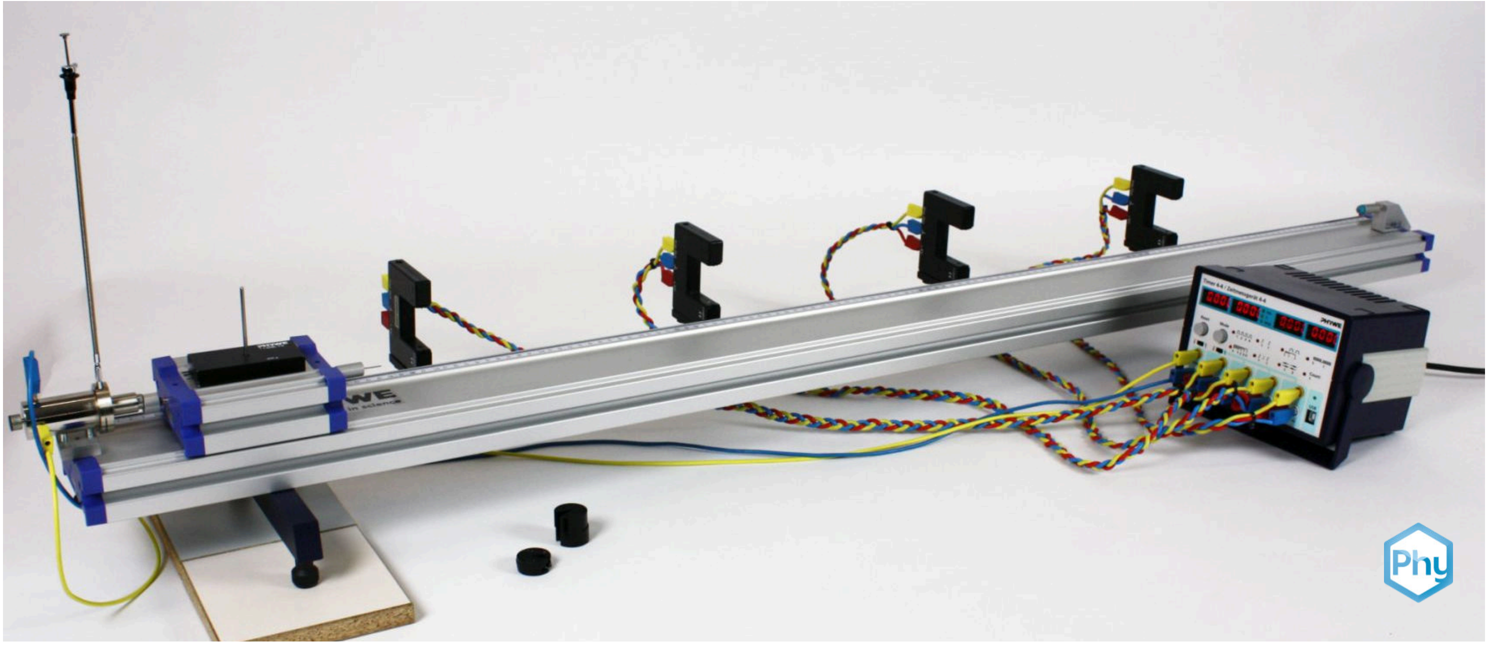
The uniformly accelerated movement on the inclined track with the roller track and timing device 4-4



Physics | Mechanics | Dynamics & Motion

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/60041950f3052e0003c4a263

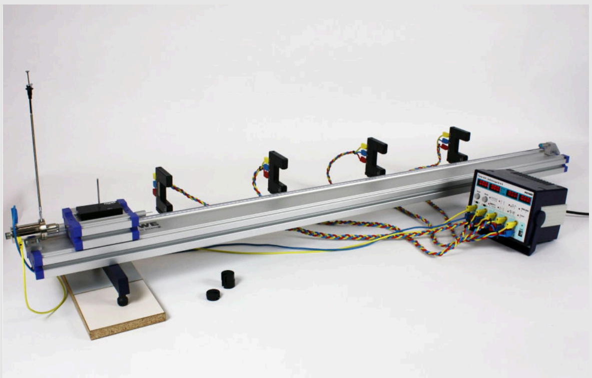
Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

General information

Application



Experiment set-up

A body experiences a constant acceleration parallel to the plane on an inclined plane due to the component of gravity acting on it.

Here, the laws of motion for uniformly accelerated motion are to be confirmed by travel time measurements of a trolley on the inclined roller track.

Furthermore, taking into account Newton's second law, the magnitude of the acceleration due to gravity can be verified.

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Other information (1/2)

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Prior knowledge

Students should be familiar with the basic concept and terminology of classical equations of motion.

Scientific principle

If an object moves along an inclined plane, it experiences a constant acceleration due to the gravitational field of the earth, which acts parallel to the said plane.

Other information (2/2)

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Learning objective

If a body is accelerated uniformly, the distance covered increases quadratically with time according to the distance-time law.

Tasks

1. Determination of the path-time dependence from several time measurements after different distances covered.
2. Determination of the velocity-time dependence from the shadowing time measurement of the light barriers at different positions.
3. Determine the acceleration due to gravity using the mass of the car and the angle of inclination of the track.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

Theory

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The speed is linear according to the speed-time law:

$$s(t) = \frac{1}{2} \cdot a \cdot t^2, v(t) = a \cdot t$$

Depending on the angle of inclination of the track, the force of gravity acting on the carriage results in a uniformly accelerated movement proportional to the acceleration due to gravity:

$$a = g \cdot sin(\alpha)$$

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Equipment

Position	Material	Item No.	Quantity
1	Demonstration track, aluminium, 1.5 m	11305-00	1
2	Cart, low friction sapphire bearings	11306-00	1
3	Shutter plate for low friction cart, width: 100 mm	11308-00	1
4	Needle with plug	11202-06	1
5	Tube with plug	11202-05	1
6	Plasticine, 10 sticks	03935-03	1
7	Weight for low friction cart, 400 g	11306-10	1
8	Slotted weight, black, 50 g	02206-01	2
9	Slotted weight, black, 10 g	02205-01	4
10	End holder for demonstration track	11305-12	1
11	Light barrier, compact	11207-20	4
12	Holder for light barrier	11307-00	4
13	Starter system for demonstration track	11309-00	1
14	Magnet w.plug f.starter system	11202-14	1
15	PHYWE Timer 4-4	13604-99	1
16	Connecting cord, 32 A, 1000 mm, red	07363-01	4
17	Connecting cord, 32 A, 1000 mm, yellow	07363-02	5
18	Connecting cord, 32 A, 1000 mm, blue	07363-04	5
19	Supporting blocks,set of 4	02070-00	1
20	Measuring tape, l = 2 m	09936-00	1
21	Portable Balance, OHAUS CR2200	48914-00	1

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Set-up and Procedure

Set-up (1/6)

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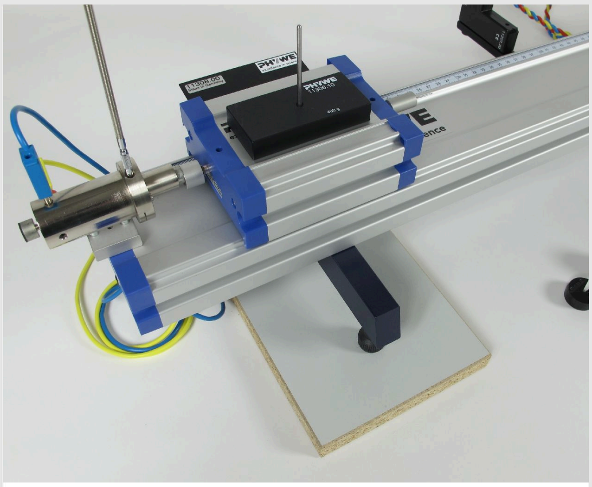

Raised launching device without shock

1. In order to compensate for minor friction effects, the track must be set at a slight angle using the adjusting screws on the feet so that the measuring carriage just does not start to roll to the right.

Then place an object (optionally blocks, books, stacks of paper, etc.) under the double-legged stand of the track to raise it by approx. 1-5 cm.

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Set-up (2/6)

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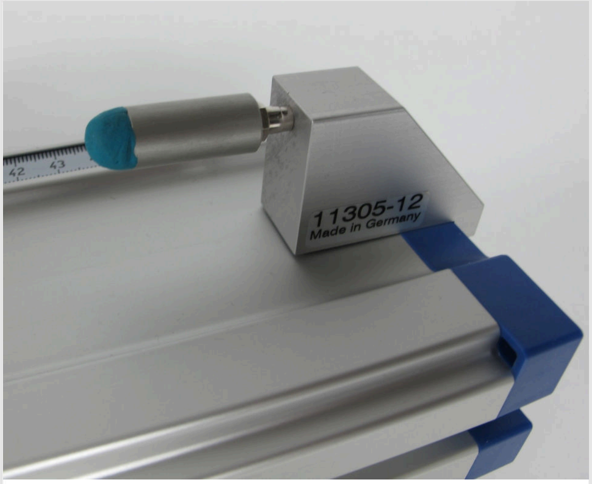

End bracket with plasticine

2. A launching device shall be installed at the left end of the runway.

Note; to start the trolley with initial pulse, the starting device must be mounted so that the punch moves away from the measuring trolley when triggered.

3. A tube filled with plasticine is attached to the end bracket at the right end of the track to slow the car down without hard impact.

Set-up (3/6)

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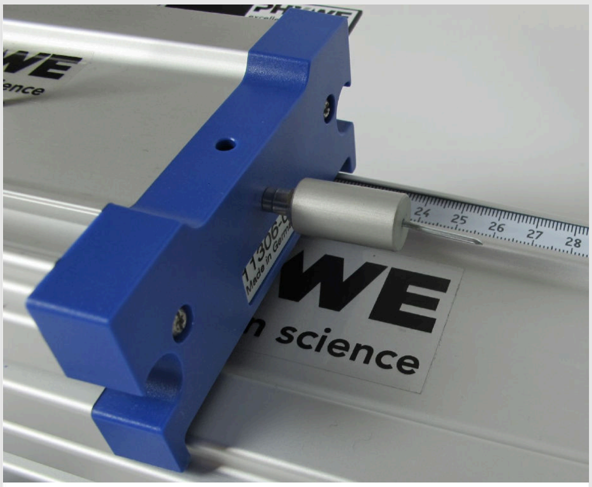

Front of the measuring carriage

4. The measuring carriage is equipped with the holding magnet with plug, a needle with plug as well as the cover for measuring carriage (b = 100 mm).

5. The mass of the trolley can be varied by means of the weights.

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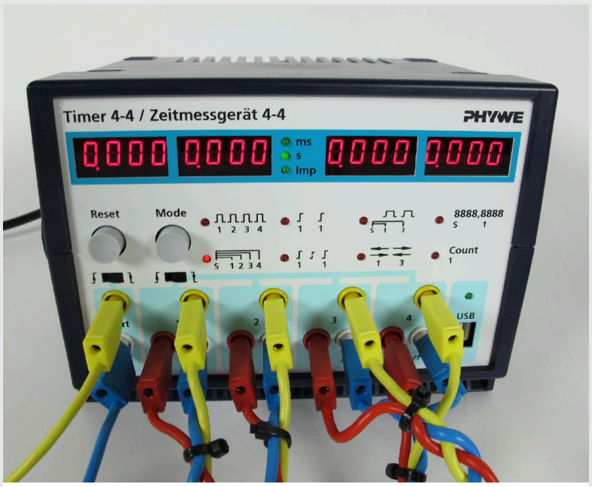
Set-up (4/6)

Mounting of the light barriers

6. The four forked light barriers are mounted on the roadway with the light barrier holders. Position the forked light barriers so that the measuring section is divided into segments of approximately equal size.

7. The mass of the car can be varied by means of the black painted weights.

Set-up (5/6)



Connecting to the timing device

8. The four forked light barriers are connected in sequence from left to right to the sockets in fields "1" to "4" of the timing device as shown in the illustration.

The yellow sockets of the light barriers are connected to the yellow sockets of the measuring device, the red sockets to the red sockets and the blue sockets of the light barriers to the white sockets of the time measuring device.

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Set-up (6/6)

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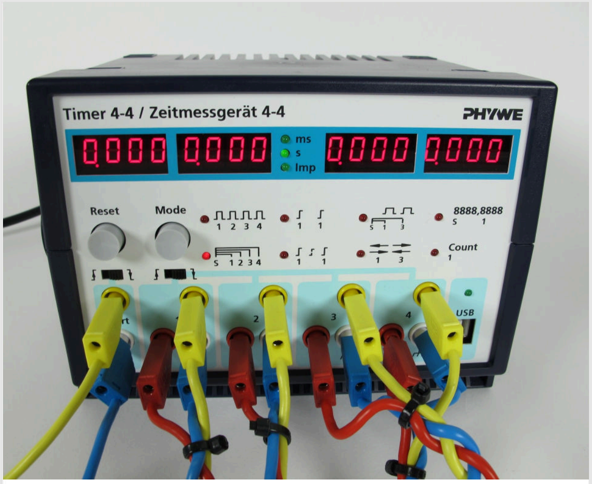

Verify settings

9. The starting device must be connected to the two "Start" connection sockets of the timing device.

Make sure that the polarity is correct.

The red socket of the starting device is connected to the yellow socket of the timing device.

10. The two slide switches on the timing device are set to the right-hand position "falling edge" ( ) to select the trigger edge.

Procedure (1/4)

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1. The distances $s_1 ... s_4$ of the light barriers to the start position of the trolley are measured.

It should be noted that the light barriers are only interrupted by the front edge of the panel mounted on the trolley.

For an exact determination of the distances, the following procedure can be followed:

- Move the carriage to the start position and set the value (x_0) on the measuring tape at the right end of the carriage.
- Move the carriage to a position where the right end of the diaphragm just interrupts the light beam of the forked light barrier i and the value (x_i) on the measuring tape at the right end of the carriage.
- $s_i = x_i - x_0$ is the distance the car has travelled from the start to the corresponding light barrier.

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Procedure (2/4)

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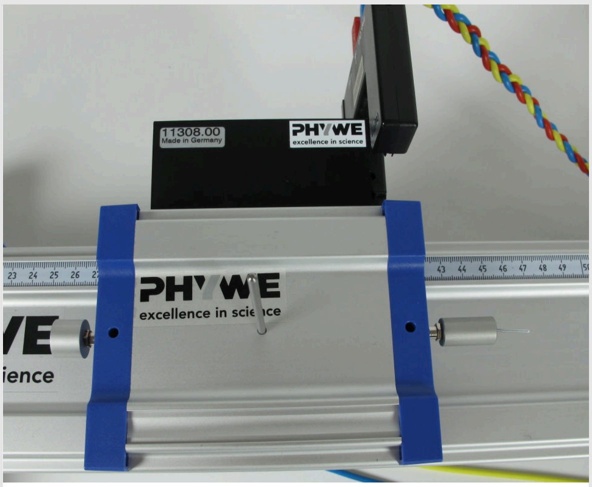

Interruption of the light barrier

2. The measuring carriage is released by the starter and experiences a constant acceleration due to the gravity component acting on it.

3. The times $t_1 ... t_4$ which are used to cover the distances $s_1 ... s_4$ from the start position to the respective light barrier are determined in mode 2 ( ). Subsequently, a measurement is performed in mode 1 ( ) to determine the corresponding velocities. The average speed during the corresponding passage is later calculated via the aperture length (100 mm) and the shadowing times $\Delta t_1 ... \Delta t_4$ of the four forked light barriers.

Procedure (3/4)

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4. The measuring times are recorded for up to five repetitions. Before each execution, press the "Reset" button to reset the displays.

5. In order to obtain a larger number of measuring points, it is now possible to reposition the light barriers and carry out another series of measurements as described above.

6. The mass of the trolley shall be determined by means of a balance.

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Procedure (4/4)

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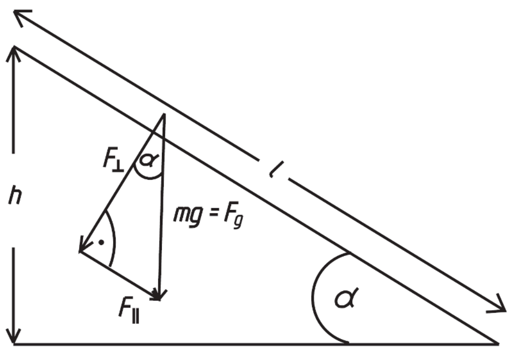
7. For the determination of the angle of inclination α of the track, measure the distance between the track stands l and the height h of the object placed under the track. Compare with the figure.



Evaluation (1/7)

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Observation

If approximately equal distances between the light barriers were selected, it can be observed that the differences in the transit times t_i and the shading times Δt_i decrease due to the acceleration of the car with increasing distance.

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Evaluation (2/7)

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Measured values

s in m	t_m in s	Δt_m in s	v in m/s	$a = v/t_m$ in m/s²	$(t_m)^2$ in s²	$a=2s/(t_m)^2$ in m/s²
0,2	1,724	0,394	0,254	0,147	2,97	0,135
0,5	2,74	0,263	0,38	0,139	7,51	0,133
0,8	3,474	0,214	0,468	0,135	12,07	0,133
1,1	4,075	0,184	0,542	0,133	16,61	0,132
0,05	0,817	0,661	0,151	0,185	0,67	0,15
0,35	2,282	0,308	0,325	0,142	5,21	0,134
0,65	3,132	0,234	0,427	0,136	9,81	0,132
0,95	3,788	0,196	0,509	0,134	14,35	0,132

Evaluation (3/7)

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a) The distance-time and the velocity-time law

1. For the five measurements each of $t_1 ... t_8$ and $\Delta t_1 ... \Delta t_8$, determine the mean values $t_{1m} ... t_{8m}$ and $\Delta t_{1m} ... \Delta t_{8m}$.
2. Calculate the velocities from the shading times $v_i(t_{im}) = b/\Delta t_{im}$ with the aperture length b = 0.1 m.
3. For the uniformly accelerated motion, the acceleration can be calculated as a with two different methods. Either via the path-time law $s(t) = 0,5 \cdot a \cdot t^2$ from the running time and the respective position of the light barriers, or via the speed-time law $v(t) = a(t) \cdot t$ from the running time and the corresponding speed.

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Robert-Bosch-Breite 10
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Evaluation (4/7)

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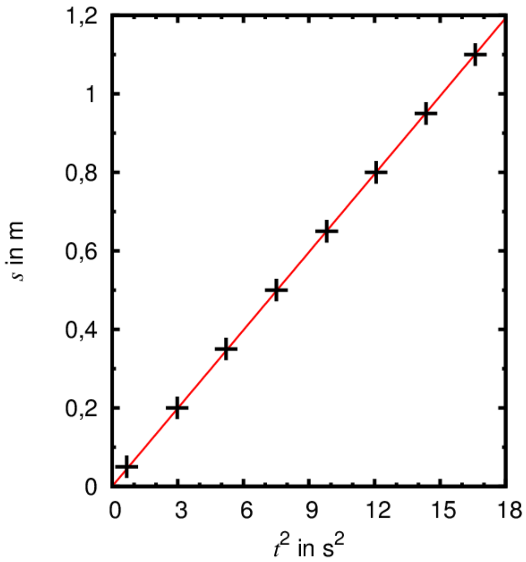
- To verify the displacement-time law, enter the measured values in a (s, t^2)-coordinate system. The acceleration a can be calculated graphically from the gradient of the straight line through the zero point $(0, 5 \cdot a)$ as well as by calculation.



Evaluation (5/7)

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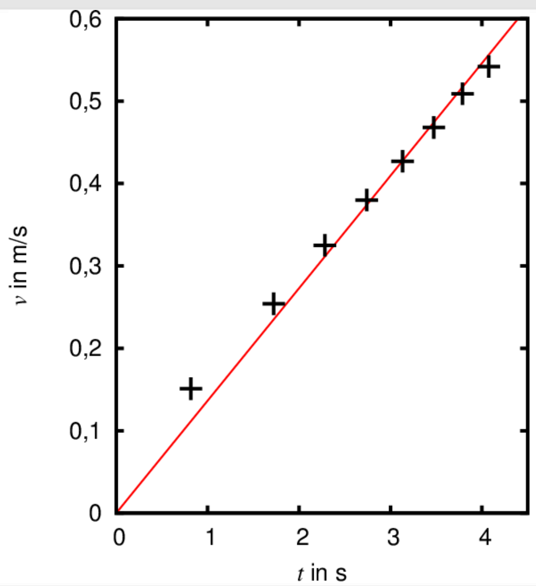
- In a (v, t) coordinate system, plot the determined velocities against the measured time. The velocity-time law is obtained graphically from the slope of the straight line through the zero point or by calculation.



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Robert-Bosch-Breite 10
37079 Göttingen
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Fax: 0551 604 - 107
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Evaluation (6/7)

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b) Determination of the acceleration due to gravity

The weight force acting on the measuring carriage F_g can be split into two parts, a component $F_{||}$ in the direction of the track and a component $F_{\perp}$ perpendicular to the path. As the angle of inclination αα increases, the component of acceleration in the direction of the path also increases $F_{||}$, causing a uniformly accelerated movement. The figure on slide 18 shows the vectorial decomposition of the force with a parallelogram of forces. Here, the following formular applies; $F_{||} = F_g \cdot sin(\alpha)$.

The angle of inclination α results from the height h of the object placed under the track and the distance l between the two track supports to $sin(\alpha) = h/l$. In the measurement example given here, h = 1.9 cm and l = 139 cm, i.e. $\alpha = 0,78^{\circ}$.

Evaluation (7/7)

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According to Newton's second law

$$F_{||} = m \cdot g \cdot sin(\alpha) = m \cdot a$$

and the acceleration determined from the figure in slide 22

a = 0.133 m/s²

results in the following value for the acceleration due to gravity

$$g_s = \frac{a}{sin(\alpha)} = 9.73 \text{ m/s}^2$$

The following acceleration due to gravity results from the velocity measurements according to the figure on slide 23:

g_v = 9,95 m/s²

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Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
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Notes

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1. The calculated speeds v_i from Δt_i are, strictly speaking, not instantaneous velocities, since an acceleration continues to act on the carriage as it passes through the light barrier. The velocities thus result from a secant slope, but not from a tangent slope of the graph of $s(t)$. With Δs= 0.1 m, a systematic error of about 2 % must be expected.
2. With a further increase of the starting position, the proportionality between acceleration and the sine of the inclination angle can be demonstrated. By repeating the measurements with different slot weights on the trolley, the fact that the acceleration and speed of the trolley (assuming freedom from friction) are unaffected by the mass can be demonstrated. This relationship can also be well demonstrated in the context of the experiment on free fall.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de