Mechanics

Harmonic oscillation

PHYSICS EXPERIMENT

Variable-g pendulum

MEASURE THE PERIOD OF AN OSCILLATING PENDULUM AS A FUNCTION OF THE EFFECTIVE ACCELERATION DUE TO GRAVITY.

- Measure the period T as a function of the effective acceleration g_{eff}
- Measure the period T for various pendulum lengths L.

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BASIC PRINCIPLES

The period of oscillation of a pendulum is determined mathematically by the length of the pendulum L and the acceleration due to gravity g. The effect of the gravitational acceleration can be demonstrated by tilting the axis of the pendulum so that it is no longer horizontal.

When the axis is tilted, the component of the gravitational acceleration g that is parallel to the axis g_{par} is rendered ineffective by the fact that the axis is fixed (see fig. 1). The remaining component that is effective g_{eff} is given by the following equation:

$$g_{eff} = g \cdot \cos\alpha \quad (1)$$

where α is the angle of inclination of the axis to the horizontal.

When the pendulum is deflected by an angle φ from its rest position, a suspended weight of mass m experiences a returning force of the following magnitude:

$$F = -m \cdot g_{eff} \cdot \sin\varphi \quad (2)$$

For small angles the equation of motion of the pendulum emerges as the following:

$$m \cdot L \cdot \ddot{\varphi} + m \cdot g_{eff} \cdot \sin\varphi = 0 \quad (3)$$

The pendulum's angular frequency of oscillation is therefore:

$$\omega = \sqrt{\frac{g_{eff}}{L}} \quad (4)$$

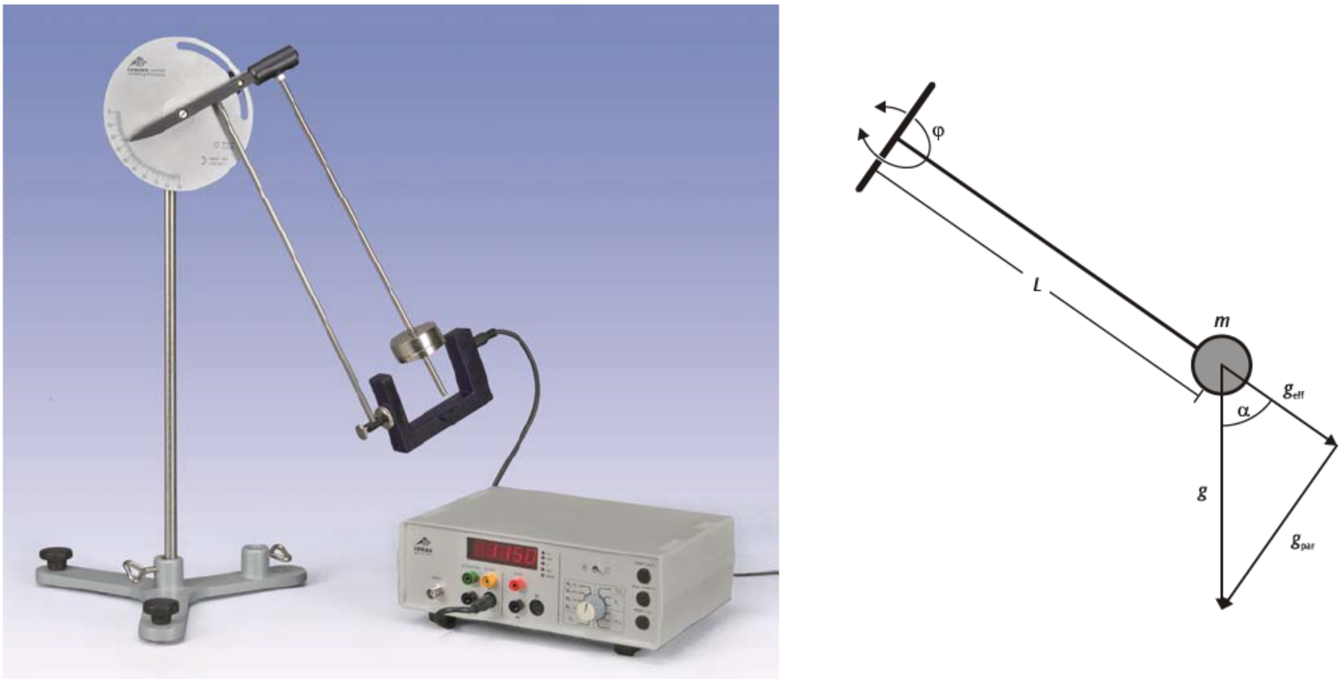

Fig. 1: Variable-g pendulum (photograph and schematic diagram)

LIST OF APPARATUS

1 Variable-g pendulum 1000755 (U8403950)
1 Holder for light barrier 1000756 (U8403955)
1 Light barrier 1000563 (U11365)
1 Digital counter @ 230 V 1001033 (U8533341-230)
or
1 Digital counter @ 115 V 1001032 (U8533341-115)
1 Stand base, 150 mm 1002835 (U13270)
1 Stand rod, 470 mm 1002934 (U15002)

SET-UP

- Mount the variable-g pendulum in the stand base.
- Fix the holder for the light barrier to the pointer of the pendulum.
- Mount the light barrier on the holder (see Fig. 1) and connect it to the START input socket of the digital counter.
- Attach the mass to the lower end of the pendulum rod.
- Move the function selector switch of the digital counter to T_A / △.

EXPERIMENT PROCEDURE

- Set the angle of tilt α to zero (0° on the scale).
- Push the pendulum to set it oscillating and press the START button.
- Read off the period of oscillation, repeat several times, and enter the average value *T* in Table 1.
- Perform similar measurements with the tilt angle α set at 10°, 20°, 30°, 40°, 50°, 60°, 70° and 80°.
- With α = 0°, change the length of the pendulum to different values by sliding the pendulum bob and measure the period of oscillation in each case.

SAMPLE MEASUREMENTS

a) Variation of the angle of inclination:

Tab. 1: Period of oscillation as a function of the effective component of the effective acceleration due to gravity calculated by Equation (1); (*L* = 34.5 cm)

α	*g* cos α (m s^{-2})	*T* (ms)
0°	9.81	1171
10°	9.66	1183
20°	9.22	1218
30°	8.50	1270
40°	7.51	1361
50°	6.31	1507
60°	4.91	1730
70°	3.36	2074
80°	1.70	3021

b) Variation of the length of the pendulum:

Tab. 2: Period of oscillation in relation to the length of the pendulum

L (cm)	*T* (ms)
34.5	1171
29.5	1090
24.5	1000
19.5	918

EVALUATION

Using equation (4), we can calculate the period of oscillation of the pendulum:

$$T = 2\pi\sqrt{\frac{L}{g_{\text{eff}}}}$$

For *L* = 34.5 cm, we get the continuous curve depicted in Fig. 2. The points plotted in Fig. 2 are also taken from Table 1 and coincide with the curve in terms of measurement accuracy.

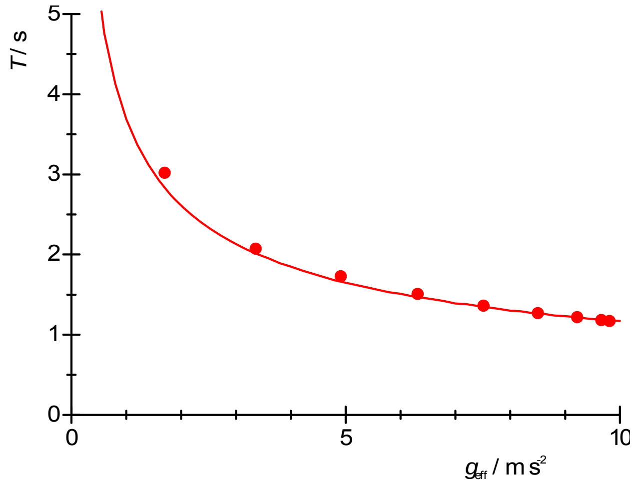

Fig. 2: Period of oscillation of the pendulum in relation to the effective acceleration due to gravity

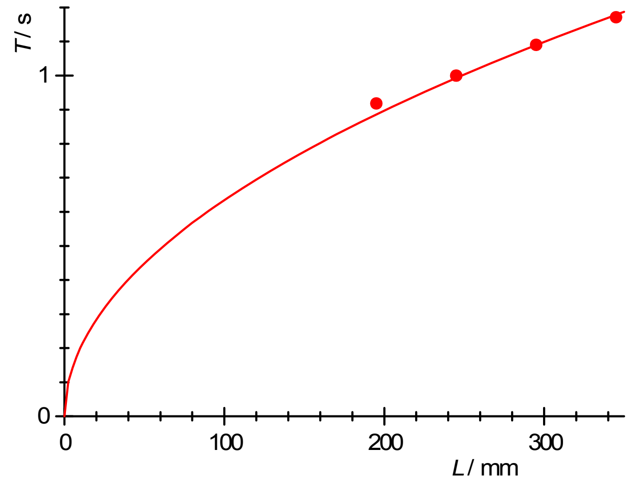

Fig. 3: Period of oscillation of the pendulum in relation to its length *L*

The continuous curve in Fig. 3 has been calculated by taking the value of the effective component g_{eff} = 9.81 ms^{-2}. The measured values are taken from Table 3 and deviate from the plotted curve, since the pendulum deviates perceptibly from the mathematical ideal for short lengths *L*.

RESULTS

The period of oscillation of the pendulum becomes shorter when the length of the pendulum is reduced and it becomes greater when the effective component of gravitational acceleration is reduced.