Related topics

Spring constant, Hooke's Law, oscillations, limit of elasticity, parallel springs, serial springs, use of an interface.

Principle and task

The spring constant D is determined for different experimental set-ups from the oscillation period and the suspended mass.

Equipment

COBRA-interface 2	12100.93	1
PC COBRA data cable RS 232, 2 m	12100.01	1
Movement sensor with cable	12004.10	1
Adapter, BNC-socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Softw.COBRA Rotation (Win)	14295.61	1
Basic Softw. f. PHYWE Windows prog.	14099.61	1
Silk thread, 200 m	02412.00	1
Weight holder f. slotted weights	02204.00	1
Slotted weight, 10 g, black	02205.01	4
Slotted weight, 50 g, black	02206.01	7
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Stand tube	02060.00	1
Rod with hook	02051.00	1
Right angle clamp -PASS-	02040.55	2
Helical spring, 3 N/m	02220.00	2
Helical spring, 20 N/m	02222.00	1

The PHYWE WINDOWS® Basic Software (14099.61) must have been installed once on the used computer for the software to work.

Problems

1. Determination of the spring constant D for different springs.

2) Determination of the spring constant D for springs linked in parallel.

3) Determination of the spring constant D for springs linked in series.

Fig. 1: Experimental set up to determine the spring constant of a spring.

Set-up

— The spring constants of the single springs are measured according to Fig. 1.

— The electric connection of the movement recorder is carried out according to Fig. 2 for the COBRA interface. The thread is lead past the larger of the two thread grooves of the movement recorder.

— Fig. 4 shows the set up to measure the spring constants for springs linked in parallel and in series.

Procedure

— COBRA: if the COBRA interface is connected to the computer port COM 1 "Osc_COM 1" is clicked on twice. If the serial port COM 2 is used "Osc_COM 2" is started.

— The maximum sampling rate <Delta t/ms> is adjusted according to computer speed. If a 486 (66 MHz) computer is used, 100 ms have proven to be a suitable choice; with faster computers, time may decrease, with slower computers, it may increase. Sampling time is set by shifting the grey slide with the mouse cursor. Modification of <Delta t/ms> must be repeated every time the programme is started. A too short sampling time is identified through the following effects:

— No measurement values are recorded.

— The measurement values are not equidistant on the time axis.

— The distance in time of the measurement points is much larger than the set <Delta t/ms> value.

Recording of measurement values

— The diameter of the thread groove of the movement recorder is entered into the input window d_0 (12 mm are set as a default value). d_1 is used to convert rad to meters. If 2000 is entered, 1 rad corresponds to 1 meter. Each of these entries must be confirmed with the "Enter" key on the keyboard.

— Each one of the springs is set to oscillate after hanging on different masses; for each case, the period and the spring constant is determined. At the beginning of the experiment, the movement recorder is adjusted in height so that it is located roughly in the centre between the end of the spring and the hook of the weight plate. It may be necessary to shift the set up to the edge of the table so the mass can oscillate downwards without being hampered.

— Two springs are suspended in parallel and in series with the same load, and the total spring constant is determined.

— The mass suspended from the springs is deviated manually downwards and released, after which the <Start> button is pressed. A new measurement can be initiated any time with the <Reset> button, the number of measurement points "n" is reset to zero.

— In total, about n = 250 measurement values are recorded and then the <Stop> button is pressed.

— Now the newly appearing <Edit> button is pressed. After a few seconds, three new order buttons appear on the screen. Click on the <Edit> button The vertical lines can be captured and shifted with the mouse button. They are positioned in such a way that all measurement values which are to be evaluated lie between the two lines. The <Edit> but-

Fig. 2: Connection of the movement recorder to the COBRA interface.

red
black
BNC "2"
BNC "1"
yellow
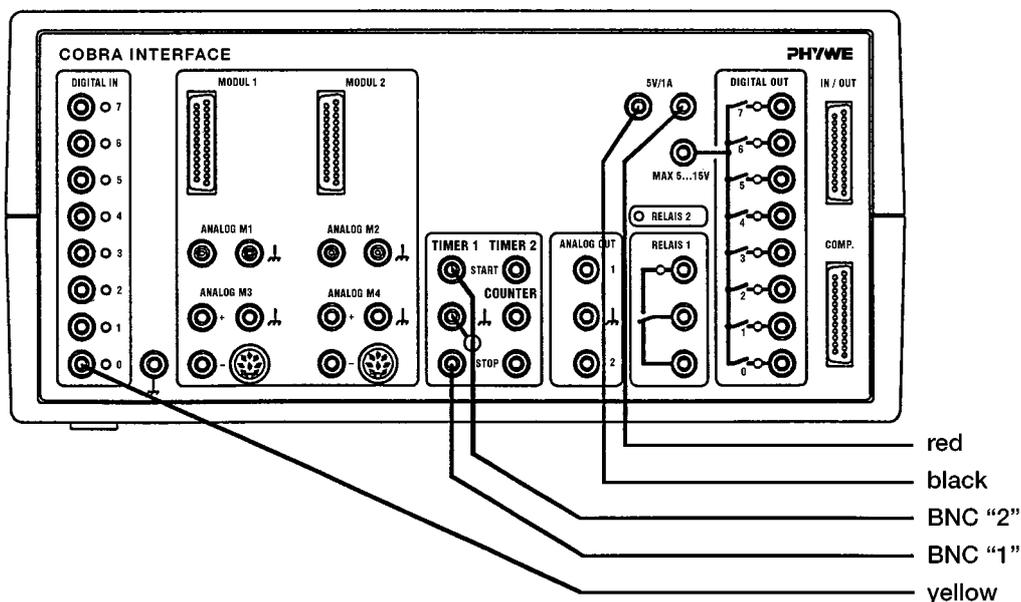
ton is pressed again, followed by the <Evaluate> button. The computer now needs some time to evaluate all data, the length of which depends on the number of measurement points. The process is indicated by a counter running backwards.

— After the evaluation, a graph similar to Fig. 4 appears on the screen. The duration of the period T and the circular frequency ω (w) of the oscillation are displayed. Press button <D>. If the spring constant D is well known it can be entered to the enter field D. ("Enter" key.) The mass suspended from the spring is displayed. If, on the other hand, the unknown spring constant D is to be determined, as in Fig. 4, the actual figure is to be entered in the input field for the mass m. D is displayed if "0" appears in the input window.

Result

— If a spring is deviated from its rest position, a force proportional to this deviation becomes effective:

$$F = -Dx.$$

— If the spring oscillates, the period T is given through:

$$T = 2\pi \cdot \sqrt{\frac{m}{D}} \cdot$$

Table 1 verifies this relation. For different masses, the absolute value of the spring constant is constant within the scope of measurement precision.

The weaker spring (Table 2) is loaded with smaller masses so as to avoid excessive extension. It can be seen that the value of the spring constants D also increases slightly with increasing suspended masses. The reason for this is that relation

$$T = 2\pi \cdot \sqrt{\frac{m}{D}}$$

only is valid for small deviations. If the deviations are larger, Hook's law, which is linear, stops being valid. In extreme cases, the spring may even be completely overetensed, so that it will no longer recover its initial shape after the load is relieved.

— If springs, also equivalent ones, are linked in parallel or in series, the total spring constant changes characteristically.

In case of parallel linking, the single spring forces sum up to a total force

$$F = F_1 + F_2 = -(D_1 + D_2)\,s$$

$$D = D_1 + D_2.$$

The total spring constant D is thus the sum of the single spring constants D_1 and D_2.

Fig. 3: Experimental set up for springs linked in series and in parallel.

If the springs are linked in series, the deviations s_1 and s_2 sum up to a total deviation s. The effective force F is identical for both springs:

$$F = -D_1 s_1 \rightarrow s_1 = -\frac{F}{D_1}$$

$$F = -D_2 s_2 \rightarrow s_2 = -\frac{F}{D_2}$$

with $s = s_1 + s_2$ we obtain

$$s = -\left(\frac{1}{D_1} + \frac{1}{D_2}\right) \cdot F$$

or

$$F = -\frac{1}{\frac{1}{D_1} + \frac{1}{D_2}} \cdot s$$

and

$$D = \frac{1}{\frac{1}{D_1} + \frac{1}{D_2}} \quad \text{or} \quad \frac{1}{D} = \frac{1}{D_1} + \frac{1}{D_2} \; .$$

The inverse value of the total spring constants corresponds to the sum of the inverse values of the single spring constants.

Table 3 shows examples of measurements which fulfil the above relation.

Indications

— If the oscillating period is very short, signal leaps or distortions may occur. These can be decreased by changing the sampling rate or by making the diagram invisible with <Clr>. Intervals recorded without faults may be cut out later from the measurement signal with <Edit>.

— As the recording of movement is not free of direct contact, a small damping of the measured oscillations occurs.

— After the autoscale button situated on the left side above the diagram has been clicked on, all measurement data are represented so that they fill the whole screen. However, an unfortunate choice of the subdivisions of the axes may occur. In this case, the corresponding scaling values for the x and y axes may be entered manually by pressing the second or respectively the fourth button over the diagram (cf. Fig. 4). After every change of the y axis magnitudes, the autoscale button should be pressed, in order to adapt the scaling factors to the actually represented values.

— The <Evaluate> button provides many evaluation possibilities and requires a certain time, before all results are calculated. For 2000 measurement values, this may take a few minutes.

— The measurement values can be saved by pressing the green <Save> button. They are written as ASCII symbols in columns into a data file, which must have the suffix "AFD" (**A**SCII **F**ile **D**ata). The following measurement values are found in the single columns: t / (s) running time, *phi* (t) / (rad) angle, *omega* (t) / (rad/s) angular velocity, *alpha* (t) / (rad/s^2) angular acceleration, maxphi (t) / (rad) positive peaks of the angle graph, T / (s) oscillation period.

The measurement data can easily be submitted to further processing or printed out under DOS or WINDOWS®.

— The <maxphi (t)> button selects the positive oscillation peaks and plots them beginning on the left side. The logarithmic oscillation decrement is obtained pressing the <LD> button. It must be noted that the first and last three values of "maxphi (t)" are not taken into account for the evaluation through <LD>.

— The green <Load> button allows to load measurement data into the running programme, so that the data are evaluated again and compared to actual data. The double button <Exp.> <Load> is used for this. <Exp.> shows the graph of the actual **exp**eriment, <Load> shows the loaded measurement.

— If a new measurement is to be carried out, the <Edit> and <Evaluate> buttons must be switched off to start with, after which the <Experiment> button is pressed. After a few seconds, the set up of the diagram already described for the recording of measurement values appears. The <Reset> button deletes the old measurement data. Once the measurement has been carried out, <Edit> is pressed. In the screen which appears then, the <Edit> button must be pressed to make the measurement values available for evaluation. If the <Evaluate> button is pressed first, no measurement values appear in the diagram. In this case, the <Evaluate> button is switched off again and <Edit> is pressed.

— It must be taken into account that the <Edit> and <Evaluate> buttons cancel each other. This means that the button pressed first is active, the button pressed after this turns red, but is not activated. For this reason, it is recommended to switch off the button pressed first before pressing the other one.

— The <Clr> button in the measurement value recording screen deletes the diagram. This saves computing time and the maximum sampling rate can be slightly increased. Pressing this button twice will let the diagram appear again on the screen, the contents are deleted.
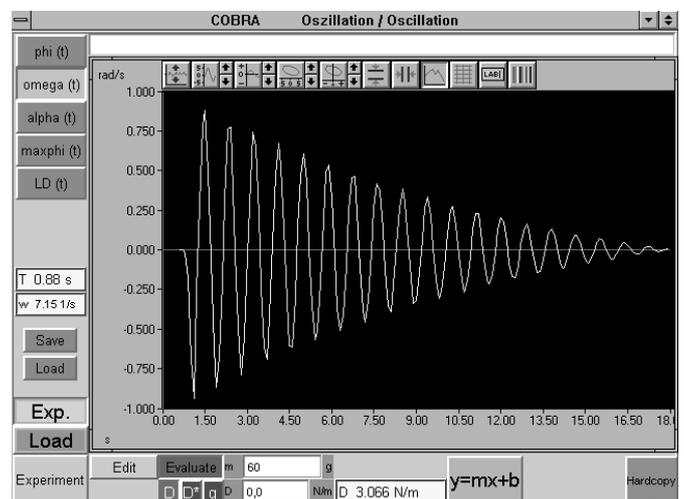
Fig. 4: Typical curve to determine spring constants.

— An arbitrary text to comment or explain the experiment can be entered in the comment line on the upper edge of the screen, before a hardcopy printout is made. The hardcopy is printed out on the connected printer when <Hardcopy> is pressed. Before printing out a hardcopy, it is recommended to change the colours of the diagram, in order to save the ink ribbon or the cartridge of the printer. Diagram colours can be modified pressing the colour selection button situated on the right side above the diagram. The following colour combinations are recommended:

Scope: instead of black - white

Data: instead of yellow - black.

— Quitting the programme: if the programme is in the measurement value recording mode, it is sufficient to click twice at the upper left corner of the screen with the left mouse button. If not, the <Experiment> key must be pressed first, so the programme will return to the measurement value recording mode.

Table 1

m / g	D / N/m	T / s
250	20.152	0.70
300	20.232	0.77
350	20.146	0.83
400	19.979	0.89

Table 2

m / g	D / N/m	T / s
60	3.066	0.88
80	3.157	1.00
100	3.221	1.11
150	3.430	1.31

Table 3

Spring, linking	$D_{measured}$ / N/m	$D_{calculated}$ / N/m	suspended Mass / g
Spring 1	2.922	–	60
Spring 2	3.216	–	60
Spring 3	20.146	–	350
Spring 1, 2 series	1.74	1.53	60
Spring 1, 3 series	2.457	2.55	60
Spring 1, 2 parallel	6.066	6.138	110
Spring 1, 3 parallel	22.018	23.068	310