Newton's law: acceleration as a function of mass with the 2-1 timer

Physics | Mechanics | Energy conservation & impulse

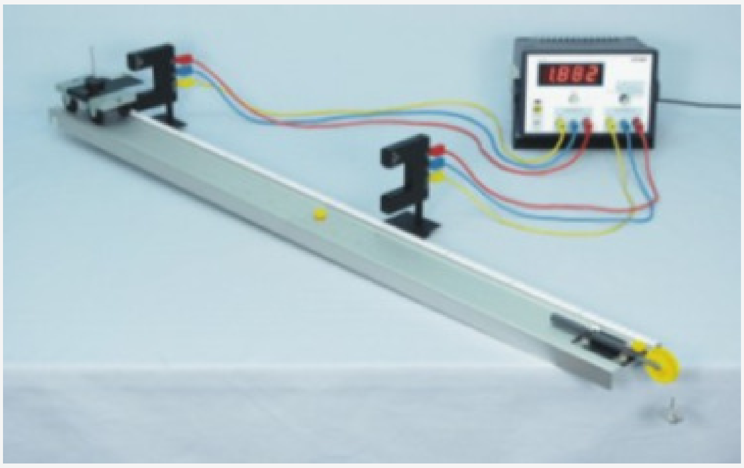
Difficulty level	Group size	Preparation time	Execution time
hard	2	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/5fdbb90d5098f00003f1edfa

Teacher information

Application



Experiment set-up

Newton's equation of motion, or Newton's 2nd law, represents a fundamental equation in mechanics. With the help of this equation, systems of mechanics can be completely described in space and time.

It states that the product of a mass m and acceleration a corresponds to the required force F.

$$F = m \cdot a$$

It is used wherever forces act on bodies with masses.

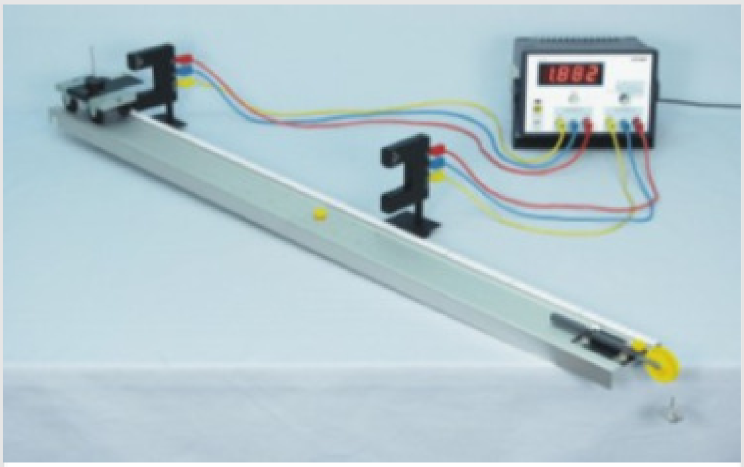
Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Application

PHYWE



Experiment set-up

Newton's equation of motion, or Newton's 2nd law, represents a fundamental equation in mechanics. With the help of this equation, systems of mechanics can be completely described in space and time.

It states that the product of a mass m and acceleration a corresponds to the required force F.

$$F = m \cdot a$$

It is used wherever forces act on bodies with masses.

Other teacher information (1/2)

PHYWE

Prior knowledge

Students should be familiar with the concepts of acceleration, force, and velocity. In addition, students should be able to mathematically determine the slope of a straight line and its dimension.

Scientific principle

The car on the roadway is accelerated uniformly by the gravitational force with the aid of the deflection pulley and the thread. The concrete value of the acceleration is calculated as follows a from traction F and the accelerated mass of the car m from Newton's second law:

$$a = F/m$$

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Other teacher information (2/2)

PHYWE

Learning objective

In this experiment, students should experimentally respond to the simplified formulation of Newton's 2nd law $F = m \cdot a$.

Tasks

1. The students accelerate a car of variable mass m on a track with the aid of an attached constant traction mass m_z and measure the travel time t required for the car to cover a distance of s of $50\,cm$. To do this, the students increase the total accelerated mass (car mass + train mass) step by step from $65\,g$ up to $185\,g$.
2. They then evaluate the measurement data and obtain a linear relationship between acceleration and accelerated mass, from which they determine the slope and its dimension.

Safety instructions

PHYWE

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

General information

A second light barrier can be added to adjust the path inclination (for friction compensation): Push the car, measure the shading times of the two light barriers. Compare both measured values (shading times) and adjust the track inclination if necessary.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Student Information

Motivation

Rocket launch

Newton's equation of motion, or 2nd Newton's law, is a fundamental equation in mechanics that can be used to completely describe mechanical systems in space and time.

It states that the required force F is the product of a mass m and acceleration a and is used wherever forces act on bodies with masses. If, for example, when a rocket is to be launched, the engine must generate such a large force effect that it permanently overcomes the acceleration due to gravity many times over.

In this experiment, you experimentally arrive at Newton's 2nd law: $F = m \cdot a$.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	Cart for measurements and experiments	11060-00	1
2	Shutter plate for cart	11060-10	1
3	Holding pin	03949-00	1
4	Silk thread, l = 200 m	02412-00	1
5	Weight holder, silver bronze, 1 g	02407-00	1
6	Slotted weight, blank, 1 g	03916-00	4
7	Slotted weight, black, 10 g	02205-01	4
8	Slotted weight, black, 50 g	02206-01	3
9	Pulley,movable,dia.40mm,w.hook	03970-00	1
10	Rod for pulley	02263-00	1
11	PHYWE Timer 2-1	13607-99	1
12	Light barrier, compact	11207-20	2
13	Adapter plate for Light barrier compact	11207-22	2
14	Connecting cord, 32 A, 1000 mm, red	07363-01	2
15	Connecting cord, 32 A, 1000 mm, yellow	07363-02	2
16	Connecting cord, 32 A, 1000 mm, blue	07363-04	2
17	Track, l 900 mm	11606-00	1

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Equipment

PHYWE

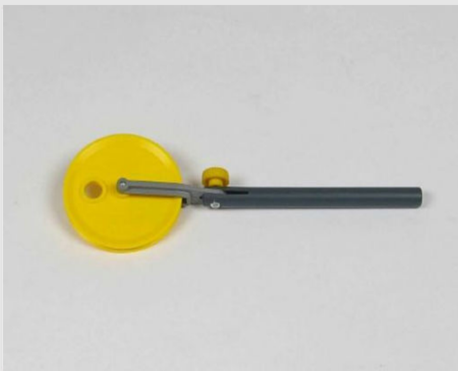
Position	Material	Item No.	Quantity
1	Cart for measurements and experiments	11060-00	1
2	Shutter plate for cart	11060-10	1
3	Holding pin	03949-00	1
4	Silk thread, l = 200 m	02412-00	1
5	Weight holder, silver bronze, 1 g	02407-00	1
6	Slotted weight, blank, 1 g	03916-00	4
7	Slotted weight, black, 10 g	02205-01	4
8	Slotted weight, black, 50 g	02206-01	3
9	Pulley,movable,dia.40mm,w.hook	03970-00	1
10	Rod for pulley	02263-00	1
11	PHYWE Timer 2-1	13607-99	1
12	Light barrier, compact	11207-20	2

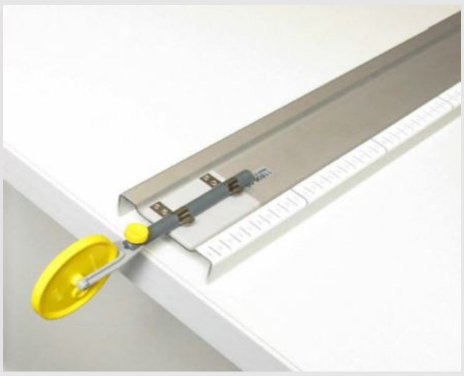
Set-up (1/5)

PHYWE

Connect the pulley to the handle and then carefully slide the handle under the brackets at the end of the track. To do this, lift the retaining clips slightly with your fingers. Position the track at the end of the table so that the pulley can rotate freely.

Take the car and attach the holding pin and the shade screen to it.





PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

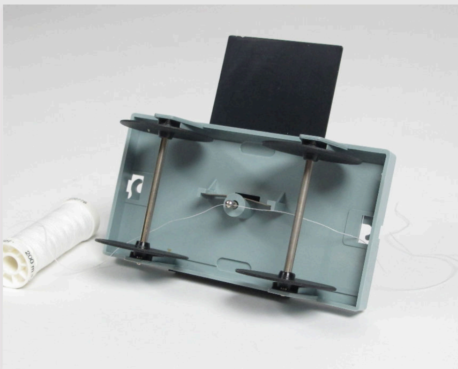
Tel.: 0551 604 - 0
Fax: 0551 604 - 107

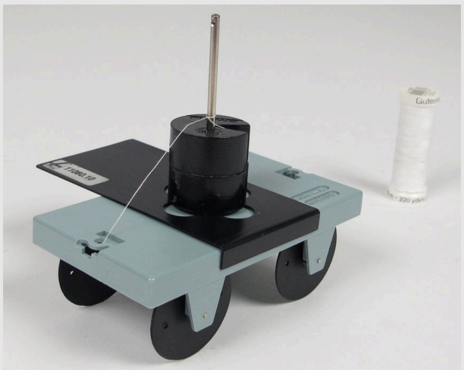
info@phywe.de
www.phywe.de

Set-up (2/5)

PHYWE

Tilt the track so that the lightly pushed car rolls on at as constant a speed as possible. To do this, set the set screw at the other end of the track to slot weights and use it to adjust the incline. Then feed the end of the sewing silk through the hole of the holding pin at the bottom of the car, feed it through to the back of the top of the car and knot it to the holding pin.





Set-up (3/5)

PHYWE

Knot end of thread to weight plate

Tie the other end to the 1 g weight plate, choosing the length of the thread so that the weight plate only touches the floor after the car has passed the light barrier set up further down.

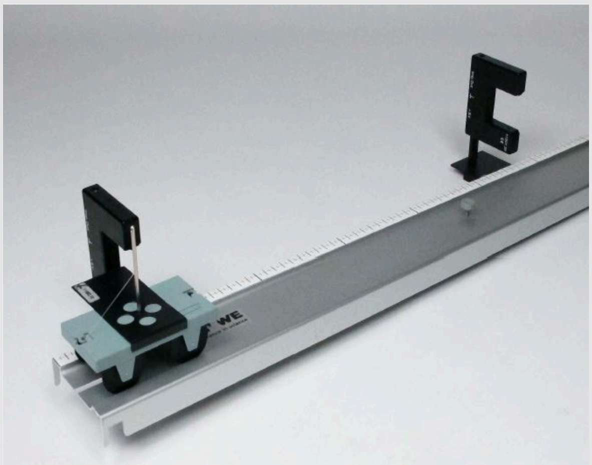
Weight the weight plate with a total of four 1 g slot weights so that the total tensile mass is 5 g.

Now place the thread that connects the car to the weight plate over the pulley. The thread should run above the axis of the car and parallel to the track.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Set-up (4/5)

PHYWE



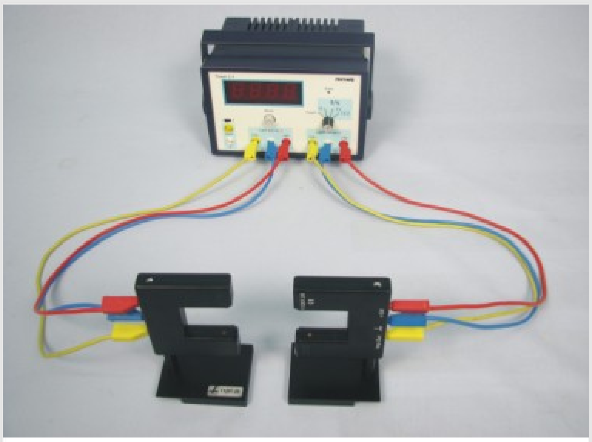
Connecting adapter plates with light barriers

Connect the adapter plates (if necessary, each with a spacer bolt) to the forked light barriers in such a way that they can be easily set up next to the carriageway and the screen on the car can pass through the light barriers without hitting them.

Set up the first light barrier at about the 8.2 cm mark on the measuring tape, measured from the top end of the carriageway, and position the second light barrier at a distance of 50 cm from the first. When starting, the car should be flush with the road surface without interrupting the first light barrier. If necessary, correct the position of the light barriers accordingly.

Set-up (5/5)

PHYWE



Connect the light barriers to the timing device

Connect both light barriers to the timing device.

Set the slide switch above the "Start" field on the timing device to the right position.

Set the rotary switch on the timing device to the third position from the left. Then the device displays the time that has elapsed between the interruption of the first and the second light barrier.

PHYWE

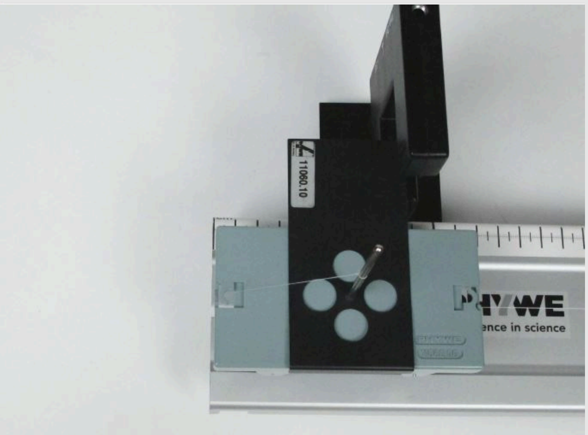
Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Procedure (1/2)

PHYWE

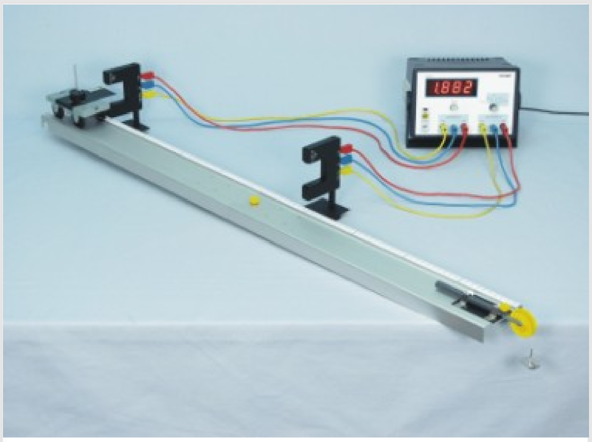


Car at the top of the lane

- Push the car to the upper end of the lane. The car should be flush with the end of the carriageway as seen from above.
- Make sure that the light barrier is not yet interrupted.
- Check whether the thread really runs over the deflection pulley and whether it can be turned freely.
- Press the "Reset" button on the timer 2-1 before each measurement. button on Timer 2-1.
- Now let go of the car without bumping it and catch it behind the second light barrier.

Procedure (2/2)

PHYWE



Test setup with car at the upper end of the lane

- Read the driving time t and note the value in Table 1 in the report.
- Increase the mass m (car mass + train mass) accelerated from 65 g (car without weights + train mass) successively to 85 g, 115 g, 135 g, 165 g, 185 g using the 10 g and 50 g slot weights.
- Before each start, check whether the yarn runs over the roller and make sure that the start light barrier is only interrupted after the car has been released.

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

PHYWE

Report

Table 1

PHYWE

Enter your measured travel times t and their squared values t^2 in the table.

Calculate both the reciprocal of the mass $1/m$ as well as the acceleration a of the car. Use for the latter the formula of uniform acceleration $s = \frac{1}{2} \cdot a \cdot t^2$:

$$a = \frac{2 \cdot s}{t^2}$$

$m\ [g]$	$t\,[s]$	$t^2\ [s^2]$	$1/m\,[1/kg]$	$a\,[m/s^2]$
65				
85				
115				
135				
165				
185				

PHYWE

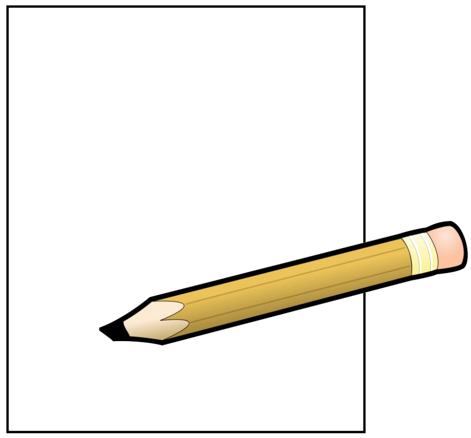
Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Task 1

Now take a sheet of paper and draw a diagram on it. In this diagram you place the acceleration a ($y$axis) as a function of the reciprocal value of the mass $1/m$ ($x$axis).



Task 2

In the diagram the acceleration a is plotted against the reciprocal of the accelerated mass $1/m$. What conclusions can be drawn from the diagram?

- ☐ The acceleration and the reciprocal of the mass are proportional to each other.
- ☐ The smaller the accelerated mass, the greater the acceleration.
- ☐ The acceleration is proportional to the accelerated mass.
- ☐ The larger the accelerated mass, the stronger the acceleration.
- ☐ If the mass were (theoretically) infinite, the acceleration would be zero.

Check

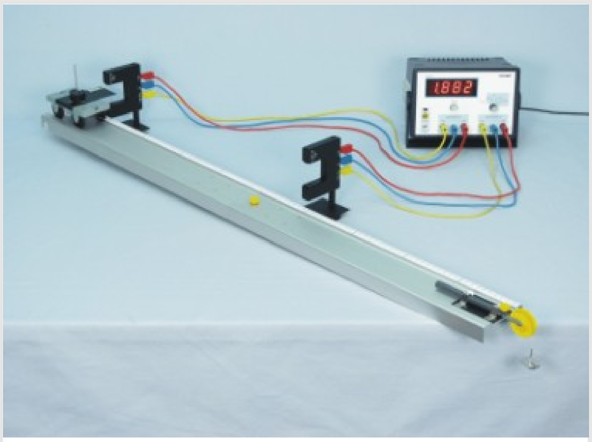
Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Task 3

PHYWE



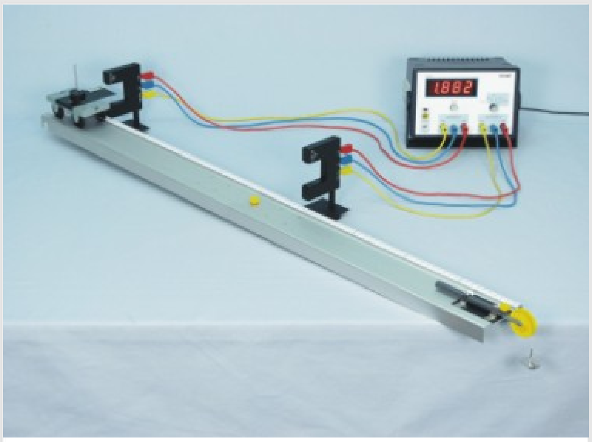
Experiment set-up

Determine the slope k of the straight lines from the diagram and determine their dimension.

$k =$ [ ] [ ]

Task 4

PHYWE



Experiment set-up

Determine the dimension of the slope k of the linear progression from the diagram and select the correct unit!

- $[k] = kg$
- $[k] = N/m^2 = Pa$
- $[k] = kg \cdot m/s^2 = N$
- $[k] = kg \cdot m^2/s^2 = Nm$

Check

PHYWE

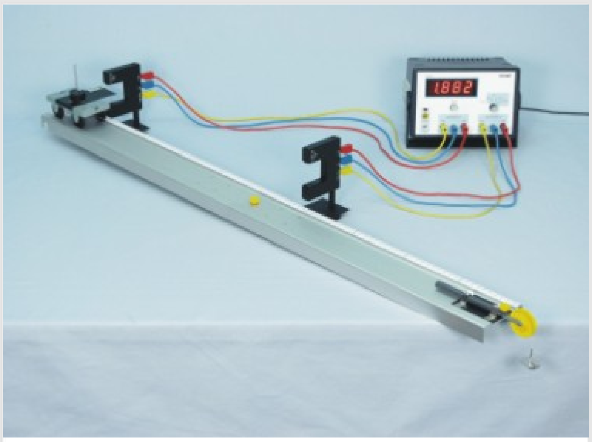
Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Task 5

PHYWE



Experiment set-up

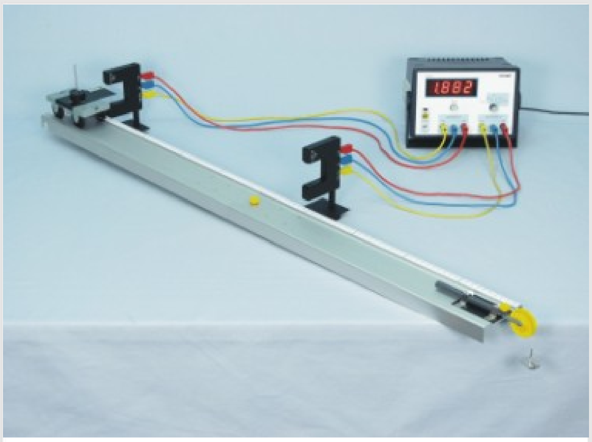
Compare the slope found k by traction $F = 5g \cdot 9,81 m/s^2 = 0,049 N$. What can you tell?

- $k \gg F$
- $k \ll F$
- $k = 2 \cdot F$
- $k = F$

Check

Task 6

PHYWE



Experiment set-up

Which of the following equations results from the diagram with the proportionality factor k found and the finding from the previous question?

- $F = m \cdot a^2$
- $F = m \cdot a$
- $F = m/a$

Check

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de