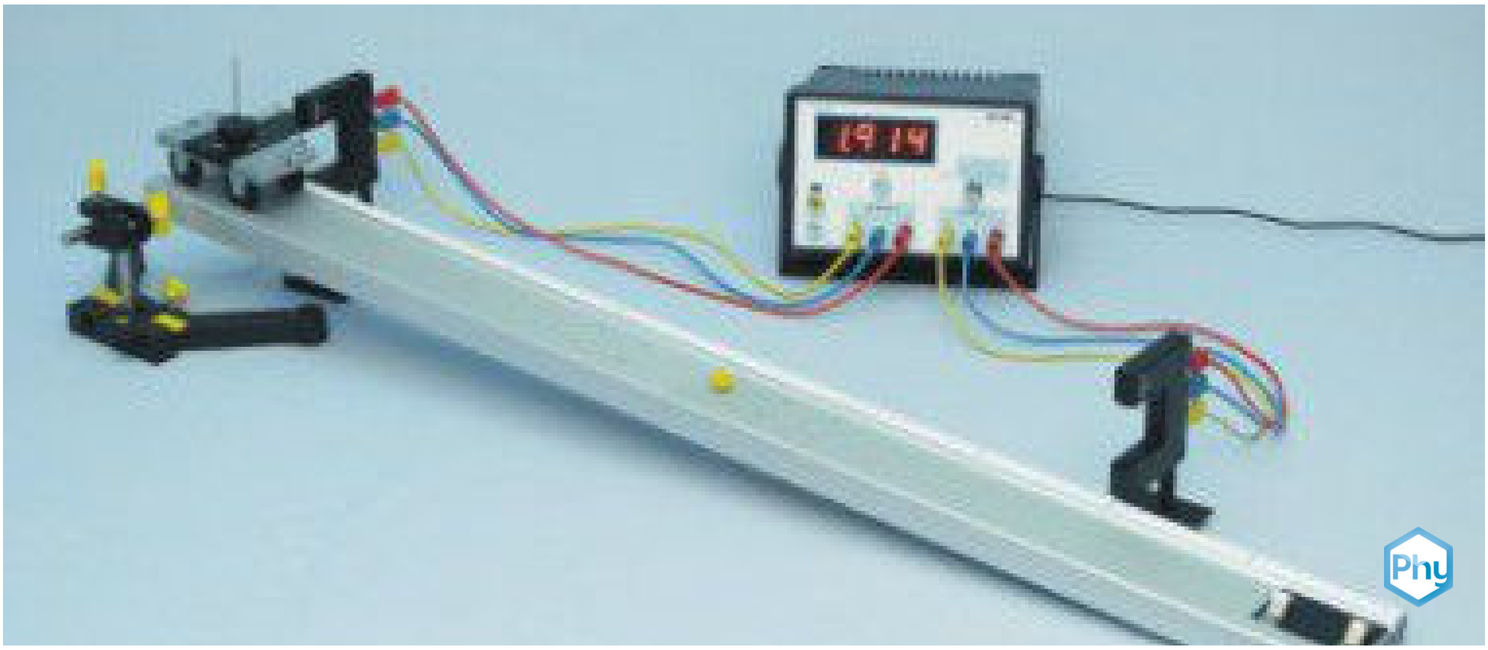
Laws of uniformly acceleration motion with the 2-1 timer



Physics | Mechanics | Dynamics & Motion

Difficulty level	Group size	Preparation time	Execution time
hard	2	10 minutes	30 minutes

This content can also be found online at:

http://localhost:1337/c/5fdbb8885098f00003f1edea

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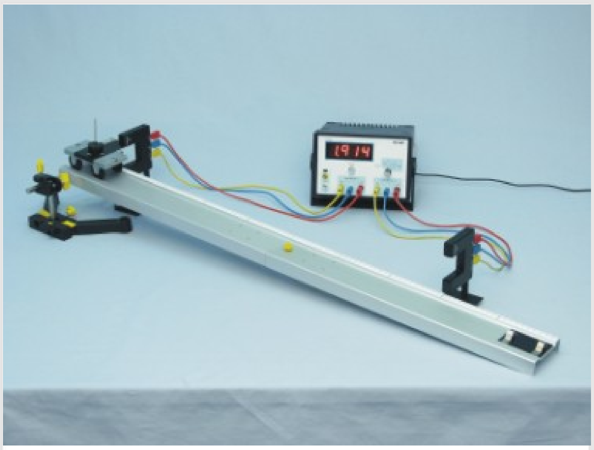
Teacher information

Application



Experiment set-up

We encounter accelerated motion everywhere in everyday life where speeds change.

One example is vehicles in traffic that brake in front of a traffic light and accelerate again when the light turns green.

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

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

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Other teacher information (1/2)

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Prior knowledge

Students should know how to calculate velocities and how to read and create distance-time diagrams and velocity-time diagrams.

Scientific principle

On the inclined plane, the car experiences a constant downhill force resulting from the earth's gravitational field, which accelerates the trolley uniformly. The acceleration a is defined as the time derivative of the velocity v which in turn is the temporal derivation of the path 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, students will investigate acceleration using the example of uniformly accelerated motion and record the laws of motion in the form of diagrams. The students should learn to read the acceleration from the speed-time diagram.

Tasks

1. The students let the car roll down an inclined plane and measure the travel time the car needs for different distances.
2. They then measure the shadowing time of the rear light barrier for the various track end points. The instantaneous velocities are calculated from this.

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Safety instructions

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

Student Information

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Motivation

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Launch of a space shuttle

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

You probably know the feeling of a strong acceleration from a visit to the amusement park or from the take-off of a passenger plane. But braking also represents an acceleration. The acceleration during the launch of a rocket must even permanently exceed the acceleration due to gravity many times over.

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

Tasks

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1. Let the car roll down the inclined plane and measure its travel times for different distances 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 velocities of the car using the width of the shading aperture.

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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	Slotted weight, black, 50 g	02206-01	1
5	Support base, variable	02001-00	1
6	Support rod with hole, stainless steel, 10 cm	02036-01	1
7	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
8	Boss head	02043-00	1
9	PHYWE Timer 2-1	13607-99	1
10	Light barrier, compact	11207-20	2
11	Connecting cord, 32 A, 1000 mm, red	07363-01	2
12	Connecting cord, 32 A, 1000 mm, yellow	07363-02	2
13	Connecting cord, 32 A, 1000 mm, blue	07363-04	2
14	Track, l 900 mm	11606-00	1

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Set-up (1/4)

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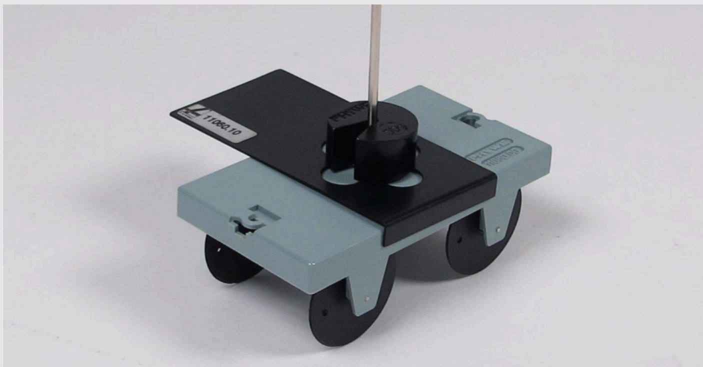
Take the car, attach the holding pin to it and place the shade screen and the 50 g slotted weight on top of it. Then attach the shorter stainless steel rod to the base of the stand, attach the double socket to it with the longer stainless steel rod lying across it and place the matching end of the track on top.



Set-up (2/4)

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Fasten fork light switch to adapter plate using spacer bolts

Fasten the two forked light barriers with two spacer bolts each to the adapter plates in such a way that the light barriers can be set up well in the upper area of the roadway.

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Set-up (3/4)

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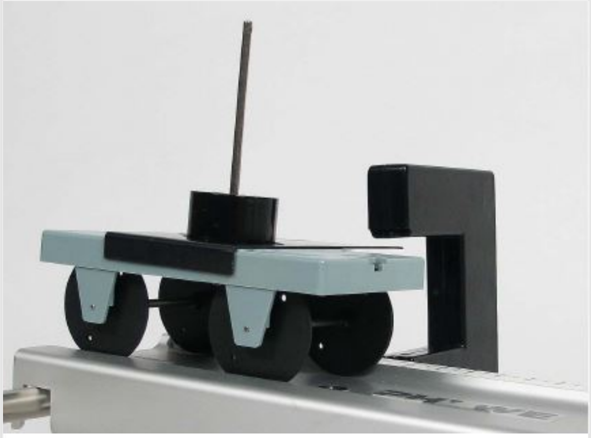

Positioning the light barrier

Place the first light barrier approximately at the 8.2 cm mark of the measuring tape on the road (orientate yourself to the middle of the light barrier). If the car is now at the upper end of the carriageway, the light barrier should only just not be interrupted. If necessary, correct the position of the light barrier slightly.

Now correct the slope of the track at the double socket so that the panel of the car can just pass under the upper edge of the light barrier without hitting it.

Position the second light barrier $\Delta s = 10\,cm$ further down. The measuring trolley must be able to roll down without bumping.

Set-up (4/4)

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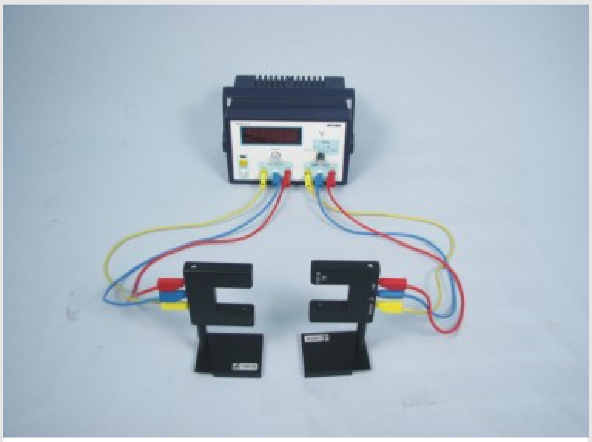

Connect the light barriers to the timing device

Connect both light barriers to the timing device and set the switch above the field labeled "Start" on the timing device to the right position.

Set the rotary switch 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.

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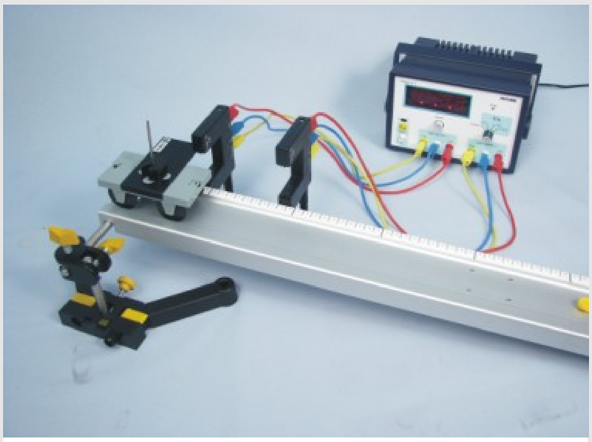
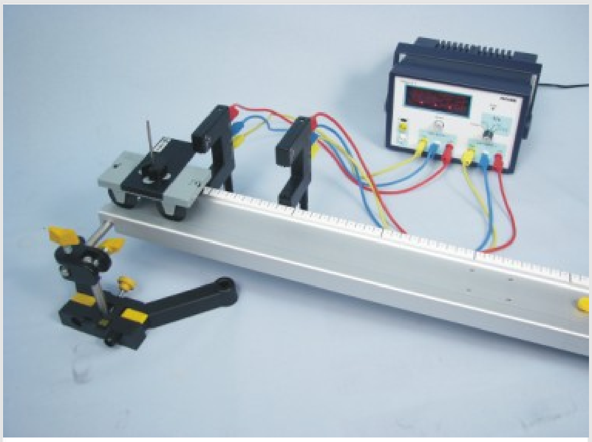
Procedure (1/4)



Experiment set-up

- 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.
- Now press the "Reset" button on timer 2-1, let go of the car without bumping it and catch it after it has passed the second light barrier.
- Note the measured value for the resulting running time Δt from the interruption of the first light barrier to the second for the distance $\Delta s = 10\,cm$ in Table 1 in the report.

Procedure (2/4)



Experiment set-up

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

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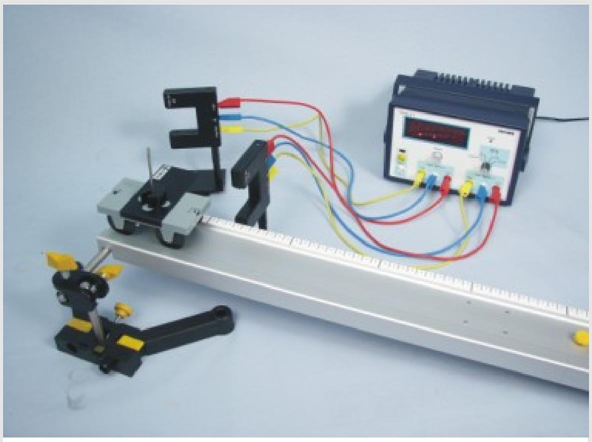
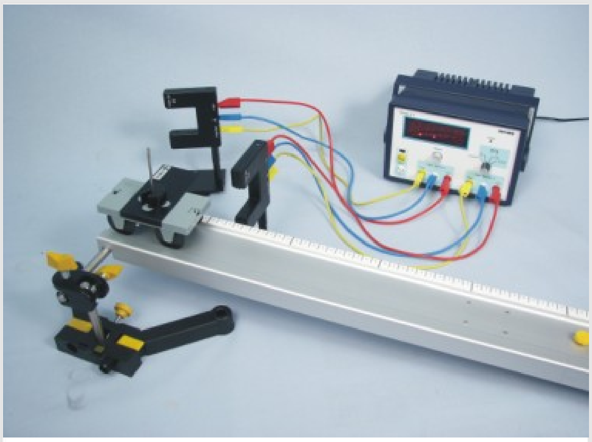
Procedure (3/4)



Remove first light barrier

- Move the front light barrier far enough away from the track so that it is no longer interrupted by the aperture.
- Set the rotary switch on timer 2-1 to the second position from the left. The device then displays the shadowing time. This is the time period in which a light barrier is interrupted by the shutter on the car.
- Now place the remaining light barrier 2.5 cm (half an aperture width) in front of the position at which it was located at the beginning of the first series of measurements. This is to reduce the measurement error that arises from the fact that in the first part of the experiment, running times were measured at the front edge of the aperture, but now the speed is averaged over the aperture width.

Procedure (4/4)



Remove first light barrier

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

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Report

Table 1

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

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

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Task 1

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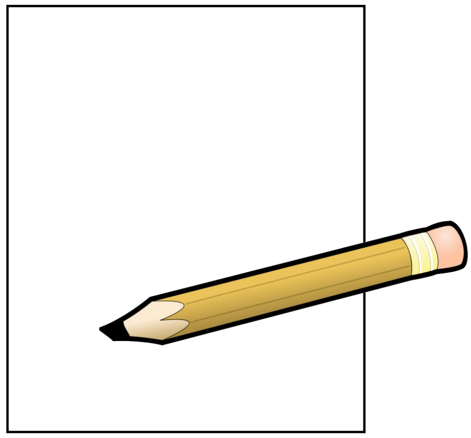
Now take a sheet of paper and create a diagram on it. In this diagram, you represent the distance traveled Δs and the average speed v_m (y-axis) as a function of the running time Δt ($x$axis).

Then take a sheet of paper and create another diagram. In this diagram you put the distance traveled Δs (y-axis) as a function of the square of the running time Δt^2 ($x$axis).



Task 2

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Experiment set-up

Which curve shape does the graph in the displacement-time diagram most closely represent?

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

Check

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Task 3

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Consider the displacement (time)² diagram. What conclusions can be drawn about the path-time diagram? Mark the answers that apply.

- The non-linearity of the curve confirms that it is an exponential curve in the displacement-time diagram.
- The displacement-(time)²-diagram basically does not allow any conclusions on the course of the curve in the displacement-time-diagram.
- The plot s versus t^2 results in a straight line through the origin. Therefore, the plot s against t (path-time diagram) must have been a parabola through the origin.

Check

Task 4

PHYWE

Experiment set-up

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

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

Check

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Task 5

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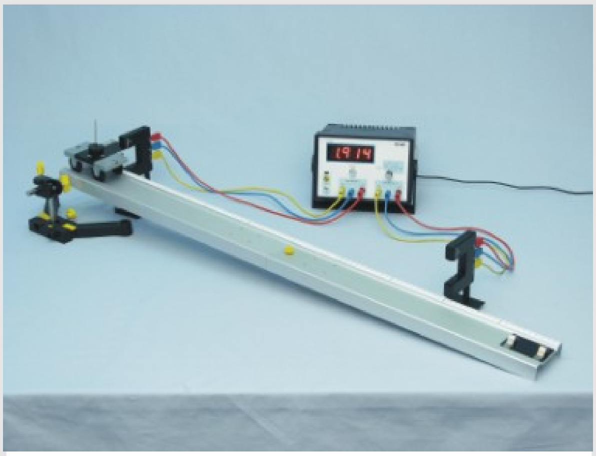

Experiment set-up

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

$a =$ ☐ $\frac{m}{s^2}$

Task 6

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The numerical value of the 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 in the first place?

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

Check

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Task 7

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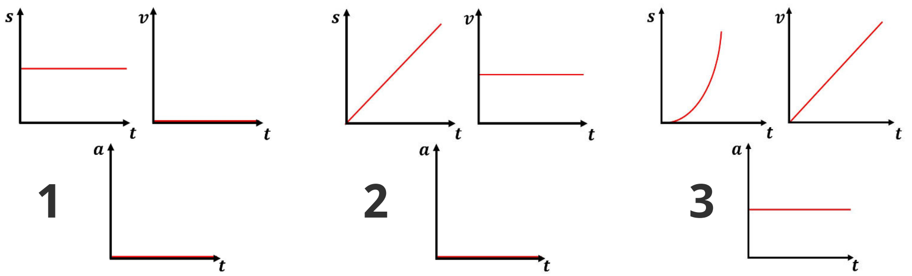
Match the diagrams!

Diagram [ ] : A vehicle is accelerated uniformly in a straight line.
Diagram [ ] : A vehicle is stationary in one place.
Diagram [ ] : A vehicle is moving in a straight line uniformly.

3 2 1

Check



Slide	Score / Total
Slide 21: Path-time diagram	0/1
Slide 22: Path (time)² diagram	0/1
Slide 23: Speed-time diagram	0/1
Slide 25: Comparison with acceleration due to gravity	0/1
Slide 26: Motion Diagrams	0/3

Total 0/7

Solutions Repeat Export text

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