Mechanics

Translational Motion

Free Fall

DETERMINE THE ACCELERATION OF A FALLING OBJECT

- Measure the time t that a ball takes to fall a distance h between a release mechanism and a target plate at the bottom.

- Draw points for a displacement/time graph for a uniformly accelerating motion.

- Verify that the distance fallen is proportional to the square of the time.

- Calculate the acceleration due to gravity g.

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BASIC PRINCIPLES

If a body falls to the ground in the Earth's gravitational field from a height h, it undergoes a constant acceleration g, as long as the speed of the fall is slow so that friction can be ignored. Such a falling motion is called free fall.

In this experiment a steel ball is suspended from a release mechanism. As soon as it is released into free fall, an electronic timer is started. After it has fallen a distance h the ball hits a target plate at the bottom which stops the time measurement at a time t.

Since the ball is not moving before it starts to fall at time $t_0 = 0$ its initial velocity is zero, i.e. $v_0 = 0$. Therefore the distance covered in time t is given as follows

$$h = \frac{1}{2} \cdot g \cdot t^2 \qquad (1)$$

The results for different fall distances are to be entered as value pairs in a displacement/time diagram. The distance h through which the ball falls is a non-linear function of the time t, as can be shown by comparing a straight-line fit with a parabolic fit for the measured data. To obtain a linear graph it is necessary to plot the fall distance against the square of the fall time. From the slope of this line, the gravitational acceleration g can then be calculated.

Fig. 1: Experiment set-up for measuring the fall time of a steel ball as a function of the distance h between the trigger mechanism and a target plate.

LIST OF APPARATUS

1	Free-fall apparatus	U8400810
1	Electronic counter; LED, 4 digits	U8533351
1	Set of 15 safety leads, 75 cm	U14200

SET-UP

- Assemble the free-fall apparatus and set a fall height $h = 65$ cm, ensuring the release lever is pointing downwards.

- Connect the electronic counter as shown in Fig. 2.

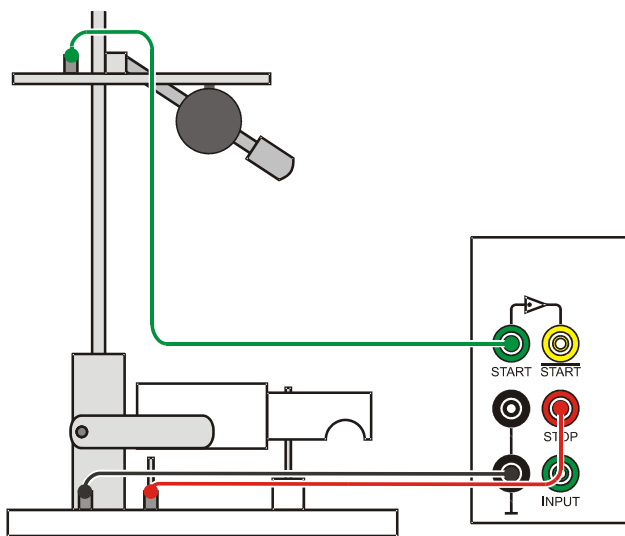- Suspend a steel ball by the pin from the release mechanism.

Fig. 2: Connection of the electronic counter to the apparatus

EXPERIMENT PROCEDURE

- Initiate free fall by lifting the release lever.

- When the ball hits the target plate, measure and record the fall time t.

- By sliding the release mechanism, reduce the fall height h in steps of 5 cm and determine the fall time t in each case.

SAMPLE MEASUREMENTS

Tab. 1: Measured values of the fall height h and fall time t

h (cm)	t (ms)	h (cm)	t (ms)
0	0	35	270
5	104	40	289
10	144	45	308
15	176	50	324
20	204	55	336
25	228	60	354
30	249	65	369

EVALUATION

First method:

Calculating the correlation between fall times and fall heights for $h_0 = 5$ cm, $h_1 = 20$ cm and $h_2 = 45$ cm:

$$\frac{t(4 \cdot h_0)}{t(h_0)} = \frac{204 \text{ ms}}{104 \text{ ms}} = 1.96 , \quad \frac{t(9 \cdot h_0)}{t(h_0)} = \frac{308 \text{ ms}}{104 \text{ ms}} = 2.96$$

The fall times are found to be in the ratio 3:2:1 and the fall heights in the ratio 9:4:1 within the limits of experimental accuracy. In other words, the fall height is proportional to the square of the fall time: $h \propto t^2$

Second method:

a) Plotting the measurement results in a displacement/time diagram (see Fig. 3):

Fitting a parabola to the measured values shows that the distance travelled h is not a linear function of the time t.
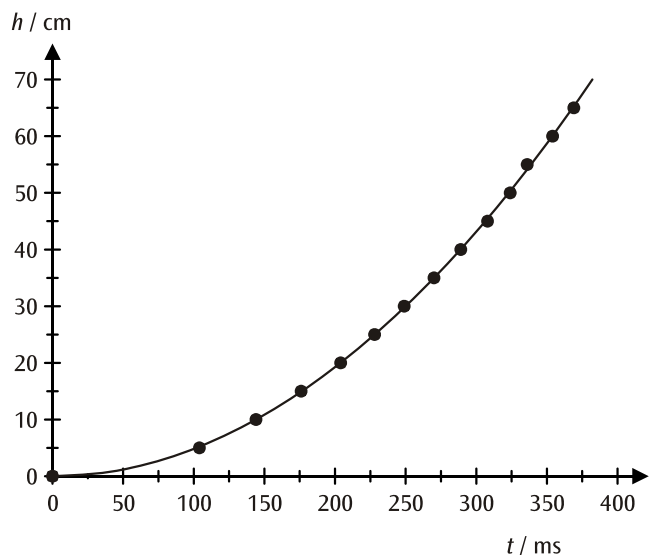
Fig. 3:   Displacement/time diagram for free fall

b) Linearisation by plotting the fall distance as a function of the square of the fall time (see Fig. 4):
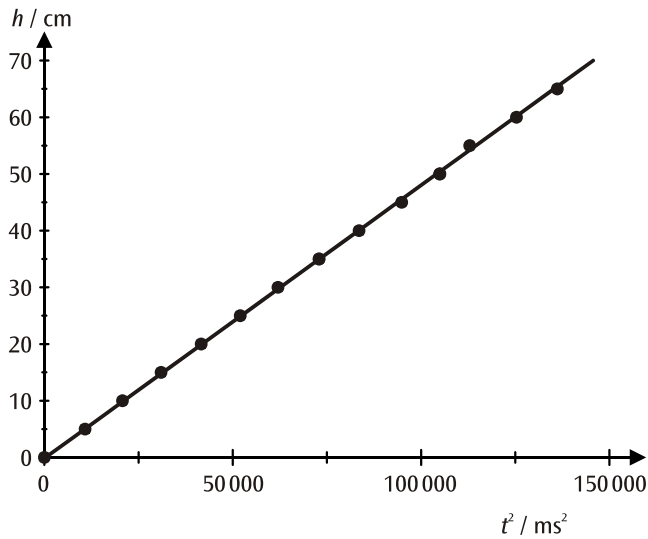

Fig. 4:   Fall distance as a function of the square of the fall time

The fit between the matched line, passing through the origin, and the original data confirms Equation (1). The acceleration due to gravity can be calculated from the slope of the line.

$$g = 2 \cdot A = 9.6 \, \frac{m}{s^2}$$