Freier Fall mit SMARTsense (Item No.: P1004169)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 16-19	Mechanics	Energy and momentum	Free fall with SMARTsense

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	2 Students

Additional Requirements:

- Tablet

Experiment Variations:

- Classic student experiment: Free fall (P1004100)
- Classic student experiment: Free fall with the 2-1 timer (P1004105)

Keywords:

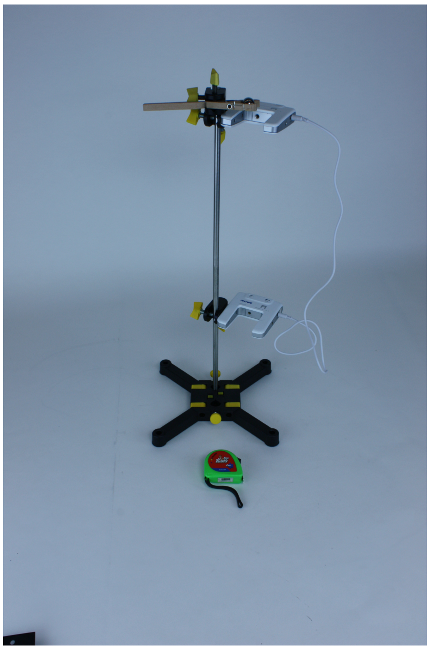
gravitational acceleration, free fall, uniform acceleration

Information for teachers

Introduction

Application
We encounter free fall in our everyday life whenever things fall to the ground.
However, the lower the density and the larger the surface of the object are, the free fall increasingly turns into a less strongly accelerated, or decelerated, fall.

Free fall in an amusement park



Experiment set-up

Educational objective
During this experiment, the students are tasked with determining the gravitational acceleration g in an experimental manner so that they can see that a free-falling motion is in fact a uniformly accelerated motion.

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Tasks

1. The students let a steel sphere fall out of a holder and they measure the times of fall t for several different heights of fall h with the help of the Mobile-Link and a light barrier.
2. The students examine the measurement data (height of fall h and time of fall t) in order to identify the laws by which the two quantities are connected.
3. The students calculate the value of the gravitational acceleration g based on the measurement values.

Prior knowledge
The students should be familiar with the concepts of velocity and motion.
In addition, the students should have the mathematical skills to determine the gradient of a straight line and to perform a dimensional analysis of the gradient.

Principle
In the Earth's gravitational field, the mass of the steel sphere produces constant force acting in the same direction, which accelerates the sphere in a uniform manner.
Frictional effects caused by the air as well as the aerodynamic lift of the sphere caused by the surrounding air can be neglected in this experiment.

Note
With this rather simple experiment set-up, the gravitational acceleration can be determined with a deviation of just a few per cent if the experiment is performed carefully.

Safety instructions

For this experiment, the general notes and instructions concerning safe experimentation in science classes apply.

Versuch: Freier Fall mit SMARTsense (Item No.: P1004169)

Introduction

Application and task

How does a stone fall?

Introduction

Have you ever let a stone fall down from a tower and asked yourself how fast it will be when it reaches the ground or how long it will take to cover the height of fall?
This experiment will show you the laws governing free fall: Therefore, you should be able to answer your questions after the completion of the experiment.
However, the experiment must be interpreted with caution, since even a small stone falling from a tower is strongly decelerated by air resistance.

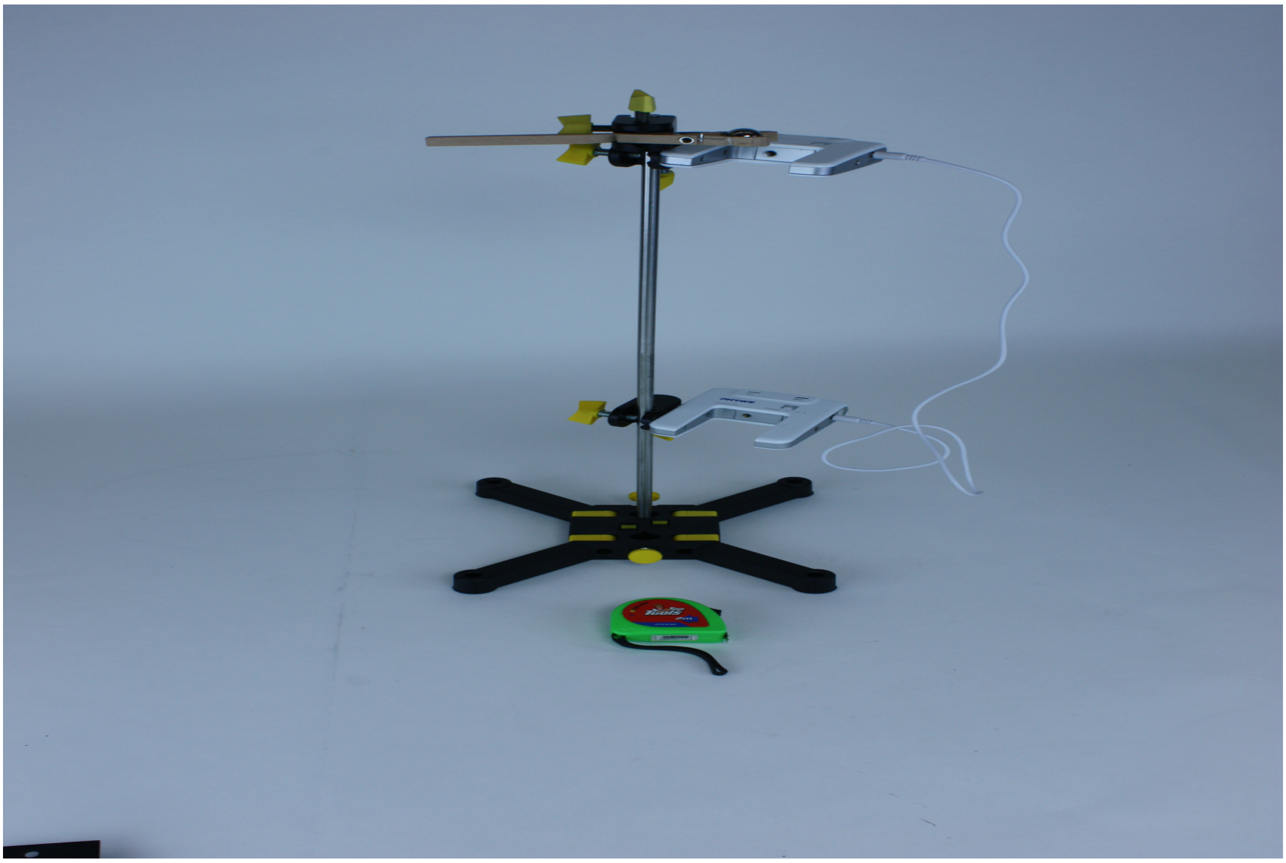
Application

You encounter nearly free-falling motion in your everyday life whenever something falls to the ground. However, air resistance plays a considerable role.
When the American astronauts landed on the Moon, David Scott dropped a hammer and a feather and both reached the ground at the same time! This was true free fall, since there is no air resistance or aerodynamic lift on the Moon.

Free fall in an amusement park

Tasks

1. Let the steel sphere fall out of a holding device and measure the time t that the sphere needs to cover the height of fall h. Repeat the experiment with different heights of fall.
2. Examine the measurement data and try to identify any laws that connect the height of fall and the time of fall.
3. Determine the acceleration of free fall on Earth based on the measurement values.



Experiment set-up

Material

Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
3	Boss head	02043-00	3
4	Cobra SMARTsense - Photogate, 0 ... ∞ s	12909-00	1
5	Ball release unit	02505-00	1
6	Steel ball, d = 19 mm	02502-01	1
7	Measuring tape, l = 2 m	09936-00	1

Set-up and procedure

Set-up

Set the support system up.
To do so, screw the support rods together (Fig. 1) and fasten them in the support base.
Fasten one right-angle clamp at the top of the rod, the second directly below that and the other one in a middle position (Fig. 2).

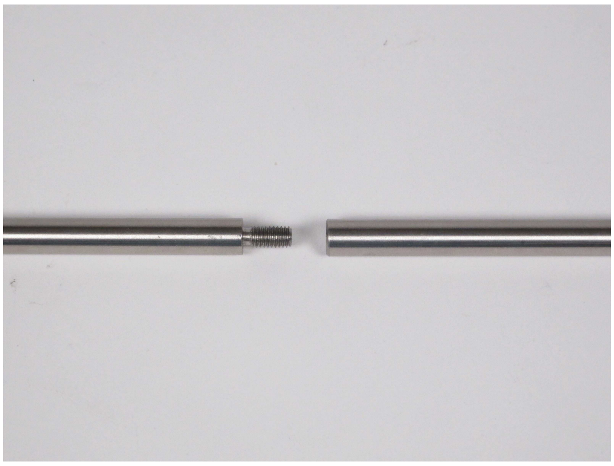


Fig. 1

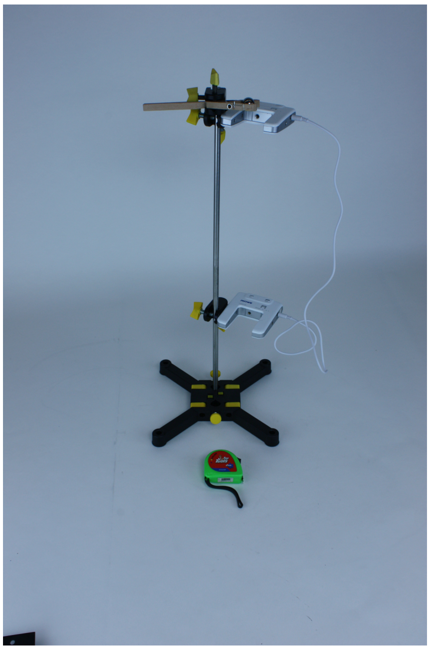


Fig. 2

Screw one distance bolt into the light barrier B and mount them in the lowest clamp (fig. 3).
Repeat that with light barrier A but mount that in the second highest clamp. Connect both light barriers with the stereo jack.

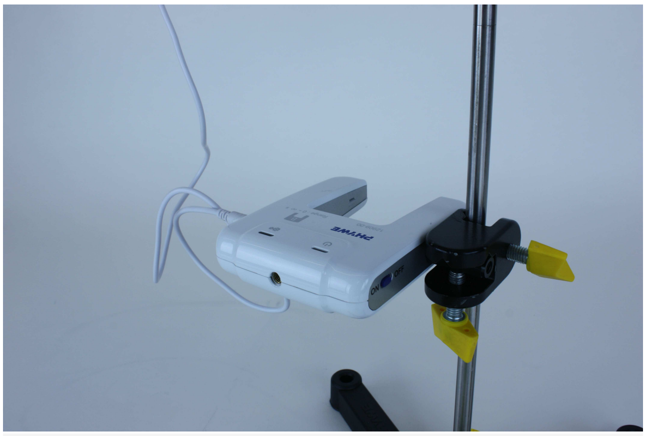


Fig. 3.

Fasten the sphere releasing clamp horizontally in the upper right-angle clamp and move the top light barrier as close to the clamp as possible (Fig. 4).
Ensure that the holding hole of the clamp is in line with the light beam of the light barrier when viewed from above.

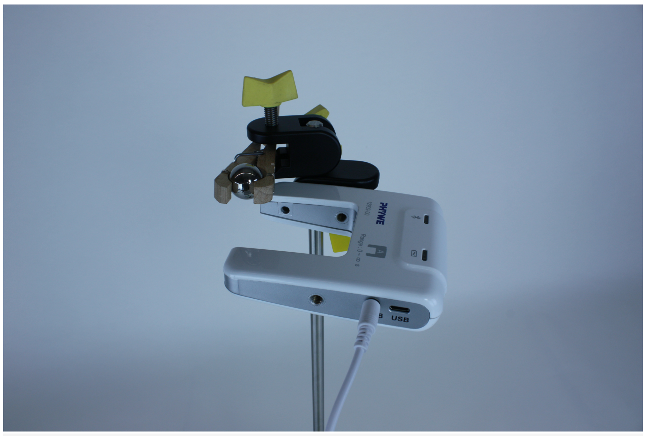


Fig. 4.

Switch both light barriers on. In the measureAPP menu "sensors" pick the option "photogate" to connect them to measureAPP. In the then appearing dialogue select the option "Run times" (fig 5.). In this mode the light barriers measure the time from starting the measurement to passing of the sphere.

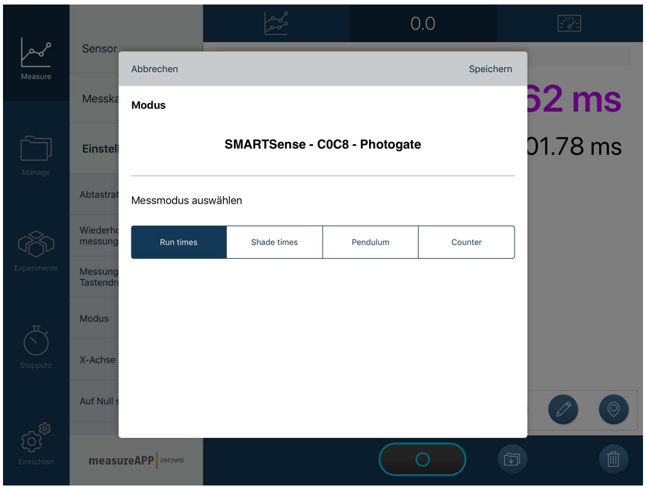


Fig. 5.

Procedure

Use the rule to adjust a distance of 7.5 cm (height *h*) between the lowest point of the ball in the holding clamp and the middle seam of the light barrier (Fig. 7). Clamp the sphere always in the same manner into the holding clamp for the individual measurements.

Fig. 7.

(Ensure that the lower light barrier is fastened to the support system at a suitable height so that you can catch the sphere underneath.)
Change the display to numerical mode 0.0 (fig.8).
Start the measurement by pressing on .
Open the clamp as quickly as possible.

Calculate the time of fall by subtracting time A from time B. This gives you the time the sphere needed to cover the distance between the light barriers. Convert the value into seconds, and enter it into table 1 of the experiment report.

Check whether other measurements with the same set-up provide identical values.
If the sphere does not touch the light beam of the lower light barrier, if it collides with the light barrier housing, or if you measure times greater than 0.5 s, readjust the height of fall and repeat the measurement until you obtain a reproducible result.

Change the distance between the lower end of the sphere and the middle seam of the light barrier to 10 cm, 15 cm, 20 cm, 30 cm, 40 cm, and 45 cm and repeat the time measurement.

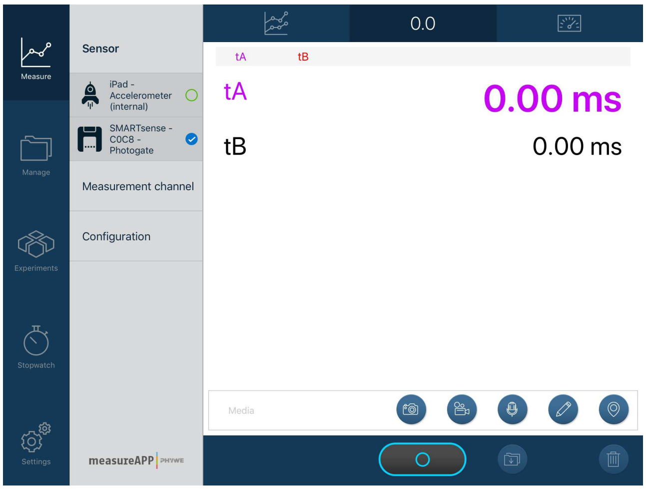


Fig. 8.

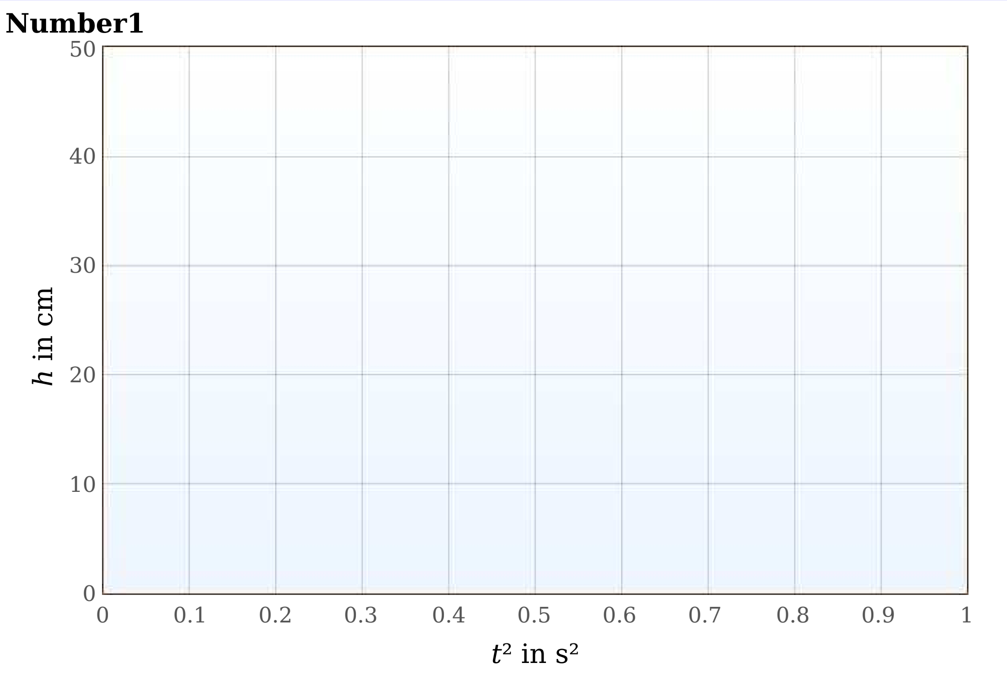
Report: Free fall with SMARTsense

Result - Table 1

Enter the times of fall *t* in the second column.

Enter the squared times of fall t^2 in the third column.

h in cm	*t* in s	t^2 in s^2
7.5	1 ±0.025	1 ±0.0039
10	1 ±0.025	1 ±0.0037
15	1 ±0.015	1 ±0.003
20	1 ±0.015	1 ±0.003
30	1 ±0.015	1 ±0.0035
40	1 ±0.015	1 ±0.0043
45	1 ±0.015	1 ±0.0046



Evaluation - Question 1

Does the time of fall t double if the height of fall h doubles?
Use several pairs of measurement values to calculate the factor by which the time of fall t increases when the height of fall h is doubled.
Enter the value into the window.

Evaluation - Question 2

Look at the measurement values and decide which of the statements are true:

- [ ] Since the time of fall t does not double when the height of fall h doubles, it is not a linear motion.
- [ ] Since the time of fall t does not double when the height of fall h doubles, the velocity must change during the fall.
- [ ] If the height of fall h quadruples, the time of fall t doubles.
- [ ] The time of fall t increases super-proportionally as a function of the height of fall h.
- [ ] The time of fall t increases sub-proportionally as a function of the height of fall h.

Evaluation - Question 3

Based on table 1, a graph has been prepared in which the height of fall h is plotted against the time of fall t^2. You should obtain a linear relationship.

Examine the dimension of the gradient k of the straight line through the origin, i.e. the proportionality factor between h and t^2, and select the correct unit.

- [ ] [k]=m/s (a velocity)
- [ ] [k]=m/s2 (an acceleration)
- [ ] [k]=N/m2 (a pressure)
- [ ] [k]=kg (a mass)
- [ ] [k]=N (a force)

Evaluation - Question 4

Calculate the value of the gradient k of the straight line through the origin and enter it into the window (in the unit that you have selected in the previous question).

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Evaluation - Question 5

What would a diagram look like in which the height of fall *h* is plotted as a function of the time *t*?

- [ ] The result would be a straight line passing through the origin.
- [ ] The result would be shifted parabola.
- [ ] The result would be a parabola passing through the origin.
- [ ] The result would be a rooted graph.

Evaluation - Question 6

In the case of a uniformly accelerated motion with the gradient a, the relationship s = 1/2·a·t2 is true for a distance s that is covered in the time t.
In this experiment, the height of fall h is the distance s that is covered.
Use this information to calculate the acceleration a and enter the value into the window.

Evaluation - Question 7

What is the cause of the acceleration and what is this acceleration usually called?

Do you know the symbol of this special acceleration?

Compare your value to the value that is given in the literature.

Assess the quality of the experiment for determining this physical quantity and state the causes that may lead to a deviation from the literature value.

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