7.5 Laws of Constantly Accelerated Motion

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interTESS (Version 13.06 B200, Export 2000)

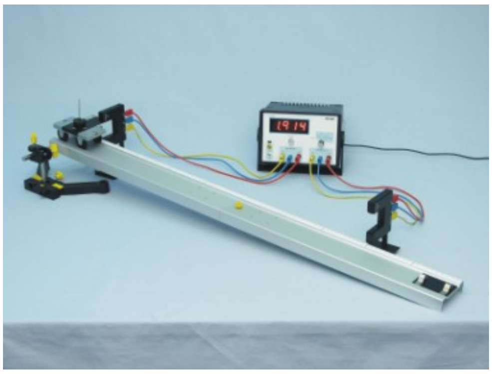
Task

Task

What laws does motion with constant acceleration follow?

A measurement car moves down a slope under the influence of the force of its weight.

Examine its behavior by measuring the time needed for the car to cover different distances from the starting point, with the aid of two photoelectric gates. In addition, measure, at the endpoints, the instantaneous speed with a timer.



Use the space below for your own notes.

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Additional Information

In this experiment, pupils will examine acceleration in an example of motion under constant acceleration, and they will sum up the laws of motion in the form of graphs. By comparing slopes contained in the s/t^2 and the v/t graphs, the proportionality factor k in the relation $s = k\,t^2$ can be determined to be approximately $a/2$. This way, the relationship $s = 1/2\,a\,t^2$ is made to be more understandable.

Material

Material from "TESS-Mechanik ME 1" (order nr. 13271.88), "TESS-Mechanik ME 2" (order nr. 13272.88) and "TESS-Mechanik ME 4" (order nr. 13283.88)

Position No.	Material	Order No.	Quantity
1	Measurement/experimental car	11060-00	1
2	Shade plate for the measurement car	11060-10	1
3	Holding pin	03949-00	1
4	Slotted weight, black coloured, 50 g	02206-01	1
5	Support base, variable	02001-00	1
6	Support rod with hole, stainless steel, 100 mm	02036-01	1
7	Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031-00	1
8	Bosshead	02043-00	1
9	Timer 2-1, incl. power supply	13607-99	1
10	Compact photoelectric gate	11207-20	2
11	Foot plate for the compact photoelectric gate	11207-22	2
12	Connecting cable, red, 32 A, 1000 mm	07363-01	2
13	Connecting cable, yellow, 32 A, 1000 mm	07363-02	2
14	Connecting cable, blue, 32 A, 1000 mm	07363-04	2
15	Track 1, l = 500 mm	11302-00	1
16	Track 2, l = 500mm	11303-00	1

Material required for the experiment

1
2
3
4
5
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7
8
9
10
11
12
13
14
15/16

Setup

Set up the track (Fig. 1).

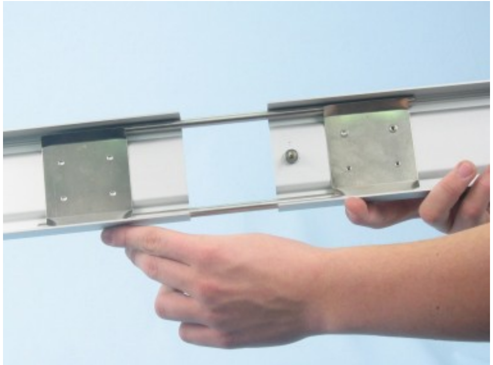


Fig. 1

Screw two spacing bolts and the foot plates onto the photoelectric gates, so that these can stand firmly next to the track, and so that the plate on the car goes throught the gate (Fig. 2).

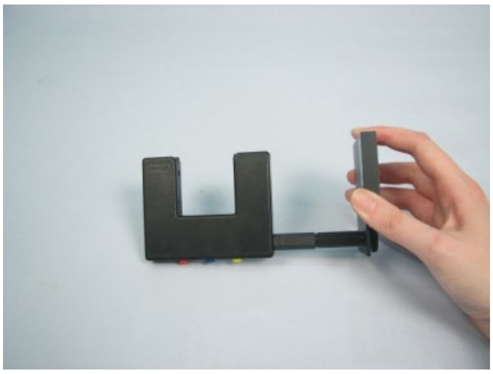


Fig. 2

Set up the inclination of the track in such a way so as to have the car's plate pass exactly through the gate which is on two spacing bolts, when the car on the higher end of the track (Fig. 3) and connect the gates to the timer (Fig. 4).

Fig. 3

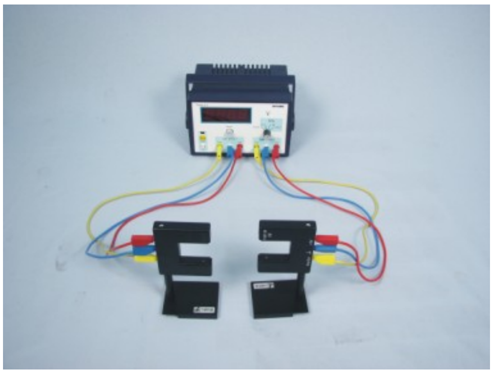


Fig. 4

On the timer, place the switch which is above the "Start" label in the position to the right .

Procedure

Experiment 1: Measurement of the travel time for the distance s

Put the rotating switch on the "ƒ⊔ƒ" position, the third from the left. This way, the device shows the time between the interruption of the light beam at the first gate and second. In this experiment, this is the time which the car needs to cover the distance between the gates.

Place the 50 g weight on the car (Fig. 5) and start the car every time from the very same point at the beginning of the track, so that the edge of the car and the edge of the track coincide when seen from the top. Start the car by letting go of it, without pushing.

Fig. 5

Place the first gate at a distance of about 8.2 cm from the end of the track where the car starts, so that the plate on the car interrupts the gate's beam immediately after the car starts.

Place the second gate at a distance of s = 10 cm behind the first (Fig. 6).

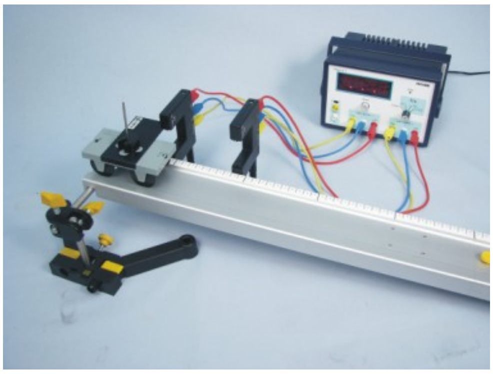


Fig. 6

To determine the position of the gate, use the middle seam of the gate and the measuring scale on the track.

Before every measurement, press the reset button on the timer.

Let the car go and catch it after it has gone through the second gate. Record the time, t, shown by the timer, on table 1. This is the time that the car needed to cover the distance s = 10 cm.

Leave the first gate where it is and increase the distance between it and the second gate in 10 cm increments, repeating the measurement each time. Record the readings on table 1. Remove the spacing bolts from the gate if the plate can no longer run through it.

Experiment 2: Measurement of the instantaneous speed, vs, after covering the distance s

Move the rotary switch to the "⎍" position, the second from the left. Now the device will show the beam interruption time. That is the time during which the light beam in the gate is interrupted by the shade plate.

Put aside one of the gates, and for each measurement, place the other one plate-width, i.e., 5 cm, away from each position where the second gate had been before. In this way an error is avoided whereby, in one part of the experiment, a measurement was taken at the leading edge of the plate, whereas now the speed is established along the width of the plate, making it only an approximation of the instantaneous speed, and not the real value.

Measure the time, Δt, which the plate of width $\Delta s = 5$ cm needs to pass through the gate, when the distance covered, s has the same value which you used in the first portion of the experiment.

Record the results on table 1.

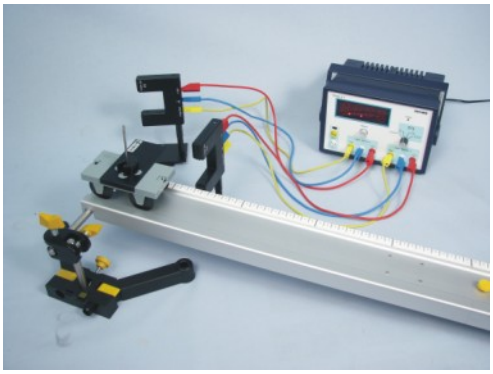


Fig. 7

Results

Table 1

s in cm	t in s	Δt in s	t^2 in s^2	$v_s = \Delta s/\Delta t$ in cm/s
10				
20				
30				
40				
50				
60				
70				
80				

Table 1

s in cm	t in s	Δt in s	t^2 in s^2	$v_s = \Delta s/\Delta t$ in cm/s
10	0.53	0.186	0.28	26.9
20	0.79	0.120	0.62	41.7
30	1.00	0.096	1.00	52.1
40	1.17	0.083	1.37	60.2
50	1.32	0.074	1.74	67.6
60	1.47	0.067	2.16	74.6
70	1.59	0.062	2.53	80.6
80	1.71	0.058	2.92	86.2

Evaluation

Question 1

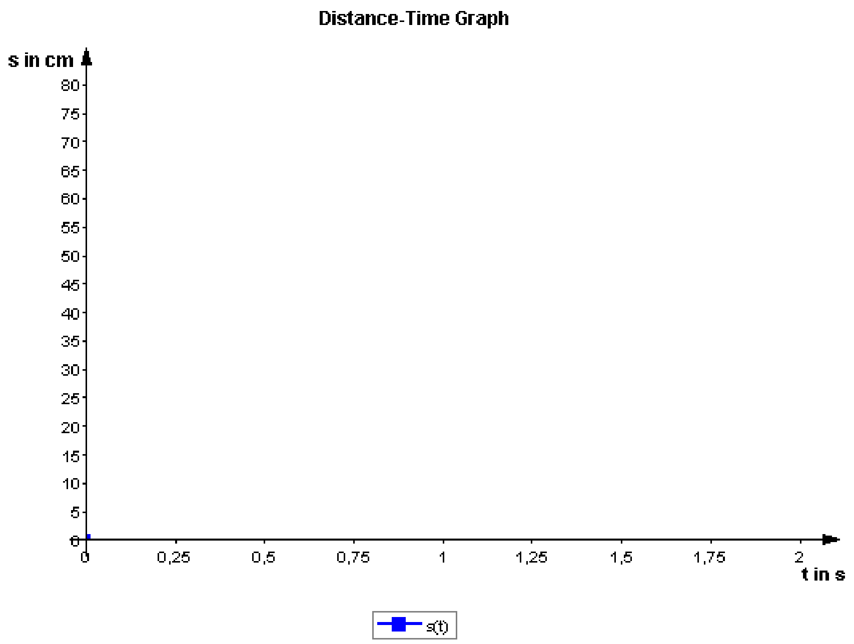
Calculate the square of the values for t and complete the t^2 column on table 1.

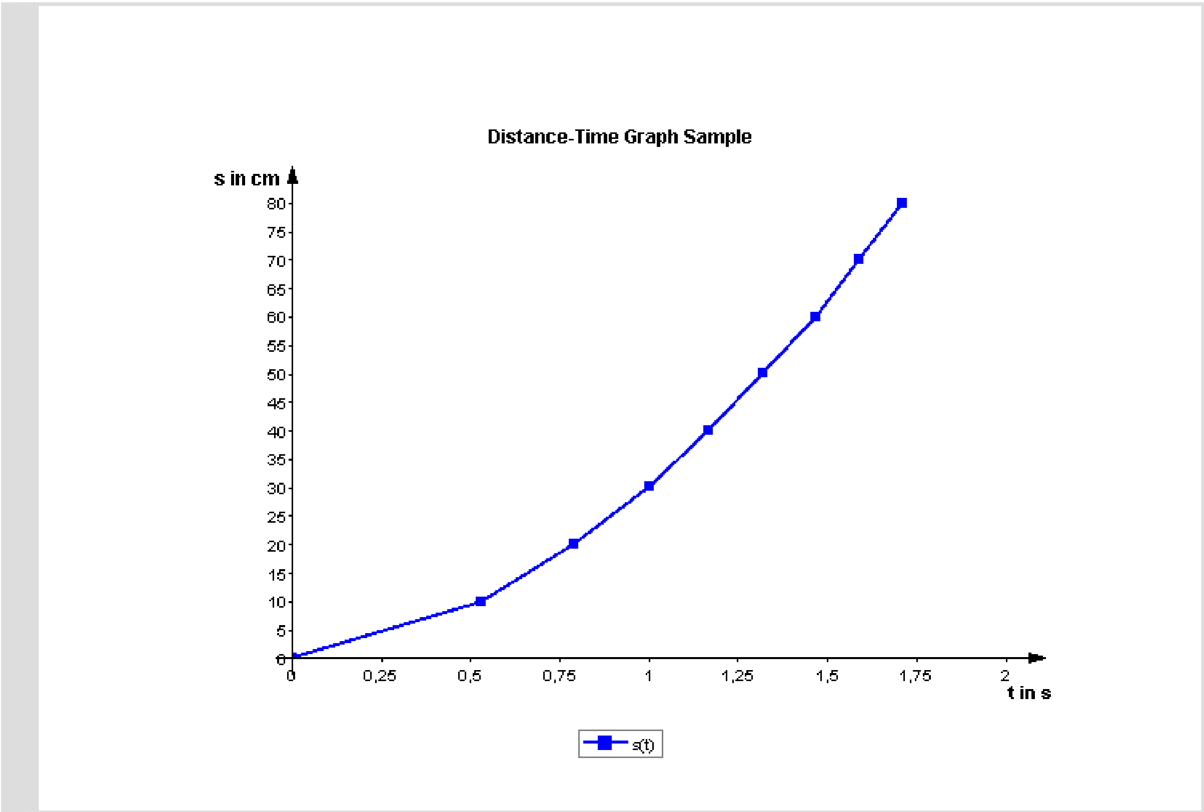
Siehe Tabelle 1.

Question 2

Calculate the instantaneous speed, v_s, after covering the distance, s, that is, the quotient of the plate width, Δs = 5 cm, and the time Δt: $v_s = \Delta s/\Delta t$. Complete the table.

See table 1.

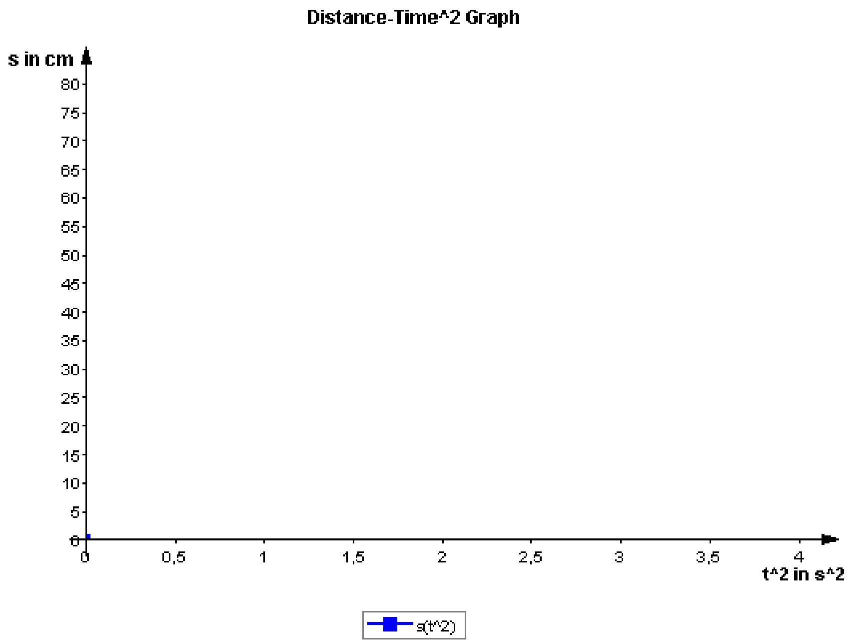

Distance-Time Graph
s in cm
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
0,25
0,5
0,75
1
1,25
1,5
1,75
2
t in s
s(t)

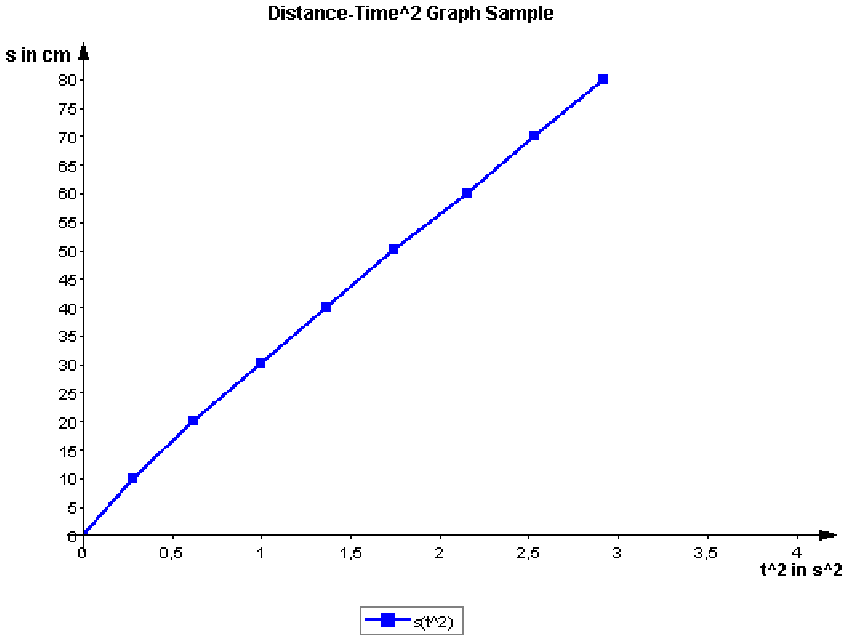

Distance-Time Graph Sample
s in cm
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
0,25
0,5
0,75
1
1,25
1,5
1,75
2
t in s
s(t)

Question 3

The *s* and *t* values were entered into the distance-time graph. Can you indicate what kind of curve you generated?

See the distance-time graph. The curve approximates a parabola at the zero-pont.





Question 4

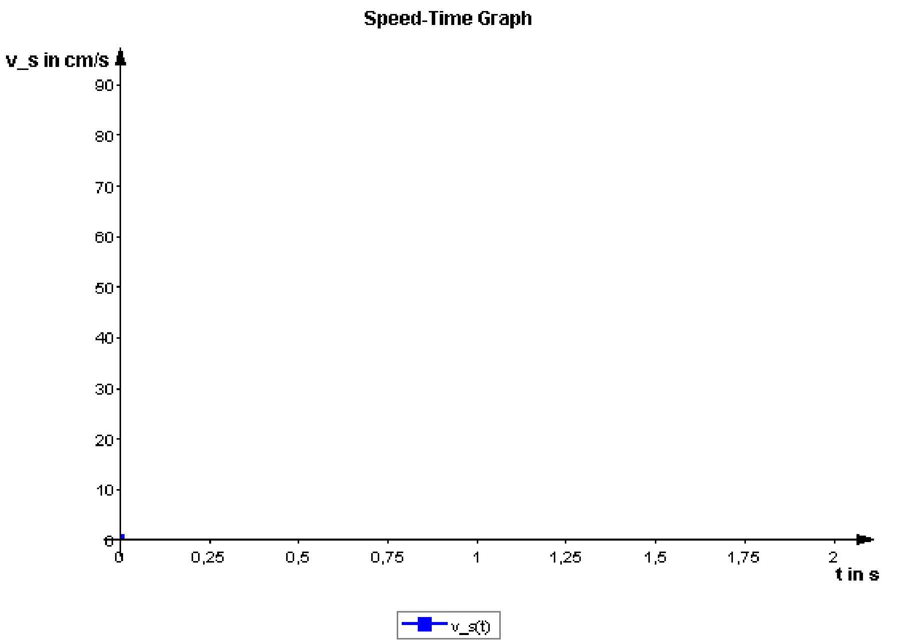
The distance *s* was plotted on the distance-t^2 graph against t^2. What shape does the curve show? Why? What shape does the distance-time graph show, then?

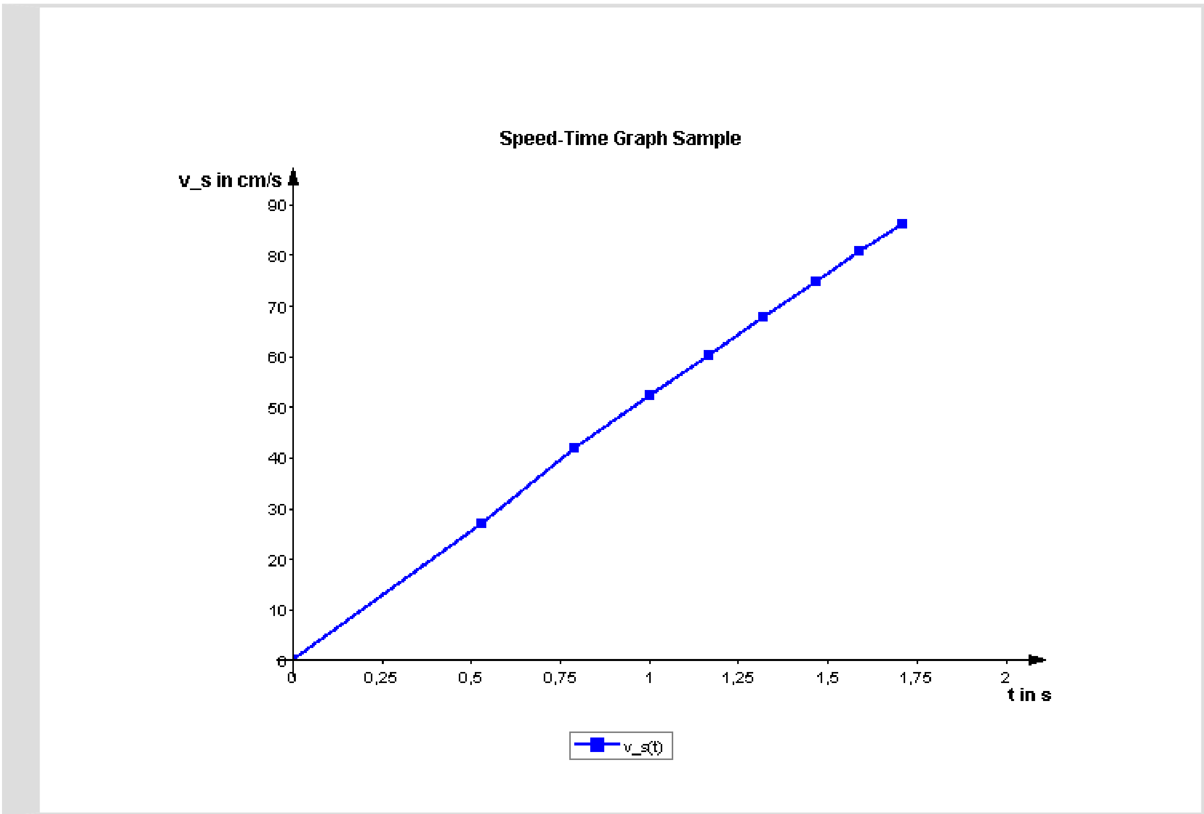
See the s–t^2 graph. The curve looks like a straight line through the zero point. Since s was plotted against t^2, and this function will only make a line through zero out of a parabola through zero, we can conclude that the curve in Figure 2 is a parabola.

Question 5

Determine the slope of the curve $k = \Delta s/\Delta t^2$ from the distance–t^2 graph.

The slope of the curve $k = \Delta s/\Delta t^2$ can be determined from the values in the table to be k = 16 cm/s^2. If the last measurement point is used, this yields k = 80 cm / 2,92 s^2 =27 cm/s^2.


Speed-Time Graph
v_s in cm/s
90
80
70
60
50
40
30
20
10
0
0
0,25
0,5
0,75
1
1,25
1,5
1,75
2
t in s
v_s(t)


Speed-Time Graph Sample
v_s in cm/s
90
80
70
60
50
40
30
20
10
0
0
0,25
0,5
0,75
1
1,25
1,5
1,75
2
t in s
v_s(t)

Question 6

The instantaneous speed values, v_s, were plotted in a speed-time graph, $v_s = f(t)$. What does the resulting curve look like?

See the speed-time graph. $v_s = f(t)$ looks like a straight line through the zero point.

Question 7

Calculate the slope of the curve $a = \Delta v_s / \Delta t$ here as well. State the magnitude of *a*. Compare the value for *a* with the proportionality factor *k* from question 5.

The slope of the curve $a = \Delta v_s / \Delta t$ can be determined from the values on table to be a = 49 cm/s^2. If the last point is used, this yields a = 86.2 cm/s / 1.71 s = 50 cm/s^2. These values are approximately double those for *k* in question 5. (*a* / *k* = 0.53 or, 0.54.)

Question 8

The term $a = \Delta v / \Delta t$ is called acceleration. How does this acceleration come to be, in this experiment?

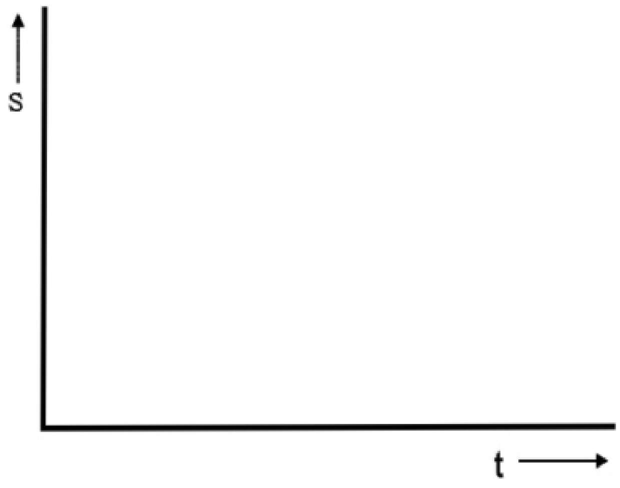
The acceleration of the measurement car results from the downhill component of the weight force, that is, it results from gravitational acceleration.

Additional Tasks

Question 1

A vehicle stands motionless at a point *s*. Draw the distance-time graph. What is its speed *v*?

Additional task: the speed of the vehicle is $v = 0$.

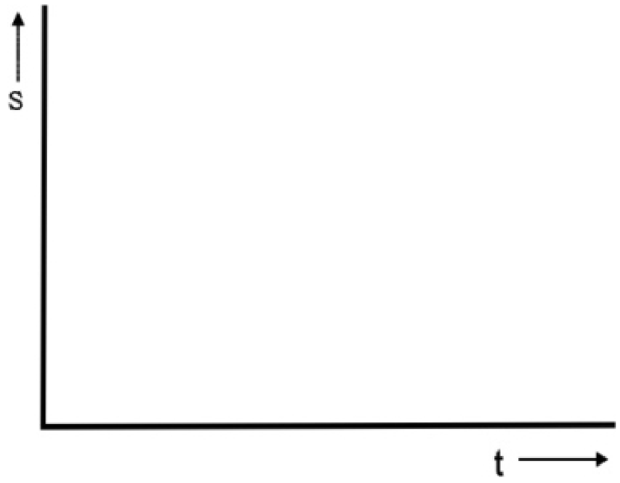


Distance-Speed Graph (1)

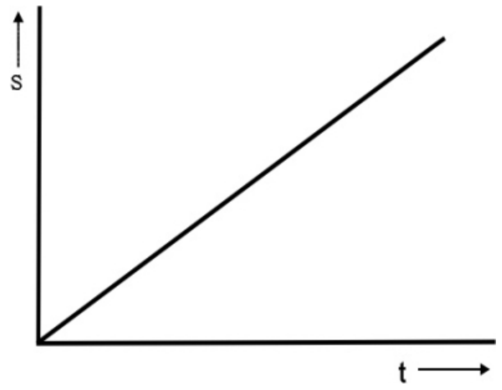
Question 2

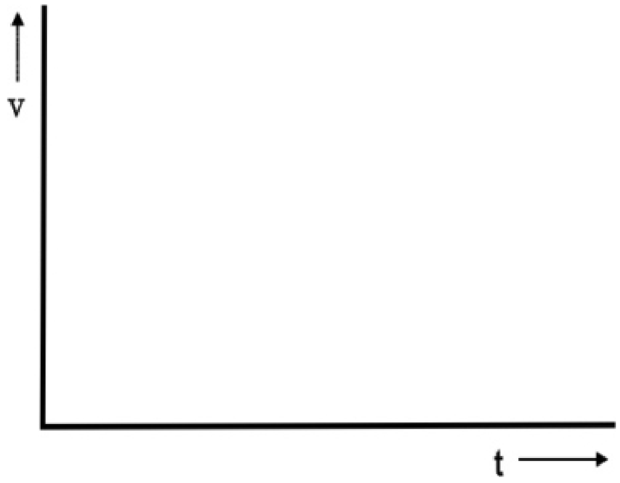
A vehicle moves in a straight line with a constant speed v. Draw the distance–time graph and the speed–time graph. What is its acceleration, a?

Additional task: the acceleration of the vehicle is $a = 0$.

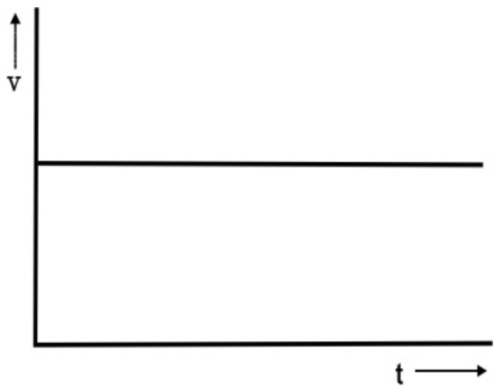


Distance-Time Graph (2)





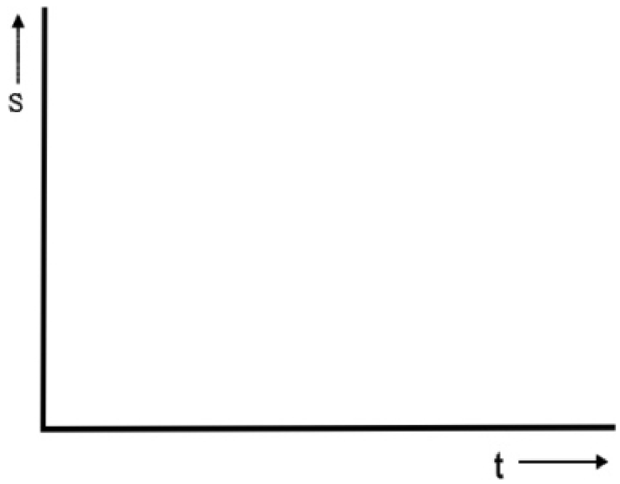
Speed–Time Graph (1)



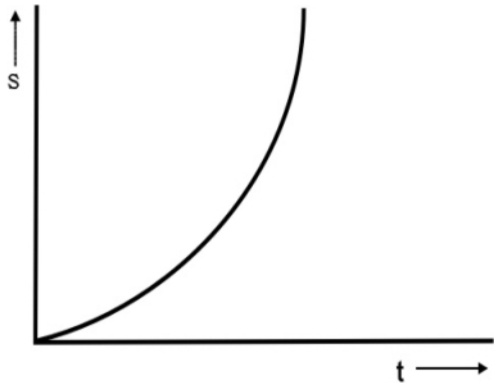
Question 3

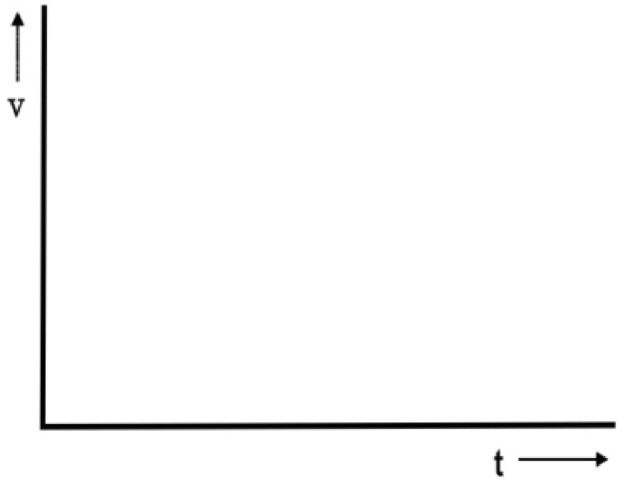
A vehicle moves in a straight line with a constant acceleration *a*. Draw the distance–time graph, the speed–time graph and the acceleration–time graph.

Additional task: the acceleration, *a*, of the vehicle is constant.

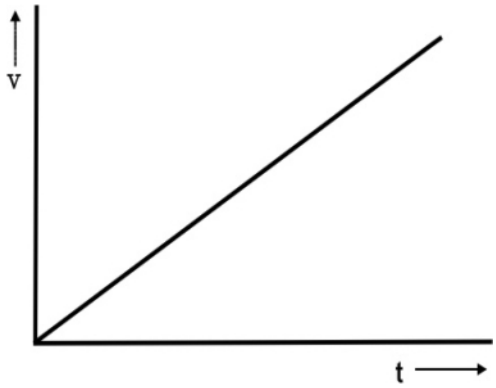


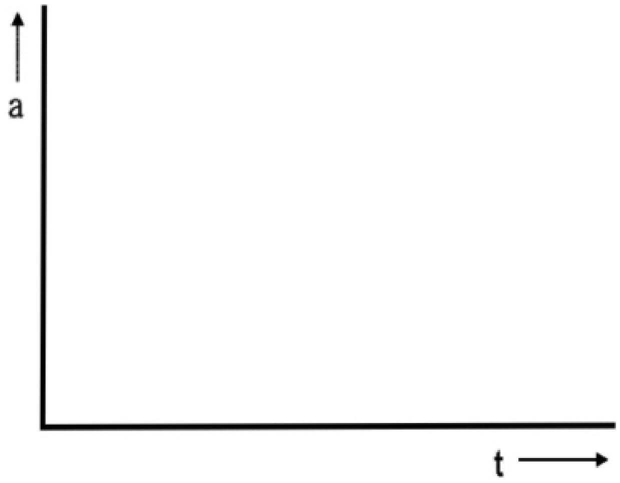
Distance–Time Graph (3):





Speed-Time Graph (2)



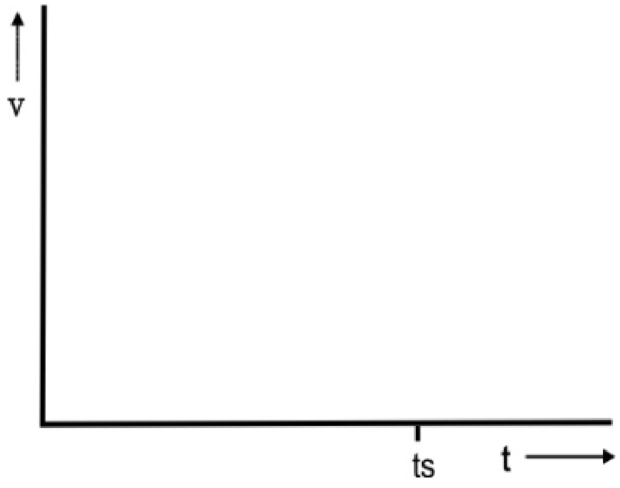


Acceleration–Time Graph (1)

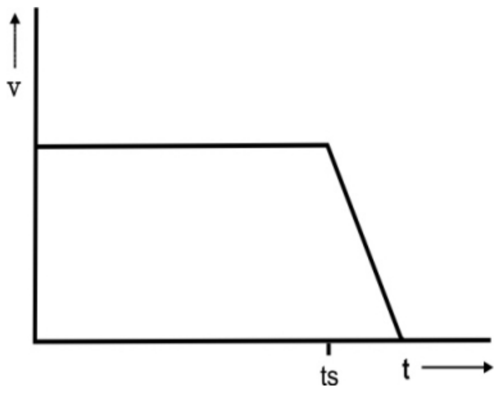
Question 4

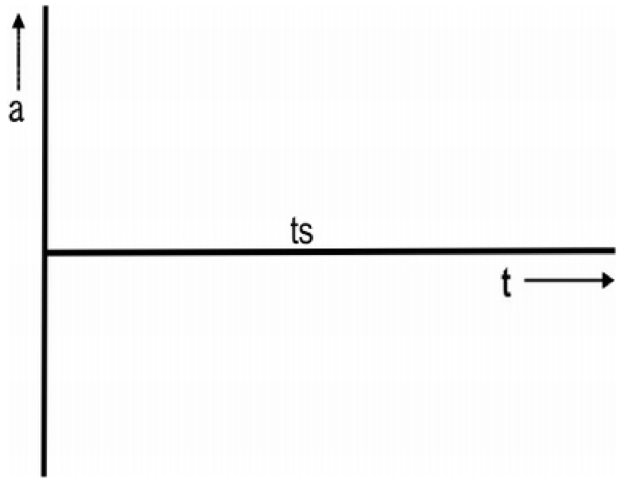
A vehicle moves with a constant speed, *v*. At point s and time t_s it is decelerated evenly and it comes to a standstill after a certain time. Draw the speed–time graph and the acceleration–time graph.

Zusatzaufgabe: Ein Fahrzeug konstanter Anfangsgeschwindigkeit wird abgebremst.
Additional task: a vehicle with a constant initial speed is decelerated



Geschwindigkeit-Zeit-Diagramm (ts)





Acceleration-Time Graph (ts)