The time it takes for an object to fall a certain distance is measured. Assuming uniform accelerated motion the gravitational acceleration g is determined using the known distance-time ratio. g is a constant for the heights measured.

Material

Experiment on the board		**P1421701**
1	Demo physics board	02150.00
1	Scale for demonstration board	02153.00
2	Pointers f. demonst. board, 4 pcs	02154.01
2	Clamp on holder f. demonst. board	02164.00
1	Release unit	02502.00
1	Impact switch	02503.00
1	Connecting cord, 32 A, 500	07361.01
1	Connecting cord, 32 A, 500	07361.04
1	Connecting cord, 32 A, 1500	07364.01
1	Connecting cord, 32 A, 1500	07364.04
1	Digital counter, 4 decades	13600.93

Experiment with stands, clamps and accessories		**P1421702**
1	Support base -PASS -	02005.55
1	Support rod "PASS", l = 1250 mm	02029.55
2	Right angle clamp -PASS-	02040.55
1	Plate holder, opening width 0 – 10 mm	02062.00
1	Release unit	02502.00
1	Impact switch	02503.00
1	Scale, l 1200 mm	11200.17
1	Cursors, 1 pair	02201.00
1	Connecting cord, 32 A, 500	07361.01
1	Connecting cord, 32 A, 500	07361.04
1	Connecting cord, 32 A, 1500	07364.01
1	Connecting cord, 32 A, 1500	07364.04
1	Digital counter, 4 decades	13600.93

The instructions on how to setup the experiment with the demonstration board (Fig. 1) is described here. The experiment can also be carried out with stands, clamps and accessories (Fig. 2).

Setup

- Fasten the impact switch using a clamp on holder at the very bottom of the edge of the board, however as close to the board as possible
- Attach the scale in a manner that the zero mark coincides with the base of the pulled up impact switch
- Fasten the release unit using a clamp on holder to the edge of the board
- Connect the release unit to the start socket of the digital counter (Fig. 1, Fig. 3)
- Connect the impact switch to the stop socket of the digital counter
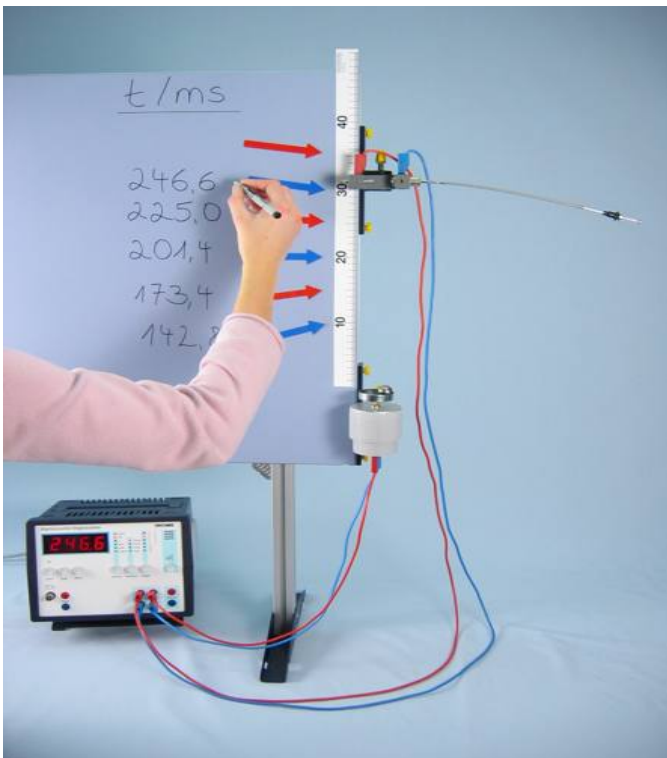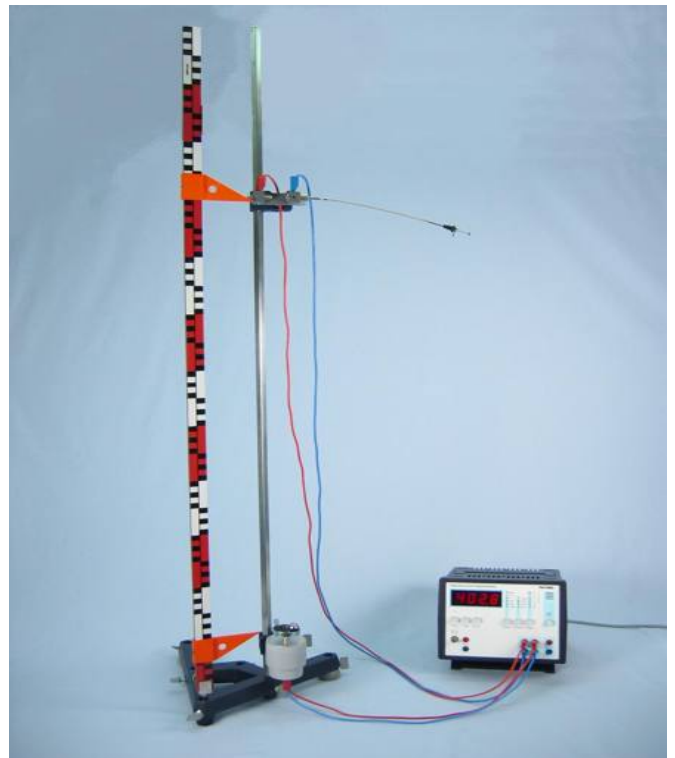
Fig. 1

Fig. 2

Remarks

The release unit is an electric switch that functions as an opener. The ball closes the contact and opens it when falling. This starts the time measurement.

The impact switch is an electric switch that functions as a closer. The plate of the impact switch is pressed down by the ball and stops the time measurement. To open the switch the plate is pulled upward before each experiment.

Release and impact switch must be adjusted in such a manner that the ball from the impact switch is safely caught and does not touch the edge of the plate.
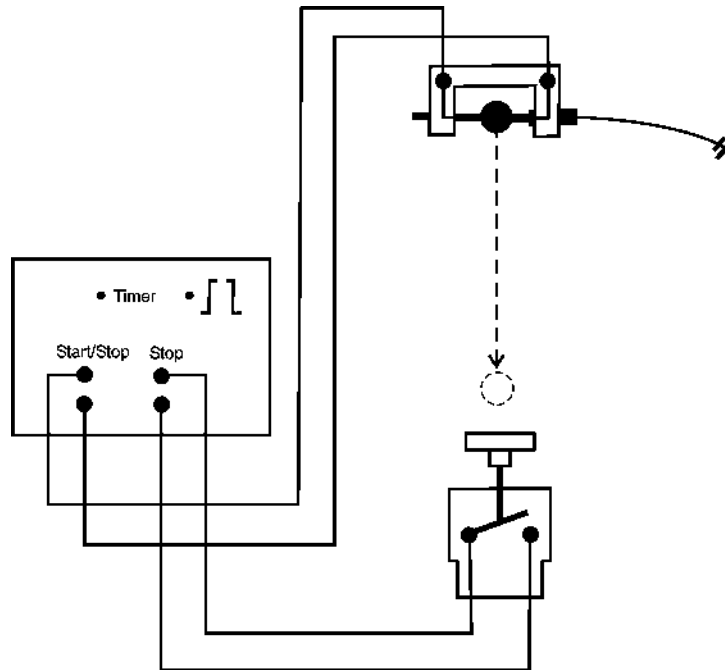

Fig. 3

Implementation

- Pull up the impact switch
- Push the clamp on holder with the release unit so that the lower edge of the release unit coincides with the 10 cm mark of the ruler. The lower edge of the release unit corresponds with the lower edge of the clamped in ball
- On the 4 decade counter select the "timer" setting (Fig. 3)
- The trigger conditions: select "rising flank – falling flank" (Fig. 3)
- Place the ball in the contraption
- Set the indicator to zero using the "reset" button, press the "start" button
- Release the ball
- The ball is caught, the time measured is displayed in ms
- Place the magnetic arrow to 10 cm and write the time measured with a water-soluble pen on the board
- The experiment can be repeated several times for the same height in order to calculate the mean value of the times measured
- Adjust the release unit on the holder to different heights, repeat the measuring process
- After the experiment clean off the board with water and dry it off with a towel

Measurement results

The measured values for the fall distance s and the fall time t are entered in a table.

Table 1

$\dfrac{s}{m}$	$\dfrac{t}{s}$	$\dfrac{g}{m/s}$
0.10	0.1428	9.81
0.15	0.1743	9.87
0.20	0.2014	9.86
0.25	0.2250	9.88
0.30	0.2475	9.79
0.35	0.2674	9.79

The greater the fall distance s, the greater the fall time t.

Evaluation

For uniform accelerated motion the following known distance-time ratio applies:

$$s = \frac{1}{2}at^2 \qquad (1)$$

Here $a = g$. This equates to:

$$g = \frac{2s}{t^2} \qquad (2)$$

s: Fall distance in m
t : Fall time in s
g : Gravitational acceleration in m/s²

Using equation (2) the measurement values are used to calculate the gravitational acceleration g and are also entered in Table 1.

The calculated values for gravitational acceleration are compared with each other. It demonstrates that the gravitational acceleration g is constant at different heights.
It can be determined using the distance-time ratio during free fall.

The mean value of all measurements is:

$$g = 9.83 \text{ m/s}^2.$$

The literature value of gravitational acceleration is:

$$g = 9.81 \text{ m/s}^2.$$

An acceleration of $g = 9.81$ m/s² means that the speed changes 9.81 m/s per second.

Remarks regarding experiments with the stands, clamps and accessories

If the experiment is carried out with stands, clamps and accessories, the gravitational acceleration can also be determined for greater distances of up to 1 m. The fall distance can also be graphically demonstrated in ratio to the fall time. This forms the parabola according to equation (1) for accelerated motion.

Larger distances of up to 0.5 m can be achieved also with the board. To do so, the construction of the board must be changed so that the right foot-stand is flush with the right board edge, which creates a continuous guiding rail. The impact tray can be positioned somewhat lower.

Measurement results for the setup with stands, clamps and accessories

Table 2

$\dfrac{s}{m}$	$\dfrac{t}{s}$	$\dfrac{g}{m/s}$
0.40	0.2855	9.81
0.45	0.3032	9.79
0.50	0.3188	9.84
0.60	0.3491	9.85
0.70	0.3769	9.86
0.80	0.4019	9.86
0.90	0.4275	9.85
1.00	0.4511	9.83

Remarks

1. In the gravitational field of the earth a force is exerted on an object. Due to this force objects do not levitate, but are rather pushed down on their surface or fall to the ground.

2. An object performs uniform accelerated motion strictly speaking only in a vacuum. The air resistance has an impact at large fall heights that an object only achieves a fixed maximum speed. In this experiment the air resistance can however be neglected.

3. The value for the gravitational force and therefore also for the gravitational acceleration can be assumed in this experiment to be constant. Actually g depends on the distance to the center of the earth. Due to the oblateness of the earth this distance is less for the poles than for the equator region. The gravitational acceleration is therefore greater at the poles.
Due to the earth rotation a centrifugal force is also exerted. This becomes less at the poles and increases towards the equator and counteracts the gravitational acceleration.

g therefore has different values for different geographic longitudes and height above sea level. The value of the gravitational acceleration fluctuates at sea level between $g \approx 9.78$ m/s² at the equator and $g \approx 9.83$ m/s² at the poles.

The literature value of the gravitational acceleration for a geographic latitude of 45° is:

$$g = 9.80665 \text{ m/s}^2.$$

The common approximate value is:

$$g = 9.81 \text{ m/s}^2.$$