UE1050311 SIMPLE HARMONIC OSCILLATIONS

OBJECTIVE

Measure the oscillations of a coil spring pendulum using an ultrasonic motion sensor.

SUMMARY

The oscillations of a coil spring pendulum are a classic example of simple harmonic oscillation. In this experiment, those oscillations are recorded by an ultrasonic motion sensor, which detects the distance to the weight suspended from the spring pendulum.

EXPERIMENT PROCEDURE

- **Record the harmonic oscillation of a coil spring pendulum as a function of time using an ultrasonic motion sensor.**
- **Determine the period of oscillation *T* for various combinations of spring constant *k* and mass *m*.**

REQUIRED APPARATUS

Quantity	Description	Number
1	Set of Helical Springs for Hooke's Law	1003376
1	Set of Slotted Weights, 10 x 10 g	1003227
1	Set of Slotted Weights, 5 x 100 g	1003229
1	Tripod Stand 150 mm	1002835
1	Stainless Steel Rod 1000 mm	1002936
1	Clamp with Hook	1002828
1	Ultrasonic Motion Sensor	1000559
1	3B NET*lab*™	1000544
1	3B NET*log*™ (230 V, 50/60 Hz)	1000540 or
	3B NET*log*™ (115 V, 50/60 Hz)	1000539
1	Pocket Measuring Tape, 2 m	1002603

GENERAL PRINCIPLES

Oscillations occur when a system disturbed from its equilibrium position is affected by a force which acts to restore it to equilibrium. This is known as simple harmonic oscillation if the restoring force is proportional to the deviation from the equilibrium position at all times. The oscillations of a coil spring pendulum are one classic example of this. The proportionality between the deviation and the restoring force is described by Hooke's law.

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The law states that the relationship between the deviation *x* and the restoring force *F* is given by

(1) $$F = -k \cdot x$$

where k = spring constant

For a weight of mass *m* suspended from the spring, the following therefore holds:

(2) $$m \cdot \frac{d^2x}{dt^2} + k \cdot x = 0,$$

This applies as long as the mass of the spring itself and any friction that might arise can be neglected.

In general, solutions to this equation of motion take the following form:

(3) $$x(t) = A \cdot \sin\left(\sqrt{\frac{k}{m}} \cdot t + \varphi\right),$$

This will be verified by experiment by recording the harmonic oscillations of a coil spring pendulum as a function of time with the help of an ultrasonic motion sensor and matching the measured data to a sine function.

The ultrasonic motion sensor detects the distance between itself and the weight suspended from the spring. Other than an offset for the zero point, which can be compensated for by calibration, the measurement corresponds directly to the variable $x(t)$ included in equation 3.

The period of oscillation *T* is defined as the interval between two points where a sine wave crosses the zero axis in the same direction. From equation (3) it can therefore be seen to be equal to:

(4) $$T = 2\pi \cdot \sqrt{\frac{m}{k}} \quad .$$

In order to verify equation (4), the measurements are made for various combinations of mass *m* and spring constant *k*, whereby the period of oscillation is determined from where a curve matching the data crosses the zero axis.

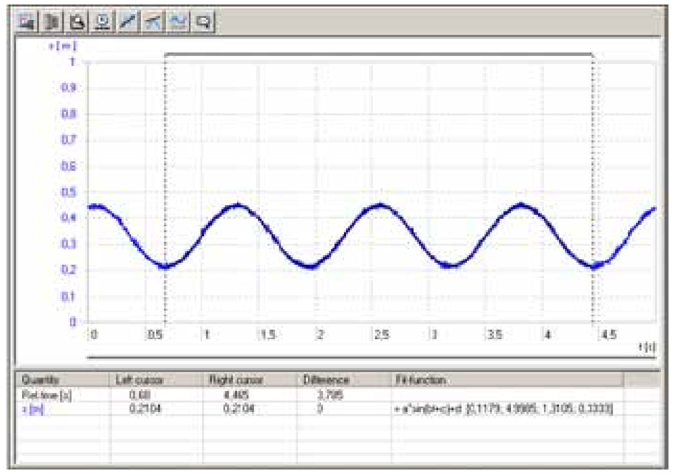

Fig. 1: Recorded oscillation data after matching to a sine function

EVALUATION

The following can be deduced from equation 4:

$$T^2 = \frac{4\pi^2}{k} \cdot m$$

Measurements are therefore plotted using various spring constants *k* as parameters in a graph of T^2 against *m*. Within measurement tolerances, they lie on a straight line through the origin, the gradient of which can be calculated using a second graph

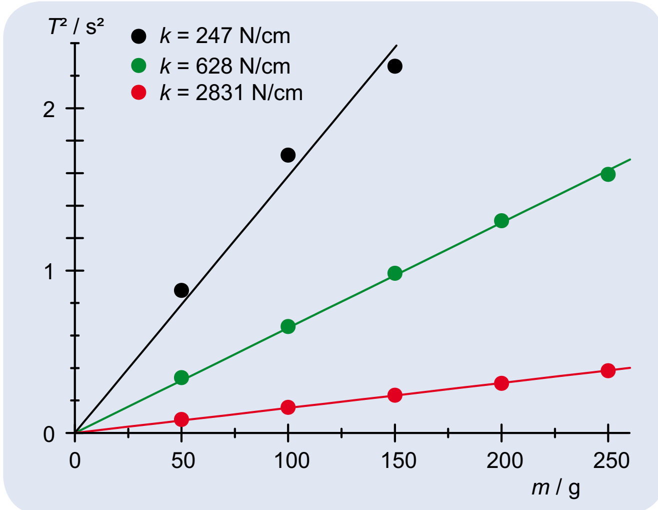

Fig. : 2 T^2 as a function of *m*

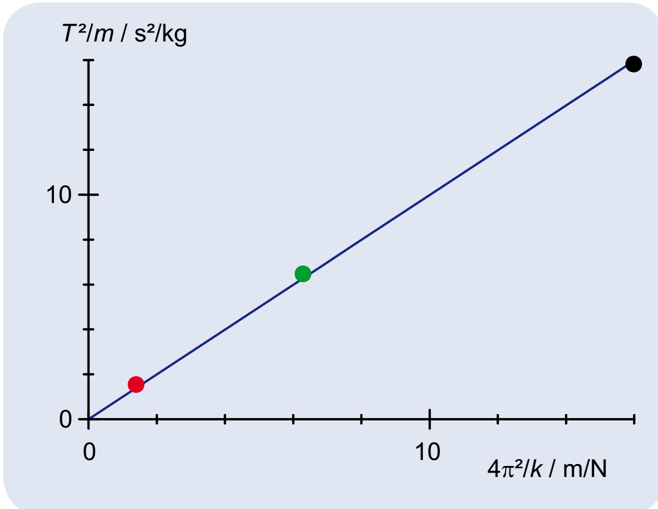

Fig.: 3 $\frac{T^2}{m}$ as a function of $\frac{4\pi^2}{k}$