	Light barrier, compact	11207-20	4
6	End holder for demonstration track	11305-12	1
7	Weight for low friction cart, 400 g	11306-10	1
8	Magnet w.plug f.starter system	11202-14	1
9	Holder for pulley	11305-11	1
10	Pulley for demonstration track	11305-10	1
11	Shutter plate for low friction cart, width: 100 mm	11308-00	1
12	Weight holder, silver bronze, 1 g	02407-00	1
13	Needle with plug	11202-06	1
14	Tube with plug	11202-05	1
15	Slotted weight, black, 10 g	02205-01	4
16	Slotted weight, black, 50 g	02206-01	2
17	Holder for light barrier	11307-00	4
18	Connecting cord, 32 A, 1000 mm, red	07363-01	4
19	Connecting cord, 32 A, 1000 mm, yellow	07363-02	4
20	Connecting cord, 32 A, 1000 mm, blue	07363-04	4
21	Slotted weight, blank, 1 g	03916-00	
22	Plasticine, 10 sticks	03935-03	1
23	Silk thread, l = 200 m	02412-00	1
Option:			
	Plate on a stem	08060-00	1
	Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031-00	1
	Support rod PHYWE, square, l = 1000 mm	02028-55	1
	PHYWE right-angle clamp	02040-55	2
	PHYWE tripod base	02002-55	1

Task

Determination of the velocity based on a measurement of the light barrier shading times at different positions after different acceleration distances.

Set-up and procedure

Set-up

Set the experiment up as shown in Figure 1:

1. In order to compensate for slight friction effects, the track must be slightly inclined by way of the adjusting screws at the track bases so that the cart is still just about prevented from rolling to the right.
2. Position the starter system at the left end of the track. Please note that, in order to start the cart without an initial momentum, the starter system must be installed so that the ram moves away from the cart when the starter system is triggered (Fig. 2).



Fig. 2: Starter system without an impulse

3. Attach a plasticine-filled tube to the end holder at the right-hand end of the track in order to stop the cart without a strong impact (see Fig. 3).

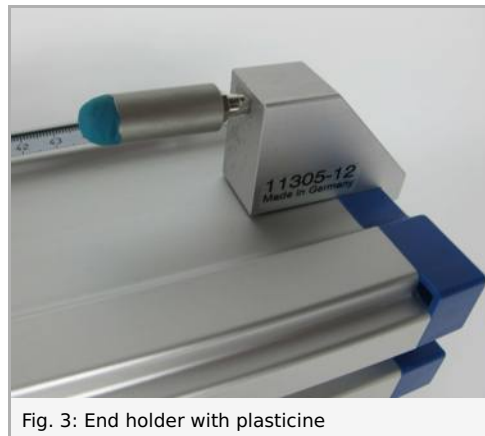


Fig. 3: End holder with plasticine

4. Install the pulley with the holder for the pulley at the right-hand end of the track and add the incremental wheel.
5. Equip the cart with the magnet with a plug and with the shutter plate ($w = 100 \text{ mm}$).
6. Insert the end of the thread from above through the vertical hole of the end cap of the cart and secure it in place by plugging the needle with a plug into the front (see Fig. 4).

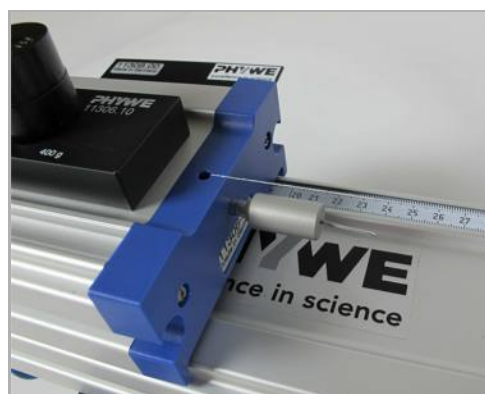


Fig. 4: Fastening of the thread on the cart

7. Lay the thread over the incremental wheel of the light barrier and knot its end onto the weight holder so that the latter is suspended freely just below the wheel (see Fig. 5). The force exerting the constant acceleration is the weight holder with 5 to 20 weights (1 g each) placed on it. Ensure that the thread is parallel to the track.

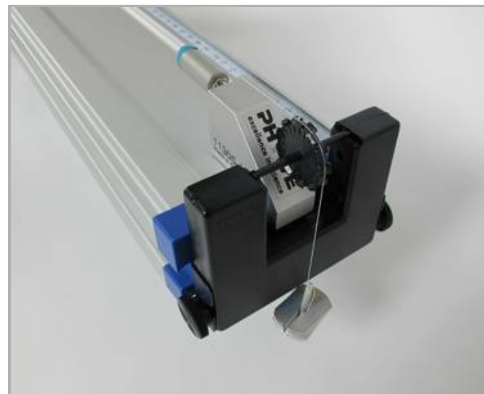


Fig. 5: Positioning of the weight holder

8. The mass of the cart can be varied by way of the black weights (see Fig. 4).
9. During the experiment, the weight holder is to be stopped at different heights before it can touch the floor so that the acceleration distance can be shortened. To do so, keep suitable objects in your environment ready for placing them under the weight holder on the floor.
10. Install the four light barriers on the track by way of the light barrier holders and distribute them evenly over the track. Ensure that the back part of the shutter plate on the moving cart can pass through all of the light barriers when the cart moves (see Fig. 6).

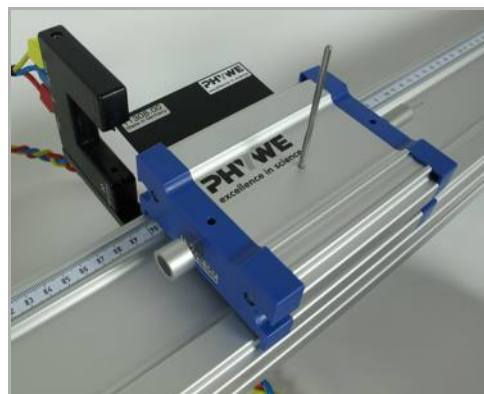


Fig. 6: Release of a light barrier following the passing of the shutter plate


11. Connect the four light barriers from the left to the right to the sockets in the fields "1" to "4" of the timer. In doing so, connect the yellow sockets of the light barriers to the yellow sockets of the measuring instrument, the red sockets to their red counterparts, and the blue sockets of the light barriers to the white sockets of the timer (see Fig. 7).



Fig. 7: Connection of the light barriers

12. In order to select the triggering edge, push the two slide switches of the timer to the right, i.e. to "falling edge" (↘)

Procedure

1. The cart is to be accelerated by the weight so that it performs a uniform motion that can be measured by way of the light barriers. Place an object under the weight holder so that it will be stopped when the cart is just about to enter the light beam of the first light barrier. The acceleration distance Δs corresponds to the distance that the cart covers from the start up to the moment when the weight holder is stopped. Vary the position of the light barrier, if necessary.
2. The cart is released by the starter system and it undergoes constant acceleration until the weight holder touches the plate. Then, it continues to move at a constant velocity.
3. In order to determine the instantaneous velocity of the cart passing through the light barriers, measure the shading times $\Delta t_1 \dots \Delta t_4$ in mode 1 ().
4. Record the times for three to five repetitions. Prior to every recording process, press the "Reset" button in order to reset the display.
5. Vary the acceleration distance by changing the object that is placed under the weight holder in order to vary the height at which the weight holder is stopped. As described hereinabove, adjust the position of the first light barrier and, in the case of longer acceleration distances, also the position of the subsequent light barriers. Then, perform a second series of measurements. This step can be repeated for other acceleration distances.

Observation and results

Observation

When the acceleration distance Δs increases, it becomes clear that the shading times Δt_i become increasingly shorter due to the longer acceleration of the cart. When the weight holder is stopped, the cart continues to move at constant velocity, since all of the shading times Δt_i are nearly identical.

Evaluation

1. Calculate the mean values $\Delta t_{1m} \dots \Delta t_{4m}$ for every acceleration distance based on the five measurements of $\Delta t_1 \dots \Delta t_4$.
2. Based on the mean values of the shading times, the mean velocities $v_{im} = w / \Delta t_{im}$ are determined based on a length of the shutter plate $w = 0.1 \text{ m}$.
3. Tables 1 and 2 show a measurement example. A comparison of the velocities at every light barrier shows, within the scope of the measuring accuracy, that the cart maintains its velocity after the completion of the acceleration process. In order to change the state of motion of an object, a force must act upon it. If there is no external force acting upon the object, it will remain at rest or in a uniform linear motion.

Table 1: Measurement example with a cart mass $m_c = 397 \text{ g}$, an accelerating mass $m = 8 \text{ g}$, and a shutter plate length $w = 0.100 \text{ m}$

Δs in m	Δt_1 in s	Δt_2 in s	Δt_3 in s	Δt_4 in s
0.555	0.229	0.231	0.233	0.232
0.555	0.231	0.234	0.237	0.238
0.555	0.233	0.235	0.238	0.240
0.555	0.233	0.236	0.239	0.240
0.555	0.232	0.235	0.237	0.238
0.425	0.261	0.266	0.274	0.288
0.425	0.261	0.264	0.267	0.267
0.425	0.264	0.270	0.273	0.276
0.425	0.262	0.266	0.271	0.273
0.425	0.265	0.269	0.272	0.272
0.200	0.395	0.404	0.415	0.426
0.200	0.395	0.403	0.413	0.421
0.200	0.400	0.416	0.435	0.457
0.200	0.399	0.415	0.433	0.452
0.200	0.398	0.413	0.432	0.454

Table 2: Mean values of the measurement example

Δs in m	Δt_{1m} in s	v_{1m} in m/s	Δt_{2m} in s	v_{2m} in m/s	Δt_{3m} in s	v_{3m} in m/s	Δt_{4m} in s	v_{4m} in m/s
0.555	0.232	0.432	0.234	0.427	0.237	0.422	0.238	0.421
0.425	0.263	0.381	0.267	0.375	0.271	0.368	0.275	0.363
0.200	0.397	0.252	0.41	0.244	0.426	0.235	0.442	0.226

Note

1. A height-adjustable plate as the one shown in Fig. 8 is particularly suitable for stopping the weight holder. If you use the optional items from the equipment list, fasten the long support rod in the tripod base and attach the plate to it by way of the short support rod and the two right-angle clamps.



Figure 8: Plate for stopping the weight holder at variable heights

2. The experiment can be performed with different cart masses and accelerating masses.
3. In order to decrease the distance between the weight holder and the incremental wheel, the thread can be shortened by turning the needle with a plug on the cart several times, thereby winding the thread up.