

Related topics

Conservation of momentum, conservation of energy, linear motion, velocity, elastic collision, inelastic collision, energy loss.

Equipment

Air track rail	11202.17	1
Blower	13770.93	1
Pressure tube, l 1.5 m	11205.01	1
Glider f. air track	11202.02	1
Slotted weight, 1 g, natur. colour	03916.00	9
Slotted weight, 10 g, black	02205.01	4
Slotted weight, 50 g, silver bronze	02206.02	4
Endholder for air track rail	11202.15	1
Starter system	11202.13	1
Magnet w. plug f. starter system	11202.14	1
Tube with plug	11202.05	1
Plasticine, 10 sticks	03935.03	1
Hook with plug	11202.07	1
Silk thread, 200 m	02412.00	1
Weight holder 1 g	02407.00	1
COBRA-interface 2	12100.93	1
PC COBRA data cable RS232, 2 m	12100.01	1
Movement sensor with cable	12004.10	1
Adapter,BNC-socket/4mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Softw. COBRA linear motion (WIN)	14292.61	1
Basic Softw. f. PHYWE Windows prog.	14099.61	1
Bench clamp -PASS-	02010.00	1
Stand tube	02060.00	1
Bosshead	02043.00	1

Support rod, stainl. steel, 250 mm	02031.00	1
Measuring tape, l = 2 m	09936.00	1
Universal balance, 2000 g	46008.93	1
Flat cell battery, 9 V	07496.10	1
Supporting blocks, set of 4	02070.00	1

PC WINDOWS® 3.1 or later

The PHYWE WINDOWS® Basic Software (14099.61) must have been installed once on the computer in order to be able to use the software.

For an alternative experimental set-up, please refer to the end of the experiment.

Set-up

— According to Fig. 1 and Fig. 2, the movement transducer must be installed in such a way that its housing is situated on the right side of the track looking in the direction of the movement of the car. If the motion transducer is installed the wrong way round, negative velocities will be measured. It must be taken care that the thread is parallel to the track. The thread is passed through the larger of the two thread grooves on the motion transducer.

Procedure

- If COBRA is connected to the serial port COM 1, click twice on the "Lin_COM1" programme. If the serial port COM 2 is used, the "Lin_COM2" programme must be started.
- Depending on the speed of the computer, the maximum scanning rate $\langle \Delta t / \text{ms} \rangle$ must be set. In the case of a 486 (66 MHz) computer, 100 ms have proved to be ade-

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



quate. With faster computers, time may be shortened and with slower computers, it may have to be lengthened. Scanning time is set by moving the grey control slide with the mouse. $\langle \Delta t / \text{ms} \rangle$ must be set anew every time the programme is started. A too short scanning time is recognisable by the following effects:

- No measurement
- The measurement values are not equidistant on the time axis.
- The time distance of the measurement points is noticeably larger than the $\langle \Delta t / \text{ms} \rangle$ value which was set.
- In order to record the measurement value, the $\langle \text{Start} \rangle$ key must be pressed to begin with. The glider is brought to the starting position and held there; then $\langle \text{Reset} \rangle$ is pressed to initiate a new measurement. The displayed number of points of measurement “n:” is “0”. If unwanted measurement points are recorded due to minimal movements, “Reset” must be pressed again.
- The glider is released. It carries out an accelerated movement and runs against the stopper at the end of its motion. Recording of measurement values begins as soon as the absolute value of the measured velocity becomes larger than 0.01 m/s. The number of points of measurement “n:” and the velocity of the glider “v:” are permanently actualised during the course of the movement. At the end of the recording of the movement, velocity drops back below 0.01 m/s and the recording of measurement values stops.
- When the recording of measurement values comes to an end, $\langle \text{Start} \rangle$ is pressed again. If more than 4 measurement values were recorded, an $\langle \text{Edit} \rangle$ key appears and must be pressed.
- After a few seconds, a new screen for the evaluation of measurement values will appear.

Result

- Press $\langle \text{Edit} \rangle$ to start with. Measurement values are represented in a $v-t$ diagram. After the Autoscale key situation on the left above the diagram was clicked on, all measurement data are represented so as to fill the screen (cf. Fig. 3). Next to the measurement points of actual interest (raising branch of the graph), other measurement points are

registered which actually are related to the collision of the glider against the stopper. These measurement points can be deleted step by step by pressing $\langle \text{Del} \rangle$. If too many measurement points were deleted by mistake, $\langle \text{Edit} \rangle$ is switched on and off. All measured values are again presented for selection. When editing is concluded, $\langle \text{Edit} \rangle$ is switched off.

- the $\langle \text{Evaluate} \rangle$ key provides a multitude of evaluation possibilities.
 - $\langle vt \rangle$ shows the velocity-time graph, a straight line according to the relation $v = at$ (Fig. 4). If the $\langle y=mx+b \rangle$ key is pressed, a regression straight line is laid through the measurement points; its slope m gives the acceleration a . (If the Autoscale key situated on the left above the diagram is pressed, all measurement values are visible; however, the axis subdivisions may have been selected disadvantageously. In this case, by pressing the second or the fourth key above the diagram, the corresponding scaling values for the y and x axis may be entered manually).
Indication: the Autoscale key should be pressed after every switching over of the y axis measurement magnitudes, in order to adapt scaling to the actually represented values.
- The time dependence of the acceleration can be displayed by means of $\langle a(t) \rangle$ (Fig. 5). The scaling difference for a must be taken into account: for $\langle a(t) \rangle$, the acceleration unit is m/s^2 whereas for the regression straight lines in the $\langle v(t) \rangle$ picture, the unit of slope m is $\text{m}/(\text{s} \cdot \text{ms})$. This explains the factor 1000. As shown in Fig. 5, for a uniformly accelerated movement, acceleration is constant as a function of time. If $\langle y=mx+b \rangle$ is pressed, earth gravitational acceleration calculated using the measurement is displayed. The following relation also is valid:

$$(m_1 + m_2) a = m_2 g \quad (\text{Fig. 8})$$

As the mass of the glider m_1 and the accelerating mass m_2 are known (they can be determined by weighing), and can be entered into the corresponding input boxes on a screen (ENTER on the keyboard must be pressed after every entry), g may be calculated when a has been measured. When $\langle a(t) \rangle$ is pressed, the average of the acceleration

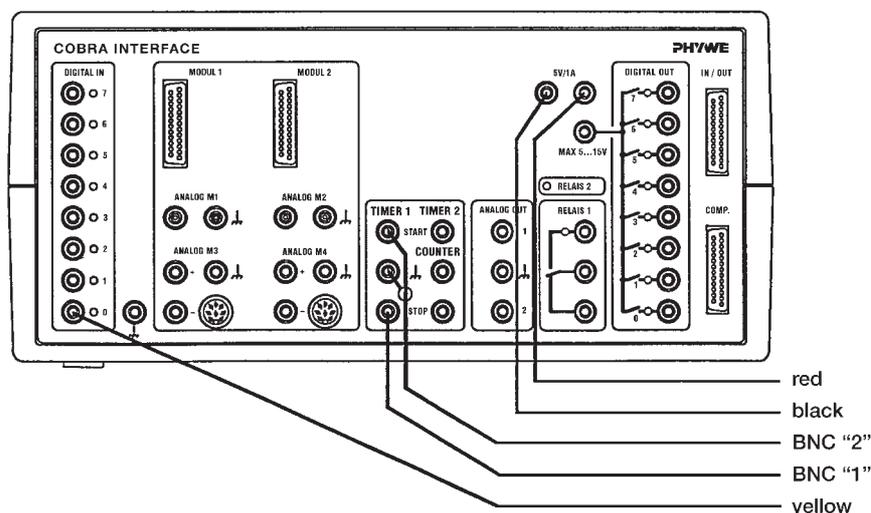


Fig. 2: Connection of the movement recorder to the COBRA interface.

Fig. 3: Measurement data before non required measurement points are deleted.

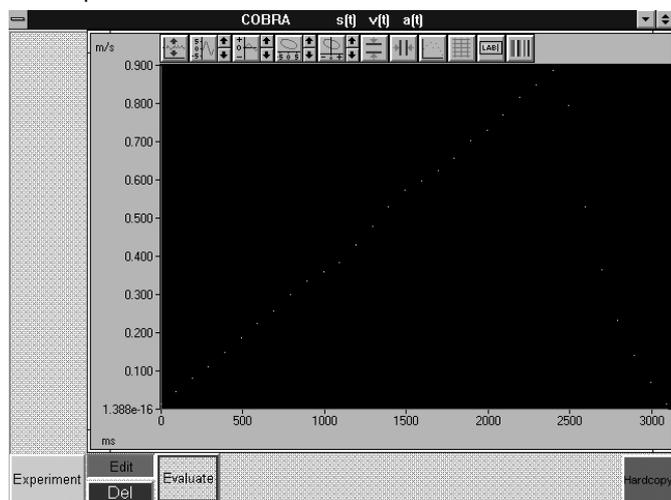
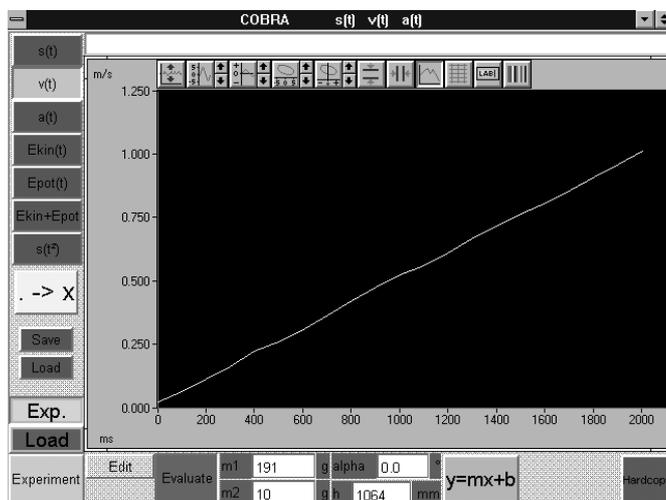


Fig. 4: Velocity-time law.



data is also calculated and entered into the above expression. Please take notice of the fact that the calculated value of g only is displayed when $\langle a(t) \rangle$ and $\langle y=mx+b \rangle$ are pressed and "0" stands in the input field for alpha.

- the time-trajectory law is obtained by pressing $\langle s(t) \rangle$. Fig. 6 shows a parabolic graph wherein the measurement points are highlighted. This is obtained by pressing $\langle .->x \rangle$. This key freezes the green selector switches for the y-axis. Other measurement magnitudes are only displayed once $\langle .->x \rangle$ has been switched off again. In the regression straight line representation, $\langle .->x \rangle$ is not active.
- The parabolic form of the time-trajectory law may be verified by means of the $\langle s(t^2) \rangle$ key (Fig. 7). There the square of time is plotted on the x-axis and one obtains a straight line, which verifies the relation $s(t) = 0.5 at^2$. By clicking on $\langle y=mx+b \rangle$, it is verified that the slope of the regression straight line is $m = 0.5 a$.

- In order to verify the energy balance, both masses m_1 (mass of the car) and m_2 (vertically falling accelerating mass) as well as the total drop height h of mass m_2 must be entered into the corresponding input boxes (after each entry, ENTER must be pressed on the keyboard). $\langle E_{kin}(t) \rangle$ shows the parabolic rise of kinetic energy.

$$E_{kin}(t) = 0.5 (m_1 + m_2) v^2$$

$\langle E_{pot}(t) \rangle$ gives the potential energy.

$$E_{pot}(t) = m_2 g (h-s(t)),$$

which decreases in time (Fig. 9). The law of conservation of energy states that the sum of kinetic and potential energy in this closed system must be constant. This can easily be verified using the $\langle E_{kin}+E_{pot} \rangle$ key (Fig. 10).

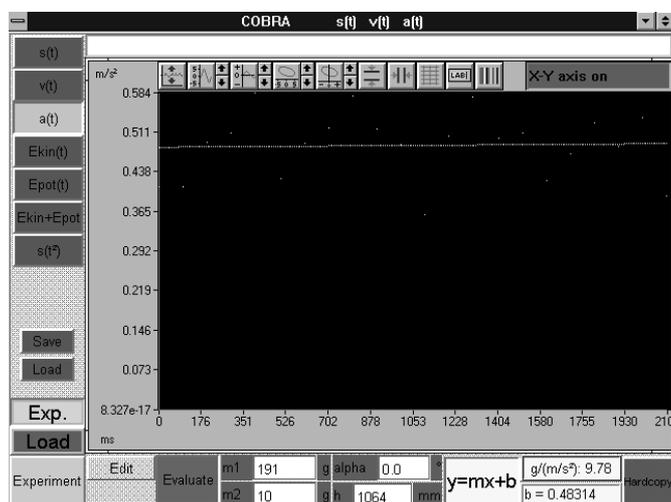


Fig. 5: Acceleration-time law.

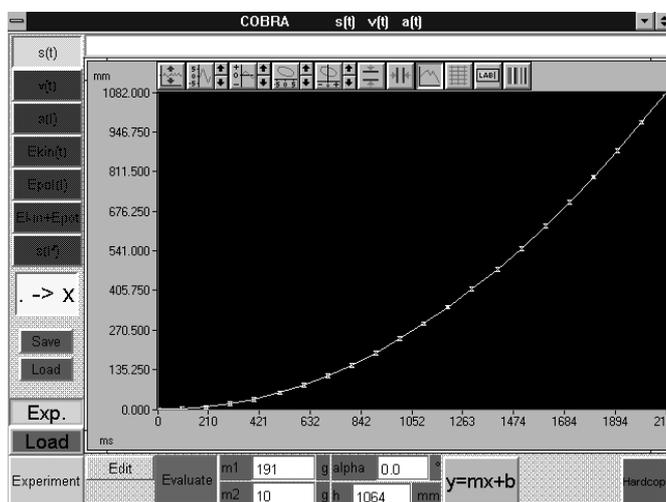


Fig. 6: Trajectory-time law.

Fig. 7: Trajectory-time low with the square of time on the x-axis.

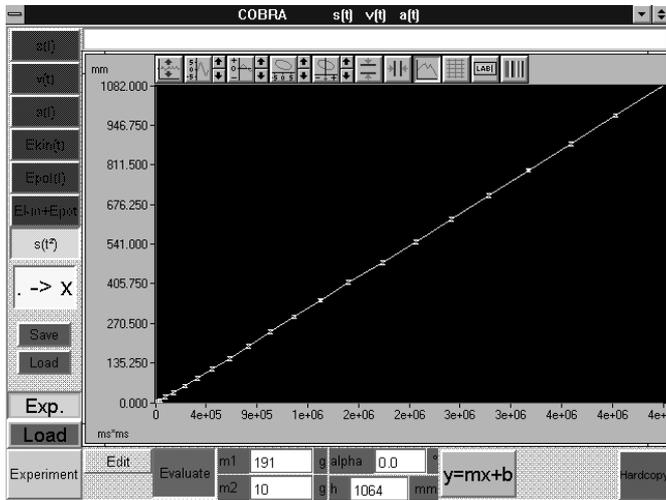
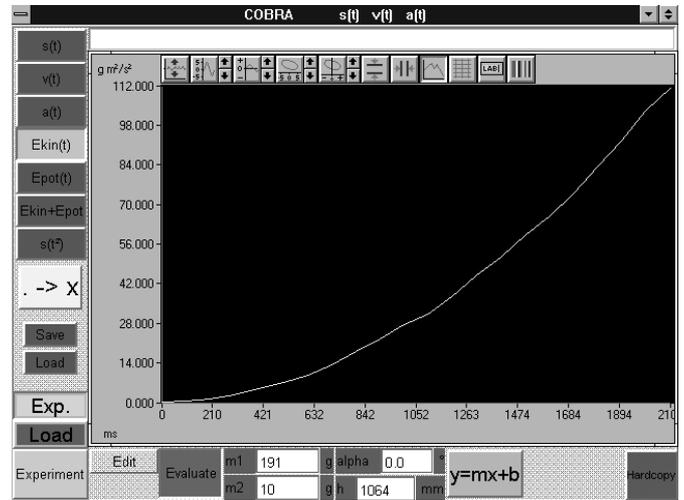


Fig. 8: Kinetic energy.



— Measurement values can be saved by pressing the green <Save> key. Measurement data are written as ASCII symbols in columns in a data file which must have “AFD” (ASCII File Data) as a suffix. The following measurement magnitudes are found in the single columns: $t/(ms)$, $s(t)/(mm)$, $v(t)/(m/s)$, $a(t)/(m/s^2)$, $E_{kin}(t)/(g\ m^2/s^2)$, $E_{pot}(t)/(g\ m^2/s^2)$, $E_{kin} + E_{pot}(g\ m^2/s^2)$.

Measurement data can easily be processed or printed out under DOS or WINDWS®.

— The green <Load> key allows to load measurement data may be evaluated anew and compared with actual data. The double key <Exp><Load> is used for this. <Exp> displays the graph of the actual experiment, <Load> displays the loaded measurement.

— If a new measurement is to be carried out, <Edit> and <Evaluate> must be switched off to start with. Then the <Experiment> key is pressed. After a few seconds, the picture set-up appears, which was already described above under recording of the measurement value. The <Reset> key deleted the old measurement data. If the measurement is carried out, <Edit> is pressed. To start with, <Edit> must be pressed in the screen which appears then, in order to make the measurement values available for evaluation. If only <Evaluate> is pressed, no measurement values appear in the diagram. In this case, switch off <Evaluate> and press <Edit>.

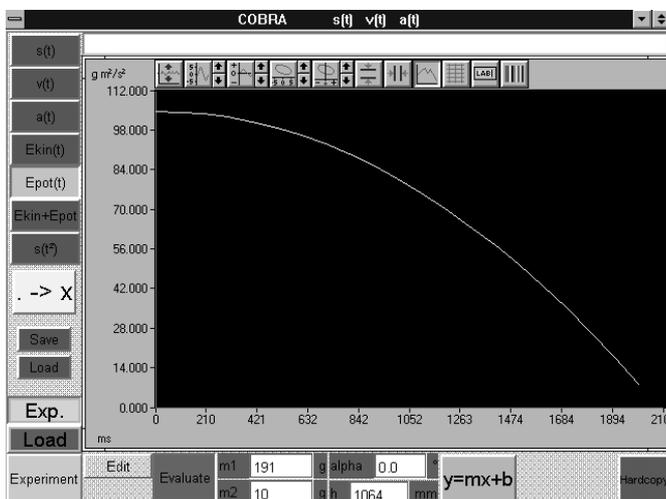


Fig. 9: Potential energy.

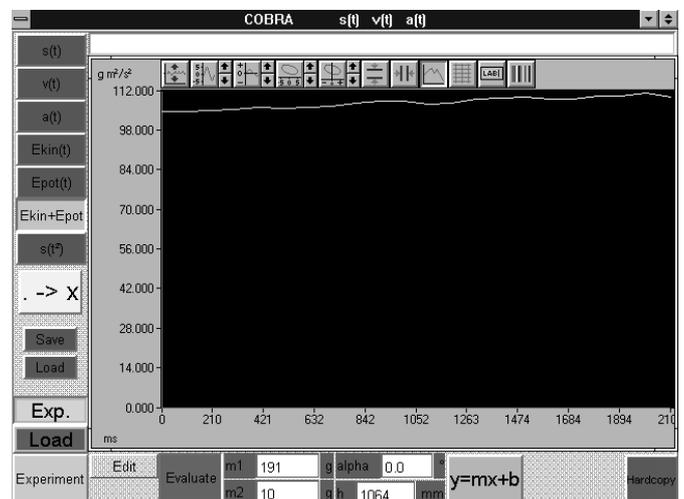


Fig. 10: Sum of the corresponding kinetic and potential energies.

Indications

- Before printing out a hardcopy, an arbitrary explanatory text for the experiment may be entered in a comment line on the upper edge of the screen. The hardcopy is printed out on the connected printer when <Hardcopy> is pressed. Before printing out a hardcopy, it is recommended to modify the colours of the diagram in order to save the ink ribbon or the cartridge of the printer. Diagram colours may be modified by pressing the colour selection button situated on the upper right above the diagram.

The following colour combinations are recommended:

Scope: instead of black – white

Data instead of yellow – black

- The experiment can also be realised with a set-up using an inclined plane. The angle α by which the track is raised from the horizontal table top may be entered in the *alpha*-input box. When <a(t)> and <y=mx+b> are pressed, earth's gravitational acceleration g is calculated according to

$$g = a / \sin(\alpha)$$

and displayed.

- If a non accelerated movement must be recorded, it is sufficient to hang one or two paper clips from the thread in order to tense it and to assure contact with the thread groove of the motion transducer. The small acceleration which is still active can now be compensated either by slightly tilting the track or by the use of a second thread which is tensed in the opposite direction of the first, also by means of a paper clip. This second thread may be laid over the edge of the table or over a second deflection sheave.

- It must be taken into account, that <Edit> and <Evaluate> exclude each other. This means that the key which is pressed first is active, the next key which is pressed turns red, but is not activated. For this reason, it is recommended always to switch off the key which was pressed previously before the other key is pressed.
- Ending the programme: if the programme is in the measurement value recording mode, it is enough to click twice on the left upper corner of the screen with the left mouse button. If not, <Experiment> must be pressed first, in order to allow the programme to return to the measurement value recording mode.

Simplified set-up with student track (Fig. 11):

The following items of the above mentioned list may be dropped:

air cushion track (11202.71), fan (13770.93), pressure tubing (11205.01), glider (11202.02), extremity (11202.15), starter system (11202.13), holding magnet with plug (11202.14), small tube with plug (11202.05), plasticine (03935.03), hook with plug (11202.07), clamping column (02060.00). Instead of these items, components from the students experiment programme are used:

Material:

Track, l = 900	16606.00	1
Measurement and experimental car	11060.00	1
Holding bolt	03949.00	1

The adjustment screw to level out the track is turned out until it can be used as a stopper for the experimental car, in order to avoid its running against the motion transducer.

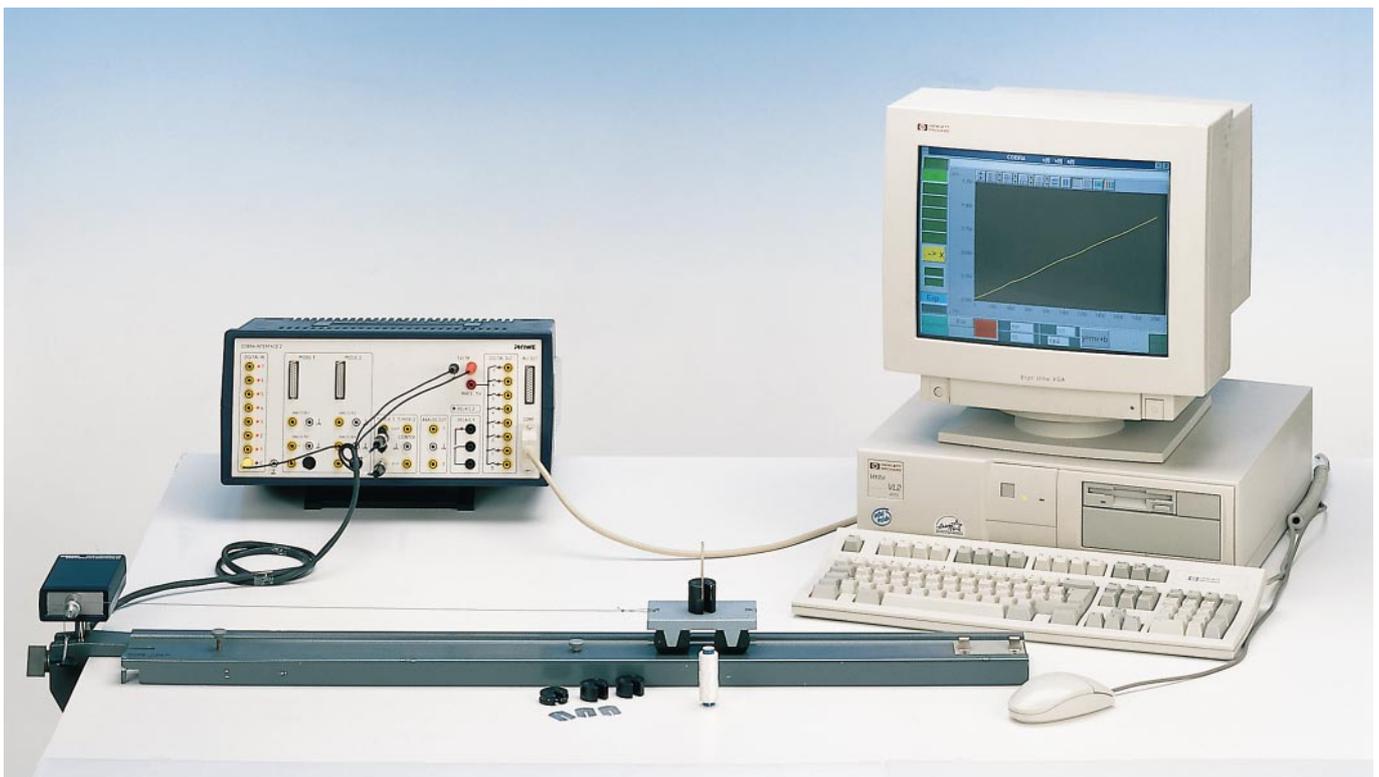


Fig. 11: Simplified student experimental set-up to measure linear accelerated movements.