Related topics

Friction less movement, acceleration, torque, moment of inertia, use of an interface system.

Principle and task

Two masses are linked to one another by means of a "mass zero thread" running over a "no friction" thread groove. Acceleration a is measured when the system moves under the influence of gravity.

Equipment

COBRA-interface 2	12100.93	1
PC COBRA data cable RS232, 2 m	12100.01	1
Movement sensor with cable	12004.10	1
Softw.COBRA Rotation (Win)	14295.61	1
Basic Softw. f. PHYWE Windows prog.	14099.61	1
Adapter, BNC-socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Slotted weight, 10 g, black	02205.01	7
Slotted weight, 50 g, silver bronze	02206.02	2
Weight holder f. slotted weights	02204.00	2
Silk thread, 200 m	02412.00	1
Bosshead	02043.00	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Tripod base -PASS-	02002.55	1

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

Problems

1) Measurement of the acceleration due to gravity for different masses

2) Analysis of the movement s(t), v(t) and a(t).

Set-up

— According to Fig. 3 the thread is laid over the larger of the two thread grooves. The length of the thread is adjusted so that when the lighter weight is held to the floor with the finger, the heavier weight just hangs below the thread groove.

— Electrical connection of the movement recorder is carried out according to Fig. 2 for COBRA.

Fig. 1: Experimental set up to measure linear accelerated movements.

Procedure

— If the COBRA interface is connected to the computer port COM1 "Lin_COM1" is clicked on twice. If the serial port COM2 is used, "Lin_COM2" 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.

— Press the <Start> button to record measurement values. The lighter weight plate is held to the floor with a finger nail, then the <Reset> button is pressed to start a new measurement. "0" is displayed as number of measurement points <n:>. If very small movements cause the unwanted recording of measurement values, press the <Reset> button again.

— The weight plate is released. It carries out an accelerated movement and at about half the height, it meets the falling plate. Now the <Stop> button can be pressed. Recording of measurement values begins as soon as the absolute value of the measured velocity is larger than 0.01 m/s. During the course of the movement, the number of measurement points "n:" and plate speed "v:" are continuously updated. At the end of movement recording and before the <Stop> button is pressed, velocity drops again below 0.01 mls and movement recording stops.

— After movement recording is finished and the <Stop> button has been switched off, the <Edit> button appears if more than 3 measurement values were recorded. Press the <Edit> button.

— After a few seconds, the new screen required to evaluate measurement data appears.

Results

— The <Edit> button which appears is pressed to start with. Measurement data are represented in a *v-t-* diagram. 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 (cf. Fig. 4). Next to the measurement points which are actually of interest (increasing branch of the graph), measurement points corresponding to the collision phase of the plates and to the following new acceleration are also recorded. These measurement points can be deleted step by step by means of the <Del> button. If too many measurement points were deleted inadvertently, switch the <Edit> button off and on again. All measurement values appear again at once for renewed correction. Once editing is concluded, switch off the <Edit> button.

Indication:
if negative velocities are recorded, the experiment is repeated inverting the weights (the thread groove of the movement recorder now rotates in the other direction). For this, switch off the <Edit> button and press <Experiment>.

Fig. 2: Connection of the movement recorder to the COBRA interface. If the COBRA interface with the turning knob is used, please notice that the stop and mass sockets of the timer are inverted as compared to the disposition for the COBRA interface. The voltage knob must be set to 5 V, that is, the knob is completely turned to the left.
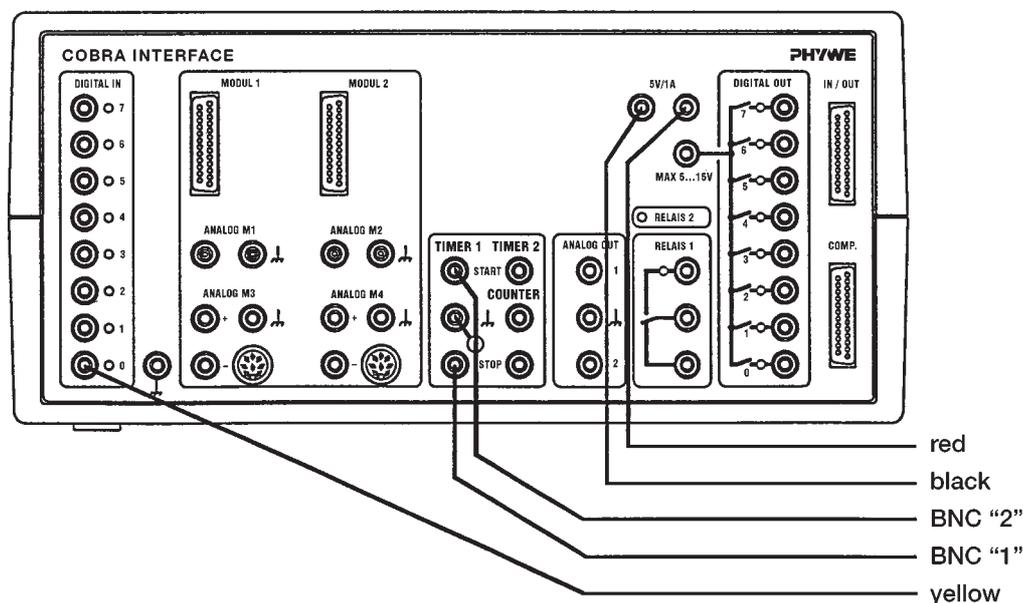
Fig. 3: Basic experimental set-up.
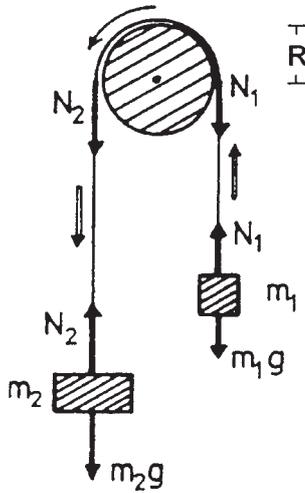
Fig. 4: Measurement data before deleting not required measurement points.
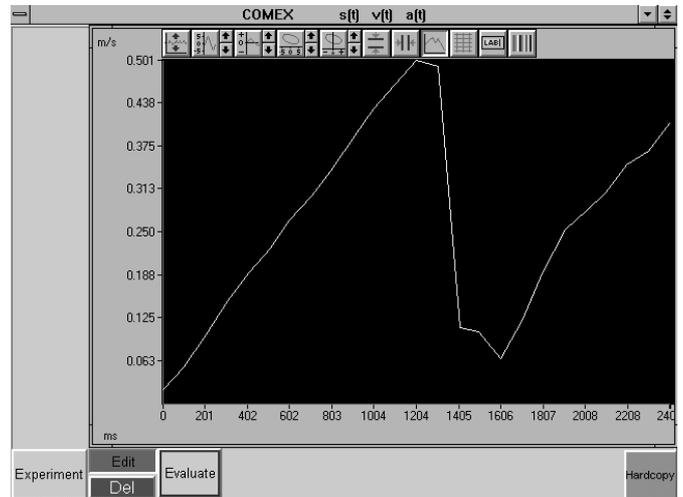
— The <Evaluate> button provides many evaluation possibilities.

— <v(t)> displays the velocity-time graph, a straight line which fulfils the relation $v = a\,t$ (Fig. 5). If the <y=mx+b> key is pressed, a regression line is laid through the measurement points; the slope m gives the acceleration a. (If the autoscale button situated on the left side above the diagram is pressed, all measurement values are displayed; however, axis subdivisions may have been selected unfortunately. In this case, corresponding scaling values for the y and x axes can be entered manually by pressing the second or the fourth button above the diagram).

Indication:
every time the y measurement magnitudes are switched over, the autoscale button should be pressed, in order to adapt the scalings to the actually represented values.

— The path-time law is obtained by pressing the <s(t)> button. Fig. 6 shows a parabolic curve.

— The parabolic shape of the path-time law can be verified by means of the <s(t^2)> button.

— The variation of acceleration in time can be displayed by means of <a(t)> (Fig. 7). Take note of the scaling difference for a: with <a(t)>; acceleration is expressed in m/s^2, whereas for the regression line in the <v(t)> diagram, the slope m is expressed in m/(s*ms). This explains the factor 1000. As shown in Fig. 7, acceleration in dependence of time is constant for uniformly accelerated movements. If the <y=mx+b> button is pressed, a regression line is drawn into the diagram. The position if this straight line allows to read the average value for acceleration a.

Based on the basic experimental set up (Fig. 3), the value of acceleration a can be deduced:

If $m_2 > m_1$, with the tensing forces N_1 and N_2 at the ends of the thread, one finds:

$$m_1\, a_1 \;=\; N_1 - m_1 g$$

$$m_2\, a_2 \;=\; m_2\, g - N_2,$$

and for the torques acting on the disk:

$$D_1 + D_2 \;=\; -N_1 R + N_2 R \;=\; R\,(N_2 - N_1) = \dot{\omega}\, J,$$

because the disk is accelerated. J is the moment of inertia of the disk and ω is the angular velocity. As the thread does no brake, is tensed and does not slide, the following is valid:

$$a_1 = a_2 = \dot{\omega}\, R\,.$$

It is assumed in this case that the thread groove of the movement recorder can essentially be considered as a cylindrical disk. Such a disk has a moment of inertia

$$J \;=\; \frac{MR^2}{2}\,,$$

where

R radius of the disk

M mass of the disk.

Fig 5: Velocity-time law.
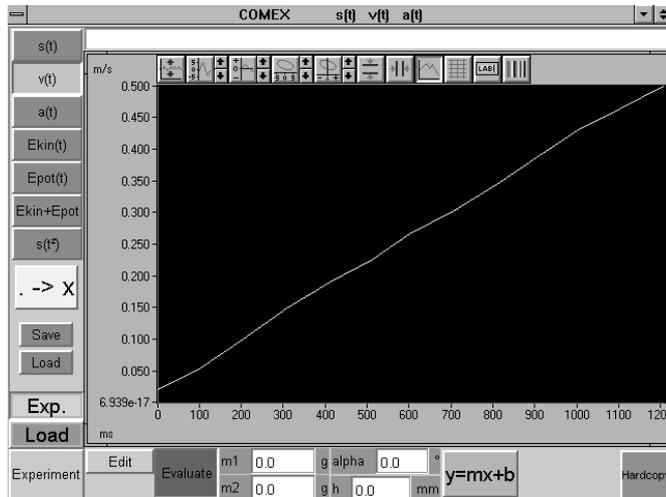
Fig. 6: Path-time law.
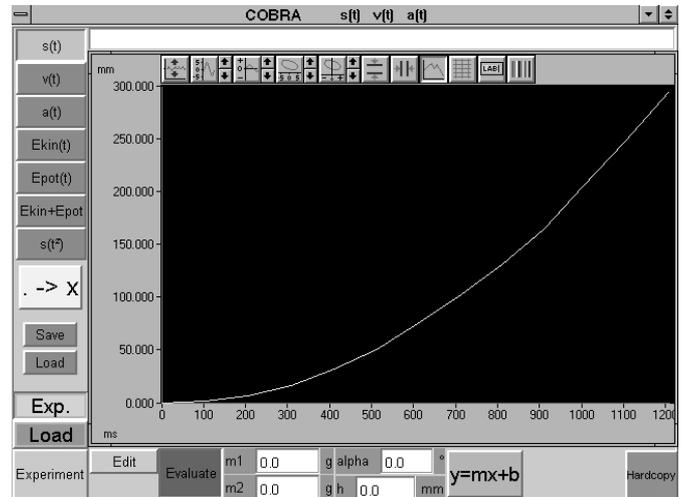
One thus obtains for the acceleration a:

$$a = \frac{N_1}{m_1} - g = g - \frac{N_2}{m_2} = \dot{\omega} R = \frac{R^2}{M R^2/2} (N_2 - N_1).$$

and thus

$$a = \frac{2}{M} (N_2 - N_1) = \frac{g (m_2 - m_1) - m_2 a_2 - m_1 a_1}{M/2}$$

and as $a = a_1 = a_2$,

$$0 = \frac{a \cdot \dfrac{M}{2} - g (m_2 - m_1) + a (m_2 + m_1)}{M/2}$$

$$= a (m_1 + m_2 + M/2) - g (m_2 - m_1).$$

Form this one obtains

$$a = \frac{m_2 - m_1}{m_1 + m_2 + \dfrac{M}{2}} g.$$

For evaluation, a value of 40 g may be assumed for M. Due to scattering in the manufacturing of the movement recorders, one must, however, assume a scattering of about ± 7 g. In case of doubt, it is recommended to average M for the used movement recorder carrying out several test measurements with different mass combinations, according to.

$$M = 2 \left(\frac{g}{a} (m_2 - m_1) - m_1 - m_2 \right)$$

The average value of M can then be used for all further measurements with the Atwood falling machine.

Indication

— 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 / (ms) , s(t) / (mm), v(t) / (m/s), a(t) / (m/s^2) , Ekin(t) / (g m^2/s^2), Epot(t) / (g m^2/s^2), Ekin + Epot / (g m^2/s^2).

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

— 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.

Fig. 7: Acceleration-time law.
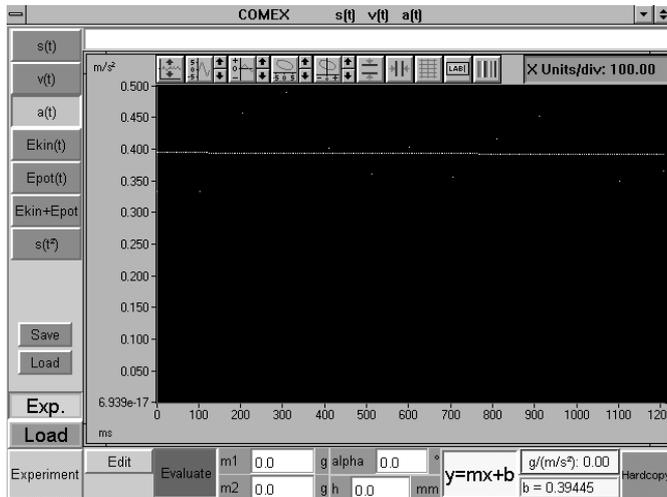
— A text to comment or explain the experiment can be entered in the comment line on the upper edge of the screen, before a hardcopy printout is made. The hardcopy is printed out on the connected printer when <Hardcopy> is pressed. Before printing out a hardcopy, it is recommended to change the colours 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.

— It must be taken into account that the <Edit> and the <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.

— 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.