Mechanics

Oscillations

PHYSICS EXPERIMENT

Harmonic Oscillation of a String Pendulum

MEASURING THE PERIOD OF OSCILLATION OF STRING PENDULUMS OF VARIOUS LENGTHS AND WITH BOBS OF VARIOUS MASSES.

- Measure the period of oscillation *T* of a string pendulum as a function of the length of the pendulum *L*.
- Measure the period of oscillation *T* of a string pendulum as a function of the mass of the pendulum bob *m*.
- Determine the acceleration due to gravity *g*.

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BASIC PRINCIPLES

A string pendulum with a bob of mass *m* and a length *L* will exhibit simple harmonic oscillation about its rest point as long as the angle of deflection is not too great. The period *T*, i.e. the time it takes for the pendulum to swing from one end of its motion to the other end and back, is dependent solely on the length of the pendulum *L* and not on the mass *m*.

If the pendulum is deflected from its rest position by an angle φ, the restoring force is as follows:

$$\text{(1a)} \quad F_1 = -m \cdot g \cdot \sin\varphi .$$

For small angles φ, this closely approximates to the following:

$$\text{(1b)} \quad F_1 = -m \cdot g \cdot \varphi$$

The moment of inertia of the accelerated mass is given by

$$\text{(2)} \quad F_2 = m \cdot L \cdot \ddot{\varphi}$$

Both these forces are equal, thus the result is equivalent for the equation of motion for simple harmonic oscillation:

$$\text{(3)} \quad \ddot{\varphi} + \frac{g}{L} \cdot \varphi = 0$$

For the period of oscillation *T* the following applies:

$$\text{(4)} \quad T = 2\pi \cdot \sqrt{\frac{L}{g}} .$$

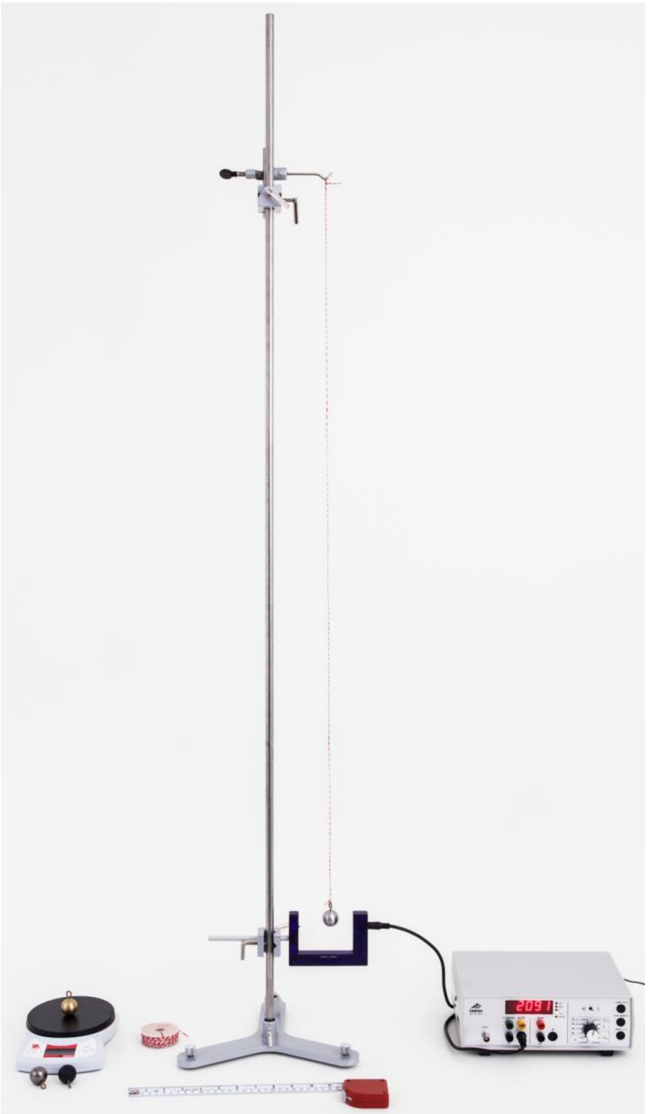

Fig. 1: Experiment set-up

LIST OF EQUIPMENT

1	Set of 4 Pendulum Bobs	U30035	1003230
1	Cord for Experiments	U8724980	1001055
1	Tripod Stand, 185 mm	U13271	1002836
1	Stainless Steel Rod, 1500 mm	U15005	1002937
1	Stainless Steel Rod, 100 mm	U15000	1002932
1	Clamp with Hook	U13252	1002828
2	Universal Clamp	U13255	1002830
1	Photo Gate	U11365	1000563
1	Digital Counter	U8533341	1001032/3
1	Pocket Measuring Tape, 2 m	U10073	1002603
1	Electronic Scale 200 g	U42060	1003433

SET UP AND PROCEDURE

- Set up the experiment as shown in Fig. 1.
- Connect the photo gate to channel A of the digital counter. Set the operating mode selector switch on the digital counter to the symbol for measuring the periods of a pendulum.
- Measure the masses of the pendulum bobs using electronic scales and enter the values into Table 2.
- Cut off 6 lengths of the experiment cord to make pendulums of lengths approximately 20, 40, 60, 80, 100 and 120 cm.
- Tie the ends of the 6 pieces of cord into loops.
- Suspend the shortest piece of cord by the loop at one end from the clamp with hook. Suspend a pendulum bob from the loop at the other end.
- Use a tape measure to measure the length of the pendulum *L* from the hook on the clamp to the centre of the pendulum bob and enter the value into Table 1.
- Deflect the pendulum slightly, measure the period of oscillation *T* using the digital counter and enter the value into Table 1.
- Measure the lengths of the pendulums made with the other 5 pieces of cord, entering the pendulum length *L* and the period of oscillation *T* into Table 1 in each case.
- Cut off another piece of cord of sufficient length to make a pendulum of length (from the hook on the clamp to the centre of the pendulum bob) of exactly 99.4 cm. Pendulums of exactly this length are known as seconds pendulums since half the period of oscillation *T*/2 is precisely equal to 1 second, i.e. *T* = 2 s.
- Tie one end of the cord into a loop and suspend it from the clamp with hook.
- Tie the other end into a loop in such a way that when a pendulum bob is attached to the end, the length of the pendulum is exactly 99.4 cm.
- Suspend each of the 4 pendulum bobs from the end one after the other, deflect the pendulum slightly and measure the periods of oscillation *T* in each case with the help of the digital counter. Enter the results into Table 1.

SAMPLE MEASUREMENT

Tab. 1: Periods of oscillation *T* for various lengths of pendulum *L*.

L / cm	*T* / s
23	1.00
43	1.30
63	1.55
83	1.80
103	2.05
123	2.20

Tab. 2: Periods of oscillation *T* for a seconds pendulum with bobs of various masses *m*.

m / g	*T* / s
10.5	2
25.0	2
61.1	2
71.4	2

EVALUATION

- Plot the measurements in a graph of *T* against *L* and a graph of *T* against *m*.

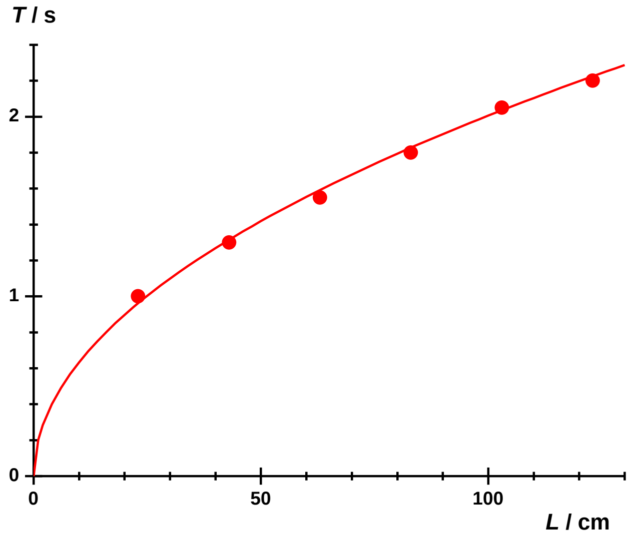

Fig. 2: Period of oscillation *T* as a function of the pendulum length *L*

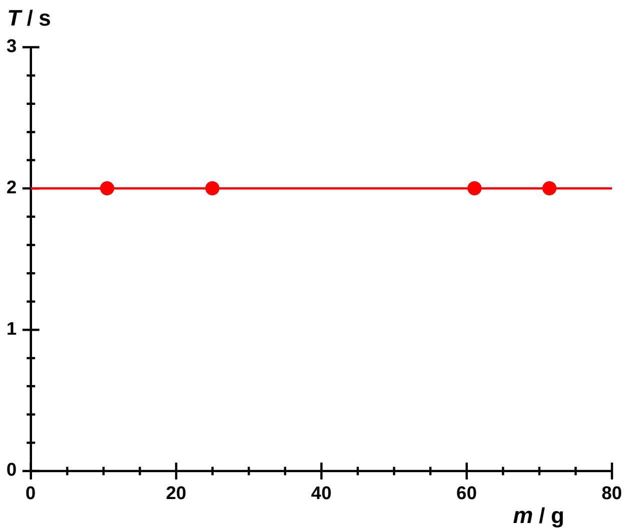

Fig. 3: Period of oscillation T for a seconds pendulum as a function of the mass of the pendulum bob m.

The graphs demonstrate, as expected, that the period of oscillation depends on the length of the pendulum and not on the mass of the bob.

From equation (4):

$$(5)\quad T = 2\pi\cdot\sqrt{\frac{L}{g}} \Leftrightarrow T^2 = \frac{4\cdot\pi^2}{g}\cdot L = a\cdot L$$

where $a = \frac{4\cdot\pi^2}{g} \Leftrightarrow g = \frac{4\cdot\pi^2}{a}$.

- Plot the square of the periods of oscillation T^2 against the lengths of the pendulum and draw a straight line through the points (Fig. 4).

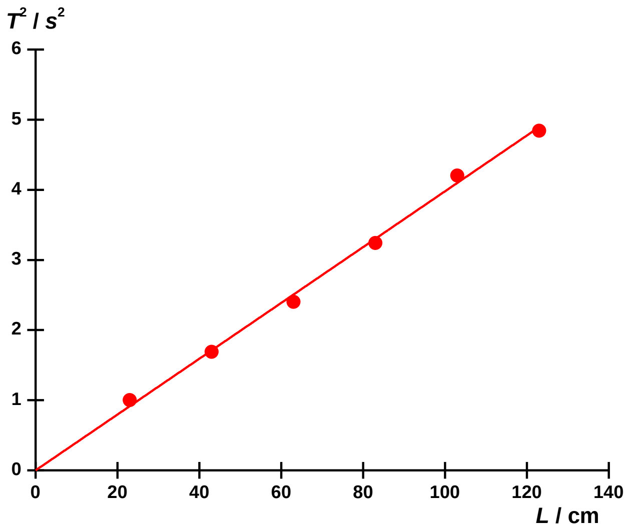

Fig. 4: Square of period of oscillation T^2 as a function of pendulum length L.

- Use equation (5) to determine the acceleration due to gravity g from the gradient of the graph a:

$$(6)\quad g = \frac{4\cdot\pi^2}{a} = \frac{4\cdot\pi^2}{0.04\,\frac{\text{s}^2}{\text{cm}}} = 9.87\,\frac{\text{m}}{\text{s}^2}.$$

The value obtained is well in agreement with the value quoted in literature of 9.81 m/s².