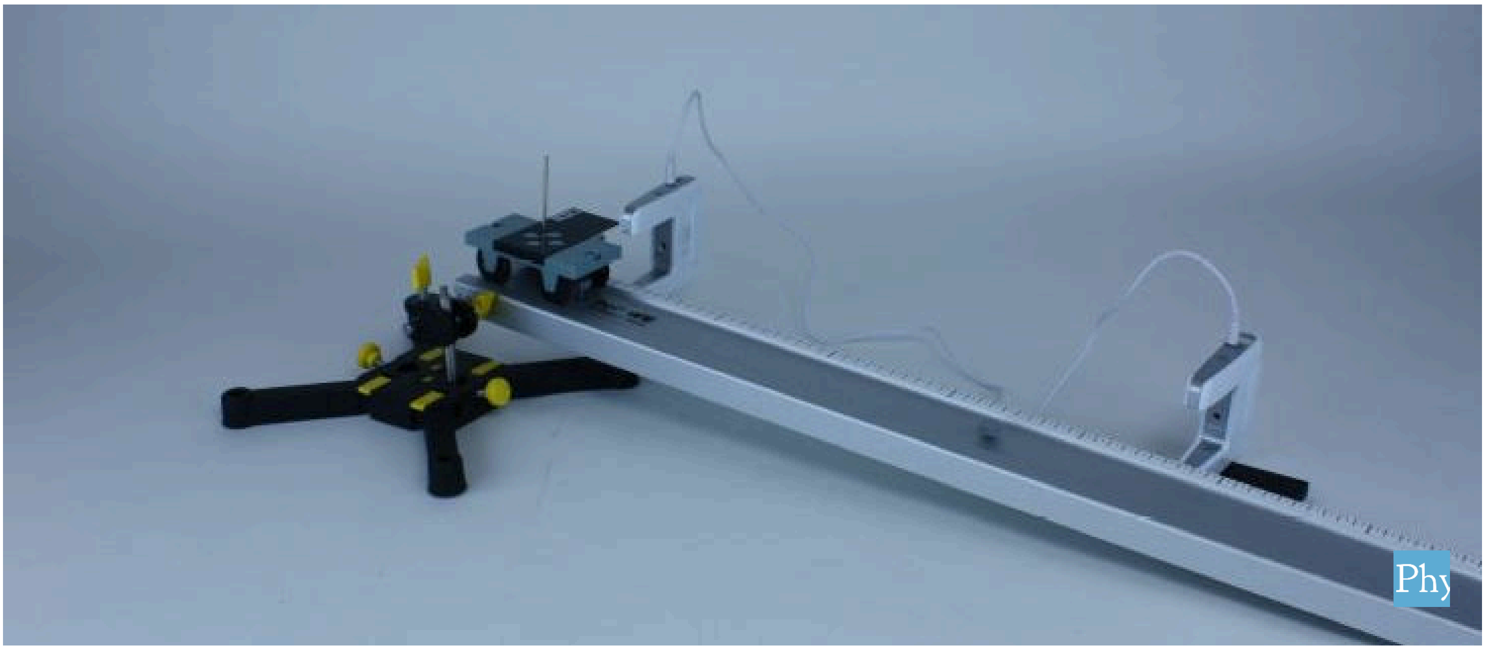
Laws of motion of uniformly accelerated motion with Cobra SMARTsense



Physics → Mechanics → Dynamics & Motion

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

Teacher information

Application

Experiment set-up

We encounter accelerated movement in everyday life wherever speeds change.

One example is vehicles in traffic that brake before a traffic light and accelerate when the light is green.

Anyone who has ever flown in an airplane will know the feeling of powerful acceleration during take-off.

Astronauts experience an even greater acceleration when launching their rocket, which must exceed the acceleration of gravity many times over in order to leave Earth.

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Other teacher information (1/2)

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Prior knowledge

Students should know how to calculate speeds and how to read and create distance-time diagrams and speed-time diagrams.

Scientific principle

On the inclined plane, the measuring cart experiences a constant slope downforce resulting from the earth's gravitational field, which accelerates the cart evenly. The acceleration a is defined as the time derivative of the velocity v which, in turn, determines the time derivative of the distance s.

$$a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}^2 s}{\mathrm{d}t^2}$$

Other teacher information (2/2)

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Learning objective

In this experiment, the students are to investigate acceleration using the example of a uniformly accelerated movement and to record the laws of motion in the form of diagrams. The students should learn to read the acceleration from the velocity-time diagram.

Tasks

1. The students let the measuring cart roll down an inclined plane and measure the travel time the cart takes for different segments.
2. They then measure the shadowing time of the rear light barrier for the various track end points. From this, the instantaneous speeds are calculated.

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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

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Motivation

Start of a space shuttle

You already know how to measure and calculate speeds, and you know the term "acceleration" at least from everyday language.

You probably know the feeling of a strong acceleration from a visit to an amusement park or from the start of a passenger plane. But deceleration also represents acceleration. The acceleration at the start of a rocket must even permanently exceed the acceleration of gravity many times over.

In this experiment, you will now learn on the inclined plane how to quantitatively measure the acceleration of a vehicle.

Tasks

1. Let the experiment cart roll down the inclined plane and measure its travel times for different routes from the starting point!
2. Then measure the shading times of the light barrier at the end points of the track and calculate the instantaneous speed of the car using the width of the shading diaphragm!

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - Photogate, 0 ... ∞ s, two pieces (Bluetooth)	12909-00	1
2	Track, l 900 mm	11606-00	1
3	Meter scale, demo. l=500mm, self adhesive	03005-00	2
4	Cart for measurements and experiments	11060-00	1
5	Shutter plate for cart	11060-10	1
6	Holding pin	03949-00	1
7	Slotted weight, black, 50 g	02206-01	1
8	Adapter plate for Light barrier compact	11207-22	2
9	Support rod with hole, stainless steel, 10 cm	02036-01	1
10	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
11	Boss head	02043-00	1
12	Support base, variable	02001-00	1
13	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

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Set-up (1/5)

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The Cobra SMARTsense Photogate and measureAPP are required to perform the experiment. The app can be downloaded for free from the App Store - QR codes see below. Check whether Bluetooth is activated on your device (tablet, smartphone).

measureAPP for Android operating systems

measureAPP for iOS operating systems

measureAPP for Tablets / PCs with Windows 10

Set-up (2/5)

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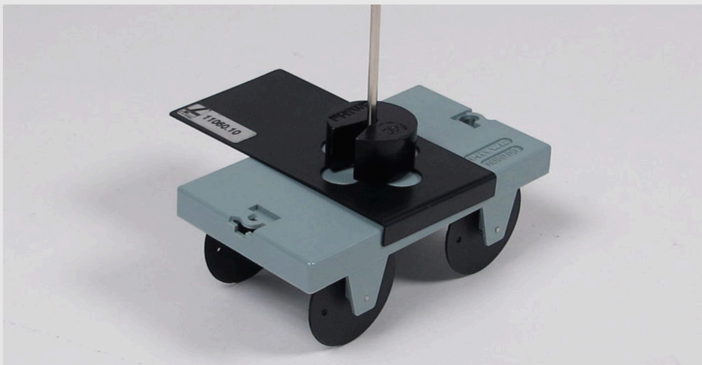
Take the experiment cart, attach the retaining bolt to it and place the shading screen and the 50 g slot weight on top of it. Then attach the shorter stainless steel rod to the base of the stand, the boss head with the longer stainless steel rod lying crosswise to it and place the appropriate end of the track on top of it.



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Set-up (3/5)

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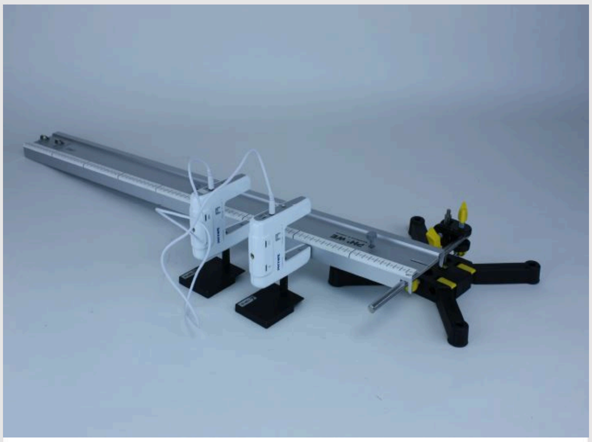

Fasten photogates to adapter plate using spacer bolts

Fasten the two photogates with two spacer bolts each to the adapter plates in such a way that the photogates can be easily positioned in the upper area of the track.

Set-up (4/5)

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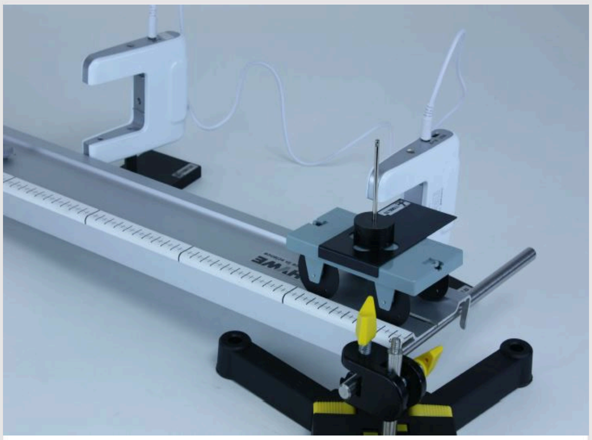

Position photogate

Place the first photo gate approximately at the 8.2 cm mark on the tape measure on the track (orientate yourself to the middle of the light barrier). If the measuring cart is now at the upper end of the track, the light barrier should not be interrupted just yet. If necessary, correct the position of the photogate slightly.

Now correct the gradient of the track at the double socket so that the diaphragm of the experimental car can just about pass under the upper edge of the light barrier without hitting it.

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Set-up (5/5)

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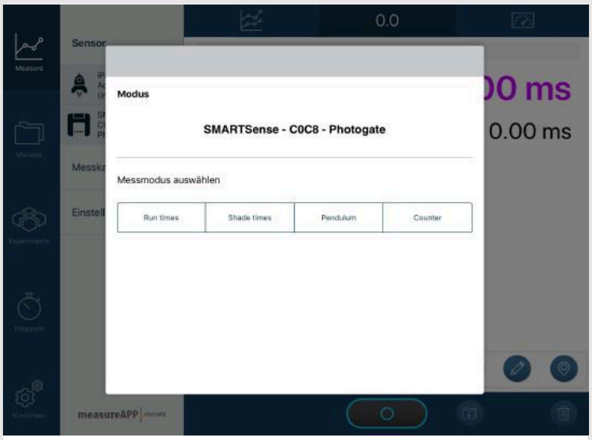

Selection of the measuring mode in measureAPP

Make sure the one with "B" indicates the rear photogate and position it $\Delta s = 10\,cm$ further down. The measuring cart must be able to roll down without hitting it.

Connect both photogates with the jack cable and switch them on.

Select the photegates in measureAPP under "Sensor" and select "Running times" in the menu which then appears.

Then select the digital measured value display in measureAPP.

Procedure (1/4)

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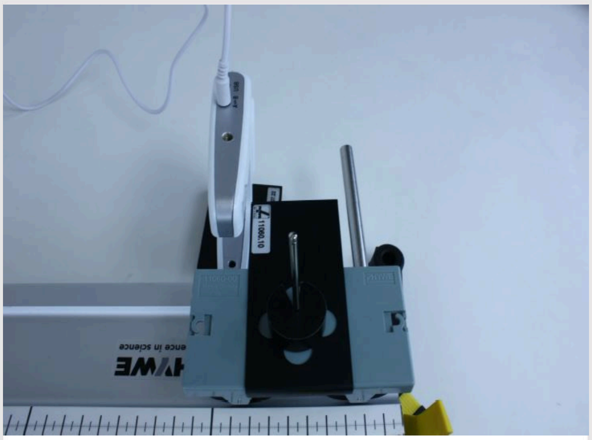

Position the measuring cart

- Push the measuring cart to the upper end of the track. The cart should end with the end of the track seen from above. Make sure that the photogate start the measurement, let go of the measuring cart without hitting it and catch it after it has passed the second photogate.
- The times at which the cart has passed the photogates after the start of the measurement are output as measured values. Finish the measurement and calculate the running time Δt as the difference between the times and note the measured value for the distance $\Delta s = 10\,cm$ in Table 1 of the Report.

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Procedure (2/4)

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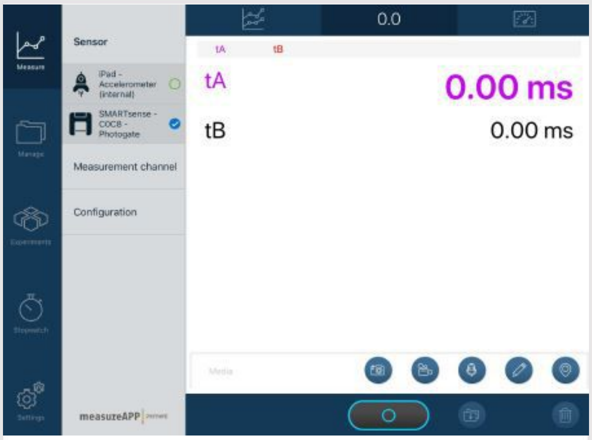

Digital measured value display in measureAPP

- Repeat the measurement for distances of the second photogate to the first of 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, 70 cm. The position of the first photogate remains unchanged.
- Before each start, check whether the shutter can pass through the second light barrier without hitting it and remove a spacer bolt if necessary.
- Again, before each car start, make sure that the start photogate is only interrupted after the measuring carriage has been released.
- Note all measured values also in table 1.

Procedure (3/4)

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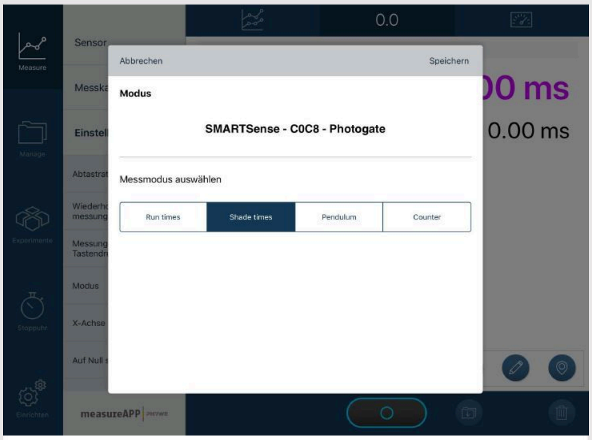

Selection of the measuring mode in measureAPP

- Remove the first photogate from the track so far that it is not interrupted by the diaphragm.
- In the "Settings" menu, press "Mode" and select "Shading" to change the mode accordingly, so that the photogates now measure the shading time, from which you can later approximately calculate the instantaneous speed.
- Now place the remaining photogate 2.5 cm (half an aperture width) in front of those positions where it was located at the beginning of the first measurement series. This is to reduce the measurement error that results from measuring transit times at the front edge of the aperture in the first part of the experiment, but now the speed is averaged over the aperture width.

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Procedure (4/4)

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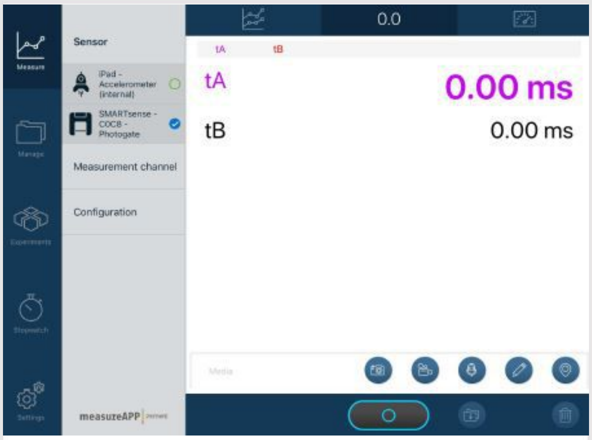

Digital measured value display in measureAPP

- Measure the time t which is the aperture with the width $b = 5\,cm$ to pass the photogate, if the distance to be travelled $\Delta s = 10\,cm$ (under the previously described adjustment of the photogate position).
- Repeat the experiment for the positions of the photogate at which the rear light barrier was located during the first series of measurements, but do not forget to increase the position by $2,5\,cm$ to correct upwards on the track.
- Note all resulting measurement results in Table 1 again.

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Report

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Table 1

Enter the journey times in the second column Δt from the first experimental part and calculate their squares Δt^2 and enter the values in the table.

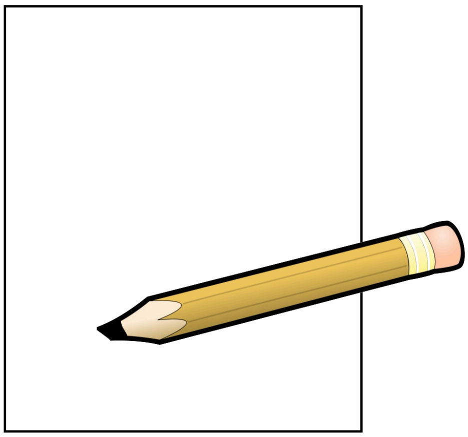
Enter the shading times in the fourth column t from the second part of the experiment. Calculate from the aperture width $b = 5\,cm$ and the shading times t the approximate instantaneous speeds $v_m = b/t$ and enter it in the last column.

$\Delta s\ [cm]$	$\Delta t\,[s]$	$\Delta t^2\,[s^2]$	$t\,[s]$	$v_m\,[cm/s]$
10				
20				
30				
40				
50				
60				
70				

Task 1

Now take a piece of paper and create a diagram on it. In this diagram you set the distance you have travelled Δs and the average speed v_m (y-axis) depending on the duration Δt (x-axis).

Then take a sheet of paper and create another diagram on it. In this diagram you set the distance you have travelled Δs (y-axis) depending on the square of the term Δt^2 (x-axis).



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Task 2

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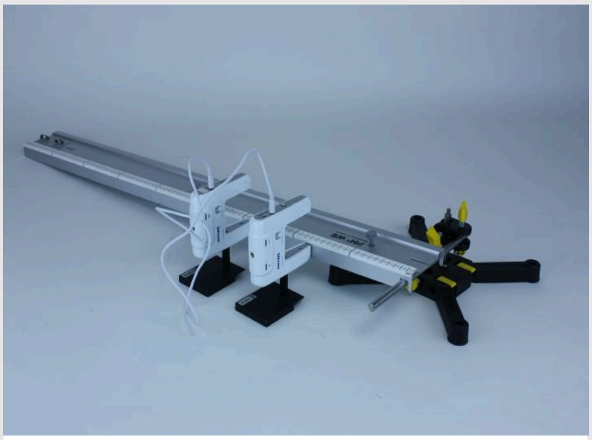

Experiment set-up

Which curve shape is most likely to be represented by the graph in the path-time diagram?

- The course resembles a parabola through the origin.
- The course is linear.
- The course is exponential.

Check

Task 3

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Look at the distance-(time)² diagram. What conclusions can be drawn about the course of the distance-time diagram? Mark the correct answers.

- The non-linearity of the curve confirms that it is an exponential curve in the distance-time diagram.
- The distance-(time)²-diagram basically does not allow any conclusions to be drawn about the course of the curve in the distance-time diagram.
- The following results from the order s against t^2 a straight line through the origin. Therefore it must be s against t (distance-time-diagram) around a parabola through the origin.

Check

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Task 4

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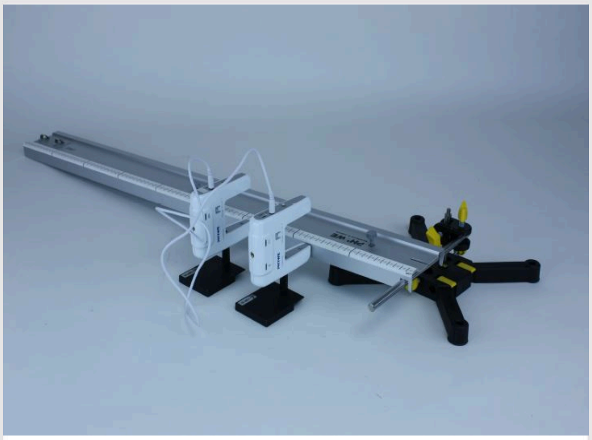

Experiment set-up

What can be concluded from the linearity of the velocity-time diagram?

- The linearity indicates that the movement is uniformly accelerated.
- The linearity indicates that the movement is linear.

Check

Task 5

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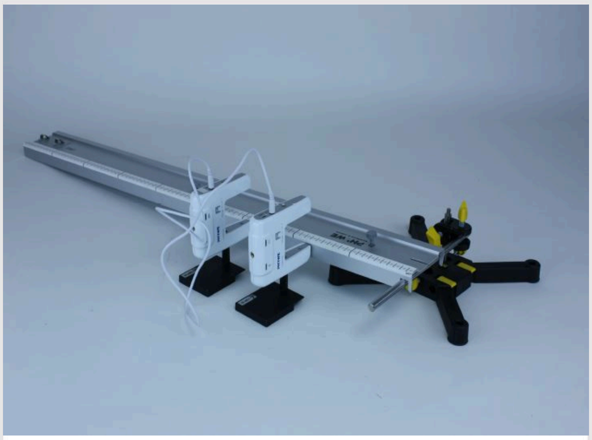

Experiment set-up

Calculate the gradient from the speed-time curve $a = \frac{\Delta v_m}{\Delta t}$. This indicates the acceleration with which the car becomes faster and faster on the road. Calculate the acceleration into the unit m/s^2 and enter the numerical value!

$a = \_\_\_\_ \frac{m}{s^2}$

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Task 6

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The numerical value of acceleration a is significantly lower than the acceleration due to gravity g with $g = 9,81\,m/s^2$. Why is that? What makes the car accelerate at all?

- ○ The value is significantly lower, since the car is accelerated parallel to the road and only a small part of the acceleration due to the gradient is involved.
- ○ The value is considerably lower, because the car is additionally slowed down by the air resistance.
- ○ There is no correlation between earth acceleration and the movement of the car.

Check

Task 7

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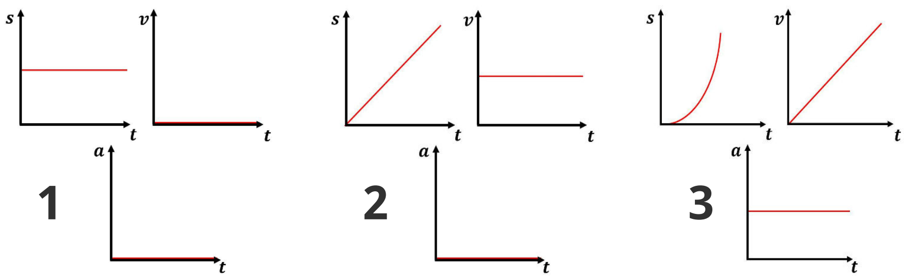
Match the diagrams!

Diagram ______ : A vehicle is uniformly accelerated in a straight line.
Diagram ______ : A vehicle stands motionless at one point.
Diagram ______ : A vehicle is moving in a straight line and uniformly.

2 1 3

Check



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Slide	Score / Total
Slide 22: Path-time diagram	0/1
Slide 23: Path (time)² diagram	0/1
Slide 24: Speed-time diagram	0/1
Slide 26: Comparison with acceleration due to gravity	0/1
Slide 27: Motion diagrams	0/3

Total amount 0/7

Solutions Repeat Exporting text

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