

Free fall with Cobra SMARTsense



In this experiment, the students are to measure the acceleration due to gravity g experimentally determine and recognize that free fall represents a uniformly accelerated motion.

Physics

Mechanics

Dynamics & Motion



Difficulty level

medium



Group size

2



Preparation time

10 minutes



Execution time

10 minutes

This content can also be found online at:



<https://www.curriculab.de/c/689de1c23c38ed0002bf6264>

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Teacher information

Application

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Experiment set-up

In everyday life we encounter free fall wherever things fall to the ground. The story even says that Isaac Newton only got the idea of his theories and conclusions about mechanics and gravity and their transfer to celestial mechanics through an apple falling from a tree.

However, the lower the density of the falling body and the larger its surface, the more the free fall becomes a less strongly accelerated or braked fall. In a vacuum, however, all objects fall at the same speed.

The acceleration of gravity $g = 9,81 \text{ m/s}^2$ is by no means a constant: it decreases with increasing distance from the earth's surface.

Other teacher information (1/3)

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Prior knowledge



Students should be familiar with the concepts of velocity and acceleration as well as potential and kinetic energy. They should know that the gravitational force results from the acceleration due to gravity. Furthermore, students should be mathematically able to determine the gradient of a straight line and perform a dimensional analysis of the gradient obtained.

Principle



The mass of the metal cylinder experiences a constant unidirectional force in the Earth's gravitational field, which accelerates the cylinder uniformly. Frictional effects of air are negligible in this experiment, as is the buoyancy of the cylinder due to the surrounding air.

Other teacher information (2/3)

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Learning objective



In this experiment, the students are to measure the acceleration due to gravity g experimentally determine and recognize that free fall represents a uniformly accelerated motion.

Tasks



The students drop a steel cylinder through a transparent tube and measure, with the help of two photogates, the transit times t_A and t_B that the cylinder requires to pass through each of the two photogates.

Using the known length l of the cylinder and the measured transit times, they calculate the instantaneous velocities v_A and v_B at the two photogates. From the height difference H between the photogates and the calculated velocities, they then determine the value of the acceleration due to gravity g .

Other teacher information (3/3)

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Theoretical Derivation

t is the time difference that the metal cylinder needs to pass through the two photogates.

Ideally, for uniformly accelerated motion, the following applies:

$$1. \quad H = \frac{(v_A + v_B)t}{2}$$

$$2. \quad t = \frac{v_B - v_A}{g}$$

In the next step, t from equation (2) is substituted into equation (1), yielding

$$H = \frac{(v_A + v_B)(v_B - v_A)}{2g}$$

Subsequently, the equation is rearranged for g and H :

$$g = \frac{(v_A + v_B)(v_B - v_A)}{2H}$$

Finally, this results in:

$$g = \frac{v_B^2 - v_A^2}{2H}$$

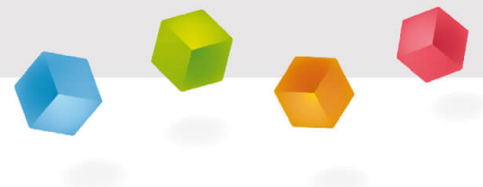
Safety instructions

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

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Student Information

Motivation

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Free fall in a theme park

Free fall occurs wherever an object is dropped from a certain height. This applies to a drop tower in the amusement park as well as to bungee jumping, parachute jumping or jumping from a 10-meter tower in the open-air swimming pool. As you know, the fall time depends on the mass of the falling body and the acceleration due to gravity. In addition, deceleration is generally caused by air resistance.

In this experiment, you will determine the height-dependent transit times of a metal cylinder using two photogates, investigate the underlying laws, and use the results to determine the acceleration due to gravity.

Tasks

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1. Drop a metal cylinder from the upper opening of the tube and measure the times t_A and t_B that the cylinder requires to pass through the respective photogates. Repeat the experiment for different height differences between the photogates.
2. Examine the measurement data for regularities that connect the measured quantities. These are the transit times and the height differences between the photogates.
3. Determine the acceleration due to gravity from the measured values.

Equipment

Position	Material	Item No.	Quantity
1	Tripod base PHYWE	02002-55	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 - Fork light barrier 0 ... ∞ s, two pieces (Bluetooth)	12909-00	1
5	Measuring tape, l = 2 m	09936-00	1
6	measureAPP - the free measurement software for all devices and operating systems	14581-61	1
7	Rod M6x100 mm	329828	2
8	Metal cylinder	02506-00	1
9	Plastic tube	03479-00	1

Setup (1/6)

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For measurement with the **Cobra SMARTsense sensors** the **PHYWE measureAPP** is required. The app can be downloaded free of charge from the relevant app store (see below for QR codes). Before starting the app, please check that on your device (smartphone, tablet, desktop PC) **Bluetooth is activated**.



iOS



Android



Windows

Setup (2/6)

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Required equipment



Attach the short steel rod
to the two fork
photogates with screws

Setup (3/6)

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- Set up the stand.
- Screw the long rod into the base and fix it vertically.
- Attach four boss heads. The two in the middle should be placed close together (about 7.5 cm head-to-head). The upper and the lower ones should each be about 20 cm apart from the middle pair.



Attach the support rod to the base



Attach the boss heads to the support rod

Setup (4/6)

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- Screw the universal clamp onto the two middle boss heads.
- Then attach photogate A to the upper boss head and photogate B to the lower boss head.

Note: If photogate A is mounted at the bottom and B at the top, the passage times t_A and t_B will be reversed.



Attach the universal clamp to the boss heads



Attach the photogates to the boss heads

Setup (5/6)

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- Attach the plastic tube using the two universal clamps.
- Make sure the tube is positioned between the two photogates. If this is not possible, it can be shifted slightly up or down. Then tighten the clamps.
- Ensure that, when viewed from above, the tube is aligned with the light beams of the photogates.
- Check that the tube is as vertical as possible relative to the horizontal plane. If not, adjust it accordingly.



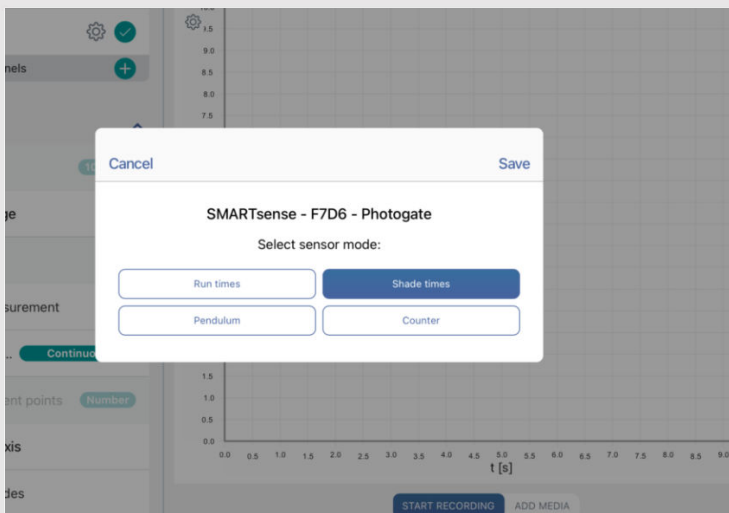
Fix the plastic tube to the boss head clamp



Adjust the plastic tube so that it stands vertically

Setup (6/6)

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Selection of the measuring mode in measureAPP

- Connect both photogates with the jack cable and switch them on.
- Then, in the measureAPP menu, select the photogate as the sensor.
- In the menu that appears, choose the option "Shade times." With this setting, the photogates measure the time it takes for the cylinder to pass through them.
- Finally, set the digital display to show the measured values.

Procedure (1/2)

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Experiment set-up

- Measure the length l of the metal cylinder.
- Using the measuring tape, set the distance between the middle positions of the two photogates to $H = 20\text{cm}$.
- Now start the measurement and let the metal cylinder fall.
- Enter the passage times t_A and t_B into Table 1 of the lab report.
- From the measured values and the length of the metal cylinder, calculate the instantaneous velocities v_A and v_B , then enter these values into Table 1 as well.
- Finally, calculate $v_B^2 - v_A^2$ and record this value in the table.

Procedure (2/2)

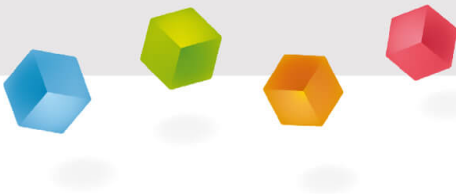
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Experiment set-up

- Check whether you obtain the same values in repeated measurements. If not, make sure that the metal cylinder can fall smoothly through the plastic tube.
- If the metal cylinder does not intersect the light beam of the photogates, adjust the drop path and repeat the measurement until you obtain a reproducible result.
- Next, change the distance between the midpoints of the two photogates successively to 30 cm and 40 cm, and repeat the measurements.
- Record all resulting measurement values in Table 1 of the report.

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Report

Table 1

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Enter your measured values into the table.

H [cm]	t_A [s]	t_B [s]	v_A [m/s]	v_B [m/s]	$(v_B^2 - v_A^2)$ [m ² /s ²]
20					
30					
40					

Task 1

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t is the time difference that the metal cylinder needs to pass through the two photogates.

Ideally, for uniformly accelerated motion, the following applies:

$$H = \frac{(v_A + v_B)t}{2}$$

$$t = \frac{v_B - v_A}{g}$$

From the two formulas on the left, the acceleration due to gravity g can be determined:

☐ $g = \frac{v_B - v_A}{H}$

☐ $g = \frac{v_B^2 - v_A^2}{H}$

☐ $g = \frac{v_B - v_A}{2H}$

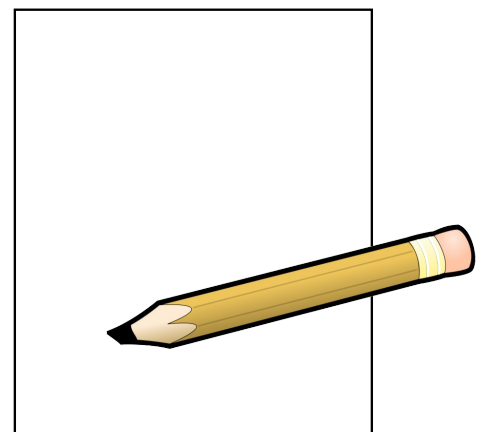
☐ $g = \frac{v_B^2 - v_A^2}{2H}$

☒ Check

Task 2

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Now take a piece of paper and create a diagram on it. In this diagram, plot $v_B^2 - v_A^2$ on the (y -axis) as a function of the height H on the (x -axis).



Task 3

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A graph was created from Table 1, in which $v_B^2 - v_A^2$ is plotted against the height difference H between the photogates. You should obtain a clear linear relationship. Examine the dimension of the slope k of the line through the origin, i.e., the proportionality factor between $v_B^2 - v_A^2$ and the height difference H , and select the correct unit!

☐ $[k] = \text{N/m}^2$ - a pressure.

☐ $[k] = \text{m/s}^2$ - an acceleration.

☐ $[k] = \text{m/s}$ - one speed.

✓ Check

Task 4

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What would a graph look like in which the total fall height h is plotted against the total fall time t of the free fall?

☐ This would result in a root-shaped course.

☐ This would result in a shifted parable.

☐ This would result in a parable through the origin.

☐ This would result in a straight line of origin.

✓ Check

Task 5

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Calculate the numerical value of the gradient k from the origin line and enter it below.

$$k = \boxed{} \text{ m/s}$$

From Task 1, we know that the factor k is a multiple of the acceleration due to gravity. Use this information to calculate the acceleration due to gravity g and enter the value in the corresponding field.

$$g = \boxed{} k = \boxed{} \text{ m/s}^2$$

Slide

Score/Total

Slide 21: Conclusions of the measured value

0/1

Slide 23: Conclusions of the diagram

0/1

Slide 24: Consideration on $h(t)$

0/1

Total amount

 0/3

Solutions



Repeat



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